TALLINN UNIVERSITY OF TECHNOLOGY
SCHOOL OF ENGINEERING
Department of civil engineering and architecture

# NEW CARBON NEUTRAL KOPLI DISTRICT IN TALLINN

## UUS SÜSINIKUNEUTRAALNE KOPLI ASUM TALLINNAS

MASTER THESIS

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## ABSTRACT

The aim of this thesis is to examine carbon neutrality as a climate target for cities, especially for the city of Tallinn, and the solutions of spatial planning, which are necessary to reach carbon neutrality. Furthermore, the thesis proposes a new carbon neutral district to Kopli area in Tallinn. Carbon neutrality will be achieved by reducing greenhouse gas emissions and and proposing a solution to compensate the remaining greenhouse gas emissions. As a conclusion, the thesis provides guidelines on carbon neutral spatial planning.

The climate of our planet has been changing throughout the history, and it has been monitored since since the industrial revolution, when the human impact on climate started to increase significantly. Climate change has occured mainly due to massive fossil fuel burning and in the last decades, the problem has grown dramatically. One of the biggest global commitments to stop climate change is the Paris Agreement. By the spring 2021 altogether 189 countries have signed the agreement and are aiming to limit global warming to a maximum of 2 degrees celcius by the year 2050.

In Estonia energy sources are carbon intensive and are rated in the European Union among the worst contributors to global warming. As Estonia is committed to reach carbon neutrality by 2050, it is necessary to carry out a fundamental energy transformation towards low-carbon energy supply.

As the thesis proposes a new carbon neutral Kopli district spatial planning, it also proposes renewable and green energy soruces to reduce emissions caused by energy production. The excess energy is calculated as carbon emission compensation and is exported outside the planning boundary over the national electricity grid so the clean energy produced can be used somewhere else. The city of Copenhagen, which aims to be the first carbon neutral capital in the World, plans to apply the same carbon offset method.

Several planning solutions contributing to carbon neutrality were identified:

1. The target area is a car-free zone. This means that only emergency and other crucial transport can access the area. The residents who own a car can leave it in the parking building at the side of the planning area and continue by foot, using a bike or a high interval tram. In Vauban area in the city of Freiburg, Germany, resepective solutions have resulted to a favorable modal share.
2. Land use mass change is limited and underground construction is forbidden in the area. This helps to furthermore keep the carbon emissions low.
3. Buildings in the area are constructed mostly from renewable materials such as timber. Recycled materials can also be used, for example from the demolishing of the existing buildings.
4. The energy concept of the area is based on one of the winning entries in the Helsinki's Energy Challenge in 2020. This includes a system with sea water heat pumps, electrical boilers and solar thermal fields. The solution for the new Kopli area also includes an off-shore wind farm and wave energy converters. The excess energy will be exported as carbon emissions compensation.

Concept of the proposed spatial planning is "Route". This is elaborated from car oriented city grid and how the street network could look like if we focused on pedestrians in the planning process.

Phasing of the construction work makes it more feasible and require less financing at once. The phases are for 2030, 2040 and 2050. For 2030, half of the energy production systems and the first building quarter will be constructed. In 2040, rest of the energy production system will be built along with another quarter. In the final phase for 2050 all of the area will be built and will be considered carbon neutral.

The project proposes a multifunctional planning area with residential, office, business, school, university, opera theatre building types and public squares. The street network is connected with Tallinn's green network and focuses on pedestrian movement in the area. This creates interesting and unexpected street network. The building heights vary from 3 to 7 storeys, where most of them are 4-storeys high.

Since Estonia has the worst electricity grid emission factor in the European Union, excess energy can benifit carbon neutral aspect greatly before the year 2050. The calculations take an estimated national electricity grid development into account and by 2050, the grid must also be carbon neutral. That means the exported energy will have less of an impact on $CO_2$ compensation.

The quantification methods of GHG emissions are not harmonized and there are no regulations or standards where the results could be compared on a planning scale. Cities define their own rules in the quantification process and the means of carbon offsetting can dilute the good intention of reducing $CO_2$ emissions.

## LÜHIKOKKUVÕTE

Selle lõputöö eesmärk on uurida süsinikuneutraalsust kui linnade, eriti Tallinna linna kliimasihtmärki, ning ruumilise planeerimise lahendusi, mis on vajalikud süsinikuneutraalsuse saavutamiseks. Lisaks pakutakse lõputöös välja uus süsinikuneutraalne linnaosa Kopli piirkonda Tallinnas. Süsinikuneutraalsus saavutatakse kasvuhoonegaaside heitkoguste vähendamise ja ülejäänud kasvuhoonegaaside heitkoguste kompenseerimise ettepaneku esitamise kaudu. Kokkuvõtteks pakub väitekiri suuniseid süsinikuneutraalse ruumilise planeerimise kohta.

Meie planeedi kliima on kogu ajaloo vältel muutunud ja seda on jälgitud alates tööstusrevolutsioonist, kui inimeste mõju kliimale hakkas märkimisväärselt suurenema. Kliimamuutused on toimunud peamiselt tänu fossiilkütuste massilisele põletamisele ja viimastel aastakümnetel on probleem dramaatiliselt kasvanud. Üks suurimaid globaalseid kohustusi kliimamuutuste peatamiseks on Pariisi leping. 2021. aasta kevadeks on lepingule alla kirjutanud 189 riiki ja nende eesmärk on piirata globaalset soojenemist 2050. aastaks maksimaalselt 2 kraadini.

Eestis on energiaallikad süsinikumahukad ja Euroopa Liidus hinnatakse neid kliimasoojenemist kõige halvemini mõjutavate tegurite hulka. Kuna Eesti on pühendunud 2050. aastaks süsinikuneutraalsuse saavutamisele, on vaja läbi viia põhjalik energia tootmise muudatus süsinikdioksiidiheitega tasakaalustamise suunas.

Kuna lõputöös pakutakse välja uus süsinikuneutraalne Kopli linnaosa ruumiline planeerimine, pakutakse selles ka taastuv- ja rohelise energia tüüpe, et vähendada energiatootmisest tulenevaid heitmeid. Liigne energia arvutatakse süsinikdioksiidi heitkoguste kompensatsioonina ja eksporditakse väljaspoole planeerimisala riikliku elektrivõrgu kaudu nii, et toodetud puhast energiat saab kasutada kusagil mujal. Kopenhaageni linn, mille eesmärk on olla esimene süsinikuneutraalne pealinn maailmas, kavatseb rakendada sama süsiniku kompenseerimise meetodit.

Leiti mitu süsiniku neutraalsust soodustavat planeerimislahendust:
1. Planeeringuala on autovaba tsoon. See tähendab, et piirkonda pääseb ainult hädaabi ja muu üliolulise transpordiga. Autot omavad elanikud saavad selle jätta planeeringuala kõrvale parkimishoonesse ja jätkata jalgsi, kasutades jalgratast või kiire intervalliga trammi. Saksamaal Freiburgi linnas asuvas Vaubani piirkonnas on välja kujunenud soodsad transpordiliikide osakaalud, mis toetavad madala süsinuki tootmise eluviisi.
2. Maakasutuse massiline muutus on piiratud ja maa-alune ehitamine on piirkonnas keelatud. See aitab hoida süsinikdioksiidi heidet madalal tasemel.
3. Piirkonna hooned on ehitatud peamiselt taastuvatest materjalidest, näiteks puidust. Kasutada võib ka taaskasutatud materjale, näiteks olemasolevate hoonete lammutamisel.
4. Piirkonna energiakontseptsioon põhineb 2020. aasta Helsingi Energia Väljakutse võidutööl. See hõlmab merevee soojuspumpade, elektrikatelde ja päikesepaneelide süsteemi. Uue Kopli piirkonna lahendus hõlmab ka avamere tuuleparki ja laineenergia muundureid. Liigne energia eksporditakse süsinikdioksiidi heitkoguste kompensatsioonina.

Kavandatava ruumilise planeerimise kontseptsioon on „Route“. See on välja töötatud autokeskse linnavõrgu põhjal ja kuidas tänavapilt võiks välja näha, kui keskenduksime planeerimisel jalakäijatele.

Planeerimisprojekti etapid muudavad selle teostatavamaks ja nõuavad korraga vähem rahastamist. Etapid on ette nähtud aastateks 2030, 2040 ja 2050. Aastaks 2030 ehitatakse pool energiatootmise süsteemidest ja esimene hoonete kvartal. Aastal 2040 ehitatakse ülejäänud energiatootmise süsteem koos teise kvartaliga. Aastaks 2050 ehitatakse kogu ala ja saavutatakse süsiniku neutraalsus.

Projekt pakub välja multifunktsionaalse planeerimisala, kus on elamu-, kontori-, äri-, kooli-, ülikooli-, ooperiteatrite hoonetüübid ja avalikud väljakud. Tänavavõrk on ühendatud Tallinna rohevõrgustikuga ja keskendub jalakäijate liikumisele piirkonnas. See loob huvitava ja ootamatu tänavavõrgustiku. Hoone kõrgused varieeruvad 3 kuni 7 korruselisteni, millest enamus on 4-korruselised.

Kuna Eestis on kõige halvem elektrivõrgu heitekoefitsient Euroopa Liidus, võib üleliigse energia eksportimine süsinikuneutraalset aspekti oluliselt parandada. Arvutused võtavad arvesse hinnangulist riikliku elektrivõrgu arengut ja aastaks 2050 peab võrk olema ka süsinikuneutraalne. See tähendab, et eksporditav energia kompenseerib järjest vähem kasvuhoonegaase.

Kasvuhoonegaaside heitkoguste kvantifitseerimismeetodid ei ole ühtlustatud ning puuduvad määrused ja standardid, kus tulemusi saaks planeerimisskaalal võrrelda. Linnad määravad kvantifitseerimisprotsessis ise oma reeglid ja süsinikdioksiidi tasakaalustamise vahendid võivad vähendada selle head kavatsust.

Lõputöö pälvis 2021. aastal Tallinna linna stipendiumi (Tallinna Raestipendium).

**CONTENTS**

## LIST OF ABBREVIATIONS AND SYMBOLS

GHG – Greenhouse gas

$CO_2$ - Carbon dioxide

IPCC – International Panel on Climate Change

EU – European Union

SECAP – Sustainable Energy and Climate Action Plan

BLRT – Balti Laevaremonditehas (Baltic ship repair yards)

OECD - Organisation for Economic Co-operation and Development

SEI - Stockholm Environment Institute

# 1. THE AIM OF THE THESIS

## 1.1 Introduction

Carbon neutrality has become the most popular climate commitment for countries, regions, cities, organizations and buildings. Carbon neutrality refers to an annual net zero balance in $CO_2$ emissions. This means reducing the $CO_2$ emissions down to a level where all the remaining $CO_2$ emissions can be compensated. Respectively, climate neutrality refers to a net zero balance but includes all GHG emissions. (Davis, 2019)

Human-induced global warming problem emerged with the industrial revolution, when the rapidly growing world population started to rely on fossil fuels and energy usage. Throughout the previous century the emissions have grown so much that it is taking effect on out planet. The last couple of decades have made people more aware of the variety of problems caused by significant climate warming. This has led to increasing number of actions being introduced to reduce this effect.

In 2016, 197 countries signed the Paris Agreement, which is a commitment to limit the global warming to maximum of 2 C degrees. (The Paris Agreement | UNFCCC). European Union has committed itself to carbon neutrality through European Green Deal (A European Green Deal | European Commission (europa.eu)). All EU member states except Poland have announced their carbon neutrality target.

## 1.2 The objectives of the thesis

The thesis aims to demonstrate spatial planning solutions which can contribute to carbon neutrality in the context of Tallinn. The solutions are based on the greenhouse gas emissions quantification of the new development. The thesis also provides an overview on the greenhouse gas quantification methods applied by the cities, and the recent developments regarding these methods.

The planning part of the thesis introduces a master plan for a new carbon neutral district in Tallinn, Kopli, as an example for future developments. The solutions may provide guidance for city planners who are looking for solutions to support carbon neutrality. The aim is to identify spatial planning solutions which can contribute to carbon neutrality.

In most cases, the urban transformation towards carbon neutrality takes place in an existing environment. However, as the World population is growing, the existing urban areas are not enough to inhabit all the people. New areas will be planned also in the future. Furthermore, demonstrating the planning solutions in a plan for a new area may help to identify the necessary processes and developments also in the existing environments.

## 1.3 Research questions / problem statement

Since more and more countries have recognised the danger of climate change caused by greenhouse gases, they are determined to implement changes to limit this coming crisis.

It is a massive problem for Estonia, where the main power for grid electricity comes from oil shale. Estonia needs to implement drastic changes in energy production to keep the Paris Agreement commitment and reach the 2050 climate neutrality goal.

Cities have been forerunners in climate action. In 2013, American political theorist Benjamin R. Barber argued that today the cities, rather than nations, are solving the global problems related to environmental sustainability: "Where states can be said to have done the least, cities have done the most." (Barber, 2013)

At the same time when states and cities are striving for carbon neutrality, the methods of GHG quantification in city level remain unharmonized. There are two main approaches in GHG quantification: in territorial approach, all the direct GHG emissions caused within the boundaries of the target area are accounted. In consumption-based approach, all the emissions caused by the global production chain of goods and services are allocated to the consumer. In the latter, the emissions may be caused also outside the target area boundaries. Today, the cities seem to apply mixed approaches and methodologies (see for example Dahal et Niemelä).

Moreover, there is no common understanding how spatial planning could contribute to the greenhouse gas mitigation. The most commonly applied strategy is densification, but according to a number of research results, densification alone will not be able to deliver the desired reductions in greenhouse gas emissions (Riikka Kyro, 2012). An analysis of the life cycle greenhouse gas emissions of a new residential area. (Heinonen & Junnila, 2011)

Through the case study Kopli, this thesis will examine the measures for creating a carbon neutral city district in Tallinn; furthermore, what cities and city planners can take as guidelines to achieve carbon-neutral solutions. The key objective is to provide deeper understanding on the spatial planning solutions which can help the cities to achieve their climate commitments and contribute to the development towards lower GHG emissions and carbon neutrality.

## 1.4 Research methods and sources

The research methods include a literature review on the newest research on the GHG emissions quantification methods in spatial planning as well as the results from the on-going international QGasSP research project, directed by TalTech. Chapter 2 provides an overview on the climate commitments of cities. Chapter 3 describes the methods for the GHG quantification in spatial planning and the recent developments in the field. Chapter 4 places the carbon neutrality target in the Estonian context, and examines the carbon reduction potential in the city of Tallinn. Chapter 5 provides the analyses of the target area in Kopli. Finally, the concluding chapter 6 describes solutions of spatial planning which can contribute the developments towards carbon neutrality.

The energy concept utilizes the results of the Helsinki Energy Challenge, an international ideas competition which ended in 2021.

The research method involves collecting data about GHG quantification methods on city district planning phase, how to implement these aspects in Tallinn and how to achieve carbon neutrality by the year 2050. The sources are scientific research articles and the existing action plans of countries and cities about achieving carbon neutrality.

Carbon neutral city can be defined in multiple ways, depending on the quantification methodology and the emission sectors included. The most important $CO_2$ emission sources conneted to spatial planning are energy consumption in buildings, traffic and land use change.

# 2. CLIMATE STRATEGIES OF CITIES

## 2.1 Climate change

Climate change is a long-term change of global and regional weather patterns. These changes have been observed since the 20th century and are mainly caused by human activities like fossil fuel burning. Climate change can also be caused by natural processes like volcanic activity, changes in the Sun's energy output and variations in Earth's orbit. (NASA, n.d.)

Global warming is a long-term heating of Earth's climate. It has been observed since the second part of 19th century. It is estimated that the global avarage temperature was risen by 1 degrees Celsius in the pre-industrial period. Today, the tempreature is increased by 0,2 degrees Celsius every decade. (NASA, n.d.)

Warming of the climate system is unequivocal, and since the 1950s many of the observed changes are unprecedented over decades to millennia. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen and the concentrations of greenhouse gases have increased. Abundant empirical evidence of the unprecedented rate and global scale of impact of human influence on the Earth System has led many scientists to call for an acknowledgment that the Earth has entered a new geological epoch: the Anthropocene. (Steffen, 2016)(Myles R. Allen, 2018) (Policymakers, 2013)

There seems to be two definitions with minor differences:

"Definitions of climate change Climate change in IPCC usage refers to a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity. United Nations Framework Convention on Climate Change February 2011 2 This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods." (UNFCCC, 2011)

According to United Nations, billions of tons of GHG are produced by humans every year and that it is at a record high production rate in the last years. This has caused the temperatures to rise and create a very risky situation for the future of our planet. If we do not limit the rising temperatures, our planets' ecosystem could be irreversibly damaged by the year 2100. Polar ice sheets and glaciers are already melting and that causes the sea levels to rise. Since many cities are located near a sea, climate change is a global danger. (United Nations, n.d.)

## 2.2 Climate commitments

The 2015 Paris Agreement is aiming to limit the rise of global temperature to 1,5 degrees. It has been legally adopted by 196 parties around the world. It works with a 5-year cycle when countries need to submit their nationally determined contributions (NDCs). There are also long-term strategies that are not mandatory for parties. The Paris Agreement also contributes to co-operation of developed countries to provide financial help to less developed countries since the climate change actions require a big amount of work. (United Nations Framework Convention on Climate Change, n.d.)

European Green Deal is a strategic plan to make the EU's economy sustainable. It provides a new growth strategy that targets a net zero emissions of GHG by 2050, economic growth decoupled from resource use and no person and no place to be left behind. European Green Deal aims to boost efficiency of resources by moving to a clean economy and to cut pollution. It proposed a European Climate Law to make the commitment into a legal obligation. To achieve these targets, they plan to invest in environmentally-friendly technologies, support industry, come up with cleaner forms of private and public transport, decarbonise the energy sector, make buildings more energy efficient and to work together with international partners to improve the standards globally. (European Commission, n.d.)

Europe aims to be the first carbon neutral continent by 2050. (European Commission)

Many countries, such as United States and China, have recently announced new, more ambitious climate targets. (The White House, 2021) (BBC News, 2021)

According to United Nations News article, the biggest commitments that cities and countries can take to reach net-zero emissions are related to energy production. The biggest impact would be to replace coal and oil power plants with renewable energy production. Another big impact would be to replace fossil fuel-powered cars with electric cars that use the same renewable energy. This also helps to reduce air pollution. (UN News, 2020)

## 2.3 Carbon neutrality as a climate target for cities

Carbon neutrality means a balance between emitting carbon dioxide and absorbing carbon into carbon sinks. Carbon sinks are natural systems that absorb carbon more than they emit, for example forests, soil and oceans. Today no major artificial carbon sink system exists that could be beneficial in a global scale. (European Parlament News, 2020)

Compared to carbon neutrality, the word "climate neutrality" covers all of the GHG not just carbon. (European Council, n.d.)

European cities are searching for solutions to achieve carbon neutrality, but none of them has reached the target yet.

C40 Cities' definition of a carbon-neutral city states four criteria for the carbon-neutral city:
1. Net-zero greenhouse gas emissions (through carbon offsetting, or through carbon dioxide removal or emissions removal measures) from fuel use in buildings, transport, and industry;

2. Net-zero greenhouse gas emissions from the use of grid-supplied energy;
3. Net-zero greenhouse gas emissions from the treatment of waste generated within the city boundaries
4. Where a city accounts for additional sectoral emissions in their GHG accounting boundary, net-zero greenhouse gas emissions from all additional sectors in the GHG accounting boundary. (C40 Knowledge, 2019)

C40 cities also propose a common consumption-based methodology for GHG quantification (see chapter 3).

Cities have published detailed action plans to identify the steps towards carbon neutrality. Typically, these plans first aim to significantly reduce the total $CO_2$e emissions, and then compensate the remaining $CO_2$e emissions. The city of Copenhagen aims to be the first carbon neutral capital in the World. (Copenhagen City Website)

In Finland, all major cities have made carbon neutrality commitments; the capital city Helsinki has committed to be carbon neutral by 2035, Espoo by 2030, Vantaa by 2030, Tampere by 2030, Turku by 2029, and Oulu by 2040. The national target of carbon neutrality is set for 2035, so Espoo, Vantaa, Tampere, and Turku are following the example of Copenhagen by introducing more ambitious city-level targets.
Laine et al. (2020) argue that the decisions of a city alone may not be enough to enable carbon neutrality. (Jani, Jukka Heinonen, & Seppo Junnila, 2020)

### 2.3.1 Masdar City

Most of the cities aim at converting their existing environment carbon neutral through transformation processes. Masdar City is one of the few attempts to create a new carbon neutral city. The Abu Dhabi government announced in 2006 that it intends to spend $22 billion to build a carbon-neutral, zero-waste Masdar City. The plan was designed by Foster and Partners studio from 2007 to 2014. (Foster & Partners)

Image 1 Masdar City masterplan (masdar.ae; https://masdar.ae/en/masdar-city/plan-yourvisit/explore-the-city)

"*Masdar City combines state-of-the-art technologies with the planning principles of traditional Arab settlements to create a desert community that aims to be carbon neutral and zero waste. The 640-hectare project is a key component of the Masdar Initiative, established by the government of Abu Dhabi to advance the development of renewable energy and clean-technology solutions for a life beyond oil. The city will become a centre for the advancement of* *new ideas for energy production, with the ambition of attracting the highest levels of expertise. Knowledge gained here has already aided the development of Abu Dhabi’s ‘Estidama’ rating system for sustainable building.*” (Foster & Partners)

Today, only phase one of Masdar City has been built. To access the area at the moment, people can only use cars to do so. There are large temporary parking lots near the front entrance. Many of the people on the streets are just tour groups looking to experience the clean-tech city. There are about 1300 residents and 4000 office workers in the area. The original estimate of residents was 50 000. (Flint, 2020) (Fast Company, 2016)

It is ~6 km2 new development near Abu Dhabi City. The city was planned for 40 000 residents and the construction was supported by Abu Dhabi government. At first, it was planned as a future city, with net zero carbon emissions and new technologies for transportation. One of the biggest goals was to eliminate personal car transport and use all-electric personal rapid transportation instead. (Sovacool)

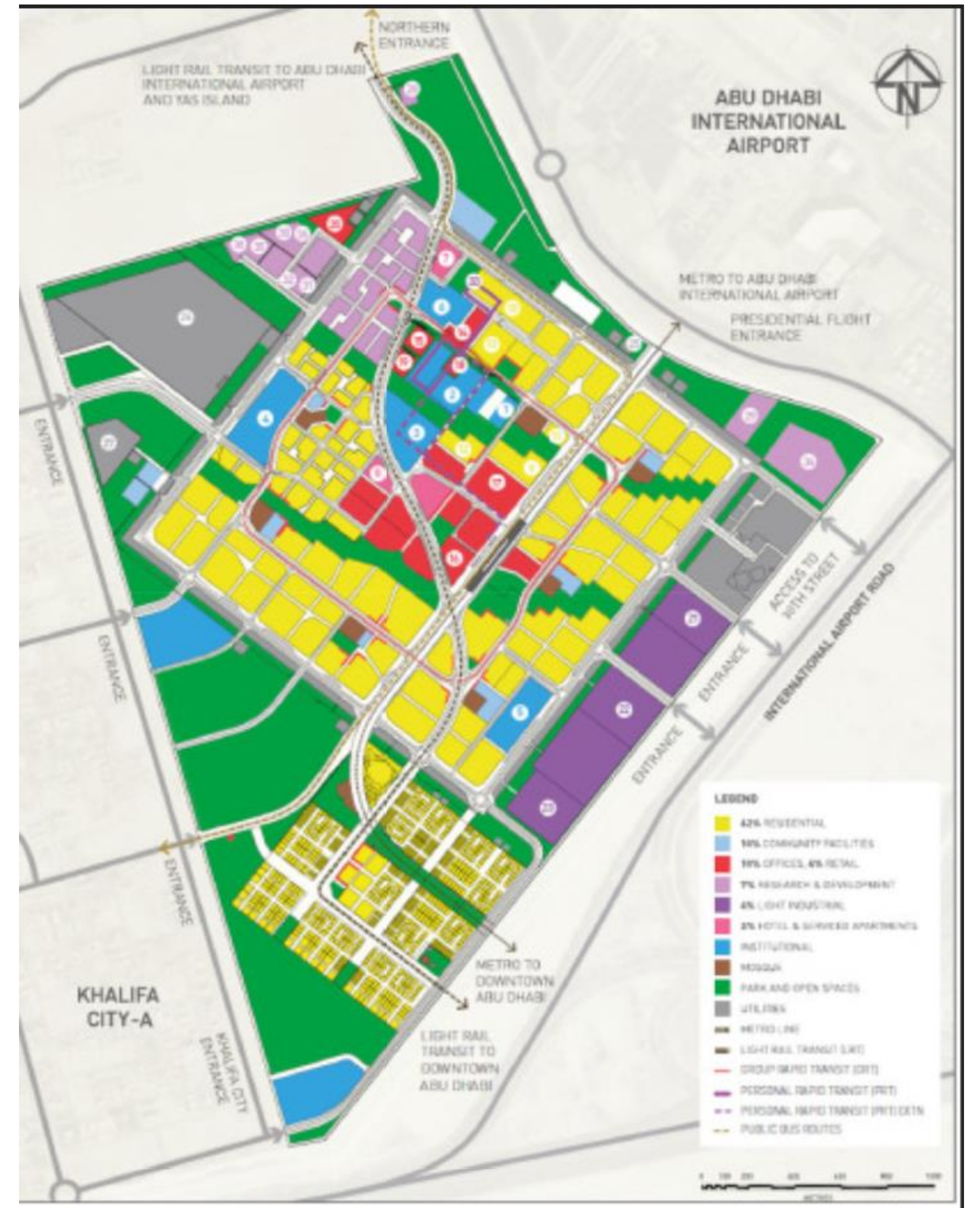


Image 2 Masdar City masterplan (Energy Research & Social Science perspective article)

There are similarities to Kopli planning area because all of the buildings were planned brand new, with the aim of making the area carbon neutral. Although it is a larger area, it can still be compared with key elements of planning such as energy harvesting solutions, public space, traffic and other aspects.


Image 3 Masdar City illustration (Energy Research & Social Science perspective article)

From the main rendered image of the city, one can see different zones and three or four building types.

The main problem with Masdar City was the big goal that they wanted to achieve in 2008 – net zero carbon emissions. At that time the technical solutions were not as developed as today. Later they changed it to aim for low carbon solutions instead. Since they changed the city's main goal, in 2019 only 10% of the city was built. Also the estimated construction time has tripled from 8 years to 20-25 years. From the previous picture and plan it is visible that the plan does not concentrate on human scale development and that the plan itself is broken into monofunctional zones. As this city plan proposed a car-free development, it also proposed a personal rapid transport technology. The characteristics of it are the same as a car's in city's planning grid. (Sovacool)

Masdar City is an example of high ambitions and pilot project experiments but overall bad calculations and underestimating the human factor in planning. The main goal of carbon neutrality was changed and that might have caused the unpolularity in the area. Like many new technologies and ideas, someone needs to experiment them first in order to convince others to follow; that can be credited to Abu Dhabi.

### 2.3.2 Copenhagen's plan for carbon neutrality in 2025

The city of Copenhagen has taken a forerunner position in climate action by announcing that it aims to be the first carbon neutral capital in 2025. (Copenhagen City Website)
Copenhagen climate plan for carbon neutrality, also known as CPH 2025, is based on four topics:

1. Energy consumption
2. Energy production
3. Mobility
4. City Administration Initiatives

In total, Copenhagen is targeting carbon neutrality even when they expect the population to grow by 20% in the next decade. The plan consists of three phases with evaluation between them: 2013-2016, 2017-2020 and 2021-2025. (The CPH 2025 Climate Plan, n.d.)

The plan for energy consumption is to reduce heat consumption by 20%, reduce electricity consumption in commercial and service companies by 20%, in households by 10% and the installment of solar panels equivalent to 1% of electricity consumption in 2025. (The CPH 2025 Climate Plan, n.d.)

Energy production aims to achieve carbon neutrality in distrit heating, to base the electricity production on wind and sustainable biomass that exeeds the total consumption in Copenhagen, to separate plastic waste from households and businesses and to biogasificate the organic waste. (The CPH 2025 Climate Plan, n.d.)

The targets are to reduce energy consumption in municipal buildings by 40%, new classifications for new buildings in the years 2015-2020 and 2020+. Copenhagens vehicles are planned to run only on electricity, hydrogen or biofuels. The energy consumption in street lighting is halved and a total of 60 000 m² of solar panels are installed on existing and new municipal buildings. (The CPH 2025 Climate Plan, n.d.)

Goal for mobility is to make 75% of all trips possible by foot, bicycle or public transport, 50% of trips to school or work are done by bikes, compared to 2009 20% more passangers use public transport. Additionally 20-30% of all light vehicles and 30-40% of all heavy vehicles should run on new fules. (The CPH 2025 Climate Plan, n.d.)
Copenhagen, as all other cities, recognizes that the $CO_2$ emissions cannot be reduced down to zero. In 2025, Copenhagen aims to compensate for the remaining emissions by exporting excess renewable energy outside the city boundaries.

### 2.3.3 Helsinki's plan for carbon neutrality in 2035

Helsinki planks to reduce it's greenhouse gas emissions by 80% for the year 2035. The remaining 20% of emissions are planned to be compensated outside the city. Since 1990, emissions have been reduced by 27% even when economic groth has increased by 65%. (Carbon Neutral Cities Alliance)

At the moment Helsinki's emissions are mainly caused by heating (57%). Other emission sources include traffic (23%), electricity (16%) and waste (4%). Electricity in Helsinki comes mainly from coal (43%) and gas (34%). Nuclear energy produces only 11% of Helsinki's electricity. (Carbon Neutral Cities Alliance)

To achieve the reduced emissions for the year 2035, Helsinki is going to focus on those key sectors: traffic, construction and use of buildings, consumption and circular economy, smart and clean growth, Helen Ltd's development programme, carbon sinks and compensation for emissions, communications and engagement, coordination, monitoring and assessment of climate work. (Carbon Neutral Cities Alliance)

In March 2020, Helsinki Energy Challenge competition results were published. The winning work "HIVE" proposed an energy solution based on already researched technologies such as seawater heatpumps, electric boilers, solar thermal fields and demand side management measures. It is also compatible to integrate new technologies when they emerge. (Helsinki Energy Challenge, 2021)

# 3 GREENHOUSE GAS QUANTIFICATION METHODS FOR CITIES

As shown by a.o. Dahal and Niemelä "Cities' Greenhouse Gas Accounting Methods: A Study of Helsinki, Stockholm, and Copenhagen", the greenhouse gas quantification methodologies of cities are not harmonized, and the results cannot be compared. The alternative approaches in GHG quantification of cities are a) territorial approach, where all the direct GHG emissions caused within the city boundaries are included b) consumption-based approach, where the GHG emissions are allocated to a resident of the city as the consumer of products and services, thus including also emissions caused outside the city borders. (Dahal & Niemelä, 2017)

Territorial approach takes all the emissions inside a city boarder into account. This is highly independent on the city's developed building types. For example, if the city has a large area for industries, then it is already producing a lot of carbon emissions even if all of the industries products are exported and never used in the city. Consumption-based approach is based on a resident of the city. The emissions produced by the residents are taken into account and summed. If the resident uses goods produced in other cities or countries, then it is still considered as the resident's city's emissions. The results gained with the territorial approach cannot be compared, whereas the consumption-based approach enables international comparisons between cities and territories. The two approaces can give results which differ from each other significantly. Today most cities use mixed approaches in their GHG inventories and climate neutrality action plans.

A hybrid method does not mean a combination of two abovementioned approaches, but refers to a combination of  methods. For example, a tiered-hybrid LCA method combines an economic input-output (EIO) method and the process LCA method. The economic input-output method applies the data on economic consumption and in practise covers all consumption. The process LCA method can be applied in sectoral analyses and it is often considered more accurate.

The recent initiative by C40 cities, as well as several researchers, have supported the idea of a harmonized methodology, which would be consumption-based. At the moment there is no consensus about a single method to be applied.

There are four main ways to compensate carbon emissions:

First one is to produce more renewable energy with zero carbon emissions and export the clean energy outside the area boundaries. This allows other regions to use zero carbon energy in their consumption.

Second method of carbon emission compensation is to use existing or create new carbon sinks. They are usually natural systems that store carbon dioxide from the atmosphare. The biggest carbon sinks on our planet are plants, ocean and soil. The world's ocean and soil sinks about half of the carbon dioxide produced by humans. Deforestration has a big negative effect on the carbon sink. (Science News, 2007), (National Geographic ).

Third option is carbon capture and storage (CCS) method. It is a way to capture carbon dioxide before it is released into the atmosphere. This can achieve up to 90% efficiency and the main areas this method can be used in are industries that burn fossil fuels and other production types such as cement production. (The London School of Economics and Political Science, 2018)

Natural soil can also be used to artificially inject carbon dioxide into the ground, this method is called geological storage. Main areas to implement this method are declining oil fields, aquifers and unminable coal seams. (The National Academies of Sciences, 2019)

Fourth method of carbon emissions compensation is to purchase carbon offsets. This can be the easiest way to strive for carbon neutrality in countries that do not have vast landmass or forests to act as carbon sinks. Carbon offset invest the money mainly into forest planting programmes and other types of carbon sink generating systems. Individuals can also purchase the offsets, for example for a travel flight to reduce their carbon footprint. Kelley Kizzier, an expert in carbon markets at the Environmental Defense Fund, also mentions that there are a lot of questionable offsets on the market. "For example, if you were to pay someone to preserve a forest, it would count as an offset if that forest had originally been scheduled for development. A landowner in need of money from the timber would then be instead paid to keep their trees standing. If there was never a threat to the forest, your payment to the landowner wouldn't count as an offset because your money provides no additional benefit—the forest would have remained regardless." (Gibbens, 2019)

There are two main approaches: in territorial approach, all the direct GHG emissions caused within the boundaries of the target area are accounted. In consumption-based approach, all the emissions caused by the production of goods and services are allocated to the consumer. In the latter, the emissions may be caused also outside the target area boundaries. Today, the cities seem to apply mixed approaches and methodologies. (Global Protocol for Community-Scale Greenhouse Gas Emission Inventories, 2014)

On a city scale, the GHG quanitifaction methods are not harmonized.

The image 4 shows the typical emission sectors applied in a community-scale greenhouse gas emission quantification. The biggest sectors of GHG emissions quantifications are stationary energy, transportation, waste, industrial processes and product use and agriculture, forestry, and land use. (Global Protocol for Community-Scale Greenhouse Gas Emission Inventories, 2014)

| Sectors and sub-sectors |
|---|
| **STATIONARY ENERGY** |
| Residential buildings |
| Commercial and institutional buildings and facilities |
| Manufacturing industries and construction |
| Energy industries |
| Agriculture, forestry, and fishing activities |
| Non-specified sources |
| Fugitive emissions from mining, processing, storage, and transportation of coal |
| Fugitive emissions from oil and natural gas systems |
| **TRANSPORTATION** |
| On-road |
| Railways |
| Waterborne navigation |
| Aviation |
| Off-road |
| **WASTE** |
| Solid waste disposal |
| Biological treatment of waste |
| Incineration and open burning |
| Wastewater treatment and discharge |
| **INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)** |
| Industrial processes |
| Product use |
| **AGRICULTURE, FORESTRY, AND LAND USE (AFOLU)** |
| Livestock |
| Land |
| Other agriculture |
| **OTHER SCOPE 3** |

Image 4 Sectors and sub-sectors of city GHG emissions. From global prtocol for community-scale greenhouse gas emission inventories summary

The emissions sectors are devided into scopes that help identify the origins of the emissions. The scopes are divided as shown on image 5.

| Scope | Definition |
|---|---|
| Scope 1 | GHG emissions from sources located within the city boundary |
| Scope 2 | GHG emissions occurring as a consequence of the use of grid-supplied electricity, heat, steam and/or cooling within the city boundary |
| Scope 3 | All other GHG emissions that occur outside the city boundary as a result of activities taking places within the city boundary |

Image 5 Scopes definitions. From global prtocol for community-scale greenhouse gas emission inventories summary

Image 6 shows the main emissions factors divided into scopes 1, 2 and 3.

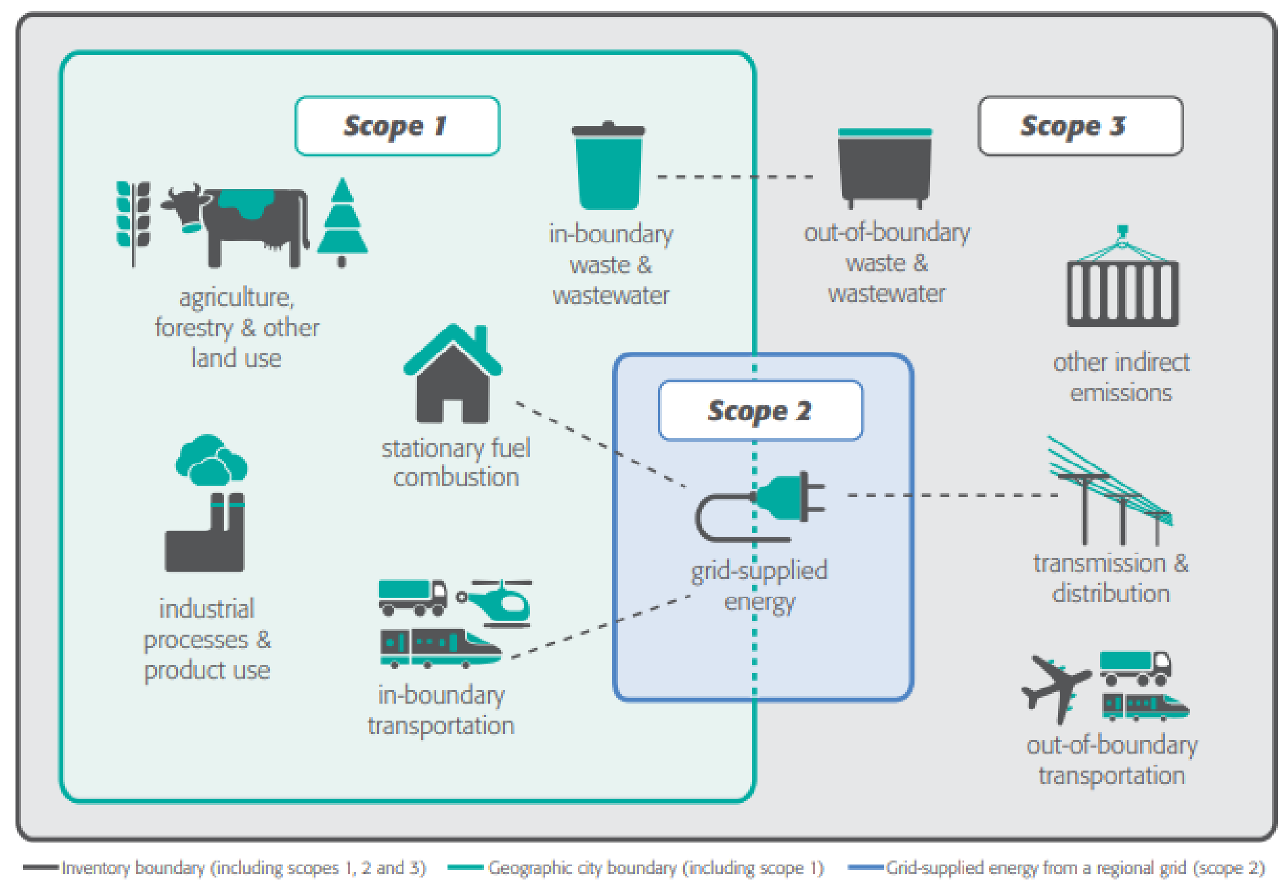


Image 6 GHG emissions sources and boundaries. From global protocol for community-scale greenhouse gas emission inventories summary

The most important sectors of $CO_2$ emissions are energy use, agriculture, forestry and land use, industry and waste as shown on image 7. (Ritchie & Roser, 2020)

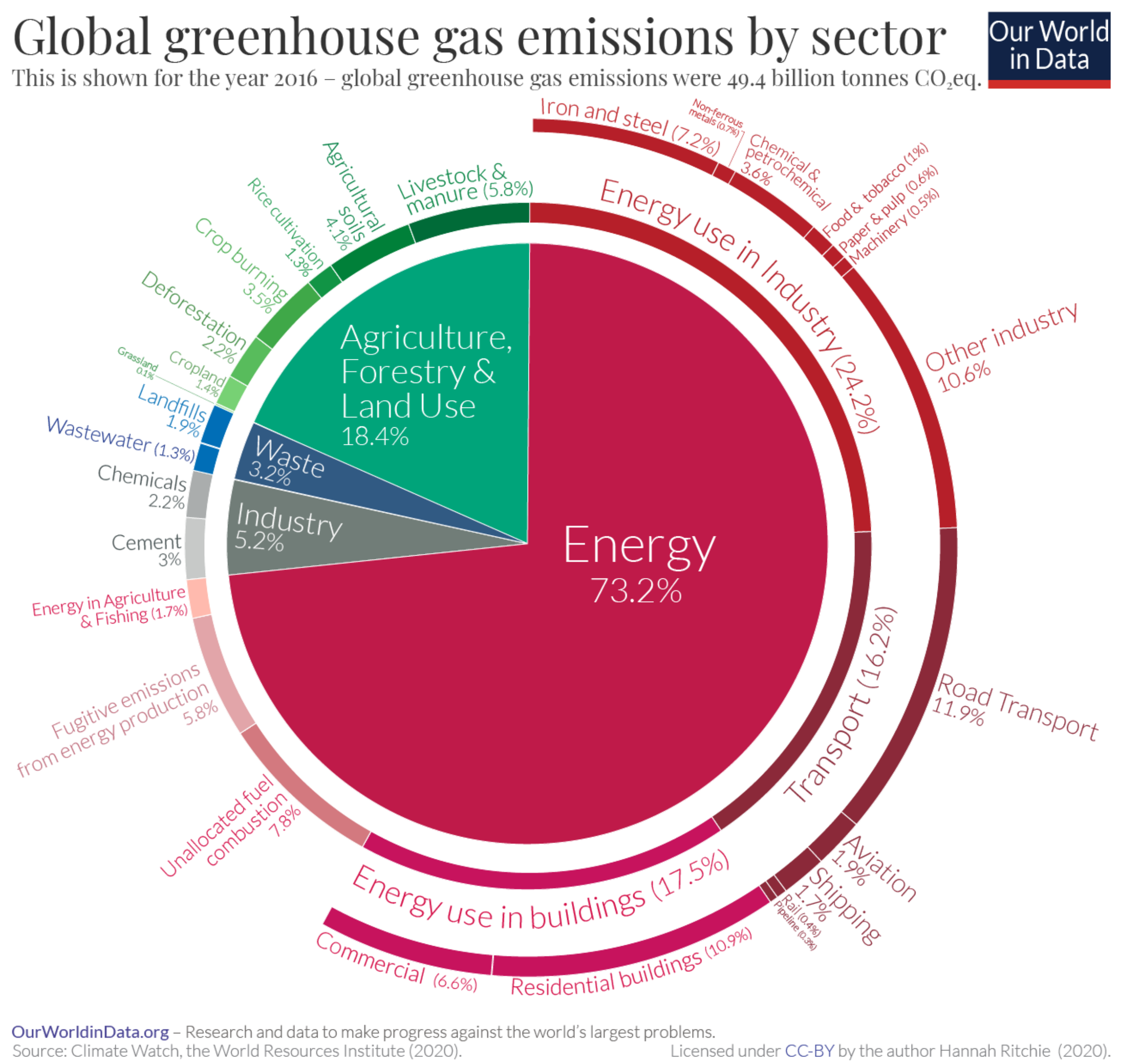


Image 7 Global GHG emissions by sector. From Our World in Data.

# 4 CARBON NEUTRALITY AS TARGET FOR THE CITY OF TALLINN

## 4.1 Estonian perspective

Today, part of the Estonian electricity grid is connected to the east and with Russia and Latvia (furthermore with Belarus and Lithuania), and other part is connected to the west and north with Finland (furthermore with Sweden and Denmark). (Elering)

"The Estonian electricity system is part of the large synchronous operational united system BRELL, which comprises the AC power lines that connect Estonia with the neighbouring countries of Latvia and Russia and their neighbours Lithuania and Belarus." (Elering)

The country is known for it's energy consumption to be largly based on oil shale. Eesti Energia has lately invested much into renewable energy sources but due to Russia's competitive energy export, the import energy from Belarus (that imports it's energy from Russia) has grown in the last years. The sources of this energy are mainly gas, coal, nuclear and partly unknown. (Statistikaamet, n.d.) (ERR News, 2019)

With the population of 1,32 million as of 2018, Estonia's energy consumption was 8,5 TWh, 6394 kWh per capita. In 2019, $CO_2$ emissions made up 9.65 $tCO_2$/capita a year and 1,159 kt of oil shale was produced. (Statistikaamet, 2021) (Statistikaamet, n.d.)

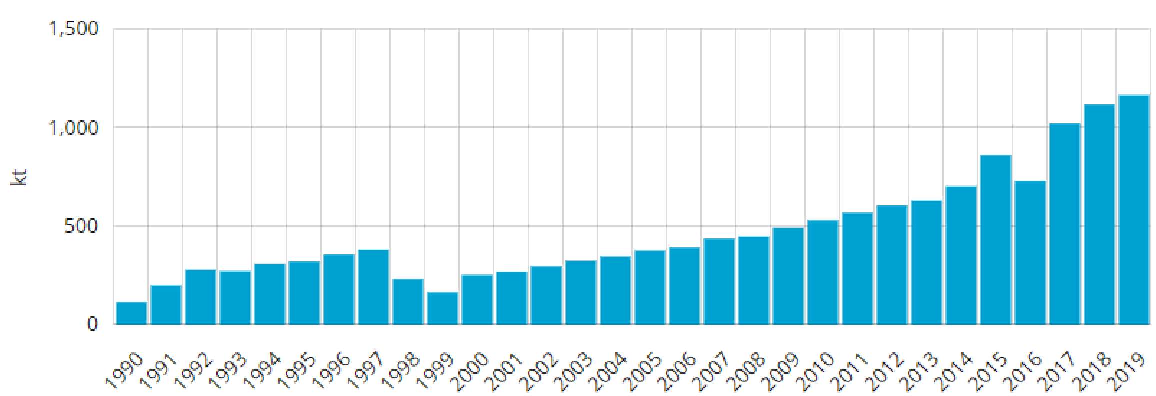


Image 8 Chart of Estonia's crude oil production. Source: Enerdata.net

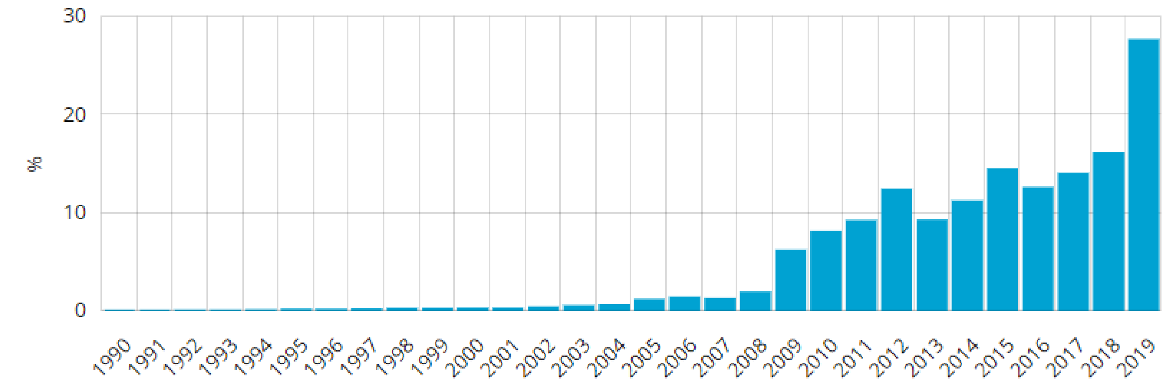


Image 9 Renewable energy percentage (27,6% in 2019). Source: Enerdata.net

As seen on the previous chart, the renewable energy share in Estonia has grown rapidly in 2019.

The long term plan for Estonia is to reduce emissions by 80% for 2050. According to Eionet Report ETC/ACM 2018/12, Estonia is about to miss it's 2030 mid-term checkpoint of reducing emissions. However, 2040 and 2050 targets still seem within reach. (Eionet Portal, 2018)

Estonia joined the Organisation for Economic Co-operation and Development (OECD) in 2010. It's statistics from 2000-2018 show that Estonia's GHG emissions have not decreased significantly. (OECD, 2017)

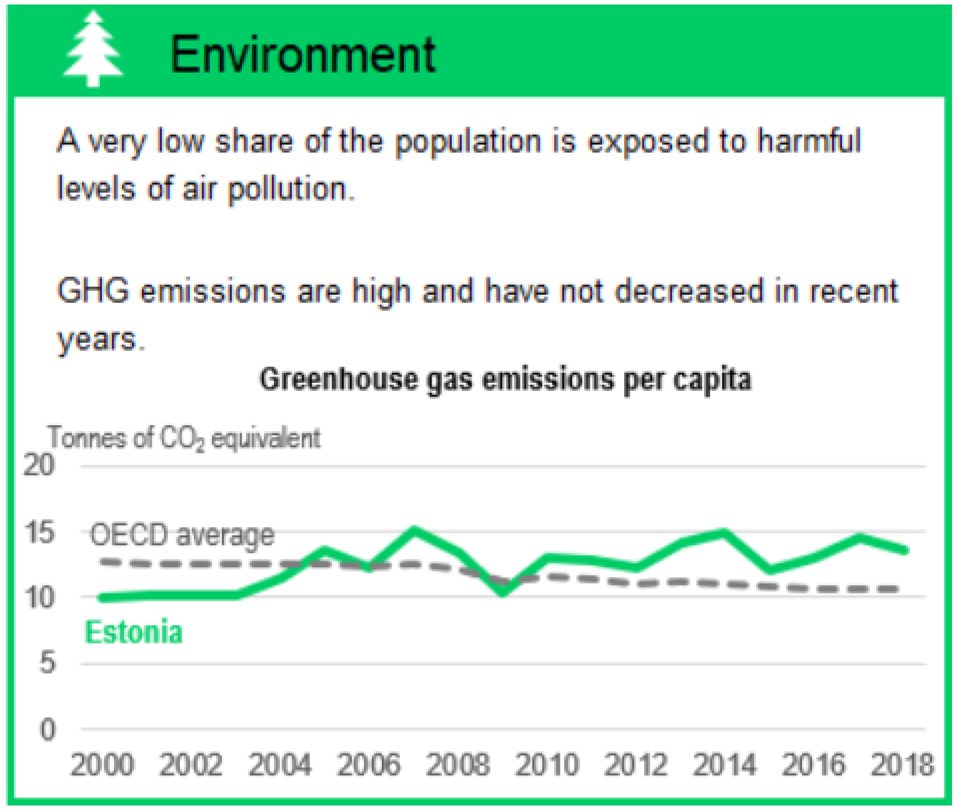


Image 10 Estonia's GHG emissions in 2000-2018, OECD report, 2021

Because of the oil shale that is used to produce electricity in Estonia, the country has the highest $CO_2$ emissions in OECD listed countries. Regarding hazardous waste, Estonia produces 35 times the EU avarage, mostly from oil shale production. Because of that, people from Ida-Viru region suffer high rates of respiratory disorders. (OECD, 2017)

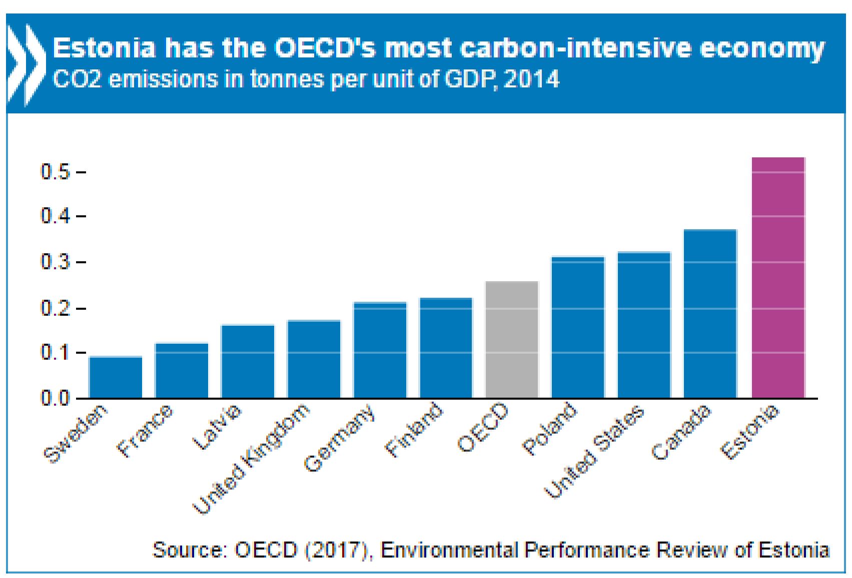


Image 11 Estonia's $CO_2$ emissions in tonnes per unit of GDP 2014, OECD report, 2021

OECD review has the following suggestions for Estonia:

1. Develop and implement specific climate change mitigation measures in order to achieve Estonia's GHG reduction goals for 2030 and 2050
2. Lower emission intensity by tapping into European electricity markets, using more renewables in place of oil shale for energy generation, and increasing energy efficiency
3. Ensure that any diversification away from shale oil is socially responsible, with retraining, employment promotion and social guarantees for affected oil shale workers
4. Strengthen measures to reduce emissions of SOx, NOx and NH3 from the industrial power generation sector, transport and agriculture
5. Strengthen eco-innovation by raising firms' (and particularly SMEs') awareness of options for financial support and simplifying the application process. (OECD, 2017)

Stockholm Environment Institute (SEI) made a publication about the steps needed to be taken by Estonia to achieve climate neutrality by 2050. The report concludes that the goal for 2050 is feasable and profitable if taking into account the economic savings of health and environmental benefits. The SEI report named the following more important steps for The Government Office of Estonia:

- "Estonia should make significant, near-term investments in broadscale energy efficiency initiatives to increase energy productivity and cost effectiveness. The report outlines an array of specific efficiency measures for the buildings, industry and transport sectors.
- Estonia must decarbonize its energy supply, and shift away from its reliance on oil shale. To ensure a just transition, new investments are needed to support and scale wind, solar and local bioresources. Meanwhile the country must explore and incubate innovation in hydrogen and carbon capture utilization and storage technologies. Decarbonization processes must take place in the transport sector, which lags behind the progress levels achieved in electricity and heat sectors.
- Estonia should leverage favourable natural assets for carbon sequestration in the land use, land-use change and forestry (LULUCF) sector. Peat soil restoration, afforestation and strategic forest management present such opportunities.
- The pace, scale and ambition of green investments must increase.
- Government must establish a clear action plan that focuses on creating favourable regulatory and financial frameworks to spur private investments that can underpin change. The government should put in place supportive economic, educational, social and business innovation policies to make sure that a just and positive transition takes place in all regions, including the oil-shale dependant North-East Estonia." (Stockholm Environment Institute, 2020)

In 2020, Estonia and Latvia signed a joint development of an offshore wind farm the the Gulf of Riga. The capacity of the farm will be 1000 MW and will be built for 2030. In total the wind farm will produce about 40% of Estonia's annual electricity consumption. (Insitute for Energy Economics and Financial Analysis, 2020)

## 4.2 Climate strategies of Tallinn

Tallinn has proposed a plan to achieve carbon neutrality in „Tallinn Sustainable Energy and Climate Action Plan (SECAP) 2030". The plan does not include detailed description of how carbon neutrality can be achieved for the year 2050 but it has a mid-term plan to achieve part of it for 2030. (Tallinn City, 2021)

On 31.03.2021 Tallinn unveiled Climate Strategy plan for 2050. The aim is to reduce the urban and economic impact on the climate and to enrich the economy and urban environment at the same time. It does not only show the intentions of the City of Tallinn but also the Country of Estonia's, private sectors' and residents'. (Tallinn City, 2021)

The strategy specifies „Tallinn 3035" plan, aims to reduce GHG emissions by 40% for 2030 and plans actions to better adapt to the changes and risks proposed by climate change. The plan also sets the objective of developing a model for community renewable energy cooperatives, promoting cycling, public transport and energy efficiency. Tallinn plans to expand it's district heating system, develop a cooling network and implement the principles of the circular economy and biodiversity. 40% reductionof carbon emissions are planned for 2030 and climate neutrality for 2050. (Tallinn City, 2021)

In detail, the implemented "Climate neutral Tallinn" strategy would bring the following changes into the city:

"• *Approximately 50,000 plug-in hybrid, electric and hydrogen vehicles are in use. Infrastructure has been set up for recharging batteries and refueling with hydrogen fuel, including the possibility for apartment associations to set up charging stations near their homes.*

• *The use of non-fossil fuels in public transport has been completely switched.*

• *An uninterrupted and standard network of cycle paths covering the entire city has been built and can be used throughout the year.*

• *The construction and reconstruction of buildings uses factory-produced modules and elements that enable faster and more energy-efficient reconstruction of buildings. In addition, widely used recycled materials (eg insulation and finishing materials made from plastic and textile waste) are used. The buildings have been made climate-resistant to both heat waves and floods. By 2030, at least 25% of Tallinn's apartment buildings have been reconstructed.*

• *District heating areas have been expanded and integrated with district cooling. The district heating cooling network has been renovated to be energy efficient and new efficient district cooling networks have been built.*

• *Residents of Tallinn have the opportunity to participate in cooperative energy production.*

• *Hydrogen energy solutions are being tested in buildings. Climate-neutral cooling solutions for buildings have been created to cope with heat waves.*

• *The circular economy will be promoted. Only waste that is not suitable for recycling is incinerated in thermal and power plants.*

• *The city's green network is connected. It provides both natural diversity and diverse mobility opportunities. This will also improve the health of the citizens.*

• *The blue network is developed in the city - nature-based solutions are used in the restoration of watercourses, rainwater is used as a resource in both buildings and landscaping. Drinking water is of high quality and available in public urban areas.*

• *Risks due to climate change (heat waves, floods caused by rainwater and storms, fires, pathogens) are mitigated and the population can cope with them."* (Tallinn City, 2021)

The cost of implementing these changes for the year 2030 is *ca* 1,5 billion euros.

The next chart shows the continuing trend of GHG emissions in Tallinn and compares it to the plan's goals for 2030.

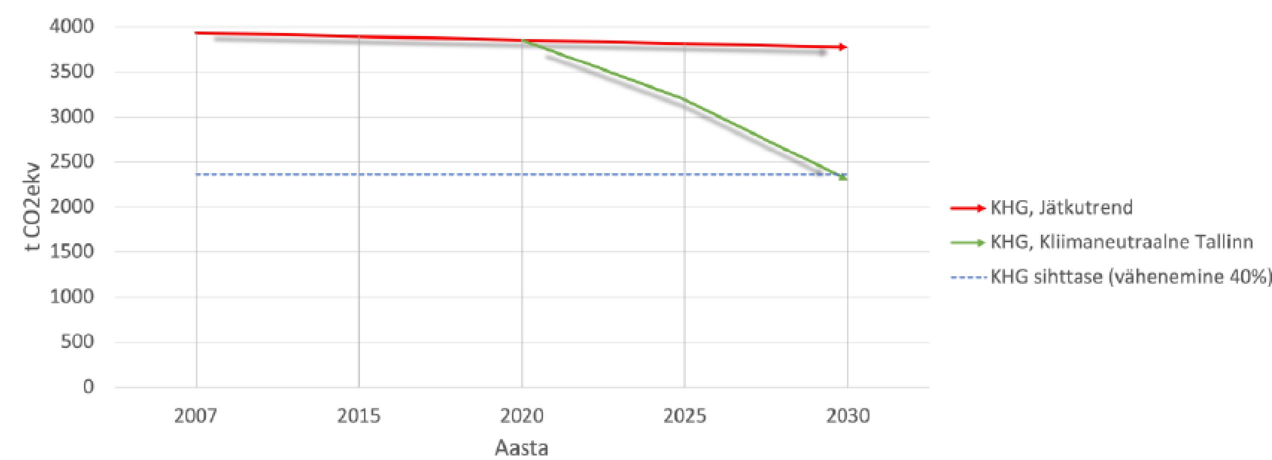


Image 12 Continuing trend of GHG emissions in Tallinn (from "Climate neutral Tallinn" plan)

# 5 CARBON NEUTRAL KOPLI DISTRICT IN TALLINN

## 5.1 Site

### 5.1.1 Site analysis

Kopli peninsula is located in the northern part of Tallinn. It is surrounded by the Baltic sea in three corners and connected to mainland Tallinn via south. The site is approximately 6 kilometers from Tallinn city center.


Image 13 Tallin City map with indicated Kopli planning area

The location makes it quite isolated from Tallinn, while still keeping the connection from south-east. That can be used to introduce more radical transportation and traffic solution for example, since it does not interfere and depend on  the rest of the city so much.


Image 14 Indicated Kopli planning area

The chosen planning site is situated between the tip of the peninsula and Estonian Maritime Academy. Today, the area contains mostly BLRT ship building company, Estonian Maritime Academy and the tip of the peninsula holds national security land with partly demolished building. Paljassaare's water purification plant is situated east of the planning area and the planned buildings are not considered in it's protection area.

About 0,58 km2 of the target area is occupied by BLRT ship building and repair factory and it's secondary buildings. About 17 of these buildings are large scale industrial hangars, storage facilities or similar type of structures. There are also some office buildings. There are 24 silo structures on the northern tip of the peninsula.


Image 15 Planning area existing buildings and plot boundaries (From maa-amet portal)

Image 16 Aerial view of the planning area (From maa-amet portal)

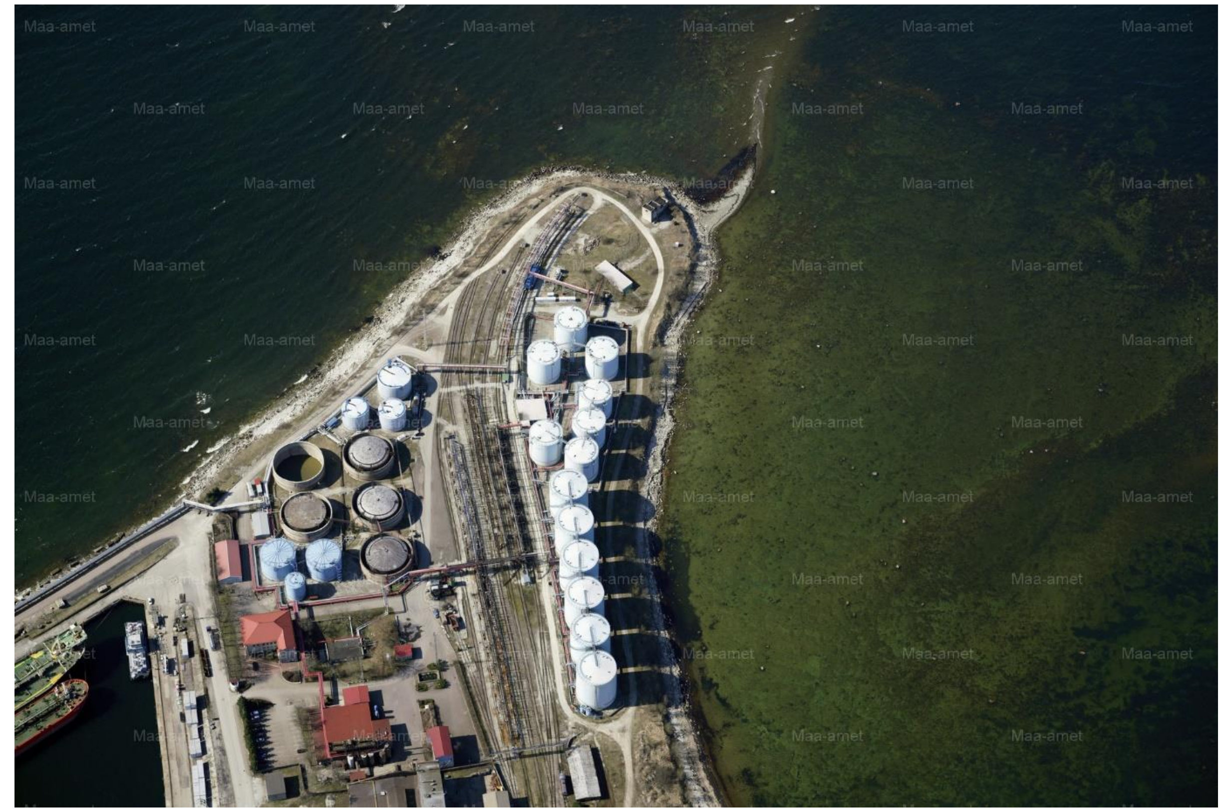

Image 17 Aerial photo of the silos on the tip of the peninsula (From maa-amet portal)

The planning area is mostly flat with natural shoreline in the north and man-made harbour area in the south and west. The land rises from north to south, peaking at around 10m from seal level. It also rises furthermore indland and reaches 12,5m at the Estonian Maritime Academy. Overall it is a very gentle change in land heights. The land use type is industrial.

Buildings surrounding the planning area are mostly industrial and residential. There are five different ports near the planning area to the southeast: Süsta, Ketta, Bekkeri, Piirivalve and Meeruse. North of the Süsta port, there are some smaller scale industrial and warehouse buildings. On Süsta and Ketta street there are old residential apartment buildings. On the eastern side of the planning area and next to Estonian Maritime Academy there is the Süsta park. Northeast of the park there is the Church of St. Nicholas and a car workshop. Situated north and east of the church, there are Kopli lines with four Liini streets. These streets have similar residential houses that are of historic value. The area is in constant development and expansion. South of Kopli lines there is Kopli Birch Park.


Image 18 Planning area contact zone (From maa-amet portal)

KTA Bekkeri Port masterplan was published in 2020. It covers the Bekkeri Port area south of the planning area and proposes new residential and multifunctional buildings. The main concept includes the shoreline and industrial heritage of the site. The project also plans to renovate old industrial buildings and bring them to a new life. It also indicates a very special building on the shoreline, a high-rise building more inland, a port for yachts and boats, small residential buildings and bigger apartment buildings. The area will be more connected to the city in the future with a developing tram line.

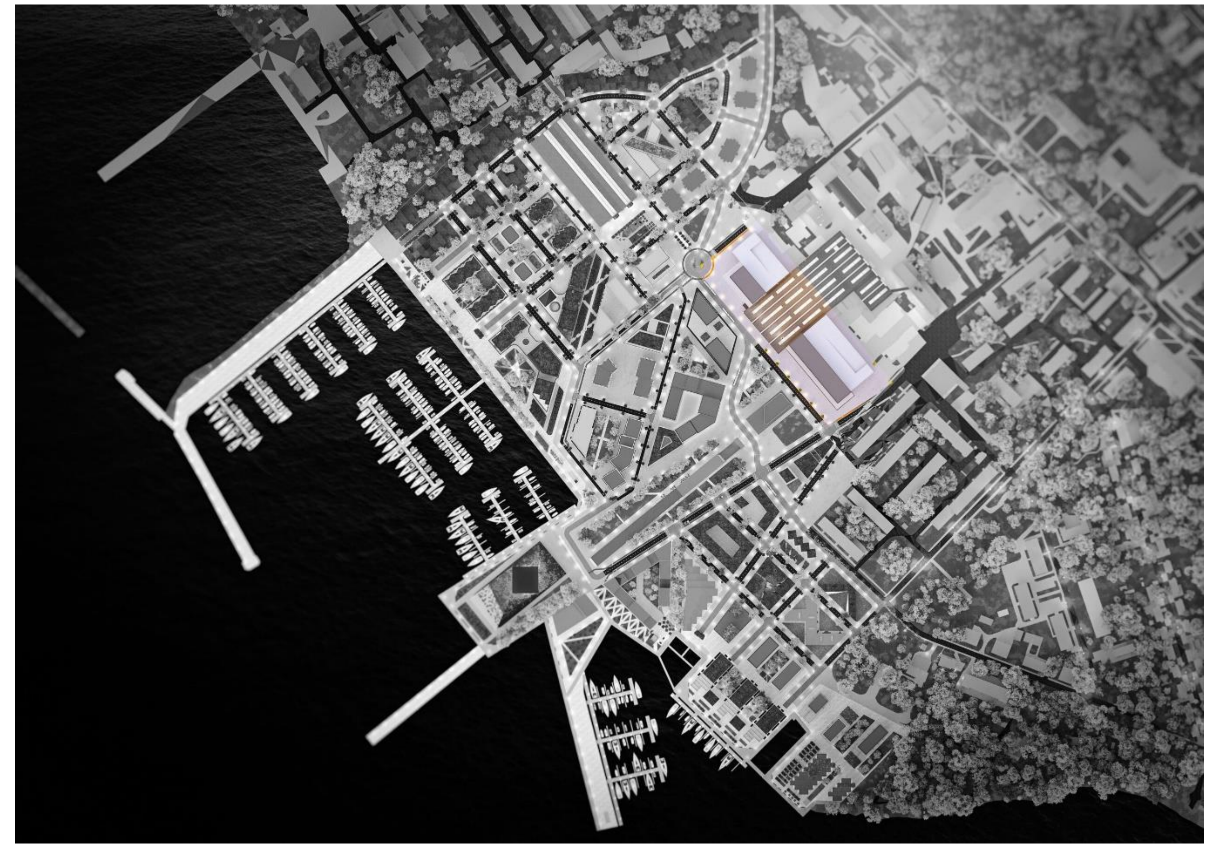

Image 19 KTA (Kadarik, Tüür. Architects) Bekkeri Port masterplan (From kta.ee)

Image 20 KTA (Kadarik, Tüür. Architects) Bekkeri Port masterplan (From kta.ee)

The planning area is connected with the railway from Paljassaare, Hundipea and Telliskivi. Railway network main connection is from the east and the rails head over to the northern tip of Kopli peninsula. They also connect the southern port area.


Image 21 Railway network in Kopli (From maa-amet portal)

At the moment, the area holds no green network and is mostly industrial wasteland. On the eastern side of planning area there are some trees and green patches but they do not seem to be maintained and serviced. Süsta park, situated on the east side outside the planning area, is the biggest greenery near the peninsula. The second greenery near the area is Kopli Birch Park futher east.

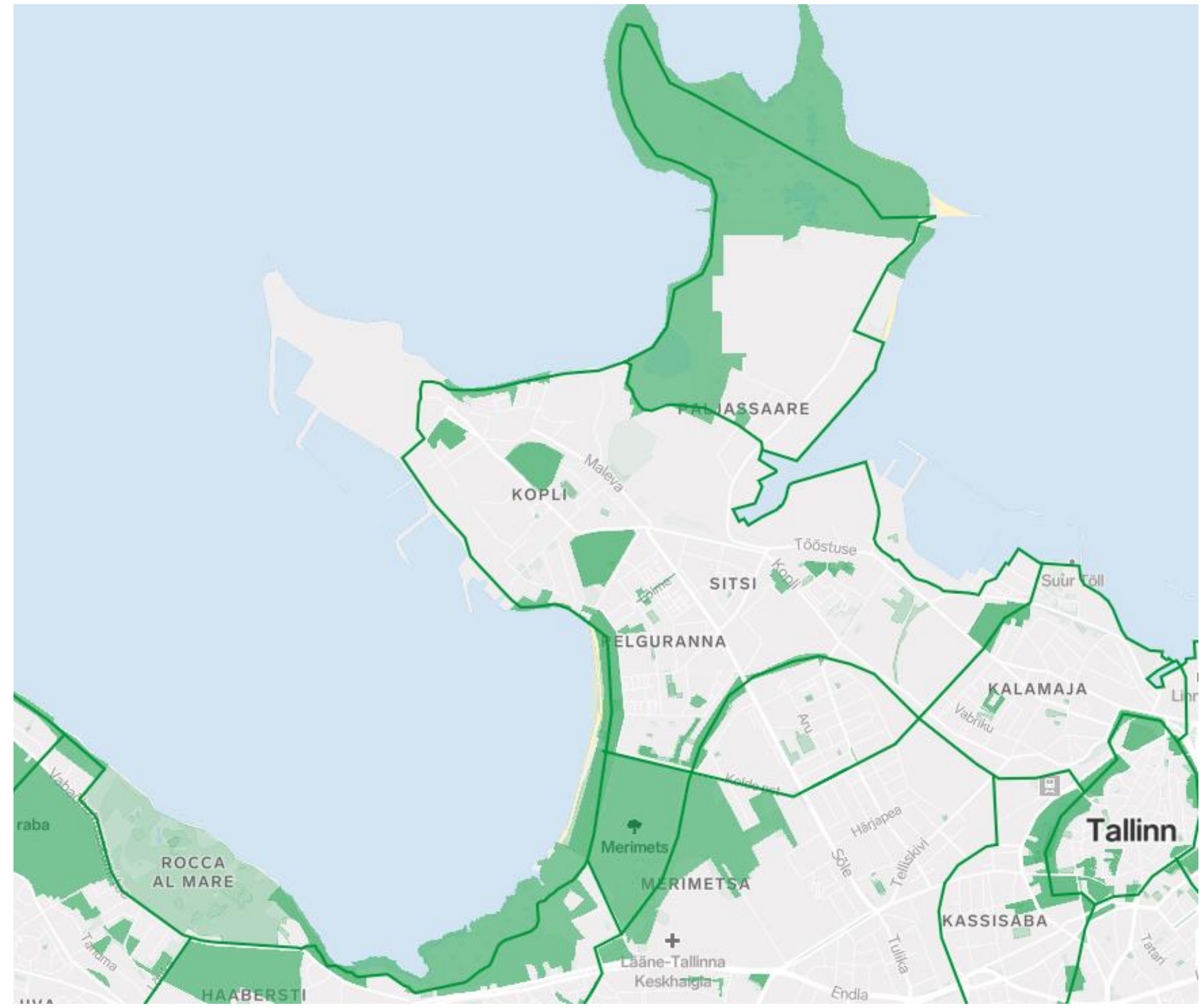


Image 22 Tallinn green connections map. (From tallinn.ee green network).

There are no existing biking or pedestrian routes on the planning area itself because it is closed to the public. Perspective pedestrian and bicycle connections can be constructed from north-east and south-east where the city of Tallinn has proposed a green connection to the area as shown on the previous scheme 14. A central biking route can also be constructed from the Kopli road and Süsta park. At the moment, this is the only connection to the site for cars and pedestrians. There is also a tram stop and a bus stop next to Süsta park.

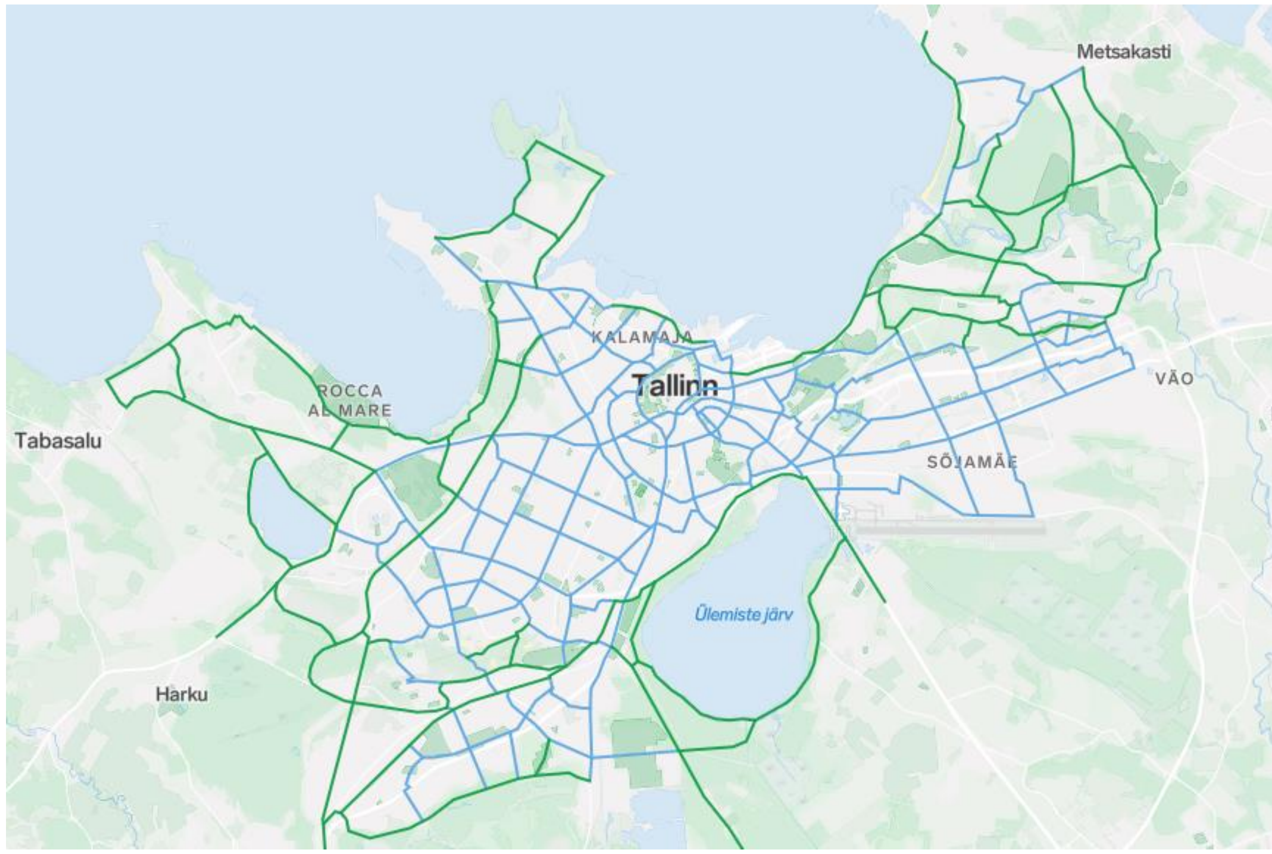


Image 23 Tallinn's planned bicycle routes. (From tallinn.ee "life in fresh air")

There is no major flooding danger on the planning area. The areas considered as flooding risk are next to the planning area on the north-eastern coastline and souh-eastern coastline. The planning area itself has man-made docks on the western side that are raised from the sea level. The northern shoreline is naturaly raised from the sea level exept for a smaller part of land.


Image 24 Flooding areas. (From maa-amet portal)

Dominating winds around the planning area are from southwest but can also blow from the south, west and northeast. (National Weather Forecast of Estonia, n.d.) (Global Wind Atlas, 2021)

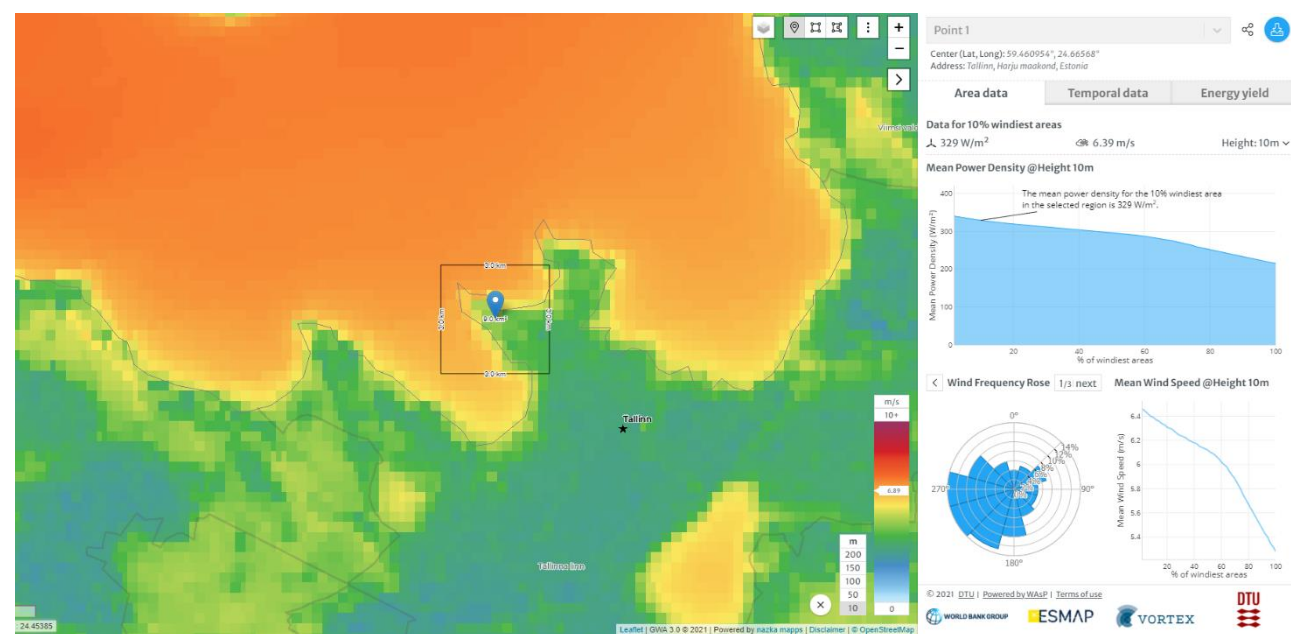


Image 25 Screenshot from Global Wind Atlas showing avarage wind speed and direction

At some situations, the winds blow the smell of ammonia and oils stored in the northern silos to the residential areas. The residents have even made a social media page about it called "Kopli poolsaar puhtaks" (Clean Kopli peninsula) on Facebook. (Kopli poolsaar puhtaks, n.d.)

The planning area has a high chance of being damaged by storms as analysed by Tallinn's sustainable energy economy and climate change adaptation plan. The solutions can be proposed by keeping the areas green for water absorbtion, creating building exclusion zones, planning more green areas and fortifying the coastline from heavy waves. (Tallinn City, 2021)

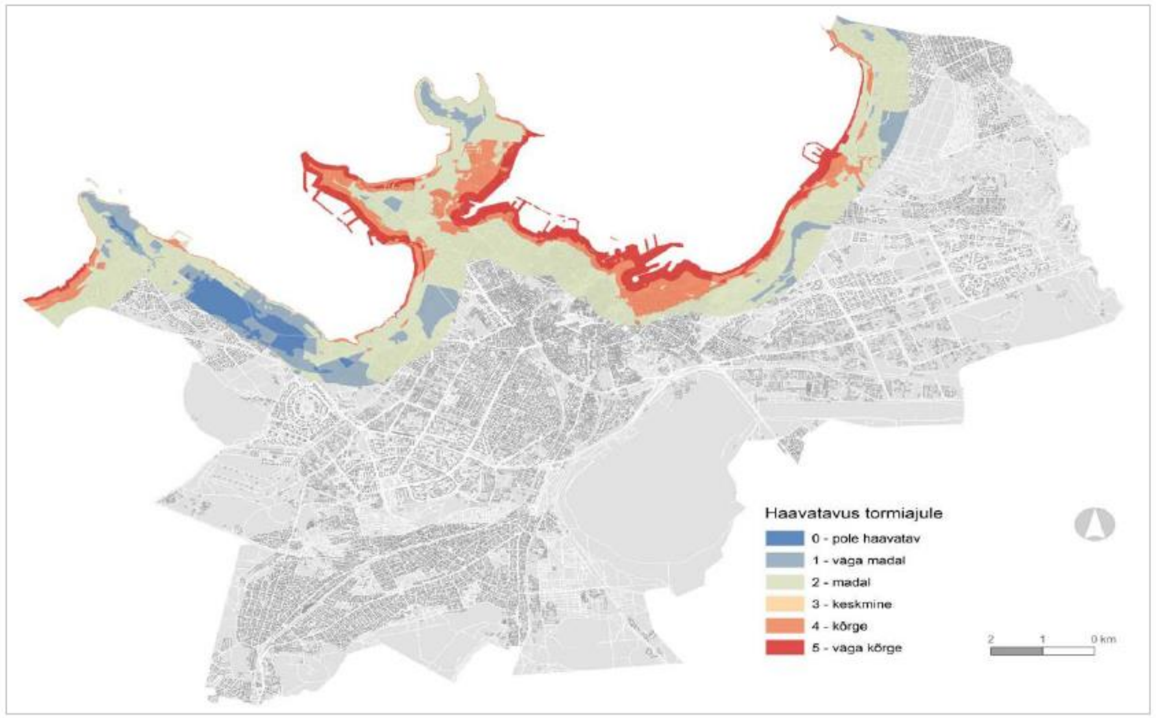


Image 26 Tallinn's flooding areas and their vulnerability to storms. (From Tallinn's sustainable energy economy and climate change adaptation plan, 2021)

Tallinn City has analysed the walking distance from schools. The planning area is not included on the map as yellow, that means it is longer than a 10 minute walk to nearest school. Since the area does not include residential or school buildings, a new school could be proposed in the planning process.

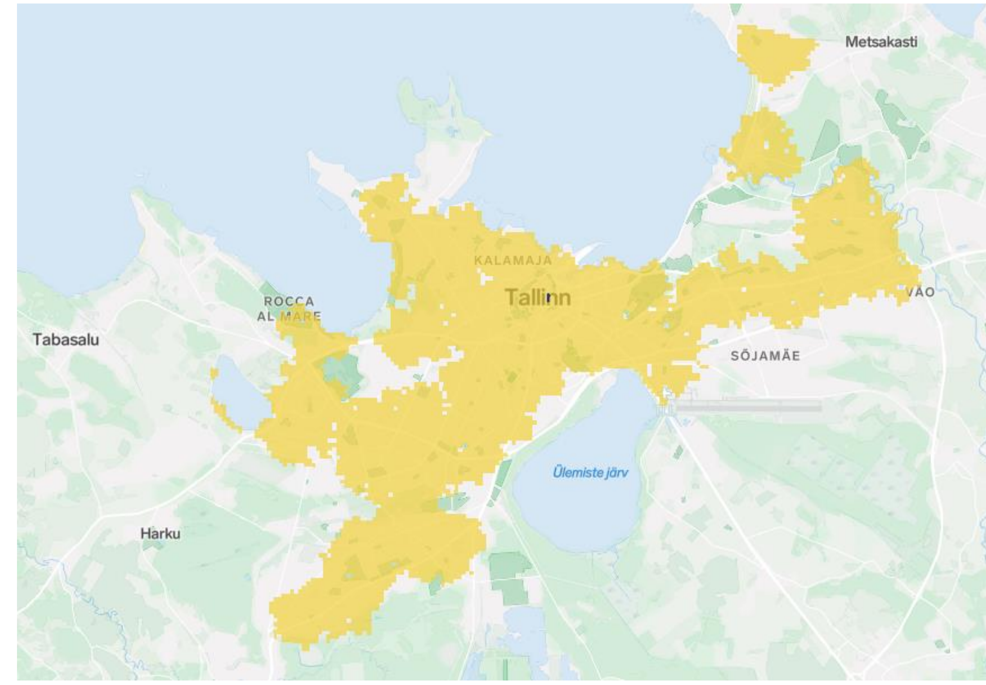


Image 27 Tallinn's 10 minute walk distance from schools. From tallinn.ee "creative world"

City centers scopes have also been analysed on Tallinn City web site. The following image shows the scopes of different centers in Tallinn. The nearest center is considered on the border of Kopli area, at the end of Sõle street. A further connection of centers could be proposed to the north-west.

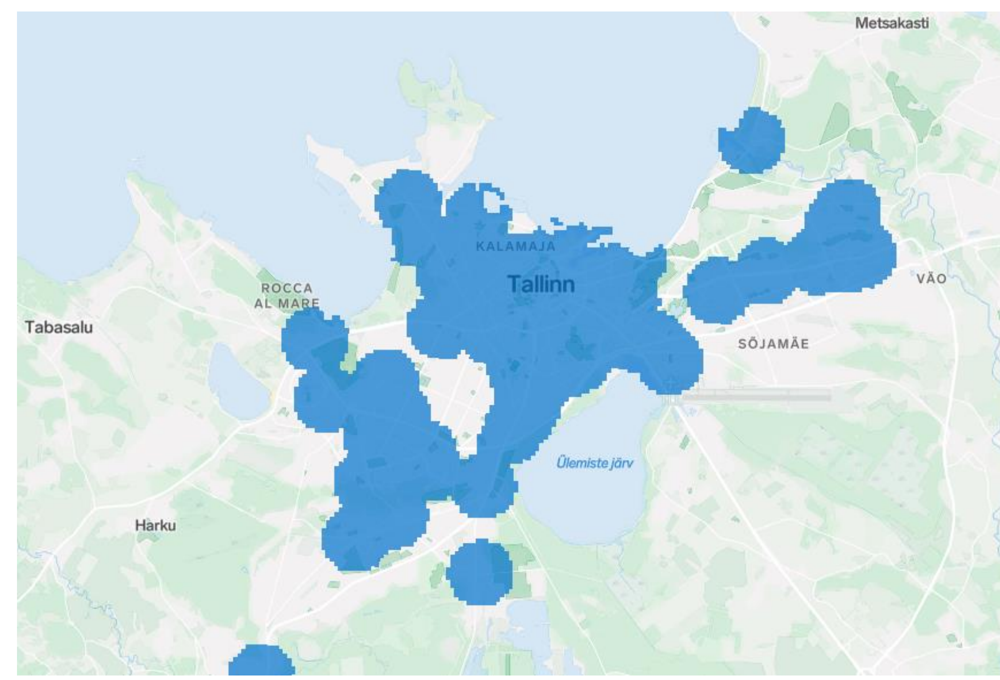


Image 28 Tallinn's centers scopes. From tallinn.ee "15-minute city"

### 5.1.2 History

In the Middle Ages Kopli district was one of the biggest pastures near Tallinn. Before the industries and harbours were built, there was an oak forest located on the tip of the Kopli peninsula. (Juske, 2015)


Image 29 Extract from „Maa-ameti geoportaal" map. Historic Estonian map "1895-1918"

In 1909, after the defeat of Imperial Russian Navy, the Russian Empire decided to build a new military harbour, sea fortress, shipyard and navy ships. The decision took effect by law on 8. December 1911 when Tallinn was nominated for this shipyard's base city. The Vene-Balti Shipyard was officially opened on 31. May 1913. The shipyard built cruisers, light cruisers, minesweepers, trawlers, artilery boats and submarines. The tram line for Kopli was opened in 1915. (Juske, 2015)

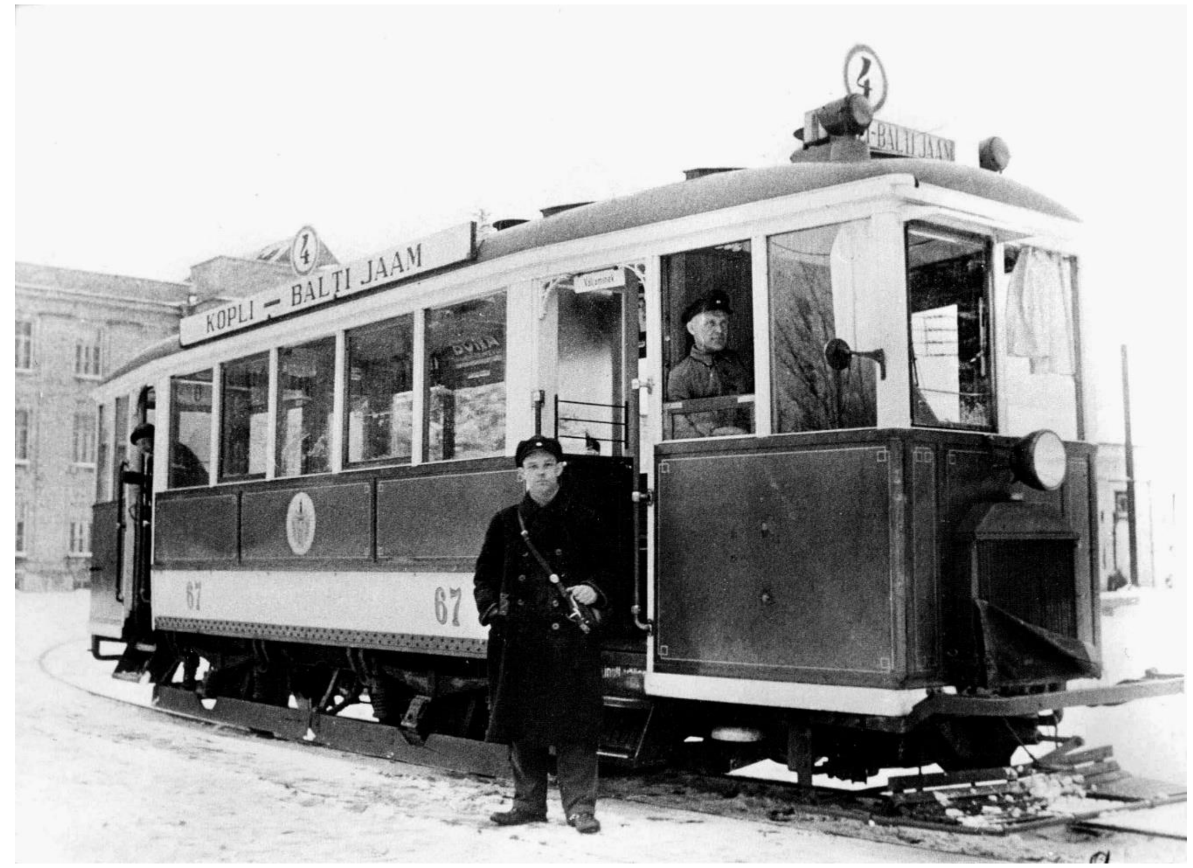


Image 30 New motor-tram No. 67 in Kopli's last stop ca. 1933. Picture from „History of Tallinn's public transport" website.

Kopli peninsula's shipyard area was closed to public and separated from Tallinn with the main administrative building. New living quarters for workers, specialists and directors were built around the shipyard. (Juske, 2015)

Image 31 Russian-Baltic Port's administrative building in 1930. Source: Eesti Ekspress 10.06.2015 article "Tallinna ja Tartu sõda tehnikaülikooli pärast"

The area also had all the functions nessecery: hospital, canteen, grocery store, society house, school, church, police station, post office, fire brigade station, cinema and sauna. This area became known as „Kopli Liinid" later in 1951. (Juske, 2015)

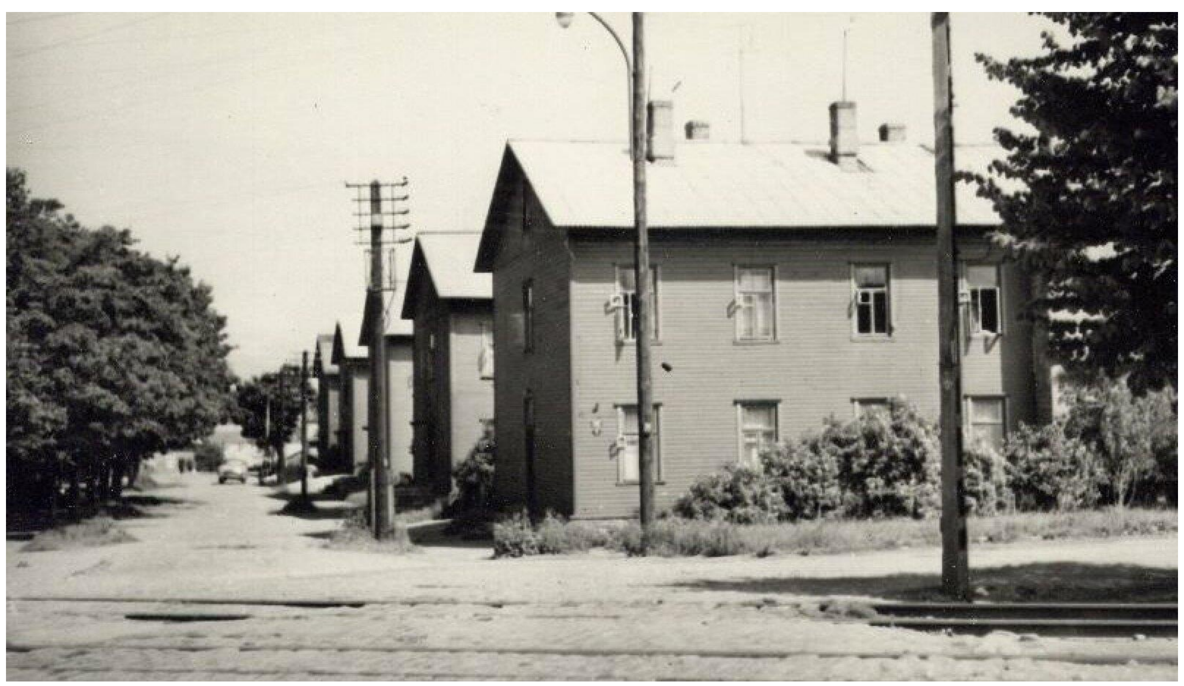

Image 32 "Kopli liinid" in Soviet Russia's occupation times, year unknown. Source: Delfi news portal article 16.06.2016 "Jaak Juskega kadunud Eestit avastamas: Kopli liinide käänuline ja mitme näoga ajalugu"

In 1917 most of the Russian skilled workers left the area due to the political situation. At the time of Estonian War of Independance the houses were half-empty and they were later used as medical centers. There was an outbreak of illnesses that lead the area to be quarantined. After the war, the area housed war refugees and the people who were left homeless. At the time of first Estonian Republic the shipyard's name was changed to Anglo-Baltic Shipbuilding Engineering Company's Committee for Estonia. At that time the shipyard held the country's grain stock. (Juske, 2015)

In 1930 the shipyard's administrative building was taken over by Tallinn University of Technology and the professors were housed in the shipyard's directors buildings. That area became known as Professorite küla (Professor's village). (Juske, 2015)

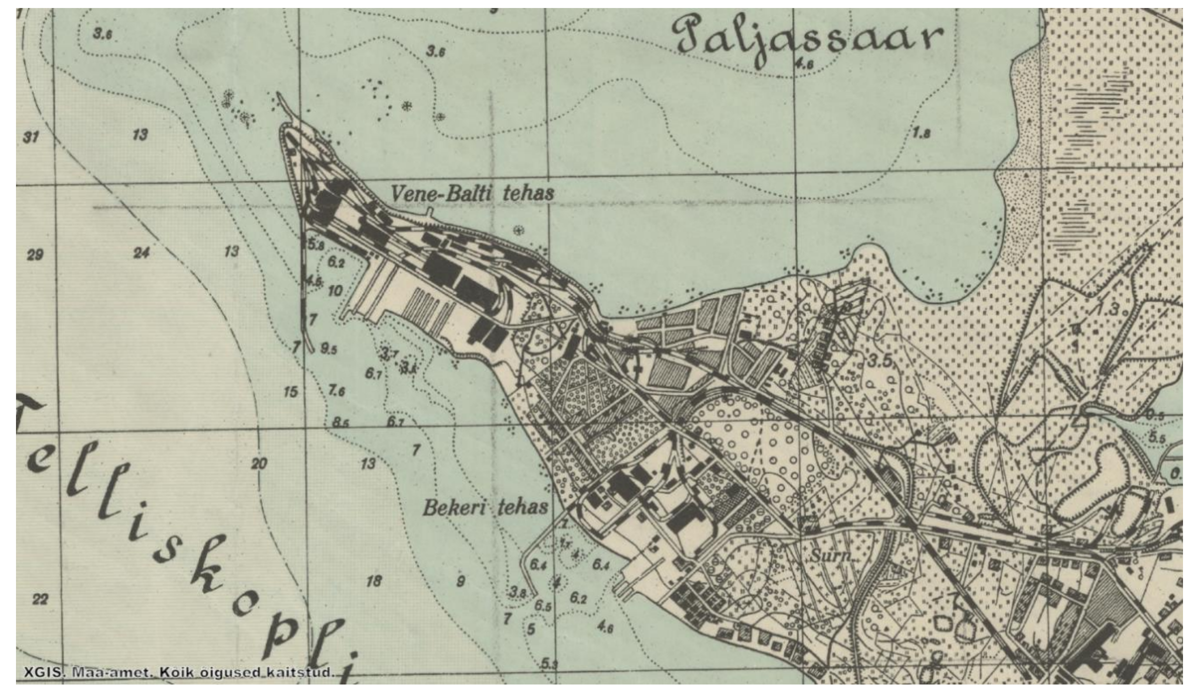


Image 33 Extract from „Maa-ameti geoportaal" map. Historic Estonian map "EV topo 25T; 1923-1935"

In 1934 there was a fire in an hangar that was used as a canteen and a church. The new church, named St. Nicholas Church in Tallinn, was built in 1936. (Juske, 2015)

Image 34 St. Nicholas Church in Kopli, photo taken 24.09.2020. Source: register of cultural monuments.

After the Second World War the shipyard was re-opened by the Soviet Union and was officially named „Factory No. 890". It started fixing the navy's ships in 1948. In 1960, after the navy ships had been fixed, the shipyard started working on fishing trawlers and that became it's main purpose for the next 30 years. In 1990 the shipyard started working on tankers, passanger ships and cargo ships. The trolleybus line to the old administrative building was opened in 1987. (Juske, 2015)

In the times of the Soviet Russia's occupation Kopli was known for crime and that reputation also spread to Põhja-Tallinn's district. Today Kopli is home for more and more young people. „Kopli liinid" houses were sold in 2015 to a private investor and in 2020 some of the restored and new apartment houses were built. (Juske, 2015)

In 2013 there was a gas explosion at the Baltic Ship Repair Factory's territory that killed one person, two were injured. (Veskioja, 2013)

### 5.1.3 Existing buildings and current use

Today, the site accommodates one of the biggest ship industry groups near the Baltic region. It provides ship building, ship repairs, real estate development, constructing metal systems and structures, mechanical engineering, transportation, equipment rental, port stevedoring service, industrial and medical gas production, scrap metal handling and casting. (BLRT, 2021)

Existing buildings on the target area are mainly industrial warehouses, offices, dock buildings and ship factory and repair buildings.

Existing land use use industrial brownfield. On the northern and southern sides of the area there are big piles of stored scrap, soil and gravel. There are also many different machines and ship industry related metal objects stored on the area. The parking areas for cars have created vast fields of asphalt.

Since the area is surrounded from three sides bt the Baltic Sea, there is a lot of coastal shoreline. Northern shoreline is natural, shaped by the sea and is mostly rocky. In the middle of the northern shoreline there is a section of a sandy shore. Southern coast is mostly man-made docks area with a variety of ship docks for smaller and larger vessles. There are two larger piers for ships and two ship housing vessles where repairs can be made.

Image 35 Aerial view of the planning area center (From maa-amet portal)

The planning area is connected to the rest of the city only from the east. The accessibility is by two entrances on both sides of the Marine Academy building.

Industrial area on this site made sense in the beginning of the previous century where it was disconnected from the rest of Tallinn with forests and grasslands. Today, the area is a very potential new development site. KTA architectural bureau has already proposed a new planning project to Bekkeri port that is next to the site covered with this project. Since Tallinn is expanding, this area could act as a local center in city plan. These industrial harbours could be located at such places like Muuga, where the area is already developed regarding these functions.

## 5.2 Planning principles and phasing

The concept of “The Route” comes from the means of city planning habits over the last 100 years and more when cars started to dominate our ways of life. With the invention of car in 1886 and the boom of industrial revolution, the city planning changed to accompany cars and to create easy traffic solutions for the vehicles. Since the cars grew bigger and started moving faster, the roads became more straight. That led the roads and streets of a city to become out of pedestrian scale.

This brings the idea of a pedestrian oriented city grid to Kopli. The streets of the planning area are wide enough to accompany emergency and service vehicles but are otherwise dimensioned for pedestrians and their movement. This creates interesting urban space with unexpected curves and buildings that can appear from behind the curves. The streets can hold more trees and greeneries since cars are no longer dominating the street network.

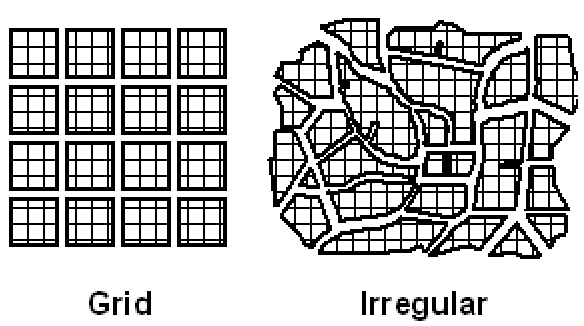


Image 36 Grid vs irregular city structure. Pinterest.es; Alvin Chua

To further enhance pedestrian and light traffic experience on the site, the following points of interests have been created. These act as movement or pedestrian comfort landmarks that can be identified.

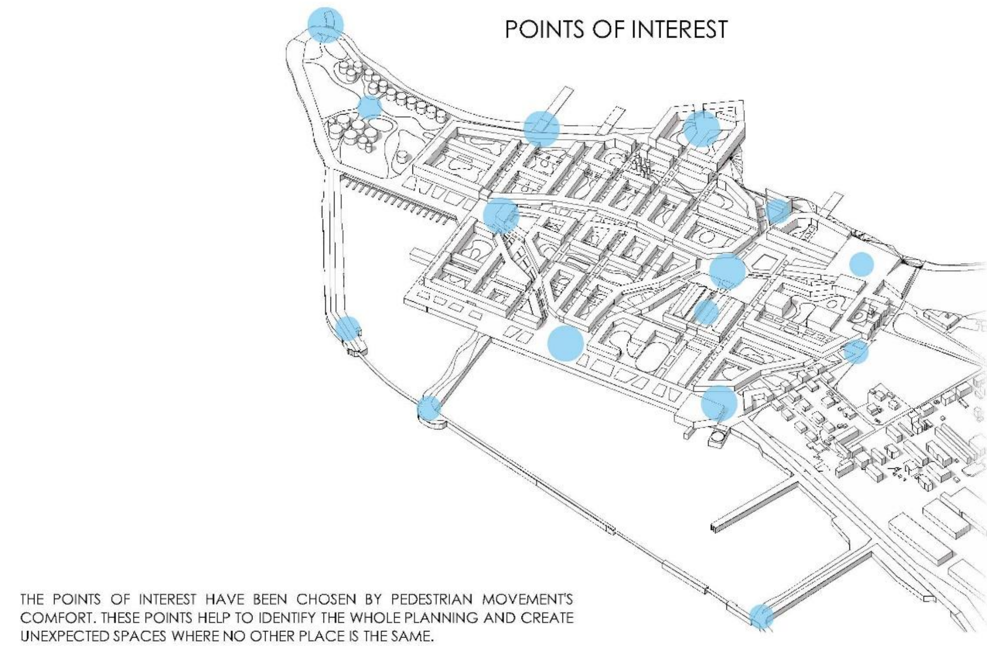


Image 37 Kopli planning area's points of interest

From points of therest, three connecting routes have been created. These help to implement easy access throughout the planning area.

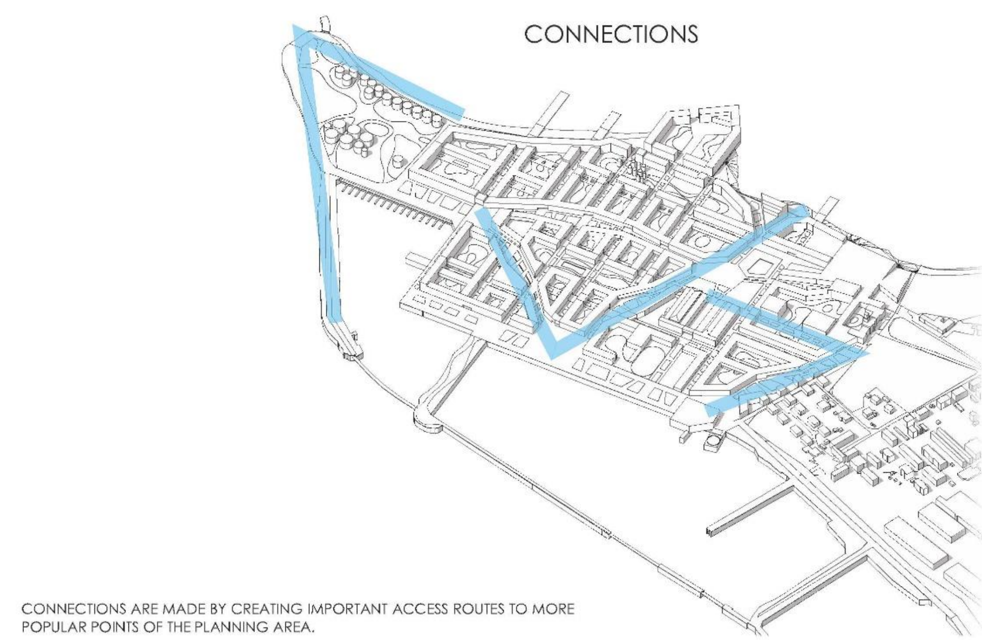


Image 38 Kopli planning area's connections

Planning phases help making the solution more achievable and it does not require all the financing at once. This also creates the possibility to use future technology when it becomes available, for example more efficient renewable energy production. The planning phases are proposed considering the existing nature of the area, the possibilities and the goal of carbon neutrality for 2050.

Three phases for the planning are proposed: 2030, 2040 and 2050.

### 5.2.1 2030 - Startup

- Demolishing the buildings and sending the materials to recycle
- Infrastructure: new tram depot and car parking building, tram line and tram power supply
- 50% energy production infrastructure of wind, wave, solar and ground heat pumps in the sea
- According to energy demand, reconstruction of existing silos to store energy
- Central area with buildings: university complex, school and kindergarten, opera theatre, some residential, office and business buildings
- Pedestrian boulevard and main connections with streets for further development
- Greeneries connected with the phase I area

### 5.2.2 2040 - Improving

- Main residential, business and office quarters
- Rest of the energy supply system and energy storage silos reconstructions
- Greeneries connected with the phase II area

### 5.2.3 2050 – Carbon neutral

- Rest of the planning area: last residential, business and office quarter
- Finishing the green network
- Renovation of industrial details on the area: cranes, lamp posts, rails

## 5.3 Solutions supporting carbon neutrality

### 5.3.1 Land-use

The existing land-use is mostly industrial and parts of the land that are not in frequent use look like wasteland. The planning does not present any big land mass changes as in land heights but indicates that the existing wasteland-like land should be transformed to housing and greeneries. The new area is planned on a brownfield area. To minimize the carbon emissions, the land mass changes are minimized and are only done to enhance the city grid concept or to make the urban space more pedestrian friendly.

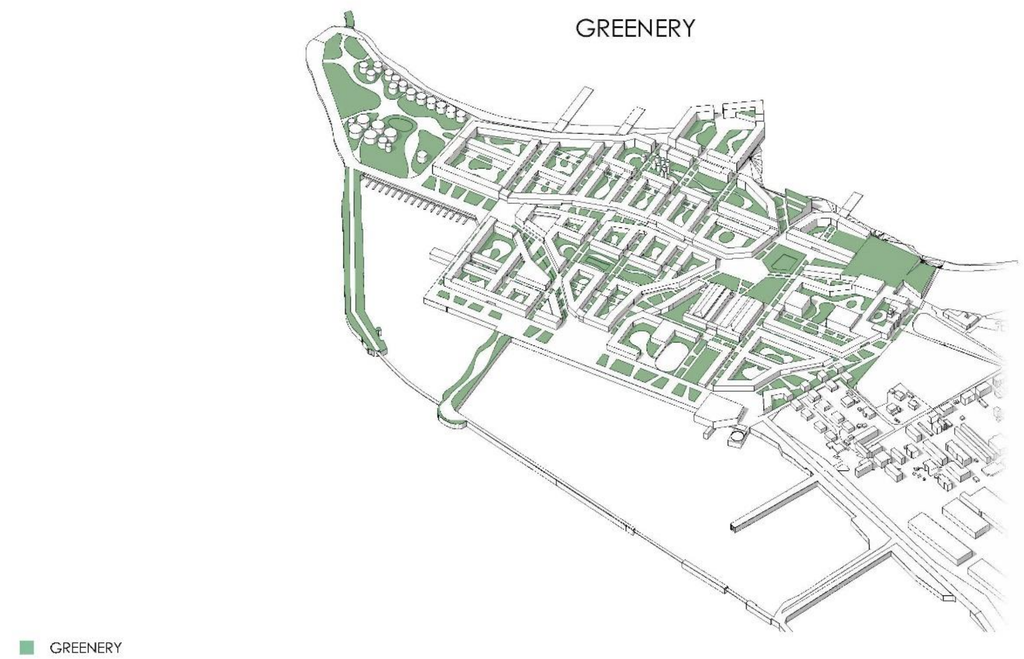


Image 39 Kopli planning area's greenery area

### 5.3.2 Traffic

The planning area is a car-free zone. The residents can still own a personal car but it must be stored to the parking area at the side of the planning site. The planning site itself has no long-term parking spaces for residents. There are temporary exceptions for emergency and other service vehicles like police, ambulance, garbage trucks and taxies. Banning the biggest portion of traffic in the area reduces emissions caused by vehicles drastically. The meaning of car-free area is identified as Steven Melia describes it in his research “Carfree and low-car development”. The planning area has an existing tram depot in the eastern side of the site. The existing depot will be demolished and a new tram depot integrated with the parking facility will be built. A tram stop will be no further than 250 meters of every building. Parking spaces are calculated accordign to Tallinn's 2020 new parking normative that indicates 1,3 parking spots per apartment in suburbs. (Tallinn City Council, 2020)

A good example of a traffic calm area is Vauban area in the city of Freiburg in Germany. It is known for car reduced areas with tram lines and bicycle route opportunities. Old military barracks have been reconstructed to environmentally and family friendly housing. (Eltis Mobility Portal, Youtube, 2014)

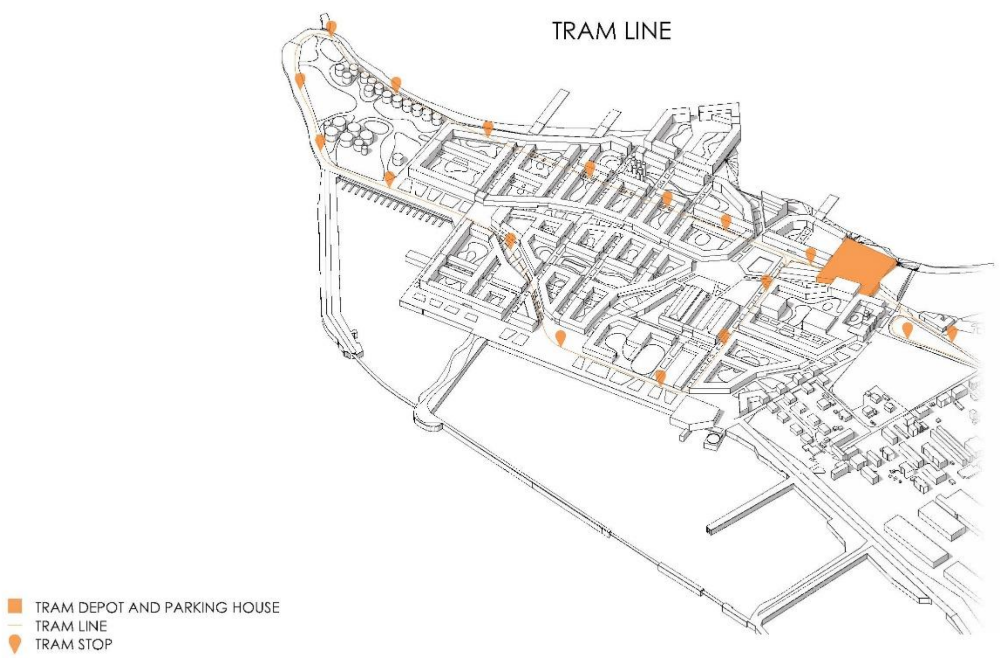


Image 40 Kopli planning area's proposed tram line

In post-oil cities (already in the city of Paris) the number of cars will be decreasing, and the land use will need to reflect on this. As the underground parking facilities contain a huge embodied carbon footprint, it might be better to plan parking facilities above the ground, and change these faciliites to other uses in the future, when the number of cars will be smaller. The model for this thesis comes from Vauban, Freiburg, where the solutions of the car-free environment have changed the modal share in a favorable direction. The modal share in Germany is otherwise very similar to Tallinn. We can assume that we reach the same modal share in the target area than in Vauban. The example of Tallinn shows that a free public transportation alone will not make people to give up private cars. There needs to be also planning solutions like the ones in Vauban. Vauban's modal share is 44% walking, 20% biking, 7% bus, 12% tram and 17% car. (Marins)

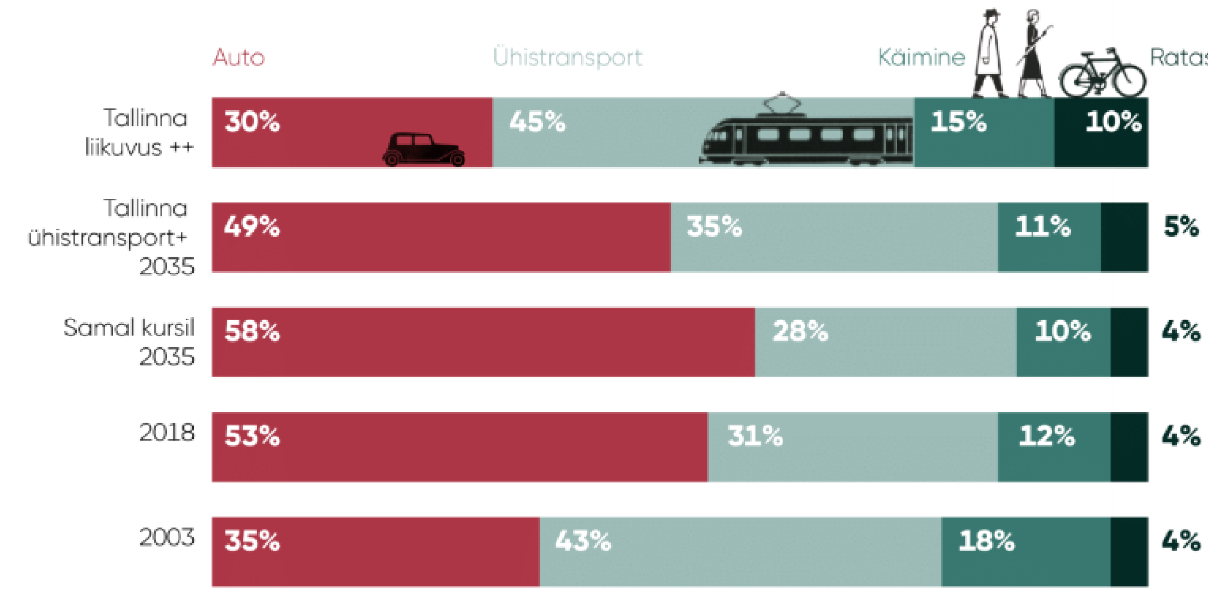


Image 41 Tallinn resident modal share (from mnt.ee "Valmis Tallinna piirkonna säästva linnaliikuvuse strateegia")

The planning area will be free of asphalt. The existing asphalt will be sent to recycle and the brownfields will be covered with greeneries and trees. Pedestrian and emergency transport routes will be covered in natural stone, reused concrete from the area and wooden chips for walkways.

The town of Arnhem in the Netherlands is dismantling the asphalt cover and replacing it by permeable surface materials. Asphalt is developed to serve car traffic, and if car is no longer a dominating component in the traffic system, the streets should be redesigned, and permeable surface materials applied. However, a superb biking network (like in Copenhagen) requires some kind of smoorth surface material, a good network and good biking culture like in Copenhagen. (Factor CO2, 2020)

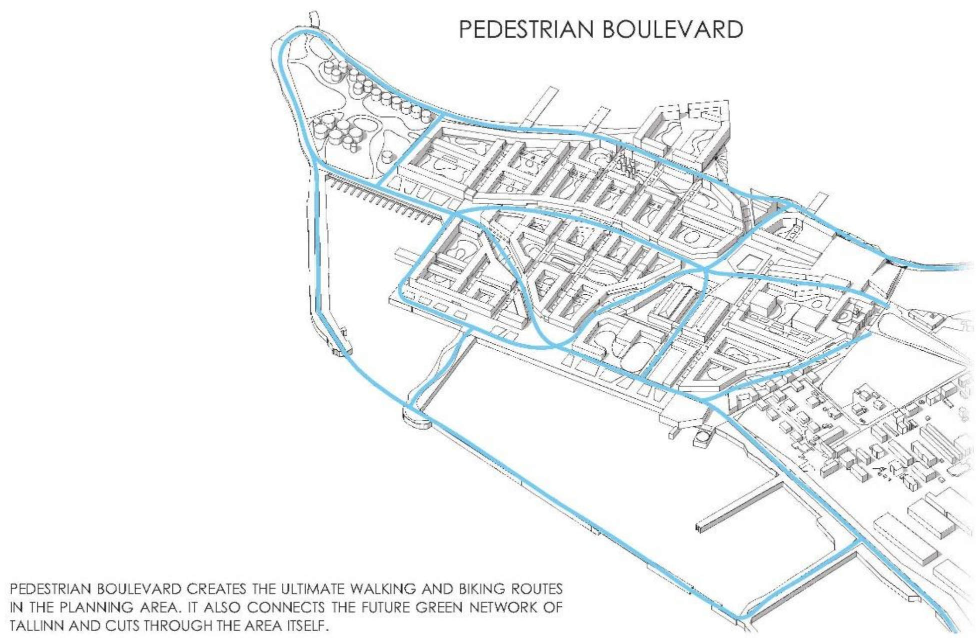


Image 42 Kopli planning area's pedestrian boulevard concept

### 5.3.3 Energy

As the Helsinki Energy Challange winning study shows, the most reasonable solution for re-thought energy production is using sea heat pumps in the Baltic sea that can provide up to 50% of a city's heat needs on Helsinki's example. Additionally solar thermal energy collection, thermal energy storages, district heating grid and wave energy converters will be used. (Helsinki Energy Challenge, 2021)

Since the site is surrounded by the Baltic Sea from three sides, it can easily house the sea heat pumps that circle the warm and cold water accordingly and store the harvested energy in the thermal energy collection silos on the tip of the peninsula. Solar thermal energy collection panels will be used on the roofs of the buildings. Wave energy can be used to create electricity with wave energy converters. Swedish wave energy industry Eco Wave Power states that their products can create an energy output of 30 kW/m. (Eco Wave Power, wave energy, global resources, 2020)

Existing silos on the northern tip on the peninsula and on the north-eastern side of the site can be used to store created thermal energy.

Nine offshore wind turbines are proposed to be built in the sea. In total, these turbines produce about 72 000 000 kW of energy yearly. (Editor, 2021)

### 5.3.4 Buildings

The existing buildings do not give any particular value to the concept and carbon neutral aspects of the planning project. Therefore, only Marine Academy, central building with inner yard and silos will be kept. Others buildings are either big and modern industrial warehouses or older industrial buildings that have been reconstructed one or more times.

Image 43 Aerial photo of existing building types (from maa-amet geo portal)

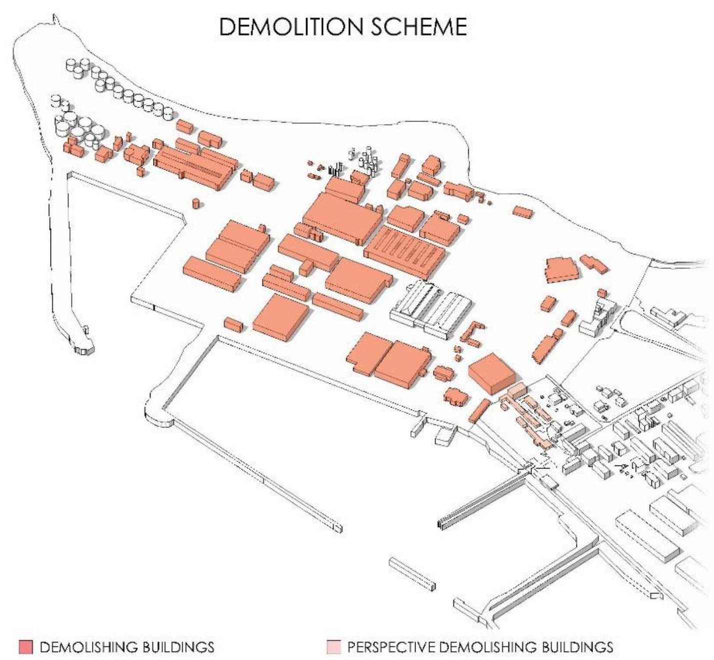


Image 44 Kopli planning area's demolishing buildings

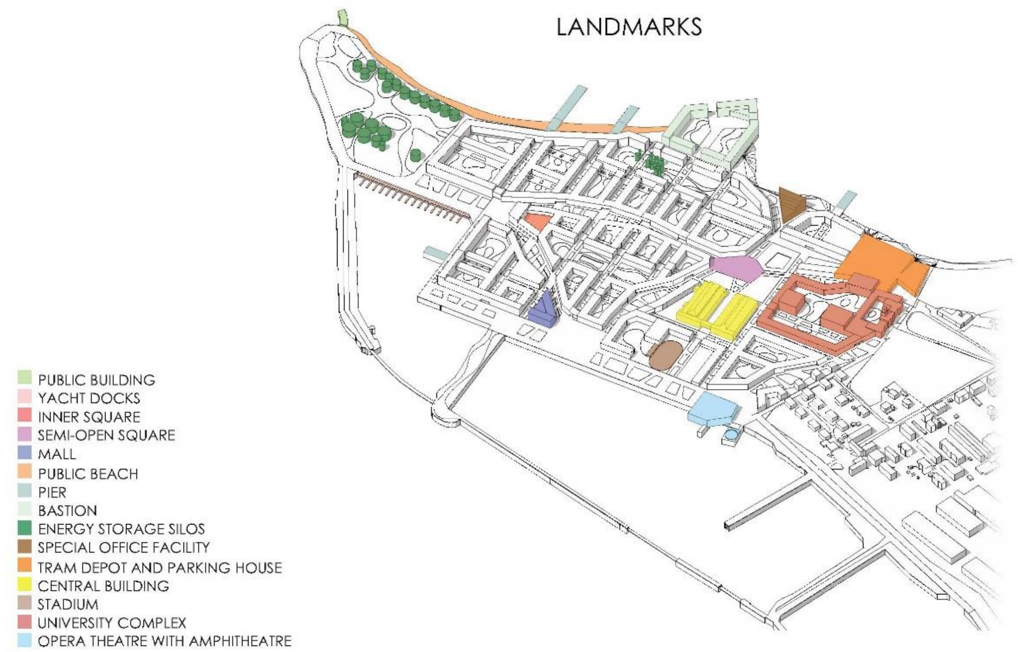


Image 45 Kopli planning area's building landmarks

Buildings will be built from renewable materials that can perform as carbon storages, for example timber and recycled materials. Other less efficient materials regarding carbon-neutrality are low-carbon bricks (made from re-using materials from coal power plants), green concrete (with recycled materials from demolishing buildings) and green tiles (over half of the materials can be used as recycled materials). (Climate Technology Centre & Network, n.d.)

The planning project proposes a parking building integrated with tram depot, school, kindergarten, university complex, opera theatre, yacht docks, public square, beach and different landmark buildings.

The building functions in the planning area are mixed and varied. Residential buildings make out the most of the volume and is followed by offices and businesses as shown on the following image.

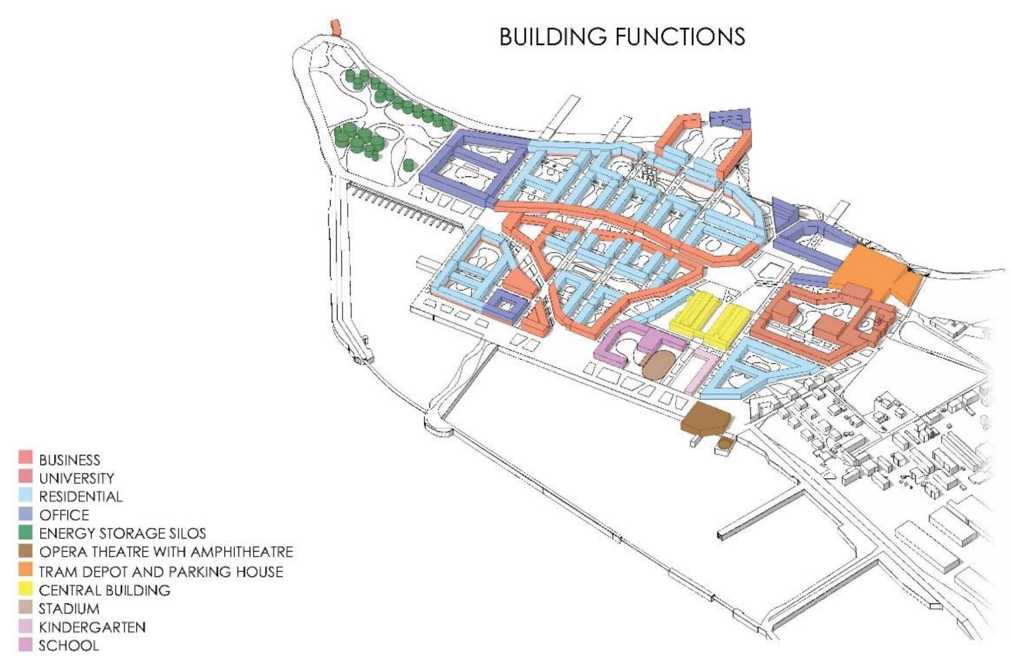


Image 46 Kopli planning area's building functions

The density of the living space is calculated based on Tallinn's avarage living area per resident that is 28,5 m2. For comparison, Helsinki's avarage living area per resident is 34,1 m2 and in Stockholm 37,24 m2 (Tallinn 2035 Development Strategy, 2021). The planning area's living space per person is calculated 30 m2.

To save emissions on clean water production, the site uses storm water collection system that can store water from heavy rains and storms and reuse it for heating water, fire hydrants, building washing, street sanitary cleaning and other types of utility systems. (Stormwater.pca, 2017)

### 5.3.5 $CO_2$ compensation

The planning area $CO_2$ consumption is achieved by exporting excess energy produced on our site from renewable energy sources. The energy production calculations are added to the thesis as appendicies.

The total energy consumption of the buildings annualy is 70 750 800 kWh. Solar panels produce 21 434 920 kWh of electricity, wave energy converters produce 24 000 kWh and wind turbines produce 72 000 MWh annually. Therefore the total energy production is 93 45 920 kWh and exported excess energy is 22 708 120 kWh. In avarage, one Estonian household uses 3000 kW of energy annually. The exported green energy can power about 7569 homes outside the planning area. (Eesti Energia, 2018)

# 6 REGULATIONS AND GUIDELINES FOR CARBON NEUTRAL SPATIAL PLANNING

The problem of climate change and global warming today is very much acknowledged by most of the countries in the world. The Paris Agreement is a cornerstone for binding the countries intentions to reduce GHG emissions and achieve climate neutrality by 2050.

Created as an example of carbon-neutral city district in Kopli, the thesis project proposes guidelines and regulations to achieve carbon-neutrality in Tallinn's district example. These can be used by city planners, architects and municipalities.

In Kopli area's case, carbon neutrality is achieved by creating a new city district that produces excess carbon neutral energy that is exported outside the target area. There are also more regulations regarding traffic and infrastructure, land-use change and buildings energy use.

To create a realistic plan, three planning phases are proposed: 2030, 2040 and 2050. Solutions for achieving carbon-neutrality can be done step-by-step and do not need all the financing at once.

The planning area is a car-free zone. It means that only emergency transport and other crutial vehicles have access to the area. These vehicles include police, ambulance and rescue, taxies, garbage trucks and others similar. Car-free areas of a city have been created before, for example Vauban, Freiburg. This regulation limits the carbon emissions not only from vehicle's engines but also from asphalt production. Like in Arnhem, Netherlands, asphalt areas of the streets are limited and planned to replace with greeneries. (Totaro, 2020) Because the traffic will be very limited, the streets can be focused on pedestrian comfort and movement. The streets can also use more natural paving materials. To ensure the public transport movement, a new tram line has been proposed in the planning area. The tram line continues from the existing tram line in Kopli and connects to Tallinn's tram grid so that existing trams can access the area. A new high-interval tram line has been proposed that only drives on the planning area's tram line loop. It connects all the nessecary points of interest very quickly and the pedestrian movement is not compromised. The planning shows that cars can be less emphasized in planning process and do not need to be the focus where buildings will be constructed around.

For land-use, the regulation limits the land mass change. Since all the land mass changes produce GHG emissions, this regulation limits it. It should be noted that for pedestrian movement and comfort, some areas still require land mass change. This should only be used for creating more exciting urban space. If possible, the land mass can be infused with buildings. In the target area, the existing land use is mainly brownfield areas. To create modern urban space, the solution is founded upon pedestrian comfort and human scale in the area. This means that the existing brownfields are transformed into greeneries and streets with natural paving materials.

Buildings and energy use is another important factor for achieving a carbon-neutral area. The buildings need to minimize the GHG emissions produced from producing the building materials untin demolishing the buildings. One of the best materials for that is widely popular and renewable building material - timber. Other natural and recycled materials such as clay, sand, earth, straw, stone, bamboo, used concrete and recycled glass can also be used. Underground building is not allowed on the planning area. This causes huge GHG emissions due to concrete production and also the construction time itself. Since the area is low from the sea level, underground construction also requires the sea water to be pumped out. For buildings energy use, all of the buildings need to achieve at least the highest target of Estonia's building energy consumption. The planning excludes single-family houses since they are one of the biggest energy consumers per person. The density of the living space is calculated based on Tallinn's avarage living area per resident that is 28,5 m2 (Tallinn 2035 Development Strategy, 2021). The planning area's living space per person is calculated 30 m2.

For energy production the solution is based on Helsinki's Energy Challange winning work. The solution uses sea water heat pumps, electrical boilers and solar thermal fields. In addition, Kopli planning area's energy production system also uses wind turbines and wave energy converters for electricity production. All the electricity produced on the planning area must be carbon-neutral. Roofs of the buildings must be at least 80% convered with solar panels or for example public buildings roofs can be given access to the public. The roofs in this case must be covered with greenery. The electricity free of GHG is used to power the sea water heat pumps. The excess green energy that is exported from the planning area can power up to 7569 households in Estonia. (Eesti Energia, 2018)

Since Estonia needs to be carbon neutral in 2050 and national electricity grid is assumed to develop, the site's exported energy will no linger be a viable method of achieving carbon neutrality in the future.

# 7 DISCUSSION

The methods that are used for quantification of GHG emissions are not harmonized. Current methologies of cities include territorial components and therefore the results of GHG quantifications cannot be compared. Therefore the net zero balance of carbon emissions will not show how difficult or ambitious the challange for a city is and how much they really have to cut their emissions to get there. In the simplest way, cities can "buy their way out" of carbon neutrality. (Niemelä, 2017)

If the cities would systematically apply the consumption-based approach (as recently proposed by C40 cities) the results could be compared but the carbon footprint of cities would look much higher, and true carbon neutrality would be much more difficult target.

Grid electricity appears to be a crucial component for carbon neutrality. This puts the cities in very different kind of positions regarding carbon neutrality: It is easy in countries such as Iceland, and extremely difficult in countries such as Estonia. As the energy production for national grids is not in the hands of cities, it is quite a big promise to go carbon neutral. By building up city-scale sub-grids, they could take this aspect in their own hands, like they do with the district heating network. Laine et al has shown that there are other aspects which seem to indicate that cities cannot decide about all issues related to carbon neutrality.

Excess renewable energy seems to be the best offsetting measure in a country like Estonia, where the grid electricity is carbon intensive. Creation of new sub-grids based on renewable energy production might be a good strategy for Estonia to decarbonize the electricity production.

Currently, the Tallinn tram traffic has very high carbon footprint due to the oil-shale use in the grid electricity. With low-carbon electricity, the tram could be a key solution for carbon neutral mobility in Tallinn, where the subway solutions are difficult because of the underground soil types.

Banning underground construction saves more emissions than changing from concrete structures to timber structures. Especially in the seaside locations, underground construction should be avoided. Structures like the 5-storey underground parking hall in Porto Franco do not contribute the carbon neutrality commitment of the city of Tallinn.

According to Karoliina Auvinen and Jyri Seppälä, the critical actions to reduce the fossile fuel emissions are: increasing energy-efficiency, increasing the production of low-carbon energy production and powering heating, traffic and industrial processes with clean electricity. The Kopli study seems to confirm this.

The minimized carbon emissions in this case are compensated by exporting the excess energy produced on the site via Estonia's electricity grid and also using carbon capture and storage method. This study has excluded carbon offset by purchasing because it cannot serve as a permanent solution for carbon neutrality.

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# APPENDICES

Calculations of $CO_2$ emissions of traffic are done by estimating the target area's population growth, Tallinn resident's avarage daily milage for transportation (Tallinn City, 2017), modal share of reference (Broaddus, 2010), emission factors from Lipasto database (Lipasto Unit Emissions, 2017), estimating electric vehicle popularity growth (IEA, 2020) and calculating it with grid electricity dependent factors (Mayors, 2017).

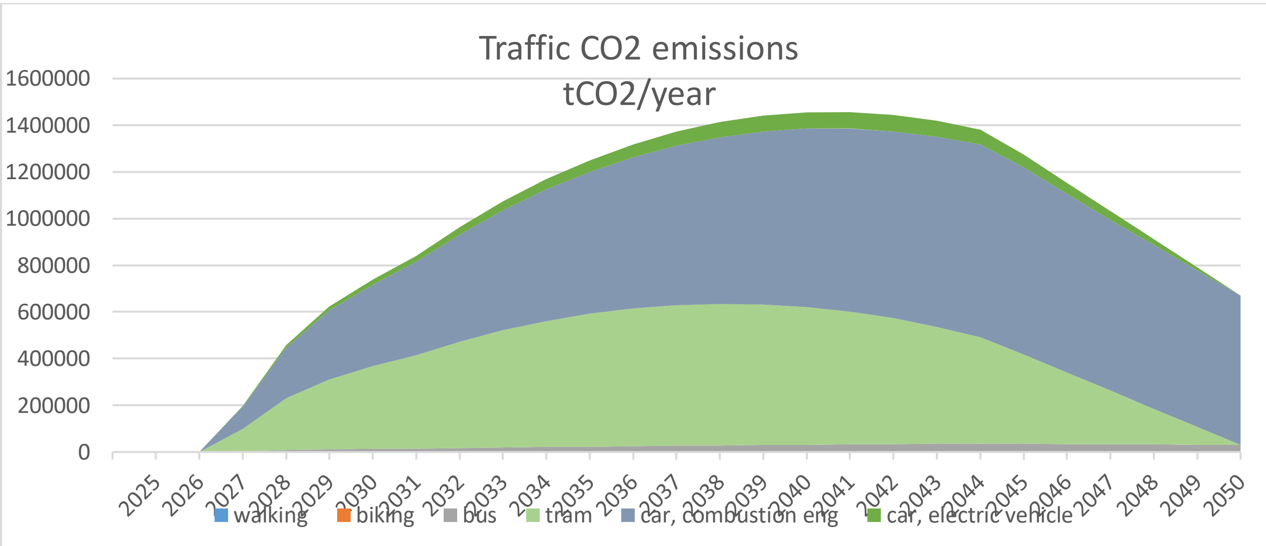



Image 47 Traffic $CO_2$ emissions ($tCO_2$/year)

To calculate energy production on the site, three energy sources are used: solar thermal, wind and wave energy. In total, solar thermal panels produce 21 434 920 kW/h per year (calculated 130 kW/h per m2) (Howell, 2021), wave energy converters 24 000 kW/h per year and wind turbines 72 000 000 kW/h per year (Editor, 2021), (Eco Wave Power, wave energy, global resources, 2020), (Mayors, 2017). In 2050, 93 458 920 kW/h energy is produced yearly.

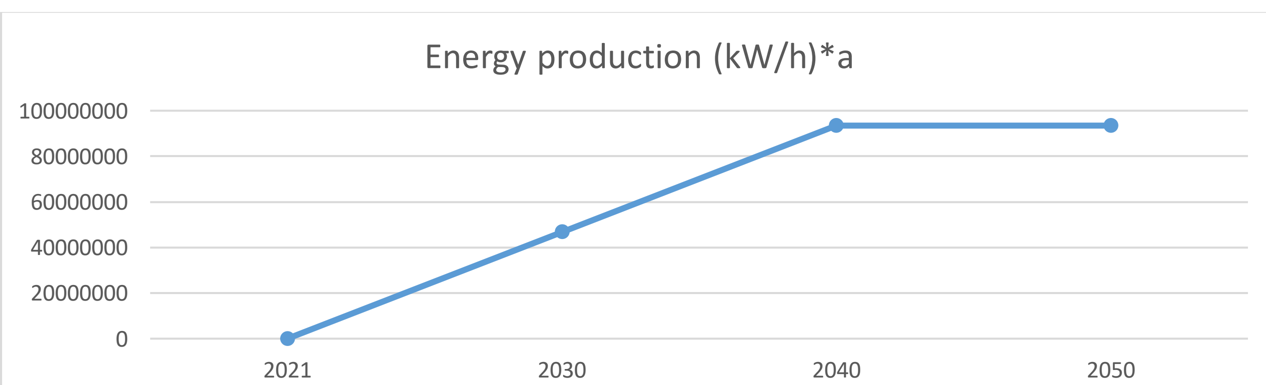



Image 48 Energy production on site

Building energy consumption is based on Estonia's energy label. Every building on the site needs to achieve the highest energy label and the consumption is calculated based on the consumption number, different number for every type of building in the list (Riigiteataja, 2019). Total energy consumption is 70 750 800 kW/h yearly.

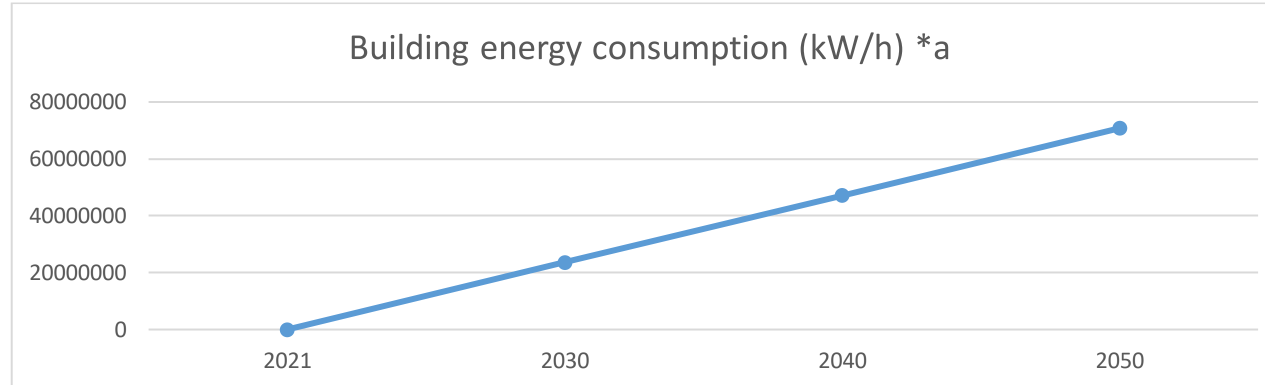



Image 49 Building energy consumption kW/h (m2*a)

For a small but mentionable $CO_2$ storage method, trees ability to store $CO_2$ emissions are calculated. Since every tree can store about 1 tonne of $CO_2$ in it's lifetime of 100 years, all the trees in the planning area can store 453 tonnes of $CO_2$ yearly by the year 2050 (Grantham Institute, 2015).

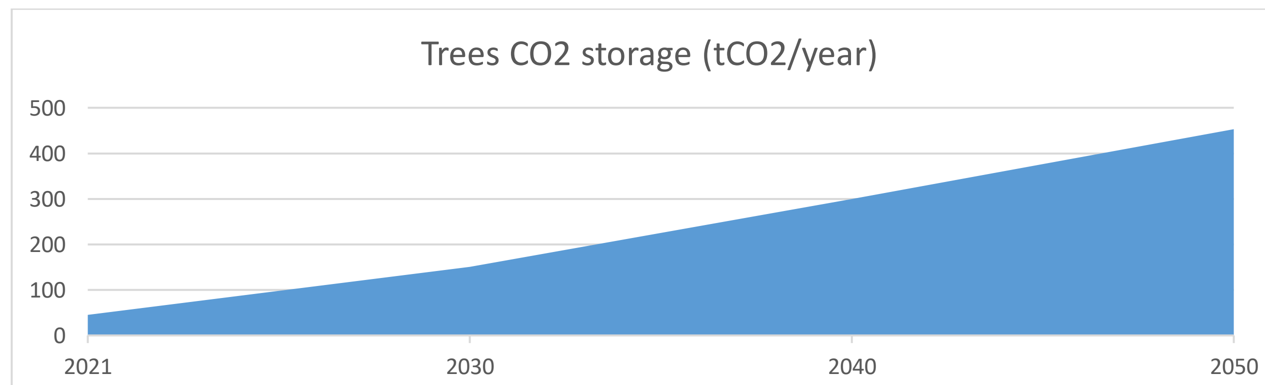



Image 50 Trees $CO_2$ storage capability per year

The following graph shows the energy production and energy consumption difference on the area. Maximum energy production is 93 458 920 kW/h yearly and maximum energy consumption is 70 750 800 kW/h yearly.

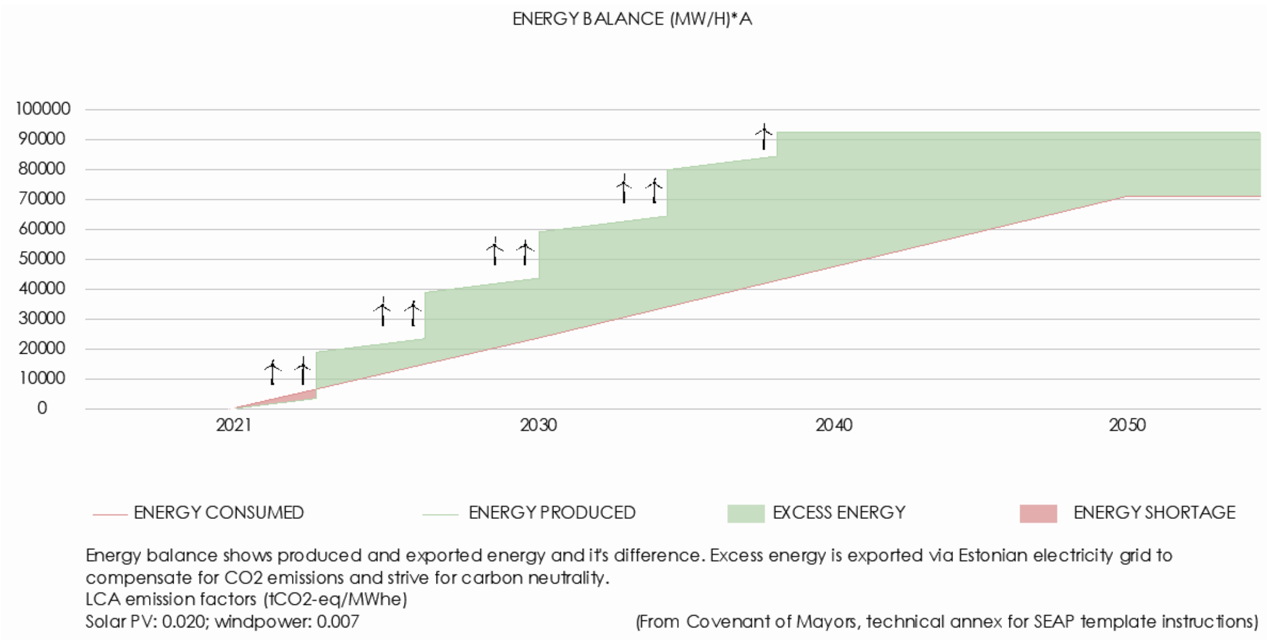



Image 51 Energy production *vs* energy consumption on site

Subtracting the energy consumption from energy production we can get excess energy value that is used for $CO_2$ compensation and is exported outside the target area via Estonian electricity grid. The excess energy for 2050 is 22 708 120 kW/h and the value will continue every year.

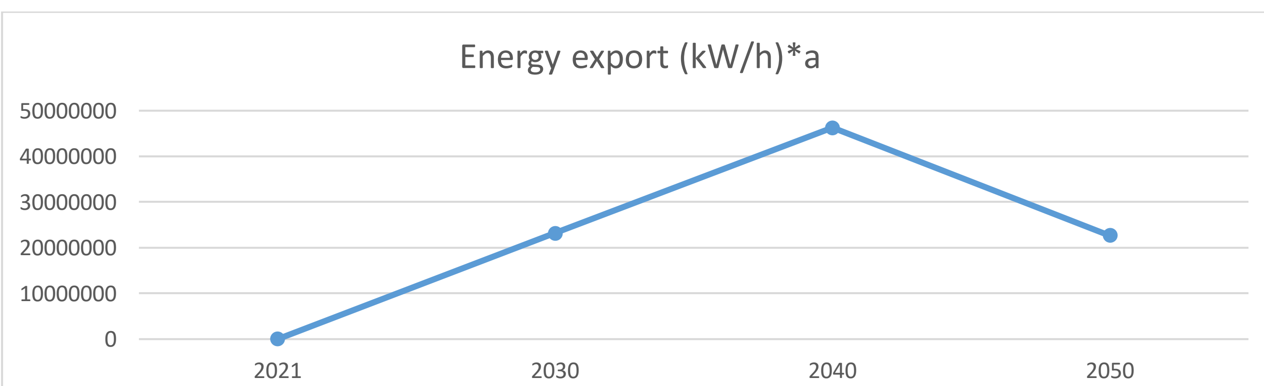
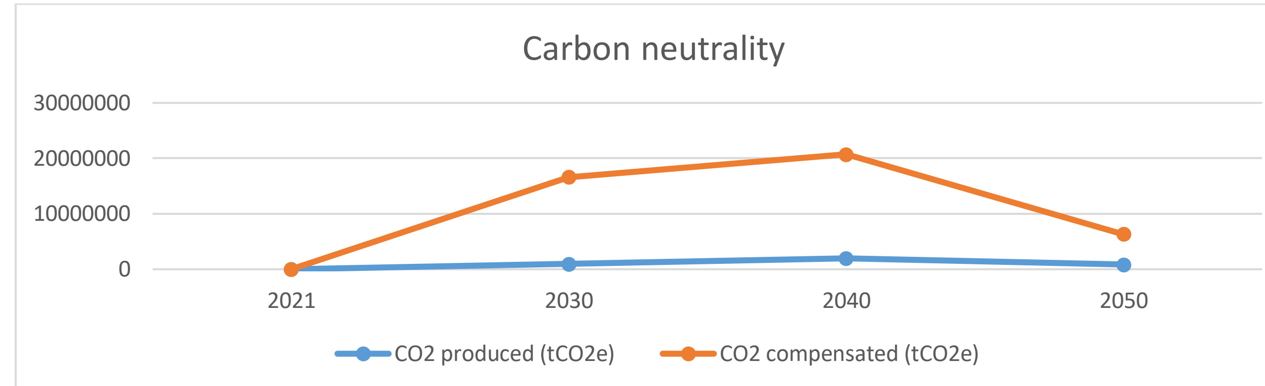



Image 52 Energy export (kW/h)*a

The final graph shows overall carbon neutrality. It can be achieved just when the energy production system is built and even before the year 2050. For this calculation, the emissions from building energy consumption and traffic are added and subtrackted from the produced energy $CO_2$ emissions value according to the emission factors of consumed electricity in Estonia. It should be noted that the calculations include an estimated growth of cleaner national electricity grid with less $CO_2$ emissions (Mayors, 2017).



## ACKNOWLEDGEMENTS

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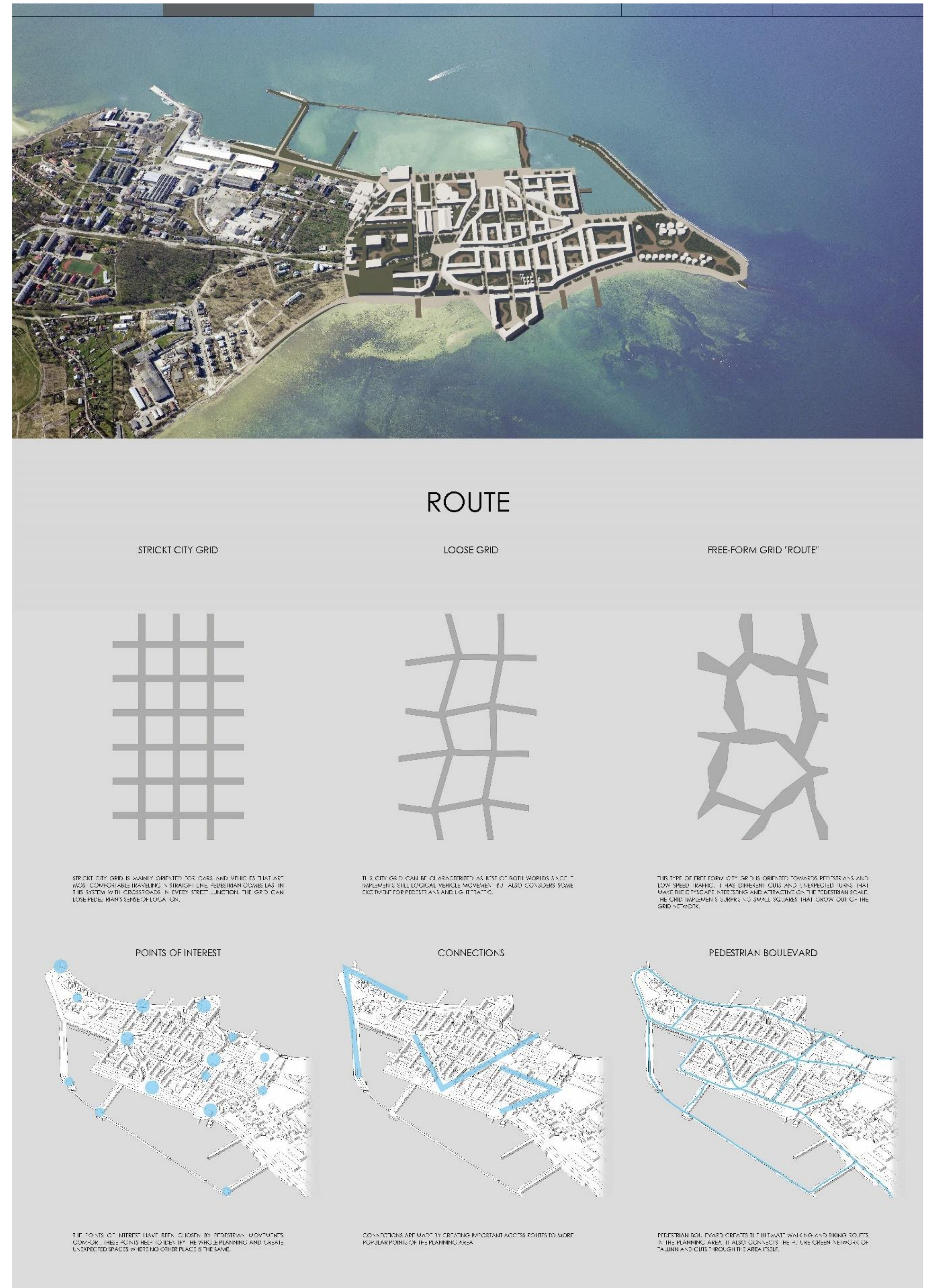
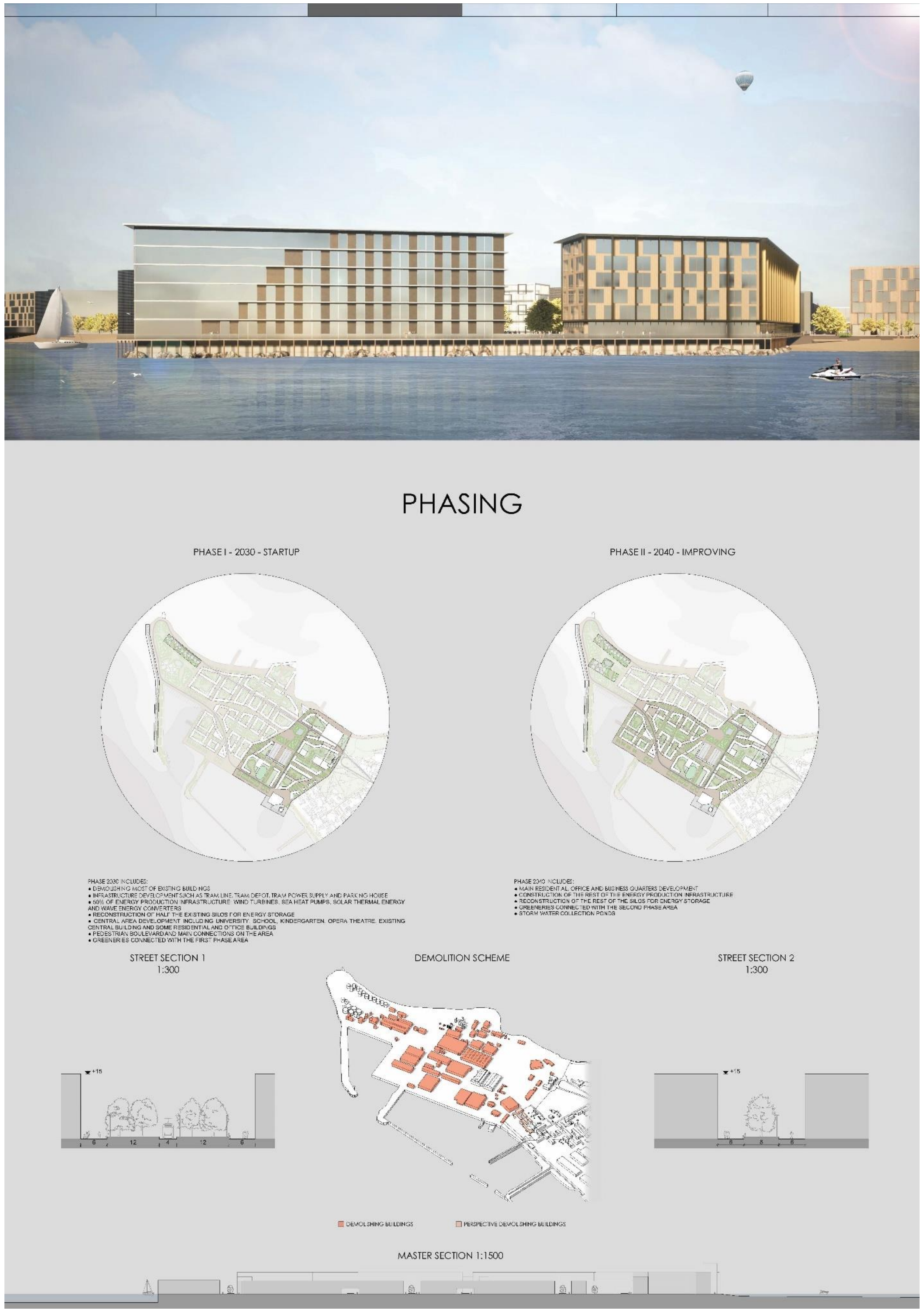
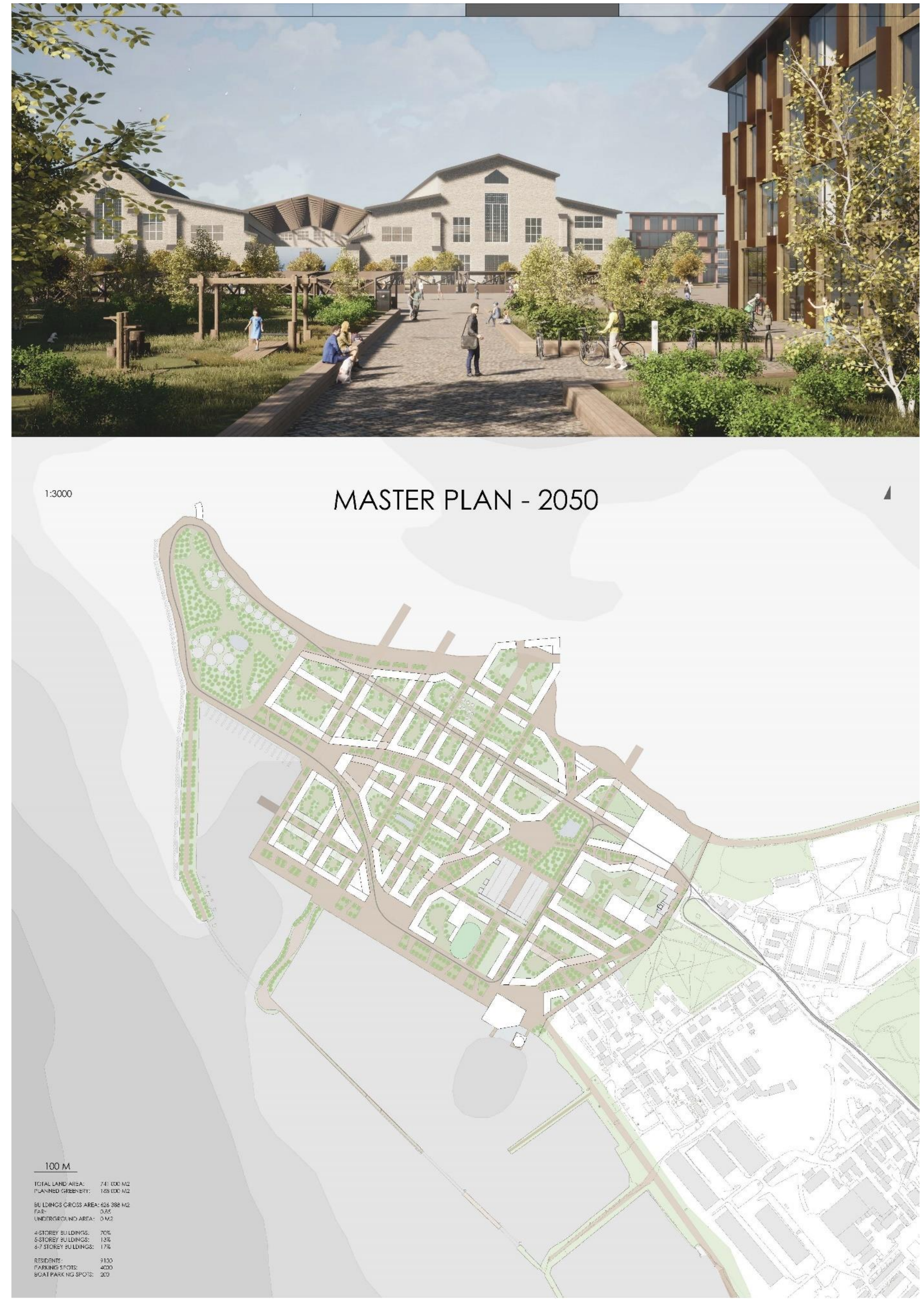
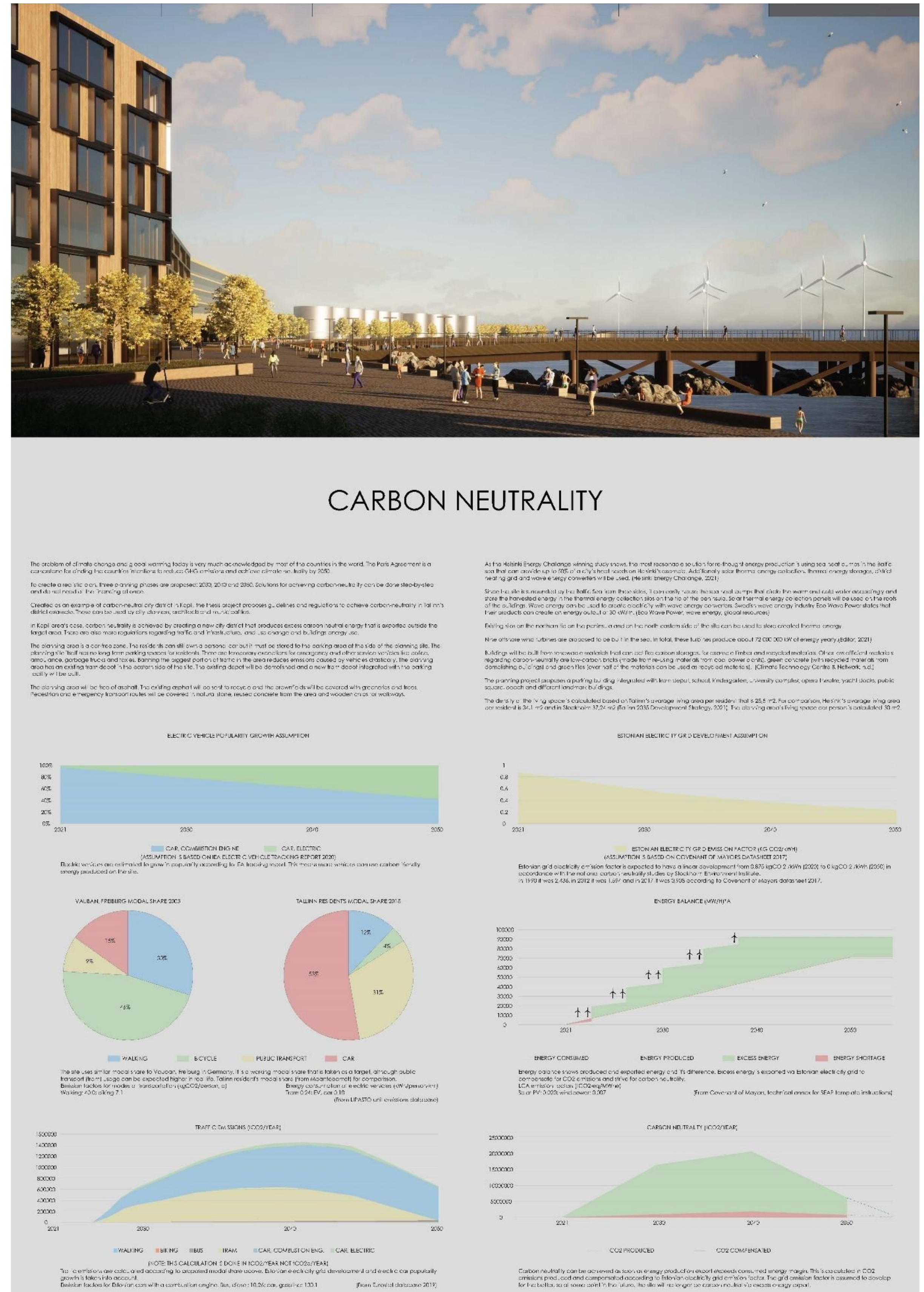
## GRAPHICAL MATERIAL


PHASING
PHASE I - 2030 - STARTUP
PHASE II - 2040 - IMPROVING
PHASE 2030 INCLUDES:
• DEMOLISHING MOST OF EXISTING BUILDINGS
• INFRASTRUCTURE DEVELOPMENT SUCH AS TRAM LINE, TRAM DEPOT, TRAM POWER SUPPLY AND PARKING HOUSE
• 50% OF ENERGY PRODUCTION INFRASTRUCTURE: WIND TURBINES, SEA HEAT PUMPS, SOLAR THERMAL ENERGY AND WAVE ENERGY CONVERTERS
• RECONSTRUCTION OF HALF THE EXISTING SILOS FOR ENERGY STORAGE
• CENTRAL AREA DEVELOPMENT INCLUDING UNIVERSITY, SCHOOL, KINDERGARTEN, OPERA THEATRE, EXISTING CENTRAL BUILDING AND SOME RESIDENTIAL AND OFFICE BUILDINGS
• PEDESTRIAN BOULEVARD AND MAIN CONNECTIONS ON THE AREA
• GREENERIES CONNECTED WITH THE FIRST PHASE AREA
PHASE 2040 INCLUDES:
• MAIN RESIDENTIAL, OFFICE AND BUSINESS QUARTERS DEVELOPMENT
• CONSTRUCTION OF THE REST OF THE ENERGY PRODUCTION INFRASTRUCTURE
• RECONSTRUCTION OF THE REST OF THE SILOS FOR ENERGY STORAGE
• GREENERIES CONNECTED WITH THE SECOND PHASE AREA
• STORM WATER COLLECTION PONDS
STREET SECTION 1
1:300
DEMOLITION SCHEME
STREET SECTION 2
1:300
DEMOLISHING BUILDINGS
PERSPECTIVE DEMOLISHING BUILDINGS
MASTER SECTION 1:1500


1:3000
MASTER PLAN - 2050
100 M
TOTAL LAND AREA: 741 000 M2
PLANNED GREENERY: 188 000 M2
BUILDINGS GROSS AREA: 626 388 M2
FAR: 0.85
UNDERGROUND AREA: 0 M2
4-STOREY BUILDINGS: 70%
5-STOREY BUILDINGS: 13%
6-7 STOREY BUILDINGS: 17%
RESIDENTS: 9100
PARKING SPOTS: 4000
BOAT PARKING SPOTS: 200


PLANNING SOLUTIONS
BUILDING FUNCTIONS
LANDMARKS
TRAM LINE
GREENERY


CARBON NEUTRALITY