DATALYST
data node center as a catalyst for urban development

ISABELLA ERIKSSON & FREDRIK ULANDER, 2012

Master Thesis
Department of Architecture
Chalmers University of Technology
SE-412 96 Gothenburg
Sweden

Cover:
Aerial perspective from south-west showing the project proposal

Gothenburg, Sweden 2012

Abstract

Internet is growing exponentially, and as such, large companies that handle large volumes of digital information need server facilities.

The planning and construction of massive server halls for Facebook are well on the way to be constructed in the outskirts of Luleå. This is the largest server facility built in Europe as well as Facebooks first establishment on the continent.

Northern Europe is ideal for constructing these facilities as from multiple standpoints of which cold climate and a good digital infrastructure is among the most mentionable and beneficial.

These server halls will, when finished, have the same energy consumption as 40 000 villas. The area need is equal to 11 football fields. There is no plan to utilize the heat produced.

This is an investigative project dealing with the question on how a server hall can be integrated into a city context and used as a catalyst for urban development.

What if the heat loss could be used for additional program? What if the server halls could come to be integrated to the city, working in close relation to urban life?

TABLE OF CONTENTS

1. INTRODUCTION

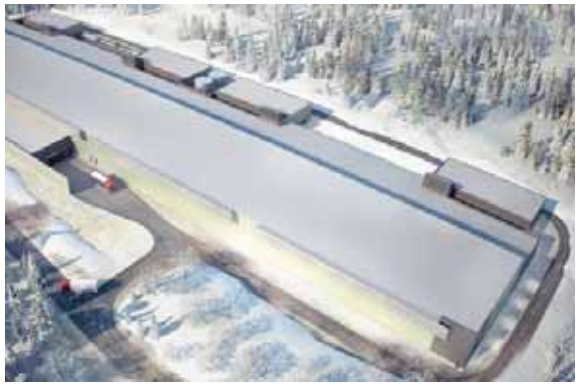
1.1 Point of departure

MÅNDAG DEN 23 APRIL, UPPDATERAD FÖR 5 MINUTER SEDAN

SvD NÄRINGSLIV

Serverhallar ska stärka Norrbotten

Det norrbottniska näringslivet har fått guldvittring. Stärkta av Facebooks miljardetablering i Luleå åkte i går en delegation till USA för att studera datacenter och kanske locka fler stora aktörer till trakten. Hur mycket Facebooksatsningen, med minst 103 miljoner kronor i statligt stöd, verkligen ger i antal jobb är dock oklart.



23 januari 2012 kl 02:00, uppdaterad: 24 januari 2012 kl 09:36

KONTRAKTSJAKT

LULEÅ Efter att den USA-baserade sociala nätverkssajten Facebook låtit svenska projekterings- och byggbolagen Sweco och NCC sätta spaden i jorden för bygget av serverhallar – som uppges kunna ge 400 jobb till Luleå – har kommunen och grannarna Boden och Piteå gått samman om utvecklingsbolaget North Sweden Datacenter Locations.

Men Norrland sitter ju i ett skruvstäd mellan två Natoländer,Norge

Maventwo

VAD GÄLLER SAKEN?

Det så kallade molnet – lagring av data på gemensam plats i stora servrar och datahallar – har blivit en stor bransch inom informationstekniken. Minst 2,5 miljarder människor i världen beräknas använda sig av molntjänster. 2010–2011 var de totala investeringarna i datacenter runt 200 miljarder kronor och i år väntas siffran bli 230 miljarder, enligt

Facebook värmer upp i Luleå

LULEÅ: Facebooks tre serverhallar i Luleå kommer att släppa ut enorma mängder värme som inte ska återvinnas.

Värmen kommer från tusentals datorprocessorer som förbrukar lika mycket ström som 40 000 villor.
Det mesta av värmen måste ventileras bort för att processorerna ska fungera.
Värmen som släpps ut kommer att höja omgivningstemperaturen med 1–4 grader, 100–200 meter utanför hallarna.

– Med den lösning som kunden valt går det inte att återvinna värmeenergin, säger Erik Nerell vid NCC till tidningen Byggindustrin.

NCC BYGGER serverhallarna tillsammans med ett amerikanskt företag som byggt Facebooks serverhallar i USA.
NCC tänkte till att börja med att det vore en spännande möjlighet att tillvarata överskottsvärmen.
– Men de hade redan bestämt att kylningen skulle se ut på ett visst sätt. Facebook ser inte någon tänkbar användning av överskottsvärmen. Behovet av fjärrvärme är redan tillgodosett i Luleå, och det finns inte plats för exempelvis växthus eller andra industrier nära serverhallarna.

TT

NyTeknik Först och främst med teknik och IT
Måndag 23 april 2012

Facebook bygger det största datacentret i sitt slag i Europa - i Luleå. Det kommer att bestå av tre serverhallar om 28 000 kvadratmeter vardera. Illustration: Facebook

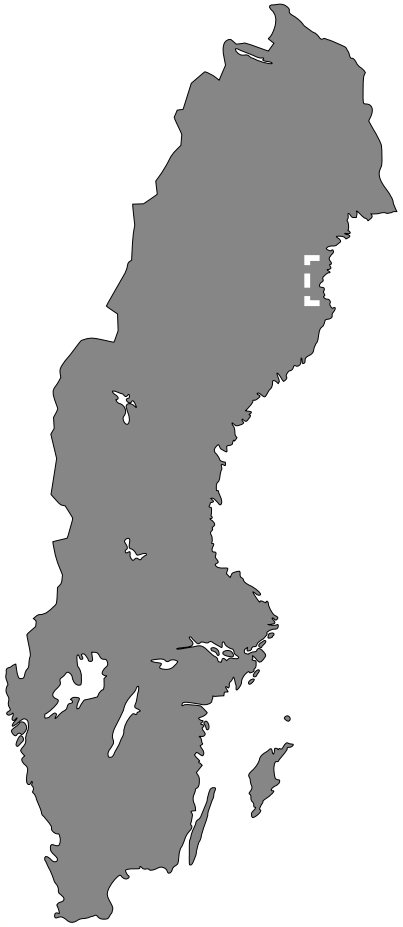
Därför storsatsar Facebook i Luleå

Av: Linda Nohrstedt 66 kommer
Publicerad 27 oktober 2011 13:35

Det har varit en hel del hyschhysch, men under torsdagen offentliggjordes Facebooks satsning på sitt första europeiska datacenter i Luleå Tre gigantiska serverhallar ska byggas – med miljontals kronor i stöd från regeringen.

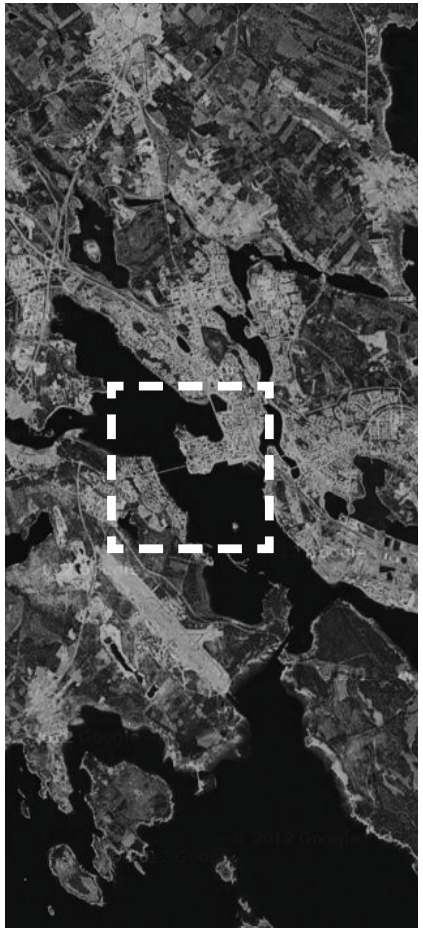
– Vi har undersökt alternativ i hela Europa och efter en omfattande process kom vi fram till att Luleå hade den bästa helhetslösningen, med ett klimat väl lämpat för naturlig kylning, tillgången till ren energi, bra mark, välutbildad arbetskraft och ett skickligt och engagerat företagsklimat, säger Tom Furlong, ansvarig för nyetableringa

The planning and construction of massive server halls for Facebook are well on the way to be constructed in the outskirts of Luleå. This is the largest server facility built in Europe as well as Facebooks first establishment on the continent.



Sweden

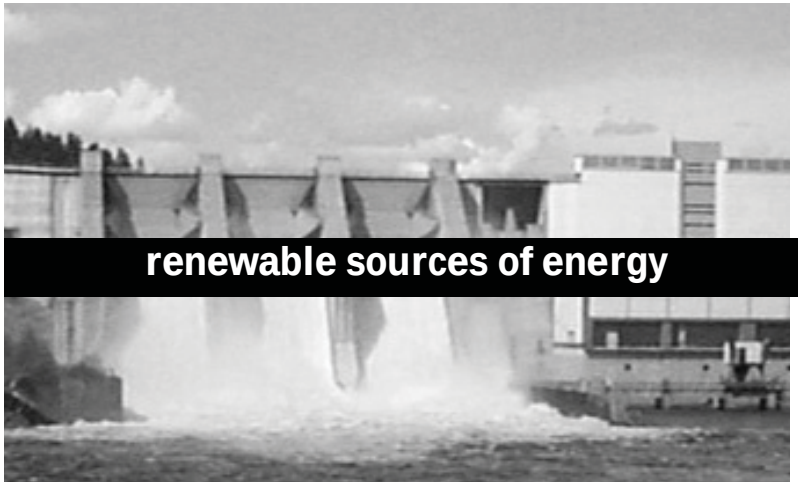
zoom



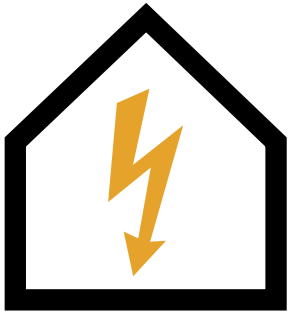
Luleå

zoom

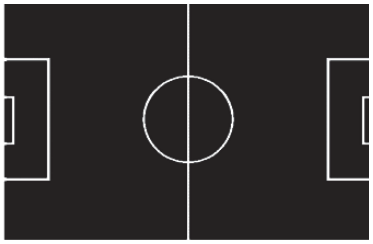
Central peninsula (Centrumhalvön)



Northern Europe is ideal for constructing these facilities as from multiple standpoints of which cold climate and a good digital infrastructure is among the most mentionable and beneficial.



= 40 000



= 11

These server halls will, when finished, have the same energy consumption as 40 000 villas. The area need is equal to 11 football fields. There is no plan to utilize the heat produced.

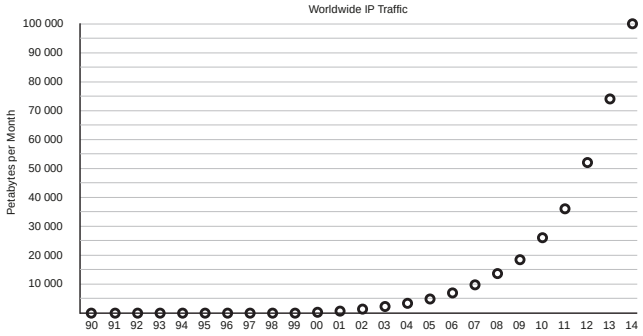
What if the heat loss could be used for additional program?

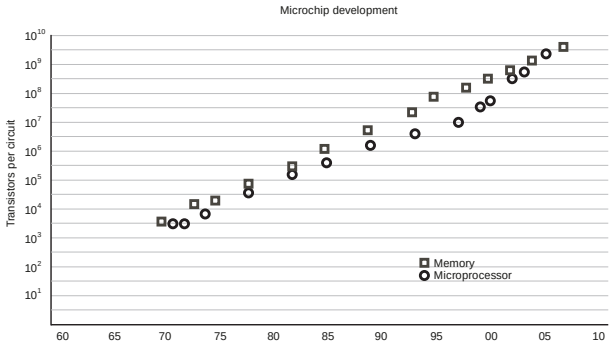
What if the server halls could come to be integrated to the city, working in close relation to urban life, adding area rather then consuming?

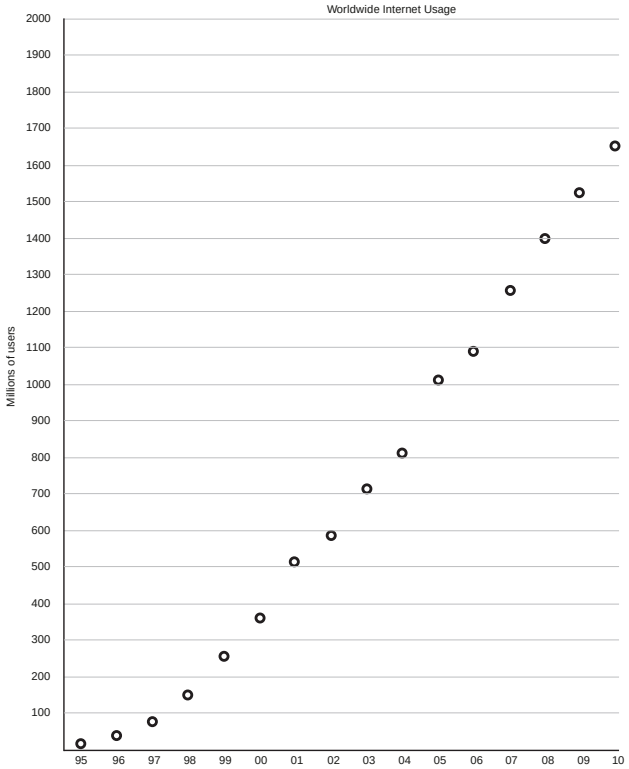
1.2 The connected world

1.2

The illustration seen above created by Chris Harrisson (chrisharrison.net) displays a map devoid of any other geographical information except digital nodal points of cities. Every connection point in the global network requires a server of some sort, each being a data node center (DNC). Most of these hubs are operated by traditional telecommunication companies and others by internet service providers or web hotel companies, to name a few.







The graphs (internetworldstats.com) show how the internet usage have exploded since the mid 90's. Today almost 2 billion people worldwide have direct connection to the internet or have the ability to connect to it in their near vicinity.

Even though the increase in the internet usag is linear, the amount of transmitted data is not. New technology and new ways to communicate, share data and the size of packets transmitted makes each persons digital footprint grow larger for every year. If this was all of the scenario the space required to store and transmit all of this data would probably overcrowd the entire planet.

Over the last 50 years, the power of computers has doubled every year and a half. This explosion of computer power is known as Moore's Law. Moore's law, named after Gordon Moore, noted the exponential advance in the power of computing in the 60s. "Moore's law isn't a law of nature, it's a law of human ingenuity." (Seth Loyd, Programming the Universe).

Luckily, this development is still continuing, but as the usage of internet continues to increase, the need for new DNC's are still a requirement. Even if the phone companies of old have adapted to the new millenium, they traditionally did not have to store data.

Server Halls/DNC's is a new type of "clean" industry and consumes a large amount with no other physical byproduct except for heat. As a further step towards a sustainable future this heat should be put to use.

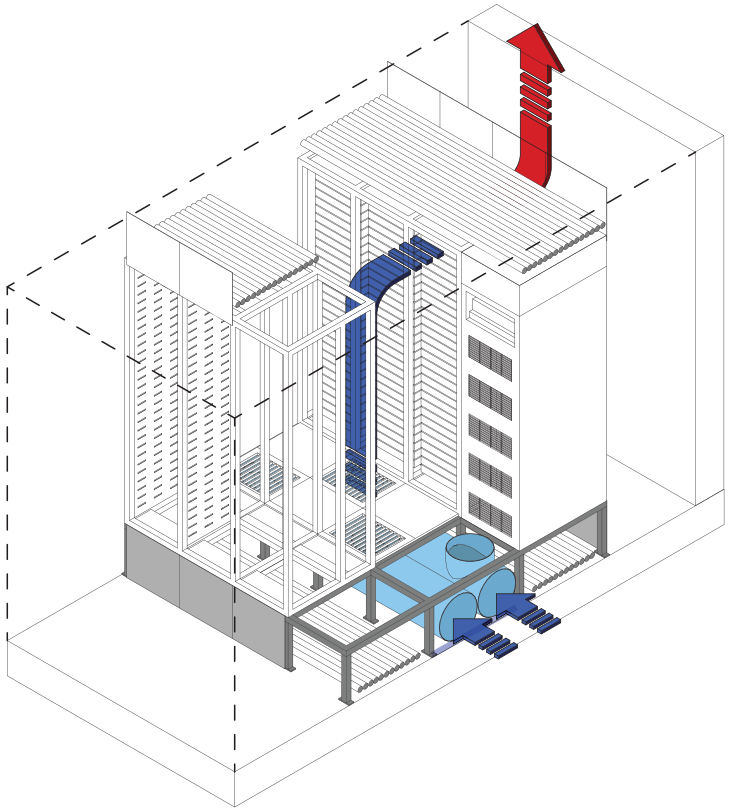
1.3 DNCs

1.3


Typologies of existing DNCs - from left to right: “high tech”, art deco and warehouse

Good references for existing DNC’s are hard to find. Most being one of the three typologies associated with these kinds of facilites today. They are generally bulky windowless buldings (warehouse-like) or preexsting art deco buildings. Some are designed to look “high tech”, as a sort of manifestation of technology or big machines.

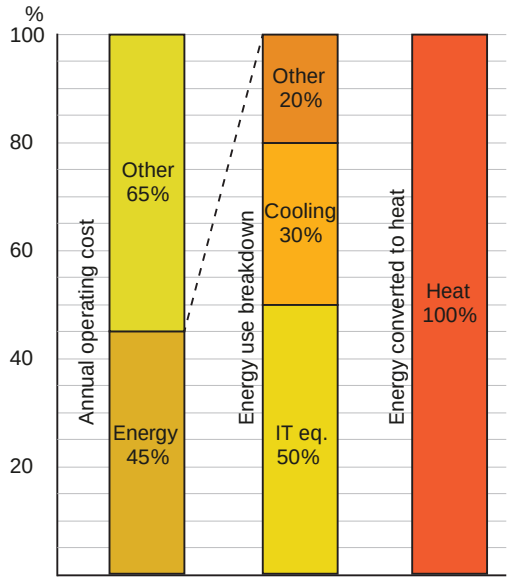
Schematic layout of a generic server hall



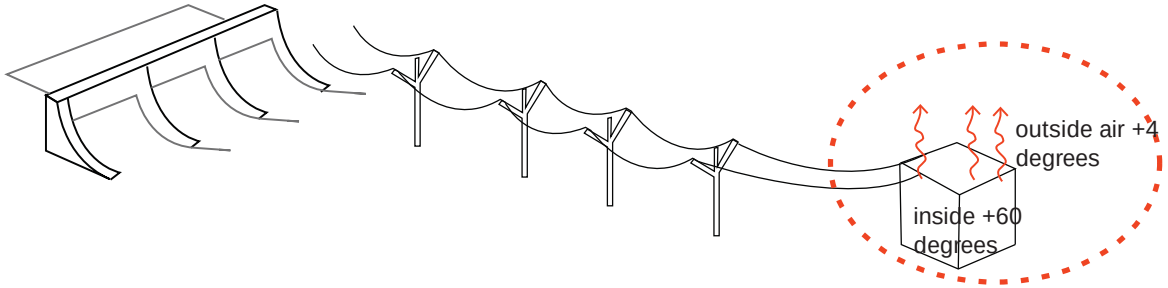
Server space

The servers are standing in racks in long rows in big halls with miles of fiber optic wires.The server racks have two sides, the cold aisle and the hot aisle. In the cold aisle cool air comes into the front of the servers and. once heated, gets transported out via the hot aisle.

1.3



Energy consumption and heat generation



Energy supply and outcome

Hydroelectricity is the energy supply feeding the DNC. The electric equipment needs to be cooled down because it operates at fairly high temperatures. The heat generated gets transported away from the facility as its only physical “product” - heated air.

A DNC of this scale with its inner air temperatures of a mean 60 degrees celcius would impact the micro climate in its surroundings by increasing the temperature within a radius of 200 meters by 4 degrees on average.

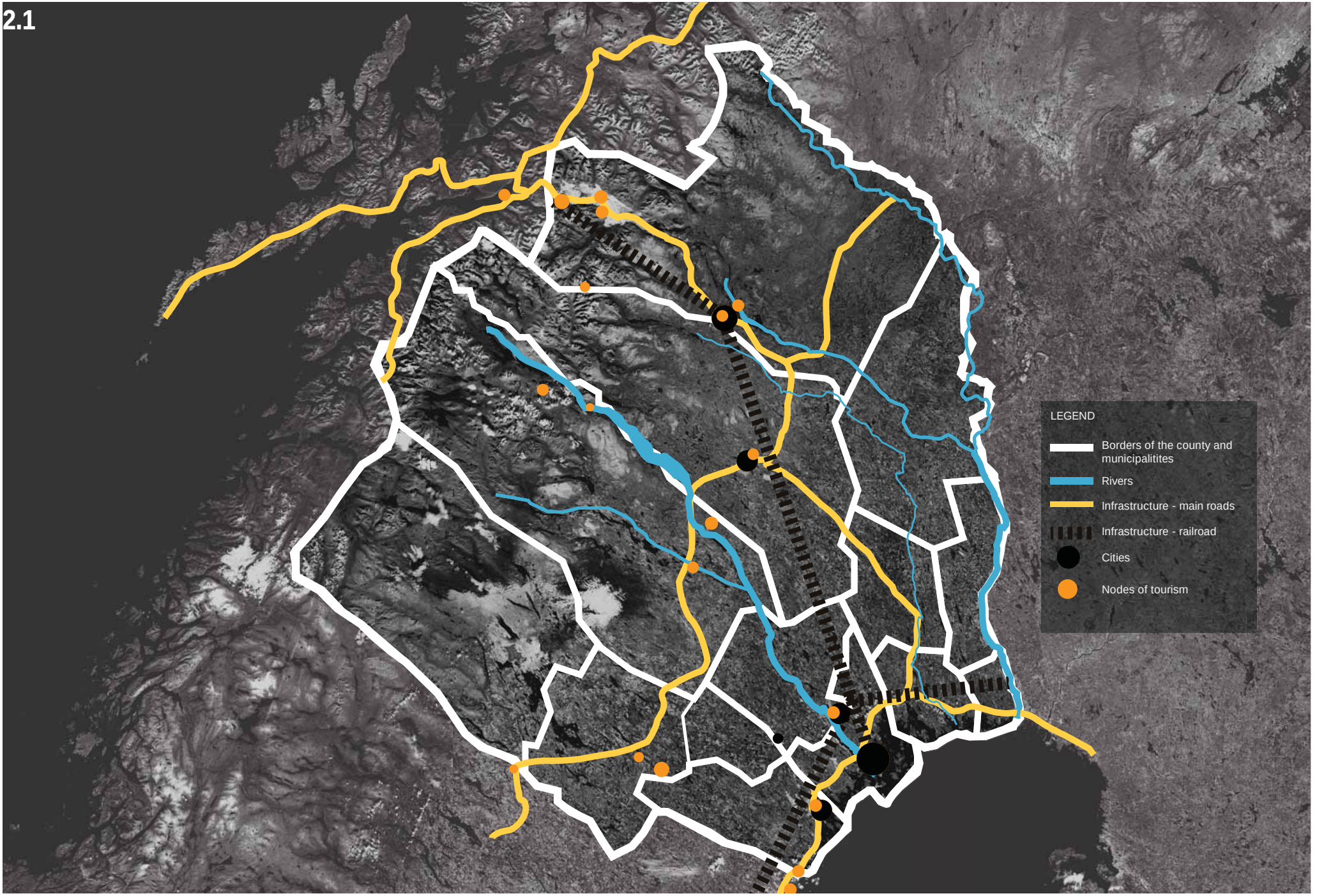
The heat is not enough to be able to heat up water, which would be needed to reuse some of the energy in district heating. This requires temperatures of at least 600 degrees. Thus, it is also not possible to transform the heat back into electricity via kinetic energies.

The conclusion of this is that for another program to be able to benefit from heat generated by the DNC, the program would have to be in close proximity to the DNC itself.

2. ANALYSES

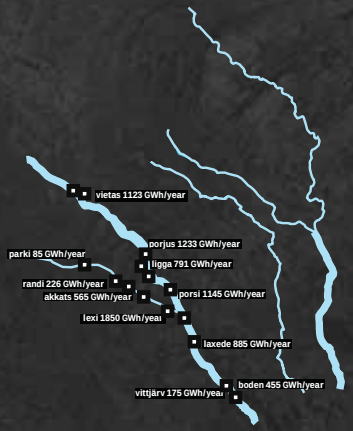
2.1 Regional analysis

2.1

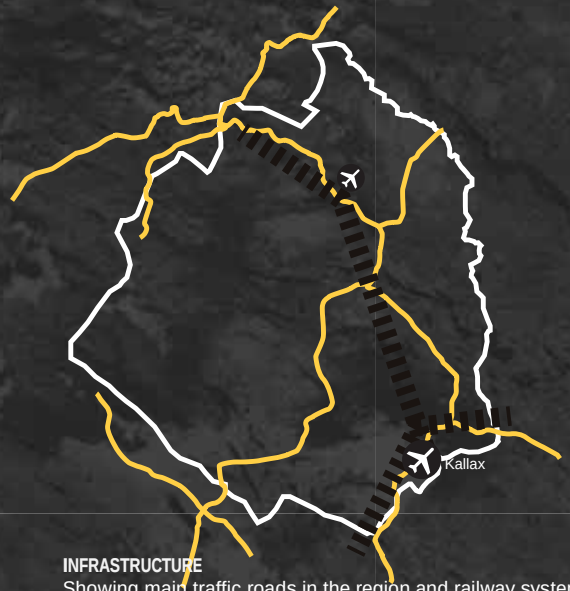

LEGEND
Borders of the county and municipalitites
Rivers
Infrastructure - main roads
Infrastructure - railroad
Cities
Nodes of tourism

NORBOTTEN COUNTY
Being the most norherly county of Sweden, it's as well the largest one - covering almost 1/4 of Swedens surface, even though being sparsely inhabited. The main capital since 1846 is Luleå

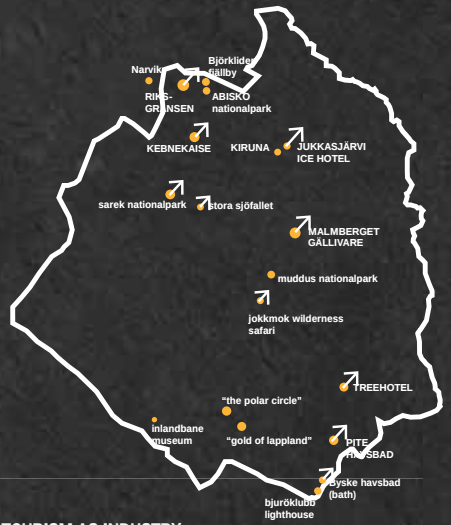
MUNICIPALITIES & MAIN CITIES
The county consists of 14 municipalities, largest in area is Kiruna and largest in population is Luleå. Luleå and Piteå had the highest frequency of increasing number of inhabitants (Luleå 70 000 inhabitants).



THE RIVERS
The three rivers in the region are of high importance, both as a geopgraphical link, infrastructural, and as producers of energy. Luleå älv (river) is the main spot for hydro electric power plants in Sweden and further, Sweden is one of ten of the largest hydroelectric producers in the world.



INFRASTRUCTURE
Showing main traffic roads in the region and railway system and the two airports in the region (Kallax being the main and largest one). Infrastructural nodes are created by the largest cities, Luleå being one of main nodes.



TOURISM AS INDUSTRY
During the last ten years tourism increased up to 23 percent (and by the last year with 4 percent). This trend is showing on increasing numbers of both national and international tourists. Matter of fact, tourism as an industry have become to be of high importance for the economical development of the region. The touristic nodes are found in basically all the other nodes in the region, except for Luleå.

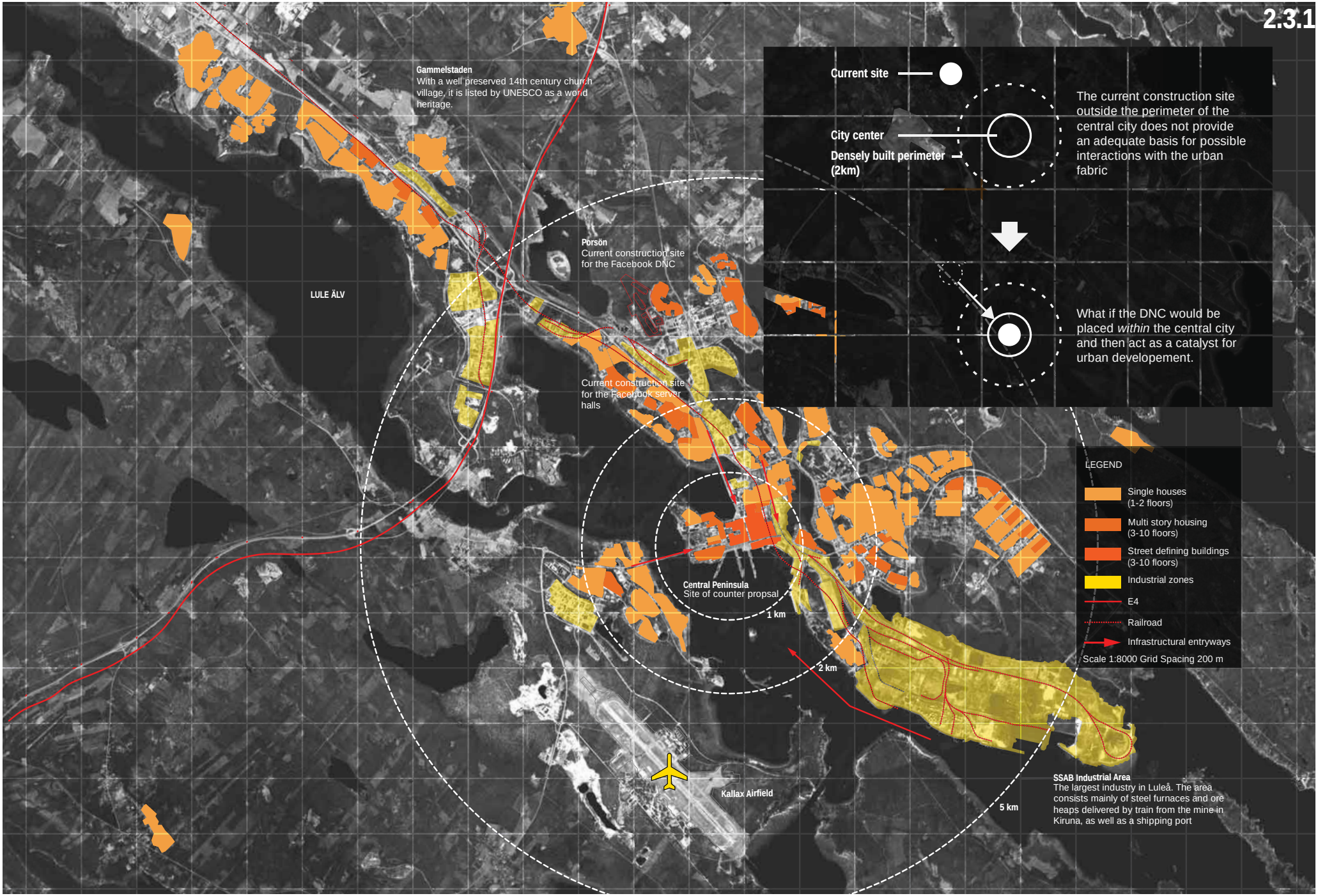
LULEÅ AS A NODE
Luleå, not only as a capital of the region, but as a gepgraphical and economical node, is a a very important link within the region. Being one of main economical and industrial nodes (SSAB, Luleå technical university) its still not constituting to being a node on the map of tourism in the region.

2.2 Program

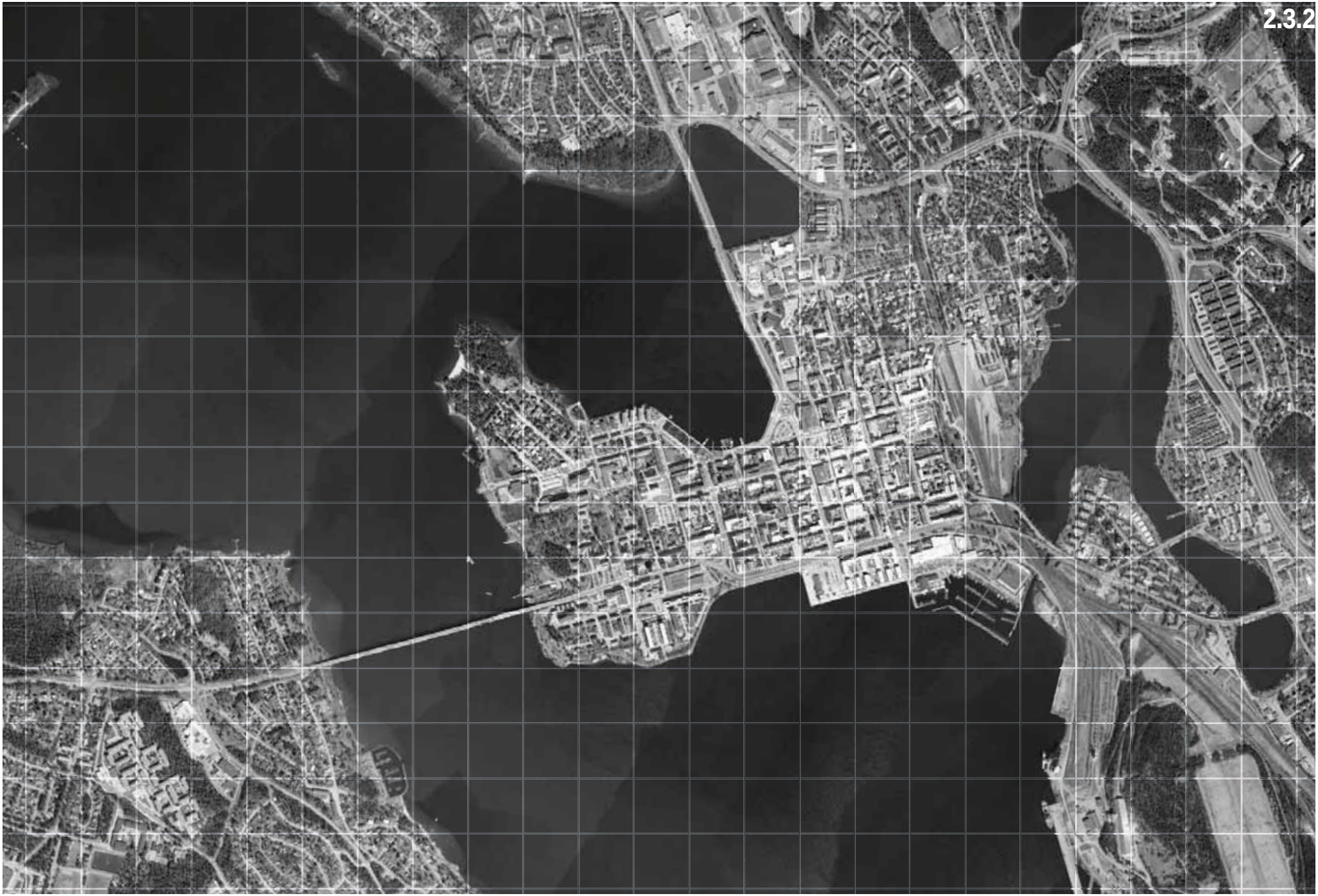
In background of given conditions at this point (the heat being a waste product actually being upheated air, meaning the program need to be in close proximity with the facilities) in background of the regional analysis concluding the non-existence of Luleå as a node in the economic loop of upoming tourism in the region, and in background with the aim to integrate the server halls with the urban fabric, within a local context, and as well in retrospect to the public and local conditions, several cathergories of possible programs were distinguished.

2.3 Local analyses

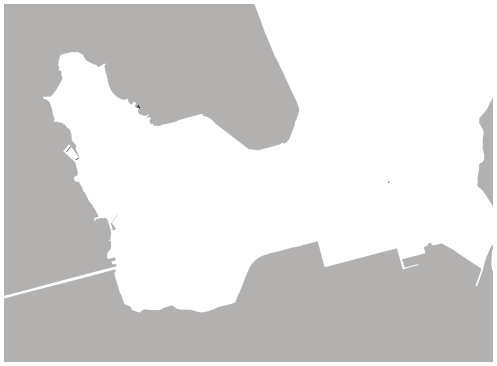
2.3.1 Luleå


Current site
City center
Densely built perimeter (2km)
The current construction site outside the perimeter of the central city does not provide an adequate basis for possible interactions with the urban fabric
What if the DNC would be placed *within* the central city and then act as a catalyst for urban developement.
Gammelstaden
With a well preserved 14th century church village, it is listed by UNESCO as a wond heritage.
LULE ÄLV
Porsön
Current construction site for the Facebook DNC
Current construction site for the Facebook server halls
Central Peninsula
Site of counter propsal
1 km
2 km
5 km
Kallax Airfield
SSAB Industrial Area
The largest industry in Luleå. The area consists mainly of steel furnaces and ore heaps delivered by train from the mine in Kiruna, as well as a shipping port
LEGEND
Single houses (1-2 floors)
Multi story housing (3-10 floors)
Street defining buildings (3-10 floors)
Industrial zones
E4
Railroad
Infrastructural entryways
Scale 1:8000 Grid Spacing 200 m

2.3.2 Central peninsula (Centrumhalvön)

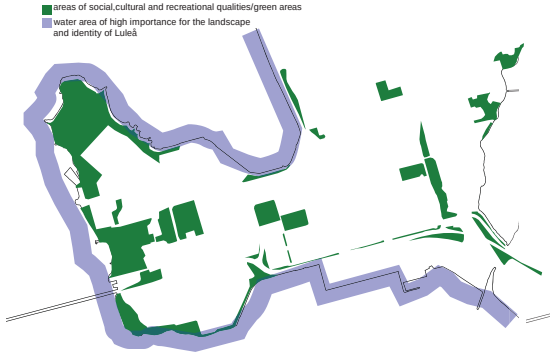


2.3.2
General analyses

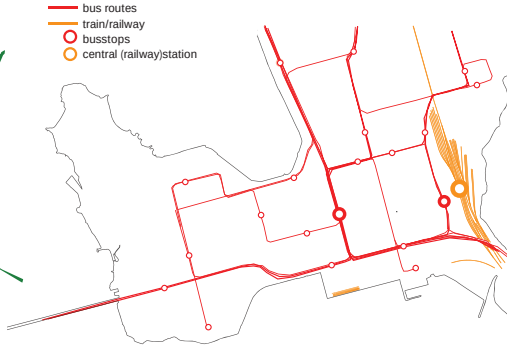


Land mass

Building mass

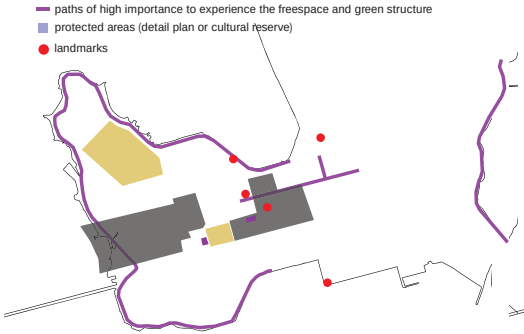


Green areas

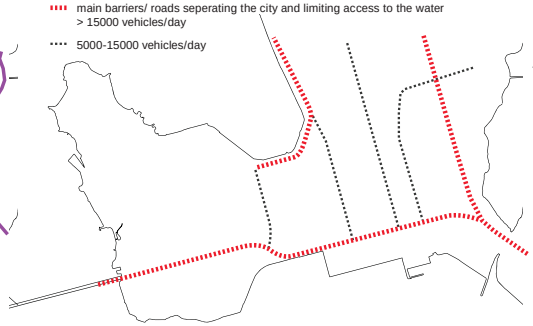


Public transport

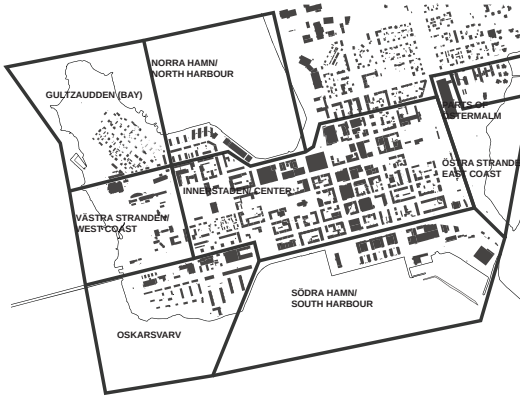
Frequency of empty areas



Social and cultural values

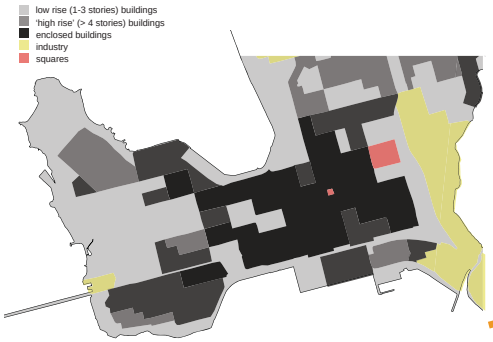


Barriers and amin trafic roads

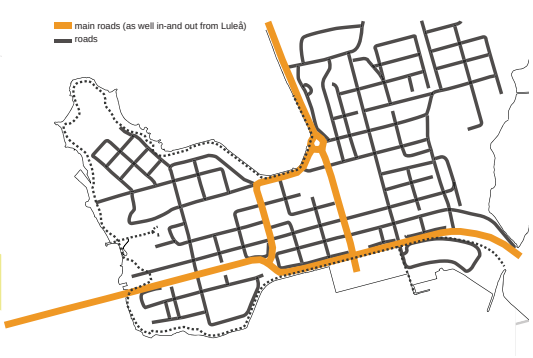


Areas

Building typologies



Building typologies- density



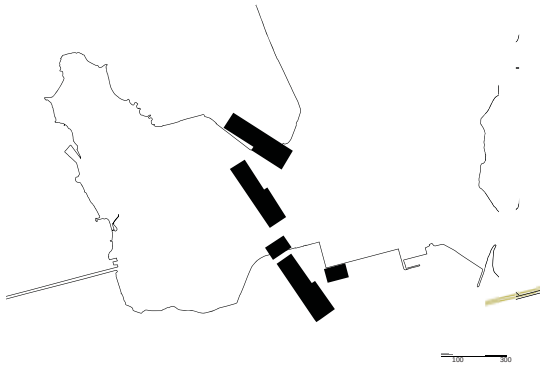
Infrastructure

User density

Areas waiting for development

Entrance points

(pdestrian) street density



User density

2.3.2

Timeline and historical maps

4 inhabitants

1300 1600 1700 1800 1850

1327.
"Lulu" as a name first time to exist in a document

1400.
Gammelstad church is built

1621.
Luleå city is founded around the spot of Gammelstad church. City rights

1649.
The city is, as a consequence of land elevation, transferred from Gammelstad to Halvön, at the entrance of Luleå river. Erik Eriksson Niure makes a cityplan according to a grid system

1732.
Carl von Linné makes a visit to the city and describes it as "en by om än skön"

1790.
Fixing up the streets

1830.
The shipbuilding industry takes of and the city experience a powerful economical growth

1856.
The county governor's residence gets built in the west end of Storgatan

1858.
Cityplan for the innercity peninsula

1883.
Installation of the first telefon line

1886.
The cityplanarea gets extended

1887.
The city is demolished due to the large fire

1888.
The railway road Luleå-Gällivare opens

1893.
The city cathedral (domkyrka) gets built

1894.
Luleå gets connected to Norra Stambanan (electrified railway). Steamboat connection to Stockholm

1901.
Södra hamn (the south harbor) starts to be built

9 500 inhabitants

11 300 inhabitants

30 000 inhabitants

60 000 inhabitants

75 000 inhabitants

1902. Hamnpiren (the harbor pier), Hamnspåret (harbor track) and Långkajen (the "long dock") are built

1907.
The harbor sheds from Norra hamn (the north harbor) are moved to Södra hamn

1930.
Tullpackshuset is built

1960.
The business/activities in the harbor are gradually transferred to Svartölandet

2012-
Södra hamn is waiting for exploatation

1900 — 1950 — 2000

1903.
Oscar II inaugurates the oretrack (Malmbanan) to Kiruna

1921.
Luleå celebrates 300 years anniversary. Festivities on Gultzaudden

1932.
Luleå city extends by incorporating Svartöstaden

1954.
connection west with the mainland with Bergnäsbridge

1969.
Luleå, Nederluleå (lower Luleå) and Råneå merge to one municipality

1988.
teknikens hus (science center)

1988.
world championships in sailing

1921.
The car makes its entrance

1940.
NJA (Norbottens ironworks) is created and Luleå becoms "the iron-and harborcity"

1955.
Swedens first indoor shopping mall, *Shopping*

1971.
Luleå technical university

1906.
Luleå steelworks sets into business

1923.
The first bus line is set in use

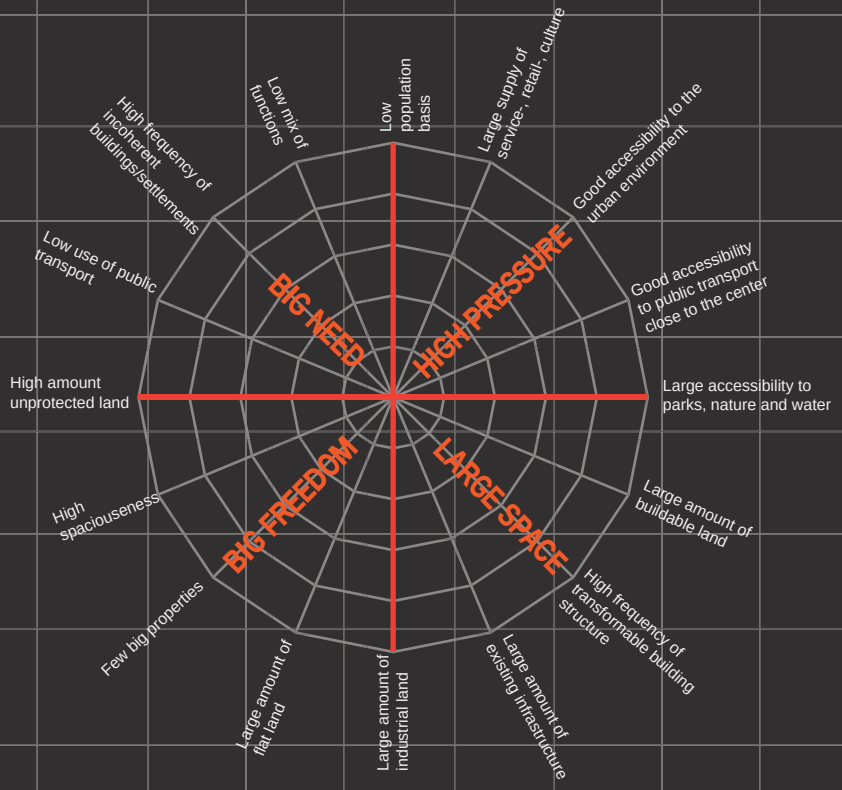
1950-
NJAs expansion due to increasing demand europe leading to building boom, housing at Örnästet and

1957.
first traffic light. Crossing of Storgatan-Kungsgatan

1980.
the parking lots from the demolishons in the 70's are built upon.

2.3.2

Densification and potential diagrams



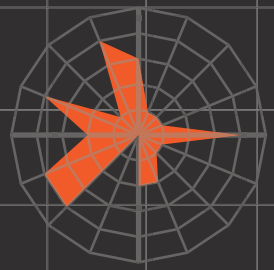
CENTER (1)
High pressure on densification
Low freedom and space

SOUTH HARBOUR (2)
Large unexploited area renders high potential for densification

NORTH HARBOUR (3)
Large space for densification and high pressure

WEST SIDE (4)
Historically protected area. No space or pressure but large need and freedom

OSCARSVARV (5)
Freedom, pressure and need is low but large areas for densification



GULTZAUDDEN (6)
Big need for densification, all other factors very low

This is a method used and described by the Stockholm City Council (2009) and applied to Luleå in a thesis at LTU (Arnedhed, Emilsson 2011).

In brief it is a diagram of four thematic quadrants describing the general potential of an area. Each are divided into 4 different indicators with a score of 1-5were distinguished.

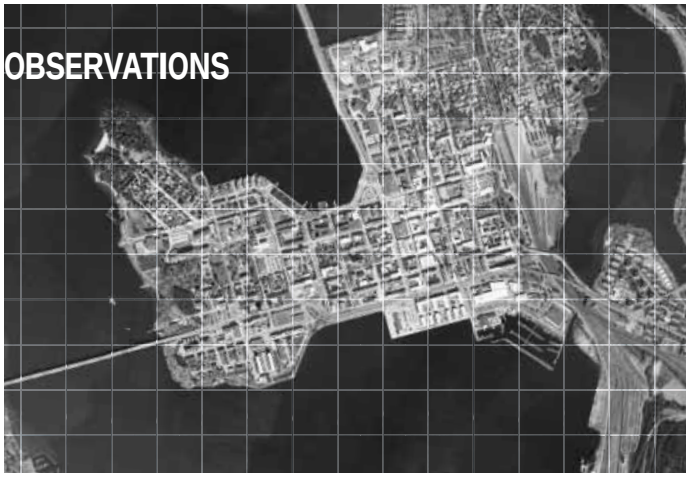
The south harbor area was chosen largely because the location has high potential and need for developement and the position in the urban context provides a platform with good qualities for the construction of a new public waterfront.


6
3
1
4
2
5

3. PROPOSAL

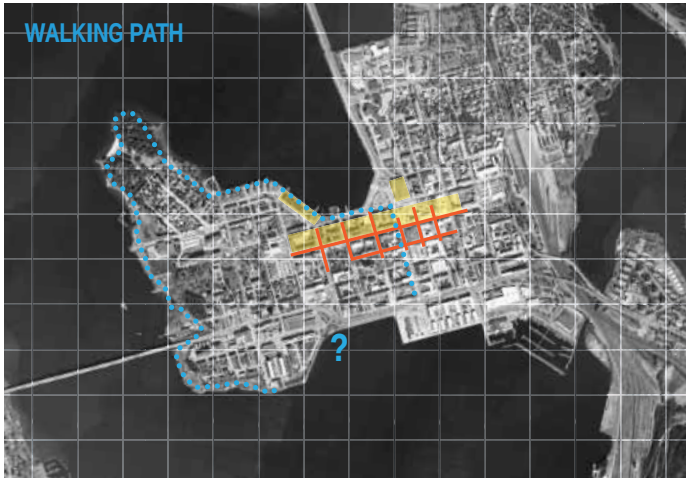
3.1 Project development

3.1

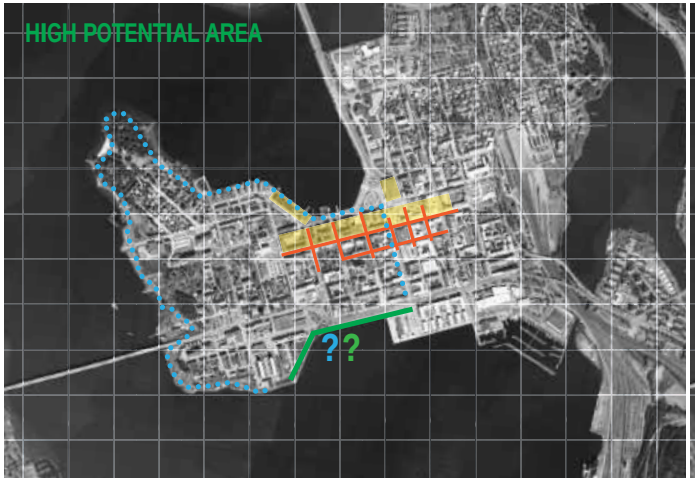


The activity is shifted towards the north of the peninsula.

The public functions of the city core is shifted to the north side of the peninsula with user intensity fading southwards.

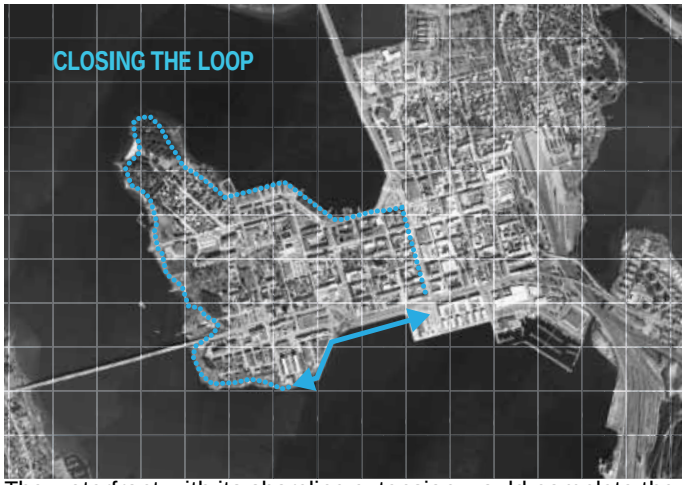


Leading around the peninsula is an important walking path that in its southern parts loses its continuity....

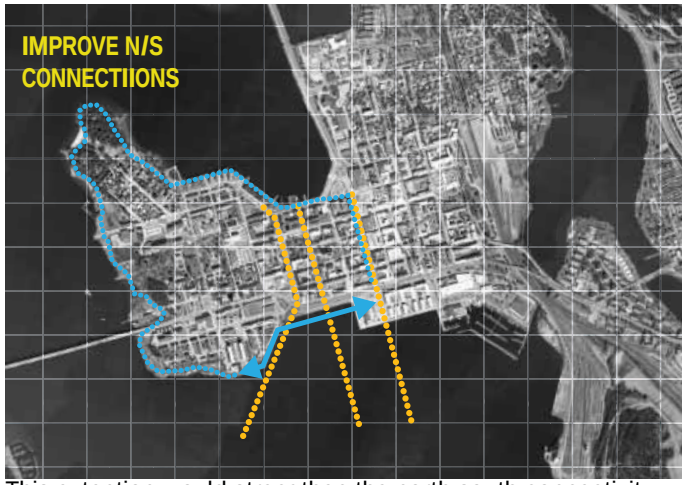


not taking advantage of the high potential area of the south harbor.

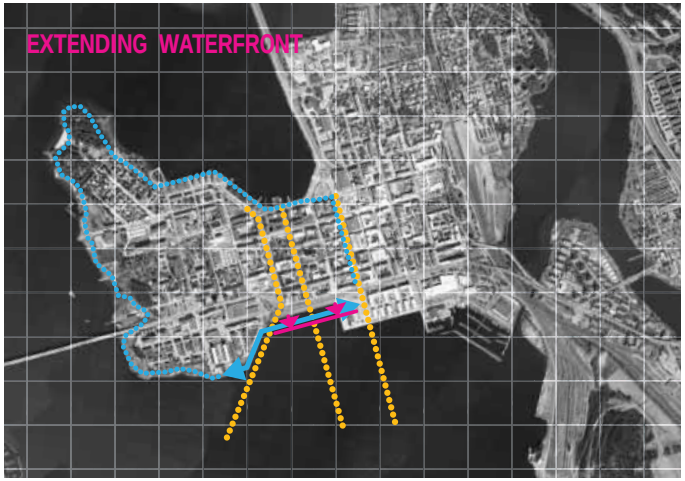
The southern harbor, which historically was buzzing with life was cut off from public accesability by a throughfare road built in the 70's.



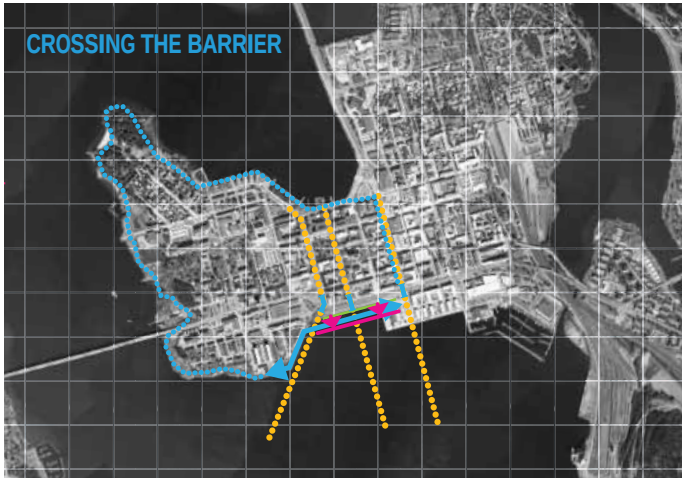
The waterfront with its shoreline extension would complete the broken continuity of the higly important walking path.



This extention would strengthen the north south connectivity between the harbor areas.



An extension of the coastline into a new waterfront would allow public life in an area that hold high potential for densification

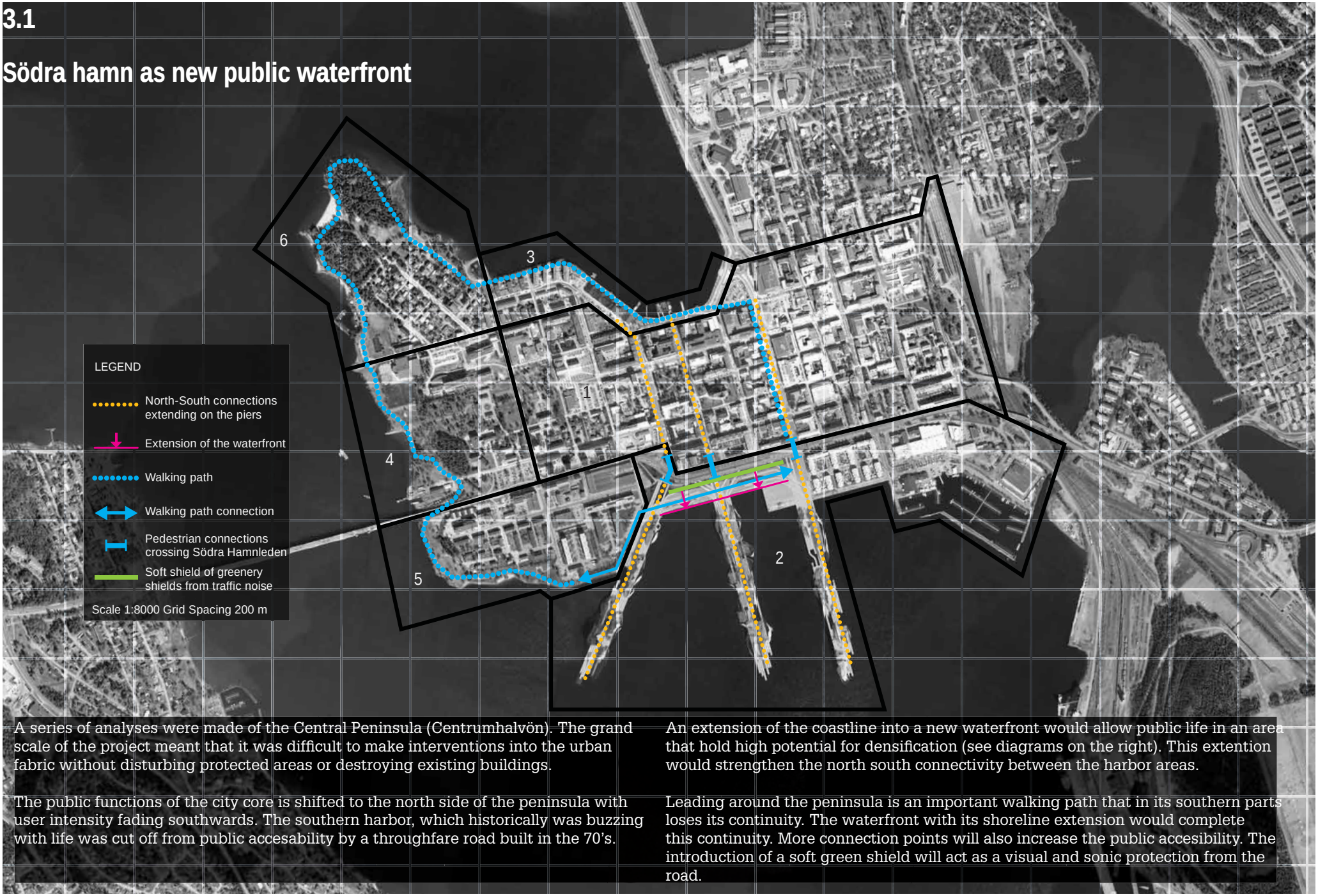


More connection points will also increase the public accesibility.

The introduction of a soft green shield will act as a visual and sonic protection from the road.

3.1

Södra hamn as new public waterfront



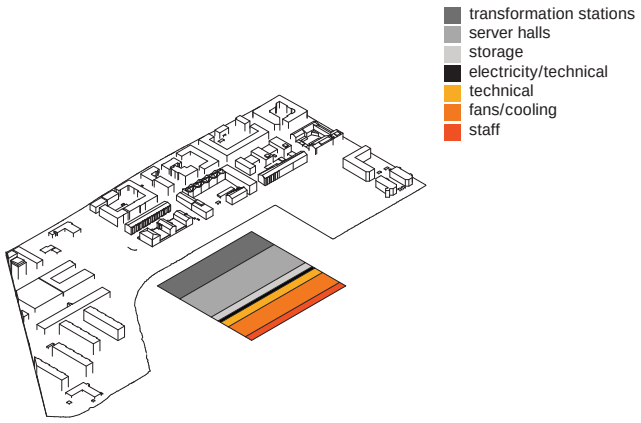
A series of analyses were made of the Central Peninsula (Centrumhalvön). The grand scale of the project meant that it was difficult to make interventions into the urban fabric without disturbing protected areas or destroying existing buildings.

The public functions of the city core is shifted to the north side of the peninsula with user intensity fading southwards. The southern harbor, which historically was buzzing with life was cut off from public accesability by a throughfare road built in the 70's.

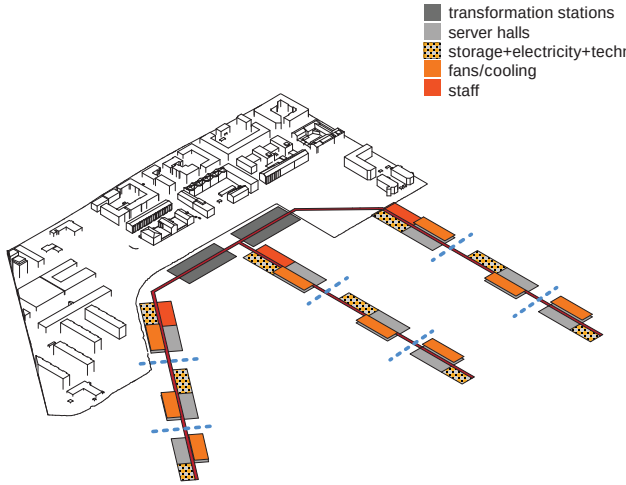
An extension of the coastline into a new waterfront would allow public life in an area that hold high potential for densification (see diagrams on the right). This extention would strengthen the north south connectivity between the harbor areas.

Leading around the peninsula is an important walking path that in its southern parts loses its continuity. The waterfront with its shoreline extension would complete this continuity. More connection points will also increase the public accesibility. The introduction of a soft green shield will act as a visual and sonic protection from the road.

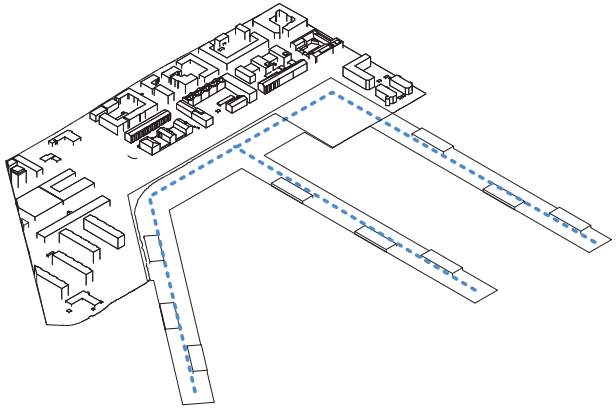
Project development on site - South Harbor



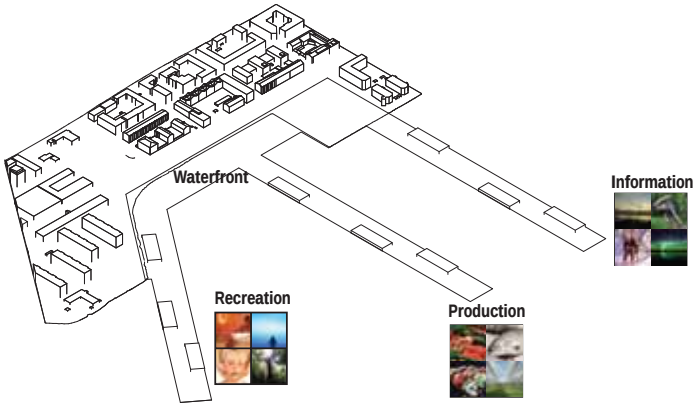
Program division
the program of the DNCs placed out on the project site, constituting the foundation of the project and program to come



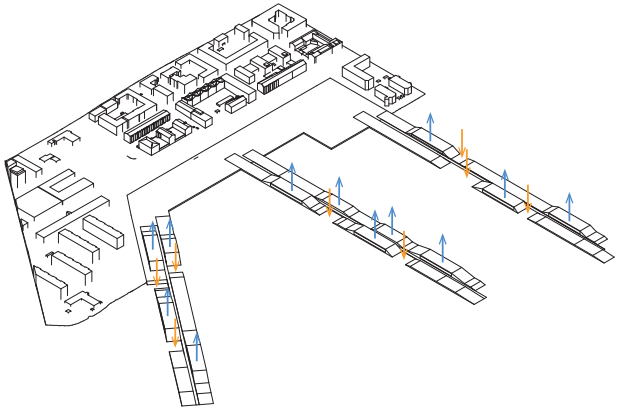
Re-structuring the program
The program gets further re-arranged in order to optimize the logistics and a subterranean accessway, connecting the DNCs with the transformation stations, is added



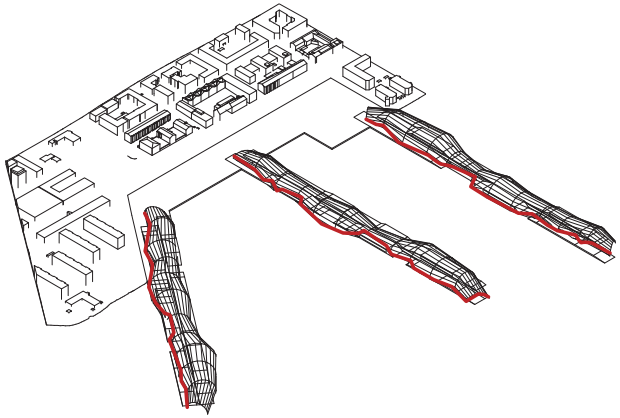
Adding public surface
The publicly accessible surfaces gets added on top of the DNCs



Public program
Program - in background of the conditions of which kind of thermal loss we are dealing with, the regional and local context and the integration of server halls into the urban fabric
according to previous analyses



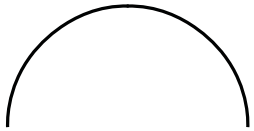
Adjusting topography of surface
The surface gets adjusted according to program specific needs, creating an accessible landscape



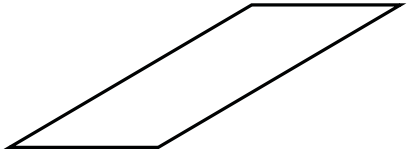
Adding membrane
A climate shield envelopes certain parts of the program and accumulate heat produced by the DNC

3.2 Key design elements

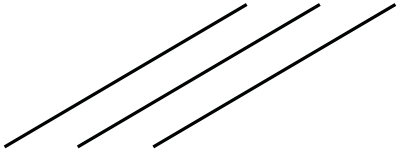
3.2



Membrane



Surface

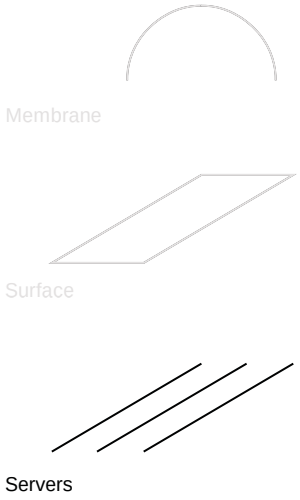


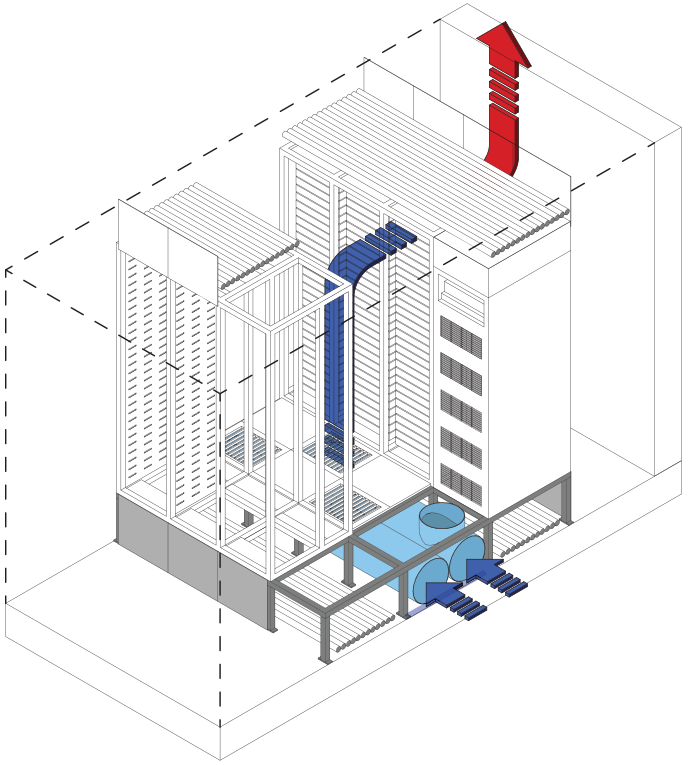
Servers

3 KEY DESIGN ELEMENTS

3.2

Servers

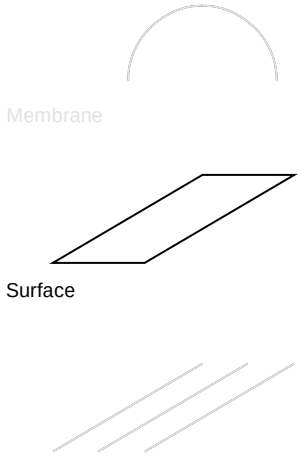


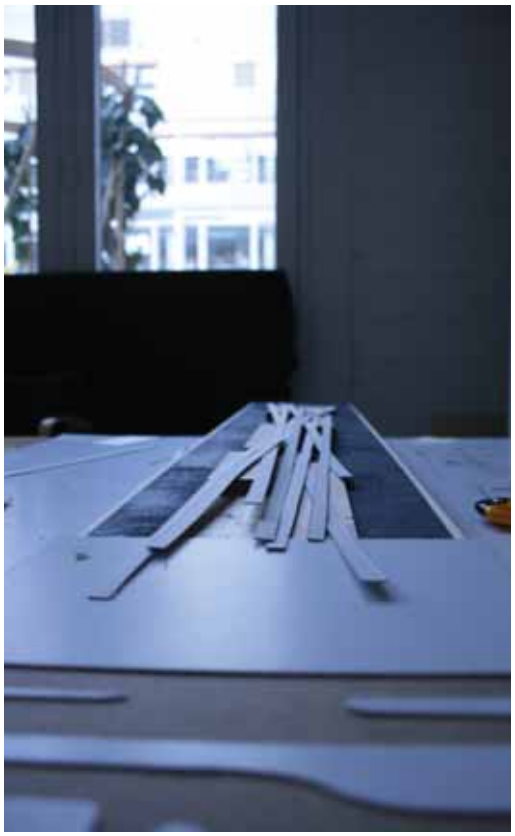


The servers- physical base of the projecs and the heat producer.

3.2

Stripes

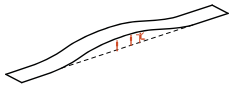




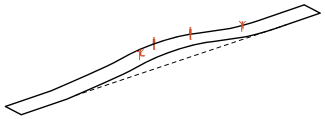
The public surface on top of the servers. The development of the stripes came from the basic setup of the server halls, with upheated corridors each fifth meters which would release the excess heat. The stripes further developed to a walkable surface that would come to define the landscape of the program.

The set up of the stripes leaves lots of possibilities, from creating a walkable surface on top of the server halls to roofing, bridges, stairs, and so on.

covering programs

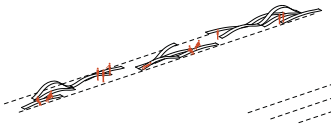


roofing

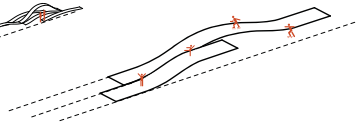


bridges

bike stands

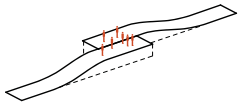


urban furniture

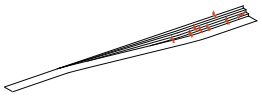


playground/skating/
working out

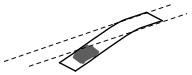
lighting



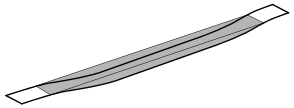
observation deck



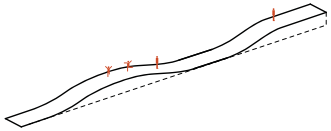
stairs



ramps (entrance/exits
parking)



water

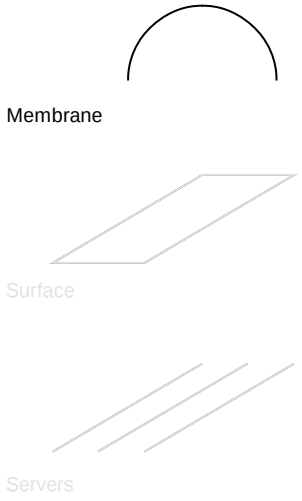


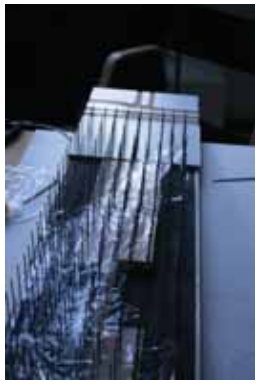
walkable/artificial landscape

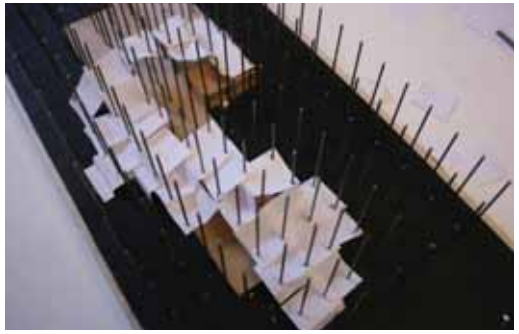
THE STRIPE: CATALOGUE OF POSSIBILITIES

3.2

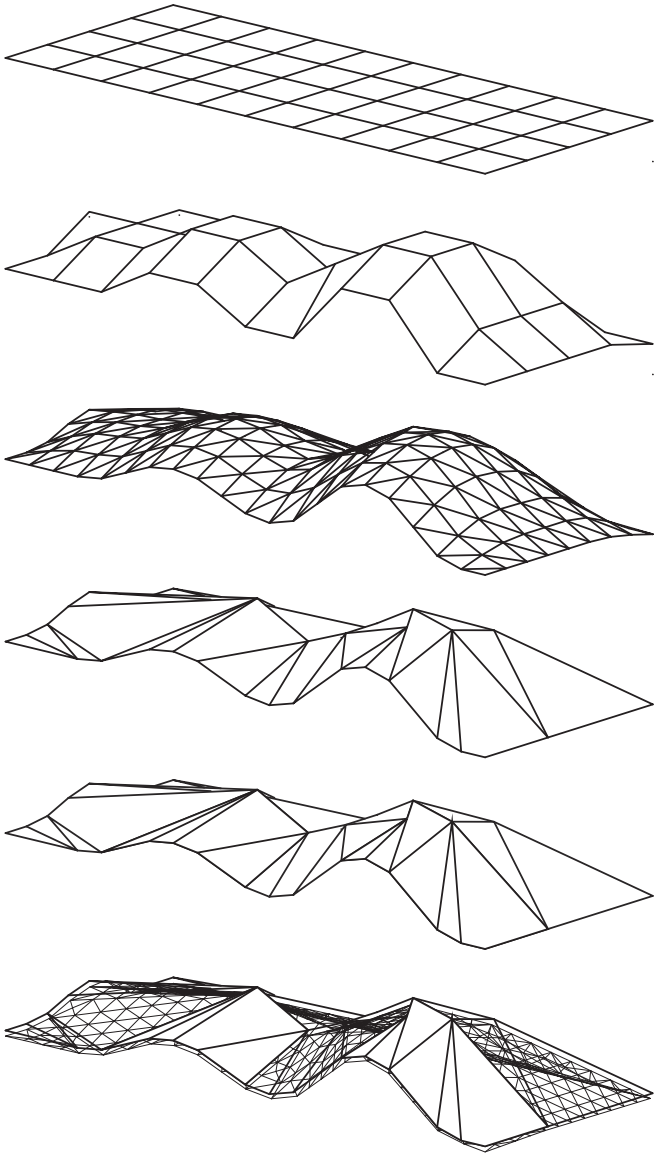
Membrane







The membrane covers areas in need for regulated temperature and weather/wind protection. Because of the large amount of air being heated up, the membrane can, in places, be left open or semi open. The indoor temperature would be regulated through openings in the membrane.



1. Grid
Starting point is a flat grid with a 5x5m spacing

2. Height adjustment
Grid is raised according to program specific heights

3. Refining the curve
The resulting shape is refined to recieve a smoother curvature to better withstand wind forces

4. Optimization
The outer boundaries are preserved and the topography of the steel construction gets simplified and as a resultant becomes more surface efficient

5. Room definition
Certain areas of the membrane are completly covered and functions as room definers and produce a visual dynamic element of the structure

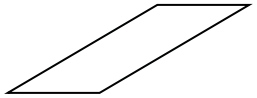
6. Glazing
The remaining open areas gets subdivided into a finer triangular grid and recievas a glazed surface attached to the inside of the steel construction.

MEMBRANE DEVELOPMENT

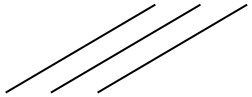
3.2

Energy circulation and heat distribution

Membrane

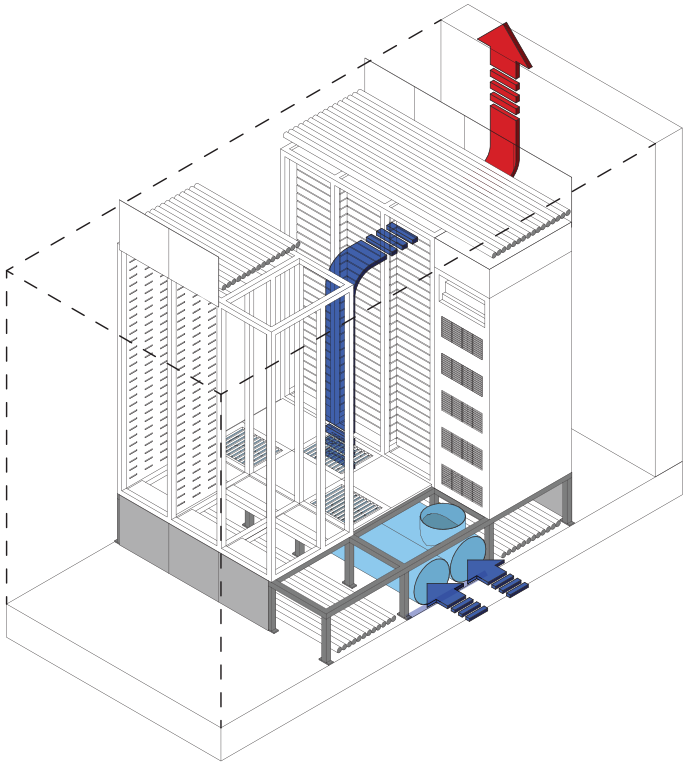


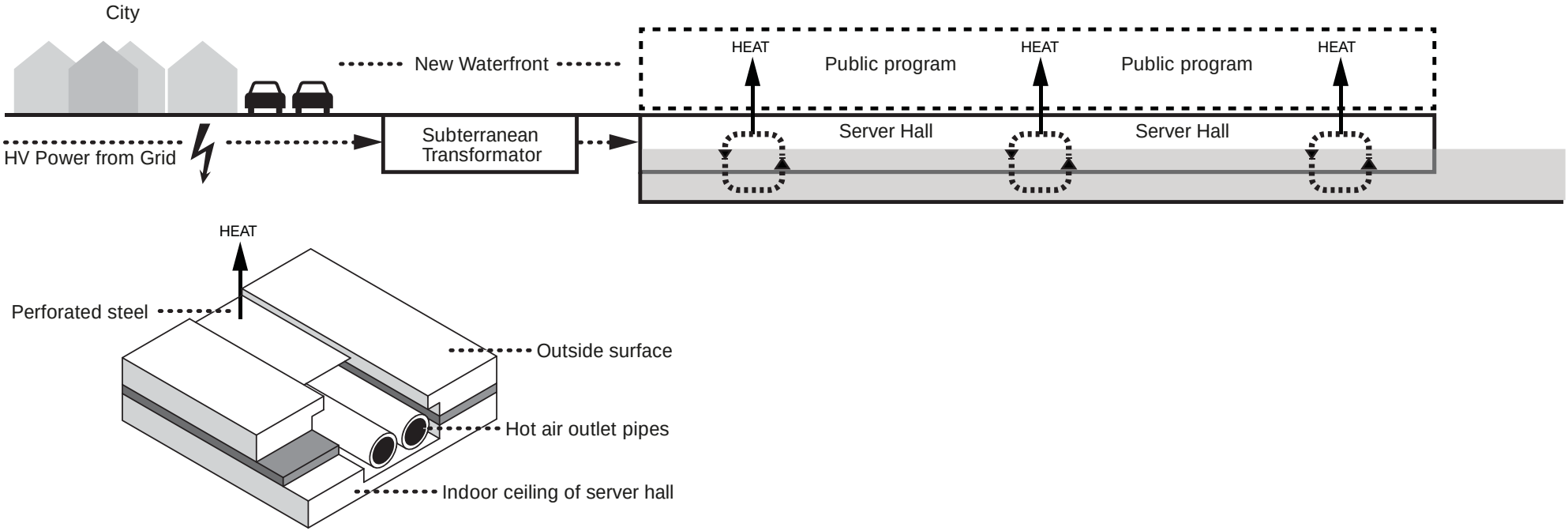
Surface



Servers

3 KEY DESIGN ELEMENTS





The above is a schematic section view showing the main energy flows of the project. High voltage electricity gets transformed to 12V low voltage that feeds the electronics. Cooling is made by an amfibic system of both air and water cooling, depending on outer conditions.

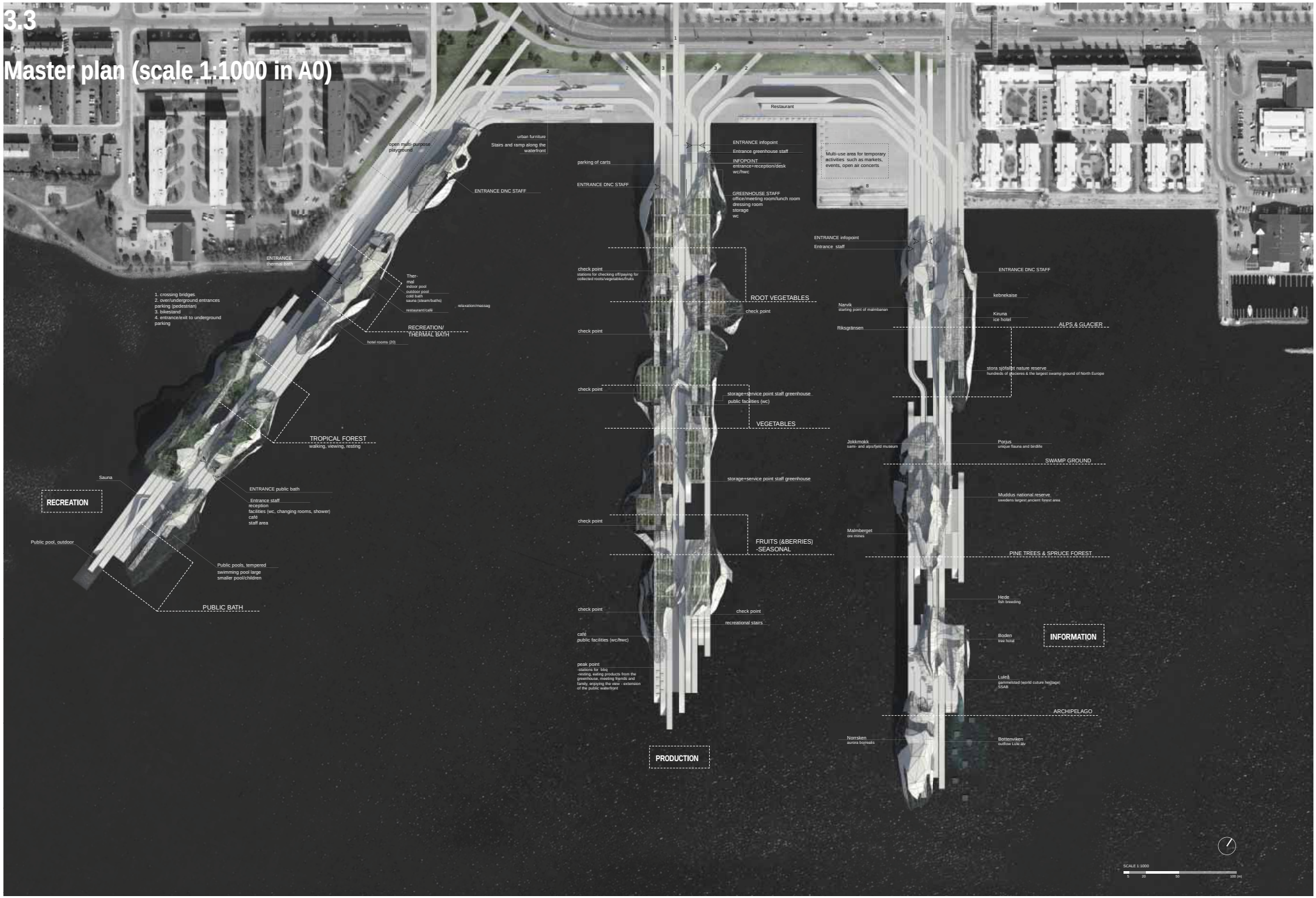
The waste gets released into the public program via channels inlayed between the “stripes”.

3.3 Project proposal

3.2

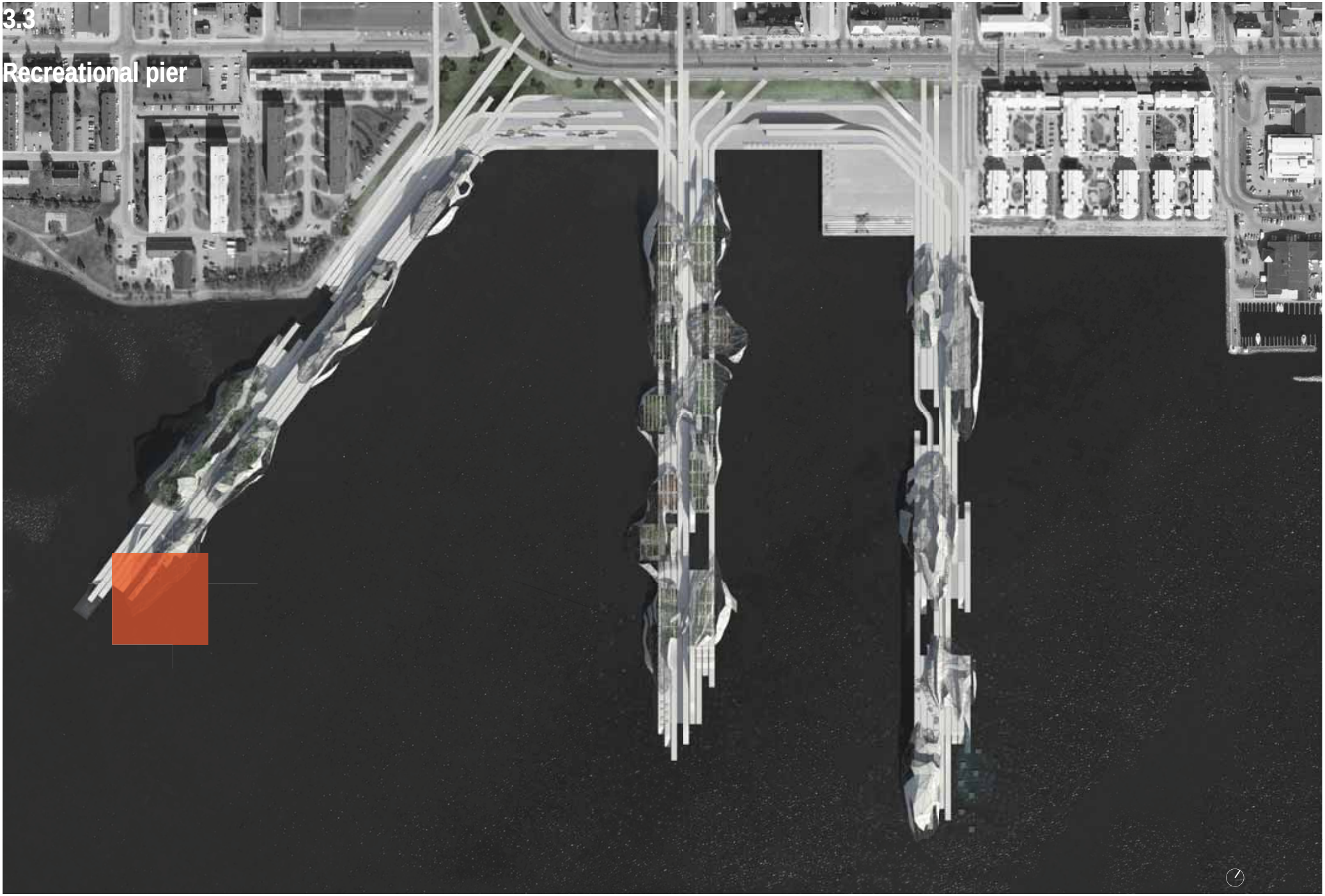
Section cut

3.3
Master plan (scale 1:1000 in A0)



3.3

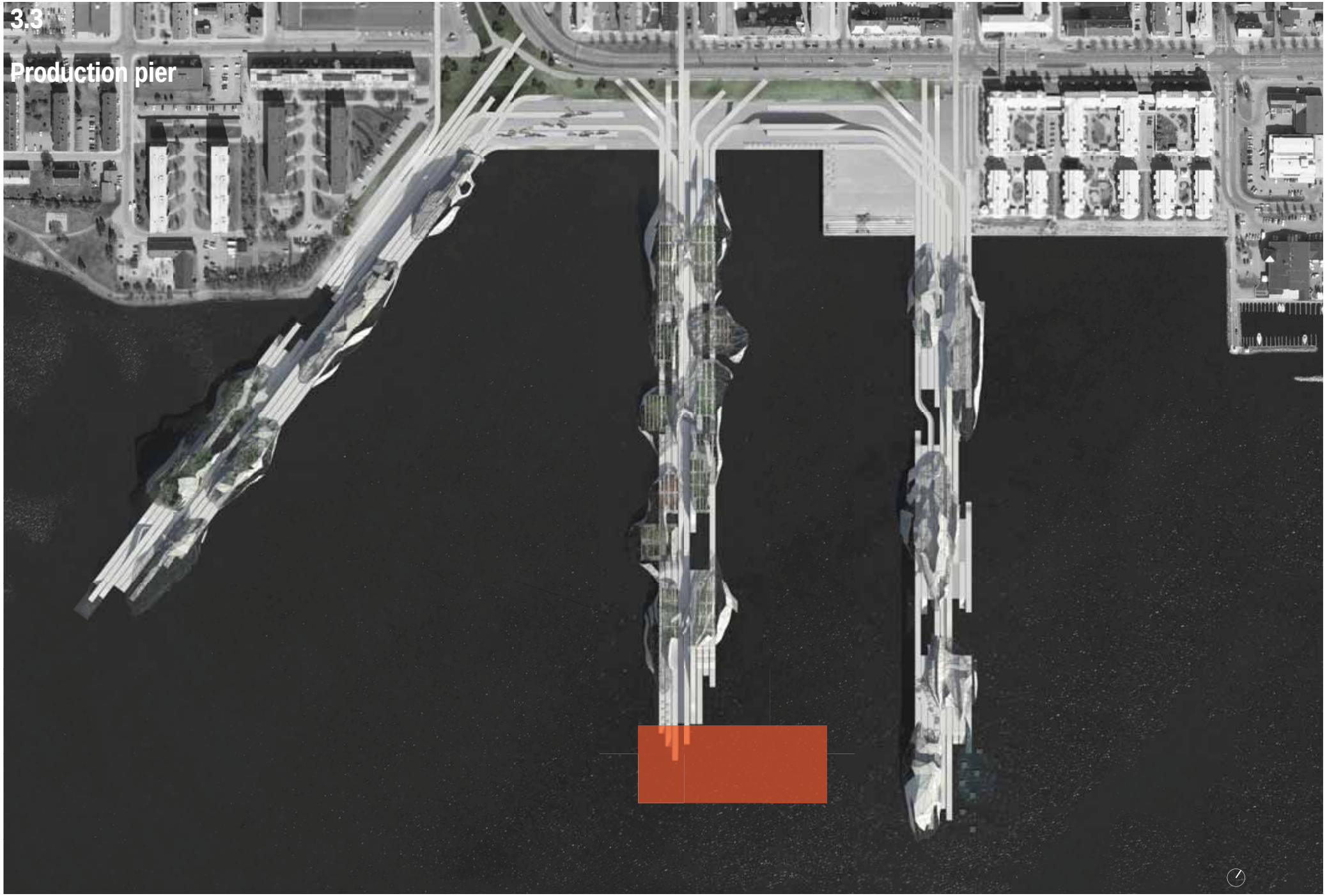
Recreational pier



INTERIOR VIEW FROM REACREATIONAL PIER - PUBLIC BATH

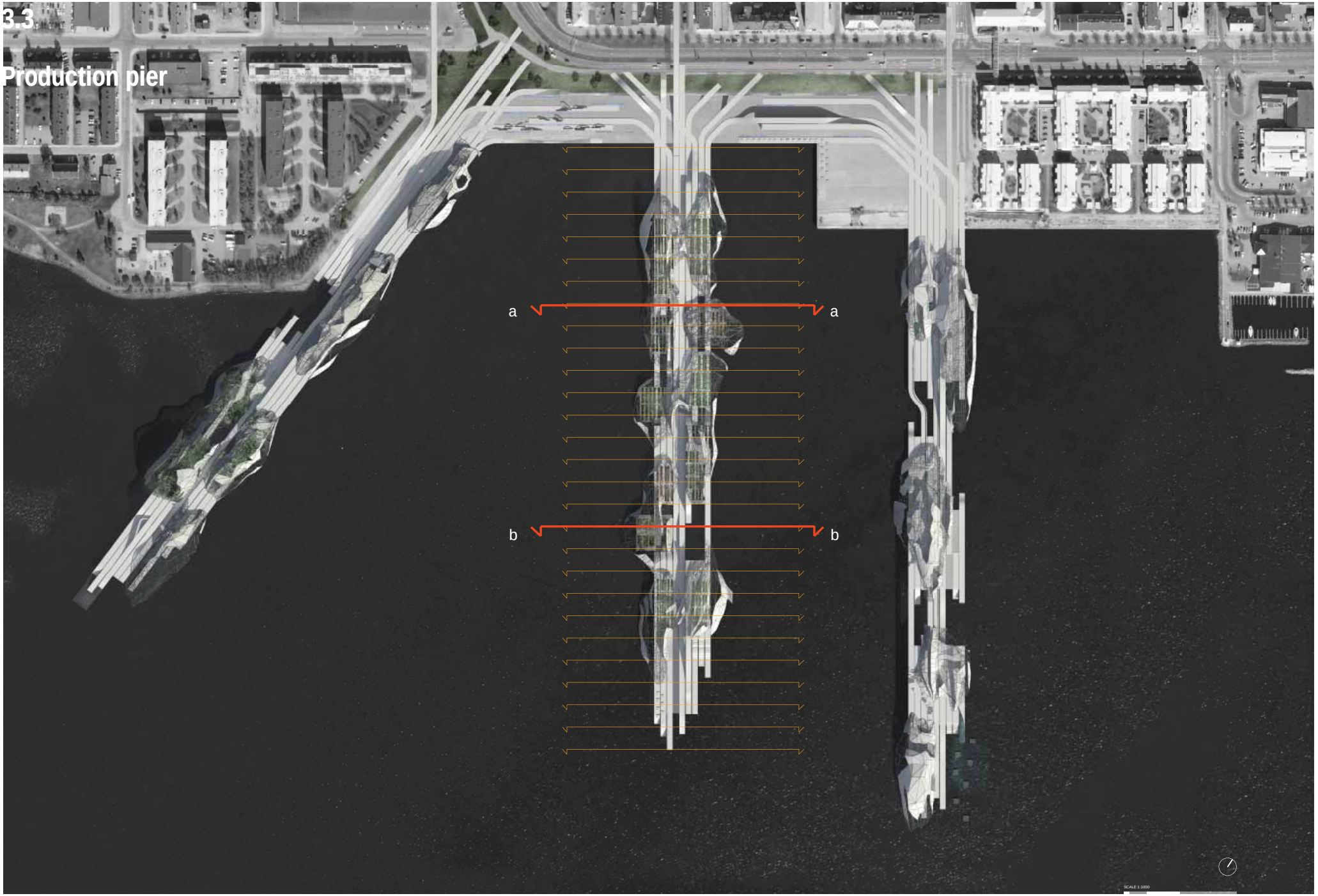
3.3

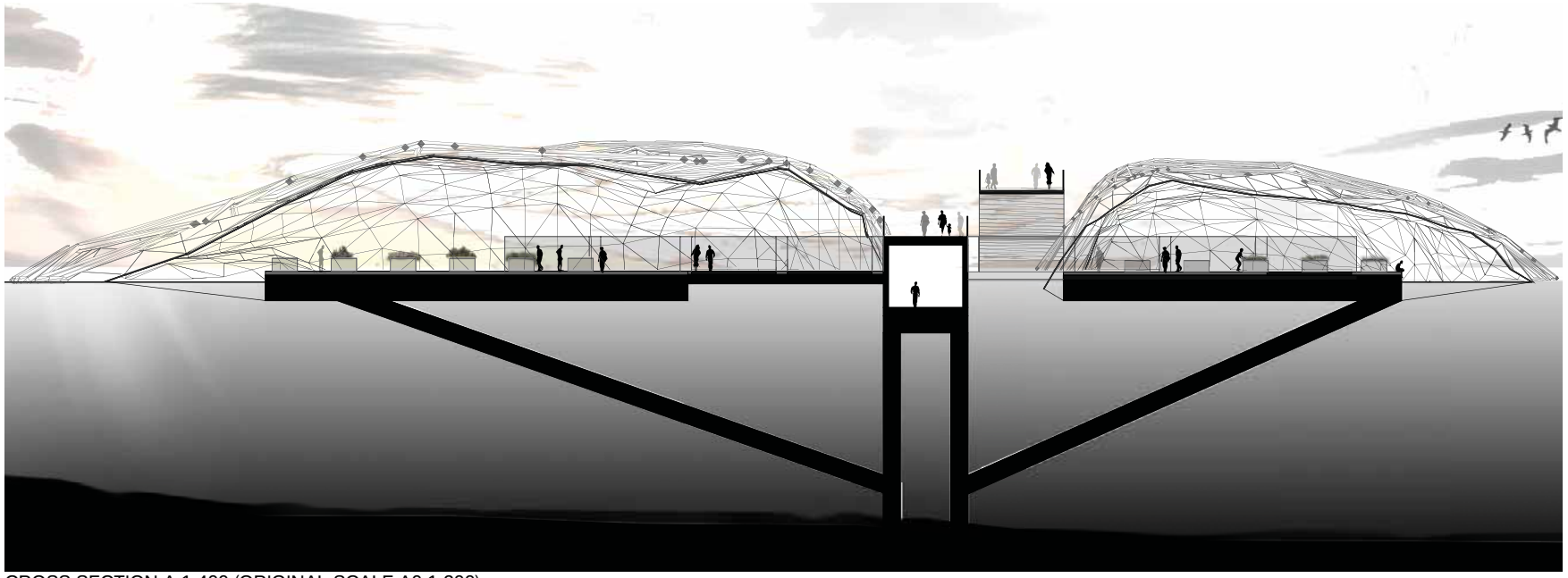
Production pier



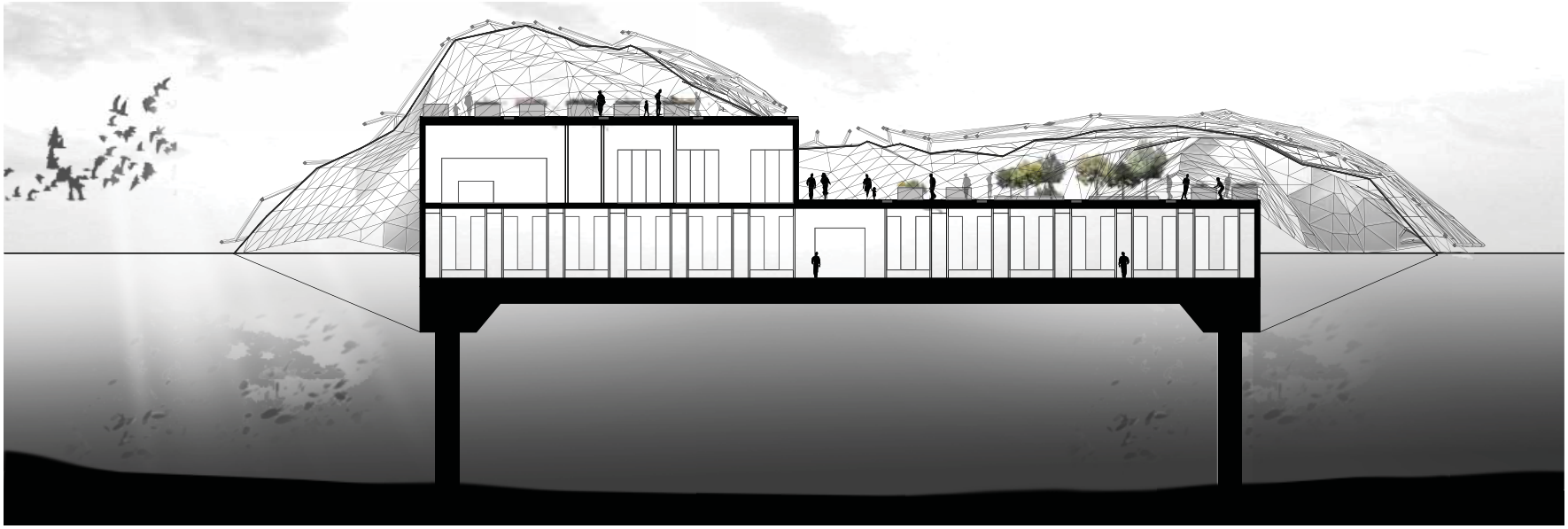
VIEW FROM THE WATER (SOUTH)

3.3
Production pier





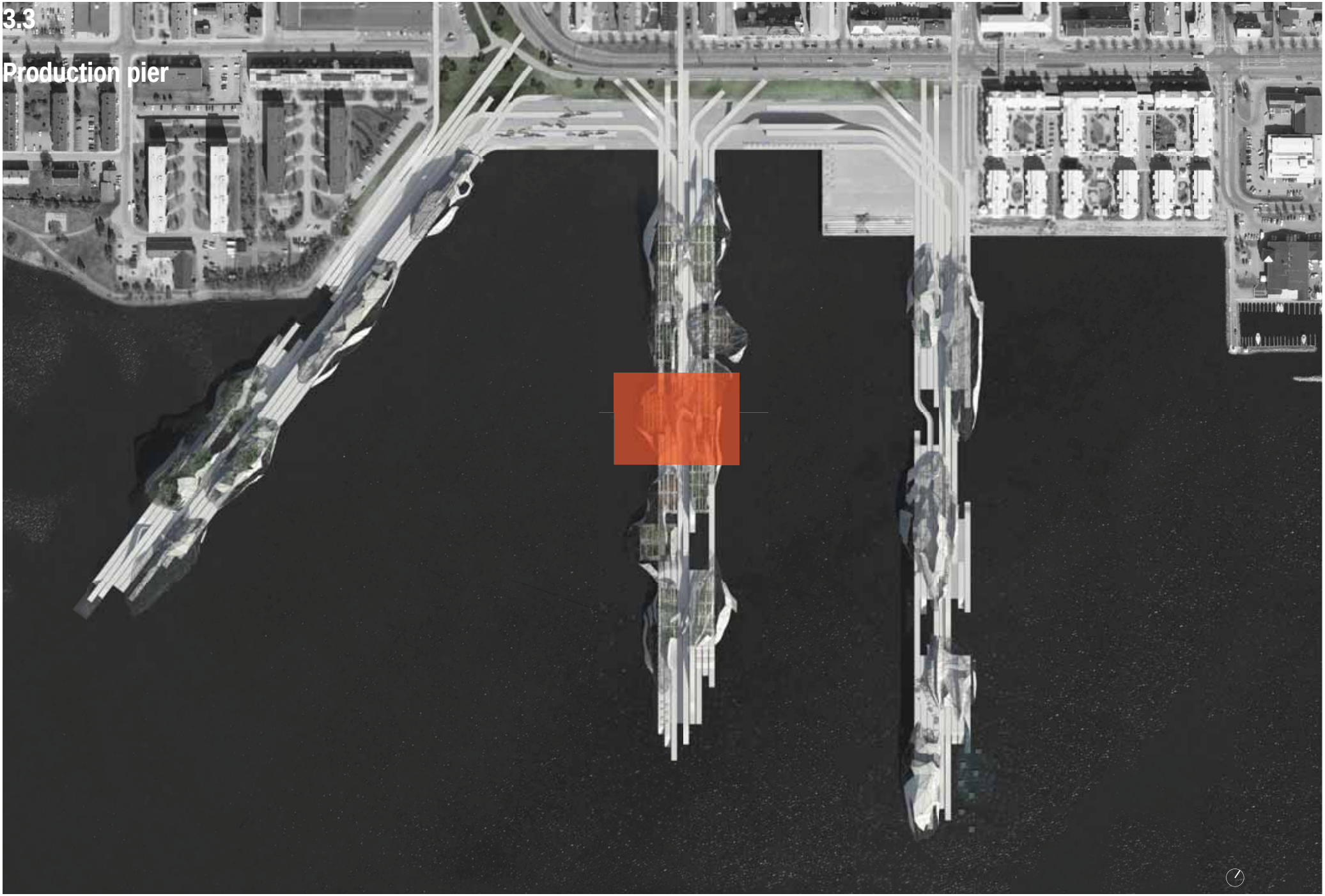
CROSS SECTION A 1:400 (ORIGINAL SCALE A0 1:200)

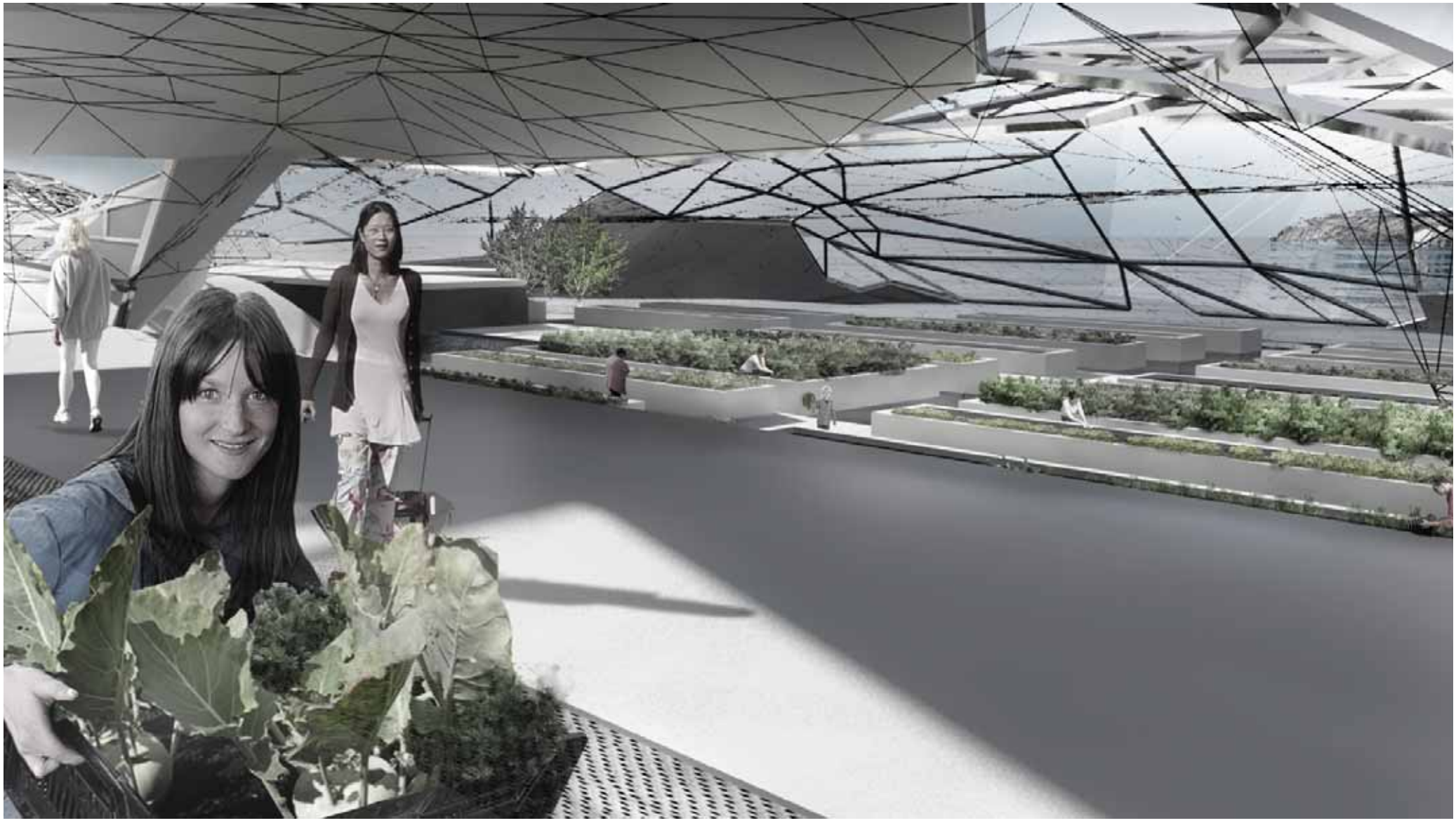


CROSS SECTION B 1:400 (ORIGINAL SCALE A0 1:200)

CROSS SECTIONS
1:4000 (ORIGINAL SCALE A0 1:2000)

3.3
Production pier

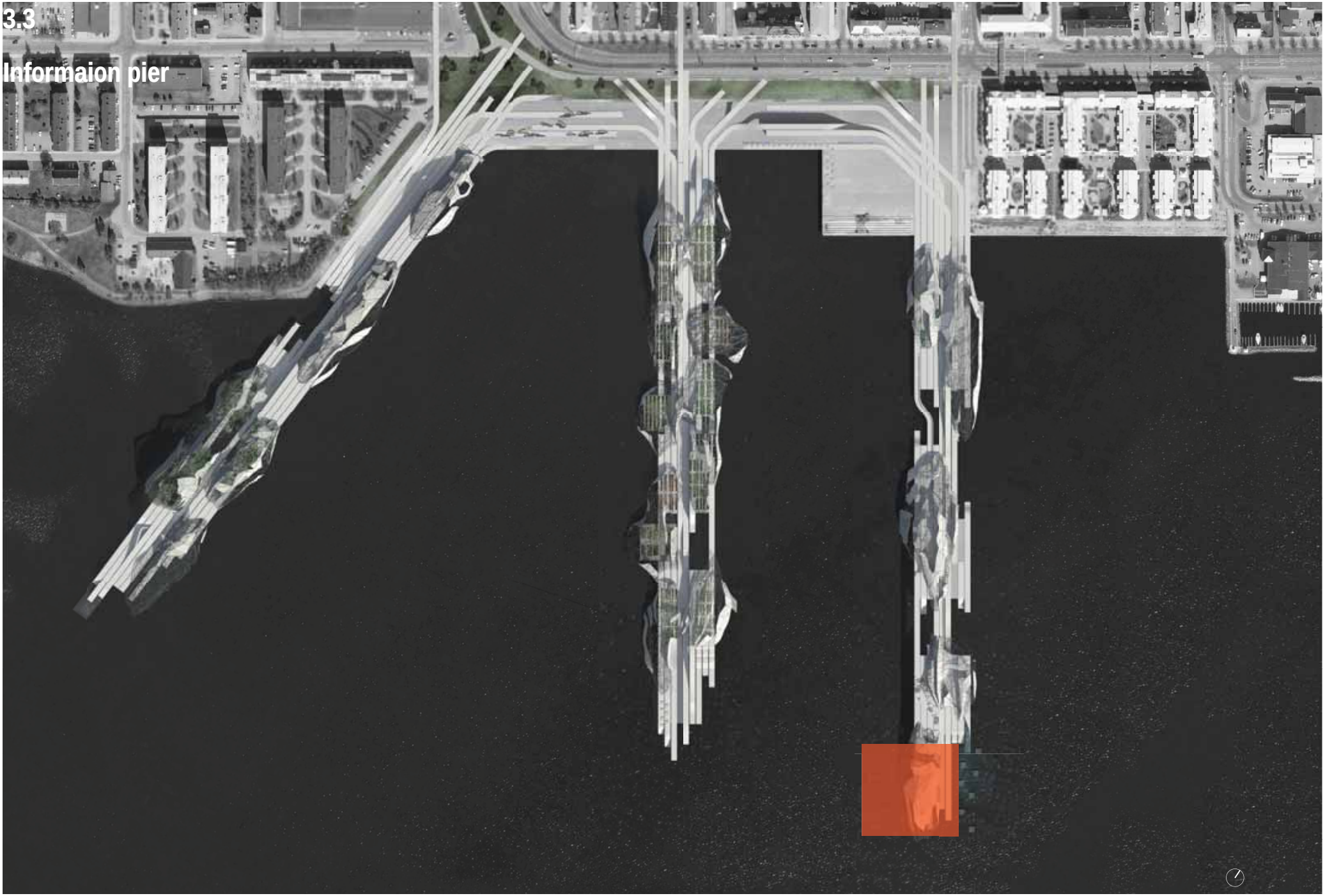


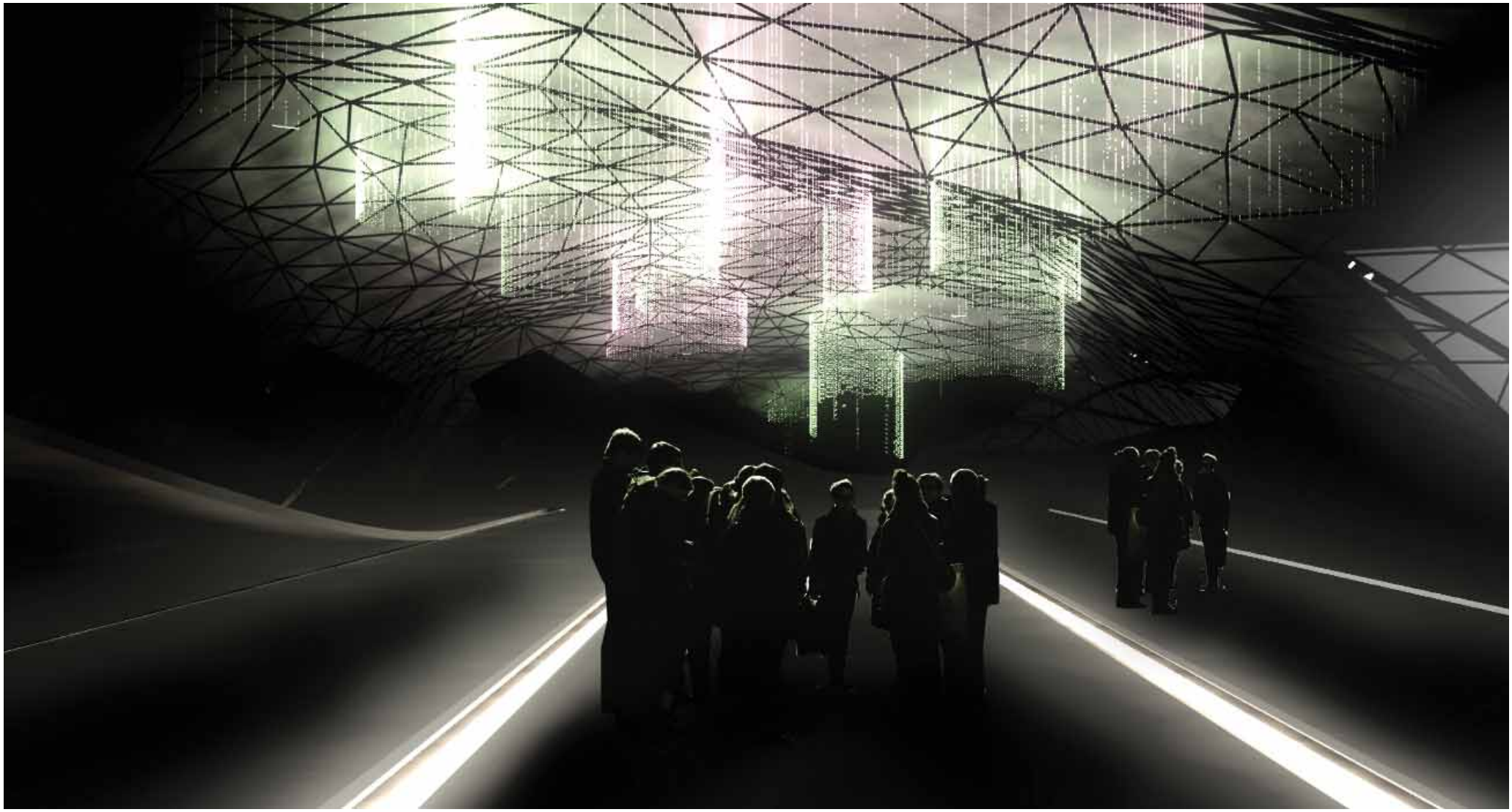


INTERIOR VIEW FROM PRODUCTION PIER - GREENHOUSE, OVERLOOKING VEGETABLE PLANTATIONS

3.3

Informaion pier

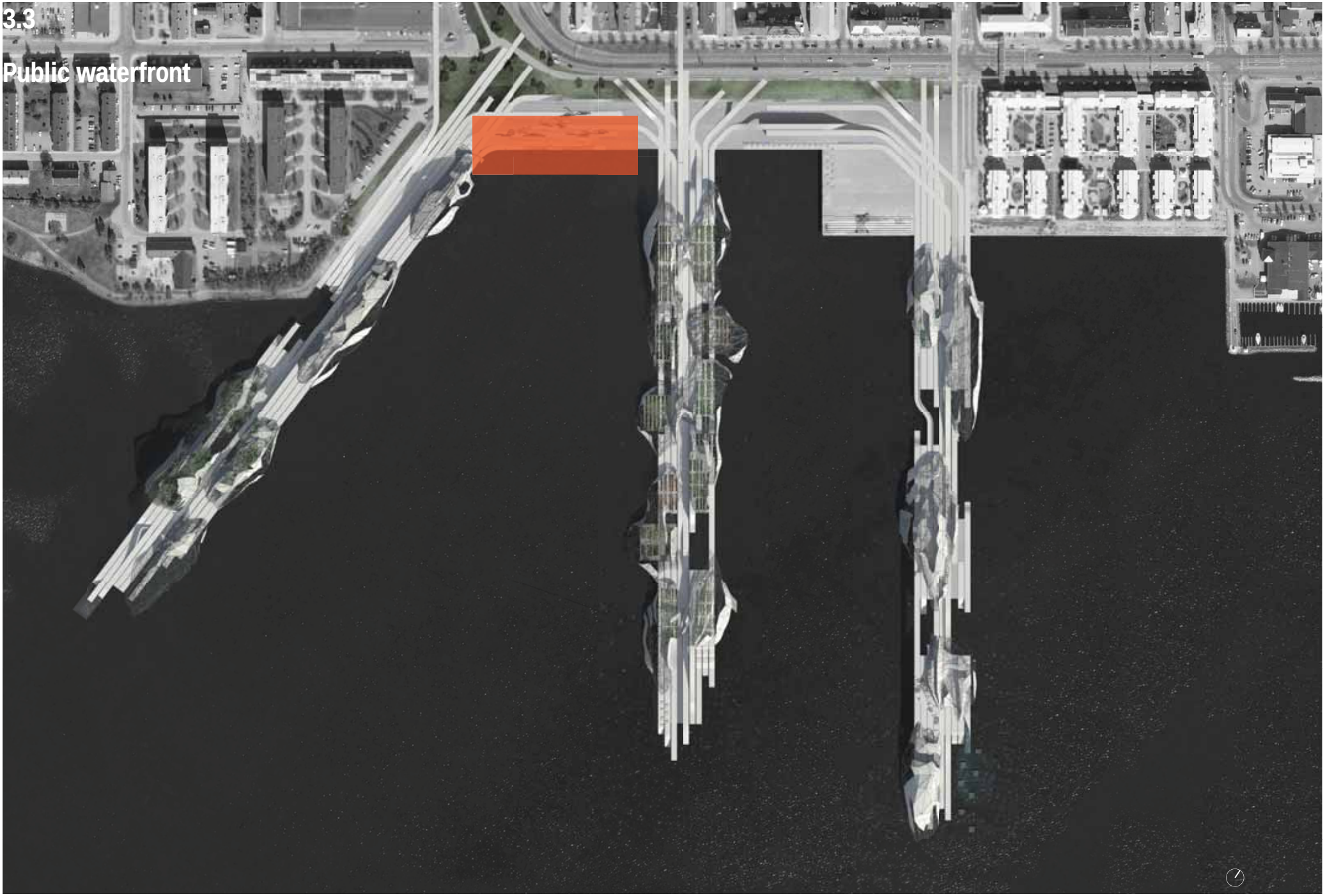




INTERIOR VIEW FROM INFORMATION PIER - AURORA BORREALIS, NORTHERN LIGHTS

3.3

Public waterfront

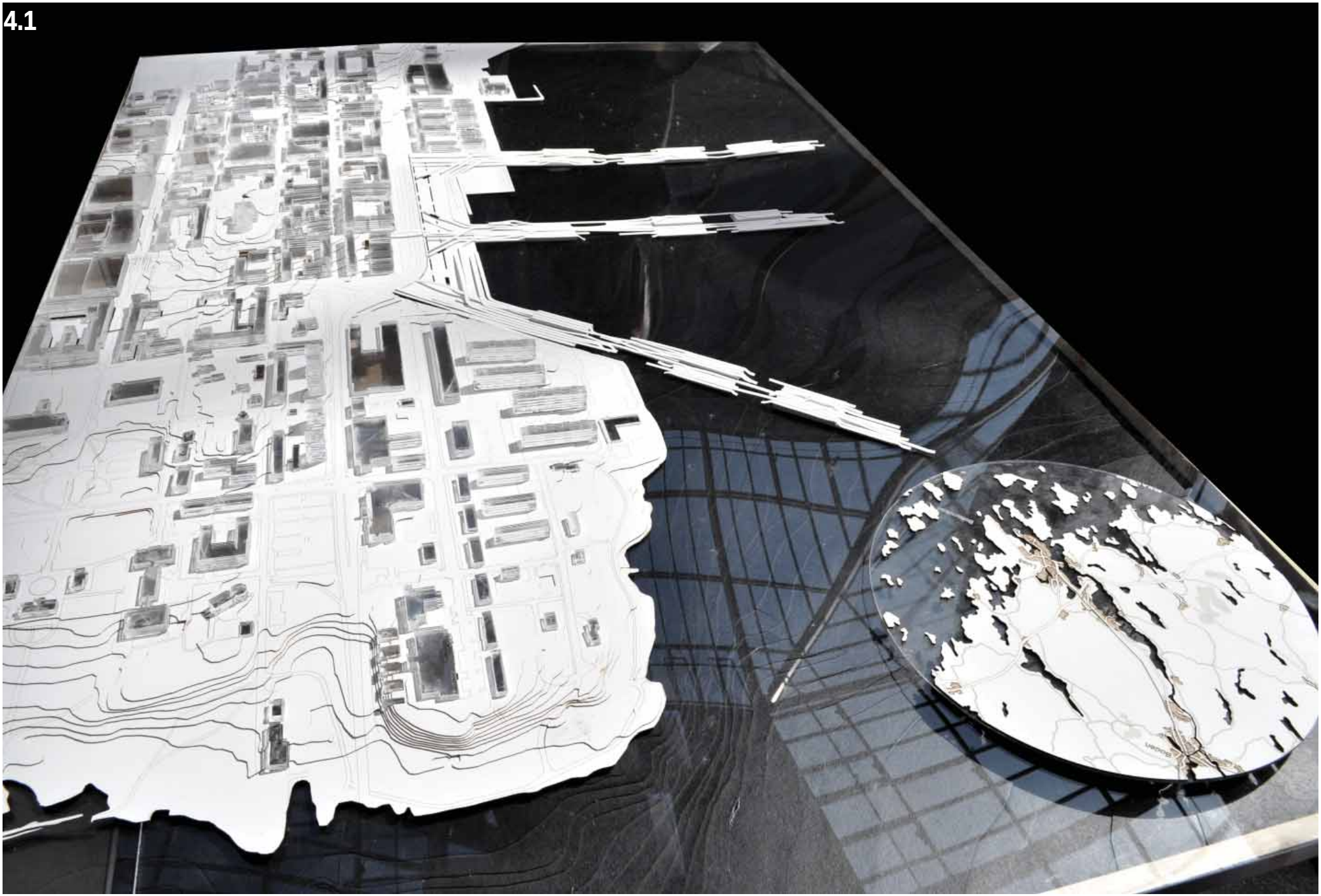


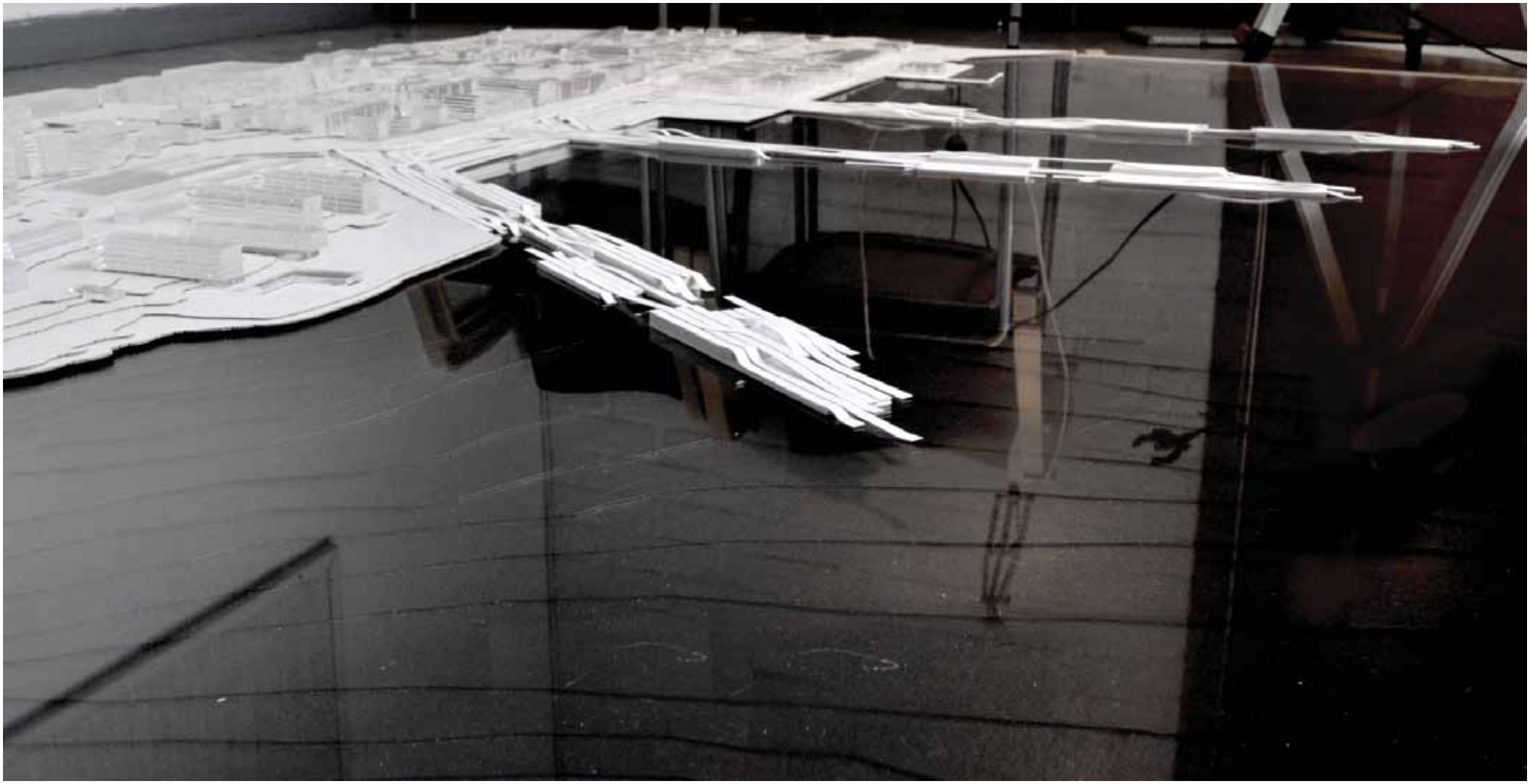
VIEW FROM THE WATERFRONT (WEST LOOKING EAST)

3.3

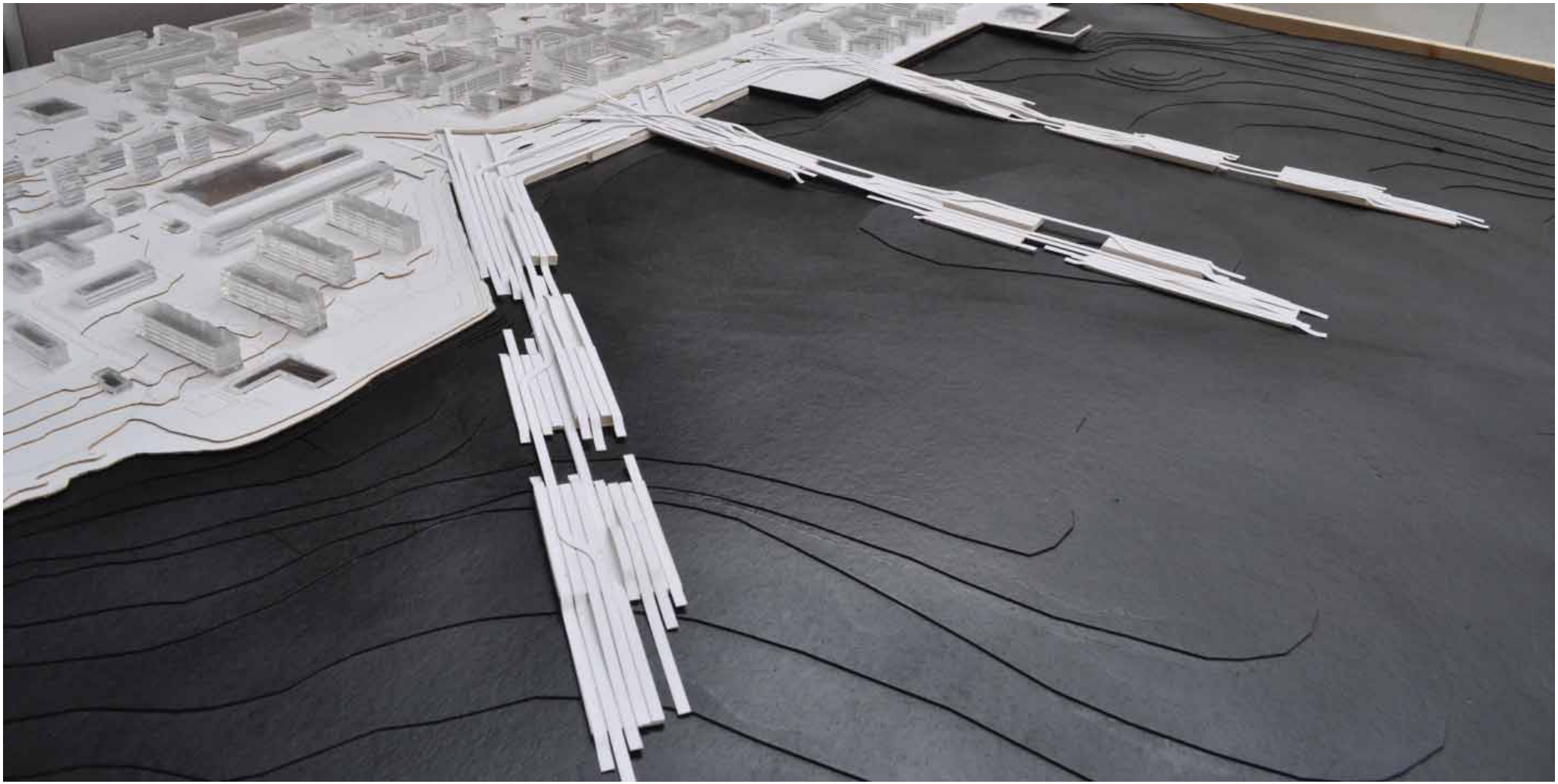
4. MODEL IMAGES

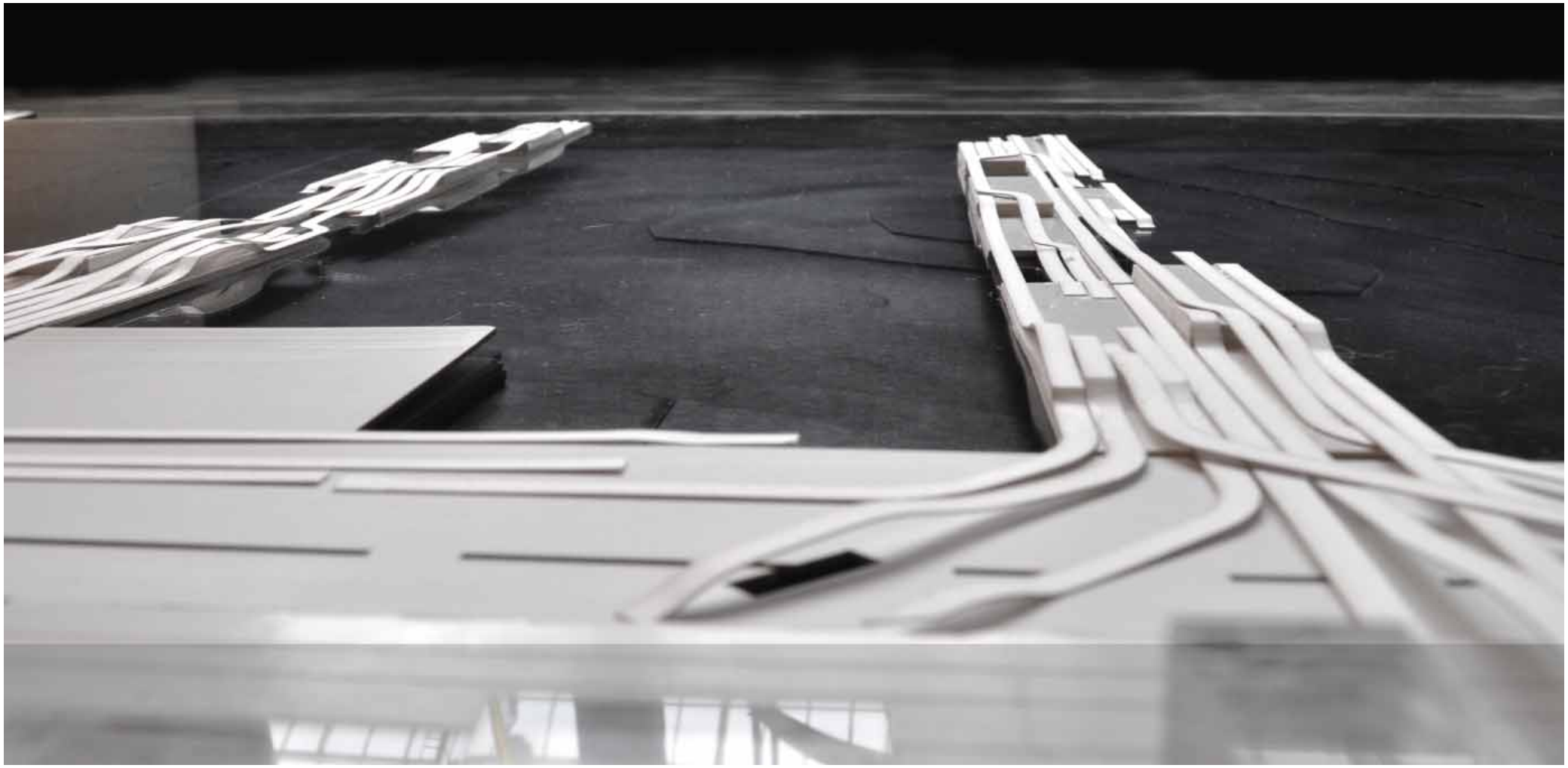
4.1 Site model 1:1000


4.1



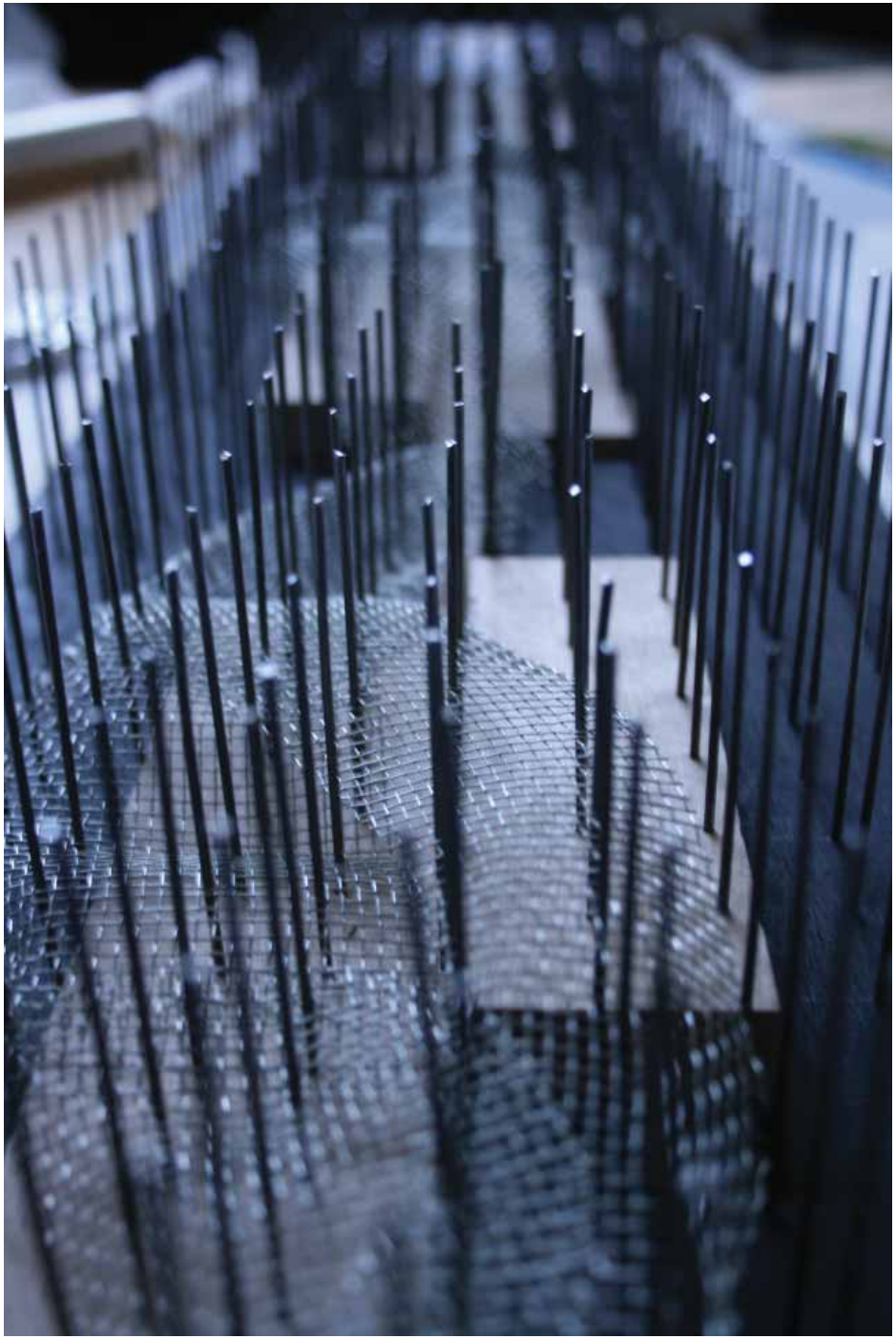
4.1

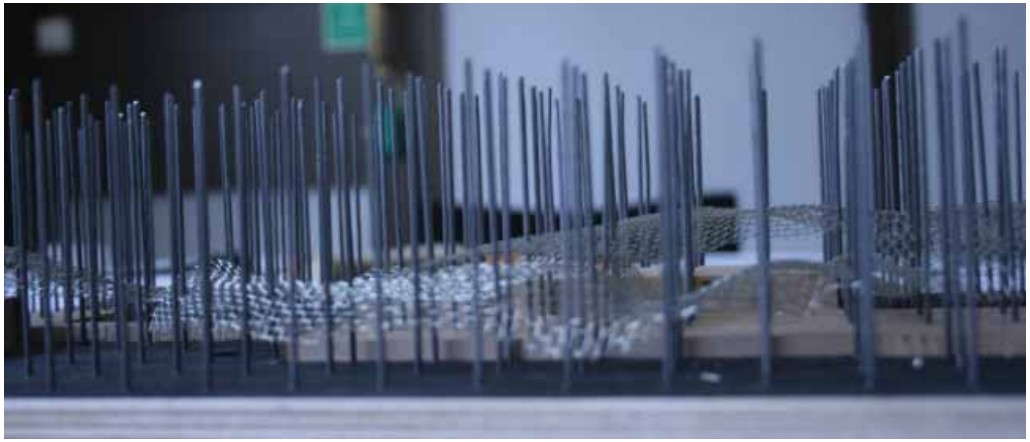


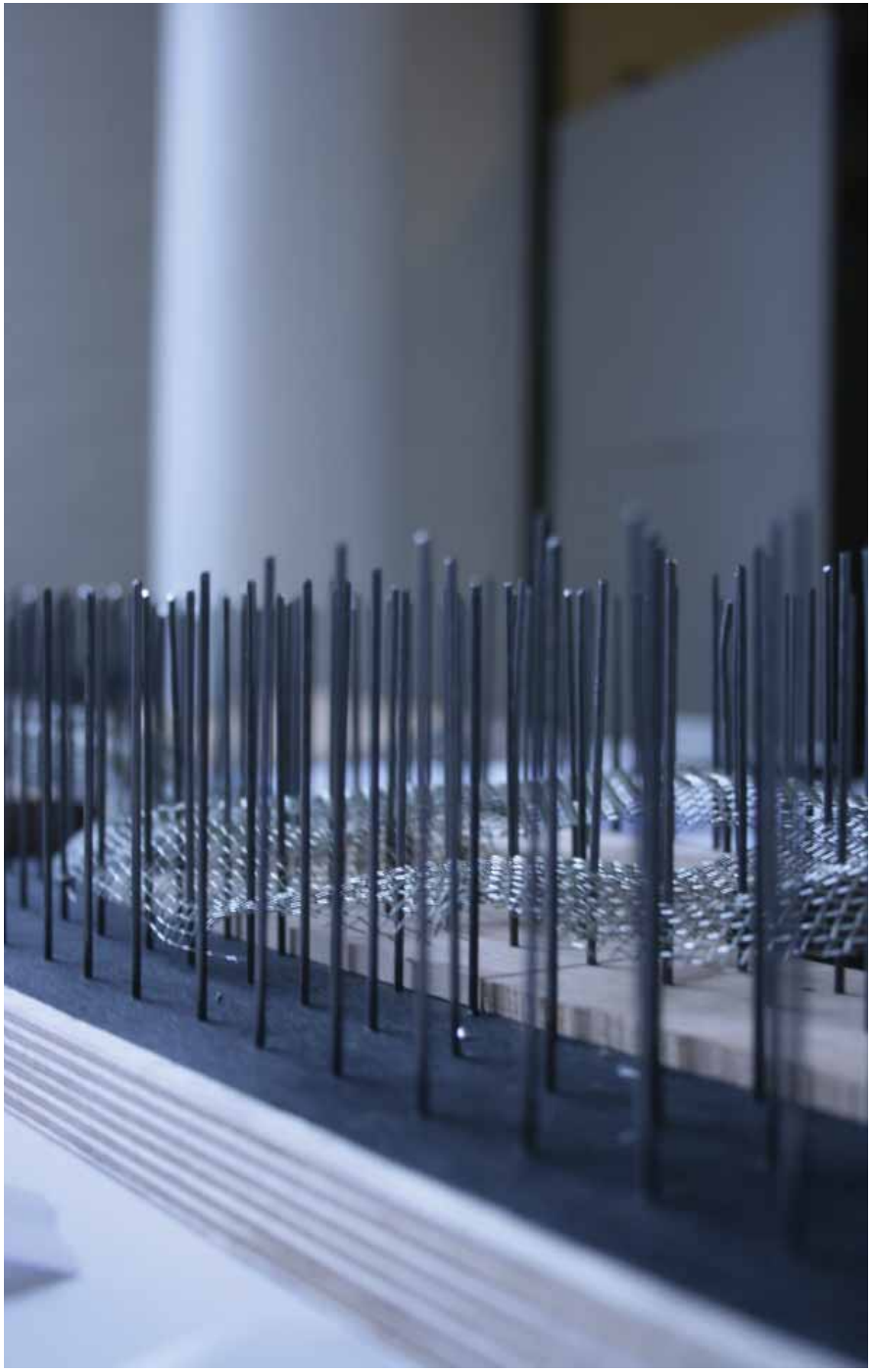


4.2 Skeleton model- membrane 1:500

4.2



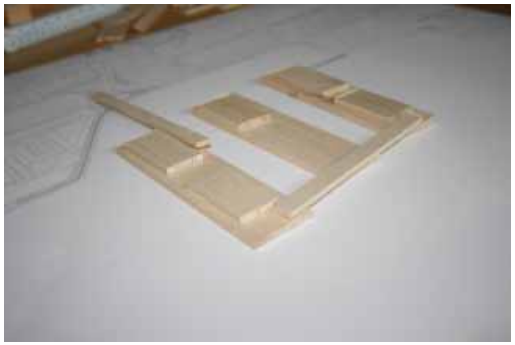
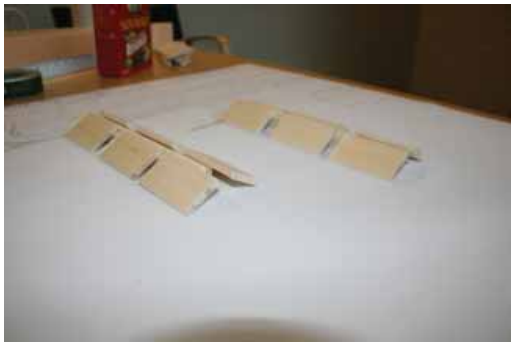
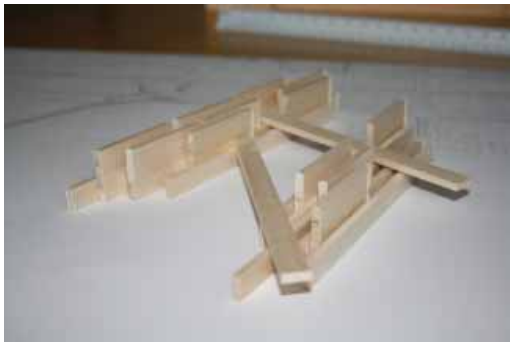
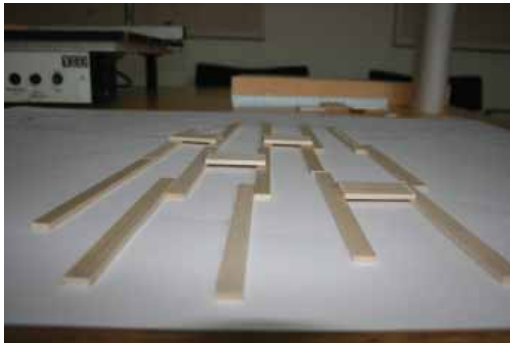
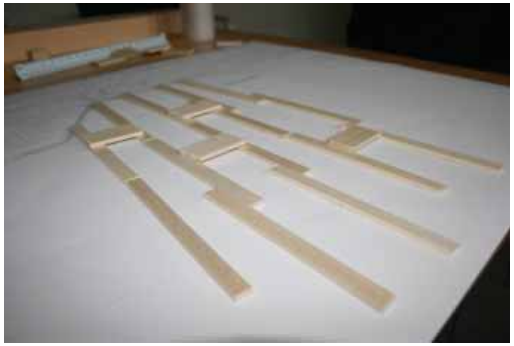
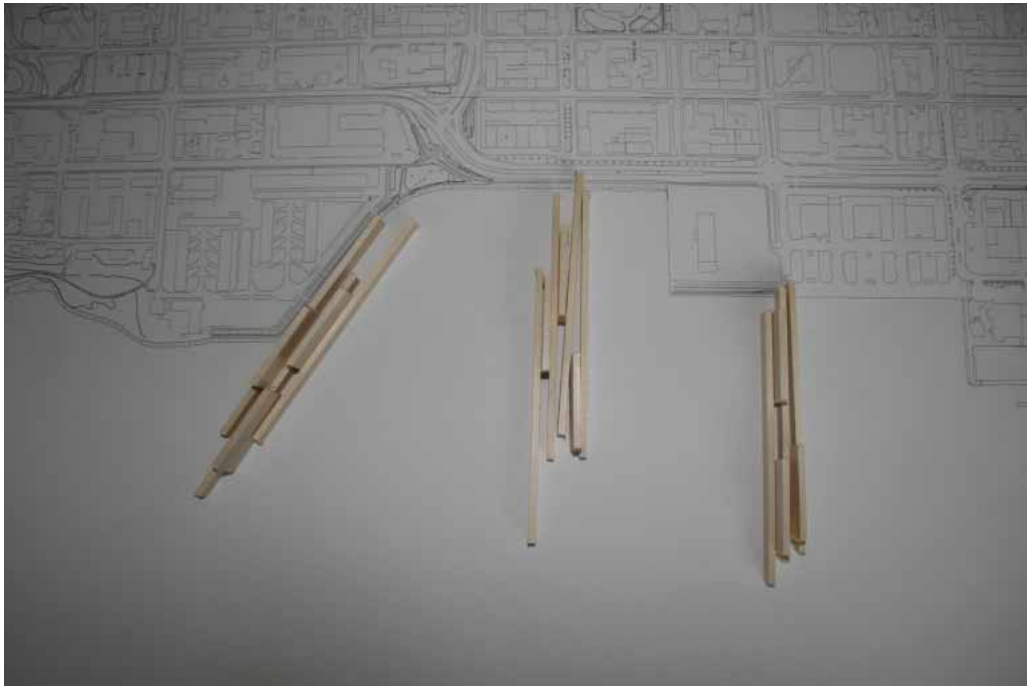
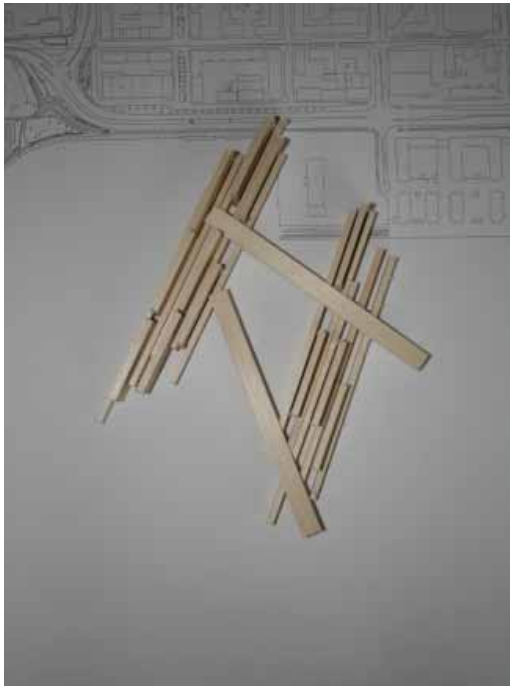




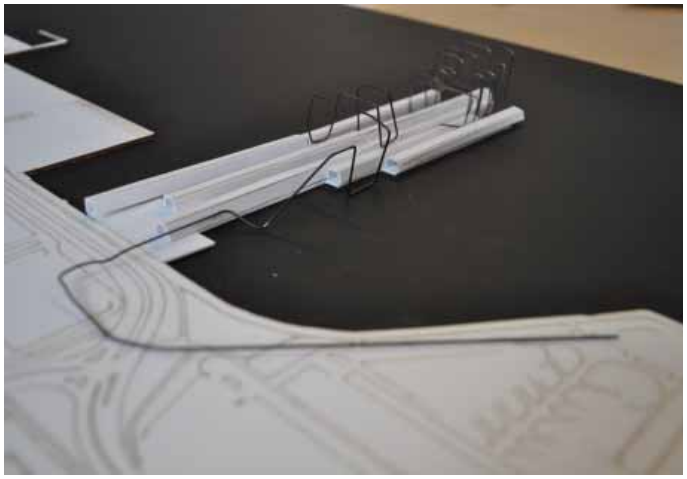
4.3 Model studies

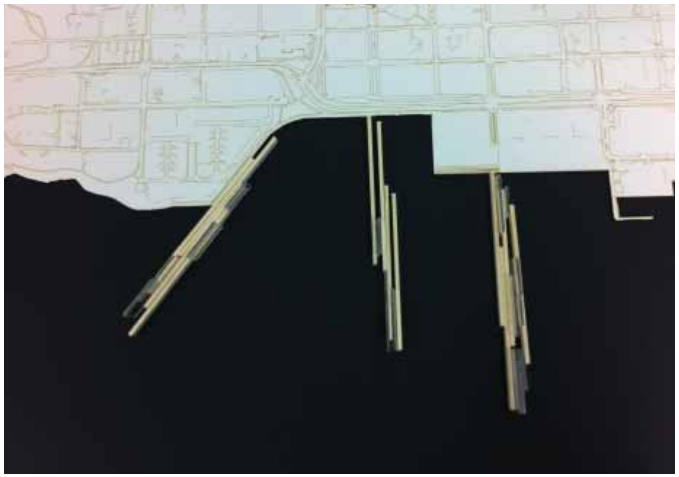
4.3

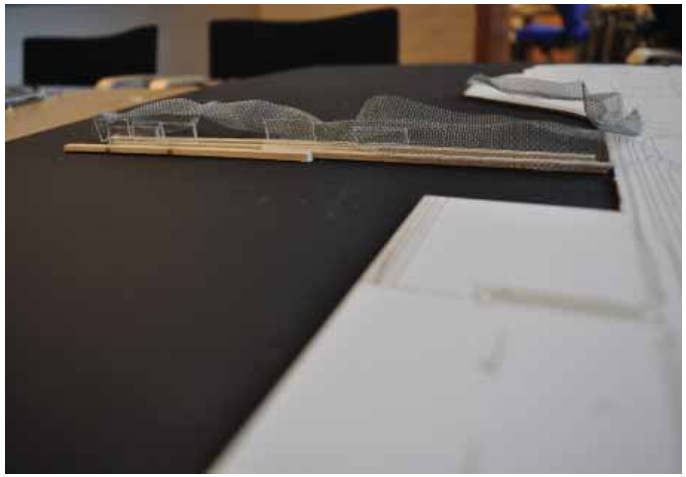
Areal studies (1:2000)

Relation and connectivity (1:2000)

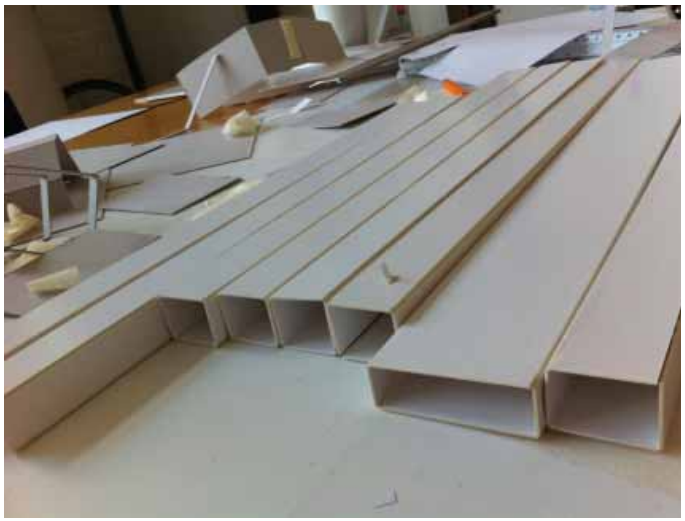
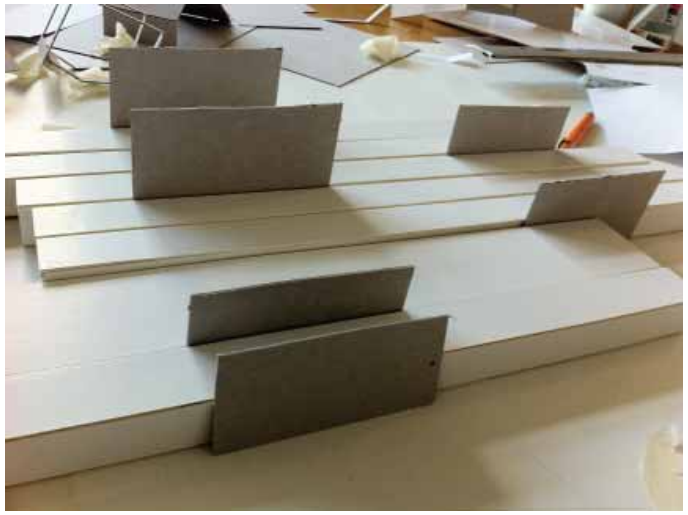
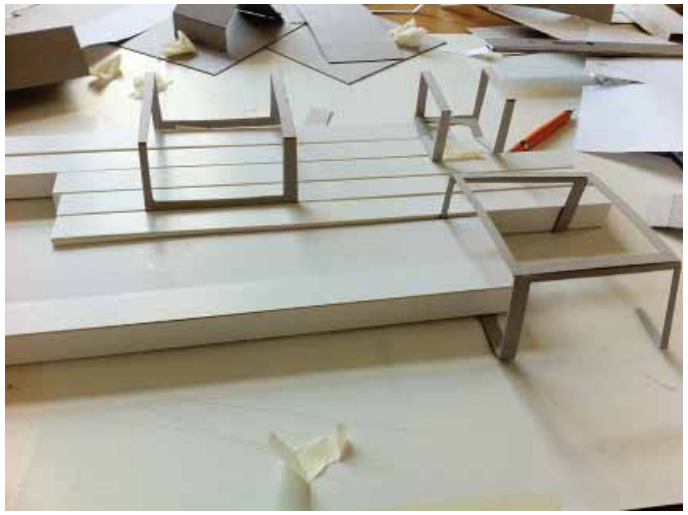



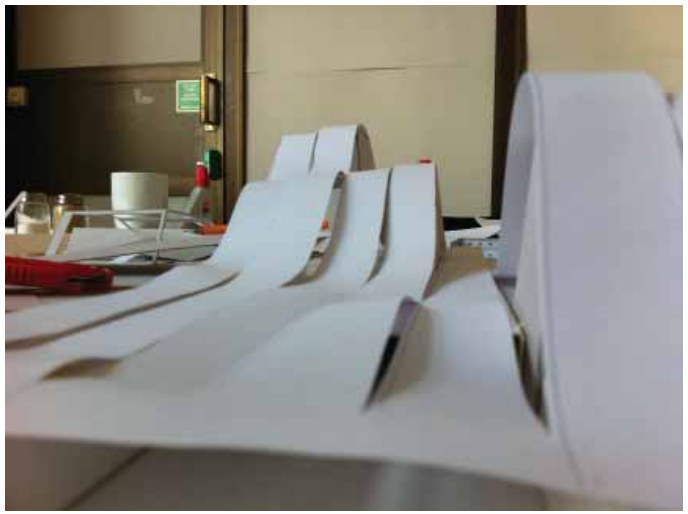




4.3

Stripes - program (1:1000)

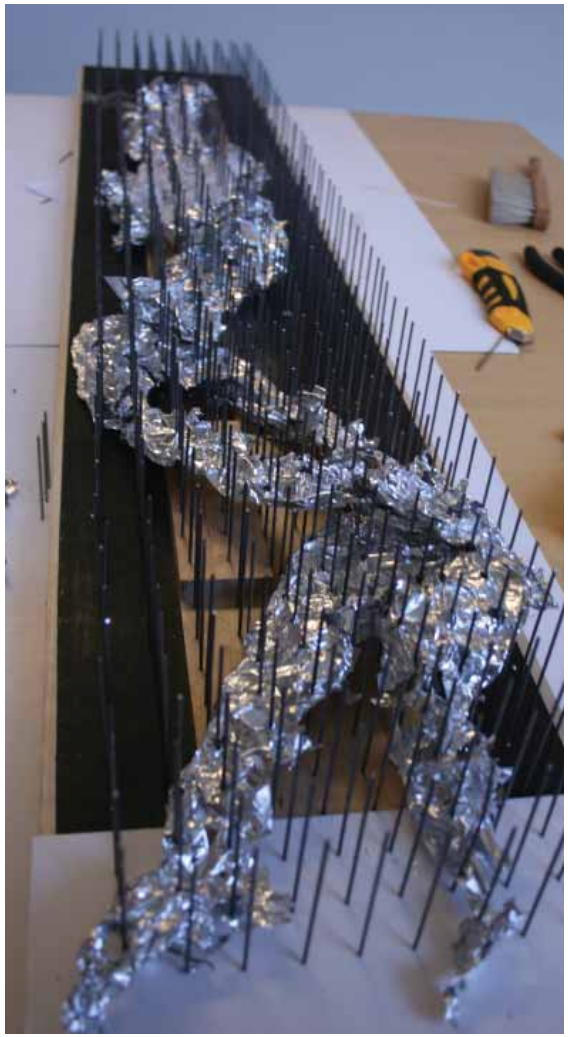
Skeleton model - stripes (1:500)

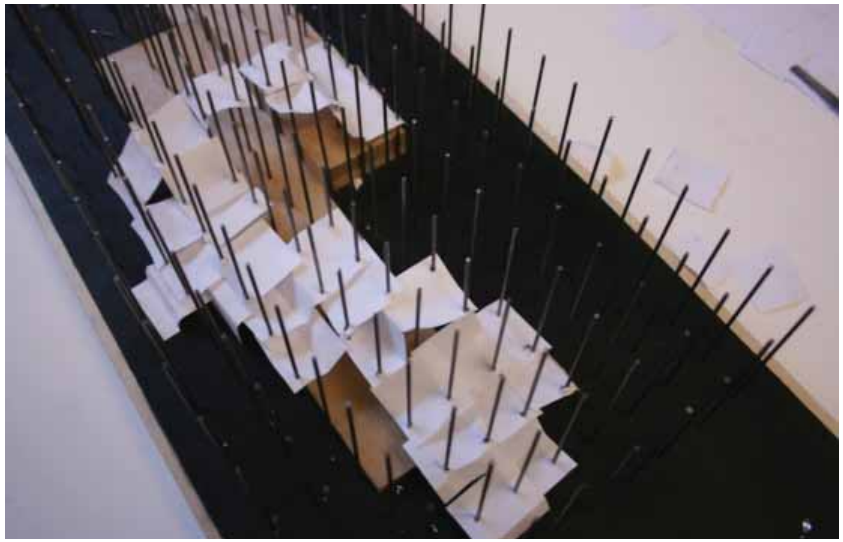



4.3

Skeleton model - membrane (1:500)





5. BIBLIOGRAPHY

BOOKS

Koch, Klaus-Michael, Karl J. Habermann, and Brian Forster. Membrane Structures: Innovative Building with Film and Fabric. Munich: Prestel, 2004. Print.

Moussavi, Farshid, and Daniel Lopez. The Function of Form. Barcelona: Actar, 2009. Print.

Schittich, Christian. Glass Construction Manual. Basel [etc.: Birrkhaüser, 2007. Print.

ARTICLES

"Facebook Värmer Upp I Luleå." GöteborgsPosten 14 Feb. 2012: 1. Print.

INTERNET

Bridle, James. "Booktwo.org." Secret Servers. 13 Sept. 2011. Web. 10 Jan. 2012. <http://booktwo.org/notebook/secret-servers/>.

Blum, Andrew. "Netscapes: Tracing the Journey of a Single Bit." Wired.com. Conde Nast Digital. Web. 20 Dec. 2011. <http://www.wired.com/magazine/ff_internetplaces/>.

Blum, Andrew. "This Is the Internet." Gizmodo. 19 Sept. 2011. Web. 16 Jan. 2012. <http://gizmodo.com/5841710/this-is-the-internet>

"Data Center Knowledge» News and Analysis about Data Centers, Cloud Computing, Managed Hosting and Disaster Recovery." Data Center Knowledge. Web. 26 Jan. 2012. <http://www.datacenterknowledge.com/>.

"Därför Storsatsar Facebook I Luleå." NyTeknik. 27 Oct. 2011. Web. 28 Oct. 2011. <http://www.nyteknik.se/nyheter/it_telekom/allmant/article3301929.ece>

Holmes, R. "The Network As Industry." The Network as Industry Mammoth // Building Nothing out of Something. 23 Nov. 2011. Web. 26 Jan. 2012. <http://m.ammoth.us/blog/2011/11/the-network-as-industry/>.

"Näringsliv - Regionfakta." Näringsliv. Web. 3 Feb. 2012. <http://www.regionfakta.com/Norrbottens-lan/Naringsliv/>.

"Open Compute Project." Open Compute Project. Web. 26 Jan. 2012. <http://opencompute.org/>.

"Serverhallar Ska Stärka Norrbotten." SvD.se. 23 Jan. 2012. Web. 23 Jan. 2012. <http://www.svd.se/naringsliv/it/facebook-i-norrland_6788607.svd>

"Tunisia, Egypt, Miami: The Importance of Internet Choke Points." The Atlantic. 28 Jan. 2011. Web. 16 Jan. 2012. <http://www.theatlantic.com/technology/archive/2011/01/tunisia-egypt-miami-the-importance-of-internet-choke-points/70415/>.

"Turism - Regionfakta." Turism - Regionfakta. Web. 30 Jan. 2012. <http://www.regionfakta.com/Norrbottens-lan/Naringsliv/Turism/>.

"Varmt Svinn Från Serverhallar." SvD.se. 15 Feb. 2012. Web. 15 Feb. 2012. <http://www.svd.se/naringsliv/varmt-svinn-fran-serverhallar_6853629.svd>

PUBLICATIONS

Arnehed, Sebastian, and Henrik Emilsson. Stadsförtätningens Teorier Och Konsekvenser : Analys Av Kvaliteter Och Förtätningspotential För Luleå Centrum. Rep. Institutionen För Samhällsbyggnad Och Naturresurser, LTH, 2011. Web. 5 Feb. 2012. <http://pure.ltu.se/portal/files/33204675/LTU-EX-2011-33102142.pdf>.

"Boende Och Inkvarteringsstatistik." Tillvätverket Boende Och Inkvarteringsstatistik. Ed. Peter Terpstra. Web. 26 Jan. 2012. <http://www.tillvaxtverket.se/huvudmeny/faktaochstatistik/faktaomturism/boendeochinkvarteringsstatistik.4.21099e4211fdba8c87b800017302.html>.

"Besöksmål Och Sevärdheter." Tillväxtverket Besöksmål Och Sevärdheter. Ed. Peter Terpstra. Web. 26 Jan. 2012. <http://www.tillvaxtverket.se/huvudmeny/faktaochstatistik/faktaomturism/besoksmalochsevardheter.4.21099e4211fdba8c87b800017216.html>.

Iqbal, Sheraz. An Urban Planner's Guide to Space Syntax A Study of Luleå City Illustrating the Uses of Space Syntax. Rep. Luleå University of Technology, 2010. Web. 5 Feb. 2012. <http://pure.ltu.se/portal/files/32605292/LTU-EX-2011-32594804.pdf>.

"Northern Sweden and Swedish Lapland." Visit Sweden. Web. 26 Jan. 2012. <http://www.visitsweden.com/sweden/Regions--Cities/Northern-Sweden/>.

"Näringsverksamhet." Statistiska Centralbyrån Näringsverksamhet. Web. 26 Jan. 2012. <http://www.scb.se/Pages/SubjectArea____11154.aspx>.

Terpstra, Peter. Fakta Om Svens Turism. Publication no. Info 0322. Tillväxtverket. Web. 29 Jan. 2012. <http://publikationer.tillvaxtverket.se/ProductView.aspx?id=1618>.