RESEARCHING NATURE INFLUENCED DESIGN

A new building in Högdalen industrial area.

A master thesis by Viktoria Ernstsson

Master's Programme Design for Sustainable Development
Department of Architecture, Chalmers University of Technology
Gothenburg, Sweden 2015

CHALMERS
UNIVERSITY OF TECHNOLOGY

RESEARCHING NATURE INFLUENCED DESIGN:
A new building in Högdalen industrial area.

Master thesis at Chalmers Architecture, presented 2015-11-13

Author: Viktoria Ernstsson
Master's Programme Design for Sustainable Development
Department of Architecture, Chalmers University of Technology
Gothenburg, Sweden 2015

Examiner: Marie Strid
Tutor: Anna Braide Eriksson
Jury: Karin Nyqvist & Pernilla Hagbert
Keywords: Biophilic Design, Greenery, Nature, Industrial area,
Industrial building, Office, Sustainability.

Viktoria Ernstsson

I have a bachelor in architecture from Chalmers University of Technology. I also have experiences from doing internships at architectural offices during a couple of months. I conclude my two years of studies within the master's program "Design for Sustainable Development" with this master thesis, also at Chalmers University of Technology.

Acknowledgements

I want to thank my supervisor Anna Braide Eriksson and my examiner Marie Strid for all the good advice. I also want to thank Liljewall Arkitekter, for introducing me to Högdalen industrial area, and Karl Palmberg for valuable input through the process.

ABSTRACT

The humans have, during millions of years, evolved in the natural world and still seems to benefit both physically and mental from being in a natural environment. Nature seems to have qualities that today can be regarded as lacking in the built environment. This master thesis explores how these qualities found in nature could be brought back into built space where we live most of our life. How they could be brought into the artificial world, our buildings, by something called biophilic design.

The objective of this master thesis is to investigate how biophilic design can affect the design and character of an industrial building. How biophilic design, including integration of greenery, can be used to create a good and attractive work environment in an industrial context.

Biophilic design and integration of greenery is explored through literature and reference projects. A building project is also developed using biophilic design as a tool for the design.

The outcome is a design of a new building in Högdalen industrial area in Stockholm, an area that is the target for an ongoing pilot project about how greenery can contribute to more attractive and sustainable industrial areas. This master thesis is however delimited to the design of a new building. The building is addressed to be an innovative platform for new companies within the sector of environmental technology and contains both office space and industrial space. The proposed design has its origin in biophilic design criterias but is also influenced by functional demands and the industrial context.

TABLE OF CONTENT

Fig.1: Högdalen industrial area

INTRODUCTION

BACKGROUND

The nature-human connection

It is toady clear that people´s connection to nature affects their health and well-being. Simply the visual appearance of a tree seems, for instance, to decrease the level of stress for people in the built environment (Kaplan, Talbot & Kaplan, 1988). Nature has appreciated values that the built environment doesn't have. What if these values could be transformed into the built environment? Can we use nature to create a better environment for humans?

This question is important in a world where we become more and more disconnected to nature. We do use the nature and we are draining its resources, but due to urbanization and modern lifestyle, a great amount of people live quite separated from it.

Building developers and architects plays an important role in this matter. They have the power to affect the built environment and can choose to make it more or less connected to nature. An important task for architects is to create a good environment for humans, hence, it seems like a good idea to be inspired and influenced by the environment in which we have lived and evolved during millions of years; nature. Nature can influence the built environment in multiple ways, for instance by greenery on walls or by natural motifs. A great amount of strategies for enhancing the human-nature connection, through architecture, fits within the term biophilic design. Biophilic design strategies, with a focus on integration of greenery, are further investigated in this master thesis and finally implemented into a design project, a new industrial building in Högdalen industrial area.

Högdalen - an area in transformation

City of Stockholm and Stockholm Business Region Development have shown interest in developing Högdalen industrial area. The discussion concerns ideas for how to make the industrial area more sustainable, for instance by more energy efficient buildings but also by more greenery integrated in the area.

Many different purposes with greenery in Högdalen industrial area has been mentioned during the work for a developed area. One idea is to use ecosystem services to, for instance, decrease noise and pollution, an action that could make it possible to build new housing areas in the existing green buffer zone surrounding the industrial area. The greenery could also make the workers environment more delightful and the industrial area more integrated in the city. Another aim with the greenery is to attract new business, mainly within the sector of environmental technology. A concept regarding integration of greenery in the area is developed by a project group. This is further presented at page 28.

Urban greenery has many benefits and I support especially thoughts of how it can contribute with ecosystem services and improve the workers environment for better health and wellbeing. The ongoing project is working with implementation of nature in the industrial area as a whole, proposing solutions at an urban scale. This master thesis is focusing on how nature, through biophilic design and greenery, can be integrated in the building scale. It could be seen as a work related to, but independent from, the ongoing project.

Role of this master thesis

Early concept sketches of how Högdalen industrial area could develop, by Liljewall architects, propose some new buildings with an architecture that can attract new companies working with environmental technology. Right in line with the vision the City of Stockholm has for the area. I was through Liljewall architects introduced to the project with the suggestion to draw a proposal for the design and placement of a new building.

There are many possibilities with a new building in Högdalen industrial area. It could be an incubator for further development of the area. This master thesis, with its design proposal, will suggest a direction for the transformation of Högdalen industrial area. It will hopefully become a source of inspiration for the stakeholders involved in the development such as the property owners, Stockholm Business Region Development, the City of Stockholm etc.

Definitions

Nature and greenery are terms commonly used in this work. They are defined as follows (www.dictionary.com).

Nature is the material world surrounding humankind and exists independently of human activities. Elements of the natural world are for instance, mountains, trees, animals and rivers.

Greenery is defined as green vegetation. Integrated greenery refers, in this master thesis, to vegetation that is a part of a building structure and/or the design of a building.

QUESTION FORMULATIONS

Main questions

How can biophilic design, including integration of greenery in buildings, be used as a tool to bring the qualities of nature into a new industrial building in Högdalen?

How is the design and character of an industrial building affected by the use of biophilic design?

Other questions

How can the new building support the city's vision of an industrial area hosting environmental technology? How can it furthermore benefit the existing companies and be a part of a sustainable development of the area?

Nature

STAKEHOLDERS INVOLVED

The following stakeholders are involved in the work for a transformed/developed Högdalen industrial area, a project that started in 2011 on the initiative of the City of Stockholm.

City of Stockholm

The City of Stockholm has a vision for the district Söderort in Stockholm which includes the idea to raise the district's 27 industrial areas, mainly to create new jobs but also to make them more environmental friendly. Högdalen industrial area is one of the districts and has in the vision been designated to become a cluster for environmental technology (http://www.stockholm.se/).

Stockholm Business Region Development (SBRD)

SBRD is the official investments promotion of Stockholm. They work on a long-term basis with the marketing and development of the Stockholm region as a business destination (http://www.stockholmbusinessregion.se/sv/). As commissioned by City of Stockholm they operate the project to develop Högdalen and create a cleantech cluster there. A part of this project is named "Renewal of urban industrial areas with building integrated plant systems that are adapted to energy and nature cycles".

The project group

A group of persons with different professions are put together to make a plan for how greenery can be used in the transformation of the area. The aim is to come up with an innovative, green solution to get investment money from Vinnova, the innovation agency in Sweden. Some participants in the project group, except from SBRD and City of Stockholm, are SP (Technical Research Institute of Sweden), Liljewall architects, Greenelizer (research and design studio), Högdalsgruppen (the association of local companies), KTH (the royal institute of technology) and IVL (Swedish Environmental Research Institute).

Property owners

The property owners have the biggest influence on what can be realized with the existing building stock. They have the possibility to invest in the physical environment. Important factors for the investments are how greenery can increase the value or decrease the costs of the property.

Renters (existing companies)

The people working in Högdalen industrial area are the ones mostly affected by the work environment and how greenery can improve it. Important for existing companies are that the rents are kept low (greenery and increased value of the property could lead to higher rents). A possible incentive for greenery is that some businesses requires an environmental permit and the greenery could decrease the environmental impact of the business.

The stakeholders interests are partly contradictory. The vision the city has for the area is hard to fit with the existing business. As an attempt to make the design project in this master thesis reasonable and sustainable the stakeholders dissimilar interests will be considered and their interests will in different ways influence the design project. The economic aspect is in many ways important for the stakeholders. It is however notable that the economic aspect is something that I have chosen to not focus at in the design project.

METHODS

The research is performed to benefit the design part of this master thesis, a new building in Högdalen industrial area. This research strategy is commonly discussed as “research for design”.

Research has been done about Högdalen and the industrial area regarding existing business and building stock as well as future plans. I have participated at meetings and workshops organized by the project group and in that way met stakeholders and users and taken part in challenges and opportunities for further development. Also literature about ongoing sustainability projects, visions and future plans in Högdalen have been a help to understand driving forces and interests as well as the context to a future building. Site visits in the industrial area have been made for participation in workshops and to gain understanding of existing movements and character of the area.

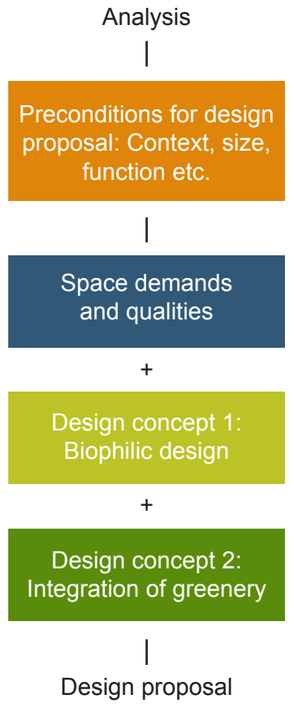
Design strategies have been formulated after research about biophilic design. The research has mainly been done by literature studies within the fields of basic theory of biophilic design and methods for practicing it. Also searching about scientific studies, investigating the need of biophilic design and greenery, has been done.

Literature and reference projects have been the primary tool regarding the research about integrated greenery. The reference projects work as a source of inspiration for how greenery can be used. Literature contributes with commonly used techniques for application of greenery in/on buildings, as well as argument for and against these techniques. Focus regarding integration of greenery has primary been on the connection greenery-people (spatial investigation) but also on the connection greenery-building (technical investigation).

The methods used for the design process is sketching and model studies in different scales, searching for a design with qualities in both the urban scale, the building scale and the interior scale.

Design process

The following diagram is an attempt to describe the design process. It is however important to mention that this kind of process never is as simple and linear as described.



In the analysis preconditions for the new building are set.

With these conditions as point of departure general space demands and space qualities can be set, like location and size of different rooms.

Biophilic design criterias gives the direction towards a nature influenced design with qualities for both humans and the environment.

Integration of greenery is the in-depth focus within the topic biophilic design. Application methods and functions of greenery are explored.

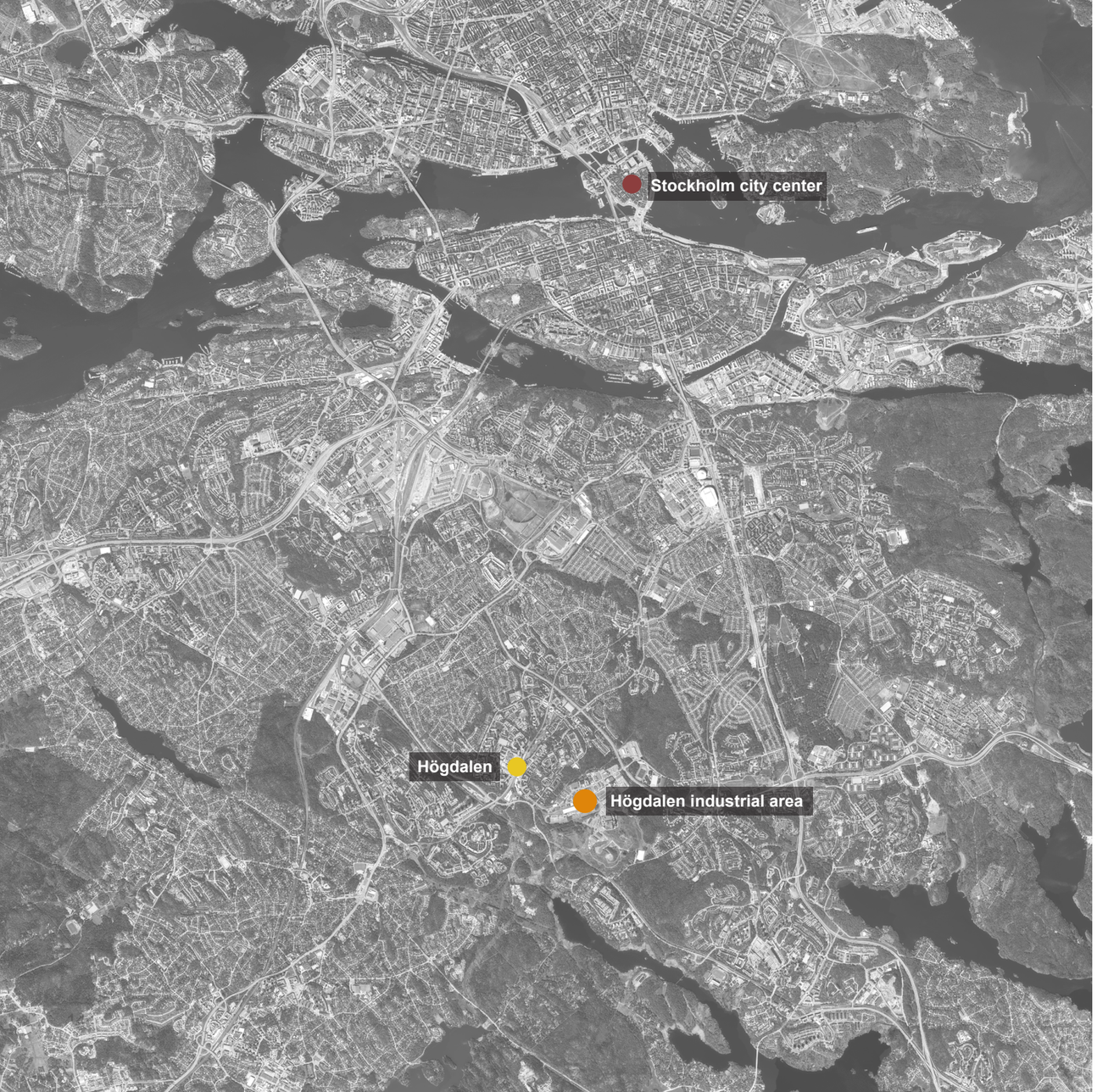
THE SITE

HÖGDALEN IN SWEDEN

One by many industrial areas

Högdalen is a suburb in Stockholm built mainly between 1950 and 1960 (Högdalen, 2014). At that time big parts of Europe were still recovering after the second world war and the industry in Sweden did very well (de Vries, 2015).The urbanization was a fact and Högdalen industrial area and residential area was growing at the outskirts of Stockholm.

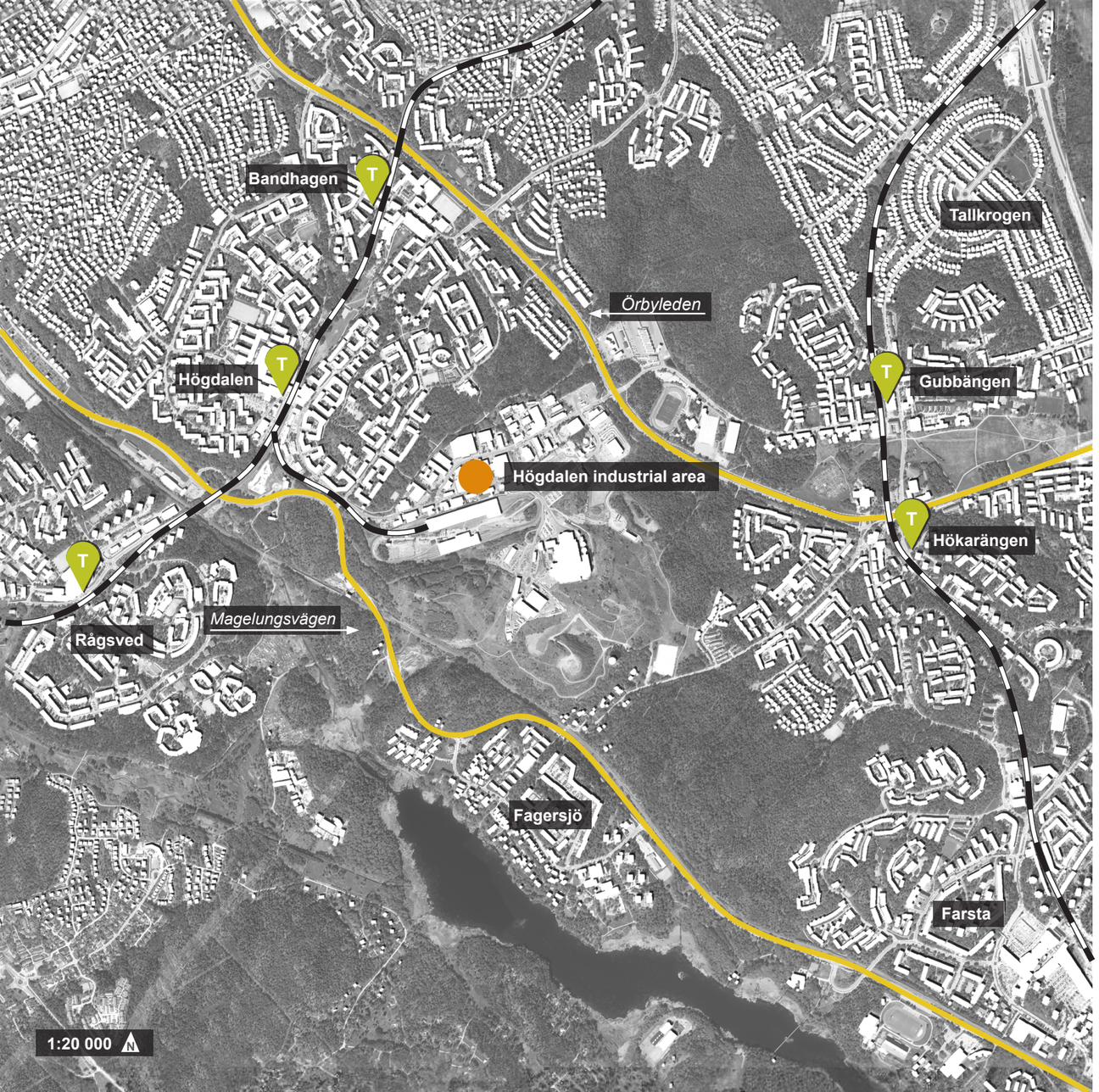
This case is however not unique, “modern” industrial areas popped up all around Sweden during the fifties. But today the situation in the world looks very different and a large amount of the industry, that was located here, has moved abroad. The industry in Sweden is changing due to globalization, increased competition and increased economic demands (Teknikföretagen, n.d.). Also social and environmental sustainability are important incentives for a transformed industry. Many actions need to be taken to meet the demands from a changed industry, for instance actions that transform the industrial areas into sustainable and competitive areas. The vision from City of Stockholm is that Högdalen industrial area should be a pilot project for how similar areas around Sweden could develop in this direction (Högdalen 2020, n.d.).



HÖGDALEN IN STOCKHOLM

The purpose of the following presentation of Högdalen, in the context of Stockholm, is to create a basic understanding of the industrial area and its surroundings. This understanding is considered important to be able to evaluate, or design, a new building in the industrial area.

Högdalen is situated 7 km south of Stockholm city center. Almost 5000 inhabitants lives in Högdalen and as in many parts of Stockholm the population increases every year (http://www.statistikomstockholm.se/). More than 3000 jobs can be found in the area, 1400 of them in Högdalen industrial area. Compared to the average in Stockholm, Högdalen has an significant increased amount of jobs in the sectors of manufacturing, energy and construction. The opposite is the case regarding jobs in the sector of business services. The presence of Högdalen industrial area is probably a major reason for the types of existing jobs.

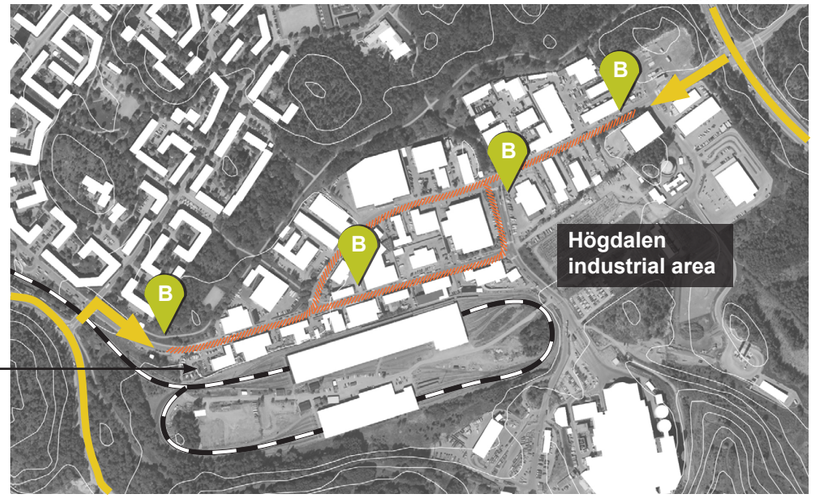


Connections

Högdalen industrial area is situated between two of the subway lines leading in to Stockholm central station. As visible on the map the subway has a side track attached to the industrial area and the tram depot. Together with Magelungsvägen the side track encloses the area in west as Örbyleden does it in east. The closeness to these big roads makes it very easy for cars, trucks and other vehicles to access the industries.

The area is well connected to public transport by four different bus stops with departures every 10th minute (http://www.sl.se). You can take the bus, or walk, to the closest subway station 700 meter away, located in Högdalen suburb center.

Scale 1:10 000



Building plot for design proposal

Subway station, to and from Stockholm.

Bus stops within the industrial area, departures every 10th min.

Main street through area.

Bigger road.

Entrance by vehicle.

Subway

Surroundings

Högdalen center 1 is a suburb center from 1957. Shops and services in Högdalen are concentrated here. The center is surrounded by residential buildings, 2 many of them built during the fifties and sixties.

Some new densification projects are ongoing at sites quite close to the industrial area. New dwelling are being built between Magelungsvägen and the subway 3. Ongoing villa projects can also be found in the forest, the buffer zone, north of the industrial area 4.

Högdalstopparna 4, the hills in the south part of the industrial area, are a result of waste disposal by landfill. For some decades (from the sixties until mid nineties) the left hill was used as a ski slope during winter. Today it is a recreational area but the amount of people using it is unclear.

Fig. 2: The ski slope in 1965

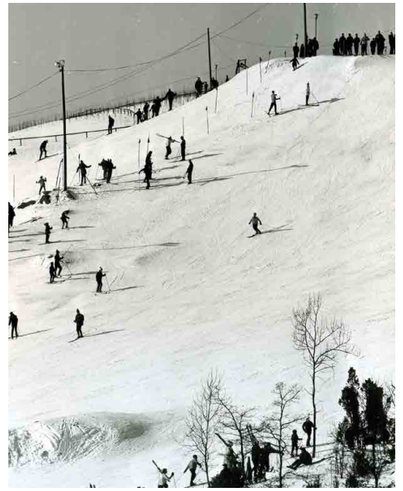
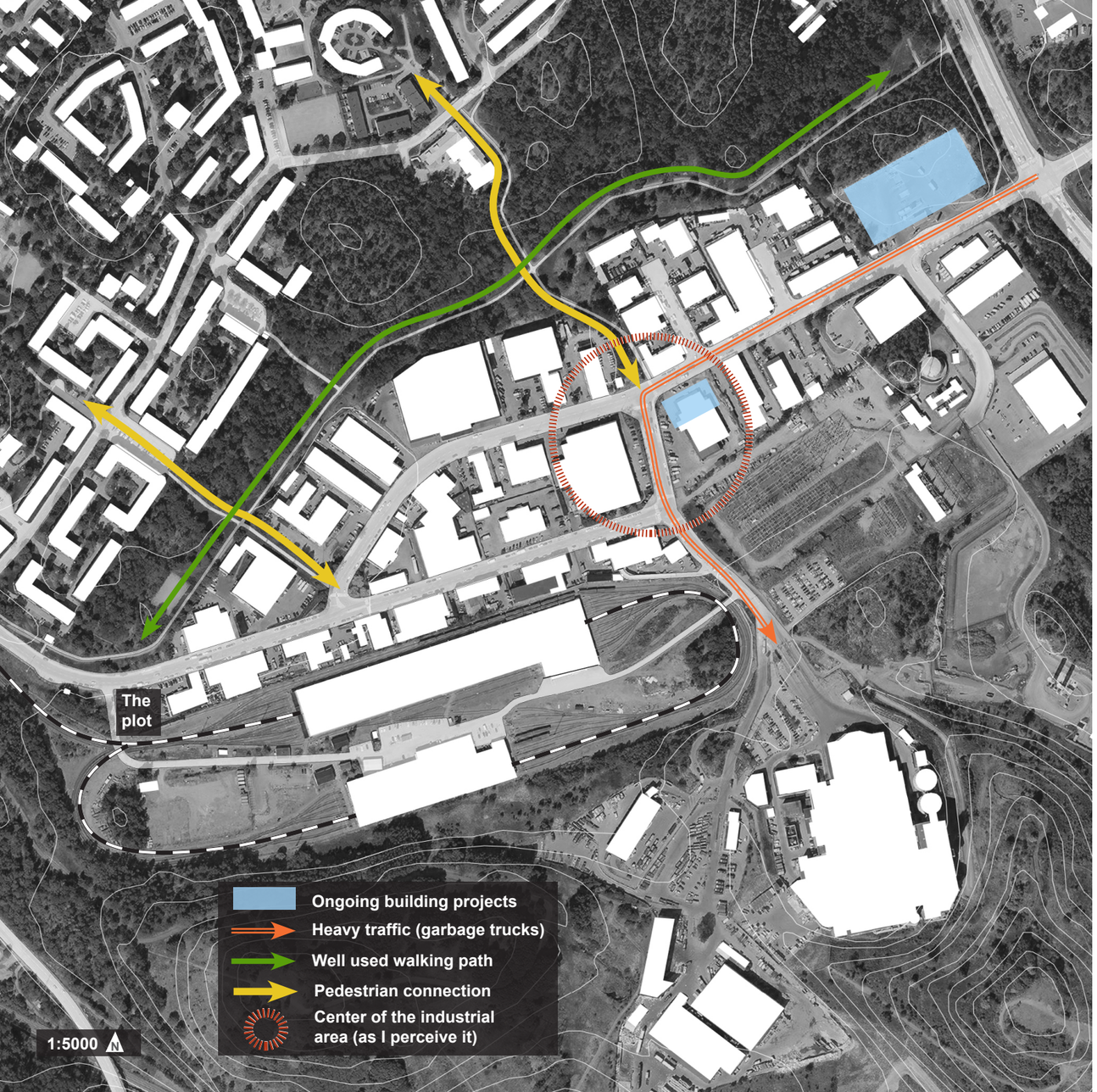


Fig.3: Högdalen center in the early sixties



THE INDUSTRIAL AREA

Högdalen industrial area is very lively with a constant flow of traffic. A few people take a walk to the local restaurant during lunchtime, otherwise the people you see are moving by car. A lot of movement is business related and the part of the road that is most exposed to heavy traffic is marked at the map beside. Along the main-road the levels are between 60-69 dBA. The noise levels could be a problem for a new residential building since the guidelines for that kind of building are maximum 60 dBa at the facade (Boverket, 2013). The noise level will however not affect a new industrial building.

Fig. 4: Noise levels.

Except the two entrances for vehicles there are two pedestrian paths which connect the residential area with the industrial area. In between these areas a smaller forest is located. It is well used for walks by the residents in the neighborhood although the industrial buildings turn their backs in this direction.

The big garage and workshop for SL-trains creates a barrier between the small scale industry and Högdalstopparna to the south. The connection and movement trough the area from north to south (or reverse) is concentrated to one road and only used by the trucks and cars visiting the south industry since the road is a dead end.

The chimney from the power plant is always present in the background.

CHARACTER

The north part of Högdalen industrial area is a dense mix of small scale industry buildings. The history is present by the buildings placement along the street and trough old signs and building details. Other buildings are located a few meters away from the street and then often surrounded by a high fence. The character is however quite urban with many windows, gates and doors facing the street. The south part of the area has a different character with its big scale industry. There the buildings are more spread out and are not facing a public main street.

Many buildings are constructed with painted or plastered concrete structures. Other materials that are significant for the area is are bricks and corrugated iron (Swedish national heritage board, 2006). Almost all ground surrounding the buildings is covered by asphalt and used for parking or/and storage of materials.

Main street

Truck and the electrical substation.

Wide streets and parked cars.

A few trees

FUTURE VISION

City of Stockholm and Stockholm Business Region Development have for the last years shown interest in developing Högdalen industrial area. On their initiative a project group has been formed. Within the frames of the project “Renewal of urban industrial areas with building integrated plant systems that are adapted to energy and nature cycles” they have developed and illustrated a transformation concept for Högdalen industrial area.

The concept “Green Artery” is the result of careful process led workshops and meetings between the project group and different stakeholders. It is worth noting that the transformation concept is not finished processing. The concept has evolved during the same time as this master thesis has progressed and has consequently, in spite of its incompleteness, become the future vision that the design project in this master thesis relates to.

The idea about the Green Artery is in a report to Vinnova, the innovation agency in Sweden, described as follows (translated from Swedish):

> *“Imagine an urban industrial area with long wide streets and low buildings. Add greenery along the streets, let it climb along some facades, let it extend out over the street and form green rooms as some important nodes, let the greenery create a green artery through the area. Let the green structure extend from the artery, let it grow over courtyards and roofs”. (Förnyelse av urbana industriområden, 2015, s.3)*

The Green Artery is described as the start of transformation this industrial area. It is argued that the transformation in a longer perspective will lead to densification of the area within existing infrastructure.

Cooperation between public and private stakeholders, between the municipality and the property owners, is in the report considered necessary to create the Green Artery and reach the stated objectives. Divided into social, ecological and economic some of these objectives for the Green Artery are (*Förnyelse av urbana industriområden*, 2015):

Social: *To create a greater amount of attractive and public meeting places in the area. To create street life and visually stunning environments.*

Ecological: *To use the greenery for eco system services. Let the plants clean the air, keep down the noise and temperature and clean the storm water.*

Economic: *To attract more companies, the best entrepreneurs and the brightest employees. To attract “business of tomorrow”, for instance companies within the sector of environmental technology.*

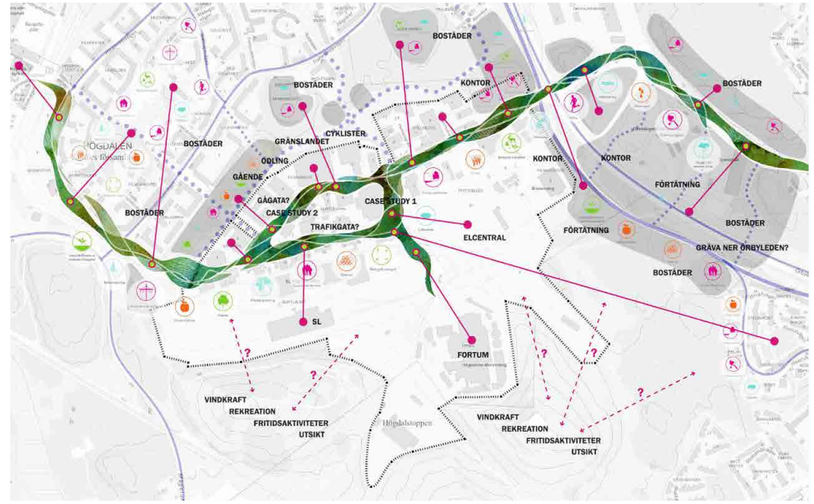


Fig. 5: Illustration Green Artery, Liljewall arkitekter.

HÖGDALENS INDUSTRIOMRÅDE - THE GREEN ARTERY
Idéskiss - 30 mars 2015 *Fig. 6: Illustration Green Artery, Liljewall arkitekter.*

liljewall

CONCLUSIONS

The area

Today the industrial area is physically separated from the city and Högdalen but the area is easy accessible with vehicles and by public transports. The accessibility for pedestrians could however become much better. Since the main road has a very urban character it could be interesting to densify along it at the border between the residential area and the industrial area to, in a long term, make the area a more integrated part of Högdalen and the city.

It happens a lot both in the industrial area and in its surroundings. The closeness to Stockholm city center makes the land valuable and the density of people makes a lot of building projects, business and activities profitable.

The vision and interest from the City of Stockholm and Stockholm Business Region Development could benefit the environment/ecology but also the industry and the people working there by improvements regarding work environment and coordination between companies. Their interest could also lead to higher attractiveness, costs and therefore a gentrification of the area.

The building stock is very diverse and the character is special. If new buildings in the area relates/connects to the existing buildings stock by, for example, shape or materials the character of the area could be strengthened instead of completely changed. By keeping different characters the city becomes more diverse and, in my opinion, more interesting and attractive.

Concluding objectives for a new building

- Place the building to decrease the barrier between the industrial area and the residential area.
- Use the building to create an improved entrance to the industrial area.
- Let the existing character of the area influence the design proposal.
- Design the building so it fit with the future vision of the area.

BUSINESS & ACTIVITIES

BUSINESS TODAY

A diverse area

Today about 120 companies are active in Högdalen industrial area. They are working within the sectors of production, service or commerce (Högdalsgruppen, n.d.). Originally there was a lot of mechanical workshops and production. Today you can find more car related business in the area (Swedish National Heritage Board, 2006).

The Swedish National Heritage Board did in 2006 an inventory of the properties. Several buildings where registered as either industrial buildings or workshops and a few buildings did according to the inventory, not contain any industry or workshop. Instead their main purpose was office or some kind of administrative activity. Some buildings were also registered that they contained both office and workshop/industrial activities.

Office/Administration
Many of these buildings contains storehouse or/and a shop. Some companies share buildings but it isn't clear if they share any space inside the buildings.

Industry/workshops
Smaller business in the north part like carpentry, smithery, garages, plumbing and mechanical workshops etc. The south part is dominated by fewer but bigger activities; the heat plant, the recycling center and the train garage.

Mixed buildings
Contains both workshop and some kind of office/administrative activity.

Electrical substation

Restaurants

FUTURE BUSINESS

What is environmental technology?

As mentioned in the last chapter there is a pronounced vision from City of Stockholm and Stockholm Business Region Development to support and attract companies working in the sector of environmental technology to Högdalen. Environmental technologies are defined, by the European Commission (2014), as all technologies “where their use is less environmentally harmful than relevant alternatives”. By using environmental technology, the best available technology, we probably could decrease the pressure on nature and speed the development for a sustainable future (European Commission, 2014).

The project Cleantech Högdalen (http://cleantechhogdalen.se/) operates projects within environmental technology in Högdalen and is working for attracting companies which develops, produces and uses environmental technology. This still means a wide range of companies since the sector of Environmental Technology covers several fields. Some examples are (Haglund, 2010):

- Waste management and recycling
- Bioenergy and Biofuels
- Noise
- District heating
- Sustainable Building
- Air purification
- Soil Remediation
- Solar energy
- Transportation
- Water treatment
- Hydropower

Why environmental technology?

The Environmental Technology sector in Sweden has more than 40 000 employees and it turns over 120 billons SEK/year (Regeringen, 2011, p.8). Furthermore the trend is that the sector is growing for every year (Tillväxtanalys, 2011, p.8) and the European Commission (2014) considers it as an important sector for a sustainable future and a good economy.

Between 2011 and 2014 the Swedish government has developed an Environmental Technology Strategy with the aim of coordinating development support and creating good prerequisites for the growth and export of Swedish environmental technology (Regeringen, 2011). In the evaluation of the strategy it is declared that Sweden’s green competitiveness is relatively good. Sweden has some prominent industries but lacks the breadth that a number of other European countries have. In a lot of sectors Sweden also seems to have lower levels of green innovation compared to corresponding sectors in several other countries. Even if Sweden is competitive in these sectors today this may indicate that, in a future greener economy, Sweden could be left behind. To broader the spectra of environmental technology and to support green innovation could play an important role to Sweden’s future competitiveness (Tillväxtanalys, 2013, p.10). The sector of environmental technology is however growing and that strengthens the existing vision of Högdalen as a future cluster of environmental technology.

BUSINESS AND ARCHITECTURE

Architecture as a tool for a successful business

Companies have for many years used architecture as a tool to signal what they stand for (*Kontorets betydelse för varumärket*, 2015). Architecture has been used to attract potential customers and to recruit the right people. This method has influenced the design for many offices, but what about the industrial buildings? Maybe the industrial architecture has had a more practical approach.

There are however many indications that architecture could be a powerful tool to create an attractive building for companies within the sector of environmental technology. To brand the business the architecture preferable should match well with environmental technology. Also architecture with an identity that stands out is, according to the researcher and architect Christina Bodin Danielsson, requested (*Kontorets betydelse för varumärket*, 2015). Her area of research is offices but an architecture that “evokes positive feelings, attracts our senses and has character” is probably also attractive for other work environments. Danielsson declares that people are tired of the big, glassed office buildings without any identity and contextual relationship. The trend is that many people are looking for other kind of buildings for their work environment.

CONCLUSIONS

The business

Högdalen industrial area could in the future become a cluster for companies in the sector environmental technology. Since environmental technology is a business working for a sustainable future it is preferable if a new building could support this business. In that case a new building should support, in particular, green innovation and smaller companies. The ambition is however also that the building can contribute to the existing business and organizations like “Cleantech Högdalen” and the workers local association “Högdalsgruppen”.

An architecture that gives the building an identity, and mirrors the content of environmental technology, will probably make a new building more attractive. Biophilic design and integrated greenery fits, in my opinion, quite well with the business sector environmental technology. Biophilic design could therefore be a good contribution to the architecture of a building hosting that kind of business.

Concluding objectives for a new building

- Do not privatize the whole building/site. Make it contribute to the existing companies and workers.
- Design the building primarily for green innovation and smaller companies within the sector of environmental technology.
- Let the architecture mirror the content. Make the environmental content visible from outside.

BIOPHILIC DESIGN

POSITIONING BIOPHILIC DESIGN

Biophilic design in the context of sustainability

Biophilic design can (when applied at buildings) be explained as an architecture that mimic and integrate nature with the purpose of human, and environmental, health.

The point of departure in biophilic design is to (re)connect humans to nature by using design (Kellert, Heerwagen & Mador, 2008). Today, with the ongoing urbanization, we are becoming more disconnected from nature than ever, even though we know about the positive impact it has on our physical and mental health. Contact with nature could also be considered as a factor for a more environmental friendly behaviour (Wilson, 1984). The nature provides us with a wide range of services that we are dependent on. A closer contact between humans and nature can make these services, and our dependency, visible and could therefore work as an incentive for actions that benefits the nature (Kellert et al., 2008).

All the services that nature provides humans with are defined as eco-system services (Millennium Ecosystem Assessment, 2003). The mental and physical health nature provides humans with, by its visual appearance, can consequently be seen as an ecosystem-service. Biophilic design take advantage of, and maximize the use of, this ecosystem service when proposing nature-inspired and nature-integrated architecture to increase human health. This approach has been lacking, or not developed into its full potential, in many building projects. It could become an important contribution to the *low environmental impact design* that today dominates many building projects with sustainable ambitions (Kellert, 2008).

Kellert argues that biophilic design is the missing link between *low environmental impact design* and *sustainable design*. It could however be considered as very human centric to maximize the use of nature for our own needs and health. But with biophilic design the building could begin to contribute to the environment and become a part of the ecosystem. Using greenery for human health could support biodiversity and other key components for a functional ecosystem (Sandifer, Sutton-Grier & Ward, 2015). What benefits humans could also benefit nature and other species. By using biophilic design the building could go from *low environmental impact design* into *positive environmental impact design* (design that contributes to the nature instead of only decreasing its damage) and that could be considered one step closer to sustainability.

BIOPHILIA AND BENEFITS

The hypothesis

There are plenty of studies that supports the theory that contact with nature is important for humans productivity, health and well-being. As mentioned before nature, merely by its visual appearance, benefits humans. But how come humans are so affected by nature?

Biophilic design builds upon the hypothesis of biophilia - literally meaning “love of life”. The hypotheses suggest that there is an instinctive bond between human beings and other living systems (Wilson, 1984). That humans have an urge to affiliate with other forms of life, the nature, to function, be healthy and feel good. The proposed reason for this is that the human body and mind, during millions of years, has evolved in a natural, not artificial or constructed, world (Kellert & Wilson, 1993).

The benefits of nature

Visual contact with nature affects both peoples mental and physical health. In terms of direct health outcomes in hospital settings, studies have shown that access to a natural view has positive effects on recovery after surgery (Ulrich, 1984). Patients with views over greenery needed less pain killers and recovered faster than patients with views over brick walls. Beneficial effects of views of nature have also been found in prisons. Inmates who had cells which looked out upon the free world farmland and forest were less apt to utilize health care than those who looked inward upon the prison yard and concrete surrounding wall (Moore, 1982). It is important to keep in mind that the circumstances in these settings are in many aspects different to those in regular work environments. Studies specified at office environments however show that views of greenery is affecting, for instance, our level of stress and job satisfaction.

The correlation between views and satisfaction in offices has been described in several articles. For instance Kaplan et al. (1988) found in a study that office employees with views of only built components had higher levels of job stress and lower levels of satisfaction than those with views of natural elements. The view over built components does however not seem to be a problem itself as long as there is some nature visible. A few trees, some landscaping or some signs of vegetation seems be enough to make a difference regarding stress and satisfaction (Kaplan, 1993).

In another study Stigsdotter (2004) confirms the importance of views of nature. The study also shows value of having the opportunity to take a break outdoors. The following table shows how access to green outdoor areas at the workspace influence the level of stress.

Access to green outdoor areas	Stress occasions per person / year
Having no view of a garden and no chance to go out during breaks.	*153.73*
Having no view of a garden and a chance of a break outdoors (once a month at most).	*104.08*
Having a view of a garden and few or no chances of a break outdoors (once a week at most).	*94.66*
Having a view of a green garden and chances of a break in a green garden (more than once a week).	*77.07*

Table from Stigsdotter (2004).

People who lack access to views and windows seems to compensate by decorating their work space with natural motifs. Heerwagen and Orians (1986) showed that occupants of windowless space used twice as many visual materials to decorate their offices. Further, materials in windowless offices were dominated by nature themes. They were decorated with more landscape motifs and fewer cityscape motifs than windowed spaces.

Another topic of research is how nature in form of material, like wood, affects people. A study by Tsunetsugu, Miyazaki & Sato (2007) indicates that rooms with wooden finish decreases the blood pressure and improves the perceived comfort.

Nature has, to summarize, restorative qualities. A theory why nature offers humans restorative experiences is that the modern man is surrounded by too much information that he must sort and assess the importance of (Kaplan & Kaplan, 1989). The theory is based on the fact that the human brain has two types of attention: directed attention belonging to the higher cognitive centres, and soft fascination linked to the old parts of the brain. In nature the higher cognitive centres can rest since nature, in contrast to city environments, contains information that stimulates the old parts of the brain. By resting the parts of the brain that we use for concentration, planning and decision making we increase our ability to resist stress and burnouts.

DESIGN GUIDELINES

What, more exactly, is biophilic design and how can it be applied in buildings? Stephen R. Kellert organizes in the book *Biophilic Design: The Theory, Science, and Practice of Bringing Buildings to Life* (2008), biophilic design into two dimensions, six elements and 70 design attributes. The purpose with this specification is to assist designers and developers in purchasing the practical application of biophilic design in the built environment. The specification shows what kind of design features that is considered to (re)connect people to nature and make people feel good and healthy.

Dimensions

One of the two dimensions is the *place based* or *venecular dimension*. It reminds us about the fact that a building also is a part of a context, a whole. To become a functional part of the whole the building must connect to the local culture and ecology (Kellert, 2008). The other dimension, the *organic* or *natural dimension*, is as I see it, the core of biophilic design. It is about how the qualities of nature can be implemented in buildings (Kellert, 2008). Three different ways, strategies, for how this dimension can be applied are described below. The strategies are based on Browning and Cramer (2008).

Nature in the space
The strategy is to incorporate nature, for instance plants, water, daylight, animals and natural materials, into the built environment. “Nature in the space” advocates, in contrast to the other strategies, contact with “real” nature. Example of projects that exemplify “Nature in the space” are for instance the Japanese project “Ring House” (p.57) with its daylight inlet and green views, or the reference projects at the pages 73-83 which presents ways to integrate greenery in buildings. Studies show that this kind of biophilic design has restorative qualities.

Natural analogues
Instead of integrating “real” nature in buildings this strategy is about using design features that mimics the nature and in that way possibly evoke similar impact on humans as “real” nature have. The idea is based on the hypothesis that space and shapes in nature can be transformed to built/artificial space and shape without losing all of its natural qualities. That humans benefit from different levels of biomimicry as well as the “real” nature. It has been hard to find studies about this topic. Studies do however show that pictures and painting of nature motif has similar impact on humans as views of natural elements. But it is not clear how similar the artificial/built object must be to the nature to have any effect. One project with this kind of biophilic design is presented at page 61.

The nature of the space
Just as “natural analogues” this strategy is dealing with a kind of biomimicry. The strategy focusing at translating the spatial patterns found in landscapes preferred by humans, into space and shapes in buildings. There are many historic and contemporary examples of the use of these spatial patterns in architecture. An example of a pattern is refuge; under a tree or with a protected wall behind the back, people feel safe. A reference project dealing with prospect and refuge is presented on page 59.

Attributes and elements

To specify and narrow down biophilic design even more, to make it easier for designers to create biophilic architecture, Kellert gives several specific proposals of what kind of design features to include in a biophilic building (Kellert, 2008). The design features are called attributes and some examples are “Facade greening”, “Egg, oval and tubular forms”, “Patterned wholes” and “Reflected light”. Since they are more than 70 attributes they are spread out and grouped under six topics. Each topic is commonly called a design element. Most of them are closest connected to the natural dimension of biophilic design but the element “place-based relationship” is, for example, more connected to the placed-based dimension of biophilic design. The six topics, or elements, are as follows:

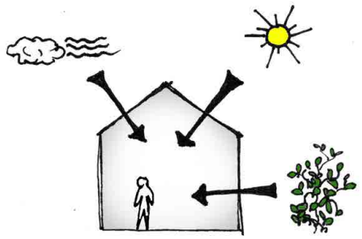
1. Environmental features
2. Natural shapes and forms
3. Natural patterns and processes
4. Light and space
5. Place-based relationships
6. Evolved human-nature relationships

The elements with its attributes are being further presented on the next pages. In addition to them I have formulated several design criterias, one for each element. The criterias could be seen as a summary of the attributes I have chosen to work with. The aim is to work with the design criterias in the design process and try to apply them in the best possible way to make the new building in Högdalen a biophilic whole.

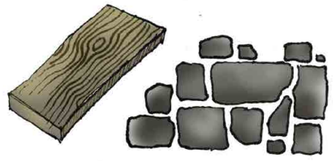
Elements & Attributes from Kellert (2008) and Design Criterias formulated by me.

Element | ***Environmental features***

Design criteria | *Let in and work with air, light and greenery in the building. Use materials and colours that exist in nature. (Nature in the space)*



Air, light and greenery



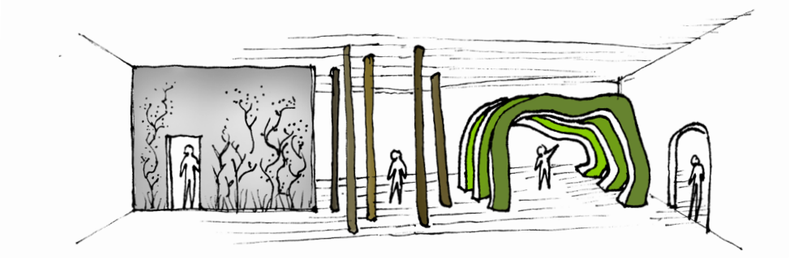
Natural materials

Attributes

- Color
- Water
- Air
- Sunlight
- Plants
- Animals
- Natural materials
- Views and vistas
- Facade greening
- Geology and landscape
- Habitat and ecosystems
- Fire

Element | ***Natural shapes and forms***

Design criteria | *Decorate with natural motifs and use organic shapes in the building structure when it benefits both the user or/ and the construction. (Nature motifs)*



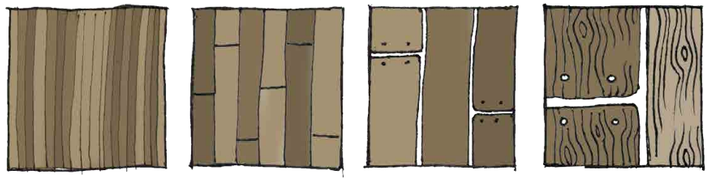
Nature motifs, columnar support and biomorphic form

Attributes

- Botanic motifs
- Tree and columnar support
- Animal motifs
- Shells and spirals
- Egg, oval and tubular forms
- Arches, vaults, domes
- Shapes resisting straight lines and right angels
- Simulation of natural features
- Biomorphy
- Geomorphology
- Biomimicry

Element | ***Natural patterns and processes***

Design criteria | *Create information richness, new information in every scale. Use materials that age with patina. (Nature of the space)*



Zoom in - wooden panel, information richness

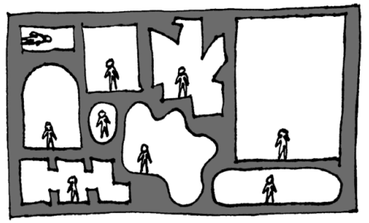
Attributes

- Sonsory variability
- Information richness
- Age, change, and the patina of time
- Growth and efflorescence
- Central focal point
- Patterned wholes
- Bounded spaces
- Transitional spaces
- Linked series and chains
- Integration of parts to wholes
- Complementary contrasts
- Dynamic balance and tension
- Fractals
- Hierarchically organized ratios and scales

Element | ***Light and space***

Design criteria | *Use daylight in different ways to create a varied light. Let also space vary in size and shape. (Nature of the space)*

Varied daylight



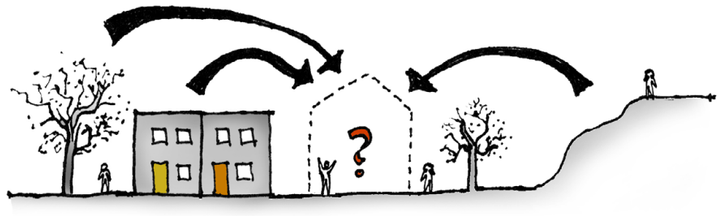
Varied space

Attributes

- Natural light
- Filtered and diffuse light
- Light and shadow
- Reflected light
- Light pools
- Warm light
- Light as shape and form
- Spaciousness
- Spatial variability
- Space as shape and form
- Spatial harmony
- Inside-outside spaces

Element | ***Place-based relationships***

Design criteria | *Relate to context when choosing function, material, shape and placement of building. (Place-based dimension)*



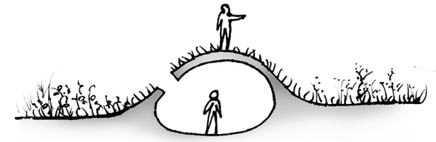
Let the context affect the design

Attributes

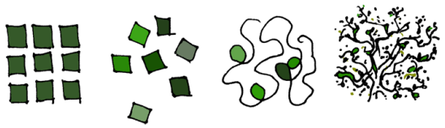
- Geographic connection to place
- Historic connection to place
- Ecological connection to place
- Cultural connection to place
- Indigenious materials
- Landscape orientation
- Landscape features that define the building form
- Landscape ecology
- Integration of culture and ecology
- Spirit of place
- Avoiding placelessness

Element | ***Evolved human-nature relationships***

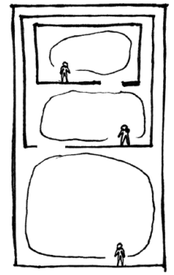
Design criteria | *Design varied levels of protected/open space. Find a balance between order and complexity. Reveal space and views in steps. (Nature of the space)*



Prospect and refuge



From order to complexity



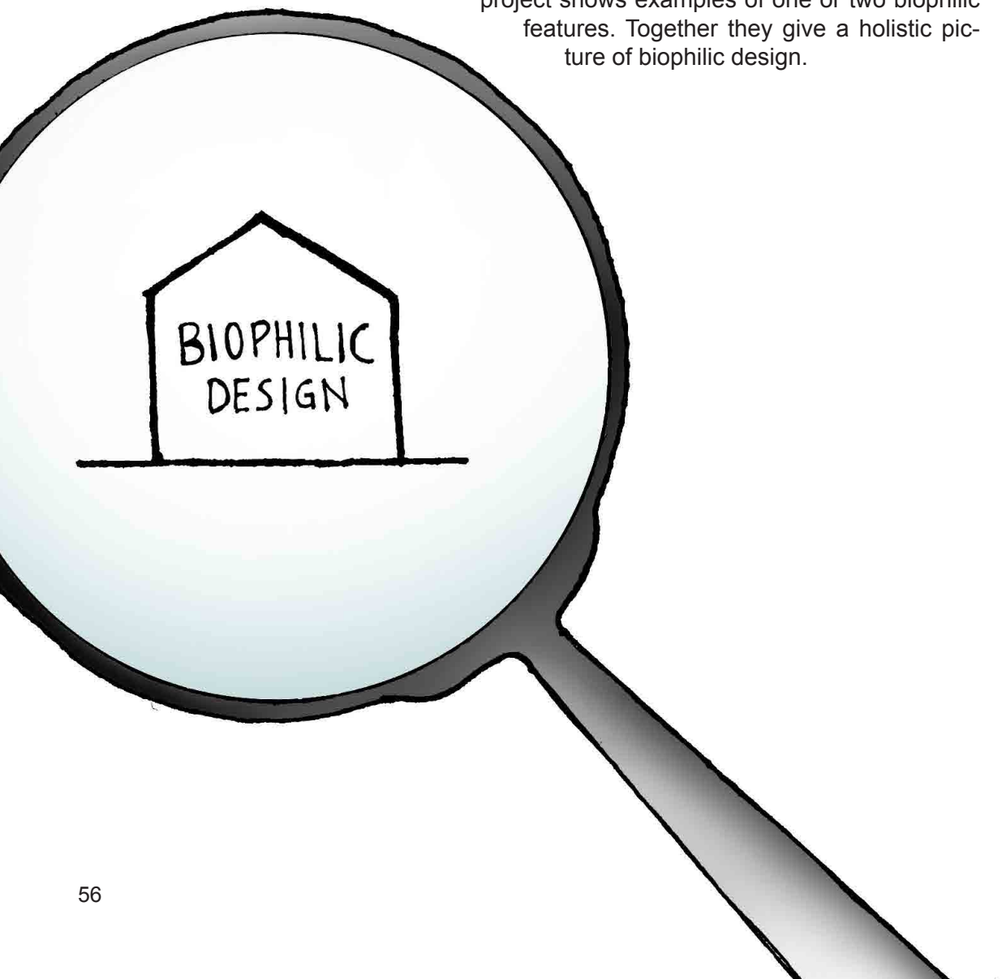
Reveal space in steps

Attributes

- Prospect and refuge
- Order and complexity
- Curiosity and enticement
- Change and metamorphosis
- Security and protection
- Mastery and control
- Affection and attachment
- Attraction and beauty
- Exploration and discovery
- Information and cognition
- Fear and awe
- Reverence and spirituality

REFERENCE PROJECTS

To clarify the concepts of biophilic design a couple of reference projects have been put together. Each project shows examples of one or two biophilic features. Together they give a holistic picture of biophilic design.



Ring House

Architects: Takei-Nabeshima-Architects
Year: 2007
Site: Nagano, Japan

A house that by its shape and facade lets in daylight and make you feel like you are in the forest even when you are inside.

Fig. 7-8: Ring House.

Loblolly House

Architects: KieranTimberlake
Year: 2006
Site: Taylors Island, USA

A family house built with inspiration from the surrounding forest. The wooden facade relate with its material, direction, irregularities and complexity. The building is raised from the ground by plinths to decrease the impact on the site

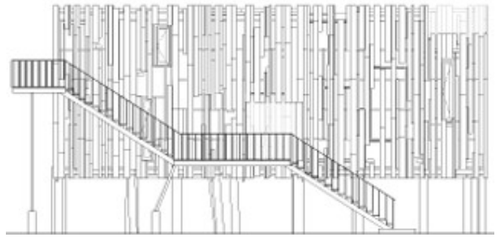


Fig. 9-11: Loblolly House.

Cuningham Group office

Architects: Cuningham Group Architects
Year: 2012
Site: Hayden Place, California, USA

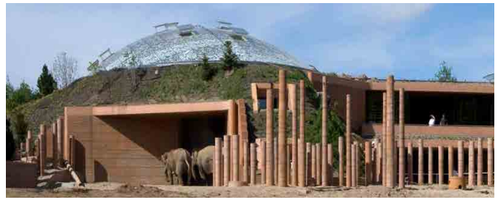
Developed with the aim to create a creative and sustainable office. Following elements are considered biophilic; the organic shape with visible construction, the great daylight from skylights and the indoor plants. Two kinds of spaces are visible; the “tube-room” offers refuge while the surrounding is more of a prospect space.

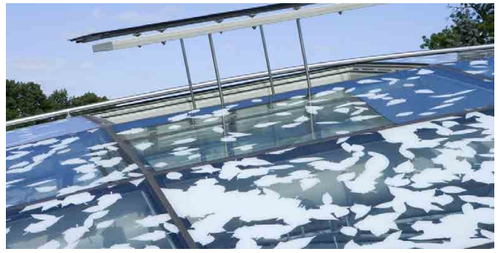
Fig. 12-13: Cuningham Group office.

Elephant House

Architects: Foster + Partners
Year: 2008
Site: Copenhagen, Denmark

The big skylight with artificial leaves, filtering light and create patterns of shadow, is one by many biophilic elements found in this building at Copenhagen Zoo.





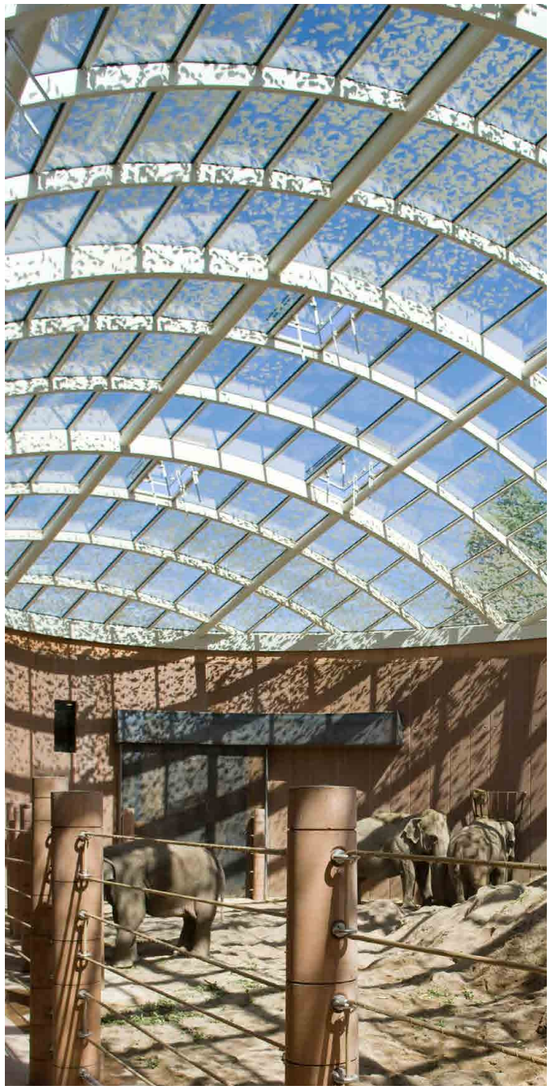


Fig. 14-16: Elephant House.

The Tote

Architects: Serie Architects
Year: 2009
Site: Mumbai, India

Transformation of a disused building. The ambition was to decrease the border between indoors and the big rain trees outdoors. The pillars of steel mimic the structure of a tree. The shape of the pillars creates, together with the ceiling, a nature influenced space without integrating natural materials, colours or plants.

Fig. 17-18: The Tote.

INTEGRATION OF GREENERY

THE USE OF GREENERY

The concept of biophilic design includes integrated greenery. Plants and facade greening is for instance attributes within the element environmental features. This chapter investigates how greenery can be integrated in buildings and what functions it can contribute with.

Greenery could contribute to the architecture, the building systems and to the people using the building. It could for instance be used to filter daylight, clean storm water or to create meeting places. To show and explore the multifunctional greenery a “library” has been developed. Possible functions for greenery are:

Spatial functions

- Divide
- Connect
- Enclose (into/under/over/between)
- See trough / Transparency

Building functions

- Sun protection
- Storm water treatment
- Noise protection
- Isolation

Spatial qualities

- Shadows
- Materiality (richness of details, life)
- Colour
- Shape

Environmental functions

- Cleaning air
- Cleaning water
- Biodiversity
- Production (growing)

Social functions

- Meet
- Coherence
- Attraction / Attention

Integration of greenery can be done with different purposes and with different techniques. A sample of techniques, for instance green roofs and walls, are described and evaluated on the next pages. Together with the “library” and the reference projects it creates a base of knowledge for the final design proposal.

APPLICATION IN BUILDINGS

As outer layer

It is possible to cover the building envelope with greenery in many different ways. Green roofs are here defined as roofs without the intention of people entering it. Lawns and roof gardens are treated later on. Facades can either be covered by plants climbing along the facade or the plants could be growing at the wall, so called living wall. Following piece of text describe pros and cons about a green envelope. Sentences in bold relate to the essence of this master thesis, the contact between the applied greenery and the people inside the building.

Pros

Conserving and improving biodiversity (Greater London Authority [GLA], 2008). Cleaning the air. **Direct positive impact on human health when visible**. Especially green roofs delays and decreases storm water runoff. Green roofs and living walls could contribute to energy gain by its insulating effect and therefore reduced need of cooling. They also have a temperature-equalizing effect and give an opportunity for branding (Capener & Sikander, 2014).

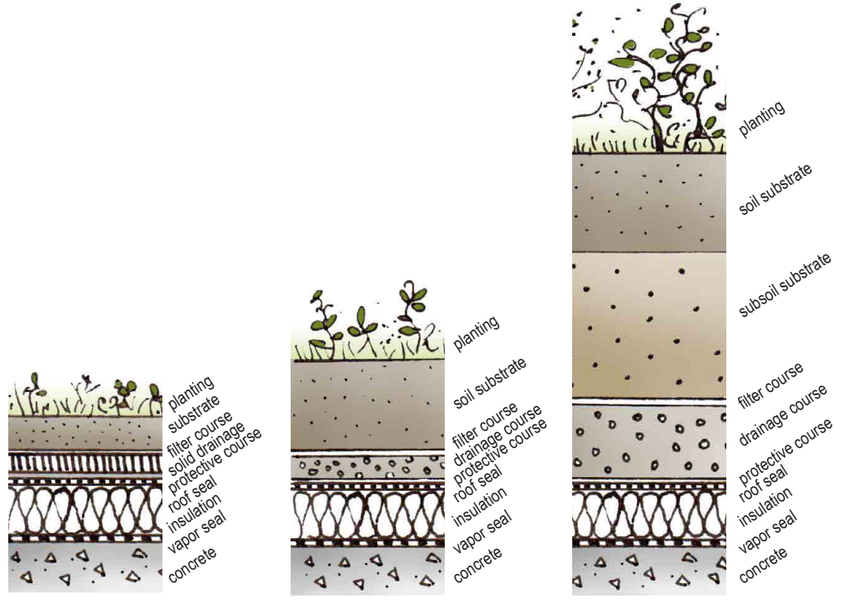
Cons

Living walls and green roofs does not contribute to any energy gain when applied at well insulated, not cooled, buildings (Capener & Sikander, 2014). Increased risk for moisture problems in the construction and need of maintenance is another problem, as well as fire hazard and increased weight. **Since the greenery is applied at the outside of the building big parts of it is hidden from the people inside**.

Thicker layer of substrate in green roofs means higher maintenance, weight and need of irrigation. It also leads to greater storm water attenuation, higher biodiversity potential and increased recreational value (Green roof guide, n.d.). Properties of green roofs with different levels of thickness are presented on next page. Figures are based on Zimmermann (2009).

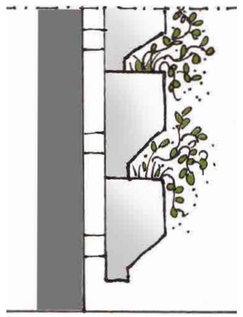
Roofs

Extensive roof	Semi-intensive roof	Intensive roof
< 10 cm substrate depth	*10-20 cm substrate depth*	*> 20 cm substrate depth*
Low maintenance	*Moderate maintenance*	*High maintenance*
Limited water holding	*Sometimes irrigated*	*Sometimes irrigated*
Limited biodiversity	*Rainwater attenuation*	*Rainwater attenuation*
Includes pre-grown vegetation mats or substrate	*Supports vegetation*	*Great biodiversity*
	Moderate biodiversity	*Increased recreational value*

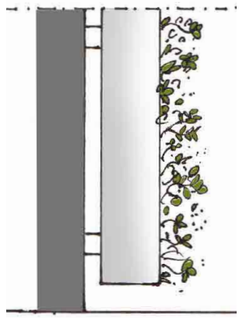


Living walls

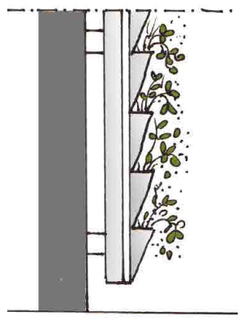
Plants in living walls can either be grown in a soil based or hydroponic way. In the hydroponic way the plants are planted in pockets of felt or in mineral wool instead of soil (Capener & Sikander, 2014). Many systems consist of modules with prepared spots for the plant. The modules are basically not a part of the construction; they only work as the “skin” of the building. Often an irrigation system supplies the plants with water and nutrients. To avoid frost damage the water in the system automatically could be emptied when the temperature approaches zero (Andersson & Karlsson, 2014).



Living wall system based on planter boxes.



Living wall system based on foam substrate, cassette system.



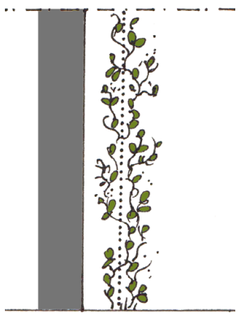
Living wall system with felt pockets.

Figures based on Perini et al. (2011)

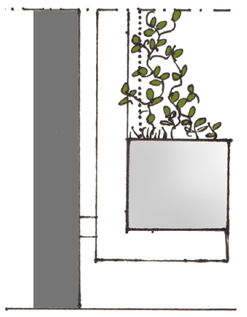
Green facades

A “green” building envelope could be created with living walls or plants climbing along the facades, so called green facades. Climbing plants is a cheaper way of adding greenery. The investment costs for living facades in a Swedish context could be set to between 5000-22000 Skr/sqm (Kristiansson, 2014, referenced in Andersson & Karlsson, 2014). The corresponding cost for green facades is 1000-2500 Skr/sqm. The green facade could however not work as a building skin in the way a living wall could. Consequently economic and environmental costs for another building skin should be considered when designing for green facades, as well as the loss of thermal capacity. Noteworthy is that the environmental burden increases drastically when a support system of steel is used for the plants in a green facade (Perini, Ottelé, Haas & Raiteri, 2011).

Green facade with direct greening system.



Green facade, indirect greening system (additional support for the plants).



Green facade, indirect greening system combined with planter boxes.

Figures based on Perini et al. (2011)

Outside spaces

Green outdoor spaces are very often applied at ground floor. How can this quality been brought higher up in the building? One solution is green terraces, balconies and atriums. They have almost the same pros and cons as the green roofs with some additions.

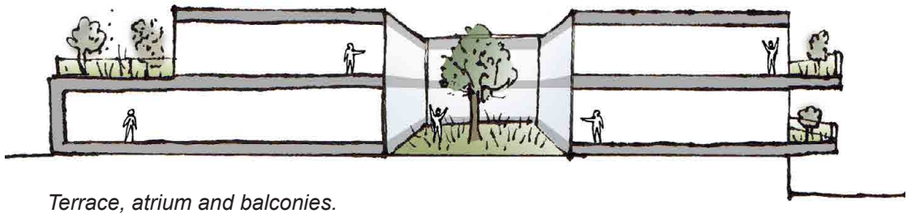
Pros

Outside views and close connection between inside and outside. A possibility to grow food, **tactile contact with nature in addition to the visual**. With the right placement greenery contributes with shadow during summer and let the sunlight through during winter. Could become a common meeting place and invites for outdoor visits.

Cons

Very heavy and maintenance demanding. Hard to manage water runoff.

Intensive roofs can be used as green outdoor space. A varied level of substrate depth increases the biodiversity (Green roof guide, n.d.).



Terrace, atrium and balconies.

In facades - visible from both inside and outside

Many systems for living walls are so far not adapted to the Nordic climate. Also the selection of plants is limited and the growing season is short. A way to handle the Nordic climate is to use a double skin facade with plants in between the skins. Basically you cover the building with a greenhouse. Examples of this is the reference projects at page 76 and 79. This method could have several benefits:

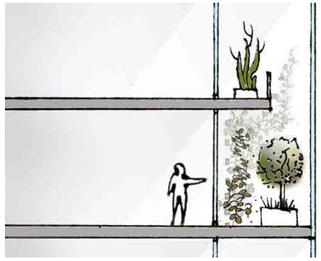
Pros

Visual contact with the greenery from both inside and outside. The in between space could be a part of the ventilation and heating system. Longer growing season. **Plants easy accessible from inside**. No risk for frost damages.

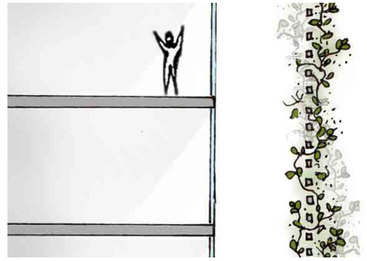
Cons

A separated room/space for the plants leads to decreased possibilities for ecosystem services. Risk for overheated plants during summer. Requires a great level of transparency, could lead to bad U-values (energy efficiency). A double skin facade also leads to use of more material.

Greenery in facades, visible from both inside and outside, could of course also be achieved by using a transparent wall and greenery (climbing plants) on an additional structure just inside or outside the transparent wall.



Double skin facade with greenery between the glassed walls.



Glassed wall with greenery on a structure outside.

Integrated indoors

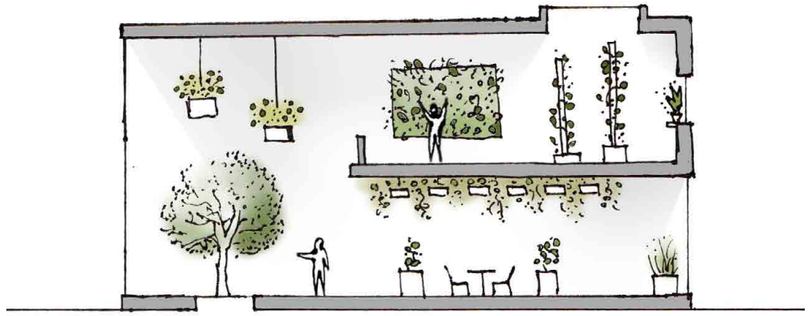
Indoor greenery is commonly used in almost all buildings as plants on the windowsill. Also living walls becomes more and more common in indoor spaces. Greenery can, if used creatively, create spatial units and requested atmospheres inside a building. Plants natural space in windows could advantageously expand to other places in the building.

Pros

Tactile and visual connection between people inside the building and the greenery. Green and growing plants during the whole year. Often easy accessible for maintenance. Capacity for absorbing noise and decreased ventilation need.

Cons

Possible allergies. No natural watering and accessibility to nutrients. Space and light demanding. Requires care and maintenance.



Indoor greenery

REFERENCE PROJECTS

As a complement to this chapter about greenery a couple of project are described and presented on following pages. They all have some kind of integrated greenery and they works as a source of inspiration.

Urbana villor

Architects:
hauschild+siegel architecture
Year: 2008
Site: Västra hamnen, Malmö

Integrated nature at balconies in a Swedish context. Open connection between balcony and living room/kitchen. The resident decide how big part of the balcony that is for plants.

Fig. 19: Section Urbana villor.

Fig. 20: Urbana villor.

Bosco Verticale

Architects: Stefano Boeri, Gianandrea Barreca, Giovanni La Varra
Year: 2014
Site: Milan, Italy

Two towers with the heights of 110m and 76m. They host together more than 900 trees. Most of them on balconies at the facade.

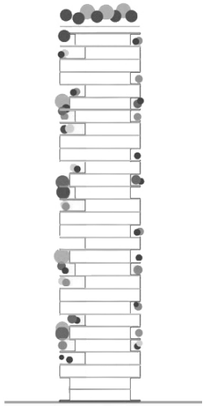
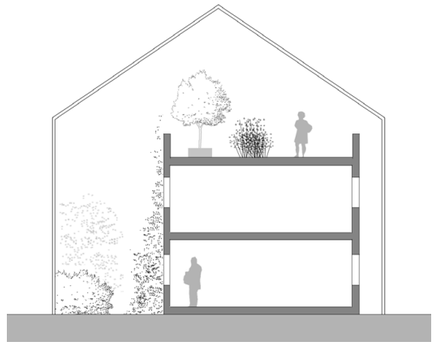


Fig. 21-22: Bosco Verticale.

Naturhus Vänersborg

Architect: Anders Solvarm
Year: 2001
Site: Vänersborg

A house in a greenhouse. The void between the envelopes is filled with greenery, an additional indoor space with several benefits for both the residents and the building.



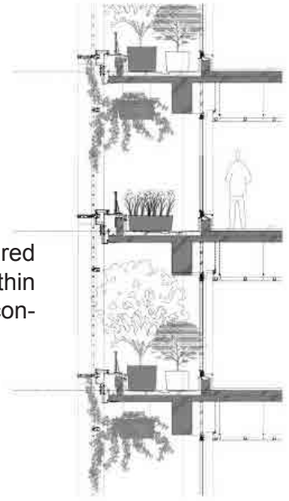
Conceptual section of naturhus.

Fig. 23: Naturhus Vänersborg

Urban farm

Architect: Konodesigns
Year: 2010
Site: Tokyo, Japan

An office building with integrated farming, built for a Japanese recruitment company. Office workers and crops share space. Both hydroponic and soil based farming are used. The green space includes over 200 species like fruits, vegetables and rice that are harvested, prepared and served at the cafeterias within the building. Also the facade consists of a green space.



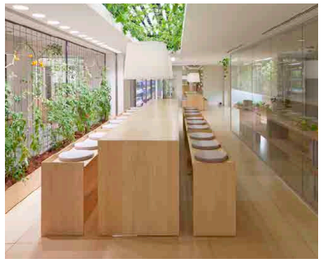


Fig. 24-27: Urban Farm.

Stacking green

Architects: Vo Trong Nghia, Daisuke Sanuki, Shunri Nishizawa
Year: 2011
Site: Saigon, Vietnam

The house is designed for a family in Vietnam. The concept is passive design methods and the green facade (and the roof garden) protects the indoor environment from direct sunlight, street noise and pollution.

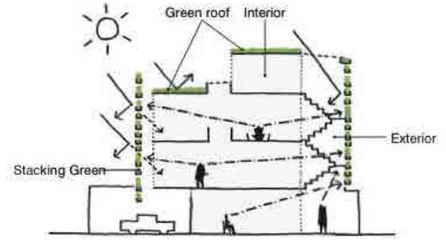


Fig. 28-30: Stacking Green.

Drivhus

Architects: Urban Design
Year: Not built yet, winning proposal in 2014
Site: Stockholm, Sweden

An office building covered by a green house. The cover is of plastic and the second building skin is of glass. The space in between the skins is dedicated to plants and it is also a part of the heating/ventilation system.

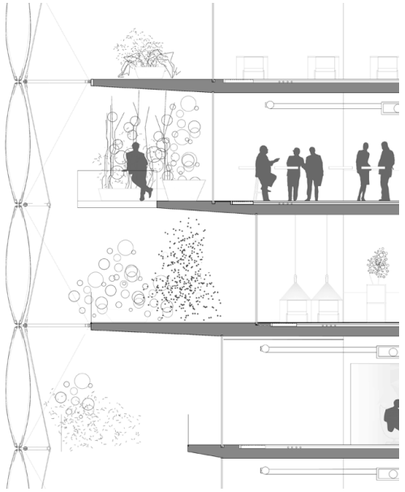
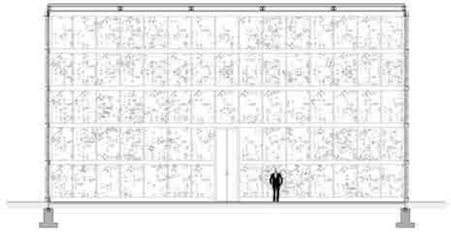


Fig. 31-32: Drivhus.

Hedge building

Architects: Atelier Kempe Thill
Year: 2003
Site: Rostock, Germany

A pavilion built with pre-grown hedge element of ivy. The horizontal structure contains soil and water for the plants.



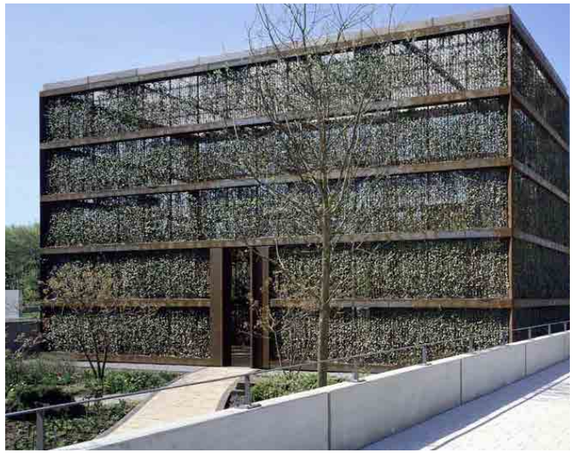


Fig. 33-36: Hedge building.

Sisii

Architect: Yuko Nagayama & Associates
Year: 2010
Site: Kobe, Japan

A showroom combined with office. The space is comprised of three actions; customers watching the cloths, meeting people, and working staffs. The indoor greenery stands in contrast to the neutral, clean surfaces and divides the space into different zones.

Fig. 37-38: Sisii.

Studioverket - Butong wall

Architect: Toki Drobnjakovic,
Per Sundberg
Built in 2012
Site: Stockholm

This is an interesting, new way of integrating greenery in walls. The wall works indoors and is under development for outside use (together with White Architects). The structure mimic natural environments for plants and do also allow curved walls.

Fig. 39-40: Butong wall.

Ursviks sopsugsterminal

Architect: Tengbom
Built in 2007
Site: Ursvik, Stockholm, Sweden

A tilted outside living wall covered by greenery in a Swedish context.

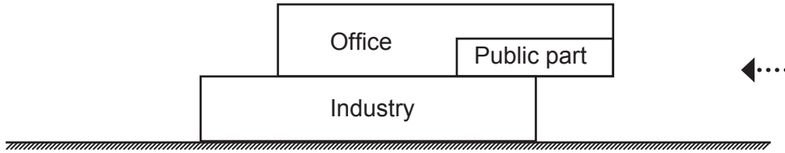
Fig. 41-42: Ursvik sopsugsterminal.

DESIGN PROPOSAL

OBJECTIVES

The design proposal in this master thesis is based on biophilic design and integrated greenery. The design proposal is also based on the concluding objectives stated in the analysis. The objectives are as follows:

- Place the building to decrease the barrier between the industrial area and the residential area.
- Use the building to create an improved entrance to the industrial area.
- Let the existing character of the area influence the design proposal.
- Design the building so it fit with the future vision of the area.
- Do not privatize the whole building/site. Make it contribute to the existing companies and workers.
- Design the building primary for green innovation and smaller companies within the sector of environmental technology.
- Let the architecture mirror the content. Make the environmental content visible from outside.



Conceptual section of the proposed building

FUNCTION AND SIZE

To meet the objectives the building hosts three different functions. The lower volume consists of industrial space while the volume above hosts an office environment. The office has furthermore a public part for organizations, workers around in Högdalen and visitors to use.

The idea is that the building combines flexible office space, suitable for smaller companies to rent, with industrial space at the ground floor. A company could work from the office and still have access to a shared part of the industrial space where they could run a smaller production, or try out new ideas, within the sector of environmental technology. The building decreases the separation between offices and industry and that is suitable especially for product development. I believe that by putting several companies (within the sector of environmental technology) in the same building, with access to an environment suitable for product development, gives opportunities for green innovations.

The more public part of the building is a place where companies within the building meet each other but also other companies in Högdalen. These meetings have the potential to lead to innovations and service/resources exchange between companies. Furthermore organizations like Högdalsgruppen, Cleantech Högdalen et al. could use this space. Parts of the space could be rentable for all companies in Högdalen and it is moreover suitable for exhibitions about Högdalen or as a place to gather future visitors.

All together the building is 2280 sqm. The industrial space measures approximately 1000 sqm and the office 1200 sqm. There is about 56 workplaces in the office, but it is possible that a couple of people only work in the industrial part so the total amount of workers could be a few more. Facilities and size of interior spaces are dimensioned for the estimated amount of workers and companies in the building. The size of the building is furthermore given by the plots size and location. The scale of the project should preferable not be bigger due to the surrounding landscape and buildings.

SITE SELECTION

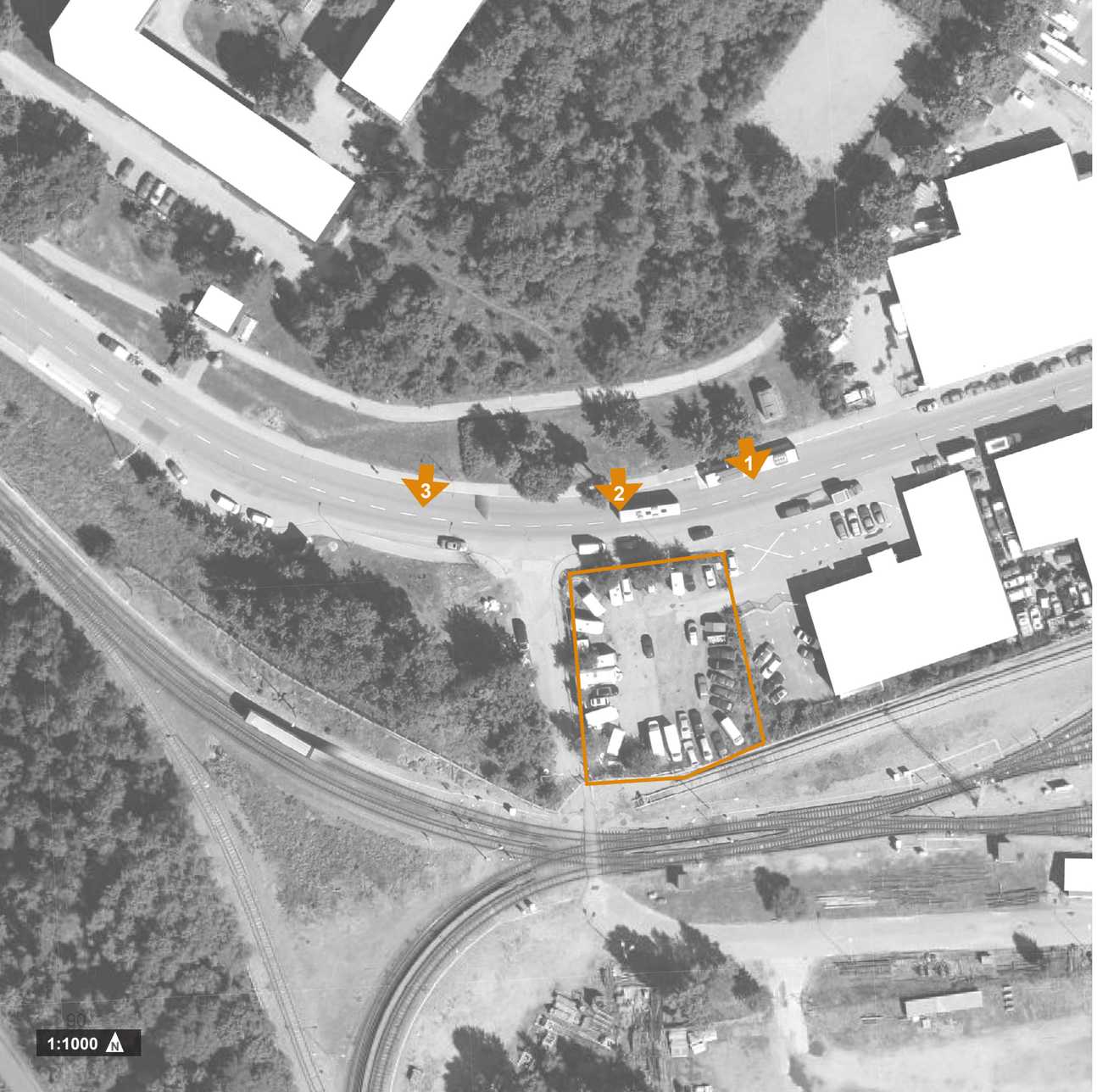
As mentioned in the analysis, the industrial area has two entrances. The entrance from Magelungslägen and Högdalen centre is situated in west. Here, at the border between the residential area and the industrial area, the plot for the new building is located. The decision to choose this plot was made after visiting the site and analysing the whole industrial area. To build here has several benefits:

1: A physical connection, with buildings, between the industrial area and the residential area will decrease the segregation. The green barrier, with its ecosystem-services and recreational qualities could in the same time be mostly preserved if new buildings are concentrated along places where people moves, i.e. the existing roads that connects the areas.

2: The placement makes it possible to create a more inviting entrance to the industrial area. The plot is located in the sightline when arriving from Maglungsvägen or Högdalen centre. When arriving with car the plot is located at the right side of the road which makes it easy to stop by.

3: A big part of the chosen plot consists of a paved surface, used as storage for vehicles/trailers and as parking lot by workers and the car service company beside. This is one of very few plots along the main road (not consisting of greenery) that is big enough for a new building.

The choice of site also includes some problems. The plot is not situated in the center of the industrial area; maybe it will be experienced as far away by the workers. The plot is partly used as an informal parking and the lack of parking space is already today a problem. This is however a general problem in the whole area and it needs a holistic solution, the problem cannot be solved in this master thesis. To build away the amount of parking space at the chosen plot will not affect the overall picture, some other solution for the parking needs anyhow to be worked out. Another thing worth to mention is that there is a development plan (detaljplan) over the plot and it will need change to make this project possible, the existing one from 1955 does not allow any buildings at the plot.



BUILDING PLOT

1

2

3

CLOSE SURROUNDINGS

1 *Car service and Thai Take Away*

MB Service has been located here since 1972. Kobs Thai restaurant is well appreciated for its good food.

2 *Mixed small scale industry*

Companies active within the sector of automotive refinishing and electricity.

3 *Residential building*

The closest residential building, a three-storey building with garage underneath.

4 *Vikinggrillen*

One of two fast-food stands in Högdalen industrial area. This one is situated between the industrial area and the residential area.

IN THE URBAN SCALE

An overhang

When entering the area the upper volume is extended over the road to create an entrance port into the area. The extended part is also visible, as a fond in the end of the road, from the central parts of industrial area. All the other buildings are in line with the road and that make the overhang stand out. This is desired because it strengthens the idea that this is not a complete private building as the other ones along the street. Instead it invites people up to either the public part of the office floor or the roof garden.

The roof garden

With a staircase that turns towards the industrial area the roof garden becomes possible to enter for anyone. This is the place to eat the food from the two take away restaurants in the close surroundings, Vikinggrillen and Kobs Thai. Seating places at the terrace is accessible in east, south and west to make it possible to find a sunny location at any time during the day.

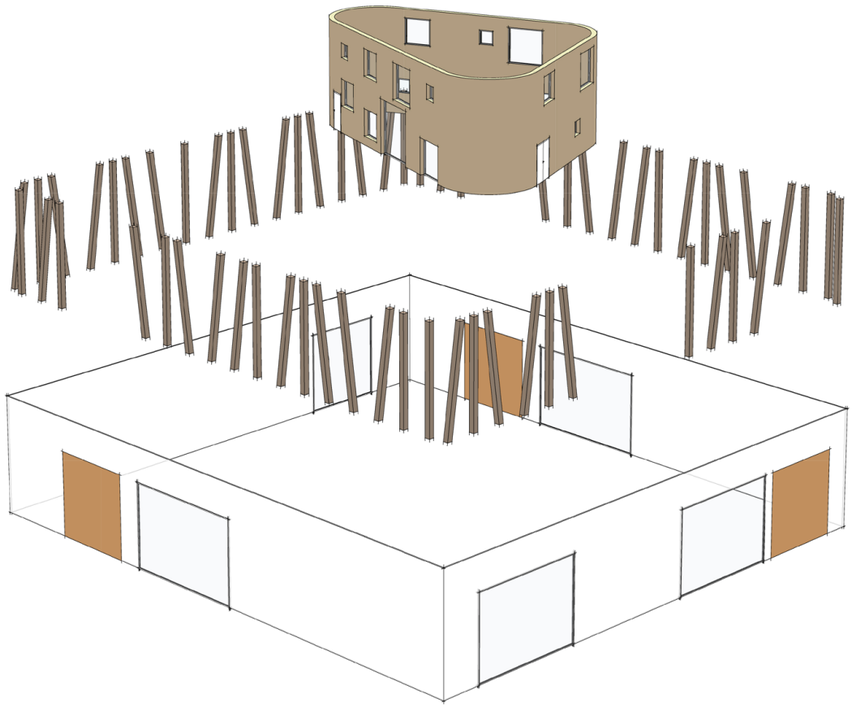
Parking, courtyard and surroundings

Around the building there are some new additions as well. A new path and a crossing make it easy for the workers to get to and from the green area on the other side of the road where there is a quite nice and used walkway. New parking space is located to the left of the building. It is also possible to park along the road. The parking places to the right of the building belong to MB service. Here the approximate numbers of parking spaces are kept but they are slightly reorganized due to one of the buildings three garage openings to the industrial space. Outside the opposite opening a bigger courtyard is located and it makes it possible for trucks and other vehicles to stop by, deliver or pick up stuff, and turn around.

The proposed building in its context.

View: From the street

The wide stair invites people up to the terrace and the overhang creates a natural entrance, both to the building and to the whole industrial area. The building relates with its square shape to nearby buildings but the greenery communicates that this building is different, it has other qualities.

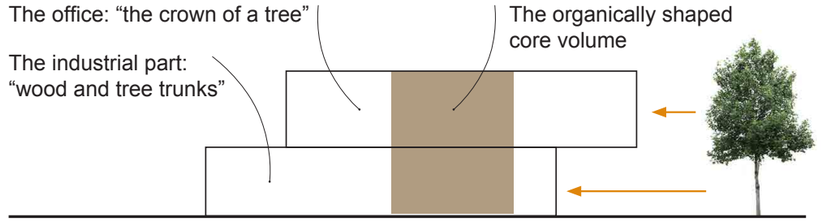


Different “layers” of the first floors.

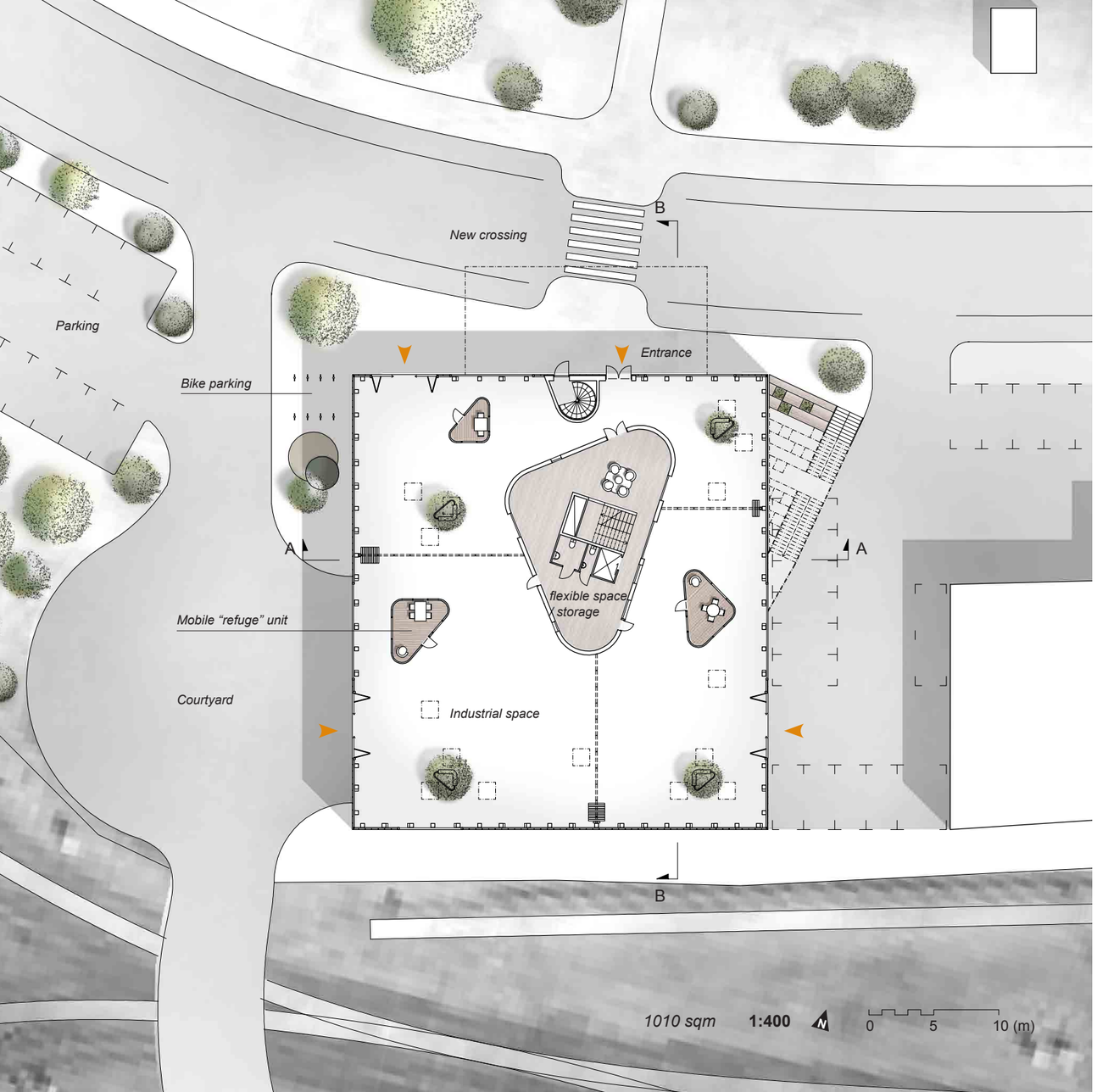
THE INDUSTRIAL PART

A consistent theme in the building is layers. The illustration to the left shows how the facade is composed with an outer layer of polycarbonate and an inner layer of irregular pillars which is a load bearing structure. Inside the square shape there is an organically shaped volume, the innermost layer. This core is the tree trunk of the building. Here the vertical movement through the building takes place. To enter the staircase you first must pass the space between the facade and the inner volume. This sequence of spaces evokes curiosity, the space is revealed in steps. Passing the layers makes other type of spaces appear.

The light transmitting facade with irregular pillars forms, together with the core, an environment that resembles a forest. The pillars on this floor are carrying the crown of the tree, represented by floor three and four, further described at page 113.

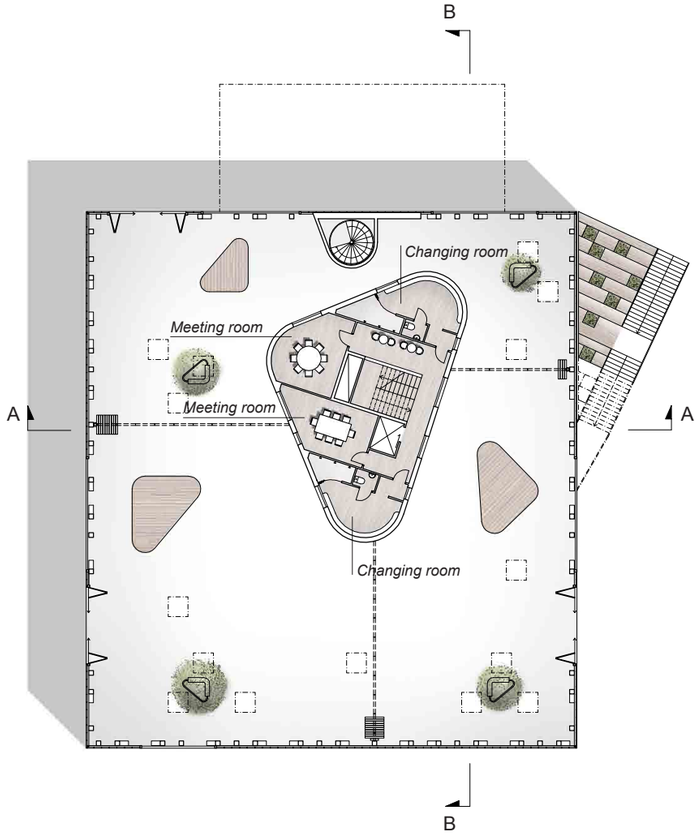


A conceptual design idea for the building.



Floor 1

This floor invites to several different room organizations and have a high level of flexibility with, for instance, movable walls (more described at page 108). The idea is that the space can be shaped to fit the various demands that different companies often have. The static elements on this floor are the core volume and the facades. The space in between them could be used for several kind of industrial business. Here mobile units become an easy accessible and calm zone for shorter breaks, meetings or phone calls. They are possible to move when a changed space demand occurs. Another important element is the trees that are planted in the space. They bring life and greenery closer to the workers.

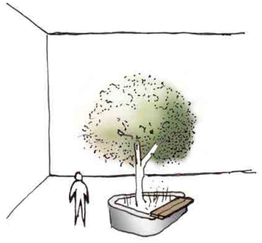


Floor 2

Because of double height in the industrial space, the second floor is limited to the core volume. Here, at the border between the industrial space and the office, a couple of meeting rooms and changing rooms can be found. The windows from this floor give nice views over the industrial space.

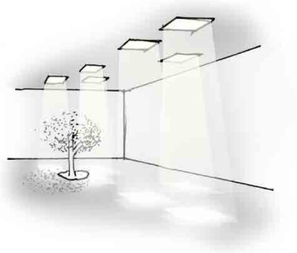
133 sqm **1:400** 0 5 10 (m)

Application of biophilic design



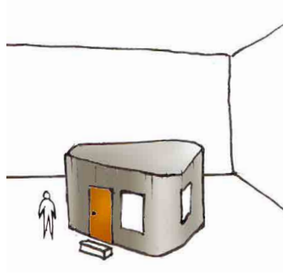
Trees

To bring the scale down and to give the workers on first floor some contact to greenery, four trees are planted in the space. They are planted in the ground and needs, due to the indoor environment, extra supply of water and nutrients. This could be solved, for instance, by an automatic water system.



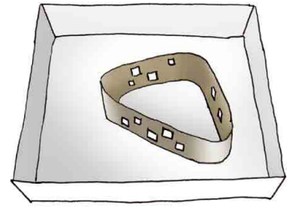
Skylights

Several skylights bring light into the industrial space. They are organized a bit irregular to simulate a varied light that usually appears under a crown of a tree. They are also organized to create “light pools” above each planted tree.



Mobile refuge units

Like the trees these units contributes to the human scale in the industrial space. They are possible to move when changes in the space demand occurs. The units contain a quiet meeting environment and are “refuge-places” for the workers in the industrial space.

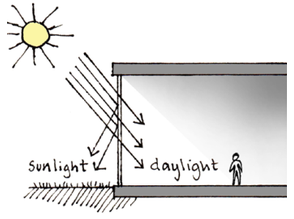


The core

Its organic shape is a biophilic feature that permeates the whole building. The core creates varied space between itself and the square facade. The finish is made of wood. It contributes with pattern, natural colours and materiality.

Facade element: wooden pillars

These pillars, just inside the polycarbonate facade, are a load bearing structure. The delightful irregularity is done with biophilic purpose. This structure is inspired of the tree trunks in a forest and is a characteristic for the whole industrial space. During evenings and night the biophilic structure could be visible from outside, trough the polycarbonate facade, due to indoor lighting.

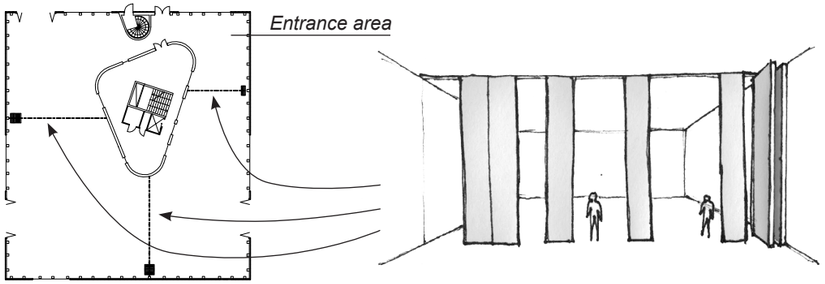


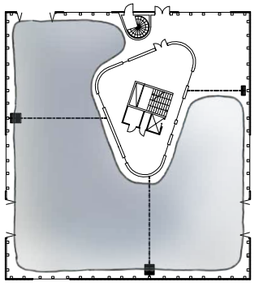
Facade element: polycarbonate

The purpose with the polycarbonate facade is to let in a great amount of daylight. The semi transparency allows light to pass through but prevents from direct sunlight and overheating. To avoid big heat losses a wall system with at least a thickness of 40 mm polycarbonate should be used. The U-value is comparable with a glassed facade (CO-EX Corporation, 2008).

Flexibility

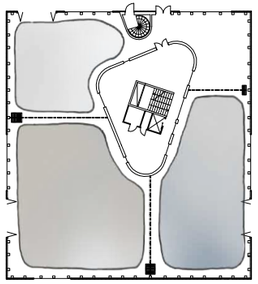
Since it today isn't clear what companies that will move into the building it preferably should be adaptable for several outcomes. To meet this demand three walls between the facade and the core is movable. The walls could be completely open, semi-open or closed. When they are closed each division has their own garage opening. Shared space and movable walls of course raises questions about insurance, fire protection and security. These questions are however not further developed in this master thesis. Following sketches show the principle of the movable wall and possible scenarios for the use of space.





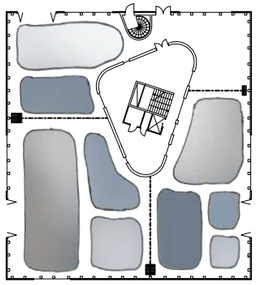
Case 1: All for one

The whole area is hired out to one company, external or internal. They can move the walls to get the room organization they need.



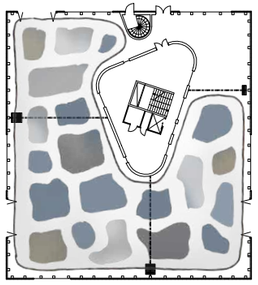
Case 2: Individual parts

Three companies, external or with workstations at the office, is renting a third of the floor. The area is divided by the movable walls and each part is accessible by an own garage opening.



Case 3: Shared rooms

Companies in the building rent a part of the floor. The walls are in general open but if some businesses have similar demands or generates much noise they can gather in one corner and be enclosed by the movable walls.

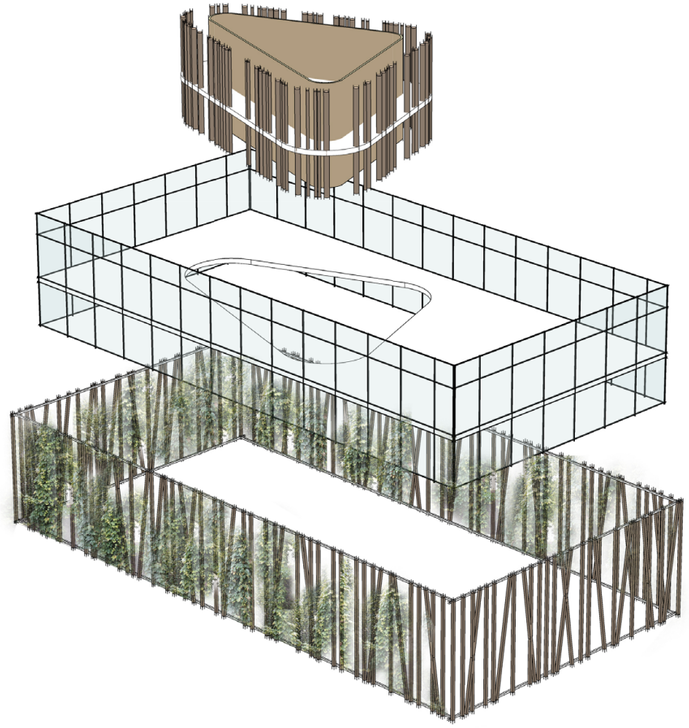


Case 4: Complete sharing

All parts of the industrial space are rented by an organization consisting of the companies in the building. When you begin to rent a workplace in the office you can decide if you also want to be a member of the organization and have access to the industrial space where there can, for instance, be useful machines and tools. The movable walls can be closed or open, they are not the border between different businesses and companies.

View: Industrial space

Elements as the central core, the movable refuge units and the facade with its pillar structure, glassed sections and garage openings are visible in the picture. This space can be used in many different ways; the picture just shows an example of usage.



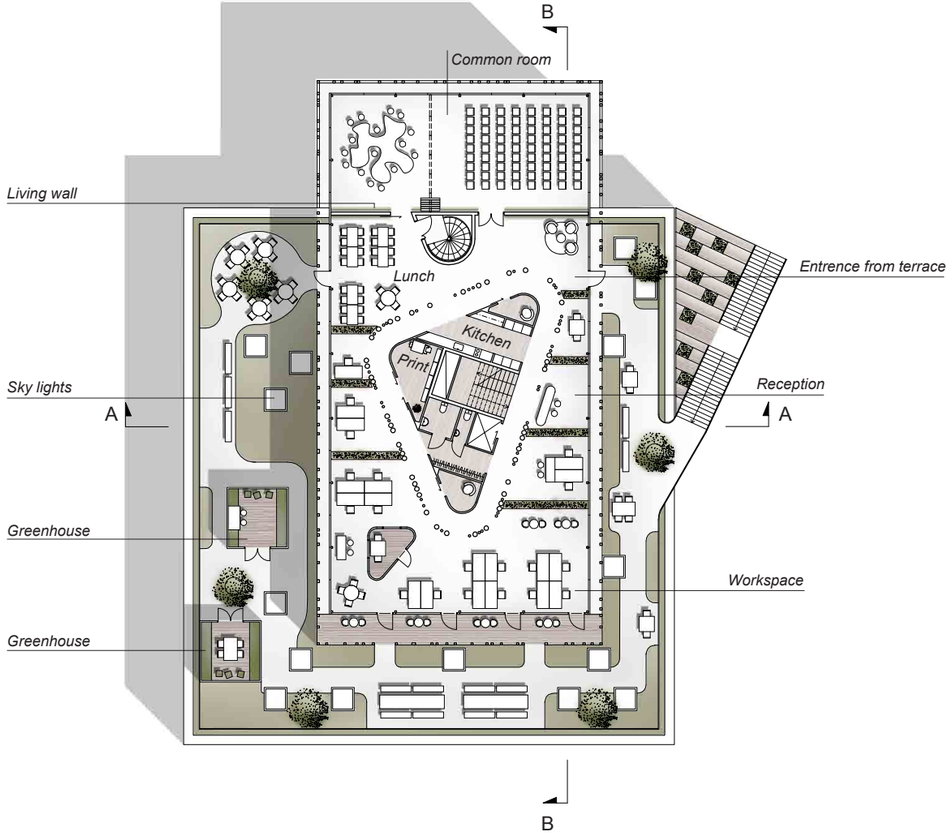
Different “layers” of third and fourth floor.

THE OFFICE PART

The design on these floors is inspired by the crown of a tree. The organically shaped core, the “tree trunk”, continues from the industrial space up, and through, the office part. This tree trunk is surrounded by greenery to imitate a tree top. The most prominent greenery is the trellis outside the glassed facade.

The design builds upon a concept of layers, just as at ground floor. The core is on these floors divided into two layers. The vertical movement takes place inside the inner core. The second layer of the core is a pillar structure that divides the corridor from the workspace.

The office floor is enclosed by a glassed facade. The biophilic element that defines the whole office part is the trellis that is placed just outside the glassed facade. Climbing plants are growing at the roof terrace and climbs on the trellis on the east, south and west facade. The plants protect from direct sunlight and prevents from overheating during summer. At the same time they let in sunlight during the cold part of the year, something that reduces the need of heating.



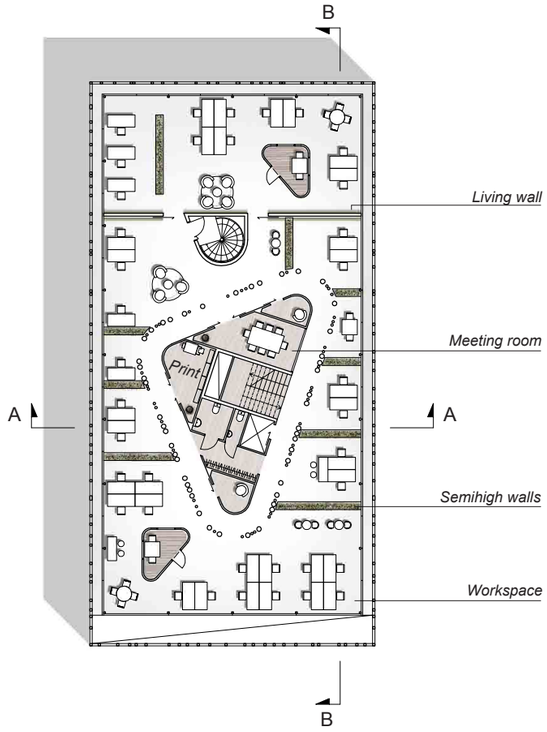
Floor 3

At this floor you find a common kitchen and lunch area as well as a couple of work stations and some common areas.

The north part of this floor is the “public” part. The big common room is possible to divide into two rooms. They are possible to rent for companies in Högdalen industrial area. During other times they can become an extended lunch area or host workstations for “drop in”. A service that is not further investigated in this master thesis but could benefit people visiting companies in Högdalen.

The “public” part is possible to enter from the central stair and elevator but also from the east part of the terrace. There is furthermore a connection between the lunch area and the terrace. The work stations in south also have the possibility to expand on the terrace.

568 sqm **1:400** 0 5 10 (m)

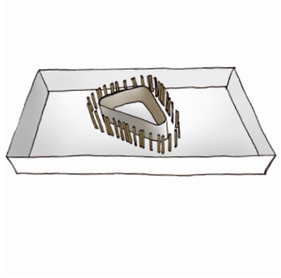


Floor 4

On this floor you find the majority of work stations. They units are, as on floor 3, divided by semi high walls with included storage and with some greenery on top. It is possible to complement these semi high walls with glassed walls, but then the openness in the building will be lost. In the proposed draft the division of the workspace is made with only the semi high walls and the degree of privacy between the work units depends on the height of the plants. These walls could be seen as branches extending from the core into the crown of the tree. Either each unit or each work station could be rented. It depends on the market and the companies demands.

568 sqm **1:400** 0 5 10 (m)

Application of biophilic design

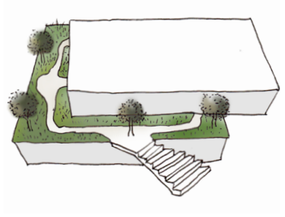


The core

The organic shape is on this floor divided into an inner shape and an outer shape. The outer shape is made of an irregular pillar structure. When moving in the corridor between the shapes you get a glimpse of what is happening outside the core structure. Just as on ground floor the organic shape of the core contributes to a variation in the size and shape of the space around it.

Glass facade + trellis

This facade is an attempt to create visual contact with greenery. The plants will, as described before, also contribute with sun protection. Another beautiful thing is that the plants are growing outside so they will change appearance over the year. Something that will affect the indoor space and make it change character as the seasons change.



Terrace

Access to green outside space does, as mentioned in the chapter about greenery, affect workers stress levels. The proposed terrace invites all workers in the area. It also gives opportunities for common activities, like growing and lunch gatherings.

Semi-high walls

These walls divide the work area into units. On top of the walls it is possible for plants to grow. The privacy between the units could be controlled by the height of the plants. In comparison to the greenery on the terrace and in the facade this greenery is closer to the user and contributes with more to the inner environment than just a visual appearance. These plants are also staying green the whole year.

Living wall

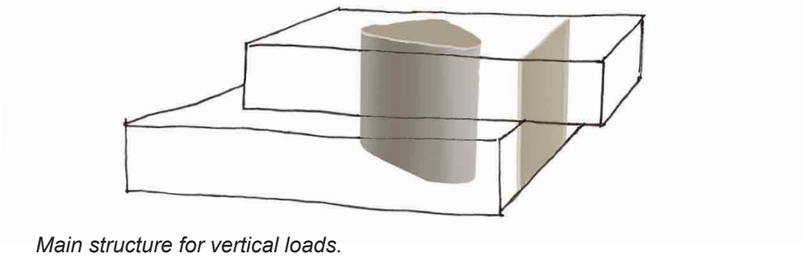
The common room on floor three is divided from the work area with a living wall, for example a butong wall like the one showed in the reference project at page 82. The purpose of the living wall is partly to be a showcase but also to bring greenery into the part of the building that is a bit away from the terrace.

View: Office space

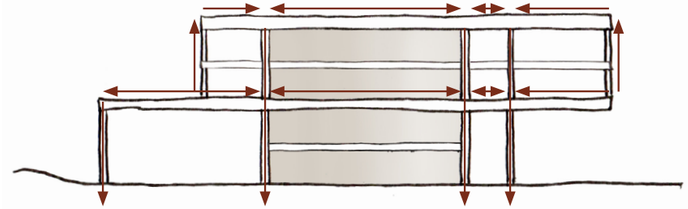
This view from floor 4 gives an idea about the indoor office environment. Outside the glassed wall you see the trellis and the climbing plants. The central core with its pillar structure is also visible to the right in the picture. Some of the pillars could be real tree trunks, perhaps some with a beautiful pattern like the ones from birch trees.

CONSTRUCTION - BASIC IDEA

You can see the core volume as the “tree trunk” in the building. It carries most of the loads down to the ground. The wall next to the core carries loads from the “overhang”. Forces are led from the roof and the floor of the overhang and then down through the wall.



Main structure for vertical loads.



Sketch of the forces in the load bearing structure.

The floor structure (the horizontal structure) in the building is made of concrete. The vertical load bearing structure in the facade is of wood (lower volume) and steel (upper volume).

SECTIONS

Section A-A

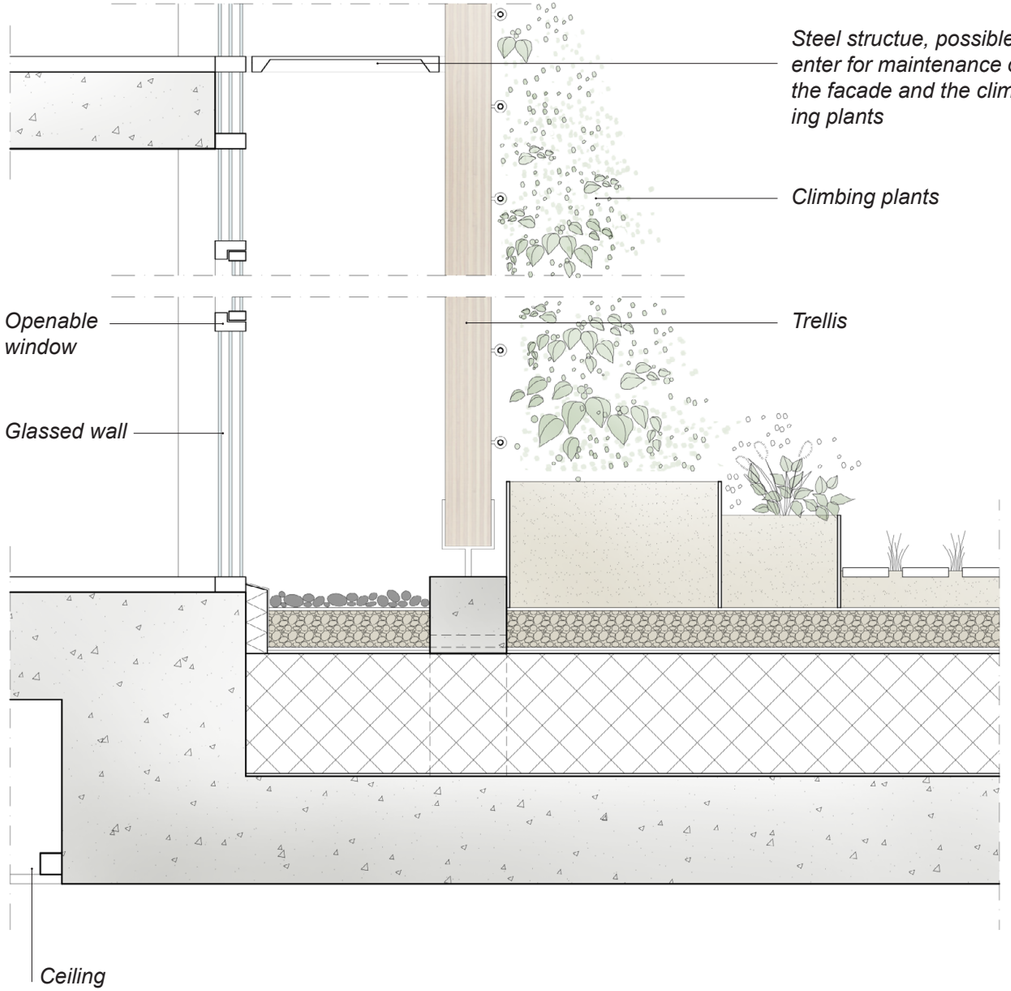
Section B-B

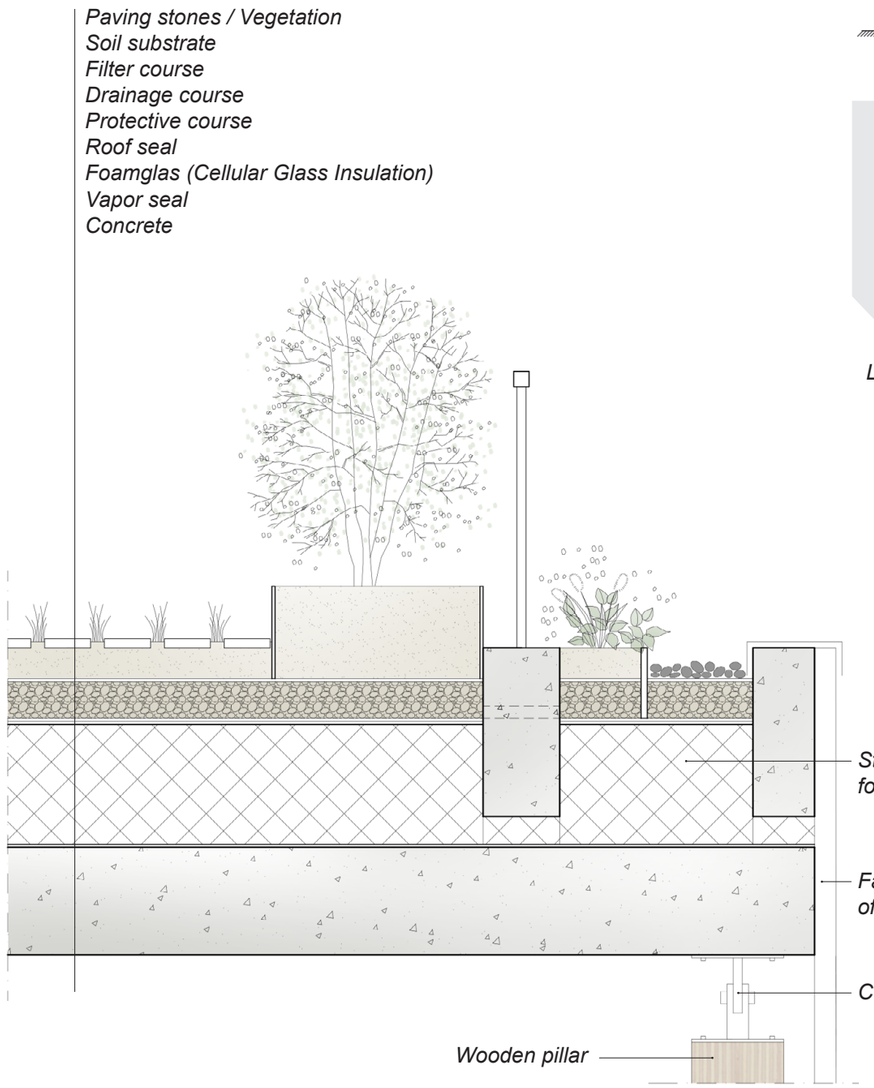
1:400

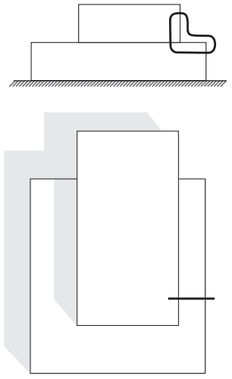
0 5 10 (m)

Section B-B **1:100**

DETAIL TERRACE







Location of detail cut.

1:20

FACADES

North elevation

South elevation

West elevation

East elevation

1:400

0 5 10 (m)

CONCLUDING REFLECTION

SUSTAINABILITY

Reflections about sustainability

Even if I have the ambition to always have the aspect of sustainability in mind when I design new buildings there are several things that could be considered as non sustainable, both in this project and more general. You could argue that the most sustainable is to not build new buildings at all. Every square meter has an environmental impact and therefore should the amount of square meter stay as low as possible. On the other hand there are possibilities by building new buildings. If you manage to create a design that not only demands energy but also contributes to the environment, a new building gives the economic opportunity to actually make an area more green and maybe more sustainable.

In this master thesis I have focused on biophilic design and greenery in buildings. There is a lot more to develop in the design proposal regarding, for instance, the buildings energy demand and heating/electricity systems. Without immersing myself in the subject I can see a conflict in for instance the choice of materials in the facades and a building with low energy demand. The facades are the designed with biophilic design in mind, they are designed to maximize the use of nature in terms of light and contact with greenery. They are anyhow not the best choice if you want to keep the heat as long as possible inside the building. Energy efficiency is important and a factor that needs to be further developed in the design proposal. There is however always a need to compromise and consider other aspects as well.

Positive effects of the design proposal

The proposed design may in its current form be regarded as insufficient within the field of sustainability, especially concerning energy efficiency. Hence it becomes important to mention that the design proposal also has some strengths. Following text describes the buildings positive effects; it describes how the building contributes to economic, social, and environmental sustainability. This is a commonly used structure to cover essential aspects of sustainability.

Economic sustainability

By designing a building that contains space for several smaller companies it supports diversity of business and in that way a more resilient economy. By space sharing, each company have access to much space and functions (when needed) to a lower cost.

Social sustainability

Biophilic design makes the foundation for an innovative and healthy work environment. The “public” part of the building, dedicated to visitors, coordination organisations and all companies in the industrial area gives opportunities for networking and could become a place for fruitful meetings.

Environmental sustainability

Integrated greenery in the building contributes to increased biodiversity, local food production and ecosystem services as cleaning the air and taking care of the storm water. Furthermore the building encourages meetings and in that way support service and resources exchange between both the new companies in the building and the existing ones around in the industrial area. In that way less waste could be produced. Finally the building supports companies within the sector of environmental technology and that will benefit the ecology in a long term perspective.

THOUGHTS ABOUT BIOPHILIC DESIGN

Biophilic design vs. Industrial design

I would like to argue that there is a tension between industrial design and biophilic design. Many industrial buildings have a design that is far from what I would call biophilic. Is it possible to combine this “straight line, big scale, box architecture” with the much more soft, human centred, organic and nature influenced design called biophilic? The design project in this master thesis is one proposal for how it can be done.

The building would probably be “more” biophilic if it was in another, non industrial, context. It does however not mean that it would be a better building. The industrial context, and the intended business, demands industrial features like functionality, rationality, and simplicity. But I would also like to argue that the building as a workplace, and a part of a world in need of environmental sustainability, requires biophilic features like for instance greenery and daylight.

The projects quality is for me found in the tension between the industrial and the biophilic features. The tension is, to exemplify, visible between the organic core and the simple box around it. Also such a simple thing as having a few trees placed in a workshop reveals the tension due to peoples perceived contradictions between nature and industry.

Biophilic design - different from ordinary architecture?

Biophilic design is identification and structuring of features that exist in nature, an environment which in different ways has positive impact on people’s health and wellbeing. The idea is to bring the appreciated values nature have into the built environment.

By the identification and structuring of biophilic features it becomes easier for architects to include these in the design. This does not mean that biophilic features are completely missing in buildings built without any knowledge about biophilic design.

Biophilic features are present in almost every building, an example is the presence of daylight. Some architects have by them self included a lot of biophilic features in buildings because they have discovered, or been of the opinion, that this features makes the architecture more qualitative.

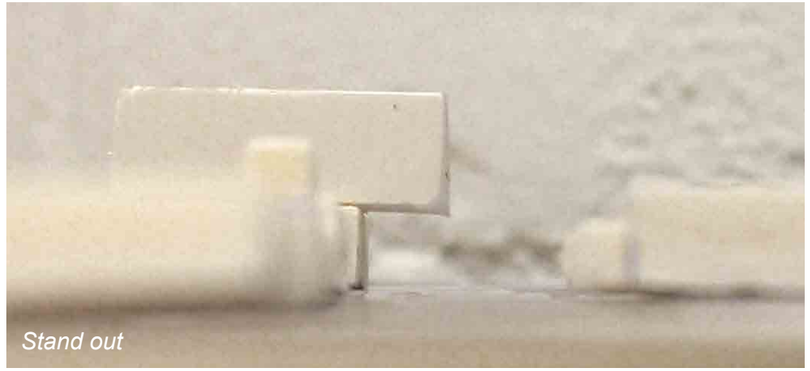
What is then the difference between ordinary architecture and biophilic architecture? I would say that the quality and amount of biophilic features matters. When using the strategies known as biophilic design, it is easier to optimize the biophilic features and to bring a greater amount of them into the architecture. This compared to how it would have been if you, as an ordinary architect, only designed with your personal knowledge about space and shape. Biophilic design does also give architects arguments, founded in more or less scientific studies, for the choice of design.

Biophilic design as a design concept

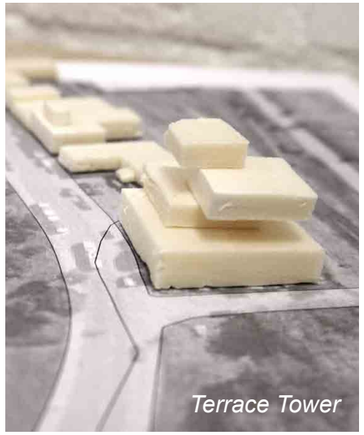
I would like to clarify that the design proposal in this master thesis should not be considered as a final design proposal. It is possible, and often necessary, to delimit the task when writing a master thesis. This master thesis is delimited to the investigation of biophilic design in an industrial building. Hence, there are many things in the proposed design that requires more processing in order to create a functional and sustainable building design. I think that biophilic design is a good design concept but that it needs to be supplemented by other design concepts as well. Some examples of important topics that I haven't dealt with in this master thesis are: The buildings energy demand, the building materials impact on the environment and the buildings technical systems. Two design concepts that are dealing with these topics are for instance the Passive House concept and the Cradle to Cradle (C2C) concept. I believe that biophilic design could work in synergy with other design concepts, for instance the two just mentioned. I also think that the chance of getting biophilic features realized in building projects could increase when biophilic design works together with other design concepts. There will, for instance, be more arguments for including greenery in buildings if the greenery contributes to the buildings technical systems, as the ventilation system or the water system. I think that the benefits from biophilic design could be hard to measure and they are therefore easy to prioritize away in the building process due to economic reasons. As mentioned in the introduction, the focus of this master thesis is not the economic aspect and several topics within that field are therefore not further investigated in this master thesis.

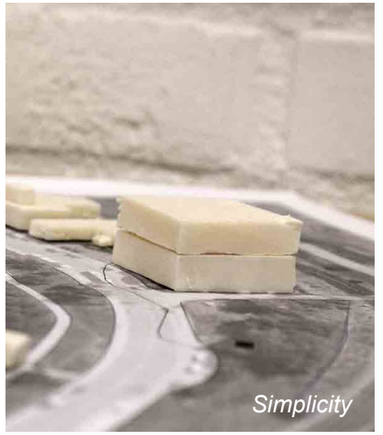
THE PROCESS

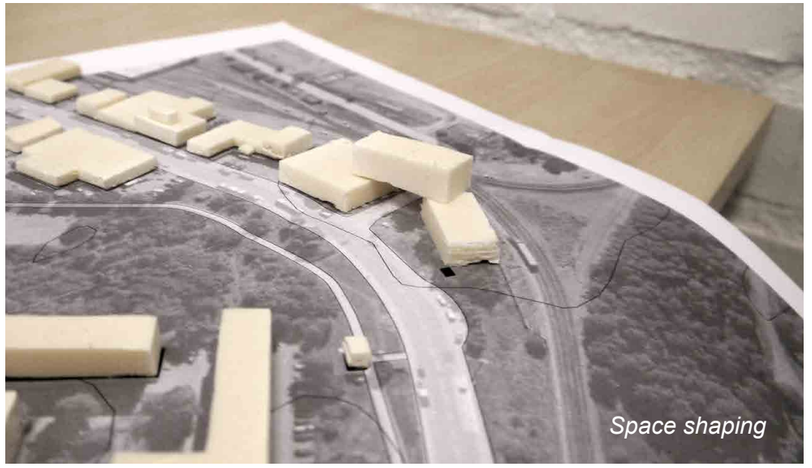
SEARCHING IN THE URBAN SCALE

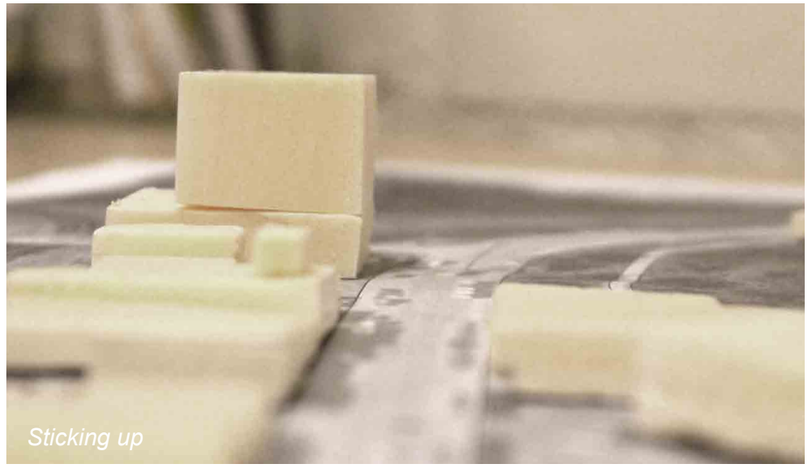

Stand out


Scale

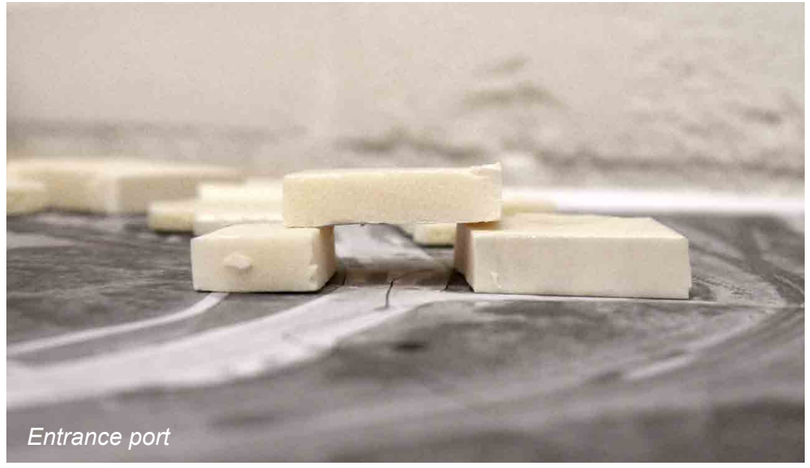

Terrace Tower


Simplicity

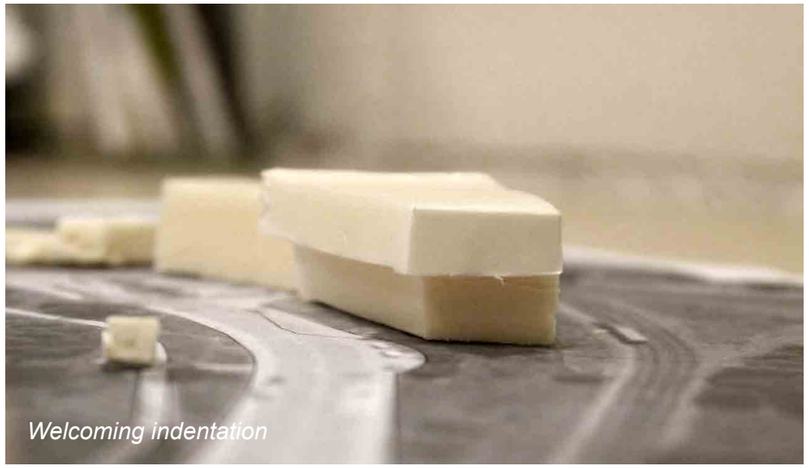

Space shaping



Sticking up



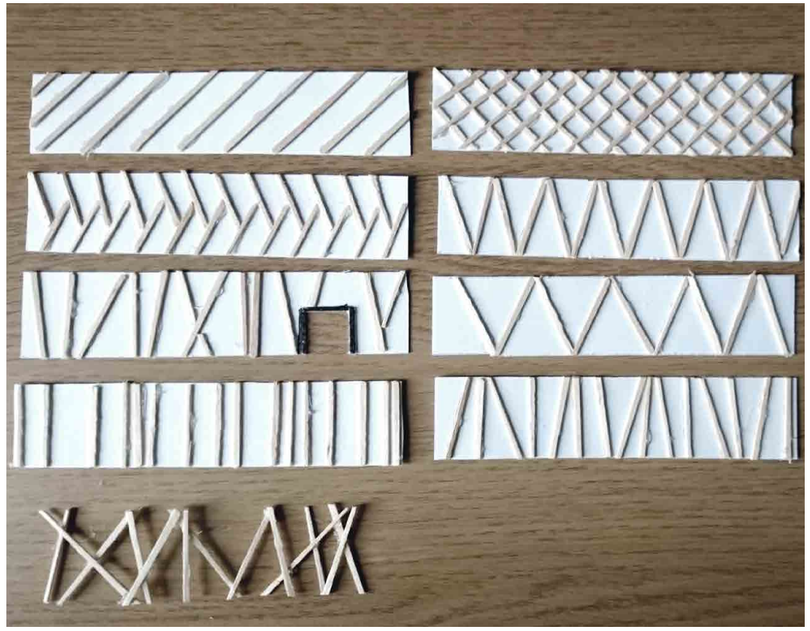
Entrance port



Welcoming indentation

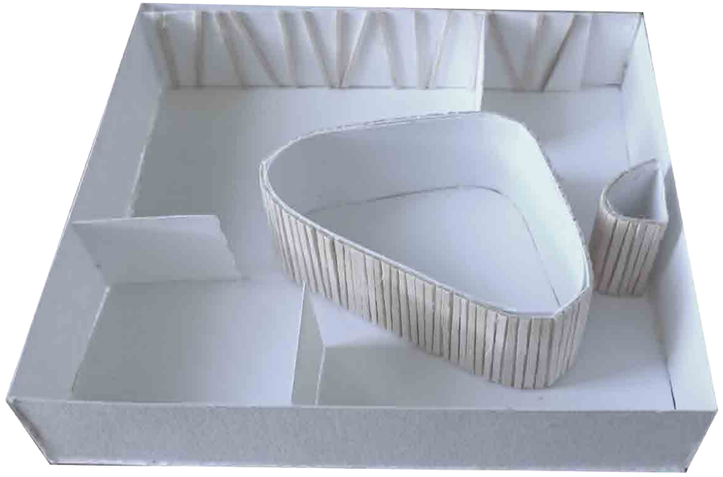
Three volumes

SEARCHING IN THE BUILDING SCALE

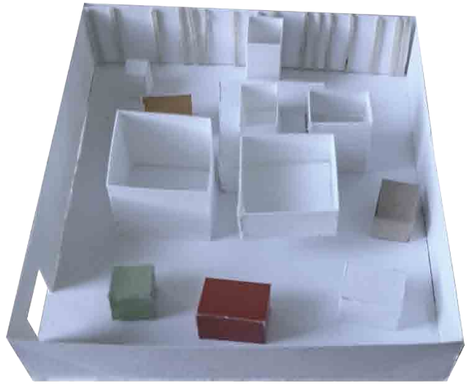


Facade structures

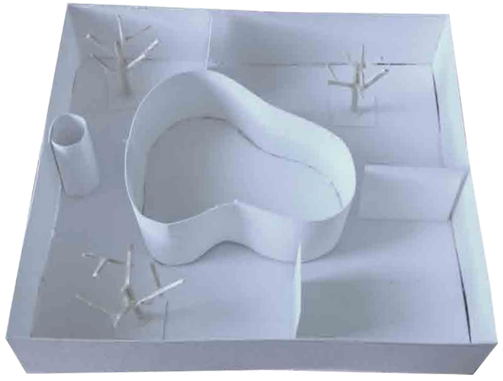
Trellis

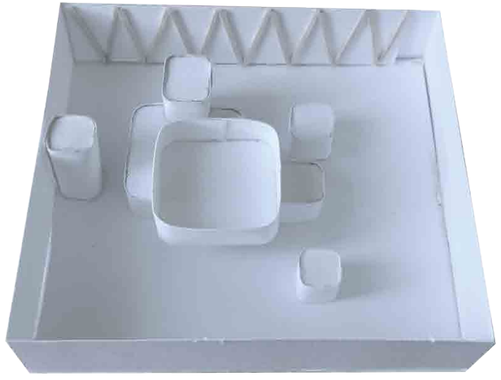


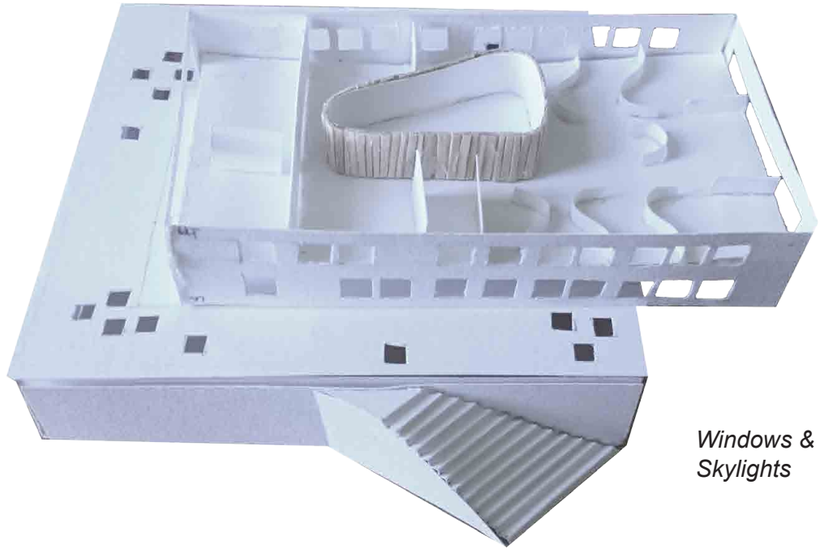
Divide space



Organic vs. Square

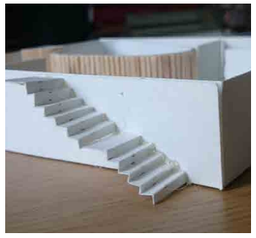


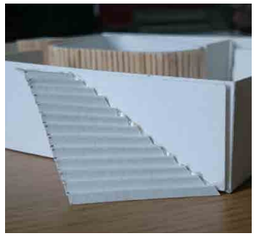


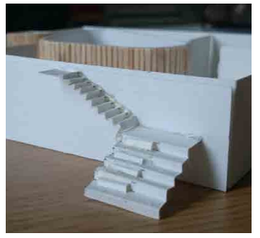


Windows & Skylights

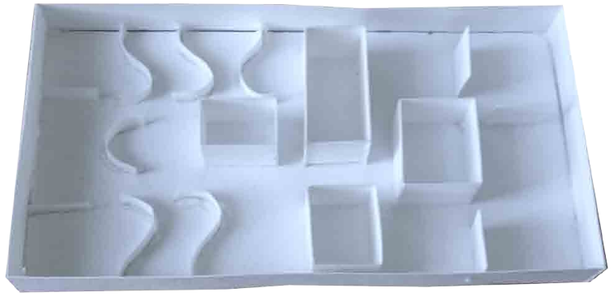
Stairs

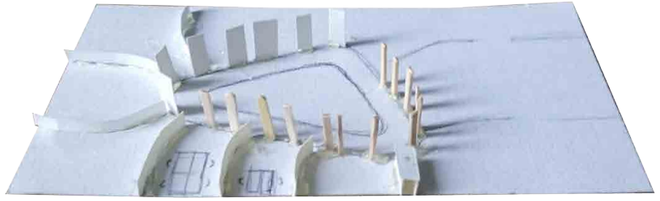




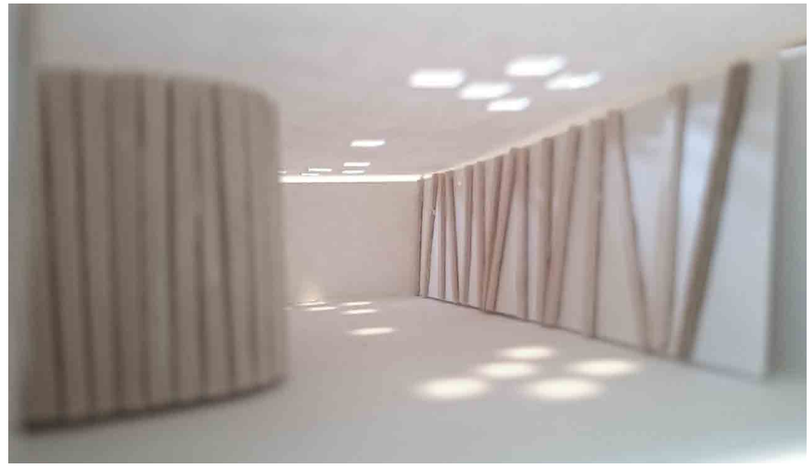


Organization on upper floors





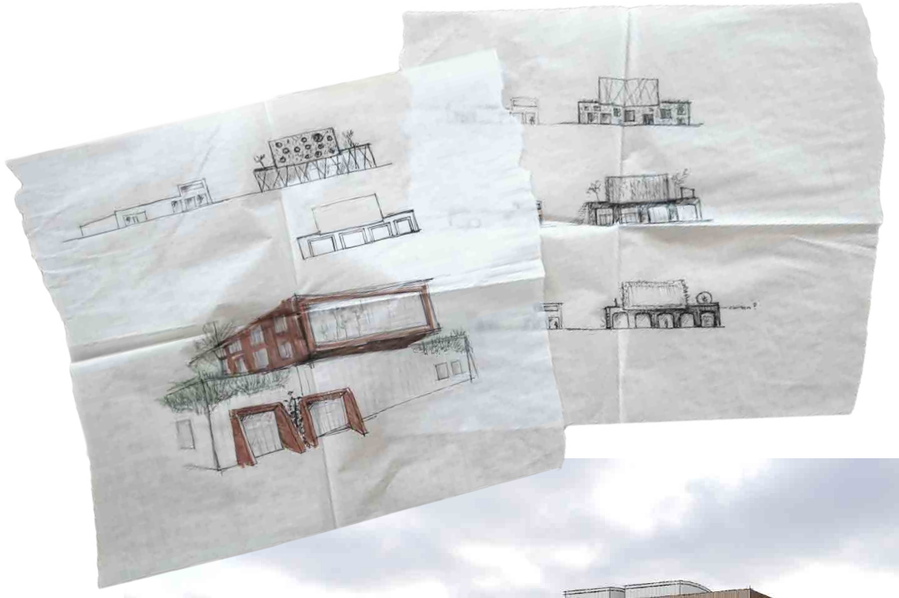
Skylights

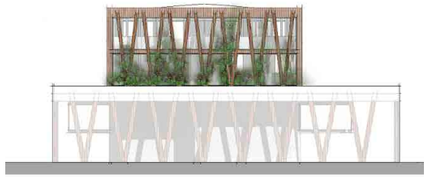


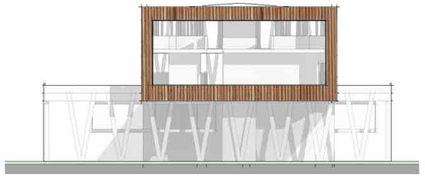
Human scale

Scale and tree

SEARCHING FOR THE EXTERIOR

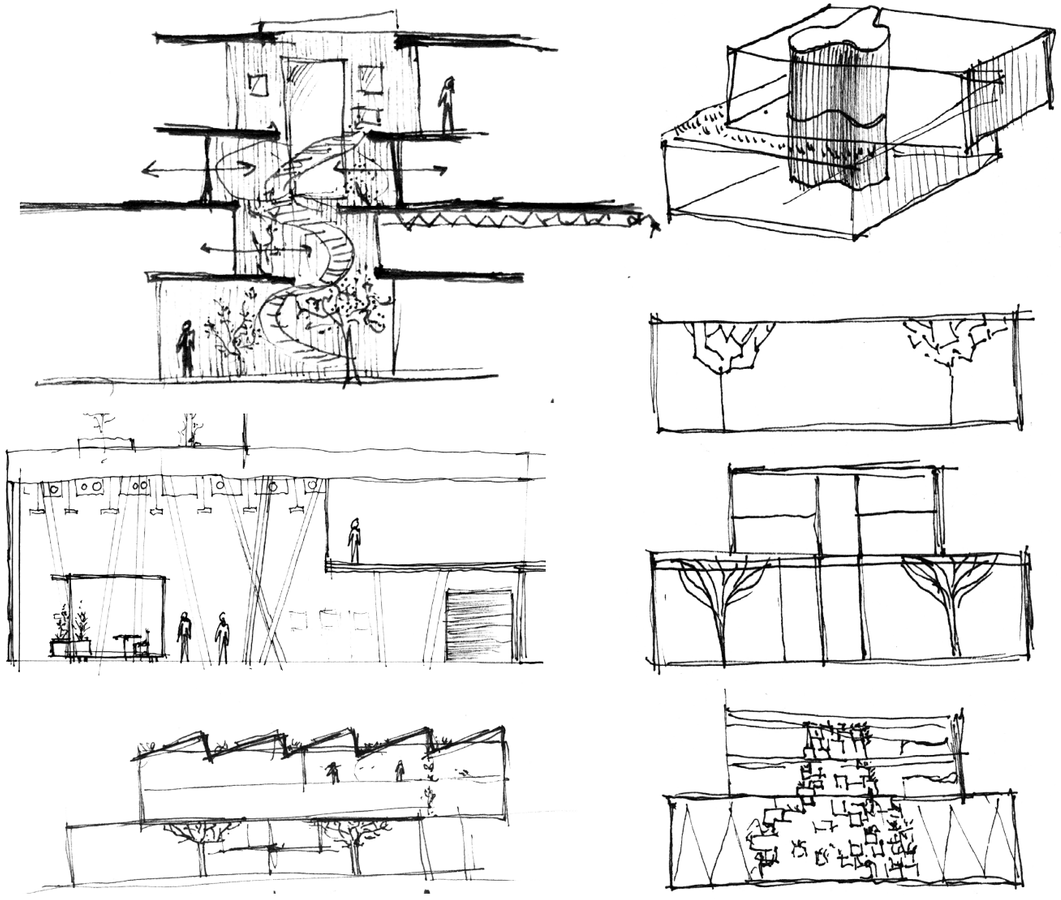


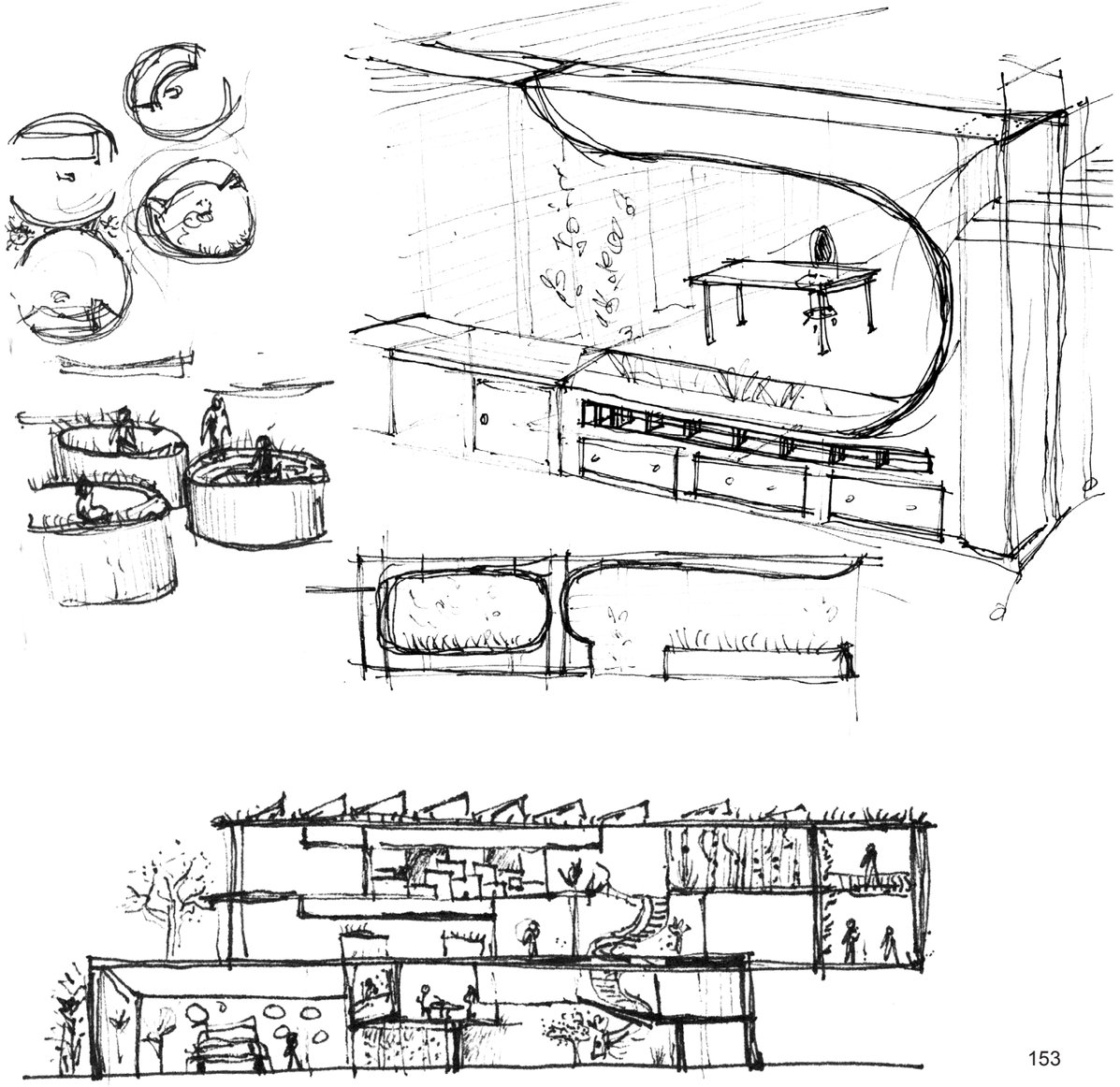




SEARCHING BY SKETCHING

A few sketches from the design process.



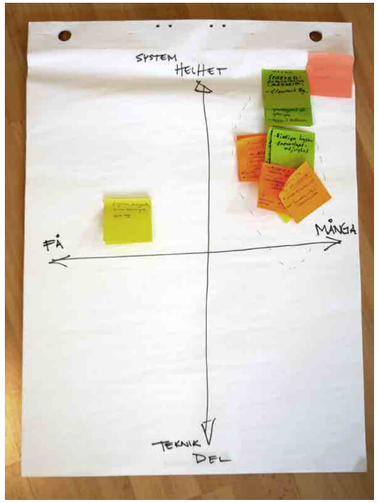


MEETINGS AND WORKSHOPS

As mentioned in the introduction there is a project group working with Högdalen industrial area. The project is named “Renewal of urban industrial areas with building integrated plant systems that are adapted to energy and nature cycles”.

During my master thesis I have participated at two meetings with this project group. One start up meeting at Liljewalls office in Stockholm and one workshop at Högdalen industrial area. During the workshop a lot of people with different competence participated. We listened to a presentation about C/O city, a project by City of Stockholm about urban development with ecosystem services. We did also discussed the lack of a common vision for all stakeholders involved in the transformation about Högdalen.

In the end we came up with ideas for further development of Högdalen industrial area within the frames of the project. Requested ideas were the ones that proposed changes that a lot of people and stakeholders gained from. The ideas should also be holistic and not focus on technical details (like a new kind of living wall) which often are the case when innovations in the area of ecosystem services are developed. The workshop resulted in the idea about the “green artery” described earlier in the booklet at page 28.



Strengths and problems about Högdalen industrial area.

REFERENCES

REFERENCES

Andersson, J., & Karlsson, A. (2014). Utmaningar och möjligheter med levande väggar i ett svenskt klimat: En erfarenhetsstudie (C 45). Stockholm: IVL Svenska Miljöinstitutet. Retrieved from http://www.ivl.se/download/18.15a855cb14c38029e641e8/1427374586148/C45+vers+2+Utmaningar+och+m%C3%B6jligheter+levande+fasader+FINAL+med+EU+logga.pdf

Boverket. (2013). *Remissvar på Bullersamordningsutredningens delbetänkande SOU 2013:57 samt huvudbetänkande SOU 2013:67.* Retrieved 11/03/15 from Boverket, http://www.boverket.se/contentassets/c8273165a5f0476eab1ad1fb7411fbee/boverkets-yttrande-over-bullersamordningsutredningen.pdf

Browning, W.D., Cramer, J.S. (2008) Transforming Building Practices Through Biophilic Design. Kellert, S.F., J.H. Heerwagen, & M.L. Mador (Eds.), *Biophilic Design: The Theory, Science & Practice of Bringing Buildings to Life* (p.335-346). Hoboken, NJ: John Wiley & Sons.

Capener, C-M., & Sikander, E. (2014). *Gröna klimatskal - fuktförhållanden, energianvändning och erfarenheter.* (SP Rapport 2014:53). Borås: SP Technical Research Institute of Sweden. Retrieved from http://www.sp.se/sv/publications/Sidor/Publikationer.aspx?PubIId=16645

CO-EX Corporation (2008). *Multi-wall polycarbonate panels.* [Brochure]. Retrieved from http://www.co-excorp.com/pdf_files/mac.pdf

de Vries, R. (2015). *Sverige under 1900-talet*. Retrieved 05/02/15 from SO-rummet, http://www.so-rummet.se/kategorier/historia/det-korta-1900-talet/sverige-under-1900-talet#

European Commission. (2014). *About ETAP.* Retrieved 06/02/15 from European Commission, http://ec.europa.eu/environment/ecoap/about-action-plan/etap-previous-action-plan/index_en.htm

Förnyelse av urbana industriområden med energi och kretsloppsanpassade byggnadsintegrerade växtsystem (2015). UDI – slutrapportering Steg 1 Initiering.

Greater London Authority (GLA). (2008). *Living Roofs and Walls: Technical Report: Supporting London Plan Policy.* London: Greater London Authority. Retrieved from https://www.london.gov.uk/sites/default/files/living-roofs.pdf.

Green roof guide. (n.d.). *Green roof guidelines*. Retrieved 15/04/15 from Green roof guide, http://www.greenroofguide.co.uk/pdfs/

Haglund, U. (2010) Miljöteknik – framtidens teknik?. *Källa:SCB - statistiska centralbyråns kundtidning,* (2),14. Retrieved from http://www.scb.se/statistik/_publikationer/OV9999_2010K02_TI_A08TI1002.pdf

Heerwagen, J.H. & Orians, G. (1986). Adaptations to WindowlessnessA Study of the Use of Visual Decor in Windowed and Windowless Offices. *Environment and Behavior, 18*(5), 623-639. doi:10.1177

Högdalen. (2014). *Wikipedia,*. Retrieved 05/02/15 from http://sv.wikipedia.org/w/index.php?title=H%C3%B6gdalen&oldid=24780104

Högdalen 2020: Ett industriområde i världsklass (n.d.). Retrieved 05/02/15 from Boverket, http://www.boverket.se/contentassets/c9d5cae21502490c9594748a3630db78/slutrapport-hogdalen.pdf

Högdalsgruppen (n.d.) *Om oss.* Retrieved 05/02/15 from Högdalsgruppen, http://www.hogdalsgruppen.se/?page_id=21

Kaplan, R. (1993). The role of nature in the context of the workplace. *Landscape and Urban Planning, 26,* 193-201. Retrieved from http://deepblue.lib.umich.edu/bitstream/handle/2027.42/30542/0000175.pdf?sequence=1

Kaplan, R. & Kaplan, S. (1989). *The Experience of Nature: A Psychological Perspective*. Cambridge: Cambridge University Press.

Kaplan, R., Talbot, J.F. & Kaplan, S. (1988). *Coping with daily hassles: The impact of nearby nature on the work environment.* Project Report, US For. Serv., North Central Forest Experiment Station, Urban Forestry Unit Cooperative Agreement.

Kellert, S.F. (2008) Dimensions, Elements, and Attributes of Biophilic Design. Kellert, S.F., J.H. Heerwagen, & M.L. Mador (Eds.), *Biophilic Design: The Theory, Science & Practice of Bringing Buildings to Life* (p.3-19). Hoboken, NJ: John Wiley & Sons.

Kellert, S.F., J.H. Heerwagen, & M.L. Mador (Eds.). (2008). *Biophilic Design: The Theory, Science & Practice of Bringing Buildings to Life*. Hoboken, NJ: John Wiley & Sons.

Kellert, S. R. & Wilson, E. O. (Eds.). (1993). *The biophilia hypothesis*. Washington, DC: Island Press.

Kontorets betydelse för varumärket (2015). *Lokalguiden, Västra Götaland, 21*(5), 28.

Millennium Ecosystem Assessment (MA). (2003) *Ecosystems and Human Well-being: A Framework for Assessment.* Washington, DC: Island Press. Retrieved 06/10/15 from Millennium Ecosystem Assessment, http://www.millenniumassessment.org/en/Framework.html

Moore, E.O. (1982). A prison environment's effect on health care service demands. *Journal of Environmental Systems*, *11*(1), 17-34.

Perini, K., Ottelé, M., Haas E.M., & Raiteri, R. (2011). Greening the building envelope, façade greening and living wall systems. *Open Journal of Ecology, 1*(1), 1-8. Retrieved 06/10/15 from Scientific Research: An Academic Publisher, http://www.scirp.org/journal/PaperInformation.aspx?PaperID=5146.

Regeringen. (2011). *Strategi för utveckling och export av miljöteknik 2011–2014.* Retrieved 05/02/15 from Regeringen, http://www.regeringen.se/content/1/c6/17/40/71/f06ab2d4.pdf

Sandifer, P.A., Sutton-Grier, A.E., Ward, B.P. (2015). Exploring connections among nature, biodiversity, ecosystem services, and human health and well-being: Opportunities to enhance health and biodiversity conservation. *Ecosystem Services, 12,* 1-15. doi:10.1016. Retrieved 06/10/15 from http://www.sciencedirect.com/science/article/pii/S2212041614001648

Stigsdotter, U. A. (2004). A garden at your workplace may reduce stress. Dilani, A (ed.), *Design*
and Health III – Health Promotion through Environmental Design (p.147-157). Stockholm: Research Centre for Design and health. Retrieved from www.designandhealth.com/upl/files/113523

Swedish National Heritage Board. (2006). *Högdalen Industrimoråde.* Retrieved 05/02/15 from Bebyggelseregistret, http://www.bebyggelseregistret.raa.se/bbr2/anlaggning/visaRelationer.raa?anlaggningId=21300000020323&page=relationer

Teknikföretagen. (n.d.). *Svensk Produktionsforskning 2020.* Retrieved 05/02/15 from Svenska Produktionsakademien, http://www.produktionsakademien.com/Forskningsstrategi_files/svensk_produktionsforskning_2020.pdf

Tillväxtanalys. (2011). *Statistik om Miljösektorn 2003 - 2010: Statistik baserad på SCB:s miljöföretagsdatabas* (Statistik nr 2011:08). Östersund: Myndigheten för tillväxtpolitiska utvärderingar och analyser. Retrieved from http://www.tillvaxtanalys.se/download/18.56ef-093c139bf3ef8902aef/1349864460691/Statistikrapport_2011_08.pdf

Tillväxtanalys. (2013). *Utvärdering av regeringens miljöteknikstrategi: Resultatuppföljning och konkurrenskraftsanalys.* (Rapport nr 2013:09). Östersund: Myndigheten för tillväxtpolitiska utvärderingar och analyser. Retrieved from http://www.tillvaxtanalys.se/download/18.2cfe903f142e67167a18ea/1387457834685/rapport_2013_09.pdf

Tsunetsugu, Y., Miyazaki, Y. & Sato, H. (2007). Physiological Effects in Humans Induced by the Visual Stimulation of Room Interiors with Different Wood Quantities. *Journal of Wood Science, 53* (1), 11-16.

Ulrich, R.S. (1984). View through a Window May Influence Recovery from Surgery. *Science, 224,* 420-421. Retrieved from http://www.majorhospitalfoundation.org/pdfs/View%20Through%20a%20Window.pdf

Wilson, E.O. (1984). *Biophilia.* Cambridge, MA: Harvard University.

Zimmermann, A. (2009). *Constructing landscape: Materials, techniques, structural components.* Basel: Birkhauser.

FIGURES

Fig.1: Högdalen industrial area. Picture from the project *Förnyelse av urbana industriområden med energi och kretsloppsanpassade byggnadsintegrerade växtsystem.* (2009).

Fig. 2: The ski slope in 1965. Glase, G. Retrieved from http://www.stockholmskällan.se

Fig. 3: Högdalen center in the early sixties. Unknown. Retrieved from http://www.stockholmskällan.se

Fig. 4: Noise levels. Map done by the author with noise information from City of Stockholm, http://www.stockholm.se/TrafikStadsplanering/Trafik-och-resor-/Trafik-och-miljo/Trafikbuller/Bullerkartor/

Fig. 5-6: Illustration Green Artery. Liljewall arkitekter. (2015).

Fig. 7-8: Ring House. Retrieved from http://www.tna-arch.com/index.html

Fig. 9-11: Loblolly House. Retrieved from http://kierantimberlake.com/pages/view/20/loblolly-house/parent:3

Fig. 12-13: Cuningham Group office. Retrieved from http://www.cuningham.com/projects/workplace-corporate#8665-hayden-place

Fig. 14-16: Elephant House. Retrieved from http://www.fosterandpartners.com/projects/elephant-house-copenhagen-zoo/

Fig. 17-18: The Tote. Retrieved from http://www.serie.co.uk/projects/tote

Fig. 19: Section Urbana Villor. Retrieved from http://www.arkitektur.se/bara-tva-nominerade-till-salinpris

Fig. 20: Urbana villor. Retrieved from http://www.hauschild-siegel.com/wordpress_de/?page_id=7

Fig. 21-22: Bosco Verticale. Retrieved from http://www.dezeen.com/2014/05/15/stefano-boeri-bosco-verticale-vertical-forest-milan-skyscrapers/

Fig. 23: Naturhus Vänersborg. Retrieved from http://www.ecorelief.se/

Fig. 24-27: Urban Farm. Retrieved from http://konodesigns.com/portfolio/Urban-Farm/

Fig. 28-30: Stacking Green. Retrieved from http://www.archdaily.com/199755/stacking-green-vo-trong-nghia/

Fig. 31-32: Drivhus. Retrieved from http://www.urbandesign.se/#!kontor/c1bdt

Fig. 33-36: Hedge building. Retrieved from http://www.e-architect.co.uk/germany/hedge-building-rostock

Fig. 37-38: Sisii. Retrieved from http://www.archdaily.com/478686/sisii-yuko-nagayama-and-associates/

Fig. 39-40: Butong wall. Retrieved from https://www.designworld.se/2013/12/18/studioverket-strippklubb-blir-kontor/

Fig. 41-42: Ursvik sopsugsterminal. Retrieved from http://stockholmprojekt.blogspot.se/2014/09/sopsugsterminal-med-gron-vagg.

Other illustrations, pictures, drawings and photographs are created by the author.