

# TO BUILD A TREE

a master thesis by Malin Fredriksson



**CHALMERS**

TO BUILD A TREE  
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# abstract

Our impact on nature is one of the major questions of today. The building industry stands for about 40 % of the world's total energy consumption, but with a growing population it is a necessary industry. Sustainable development have so far been focused on reducing our environmental impact and for the building industry that have meant to reduce the energy consumption during the utilization of the building. But we can and have to do more.

Cradle to Cradle (C2C) is a design strategy that aims at adding a positive value instead of looking at only reducing

our impact. The strategy was developed during the 1990s but so far no building has been built in total unison with the strategy. To make that happen the system of production needs to be changed and more people, companies, municipalities and countries have to adopt this approach.

As with many new approaches examples have to be shown in order to convince others to do the same. The aim of this master thesis is to explore how a building that is inspired by a tree and its features can be designed. A building that is built like a tree utilizes the renewable energy

sources supplied by earth, it changes over the seasons and years, it have a positive impact on its surroundings and when it is deconstructed it gives life to new products and buildings.

The goal is for this building and site to be a showcase and to inspire and teach others about Cradle and Cradle. In that way the word of Cradle to Cradle can be spread.



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# Introduction



## what?

Someone once said that the best kind of energy is the energy not used. It is possible to say the same thing about materials, that the best kind of materials are the materials not used. But it will be difficult to live in a house that doesn't demand energy and that is made out of no materials.

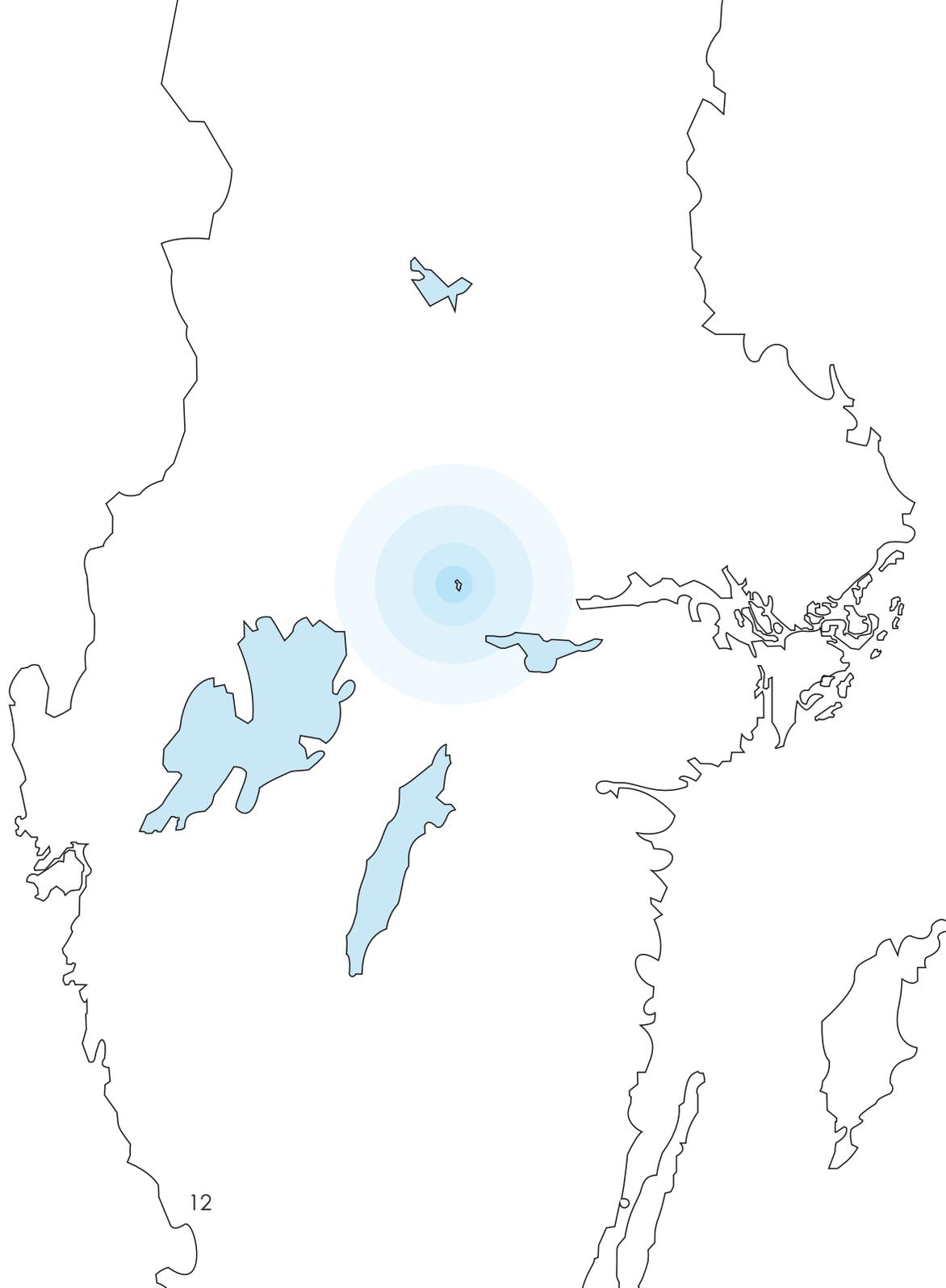
But what about building a house like a tree? A tree is made out of materials from nature, it consumes renewable energy, it gives nutrients to other living organisms and when it dies it will be returned to earth without any waste. The tree will have used nature's resources but will have had a positive impact on its

surroundings.

This master thesis will be dedicated to designing a residential building and plot that is inspired by a tree. The plot and building should have a positive impact on its surroundings, just like a tree and they should work as a showcase. A showcase of Cradle to Cradle inspired design, where things are not just designed based on the current conditions, but for future conditions as well. A design which is based on the idea that the conditions can and most likely will change in the future.

## where?

The site is located in Nora, a small town in Bergslagen, Sweden. Nora have a history stretching back to the 12th century and a town centre dating back to the 18th century. It is in this town centre that the site is located, between buildings from the 1800s and mid 1900s and the old railway facilities from 1901. It is a historically interesting site where new additions have to be made with care.



## why?

By now most people know that the way we live today can't last forever. Our way of living is causing global warming, depletion of earth's resources and extinction of hundreds of species each year. We don't need to save earth. Earth will still be here when we are not, the question is how long we will be here and what conditions future generations will have to deal with. To change that outcome we have to change our way of doing things.

One sector that have a large contribution to the environmental impact is the building industry. To affect that industry's impact

would therefore be very beneficial. The industry have started to work with sustainability and the focus have been set on reducing the energy consumption of the buildings. This mind set has given us buildings that doesn't require any heating and further on buildings that actually generates energy, even more energy than they need.

The development has been positive, but there is still more that can be done. That is why this master thesis will explore the possibilities of a Cradle to Cradle inspired mindset when it comes to building design.

The reason for designing a residential building and for it to be located in Nora is simple. There is a need for apartments in Nora and there is a property owner that is about to build apartments in Nora. The property owner is also interested to see what possibilities there are of constructing a more environmentally friendly building without only focusing on the energy consumption.

## how?

The theoretical background of this master thesis is the Cradle to Cradle design strategy. To gain a better knowledge of what the strategy implies literature about it will be studied along with projects that have been inspired by the strategy. Cradle to Cradle does not give specifics on how to design things it is more a strategy of how to make decisions regarding the design. Aspects like materials, greenery, energy and water management are important within Cradle to Cradle and will be studied depending on what direction the project will take. The specific site and

setting is important within Cradle to Cradle and also in the field of architecture. Studying the history of Nora and visiting Nora and site will therefore be important elements in the process.

# explanations

The thesis is divided into four parts. Cradle to Cradle is the first part where the Cradle to Cradle strategy is explained and where some reference projects can be found. Nora is the second part and gives a deeper knowledge about Nora and its history. The third and biggest part of the thesis is the proposal. Here all information about the project is gathered. Last is a conclusive part with conclusions from the project and guidelines for designing a Cradle to Cradle inspired building.

Throughout this booklet this type of blue boxes will appear. They refer to the tree and how different sections of the thesis relate to the tree

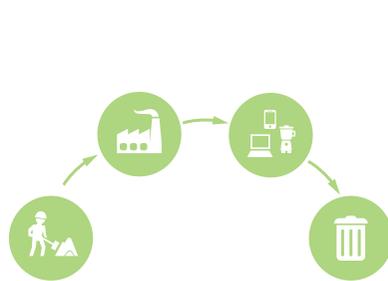


Time is an important aspect when it comes to Cradle to Cradle inspired buildings. The arrow above indicates the aspect of time and often refers to how things can be changed or evolve in the future.



# Cradle to Cradle

- how a building can be seen as a tree



Cradle to Grave



Cradle to Cradle

## what is Cradle to Cradle?

Cradle to cradle (C2C) is a design strategy that were developed by the chemist Michael Braungart and the architect William McDonough during the 1990s (Vugge til Vugge Danmark and GXN, 2013). The strategy is inspired by nature's integrated system, where everything is a nutrient for something new. The system we have today could be called "cradle to grave". Products are being produced, used and then

thrown away. Valuable materials are lost at waste disposal sites and new raw materials are constantly extracted from our planet. But if we would look at how nature handle its resources we could find a new system which everyone could benefit from. So if we would look at a tree. It has leaves which release themselves when fall comes. As they land on the ground they start to molder and become nutrition for microorganisms and

fungi. While the microorganisms and fungi decomposes the leaves they release nutrition to the soil which the tree can benefit from as it grows. Using this as inspiration our system could function in a similar way. Products could be produced, used, disassembled and then go back into production as materials for new products. C2C is a new way of thinking about our resources. It is not about doing less bad but doing more good.

# main principles

## **Waste = food**

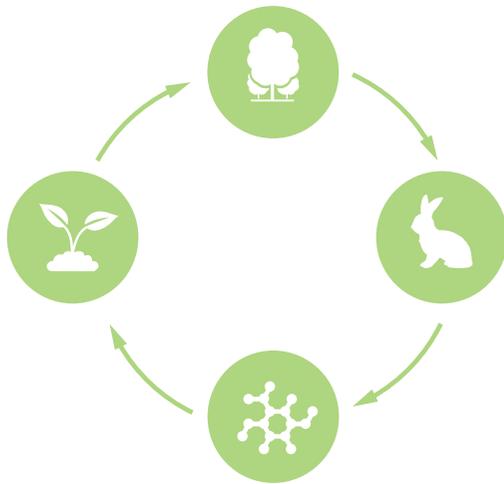
In nature there is no waste, because in nature waste is nutrition for something else. The first C2C principle says that all materials are resources for either the biological or technical cycle.

## **Use current solar income**

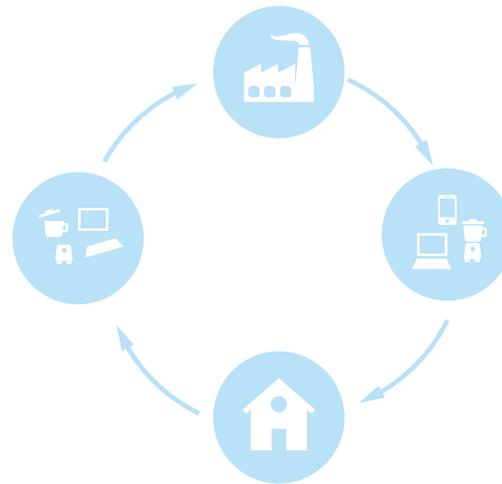
All biological systems are run by energy from the sun. The second C2C principle says that our energy consumption should be covered by renewable energy sources, such as wind- and solar power.

## **Celebrate diversity**

In nature there is a big variety of species and nature is constantly evolving. This inspire the third principle which is celebrate diversity in species, culture and solutions.



Biological cycle



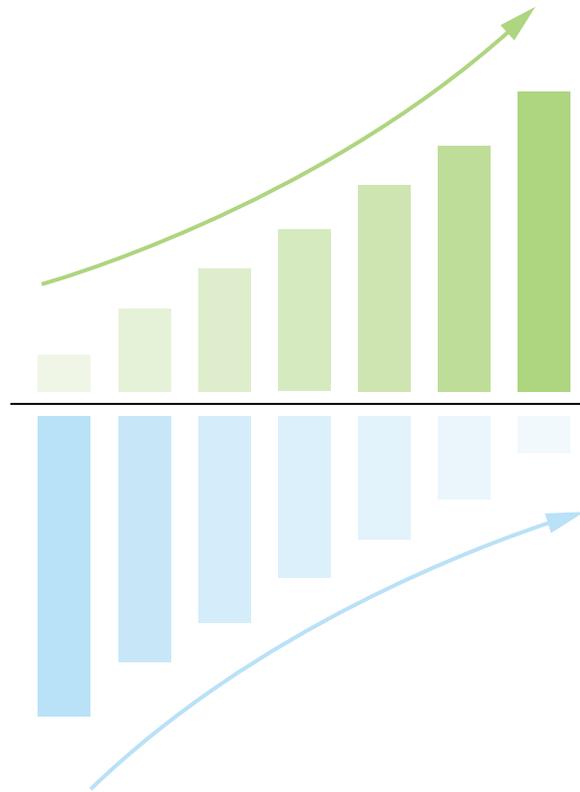
Technical cycle

# biological and technical cycle

The biological and technical cycle is important to the C2C concept. The ambition is that all materials should either belong to the biological cycle or the technical cycle. Used products or materials should not be seen as waste but as resources for new products. Materials that are biodegradable and that can degrade without being harmful to nature belong to the biological cycle. The technical cycle consist of materials that after their usage may be disassembled and reused in new industrial products without any loss of quality. Since many products of today consist of a numerous amounts of different

materials it is important for the C2C concept that products can be disassembled in an easy way. Of course products may also consist of materials from both the biological and technical cycle and then it is of even greater importance that the product can be disassembled so that the materials may be incorporated into their right cycle. However the quality of the materials after disassembly is also important for how many times the materials can be reused and to what extent they can be reused. Upcycling and downcycling are terms used to express how well materials can and are being

reused. For example a concrete wall that after use gets crushed and used as road fill are a kind of downcycling. The material has lost qualities and functionalities and this reuse is only seen as an extension of the materials way to the landfill. An example of upcycling is when plastic waste are used in the production of carpets. The ultimate goal is to keep the original quality of the material and that is of great importance to bear in mind when designing new products and buildings.



## less bad is no good

The headline “Less bad is no good” is a quote from the book “Cradle to Cradle: remaking the way we make things” by William McDonough and Michael Braungart. What they mean is that by just reducing our environmental impact won't make things better and from that perspective the best thing would be for us not to exist at all. When working with the C2C concept all goals

should be stated as positive. As an example, increasing the amount of chemicals that have a positive effect on humans and nature instead of reducing the amount of harmful chemicals. Of course the reduction of harmful chemicals will be a step towards increasing the amount of good chemicals but it is not the goal. An example found in the book “Cradle to Cradle – I det byggede miljø”

(Vugge til Vugge Danmark and GXN, 2013) is that reducing the energy consumption is not a positive goal. But if the energy consumption is reduced as a step so that renewable energy sources could cover the need then it is a positive goal. The goal for a C2C product or building should always be to have a positive impact, for its users and for its surroundings.

## in the built environment

Since C2C is still a quite new concept there are a limited amount of C2C products on the market. Because of that there is no 100% C2C building, but there are buildings that have been inspired by the concept and uses C2C innovations and products. Since it is hard to find elements, materials and solutions today that work a 100% according to the C2C concept many projects mention time as an important aspect. The buildings may not produce as much energy, clean as much air or recycle as much water as necessary to begin with, but as time pass there may come new more efficient solutions which can enable the processes to be sufficient. Therefore goals

for C2C projects often come with a time frame. As an example: First the building should have a low energy demand. Then the building should produce energy to cover part of the energy demand. After a while the building should produce enough energy to cover its whole demand and then finally the building should produce more energy than needed and sell the surplus to the grid. By each step the building gets closer to its C2C goal and each step is a positive one.

In the book "Cradle to Cradle: I det byggede miljø" (Vugge til Vugge Danmark and GXN, 2013) they write not about C2C

materials but C2C elements. As written earlier it is not possible to build a 100% C2C building today, but it is possible to create and build elements. Parts of the construction that are C2C. As with normal buildings materials and elements age and will have to be exchanged over the lifespan of the building. Elements that cannot be build according to C2C today may be possible to build according to C2C the day they have to be exchanged. In this way the building can get closer to becoming a C2C building. I have chosen three quite different C2C inspired projects to look at. They all have different goals and approach C2C in different ways.

# reference projects



## Solhuset

Day care centre with a focus on renewable energy.



## Urban mountain

Office building and a mall with focus on resource management and air quality.

## Ronneby municipality

A Swedish municipality with a vision of a whole city district inspired by C2C.



**Location:** Hørsholm, Denmark **Completion:** 2011 **Architect:** Christensen & CO architects **Type:** Day care centre **Goals:** optimized energy consumption, production of renewable energy, healthy air, healthy materials  
(Christensen & CO arkitekter, n.d.)

## reference project - Solhuset

Solhuset is built as an “active house” which means that it generates more energy than it uses. The roof have been carefully designed to harness as much sun as possible. For electricity there are 250 m<sup>2</sup> of photovoltaic panels placed on the roof and for heating and hot water there are 50 m<sup>2</sup> of solar collectors on the roof along with a heat pump based on heat from the earth (Sloth, n.d.). During eight months the day care centre have a surplus of energy which is sold to the national grid and during the four darkest months renewable energy is

bought back from the grid (Sloth, n.d.). Calculations have shown that in about forty years Solhuset will have generated a surplus of energy which covers the construction of the building (Vugge til Vugge Danmark and GXN, 2013). The building have a compact triangular shape but despite its compact shape it has more natural light than a regular building. Much thanks to the substantial amount of skylights and windows placed on the two longer facades which faces south-east and south-west (Sloth, n.d.). The skylights are also automatically opened

and closed to contribute to the natural ventilation of the building (Sloth, n.d.). Where the roof is not covered by solar panels sedum has been used. It has many positive attributes such as encouraging biodiversity, insulating the roof, preventing water run offs and cooling the photovoltaic cells which work better at lower temperatures (Sloth, n.d.). When it comes to materials they were chosen carefully in consideration to durability and impact on the health of humans and nature.



**Location:** Oslo, Norway **Completion:** Proposal **Architect:** Schmidt Hammar Lassen architects and LOOP architects **Type:** Refurbishment, office + mall **Goals:** waste as a resource, enhanced air quality, flexibility, increased biodiversity, recycling water, recycling heat

(Schmidt Hammar Lassen architects, n.d.)

## reference project - Urban mountain

Urban Mountain is a winning entry to a competition aiming at refurbishing an old office building. The proposal is very ambitious and the most significant parts of the proposal is the utilization of materials, the innovation lab and the green lungs. The goal is to reuse as much as 90 % of the demolished materials from the existing building as new and upgraded building materials (Rosenfield, 2013). 80 % of those materials would be reused on site in the refurbishment, for example all the façade elements would be reused in the new façade (Rosenfield, 2013). In line with the C2C concept all materials

would be seen as a resource. Food waste from the restaurants would be used in the production of biofuel and CO<sub>2</sub> should be seen as a resource for growing vegetables (Schmidt Hammer Lassen architects, 2013). On top of the building there would be a greenhouse and innovation lab. The greenhouse would utilize CO<sub>2</sub> for growing vegetables which would be sold in the mall or used by the restaurants in the building (Schmidt Hammer Lassen architects, 2013). In the innovation lab new green technologies could be tested and researched (Schmidt Hammer Lassen architects, 2013).

Green lungs is what the architects call the green spaces within the building. These would be a part of the natural ventilation system and the purpose of them would be to enhance the indoor air quality. In parallel they would also create a pleasant space for the people working and visiting the building. Plants found in the region would be used in these spaces to clean, humidify and reduce the CO<sub>2</sub>-concentration in the air (Rosenfield, 2013).



**Location:** Ronneby, Sweden **Completion:** Ongoing **Architect:** Several **Type:** Varied **Goals:** A whole municipality which work in unison with the C2C strategy

(Cefur, n.d.)

## reference project - Ronneby municipality

The municipality of Ronneby has as the first municipality in Sweden chosen to work with C2C and is letting it infiltrate all areas within the municipality's work (Cefur, 2012). To encourage, inspire and teach residents, companies and employees within the municipality an organisation called Cefur was started (Cefur, 2012). In 2012 the municipality adopted a quality program regarding sustainable development within the building industry. This is a quote from the programme:

"Future development within the municipality of Ronneby - new constructions as well as refurbishment of existing constructions - shall meet the measurable goals stated in

the project specific quality programmes. These goals shall be inspired by the principles originally presented by Michael Braungart and William McDonough in the design strategy Cradle to Cradle, C2C." (Cefur, 2012).

Within the built environment the municipality have mostly focused on a concept for healthy day care centres and an urban renewal project regarding a district called Kilen (Cefur, 2013). A district that are to be transformed from an industrial area into a mixed sustainable district with dwellings, offices, businesses, schools and culture (Ronneby.se, 2014b). In March 2014 three invited teams consisting of architects,

engineers and other professionals participated in a workshop regarding Kilen (Ronneby.se, 2014a). The task during this workshop was to present how the district could be developed upon the design strategy of C2C. The result of the workshop was meant to form the basis of the local plan of the district. The vision for the district is for it to be an inspiring setting for innovative solutions, have a positive footprint in the environment, contribute to the health of humans, be a meeting point and make Ronneby more visually attractive (Ronneby.se, 2014c).

Ronneby is now in the process of determining the local plan and it will be interesting to see how the district evolves.

## conclusion reference projects

The three reference projects are very different in scale and in how far the projects have been completed. To begin with I was determined to find a housing project inspired by C2C. I did not manage to do that since I couldn't find any housing project with enough information. This along with the fact that the only C2C inspired projects found in Sweden is the projects launched by the municipality of Ronneby only makes me more certain that we need C2C inspired projects in Sweden. To inspire and spark the interest in others.

Each of the reference projects have its own approach to C2C

and I think that there are things to be learned from all of them.

Solhuset is sort of a continuation of a "traditional" sustainable building, where a lot of focus has been on making the building energy efficient and producing energy. However a difference is that it does not only produce as much energy as it needs it produces a surplus. In addition the building have been consciously designed to utilize the sun to the max and employ natural ventilation. Materials have not only been chosen for aesthetical reasons, but for the way they enhance the building as a whole. For

example the sedum roofs insulating and cooling qualities and its contribution to increasing biodiversity. The things I'll bring from this project is of the roof is designed to utilize the sun and how materials can have more benefits than their aesthetically appearance or constructional qualities.

Urban mountain is not yet built and it will be interesting to see how much of the ambitious ideas they will go through with. Since this project is a refurbishment they do not have the same amount of freedom when it comes to designing the shape of the building. However, by

making some smart alterations they manage to create a whole new type of spaces within the building. Spaces that are not only aesthetically or spiritually pleasing but also have the purpose of providing clean and healthy air for the people within the building. From this project I'll take the resource management, where everything is seen as a nutrient, and the way they use plants as a way of providing healthy air.

The last project is not really one project it is more the work of a whole municipality. I am truly interested to see what Ronneby can accomplish and how Kilen will be developed. I did have a

look at the different ideas the teams had after the workshop. Many of the ideas concerned the stream, which runs through the district, and how the stream can become more incorporated into the district and how it can be utilized. The most important thing to take from Ronneby and the suggestions made by the teams is the aspect of time. In all suggestions they mention time. Kilen is a much bigger project than the project that this master thesis concerns so everything can't be done immediately. But it is still similar in the idea that the area/building can develop and improve over time.



C2C is the framework for how a building can work as a tree.



# Nora

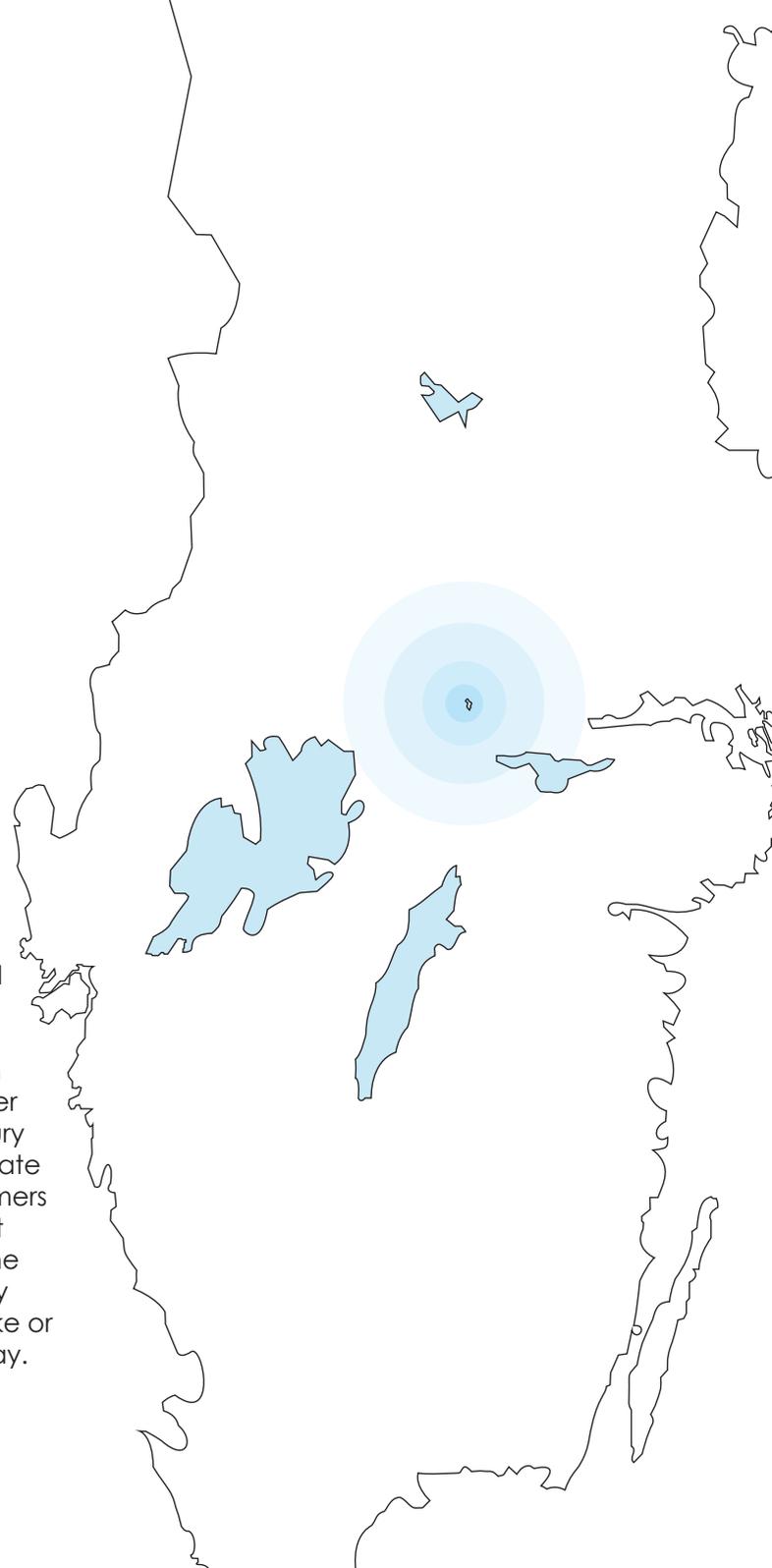
- the seed from which the tree springs

The seed gives the project its DNA. It contains information that generates a tree, which is adapted to its context. Not all trees can grow in all locations and this tree might only grow in Nora.

## today

Nora is a small town located in Bergslagen, next to the lake Norasjön. It is situated 200 km west of Stockholm and the closest cities are Örebro, 30 km south of Nora, and Lindesberg, 30 km north-east of Nora. There are about 10 400 inhabitants in the municipality and about 6 500 of them live within the main town (SCB, 2013a). Despite its size Nora has a quite active centre with restaurants, coffee shops, stores, grocery store, Systembolaget,

two hotels and a store where the locally produced ice cream Noraglass is sold. Nora is known for its old wooden town centre which still have the same character it had during the 18th century with distinct blocks and private courtyards. During the summers tourists come to Nora to eat Noraglass, stroll around in the centre, visit any of the many antique shops, enjoy the lake or take a ride on the old railway.



## town centre

Nora have quite a compact town centre with a distinct grid plan. There is one main approach into the town from the west. There are no traffic lights in Nora but there is one small roundabout which is passed on the way into the centre.

Cars is the most common mean of transportation in Nora and it is obvious by the amount of parking spaces provided in the centre. Along the lake there are marinas for smaller private boats. Close to the old railway station and

new bus station in the south-east part of the centre is the port for the small ferry Plaskus. Plaskus transport people to the main island in the lake, Alntorpsön, where they can sunbathe, have a picnic or take a walk.

The church and main square have been located in the same place since the 1200-century. The blocks around these are the most active with grocery store, restaurants, cafés, shops, Systembolaget and hotel. The commercial areas reach down to

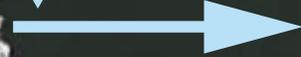
the lake where Noraglass is sold in the popular café Strandstugan during the summers. In the south part of the town centre a big gravel-yard have been saved. This is used for the annual fair (Noramarken), which is one of the biggest and most famous fairs in Sweden.

The municipal services located in the town centre are two schools, some sport facilities and a care centre.

main approach way



transportation



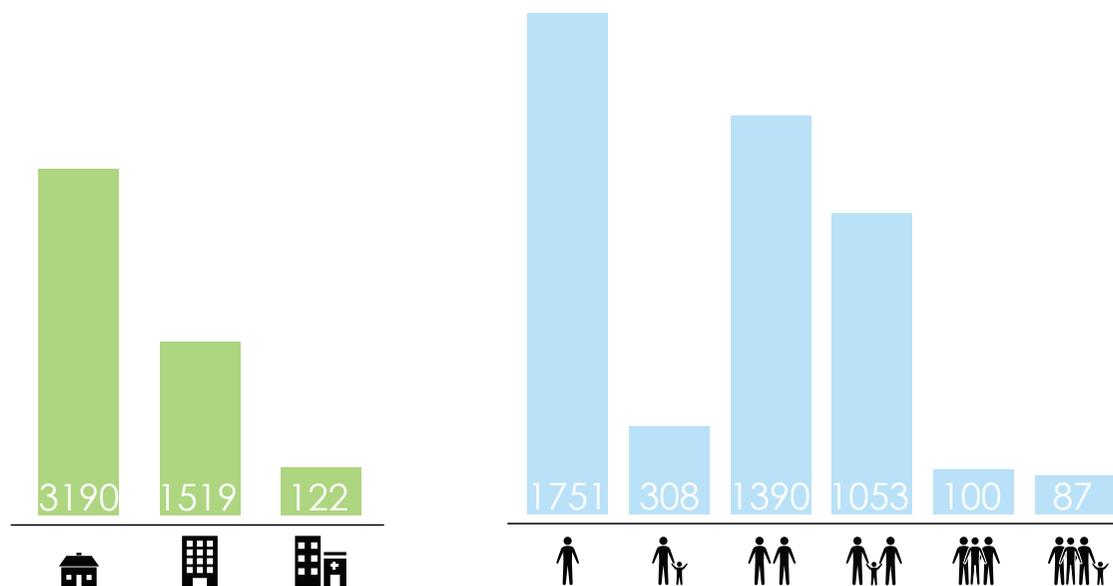
business activities





municipality services





## demographics

Today there are about 10 400 inhabitants in the municipality and 6 500 inhabitants within the main town of Nora. Most of the inhabitants within the main town live in detached houses located in the neighbourhoods surrounding the town centre. The average age of the population in Nora is 44,4 years which is a bit higher than the average of Sweden which is 41,1 years (SCB, 2014b). About 2000 of

the inhabitants work within the town and there are about 300 different work places in Nora (SCB, 2013b). Compared to the whole country the households in Nora is a bit smaller with an average of 2,16 persons per household and the average for the whole country being 2,22 persons per household (SCB, 2014a). There are about 4700 households in the municipality of Nora and more than half of

them are households without kids (SCB, 2014d). The most common type of household is a single person household without kids and the most uncommon type of household is the ones with more than two adults (SCB, 2014d). Diagram to the left show number of detached houses, apartments and special housing units in the municipality. Diagram to the right shows number of different types of households in the municipality.



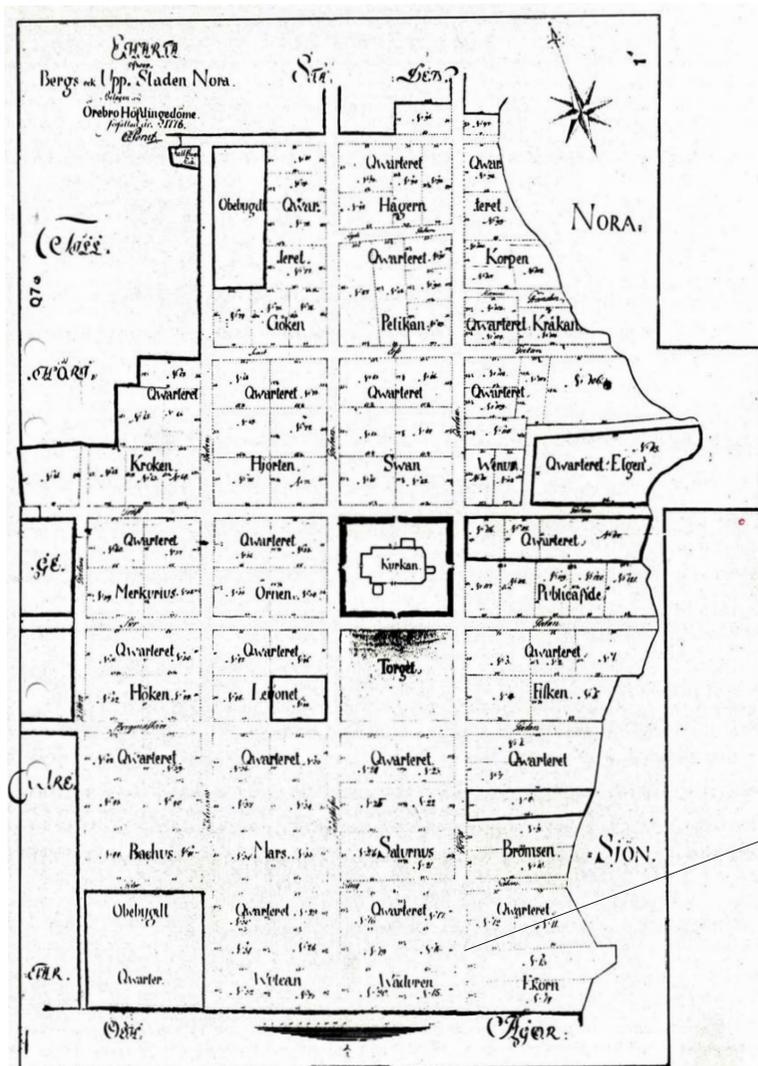
## history beginning 1100-1650

Nora has been an important trading and meeting place since the 12th century (Oldén, 2010). During this period the region was known for its mines and the locally mined iron along with wood and skins were traded in Nora for corn and other requisites (Oldén, 2010). The series of rivers and lakes that connect Norasjön with Mälaren made it possible to transport goods by boat and enabled the prosperous trading (Oldén, 2010). During the 13th century Nora became

its own parish with a square and a church located in the same spot as they are located today (Oldén, 2010). At this time Nora consisted of 15 farms, about 80 small huts for the miners, 4 houses intended for goods that had been taken as taxes and 6 houses intended for trading (Oldén, 2010). The dwellings and cattle houses consisted of long and low unpainted timber houses with only small openings for light and the roofs were covered by turf (Oldén, 2010). In 1608 a fire

destroyed 33 of the 44 existing farms (Nora turistbyrå, n.d.). The farms were rebuilt over time and in 1643 when Nora got its town charter there were about 400 inhabitants in the town (Oldén, 2010). The first town plan was approved in 1644 and was typical for its time as a grid plan with rectangular blocks and surrounding streets (Oldén, 2010). One block was dedicated for the church and another one for square, which were laid with cobblestone in 1650 (Oldén, 2010).

The block Väduren where the plot of the project is located.



Town plan 1778 (Oldén, 2010, p. 23).

## history the wooden town ~1731-1850

In 1731 another fire devastated Nora and most buildings except the church were destroyed (Nora turistbyrå, n.d.). Nora was once again rebuilt and in 1778 a new town plan was approved (Oldén, 2010). The structure of this town plan was similar to the earlier one and it is the foundation to the structural plan of Nora today. The buildings were mostly one story buildings in timber which were placed so that they created inner courtyards (Oldén, 2010). The roofs were covered with turf and most buildings had an attic with a gallery towards the courtyard. The courtyards were filled with storage buildings, stables, cowsheds, barns,

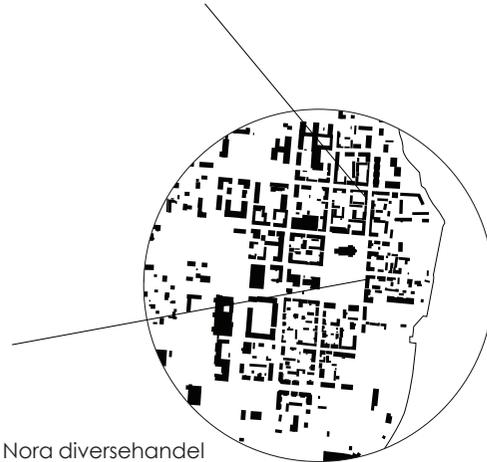
laundry, bakehouses and accommodation for the servants (Oldén, 2010). The structure and appearance of the buildings and the courtyards from this period have given a lot of character to Nora. A character which Nora is known for today.

The trading with iron, which culminated in the end of the 18th century and ended during the first decades of the 19th century, gave great wealth to Nora and contributed to the will of redesigning many of the buildings in the town (Oldén, 2010). In many cases an extra floor was added to the one story dwellings, the stone foundation was plastered, the

wooden facades with splines were painted in red color from the mine in Falun or light colored oil paints and the roofs were covered by tiles (Oldén, 2010). The buildings were ornamented with classicistic details but the new expression was most prominent in the dwellings that the wealthy bourgeois built during this period (Oldén, 2010). These buildings were often both higher, wider and more ornamented to show the wealth of their residents. The facades were covered with planed panels or plaster and ornamented with pilasters, capitals, cornices, temple gables and other classicistic elements (Oldén, 2010).



Exterior of Bergströmska gården. A building that dates back to the 18th century with its the typical courtyard. The facade has been changed and have a 19th century character. To the right is a portliden from the same building. A typical way of designing the entrance to the courtyards.  
 Photo: Left: Oldén, 2010, p. 20. Right: Oldén, 2010, p. 21.

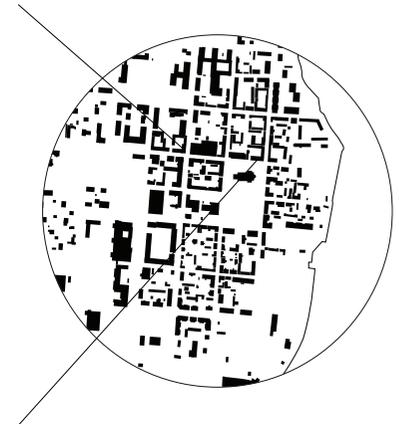


Nora diversehandel have a typical character of the era of the wooden town.  
 Photo: By author.

Hedborgska gården from 1855. Ornamented with classicistic elements such as pilasters, cornices and temple gables. Photo: Oldén, 2010, p. 22.



Wedbergska gården from the end of the 18th century. Photo: Oldén, 2010, p. 19.





## history the stone town ~1850-1930

In June 1856 the first railway track in Sweden was opened between Nora and Ervalla (Nora Bergslags Veteranjärnväg, 2012). The station facilities and the station house which were built in 1901 are still preserved today. With its rising importance it was decided that Nora needed a new church that could represent the town better and the new church was opened the 31st of December 1880 (Nora turistbyrå, n.d.). This is the same church that stands in the middle of the town today. A new town plan was established in 1912 and incorporated a new part of the town which was laid out in an irregular organic way, inspired by the garden cities (Oldén, 2010). The regulations for

the existing grid plan was also edited with the possibility to build higher buildings (10-12 meters to the roof base) and the streets were widened to manage the new type of traffic (Oldén, 2010). Since the new plan cut through some of the existing buildings regulations were changed to enable demolition of them (Oldén, 2010). Fortunately few buildings were replaced with newer ones but those buildings that were built after this are characterized by their placement a bit further away from the streets. During this period the buildings were first inspired by shapes from the ancient world, after that the ideal transcended into Art Nouveau and national

Romanticism and around 1920 the classicistic ideals were back again (Oldén, 2010). During the end of the 19th century the social responsibility grew and this was shown by the construction of important public buildings within the town centre (Oldén, 2010). The buildings were built in brick with plastered facades and they were the elementary school from 1841 (which now works as town house), the town hall and hotel from 1875 (now only hotel) and the courthouse from 1905 (Oldén, 2010). Together with the station facilities these buildings emphasize the character of preindustrial small town and commercial centre which Nora were during this period.



Buildings with a character typical for the period of the stone town. The bottom one is the main hotel in Nora. Both located around the main square. Photo: Top: By author. Bottom: Oldén, 2010, p. 28.





The station house from 1901. Today it mostly functions as a museum. Photo: By author.

## history the modern and postmodern town ~1930-

After the First World War the expansion of Nora has been slow but stable. The town has seen few changes to its structure and only a few new buildings have been added (Oldén, 2010). During the 1960 many cities were subject to urban renewal and in 1963 came a plan for urban renewal in Nora (Oldén, 2010). It was positive to preserving the existing development but promoted the construction of numerous buildings in a style appropriate to its surroundings (Oldén, 2010). Since then several buildings have been built within the grid plan and they have been adapted to its surroundings in terms of size and façade

materials. Unfortunately the small scaled buildings in the courtyards have often been forgotten. In 1966 the railway was closed for transportation of people and in 1985 it was closed for transportation of goods as well (Nora Bergslags Veteranjärnväg, 2012). As the residential areas, which mostly consist of detached houses, have grown the well-defined border between town and countryside have slowly been erased (Oldén, 2010). Some bigger constructions on the basis of social commitment were built, such as two schools, sport facilities, a library and a small shopping complex. The new buildings do not follow the

old structure with courtyards and are placed more freely within the blocks which makes the grid plan indistinct. The scale and choice of materials also distinguish these buildings from the surrounding buildings and the same goes for many other of the buildings built after 1912. The approach to the old town centre have changed since the 1930s, first it was said that the whole town centre should be modernized but today the idea is that new buildings should reflect our time but be adapted to the surrounding in shape, size, placement and choices of materials (Oldén, 2010).



Building with commercial facilities, such as Systembolaget, Noraglass and a restaurant. This building does not follow the old grid plan. Photo: Oldén, 2010, p. 32.



Nora parish house built in 1997 and praised for its design. Modern but adjusted to its environment. Photo: Oldén, 2010, p. 31.



- The seed includes:
- wooden constructions
  - volume and shape
  - positioning of the buildings
  - the structure of the courtyards
  - outbuildings



# Proposal

-a tree emerges





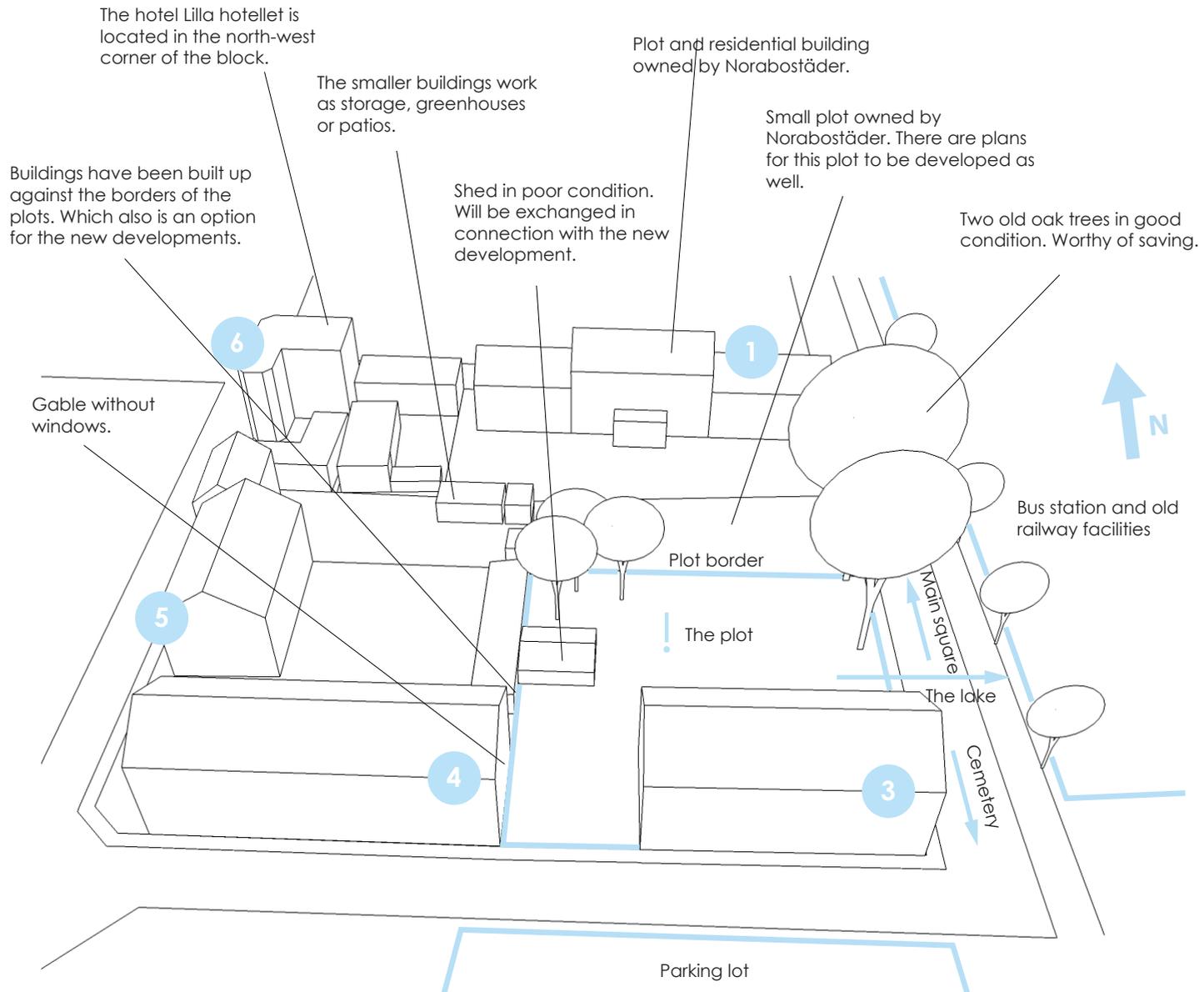
Våduren

## site analysis

Nora have been presented closely and now it is time to make a more elaborate presentation of the particular site.

The concerned plot form a part of the block Våduren. Våduren is located two blocks south of the square, adjacent to the old station facilities and the new bus station. Våduren is divided into six plots and the plot in the south-east corner is the referred one.

# site analysis - Väduren





**1.** Residential building from the 19th century. Located in the north-east corner of the block and facing the plot.



**2.** View of the plot from bus station. With the existing warehouse and two oak trees.



**3.** Existing warehouse. This building is currently being rebuilt into apartments and will have a light coloured plastered facade after the refurbishment.



**4.** Residential building. Built on the border of the plot. Potential to build up against the gable.



**5.** Residential building.



**6.** Residential buildings in the foreground and the white building is Lilla hotellet.

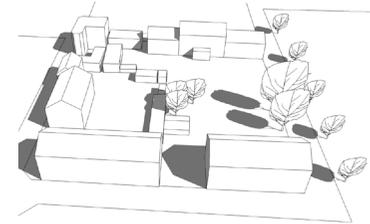
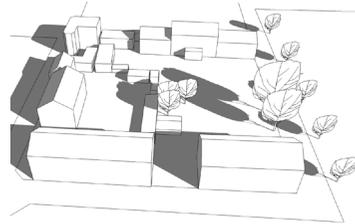
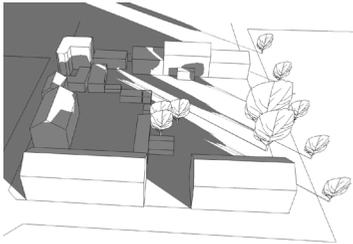
# site analysis - shadows

February

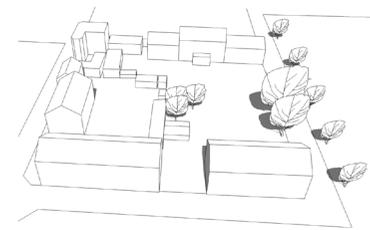
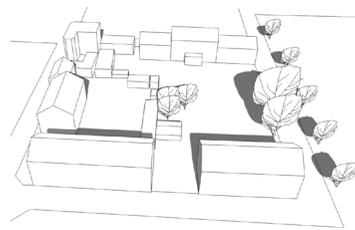
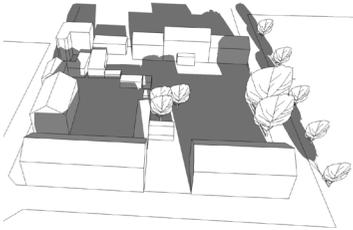
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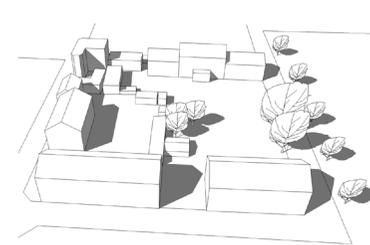
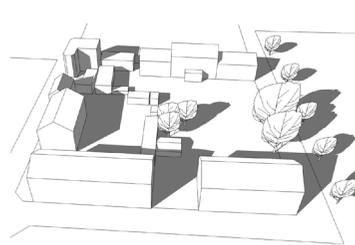
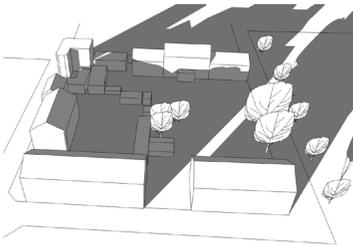
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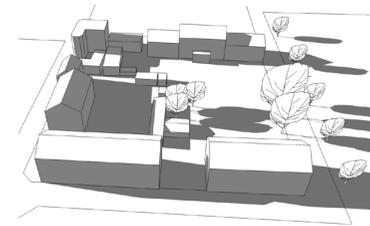
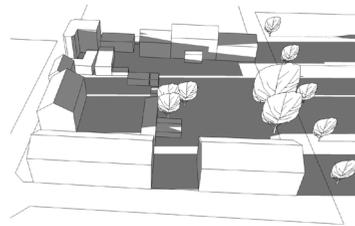
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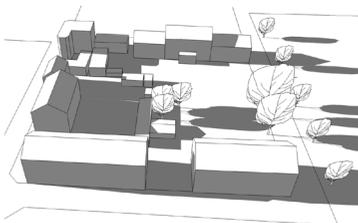
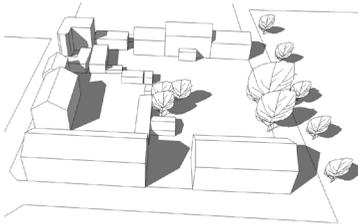
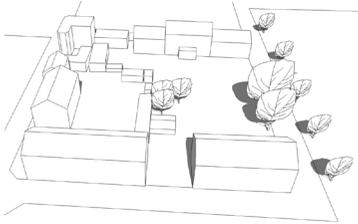
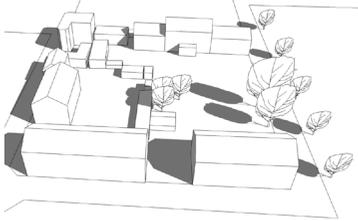
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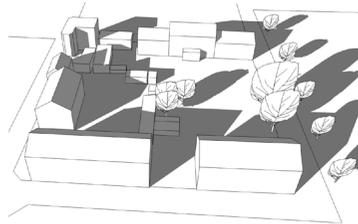
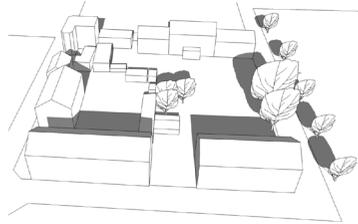
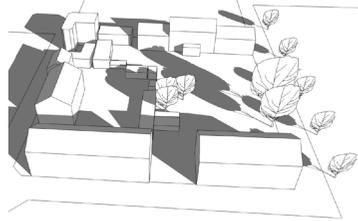
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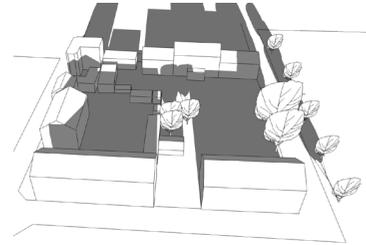
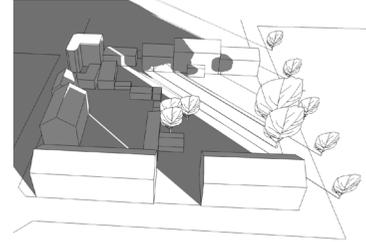
August



October



December





## program

The program for this proposal have been developed upon the ideas of C2C, the research about Nora and the site analysis. The program have been divided into four different scales; site, residential building, multifunctional building and apartments. Each scale have been described in six different categories; activities, functions, spacial and aesthetic qualities,

users, energy and performance and future. As materials are an important aspect to work with when designing a C2C inspired building and site it has its own section in the program. To ensure the influence of C2C in all aspect of the proposal five general C2C inspired goals have been determined, each with their own strategies.

## program - C2C inspired goals

In the beginning of the project five C2C inspired goals were determined. **Renewable energy** which is inspired by the second principle, use current solar income. It is also somewhat inspired by the third principle, celebrate diversity, in the sense that a diversity of strategies for producing renewable energy will be used. **Site as a showcase** is not really inspired by any of the main principles but is important for the increased awareness of the C2C concept among the public. **Waste as a resource** is taken straight from the first

principle, waste=food. **Enhance air quality** comes from the first principle, waste=food. Since air is a part of the biological cycle it is important to strive for it to have a better quality to further enhance the quality of the other parts of that cycle. CO<sub>2</sub> in the air will become nutrition for plants, the plants will release oxygen, which humans need and the humans will in turn release CO<sub>2</sub>, and so the continuous loop proceeds. The same goes for the last goal **water recycling** and by managing more of the water cycle on site less strain will be put

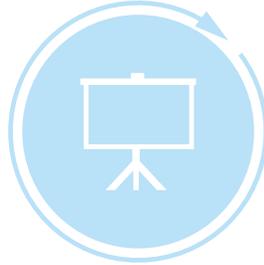
on the common water cycle and it is easier to ensure that nutrients are not wasted. A common C2C goal is usually increased **biodiversity**. I have decided not to make that one of my five goals. Since plants and greenery will be part of the strategies for some of the other goals I figured that increased biodiversity will follow as a result without further efforts. The biodiversity should still be increased but the focus will be on the goals that might need a little more effort.



### renewable energy

Energy should be used thoughtfully and all energy used should come from renewable energy sources.

- Using energy efficient solutions for the buildings
- Using a compost to produce heat
- Using photovoltaic cells to produce electricity
- Using solar panels to heat water
- Purchase energy from producers that use renewable energy sources



### site as a showcase

The site should be educational and work as an inspiration for others to start their own C2C projects.

- Invite people to the site by having functions they can make use of
- Functions such as a workshop, atelier or shop where materials get reused and sold
- Using new innovative materials to show and test their possibilities
- Using a variety of materials to showcase their possibility
- Make different C2C solutions visible for residents and people visiting



### waste as a resource

When materials or elements are no longer needed they should go back into the technical or biological cycle and become a resource for new products.

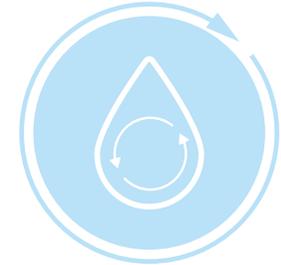
- Using healthy materials which belong together the technical or biological cycle
- Using CO2 as a resource for plants and cultivation
- Compost food waste to produce nutrient soil and heat



### enhance air quality

Both the inside and outside air quality should be considered. The outside air should be cleaner after the construction of the buildings than it is today and the inside air should be healthier than the air in an average home.

- Using plants to clean and humidify the air
- Using healthy materials to avoid emission of harmful particles
- Using new materials that extract harmful particles from the air



### water recycling

Water should be seen as a valuable resource and be managed on the site.

- Collect rainwater and use it for cultivation and flushing toilets
- Clean vv on site
- Separating toilets

# program site

## ACTIVITIES

Learn  
Cultivate  
Relax  
Socialize

## FUNCTIONS

### Purification of greywater

This can be done in a natural way with a series of basins with different plants in them. The greywater is filtered and purified step by step as it pass through the different basins. Once it has been cleaned the water can be released in the nature or used to water plant.



### Cultivation

Possibility for the residents to grow their own vegetables, herbs, fruits or plants. Since the period for cultivation in Sweden are limited it could be a good idea to have a greenhouse or similar to prolong the season.



### Compost

By making use of the biological

waste of the residents nutrient soil would be produced. It would also be economically beneficial for the landlord since less waste would have to be collected from the site. If more soil than needed would be produced the soil could be sold which would generate additional income.



### Digital information boards

To make information visible and clear digital information boards that describes the site, its functions and different systems should be placed on the site. Both for visitors and residents.



## SPATIAL AND AESTHETIC QUALITIES

### Placement of buildings

The buildings should be placed to enhance the characteristic layouts of the blocks in Nora. They should also be placed to utilize the sun as much as possible.

### Greenery

Plants, trees, bushes and other

types of greenery are not only pleasant, beautiful and relaxing they also work as air humidifier and purifier. Greenery will also work as habitat for insects, birds and smaller animals and will in that sense help to strengthen the local ecosystem.



### Public and semi-private

One of the main goals is to make the site and buildings a showcase of C2C design which means that the public should be able to come to the site and experience it. However it is still a residential site so it is important that there are both spaces where the public is invited but also that there are more private spaces reserved for the residents.



## USERS

### Residents

Both residents in the refurbished building and the new building, and in addition their families and friends. They should feel welcomed and have a sense of home.

## Public

Visitors may come to look at the new area to get inspired and educated in C2C strategies. It should be easy for them to get information and C2C solutions should be visible on the site.



## Plants and animals

They are both living organisms that live in the same ecosystem as us and considerations on how to include suitable environments for increased biodiversity is essential when working with C2C design.



## ENERGY AND PERFORMANCE

### Generate renewable energy

Depending on the layout of the site there are different types of renewable energy sources that could be used.



## FUTURE

### Study visits

As the site evolves study visits might be an important part in spreading the knowledge of C2C.



### Renewable energy sources

There are a lot of research going on about new types of renewable energy sources. If this site should be able to continuously inspire and teach people it is important that new energy sources are implemented as they developed. One example are algae panels which could generate heat and electricity. Or algae street lamps which don't need any other energy than the radiation of the sun.



# program residential building

## ACTIVITIES

Everything that people do in their homes.

## FUNCTIONS

### Multifunctional building envelope

The building envelope should not only protect the interior and control the indoor climate it should also add additional value. An example are sedum roofs, they purify the air, absorb rainwater and is a habitat for insects.



### Collection of rainwater

The rainwater collected could be used to flush toilets or water plants. With this approach less water have to be purified and delivered from the common grid of the municipality.



### Buffer room

On each floor there should be at least one room that can be reached from the stairwell and two separate apartments. The intention with this room is to give

a flexibility to the apartments.

### Digital monitors

The monitors should be placed accessible for all residents in the building and it should provide information about the different systems in the building. Energy produced and water saved are data that the resident should be able to acquire through the monitors to be able to see and ensure the performance of the building.



## SPATIAL AND AESTHETIC QUALITIES

### Greenery in stairwells

The greenery will give a pleasant feeling to the common stairwells and will also improve the air quality of in the stairwells.



### Innovative materials

Materials used should follow the criteria established in the material section of the program but some materials should also be innovative. Innovative in this

case mean new, not traditionally used by the building industry or materials that do something extra, for example purify the air.



### Classic shape

The shape and the volume of the building should correspond to other buildings in Nora.

### Solar shading

The sun should be used during winter as a source of heat but with a well-insulated building the summer sun may be a problem. Therefore it is important to provide the building with solar shading that can be used when needed. The solar shading should be both aesthetic and functional and work as a part of façade.

## USERS

### Residents and visitors

The building should be inviting and pleasing. The residents should feel welcomed and they should feel a sense of home.

### Resident of the existing building

The buffer room may be rented by the residents in the existing

building as well. Therefore they should be accessible and easy to find.

## ENERGY AND PERFORMANCE

### Generate renewable energy

The building envelope might be used to produce renewable energy. It could be solar panels, photovoltaic cells or small wind turbines. Windows could also be coated with a photovoltaic film which generates energy.



### Energy saving

To cover the whole energy consumption with renewable energy the demand have to be as small as possible. Therefore it is important to install devices with low energy consumption and construct the building to have as little energy losses as possible. The size and placement of windows are important as well as shape factor, insulation and thermal bridges.



## FUTURE

### Renewable energy

There are a lot of research going on about new types of renewable energy sources. If this site should be able to continuously inspire and teach people it is important that new energy sources are implemented as they developed. One example are algae panels which could generate heat and electricity. Or algae street lamps which don't need any other energy than the radiation of the sun.



### Alterations of apartments

Over time the buffer room should be able to change its purpose and which apartment it belongs to. There could also be a flexibility where other rooms are alternated between the apartments.

# program multifunctional building

This is a smaller building that will be placed in the courtyard. It is inspired by the structure of the old courtyards in Nora where additional functions were located in buildings placed in the courtyards.

## ACTIVITIES

Parties  
Dinners  
Workshops  
Seminars  
Play music  
Lectures  
Relaxation  
“Fika”  
Cultivate  
Socialize

## FUNCTIONS

### Cultivation

Possibility for the residents to grow their own vegetables, herbs, fruits or plants. Since the period for cultivation in Sweden are limited it could be a good idea to have a greenhouse or similar to prolong the season, and that could be placed in this building.



### Storage

To make this building versatile there should be a possibility to furnish it in different ways and it should be possible to store the furniture somewhere if they are not needed.

## SPATIAL AND AESTHETIC QUALITIES

### Flexible

It is important that the spaces within this building are flexible so they can be used for different purposes and in that way be useful for more people.

### Smaller volume

The volume of the building should be adapted to the surrounding and be smaller than the residential building.

### Other materials

As the site should be a showcase it is a good idea to use other materials for this building than the residential building. In that way the public could see what possibilities there are and different materials could have different performance.

### Natural light

Natural light should be utilized as much as possible to avoid artificial light and create a pleasant atmosphere.

## USERS

### Residents

The spaces within this building should be open for the residents but it should also be possible for them to rent it for private gatherings.

### Public

Certain spaces which have the purpose of spreading the C2C concept should be accessible for the public.



### Business

If there is a demand certain spaces could be rented for businesses. The businesses should have some connection to the C2C concept and therefore be a part of the educational and inspirational part of the site.



## ENERGY AND PERFORMANCE

### Generate renewable energy

The building envelope might be used to produce renewable energy. It could be solar panels, photovoltaic cells or small wind turbines. Windows could also be coated with a photovoltaic film which generates energy.



## FUTURE

### Building of inspiration and education

The goal with this building is that it overtime transforms into centre for C2C in Nora. A centre where people can come to learn and get inspired. Different activities could take place and people could get involved.



# program apartments

## ACTIVITIES

Sleep  
Eat  
Cook  
Relax  
Socialize with family and friends  
Reside

## FUNCTIONS

### Private outdoor space

To have your own private space are important to many people and to be able to enjoy the outdoors with a cup of coffee or grow your own plants are a luxury for many. There is also an idea that if people enjoy nature they are more likely to want to take care of it.

### Proper kitchen

We need to eat and the kitchen are often the space where people gather during a party. It is a central space within our homes and having the possibilities to cook and bake in a proper kitchen is very pleasant.

### Cultivation

Possibility for the residents to grow their own vegetables, herbs, fruits or plants close to their own apartments.



### Separating toilets

The urine is separated from the rest of the blackwater in order to take advantage of the nutrients it contains. The urine may be used as fertilizer and the rest of the blackwater will be brought to a biogas plant for energy production.



## SPATIAL AND AESTHETIC QUALITIES

### Line of sight

The apartments should stretch through the building and there should be a line of sight from one side to the other.

### Natural light

Windows should be placed thoughtfully to make the best out of the natural light.

### Individually shading

Different resident may have different needs of daylight and temperature, therefore they should be able to individually control the shades.

## USERS

### Residents

Households of 1-2 persons. Younger adults that are starting their own life away from their parents, by themselves or with a partner, or older persons with grown kids or no kids at all. The residents are aware of the focus of the building and have some interest. This is important as some functions need the participations of the residents to work.

## ENERGY AND PERFORMANCE

### Individual climate control

Each apartment should have the possibility to adapt their indoor climate. The needs can differ if the residents are home all day and are active or if they are only home during the nights.

## FUTURE

### Adaptability

The buffer rooms should provide the possibility of adapting the size of the buildings as the families change.

# program materials

There are many aspects to consider when it comes to materials and construction. It may be one of the most important parts when working with a C2C inspired building.

## FORWARD

The materials used should go back into the biological or the technical cycle after deconstruction. It is vital that the materials are not be harmful to nature or humans while in use or after usage. How the materials can be returned to the respective cycles is also important. Downcycling is not a desired output so it is important not only to ensure that materials or elements can be reused but that they can be reused in a proper way.

## DISASSEMBLE

It might be easy to find appropriate materials, but buildings are complex and they consist of a substantial amount of different materials. Materials that need to work together while in use but have to be disassembled in order to be reused. Each constructive element have its difficulties but the overall strategy

is to simplify the details and reduce the amount of layers and materials that each element consists of. This is to make the disassemble easier or even possible.

## REUSED MATERIALS VS.. NEW MATERIALS

An other aspect that can be considered when choosing materials for a C2C inspired building is the choice of working with new materials or reused materials. The goal is for the materials to be reused after the building is deconstructed but it is also possible to construct the building out of reused materials or elements to begin with. In this way the building would be in the material cycle from the beginning. Some materials or elements might be more suitable for reuse than others and there are pros and cons with both new and reused materials.

### Reused materials or element:

- + No new energy is needed for the production of the material
- + No new raw materials have to be extracted
- + Could give a beautiful patina and genuine feeling
- Maybe not designed to be reused

(causing downcycling)

- Hard to ensure quality (an example is the U-value of windows)
- Could contain unknown substances that might be harmful
- Smaller range to choose from
- Energy might be needed to adapt the materials or elements

### New materials:

- + Easier to ensure quality
- + Chose materials that can be reused without downcycling
- + Possible to ensure what type of substances it contains
- + Possible to choose materials or element that really fit the aesthetic expression
- + Bigger range to choose from
- New raw materials have to be extracted
- Energy have to be put in order to develop the new materials or elements

However regardless of the materials are reused or new the most important thing is that they are appropriate from a C2C point of view.

A tree consist of materials that become nutrients for other living organisms in the end of its life. The building materials used in the buildings should to the same.

# program material - flows

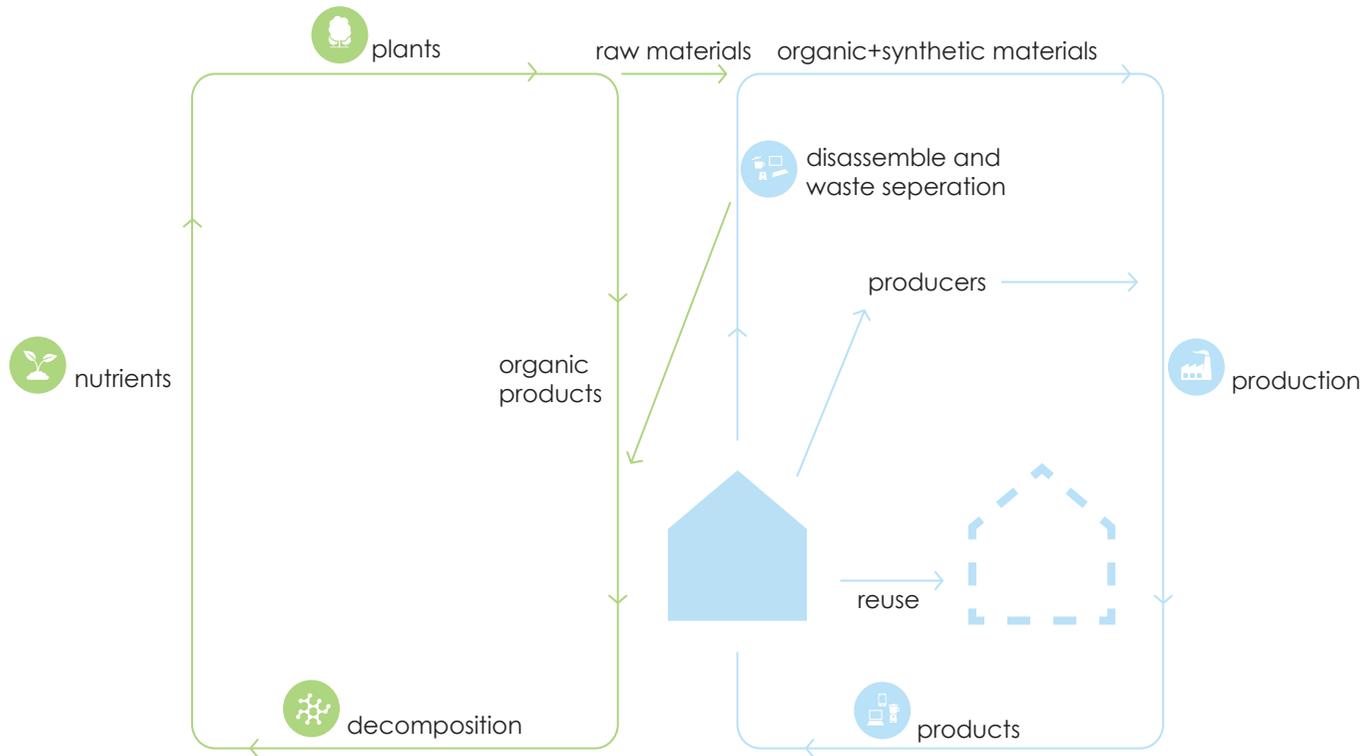
These cycles are the biological and technical cycles that were described in the first chapter.



A goal for this project is for all materials to be incorporated into the biological or technical cycle.

However in a building materials and elements are mixed. An element can consist of materials from both the technical and biological cycle. Therefore it is important for those elements to be disassembled and the materials returned to the right cycles. Some element might be reused as whole elements while others need alterations. For technical devices, bathroom equipment and other appliances

there should be a leasing contract with the producers. In this way the producers own the materials that the products consist of. Thus the producers will save money if the products are designed in a way that the producers can reuse the materials they consist of. Below is a more developed chart of the material flows in the building.



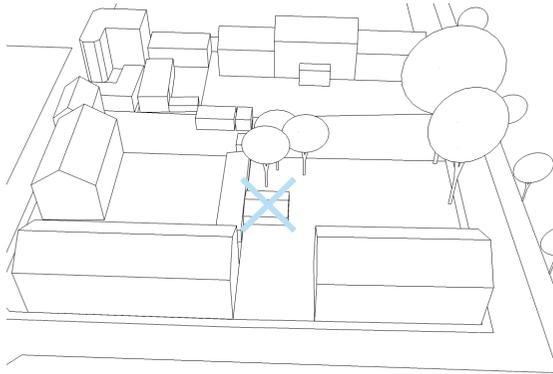


# site and buildings

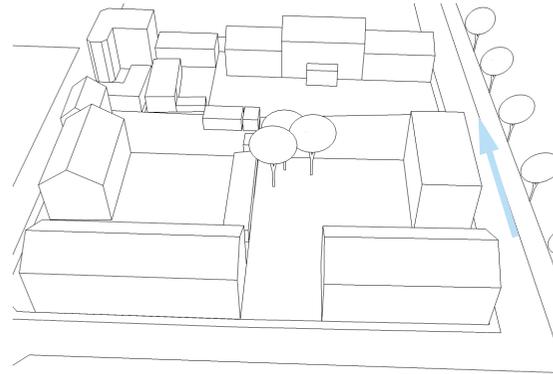
All the previous chapters, the site analysis and the program ,developed upon them, have resulted in a design proposal for a site, residential building and multifunctional building.

# development of the buildings

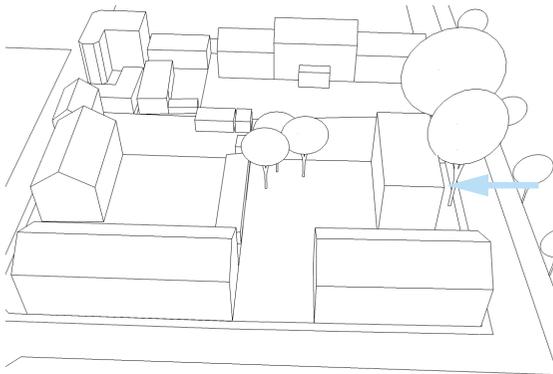
The development of the volumes.



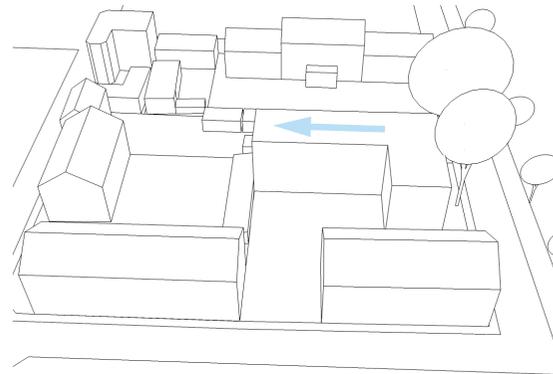
1. The shed which is placed in the courtyard is unused and in bad condition. To make room for the new buildings the shed is removed.



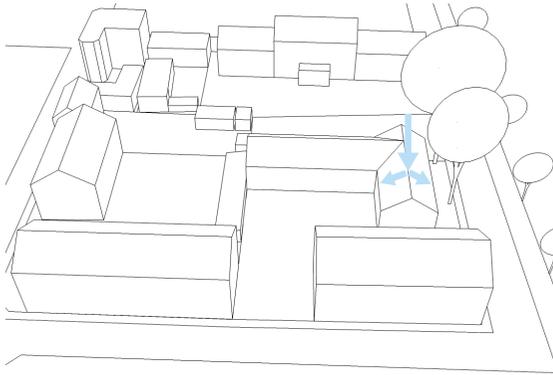
2. The volume is placed along the street to frame the courtyard and block. A traditional way of placing a residential building in Nora.



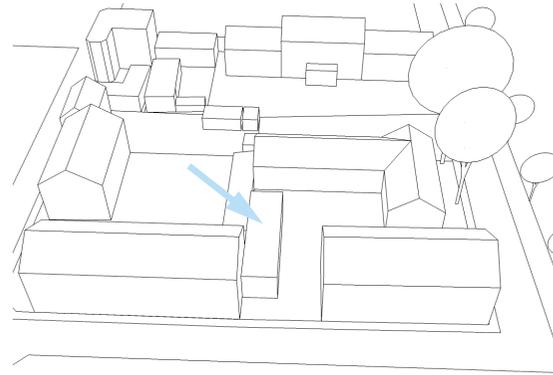
3. To preserve the two big oak trees, located along the street, the volume is pushed back.



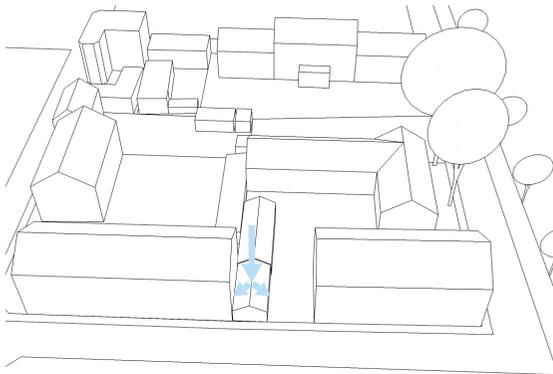
4. The volume is extended to further frame the courtyard, increase the building area and capture the southern sun. The smaller trees are removed but later replaced by new ones.



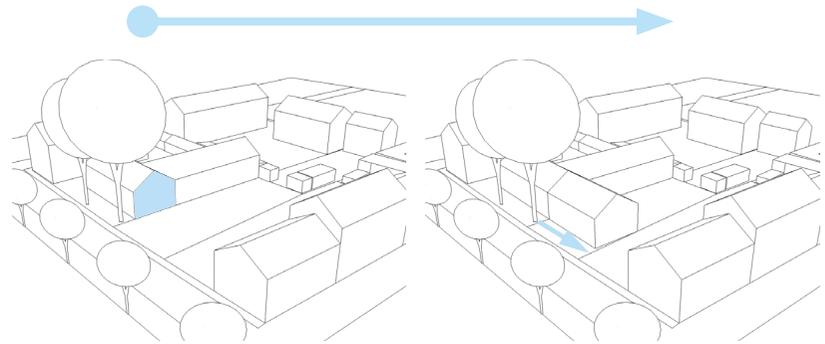
5. The size and shape of the volume is modified to work in with the surrounding buildings and the scale of the town.



6. A smaller volume is placed in the courtyard, in the same way as outbuildings were placed in the courtyards back in history.



7. The small volume is divided into two parts with different sizes depending on the functions they will house. The volume is given a classic shape and the lower part is placed with its gable facing south.



The north gable of the bigger building is a windowless gable. The purpose of that is to create the opportunity of extending the building in the future, on to the narrow plot north of the site. The narrow plot is hard to develop in any other way even without the new buildings and it supports the historical structure of the blocks.



Flyttåda Mellan



site plan 1:400

All ground covering materials are permeable to allow the ground to absorb rainwater. This is to avoid run offs and prevent flooding. Gravel is traditionally used in Nora and is the main ground covering material used on the site. The gravel is framed by grass that is planted

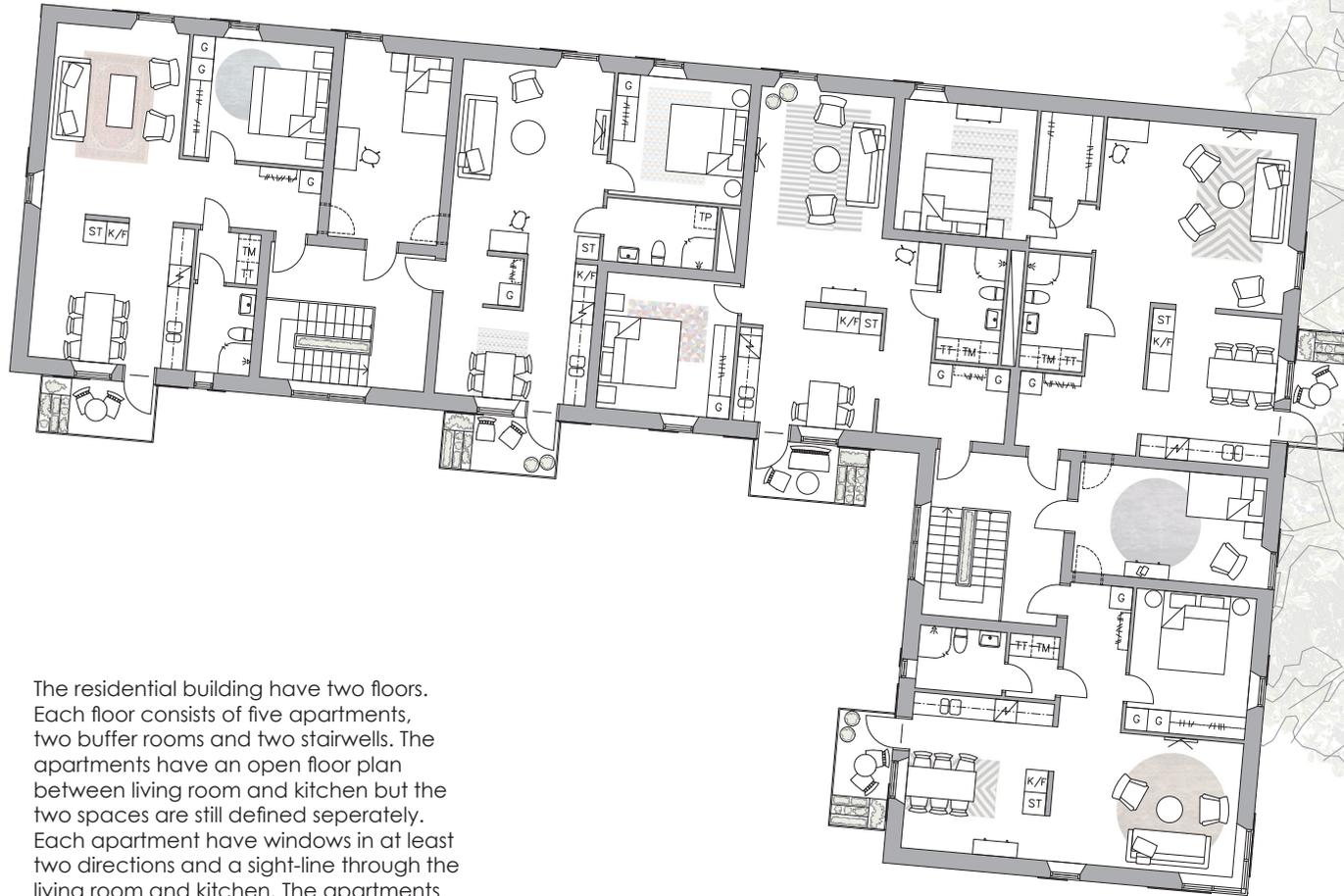
along the buildings. Smaller trees, bushes and other greenery are planted on the site to create a pleasant atmosphere and in the same time provide clean air. A grass "island" with plants and greenery is placed in the middle of the courtyard to divide it into one more private part and

one more public part. Stones are laid in front of the entrances and as two tracks in the gravel. The tracks are meant to be used by the garbage truck and if needed other type of bigger service trucks. Cars are not allowed on the site and parking spaces for the residents are provided just south of the site.

first floor 1:200



second floor 1:200



The residential building have two floors. Each floor consists of five apartments, two buffer rooms and two stairwells. The apartments have an open floor plan between living room and kitchen but the two spaces are still defined seperately. Each apartment have windows in at least two directions and a sight-line through the living room and kitchen. The apartments have one bedroom and the possibility of adding an extra room (see the part about adaptability). All apartments have private outdoor spaces where they have the possibility of enjoying the sun and growing vegetables and plants.

# adaptability



Each floor have two buffer rooms. These rooms can belong either to any of the two adjacent apartments or the stairwell. When belonging to the stairwell it works as a rentable room. A room which can be rented by any residents on the plot, even

the residents in the existing building. It can be suitable when relatives or friends come to visit for a weekend or when someone needs a temporary office.



How the layout of two apartments and a buffer room could change over time.

The buffer room is used as a rentable room.



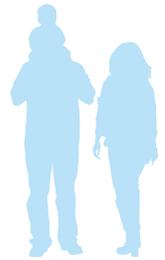
In the left apartment an older couple moves in. They have sold their house and are looking forward to live a less demanding life in their new apartment.



In the apartment to the right a young couple moves in. It's their first apartment and they have the future ahead of them.



The couple live happily in their apartment. They grow their own vegetables on the balcony and enjoy the orangery during rainy days.



The young couple have turned into a family of three. The buffer room have been incorporated into their apartment as their son's bedroom.





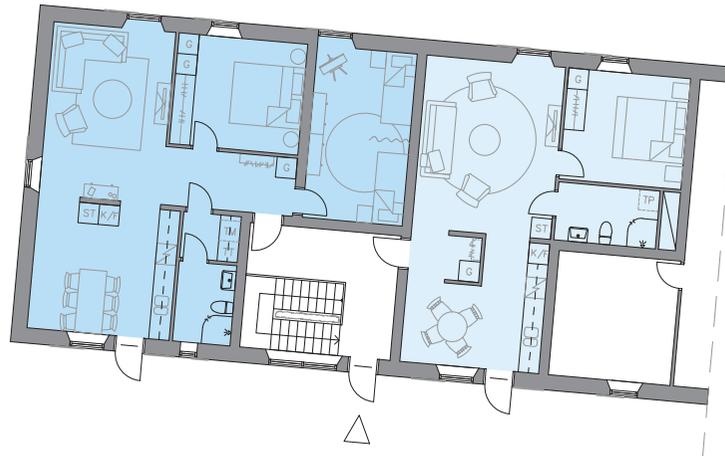
The old couple have moved into a home for elderly. Unfortunately the younger couple have to split up. Luckily they are still good friends. The woman have moved into the left apartment.



The man stays in the right apartment. The couple's son can keep his bedroom and change which apartment to belong to when he switch which parent to stay with.



The woman have met a new man and moved out. A single mom with two kids have moved in. The buffer room is used as the children's bedroom.



The son have now grown up. The father have moved out and instead the son lives in the right apartment together with his boyfriend.



The final scenario implicates some more extensive alterations, like adding and removing some interior walls. But the kitchen and bathroom installations can be kept when the two apartments and buffer room is turned into one big apartment for a collective.



The single woman have moved out. The two apartments and buffer room have been joined into one big apartment. Where the son and his boyfriend live in a collective together with four others. There is now four bedrooms, two bathrooms, one living room and two kitchens in the apartment. The kitchens can be used separately when someone want a more private dinner for example.



The residential building have a wooden facade, with thin vertical panels. The same sort of panels continue on to the roof to create the feeling of a solid volume. Windows and glazed doors are equipped with shutters to prevent overheating and offer privacy. The shutters are made in the same way as the façade but the vertical panels are mounted with a distance between them to let in some light to the apartments when they are closed. The balconies are also made in wood and are designed

to blend in with the rest of the façade. The south part of the roof are completely covered by photovoltaic cells and solar panels to provide electricity and hot water to the building. In addition the glazed openings of the stairwells have semi-transparent solar cells to provide even more electricity. The intergraded gutters collect rainwater which is used to flush the toilets and run the washing machines on. The facade facing east creates on of the two entrances to the site.

facade facing south 1:200



facade facing west 1:200



facade facing north 1:200

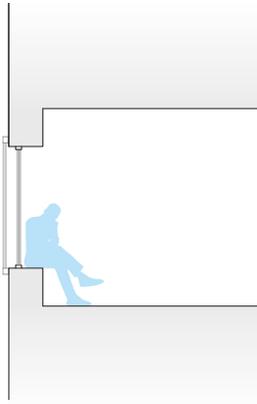


facade facing east 1:200



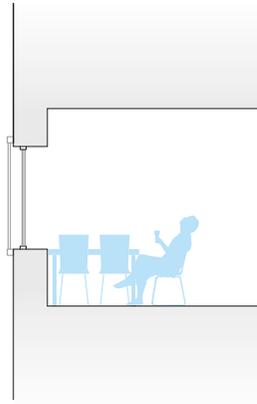
# quality of light

## PRINCIPLES SILL HEIGHT



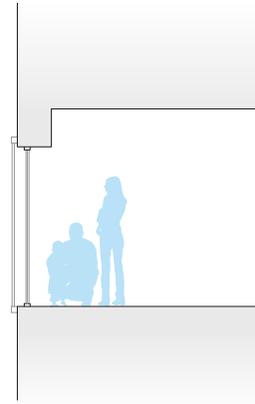
Bedroom

500 mm  
sit + for everyone +  
connection with outside



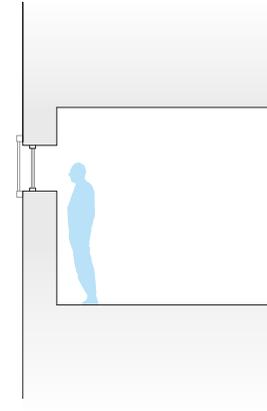
Kitchen + corners

750 mm  
possible to place  
furniture against it



Living room + buffer  
room

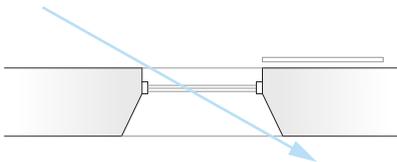
to floor  
more light + for  
everyone + connection  
with outside



Bathroom

1500 mm  
see out without  
exposure

## WINDOW RECESSES



As the amount of insulation increases the walls grow thicker and the window recesses are made deeper. By angling the window recess more light can shine in and the windows will feel bigger.

Light seeping through the shutters at night.



The facade with the shutters closed.



## THE SHUTTERS

The shutters will be made in a similar way as the rest of the wooden facade. They will consist of thin vertical panels and be mounted on rails so that they can be adjusted depending on the needs of the residents.

During sunny days they'll provide protection from the sun and cast intriguing shadows on the interior surfaces. During night the light from the apartments will seep out through the shutters and as the shutters can be moved the façades will constantly change appearance.

When the shutters have to be exchanged due to aging they can be replaced with solar panels. The shutters will provide both protection for the inside and produce energy. Photo: <http://www.solardecathlon.upm.es/en/bwfacade.php>



As a tree's leaves render shadows the shutters provide shelter from the sun during hot summer days. The shutters will be moved and the facade, as a tree, will shift appearance during the seasons and years.

# the multifunctional building



This building is located in the south-west part of the plot. It contains garbage room, a room for reuse, a workshop, a storage room and an orangery. The purpose of the reuse room is for residents to exchange items that they are no longer using. All residents have access to the workshop. In the workshop they can mend broken things, build new things out of reused materials or refurbish old furniture. The orangery are located in the south part of the building and have a gable facing the street. Here the residents can come to relax or grow vegetables, plants or flowers. The containers which are used for cultivation are equipped with wheels to make them movable. In the storage room there are tables and chairs which can be used if the resident wants to have dinners or parties in the orangery.

The purpose of the reuse room and the workshop is to use people's used items as a resource and make something new out of them. Just like a tree's waste becomes nutrition for other living organisms.

facade facing east 1:200





The workshop may be rented to people who want to arrange courses that correspond to C2C.

Natural purification of the greywater coming from the multifunctional building, should be established if enough space can be made available.

Composts generate heat and if a compost is established it can be used for heating water.

As a tree changes appearance over the seasons and years the multifunctional building will change appearance. Two big shutters may be pushed aside and the sedum roof and greenery will change color and appearance with the season.

# materials and construction

Materials are a vital element for any building but they are especially important for a C2C inspired building. Buildings can't be built with one single material and the materials have to work together, therefore it is important to also study the construction of the different building elements.

# foundation

The foundation is in direct contact with the ground and is constantly exposed to moisture. It has to be well insulated, support the rest of the construction and protect it from moisture coming from the damp ground.

## COMMON

The most common type of foundation is a foundation slab in concrete. It is a fairly simple type of foundation that basically consists of concrete and inorganic insulation, materials that are inappropriate from a C2C perspective. Concrete can be crushed and used as landfill, but that is a type of downcycling. The insulation is also hard to

recycle or reuse in a proper way. Because of that and the fact that it is hard or impossible to disassemble in a good way it is not a good choice for a C2C inspired building.

## ALTERNATIVE

There are other ways of constructing a foundation but a foundation slab is the most commonly used one. Concrete should be avoided but there are other options. One is to build the slab of elements made out of steel beams and foamglass, called Koljern elements (Koljern, 2014). The steelbeams create a frame around an insulating core made out of foamglass. The

elements are both loadbearing and insulating so the foundation can consist solely of these elements. To obtain a well insulated foundation additional elements of foamglass are placed under the constructive elements. Depending on what the specific ground consists of the slab might be in need of extra support underneath the loadbearing element.

## CONSIDERATIONS

It is not said that this type of foundation is the optimal way of constructing a foundation, but for this project it might be the best option. It is not possible to construct a building 100% in line

with the C2C concept today. Instead one has to decide what the most important aspect is for the particular element and try to design the element based on that. For the foundation that aspect was to avoid concrete. Mostly to see what options there are but also because concrete is a non desired material in a C2C building. Steel is used in this type of foundation, it is not a completely desired material either but between concrete and steel, steel is the better option.

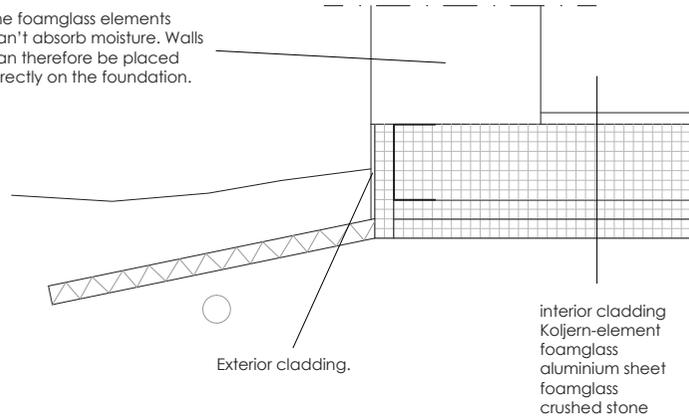
#### MATERIALS

The foundation does not have as many aesthetic properties as the other components of the

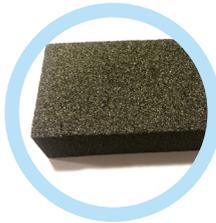
building envelope. The only visible part is of the foundation is that between the ground and the wall cladding. This part usually have some sort of exterior cladding to protect the foundation and for aesthetic reasons. Both the residential and multifunctional building will have a stone cladding.

## constructive example 1:20

The foamglass elements can't absorb moisture. Walls can therefore be placed directly on the foundation.



## materials



### FOAMGLASS

What: Insulation boards made out of more than 66% recycled glass, waste glass from the industry.

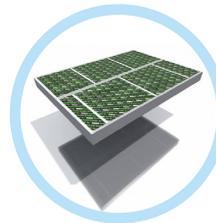
Properties: Water- and vapourproof, non absorbent, fireproof, non desirable for vermin, high compressive strength, chemical resistant, easy to shape, contains no flame retardants or environmentally harmful adhesives.

Lifespan: At least 50 years.

Afterwards: If the elements are not harmed they can be reused.

Other: Has been awarded multiple environmental certifications for being an environmentally friendly material.

More: <http://www.foamglas.se/hem/>



### KOLJERN ELEMENT

What: Constructive elements made of 90% foamglass and 10% steel beams.

Properties: Same as foamglass with the addition that they can be joined together and form structural elements.

Lifespan: At least 50 years.

Afterwards: If the elements are not harmed they can be reused.

Other: Has been awarded multiple environmental certifications for being an environmentally friendly material.

More: <http://www.koljern.se/>

# exterior walls and load-bearing structure

The exterior have to be well insulated, work as loadbearing system and protect the interior from rain, wind and sun. An important feature of the exterior walls are also windows, a visual connection between the inside and outside.

## COMMON

Wood have been the traditional building material in Nora for a long time. A traditional wooden stud frame could be a good option considering the scale of the building, the costs and knowledge about this type of walls. However, in a C2C perspective this type of wall is not an ideal option. It

consists of multiple layers and materials which make it hard to disassemble. Another liability is the need for inorganic materials such as a plastic vapour barrier and usally gypsum boards as interior cladding.

## ALTERNATIVE

There are other ways of constructing walls in wood. One is with CLT, cross laminated timber. CLT is a solid wooden board made out of planed fir lamellas that are glued together in layers. The boards can also be screwed, nailed or assembled with wooden dowels. The glue free kinds are better for the envrionment, but if the glued ones are used the

plastic vapour barrier can be eliminated since the boards work as a vapour barrier themselves. The CLT may be used for walls, roofs and slabs. Compared to concrete and many other types of building systems this type have a lot of benefits. The construction time is reduced with prefabricated boards that are assembled quickly on the building site. A construction without concrete eliminates the time needed for curing. In addition, wood is a renewable building material which retains carbon dioxide.

## CONSIDERATIONS

The possibility to dissassemble the

walls is important. Reducing the amount of layers and materials in the walls improve that possibility. The most common way of insulating a wall like this is to use cellulose based insulation placed in a wooden stud frame. However the thickness of the insulation will result in such thick studs that they could be the loadbearing structure and the need for CLT for constructive purposes would be lost. This creates a dilemma, since by using CLT the vapor barrier can be eliminated and the CLT could also work as interior cladding which would eliminate the gypsum boards as well. Another option to the organic insulation could be inorganic rigid

insulation boards that can be mounted directly on to the CLT, without studs. However the issue with this option is the insulation itself. Manufacturing it is energy demanding and it is hard to recycle or reuse. The preferred solution would be an organic rigid insulation board that can be mounted straight on to the CLT. Fortunately there are such boards made out of softwood. The boards come in a variety of thicknesses and treatments. There are boards that are treated to withstand weather, which eliminates the need for weather-boards and there are plain untreated boards. For a C2C inspired wall this is a

good option since the number of materials is reduced and the insulation can be returned to the biological cycle after usage.

Outside of the insulation boards the joists are mounted with nails going through the insulation into the CLT, and outside of them the cladding is added.

This type of construction has been verified both by Martinsons, the producers of the CLT elements, and Miljöbyggsystem, the company which sells the insulation boards in Sweden. The construction was also tested and elaborated in a master thesis called Urban Timber (Esbjörnsson,

Ford and Magnusson, 2014).

#### WINDOWS

The walls are constructed without studs. But when windows are to be inserted they require a stud frame. That is if they are not placed in the innermost layer, in the CLT. This placement would create shallow window recesses and deep openings in the facade, a for this project non desired expression. This leaves the option of placing the window further out in the wall and putting a stud frame around each of them. Consequently each window does not only mean that materials for that window have to be manufactured, it also

implicates the construction of an additional stud frame and the manufacture of other necessary elements. The window sections are composed out of more elements and layers than the rest of the wall sections. Therefore they will be more complicated to both construct and disassemble. Placement of windows should therefore be done thoughtfully and the amount of windows is significant. One big window is better than two small ones both from a material point of view and from an energy point of view. The weak part of a window is the window frame and the connection between the window

and wall. Two small windows will together have a longer perimeter than one big window has, and that is why it is the poorer choice.

#### MATERIALS

The exterior walls are important both from a constructive point of view but also from an aesthetic point of view. The residential and multifunctional building will have the same load-bearing structure but different claddings.

The residential building will have a wooden facade, with thin vertical panels. The shutters will be designed similarly but with a distance between the panels so that some light may

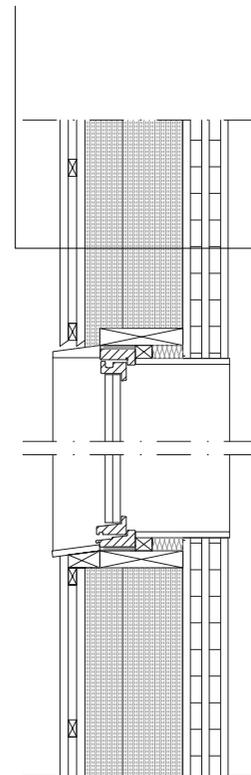
## constructive example 1:20

penetrate them. To make the panels more durable they will be heat-treated. The same sort of panels will continue on to the roof to create the feeling of a solid volume. The choice of using wood as facade material originate in the fact that Nora is called a wooden town and that it is a traditionally used material.

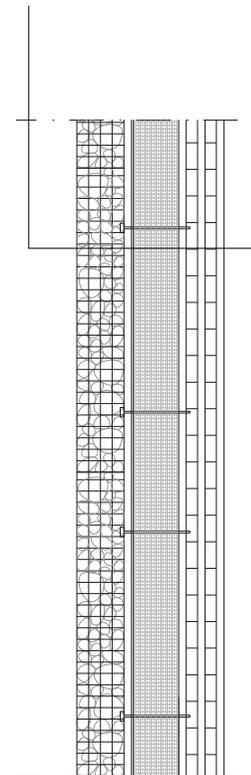
The multifunctional building will have a facade made out of gabions. Gabions are metal cages that can be filled with any given material. In this case they will be filled with crushed rock, a left-over from the local mining industry. The gabions are placed outside of the walls and

are stabilized with long screws that are screwed into the CLT. The sections with doors and windows will have a wooden cladding. In that way the gabions only appear where they can be placed on the ground and support themselves.

CLT  
rigid wood fibre insulation  
vertical joists  
horizontal joists  
vertical panels



CLT  
rigid wood fibre insulation  
masonite board  
gabions



## materials



### Cross laminated timber

What: Cross laminated timber. Solid wooden boards that can be used as loadbearing structure.

Properties: Easy to assemble on site, relatively lightweight, dimensionally stable, prefabricated elements, no drying time, contribute to a pleasant interior climate with its capacity to buffer moisture, good resistance against fire and made out of renewable materials.

Lifespan: More than 100 years.

Afterwards: Reused or burned for energy recover.

Other: A more environmentally friendly option compared to other type of prefabricated elements.

More: <http://www.martinsons.se/>



### WOOD FIBRE INSULATION

What: Rigid wood fibre insulation boards.

Properties: High insulating capacity, work well as sound insulation due to their porous structure, air tight, open for diffusion which contribute to a pleasant interior climate and made out of renewable materials.

Lifespan: If not damaged, as long as the loadbearing structure.

Afterwards: If they are not damaged they can be reused otherwise they can be composted.

Other:

More: <http://www.pavatex.se/se/hem/>



### Heat-treated pine used for exterior cladding

What: Swedish pine that has been heat-treated and in that way made more durable. An environmentally friendly option to other impregnating methods.

Properties: No chemicals are used, the wood obtains a darker color and after the treatment the wood is classified as resistant (according to EN 350-2), the second highest classification.

Lifespan: Longer than untreated wood.

Afterwards: Can be composted or burned for energy recovery.

Other: The wood can be treated with linseed oil in order to keep its color. If not the wood will turn grey. The downside of this treatment is that it is more energy consuming than other treatments.

More: <http://www.heatwood.se/> or [http://www.tracentrum.se/media/10533/V%C3%A4rmebehandlat\\_tr%C3%A4.pdf](http://www.tracentrum.se/media/10533/V%C3%A4rmebehandlat_tr%C3%A4.pdf)



### GABIONS FILLED WITH CRUSHED ROCK

What: Metal cages shaped as cylinders or boxes. Can be filled with any given material. In this case they will be filled with crushed rock that was left after the local mines.

Properties: Durable, possible to modify the expression, mounted outside of the exterior walls or placed independently.

Lifespan: At least 85 years for the gabions, the stone will last forever.

Afterwards: The gabions can be reused as they are or the crushed rock can be emptied and replaced with another material.

Other: A great way of reusing materials.

More: <http://www.gabionersweden.se/start>

# roof

As hot air rises the roof has to be well insulated to reduce the heat losses and it has to be impenetrable to protect from rain, snow, sun and wind.

## COMMON

The common way of constructing a roof in wood is to use wooden roof trusses. This type of construction has the same issues as the wooden stud frame walls. It has many layers consisting of different materials and a plastic vapour barrier is needed to protect the construction from moisture problems.

## ALTERNATIVE

There are other ways of constructing a roof in wood. One is to use the same principle as with the exterior walls, i.e. cross laminated timber, CLT. The structure of the roof would then be similar to that of the walls with the CLT as load-bearing and then the rigid wood fibre insulation placed on top. As with the walls, the joists are mounted outside of the insulation with nails that go through the insulation into the CLT. Outside of the joists the roof cladding is mounted. With this type of construction it is possible to create spaces that are open up to the ridge.

## CONSIDERATIONS

The roof construction with the CLT elements will be used in the multifunctional building. With the short span of the building the construction is simplified and the spaces within the building will benefit from being open up to the ridge. For the residential building however it doesn't work as well. The span is longer and it would create a lot of space underneath the roof. The more traditional roof truss construction however could be used to create an attic, which could be used as technical room. If a similar space were to be created with CLT elements it would implicate the construction of a slab in

addition to the roof construction. This would be a more complex construction and the benefits of using the CLT would be lost. Therefore the residential building will have a roof truss construction and the attic that is created will be used for installations and technical equipment.

#### MATERIALS

The residential building will have the same cladding on the roof as it has on the facade, that is thin heat-treated pine panels. To keep the clean shape of the building the gutters will be integrated in the roof. The roof of the multifunctional building will be cladded with sedum. The

sedum help insulate the roof, will cleans the air and help to increase biodiversity as it will create a habitat for insects and birds. The sedum is mounted on top of a drainage mat that in turn is mounted on top of the sealing layer of the roof.

## materials



### VT-FILT

What: A drainage mat made out of recycled textile fibers.

Properties: Balance the water levels by draining and holding water.

Lifespan: -

Afterwards: -

Other: -

More: <http://www.vegtech.se/grona-tak--gardar---fasader/sedumtak/vt-filt/>



### SEDUM

What: Mats made out of 15 different species of sedum that are mounted on top of the sealing layer of the roof.

Properties: Grown in Sweden, plants adapted for the Swedish climate, creates a habitat for insects and birds, cleans the air, require little maintenance and help insulate the roof.

Lifespan: As long as the plants get the right amount of water, and nutrition.

Afterwards: Can be composted.

Other: It will change appearance over the seasons and years.

More: <http://www.vegtech.se/hem/>

## interior surfaces

### THE RESIDENTIAL BUILDING

The cross laminated timber, CLT, can both serve as loadbearing and interior surface. This will be used in the residential building. The CLT will be visible on the inside of the exterior walls and on top of the slab, e.i. as floor covering on the second floor. The ceilings will be clad with panels and the floor covering of the first floor will be a wooden floor. The walls and ceilings will be stained white and the floors will keep their natural colors. This is a common color scheme and it can be seen as quite neutral. With neutral surfaces it is possible for the residents to adapt their apartments with their furniture

and interior design without the need of adapting the color scheme for every new resident that moves in. Installations are avoided in the exterior walls and instead the interior walls are used for that. The interior walls are constructed with a wooden stud frame with gypsum as cladding.

Här kommer det följa ett resonemang om varför väggarna konstrueras som vanliga träregelväggar och varför gips kan tillåtas användas i vissa fall.

Installationerna kommer dras i innerväggarna för att sedan dras i installationslister längs med de massiva träelementen där det

behövs. På så sätt kan eluttag placeras ut på de massiva träelementen utan att man behöver göra urtag ur dem.

I badrummet kommer vitt kakel användas. Vitt kakel är vanligt och på många byggen beställer man för mycket kakel för att vara på den säkra sidan. Därför går det att få tag på överblivet vitt kakel i olika dimensioner (ett ställe där sådant kakel kan köpas är återbruket i Göteborg). Ett utsnitt av badrumsväggen kommer ha en mosaik av Bergslagssten. Det är egentligen slaggsten som är en restprodukt från järnframställningen. Det är stenar som har en glasartad

blå-grön hinna på sig. Dessa stenar går att hitta i högar utanför de stängda gruvorna och genom att ta in dessa som ett element i badrummet används en restprodukt som en resurs och det kan även inspirera till att använda okonventionella byggmaterial.

THE MULTIFUNCTIONAL BUILDING  
Även här kommer the massiva träelementen fungera som invändig beklädnad till väggar och tak. Golvet kommer täckas med återanvänt tegel. Det är ett tåligt material som är möjligt att återanvända och som klarar de lite hårdare förhållandena som råder i den multifunktionella

byggnaden.



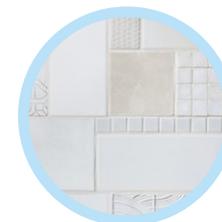
White stained wood



Cinder stones



Reused brick



White tiles

## c2c inspired goals

Many of the C2C inspired solutions have been seen and described in previous chapters. In this chapter each goal is examined more closely and the solutions is presented.

# renewable energy



Energy should be used thoughtfully and all energy used should come from renewable energy sources.

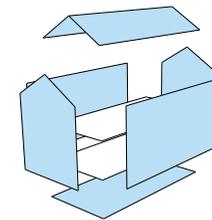
## REDUCE

Today renewable energy sources are not as efficient as other types of energy sources, like fossil fuels. In order to cover the energy demand of this site and buildings with only renewable energy the demand have to be small. The shape, construction type, amount of insulation and amount of windows all influence the demand.

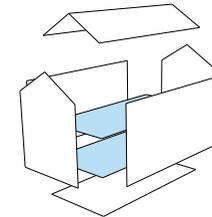
## SHAPE AND SHAPE FACTOR

The shape of the building can have a great affect on the energy demand. A non-compact shape, with a lot of angles and protruding elements, will most likely have more thermal bridges and heat losses, which will require more energy for heating. A more compact shape in contrary will have less heat losses and thus a lower energy demand.

How compact and somewhat energy efficient a shape is can be measured by the shape factor. The shape factor is the ratio of the surface area of the building divided by the heated floor area.



Surface area



Heated floor area

Shape factor =  
surface area/heated floor area

Small shape factor = little heat losses  
Big shape factor = great heat losses

The residential building has been given a quite compact shape with no protruding element and it has a shape factor of:

Surface area: 1822 m<sup>2</sup>  
Heated floor area: 808 m<sup>2</sup>  
Shape factor: 2,25

It is not an optimal shape factor and it mostly depends on the height and shape of the roof. With a lower and flat roof the shape factor would be lower.

#### WINDOWS

Windows should be placed thoughtfully. Even though the windows themselves contribute to little heat losses. The connection between the wall and windows often create thermal bridges and contribute to increased heat losses. One big window will have less perimeter than two small ones which make one big window the better option.

The amount of windows have been reduced in the residential building. Bedrooms and most living rooms have been provided with only one window but instead the size of the windows have been increased.

The rule of thumb, when it comes to passive houses (houses with no demand for heating), is that the area of all windows should be approximately 15% of the floor area (Passivhuscentrum, 2014). This applies to windows with an U-value of 0,9 W/m<sup>2</sup>K, with windows with lower U-values the window area can be increased.

The U-value of the windows used for the residential building has not been defined. But the windows should have as low U-values as is possible for windows with wooden window frames.

The residential building have a total window area of 87 m<sup>2</sup>

including the glazed openings of the stairwells. If the glazed doors would be included as well the total area of glazed parts would be 110 m<sup>2</sup>. With a floor area of 808 m<sup>2</sup> it is possible to have a glazed area of 121 m<sup>2</sup> and still meet the criteria for passive houses.

#### DEMAND

With the construction described in the material and construction section the energy demand of the residential building have been roughly calculated with the help of "Energihuskalkylen" (<http://www.energihuskalkyl.se/menus/index/23>). The whole result can be found in the appendix of

the master thesis.

The energy demand has not yet been calculated but will be done as soon as possible. A summary of the calculations will be presented here along with a short conclusion, and the rest of the calculations will follow as an appendix.

#### PRODUCTION

Photovoltaic cells and solar panels will be mounted on the roof of the residential building, on the part of the roof that is facing south. On the orangery and the glazed openings of the stairwells semi-transparent solar cells have been installed.

Den här delen ska fyllas på med hur mycket el som kan produceras och liknade. Den kommer även kompletteras med en sektion som visar energiproduktionen och energiförbrukningen.



There are a lot of ongoing research in the field of renewable energy and as new products are developed they should be incorporated on the site.

As photovoltaic cells are getting more efficient it could eventually be an idea to put photovoltaic cells on the other parts of the roofs as well.

When the wooden shutters need to be replaced they can be replaced with solar cells which would make the shutters have double purpose.

Another type of solar cells that are research right now is transparent solar cells. When they have become more

efficient and can be made completely transparent they could be a possible option for increasing the energy production on the site.

A less technical solution is to use a compost to heat water. As the compost moulders heat are generated and that heat can be used to heat water.

There are now research made on lamps that are powered by algae. They work with the help of the photosynthesis as they absorb solar radiation and consumes carbon dioxide. When it gets dark the lamps continue to glow and can work as streetlamps, a good option for a site like this, as they are powered by themselves

and clean the air by consuming carbon dioxide.

Photo: <http://www.smithsonianmag.com/innovation/can-an-algae-powered-lamp-quieten-our-thirst-for-energy-3509307/>



## site as a showcase



The site should be educational and work as an inspiration for others to start their own C2C inspired projects.

### EDUCATE

There is no requirements for the people moving here to know anything about C2C, but the expectation is that they will learn while living here. It should also be possible for visitors to learn while visiting the site.

### INSPIRE

While people learn more about C2C and different features connected to it they'll hopefully get inspired in the same time. Inspire to do even small and

simple things like adding greenery to purify and humidify the air. Working with C2C doesn't mean that everything have to change at once, it can start small and then continue to develop.

### CINDER STONES

Cinder stones are used as mosaic in the bathrooms. Not only are they a waste product they can also show the possibility of using unconventional building materials.

### TOUCH SCREENS

Touch screens are installed in the stairwells to inform the residents about the different systems on the site and for example how

much energy the site produces.

There are also two touch screens, powered by integrated solar cells, placed at each entrance to the site. They are placed so that they are accessible even for people who are not entering the site. These screens have information about what C2C is, the different systems on the site and important features that the visitors may want to know about. It is possible to have a digital tour around the site without the need of entering it.

### GABIONS

Gabions are metal cages that can be filled will essentially

whatever material that can be found close to the site. They show a good example of façades that can be made out of waste materials such as damaged bricks, soda cans or as in this case crushed rock, left-overs from the local mines.

Gabions have also been placed in the orangery, as an interior wall. The purpose is for that wall to work as thermal mass. The wall will be heated during the day while the sun shines on it. As the sun goes down and the temperature drops the rocks will start to emit heat and the wall will work as a radiator.

#### THE MULTIFUNCTIONAL BUILDING

The purpose of the workshop and reuse room is to reduce the amount of items and materials that are wasted, but also to teach and inspire the residents and visitors of how to reuse them.

The workshop is not only meant for residents that already know how to mend broken things or build things out of reused materials. The goal is that the workshop are used by all residents and that they teach each other how to utilize items they already have and make the best out of them.

The reuse room are meant to show the residents the amount of useful things that are thrown away and make them appreciate the things they own.

#### SEMITRANSSPARENT SOLAR CELLS

Semitransparent solar cells are installed on parts of the orangery and on the glazed openings of the stairwells. An inspiring example of new possibilities in the field of renewable energy.

## waste as a resource



When materials or elements are no longer needed they should go back into the technical or biological cycle and become a resource for new products.

### THE REUSE ROOM

Instead of throwing away items that are not used anymore the residents can place them in the reuse room, located in the multifunctional building. In that way someone else can make use of them, either by using them as they are or alter them to fit their needs. It could be a piece of furniture that is outdated but with some paint and other alterations looks like new again.

### CO<sub>2</sub>

Carbon dioxide is often seen as a waste product, a bad substance and something that should be avoided. It is a greenhouse gas and it contributes the greenhouse effect. Therefore the amount that is released should be limited. Working with C2C however implicates that CO<sub>2</sub> should be seen as a resource, and the best way to utilize CO<sub>2</sub> is to cultivate and let plants and greenery use it as a nutrient. Plants and greenery are therefore important features in the design.

### SEPARATING TOILETS

By installing separating toilets urine and feces can be used

as a resource. As the two are separated the urine can be used as fertilizer and the feces as biofuel. In this way they are no longer just human waste but a resource.

### FROM THE MINES

Nora was established because of the mines that was located in Bergslagen. Without the mines Nora would probably not have grown to the size it has today. The mines have been closed for about 100 years but their remains are still there.

Crushed rock is one of the remains. This rock was mined but never processed because of their low iron content. The rock were placed in piles outside of the mines and as time passed the piles grew larger and larger. Today these piles look more like hills. The intention is to use this

rock, which is a waste product, in the project. The rock will be put into gabions which will be placed along the exterior walls of the workshop as cladding. In this way a beautiful facade will be created, a waste product is used as a resource and a bit of history is brought back into town.



Another waste product of the mining industry is the cinder stones. The cinder stones can also be called Bergslagssten, a name they got from being a common material in Bergslagen due to the mines there. They look like stones that have been coated with a blue-green glazing. Cinder stones are a waste product from the manufacturing of iron and the blast furnaces. For hundreds of years it was used for masonry either in the irregular shape they had or in the shape of bricks. Buildings with façades made out of cinder stones may still be found in Bergslagen. As the manufacturing process of iron was changed the structure of the

cinder stones were changed and they were no longer suitable as a building material.

Pieces of cinder stones may still be found in the piles outside of the closed mines and the intention is to use them as mosaic on certain parts of the bathroom walls.



As the materials on the site are replaced they should be replaced by materials that is known to be reusable or easily returned to the biological or technical cycle. That might not be true for the materials used today but with every replacement the site should be improved.



A compost which can produce nutrient soil out of the residents' food waste should be established as soon as the residents agree on where it best fits.

## enhance air quality



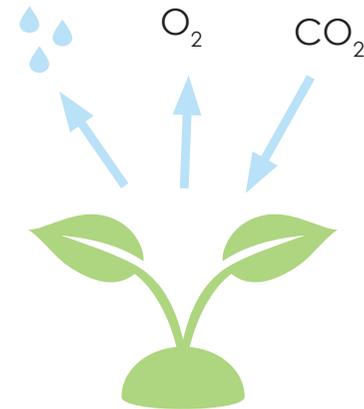
Both the inside and outside air quality should be considered. The outside air should be cleaner after the construction of the buildings than it is today and the inside air should be healthier than the air in an average home.

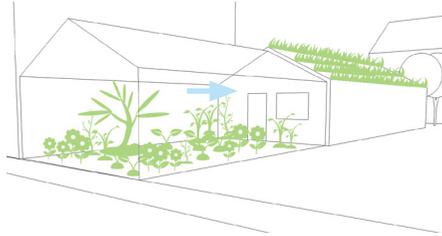
### MATERIALS

Building materials, furniture and stuff can emit harmful substances. Choosing natural and renewable building materials reduce that risk. The timber walls and wood fibre insulation are natural materials that don't emit harmful substances and will help to regulate the air humidity.

### PLANTS AS NATURAL PURIFIERS

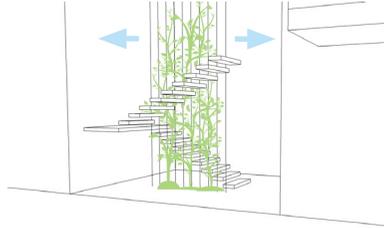
Plants and greenery are natural air humidifiers and purifiers. They purify the air by absorbing carbon dioxide ( $\text{CO}_2$ ) and other chemical substances. By the photosynthesis the  $\text{CO}_2$  is used as a nutrient for the plants and oxygen ( $\text{O}_2$ ) is released into the air. The plants also contribute to an improved air quality by humidifying the air.



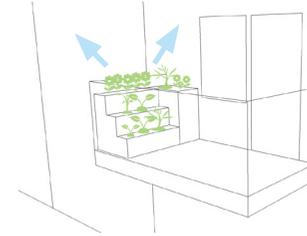


### GREEN LUNGS

The orangery is full of plants which will provide healthy air to the workshop and reuse room. The air is led through the orangery which will purify and preheat it. The sedum on roof of the workshop is not only beautiful it will also clean the air and insulate the roof.



The stairwells are equipped with wires which plants can cling to as they grow. As time passes the plants will grow and the stairwells will become green lungs, which will provide healthy and fresh air. The air can seep into the apartments and improve the interior climate.

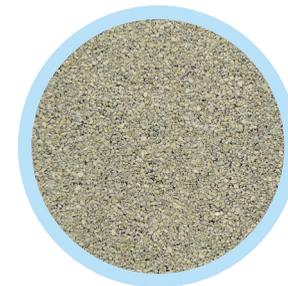


On the site and around the buildings greenery and plants are added. The residents are encouraged to cultivate on their balconies with the help of boxes that have been provided solely for that purpose.



The residents will have learned more about the C2C principles and understand the importance of choosing appropriate furniture, materials and items that they bring into their apartments. By making appropriate choices and adding more greenery into their homes the residents will continuously contribute to improve the air quality.

Materials are developed and improved continuously. There are already roof membrane that with the help of the sun extract harmful nitrogen oxides from the air and convert them into harmless nitrate (Icopal, n.d.). As materials need to be replaced they should be replaced by materials like this, that help to improve the quality of the air.



Air purifying roof membrane.

# water recycling



Water should be seen as a valuable resource and be managed on the site.

## SEPARATING TOILETS

By installing separating toilets the strain on the waste water treatment plants can be reduced. The separating toilets separates urine from feces and makes it possible to use human waste as a resource. Urine can be used as a fertilizer while feces can be used as biofuel. In this way less water is polluted and no chemicals are needed for treating polluted water coming from the toilets. The toilets look like ordinary toilets with the difference that they have two

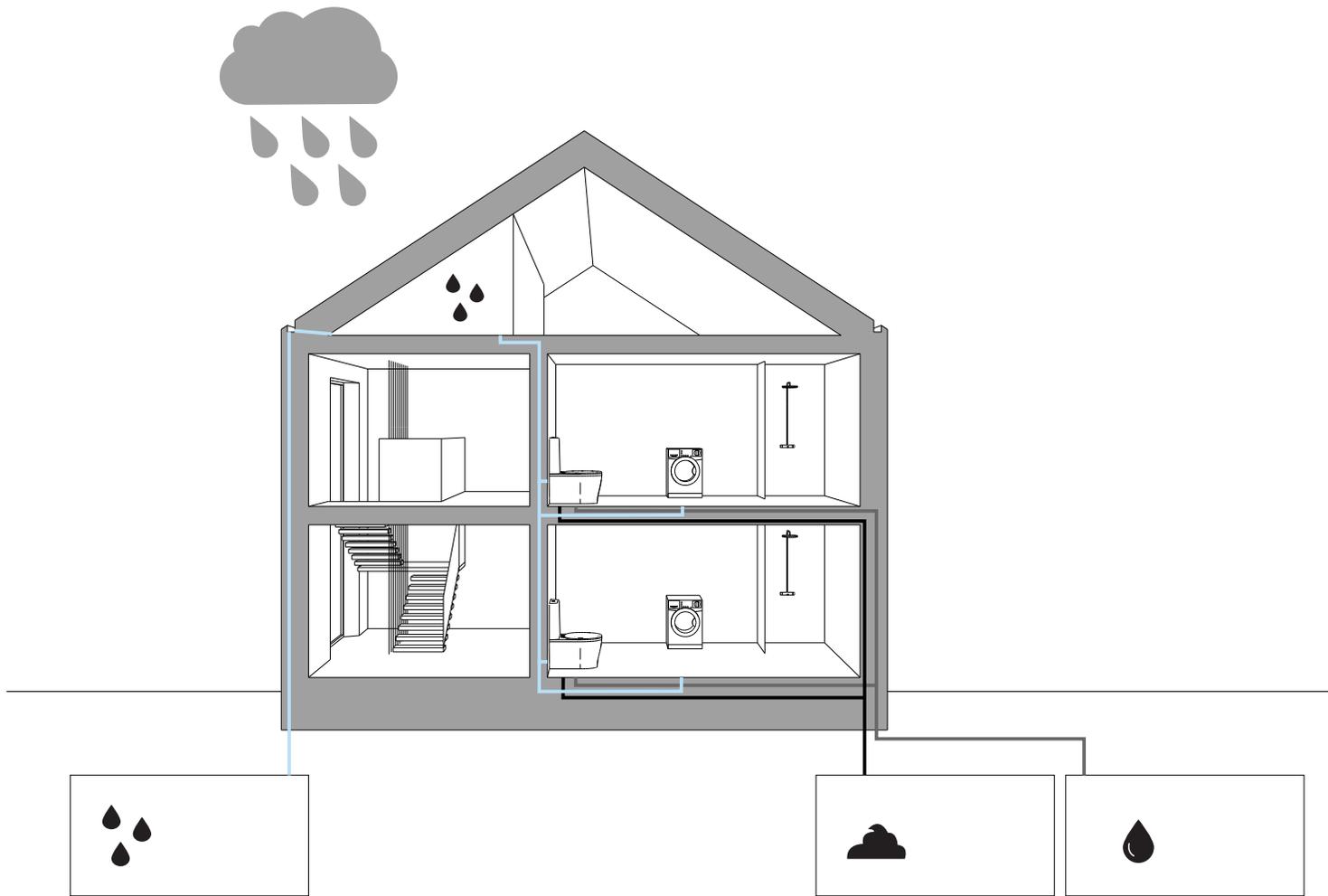
separate compartments for urine and feces. The two are stored in tanks under ground before they are collected and transported away for utilization.

## RAINWATER

In Sweden we get a lot of rain and in Nora they get 700-800 mm of rain annually. A lot of rain can cause problems but the rain can also be a resource. By collecting the rainwater, filter it and store it in tanks it can be used for flushing toilets or water plants. It is even possible to run the washing machine with rainwater once it has been filtered.

Rainwater will be collected from the roof of the residential building and stored in two tanks. The smaller tank is located in the attic and the bigger under ground. The smaller tank will be used at first-hand and by its location on the attic no pump will be needed to transport the water to the apartments. Gravity will be the driving force and energy will be saved. The small tank will be filled first but during drier periods it might be drained then the bigger tank can be used. If both tanks are drained water from the grid will be used.

Rainwater will also be collected from the roof of the



multifunctional building. A tank will be placed in the orangery and with a tap the water can be used directly to water the plants.

How much rainwater could be collected and what could it cover?

Nora have a precipitation of 700-800 mm each year. The roof of the residential building is 450 m<sup>2</sup>. The amount of water that could be collected is then 315-360 m<sup>3</sup>, which is 315 000-360 000 liters per year.

That would cover 78 750-90 000 toilet flushes (4 liters each) or 6 300-7 200 washing machines

(50 liters each). Estimated per apartment they could run 1 washing machine and flush the toilet 9 times each day.

The roof of the multifunctional building is 140 m<sup>2</sup> which means that about 98-112 m<sup>3</sup>, which is 98 000-112 000 liters, of water could be collected each year.

The amount of water needed to water plants are about 30 liters per m<sup>2</sup> and week. The orangery is about 45 m<sup>2</sup> big, if it would all be covered by plants the demand would be about 1 400 liters annually. Therefore it might be good to lead some of the water to a tank outside of the building

so that it could be used for the greenery on the site as well.



With the help of plants it is possible to naturally purify greywater. Greywater is all waste water that comes from a building except the waste water from the toilets. If enough space could be made available a purification system like that would be a really good way of enhancing the water treatment further.



# Conclusion

- can a building really be built like a tree?

# conclusion

It is not possible to build a building like a tree today but one can come far. It is possible to plant a seed and see it grow, and maybe in the future it will grow into a tree.

In order for the tree to evolve, the building industry has to change. Making the building industry understand that the C2C strategy is beneficial not only for the environment but for them as well is key. C2C inspired buildings don't have to be more expensive than other types of buildings. They do not have to be more complicated to build either. On the contrary, a C2C inspired building can be both cheaper

and less complicated to build.

Even without a changed industry one can come further in the quest of building a building like a tree. The key is to simplify. Find the most simple solution and work with natural and healthy materials. Since a C2C inspired building is evolving over time the tree doesn't have to be built all at once, it can start as a seed that evolves into a plant and then maybe some day a tree.

# to consider

A summary of what to consider when attempting to build a building like a tree.

## DISASSEMBLE

Details should be simplified and all elements should have as few materials and layers as possible.

## ENERGY

The energy consumption should be reduced in the same time as the production of renewable energy should be increased. There are a lot of research made in this field right now.

## MATERIALS

The material choices should be considered thoroughly. Can the

materials be returned to the cycles? Are they harmless to humans and nature?

## PLANTS

Plants are natural air humidifiers and purifiers. They are also beautiful and contribute to a more pleasant atmosphere.

## SHAPE FACTOR

The ratio of the surface area of the building divided by the heated floor area. Small shape factor = little heat losses.

## TIME

There might not be a perfect solution to all problems today, but as a tree the building can

continue to evolve and improve.

## WASTE

Before discarding something like waste it should be considered a resource.

## WATER

Water is a valuable resource and it should be used thoughtfully, even in a country like Sweden.

## WINDOWS

The insertion of windows involve complex details that are both problematic from a C2C and a energy point of view. Few big windows is better than many small ones.

## reflections

Working with this master thesis have been both more exhausting, interesting and fun than I thought it would be. It has been exhausting in the sense that there are so much to learn and so little time to learn everything that I want to learn. I feel like I have only scratched the surface and I want to know more. The things that have been interesting is everything that I have learned. From the history of Nora, a town which I have spent a lot of time in but now gotten another understanding for, to all the information I have found about different constructions and materials. The fun part is the proposal itself. To see how all my

findings are merged together and how a building and site emerge upon them.

I think that my work cover a lot of different aspects. The range of the master thesis is a bit too big for me to solve everything as good as I would have liked to. In retrospect it might have had been better to concentrate on one or two more specific aspect rather than scratching the surface of many. However C2C is a holistic approach and it could be hard to leave something out. The part I have found most interesting and where I feel like there are a lot of more

research to be done is the part about materials and construction. Trying to do something new in an industry that like things to be done as they always have been is difficult. The constructive solutions that are presented are far from done and I could and would have liked to spend more time on the details.

Overall I think that my work have a solid base and that most decisions are grounded in the research I have made. I would have liked to come further with the material research, the goal of making the site a showcase of C2C principles and also the implementation of water

treatments, other renewable energy sources and more innovative materials.

Moving forward into my professional career I hope that I will have the opportunity to continue to work with C2C. If not expressed explicitly I still hope to work with the same type of questions. Looking at materials, different systems and how a building is not only designed for today but for the future and the possibility of being transformed as the needs and conditions are changed.

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