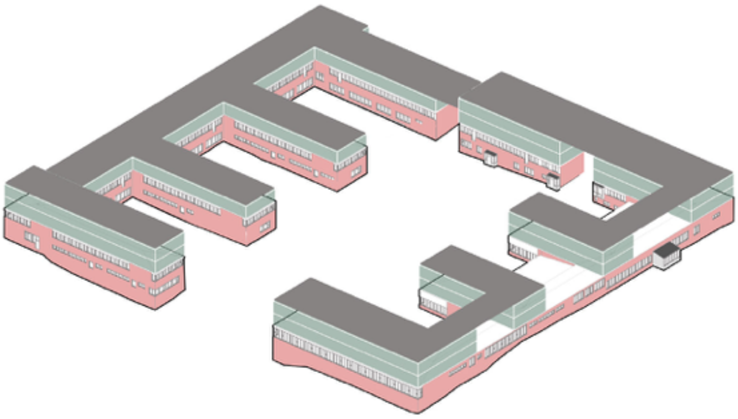
DENSIFICATION THROUGH TRANSFORMATION

A transformation of a former school into a sustainable mixed-use residential block



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Publication year: 2024
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CHALMERS
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Profile: Building Design and Transformation for Sustainability
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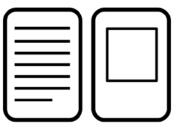
Reading instructions for this thesis
The thesis is best read when viewed as a double page spread



Abstract

In recent years, Sweden has experienced a significant housing shortage, driven by a growing population and a lack of affordable apartments. To address this, major cities are undergoing inward expansion within the relatively sparsely built Swedish cities, commonly referred to as urban densification.

The purpose of this thesis is to design dense low-scale urban densification through the transformation of a former school, as opposed to demolition and new construction. The focus is on Tynneredsskolan, a school in western Gothenburg scheduled for demolition and replacement with residential buildings. This approach aligns with the current densification trends in western Gothenburg, where schools are often demolished and replaced with densely built residential areas. This practice is part of a larger wave of demolitions across the country, where fully functional buildings are demolished instead of being transformed.

The aim is to create a healthy and sustainable residential project using research by design as a starting point and to understand the causes and consequences of urban densification on a neighborhood scale. Previous research suggests that profit-driven urban development may negatively impact well-being and indoor climate, resulting in issues such as inadequate natural daylight in apartments, compromised privacy, and low-quality outdoor common green spaces.

The transformation proposal primarily focuses on adapting the residential layout to the existing structure, ensuring good daylight, and maintaining residents' privacy. A comparison is made through an life-cycle analysis (LCA) between the transformed school and conventional multi-family buildings that have replaced former school sites. The proposal demonstrates how an already built, function-specific structure with good architectural qualities can be transformed with positive results on multiple scales. The LCA shows that there are environmental gains to make by transforming the existing school instead of demolishing it, but it also comes with challenges.

Another conclusion is that there needs to be a reevaluation of existing buildings currently deemed not valuable, as it is not sustainable to continue with the trend of unnecessary demolitions.

Keywords: transformation, LCA, residential, urban densification

Author

Having studied in different countries allowed me to get broader perspectives and understanding of architecture in different places, scales and climates. The master program also gave me an opportunity to work to explore and expand my knowledge within LCA and transformations

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INTRODUCTION

01

Problem statement

what is happening?

Nearly 36 million tons of waste was generated in Sweden in 2020, and according to the Swedish Environmental Protection Agency, the building sector stands for nearly 40% of the total waste. Between 2014 and 2020, the amount of waste from the building sector increased with 5,3 million, which is an increase of 60% (Naturvårdsverket, n.d.)

There are no national statistics regarding demolitions, nor a category of buildings being demolished, except for residential dwellings in multi-family housing. From that data we can see that most of the buildings that were demolished in 2022 were built in the years 1961-1970 (SCB, 2023d). The statistics, however, do not state the causes of demolition. A similar trend can be seen in Europe, despite new regulations and initiatives. Even newer buildings are being demolished and replaced with something allegedly better (Haselsteiner et al, 2023).

why is it happening?

One of the driving forces behind the demolitions is the national housing crisis. Boverket, the Swedish National Board of Housing, Building and Planning estimates that there is a need of 67,300 new housing units per year until 2030. However, the most concerning aspect is that the existing housing shortage, which is already significant, may worsen due to a stagnant housing construction industry and a growing population (Boverket, 2023a).

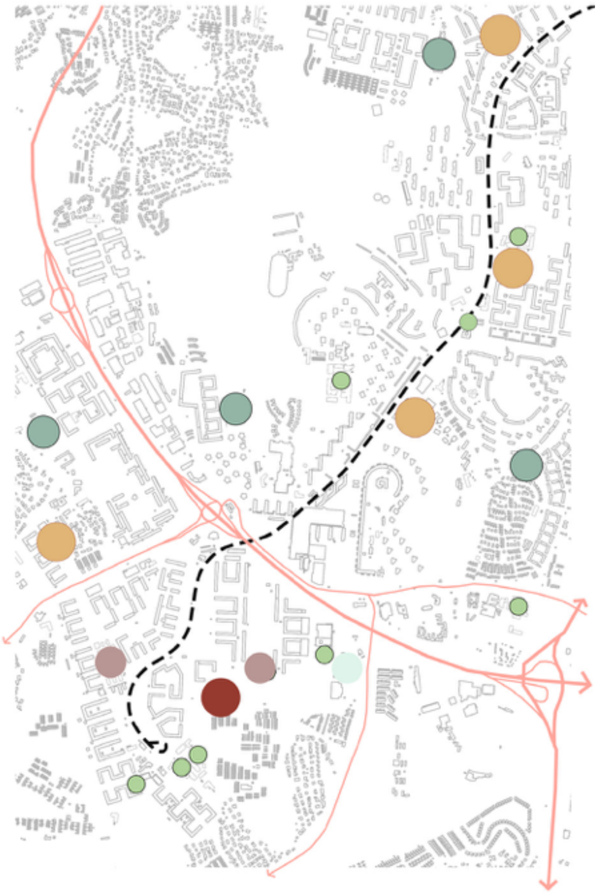
According to Lone-Pia Bach, professor at the Royal Art Institute of Stockholm, the current wave of demolitions is driven by both political and economic incentives, in a bid to create high levels of comfort and an industrialized building sector that lacks resources and knowledge in transformation. In addition to that, many architects think of sustainability through new constructions rather than taking care of what's already existing (Zawieja, 2022).

Other common reasons to justify demolitions include, but are not limited to:

- Expensive renovation costs
- Buildings not fit for the current use
- A desire for increased space efficiency - aiming to generate more square meters to boost profitability during sales or rentals (Norwegian Green Building Council, 2019).
- Reach of final technical age - where developers prefer to demolish a building in order to have a "fresh" start and free hands over the design of the new building, its program layout (Baker et al, 2021).
- Transformation comes with less advantages on property taxes than to demolish and build new structures (Boverket, 2021)
- Structures is in a disrepair

Figure 01. Densifying Gothenburg
Photographer: Author

where is it happening?



Tynneredsskolan

Demolished and replaced with residential housing

Will be demolished and rebuilt

Have been demolished and rebuilt

Existing schools, no plan for demolition

New school planned to be built

Tram railroad

Figure 02. Diagram showing the demolished schools that have been replaced with residential areas. Most of them are located near the tram network in southwestern Gothenburg, an efficient mode of transportation in the city. Several other school buildings will in the coming years be demolished and replaced with new school buildings on the same site. The reasons vary, but are similar: deemed not suitable for pedagogic uses, reach of technical age or having issues with the indoor climate.

The schools mapped are both public and private. All of the demolished ones have been public schools.

One way of coping with the housing crisis is to densify the already built cities, a practice occurring all over Sweden, but more specifically in the larger urban areas, including in Gothenburg. The municipality is prioritizing constructing within the city; parking lots, green pockets, and buildings are being replaced in order to make room for new (and often taller) buildings. Urban densification can be good in terms of increasing the efficiency of public services and infrastructures, or to support commercial services.

Municipalities, developers, and buyers are making profits from the densification, but it is important to mention that we are also losing important qualities. Smaller and shadowed courtyards and decreasing green areas, less natural daylight qualities and smaller, more expensive apartments are a common result of densification. Ola Nylander, professor at the University of Chalmers, points out that the 2010's is the first decade where we actually built worse housing units than in previous decades (Caldenby & Nylander, 2020).

The development in western Gothenburg during the last 10-15 years has partly been made on sites formerly being educational premises. Four schools in total have been demolished and replaced with highly densified residential urban fabric, and more schools are planned to be demolished and replaced with housing, including the subject of this thesis, Tynneredsskolan. School premises are often quite large and strategically located within the district.

The municipality of Gothenburg itself mentions in the comprehensive plan of the city that there will be "urban planning dilemmas", sometimes at the general level, but also at site-specific levels. They include the challenge of maintaining nature and cultural values of the city at a time when the city is growing and demands spaces for other uses. Meanwhile, they also mention that they are looking for new solutions. Could transformation instead of demolition be one of them?

Figure 03. Picture of Högsboskolan being demolished in 2013. Photographer Markus Andersson/Tidningen i Väster

Research questions

How could a sustainable transformation instead of demolition of Tynneredsskolan lead to a more sustainable urban densification?

-How have former educational premises in western Gothenburg been developed, and what can we learn from them?

Aim

The general aim is to provide knowledge, and evaluating several aspects related to urban densification that comes from the already existing structures. How can we better incorporate and understand the buildings on the site, and from there densify with positive results both at the building scale and the urban scale.

Another important aspect is to demonstrate the opportunities that emerge with a sustainable transformation, to show that we do not need to demolish exiting buildings in order to get good results, and that they can be as energetically and environmentally friendly as new sustainable buildings, if not better.

Delimitations

- The thesis will only partly take into consideration the future plan of the neighborhood with the exception of the plot of the school.
- This thesis will not express on how to generally solve all problems related with densification or transformations; it is place specific and will express one solution out of many solutions.
- The safety bunkers under the school will be considered, but not the culverts.
- Geological conditions of the site will not be considered.
- Asbestos is likely to exist in some parts of the structure, such as around some windows and in parts of the structure of the roof. It will be mentioned but not be considered fully in this thesis since the decontamination can be carried out without affecting the architectural solution of the project.
- All the numbers and values, such as the loadbearing capacity of the existing structure, are based on estimations. There have not been any calculations or collaboration with structural engineers.
- The proposal will only cover a part of the building, which could be seen as representative for the structure as a whole. That part of the building will be focused on residential housing.
- Life-cycle models and analyses are scenarios and simplifications of reality. They should only be seen as guiding tools and not absolute numbers.

Methods & Processes

This thesis will include a multi-scale approach of Research by design and research for design. There will be both quantitative and qualitative evaluations. The overall method can be divided into the following methods:

Theoretical research
Study of literature, reports, and scientific research on relevant topics, such as density, adaptive reuse & transformation, housing & population, and passive design strategies. These topics will make the reader relate to and understand why architects need to practice transformation as a one of our tools for lowering our emissions in a world with an increasing urban population.

Research for design
This includes a site and context analysis of Tynneredsskolan, including a building quality assessment on matters of structure, construction, spatiality, and climatic solutions. The future plans of the surroundings will also be consulted.

Research by design
Experimentation and comparison with a life-cycle assessment tool called CAALA (Computer Aided Architectural Life-cycle Assessment) and design & volumetric experimentation on how and where to place the future extensions. There will also a daylight and overheating assessment. Additionally, case studies will be included and analyzed, focusing on transformation projects, densification examples and apartment layouts.

The CAALA will give values regarding Primary Energy Demand (PED) and the Global Warming Potential (GWP), with the emissions counted in CO_2-equivalents. Those will be fundamental in understanding the ecological footprint of the extensions. This will be done with the author comparing a transformation of Tynneredsskolan with two low-energy multi-family buildings of similar size.

Daylight will be analyzed using Velux software and more specifically focus on the daylight factor (DF). The daylight factor is a percentual measurement measuring the amount of daylight within a space during a cast day.

The evaluation criterias will be further expanded in the theory chapter.

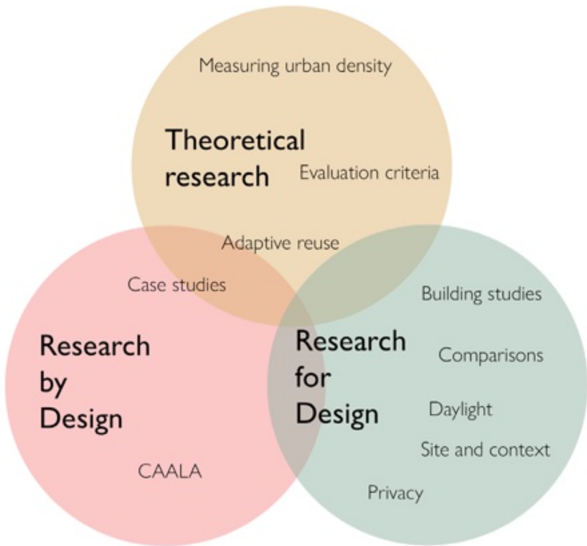


Figure 04. How this thesis will combine differnt methods

BACKGROUND

Picture of a street in Högsbo, Gothenburg

02

Swedish Population and Housing Development

The Swedish population has increased from 8,6 million inhabitants in 1990 to 10,5 million in 2022. Despite that, Sweden remains one of the least populated countries in Europe with a population density of 25,8 inhabitants per square kilometer (SCB). The number of households are 4,8 million, up from 3,9 million in in 1990. The most common household, single household, stands for 40% of all households, followed by single-parent with children (24%) and couples with children (21%) (SCB, 2023)

The economic recession in Sweden in the 1990's resulted in a low number of building constructions. Housing developers saw no need in building new projects, and there were plenty of assets available on the housing market. Around 12.000 residential units were built across the country during those years. The number later increased to 30.000 units in 2007-2008, and then decreasing again in 2009-2010 due to the financial crisis. The production increased rapidly again after the crisis. Low unemployment, low interest rates, higher wages and a growing stock market contributed to a better household economy. People could now afford buying and investing in housing investments. A building boom was initiated, with levels reaching similar to those in the 1980's (Nylander, 2018).

According to Boverket, there is a need for 67.000 residential units during the years 2021-2030 in order to meet the housing demands. It may be difficult to reach those levels due to the current economic situation. Increasing household expendiures, tripled housing interest rates, sharply increased construction costs and less investments lead to a very rapid decline in housing construction. The estimation is that 40.000 units and 25.000 units will be built in 2024 and 2025 respectively (Boverket, 2023a).

The situation is the worst in the major cities, including Gothenburg. The municipality reported on Boverket's housing market survey in 2023 that there is a deficit. This includes a deficit on large units, small units, and apartments with a reasonable rent. There are several reasons for that, including rising building costs and difficulties for developers to secure a financing. There is also a particular need for three- and four-bedroom apartments (Boverket, 2023b). The municipality estimates that 4000-5000 units are needed yearly. Around half of the new residential units in the city are rental apartments, and the most common apartments are the two-bedroom apartments (41%) and one-bedroom apartments (25%) (Göteborgs stad, 2023).

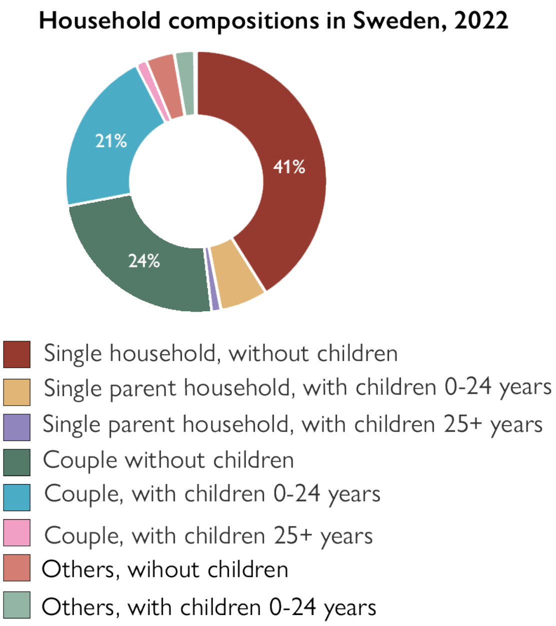


Figure 05. Household compositions in Sweden 2022. More than 40% of the Swedish households consist of a single household, which is almost the same as couples without children and single-parent households combined. This graph shows that there is a need for different sizes of residential units, but with a focus of housing for the growing single household category.
Source: Statistics Sweden

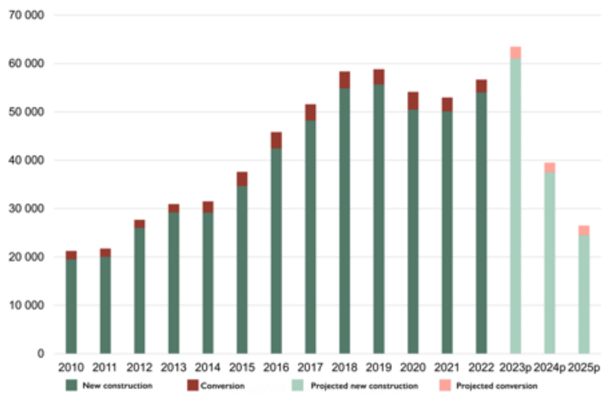


Figure 06. Chart about the estimated units being buillt. The figure shows the projected rapid decline in constructed units from 2024. The conversions also decrease, which numbered roughly 2500 in 2022. How come the conversions, that are cheaper in general compared to new constructions, do not increase in times of uncertainty?
Source: Boverket

Swedish housing development in the 1960-70's: Miljonprogrammet

Around one fifth of the current housing stock in the country was built during the "Million programme" (MHP), which spanned from 1965-1974 when one million residential units were built. This was a result of the government investing in a massive renting-housing development throughout the country in order to battle the housing shortage (Boverket, 2020).

Housing, welfare and public service were developing in a large scale, and the expansion of the highways and separation between cars and pedestrians allowed for the construction the new large-scale suburbs. The cities were also zoned and separated in single-use areas, and housing quality was high compared to earlier constructions (Björk et al, 2012). The new suburbs were usually built on farmlands near the city centers, but large areas within the cities were also demolished and replaced with new buildings (Verkasalo & Hirvonen, 2017).

Many people usually associate the MHP buildings with concrete highrises although the most common typology was the three-storey apartment block. There were also reactions to this, since many people also desired to live in villas and other small-scale housing, which constituted to a significant part of the new housing stock in the 1970's (Björk et al, 2012).

Despite the good housing qualities, many with rational plans, MHP areas were criticized due to the high exploitation and density. People also complained that the rents were too high, bad service and poorly designed outdoor environments. Some areas early became unattractive in the housing market (Boverket, 2020). Some of the housing stock were demolished in the 1990's and early 2000's due to the surplus number of dwellings, financial crisis and difficulties renting them out (Björk et al, 2012). Today, many of the buildings built during this era are in need of renovation.

Districts in Gothenburg built during this era inlcudes Frölunda, Tynnered, Angered, Biskopsgården and Backa.

Figure 07. Opaltorget, typical Million House Programme in Tynnered. Photographer: AB Flygtrafik/ Vänersborgs museum

Figure 08. View over Frölunda, built during the 1960's Photographer: AB Flygtrafik/ Vänersborgs museum

Densification in Gothenburg

There are several factors that drive the densification in Sweden's urban areas: population growth, housing shortages, and urban sprawl. Densification, building within the city, aims to counteract these issues by reducing car dependence, preserving natural land, and promoting sustainability through shorter travel distances and improved public transport. The municipalities' comprehensive plans use densification as a tool to connect districts, reduce segregation, and enhance security. Isolated densification pockets fill gaps in the urban fabric. Many municipalities also aim to attract residents and visitors in order to improve the foundations for services and cultural offerings (Boverket, 2016).

Gothenburg is a growing city, and passed 600.000 inhabitants in may 2023, and the forecast shows that the population will be 700.000 in 15 years (Göteborgs stad, 2023b). The municipal comprehensive plan states that the city must be more dense for the citizens to have a services and public transportation within walking distance. starting point. The densification should also be made with sustainability in mind, with a starting point on a "dense, green mixed city by supplementing the built environment". This will be made together with construction in "strategic nodes" (Översiktsplan Göteborg, n.d.).

The city is divided into three categories; the inner city, the middle city and the outer city. The middle city, in which western Gothenburg and Tynnered are included, is set to have a relative high density in order to maintain a high level of service. Strategic hubs, like Frölunda Torg, are important in terms of public transportation, culture and commercial activities.

The general guidelines for the middle city include a mix of housing types and typologies, public spaces and meeting points. High level of density near the strategic hubs and replacing parking lots with new structures and the creation of "city-life". Other aims are to also create better connections between the districts, secure green areas for recreation and to protect cultural heritage.

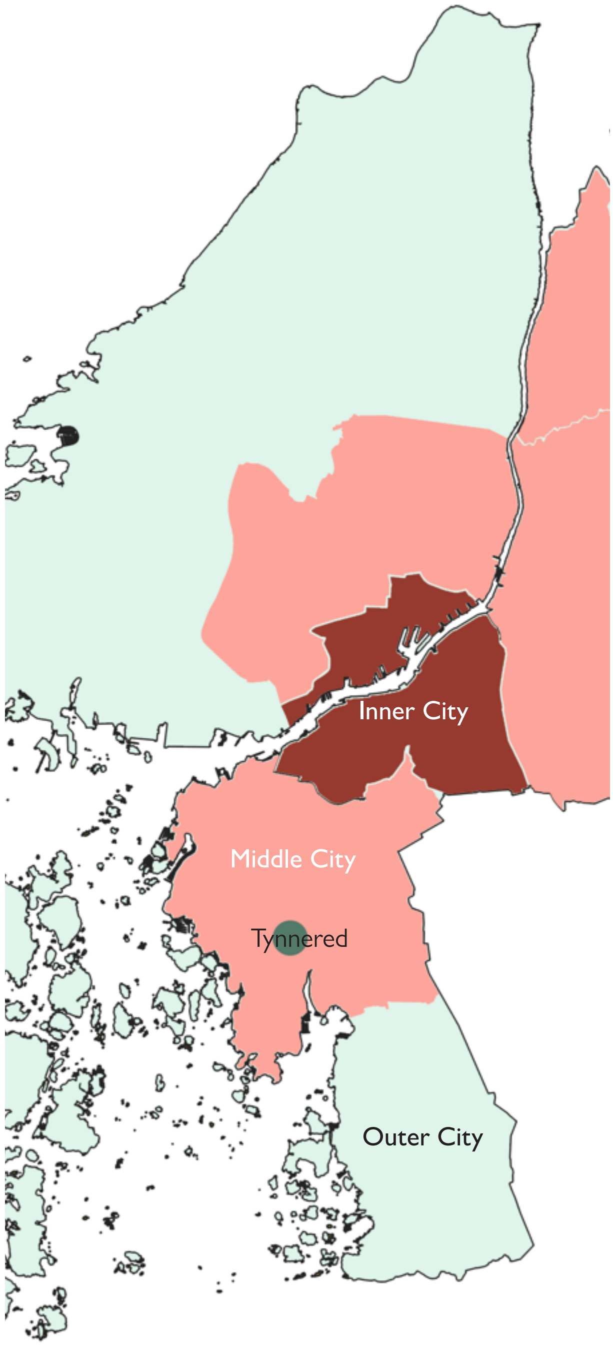


Figure 09. The three urban categories of Gothenburg. Source: Göteborgs stad, redrawn by author

Tynnered

DISTRICT

The urban fabric of Tynnered and Frölunda was mainly shaped during the 1960's and -70's and is a typical example of Miljonprogram-areas that are common all over Sweden. The zoning has historically been strict with clear distinction between residential, commercial, and industrial areas. Multi-family housing blocks is the dominant typology and is centered around Frölunda Torg and along the tramlines. The buildings to the west, north and east of Frölunda Torg are between 8-17 stories high, while the areas to the south, in Tynnered, are 3-5 stories high.

The district is characterized by the geography, which is mainly low hills and valleys. Denser built areas tend to be in the valleys. Many of the buildings also adapt to the topography that they are built on.

The district map to the left shows Tynneredsskolan and its property, which also includes Ängåsskolan and a temporary pre-school, is in relation to its surroundings. The school is placed between different building typologies, ranging from rowhouses to the south, and a mix of public and privately owned apartments in the other directions. The school itself is placed on a hill with views of the surroundings.

Frölunda Torg , one of the largest malls in Gothenburg and the main transportation hub for western Gothenburg, is not located far away. Opaltorget, another smaller, more local hub is a short walking distance away. Both centers contain shops, supermarkets pharmacies, restaurants, among others. Culture centers can be found at Frölunda Kulturhus, just next to the mall, and a library at Opaltorget. There are several schools and pre-schools in the area, both public and private. Greenery in the district, with parks and nature reserves. Sport facilities include a Basketball stadium and Välen Sport facility, both located at Näsetvägen.

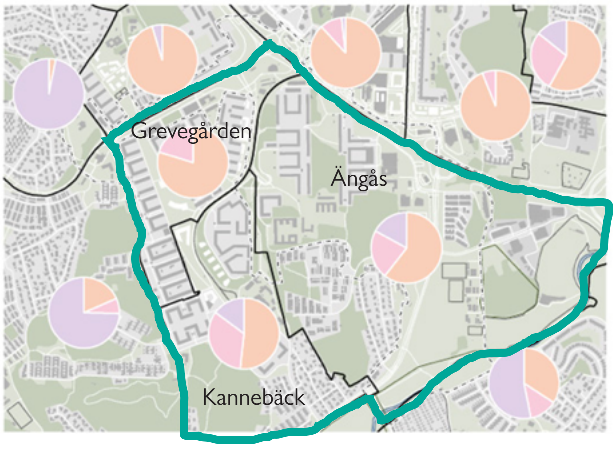


Figure 10. Circle diagrams showing the type of ownership in municipal designated base areas (black boundaries). In the base area where the school is located (Ängås), and in the other two marked within the green line (Kannebäck and Grevegården), a majority of the units are rental units. A large portion och owned apartments can be found in Kannebäck. A signifcant part of the units in Ängås are property owned. Source: Program för Tynnered, 2022

Figure 11. Screenshot from Google Earth showcasing the the typography, greenery and urban context of Tynnered

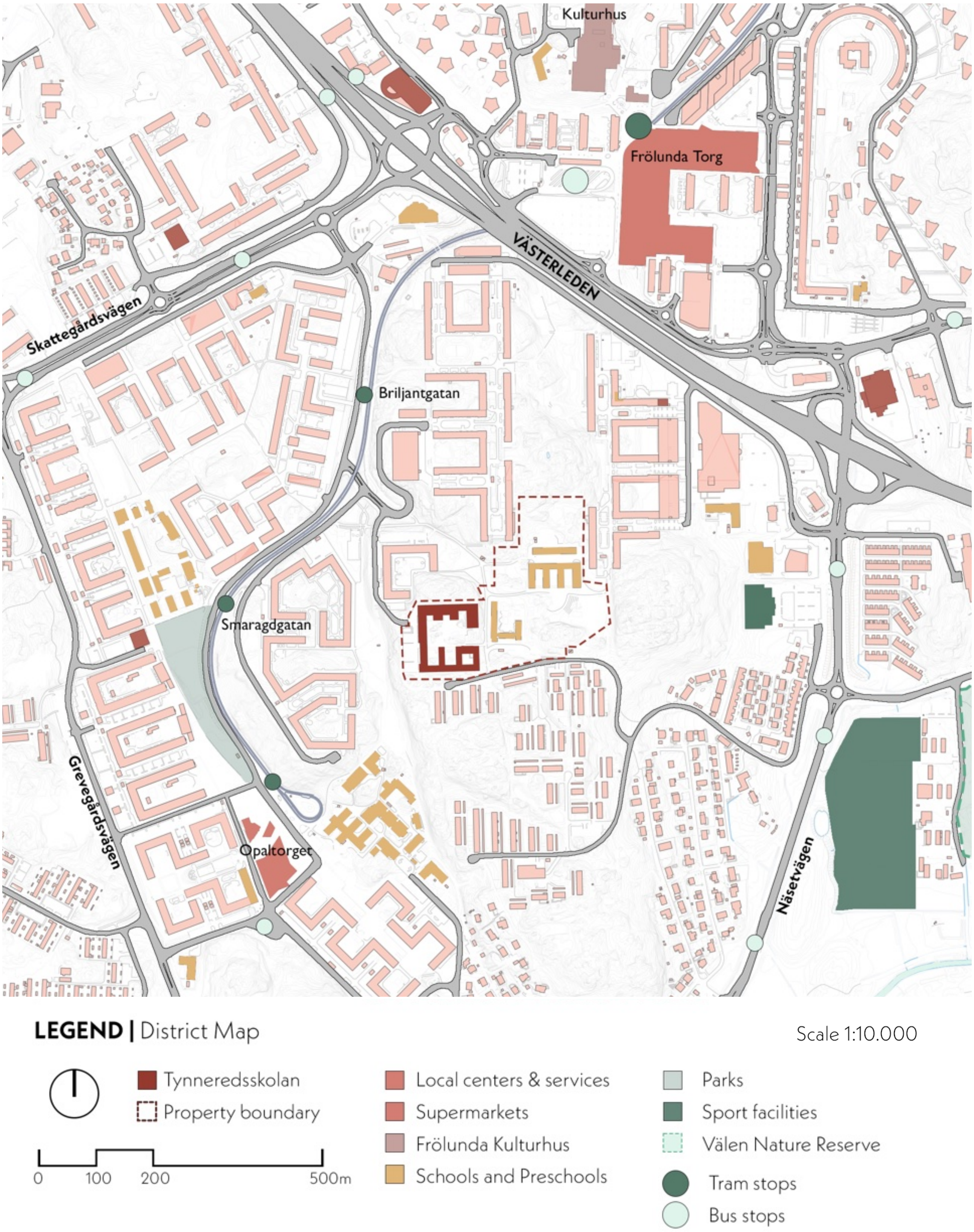
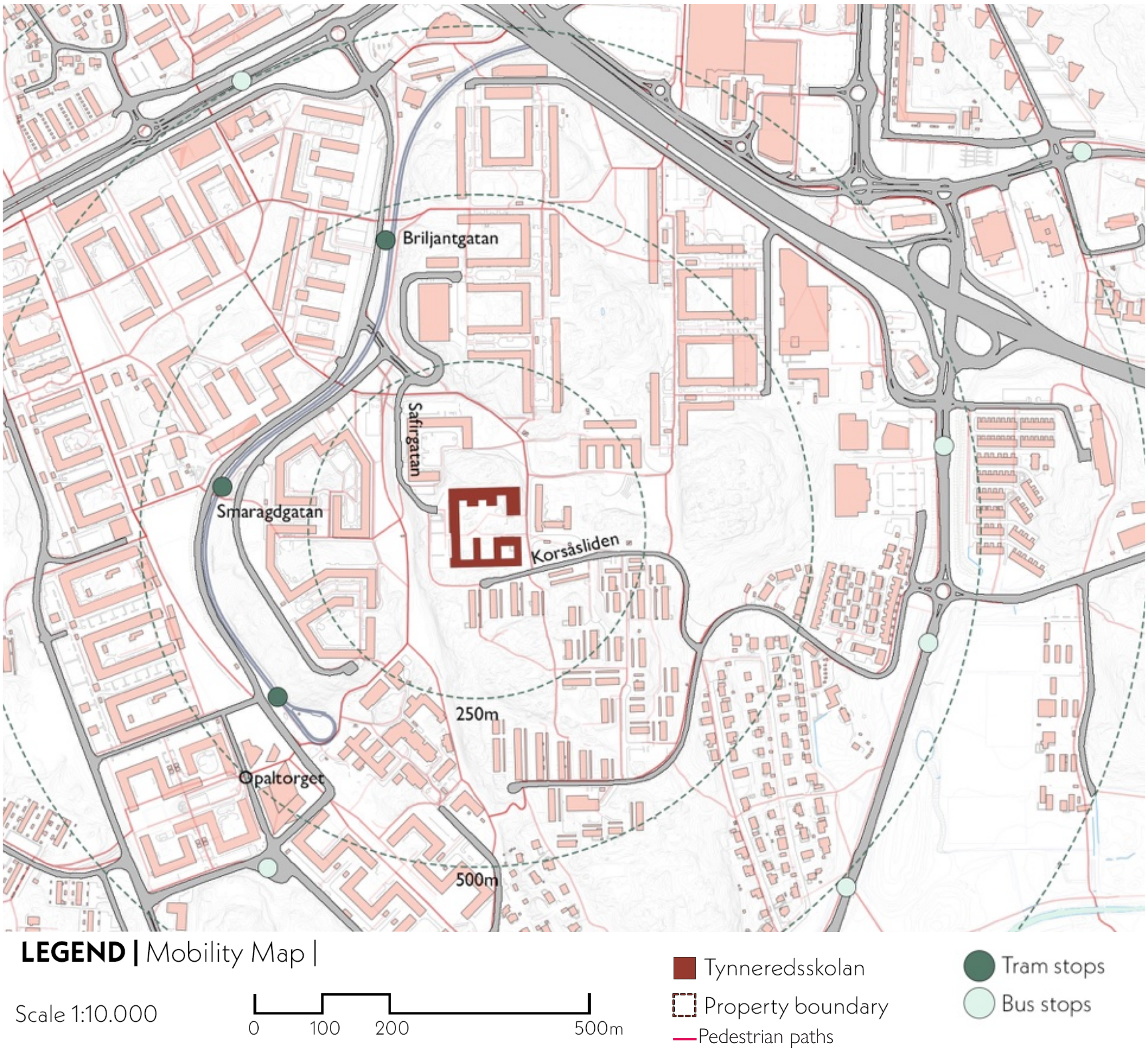


Figure 12. District map. The urban fabric of the million program is clear in Tynnered and Frölunda, and is also adapted to the terrains of the district, which is a mix of small hills and valleys. Residential multi-family buildings are dominating the district. The main hub is Frölunda Torg which also functions as a commercial, cultural and public transportation hub in western Gothenburg. Opaltorget is a smaller, local center in Tynnered which is currently undergoing a densification process.

Schools and municipal services are scattered across the district. A new park recently opened just north of Opaltorget



MOBILITY - PUBLIC TRANSPORTATION AND CAR ACCESS

The communications map above highlights the mobility of the district. Västerleden is the main connector between western Gothenburg and the city center, but also functions as a barrier between Frölunda and Tynnered with five crossings between the areas in the scale of the map. Furtermore, Frölunda Torg is a major transportation node in the western parts of Gothenburg linking the district with the city center, Mölndal, Mölnlycke and Hisingen.

Three roads, besides Västerleden, circles the area around Tynneredsskolan: Näsetvägen, Skattegårdsvägen and Grevegårdsvägen. Reaching the school by car can be made through Korsåsliden via Näsetvägen, or Safirgatan through Skattegårdsvägen. All the other connections within the area are for pedestrian traffic only.

There are three tram stops near the school, with the nearest ones being Smaragdgatan and Opaltorget around 400m away. Bus stops are placed further away, and has less frequent traffic, and go to either Frölunda or Näset, making traveling by tram the smoothest option.

PEDESTRIAN PATH NETWORK

As mentioned earlier, the pedestrian network within the district is separate from the motorized network, which is a common in a "Million house program" area. The pedestrian network is extensive and connects the different neighborhoods with each other. This separation has also created many tunnels below the car roads, and stairs and slopes to due to terrain of Tynnered.

Focusing on the area around Tynneredsskolan, we can see that the area has good connections with Frölunda Torg, Opaltorget and Smaragdgatan, which connects to paths even further away. This means that there are more and easier opportunities to get to the site by walking compared with the car access.

While separation between cars and pedestrians is good, specially for children going to and from schools in the area, it is also regarded as unsafe, particulary during the dark hours (Program för Tynnered, 2022).

Future plans

In 2022, the municipality published *Program för Tynnered*, which is a municipal program that serves as an intermediate step between the comprehensive plan and the detail plan. It highlights the municipality's intentions regarding the land use regarding housing, services parks workplaces and other uses in the future, providing a foundation for forthcoming detailed plans.

Two proposals will be seen here, one that is found in Program för Tynnered, and one that a working draft delivered by the urban planning department on 12/10-23. A third proposal is underway and is expected to be published during the autumn 2024.

This municipal program highlights creating a neighborhood with a variation of typologies and better connections, and that the new buildings should be based on the identity and the character of the area.

Both proposals regarding the site of Tynneredsskolan includes a demolition of both Tynneredsskolan and Ängåsskolan since both schools are considered to have reached the technical age and are deemed not suitable for pedagogical purposes. The schools are planned to be replaced with a new school with a capacity of 600 students and a gymnasium on the site where Ängåsskolan stands today. Two-hundred rowhouse units are planned to be built according to a political decision (*Planbesked för bostäder med mera vid Ängåsplatå (Järnbrott 164-24 med flera) inom stadsdelen Järnbrott)*. Additionally some multi-family residential buildings, a new park and a cultural house are also planned.

Another aim is to join the disconnected neighborhoods and reduce the number of isolated pedestrian pathways. Many people feel unsafe walking there, especially around Tynneredsskolan. This might also give opportunities for more commercial activities, life and movement. (Program för Tynnered, 2022).

According to Anders Dahlgren, urban planner working with the development of the area, there might be difficulties in reaching the political goal of having 200 rowhouses due to various reasons, among them the space available and the terrain. It is easier and cheaper to build them to the east of Tynneredsskolan rather than on the site of the school. Having multi-family buildings there would moreover generate more money than rowhouses. A majority of the new residential units would also be for sale and not for rent for the reason that the municipality wants to strengthen the socio-economic demographics in a district dominated by rental housing (Interview with Anders Dahlgren, 26/2-2024).

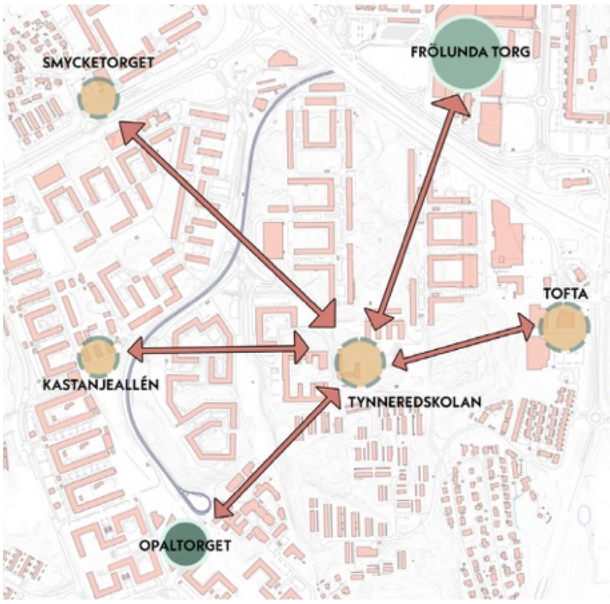


Figure 13. Strategy plan of creating and connecting existing and new nodes presented in Program för Tynnered (2022), interpreted by the author. The green dots are the existing nodes, while the orange are future nodes. The site around Tynneredsskolan could be one of them in the future. A local node with housing, schools and culture.

Figure 14. Picture of new urban densification project in Frölunda, with high explotation numbers, under construction. The buildings are being placed close to existing structures. Is this ths the type of densification we will see on the grounds of Tynneredsskolan?
Picture: author

Legend for figure 15a

Former Tynneredsskolan and Ängåsskolan

Rowhouses

Multi-family buildings

Culture and/or Gymnasium

Schools and preschools

Red line is the new local main road

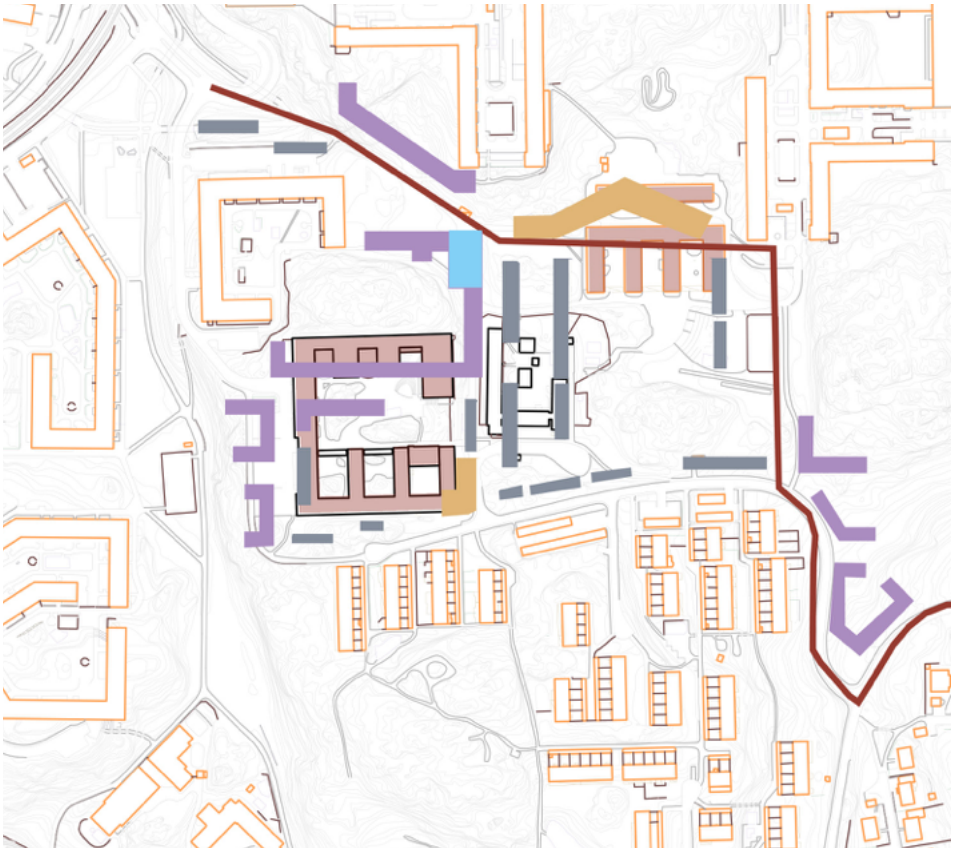
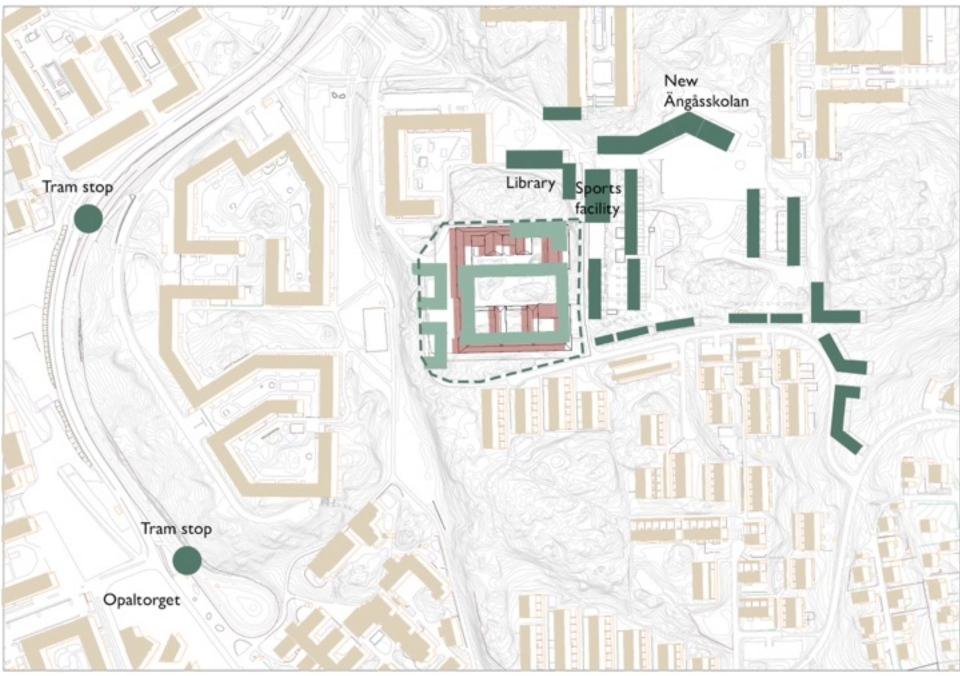


Figure 15a. The proposal from Program för Tynnered (2022), redrawn by the author. New local road that cuts through the area. Multifamily buildings at the edges, and rowhouses in the center or along Koråsliden. Very long building at Tynneredsskolan's northern sector. New Ängåsskolan where the old one used to be and a preschool at Tynneredsskolan's southeastern corner. Redrawn by the author

Figure 15b: Non-published working draft delivered by the Urban planning department of Gothenburg on 12/10-23, partly redrawn by the author. The main road proposal is the same as previous proposal. Gymnasium appears next to the culture building. The proposal is more well-defined and is similar to previous plan in general, except for where Tynneredsskolan is. Rowhouses have been replaced with a quarter of multi-family buildings, and the long building is replaced with a preschool. The proposal includes demolitions of Tynneredsskolan and Ängåsskolan, to be replaced by a new Ängåsskola. There will be a mix of housing typologies, with 100-300 units where Tynneredsskolan stands today and around 100 rowhouses nearby. The area will become a local node with a sports facility, library/culture facility and a new preschool.



None of the figures are to scale

Former schoolsites

This is a short section about the former school sites in Högsbo, Järnbrott and Flatås that have been demolished and replaced with residential areas. Site visits were made by the author in order to document how they have developed.

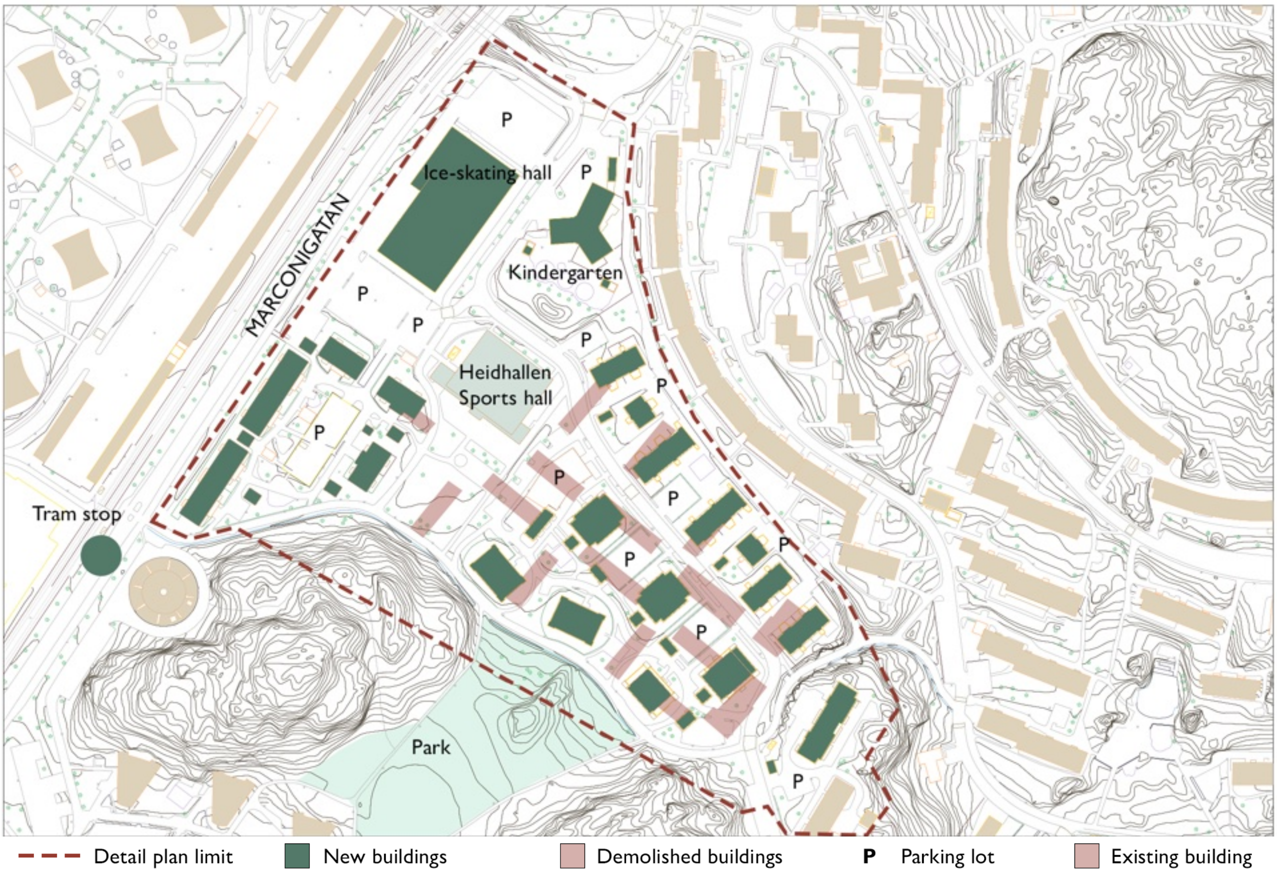
All of the schools were run by the municipality, and the reason to why they were closed and demolished were of several factors, including poor student performance, "inadequate" school environments and buildings in a bad condition. Their locations also played a role, since they are conviently placed along the tram network and with good connections both locally and wihtin the city, reducing the need for a car.

Figure 16. Map showing the placement of Tynneredsskolan and the former schoolsites in western Gothenburg. Not to scale.

Figure17a: Järnbrottsskolan year 2000. Picture Eva Löfgren/ Göteborgs stadsmuseum

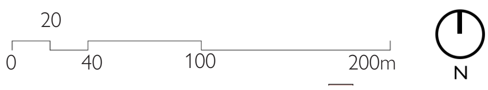
Figure 17b: Motortekniska gymnasiet year 2010. Picture: Bildinsamling: aug. 2010 © 2024 Google

Figure 17c: Högsboskolan year 2012. Picture: Photography: Lindholm Restaurering AB



JÄRNBROTT
Järnbrottsskolan

1957-2011



Scale 1:4000

Residential units:	250-300
Area:	6,9 hectares
Other functions:	Kindergarten, indoor ice-skating facility, indoor sports hall

Built in the 1950's and consisted of 16 pavilions grouped as an "U" along a "main street". The buildings were a mix of one and two-story buildings according to a function separation. The school gymnasium is a later extension and still exists today as "Heidhallen".

There are no records regarding the structure of the buildings, but the façades were of both wood panels and brick. Originally, all the buildings were covered in wood panel. The panels had a yellow color (Riksantikvarieämbetet, n.d.).

The new detail plan was approved in 2009, which itself was a part of a larger plan covering Frölunda that was adopted in 2006. The new urban structure consists of four clusters; five residential blocks along Marconigatan to the west, six tower blocks in the center, seven rowhouse structures to the northeast and a single multi-family structure to the southeast. The proposal also includes a kindergarten in the northeastern section of the area and an ice-skating hall along Marconigatan.

The apartment blocks close to Marconigatan are grouped together around a rectangular yard containing storages, parking lots and a small playground. The buildings, together with the ice-skating hall function as a noise barrier towards the trafficked Marconigatan, creating a calm environment in the area as a whole. A common feature all over the area is that there is a good distance between the buildings with good daylight and low exposure to privacy.

However, it is very noticeable that much of the unbuilt spaces are for cars, as there are parkings between many of the multifamily buildings. Only one is underground, while another has one floor above the ground. This gives a boring impression of the area, together with the boring green spaces, which is mostly just grass. Even the playgrounds have little to offer.

Figure 18a. Courtyard of the residental blocks by Marconigatan. The space is dominated by a parking lot. A small playground in the foreground. The playgrounds are quite basic and simple throuhout the area. This could partly be explained that there are larger and more equipped ones just outside of the area.

Figure 18b. Heidhallen, the only remaining structure from Järnbrottsskolan. The space in front of the building is an open space with no clear function, just some pavement and a grass lawn. It seems unlcear, uninviting and unattarctive.

Figure 18c. Multi-family structure in the southeastern sector, placed according to the same rythm as the building to the right.

Figure 19a. One of the rowhouses to the east of Heidhallen. The rowhouses have small frontyards and somewhat larger backyards. Parking spaces and streets are almost surrounding the buildings on all sides. It is also appreciated to have small structures in this district, which is dominated by large multi-family buildings.

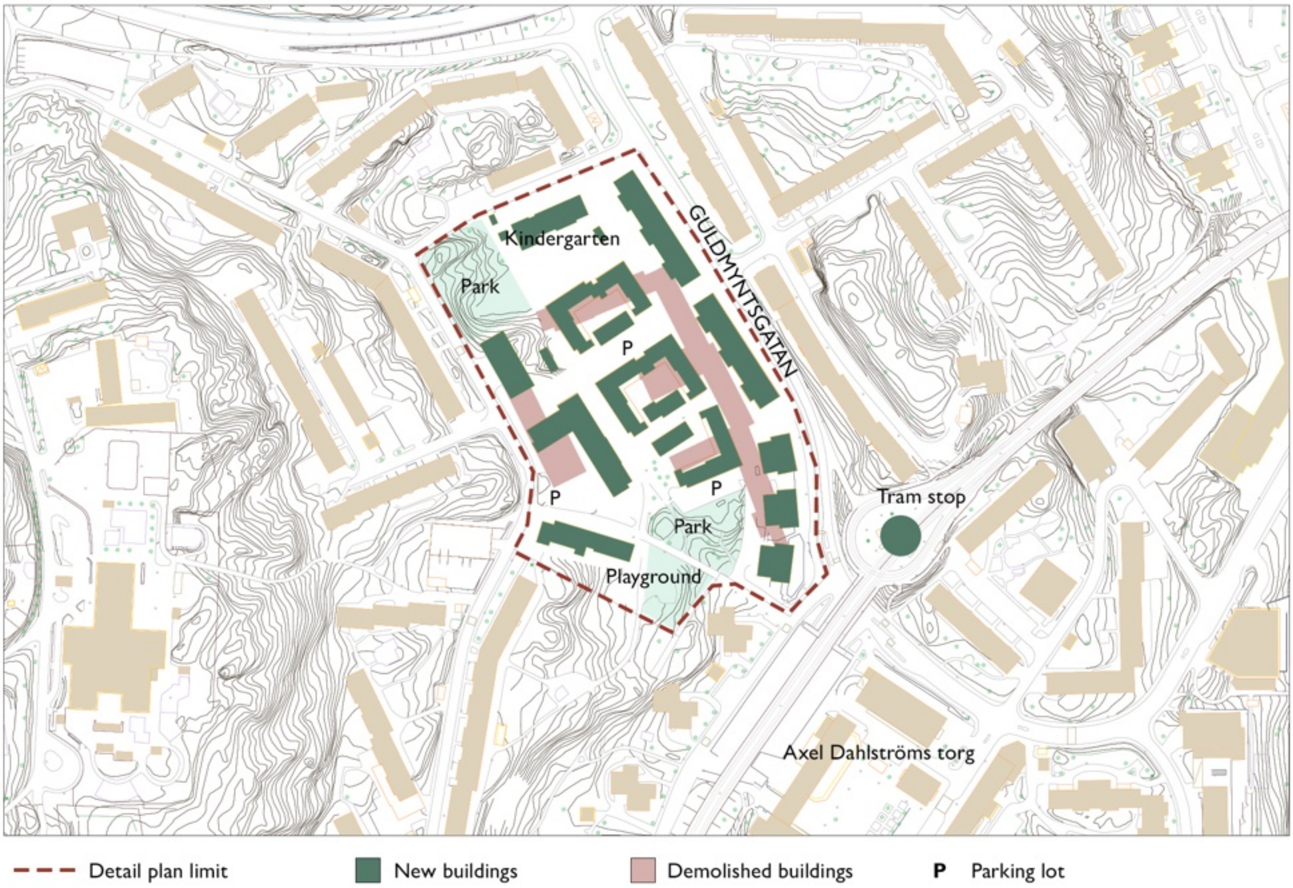
Figure 19b. One of the many parking lots between the tower structures, clearly indicating the dominance of cars.

Positive qualities

- Good distance between the buildings
- Part of the former school integrated into the new area and with the same function (sports hall).

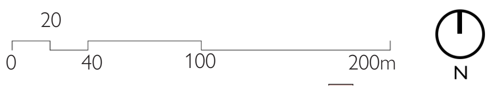
Negative qualities

- Cars take up a large amount of the space.
- Low quality (boring) green spaces.



HÖGSBO
Högsboskolan

1954-2013



Scale 1:4000

Residential units: ca 400
Area: 3,2 hectares
Other functions: Kindergarten, commercial spaces

The school was designed by White Arkitekter and built during the expansion of the Högsbo district in the 1950's. It was a two-story building, where the classrooms were ordered two and two together with a staircase, which removed the need for corridors The building also adapted to the terrain, creating a souterrain level towards the north. Three wings were added to the main building, and a separated pavilion was built on the other side of the property. Brick and concrete were the materials used, with horizontal windows towards the south and smaller square-shaped windows towards the north (Caldenby et al, 2018). The school was closed in the late 2000's but was used as a temporary school while a nearby school was undergoing renovation.

A detail plan for the area was adopted in 2015, which allows for the development of more than 400 residential units. The intention was to create housing close to services, workplaces, and public transportation and to increase the basis for the current services and residents in the area. The plan allows for the construction of fifteen new buildings, including a kindergarten, and two smaller green areas/parks. The plan is "flexible" according to the municipality, in order to allow for different property developers to participate, and it allows both tower structures and horizontal apartment buildings. Besides the wish for increased urbanization, the municipality also expressed a wish for a coherent scale with the surroundings, together with the greenery near the buildings, which is a characteristic of the district (Göteborgs stad, 2015)

There is nothing left from the school, besides some small pockets of greenery to the south and in the northwest, next to the kindergarten. The rest of the greenery that existed on the site have been removed, as well as flattening of the terrain. Except from that, there is not much greenery within the area, but that is compensated with the abundant greenery of the district and the proximity to Ruddalen recreation area and Slottsskogen.

The area is highly urban and consists of different typologies, such as apartments for purchase, rental apartments, rowhouses, senior housing and a form of co-living. The buildings materiality and colors have been inspired by the surrounding 1950's buildings with earthy color schemes. The southernmost buildings are three red-bricked tower structures with 6-7 stories, that are placed close to L- and U-shaped apartment blocks. A narrow one-way street is the only separation between them. The U-shaped apartment blocks forms a small urban quarter together with rowhouses placed to the south, that together creates a small inner courtyard.

The eastern sector consists of two five-story apartment blocks. They are roughly placed where the main school building was placed. They have a souterrain level towards Guldmyntsgatan containing commercial uses. Stairs are located between them, allowing for a connection to Guldmyntsgatan that continues as a horizontal pedestrian axis.

The kindergarten is placed in the northernmost part. It is also from here that the pedestrian path starts, creating a vertical link between the area and Axel Dahlströms torg to the south.

Figure 20a. Narrow one-way street separating the tower structures from the apartment blocks. Privacy issues as the neighbors will have free view into each other's apartments.

Positive qualities

- Part of the greenery and nature kept, such as the natural rock formations.
- Different typologies, urban feeling towards Guldmyntsgatan with commercial spaces
- Exterior-gallery access buildings is wide enough to function as a balcony and becoming a more social space.

Negative qualities

- Lack of privacy with buildings being too close in some places. Rowhouses almost fully surrounded visually from all sides.
- Some parkings are placed too close to the apartments and their windows.
- Plenty of hard surfaces

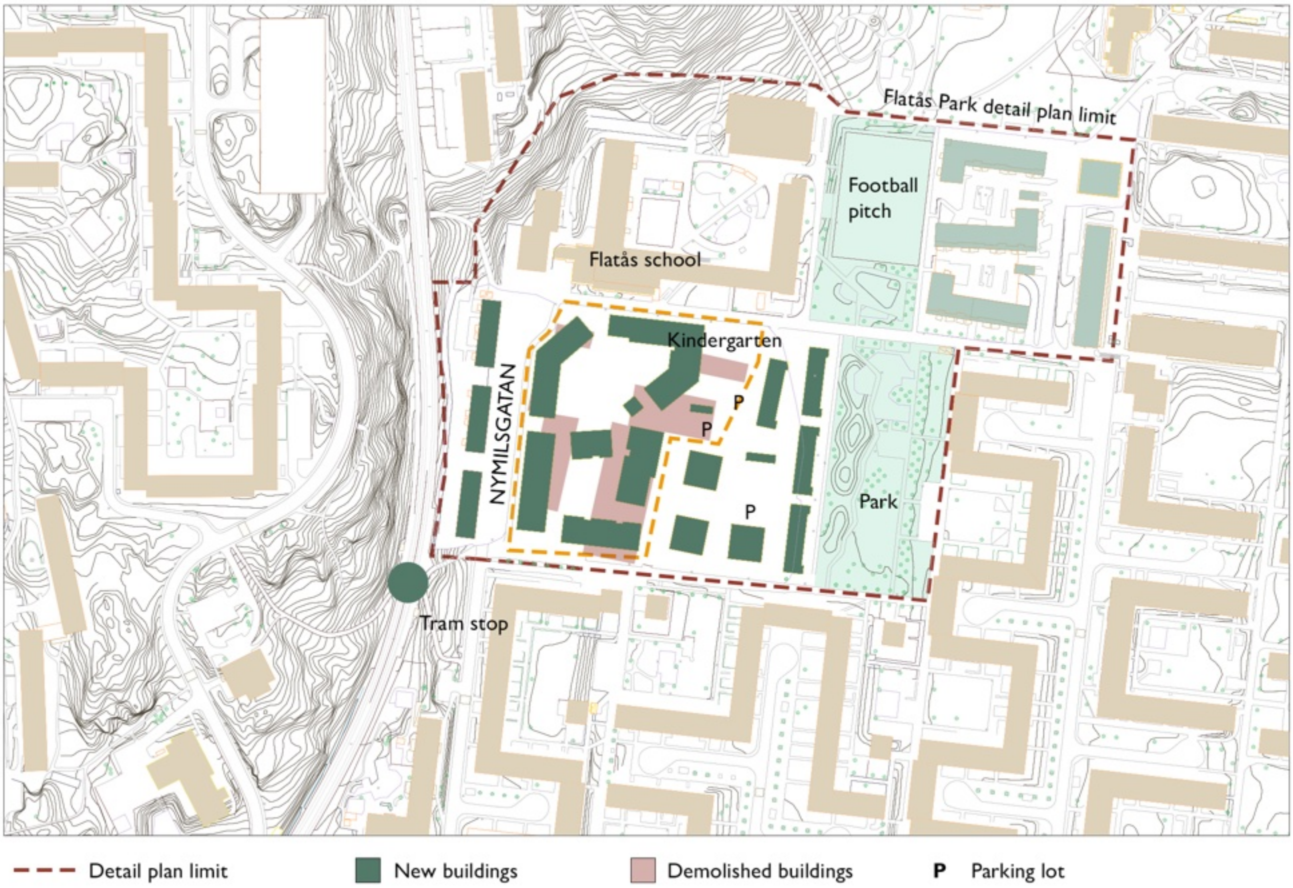
Figure 20b. New yellow brick buildings (left) inspired by the older buildings on the opposite side of. Guldmyntsgatan. Commercial spaces on the ground floor. Photography: Bildinsamling sept 2022. © 2024 Google

Figure 21a. Residential block with parking spaces just outside the apartments. Not an optimal solution as the lights from the cars will light up the apartments, in addition to the noise from the cars. Large windows allows for much daylight, but will also have privacy issues on the groundfloor.

Figure 21b. Rowhouse and apartment block. They are placed very close to each other. This particular apartmentblock is placed to the south of the rowhouse, which will give a mostly dark courtyard for both the residents in the block as well on the terraces of the rowhouses.

Figure 21c One of the courtyards The exterior corridor of the apartments is wide enough to be used as a balcony by the residents. The courtyard has a small playground and bike parkings, in addition to a large common bike storage in the apartment block. The apartments have mostly kitchens facing the courtyard, which is one way to solve the privacy issues with full view into the apartments. However, some bedroms are also facing the yard, which is problematic, specially on the ground floor.

Figure 21d. Some of the remaining nature of the former school yard. Maybe too small, but a good contrast to the hard and artifical surfaceses in the courtyards.



FLATÅS
Motortekniska gymnasiet

1965-2017

Scale 1:4000

Residential units: Ca 620
Area: 2,8 hectares
Other functions: Kindergarten, commercial spaces

The site of the densification of Flatås Park used to house various municipal functions, including Motortekniska Gymnasiet (MTG) that opened in 2002, a job coaching center and a The building was first built in in the 1960's and initially functioned as a vocational school. The buildings were one-two storeys high and had different looking facades, including brick, wood, and metal panels. All functions had moved out by 2017.

The new construction consists of two detail plans; *Housing by Nymilsgatan* (Bostäder vid Nymilsgatan) and *Flatås Park*, where the first area is completely embedded within the second area. *Housing at Nymilsgatan* consist of six multi-family buildings of 5-9 stories, with the tallest one located at the northwest corner. There are around 300 residential units, many of them being single bedroom studios. *Flatås Park* is slightly more varied with lower slab buildings to the east (three levels), taller slab buildings (seven levels) to the west and five levels high tower blocks, with around 320 housing units. A park with a large playground and football pitch is located just east and northeast of the site, together with new housing that are not part of this study.

Starting with the slab buildings near the tram stop at the western entrance to the site, the buildings are of similar appearance to the slab buildings in Järnbrott that was mentioned earlier. Large windows towards the tram tracks allows for views could be problematic for the privacy, specially for the people living on the first floor as that floor is almost at the same level as the trams. Three tram lines passes by, so that could also limit the use of balconies and terraces due to noise and lack of privacy.

The housing complex in the middle of the area, *Housing by Nymilsgatan,* is densely built with two "quarters" with the northern one housing the taller building and kindergarten. The buildings are white, simple and plain towards the street, but more colorful and dynamic towards the courtyard. The apartments vary in size, but many of them are facing only one direction, and are both for sale and rental apartments. The quarter to the south, which is more enclosed and less green than the northern one, consists of apartments with 1-3 bedrooms, many of them being student accommodation. It is easy for pedestrians to look into the apartments, and the ones with balconies are very close to each other.

The privacy issue is also present in the three-story slab buildings, with large windows towards the street and with little to no space to the pedestrians outside, allowing for a view of the apartment unless the blindes are down. The space between the slab buildings and the tower structures is parking and some form of an uninviting square with no clear function. Most of the parking is otherwise under the buildings.

Positive qualities:

- Close to public network, municipal services, and parks
- Variation of architecture and typologies in a monotonous district

Negative qualities
- Lack of privacy in many of the typologies
- Buildings placed close, could have an impact on daylight qualities.
- Plenty of hard surfaces

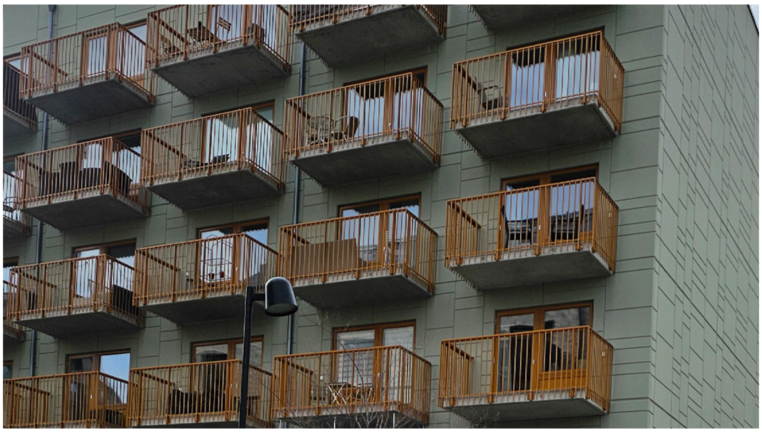


Figure 22a. Balconies placed very close to each other between the studio apartments. Could be problematic from a privacy point of view, but maybe also a space for socializing with the neighbors?

Figure 22b. Residential blocs near the tram tracks. Large windows allow strangers to view the interior of the apartments from the tram and the tram stop. The ground level is also placed lower than the tram tracks The balconies are facing west, which is pleasant, but the noise and trams could disturb the experience..

Figure 22c. Ground floor on the buildings to the right seems like commercial spaces at a first glance, but is acrually parking spaces within the buildings. The building to the left have privacy issues, like other new buildings in the area. Many of the blinders were down at the time of the visit.

Figure 23a One of the entrances to the buildings of the southern block of Housing by Nymilsgatan. The courtyard is quite dark at some places due to the building placement, facade color and concrete ground surface

Figure 23b. Colorful facade in the northern quarter of Housing by Nymilsgatan. The courtyard is not large but does have some greenery and variation compared to the other public spaces in the area.

Figure 23c. Pedestrians walking on the main street will have a clear insight into the apartments on the ground floor. As a result, many of the blinds were down in otder to preserve the privacy.

Figure 23d. Similar situation as in figure 23c, now with practically no distance at all between the residents of this corner apartment on the main street.

Figure 24a. Aereal photographies of Högsbo. Not to scale.
Lantmäteriet/ SWEREF 99 TM, RH 2000

Figure 24b. Aereal photographies of Flatås Not to scale.
Lantmäteriet/ SWEREF 99 TM, RH 2000

Conclusion of the site visits

There are both similarities and differences between the sites. Järnbrott, the oldest area of the three, is more suburban with a "house in park"-approach, giving plenty of space between the buildings. This can be seen in contrast with the other two areas which are both smaller and much denser. The other two may have a smaller percentage of greenery within their areas, but they are of higher quality than the one in Järnbrott, with more vegetation. It is worth to note that there is plenty of greenery just outside the limits of all three areas.

Högsbo and Flatås have more issues with the lack of privacy and in some parts also with the daylight. Windows are large and should offer good daylight, but the buildings are too close in some cases, which creates exposure into the residences, especially the ones on the ground floor.

It is interesting that the three areas show a change in the city's urban planning policies. The cars take a physically smaller space in Högsbo and Flatås, and most parkings are underground compared to Järnbrott. All three are placed close to public transportation and municipal services and is something that was taken into consideration when densifying Högsbo and Flatås, decreasing the need for a car. Although limited Högsbo and Flatås have some commercial spaces, while Järnbrott have sports installations. This could be explained by Järnbrott's proximity to Frölunda Torg.

Overall, none of the areas could be considered "bad", but there could have been different decisions taken, especially regarding the lack of privacy and daylight in some buildings. This is, however, as mentioned earlier a common downside of densification.

Figure 24c. Aereal photographies of Järnbrott Not to scale.
Lantmäteriet/ SWEREF 99 TM, RH 2000

THEORY

03

Adaptive reuse & Revaluation

REUSE & ADAPTABILITY

Adaptive reuse is the practice of transformation an existing structure into a new use. It is not a new practice since buildings and structures tend to last longer than their function. Until the last decades, the main approach was to preserve protected buildings' original appearance. And whenever the building became ineffective or old-fashioned, the function could easily be replaced with a new one.

There has been a change in the last decades, where an appreciation of the built has grown stronger, and now also including all types of buildings. There are various reasons for that, including increased urban density restricting space for new development (Plevoets & Cleempoel, 2019). Another important reason is that transformation can lead to reduced use of material, transportation, and energy consumption, as well as lowered pollution. This, in turn, contributes significantly to sustainability (Bullen, 2010).

Adapting an existing structure to a new use can be challenging, and the cost is often the primary obstacle when it comes to adaptability, with the argument being that the adaptable solutions are more expensive than the non-adaptable alternatives (Schmidt, 2016), despite data showing that it potentially could be cheaper with adaptive reuse, providing the structure remains (Bullen, 2010; Schmidt, 2016). The Norwegian Green Building Council argues that construction costs are relative, depending on who makes the calculations. Most new projects are traditionally calculated in price per square meter as the only consideration, and it is also generally more predictable to estimate the building costs of new buildings compared to renovated. It is economically more profitable to think in this mindset. But if we are to consider greenhouse emissions, demolition and new construction typically leads to increased emissions compared to a refurbishment project. These calculations have the potential to influence loan conditions, investment decisions, the approval of demolition and building permits, and the overall market interest of the project. Furthermore, the EU requirements of reusing more existing materials is likely to increase the demolition costs (Norwegian Green Building Council, 2019).

A building is not a static monument, but a dynamic structure in different shearing layers, which age differently. There will always be a need of changes and reparations, raising the total cumulative costs. Buildings that cannot be adapted in a cost-effective manner may not be fit for purpose and could eventually become disused or demolished. (Schmidt, 2016).

Bullen and Love writes in their paper that the building is eventually demolished when it is perceived to not have any value, referencing to Kohler and Yang (2007, as cited in Bullen and Love, 2011). In most cases, it is the market that sets this value, even if the value could be based on wrong grounds (Douglas, 2006, as cited in Bullen and Love, 2011). Bullen and Love (2011) refers to earlier arguments (Ball, 2002 as cited in Bullen and Love, 2011) that there is value attached to the architecture and character of the building, and that it generally is more favorable to repair the building instead of replacing it with a new one that is not necessarily better. Bullen (2007) contrasts with that a repaired and transformed building may not reach the same performance as a new building, but the difference could be made in gains for social values instead. Bullen and Love continues, with reference to Itard and Klunder (2007) that demolition should be seen as an "environmentally unfriendly process" as a study of theirs showed that an adaption process generated less waste and probably used less energy compared to demolishing and rebuilding (Bullen and Love, 2011).

REVALUATION

”To calculate the value of something again, especially to give it a higher value than before”

- The Cambridge Business English Dictionary

John Allan (2023), in the second part of his book Revalue Modern Architecture, advocates for a more effective approach than just heritage preservation, that we in the future need to broaden our perspectives regarding conservation, shifting the focus from “elite heritage” to the adaptive reuse and sustainability of “ordinary” modern buildings. These buildings may not be heritage designated, but still too significant to be demolished. An example of that are buildings that are around 50-70 years old with no significant historic heritage but could still hold economic or potential reuse values. Allan argues that social, economic, and ecological factors should be considered when argument for the preservation of these buildings rather than relying only on heritage arguments. He further continues arguing that we cannot withstand the climate crisis: we have to learn how use more of what already exists.

Preservation and improvement should focus on three important aspects- repair, upgrade and reconfigure, with the latter one being about intervening and adapting buildings in order to add value or to accommodate new requirements. Architect’s must balance these three aspects, and with different stakeholder’s interests, this will be different for each project. Conservationists would be concerned about the authenticity of the building, building users on the functionality while investors would focus on the market value enhancements like additions or alterations of the image of the building. This reality necessitates a growing emphasis on the skills of adaptation and upgrade in modern conservation, moving beyond a strict heritage focus to embrace broader, more practical considerations in building reuse. (Allan, 2023)

SWEDISH ARCHITECTURE POLICIES

The Swedish government published a national architecture policy in 2018, and some of the stated goals could be related to adaptive reuse, including:

- Durability and quality must not be subject to short-term financial considerations
- Aesthetic, artistic and cultural-historical values are taken care of and developed
- Knowledge about architecture, form and design is developed and spread

(Boverket, 2022, Regeringens proposition 2017/18:110)

The municipality of Gothenburg is using this national architecture policy as a base for its own policies. The idea is to implement this policy into the comprehensive plan and be a complement to other strategic documents regarding the development of the city, such as the earlier mentioned ”dense, green mixed city” from 2014.
The policy furthermore expresses the following intentions of the city

- Gothenburg will be a brave precursor through good architecture in planning, building and management
- New architecture will relate to culture history, contemporary times and strengthen the identity for the future.
- Sustainability and architecture should be prioritized before short-term economic interests in the land allocation processes.

(Arkitekturpolicy för Göteborg, 2018)

Author’s reflections

Demolishing fully functional buildings is a problem in many countries, Sweden included, and for many reasons; one of them being that the new structure would perform better. It is true that it could be the case, that the new building would perform better, but not necessarily. When taking other aspects in consideration, such as green house emissions, cultural and social values, and even in economy, it could be better to reuse the building or structure. We must not fix ourselves with only viewing short term economic gains and monetary profits, which both the national and local architecture policies mentions, yet Gothenburg seems not to follow their own guidelines. Tynneredsskolan is a great example of that, if we include the future plans presented earlier in the thesis, where the municipality currently own 100% of the site, but have not conditioned on how the site should develop according to ”relation with culture history” and ”strengthening the identity for the future”. Are these policies more for green-washing or to actually (at least have the intention to) be followed?

Life Cycle Analysis (LCA)

INTRODUCTION

This section will shortly explain the concept behind LCA and the impact of materials. The LCA in this thesis will be made through the software CAALA (Computer-Aided Architectural Life-Cycle Analysis), and that will be the used in a comparative study of materials and energetic performance of a transformed Tynneredsskolan and two low-energy buildings from Järnbrott and Högsbo later in the thesis.

LIFE CYCLE ANALYSIS

A Life Cycle Analysis (LCA) is a tool that is used to calculate the environmental impact of a product throughout its life cycle – from production until disposition, recycling, or reuse. In architecture, this can be used to determine when and at which stage a building component is having its largest impact in terms of emissions, energy use and energy demand. Using a life-cycle tool early in the design process could help in making more environmentally friendly decisions in the construction process and comparing different results with each other (Boverket, 2019).

A building's life cycle is first divided into several stages, such as production phase and use phase, and can then further be divided into two main fields of impact: embodied impact and operational impact. The operational impact includes the energy use of the building, for instance the energy needed for heating and cooling, while the embodied carbon takes into account the emissions from the extraction and production of the material. For example, a building with more materials (insulation, building mass etc.) might have a higher share of embodied carbon. The different stages are seen in figure 25 according to the European standard EN15978.

Figure 25: Life-cycle stages according to the European standard EN15978 redrawn by the author. It is divded into production, construction, use and end-of-life and their categories. The last component (D) can be included when quantifying the loads or benefits of reuse, recycling or energy recovery of materials (which will not be a

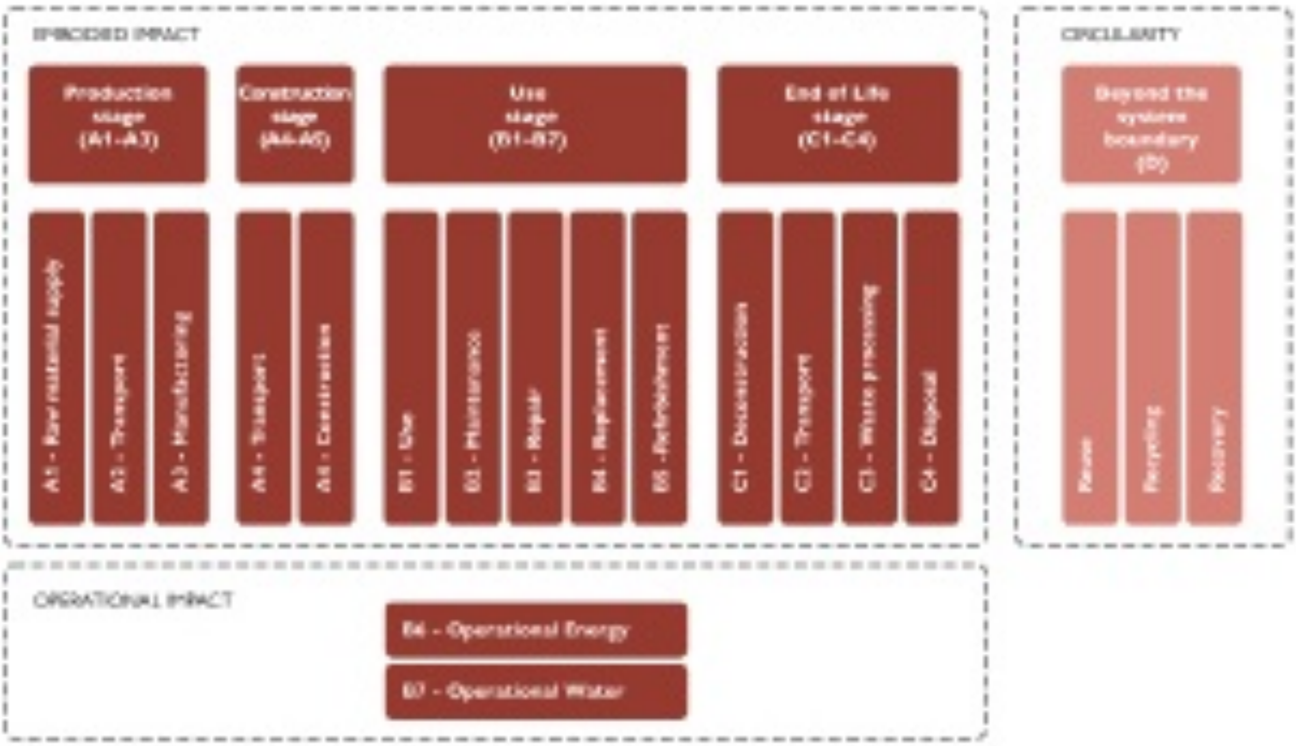


Figure 25

IMPACT OF MATERIALS

Buildings and the building and construction sector have a large impact on the environment, which stands for 37% of the global greenhouse emissions and 34% of the energy consumptions according to a report released by the United Nations Environment Programme (2024). Furthermore, the production of the construction materials alone contributed to 10% of the global energy and process emissions in 2022 (United Nations Environment Programme, 2024). A quick glance at the "Material Pyramid" (fig 26a) illustrates the impact of different materials. CINARK, the Center for Industrialized Architecture at the Royal Danish Academy have developed a "construction material pyramid" that is based on Environmental Product Declarations (EPD) of common building materials. While not an LCA tool, it gives an easy-to-read view of the sustainability of different materials (in form of emissions/ecological footprint). Materials with lower impacts, such as wood and straw, are in the bottom of the pyramid, while high-impact materials, like metals and glass, are in the top.

One way of measuring the carbon footprint is with a **Global Warming Potential (GWP)**. It is a standardized measurement unit made in order to compare the global warming impacts of various greenhouse gases. Essentially, it quantifies the amount of energy that the emissions of 1 ton of a gas will absorb over a specified period, relative to the emissions of 1 ton of carbon dioxide (CO2). A higher GWP means that there is a greater impact on the environment(United States Environmental Protection Agency, 2023) . The GWP is the measurement that will be used in this thesis through CAALA, together with two other factors related to energy. The first one is the **Primary Energy Demand (PED)**, which is the total energy demand of a building, the amount of energy normally needed for a year. This includes energy for heating, domestic hot water, building electricity (for example, for elevators) and cooling. User energy, such as the household energy (electric devices like computers, phones etc) are not included. The second is **Primary Energy Demand Non-Renewable Total (PENRT)**, which is the amount required to deliver primary energy that comes from a non-renewable source, such as oil, gas and coal.

Figure 26a: The Material Pyramid. showing different materials and their GWP (kg CO2 eq / kg) in a Nordic context. Materials and components with high GWP include aluminium, EPS and glass. Examples of low-impact materials are thatch, wood and gypsum fibre boards. It is important to bear in mind the amount of materials used as well.

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Evaluation Criteria

LOW TECH

The evaluation for the low tech will be more of a qualitative aspect. it will not be graded, but rather implemented in the design process.

Low-tech building design are architectural strategies that emphasizes the architecture being a part of the overall approach to sustainability, contrasted with the over-reliance to high-tech technical systems. It is about a simple, yet robust system that can vary greatly depending on location, as it is site-specific. A building could be considered low-tech when its design, structure and concept are in harmony with local environmental conditions. The use and the comfort of the interior should aim to require as little energy as possible. Low-tech does not oppose technology per se, but rather attempts to integrate it more efficiently, and the borders between the two are fluid. Edeltraud Haselsteiner, an Austrian researcher, puts it together as written in the quote below:

"The goal is to make use dynamic unity formed by people, building, location, nature, and eco-system and to develop based optimized concepts based on it. (Haselsteiner et al, 2023)

According to Christian Hönger and Roman Brunner of the Lucerne University of Applied Sciences and Arts, there are three architectural and spatial strategies where we can reach the requirements of climate, energy and resources without relying on the dependency of high-tech building technology:

- The savings - to reduce heat losses
- The gain - to make optimal use of solar energy gains
- The evasive - to design ventilated, usable spaces with an exterior envelope as sun shelter, varyingly used depeding on the time and year.

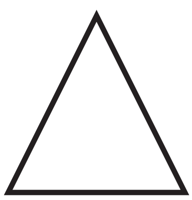


Figure 26b: Approaches for the savings could, for example, be thicker exterior walls to prevent heat loss and/or to function as a storage mass or that usable areas are reduced during the winter. Meanwhike, for the gains, it could be to open up and make use of the solar gains. The third approach is much about the temporarility of the use. Not all the spaces are used all the time.

MILJÖBYGGNAD

The criteria for the daylight and overheating are from Miljöbyggnad 4.0, which is a Swedish environmental certification system issued by the Swedish Green Building Council. The certification is aligned with EU taxonomy and covers four aspects: energy & climate, indoor climate, exterior environment and circularity. They are further divided into sixteen subcategories, or indicators, such as daylight, energy use, ecosystem services and circular material flows. In this thesis, the focus will be on the daylight, overheating and indoor climate. Miljöbyggnad have three grading levels: bronze, silver and gold. Broze corresponds to the current building rules, standards, and environmental goals, while silver requires higher efforts and ambitions. Gold would be difficult to reach, but not impossible (Sweden Green Building Council, 2022).

Daylight and overheating will be explained shortly in the following page, while the numerical values of the criteria will be presented together with the evaluation.

DAYLIGHT AND SOLAR HEAT

Daylight consists of direct sunlight, diffuse daylight, and reflected light. It is crucial for human well-being and significantly impacts urban planning and architecture. Daylight also directly affects our health by regulating our daily rhythm, which is especially important in Nordic conditions with short, light summers and long, dark winters. Marie-Claude Dubois, architect and lecturer at Lund University, argues that "architectural trends change, but human beings' need for sunlight and daylight does not." The current trend is building densely, in contrast to the more open designs of modernism. Architect and daylight expert Paul Rogers further notes that "light, air, and hygiene" have traditionally held a special place in Swedish urban regulations, making specific daylight regulations less necessary. Current regulations originated from the 1970s energy crisis when windows were made smaller to reduce energy demand and heat loss (Boverket, 2024).

Current regulations regarding daylight in Sweden are outlined in Boverkets Byggregler (BBR), which distinguishes between sunlight and daylight. Sunlight refers to strong, direct sunlight, while daylight includes diffuse light from the sky or reflected from surfaces. There is a requirement for direct sunlight in at least one habitable room in a residence, except for student housing up to $35m^2$. The requirement for daylight is a daylight factor (DF) of 1%, with a recommendation that the window glass area should be at least 10% of the floor area (Boverkets byggregler, 2011:6).

Solar heating is when there are energy gains from the sun. It could be both positive and negative, depending on place and time of the year. In Sweden, it is in general good with solar heat gains during the winter, which could reduce the energy need, while it should be avoided during the summer as it can cause overheating. The energy transmission occurs in two forms: direct transmission and absorption. The definition of overheating is regulated according to the Miljöbyggnad criteria, and the solar heat is measured during the spring and autumn equinoxes (EBAB, 2018).

Figure 26c: Example of modern urban planning where buildings are placed close to each other, causing issues with the privacy exposure

EXPOSURE OF PRIVACY

The privacy exposure, or visual privacy, is one of the consequences of the urban densification, among others such a decrease in visual overviews, shadowed courtyards, and smaller green spaces (Boverket, 2024). The architect and professor Bengt Sundberg states that another outcome of the urban densification is less amount of daylight, and residences in dense areas usually have less outlooks and more insights into the apartments. The risk of privacy exposure depends on how buildings are placed and oriented. Closer buildings mean a higher risk of privacy exposure, specially when they have large windows (Sundberg, 2010). Sundberg continues with that the distance between buildings have decreased in general due to economic reasons, which generally could be around 10 meters, which is in contrast to a recommendation of 25 meters from Handboken Bygg (1962). A distance of at least 20 meters is recommended by Sundberg, and if the distance is lower, angled windows could be a solution. Furthermore, several smaller windows are to prefer over few large windows in a dense urban area, in combinations with other elements like balconies, terraces or bay windows. Window placement also have an impact and should not be placed right in front of other windows, as the residents might protect themselves with blinds and curtains, and the window might lose its function. A solution to that could be slanted windows, preventing direct views into the residence. (Sundberg, 2010).

Danish urban planner Jan Gehl argues that there are some visual thresholds of what humans can see and experience. For example, there can be a direct contact up to a distance of 6-7 meters before it gets too inconvenient, and short messages can be used up to 20-25 meters, which is also the threshold for reading facial expressions. While visual connections are important, so is also the fine border between the public and the private sphere (Gehl, 2010). An example of that could be BRF Viva in Gothenburg, an apartment complex with large windows and an exterior gallery-access to the apartments. A recent study by Braide and Nylander (2021) there showed that the residents were happy with the large amount of daylight they received. The exterior gallery corridor also functions as a balcony, with views towards the dining space. Many of the residents say they appreciated this social space, but others were more concerned about the visual privacy and people passing by.

Privacy exposure is experienced differently by different people, and it is difficult to give an exact number to what is acceptable or not. More people would accept it if the view and outlook is beautiful. A direct view or exposure into a bedroom should be avoided. There are also various ways to protect against insights, such as solar screens, frosted glass, curtains, and vegetation (Sundberg, 2010).

CASE STUDIES

04

Trikåfabriken.
Photographer: Av Arild Vågen / Wikimedia

Urban transformations

Nybodahöjden, Stockholm, Sweden
Various architects (1998)

Nybodahöjden is a residential area located in Årsta in Stockholm. The area was first constructed in the 1930's with an orphanage called Nybodahemmet, that was closed down in the 1980's. Plans were made to build new housing complexes on the hill. A master plan was developed by the municipality, allowing for 800 new units, a new school, and a railroad to the city center. The Swedish financial crisis of the 1990's and economic downturn halted these plans. The Stockholm Building Master's Association was offered Nybodahöjden as a land allocation. They suggested that Nybodahöjden could serve as a residential exhibition, a proposal that the municipality welcomed.

ByggaBo98, as it was called, was the new master plan. It had a lower degree of exploitation than previous proposals, comprising 156 units. The area is divided into two parts: a rectangular shape with townhouses and apartments in north/south and east/west directions and a horseshoe-shaped area with apartment buildings and townhouses.

Two pavilions belonging to the old orphanage were demolished, while other buildings were renovated and adapted for residential use. Additionally, several new buildings with mixed typologies were added. The area was completed for the exhibition in 1998 and received mostly positive reviews regarding the low degree of exploitation, beautiful houses, good floor plans, and adaptation and proximity to nature. Some critics, however, pointed out the lack of nearby community services and increased car traffic in the area (Nylander, 2006).

What we take from this:
- Adaptation to the topography
- Maintaining the greenery
- Keeping most of the original structures
- Mix of typologies
- Human scale structures
- Prioritizing lower amount of housing units over fully densifying the available space

Figure 27a:
View of the old orphamage
Photography by Holger Ellgaard

Figure 27b: Aereal view of Nybodahöjden. The two areas, rectangular and horseshoe-shaped are clearly visible within the nature. The former orphanage are the three buildings to the left and the three L-shaped pavilions in the center.
© Lantmäteriet. Skala 1:2 800, SWEREF 99 TM, RH 2000.

Building transformations

Trikåfabriken, Stockholm, Sweden
Original 1929, transformation by Tengbom 2015-2019

The building, an old factory, was renovated and transformed during the years 2015-2019 when it was turned into an office building. The original building, built in brick and reinforced concrete, was built in 1929 and was extended several times, both in the 1940's and 1960's. The transformation included a total renovation and a roof-top extension made with structural CLT-wood (pillars, beams, walls and slabs). The brick building was reinforced in the foundation and in the concrete columns, while the 1960's extension was reinforced in the columns. This allowed for an extension with four floors in the original brick building and six floors in the 1960's extension. The decision to use wood was because it is much lighter than steel or concrete, and thus required less reinforcements. The building has received a "Very Good"- score according to Breeam, (Tyréns, n.d.)

The new extension follows the original architecture, with a modern look that respects the original rythm. It has a glass facade and corten steel, while the interior is more intimate and showcases the wooden extension. The heart of the building is a large atrium that connects all the levels together. (Tengbom, 2024).

What we take from this:
- Wood is a light material suitable for a roof-top extension which requires less reinforcements to the existing structure.
- The new extension respects and complements the original architecture.
- This building reached a high score in Breeam, showing that it is possible to reach it through a transformation.

Figure 28a: Exterior of Trikåfabriken, showing the original brick building and the roof-top extension.Picture by Arild Vågen / Wikimedia commons CC BY-SA 4.0,

S:t Görans Gymnasium, Stockholm, Sweden
Charles-Edouard & Léonie Geisendorff (1960)

Transformation: Södergruppen arkitekter and AIX arkitekter (2017)

The building was first built as a Household- and sewing school for girls before being transformed into a high school in 1971. It was closed in 2008 (Skolregistret - S:T Görans Gymnasium, n.d.). The building is one of the few examples of the "International style" architecture in Sweden and is heritage listed. It was empty and unused for several years. There were plans to renovate the building and use it as a school, but it would be too expensive. The municipal housing company Svenska Bostäder decided that they would turn the building into student housing with 240 apartments (S:T Görans Gymnasium - AIX, 2021). There is also a preschool and a hostel in the building (Ombyggnaden Av Sankt Görans Gymnasium Klar, n.d.)

What we take from this:
- A school-building that was transformed into housing
- Keeping much of the original looks of the building
- Multi-use, including residential, hostel and a pre-school

Figure 28b: Photograpies of St Görans Gymnasium by Antonius van Arke

Low energy solutions

Vocational School for Photography, Optics and Acoustics (TFBS), Hall in Tirol, Austria
New extension, 2022-2023

The extension was made when the school grew and needed more space for the new students. The structure is a hybrid structure with a flat concrete foundation, steel pillars on the ground floor and CLT-wood in the two upper levels.

The climate and energy concepts are to self-regulate the indoor climate using low-tech solutions. The ventilation system is using natural ventilation through a trickle-vent that pre-heats the air if needed. The air exits the room thanks to the natural stack effect using grills over the door and through to the staircase. There are also ceiling fans that provides thermal comfort during warm summer days. Furthermore, the windows are opened during the breaks to enhance the air quality. This is an effective system even during the winter. The trickle-vents also contains a heat-recovery system, and solar panels on the roof further reduces the energy need of the building.

The ground floor and the northern side of the upper floors have radiant floor heating. (Extension of the Tyrolean Vocational School for Photography, Optics and Hearing Acoustics | Transsolar | KlimaEngineering, n.d.)

What we take from this:
- Effective ventilation system using trickle-vents to pre-heat the air, lowering the energy need
- A mix of low-tech solutions functioning together
- Solar panels on the roof to reduce the energy need

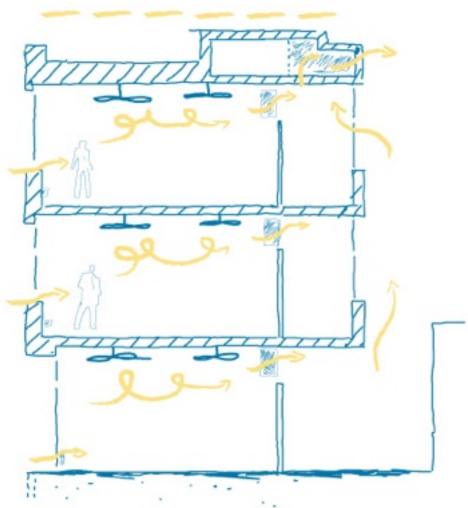


Figure 29a: Sketch from Transsolar showing the ventilation concept of the vocational school extension. It is a combination of various low-energy and low-tech solutions. It works great in a public building, so the question is if it can be applied in a residential building?
Sketch made by Transsolar KlimaEngineering

Figure 29b: Picture showing the classroom. The wooden box below the windows is where the trickle-vent is located. The fan on the ceiling further enhances the air quality during the warm summer days. Picture: Günter Richard Wett

EXISTING BUILDING

05

Picture of Tynneredsskolan showcasing the facade and different window rythms

Tynneredsskolan

HISTORY

Tynneredsskolan a secondary school built in 1969 together with the nearby Ängåsskolan, which used to be a part of Tynneredsskolan. It was designed by Lars-Gunnar Jönsson at White Arkitekter and is a typical representation of the 1960's school in Gothenburg and in Sweden. The building is 1-2 stories high and is placed on top of a hill, surrounded by multi-family buildings and rowhouses. It has a shape that resembles a "U" with extensions towards the school yard.

The school was built to accommodate the residents of the growing neighborhood of Tynnered, and was planned together with teachers, students, and architects, as a result to previous schools that have been critized for having bad outdoor spaces, lack of lounges and boring interiors. An article in "Göteborgs handels- och sjöfartstidining" (newspaper) wrote that "It is difficult to imagine a more open and friendly school environment" (Jonsson & Lindman, 2021).

The concept was to create a school with a good teaching environment and social spaces both inside and in the courtyards. The difficult terrain was solved by incorporating the building within the terrain, creating different floor heights but maintaining same roof height (Caldenby et al, 2018). The façade is of red bricks and continuous, horizontal aluminum-framed windows that are interrupted by French balconies in some parts, and the structural elements are of concrete columns embedded in the facade. Corridors are long, and generally placed along the east and west facades, while the classrooms are on the other two.

The southern section of the school is where most of the classrooms are, while the northern contains the school cafeteria, the main auditorium (that was later transformed into classrooms) and the school gymnasium. The western sector is where we find the handicraft classrooms, administration, and teacher's offices. The school also used to contain spaces and officers for dentists, school doctors and nurses. The eastern section is open, facing the football pitch and Ängåsskolan.

There have been several changes and renovations throughout the building's history, such as an extention in 1976 for the youth center, change and decrease in size of the windows in the 1980's and changes in the floor plans in 1994 (Jonsson & Lindman, 2021).

The school was closed in 2016, despite receiving extra funds to boost academic performance, due to declining enrollment and insufficient grade improvements. The school's academic results have consistently lagged behind, with only 44% of students passing all subjects in 2015, compared to a district average of 79%. The decreasing number of students and unattractive facilities made it challenging to provide a good-quality education (Göteborgs-Posten, 2016).

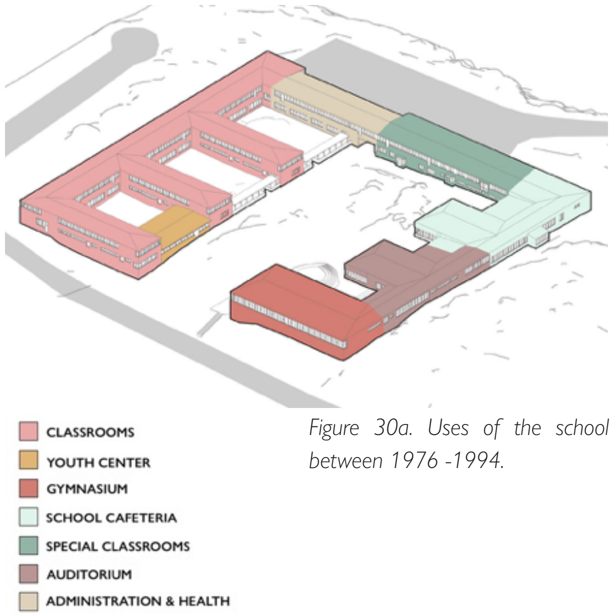


Figure 30a. Uses of the school between 1976 -1994.

The building is not empty or abandonned today. It is currently still being used for educational purposes while pending for demolition. The current uses are:

Kulturskolan (Culture school) currently houses in the southeastern sector of the school. Partly renovated in 2021 for this purpose.

Vättnedalsskolan moved in in January 2024 and is housed in on the ground floor of the southern section and in two of the wings. A renovation was made prior to the establishment. Original Vättnedalsskolan is currently undergoing a demolition, and Tynneredsskolan will function as a temporary location until the new school is finished.

The school cafeteria and special classrooms is being used by the students from Vättnedalsskolan and nearby **Ängåsskolan.** The gymnasium is also used by local sports associations in the after-school hours.

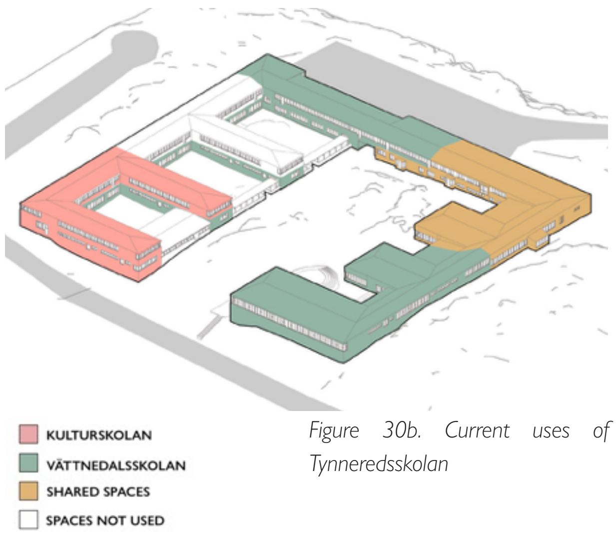
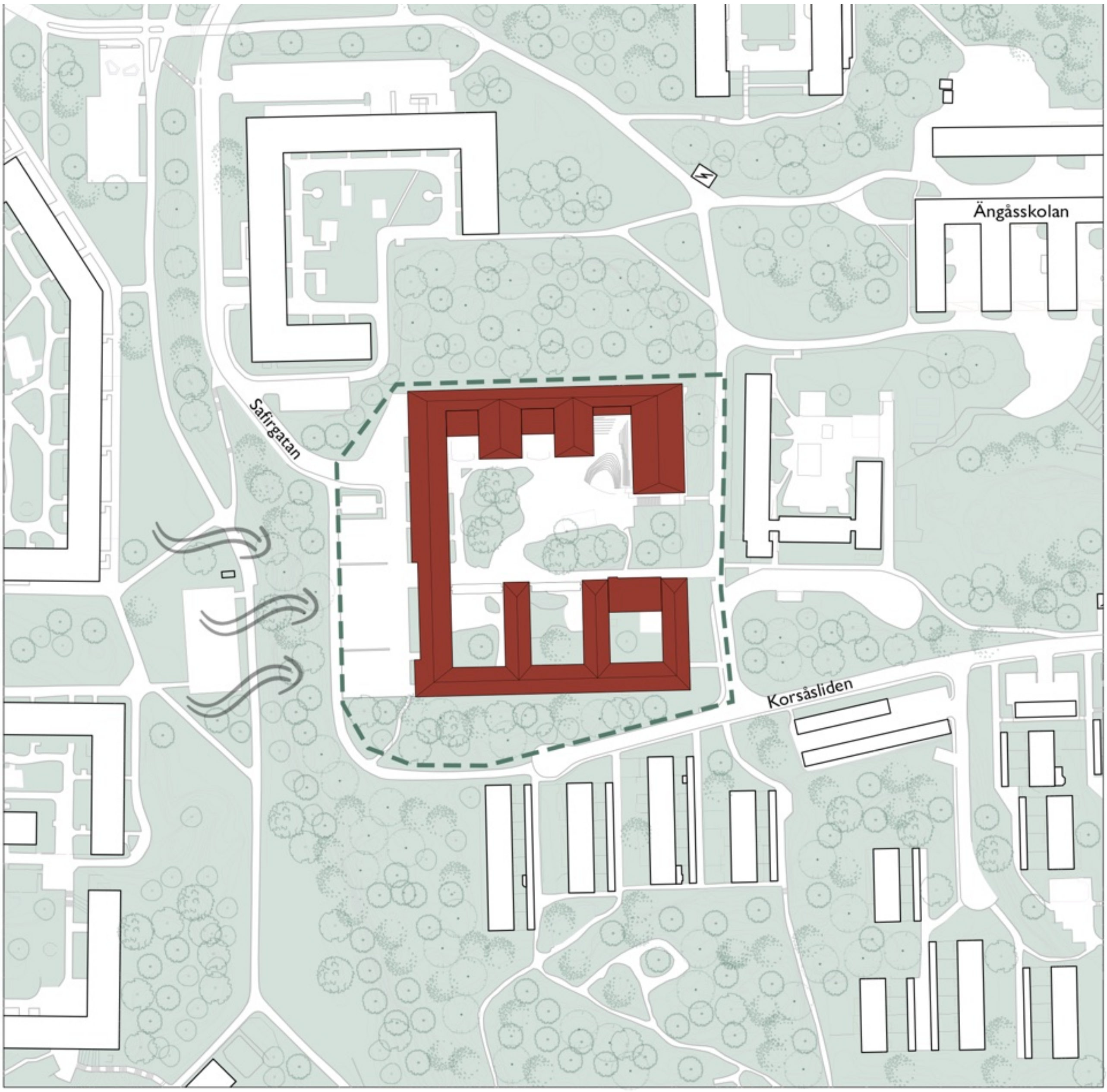


Figure 30b. Current uses of Tynneredsskolan



SITE PLAN

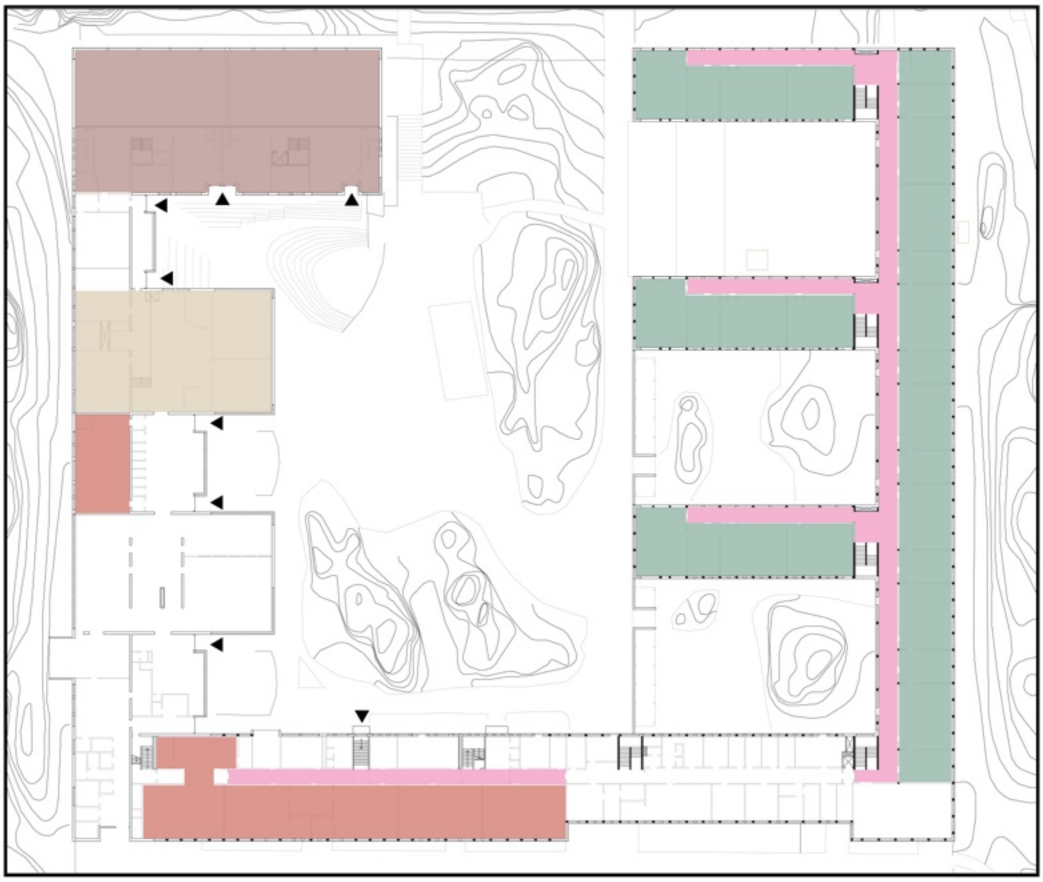
- - - Property boundary

0 25 50 100 150 250m

The school is located on a small hill overlooking the surriundings to the east and west. The site features varied vegetation; some areas are lush while others are sparser. The courtyard's center boasts trees and large asphalted spaces that accommodate vehicle movement. To the north and south, dense trees give the impression of closeness to nature. The trees to the south also provide solar protection during the warmer months. The east and west sides are more exposed, with solar protection on the facade towards the latter. Wind tunnel effects may occur on the western side, exacerbated by sea winds and the narrowing passage through the portico

As mentioned earlier, Gothenburg has a coastal climate with mild to warm summers and mild to cold winters. Rain and humidity are part of the everyday climate, and the prevailing southwestern winds affect the site, which sits atop a hill offering views towards the sea.

First Floor

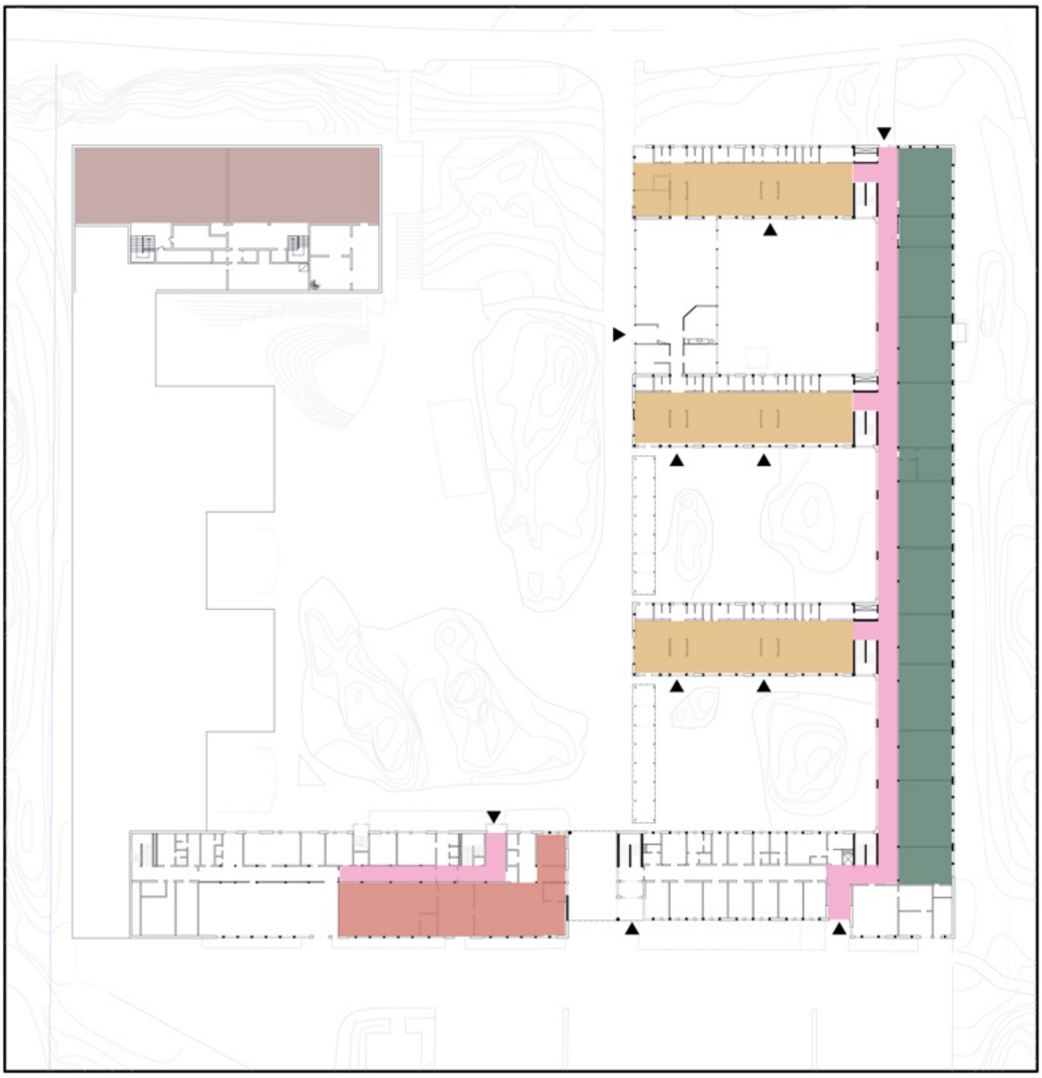


- Social spaces
- Corridors
- Home classrooms
- Subject-specific classrooms
- Practical classrooms
- Gymnasium
- Auditorium

Figure 31: Student space distribution. Scale 1:1000

First floor. Main classrooms in the south and common functions in the north

Ground Floor



The wings were the original entrances, and the ground floor was dedicated for the lockers, and also functioned as a social space for the students. Special classrooms for subjects like chemistry, physics and geography was located along the southern edge with a long corridor going east/west.

Distribution of student spaces

BUILDING OVERVIEW

The building measures approximately 115x105 meters, with the width varying across different sections. The southern sector and wings are about 9.8 meters wide (Figure 32a), while the western sector ranges from 11-13 meters (S2-S3 in Figure 32b). The school cafeteria and former auditorium are around 15.5 meters wide, and the gymnasium spans 20 meters.

Inside, classroom ceilings are about 3 meters high on both levels, with corridors slightly lower at 2.8 meters. The auditorium and school cafeteria have higher ceilings, approximately 4.2 meters, while the gymnasium's ceiling reaches 5.8 meters, providing ample vertical space.

The building's foundation is concrete cast on-site on footings, designed to adapt to the existing terrain conditions as a souterrain-type structure. Consequently, some parts of the building include bunkers, with one located at the gymnasium and two beneath the wings. These bunkers, currently used as basements, have a capacity for 600 people. Additionally, culverts run beneath the entire building.

Structural support is provided by concrete pillars embedded in the façade, measuring 18x25 cm and spaced at 2.2 meters, though irregularly in some areas. Some loadbearing walls, made of 15 cm concrete and about 1 meter in length, also contribute to the building's stability. Inside, non-loadbearing brick walls between classrooms and corridors feature embedded pillars, which are 20x20 cm on the ground floor and 20x14 cm on the first floor, all cast in-situ.

The floor slab is constructed using a TT-cassette concrete slab (Kaiserbjälklag, TT-kassett in Swedish), which is suitable for longer spans. This 50 cm thick slab is mostly hollow, allowing for additional insulation and installations, especially under the corridors where ventilation channels are located.

The façade is composed of infill brick walls and windows, with a thickness of 34 cm. The components vary slightly depending on whether it is an infill brick wall, a load-bearing wall, or a column, as detailed in Figure 35a. The windows, updated in the 80s and some as recently as 2021, are smaller than the original ones, likely due to the 1970s energy crisis. These windows vary in size, mostly around 1.6 meters tall, with those along the ground floor corridors being typically taller.

The roof structure incorporates glulam trusses and beams, insulated with mineral wool and enclosed with two sheets of roofing felts. Air cavities are present by the edges, ensuring proper ventilation and insulation.

According to the school's janitor, whom I met in February 2024, the school's structure is in good condition except for the roofing, which is need of change. The ventilation is also not working properly in some parts of the first floor, and those parts are therefore deemed unfit for use. The same goes for the former youth center, which has large problems with mold (see figure XX).

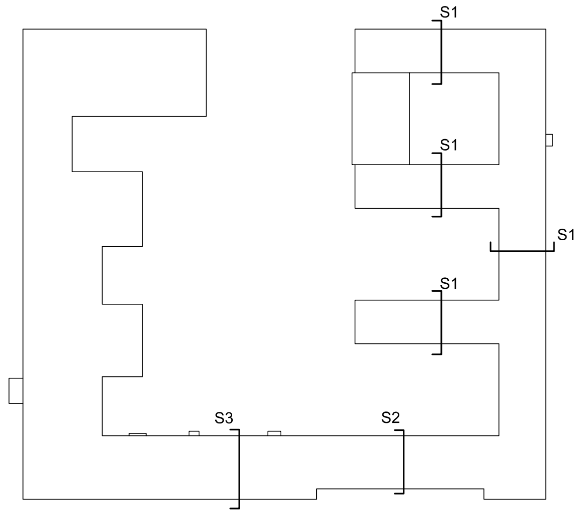


Figure 32a: Diagram showing the section cuts (general sections) Not to scale

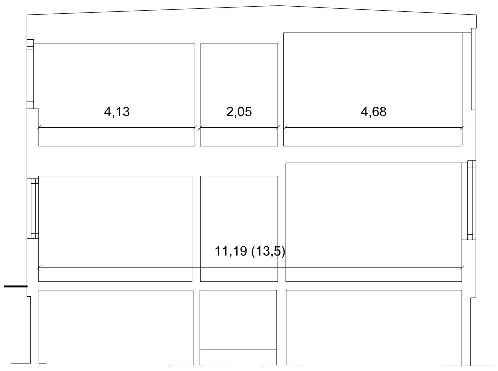
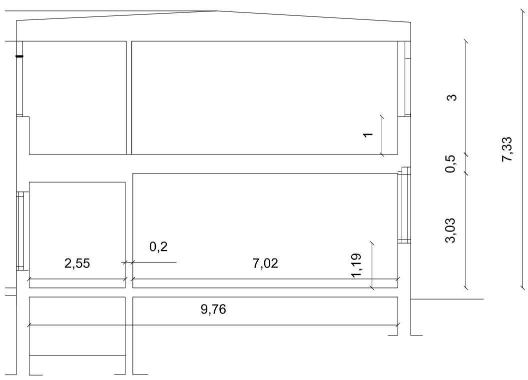


Figure 32b: General section for type S2 (S3 value within brackets). Same idea as section S1, but with the corridor placed in the center. Scale 1:200



ROOFING (OVER CLASSROOMS)

Roofing felt	0,5mm x 2
Roof truss	100mm
Glulam beam	335x56mm
Mineral wool mat	30mm
Mineral wool board	120mm
Plastic wrap	0,1mm
Wood battens	2x75mm
Air cavity, mineral wool (edges)	30mm
Corrugated eternite	10mm

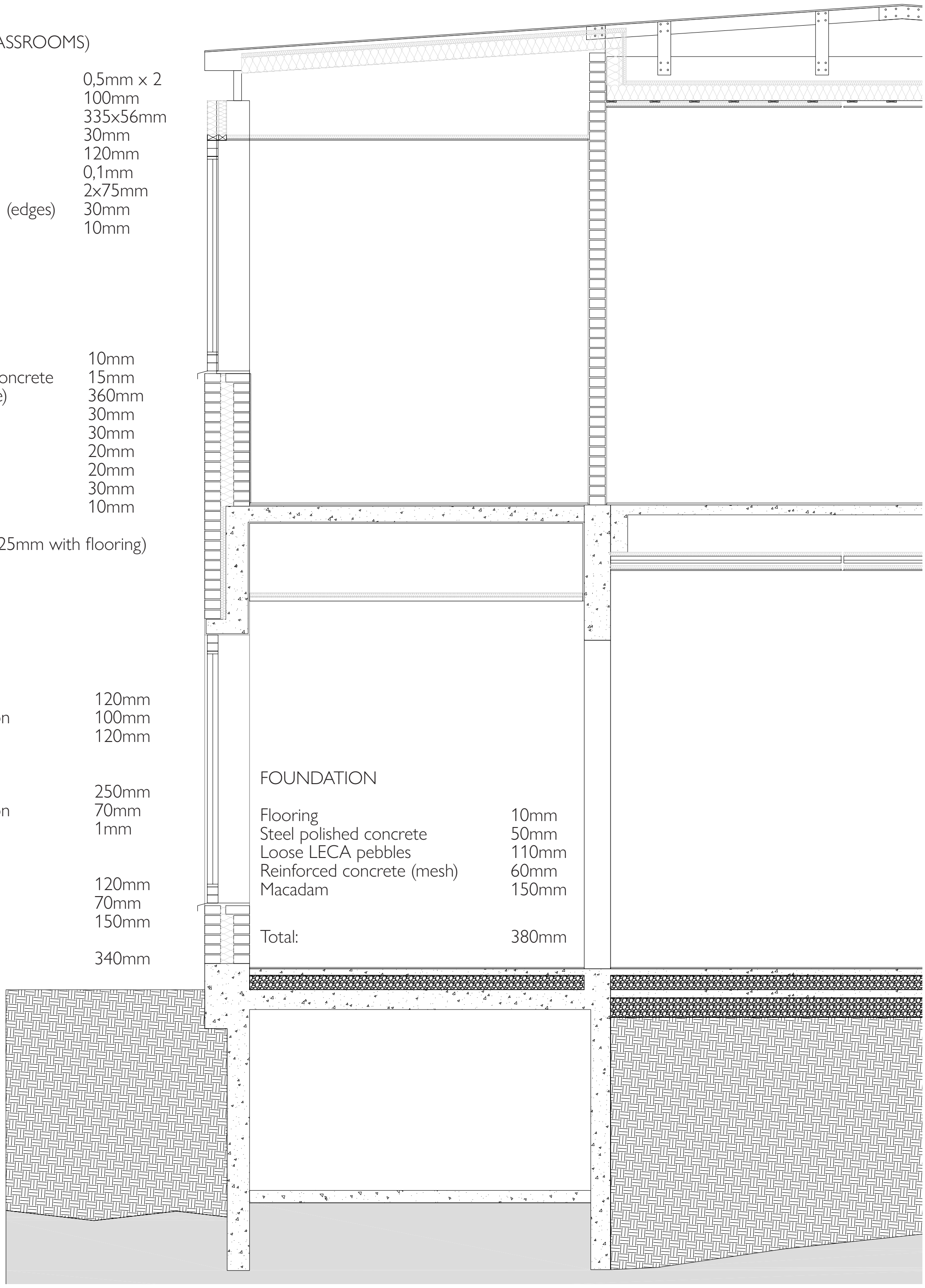
FLOOR SLAB

Flooring	10mm
Steel polished plastic concrete	15mm
Kaiserslab (TT-cassette)	360mm
Mineral wool mat	30mm
Wood battens	30mm
Wood boards	20mm
Air cavity	20mm
Mineral wool board	30mm
Corrugated eternite	10mm

Total 500mm (525mm with flooring)

EXTERIOR WALL

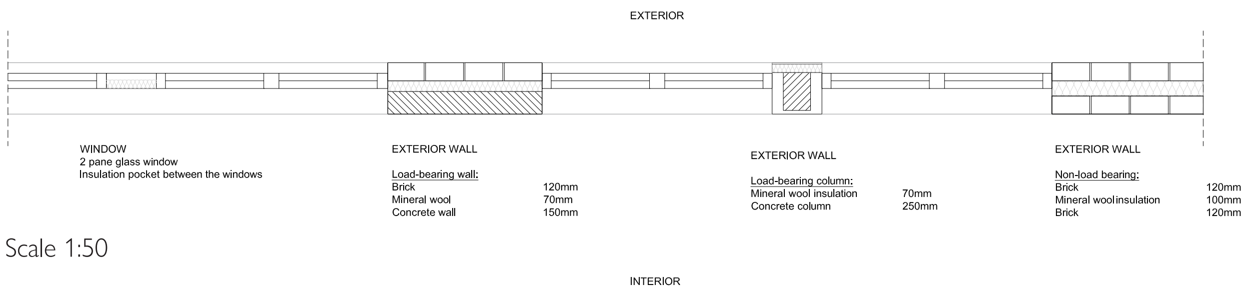
Non-load bearing:	
Brick	120mm
Mineral wool insulation	100mm
Brick	120mm
Load-bearing column:	
Concrete column	250mm
Mineral wool insulation	70mm
Aluminium sheet	1mm
Load-bearing wall:	
Brick	120mm
Mineral wool	70mm
Concrete wall	150mm
Total thickness	340mm



Scale 1:50

Figure 33a: Above. Detailed section highlighting the structural and facade elements.

Figure 33b: Below. Section in plan showing the main components of the facade. The insulating layer is on different levels, which could be a problem regarding thermal bridges.



Scale 1:50

CULTURE HERITAGE VALUES

Spaces:
The schools of Gothenburg built between 1950-2000 were subjected to an inventory made by the City Museum of Gothenburg, and Tynneredsskolan was one of them receiving the "Culture Class A" designation for its architectural heritage. It is a good example of the 1960's schools with the student in center. Extra attention was placed on the social spaces, both in the interior and the exterior. Tynneredsskolan had generous social spaces; both the smaller and larger courtyards were used, as well as the spaces by the entrances to each year grade. The youth center, an extension from 1976, is not included in the heritage.

The home classrooms were located on the first floor, with special subject-specific classrooms on the ground floor. Special practical classrooms, such as woodwork, textile and cooking classrooms were, and still are, located in the western section of the building

Architectural expression:
The red bricks, white lintels and the continuous ribbon windows. A common expression for the 1960's, but this also links the school with the surrounding residential areas at Briljantagatan and Topasgatan, which has similar expressions

The building is also valued for its comb-shape and its ability to adapt to the difficult terrain, as well as maintaining the nature in the courtyards. The distance between the courtyards is roughly 20 meters.

Figure 34a: Red brick facade, white lintels and continuous ribbon windows. The windows on the ground floor were changed in 2021 and the ones on the first floor were changed in the 1980's.
Photography: the author

Figure 34b: The architecture of the school is clearly linked with one of the surrounding residential areas (Topasgatan and Briljantgatan). It is visible in the materiality, and how both the school and the residential area is integrated with the local topography. Both were designed by White Arkitekter.
Photography: the author

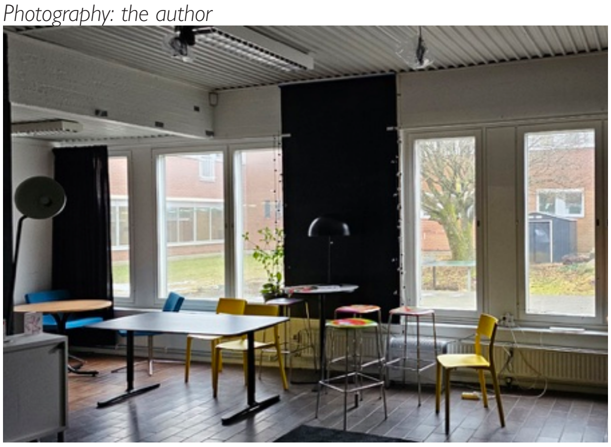


Figure 34c: One of the former social spaces, now used by Kulturskolan
Photography: the author

Figure 35a. Picture of the former youth center, Tyrolen. It is not used due to a mold infection in the ceiling.

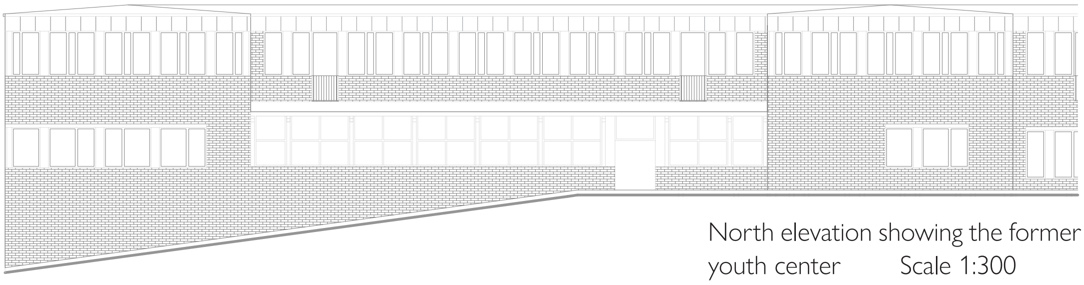
Figure 35b A view over one of the two gymnasium halls. Large windows that allows much daylight

Figure 35c. Renovated corridor on the ground floor, currently being used by the pupils of Vättnedalsskolan

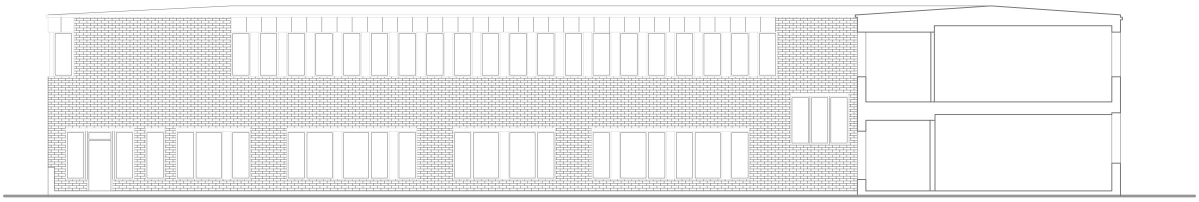
Figure 36a The parking lot to the west of the school. We can get a clear view of the façade with the continuous horizontal windows and the portico that leads to the school yard

Figure 36b. Corridor on the first floor, in the unused part of the building. The area has not been renovated

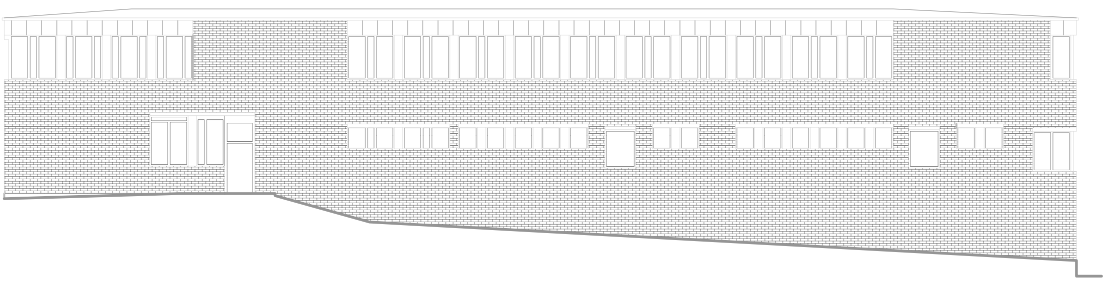
Figure 36c View from the first floor towards the courtyard and the gymnasium. Notice the buildings at Briljantgatan on the hill in the background.



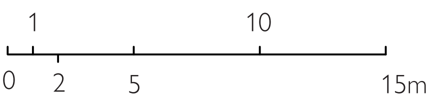
North elevation showing the former youth center Scale 1:300



West elevation
Scale 1:300



East elevation
Scale 1:300

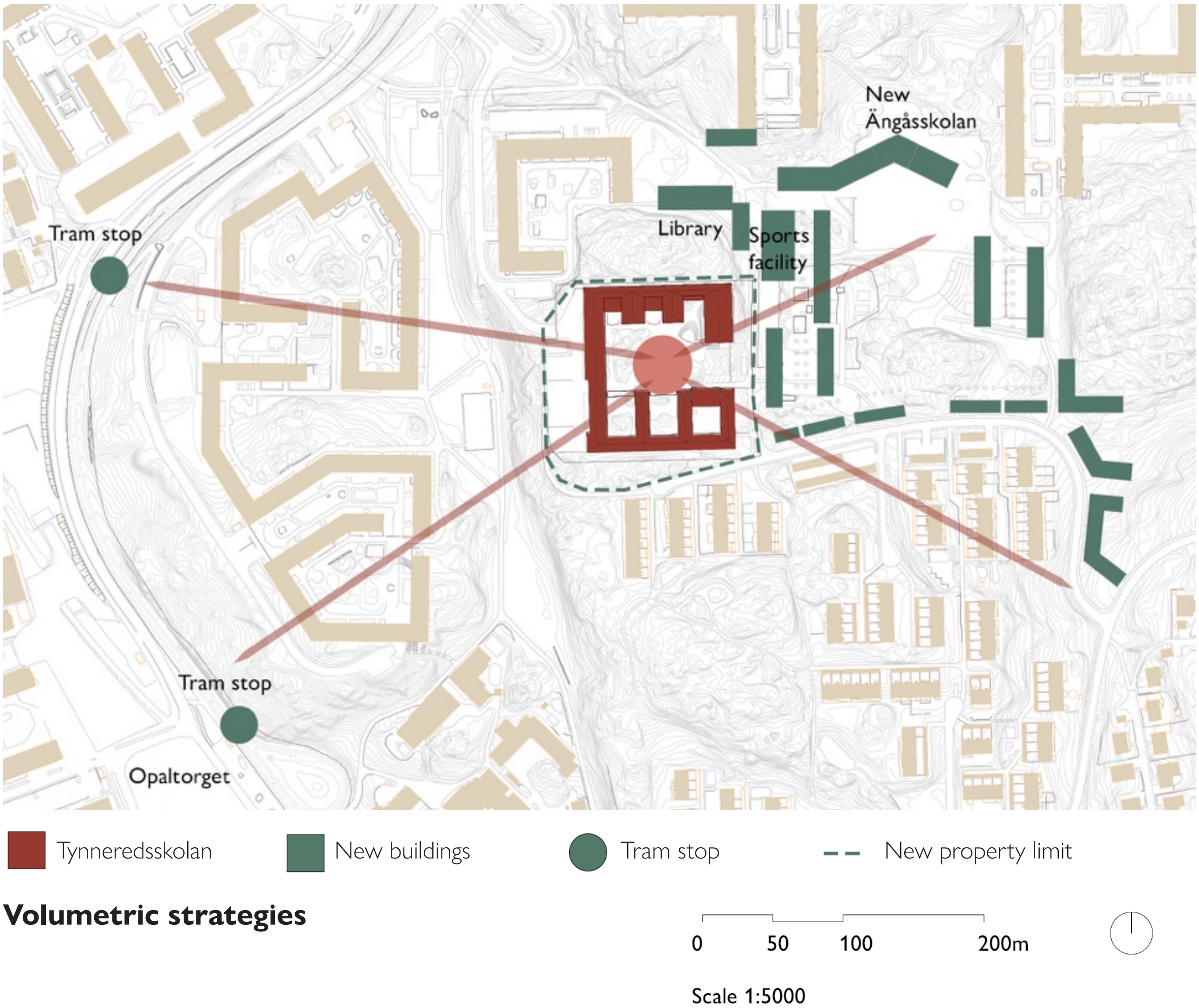


TRANSFORMATION

06

Rendering. View of the exterior gallery-access balcony which also functions as a social space

Design strategies - Urban scale



Volumetric strategies

The tranformation of Tynneredskolan will link with both the existing and new surroundings. Since the municipality is still working with the development of the area, this will depart from the working draft delivered by the municipality in October 2023 presented earlier in the thesis, and as already mentioned, the transformation will only focus on Tynneredsskolan.

As seen in the figure above, Tynneredsskolan is conviently placed between the old and new neighborhoods. It is supposed that there will be pedestrian traffic movring through the area, mostly towards new Ängåsskolan and the new educational and sports facilities, but also towards Smaragdgatan, Opaltorget and the tram stops. Tynneredsskolan thus becomes a local center

Figure 40. Tynneredsskolan in its current state. Axonometric view from the northeast that will be used to describe the decistions regarding the volume of the future extensions. The existing building is placed like a fortress ontop of a hill and integrated with the terrain. Surrounded by the greenery. Large opening towards the east.

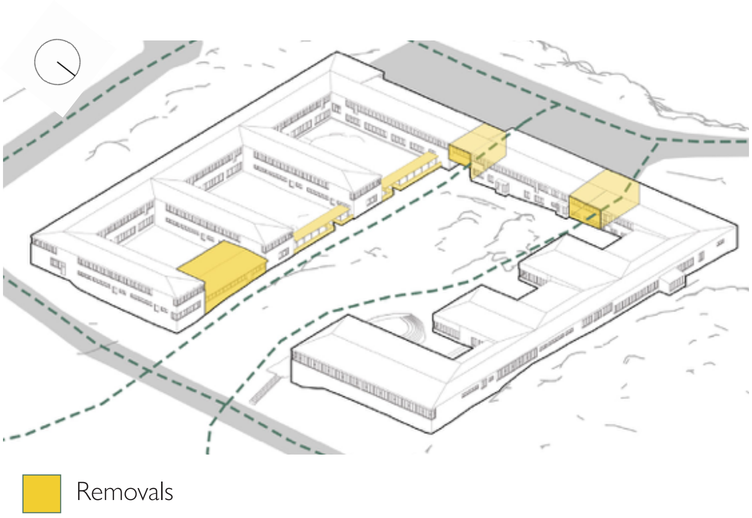


Figure 37a. The demolitions highlighted together with the east-west pedestrian movement. The openings towards the west are made in order to strengthen the connections and movements to the surroundings. No openings are created towards the north or the south as there is no need for movement towards these directions. Both sides are forested, and it is better to maintain the greenery. The former youth center is demolished because of its bad state.

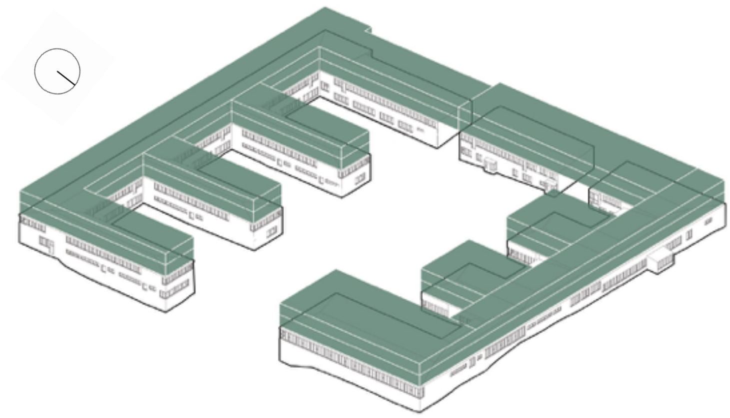


Figure 37b. Adding the maximum volume the building can handle. It its desirable to keep the continious roof line, but not the volume would be out of scale, and create dark courtyards

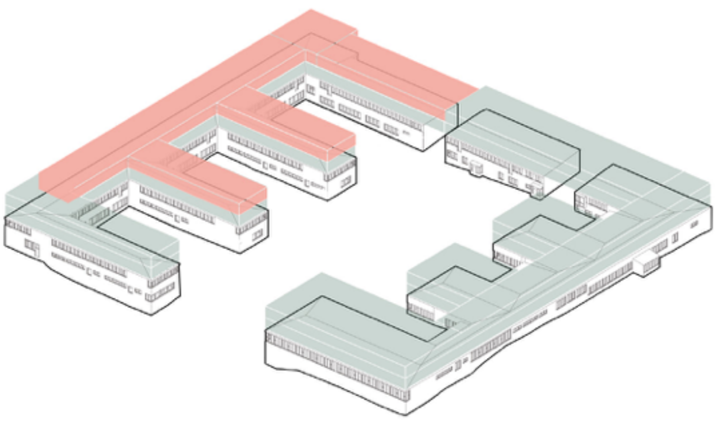


Figure 37c. Taking away volume around the courtyards in order to maintain good daylight conditions.

Starting with the intention that Tynneredsskolan will be a local center, there is a decision to ”break down” the enclosed building. As a result, there school will be divided into three parts. This allows for more natural approaches to and from the site in an east-west direction. The opening towards the east is already of good proportions, while the west only has the existing portico. The level above the portico is demolished, together with another section nearby to create a more welcoming approach from the west (fig 37a)

The former youth center extension will also be demolished because of it being in a bad state, containing mold infections. It was also built as an extension in the 1970’s, and not being a part of the architectural heritage of the building. The brick walls towards the smaller courtyards are also taken away as they are not needed anymore.

The second step would be to add volumes on top of the existing structure. As stated earlier, the assumption is that the structure can handle two new levels if made lightweight. It is maximized as the municipality wants to build 100-300 units on the site of the school (fig 37b).

Maximizing would not be an option, as it would create many problems, such as very shadowed inner courtyards and volumes out of proportions. There is also a concern that it would be experienced as too enclosed if fully implemented. Beginning in the southern sector, almost an entire floor is removed to allow for more sunlight during the day and around the courtyards, allowing for more afternoon sun in the courtyards (fig 37c).

The next step would be to reduce the volumes in the northern part in order to inhance the visual connections with the greenery around the building and to narrow down the new volumes so that they would better match the existing structure (fig 38a).

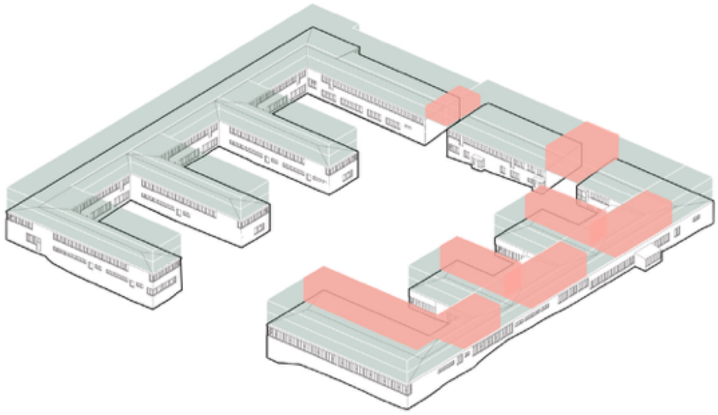


Figure 38a. Removing volume so that good visual connections can be established. The new volumes will also be narrower than the existing ones.

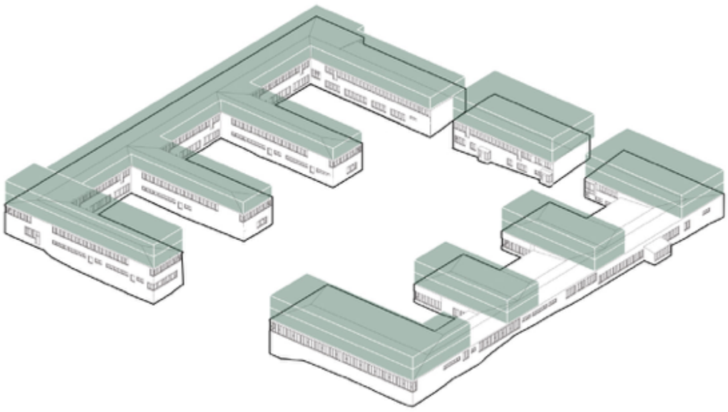


Figure 38b. New volume defined. Based on the exising comb-shapes which is a characteristic of the school. The large volume is broken down into three parts.

The new volume is now defined (fig 38b) and closely resembles the existing school with the comb-shape. The last step now would be to add the roof to link the volumes together.

The building and volumes can at this stage be divided into functions. The ground floor is divided into two roughly equal parts, one public and one private (fig 38c). The reason for that is because of how the flows would be in the area, where there will be more movement near where the public functions are, and to maintain the privacy of the smaller courtyards to the south. The smaller courtyards wcere more private when the building was a school, which is a function that can be incorporated into the transformation.

The new functions would be a café/bakery in the former school cafeteria, making use of the existing infrastructure and delivery spaces. The former auditorium and gymnasium would be a permanent seat for the culture school, and the ground floors towards the west would house commercial or common spaces.

The final step would be to define the housing typologies. There will be rowhouse-apartments on top of the culture school and café/bakery, student housing on the western sector and multi-family housing on the southern sector (fig 38d), which is where the focus of this transformation is located.

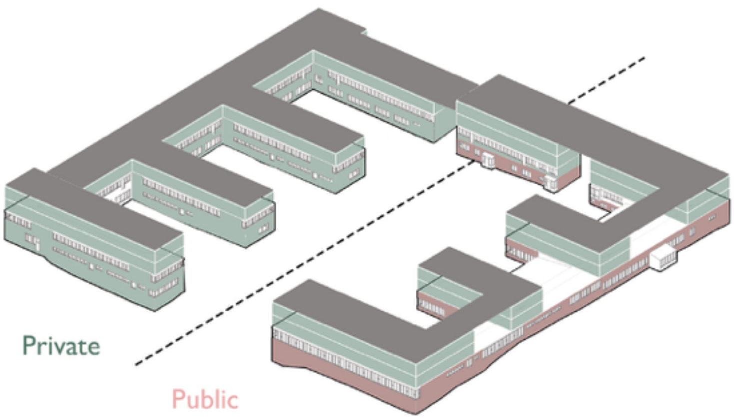


Figure 38c. Dividing the building based on private and public functions.. Public functions are placed on the ground floor in the northern part of the building, keeping the southern part more private.

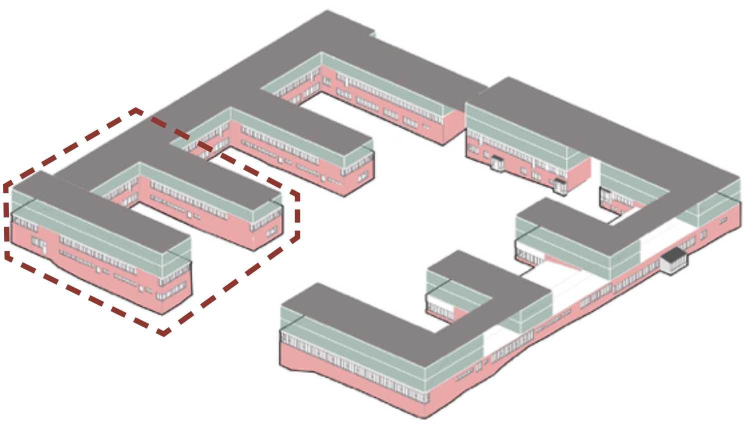


Figure 38d. Final shape of the building. All new additions ontop of the existing isreserved for housing. The dotted area is the focus of this thesis. It could be seen as a representative of the transformation of the school building as it contains both a single and double floor addition, and a courtyard with both challenges and possibilites.

Ground floor use. The areas to the south are kept more private, and the new main axis will run near the northern section. The public functions include a space for Kulturskolan Väst in the former auditoium and gymnasium. A café/bakery is placed in the former school cafeteria. Spaces in the west facing the parking are reserved for shops or common spaces for the residents. The green areas are proposed to be increased since there is plenty of asphalted spaces in the current situation

The marked area is the focus are of this thesis. It is a residential part of the building, where 34 apartments of ca 114 are located.

Design strategies

DESIGN PRINCIPLES

The following design principles have been applied in the transformation. The first one, Volume, has already been presented. The Housing qualities and Structure & Heritage are presented in the floor plans, elevations and sections. The climatic adaptations are shown in some sections, but will above all be a part of the LCA analysis in the last chapter where the comparisons will be presented.

VOLUME

- Daylight & Natural Sunlight
- Densification in accordance with the existing structure and conditions

HOUSING QUALITIES

- Spacious and continous layouts
- "Compensation" with unfavorable locations

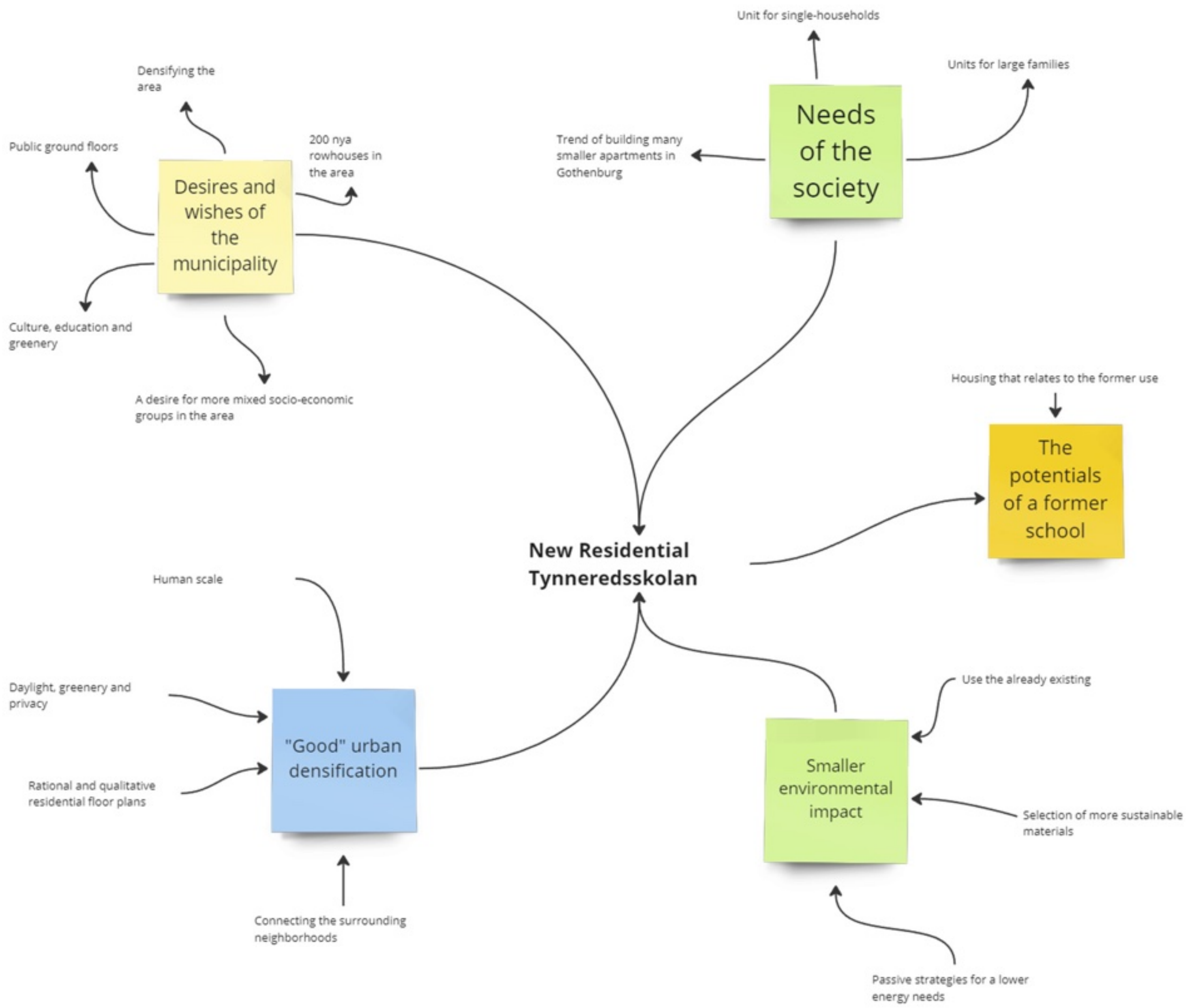
STRUCTURE & HERITAGE

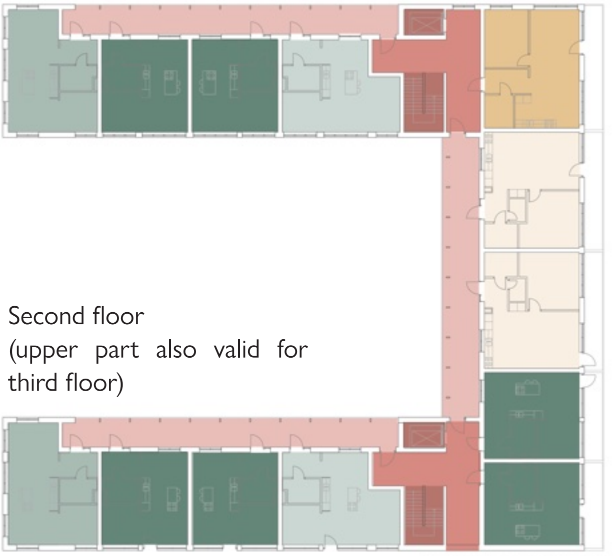
- Maintaining the existing structure
- Maintaining the facades as much as possible
- Restrictive demolitions
- Careful integration of the architectural heritage
- Social spaces

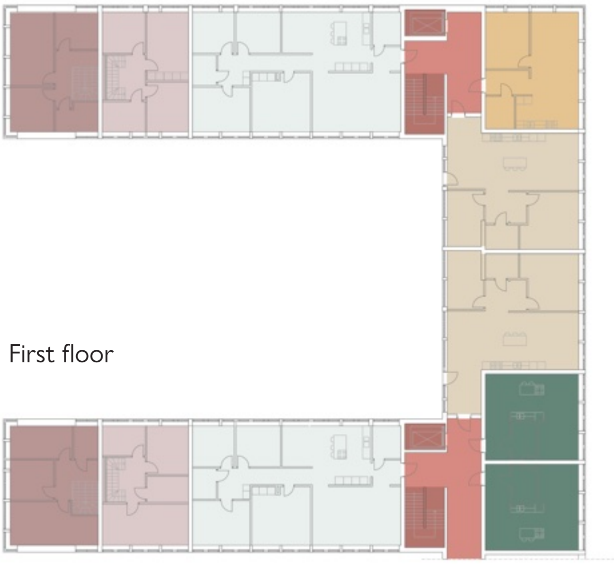
CLIMATIC ADAPTATIONS

- Implement passive strategies that relates to the site and functions.
- Sustainable materials for the new extensions

Figure 39a. The design principles put together with the aims and wishes of the society, a guiding tool for this transformation







APARTMENT DIAGRAM

The diagram to the left shows the placement and configuration of the apartments. There are in total 34 apartments in this section of Tynneredsskolan.

The entrance is in the middle of the courtyard, leading towards the staircases on either side. The rowhouse-apartments (type 40a and 40b) have their access directly from the courtyard, where they also have fontyard and a backyard terrace. The most common apartment type is type 10 (with variations a-c) and are mostly located the extensions on top of the original building. They have slight variations depending on the placement, and most of them have their access through an exterior gallery, which also functions as a balcony/social meeting space.

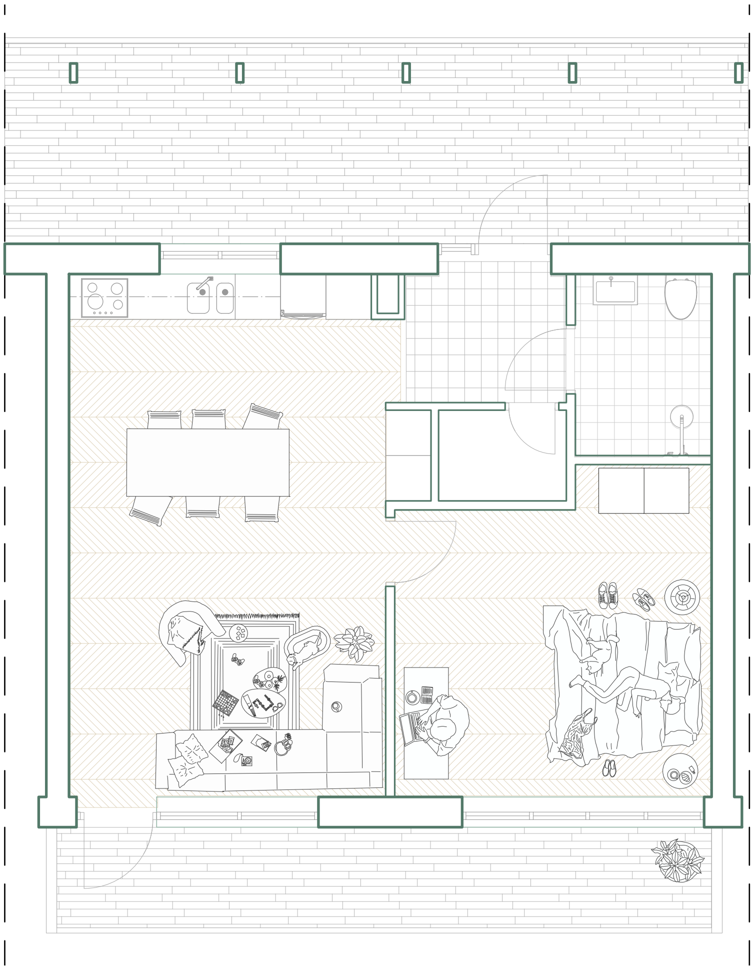
Type 50 is the largest apartment, located on the ground and first floors, next to the staircases, and there are slight differences between the ones on the ground floor and the ones on the first floor because of existing structure on the ground floor (later plans).

The 2-3 bedroom apartments are quite similar, with type 20a being placed in the corner, and 20b and 30a having the same layout, with the difference being that type 30a, located on the first floor, has an extra bedroom above the corridor on the ground floor. This was made so that more apartments could have double facades, leaving only five out of 34 apartments with a single facade.

COMMON SPACES

- ▶ Entrance
- Interior common corridor
- Exterior common corridor
- Elevator & Staircase

	Nr. of units
1,5 - 2 BEDROOM	
Type 10a - 42m²	11
Type 10b - 51m²	3
Type 10c - 51m²	3
2 BEDROOM	
Type 20a - 61m²	3
Type 20b - 57m²	4
3 BEDROOM	
Type 30a - 83m²	2
4 BEDROOM (Rowhouse-apt)	
Type 40a - 110m²	2
Type 40b - 111m²	2
5 BEDROOM	
Type 50a - 132m²	4



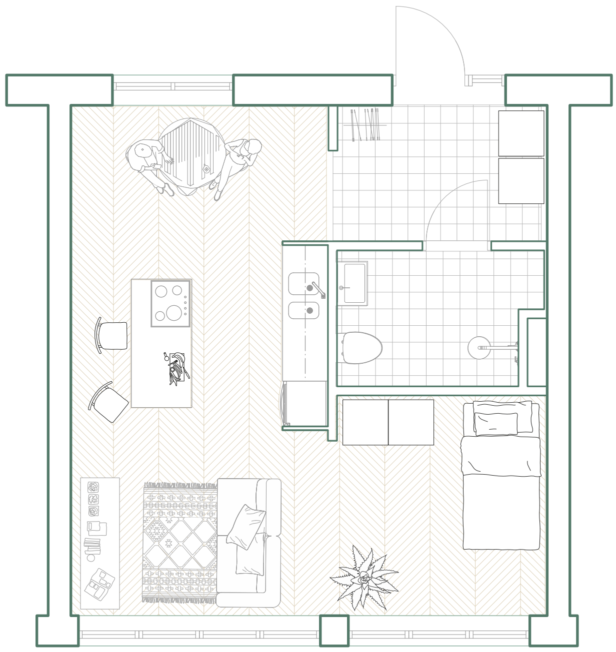
APARTMENT TYPE 20A
SCALE 1:100

Apartment type 20a

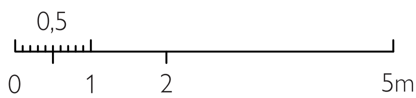
A spacious apartment that can be found on the ground floor and second floor. This example to the left is one from the second floor. The residents will have access to a large exterior gallery-access balcony that also functions as a social space for the people living on the same floor. It is wide enough so that furniture can be placed on the outside. The smaller, private balcony is 1,4m wide and faces the south. A small window is placed above the kitchen sink, allowing for views and natural ventilation

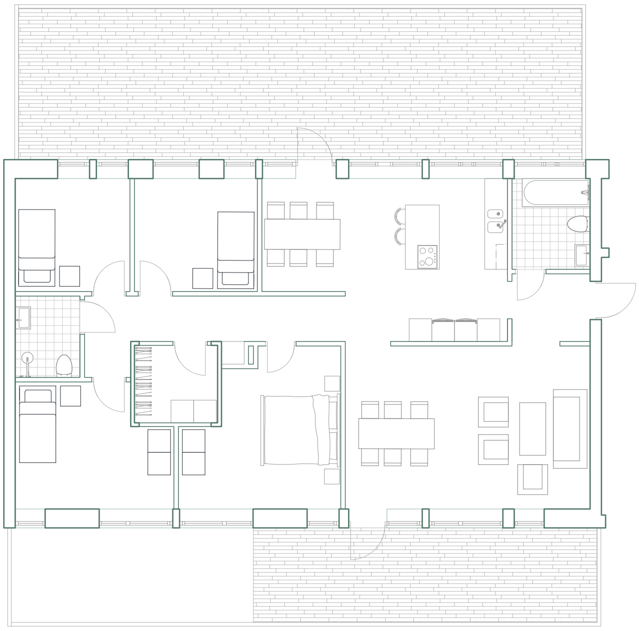
Apartment type 10a

The most common apartment, targeting single-households. It is a small apartment, yet light and spacious. The found on the second and third levels have exterior gallery-access balconies, just like the previous apartment shown earlier. The ones on the ground floor will have a terrace towards the south instead. The layout is very similar to apartment type 20a. There is also a possibility of turning the sleeping alcove into a small, separate bedroom.

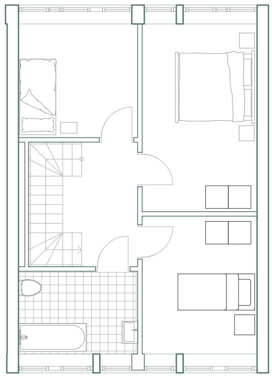


APARTMENT TYPE 10A
SCALE 1:100

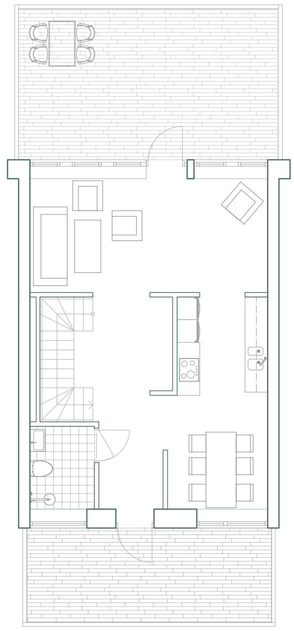




APARTMENT TYPE 50A
SCALE 1:200



First floor



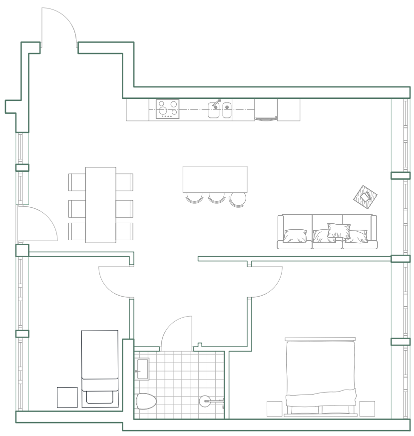
Ground floor
APARTMENT TYPE 40B
SCALE 1:200

Apartment types 30a, 40b and 50a

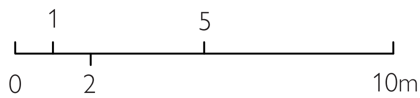
Apartment 30a is a larger version of apartement type 20b with an extra bedroom. The concept is to have a large, open living and kitchen spaces with a clear separation between private and public spaces of the apartment.

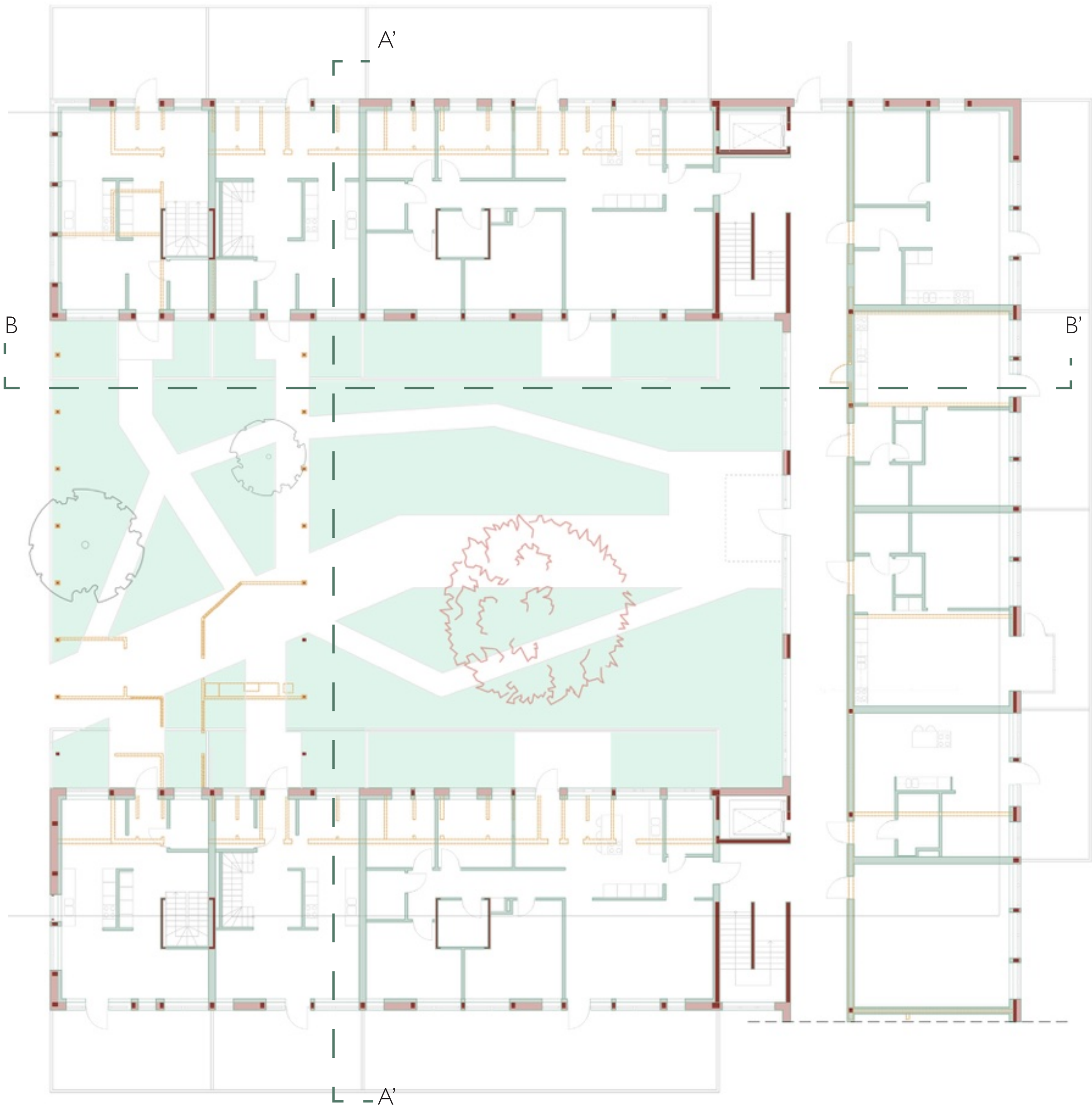
Apartment 40b functions as a small rowhouse, and there are four rowhouse apartments. Public spaces are on the ground floor with plenty of storage spaces, and private spaces upstairs. There is a small frontyard by the entrance, and a larger terrace at the back.

Apartment 50a is the largest apartment with generous spaces. There is an existing structure between the bedrooms, which used to be an old entrance to the school, but now transformed into storage space, which is needed for large apartments. Just like with the rowhouses, the exterior spaces includes a frontyard and a backyard.

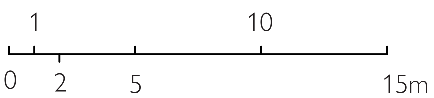


APARTMENT TYPE 30A
SCALE 1:200





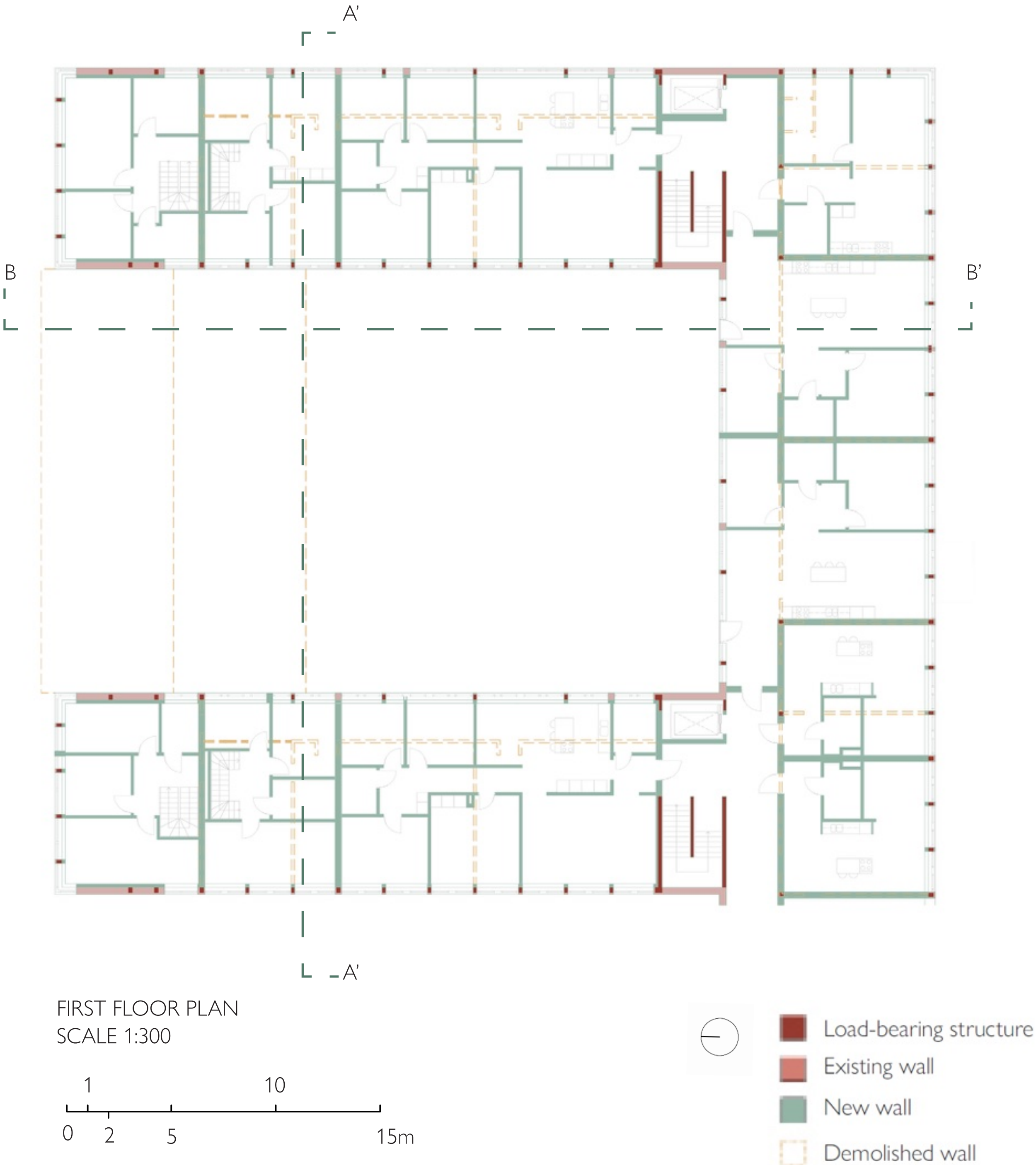
GROUND FLOOR PLAN
SCALE 1:300



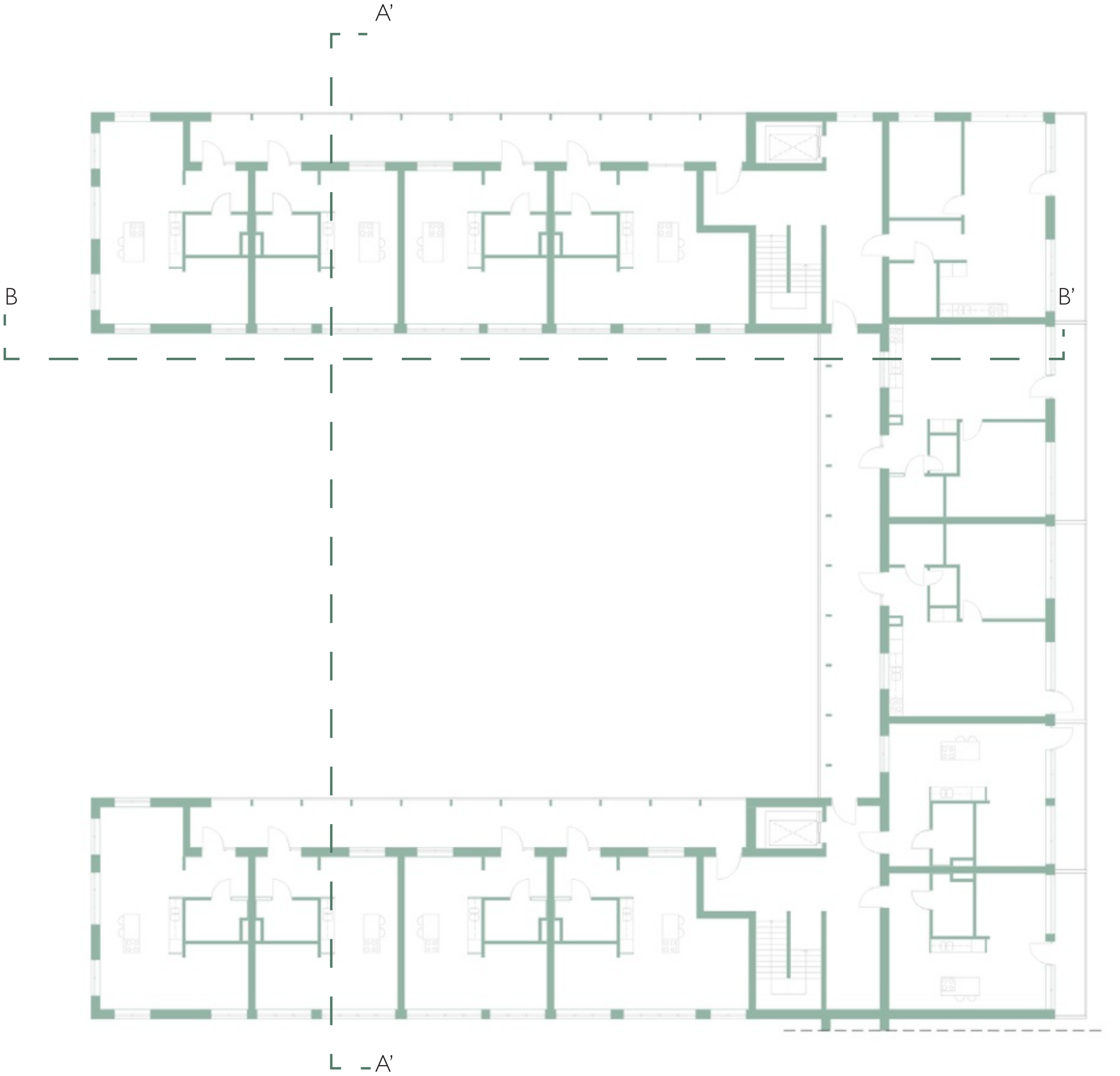
Certainly! Here's an improved version of your text:

The ground floor plan showcases the existing, added, and demolished structures. All loadbearing walls and columns have been preserved. The non-loadbearing interior walls have been demolished and replaced with new ones, including both apartment divisions and space divisions within the apartments. The new walls have generally been placed in accordance with the existing structure, resulting in slightly larger apartments than newly produced ones, as they follow a grid based on the 2.2m spacing of the pillars. This approach reduces the need for creating openings in the walls or closing existing windows. Most of the loadbearing structure is embedded in the facade, except for some walls in the interior.

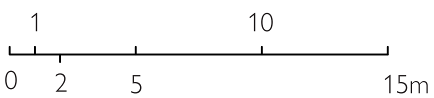
The main corridor on this level has been kept intact, with the most significant change being the addition of an elevator where a former ventilation shaft was located. Another noteworthy change is the demolition of the former youth center, which is highlighted in the floor plan.



First floor plan, and the structure is similar to the ground floor. The main difference is that there were less partition walls to demolish, and there is not any loadbearing wall or column in the interior except for the columns located in the former walls between the corridors and classrooms. The corridors have almost completely disappeared on this level.



SECOND FLOOR PLAN
SCALE 1:300

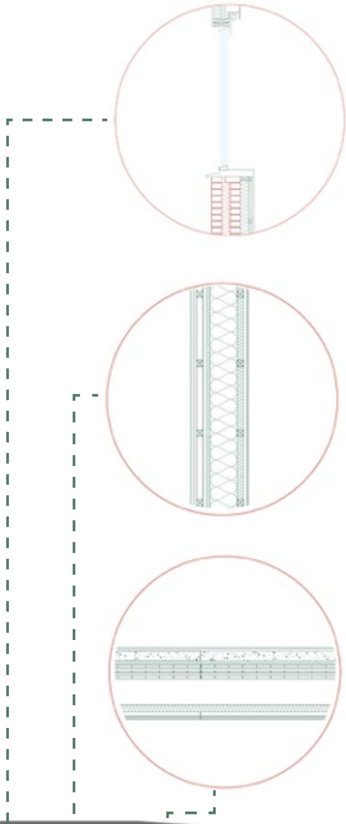


Second floor (upper part also valid for the third floor). This level is all new. The corridors are back again, but as the exterior-access galleries mentioned earlier. With this approach, daylight and natural ventilation can be offered to all the apartments on this level. Even though it is new, it still follows the rythm of the old structure below. Another aspect to mention is that although not visible on this plan, the roof former roof have also been demolished.

North elevation, section A-A'
Scale 1:300

Elevations and sections highlighting changes in the facades. There are no changes on the northern facade except for the new entrance door and a glass rain shelter just above the entrance. The west facade have some changes, which includes several openings where the former youth center was placed, a door on the ground floor and a new opening on the first level to allow for daylight in the space behind the facade.

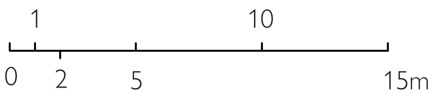
The smaller details to the right (not to scale) showcases old and new materials, which are explained on p 79.

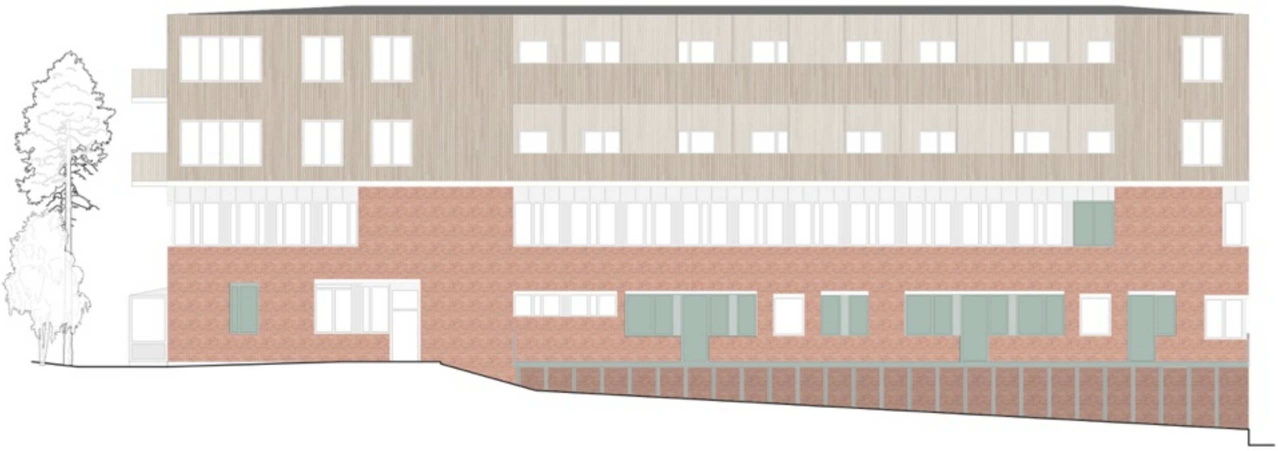


New opening or enlargement

Demolished structure

West elevation, section B-B'
Scale 1:300

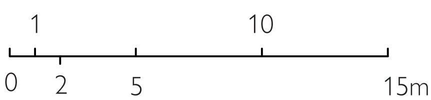




East elevation
Scale 1:300

The east elevations has a new terrace, two new openings. The windows on the ground floor have been enlarged. They were previously of the same size as the smaller windows which have been left in one part of the facade, as there is no need to make them larger. Towards the south, some enlargements in form of doors have been made to the terraces.

South elevation
Scale 1:300



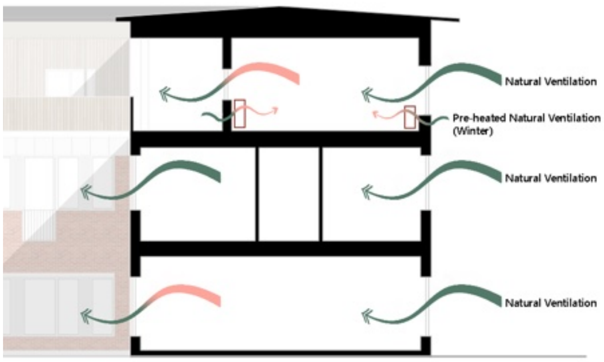
Heating, cooling & ventilation

HEATING

The building is already connected to the city's district heating system, and the current heating system will therefore still be in use in the existing part, where there are radiators below the windows. The new addition will have floor heating as it is more efficient than normal radiators. All the apartments will be heated, but not the corridors.

VENTILATION

There will be both mechanical and natural ventilation, as most apartments have two facades. A trickle-vent is installed in the new extension for pre-heating the air during cold winter days, just like in the case study presenter earlier in the thesis.



EVALUATION AND COMPARISON

07

Rendering. View of the courtyard

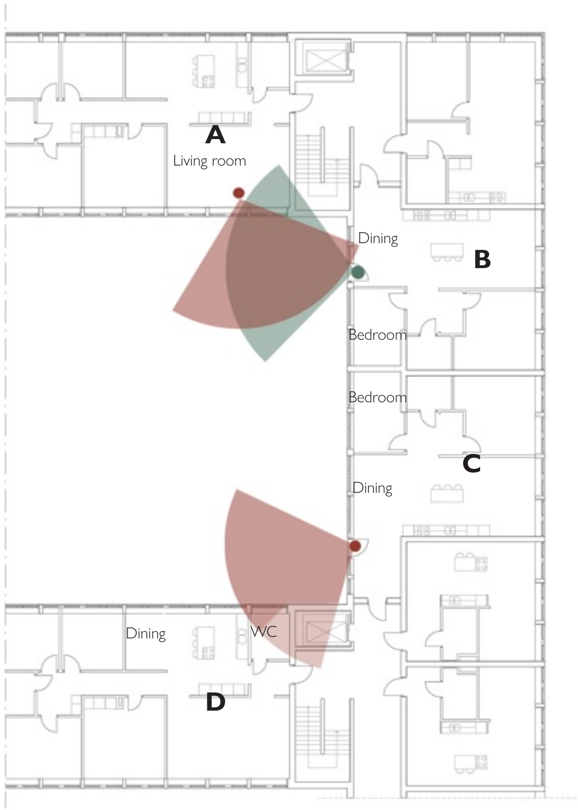
Privacy

This section will be about analyzing and evaluating the privacy issue through the theories and recommendations presented earlier in the thesis by Sundberg and Gehl. Sundberg recommended a minimum distance of 20m between buildings placed parallel to each other, which is the case at Tynneredsskolan, where the width of the courtyards is just over 20m (see figure 40c). There was also an attempt to use angled windows, but it was not deemed necessary nor in compliance with the architectural language of the building where the facades are flat.

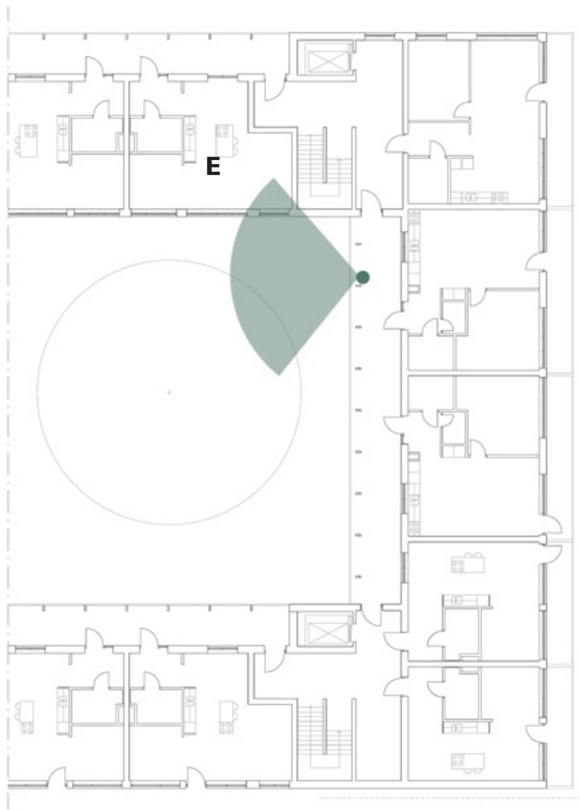
The second step was applied to the inner corners, which are much more problematic in a privacy aspect. Gehl's 7m threshold was applied here, and from this we can see that there are limited views between the apartments on the corners (marked A-E), starting on the first floor and the apartments A and B. They are placed close to each other, but the views are limited. The insight is mostly between public spaces of the apartments (dining space and living room). It can be somewhat problematic for the bedroom in apartment B, where the distance to apartment A is ca 9-10m. However, it is important to note that is not a straight angle, and the windowsills on this level are 1m from the floor, which limits the views (see figure 40a). Between apartments C and D, the main issue would be view from the dining space of apartment C and bathroom of apartment D. One solution could be to have frosted glass on the windows of the bathroom. For apartment E on the second floor, there is a limited view from the exterior-access balconies into the living space. Solutions to this could be to have some sort of lattice that is at least 3-3,5m long (not applied in this thesis proposal).

In general, the bedrooms in apartment B and C could have some issues also when taking into account the diagonal insights from the other levels, but it is considered better to offer larger apartments there rather than to have oversized corridor spaces.

It is good to remember that privacy is very personal, and that some people would believe the distances are too small, while others would not mind. The results are in general good, especially in the circumstances as in Tynneredsskolan, where there are many inner corners and with the staircase placed right at the corner, preventing one apartment to completely "own" that corner and minimizing the privacy issues.



First Floor



Second Floor

Scale 1:400

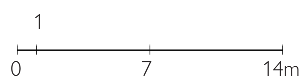
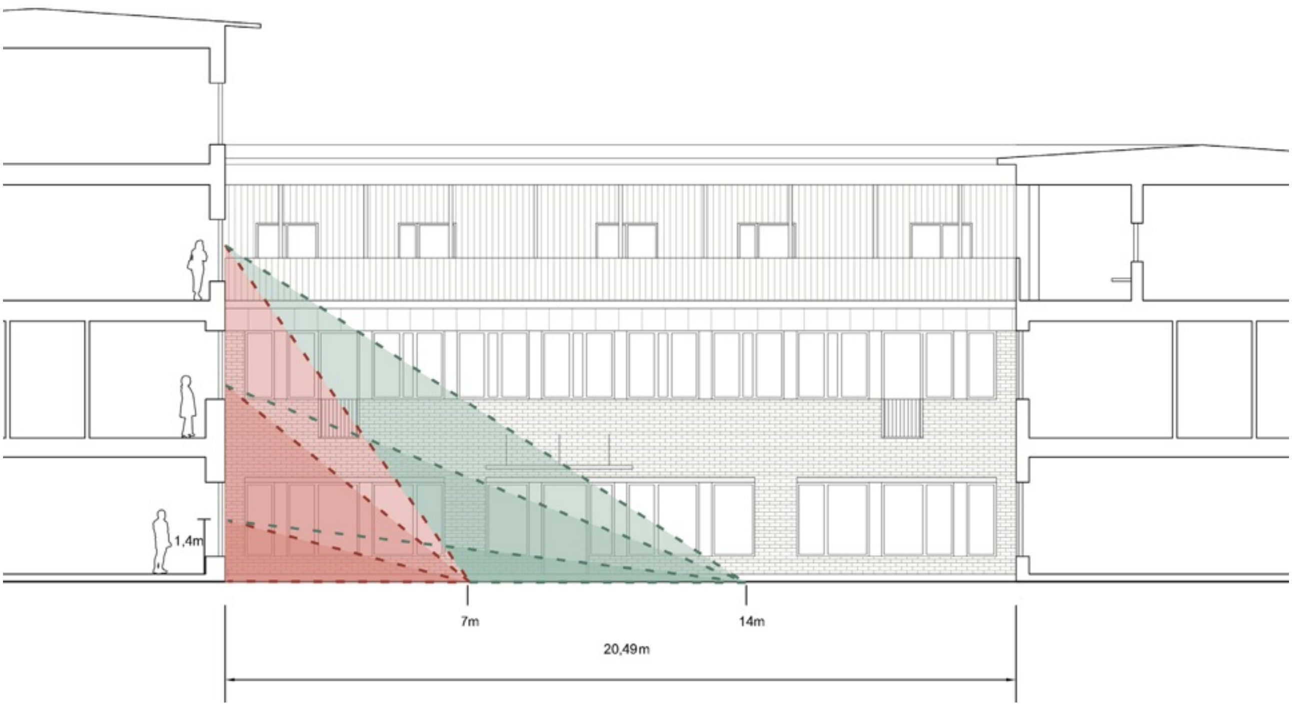


Figure 40a. Picture of the existing corridor on the first level. The windowsills are located ca 1m above the floor, which also affects the amount of privacy exposure into the apartments on the first floor, despite having large windows. Plants, decoration and curtains willl also reduce the insight to the apartments.

Figure 40b. Residents on the ground floor might have some insight, but they are compensated with private terraces along both facades of with a width of 2,5 - 4m. There will be fences and possibilies to use plants to reduce the insight.

Figure 40c. Section (not to scale) through the courtyard showing the width. It is just at the minimum of 20m that Sundberg recommends. Gehl's 7m and 14m thresholds are also applied. They show that it will not be an issue in the middle of the courtyard, but could be more problematic near the inner corners, especially in a diagonal direction.



Daylight & Overheating

DAYLIGHT

The daylight situation, simulated in Velux, using the daylight factor with the settings set to an overcast sky, so this does not take into account direct sunlight.

We can see in the figures to the left that there is plenty of light in most apartments except for some in the center part on the ground floor and first floor. The 1% curve still reaches the middle of those apartments. Allowing natural daylight might reduce the need for artifical light, but can also be problematic due to overheating, and we can see that with the current window set up, there will be problems with overheating on the facades facing south and west (more about that in the next page).

Most of the dark areas are service areas such as bathrooms and corridors, while the rooms and spaces along the facades are have good amounts of daylight. Also notice the difference between the first floor and the two other floors on the southern facade, which has a lower value, which is a result of the balconies on the level above. The values are lower, but the 1% curve still reaches to the middle of the room, partly thanks to the apartments having access to two facades.

The two marks, 10a and 30a, are two rooms where a simplified calculation method was applied. Those two rooms have also been selected for a simplified overheating analysis which can be seen on the next page. According to that calculation, the room in 10a would reach Gold and the room in 30a would reach Silver, which is in line with the Velux calculations where we can see that there is much more daylight in 10a compared to 30a. The ratio between window area and floor area (daylight window share in figure below) is much higher in 10a compared to 30a

Grade	Bronze	Silver	Gold
Daylight window share in %	10	15	20

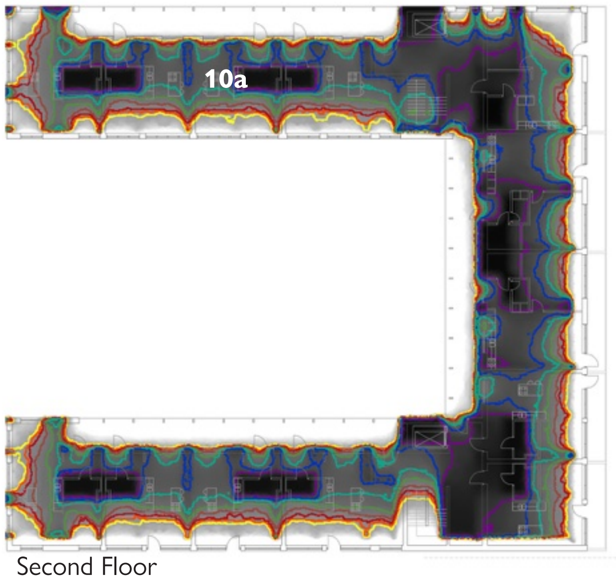
Apartment 30a

Daylight score	Silver
Total area of window glass	4,28 m^2
Demand of window share	10%
Daylight window share	19%
BRONS = Swedish law, BBR	

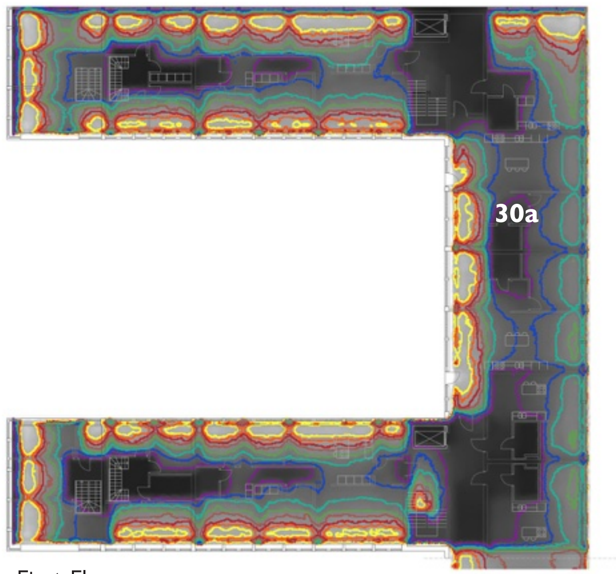
Apartment 10a

Daylight score	Gold
Total area of window glass	10,91 m^2
Demand of window share	10%
Daylight window share	30%
BRONS = Swedish law, BBR	

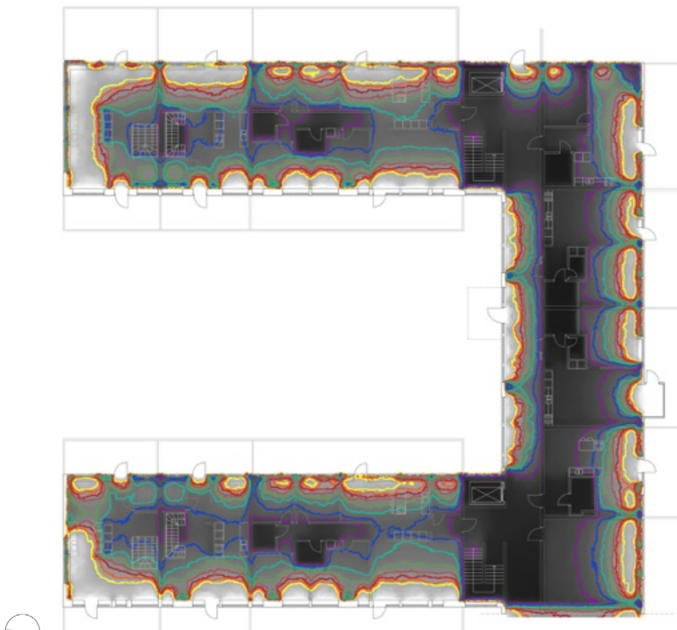
Figure 41: Simplified daylight calculation according to Miljöbyggnad as a complement to the more detailed Velux diagrams to the right and the overheating calculations on the next page.



Second Floor
(upper part also valid for third floor)



First Floor



Ground Floor

OVERHEATING

As seen in the Velux daylight analysis, there is a need to have sun protection in order not to get overheating. A simplified Miljöbyggnad calculation was made to check the overheating in a room during the summer months. Most rooms would have failed the evaluation without some type of protection. Two rooms are evaluated and compared here, with the first onebeing a 1,5-bedroom apartment, the most common type in the complex. The other is the bedroom of apartment type 30a, located in the existing part. In that way we can see differences in different apartments with diferent sizes and orientations, as well a comparison between the existing building and the new addition. The evaluated rooms are highlighted in orange.

Due to the existing building's architectural language, the decision was taken that the solar protection will be interior blinds. Performance-wise, it is better to place the solar shading on the exterior, but it is more economic and easier to maintain in the protection is located in the interior, which is the case here.

We can see that both rooms pass the criteria, but with the bedroom in apartment 30a having better score, despite being to the south. The reason is the balcony above giving shade. A full evaluation can be found in the appendix.

Grade	Bronze	Silver	Gold
W/m2	≤ 38	≤ 29	≤ 18

Figure 42: The evaluation criteria from Miljöbyggnad 4.0 regarding solar heat gains. The purpose is to reward buildings designed and constructed to limit overheating and reduce the cooling power demand for comfort during the summer months, with the solar heat load in W/ m² of floor area during the summer months defined as the solar heat passing through windows and contributing to room heating, measured per square meter of floor area

Apartment 10a

Floor area of room	36 m²
Added area balconies, shading	0

Window	Glass area	Orientation	g-value
Window 1	8,33 m²	West	0,36
Window 2	2,58 m²	East	0,5

Overheating score	Bronze
Total overheating window area	10,91 m²
Overtemperature window share	30%
Total g-value	0,21
Solar heat gain	36,3 W/m²

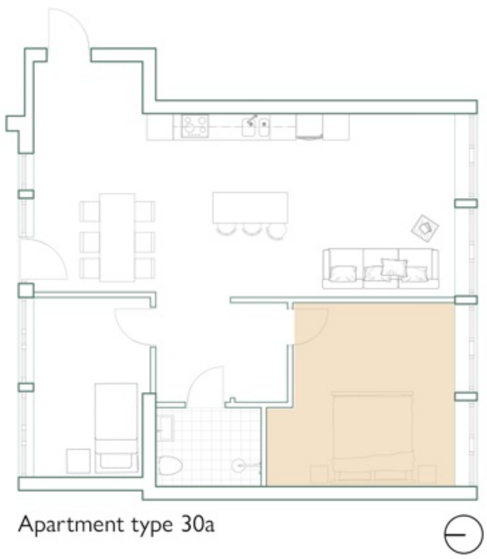
Apartment type 10a

Apartment 30a

Floor area of room	16,5 m²
Added area balconies, shading	5,7 m²

Window	Glass area	Orientation	g-value
Window 1	4,28 m²	South	0,5

Overheating score	Silver
Total overheating window area	4,28 m²
Overtemperature window share	26%
Total g-value	0,13
Solar heat gain	18,6 W/m²



Apartment type 30a

Materials

As mentioned in the chapter regarding LCA and the impact of materials, the materials have a significant impact on the Global Warming Potential (GWP). For that reason, and in search of a lightweight material that the current structure can support, the decision have been made to use mostly wood-based construction materials.

The loadbearing structure of the new extension is a wood-frame system with wood fiber insulation, while the floor slab is a CLT-rub system. From the CAALA LCA analysis, (fig 43a) we can see that it is the precisely that component together with the windows which stands for the most GWP. As we saw earlier, glass is a material that is placed quite high in the material pyramid, since it requires much energy to produce. One of the reasons the new floor slab might have the highest GWP in this transformation is that it is has the highest mass among all the building components (fig 43b) despite wood being a material that stores/embodies a large amount of carbon (fig 43c). In the same figure, we can see that it is the windows that have the highest GWP in the production stage.

Drawings of three of the components can be found on the next page, and there will be more comparisons further into the thesis. More detailed explanations can be found in the appendix.

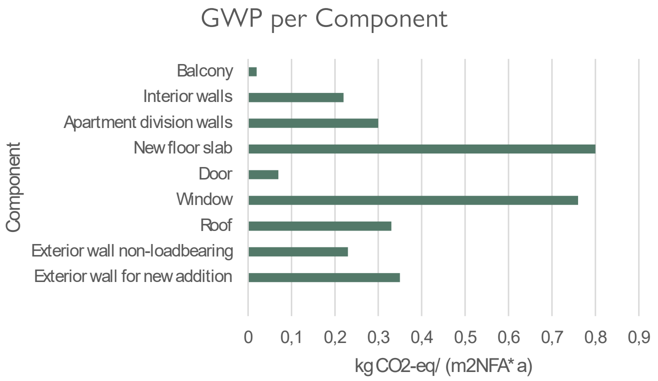


Figure 43a. Global Warming Potential (GWP) per Component. Most of the components are wood-based and therefore have low GWP. This takes into account production (A1-A3), replacement (B4) and End-of-Life (C3-C4). The reason to why there are positive values is because of the End-of-Life stage where it is assumed that the disposed wood would release the embodied carbon into the atmosphere, and the energy needed for production

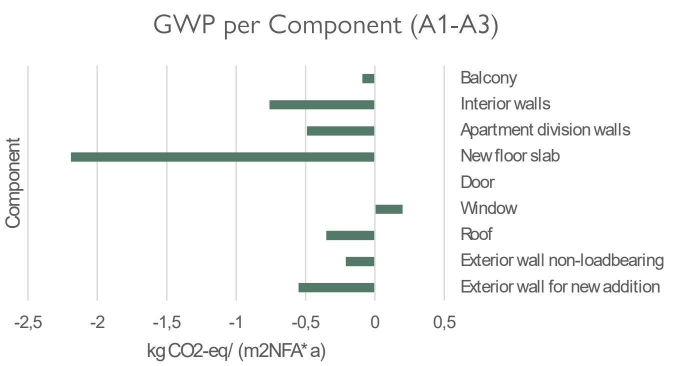


Figure 43b. Global Warming Potential (GWP) per Component (A1-A3). Only considering the production of the material, and it is very clear here how much CO_2 is stored in wood. The production of windows (wooden frames) is the component. The contrast is large when excluding the End-of-Life, as seen in the figure above.

Figure 43d. Drawing of Stora Enso Sylva CLT Rib, the floor slab system used in this transformation. The drawing is a courtesy of Stora Enso

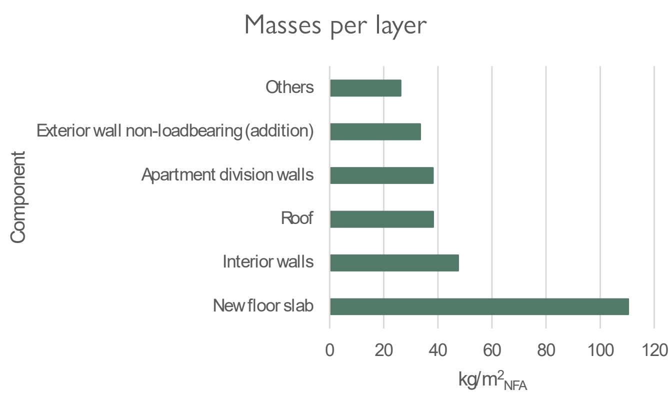


Figure 43c. Masses per layer. The weights of the materials. Most of the materials are considered lightweight. Wood-based materials in the new floor slab, apartment divison walls and exterior wall addition stands for most of the weight. The second one in mass are the interior walls, where plaster is the most common material.

Building components explained in layers for a better understanding of the materials. The drawings to the right are not to scale

NEW EXTERIOR WALL

Vertical wood panels	22mm
Cover strips	22mm
Air cavity with wood boards	45mm
Wind sheet/vapor barrier	0,5mm
Wooden board	22mm
Insulated cladding panel	30mm
Wood framw with wood fiber insulation	195mm
Water proofing sheet	0,5mm
Service layer	45mm
OSB Board	22mm
Gypsum board	12,5mm
Total thickness:	416mm

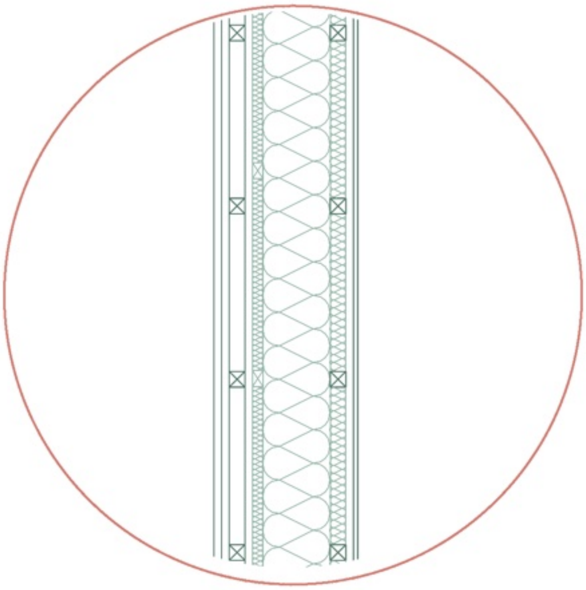


Figure 44a. New exterior wall

NEW FLOOR SLAB

Cement screed with floor heating	70mm
Impact sound insulation, mineral wool	30mm
CLT (Stora Enso, Sylva CLT Rib	100mm
Glulam timber ribs, 160x240	240mm
Mineral wool insulation	50mm
Metal channel	27mm
Gypsum board	2x12,5mm
Total thickness:	542mm

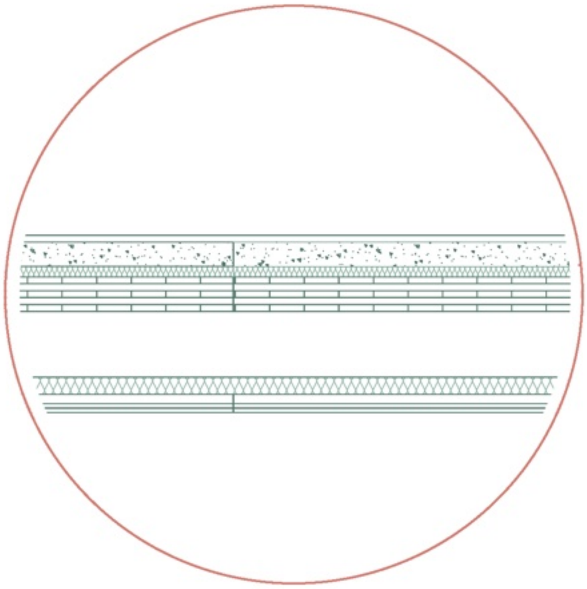


Figure 44b. New floor slab

EXTERIOR WALL (non-loadbearing)

<u>Existing</u>

Brick	120mm
Mineral wool	100mm
Brick	120mm

<u>Addition</u>

Wind sheet/vapor barrier	0,5mm
Wood frame with wood fiber insulation	95mm
Service layer with wood fiber insulation	45mm
Gypsum board	2x12,5mm
Total thickness:	505mm

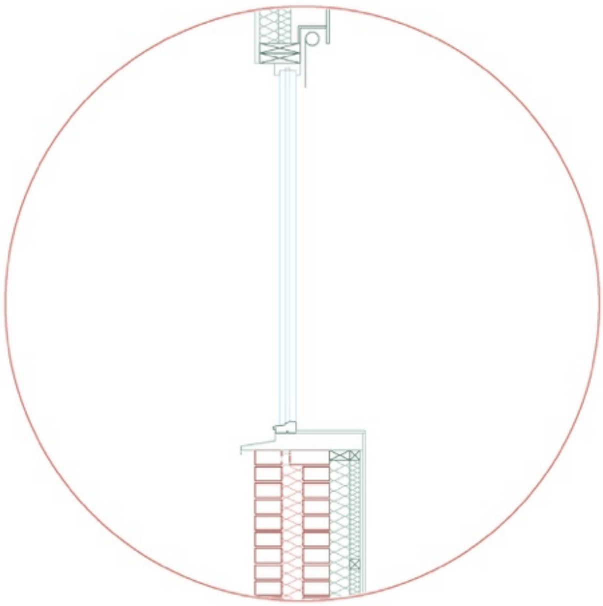


Figure 44c. Non-loadbearing exterior wall with additions in green

CAALA Comparisons

This section will showcase the difference in a LCA analysis made in CAALA between Tynneredsskolan in its current state, the transformation and the two selected buildings in Högsbo and Järnbrott. The comparisons are made through the following parameters:

Primary Energy Demand (PED)
Global Warming Potential (GWP)
Primary Energy Non-Renewable

The common scope for all comparisons are the following:

- Study period: 50 years
- Life cycle modules: A1-3, B4, B6*, C3-4
- Climate region: 10 (German standard, which is the region with a climate similar to the one in Gothenburg)
- Database: Oekobaudat 2020
- Primary Energy Factor: 1,8
- Mechanical ventilation with heat recovery. Faction set at 0.85

** = There will also be comparisons excluding B6 so that we can easily compare the difference impact in materials*

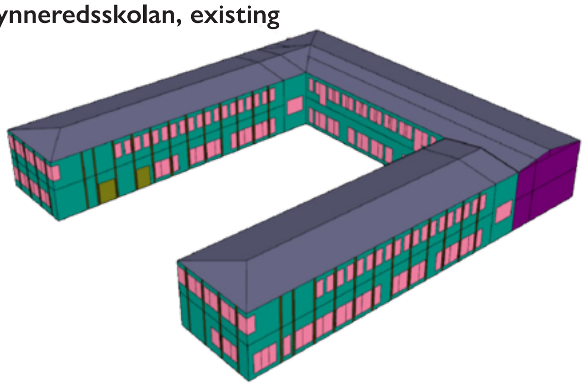
This is made in order to understand the impact and difference of the transformation, and the impact of the materials selected. Figure 45a shows the main materials used in each building (excluding former Tynneredsskolan). A more detailed description can be found in the appendix. More information of the buildings can be found on the next page.

Layer	Tynnered	Högsbo	Järnbrott
Exterior wall			
Foundation	(existing)		
Roof			
Floor slab			
Interior walls (non-loadbearing			
Extension materials			

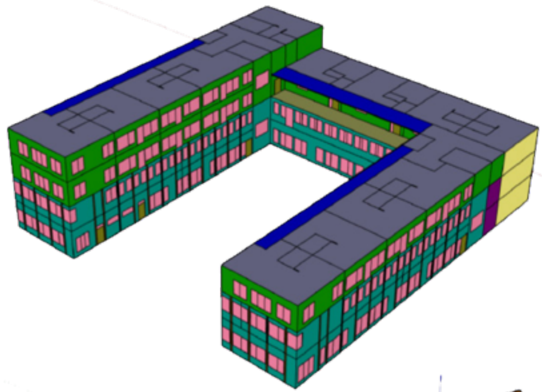
CLT	Wood frame	Other wood	Concrete	Not applicable

Figure 45a. Simplified table showcasing the materials of the buildings in the comparison. Högsbo and Järnbrott are both built of concrete, while the extension of Tynneredsskolan is mostly made from wood. All buildings have non-loadbering interior walls made of wood and gypsum. The extension materials refer to the additions to the existing structure mentioned earlier in the thesis.

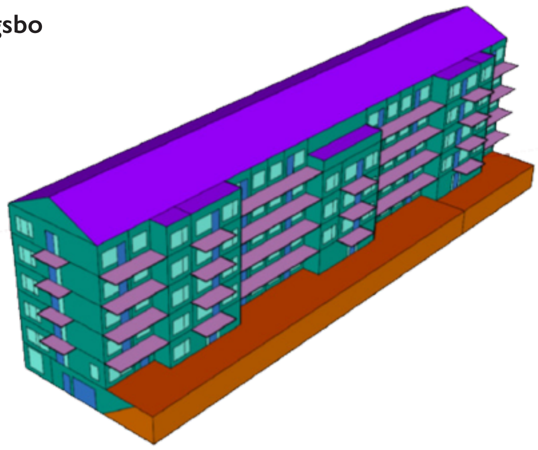
Tynneredsskolan, existing



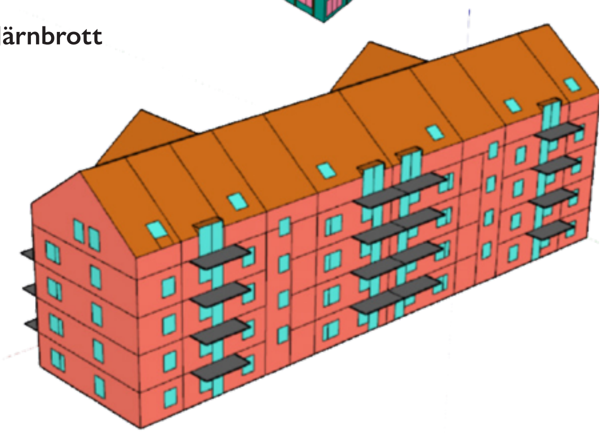
Tynneredsskolan, transformed



Högsbo



Järnbrott



	Tynnered Existing	Tynnered Transformed	Högsbo	Järnbrott
Thermal bridge	0.10W/m2K	0.10W/m2K	0.05W/m2K	0.05W/m2K
Air tightness	n50 = 6h-1	n50 = 6h-1	n50 = 4h-1	n50 = 4h-1
Construction year	1969	2024	2013	2021
Area (GFA)	1898,5 m²	3133,4 m²	5546,5 m²	2849 m²

Figure 45b.Information about the setttings in CAALA regarding thermal bridges, air tightness, construction year and area, which are data that will be used for the LCA.

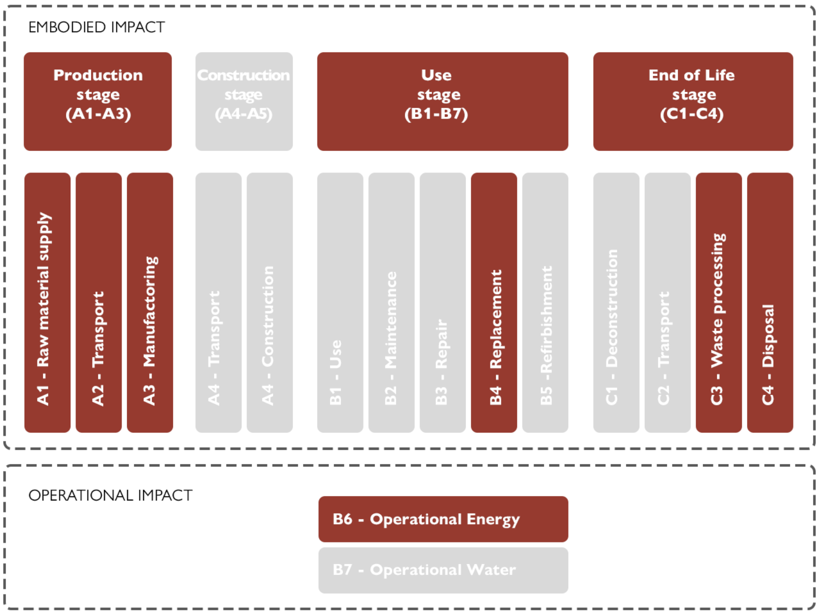


Figure 46a. The modules used in CAALA are A1-A3, which is about the production of the material, B4 and B6, which are from the use stage of the building. B4 is about the replacement since building components requires a change after some time, depending of the material. B6 is the operational energy required for the building and its systems to function. Lastly, C4-C5 is about the disposal of the building materials.

As seen, the LCA here will exclude transportation to the building site and construction, as well as several components from the use stage, such as use, repair and maintenance.

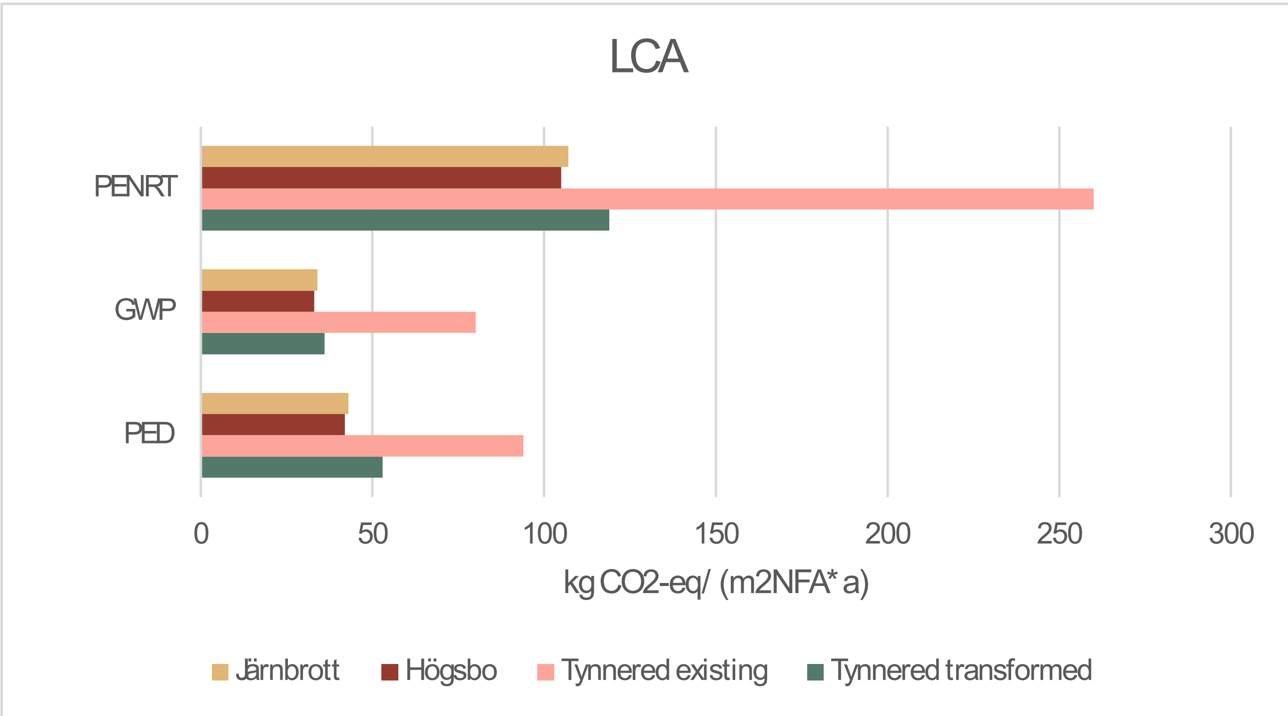


Figure 46b. The diagram illustrates the environmental impacts of four buildings—Järnbrott, Högsbo, Tynnered existing, and Tynnered transformed—based on the three parameters mentioned before:: PENRT, GWP, and PED. Tynnered existing consistently shows the highest impact across all metrics, particularly in PENRT. In contrast, Högsbo exhibits the lowest overall impact, especially in GWP and PED. Järnbrott and Högsbo display similar environmental performances, with Järnbrott slightly higher in PED. The transformed version of Tynnered demonstrates improvements over its existing state but still lags behind Järnbrott and Högsbo, particularly in PED. This comparison highlights the substantial benefits of transforming Tynnered, though further optimization is needed for reaching the efficiency levels of Järnbrott and Högsbo.

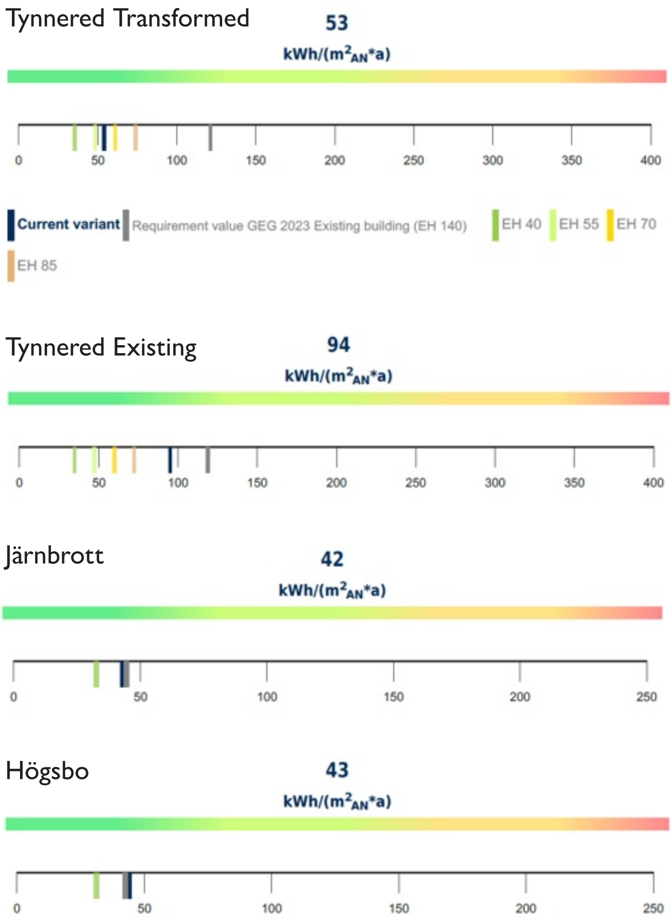


Figure 47a. PED of the buildings. Existing Tynnered is the worst, as it has issues with thermal bridges and windows with higher u-value. Improving those two aspects, among others, will significantly lower the PED, as seen in the transformed version. However, the transformed Tynnered is not as energetically efficient as Järnbrott or Högsbo

COMPARISON OF PED

The multi-family buildings in Högsbo and Järnbrott are both low-energy structures, which can be seen in this estimation from CAALA. Both have low values, 42-43 kWh/m2*A, which is better than what the transformed Tynneredsskolan will perform. All three buildings have low values mainly to the fact that they all are heated with district heating, and they all use an FTX-ventilation system. For Tynneredsskolan, it was the ventilation system and improved thermal perfomances, and the transformed building would perform almost 56% better.

The gains and losses of the buildings are also different, mainly Tynneredsskolan compared to the other two. The transmission loss for Tynneredsskolan is higher, which could be explained by that it is a transformation project, which is more challenging to air-tighten, and the large amounts of windows. Högsbo and Järnbrott gets a B-class in energy efficiency, while Tynnered obtains a C-class. Another interesting aspect related with the windows is that Tynneredsskolan has an opportunity to harvest solar energy for heating should those strategies be implemented in the design.

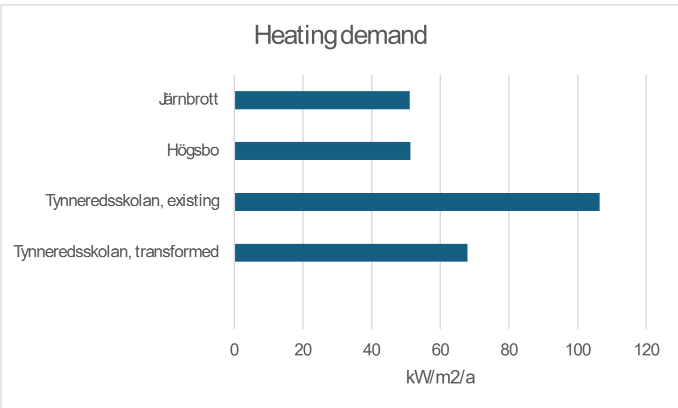
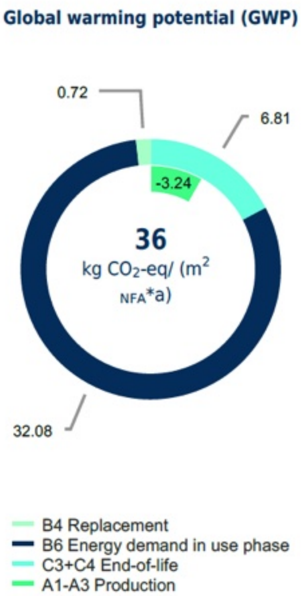


Figure 47b. Heating demand. It follows the similar pattern as the PED. Högsbo and Järnbrott have a similar performance, and both are lower than the transformed Tynnered. This transformation would lower the heating demand by roughly 35% compared to the existing Tynnered.

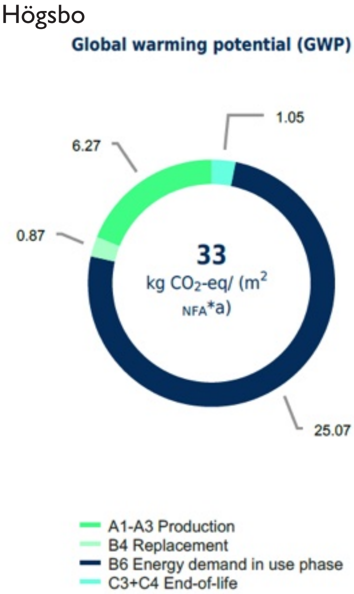
	Tynnered, transfomed	Tynnered, existing	Högsbo	Järnbrott
Energy class	C	F	B	B

Figure47c. Energy Classification according to CAALA, based on the energy demands

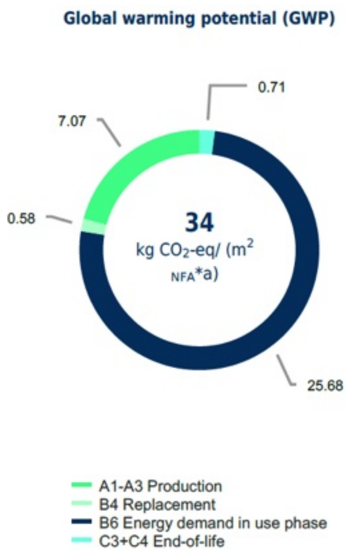
Tynnered Transformed



Högsbo



Järnbrott



Global Warming Potential, GWP

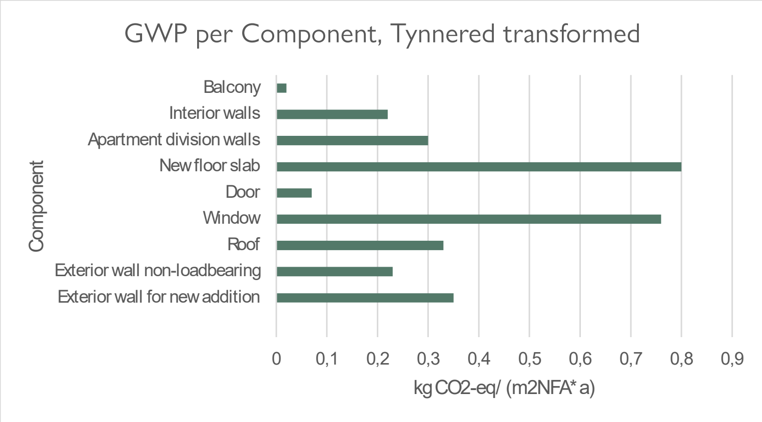
Starting with the GWP, we can see that the most emissions comes during the use phase, and all of the buildings are around 35kgCO2-equivalents/m2 in emissions per year. The values do differ though, with 32 kg CO2/m² for Tynnered transformed and around 25 kg CO2/m² for the other two. In percentage, that would roughly correspond to almost 90% for Tynnered and 75% for Järnbrott and Högsbo.

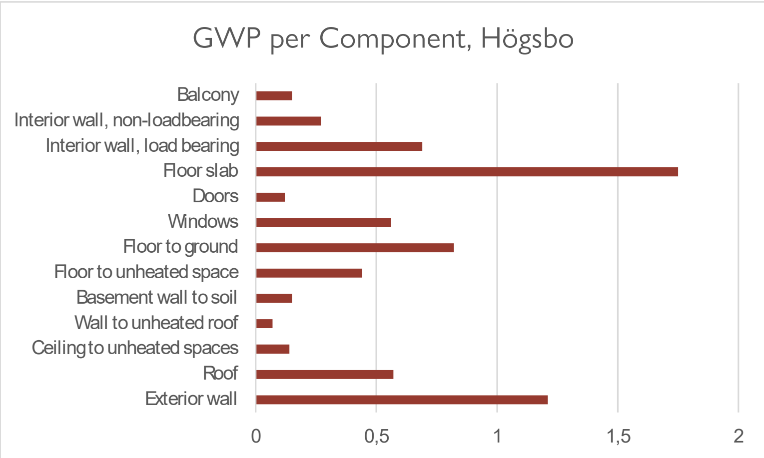
The values will be different if we exclude B6. That will give us a more emphasis on the building material instead. We would then have the following values:

3,92 kg CO2/m² for Tynnered
7,93 kg CO2/m² for Högsbo
8,32 kg CO2/m² for Järnbrott

From this, it is clear that the GWP of the wood-based structural materials of transformed Tynneredsskolan is much lower than those of the concrete structures in Högsbo and Järnbrott. The impact of the concrete structures is roughly double that of the wood-based structure. This highlights the significant environmental benefits of using wood-based materials in reducing the GWP of building construction and use.

The GWP will be furter analyzed in the following pages. It will be broken down into components so that it will be easier to showcase and highlight the impact of each layer, both in an overall GWP and in a GWP with focus on the production stage A1-A3.





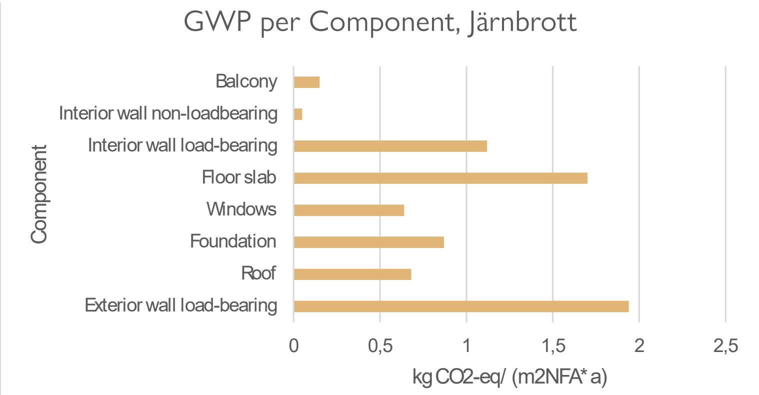


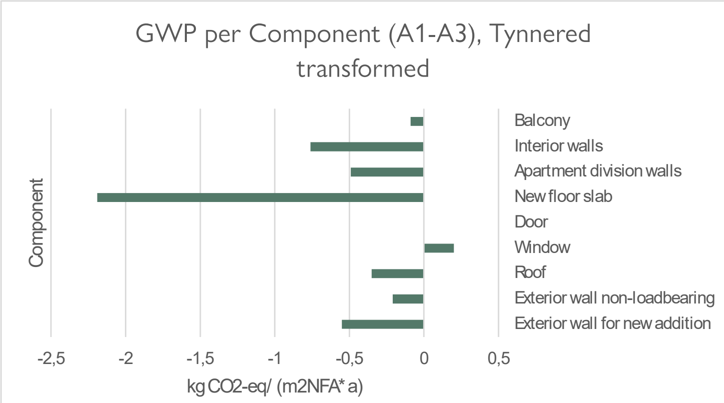
Figure XX. The diagramsto the left illustrate the Global Warming Potential (GWP) per component. In this comparison analysis, LCA modules A1-A3, B4, B6 and C3-C4 are used. A separate analysis for A1-A3 will be presented in the following page.

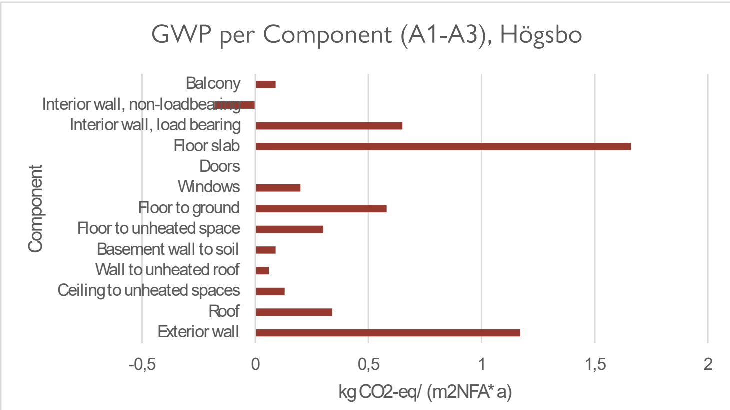
As mentioned earlier, for Tynnered transformed, the new floor slab and windows are the largest contributors to GWP, each contributing around 0.8 kg CO2-eq/(m^{2}NFAa). Other significant components include apartment division walls, interior walls, and exterior walls for the new addition, each contributing around 0.3 kg CO2-eq/(m^{2}NFAa).

*In Högsbo, the floor slab and exterior wall are the highest contributors, with the floor slab around 1.8 kg CO2-eq/(m^{2}NFAa) and the exterior wall around 1.5 kg CO2-eq/(m^{2}NFAa). Other notable contributors are the floor to ground, windows, and interior wall load-bearing, each contributing between 0.6 and 1.0 kg CO2-eq/(m^{2}NFA*a). Lesser contributors include interior wall non-loadbearing, roof, and floor to unheated space, suggesting a higher overall GWP for more components compared to Tynnered transformed. Högsbo also have more components than the other two due to also being a souterrain structure with an underground parking.*

*Järnbrott stands out with the exterior wall load-bearing and floor slab being the highest contributors, with the exterior wall load-bearing around 2.0 kg CO2-eq/(m^{2}NFAa) and the floor slab slightly below 1.5 kg CO2-eq/(m^{2}NFAa). Other significant components include the interior wall load-bearing, windows, and foundation, each contributing between 0.5 and 1.0 kg CO2-eq/(m^{2}NFA*a). Järnbrott has the highest individual GWP contributions for specific components, particularly the exterior wall load-bearing and floor slab.*

Overall, we can see that Järnbrott and Högsbo have higher GWP values than the transformed Tynneredsskolan when it comes to the materials and components only, as opposed to the overal GWP presented on the previous page. The exterior walls and floor slabs are the ones with the highest GWP in general, with the esception of the exterior wall of Tynnered. The windows had similar values in all three, with slightly higher values in Tynnered, which has large amounts of windows.





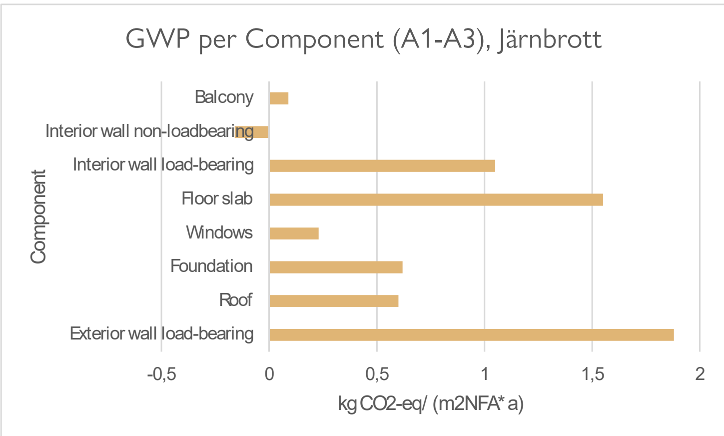


Figure XX. Focusing only on the A1-A3 production stage, we get a more clear view of the impact of the materials. There is a large difference between the wood-based transformation of Tynneredsskolan compared to the concrete-based Järnbrott and Högsbo.

*For Tynnered transformed, the new floor slab significantly contributes to GWP, with a value of approximately -2.2 kg CO2-eq/(m^2NFA*a), indicating a net reduction in emissions. This is because of the embodied carbon in the wood, and the floor slab has a large net value due to the amount of wood compared to the other wood-based materials.*

*In Högsbo, the floor slab and exterior wall stand out as the largest contributors to GWP, with the floor slab contributing around 1.5 kg CO2-eq/(m^2NFA*a) and the exterior wall around 1.0 kg CO2-eq/(m^2NFA*a). The interior wall load-bearing and floor to ground components also show significant contributions, each around 0.5 kg CO2-eq/(m^2NFA*a). Lesser contributors include windows, doors, and various floor and wall components to unheated spaces. The data indicates higher overall GWP contributions from a wider range of components compared to Tynnered transformed.*

*Järnbrott shows the highest GWP values for specific components, particularly the exterior wall load-bearing and floor slab. The exterior wall load-bearing component has a value around 1.8 kg CO2-eq/(m^2NFA*a), and the floor slab is slightly above 1.0 kg CO2-eq/(m^2NFA*a). Other significant components include the interior wall load-bearing and foundation, each contributing between 0.5 and 1.0 kg CO2-eq/(m^2NFA*a).*

Overall, the analysis indicates that while Tynnered transformed shows a balanced approach with some components providing net GWP reductions, Högsbo and Järnbrott have higher GWP impacts from specific components. Högsbo's contributions are more evenly spread across various components, whereas Järnbrott has particularly high impacts from its exterior wall load-bearing and floor slab.

From this, we can conclude that the wood have a much lower impact on the GWP compared to concrete. However, it is important to also consider the overall GWP that we saw earlier. The wood will eventually release the embodied carbon upon reaching the disposal stage. Only focusing on the A1-A3 stages can be misleading.

DISCUSSION

08

DISCUSSION

URBAN DENSIFICATIONS

One of the main outcomes of the thesis is that the new housing areas in Järnbrott, Högsbo and Flatås are not necessarily better just because they are new. Although they have good energy values, that is not everything. We need to move beyond only focusing on those numbers and also include other aspects, including but not limited to those presented in this thesis. Högsbo and Flatås were both dense and had issues with the privacy exposure, while Järnbrott had large open areas with less privacy issues. Common for all of them was the municipality's desire for densifying the city in its efforts against the housing crisis. And this is where the quality has been put aside for quantity, neglecting the consequences that urban densification brings. This is where this thesis explores on the urban quality, through some of turning a building transformation into a catalyst for a neighborhood rejuvenation and development. The number of housing units will be less than the desired one of the municipality, but hopefully with better housing and environmental qualities.

TRANSFORMATION & ATTITUDES

This research reveals valuable theoretical insights relevant to urban densification and sustainable architectural practices. An important finding is the municipality's approach to urban planning, where short-term economic gains are often prioritized over long-term environmental impacts. This appears to be a discrepancy between the municipality's actions and its stated goals in the architectural policy adopted in 2018, which illustrate the complex dynamics in sustainable urban redevelopment and highlight the need for more nuanced, balanced approaches that consider social, economic and environmental sustainability

This ties directly into arguments regarding the revaluation of existing buildings and a more serious attitue to sustainability. The potential for buildings to be transformed into something not only different but potentially better, underscores a significant opportunity in urban development. However, this is not without its challenges. The transformation process is inherently complex, particularly when adapting structures from one use to another. The difficulty in achieving space efficiency highlights the inherent trade-offs involved. This balancing act, coupled with the potential for unexpected costs (although not considered in this thesis), offers a plausible explanation for why developers might prefer demolition and new builds over transformations.

SUSTAINABLE APPROACHES

One aspect learned from this thesis is the adaptation of an existing building with sustainable approaches. From adding sun shading, to balancing the need of daylights and views to maintaining privacy, there are many decisions to take, and some better than others. Due to time limitations, the ventilation, heat, and cooling strategies are not as developed as one would have hoped for, and is something that would have been interesting to continue with.

EVALUATIONS

The evaluations made are good on their own, but even stronger together. From the LCA-analysis, we got results shwing both the potentials and setbacks of transformation. The transformed school did perform well when looking at GWP and the materials. Wood have less impact on the GWP compared to the concrete structures. The transformed building performed worse (but not bad) than the buildings in Järnbrott and Högsbo, and the overall GWP exhibited a higher operational impact, indicating that the energy use remains greater than anticipated. More optimization with materials and ventilation, together with the use of solar panels (not included in this thesis) could have improved those values (and maybe also cost more). We must be careful though with the data, as it all depends on what we use as an input for the calculations, and not be too fixed with the numbers. However, it is still good to use LCA results as indicators, which is how it was made in this research.

The daylight and overheating analysis showed another aspect to have in mind, and that can sometimes have less priority in urban densification projects. The existing school building offers good daylight conditions, which are important in a school environment. This is also proved to be an opportunity when transforming the school into housing. The issues are more with the overheating, and there could have been more improvements.

The privacy exposure is in many cases overlooked in regardings to urban transformation. The site visits clearly showed that in Flatås and Högsbo. Transformed Tynnered also had some issues with it.. According to the analysis, the issue would mostly be in the spaces related to the inner corners of the courtyard. In this transformation, the attempt was to try to reduce the impacts of it by having more public spaces in the most affected zones. This could maybe have been solved differently if there was a more experimentation with the typologies along the inner corners.

FINAL THOUGHTS

The aim here was to transform Tynneredsskolan, a school waiting for its destruction, into something that we can enjoy and benefit from. It was first praised in the beginning, only to be considered problematic in the later years. It was a challenging process working with this thesis, and at the same time a necessity as we architects have been too comfortable in starting off with a "blank page". By transforming instead of demolishing, not only do we keep a part of the site's identity and character, but also strengthening it. Working on this thesis, and studying different types of theories and case studies have tought me that transformations are a certain aspect of the future of architecture.

Figure 48. View of the courtyard

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INTERVIEWS
Interview with the urban planner Anders Dahlberg (Gothenburg municipality) on 12/10-2023

IMAGES AND DRAWINGS

Images and drawings not taken or drawn by the author will be listed here

Figur 03. Picture of Högsboskolan being demolished in 2013. Photographer Markus Andersson/Tidningen i Väster via https://issuu.com/direktpressgbg/docs/vaster-130317/1

Figure 07. Opaltorget, typical Million House Programme in Tynnered. Photographer: AB Flygtrafik/ Vänersborgs museum

Figure 08. View over Frölunda, built during the 1960's. Photographer: AB Flygtrafik/ Vänersborgs museum

Figure 10. Retrieved from Program för Tynnered, 2022

Figure17a: Järnbrottsskolan year 2000. Picture Eva Löfgren/ Göteborgs stadsmuseum https://bebyggelseregistret.raa.se/bbr2/anlaggning/visaSelectedAnlaggningFoto.raa?fotoId=21500000006821

Figure 17b: Motortekniska gymnasiet year 2010. Picture: Bildinsamling: aug. 2010 © 2024 Google

Figure 17c: Högsboskolan year 2012. Picture: Photography: Lindholm Restaurering AB

Figure 20b. Photography: Bildinsamling sept 2022. © 2024 Google

Figure 24a. Lantmäteriet/ SWEREF 99 TM, RH 2000

Figure 24b. Lantmäteriet/ SWEREF 99 TM, RH 2000

Figure 24c. Lantmäteriet/ SWEREF 99 TM, RH 2000

Figure 26a: The Material Pyramid © CINARK/The Royal Danish Academy and Vandkunsten Architects. https://materialepyramiden.dk/#

Figure 27a: Photography by Holger Ellgaard - Eget arbete, CC BY-SA 4.0 https://sv.wikipedia.org/wiki/Nybodah%C3%B6jden

Trikåfabriken Av Arild Vågen - Eget arbete, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=88820254

Figure 27b: © Lantmäteriet. Skala 1:2 800, SWEREF 99 TM, RH 2000.

Figure 28b: Photographs of St Görans Gymnasium by Antonius van Arke

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Figure 29a: Sketch made by Transsolar KlimaEngineering https://transsolar.com/projects/hall-erweiterung-der-tiroler-fachberufsschule-fur-fotografie-optik-und-horakustik

Figure 29b: Picture by Transsolar KlimaEngineering https://transsolar.com/projects/hall-erweiterung-der-tiroler-fachberufsschule-fur-fotografie-optik-und-horakustik

Figure 43d. The drawing is a courtesy of Stora Enso https://www.storaenso.com/-/media/images/products/wood-products/content/clt-rib-panel-illustrations/clt-rib-panel_type-1_600x400.ashx

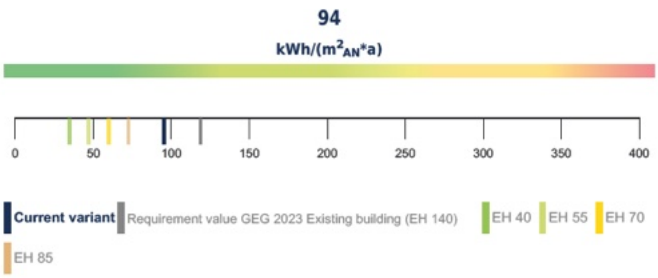
APPENDIX

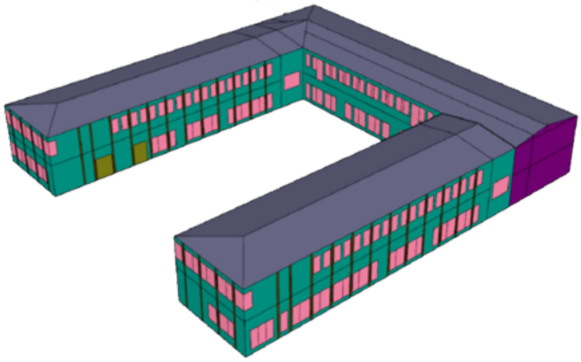
CAALA APPENDIX

TYNNEREDSSKOLAN EXISTING

2. Overview

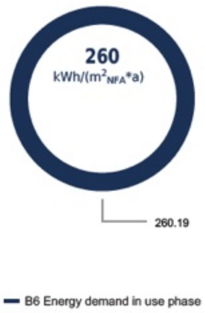
2.1. Primary energy demand



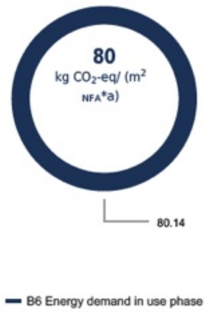


2.2. Life Cycle Assessment

Primary energy non renewable (PENRT)



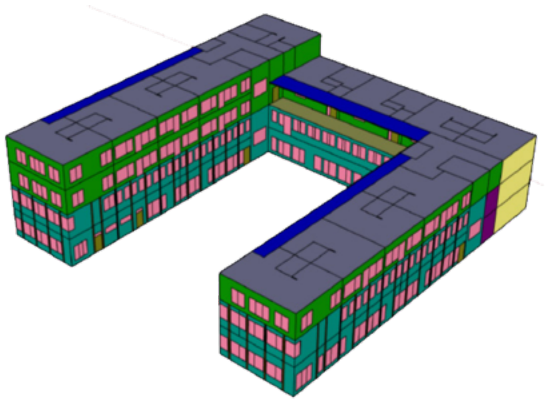
Global warming potential (GWP)



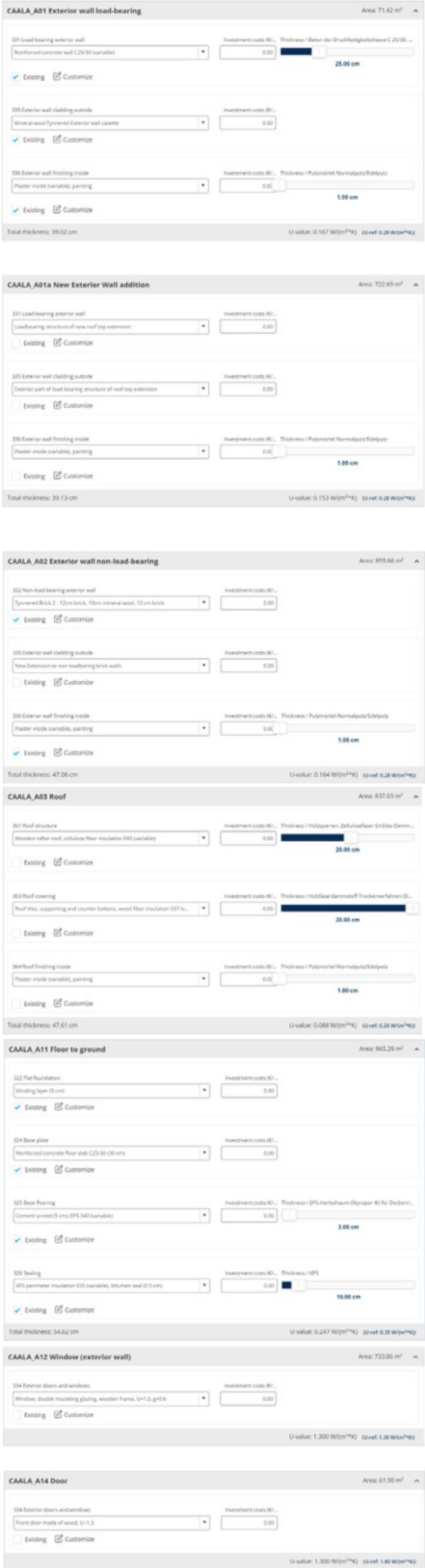
Energy performance parameters

Energy reference area(A_N)	1,816.79 m²
Specific area-based transmission heat loss H_T' ⓘ	**0.729 W/(m²*K)**
Specific area-based transmission heat loss H_T' reference building	0.402 W/(m²*K)
Energy efficiency class ⓘ	F

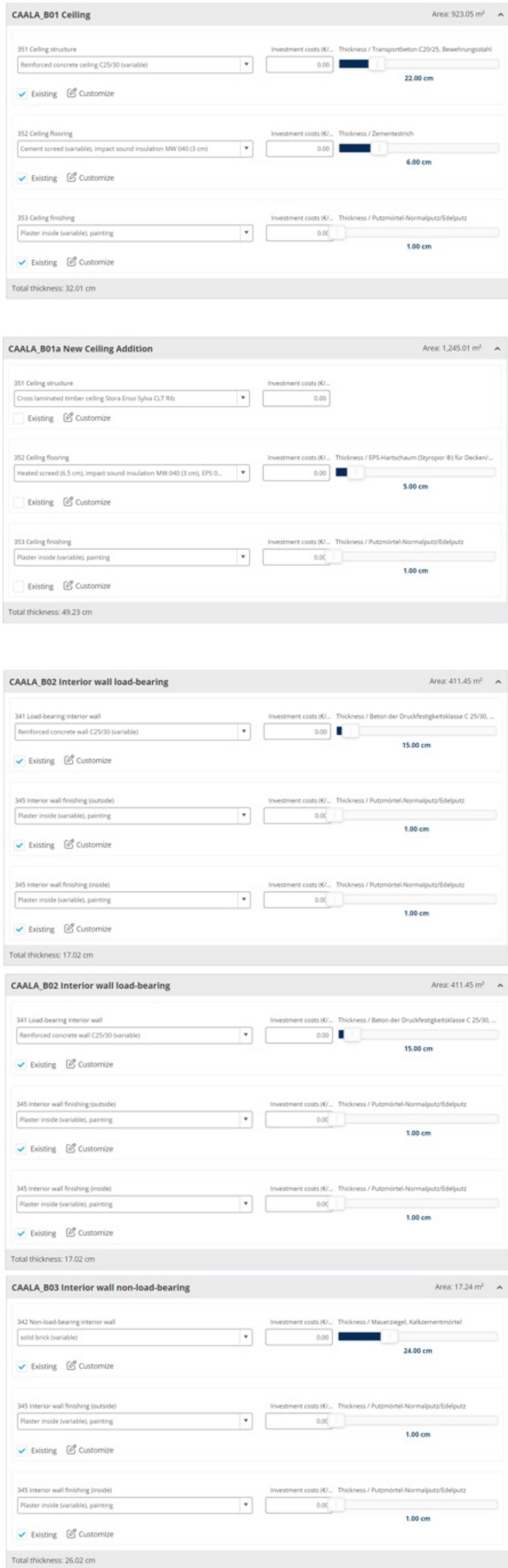
TYNNEREDSSKOLAN TRANSFORMED



CAALA_A01 Exterior wall load-bearing	Area: 71.39 m²	
Total thickness: 39.02 cm	U-value: 0.167 W/(m²*K)	(U-ref: 0.28 W/(m²*K))
CAALA_A01a New Exterior Wall addition	Area: 722.69 m²	
Total thickness: 39.13 cm	U-value: 0.153 W/(m²*K)	(U-ref: 0.28 W/(m²*K))
CAALA_A02 Exterior wall non-load-bearing	Area: 855.66 m²	
Total thickness: 47.06 cm	U-value: 0.164 W/(m²*K)	(U-ref: 0.28 W/(m²*K))
CAALA_A03 Roof	Area: 837.03 m²	
Total thickness: 47.61 cm	U-value: 0.088 W/(m²*K)	(U-ref: 0.20 W/(m²*K))
CAALA_A11 Floor to ground	Area: 965.29 m²	
Total thickness: 54.62 cm	U-value: 0.247 W/(m²*K)	(U-ref: 0.35 W/(m²*K))
CAALA_A12 Window (exterior wall)	Area: 734.00 m²	
	U-value: 1.300 W/(m²*K)	(U-ref: 1.30 W/(m²*K))
CAALA_A14 Door	Area: 61.90 m²	
	U-value: 1.300 W/(m²*K)	(U-ref: 1.80 W/(m²*K))
CAALA_B01 Ceiling	Area: 923.05 m²	
Total thickness: 32.01 cm		
CAALA_B01a New Ceiling Addition	Area: 1,245.01 m²	
Total thickness: 49.23 cm		
CAALA_B02 Interior wall load-bearing	Area: 411.45 m²	
Total thickness: 17.02 cm		
CAALA_B03 Interior wall non-load-bearing	Area: 17.24 m²	
Total thickness: 26.02 cm		
CAALA_B03a New interior walls non-loadbearing	Area: 1,299.04 m²	
Total thickness: 30.02 cm		
CAALA_B03b Room divisions within apartments	Area: 1,476.71 m²	
Total thickness: 12.02 cm		
CAALA_B06 Internal column	Length: 78.72 m	
CAALA_B10 Balcony	Area: 164.50 m²	
Total thickness: 32.47 cm		

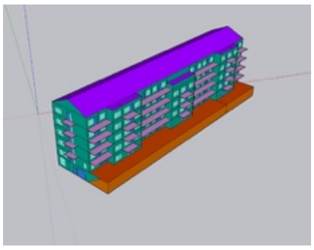


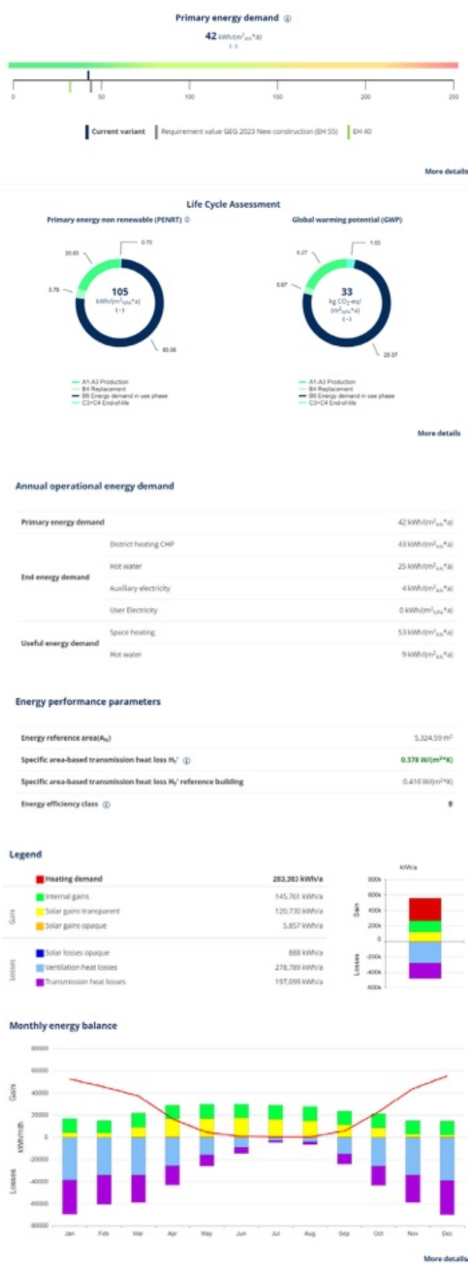
CAALA_A01 Exterior wall load-bearing
Area: 71.42 m²
331 Load-bearing exterior wall
Reinforced concrete wall C25/30 (variable)
25.00 cm
335 Exterior wall cladding outside
Mineral wool Tyrvinered Exterior wall casette
336 Exterior wall finishing inside
Plaster inside (variable), painting
1.00 cm
Existing
Customize
Total thickness: 39.02 cm
U-value: 0.167 W/(m²*K)
CAALA_A01a New Exterior Wall addition
331 Load-bearing exterior wall
Loadbearing structure of new roof top extension
CAALA_A02 Exterior wall non-load-bearing
CAALA_A03 Roof
CAALA_A11 Floor to ground
CAALA_A12 Window (exterior wall)
CAALA_A14 Door

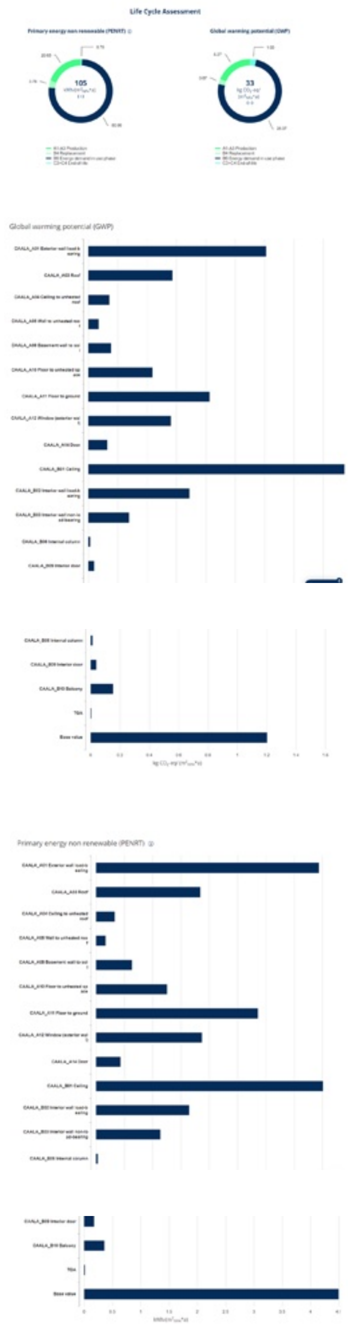


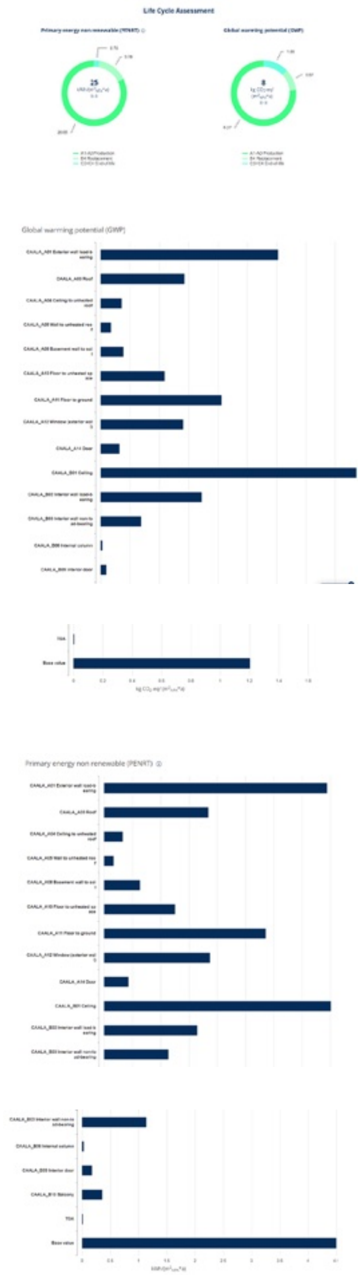
CAALA_B01 Ceiling
Area: 923.05 m²
351 Ceiling structure
Reinforced concrete ceiling C25/30 (variable)
Thickness / Transportbeton C20/25, Bewehrungsstahl
22.00 cm
352 Ceiling flooring
Cement screed (variable), impact sound insulation MW 040 (3 cm)
Thickness / Zementestrich
6.00 cm
353 Ceiling finishing
Plaster inside (variable), painting
Thickness / Putzmörtel-Normalputz/Edelputz
1.00 cm
Existing
Customize
Total thickness: 32.01 cm
CAALA_B01a New Ceiling Addition
Area: 1,245.01 m²
351 Ceiling structure
Cross laminated timber ceiling Stora Enso Sylva CLT Rib
352 Ceiling flooring
5.00 cm
353 Ceiling finishing
Plaster inside (variable), painting
1.00 cm
Total thickness: 49.23 cm
CAALA_B02 Interior wall load-bearing
Area: 411.45 m²
341 Load-bearing interior wall
Reinforced concrete wall C25/30 (variable)
15.00 cm
345 Interior wall finishing (outside)
345 Interior wall finishing (inside)
Plaster inside (variable), painting
1.00 cm
Total thickness: 17.02 cm
CAALA_B03 Interior wall non-load-bearing
Area: 17.24 m²
342 Non-load-bearing interior wall
solid brick (variable)
Thickness / Mauerziegel, Kalkzementmörtel
24.00 cm
Total thickness: 26.02 cm

HÖGSBO

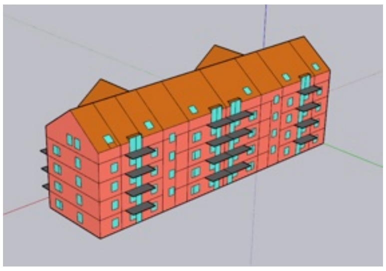


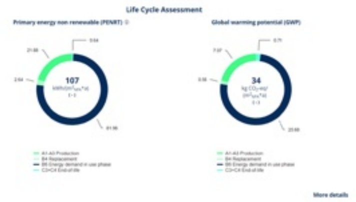

Primary energy demand
42 kWh/(m²AN*a)
Current variant
Requirement value GEG 2023 New construction (EH 55)
EH 40
More details
Life Cycle Assessment
Primary energy non renewable (PENRT)
Global warming potential (GWP)
105
33
A1-A3 Production
B4 Replacement
B6 Energy demand in use phase
C3+C4 End-of-life
More details
Annual operational energy demand
Primary energy demand 42 kWh/(m²AN*a)
End energy demand
District heating CHP 43 kWh/(m²AN*a)
Hot water 25 kWh/(m²AN*a)
Auxiliary electricity 4 kWh/(m²AN*a)
User Electricity 0 kWh/(m²AN*a)
Useful energy demand
Space heating 53 kWh/(m²AN*a)
Hot water 9 kWh/(m²AN*a)
Energy performance parameters
Energy reference area(AN) 5,324.59 m²
Specific area-based transmission heat loss HT' 0.378 W/(m²*K)
Specific area-based transmission heat loss HT' reference building 0.416 W/(m²*K)
Energy efficiency class B
Legend
Heating demand 283,383 kWh/a
Internal gains 145,761 kWh/a
Solar gains transparent 120,730 kWh/a
Monthly energy balance
More details





JÄRNBROTT





Annual operational energy demand

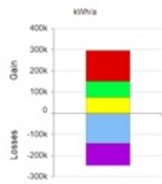
Primary energy demand		43 kWh/(m²$_{AN}$*a)
End energy demand	District heating CHP	45 kWh/(m²$_{AN}$*a)
	Hot water	25 kWh/(m²$_{AN}$*a)
	Auxiliary electricity	4 kWh/(m²$_{AN}$*a)
	User Electricity	0 kWh/(m²$_{NFA}$*a)
Useful energy demand	Space heating	53 kWh/(m²$_{AN}$*a)
	Hot water	9 kWh/(m²$_{AN}$*a)

Energy performance parameters

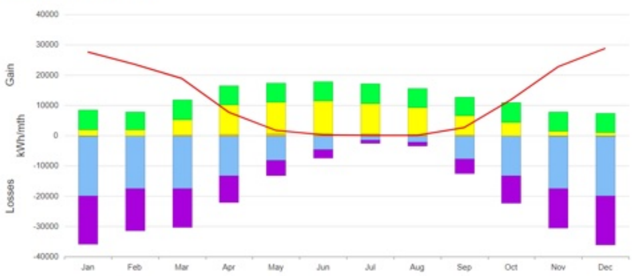
Energy reference area(A_N)	2,735.04 m²
Specific area-based transmission heat loss H_T'	**0.395 W/(m²*K)**
Specific area-based transmission heat loss H_T' reference building	0.393 W/(m²*K)
Energy efficiency class	**B**

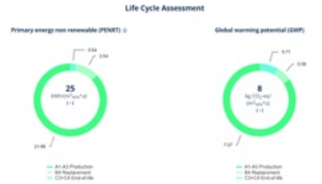
Legend

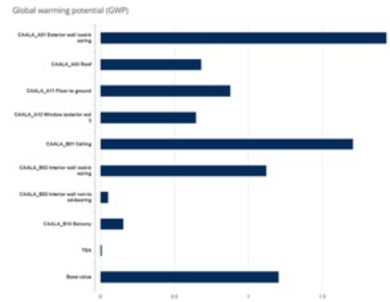
	Heating demand	**145,146 kWh/a**
Gain	Internal gains	74,872 kWh/a
	Solar gains transparent	72,622 kWh/a
	Solar gains opaque	3,346 kWh/a
Losses	Solar losses opaque	657 kWh/a
	Ventilation heat losses	143,188 kWh/a
	Transmission heat losses	102,960 kWh/a

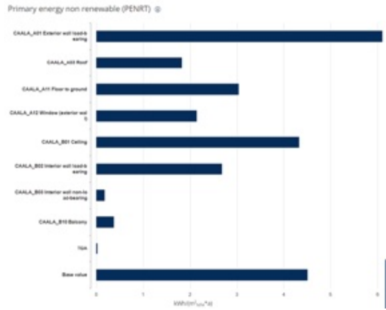


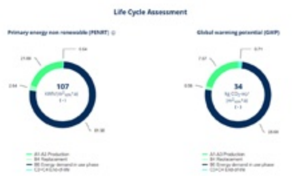
Monthly energy balance

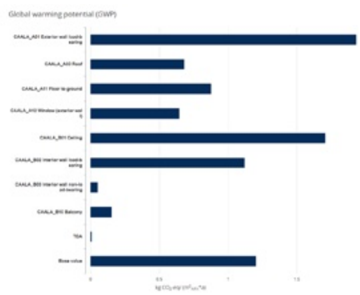


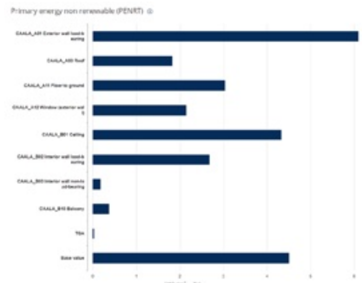




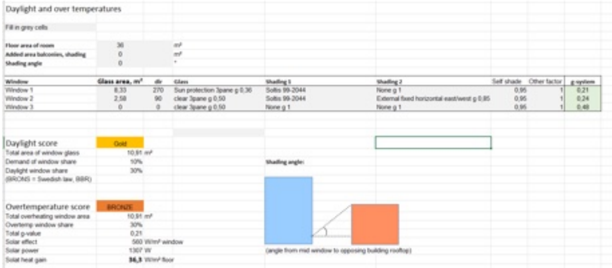








Type 10a. All area med fönsteryta



Daylight and over temperatures

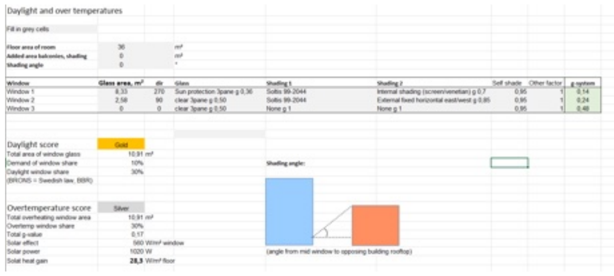
Fill in grey cells

Floor area of room	36	m²
Added area balconies, shading	0	m²
Shading angle	0	°

Window	Glass area, m²	dir	Glass	Shading 1	Shading 2	Self shade	Other factor	g-system
Window 1	8,33	270	Sun protection 3pane g 0,36	Soltis 99-2044	None g 1	0,95	1	0,21
Window 2	2,58	90	clear 3pane g 0,50	Soltis 99-2044	External fixed horizontal east/west g 0,85	0,95	1	0,24
Window 3	0	0	clear 3pane g 0,50	None g 1	None g 1	0,95	1	0,48

Daylight score	Gold	
Total area of window glass	10,91	m²
Demand of window share	10%	
Daylight window share	30%	
(BRONS = Swedish law, BBR)		
Overtemperature score	BRONZE	
Total overheating window area	10,91	m²
Overtemp window share	30%	
Total g-value	0,21	
Solar effect	560	W/m² window
Solar power	1307	W
Solat heat gain	**36,3**	W/m² floor

Type 10a All area med fönsteryta med persienner



Daylight and over temperatures

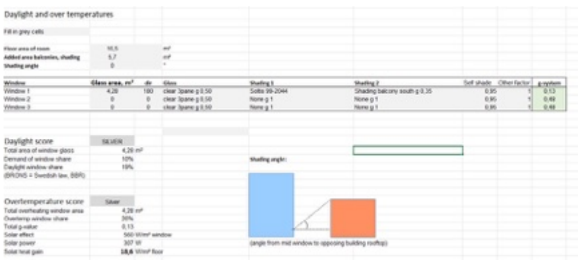
Fill in grey cells

Floor area of room	36	m²
Added area balconies, shading	0	m²
Shading angle	0	°

Window	Glass area, m²	dir	Glass	Shading 1	Shading 2	Self shade	Other factor	g-system
Window 1	8,33	270	Sun protection 3pane g 0,36	Soltis 99-2044	Internal shading (screen/venetian) g 0,7	0,95	1	0,14
Window 2	2,58	90	clear 3pane g 0,50	Soltis 99-2044	External fixed horizontal east/west g 0,85	0,95	1	0,24
Window 3	0	0	clear 3pane g 0,50	None g 1	None g 1	0,95	1	0,48

Daylight score	Gold	
Total area of window glass	10,91	m²
Demand of window share	10%	
Daylight window share	30%	
(BRONS = Swedish law, BBR)		
Overtemperature score	Silver	
Total overheating window area	10,91	m²
Overtemp window share	30%	
Total g-value	0,17	
Solar effect	560	W/m² window
Solar power	1020	W
Solat heat gain	**28,3**	W/m² floor

Type 30aEndast sovrummet



Daylight and over temperatures

Fill in grey cells

Floor area of room	10,5	m²
Added area balconies, shading	5,7	m²
Shading angle	0	°

Window	Glass area, m²	dir	Glass	Shading 1	Shading 2	Self shade	Other factor	g-system
Window 1	4,28	180	clear 3pane g 0,50	Soltis 99-2044	Shading balcony south g 0,35	0,95	1	0,13
Window 2	0	0	clear 3pane g 0,50	None g 1	None g 1	0,95	1	0,48
Window 3	0	0	clear 3pane g 0,50	None g 1	None g 1	0,95	1	0,48

Daylight score	SILVER	
Total area of window glass	4,28	m²
Demand of window share	10%	
Daylight window share	19%	
(BRONS = Swedish law, BBR)		
Overtemperature score	Silver	
Total overheating window area	4,28	m²
Overtemp window share	30%	
Total g-value	0,13	
Solar effect	560	W/m² window
Solar power	307	W
Solat heat gain	**18,6**	W/m² floor

Soltis 99

PRODUCT SOLTIS 99-2044

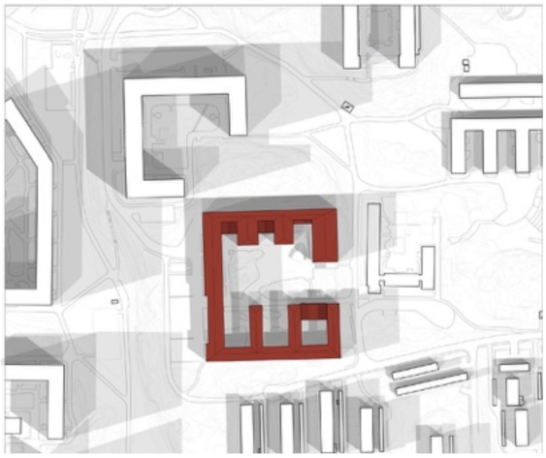
Thermal and light transmission properties
(according to EN 14501)

		Width (cm-in) 177 69.7	Width (cm-in) 267 105.1	TS	RS	AS	TV n-h	ISO 52022-3* Type D glazing g_{tot}^{i}	Al
Color*									
99-2011		●	●	12	44	44	8	0.19	9
99-2044		●	●	23	66	11	21	0.12	9

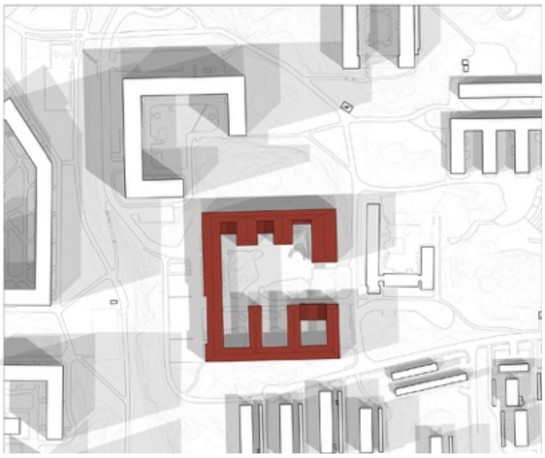
SOLAR STUDIES

The site is well exposed to the sun through out the year. Nearby buildings do not cast any shoadows maybe except for some time during the winter when the sun is very low. The issue is more the school itself, as the courtyards will be shadowed during the autumn and spring, especially in the southern sector.

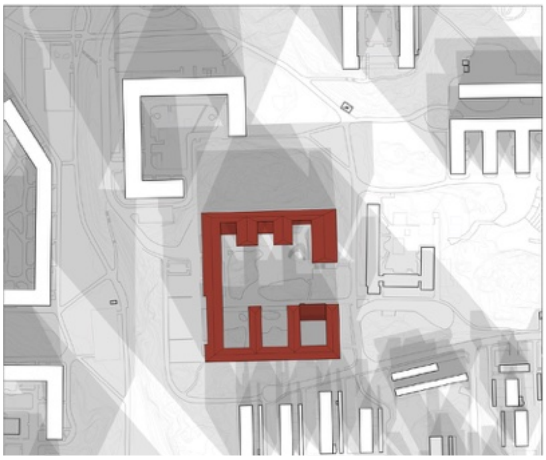
Summer, shadows at:
09, 12, 15, 17 hours



Spring, shadows at:
09, 12, 15, 17 hours



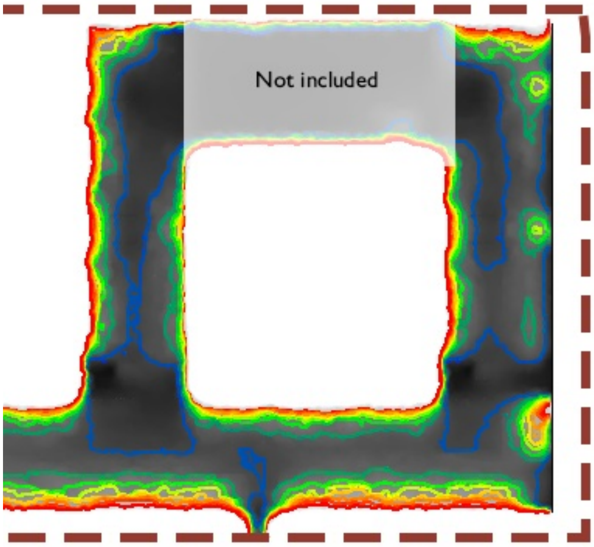
Autumn, shadows at:
09, 12, 15, 17 hours



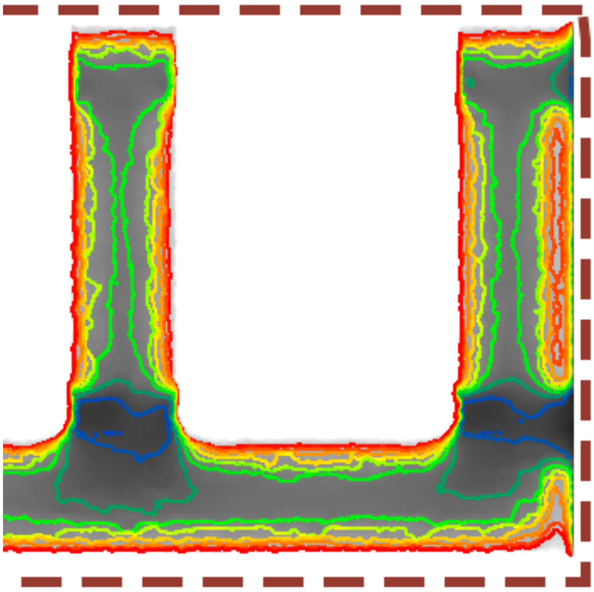
Winter shadows at:
09, 10, 12, 14 hours

DAYLIGHT STUDIES

Daylight studies were performed in order to understand how the current situation is and how we can use it for the future transformation. In this study, all the non-loadbearing interior walls have been removed, only keeping the structure and the facade of the building.



Ground floor



First floor

CHALMERS
UNIVERSITY OF TECHNOLOGY

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Chalmers University of Technology
Department of Architecture and Civil Engineering
Profile: Building Design and Transformation for Sustainability
Publication year: 2024
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