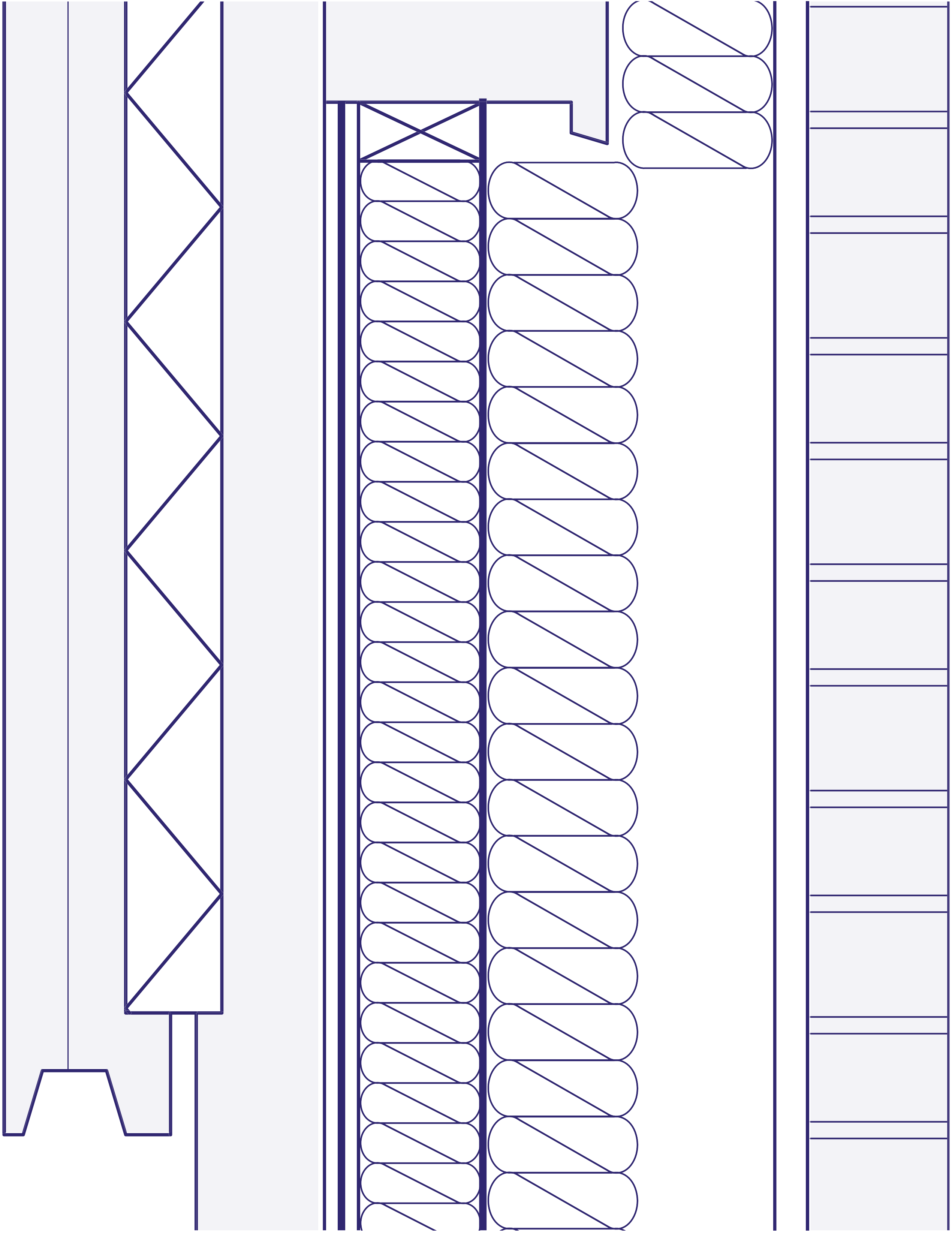

SUNDPARKEN.

SOURCING, REUSE AND TRANSFORMATION

GROUP 02

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ABSTRACT

This architectural master thesis project will provide a transformative design proposal for the social housing neighbourhood Sundparken in Horsens, which has been on the Danish government's ghetto-list since 2010 and is thus required to conform to the regulations within the parallel society act by 2030. The primary goal of the project is to reduce the percentage of social family housing from 86.67% to 60% while promoting integration and community among residents.

Almost 9000 apartment units nation-wide risk getting demolished due to the parallel society act and many of these have recently been renovated. The demolition of these units will release large amounts of embodied carbon, damaging the environment and lowering the chances of reaching local and global climate goals.

The master thesis will address this problem by evaluating the environmental impact of different transformation approaches through the use of Life Cycle Assessment (LCA). Additionally, the project will employ design-for-disassembly as a critical principle to enable the reusability of materials from the existing apartment blocks, when building new, thus reducing waste.

The LCA results will in combination with the analytical and theoretical framework be used to determine the design approach used for the final proposal of a social and environmentally sustainable neighbourhood.

Ill. 01 | Sketch of concept.

READING GUIDE

The report is organized in ten chapters. Each chapter elaborates a group of topics which are sub-concluded by key concepts.

The first seven chapters introduce the problem. Starting with the Theoretical Framework, it presents the project's context, state-of-art and the approach in this study. Inside this section, the different topics are further developed with a Study Case. A description of the Methodology afterwards establishes the parameters and the procedure of the study, followed by an initial analysis of the existing conditions of the site and the building. This pre-study phase is concluded with a vision, the target user group and the design strategies that directly connect to the next chapter, the design process. Here, the problem is developed by the study of the principal concerns of this Thesis, the different iterations, comparisons and conclusions. The iterations are numbered from 1 to 10 on each sub-chapter but these do not necessarily correlate. The Design Presentation. The final part reflects on the process, the limitations and the potential of further development of the study.

For orienting purposes, the reader can find the name of the chapter at the left bottom of the left page of a spread.

Every illustration is numbered and the credits can be found at the end of the report. In the case of maps and diagrams, the legend is placed below the image. The reference and the north and on the right corner.

We wish you a nice reading

TERMINOLOGY

Circular economy (or circularity)
In the construction industry it refers to a circular model in which both materials and buildings are not design to be disposed (cradle to grave), but for longevity, adaptability and disassembly, increasing the elements lifespan. In this sense, the objects can be renovated, reused or recycled (craddle to craddle).

Disassembly
A process of dismantling carefully without damaging the elements, preserving their qualities and giving materials the opportunity to a second life.

Transformation
A process that combines multiple strategies such as renovation, relocation, partial dismantling, and reuse of a building, changing the structural and spatial organization. This can involve modifications on the building typology or the function itself, and the main goal is to have an impact, not only on the image of a single building, but the whole area, increasing the residential mix in terms of typologies, functions and residents.

Demolition
A process of dismantling by wrecking, breaking elements apart and removing in a way that there is little opportunity for giving materials a second life.

Renovation
A process of modification to improve the quality and performance of a building in terms of energy efficiency and indoor climate.

Reuse
The direct re-utilization of an element without a change of purpose. This process does not involve extra treatments, materials, or energy. For this thesis, in the building environment, this reuse implicates no change in the program.

Repurpose
The direct re-utilization of an element with a change of purpose. This process does not involve extra treatments, materials, or energy.

Recycle
The reprocessing of discarded waste material in combination with virgin materials to give a new purpose to it and manufacture a new element. This process may involve a higher need for treatments, materials, and energy than restoration.

*Definitions are based on a combination of sources from Lendager Group, 3XN and Arup. Though, the thesis make its own interpretation to adapt it to the project work.

TABLE OF CONTENT

#01 | INTRODUCTION.

INTRODUCTION

“A Denmark without parallel societies” this is what the Danish government aims to achieve by 2030, in during so, there has been enacted several new initiatives within the social housing sector to halt the development of parallel societies. The catalyst for this master’s thesis is the initiative to reduce the percentile of social family housing down to 40% by 2030 in the neighbourhoods classified as transformation areas. This will require a substantial change to the built environment that will affect around 9000 housing units country wide and most likely result in the teardown of several apartment blocks. How can we approach this task in a way where the environmental impact isn’t overshadowed by but is of equal importance as the social sustainability aspect?

Between 1945 and 1989, 28 thousand multi-storey apartment buildings were built across Denmark using a prefabricated concrete construction, thanks to the development of the building industry after the Second World War (Engelmark, Jesper, 2013). This type of construction has a lifespan of 80 to 120 years (Haugbølle et al., 2021), but the Building Regulations back in those times had different standards than the ones used in the present (Historisk Bygningsreglamenter, 2023). This led to several of them being renovated from the 90s to improve the energy performance and the indoor environment quality. Some of these neighbourhoods was rented as social housing and a large percentage would later be used by immigrants , as the years passed, some of these areas turned into smaller communities of people sharing the same ethnicity and culture this made it an attrative place to live for people from similar background and the communities started growing and some of these area turned into parallel societies. The Danish Government has been keeping track on parallel societies within Denmark since 2010 and has stated some restriction in order to dissolve these by 2030. There are 9 residential building areas that fulfil the criteria to be considered as areas that must be transformed. Several studies, development plans and projects have been proposed in the last decade, both in the social and building construction field, in order to improve these areas and promote their way out of the list. COWI, JAJA Architects, GXN and other firms are some of the ones involved in thinking potential solutions for this problem by opening up the areas towards the surroundings, establishing connections to the outside to boost integration, and in some cases trying to avoid demolition as well, which has high CO2 emissions and has become a bigger issue in the past years. Some areas have had more success than others, since the list got reduced by 6 in the last 4 years, but some other still have a lot of progress ahead.

One of the areas that didn’t make out of the list before getting classified as a transformation area, was Sundparken in Horsens. They now have to go through a substantial transformation to reduce the percentage of social family housing to 60%., with the aim of improving the social sustainability for the area as a whole.

PROBLEM STATEMENT

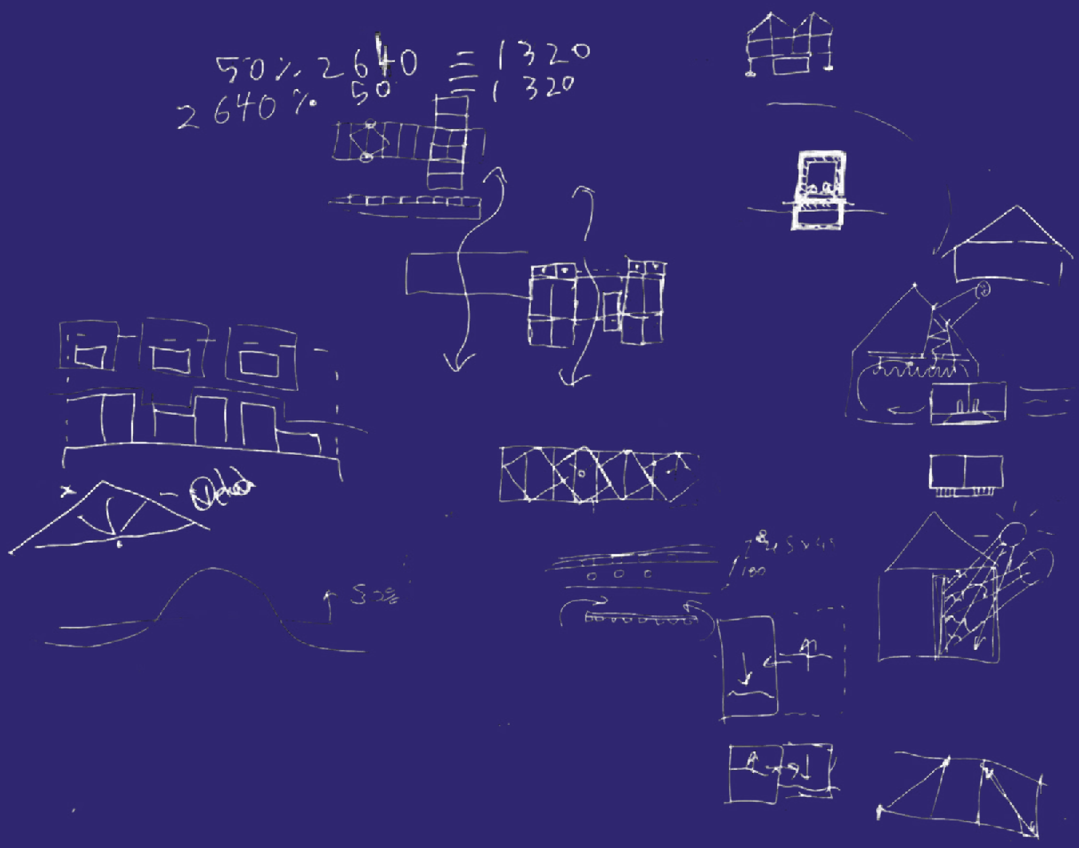
Sundparken is considered a Transformation Area since it meets the Parallel Society criteria. At the same time, it is a safe and well-functioning housing area, where the construction quality and the outdoor facilities are objects of satisfaction to its residents and people around the area, such as social workers and neighbours. Because of this, it has been granted an exemption to reduce family apartments to 60% instead of 40%. Nevertheless, the area must comply with the Danish government's restriction by 2030, which in case of demolition and re-construction would cost the environment a considerable amount of carbon dioxide emissions.

The thesis aims to explore the possibilities to comply with the governments demand within Sundparken, while considering different transformation strategies that evaluate models for demolition, disassembly and renovation based on LCA results.

As such this thesis will examine the demolition and reuse of existing building materials in a building-LCA context, where reused materials can be beneficial in lowering the overall CO2e emissions (Andersen, C. et al. 2019). Meaning reusing building materials can become an active strategy in reaching the climate impact goals of the 2023 Danish Building Regulation. Furthermore, the thesis will explore state of the art methods for non-destructive demolition and design for disassembly in the design process, such that future buildings can be a part of a common circular economy (Køster, A. et al. 2019).

With this ideas in mind, and considering that this building typology is frequent in Denmark, it is expected to provide potential solutions for re-using parts of buildings and materials with a high global warming potential in similar cases.

“HOW CAN THE SOCIAL HOUSING AREA OF SUNDPARKEN BE TRANSFORMED, COMPLYING WITH THE REDUCTION TO 60% FAMILY HOUSING REQUIREMENT OF THE PARALLEL SOCIETY ACT, TO CREATE A NEIGHBOURHOOD INVITING A GREATER VARIETY OF RESIDENTS AND USERS, WHILE DOING SO IN AN ENVIRONMENTALLY SUSTAINABLE WAY, PRESERVING AND REUSING EXISTING BUILDING STRUCTURES AND MATERIALS?”


50% 2640 = 1320
2640 % 50 = 1320

#02 THEORETICAL FRAMEWORK.

THE PARALLEL SOCIETY ACTS

The Danish government has since 2010 monitored the development of social housing areas around the country, based on criteria like ethnicity, income, education and crime rates. The neighbourhoods that fulfilled the underlying criteria would be listed on the government's ghetto list.

These yearly reports would later also include listings of at-risk neighbourhoods and, also a tough ghetto category which would list the neighbourhoods who had been listed on the ghetto list for 5 years in a row.

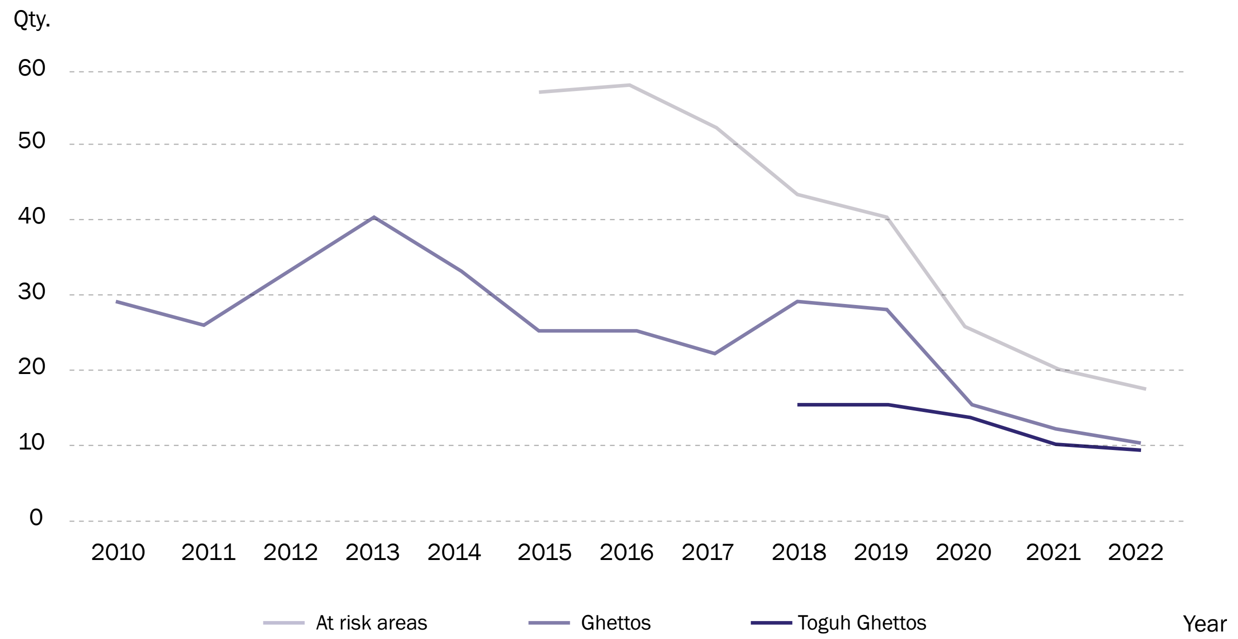
The terminology regarding the classification of the neighbourhoods as ghettos in official documents has been criticised and was changed in 2021. Henceforth ghettos would be reclassified as "parallel societies" and the term "tough ghettos" would change to "transformation areas". A new category was also introduced in 2021 called precaution areas (BL,2022).

The selection criteria have changed multiple times during the 12-year existence of the "Ghetto list", but as shown on the graph, it seems to depict a downward trend of the number of parallel societies in Denmark.

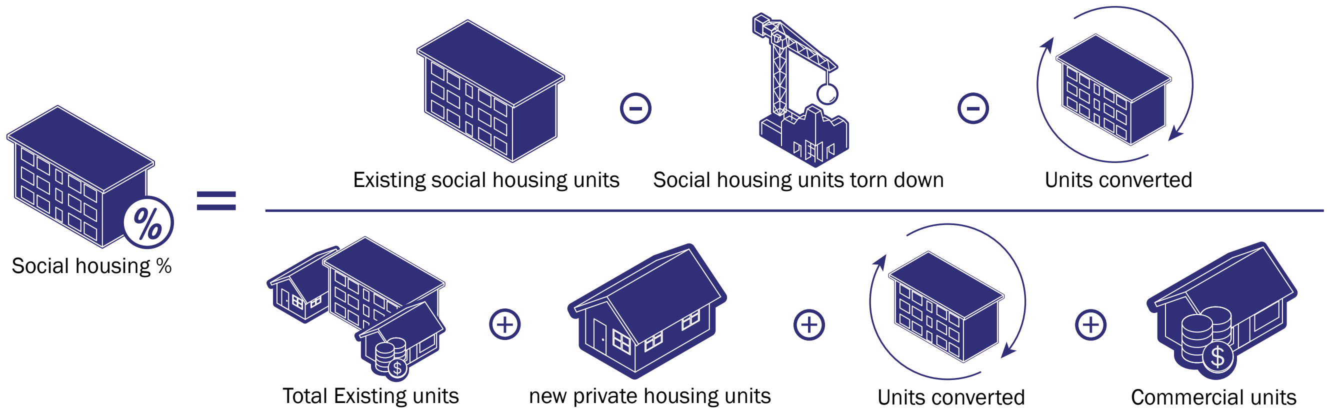
Even if this trend continues and several of the transformation areas (formerly known as tough ghettos) would go off the list, they are still required by law to go through an extensive transformation that would reduce the percentage of family apartments down to 40%.

"Reducing the share of public family apartments can be done in different ways: through densification through private construction of owner-occupied housing, cooperative housing or private rental housing; through conversion to other forms of public housing, e.g. housing for the elderly or young people; when selling general family housing, targeted demolition or attraction of businesses and municipal workplaces" (Statsministeriet, 2018).

Some of the transformation areas can receive a dispensation that allows the area to have a higher percentage of family apartments than 40% in cases where it is deemed necessary.



Ill. 02 | Parallel society list development from 2010 to 2022.



Ill. 03 | Formula for the calculation of the percentage of social housing on the site.

To verify that the proposals comply with the required percentage a specific formula is applied. The calculation takes into account only the different residential types, being family, student or elderly housing, and the commercial use inside the site. In this case, 75m^2 is equivalent to one apartment. The percentage is defined as the ratio between the number of family units being preserved and the new total number of units. The apartments preserved are the difference between the existing units and the ones being removed and transformed. The new total is the sum of the existing total apartments, the new private units, the converted residences and the commercial area, counting as one apartment every 75 m^2.

This formula is implemented in the Thesis during the design process.

THE WAY OUT THE PARALLEL SOCIETY LIST

It is a long process exit the Parallel Societies List, and it requires big effort and hard work both from the municipalities and the residents, managing the social, urban and architectural scale of the problem. This is reflected on the different Development plans designed around 2018 by the municipalities affected by the Parallel Societies Act, which stated how they would comply with the regulations. This specifies how much will be demolished, built, and what are the strategies to improve the district from the present until 2030, the deadline set by the Government. (Transportministeriet, 2018).

As mentioned before, there are different classes within the list, according to the accumulation of years and severity of the case. These are “Vulnerable residential areas”, “Prevention areas“, “Parallel societies” and “Transformation areas”, (Bolig og planstyrelsen, 2022). A group of criteria defines whether to include an area on the list of vulnerable areas or not.

Ill. 04 | Relevant aspects for an area to be considered on the list

Basic criteria:

- The area must have over 1000 residents.

The areas will become part of the list if they meet at least two of the following social criteria:

- Labor market: over 30% of the residents aged between 18 and 65 are unemployed.
- Level of criminality: over 1.45% of the residents have criminal records regarding the Criminal Act, weapons or drug consumption.
- Level of education: over 60% of the residents aged between 30 and 59 have only primary education.
- Income: the average income of taxpayer residents aged between 15 and 64 is less than 65% of the average income on the region. (Transportministeriet, 2018).

Areas that fulfill the etnicity criteria will be considered a prevention area:

- Ethnicity: at least 30% of the residents must be from non-western Europe countries. Over 50% it is considered a Parallel Society.

		residents	outside jobmarket	non-western EU	criminal record	only primary education	income	total change
Thresholds	Hård ghetto		40	50	2.18	60	55	
	Prevention area	1000	**30**	**30**	**1.45**	**60**	**65**	
Tingbjerg	**2018**	6526	27.6	73.1	1.83	76.3	51.4	
Copenhaguen	**2022**	5873	25.5	72.4	1.95	66.6	55.3	
	% change	10.0	7.6	1.0	-6.6	12.7	7.6	22.3
	ppl diff	-653						
Gadehavegård	**2018**	2186	39.4	56.5	1.86	72.5	54.8	
Høje-Taastrup	**2022**	2195	31	57.3	1.66	71.3	56.1	
	% change	-0.4	21.3	-1.4	10.8	1.7	2.4	34.7
	ppl diff	9						
Ringparken	**2018**	2023	43.3	55.6	2.19	70.9	56.5	
Slagelse	**2022**	1671	35.7	57.6	1.77	66.2	60.3	
	% change	17.4	17.6	-3.6	19.2	6.6	6.7	46.5
	ppl diff	-352						
Motalavej	**2018**	1680	40.4	53.3	2.14	72.8	58.8	
Slagelse	**2022**	1405	38.2	50	2.16	71.2	58.3	
	% change	16.4	5.4	6.2	-0.9	2.2	-0.9	12.0
	ppl diff	-275						
Munkebo	**2018**	1476	42.9	60.2	1.47	71.8	62.4	
Kolding	**2022**	1239	35.9	64.5	1.59	68.6	64.6	
	% change	16.1	16.3	-7.1	-8.2	4.5	3.5	9.0
	ppl diff	-237						
Finlandsparken	**2018**	1611	41.5	73.5	1.43	77.3	60.8	
Vejle	**2022**	1503	36.6	70.9	1.81	72.6	63.3	
	% change	6.7	11.8	3.5	-26.6	6.1	4.1	-1.0
	ppl diff	-108						
Sundparken	**2018**	1492	52.7	69.6	1.09	80.1	55.3	
Horsens	**2022**	1400	42	66.8	1.28	79.3	56.9	
	% change	6.2	20.3	4.0	-17.4	1.0	2.9	10.8
	ppl diff	-92						

2018: value exceeds hard ghetto criteria
2022: value exceeds hard ghetto criteria

Ill. 05 | List of areas that developed from Transformation area in 2018 to a Prevention area in 2022. The list compare these cases with Sundparken.

There are six cases that from 2018 to 2022 achieved a relevant level of improvement from a Transformation area to a Prevention area. According to the Act, this does not exempt them from the 60% family housing reduction, but it showcases the positive results of the initiatives carried on the district. Depending on the magnitude of the area and the percentage of family housing reduction that each must achieve, they combine demolition with new buildings, relabelling and selling to private owners.

The cases are Tingbjerg/Utterslevhuse in Copenhaguen, Gadehavegård in Høje-Taastrup, Ringparken (see: Case Study / Ringparken) and Motalavej in Slagelse, Minkebo in Kolding and Finlandsparken in Vejle. (Indenrigs og boligministeriet, 2022). Different circumstances allowed this change, but in general, the municipalities focus the development plan on the following:

- raising employment rates, for instance by offering pocket jobs or introducing Job Center offices nearby.
- encouraging education, by introducing initiatives to engage students by helping others, cultural centers, libraries and institutions
- improving the indoor environment quality by renovating the apartments facades (windows and insulation), bathrooms and kitchens.
- improving the quality of life by increasing connectivity with paths or roads, integrating the area to the surroundings, introducing nature and rich outdoor areas with playground, urban furniture, art, gardens or sport facilities.
- increasing the opportunity for positive social exchange through mixed neighborhoods with different housing typologies, functions or resident types. Also stating a clear zoning between public, semi-public and private areas for the community.

The way that some of the criteria are evaluated, like education and income, congest the possibility of quick improvement, and for that reason it is visible that most of the cases have bigger impact on the employment.

CASE STUDY / RINGPARKEN, SLAGELSE

Slagelse Kommune is facing a similar situation to Sundparken, in the sense that thay have been in the Parallels Society list for over five consequent years. Despite the fact that Rinparken has left the Transformation Areas list in 2021 because of improvements on the criminality rate, they must carry on with the reduction of 60% of family housing in the area. The development plan proposed by the Municipality expects to demolish 149 housing units and transform 63 into 104 new student apartments, and there is a 5-year plan to alternate short-term relocation of residents, renovation and demolition (FOB, 2019).

The masterplan has been developed in collaboration with Sweco Architects, Kant Arkitekter and Niels Bjorn, proposing to restructure the area into three smaller neighbourhoods that differ in quality (Ill. 06).

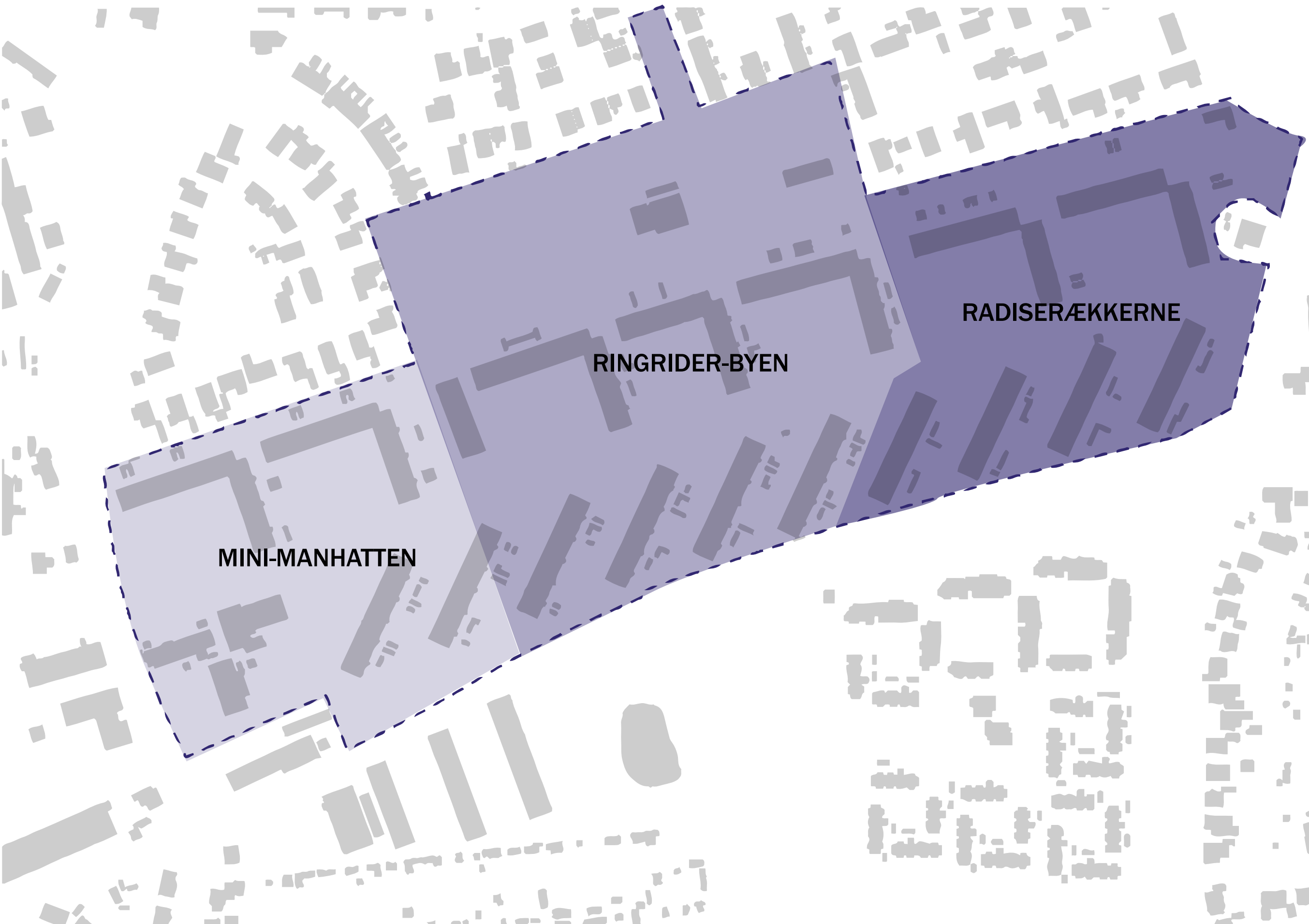
The neighbourhood's zones

1. Mini-Manhatten in planned as the most dynamic area, consisting of family and student housing, co-existing with a shopping area and a food court.

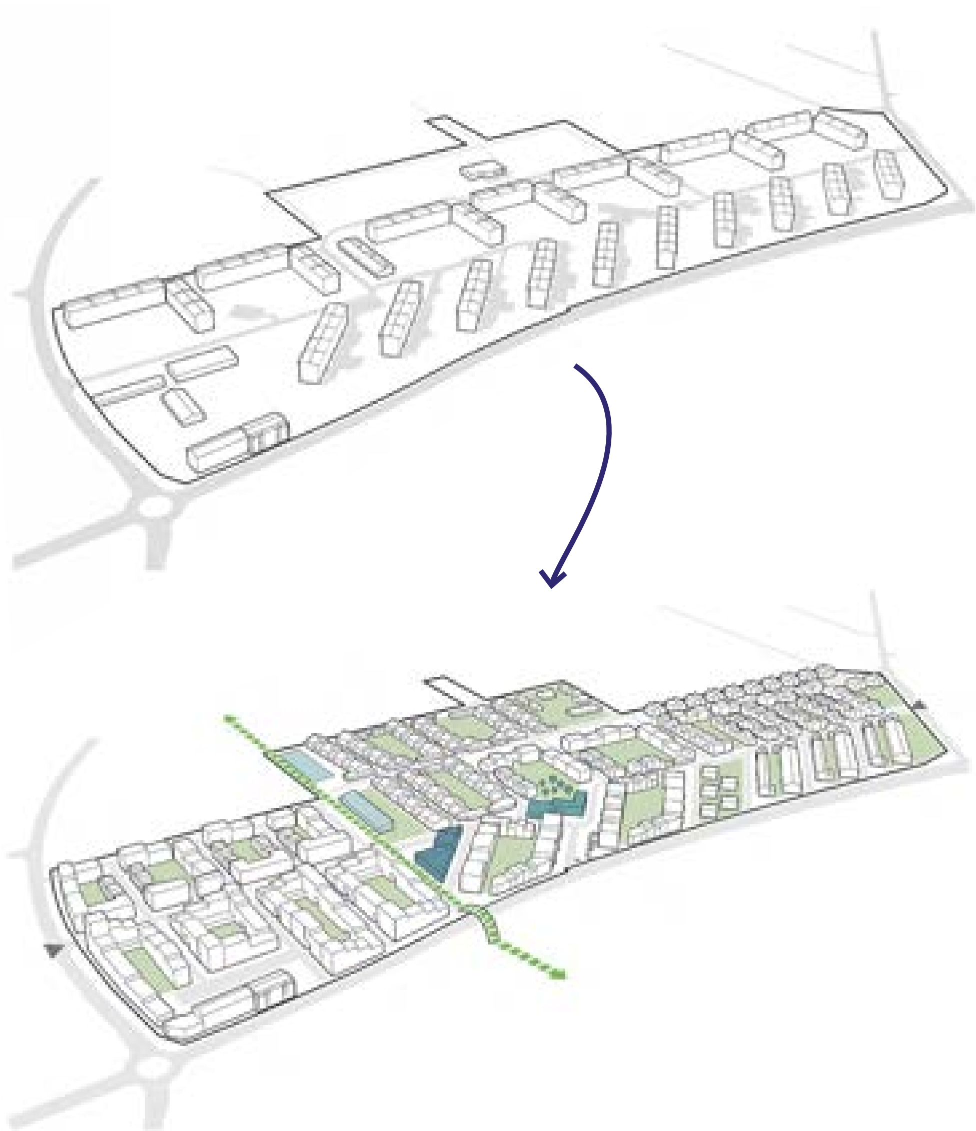
2. Ringrider-byen is mainly occupied by family housing activated by the surrounding cafes, gardens, sports facilities and playgrounds.

3. Radiserrækkerne is a senior-friendly area with elderly apartment and row-houses that invites social interaction between neighbours.

This zoning encorages a gradient of activity levels, bringing demographic diversity and programmatic mixture. It provides an environment well-equipped with facilities for the specific users, such as playgrounds in family areas, coffe places where to study for the students, or a quieter lower density area for the elderly.



Ill. 06 | Site map of Ringparken's current setting and the proposed subdivision into three areas with different qualities.

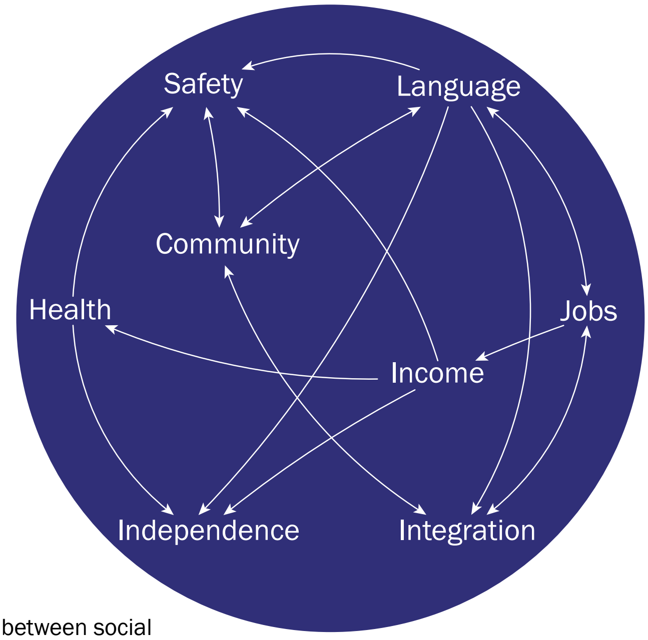


Ill. 07 | Masterplan proposal sketch. On the top, Ringparken's current setting. In colors, the new proposal. Sweco Architects. 2016-2022.

Other strategies applied in the area are the break down of the blocks to a human scale, in which the urban pattern also blends bettwe with the surroundings.
The infrastructure inside is also changed in order to increase the connectivity to the city and allow the residents to thrive (Sweco, 2023). The connecting paths are restructured, new car parking lots and roads used by the residents will tie the area together. and Kierulffsvej will be opened up to slow car traffic from east to west.

Conclusion
To support the residents, it is important to have a clear understanding of how to fulfill their needs and reflect that on architecture. One way to do that can be by organizing the site in a way that can fit different profiles without necessarily promoting distance. bringing demographic diversity and programmatic mixture. The gradient proposed in Ringparken and the restructuration of the paths are an example on how to execute that.

SOCIAL SUSTAINABILTY CHALLENGES

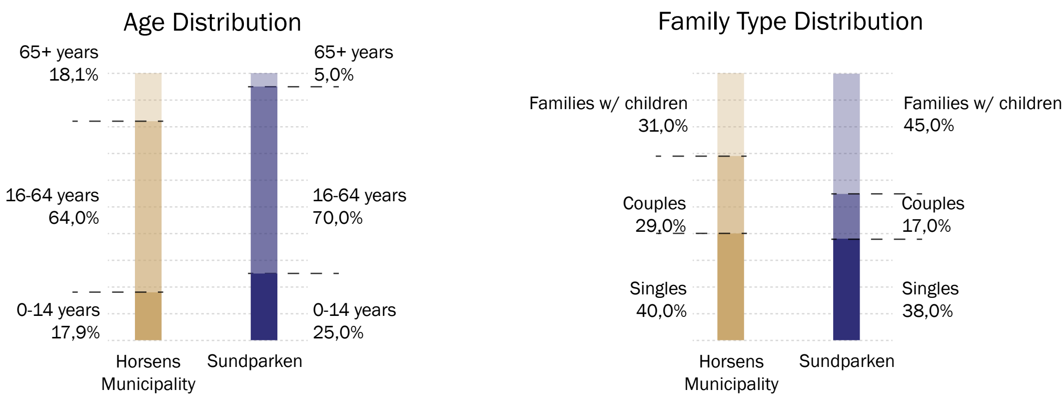


Ill. 08 | Complexity of connections between social issues regarding the residents of Sundparken

The analysis of the residents of Sundparken and Horsens municipality at large is based on data three documents describing partial agreements on social initiatives in the area released by Landsbyggefonden together with Bo Trivsel, the social housing effort in Horsens (in Danish boligsocial indsats), called “prevention and parental responsibility (2020a)”, “Safety and Well-being (2020b) “ and “Education and Employment (2020c)”. These documents compile information from various litterature studies and statistics from VIVE (The national research and analysis center for welfare) and CFBU (center for social-housing development) and puts them into the context of Sundparken and other social-housing areas of Horsens. For statistics related to the transformation areas as a whole and academic literature studies within the field of social housing, the thesis looks to VIVE’s report “Omdannelsesområderne på vej (2022)”.

The texts highlight a multifaceted, complex issue with multiple causes resulting in a multitude of issues affecting the residents of Sundparken, this is conceptually illustrated in figure 08. The chapter will firstly present, broadly, the demographic of the residents in Sundparken compared to Horsens municipality in general, and from there go on to describe the residents’ challenges in-depth regarding data specific for Sundparken and the transformation areas as a whole.

As figure 09 shows, the residents in Sundparken have a significantly higher percentage of children (0-14 y.o.) compared to the rest of Horsens, while also having a much smaller portion of elderly people (65+ y.o.). This corresponds similarly with the dominant type of family in Sundparken being families with children making up around 45% of all households. This indicates a small homogeneity in the neighborhood, with a high number of people in education but fewer people with life-experience to look up to in the nearby community (Landsbyggefonden, 2020a).



Ill. 09 | Demographic of Sundparken’s and Horsens Municipality’s residents, 2018. Source(s): Omdannelsesområderne på vej (2022); DST - Danmarks Statistik

ADOLESCENTS, EDUCATION AND EMPLOYMENT

The proportion of residents in the age group 30-34 years old who do not have a job, have not completed a middle school education, or higher level of education, is 41%, while the unemployment rate is 57,4% for Sundparken as a whole. (Landsbyggefonden, 2020a) This has an effect not only on the residents themselves, but on their children as well, as the adults are not sufficiently able to help with schoolwork. furthermore, the children as a result often do not have a good role model for education or employment at home and are therefore more likely themselves to not complete higher education and, without intervention, will likely follow the pattern of low-employment and living on social benefits (Landsbyggefonden, 2020a).

The low level of education and employment results in the average yearly income pr. household in Sundparken being 357.000 kr, which is about 33% less than the average yearly income in Horsens municipality of 528.000 kr (Landsbyggefonden, 2020a).

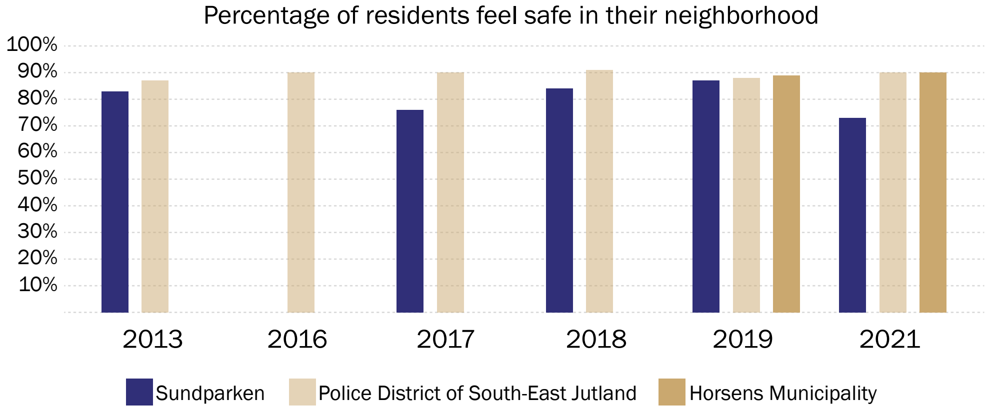
Children coming from households with a low-income and of families of non-western ethniticites are both under-represented in local sports clubs at around 60% participation compared to children born in Denmark and from families with a high income, which is about 85% (landsbyggefonden, 2020b). This indicates a potential for community-building between children from Sundparken with the surrounding neighborhoods in a context of organized sports. Sundparkhallen is already a good example of an institution that brings children together across neighborhoods, however at a less organized level (Bech-Danielsen, C., Nordberg, L.W. and Sundstrup, R.B., 2022).

For children and adolescents struggling with school, and who may find themselves getting in trouble in their spare time, getting a spare time job can be a good opportunity for these young people to find something meaningful and positive to spend their time on. Performing well at their job can lead to increased self-worth and belief in one's own skills. A study performed by VIVE shows that teens with a spare time job are pursuing a higher level of education in 85% of cases, compared to 60% for their peers who do not have a spare time job (Landsbyggefonden, 2020c). Furthermore, in Horsens, Bo Trivsel will help some children and teens in finding jobs in their neighborhood, so the trouble-causing young people can be seen as responsible, performing their job, and in turn both their external perception, from neighbors and alike, and their internal perception and outlook on life can change for the better (Landsbyggefonden, 2020c).

FAMILY, SAFETY AND WELL-BEING

A low level of education, employment and low income are problematic issues in of itself, however, they are only adding pressure onto an already stressful situation and in many cases the level of stress is so high that residents don't seek help in their community or social housing initiatives due to a lack of energy and motivation (landsbyggefonden, 2020c). This especially goes for the fathers in the families, who have a cultural expectation to be the provider of the family, whose sense of self-worth is centered around employment. This can lead individuals or families to self-isolation and growing lonely (Landsbyggefonden, 2020b). Statistics show that 47,7% of residents in social housing areas do not participate in common activities, while that number is only around 20% for various increasingly private forms of ownership (Landsbyggefonden, 2020b). This highlights the difficulty in recruiting and getting vulnerable residents to participate in community building and self-improving activities and programs.

There is also a significantly higher degree of pscychiatric diagnoses in the transformation areas compared to the country average. There are multiple reasons for this, but it is often associated with traumatic experiences related to war, oppression or fleeing their home countries (Landsbyggefonden, 2020c). This means that while some residents may seek guidance in pursuing education or finding employment, often there are concurrent issues to deal with that make the overall process less straight forward (Landsbyggefonden, 2020c).



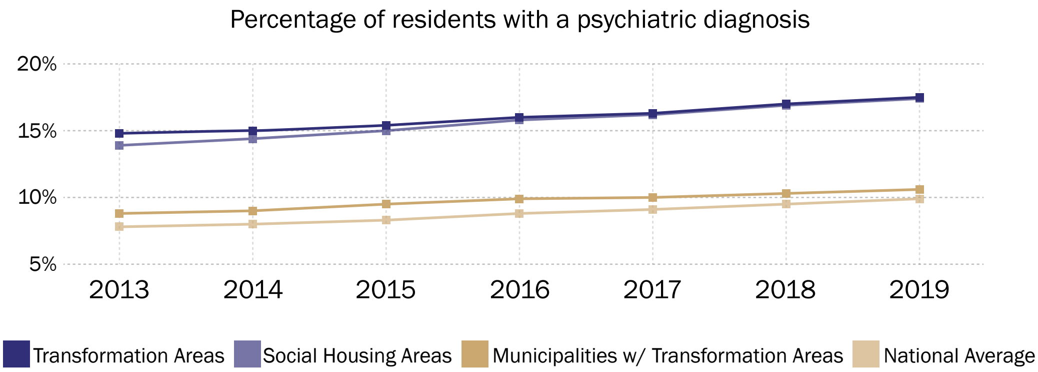
Ill. 10 | Feeling of safety in the neighborhood of Sundparken, Horsens Municipality and the police district of South-East Jutland, which includes Sundparken and Horsens. Source(s): Politiets Tryghedsundersøgelse 2016-2019; Justitsministeriets Tryghedsundersøgelse 2021

Despite low levels of education, employment and income the residents of Sundparken have throughout the last number of years felt safe in their neighborhood as figure 10 shows, and within the transformation areas, it is one of the safest neighborhoods according to the residents of the various areas (Christensen, G. et al. (2022). In 2021 however, the percentage of people feeling safe in their neighborhood, Sundparken, fell to 72,8%, which is unfortunate, especially since no explicit reason has been correlated to this sudden drop in satisfaction, which means it is hard to implement a specific strategy to help the residents feel safe as before.

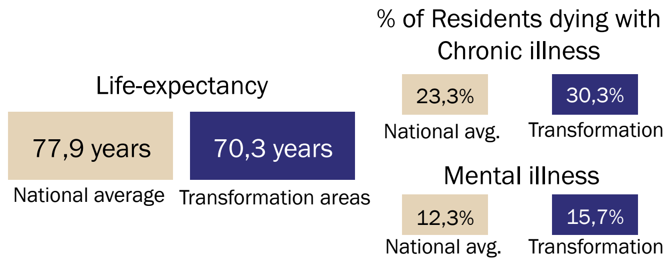
HEALTH

The problematic areas of the residents in Sundparken culminate in their personal health, where it is clear that the challenges the residents face have clear consequences. The level of education especially has been correlated to the overall health of a given individual and in turn also their expected lifespan (Christensen, G. et al. (2022). This can also be seen in figure 12, where the transformation areas have a significantly lower life expectancy compared to the national average, other social housing areas and the municipalities which include the transformation areas.

As discussed, earlier residents in the transformation areas have a higher rate of psychiatric diagnoses compared to the national average likely caused by various traumatic incidents throughout the residents' lives, this can be seen in figure 11. Not only do they the vulnerable residents have a higher rate of illness, but statistics also indicate they have a lower degree of mastery of their illness, leading to a higher rate of death following mental and chronic illness, this can be seen in figure 12.



Ill. 11 | Statistics for residents with one or more pscychiatric diagnosis in the Transformation areas and social-housing areas compared to the municipalities which host the transformation areas and the national average. Source: ustitsministeriets Omdannelsesområderne på vej (2022)



Ill. 12 | Statistics for life-expectancy and illness-mastery in the Transformation areas. Source(s): Omdannelsesområderne på vej (2022)

While the health of the residents is undeniably important, it is not a a direct goal for improvement through design in this thesis, and as such will only be tackled implicitly through improvements related to community-building, education and employment in the project, which all have some influence in the residents' health, education being the most influential factor, as mentioned earlier.

SOCIAL MIXING

When trying to broaden the social mix in a given area it is important to find/give common ground between the different residents, especially if there is a large socio-economic difference between residents (Christensen, G. et al. (2022). If there is not a common understanding between residents, they will have a hard time feeling connected with one another and are more likely to form smaller homogenous groups internally in the neighborhood.

A problem that is seen in the transformation areas as a whole is that a larger part of the residents moving into the areas are part of the NEET-group, Not in Employment, Education or Training, than out of the areas (Christensen, G. et al. (2022). This means positive development in the area as a whole is not happening, but rather it indicates growth at an individual level that then allows the residents to leave the area again.

VOLUNTEERING

The Safety and Well-being paper from Landsbyggefonden (2020b) discusses volunteering as a highly beneficial strategy for activities in the Sundparken neighborhood. Where volunteering in the traditional sense is considered doing something good for others while expecting nothing in return, studies show a number of positive effects can be derived from volunteer-work (Landsbyggefonden, 2020b). A sense of meaningfulness, development of personal skills and community building can be derived from the voluntary work, which all help the individuals feeling of self-worth, a struggle for many of the residents in the transformation areas, as discussed earlier. This means that volunteers are beneficial in two ways: firstly, the volunteers help the vulnerable residents of Sundparken leading to any number of effects on family dynamics, education and employment depending on the specific activity, while the volunteers get a great sense of satisfaction and increased confidence (Landsbyggefonden, 2020b). Furthermore, it is expected that residents who have a positive experience will share their new-found knowledge with their network and neighbors, meaning the effect on the individual may trickle down further and increase inclusion in the community to more people than just the residents who are initially reached (Landsbyggefonden, 2020a).

CONCLUSION FOR DESIGN

Centrally placed opportunities for social interaction between residents in the neighborhood and with outside residents and social workers. Functionality could include creating job opportunities for adolescents in the area – for example they may serve in a café, help in the administration of activity centers or help cleaning facilities

Use the existing football field in the planning design to enhance community building for children and adolescents to meet around sports.

Create row-houses and private apartments to attract new residents and for current residents to move into, such that they don't move out of the community when they are doing better in life.

CIRCULAR ECONOMY

In 2020, the Danish Government has adopted the Climate Act, which states that Denmark must reduce its CO_2 emissions by 70% by 2030 compared to 1990, and a 50-54% by 2025 (Retsinformation klimaloven, 2021). In the building sector, footprint reduction could be achieved by improving the quality of the construction, decreasing waste and energy consumption, and increasing the lifespan of materials, elements and buildings (Ministry of the Interior and Housing, 2021, p. 8). There is room for improvement of circularity in the construction sector, and especially concrete remains an untapped potential, since it currently is turned into road fill, ignoring its lifespan of approximately 120 years (BUILD, 2021).

One way to minimize the environmental impact caused by the construction sector is to implement circular economic strategies, and in this case especially circular tear down.

The global economic and population growth will lead to an increased consumption of natural resources and our throw-away culture is not sustainable long term. Circular Economy challenges the idea of a linear value chain that starts with resource extraction and ends with waste. It introduces a circular way of thinking that encourages us to think of new ways to allow products and materials to stay within the economic circuit at the highest possible value and for as long as possible (Miljøministeriet, 2015).

The use of Circular Economy in Denmark has the potential to increase BNP by 0,8-1,4%, create between 7000 and 13000 jobs, reduce Denmark's CO_2 footprint by 3-7% and possibly reduce the use of new resources by 5-50% depending on the material, while potentially increasing the export by 3-6% (Shepard, 2015).

When applying circular economy to the construction sector, the focus is on the fourth phase of a buildings life cycle: End of use. Business as usual would be a conventional tear down and constructing new. This is clearly not a sustainable approach, and to improve we most look at the end of use phase as the beginning of something new.

Resource mapping
It is therefore essential that a resource mapping is conducted during the end-of-use phase. Resource mapping is divided into four phases:

Phase 1: Purpose clarification
It's important to clarify with the client what their wishes are and how ambitious they want to be in this process.

Phase 2: Desk research
secondly as much research as possible will be gathered before making the physical building examination. This includes existing technical drawings and material descriptions.

Phase 3: Building examination
Thirdly the building is examined on site to determine the state of the materials and elements.

Phase 4: Data processing
Lastly the collected data is processed and analysed and from there the quality and quantity of the building components are evaluated.

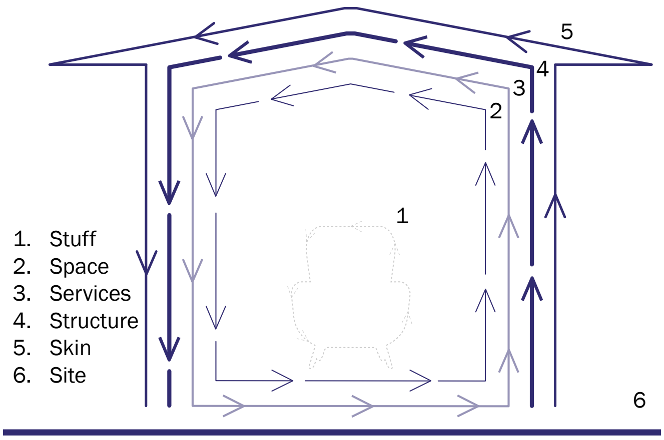
This study will use these phases to structure the investigation and the design process.

Planning and projection
After the resource mapping has been completed the project moves on to planning. No matter what all current building and safety regulations. This means that if some of the materials have been contaminated by hazardous substances it either must go through a treatment or if that is not an option it has to be classified as waste. This is what the results of the Resource-mapping will conclude. The materials will be classified into three categories: Green for materials with no issues, yellow for materials that must go through some kind of treatment and red for materials that can't be reused in any way (Cirkulær nedrivning, n.d.).

Specify material extraction methods
It's fundamental to consider how the materials are extracted since it can affect their ability to be reused. This can as an example be which tools to use and how they affect the materials and their qualities, or whether or not an element is being extracted as a whole or in smaller and if wille be put back together og are the parts used separately.

The shearing layers of a building

In 1994 Stuart Brand described the 6 shearing layers of change of a building according to the lifespan (Ill. 13) to explain the process of change and adaptation of a building and bring awareness on how to work with time. The scale serves as a guide for designers aiming for a circular building, such as Arup and GXN, who adapted the theory to their own investigations. Originally, the author identified 6 different layers: the site is eternal and the structure is the most durable of the construction. This is followed by the services, such as plumbing, mechanical, electrical and HVAC systems and so on; the skin, referring to the façade; the space, which is defined by the room layout and surfaces; and the most ephemeral, the stuff, describing non-fixed furniture and fittings (Buchard, 2021).



Ill.13 | The shearing layers of a Building. Stuart Brand, 1994 (Adapted).

GXN Innovation attributes specific years to these lifespans, assuming that furniture can last up to 5 years, while services are renovated every 25 years, the façade 50 years and the structure up to 100 years (GXN and Responsible Assets, 2018, p. 47).

When it comes to circularity, it is important to consider these lifespans to design the connections and the accessibility to them, maximize the adaptability of layout in the future to facilitate this natural lifecycle and provide opportunities for their recyclability and reuse.

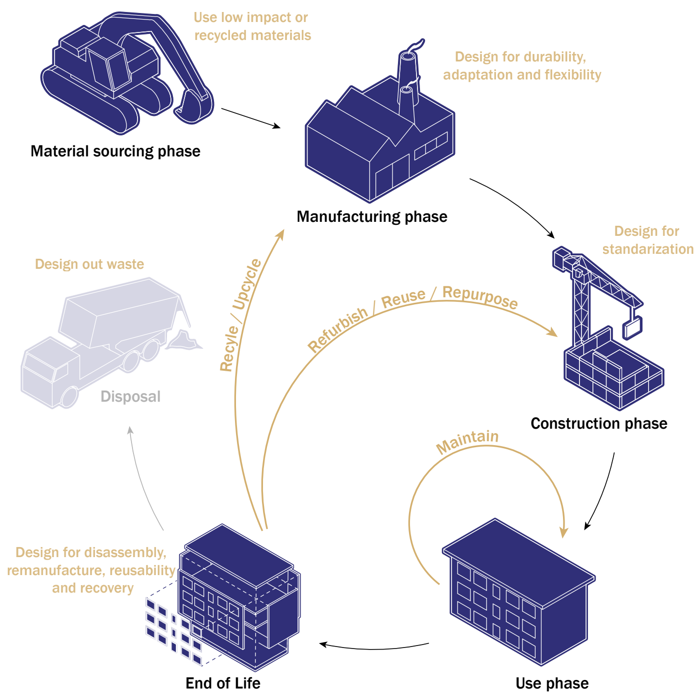
Circular design principles

Circular desing becomes key for the implementation of circular economy in the building industry, and the main goal is to prevent waste and pollution from the initial stages through the circulation of products and materials (Arup, 2016). To achieve this, the following principles should be followed:

- USE HEALTHY MATERIALS
- TRACK LIFE-CYCLE
- DESIGN FOR MODULARITY
- PRIORITIZE PRESERVATION TO REFURBISHMENT TO RECYCLE
- MAXIMIZE RECICLABILITY, REUSE AND RECOVERY
- RENEWABLE ENERGY AND MATERIALS
- REGENETERATE AND RESTORE VALUE
- OPTIMIZE DURABILITY AND REVERSE LOGISTICS

Illustration 14 shows the circular system and how principles (in yellow) can be applied throughout the cycle.

The next topic presents three case studies, Circle House, Resource Rows and Upcycle Studios, based on circular principles.



Ill.14 | Circular economy model in the construction industry and principles.

CIRCLE HOUSE / CASE STUDY

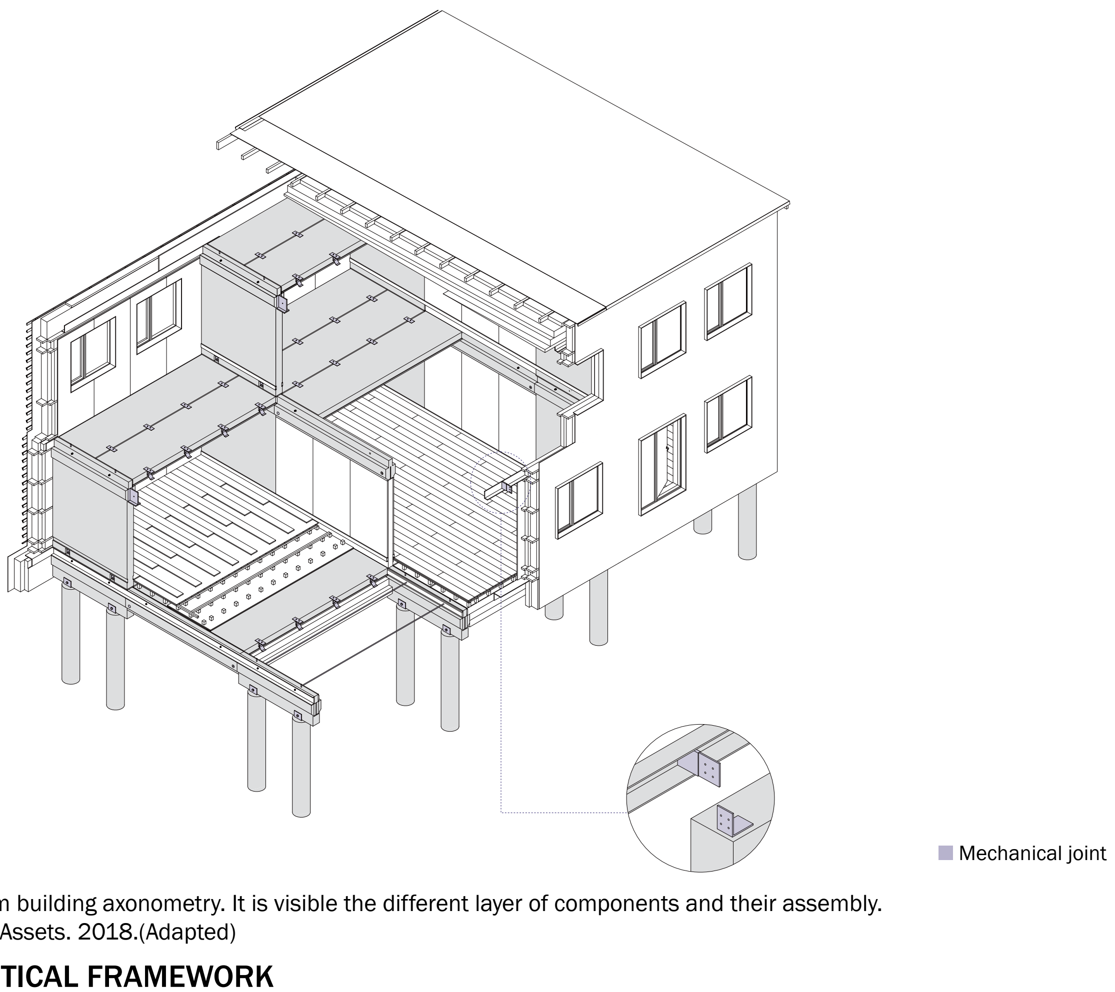
Concept
Circle House is a project for social housing based on circular principles, developed in collaboration between over 30 different companies along the value chain of the building sector and 3XN, Vandkunsten, and Lendager Group as the leading designers. This collaboration is key for its success, considering that circularity is a concept that is still being introduced in the market. The biggest challenge was to assure that 90% of the materials are reusable or recyclable without losing value after their disassembly. The research puts great attention to mechanical joints and connections, aiming to create a system that allows assembly, disassembly, and re-assembly in a fast, efficient way that prevents material damage.

Project description
The project consists of 60 housing units located in Lisbjerg Bakke, on the outskirts of Aarhus, in a total area of 5.400m². It combines 2 and 3-storey row houses and 5-storey tower blocks separated by parallel roads and private or semi-private gardens. The living units vary from 35 m² to 90 m² and 110 m².

Circularity of space
Buildings are most likely to be designed to endure, but to avoid demolition and ease refurbishment, the 90m2 unit is more flexible, making it easy to subdivide the bedrooms differently, from two big ones to four smaller ones according to the need of the occupant or the owner. This is possible thanks to the drywall system that allows to effortlessly install and demount easily with screws.

Circularity of the facade
The façade is a lightweight system with hangers outside the structure that makes it simple to maintain, reuse, but also personalise.

Circularity of the elements
All joints in the project have been simplified and turned into mechanical ones in pursuit of circularity; some have a Cradle to Cradle® certification, some are manufactured from recycled materials, and most of them involve lower carbon emissions than conventional ones. The structure, the installation pipes, the internal walls, the flooring, the façade, the



Ill.15 | Modular system building axonometry. It is visible the different layer of components and their assembly.
GXN and Responsible Assets. 2018.(Adapted)

furniture, and so on, is mounted either with screws, connection plates, anchors, hangers or click-in systems, avoiding adhesives, plastering or other types of permanent fixings (Ill. 15). Moreover, the elements include material passports with essential information on the installation, the material composition, the reuse potential, among others. In the case of the concrete elements, these have an RFID chip embedded for tracking and accessing data on the material recipe, casting time and any detail required to study its condition for reuse. Information about changes or repair can be added to the report.

Circularity of concrete structure

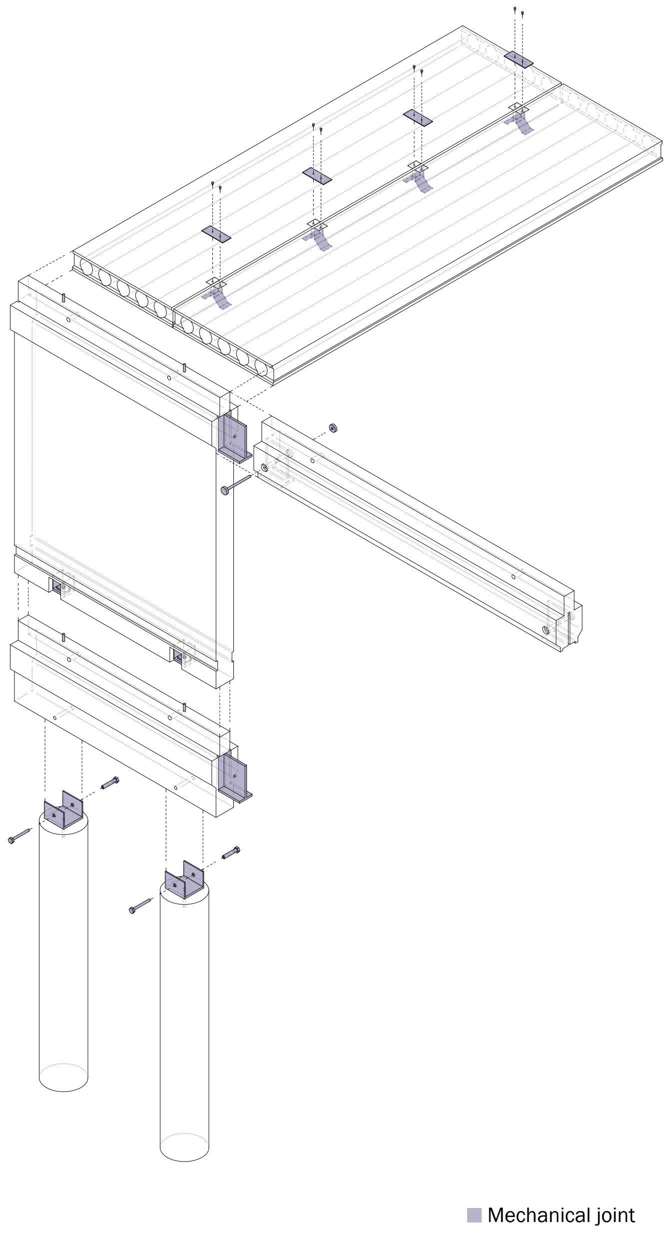
In the case of the concrete structure, joints are simplified by two means:

1. All three typologies use only six different precast concrete elements designed to be reusable: two types of beams, walls, two types of hollowed slabs and the foundation. The edges are shaped to facilitate connection and support between them.

2. The conventional casting of parts into a single unit is replaced by Peikko bolted connections, consisting of shoes casted in the bottom of one element and anchor bolts on the top of the other element. These are fixed together with nuts and AL washers, and the volume in between is grouted with lime mortar to protect from corrosion and fire. At the time of disassembly, the mortar is easily removed, and the structure is unscrewed. A similar concept is applied to the slabs. This process is significantly faster to mount than traditional concrete construction (Ill. 16).

Circularity and its aesthetic value

Materiality is a big topic since circularity in the building environment implicates rethinking the current construction techniques and has an impact on the building's appearance and the users. In this project, joints are exposed, and materials are shown as they are, all becoming an ornament to space instead of being hidden. In this way, the production chain is reduced, and recyclability is maximized.



Ill.16 | Axonometry of concrete element assembly system and mechanical joints. GXN and Responsible Assets. 2018. (Adapted)

Conclusion

Circle house is a great future-minded example of how to work with building circularity, serving as an example on how to work with architecture and time simultaneously, not only in terms of material and elements, but space. It also shows the impact in architecture quality, acting also as a material library of products from companies that already have design for disassembly in their agenda.

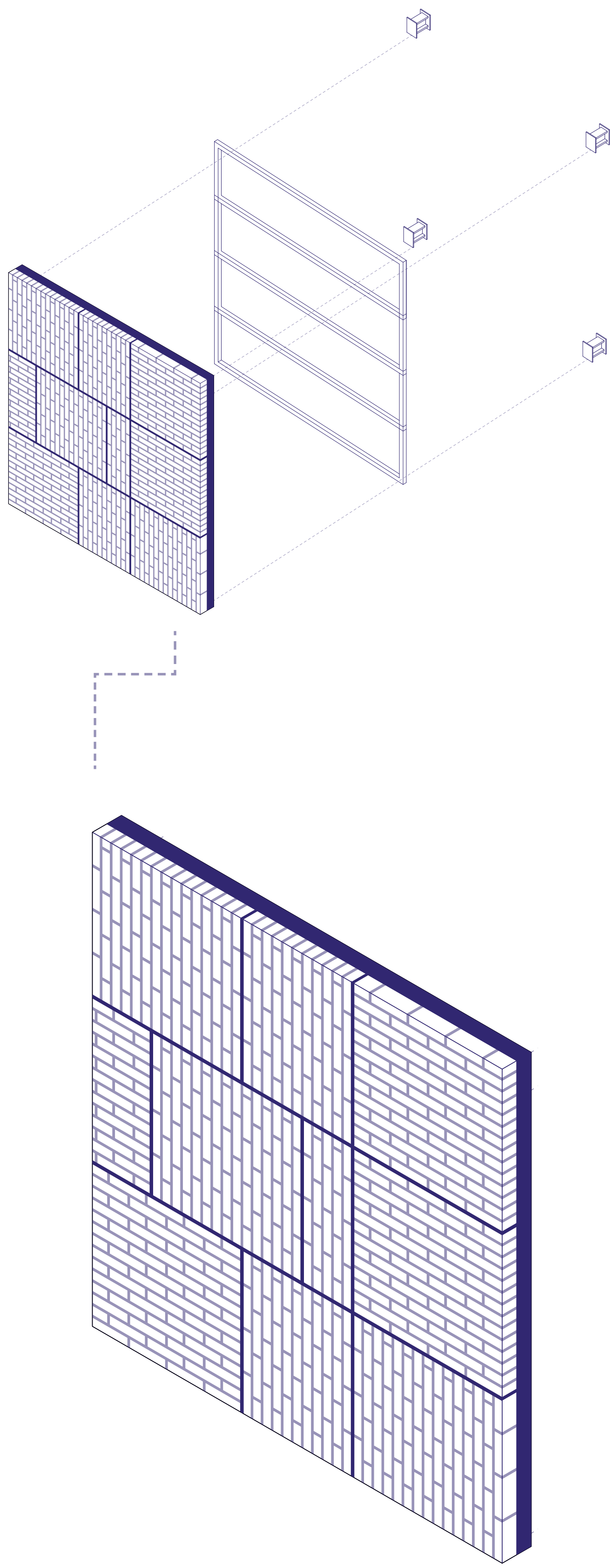
THE RESOURCE ROWS / CASE STUDY

Concept
Ressourcerække is a housing project by Lendager Group, NREP and MOE where 9% of the materials are recovered from different abandoned projects. These are brick facades from the 60s, windows, wood cladding and a structural beam. After recovery, these are processed regaining value. The designers calculated the LCA of these products in order to understand the benefits compared to the current business-as-usual. In most of the cases the the CO_2e- are better eventhough there is still room for improvement (Lendager Group, 2020).

Project description
The project is located in the outskirts of Copenhagen, and consists of three-story terraced houses and five story-apartment blocks around a courtyard.

Recyclability of brick
The material is recovered from abandoned schools and Calrsberg Factory, built in a period where bricks where mounted with concrete mortar instead of lime. This makes it impossible to disassemble without breaking the bricks, and therefore are cut in panels of maximum 1x1m (NREP, 2019). These are then casted together forming panels of 1x3m, with a concrete mortar layer on the back, mounted on steel welded profiles and attached to the construction through I profile brackets (Wilson, 2019). The element is selfsupporting and its founded on top of the plinth, in this case constituted by clinker blockwork.
The concept offers a broad variability in terms of aesthetics since the 1x1 units that compose a panel can differ in size, if cut smaller, color, texture and brickwork orientation, creating different patterns.
According to the final studies, the Upcycled bricks have 38% less CO_2e- emissions than a conventional wall built with new bricks, insulation and a concrete wall. This can be improved by reducing the amount of concrete behind or replacing it with a steel frame (Lendager Group, 2020).

Conclusion
The project acts as a guide on how to recycle brick facades, often present in Danish buildings that require to be demolished or refurbished. It proposes a way to give new value to the material while saving resources, according to the principles of circular economy.



Ill.17 | Exploded axonometric od Upcycled brick wall in Resource Rows, Copenhagen, Lendager Group, 2015.

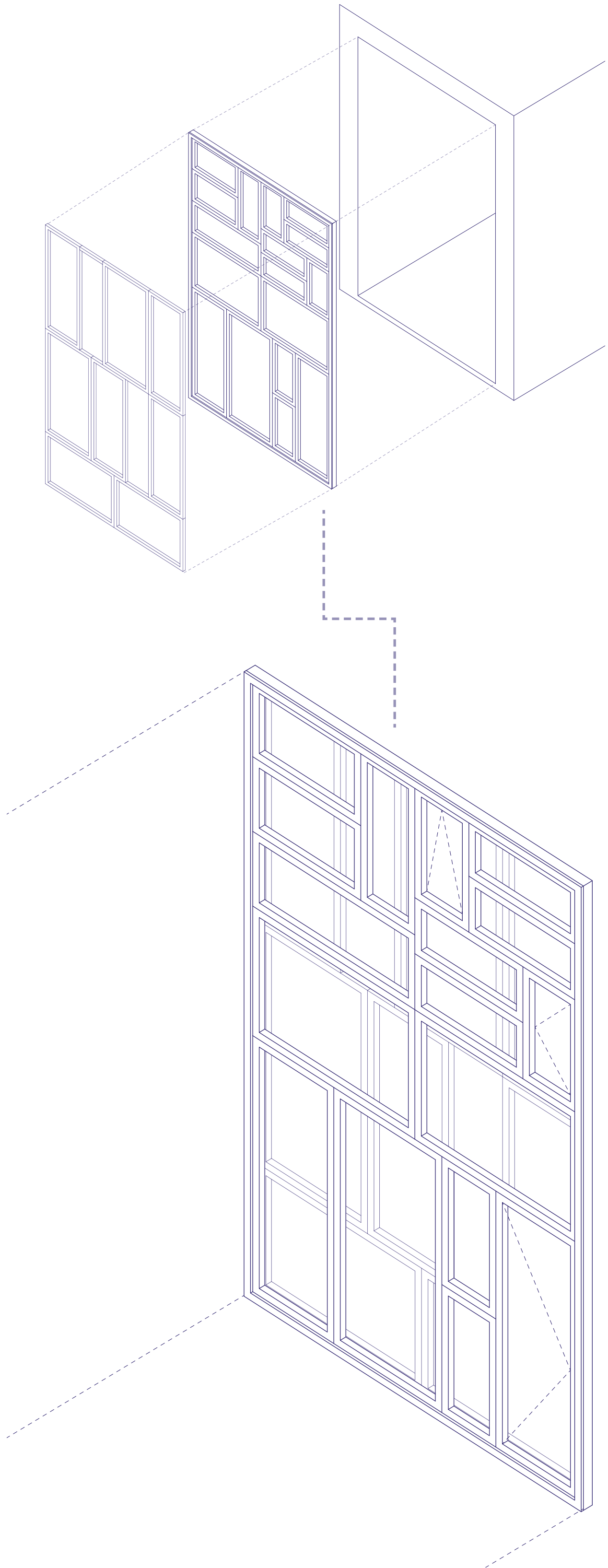
UPCYCLE STUDIOS / CASE STUDY

Concept
Upcycle Studios is a housing project by Lendager Group, NREP and MOE where 69% of the materials are recycled. These are windows, wood flooring and concrete from the old DSB Station. In this case, the windows are collected from building demolitions big number of renovations currently happening. As in Resource Rows, these elements are processed and their LCA is calculated to keep track of their impact savings.(Lendager Group, 2020).

Project description
The project is located in the outskirts of Copenhagen, with a total area of 3000m2. and consists of 20 two-storey townhouses with a roof garden.

Recyclability of windows
The element is result of the combination two frames, one consisting of a recycled two-layer thermal glass windows recovered from discarted buildings, and one containing new double-layer glazing and safety-glass windows. The supporting frame is made of pine, treated with linseed oil to lenghten its longevity, and door openings are solved with new three-glazing doors. The final product has a U-value of 0.69 W/m^2K and a G-value of 0.49, meeting the 2020 energy requirements. The panes cover between 4-30m^2, being adaptable to other building layouts, and have a lifespan of 24-36 years.
These two frames differ in color and overlap different patterns, exposing the element's second-handed nature and becoming its tectonic expression.
According to the final studies, the Upcycled windows have 32% less CO_2e- emissions than a conventional three-layer new windows. This can be improved by increasing the proportion of recycled windows from 50 to 81%, saving up to 69% of CO_2e emissions (Lendager Group, 2020).

Conclusion
Sundparken is one of the many projects that require a renovation to meet the 2020 energy requirements, and therefore it has great potential to apply Lendager Group's proposal to recycle windows, among other materials, but also minimize waste and save CO^2e emissions.



Ill.18 | Axonometric od Upcycled windows in Upcycle Studios, Copenhagen, Lendager Group, 2020.

DESIGN FOR DISASSEMBLY

A big obstacle for the implementation of Circular economy in the construction sector is taking the existing buildings apart and reusing as much of the materials as possible. Eventhough this may be a common matter, it is not always the case in all projects. Buildings built before the second world war are typically significantly easier to disassemble and recycle (GXN and Responsible Assets, 2021). This is due to prevailing building practices during the time and less occurrence of contaminated materials due to substances like PCB and asbestos (Jørgensen et al., 2022).

The introduction and adaptation of new building techniques in the first half of the 20'th century such as cement mortar instead of lime mortar, precast concrete elements joined with poured concrete and sealant with PCB, stressed the opportunity to disassemble the buildings from this period as well as getting the materials approved for reused due to the risk of contamination.

This combined with the fact that 56% of the English housing stock was built in this period where any one of these prevailing building practices could make it more difficult to recycle the building materials. (Department for Communities and Local Government, 2016)

In other words, constructions prior to the 50s generally require less process and are more practical to recycle. One way to prevent this from happening in the future is to include disassembly as part of the design. In this regard, the six sharing layers from Brand become crucial as not every part of a building have the same lifespan and therefore, requirements for the connections and the materials are also alike (GXN and Responsible Assets, 2021).

Designing for disassembly (DfD for short) has gained popularity in recent years due to the growing concern regarding the high consumption og resources and low recycling rate within the construction industry (Archdaily, 2022).

The goal of Design for disassembly is to extend the lifespan of both the building and its parts by reaching the potentials of the product also at the presumed end of service life (GXN and Responsible Assets, 2021). A building oftentimes outlasts its initial purpose. A family housing block might offer too large apartments to an area where the demographic has changed significantly over time, or the area might have grown in a way where local businesses thrive and perhaps that calls for the introduction of stores to the ground floor area. Eventhough these changes are hard to predict, the transformation of a building to comply with these new wishes can be eased by planning for deconstruction.

EASY TO DISASSEMBLE
reversible joints such as bolted, screwed or nailed connections

ACCESSIBLE CONNECTIONS
to make the process easy and fast

STANDARIZATION
of modular replaceable prefabricated elements

PURE HEALTHY DURABLE MATERIALS
avoid toxic treatments and non-removeable chemical joinery such as binders, sealers, glues or welding

DESIGN WITH TIME
considering the shearing layers to make flexible spaces and adaptable structures. Preserve VS temporary

DOCUMENT
relevant information about the elements, the procedures and the quality to assure reusability

SAFETY
provide a stable plan for dismantling that is safe for workers, the surroundings and the environment

Ill.19 | Principles of Design for Disassembly

RESOURCE BLOKKEN / CASE STUDY

Ressource Blokken is a joint research project between GXN, SBi and others, supported by Realdania, that strives to ensure a sustainable way of handling Denmarks social housing units from the 60s-70s presently and in the future. The study is done in collaboration with leading actors within the construction industry from different fields of expertise.

The governments parallel society act from 2018 acts as the catalyst for both the creation of Ressource Blokken, but also this Master thesis. Ressource Blokken is critical of the requirements that could result in the tear down of a huge number of housing units corresponding to 1,3 million square meters.

Different firms were tasked with creating design proposals that would inspire new ways of using old materials and elements from these residential blocks.

In this section, the proposal done by EFFEKT for design for disassembly of individual elements is presented.

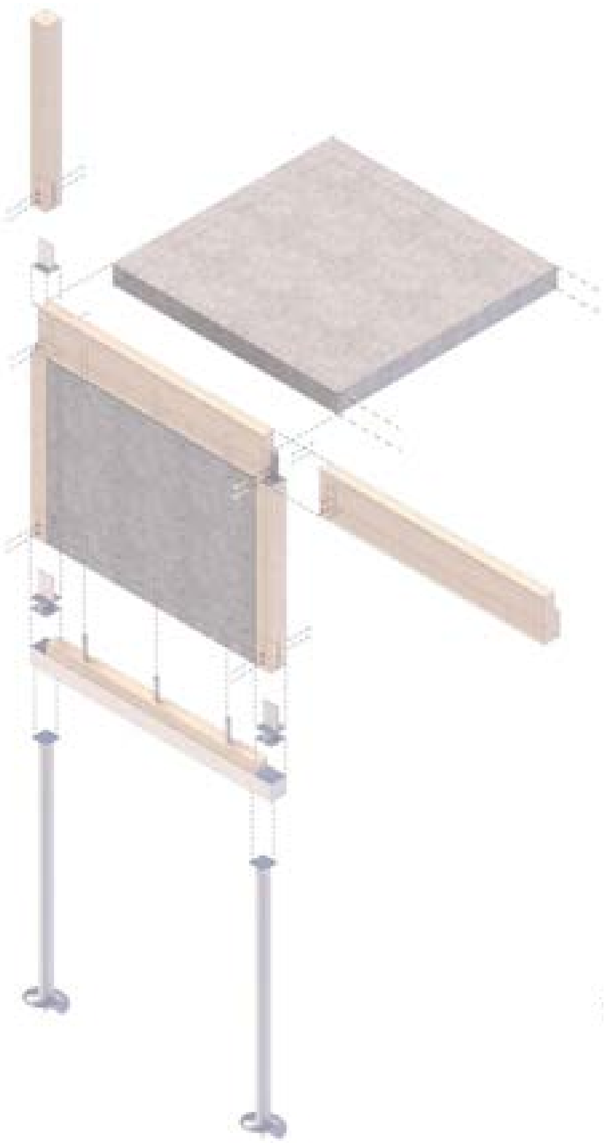
HYBRID TRÆKONSTRUKTION

Concept

The proposal made by EFFEKT for Vollsmose aims to bring awareness of the impact of design decisions on the environment. According to the architects, the Preservation of a building is the action that has the highest potential for savings. This is followed by Reuse and lastly, Upcycling, since it involves a longer chain of processes that consume other resources. Hence, the project proposes a partial tear-down where the existing buildings resources are saved and re-valued as much as possible instead of being fully carelessly demolished.

Recyclability of concrete elements

EFFEKT applies a hybrid strategy, turning the old concrete components into a modular scalable system that can adapt to several sites and building typologies. The concrete walls and slabs are combined with glulam which acts as a timber framework (Ill. 20). This allows the reuse of a larger extent of the material without compromising the structure. Easy assembly and disassembly is provided by the connections, made by metal brackets between wooden parts. Every three reuse cycles, each concrete panel saves between 30 and 60% of CO_2e- emissions compared to disposing and re-building (EFFEKT, 2021).

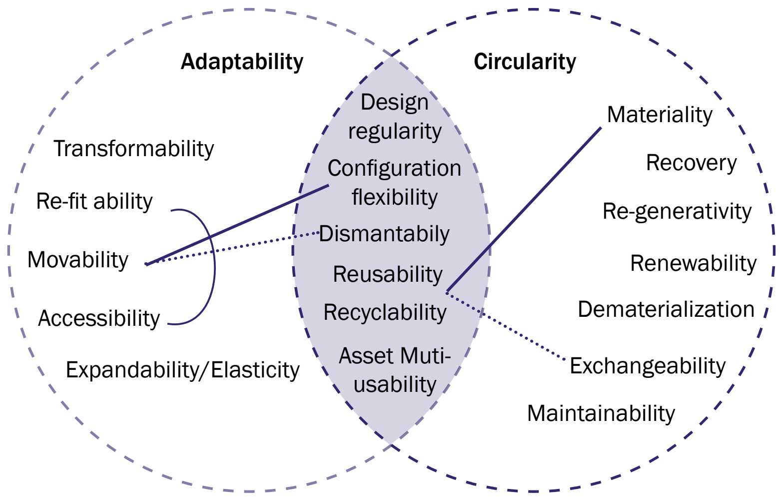


Ill.20 | Axonometry of reusable concrete element components. EFFEKT. 2021.

Conclusion

Hybrid Trækonstruktion is a great example of how to follow design considering most of the principles of design for disassembly while saving resources, by making a modular, adaptable and easy-to-standardize system; providing accessibility to simple connections with the metal brackets, avoiding unnecessary treatments, and supporting re-usability.

BULDING TRANSFORMATION



Ill.21 | Overlaps between adaptability and circularity in a building. (Adaptation of Hamida, Mohammad et al., 2022),

Transformation refers to adaptation and refurbishment activities in a built environment, often seen in the positive sense of improvement. The term sometimes refers to transformative design, which is a human-centred design philosophy that seeks to make long lasting positive behavioural change through a positive built environment (Circuit, 2022).

When performing a transformation on a building or a built environment it usually indicates a notable change in the use of the building. This could be done through a complete change of functions (Structural Changes) such as converting industry into housing or significant alterations to the existing functions like changing family apartments into student or senior units. Transformation can however also refer to actions that do not affect building functions, but otherwise result in a dramatic change in appearance such as façade renovations (Non-structural changes) (Circuit, 2022).

A study conducted by Det kongelige Akademi and Copenhagens municipality concludes that architecture affects how people behave and act around each other. Neighbourhoods that fulfil the need for safety, include different levels of privacy, are built in a human scale, are within walking distance of critical functions, shield from unpleasant influences such as traffic and have a unique sense of identity and openness all have a higher likelihood of being an area where people want to stay around and have social interactions. This can be achieved through structural and non-structural changes. The study does conclude that Non-structural changes by itself does not create long-term social, economic or behavioural changes among the residents in the area (Københavns kommune, 2014).

How challenging it is to transform a building can be highly dependent on circular building adaptability. Circular building adaptability is determined by the buildings ability to adapt to new functions and users. This could be how flexible the building layout is, such as the ability to move internal walls, open up the façade or the option of creating level-free access.

The other aspect is circularity which mainly focuses on building materials, elements and system and how easy they are to recycle, reuse and maintain. This could be the use of materials with a long lifetime and no toxic treatment that make them easier to recycle and reuse in new building projects.

The area where these two fields overlap includes design solutions that both make it easier to adapt the building to new functions and take the building apart to reuse the materials (Ill. 21). An example of this could be Designing for disassembly (Hamida et al., 2022).

Transformation within the construction sector has always been present. It happens organically as our cities grow and change over time. How sustainable that transformation will be depends on how well actors within the construction sector choose to tackle the task, but it also by how architects choose to design

RESOURCE BLOKKEN / CASE STUDY

Panum&Kappel is one of the many firms who took part of the Ressource Blokken research. In this section, their proposal for design for disassembly of individual elements is presented.

MONTAGERÆKKERNE

Concept

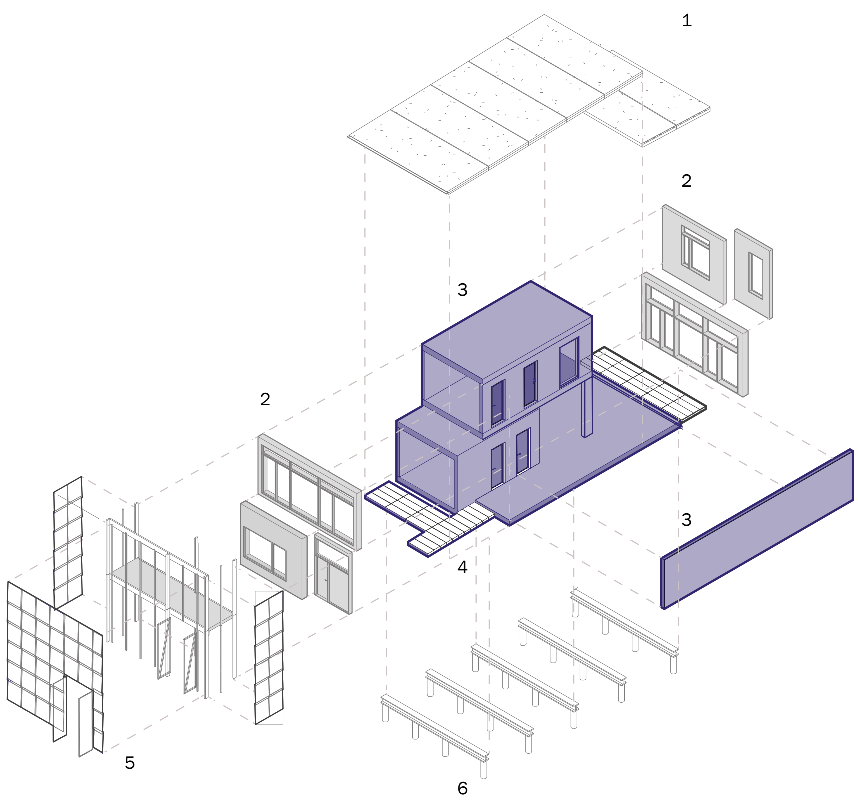
The firm intents to reuse and recycle elements from the dismantling of a block in Birkeparken, Vollsmose. In this way, 74% of the concrete in the proposal is reused, When cutting the components as rooms or blocks, meaning floorplate, top plate, and walls, there is opportunity to reuse it as the structural system for the new project and transform it into row houses of around 120m2. The extra added materials are in wood and painted to create a contrast. Non-reusable elements have been recycled as aggregates on the concrete floor finish.

Recyclability of concrete blocks

Panum&Kappel reuse the concrete block as the main core of the new row houses. This carries some restrictions, such as openings placement and the dimensions, defining accessibility and the room sizes on the new project. The blocks are piled on top of each other to avoid structural complications, and openings for daylight happen on the non-supporting sides of the block. Living areas are strictly located inside the reused rooms, which are thermally insulated, but the transition between spaces happens through an adjacent corridor, designed as an unheated area. This area is enclosed by a secondary facade of recycled windows with a more loose energy requirement. The project reaches a total reduction of 273 kg CO2e- compared to a new construction, (Ressource Blokken, 2021)

Conclusion

The architects prove that there is great potential in the reuse of concrete elements as a block, but it is also crucial to consider the limitations related to this, in order to include it in the design. Thus, the architectural quality and the benefits are preserved while potential inconvenients are avoided.



Ill.22 | Exploded axonometry. (1) Prefabricated roof cassettes in three. (2) Prefabricated facade elements in three. (3) Recycled block, walls and slabs concrete elements (4) Recycled "non-weathering" concrete facade panels (5) Second recycled windows facade (6) New foundations. Panum & Kappel. Ressource Blokken. 2021. (Adapted).

FOUNDATIONS' SECOND LIFE

There are different ways to reuse foundation depending on the reason and the character that leads to it. This may be necessary when the facade of a building needs to be preserved when there is an expansion, when a building must be adapted, or a new project is built on the site. Even though it presents challenges and uncertainties, this kind of practice is also applied to bridges and highways due to great savings in terms of cost, time, natural resources and environmental impact (Agrawal et al., 2018). In fact, this was a rule during the XVIIth century in London, where urban space was already limited, and the demand got worse after the Great Fire in 1666. With the improvement in calculating methods, precision and regulations, this became a less common practice both for structural and aesthetic reasons. In addition, the mentality behind the composition of space altered the floorplan layout, where buildings are taller and spans are larger (Chapman et al., 2007). It is important to take these considerations before deciding to reuse foundations.

Environmental drivers

Reusing existing foundations is a good way to save resources, installation and operational energy (Ill. 23). This situation is even more significant when buildings are being demolished earlier than their actual lifespan (Chapman et al., 2007).
Moreover, this reduces waste, transportation, noise pollution during the installation and land use.

Decision making models

The Construction Industry Research and Information Association (CIRIA) and SPeAR have developed Decision-Making models that provide orientation to identify benefits and risks. To be able to use these models, it is important to assess the existing foundation by doing a desk study with the available original documentation, analyse the current conditions of the structure and the site, verify the performance and compare with the new project proposal. These studies go beyond the scope of the thesis, except for the desk study (See sub-chapter: Row Houses).

Relevant points to consider (Chapman et al., 2007):

FULL OR PARTIAL COMPATIBILITY BETWEEN NEW STRUCTURE FOOTPRINT AND EXISTING FOUNDATION

LOAD-BEARING CAPACITY OF EXISTING FOUNDATION COMPARED TO NEW PROJECT

RELIABILITY OF CURRENT CONDITIONS OF EXISTING FOUNDATION

SEVERITY OF RISKS

ADVANTAGES OVER A NEW FOUNDATION

Foundation	Need for new non-renewable materials (concrete, stone)	Need for installation energy	Need for operational energy
Completely new	High	High	Lowest (if new building is not constrained)
Completely new + old foundation removal	High	Very high	Low
Reuse of foundation + supplementary new foundation	Medium	Medium	Low to medium
Reuse of foundation	Low	Low	Medium to high (if building is constrained)

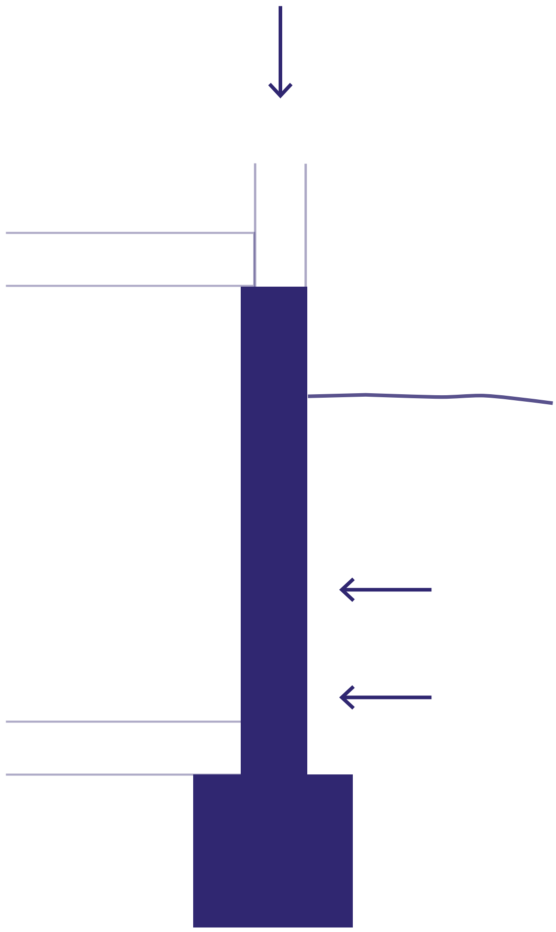
Ill.23 | Energy and resources required for different foundation solutions. Chapman et al., 2007. (Adapted).

When foundations are found to be insufficient, these can be complemented with new piles if there is space for it.

Naturally, the more m2 a project has in relation to the foundations, the smaller their impact is on the final LCA result, and therefore the number of storeys also can be decisive on whether the advantages are worthy.

Basement
In the case of basements, the situation can be more critical since soil conditions in general are susceptible to changes and the process of removal can cause problems to the surrounding buildings. The walls of a basement are dimensioned to receive horizontal loads from the ground and carry the vertical loads of the building (Ill. 24), and therefore the procedure in case of reuse is the same as for foundations (Chapman et al., 2007). Consequently, its reuse can have great environmental benefits if the new building is compatible, but it can also be very restrictive. Therefore, it should be incorporated early in the design phase to avoid big inconvenience.

Conclusion
The demolition and re-construction of foundations and basement involve a high use of resources and energy. One way to reduce the impact is to reuse the existing elements, but it is highly important to consider the conditions of the new project, the risks and the restrictions on the new layout and weight limit early in the process.



Ill.24 | Horizontal and vertical load preassure on basement wall.

THE POTENTIAL OF THERMAL MASS

Wooden structures have seemingly become the unanimous choice when it comes to building environmentally sustainable buildings, while concrete typically is perceived in a negative light due to its high global warming impact.

Concrete does, however, have a lot of beneficial properties that if used correctly can help improve the architectural quality of our buildings, such as its high thermal mass.

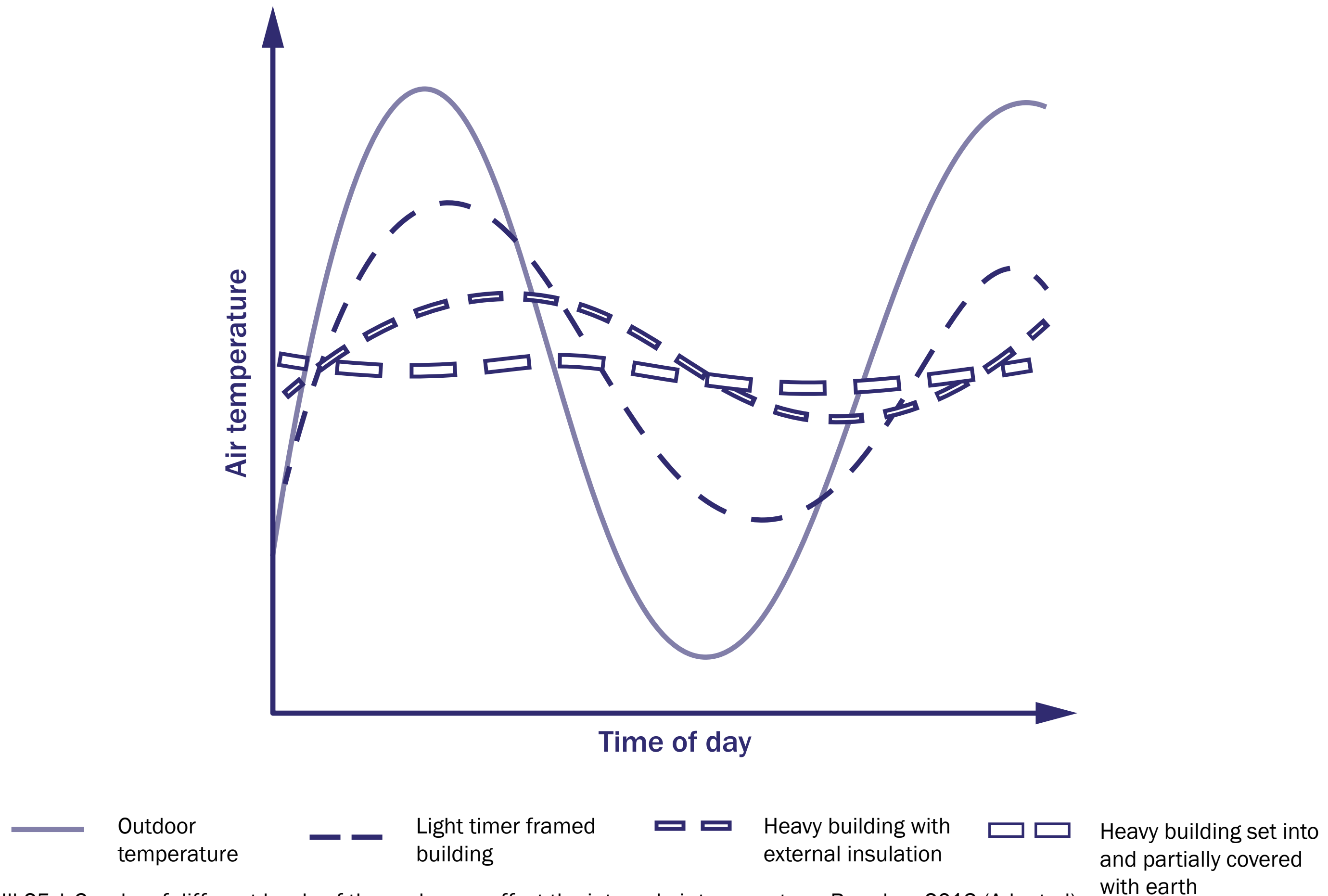
Thermal mass is a material property that defines its ability to absorb, store and release heat. Materials such as timber and cloth have a low thermal mass and thus lack the ability to both store and transfer heat. A material such as steel can easily absorb heat, but also lacks the ability to store it due to its high thermal conductivity, this can be described as a short thermal lack. Thermal lag is the rate at which heat is absorbed and released by the material (Reardon, 2013).

Materials with a long thermal lag, such as brick and concrete, will absorb and release heat slowly. This ability can be used to improve the thermal comfort within buildings and is especially relevant in cool or cold climates where supplementary heat is required.

High mass construction is also appropriate in warm and mild temperate climates but requires a sound passive building design to avoid overheating in summer. To stabilize temperatures high mass construction should ideally be used on lower floors, while low mass would be applied for the upper levels. This ensures that heat is not stored on the upper floors as hot air rises (Reardon, 2013).

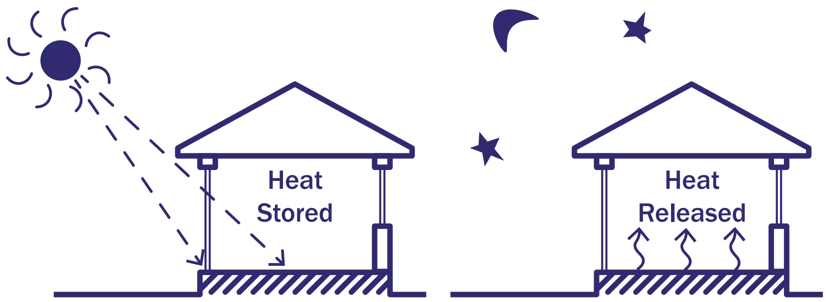
The graph below (Ill. 25) illustrates how different levels of thermal mass affect the internal air temperature. High thermal mass can thus be used to create a more stable internal air temperature through night and day.

THERMAL MASS IMPACT:



Ill.25 | Graphs of different levels of thermal mass affect the internal air temperature. Reardon, 2013 (Adapted).

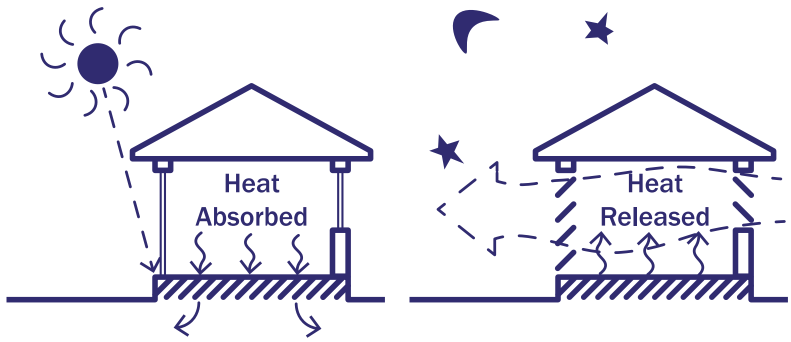
WINTER SITUATION



During winter heat should be stored withing high thermal mass materials throughout the day and then released during the night. This lowers the energy needed to heat the home during winter, since the buildings start temperature in the morning has increased (Reardon, 2013).

Ill.26 | Sketchual concept thermal mass effect during winter. Reardon, 2013 (Adapted).

SUMMER SITUATION



During the summer the same effect is in play, but instead helps to cool the building. In this case its important to minimize the effect of overheating by implementing effective shading. In this scenario the excess heat is stored within the high thermal mass material during the day, ensuring that the internal temperature rises more slowly. The heat is then released during the night and is then ventilated out of the building (Reardon, 2013).

Ill.27 | Sketchual concept thermal mass effect during summer. Reardon, 2013 (Adapted).

CALCULATION METHOD

Internal surface	Heat capacity [Wh/K m2]	Internal surface	Heat capacity [Wh/K m2]
Ceiling		Outer walls	
Gypsum	3	Gypsum	3
Suspended ceiling	3	Aerated concrete	7
Clinker concrete	45	Brick	17
Concrete	60	Concrete	30
Floor		Inner walls	
Wood on insulation	4	Gypsum	7
Wood on concrete	10	Aerated concrete	7
Carpet on concrete	30	Brick	19
Concrete	60	Concrete	33
Furniture = 10			

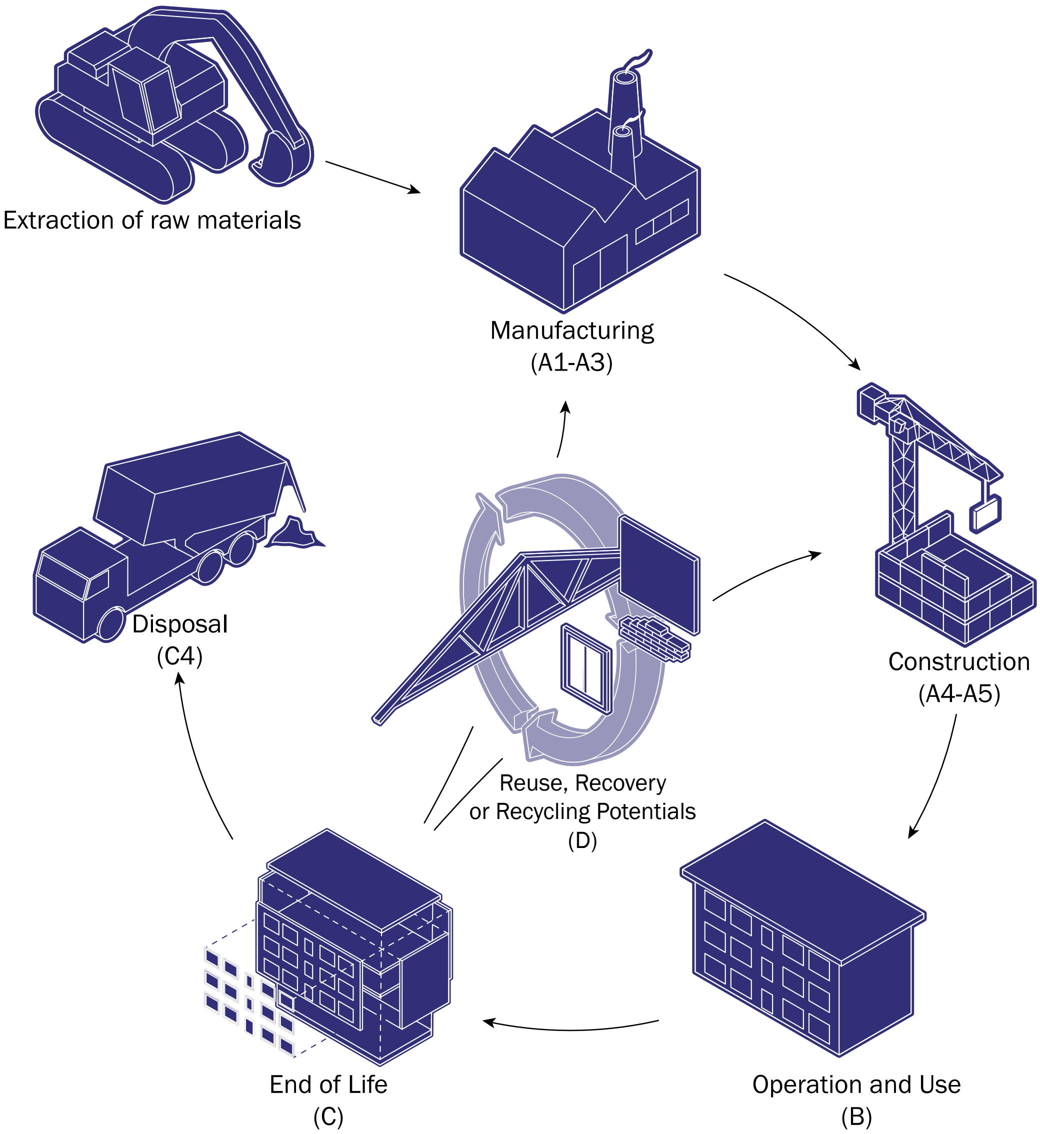
Heat capacity = Ceiling + Floor + Outer Walls + Inner Walls + Furnitı

Ill.28 | Table with calculation values for thermal mass. Source: SBI 213 (NRGI, 2023).

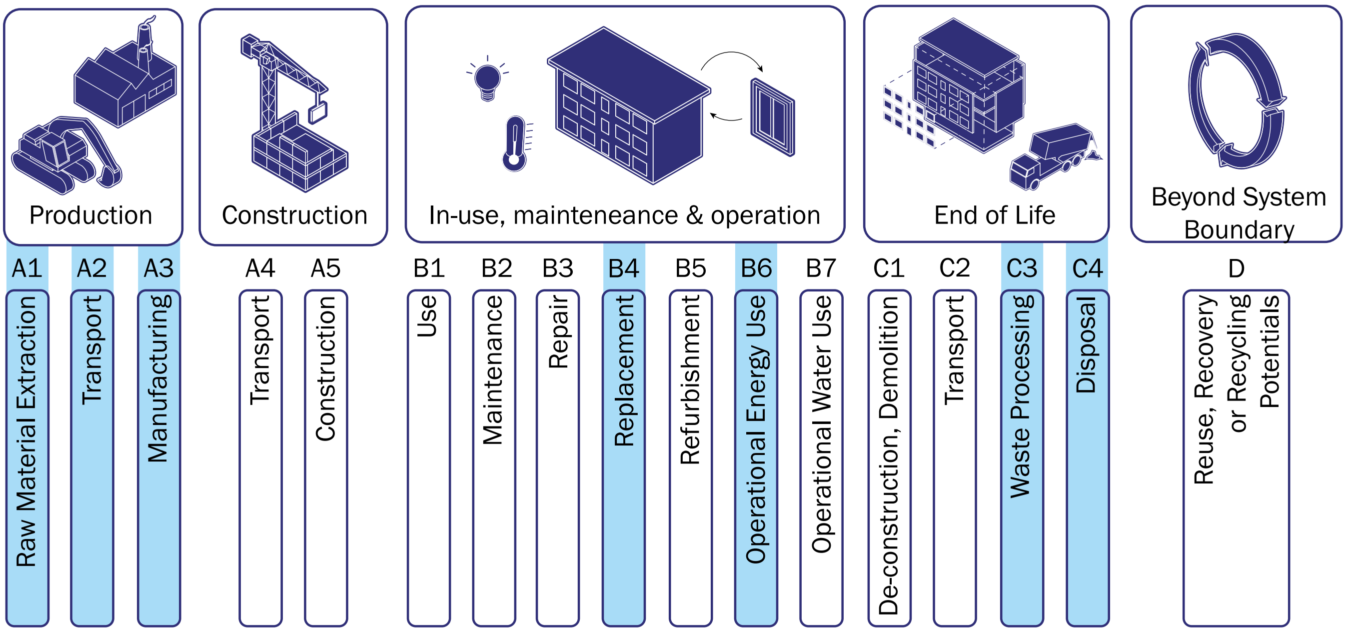
A building's thermal mass can be calculated in different ways. In this project, the thermal mass will be determined based on an approximation method, described in SBI 213 (NRGI, 2023). The ledger to the right is a simplified version for medium compact buildings and will be used for any thermal mass calculation during this thesis.

LIFE-CYCLE ASSESSMENT

Life-Cycle Assessment, LCA, is a quantitative analysis that documents the environmental impact of a given product, system or service (Golisano Institute for Sustainability, 2020). The LCA will typically look into the inputs, processing and outputs of a product throughout its life cycle phases. Inputs include, but are not limited to, materials, energy, water and land-use, while processes include any mechanical or chemical treatments that are necessary in order to turn raw materials into a product. Finally, the output contains the final product but also the emissions, waste and by-products from the production. The analysis results are presented in a number of indicators related to material use, energy use, toxicity and bio- diversity among many others.



Ill.29 | General building lifecycle.



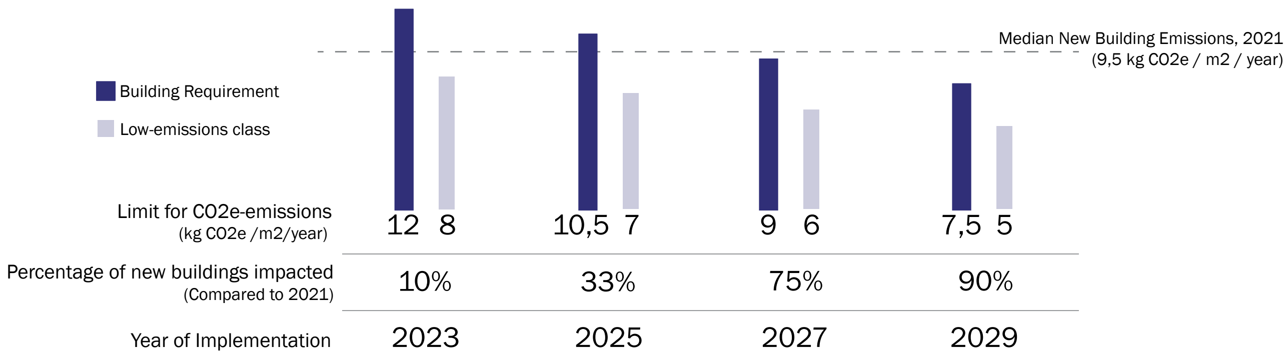
Ill.30 | Building LCA modules. Highlighted modules are within the system boundary.

Within the building industry, LCA is performed differently, in that each building material is represented with LCA data presented in an Environmental Product Declaration, EPD (Rasmussen, F. N. 2015). Alternatively generic LCA data can be used to represent a more general material for early phases of the design process, in Denmark the German database Ökobaudat is used. The LCA data of each material in the building is collected at a component level and the analysis is applied to the whole building. A building's life cycle is split into five phases: production, construction, in-use, end-of-life and the next product cycle, as showcased in figure 29. Each of these phases includes multiple modules of which there are 17 in total, these are all visible in figure 30. Not all of these modules have been deemed equally important, as such the process is simplified, and the standard system boundary includes:

A1 – Raw Material Extraction
A2 – Transport
A3 – Manufacturing
B4 – Replacement
B6 – Operational Energy Use
C3 – Waste Processing
C4 – Disposal

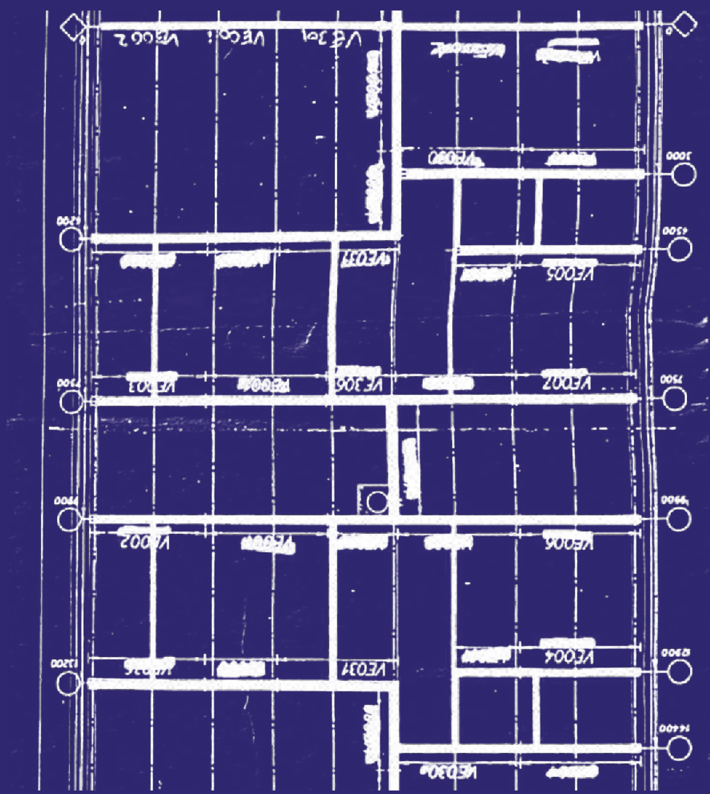
These are also highlighted in figure 30. Any building product will typically include A1-A3 and C3 or C4. B4: replacement, occurs when the expected lifetime of a given building product is shorter than the estimated lifetime of the building, at which point the environmental impact of the product is multiplied by the number of replacements it undergoes in the building's lifetime. B6: operational energy-use, is based on the energy consumption calculated for the building in Be18.

In 2021 the Danish government finalized a national sustainability strategy for the built environment (Indenrigs- og boligministeriet, 2021). The strategy contains goals related to environmental, social and economic sustainability with an overall focus on reduction of carbon emissions, increasing indoor environmental quality and eliminating use of hazardous chemicals, innovation within the field of reusable materials and improving energy performance on existing budlings (Bolig- og Planstyrelsen, 2021). As a pilot project for the sustainability requirements the Voluntary Sustainability Class was introduced in 2020, with the goal of gathering information on the implementation of the sustainability strategy in case-buildings. The voluntary sustainability class introduced LCA into the building industry at large, whereas the tool earlier had primarily been used in research studies (Rasmussen, F. N. 2015). The main implementation of the national strategy is a limit to CO2e emissions for new buildings applied to the Building Regulation from 2023. The requirement starts at 12 kg CO2e /sqm / year and gets more ambitious with time, as seen in figure 31.



Ill.31 | Future Co2 emission restriction requirements.

This indicates a need for drastic reductions in the CO2e emissions occurring from new buildings in the building sector. As such, when looking into the potential savings of climate impact during transformation and reuse of existing buildings, compared to new buildings; the main environmental sustainability parameter of this thesis will be CO2e emissions analyzed through life-cycle assessment.



#03 METHODS.

INTEGRATED DESIGN PROCESS METHODOLOGY

The research and design methodology is a combination of the Integrated Design Method with multiple tools and methods.

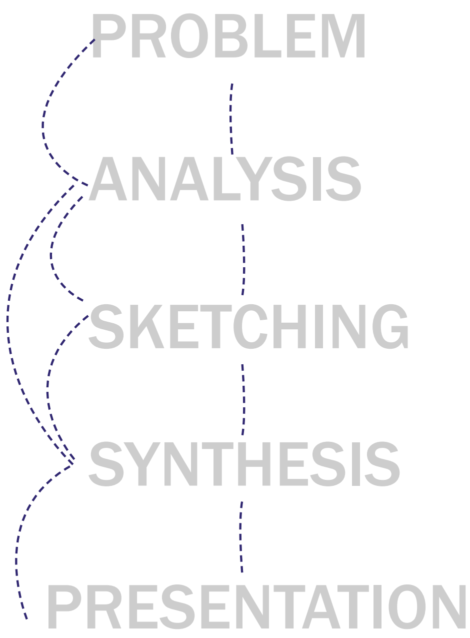
The integrated design method has a holistic approach that integrates knowledge in engineering and architectural to solve complex problems. It is driven by a sustainable goal (Knudstrup, 2005), and its iterative nature based on the optimization design loop makes it possible to address functional, technical and aesthetic aspects simultaneously to concile the solution in one high-quality design without compromising time. The method is structured in five non-linear phases (Ill. 32):

1 II Defining the **problem**
2 II **Analysing** data
3 II **Sketching**, idea testing and initial calculations
4 II **Synthesis** of problems in a single design proposal
5 II Final design **presentation** communicating the integrated iterative design process.

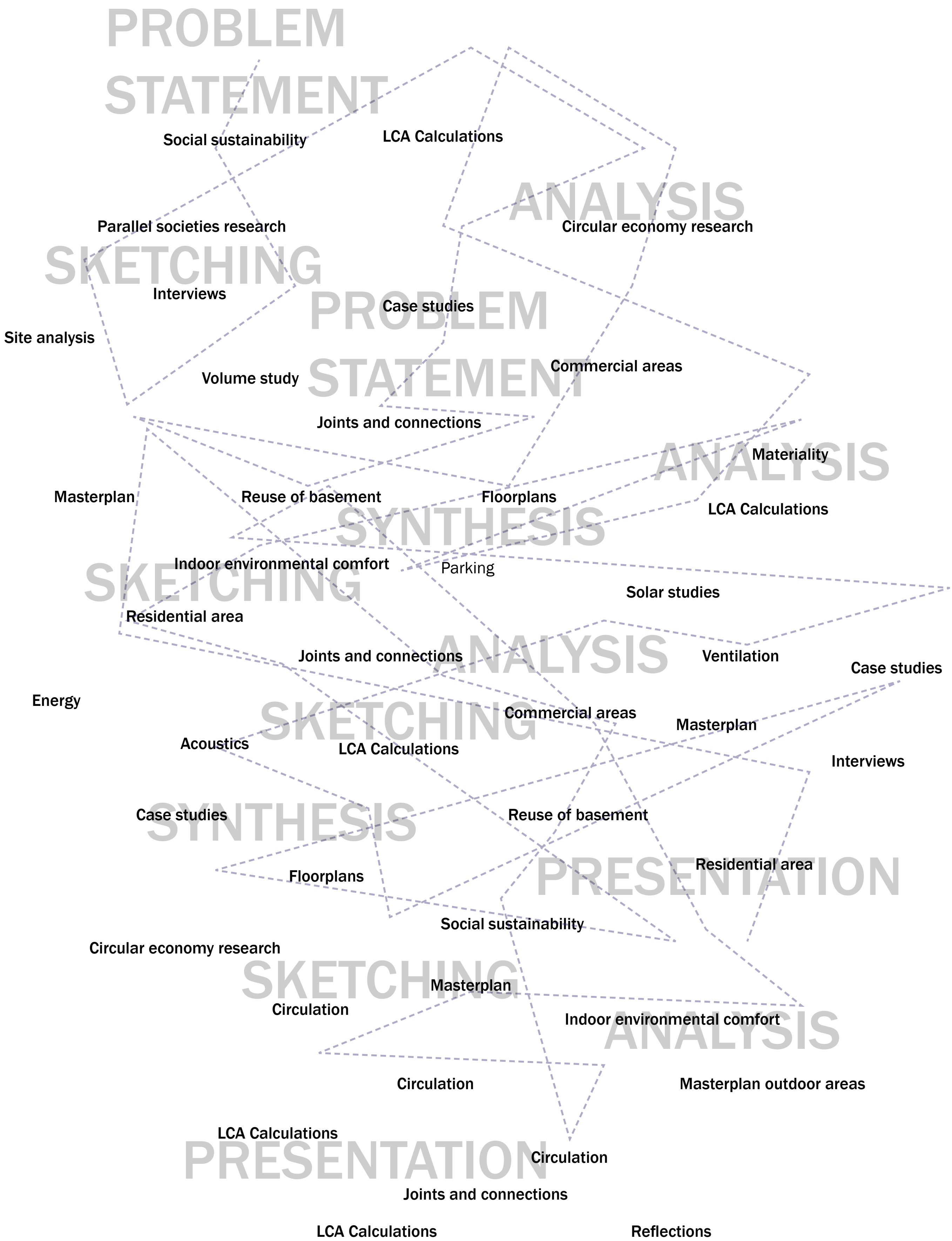
Eventhough the process of design is not linear, is has been synthesized to present the whole process in the report. Ill. 33 shows the application of the method in the thesis.

To inform the design decisions a group of different methods are used.

1 II **Literature research** - combining academic papers, practice-based research and theory.
2 II **Interviews** - with actors involved in the problem, such as the directoy of the social housing company that owns of Sundparken and social workers.
3 II **Case studies** - to gain knowledge on tested solutions and existing challenges regarding the topic.
4 II **Site visit** - to understanding the site in a dimension that theretical reading cannot not provide
5 II **Sketching and modelling**
6 II **Visualizations and modelling**
7 II **Calculations and simulations** (Methods for calculations are described in the following pages of this chapter).



Ill.32 | Integrated design process in theory.



Ill.33 | Integrated design process in this Thesis

LIFE-CYCLE ASSESSMENT PROCESS DESCRIPTION

The project uses LCA studies at three different levels of detail in the design process from the initial calculations going into more specific solutions and lastly calculations of the final design proposal. The three different categories can broadly be summarized as:

Early design process

The early design process studies serve as a benchmark examining the embodied CO_2e emissions in the existing constructions. The goal of these studies is to examine the potential climate impact reduction in preserving existing structures and which materials have the greatest potential for reducing emissions when reused in new row-houses. The reuse scenario is lastly compared to demolishing the existing buildings and building new from virgin materials.

In the initial stages of the design process, generic studies on the building envelope are performed, to understand the potential in lowering the energy consumption of the existing buildings through renovation strategies improving the U-values of selected constructions.

Detailed design process

A number of LCA studies were performed during the design process, using mostly finalized building geometries to balance the environmental impact of passive and active building strategies to reduce the energy consumption of the buildings, while optimizing for embodied carbons in the added building products.

Final design proposal

Implementing the design conclusions from the earlier levels of LCA studies, this part evaluates the final design proposal in two different scenarios. The first scenario examines buildings where, as much as possible, the existing building structures have been preserved in building new row-houses. The second scenario investigates new row-houses built from the materials of the existing buildings, put together in systems designed for disassembly. Both scenarios are compared to the average row-house described in the early design process.

LCA CALCULATIONS METHODOLOGY

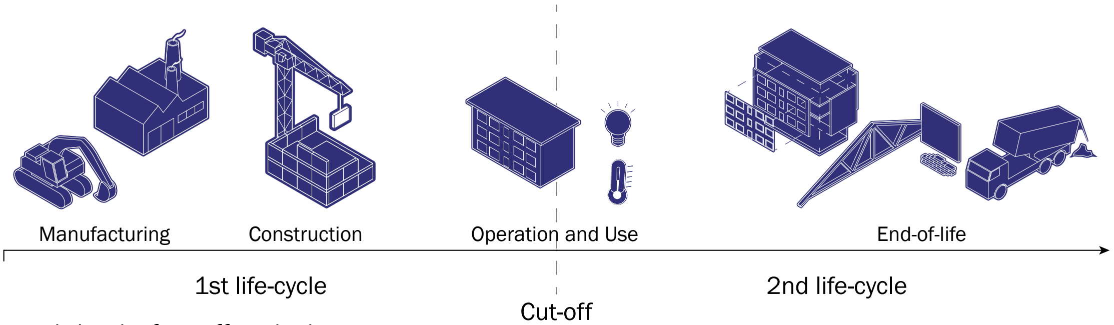
The life cycle assessment calculations in the report are made in accordance with the DS/EN 15978:2012 standard. LCA calculations are made in the tool LCAbyg (5.2.1.0) using the generic Ökobau-database, to ensure comparability amongst different scenarios. Despite this database being based on production of materials in an average German context, this is the common generic LCA database in Denmark and was also used for the 2021 BUILD report "Climate Impact From 60 Buildings", which is used as the dataset for the average row-house in the early design process. In design process study for exterior wall insulation, the material database will be expanded to include industry and product specific EPDs.

The functional unit of analysis and results throughout the report will be kg CO2e /m2 /year, which is in accordance with the functional unit used in the LCA requirements for the Danish Voluntary Sustainability Class and 2023 Building Regulation. Of the nine evaluation factors available in LCAbyg, the analysis will be concentrated around the GWP factor, global warming potential, following the evaluation method of the 2023 Danish Building Regulation, as it is the only indicator with a clear limit. Furthermore, it is the only indicator accounted for in the generic data for circular materials.

Life expectancy of materials will be set in accordance with BUILD's table for life expectancy (Haugbølle, K. et al. 2021).

The analysis will use a reference-study period of 50 years for new constructions in the LCA-calculations, which is in-line with current standard practice in Denmark (Kanafi, K. & Birgisdottir, H. 2021).

Existing constructions will follow the cut-off (100:0) as described in the report: Comparison of environmental assessment methods when reusing building components: A case study by De Wolf et. al. This means that when the existing buildings and components go from one life cycle to the next, the CO2e emissions from the production phase of A1-A3 are attributed only in the first life cycle, while the end-of-life stage C3/C4 are counted only in the last life cycle. (De Wolf, C., Hoxha, E., and Fivet, C., 2020) This is illustrated in figure GG.



Ill.34 | Conceptual sketch of cut-off method.

For operational emissions, the energy consumption will be based on Be18-models. The LCA calculation will use 2020-2040 projections for district heating and electricity, respectively (COWI, 2020). The starting year for all calculations will be 2023.

The LCA calculations will consider the following construction groups listed to the right of the text.

LCA Inventory

Foundations
Line foundations
Point foundations
Plinths

Terrain slab

Slabs
Basement slabs
Floor slabs
Build-up wood floor construction

Interior walls
Load-bearing concrete elements
Insulation construction
Interior finishing, plywood

Exterior walls
Sandwich elements
Brick facades
Light weight wood construction

Roofs
Wood rafters
Aluminium cladding construction

Columns & ceams
Basement beams and columns
Design-for-disassembly system

Windows, doors & curtain walls
Internal doors
Terrace glazing
New windows, triple-layer glazing
Reused double-stacked windows

Stairs and ramps

Balconies

Ventilation & cooling
Ventilation AHU
Ventilation shafts

Electrical- and mechanical installations
Photovoltaic panels

CIRCULAR BUILDING MATERIALS IN LCA CALCULATIONS

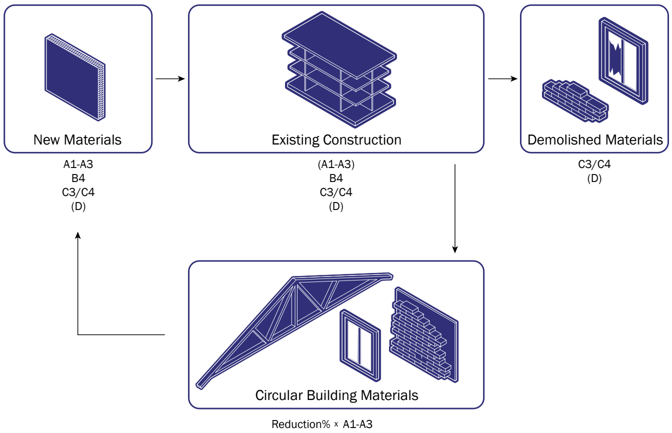
Figure 35 shows the distribution of emissions of the existing case building in Sundparken as well as an average row-house based on the datasets presented in the 2021 BUILD report "Climate Impact From 60 Buildings". The multi-storey apartment building from Sundparken has a lower amount of embodied emissions compared to the average row-house, this is likely due to this building having a higher compactness than a row-house, meaning there are more square meters on which to distribute the environmental impact of the materials. On the other hand, the older constructions following less ambitious energy requirements, mean that the operational emissions from the existing buildings are significantly higher than a modern, average row-house.

The chapter of the parallel society act describes demolition as a necessary catalyst to transform these underperforming, family housing areas into areas with a higher social mix. While demolition of existing buildings is not calculated as part of the LCA for new buildings, it is still relevant to point out that 1,29 kg CO2e / m2 / year of embodied emissions are released as part of the waste processing and disposal, when not reusing or recycling any building materials at the end-of-life of the existing buildings.

The study examines the potential in environmental impact savings of reusing the building elements, according to the data from the environmental impact assessment report of the Circular Builders project (Butera, S. and Fruergaard Astrup, T., 2022), to create new row-house typologies.

The circular baseline describes a scenario in which the existing building is rebuilt assuming all possible building materials are reused following the reduction factors from the Circular Builders project report. For materials that have no reduction potential, it is applied as a new material, with no reduction. Furthermore, 20% waste of all materials is assumed, for disassembly and cutting elements to size. This scenario has 1,11 kg CO2e / m2 / year of embodied emissions, a 75,5% reduction from the original building. This is the most optimal scenario and is likely not possible in practice.

To create a more realistic scenario, this time only half of the materials are assumed to be reused while the other half will be made up of virgin materials. The building in this scenario has a total GWP of 3,05 kg CO2e / m2 / year, a reduction of 32,3% compared to the original. Based on the case studies in this report, this is a more realistic goal and serves as a more accurate approximation of what can be expected in the final design proposal evaluation.



Ill.35 | Conceptual sketch of reused building materials phases with reduction factor.

As figure YY shows, the roof, interior walls and exterior walls are the three largest contributors to the embodied emissions, with the slabs following closely. This is in large part due to five main constructions in the building.

The Kalzip roof has 4mm aluminium sheets as the exterior cladding of the roof with rafters sitting directly on top of the loadbearing concrete hollow-core slab. The aluminum roof has the potential of 99% environmental impact saving, compared to virgin aluminum sheets (Butera, S. and Fruergaard Astrup, T., 2022), and as the joints are easily dismantled, the roof can be cut into sections to be used directly in new houses.

The hollow-core slabs and load-bearing inner walls can either be cut out as boxes or reused as single elements as described in the material atlas. The sandwich elements can be handled similarly. Directly reusing concrete has a 96% reduction compared to using virgin materials (ibid.).

Lastly the bricks in the façade can be cut and recast into brick wall-elements with a concrete backing as described in the case study for Ressourcerækkerne. In spite of the added concrete support, the savings in embodied emissions still reach 61% (ibid.).

ENERGY PERFORMANCE STUDY

Energy performance calculations in this report are made using Be18 V.10.19.7.22.

The energy performance calculation of the existing buildings is based on the same representative building and 3D-model as the LCA-calculation. From a report of the energy label of the existing buildings in Sundparken, they are described as being in energy class B, corresponding to 70 kWh/m2 / year (Energistyrelsen, 2023). The energy frame calculated in Be18 is 69,1 kWh / m2 / year, which is deemed within an acceptable tolerance, given no detailed of the buildings' energy consumption is available. The full Be18 model of the existing building is available in appendix 1.

The building geometry for the documentation in the report is based on one of the final process models so exact glazing areas and overhang angles may vary from the final iteration. The model consists of a cluster of 2 two-storey row-houses and a single 1-storey row-house. The basements and attic spaces are treated as unheated rooms with a dimensioning temperature of 5 degrees Celsius, in accordance with the building regulation. The energy frame goal in the project is 33 kWh/m2 pr. year, which is in line with the requirement in the Danish Building Regulation. The full Be18 model data is available in Appendix 2.

The U-values of the building envelope are calculated using a mix of generic and product specific material data from the material library of Ubakus. The U-values and g-values of windows are based on product specific data, system settings for heating, hot-water usage and infiltration are based on generic renovation data provided as lecture materials in the 2021 semester course, Advanced integrated design 2: green building strategies with focus on energy and emission assessment (AGB) of the AAU Architecture master. system data can be found in Appendix 6.

In this project Be18 is used as a tool for evaluating the buildings' energy performance, which combined with the district heating and electricity projections from LCAbyg, provide data to be used for calculating the operational emissions in the life-cycle assessment and various design studies. With this data as a baseline, it was possible to examine optimization potentials in balancing embodied emissions with operational emissions of passive and active design strategies. Specifically, Be18 was used as a tool in selecting the insulation materials in the envelope, the ventilation strategy for the row-houses and to examine the emissions related to implementing photovoltaic panels.

The insulation material study in the design process examines the façade to the south as well as the gable constructions in the row-houses. Ventilation losses, internal loads, glazing areas, systems and envelope elements, except for the ones being examined, are held constant.

The variable for the study is the U-value of the walls which start at the building regulation maximum of 0,3 W/m2K and get lowered in increments to 0,08 W/m2K. The variance in U-value comes from increasing the insulation layer of the walls, and the differentiation between materials is based on both product specific EPD and generic Ökobau LCA data along with the thermal conductivity of the material.

The ventilation strategy study compares ventilating using only natural ventilation with implementing mechanical ventilation with heat recovery using natural ventilation in summer, leading to a hybrid ventilation strategy. In this study internal loads, glazing areas, systems, envelope elements and the natural ventilation rate in summer are all held constant. Ventilation during the summer is generally set to 3 l/s/m2 in both scenarios, enough to reduce the cooling demand to 0 kWh/m2/year.

In the natural ventilation winter-scenario, there is assumed to be a natural ventilation rate of 0,4 l/s/m2. This is a combined value of a 0,1 l/s/m2 infiltration/exfiltration rate and a basic air exchange rate of 0,3 l/s/m2, the minimum required in the Danish Building Regulation.

The hybrid ventilation scenario assumes a natural ventilation rate of 0,1 l/s/m2 from infiltration/exfiltration and a year-round 0,3 l/s/m2 ventilation rate from the mechanical ventilation system. The mechanical ventilation system is based on an existing product down throttled to a lower ventilation rate than specified in the product datasheet. The system has an 88% heat recovery and the specific electricity consumption for the fan is 0,404 kJ/m3 and 0,302 kJ/m3 respectively, depending on the size of the row-house.

The study of implementing photovoltaic panels examines the balance between the embodied emissions spent on the production of the PV elements with the reduction in operational emissions. This study considers both product specific and generic LCA and EPD data combined with the respective performance data of each unit, to get a broader perspective of what is available on the market. For the study internal loads, glazing areas, systems, envelope elements and ventilation losses are all held constant. The peak power of the PV elements is based on each product and an overall 80% system efficiency is assumed. EPD sources on each product can be found in Appendix 3, in the study itself these data will be presented as an average value. The orientation and angle of the panels is based on the roof geometry of the row-houses. This means the panels are orientated to the south with the roof pitch having 25-degree angle. The panel area is set to be the lowest available in order to reduce the energy frame to below 33,0 kWh/m2 yearly.

THERMAL BRIDGE INVESTIGATION

Calculations of the thermal bridge effect in joints and simulations of heat flow through constructions are made with Rhino 6 using THERM 7.6 for Honeybee v. 0.068. General material conductivities are taken from Ubakus, to be in-line with values from other analyses and documentation in the report.

There are two exceptions to this in the calculations: the first is the hollow-core concrete slab, which is assumed to have a thermal conductivity of 1,34 W/mK based on the 180mm PE slab from CRHConcrete. The second material is the airgap which is found in the original wooden floor construction in the existing floor slab, based on the thermal conductivity of the holes in the concrete slab, this value is set to 0,16 W/mK.

The goal of these calculations is to test insulation strategies in two critical joints. 1) Where the structure of the new row-houses in the project do not line up with the existing structure in the basement, leading to a thermal bridge in the existing hollow-core slab. 2) The joint in the existing concrete wall in the basement leading directly to the floor slab in the row-houses.

In order to calculate the joint including the wooden wall construction with its inhomogeneous layers, this construction is modelled as a single material with a U-value of 1,01 W/m2K. This means that the lines indicating the heat flow through the construction are spaced more evenly than would be the case if the wall section could be modelled in more detail. It is a small source of error for depicting the heat flow but should not change the numeric result of the U-value calculation for the joints.

For the calculation the following boundary conditions apply:

Indoor temperature, living space	20°C
Indoor film coefficient, living space	0,13 m² K/W
Outdoor temperature, basement	5°C
Outdoor film coefficient, basement	0,04 m² K/W
Outdoor temperature	-12°C
Outdoor film coefficient	0,04 m² K/W

An outside temperature of −12°C is used when calculating the joint between the inside of the row-house to the outside through the outer wall and hollow-core floor slab, while 5°C is used when calculating between the inside and the basement.

DAYLIGHT STUDY

Daylight Simulation

Daylight calculations are made in Ladybug and Honeybee (1.4.0) plugin for Grasshopper in Rhinoceros 7. This software is based on Radiance and Daysim in Honeybee and allows to run an hourly annual daylight simulation for a typical year, computing illuminance on a sensor grid on a reference plane. In this analysis, the results show the percentage of occupied hours above an illuminance level of 300 lux for all rooms, according to the BR18 requirements.

The weather file used is a DRY 2001-2010 Energy Plus Weather (epw) file of Denmark obtained from BUILD.dk.

The 3D model contains the surrounding context, including terrain, buildings, adjacent constructions, roof and fixed overhangs. External and internal walls, floor, ceiling, and the openings, constituted separately by the glass and the window frame. The values for the surface reflectance of each element are set according to BR18 §379-381 and the DS/EN 17037:2018, being:

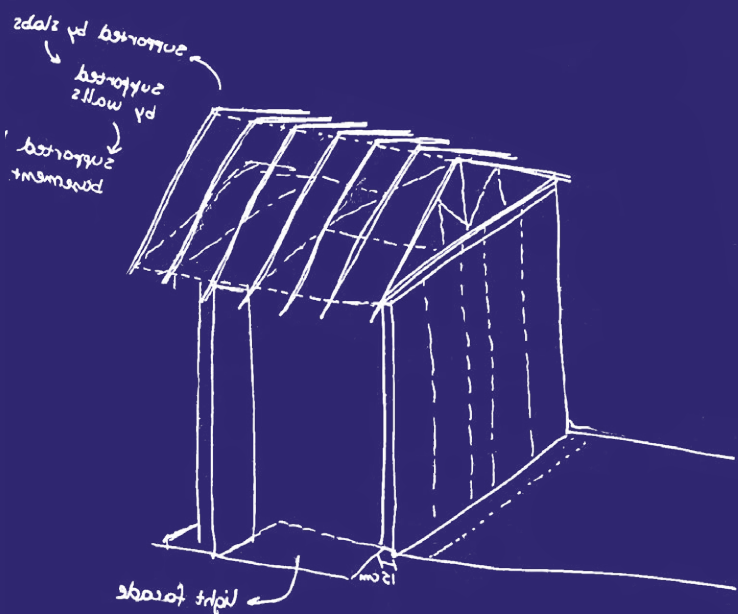
ceiling 0.7, interior walls 0.5, floor 0.2, exterior walls 0.2 and exterior ground 0.2 (Danish Standard, 2018).

The reference plane has a grid with 0.25 meters of distance between the sensors. It is placed at a height of 0.5 meters from the ground level as demanded by the BR18 for residence spaces, and it has an offset of 0.50 meters from the limiting room walls (Bygningsreglementet, 2018).

The simulation has been run with a low resolution.

10% Rule Calculation

The 10% rule method for daylight provision is assessed using MOE´s Excel sheet for correction calculator based on the Building Regulation's guide. The excel sheet calculates the reduction factor of a window according to the shades provided by the context. The information required has been measured on the projects 3D model, providing areas, distances and angles.


supported by slabs
supported by walls
supported basement
light facade
15cm

#04 SUNDPARKEN.

PURPOSE CLARIFICATION

Ill.36 | Sundparken, Horsens. View though passage in between buildings from the parking to the green facilities.

CONTEXT AND DEVELOPMENT PLAN

Sundparken was constructed from 1968 to 1972 and is situated in the northeastern part of Horsens. It consists of 1-room to 5-family apartments. 509 units are multistorey apartments and 68 units are categorized as low-rise high-density housing.

The development plan includes these initiatives to the built environment (Udsatteområder, 2022)

Residents from non-western European countries (>50%)	66.8%
Unemployment (>40%, 18 to 59 yr)	42.0%
Criminal record (>2.18%)	1.28%
Lack of Secundary education (>60%, 30 to 60 yr)	79.3%
Low income (<55%)	56.9%

Source: Indenrigs og boligministeriet, 2021.

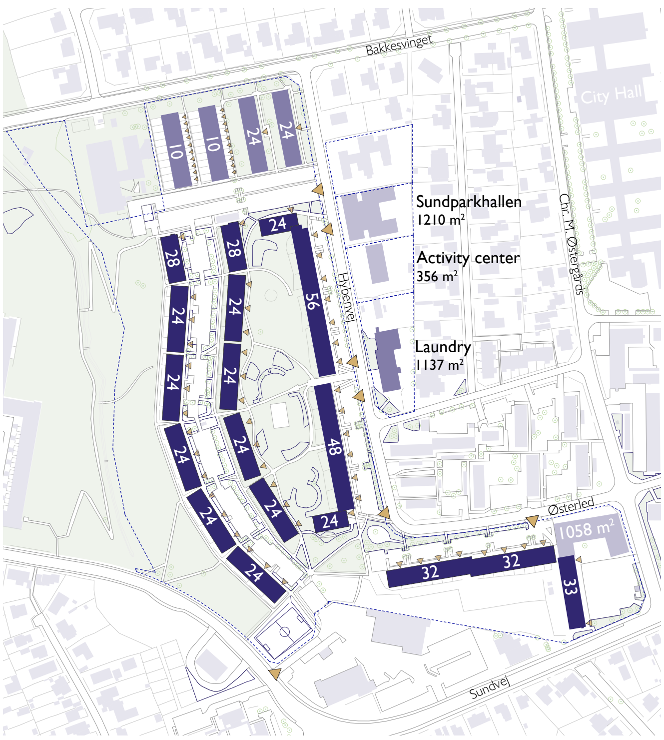
- Reduction of 124 family housing units by demolition
- Construction of 74 new private housing units
- Horsens municipality will move around 1000 workplaces to the area
- The establishment of a private business park

According to the municipality's development plan 124 housing units as to be removed. 48 will be torn down in 2024, 24 in both 2025 and 2026 and the last 28 will be torn down in 2027. 74 new housing units are planned for construction from 2026 to 2029 (Horsens Folkeblad, 2022).

There are 1400 residents living in Sundparken (Indenrins og boligministeriet, 2022)

Ill.37 | Horsens. Denmark.

The chosen site for this study is Sundparken in Horsens. The area has been on the ghetto list since its inception in 2010 and has never been off the list during the past 13 years. The area has however been in steady improvement and is very close to getting off the list, but even if that happened next year the area is still classified as a transformation area and has to reduce the number of family housing units from 87% to 60% (Indenrigs og boligministeriet, 2021).



Ill.38 | Sundparken, Horsens. Site plan with number of apartments per block. Currently, 86,67% of the site is occupied family housing.

DEVELOPMENT PLAN EVALUATION

A mandatory development plan was drafted after Sundparken was categorized as a Trasnformation area. This started a process centered around the development of the area in and around Sundparken and the neighbouring social housing area Beringsvænget.

The product of this collaboration was an idea catalog, that laid out three focus areas: The atractive neighbourhood, new communities and the active outdoors (Bech-Danielsen, Nordberg and Sundstrup, 2022).

The atractive neighbourhood:
To make Sundparken an atractive neighbourhood, the area should provide a larger variaty of housing typologies to ensure a more diverse residential mix.

New communities:
A new community house was proposed as an idea that could enqurage new relationships between Sundparkens own residents and the people living in the sorounding area and the rest of Horsens.

The active outdoors:
The area around Sundparken has many green recreational areas. It has a beautiful landscape and great connection nature and the water to the north. The idea is to utilize these qualities by making a green path with differetn activites, that connects the different areas with eachother and the green soroundings (Bech-Danielsen, Nordberg and Sundstrup, 2022).

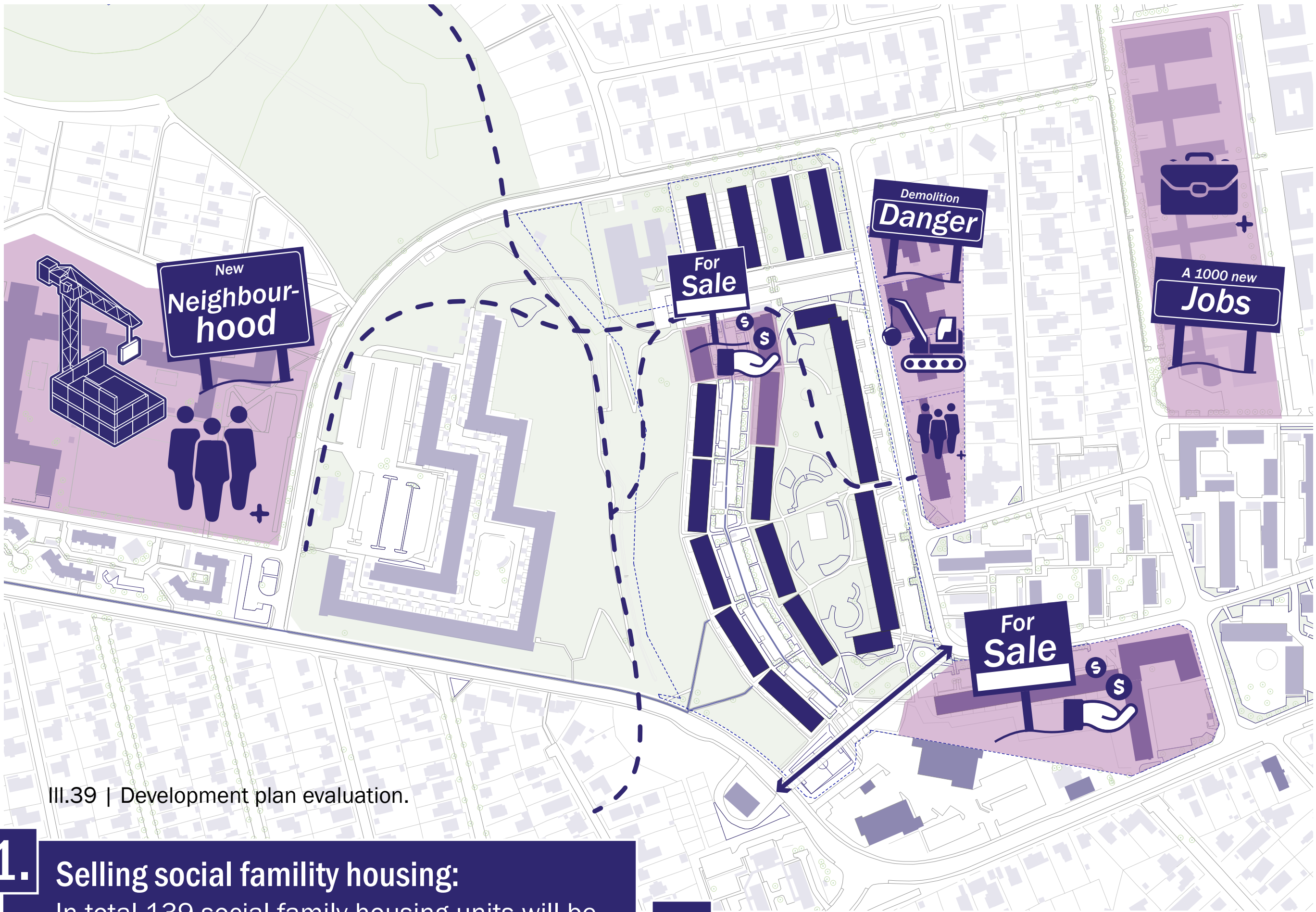
Development plan (2019)
The objective of the development plan is to achieve a percentage of 60% social familiy housing, since Sundparken has recieved a dispensation. The development from 2019 works with two scenarios to achieve the 60%.

The first scenario wants to achieve the goal by converting the apartments and selling them, while the other is selling off a larger number of blocks to developers. Both scenarios use the following principles: Selling, teardown and densification. The two scenarios are descirbed on the page to the right (Bech-Danielsen, Nordberg and Sundstrup, 2022).

Revised development plan (2021)
The development plan was revised in 2021, since selling the blocks to private investors was no longer an option.

The focus was thereby changed from selling to demolision suplemented by remodeling and new construction of private housing units. This third scenario is how the development plan currently is described and can be seen on the page to the right.

This development plan will be suplemented by a larger strategic development plan for the area around Sundparken.



Ill.39 | Development plan evaluation.

1.

Selling social famility housing:
In total 139 social family housing units will be sold. This is equivilant to one big block and three small blocks.

Teardown and densification:
The sportshall and the activity house east of Hybenvej must be torn down to establish building plots for private investors, so 35 private row houses can be built.

2.

Selling social famility housing:
Six of the 24 unit blocks will be sold to private investors.

Teardown and densification:
The sportshall and the activity house east of Hybenvej must be torn down to establish building plots for private investors, so 35 private row houses can be built.

3.

Demolition:
Selected housing blocks (124 units) will be demolished, to give Sundparken a more open expression and connect it with the sorounding

Remodeling:
Selected housing blocks will be remodeled, by for example removing the top floors or creating opening by reducing the length some of the housing blocks to create new passages and pathways.

New construction of private housing:
The sportshall and the activity house east of Hybenvej must be torn down to establish building plots for private investors, so 35 private row houses can be built. In adition to 39 units within Sundparken. A total of 74 new private housing units.

URBAN SURROUNDINGS

CONNECTION TO HORSENS

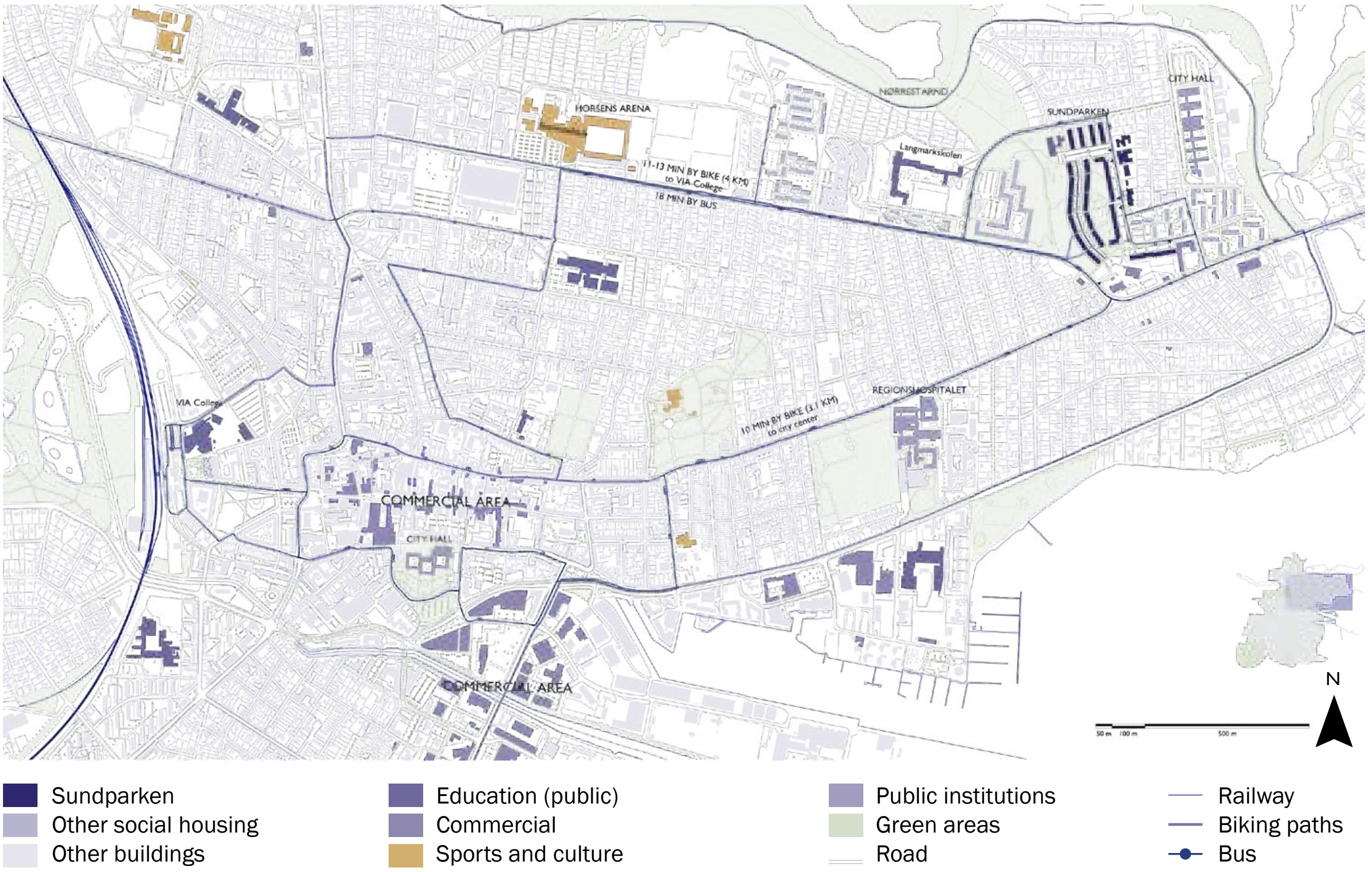
Sundparken is located 2km away from Horsens city center, in an area surrounded by other social housing buildings and single-family houses of a significantly smaller scale (Ill. 40). It is well connected to the city center, VIA University College and Horsens Railway Station through 4 different bus lines with bus stops around the plot. There are biking paths on the main roads, such as Landmark and Sundvej, and around Nørrestrand Lake, leading to other active areas of the city and the natural reserve on the north, which offers different kinds of activities in connection to wildlife. The site is also 6 to 10 minutes away from sport facilities such as Horsens Svømmerklub and cultural centers or museums.

This gives access to a variety of opportunities to the users such as work, education and leisure.

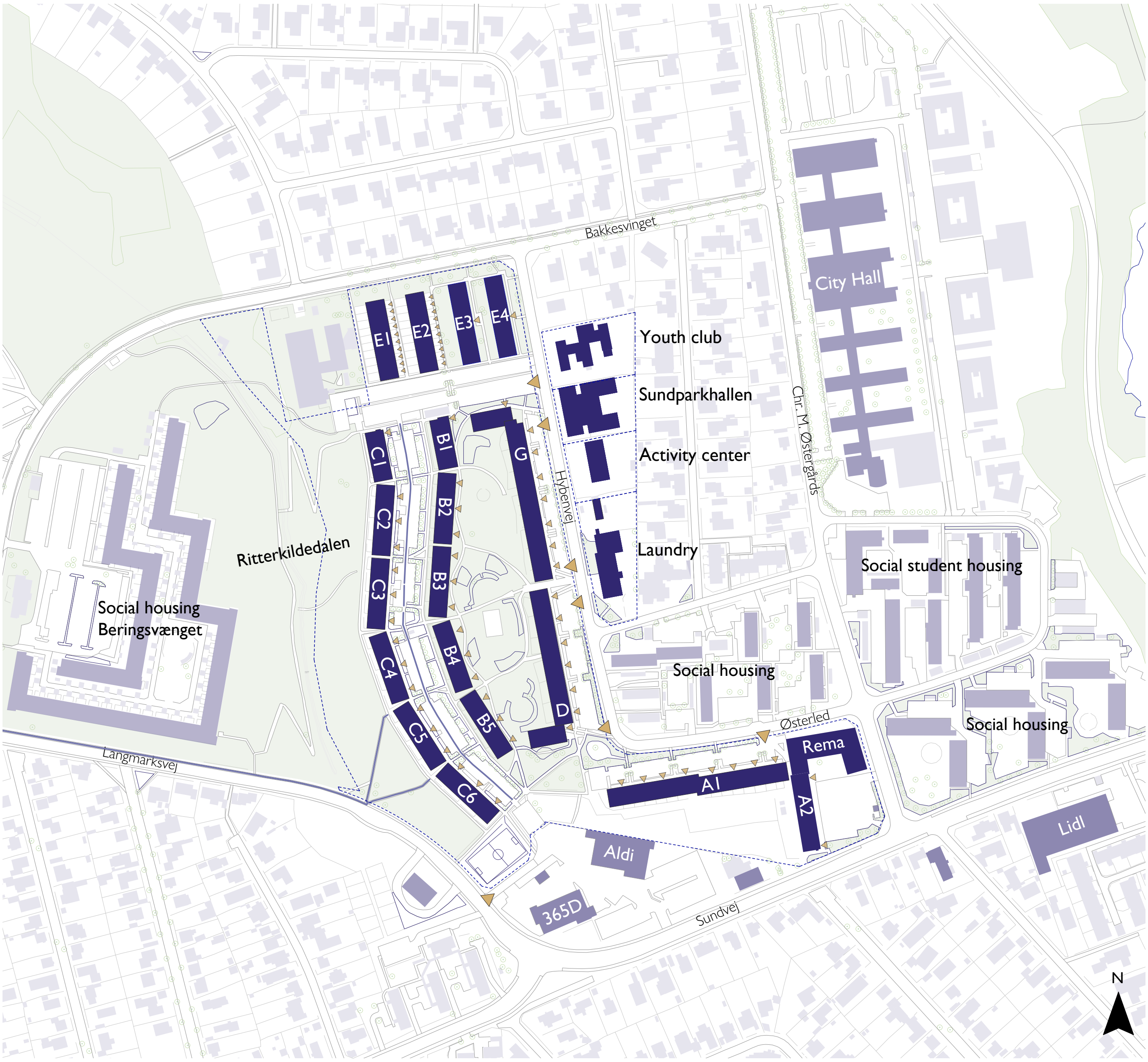
EDUCATION AND EMPLOYMENT

There is a day care center and a primary school nearby, Børnehuset Rytterkilden and Langmarkskolen respectively, although there are plans to move the second one in the upcoming years. Currently, most residents educate their children in these institutions, but there are other public primary schools within reach.

Rådhuset Horsens has recently been moved adjacent to the site, replacing the old location of VIA University College. This caused a reduction of clients demand on the Rema 1000 next to Sundparken, and will be moved to the current Aldi's location, which coulb be an opportunity for new jobs. In 2018, Job Center Office has been moved next to the site, intending to contribute to the employment of current residents.



Ill.40 | Sundparken, Horsens. Site plan with transport network and key facilities in the area. Educational institutions, commercial areas, social housing and city hall. 1:23000. The site is 3.1 km away from the city center and 4km away from VIA College. It is connected by the bus line 1, 2, 11, 12 and 306. Biking paths, roads and walking paths also lead to points of interest.



Ill.41 | Sundparken, Horsens. Site plan with direct surroundings and masterplan of Sundparken, 1:5000. On the west, Ritterkildedalen green areas equipped with playgrounds and paths. On the north, terraced houses. On the east, the City Hall and row of common facilities. On the south, local commercial centre, other social housing blocks.

SUNDPARKEN SITE

Sundparken is constituted of a group of 19 residential blocks containing 577 apartments. The site can be understood as organized into four areas according to their function, building composition and distribution (Bech-Danielsen et al., 2022, p. 16). On the north, the apartments are distributed in 2 parallel blocks of terraced houses (E1, E2) together with 2 other blocks containing student apartments (E3, E4); In the center, 13 buildings with family apartments, organized in three rows separated by green areas and parking (B, C, G, D); In the south, 2 blocks, placed in an L shape on top of convenience shops and next to a supermarket. On the East, there is a row of shared common facilities on the other side of Hybenvej, which belongs to the complex but is also open to people from the surrounding neighborhoods and offers activities for social integration and self-development.

The dwellings are between 41 and 163 m2, having one to five rooms correspondingly. The overall residential area is 51.600m2, and 1798 m2 is destinated to commercial use. The residential buildings are surrounded by well-equipped public green areas and Rytterkildedalen to the west, a mixed-use block and commercial tenancies on the south, and shared facilities to the east

.

Next to the intersection between Langmarksvej and Sundvej, between the buildings and the supermarkets there is a sports court with potential for improvement, becoming more active in its role and increasing the connection its function and to between buildings A and B-C-D.

SHOPPING DISTRICT ANALYSIS

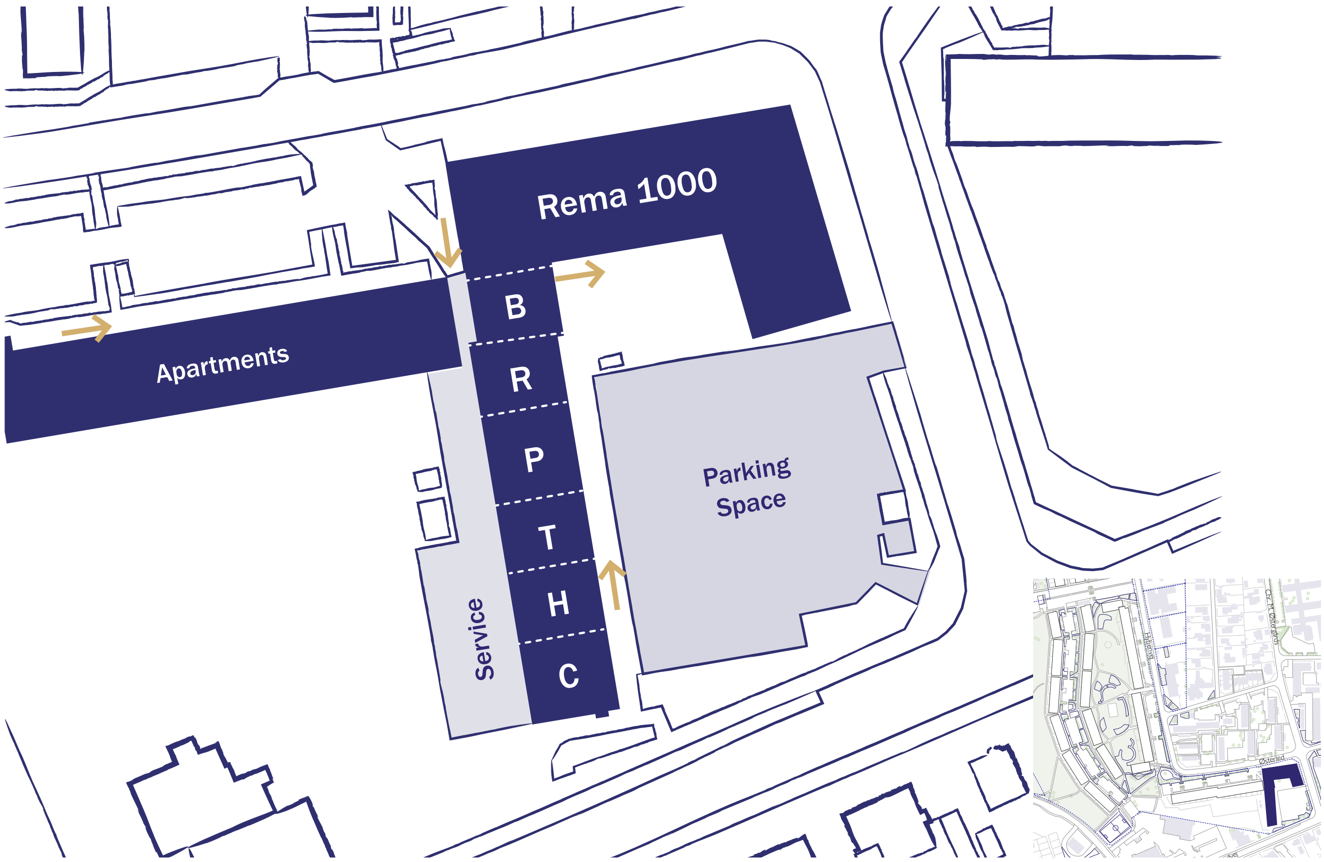
The 1798 sqm commercial area is located on the southeastern edge of Sundparken roughly 300 meters away from the center of the residential area. The shopping district consists of seven different commercial functions. The largest of these is Rema 1000, it takes up almost half of the total commercial area and is by far the most visited of the seven. The other six are represented on the map by a letter each.

The small shops have quite a variety including food, products and services. The stores are small and take advantage of the flow of customers going in and out of Rema. This dependency can however become problematic.

The relocation of Rema 1000
The local Rema will in the near future not be found within the shopping district but will instead be found 200 meters to the west in Aldi's old building (Vollandt, 2022). This could leave the small business at risk, since the overall foot traffic within the shopping district will be reduced and instead redirected towards Rema's new location next to the 365 Discount store. Reduced foot traffic tends to lead to reduced sales, which in the long term could force the stores out of business (Kenton, 2022).

Ill.42 | View of passage from apartments to commercial area.

It is necessary from a social sustainability standpoint to have areas where social interaction is encouraged. A shopping district is the perfect place for these interactions and should be given serious consideration when transforming the area.



B = Butcher shop, R = Røde Kors, P = Pizza restaurant, T = Tile shop, H = Hair dresser, C = Foot clinic.

Ill.43 | Sundparken, Horsens. Map of commercial area.

Position of camera for pictures

Sundparken.

N

Meeting the district
Meeting the existing shopping district coming from Sundparken is not that inviting. As seen on the picture on the left page, the residents of Sundparken walks along a straight path with the huge apartments blocks to the south, blocking the sun, while the shopping districts seems to turn its back towards Sundparken.

The quickest access point for the residents is through a small dark tunnel. The districts orientation is clearly not aimed at people living in Sundparken especially when one examines the picture to the right and considers that the service splits the area in two, as if the two areas doesn't want to interact.


Ill.44 | View to service area. Sundparken, Horsens.

Visiting the district
The façade of Rema can be described as unwelcoming. Its yellow panels make the building seem unfinished and monotonous. The other stores are more inviting with their glazed curtain walls, that allow the visitors to clearly see what each store has to offer.

All of the stores are equipped with a external overhang, sheltering the visitors from the rain. The area does however seem a bit empty on the last picture, but this can be due to the time of day and year.


Ill.45 | View of Rema 1000's facade. Sundparken, Horsens.

Conclusion
Sundparkens shopping district as it is named does not seem to live up to its name. It orientates itself away from Sundparken and is not equally inviting towards visitors and residents. From the street it can be hard to even see the rest of Sunparken even though they are by far the biggest buildings in the area.

The future for the small buisnesses is uncertain due to the relocation of Rema. This concern should be addressed in the final design proposal.


Ill.46 | View of shops' facade. Sundparken, Horsens.

LANDFORM

The site has a regular inclination (top to bottom) from the center to the south and the north and from the east to the west. On two sides of the area, the site elevates radically, bringing certain limitations for the building placement. The blocks follow the curvature of the topography lines and frame the parking and the green areas, which have a man-made sloped character after landscape work in 2000.

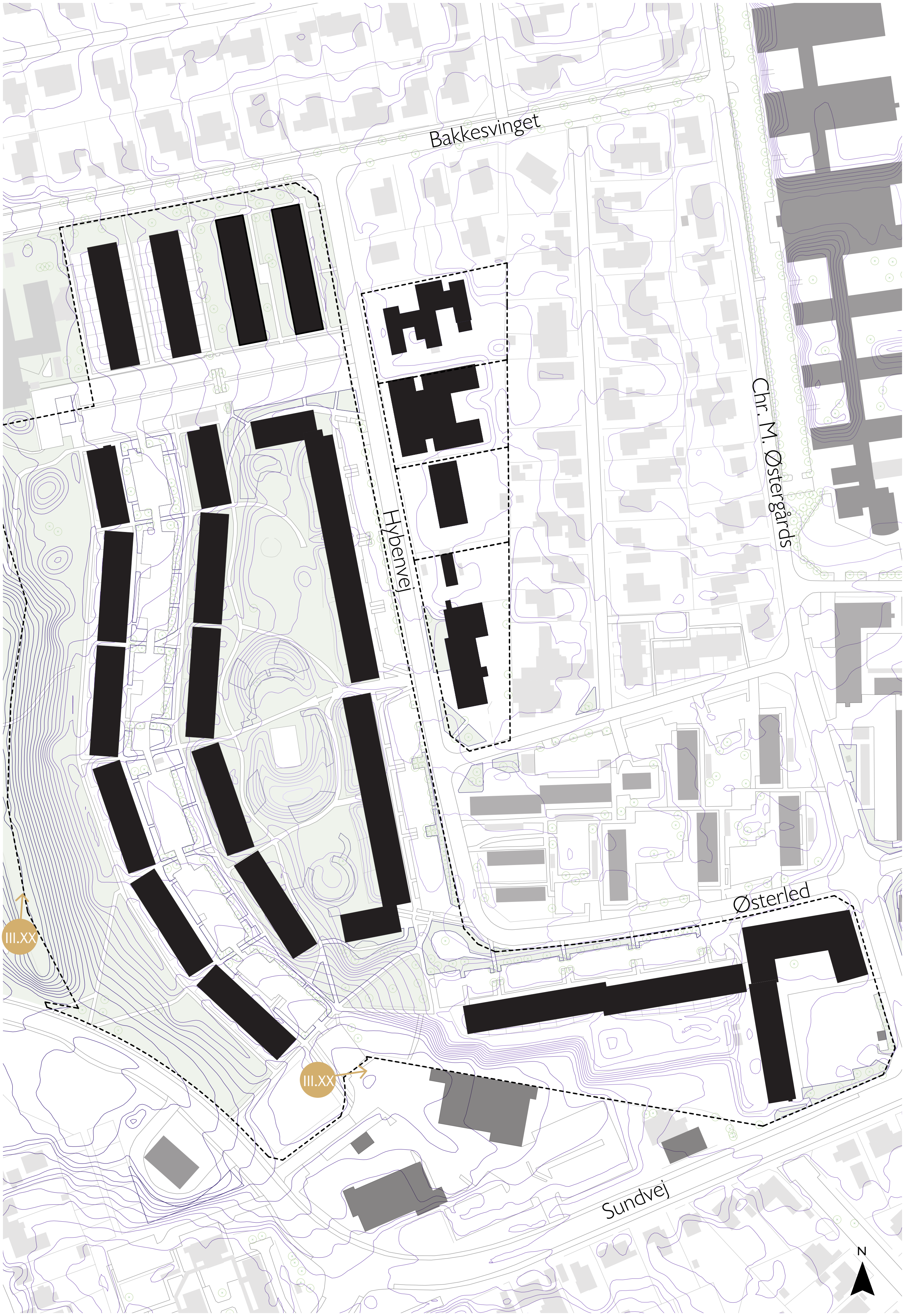
On the West side, Sundparken is separated from the next plot by a valley, standing on the top of the hill around 9 meters above the lowest point. Realdania funded the renovation of this valley in 2017, which has been developed as a public recreational area with paths, playgrounds and exercising equipment along the stream.

On the South front, the blocks stand in front of a narrow plane that is defined by a steep ravine 6,5 meters above the convenient stores next to it. The areas are connected through winding paths and stairs, but the visual connection is mostly interrupted by tall trees that create a sort of barrier.

On one hand, the inclination along the terrain presents opportunities to design with the landscape, combining heights of entrances and terraces, creating different levels of privacy, but it can become a difficulty for the construction and the sustainable aspect if not considered carefully. The steep sides must be especially contemplated in the building placement and orientation.

Ill.47 | Sundparken, Horsens. West side, view from the valley. The blocks stand on top of the hill.

Ill.48 | Sundparken, Horsens. South side, view from the convenience stores area. The blocks stand on top of the slope. It is possible to see a stair on the slope connecting both areas.



Ill.49 | Sundparken, Horsens. Topography map, 0.5 meter curves. 1:2500.

SUNLIGHT STUDY

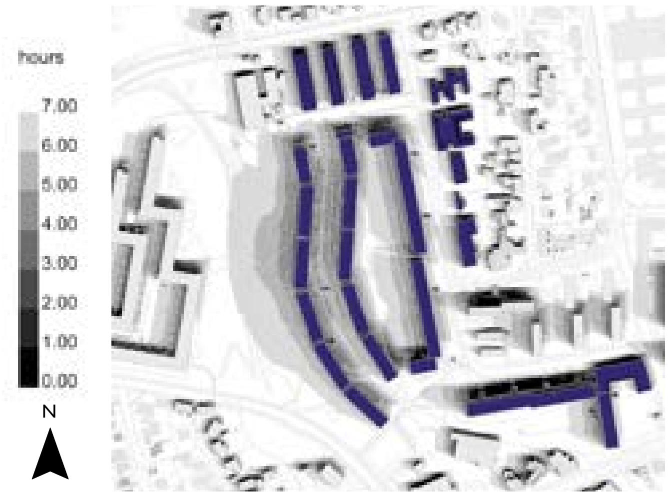
Winter morning 6:00 - 14:00

The daylight study of Sundparken during a winter morning shows the strength of the modernist design principles the area was built upon. By placing the apartment blocks in a chain with a north-to-south direction it allows sunlight to reach around three-quarters of the main courtyard, where only the southern part is covered in shade in this time period. The remaining area receives 4 to 5 hours of direct sunlight in the eight-hour period.

Ill.50 | Sundparken, Horsens. Direct Sunlight Hours. Winter morning.

Equinox morning 6:00 - 14:00

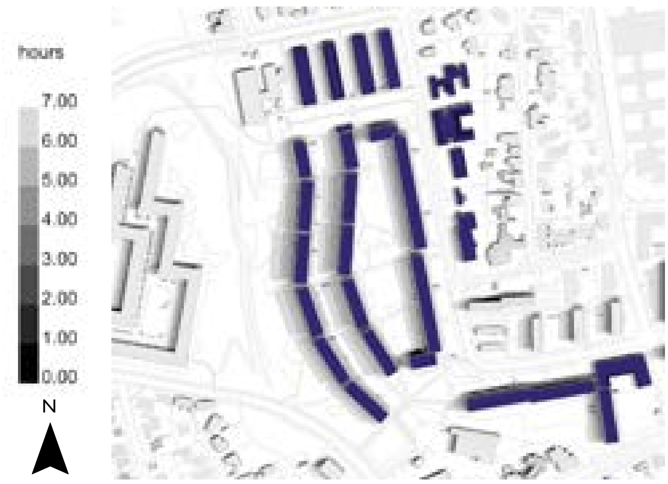
Most of the outside areas receive a decent amount of sunlight hours during the morning hours from 6 am to 2 pm, as previously mentioned due to the modernist design principles applied to the urban-planning. These principles have however not been applied to all the apartment blocks. In the south-eastern part of Sundpark the apartment blocks are placed in a chain going from west to east. This contradicts the guiding design principles and as a result, casts shade along the path leading to the convenience store. This could be problematic since this area arguably is a central mixing point where residents within Sundparken could interact with people from outside the area.



Ill.51 | Equinox morning.

Summer morning 6:00 - 14:00

During the summer exterior areas rarely lack sunlight. This is also the case during the morning in Sundparken. Most of the area has 7 hours of sunlight and even the areas close to the building blocks receive four to six hours. The only place where there is a significant lack of sunlight is the pathway connecting Sundparken to the convenience store. Even in the summer, this path is in the shade.



Ill.52 | Summer morning.

Winter afternoon 14:00 - 22:00

As the day continues the sun starts to fade away this is especially true during winter. In the period from 14:00-22:00, almost no sunlight reaches any of the areas around the buildings. area with the best chances of receiving some sunlight is the open grass field to the south of Sundparken. The area receives no shade after noon and is the only place with the opportunity to enjoy the sun after work.

Ill.53 | Winter afternoon.

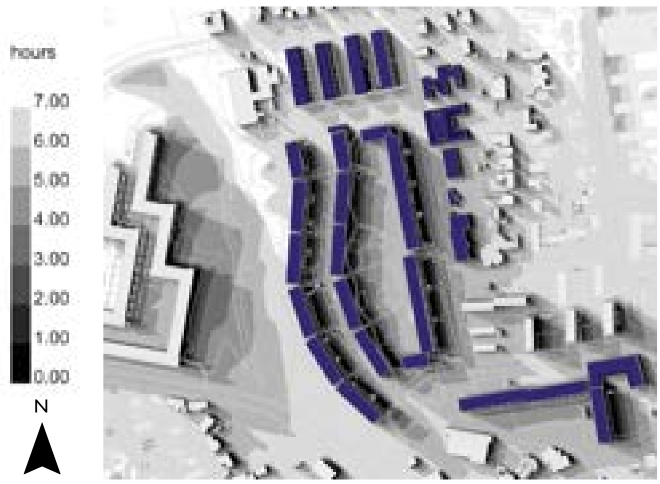
Equinox afternoon 14:00 - 22:00

When reaching equinox, the sun sets around 19:00. This gives the residents a substantial increase in the number of sunlight hours they can enjoy after work. The middle chain of apartment blocks seems to have the least direct access to the areas with best sunlight conditions, since the outside area to the east is shaded by their own shadows and the area to the west is shaded by the neighbouring chain of apartment blocks.

Ill.54 | Equinox afternoon.

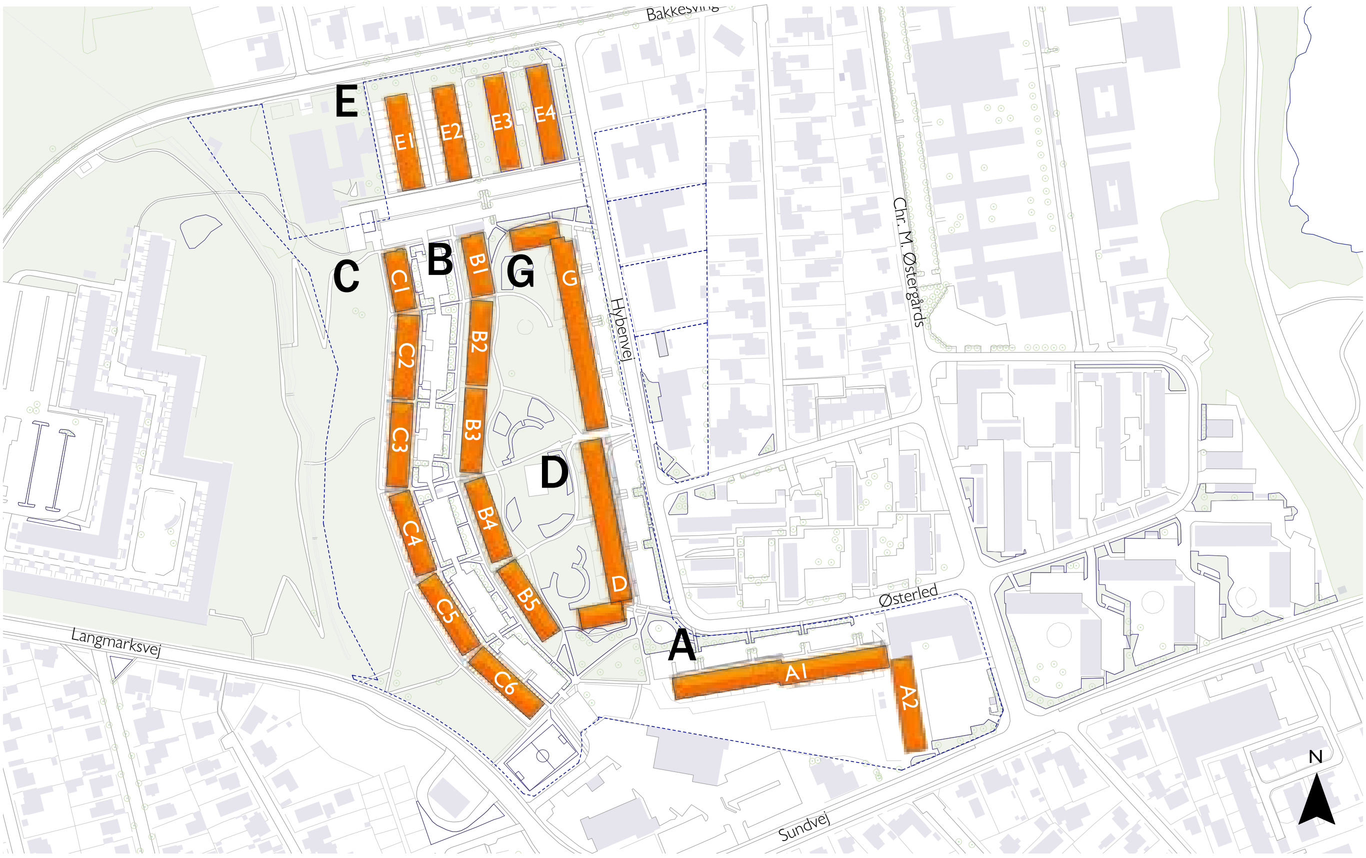
Summer afternoon 14:00 - 22:00

Sunlight during the summer is generally not a problem. On some days people might seek shelter from the sun within the shade. There are three small common areas surrounded by trees and bushes to the west of Sundparken. These areas might provide the residents with the necessary shade needed during a hot summer day.



Ill.55 | Summer afternoon.

SOLAR RADIATION



Ill.56 | Sundparken, site map with solar radiation on the roof.

A solar radiation analysis of the existing buildings in Sundparken has been conducted to evaluate the potential benefits of implementing photovoltaics in the built environment. The maximum solar radiation potential on a flat surface in the area is around 1000 kWh/m2. This it the upper limit value while the lower limit is defined as an area with no direct sunlight where the value is 0 kWh/m2. The values in between are divided into intervals of 200 on a scale ranging from blue to red.

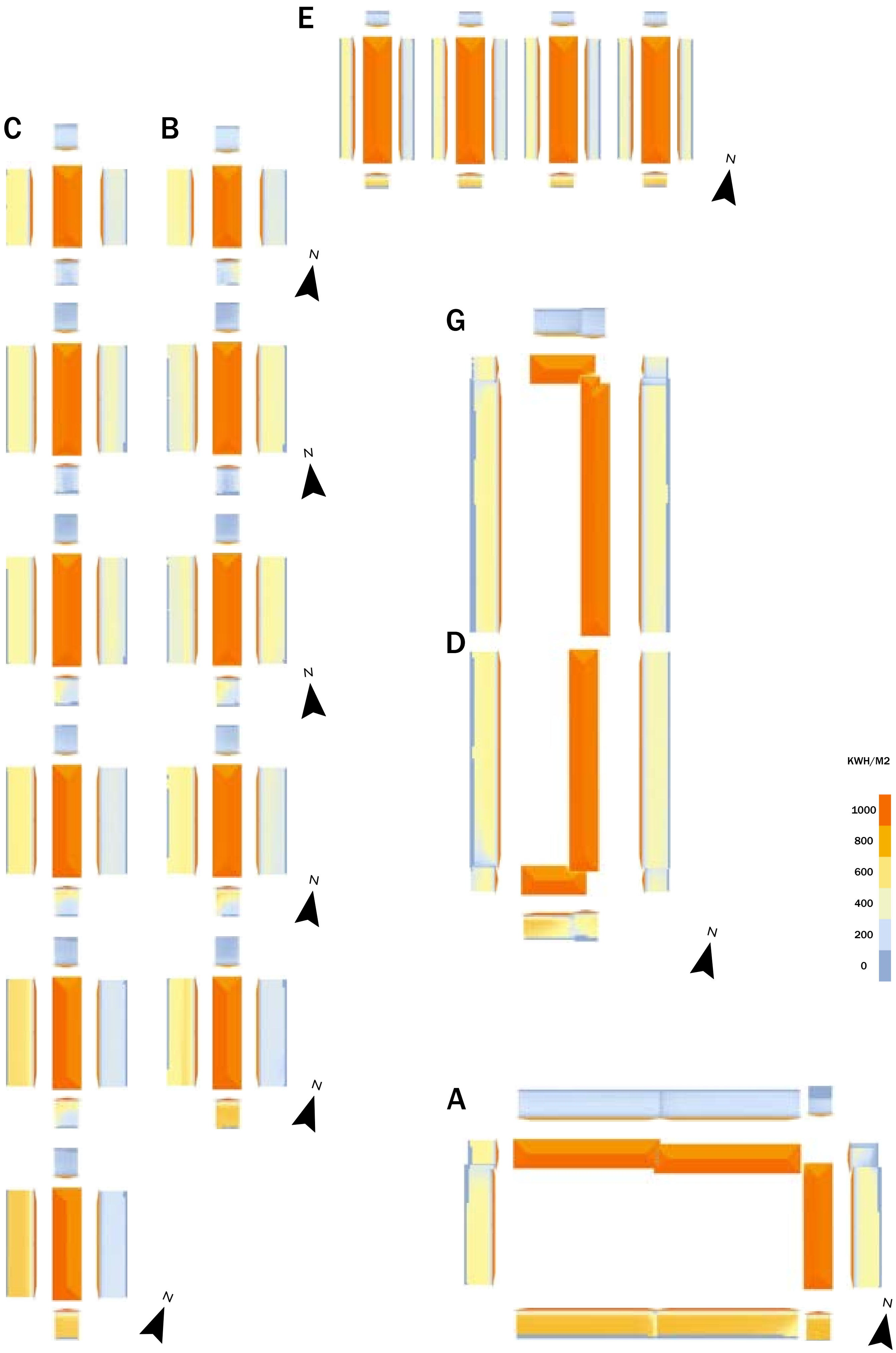
A quick overview of the results clearly indicates that all of the roof top areas receive between 800 to a 1000 kWh/m2 during a year. This is due to the low angle on the sloped roof and the height of the buildings compared to their surroundings. The roofs do therefor not receive any external shading and almost no self-shading as well.

Looking at the solar radiation of the building facades they have a high degree of variability ranging from 0 to 800 kWh/m2. Most of the facades receive around 400 kWh/m2 making them less attractive for implementing photovoltaics on the facades.
Facades with a greater solar radiation potential.
The southeren facades on the building in category A have a high solar radiation potential. The walls receive 800 kWh/m2, which could make them suitable for photovoltaics.

The two southern blocks C5 and C6 in category C also have a greater solar radiation potential due to the facade's orientation toward the southwest. They receive between 600 to 800 kWh/m2.

The Southern gables on C6, B5, D1 and E1 to E4 also have areas that receive up to 800 kWh/m2.
The remaining exterior wall areas have a low to medium potential for solar radiation.

The roof area is clearly the most suitable for the implementation of photovoltaics and due to their identical roof construction, none of the building blocks are noticeably better than the others for this purpose.



Ill.57 | Sundparken, solar radiation on each surface of every building. Blocks unwrapped from the top the each facade.

SUBCONCLUSIONS ON SUNDPARKEN

The theoretical framework and site analysis has created a comprehensible overview of Sundparkens current conditions and which principles that potentially could be applied during the transformation.

This section will collect critical observation and use these to determine the area of focus before going forward with the design development.

The illustration to the right divides Sundparken into four different areas. A main body area in the middle, a student and row house area to the north, a social facilities area to the east and the area to the south includes the A-blocks and the shopping district.

Which buildings should be preserved?
Preservation and renovation are from an environmental standpoint the most sustainable. The buildings marked with yellow in the illustration are determined to have a high preservation value.

The blocks with small apartments have a high conversion potential. They can be converted into either student or elderly apartments. The A2 blocks are especially interesting since it already has an elevator installed.

Student and row house area:
The student and row houses to the north should be preserved as is. The student apartments help reduce the percentage of social family housing and the row houses are already a desirable typology and could potentially be sold as private housing.

Social facilities area:
The social facilities are going to be demolished according to the current development plan. The research done on social initiatives indicates that these facilities have been an important part of the positive development in the area. It's an area that brings people from the outside to the area. These buildings and their activities should stay and be a part of the transformation.

Main body area:
The solar analysis clearly showed the strength of the modernist design principles that Sundparkens design was based on. The central courtyard is a green and sunlit area accessible to all its residents. The landform study showed how the buildings are placed according to the landscape, making them an integrated part of the natural surroundings adding aesthetical value to the area.

A-Blocks and shopping area:
This area seems to have the highest transformation potential. The analysis of the current shopping district highlights how the area turns its back on Sundparken and how uninviting it seems from the resident's perspective. This combined with the fact that Rema is relocating is a course for concern.

The solar analysis also shows how the solar condition in the area is worse compared to the main body, since it doesn't follow the same design principles. From a masterplan perspective, the area seems to be independent from the rest of Sundparken, seemingly its own island.

The area is marked as a potential plot for private investors in the development plan from 2019. This makes sense since the apartments in these blocks do have a great view towards the water, giving them Penthouse potential.

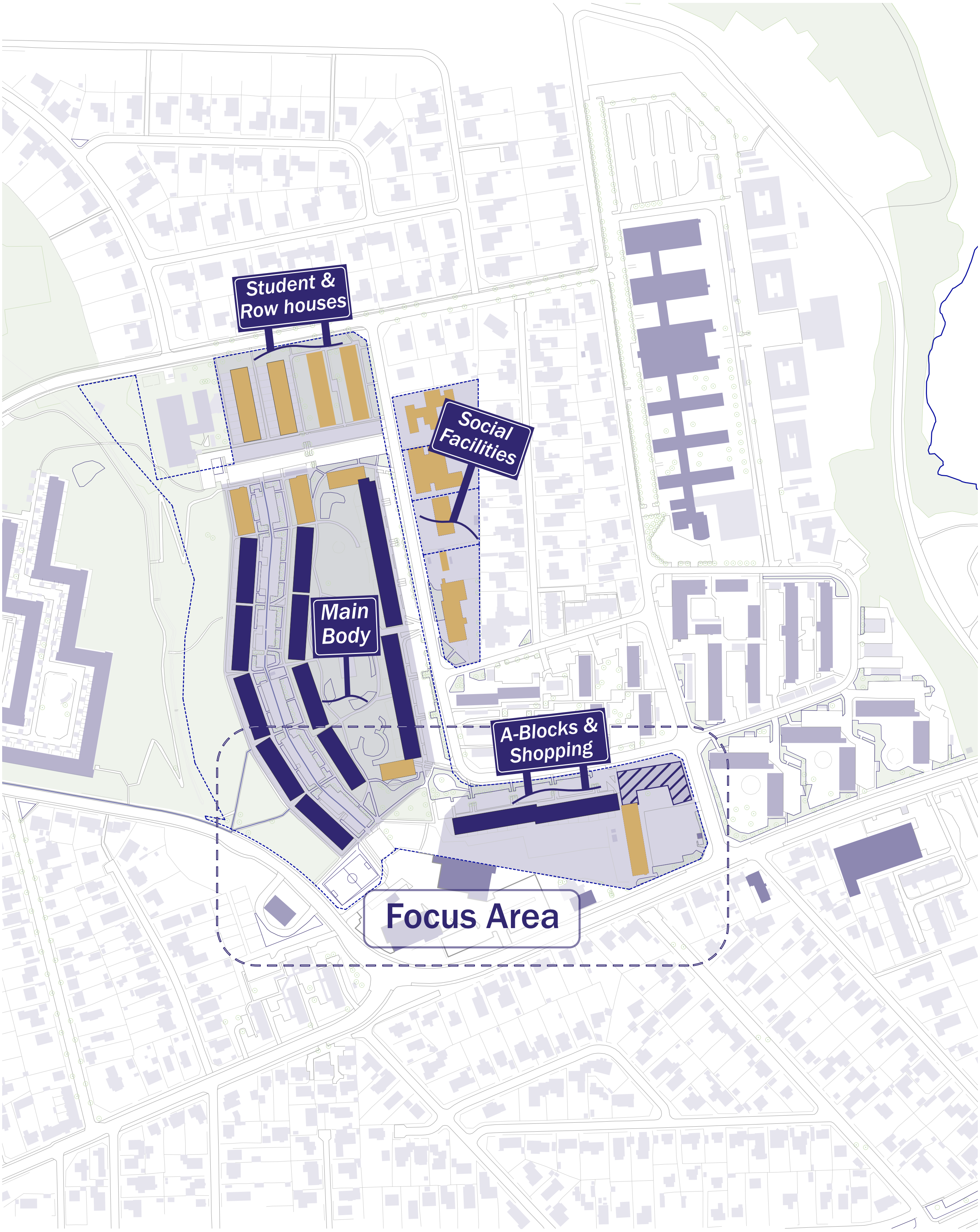
These qualities do not improve the overall quality of Sundparken as a whole. The view from the individual apartments comes at a cost. The building blocks the visual and physical connection between Sundparken and Horsens as a whole.

The focus area:
The southern part of Sundparken seems to have the highest transformation potential. The current shopping district will have to be redesigned since Rema is relocating to the old Aldi building.

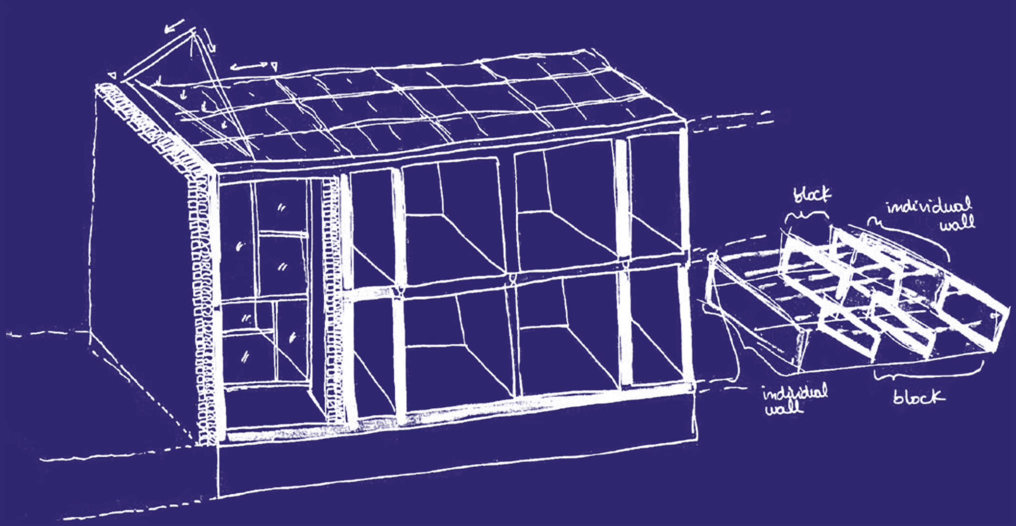
A new commercial district could potentially be designed and placed with a stronger connection to the convince stores in the area.

This would leave the current shopping district empty and would require transforming the area and giving it a new function.

The A1 block is from a masterplan perspective the most disruptive of the apartment blocks and should be considered to have a high transformation potential.



Ill.58 | Sketch of subconclusions on Sundparken's site analysis.



block
individual
wall
individual
wall
block

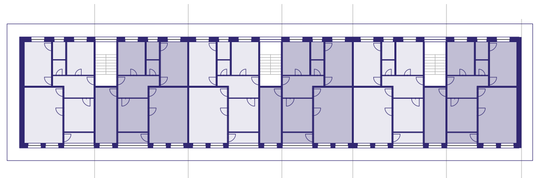
#05 EXISTING BUILDING CONDITIONS.

DESK RESEARCH

FLOORPLAN TYPOLOGIES

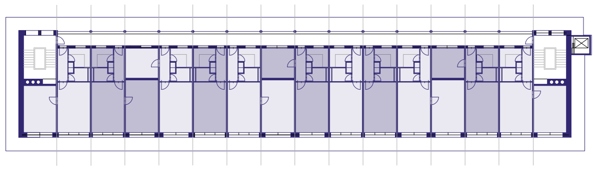
The 19 blocks of Sundparken can be grouped into three different floorplan typologies with minor variations. The study of these is relevant to understand the potentials for reuse of the buildings.

Typology 1
The most frequent one is the 3 to 4 room apartment buildings (Ill. 59), present in 12 of the blocks. These are currently the most suitable for families of different sizes. The walls have varied distances to defined rooms, but the overall apartment widths are 7.5 meters and 9.9 meters. This block is further studied to consider the possibilities for adaptation of the floorplan to different purposes or disassembly and reuse of its parts.



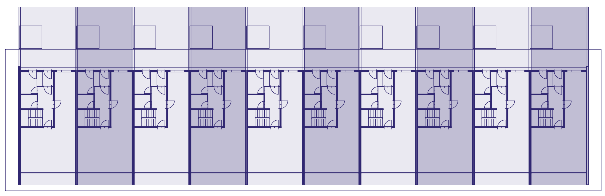
Ill.59 | Sundparken, Horsens. Typology 1. Representative floorplan of 3-4 room apartment blocks.

Typology 2
The second typology organizes apartments of 1 to 2 rooms, additionally to kitchen and bathroom, in regular spans of 3.6 meters. This typology is more suitable for small family groups and students. In fact, two out of the 5 blocks containing this floorplan are for students exclusively. The short blocks adjacent to the long ones (D and G) also consist of this layout. Three of them are provided with elevators, increasing the potential for transformation into elderly apartments.

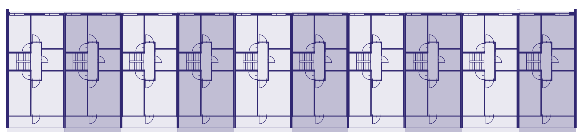


Ill.60 | Sundparken, Horsens. Typology 2. Representative floorplan of 1-2 room apartment blocks.

Typology 3
The third typology is the two-story row houses placed on the northern part of the site. There are two blocks defined by this floorplan. The ground floor contains common areas, while private bedrooms are on the second floor. The staircase is placed horizontally in the middle, separating service areas from the living room. The houses have a NE-WS orientation, which Favors the gardens both in front and behind, receiving sunlight on the facade during the morning, while the living areas and the garden on the back face the sunset. These row houses are a reference to the composition of new row houses in the area, matching the existing ones.



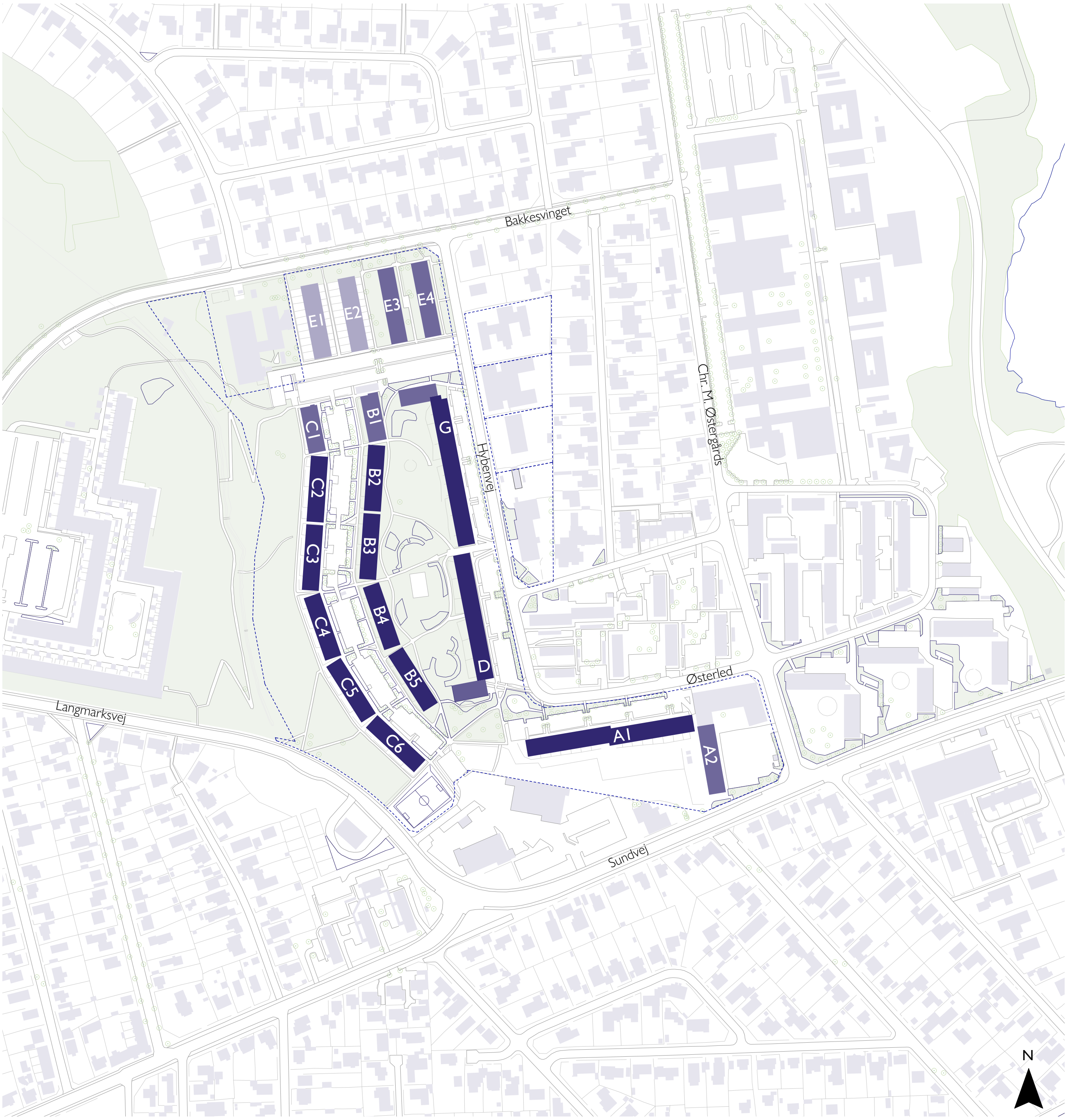
1st floor



2nd floor

Ill.61 | Sundparken, Horsens. Typology 3. Representative floorplan of row houses blocks.

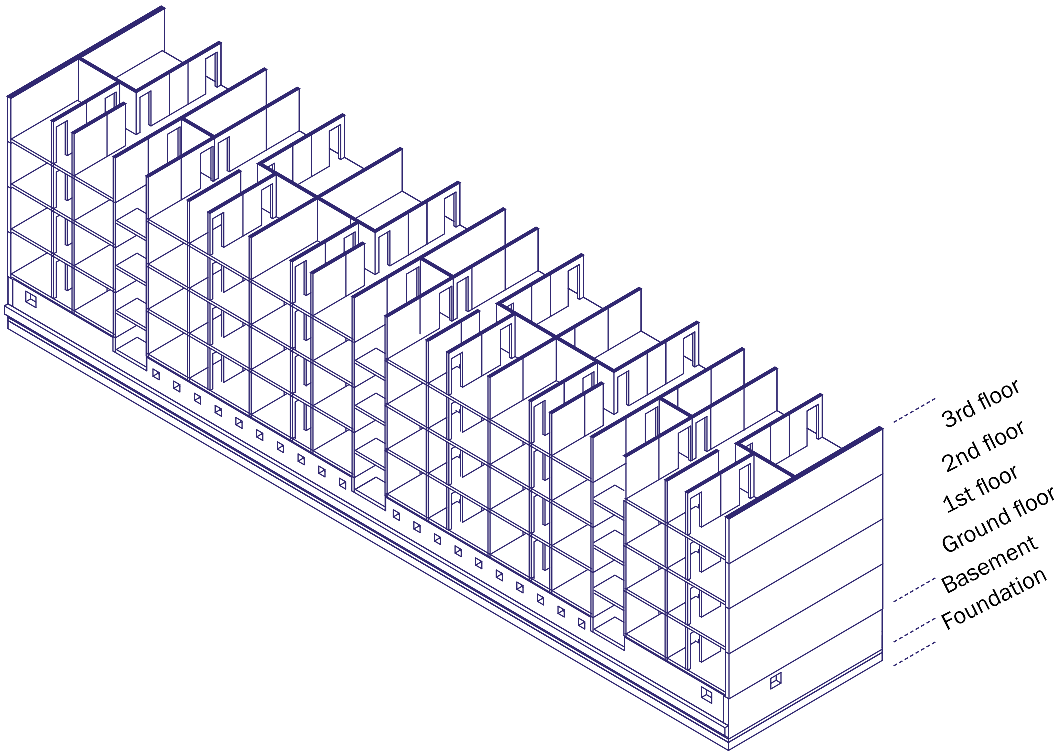
N



3-4 room apartment buildings 1-2 room apartment buildings Two-story row houses Surroundings

Ill.62 | Sundparken, site map with floorplan typologies.

STRUCTURAL SYSTEM



Ill.63 | Axonometry of Sundparken's prefabricated concrete elements. Typology 1.

The building is supported by a slab-wall system (*plade/skive konstruktioner*) that consists of modular prefabricated concrete elements with minimum reinforcement for transport purposes and prestressed hollow slabs. The load is distributed between the indoor walls and the gables, providing more freedom to the façade, which in its original design was almost half glazed following a horizontal stripe pattern. The floorplan is long and narrow in proportion (52.5m x 11.2m), and can be subdivided into two parts by an interrupted wall along the long side, and 6 main parts by continuous walls across the short side, defining the 6 apartments. This fact puts the slabs in a key role, as it is the only element that connects the whole in the long direction.

The walls on the perimeter of the building are sandwich elements, constituted by two concrete panels with rigid insulation in between, and have a thickness of 25 centimetres. The walls on the inside have a thickness of 15 cm, and the way that loads transfer from one floor to another is simple, vertical and axial since the floorplan arrangement is the same in every floor.

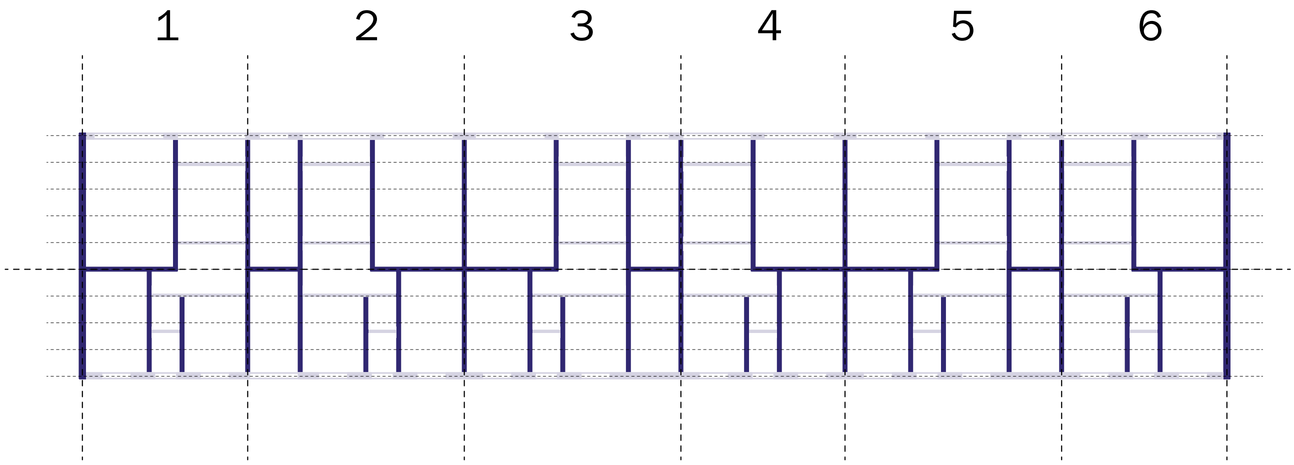
The situation is more complex in the basement, since in some occasions it has a layout variation. The perimetral walls are 35 cm thick, the inner walls are 20 cm and the ones altering the layout are 40 cm. To redistribute the loads from the construction above, these are interconnected with beams of 34 x 29 cm (HxW) and colums when the span is bigger than 3.5 m. This floor has been cast in situ, and therefore is supported by solid reinforced concrete walls and a 20cm thick terrain slab of pure reinforced concrete.

All the loads of the 4-storey building and basement are finally transferred to the strip foundation that follows the perimeter and the center through the length of the building. The nodes between walls are reinforced with pad footings of 120x120x50cm, as visible in figure XX.

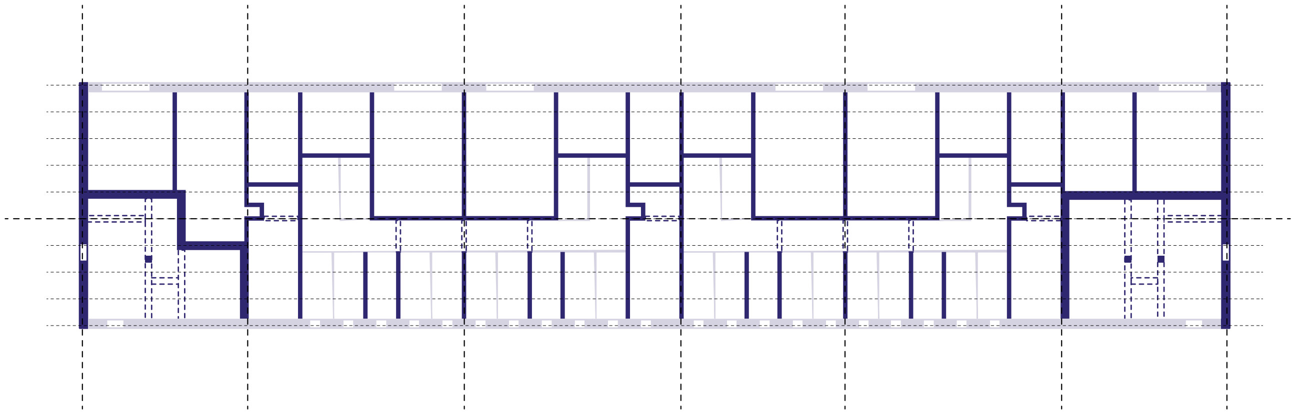
Sundparkens envelope has been renovated in 2000-2003, adding extra layers on the outside of the building. To balance these loads, a plinth beam of reinforced concrete and Leca blocks has been added, providing support and redistributing the weight to the foundation.

The roof was originally flat with a wooden butterfly-shaped trusses, but has been renovated in 2000-2003 into a roof with a closer Danish traditional appearance, supported by a wooden fink truss with a 10° inclination.

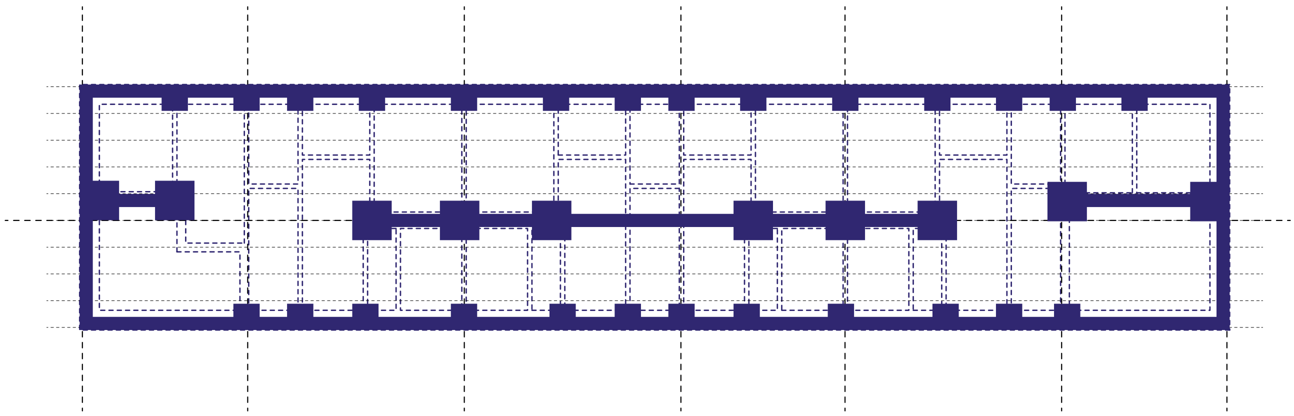
In this regard, when thinking of disassembly and transformation, it will be substantial to consider the concrete elements as part of the strategy to prevent perjudicial damage and discover its potential for re-use.



Ill.64 | Sundparken's structure plan. Typology 1. Representative floorplan.



Ill.65 | Sundparken's structure plan. Typology 1. Basement.



Ill.66 | Sundparken's structure plan. Typology 1. Foundation.

BUILD-UPS

Gables

The walls on the perimeter of the building have a thickness of 25 centimetres, constituted by two concrete panels of 100mm and 75mm, and a 75mm of polystyrene foam. This presents a U value of 0,58 W/m^{2}K (Rockwool Energy Design). After the renovation in 2000, It has been added an extra 125mm layer of mineral wool and 108mm of bricks, separated by a 25mm ventilated air gap. This has a U-value of 0.21 W/m^{2}K.

Facade

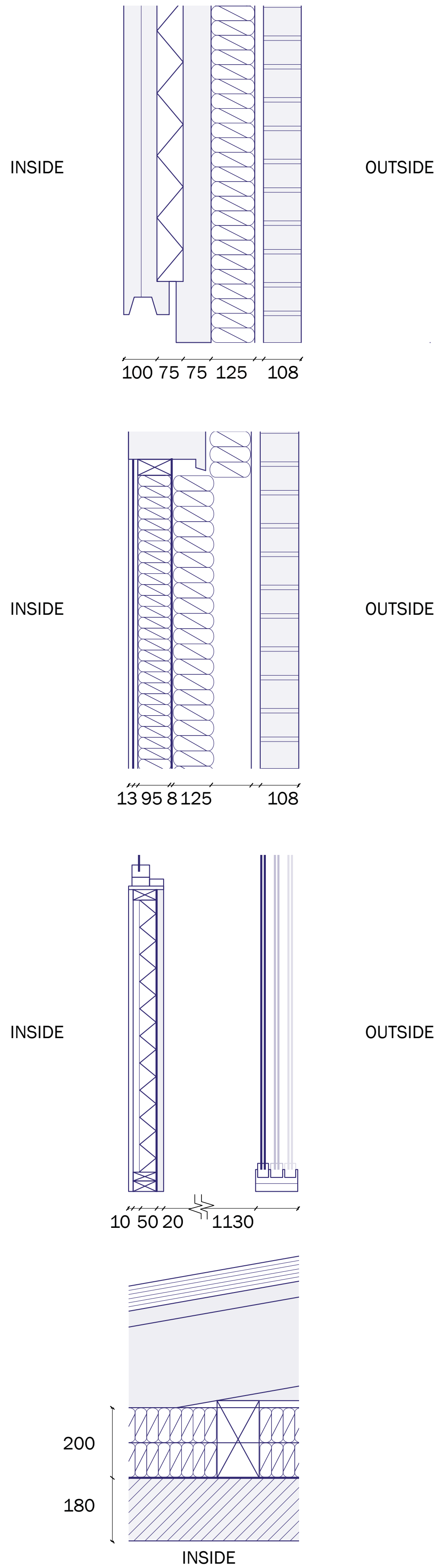
The facade can be understood as composed of two different types of build-ups since it was originally built as a horizontal stripe pattern of walls and windows. The envelope in the stripe with the concrete wall has the same solution as the one applied on the gables. But after 2000, the glazed stripe, which had 75mm of insulation was improved. The windows were reduced in size, and the area around them was replaced with gypsum followed by a vapour barrier, mineral wool, and a wind barrier board. Then, 125mm of insulation, a non-ventilated air gap, and the bricks. The U-Value is 0.16 W/m^{2}K.

Balcony

After the renovation, the balcony has been enclosed, creating a double facade. The original walls have been preserved, consisting of a gipsonite panel towards the inside, 50mm of flamingo insulation, aluminium foil and wooden lamellas. On the perimeter, the balcony has been closed with a full-height, double-layer glass sliding windows. The inner wall has 0.68 W/m^{2}K of U-value.

Roof

The roof is separated from the building by the 180mm prefabricated concrete slab, followed by 200mm of insulation and the vapour barrier. There is a big airgap created with the outside due to the wooden structure that supports the battens and the aluminium panels on the surface of the roof.



Ill.67 | Sundparken's walls and roof build-ups.

CONNECTIONS AND JOINTS

It has been mentioned that the building was built with precast concrete elements between 1968 and 72, a period affected by industrialization and fast productivity in the building environment (Engelmark, 2013). Hence, elements are precast with reinforcement in the factory and assembled on site with concrete mortar, becoming a continuous unit. The type of mortar and the inclusion of steel bars depend on the amount tension caused in the connection. In this way, the connection between a wall and the slab, two perpendicular walls or two slabs are not the same and different considerations must be taken at the time of disassembly.

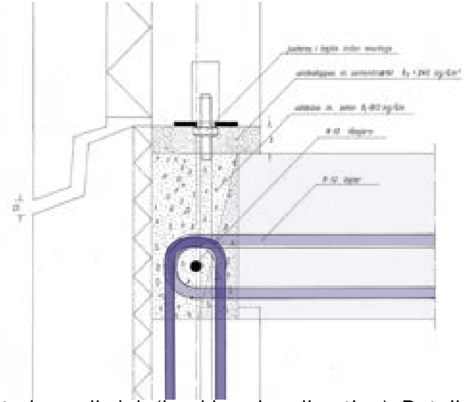
Strong joints - Gable to slab
Due to the buildings' structure, the slabs connect the loadbearing walls, leading the supporting side to meet the gable. The link is then reinforced to allow the loads to be transferred from the horizontal position to the wall. The walls and the slabs have U steel bars around a horizontal bar that runs along the connection, and the slab has a serrated edge to increase the surface contact. These are cast together with a concrete mortar and reinforced with a steel bar of 12mm diameter (Ill. 68) (Ressource blokken, 2021).

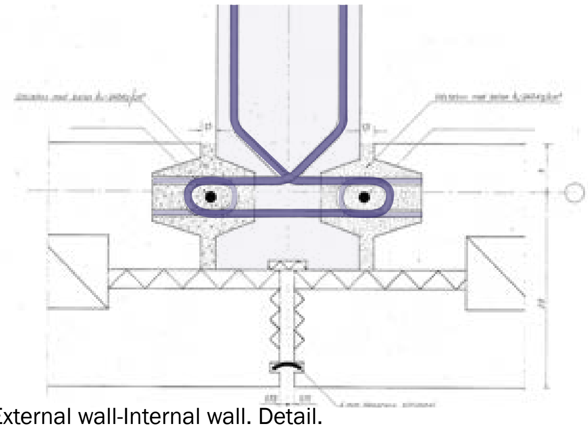
Wall to Wall
Linear, perpendicular or L shaped wall connections are solved by the reinforcement with U steel bars of 12mm cast together with 240kg/cm^2 concrete mortar (Ill. 69).

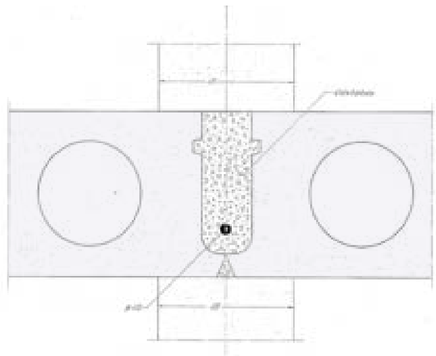
These type of strong joints can be cut apart with a concrete saw, but cutting directly through the joint should be avoided to minimize the risk of compromising the elements' performance.

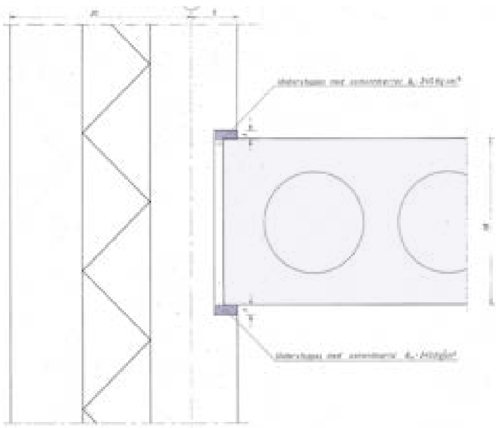
Weaker connections - Interior walls to slab
To connect the interior walls and the slabs, these are casted together with an easy-flowing concrete mortar and reinforced with a steel bar of 12mm diameter. The serrated edge of the slab in its load-bearing direction increases the surface in contact and its strenght (Ill. 70) (Munch-Petersen, 1982).

Facade to slab
Since it is not the main direction, the link is solved with 1 cm of cement mortar on the bottom and the top for sealing. The lack of concrete in this connection makes it easier to take them apart with more simple tools than a diamond concrete saw. (Ill. 71) (Munch-Petersen, 1979).


Ill.68 | Exterior wall-slab (load bearing direction). Detail.


Ill.69 | External wall-Internal wall. Detail.


Ill.70 | Interior wall-slab (non-load bearing direction). Detail.


Ill.71 | Exterior wall-slab (non-load bearing direction). Detail.

MATERIAL ATLAS

The material atlas serves as a graphical overview of the available materials when demolishing/disassembling the existing buildings in Sundparken with great care, in order to reuse as much material as possible.

Concrete elements
The concrete elements have been cast together on site, this gives some freedom in cutting them apart, since they eventually act as one continuous slab. The hollow-core floor slabs present in the building can likewise be cut apart at the seams. For the sake of building on existing constructions, and reusing the hollow-core slabs, cutting the wall elements in similar sizes to the original may be beneficial, when fitting elements together again, ensuring load distribution and spans remain comparable.
A higher level of structural integrity can be assumed when cutting the concrete in continuous blocks/rooms, as the cast joints remain in place (Heunicke et al., 2021).

Brick facade
As the brick façade was built during the renovation of the buildings in the early 2000s, it is assumed that the bricks are individually joined together with cement mortar, making it next to impossible to separate them from each other, as the joint is stronger than the bricks themselves (GXN and Responsible Assets, 2018). Because of this the bricks should instead be reused as panel elements, as mentioned in the case study for Ressourcerækkerne.

Windows and doors
As the windows were replaced in the early 2000s it is assumed that they are containing double-layer glazing, most likely not meeting the energy requirements of the current Danish Building Regulation. If the thermal glazing is good condition, it and the frames can be reused in double-stacked box windows, as described in the Up-cycle Studios case study.
Interior doors should easily be removed from the hinge and can be stored and directly reused in new buildings, requiring minor refurbishment for scuffs and marks.

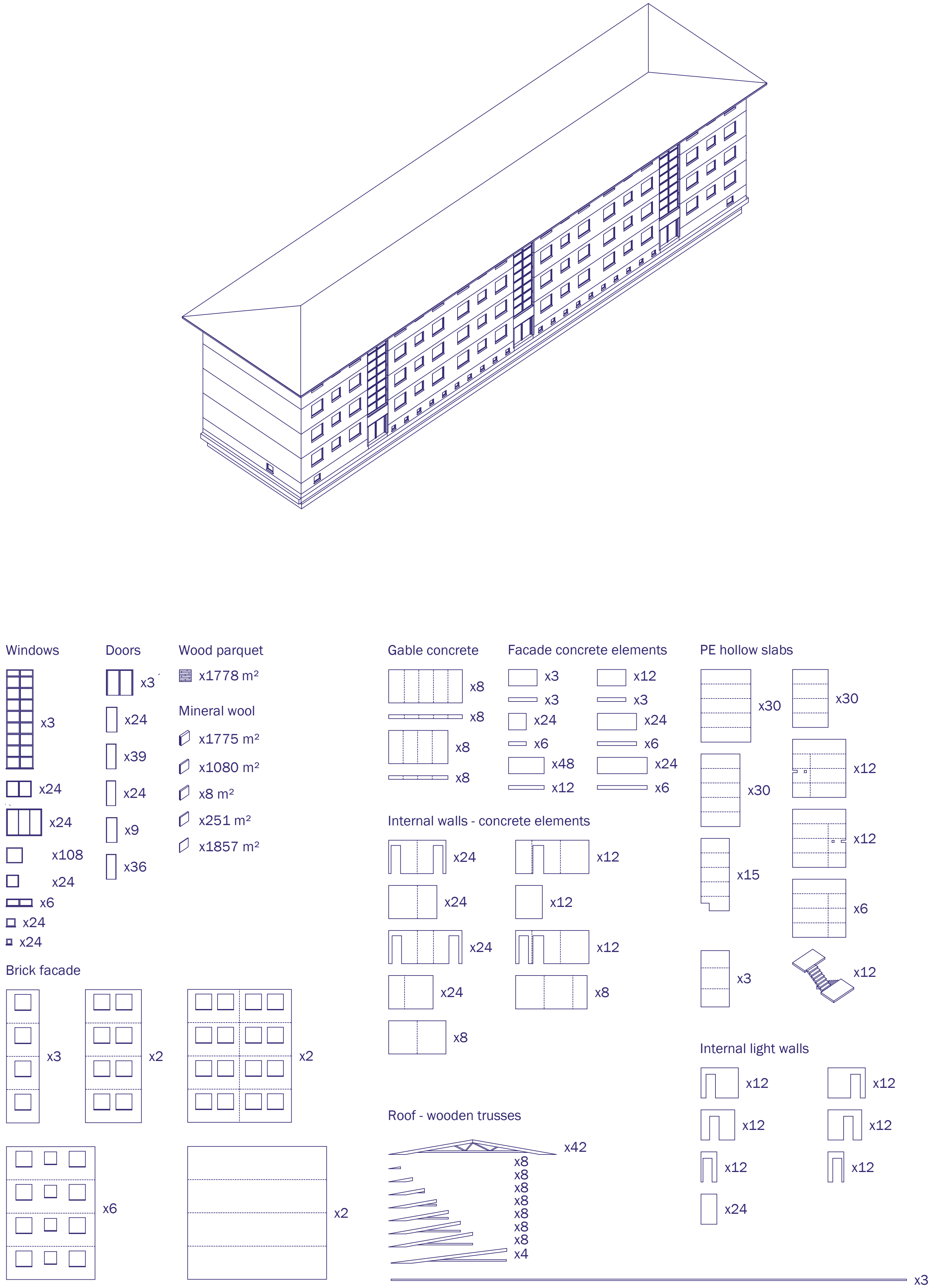
Roof
The roof cladding is made of aluminium panels which should be easily removed with simple tools by removing screws and bolts keeping it fastened to the wooden truss construction underneath. As aluminium is a durable material it should be possible to reuse the sheets for roof or façade cladding again.
The truss construction sits attached on top of a hollow-core slab and is assumed to be easily removed from it using simple tools. The trusses can either be removed as connected frames or disassembled and reused as singular elements cut to size later.

Wood parquet
The wood parquet floor is constructed on joists, meaning it should be removable by simply unscrewing the floorboards from the joists underneath. Depending on the thickness and how many times the wooden floorboards have been sanded down prior to disassembly, it could be used as a floor in new buildings again.

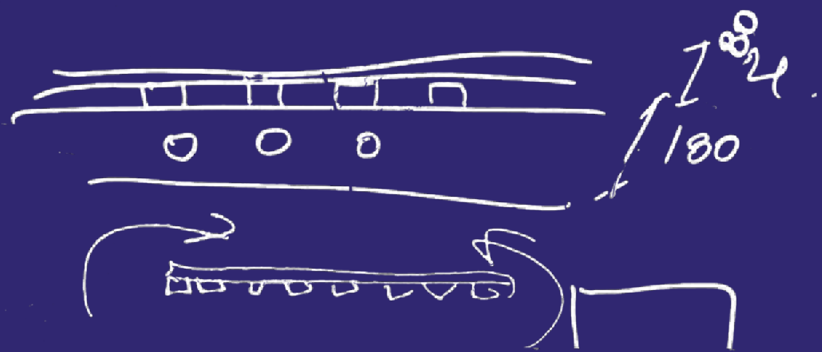
HAZARDOUS MATERIALS

When reusing materials, it is important to understand that the building, the materials and the techniques used are a product of the time it was built. This means that hazard materials that are no longer in-use could still be present in the materials which are desirable for reuse. For the existing buildings in Sundparken a general assumption of the presence of hazardous materials are based on generic assumptions from DinGeo(Boliga, no date).

The assumption is that the primary point of concern may be PCB in paint, flexible joints and insulation materials. There is a high probability of there being some presence of PCB in the paint and joints between elements and even windows used between 1950-1977 (VCOB, 2021). Any PCB in the insulation has most likely spread there through evaporation and contaminated dust from the aforementioned constructions.
As PCB is volatile material known to cause severe health problems in humans and animals, it is important it is treated to a concentration where it is more or less harmless, before it can be reused in new buildings. If the material is primarily contaminated from paint, which is assumed to be the case in Sundparken, the paint layers and part of the concrete surface can be sanded and sealed with specialized products (Golder Associates, 2021).



Ill.72 | Material atlas of a representative building. Typology 1.



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24
180

#06 LIFE-CYCLE ASSESSMENT.

EXISTING BUILDING CIRCULARITY POTENTIAL

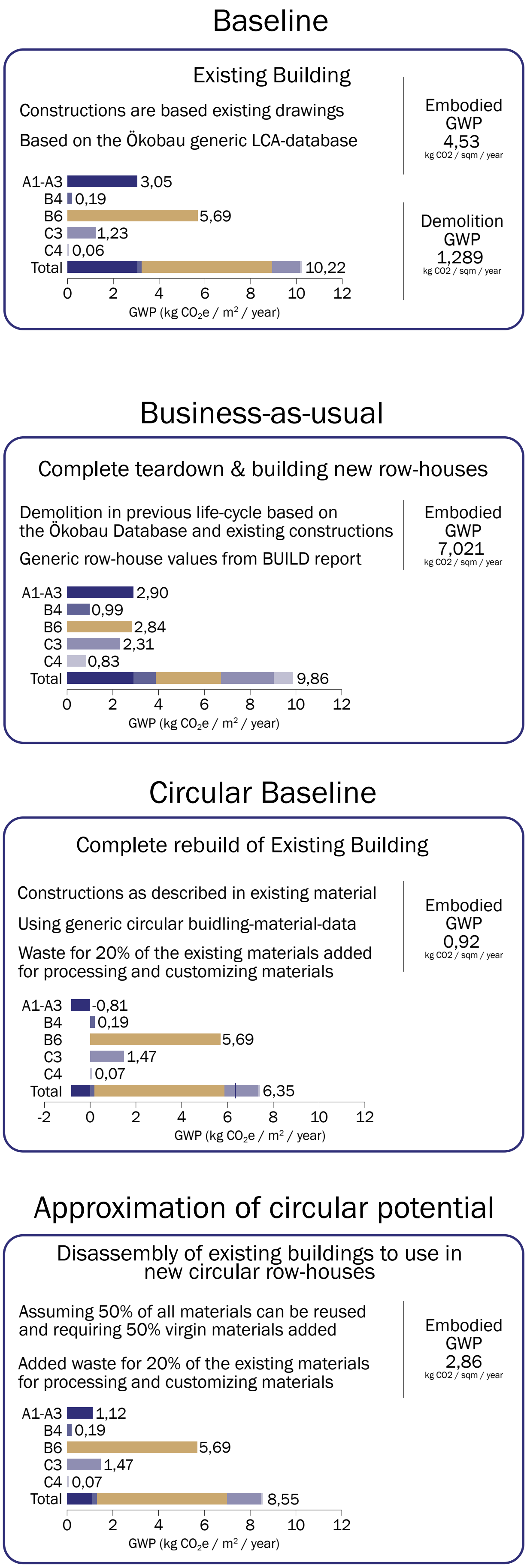
Figure xx shows the distribution of emissions of the existing case building in Sundparken as well as an average row-house based on the datasets presented in the 2021 BUILD report "Climate Impact From 60 Buildings". The multi-storey apartment building from Sundparken has a lower amount of embodied emissions compared to the average row-house, this is likely due to this building having a higher compactness than a row-house, meaning there are more square meters on which to distribute the environmental impact of the materials. On the other hand, the older constructions following less ambitious energy requirements, mean that the operational emissions from the existing buildings are significantly higher than a modern, average row-house.

The chapter of the parallel society act describes demolition as a necessary catalyst to transform these underperforming, family housing areas into areas with a higher social mix. While demolition of existing buildings is not calculated as part of the LCA for new buildings, it is still relevant to point out that 1,29 kg CO2e / m2 / year of embodied emissions are released as part of the waste processing and disposal, when not reusing or recycling any building materials at the end-of-life of the existing buildings.

The study examines the potential in environmental impact savings of reusing the building elements, according to the data from the environmental impact assessment report of the Circular Builders project (Butera, S. and Fruergaard Astrup, T., 2022), to create new row-house typologies.

The circular baseline describes a scenario in which the existing building is rebuilt assuming all possible building materials are reused following the reduction factors from the Circular Builders project report. For materials that have no reduction potential, it is applied as a new material, with no reduction. Furthermore, 20% waste of all materials is assumed, for disassembly and cutting elements to size. This scenario has 1,11 kg CO2e / m2 / year of embodied emissions, a 75,5% reduction from the original building. This is the most optimal scenario and is likely not possible in practice.

To create a more realistic scenario, this time only half of the materials are assumed to be reused while the other half will be made up of virgin materials. The building in this scenario has a total GWP of 3,05 kg CO2e / m2 / year, a reduction of 32,3% compared to



Ill.73 | Comparison of final LCA results between the baseline, business-as-usual, circular baseline and the circular building potential.

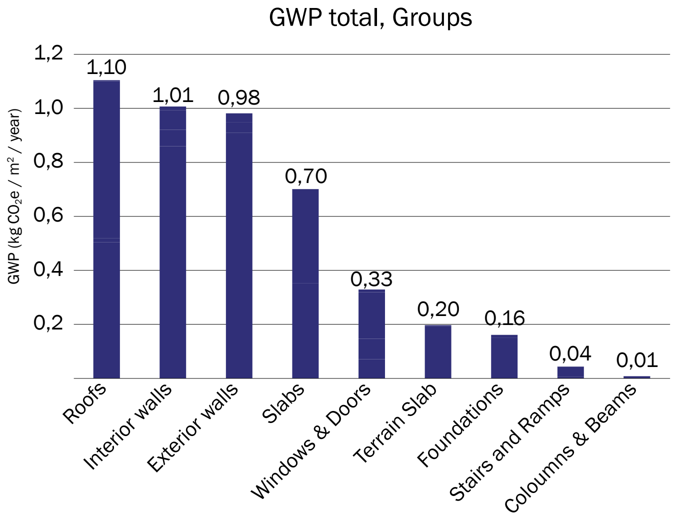
the original. Based on the case studies in this report, this is a more realistic goal and serves as a more accurate approximation of what can be expected in the final design proposal evaluation.

As figure 74 shows, the roof, interior walls and exterior walls are the three largest contributors to the embodied emissions, with the slabs following closely. This is in large part due to five main constructions in the building.

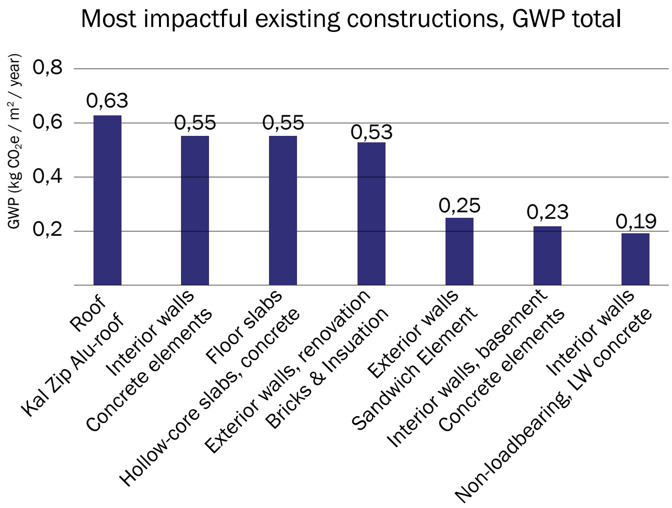
The Kalzip roof has 4mm aluminium sheets as the exterior cladding of the roof with rafters sitting directly on top of the loadbearing concrete hollow-core slab. The aluminum roof has the potential of 99% environmental impact saving, compared to virgin aluminum sheets (Butera, S. and Fruergaard Astrup, T., 2022), and as the joints are easily dismantled, the roof can be cut into sections to be used directly in new houses.

The hollow-core slabs and load-bearing inner walls can either be cut out as boxes or reused as single elements as described in the material atlas. The sandwich elements can be handled similarly. Directly reusing concrete has a 96% reduction compared to using virgin materials (ibid.).

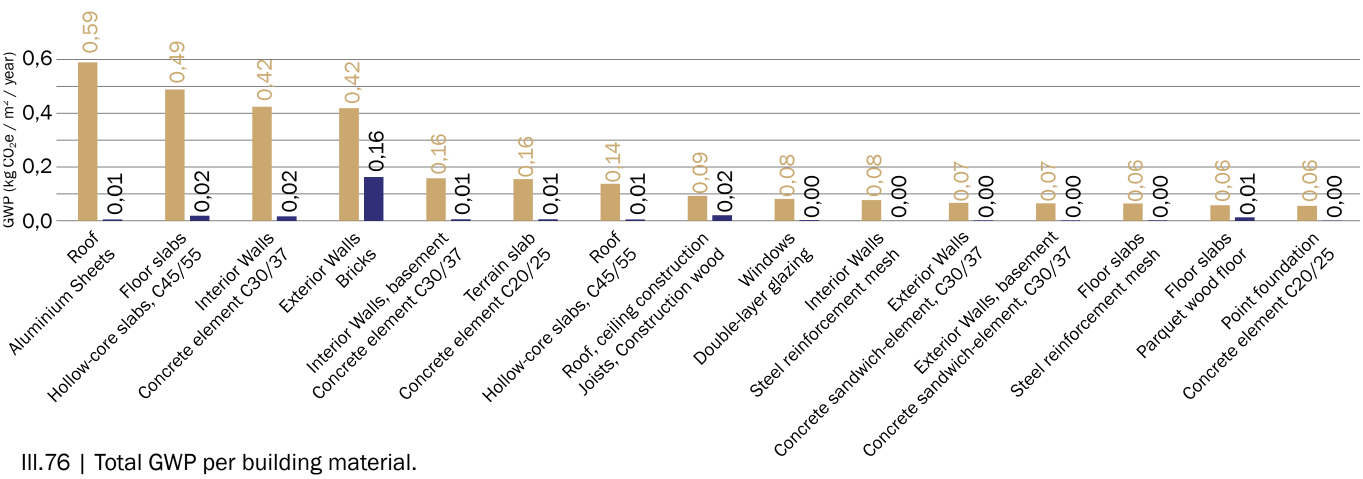
Lastly the bricks in the façade can be cut and recast into brick wall-elements with a concrete backing as described in the case study for Ressourcerækkerne. In spite of the added concrete support, the savings in embodied emissions still reach 61% (ibid.).



Ill.74 | Total GWP per group.



Ill.75 | Total GWP per construction.



Ill.76 | Total GWP per building material.

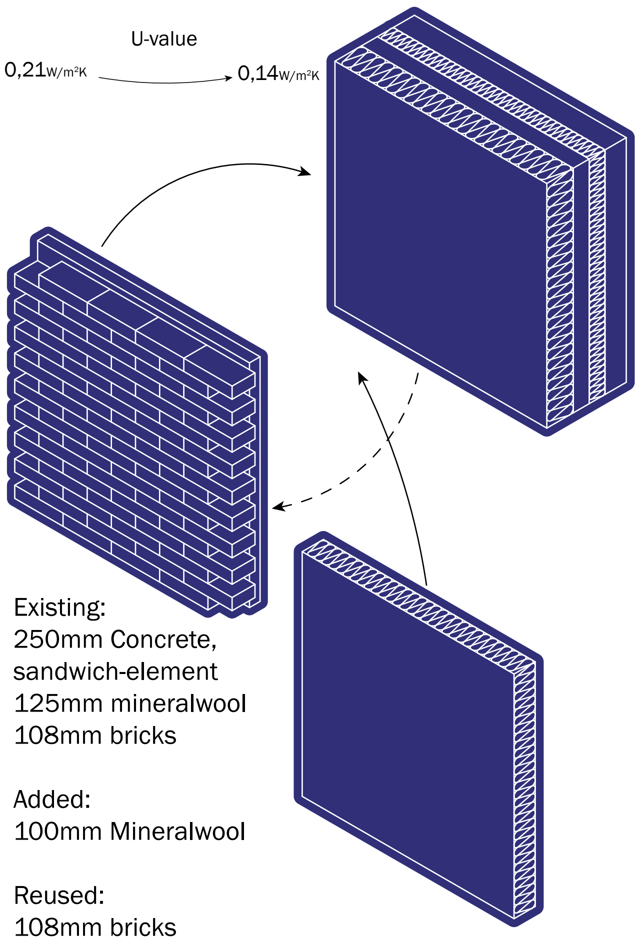
ENERGY RENOVATION OF EXISTING BUILDING CONSTRUCTIONS

Despite the existing building having a lower environmental impact from embodied emissions, compared to the average new built row-house, the existing building has a higher total environmental impact. This is due to the sizeable energy consumption for the existing buildings with an energy frame of nearly 70 kWh/m2 yearly, compared to buildings following the 2018 Building Requirement of 30 kWh/m2 yearly or lower.

As part of the renovation in the 2000s the existing 250mm concrete and EPS sandwich elements were given a new brick façade with 125mm mineral wool insulation improving the U-value of the façade from 0,58 W/m2K to 0,19 W/m2K on average. This is well withing the requirements in the Danish Building Regulation today. Furthermore, the glazing was replaced with double-layer energy glazing, assumed to be quite clear and having a g-value of 0,75 and a U-value of 1,60 W/m2K.

This study examines the viability of further energy renovation of the existing constructions, strategies that can potentially be applied later in the design processes, as the constructions should be similar.

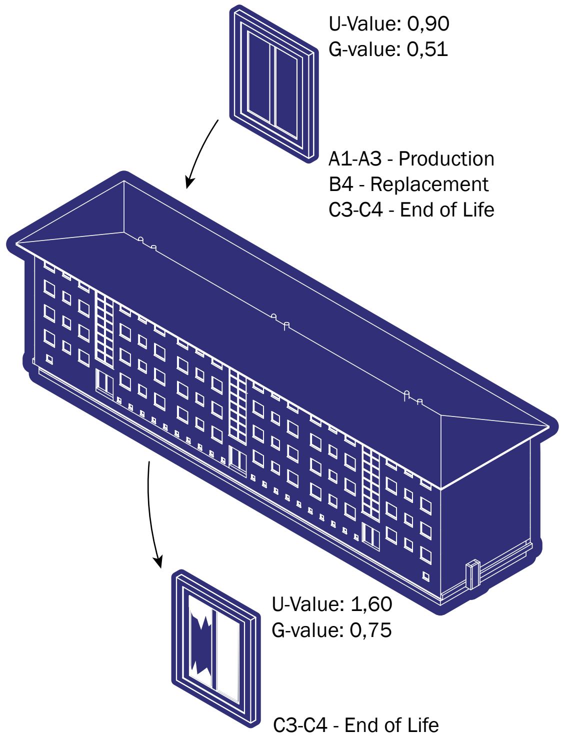
Adding 100 mm mineral wool insulation to the existing outer wall shows a 1,1% reduction in total emissions, however, because there is no leftover space between the sandwich-concrete element and the brick façade, this is not possible without removing the brick façade and putting it back. This would require cutting out the bricks and implementing a concrete (or steel) support for the brick panels, before being able to put in the insulation and put the façade back in place. Because of this, insulating the façade further actually leads to a 0,6% increase in total CO2e emissions. As such this is not a viable renovation strategy, when preserving the existing construction.



Existing Buidling		Renovation		
Embodied GWP	Operational GWP	Embodied GWP	Operational GWP	Potential reduction GWP
4,53 kg CO2 / m² / year	5,69 kg CO2 / m² / year	4,53 kg CO2 / m² / year	5,69 kg CO2 /m² / year	-0,066 kg CO2 / m² / year

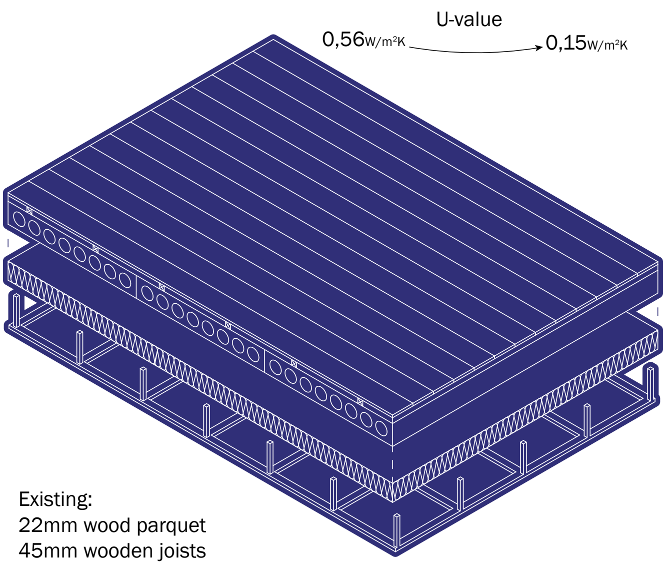
This renovation increases the total GWP by 0,6%

Ill.77 | LCA results of renovated walls.



Existing Buidling		Renovation		
Embodied	Operational	Embodied	Operational	Potential reduction
GWP	GWP	GWP	GWP	GWP
4,53	5,69	4,79	5,32	0,111
kg CO2 / m² / year	kg CO2 / m² / year	kg CO2 / m² / year	kg CO2 / m² / year	kg CO2 / m² / year

This renovation reduces the total GWP by 1,1%



Existing:
22mm wood parquet
45mm wooden joists
180mm concrete, hollow-core slab

Added: Suspended ceiling
150mm Mineralwool
Aluminium frames
Wood-concrete tiles

Existing Buidling		Renovation		
Embodied	Operational	Embodied	Operational	Potential reduction
GWP	GWP	GWP	GWP	GWP
4,53	5,69	4,59	5,14	0,493
kg CO2 / m² / year	kg CO2 / m² / year	kg CO2 / m² / year	kg CO2 / m² / year	kg CO2 / m² / year

This renovation reduces the total GWP by 4,8%

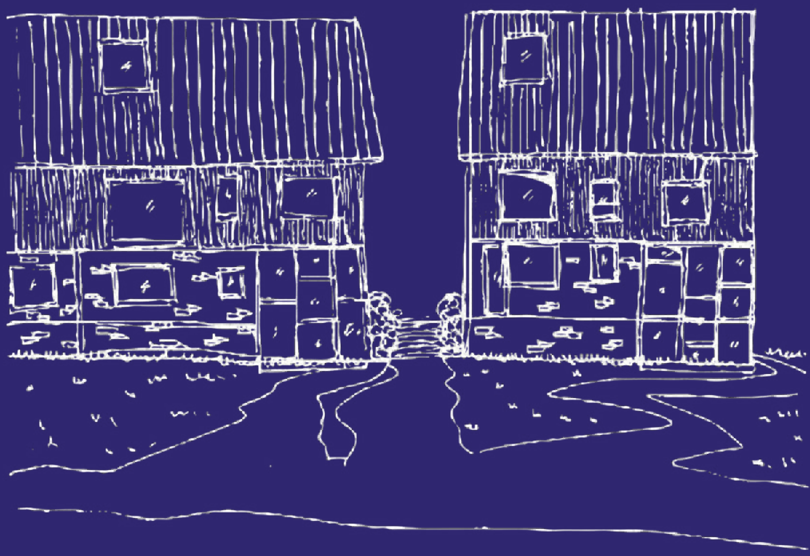
Ill.78 | LCA results of renovated windows and slabs.

Replacing the double-layer glazed windows for triple-layer-glazing gives a 1,1% overall reduction to the environmental impact of the existing buildings. Furthermore, replacing the windows in all of the existing buildings gives a significant stock of double-layered windowpanes and potentially frames, that can be reused to make double-stacked box windows, similar to the solution described in the Upcycle Studios case study.

The existing basement ceiling slab has no insulation, the construction consists of a concrete hollow-core slab with wood parquet floorboards. Even though the basement is treated as an unheated room rather than directly to the outside, the existing constructions U-value of 0,56 W/m2K leaves room for improvement. By adding 150mm mineral wool insulation in a suspended ceiling on the basement side, the U-value decreases to 0,15 and gives a total environmental impact reduction of 0,493 kg CO2e / m2 / year, a reduction of 4,8% compared to the existing conditions.


Interactive
Ground Floor
Row houses
Shopping
Rema 1000
365

#07 | CONCEPT.



VISION

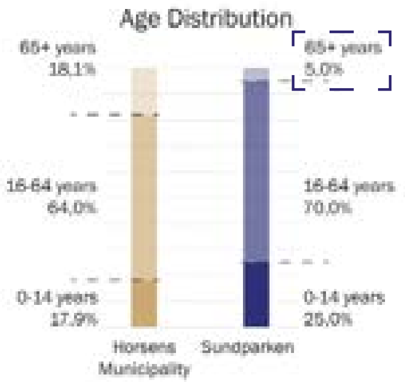
Sundparken is a well-functioning social housing area, with a low crime-rate and a high degree of satisfaction from the residents living there. The area includes Sundparkhallen, a popular informal sports hall with an existing community of children and adolescents from Sundparken and its surrounding neighbourhoods. Furthermore, the focus on providing high quality social work for the children and parents in the neighbourhood, is showing a small positive development in salary and education for the residents since 2018 (Landsbyggefonden, 2020c).

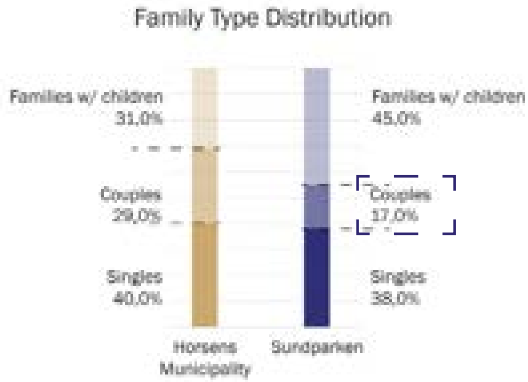
The vision for the project is to contribute constructively to the ongoing social development in Sundparken, by mixing the existing residents with people from outside the area, who have a stronger educational background and a solid position in the job market (Landsbyggefonden, 2020b). Creating this type of social mix will bring people to the area with a more comfortable excess of spare time and willingness to help and interact with current residents, while being positive role models for adolescents and adults alike.

Physically, the area could benefit from a higher degree of permeability, as the long block in the neighbourhood create an enclosed environment on themselves. This would provide the area with longer views towards the nearby nature. Especially towards the south, since opening up the blocks, would allow people and sunlight through the spaces between the blocks.

The transformation should aim to demolish few buildings, as the current residents are happy for their homes and in part to the local community present in Sundparken, focusing instead on preserving structures while both supporting existing functions and creating opportunities for new functions to thrive and contribute positively to the neighbourhood in which they are located.

USERGROUP ANALYSIS





Ill.79 | Demographic of Sundparken's and Horsens Municipality's residents, 2018. Source(s): Omdannelsesområderne på vej (2022); DST - Danmarks Statistik

One of the social sustainability challenges is, as described in the theoretical framework, The difference in age and family type distribution between Sundparken and the average within Horsens municipality.

Changing the residential mix is the primary reason for reducing the percentage of social family housing. A strategy that could be used to comply with the parallel society act, would be to mirror the age and family type distribution within Sundparken with Horsens municipality.

As seen on the illustration above, from the chapter on social sustainability challenges, only 5% of the residents in Sundparken are 65 years or older. This is significantly lower than the municipal average of 18,1%. The percentage of couples is also noticeably lower, sitting at 17% compared to the municipal average of 29%.

When reducing the percentage of social family housing, new typologies will have to be introduced. The transformation of Sundparken should integrate it better with the municipality as a whole. It thus makes sense to strive for an age and family type distribution that matches the municipality more closely.

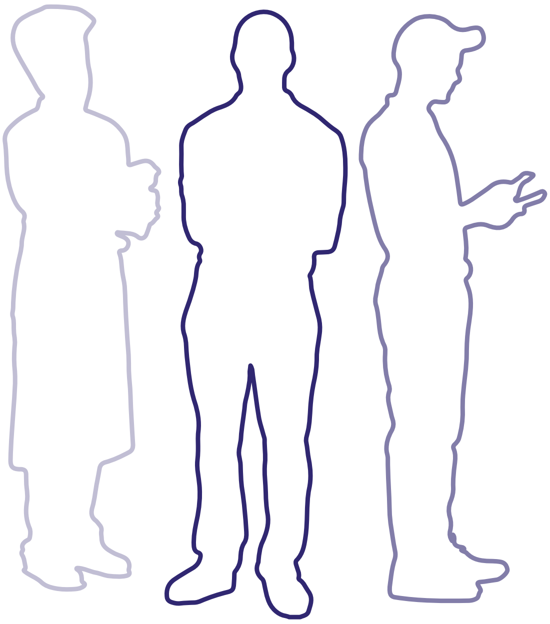
An additional argument for putting focus on the age distribution is that the number of children and youths has been decreasing. A woman in 1960 has on average 2,6 children. Today that number is down to 1,7. This is resulting in an increased percentage of people above the age of 65, a total of 250.000 people since 2008. A percentage increase of 31% (Realdania, 2021). This and the increased average life expectancy means that a considerate large part of the Danish housing market will consist of seniors in the near future.

40% of all single-family houses are currently inhabited by empty-nesters, ageing baby-boomers where their kids moved out long ago.

This is especially relevant in Horsens since the area around Sundparken is predominantly single-family houses on individual plots, this can be seen on the map of Horsens in the chapter on Urban surroundings. These houses are typically large with big gardens, which require a lot of maintenance, which over time may become a burden to the elderly residents (Realdania, 2021).

The reduction of social family housing is not purely to change the residential mix, the parallel society acts strive to attract resourceful residents with a strong income. Thus, improving the neighborhood's statistics. Attracting well-established high-income families can be hard due to the fact that they typically already own a home, so their criteria for moving can be hard to meet, first time buyers might be the perfect fit.

To transform Sundparken into a socially sustainable neighborhood, The design proposal should accommodate users such as first-time buyers and elderly couples since they bring the desired change in the residential mix.



Ill.80 | Local businesses user group

THE LOCAL BUSINESSES:

The analysis of the existing commercial district pointed out how the small local stores might struggle in the future after Rema 1000 relocates.

The reason why this could be problematic is the reduction in foot traffic and since the commercial district is a great area for social interactions to occur, it would be beneficial from a social sustainability standpoint to ensure that the local businesses thrive.

The designers should for this reason consider their demands carefully.

The stores will typically benefit by being in proximity to a high-traffic node. This is what Rema currently is providing.

People from outside the area can be essential for the growth of a business. Car Parking should therefore be in close proximity.

The commercial district consists, as previously mentioned, of different types of stores. The ones working with food such as the Pizzaria and the butcher will require a back end and a larger service area, while the other stores can be serviced from the front.

DEMANDS:

1. High foot-traffic:
More people results in more customers and higher sales.

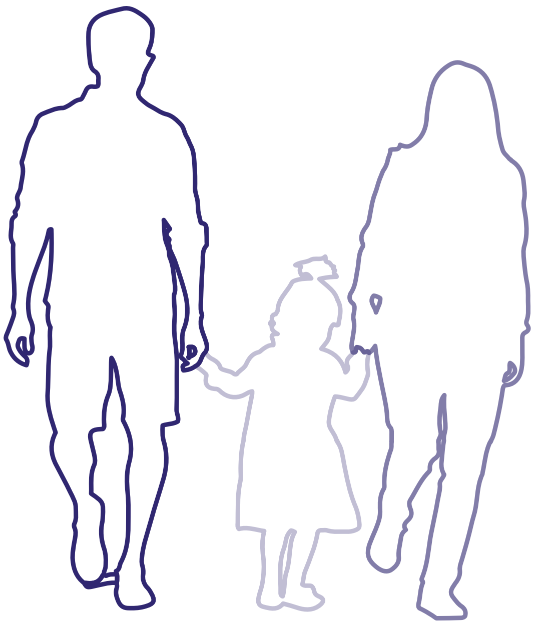
2. Back-end service area
The pizzeria and Butcher require a larger service area since their garbage disposal takes up a lot of space.

3. Commercial parking:
Visitors and customers should be able to park at a reasonable distance from the stores since the area is located far away from Horsens center.

WISHES:

1. Additional activities:
Having additional activities can be a great benefit. The adults can do their chores while their children play within eyesight.

USER GROUP



Ill.81 | First time buyer user group

FIRST TIME BUYERS:

The reduction of social family housing is not purely to change the residential mix, the parallel society acts strive to attract resourceful residents with a strong income. Thus, improving the neighborhood's statistics. Attracting well-established high-income families can be hard due to the fact that they typically already own a home, so their criteria for moving can be hard to meet. First time buyers could however be a great addition to the neighborhood. They are typically young couples who recently finished their education, entered the workforce and are looking to replace their student apartment with a bigger home with room enough to live and expand their family.

In a questionnaire conducted by YouGov the participants were asked which form of housing they in general believed would have the most child-friendly environment to raise children in.

An overwhelming 43% answered; a house with its own garden in a smaller city and 14% answered; a house with its own garden in a bigger city.

The transformation of Sundparken has to attract these first-time buyers and to do this the area has to comply with their idea of a family home. In this regard the design must implement private gardens.

DEMANDS:

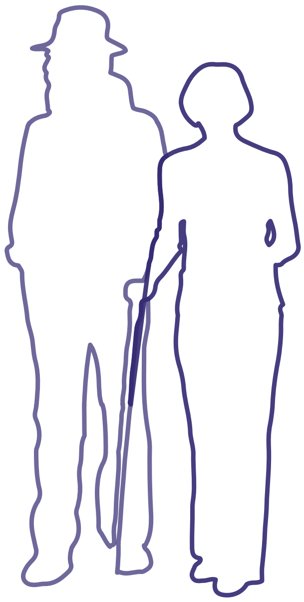
1. Private gardens:
Fulfilling the idea of a child-friendly home environment.

2. Three bedrooms:
A master bedroom, a children's bedroom and an extra room for either an additional child or office space.

3. Kitchen-dining area:
It has become a most have in Danish culture and to do without it would lower the marketability of the home.

WISHES:

1. Private parking:
A young couple with a child would typically love this luxury. It makes it easier to get the groceries and all the necessary baby equipment in and out of the car



Ill.82 | Elderly couple user group

ELDERLY COUPLES:

It is a great benefit to add Senior apartments for elderly couples to Sundparken since it improves both the age and the family type distribution making Sundparken a better reflection of Horsens, while introducing many positive qualities to the area. The older generation typically acts as role models, where younger people can seek guidance. They also stimulate local businesses during normal working hours and can help the local community with childcare and volunteer work. (Find source)

Data from Denmark's Statistics shows that the number of people above 65 years old has increased with more than 250.000 people. This equates to a percentage increase of 31%, while the rest of the population only grew by 1%. This and the increased average life expectancy means that a considerate large part of the Danish housing market will consist of seniors in the near future.

40 percent of all single-family homes are already occupied by emptynesters: Aging babyboomers, that live in homes where their children moved out long ago. These houses are typically large with their own gardens, which require care and maintenance, that over time may become a burden to its elderly residents. Especially if a spouse passes away (boliglaboratorium).

At some point these emptynesters will want to move to a home that better suits their new needs. The transformation of Sundparken can hopefully help alleviate the situation.

DEMANDS:

1. Single-storey:
Internal staircases can with time become a burden on the residents.

2. Accessible:
Seniors are typically self-sufficient, but with time some will experience a decreased range of movement.

3. Exterior access:
Many seniors are used to having their own gardens where they can enjoy the outside and participate in gardening work. A larger percentage of seniors are also smokers and access to the outside via a balcony would make that easier to deal with.

WISHES:

1. Kitchen-dining area:
Its important for seniors to be able to have guests over. Especially their grandchildren and their kids. A functional kitchen dining area will most likely be at the heart of this activity.

PROJECT GOALS

1.

Change to preserve

Transform Sundparken into a socially and environmentally sustainable neighbourhood to help the residents and the area get off the Parallel Society list.

2.

Comply with the Government's reduction demand

Reduce the percentage of social family housing from 86,67% to 60%.

3.

Preserve as much as possible

To comply with the low CO_2e- emission frame set for 2029 achieving a GWP of 5kg CO_2e-/m2/yr established by the government.

DESIGN CRITERIA

01 Create a new commercial district in relation to the convenience stores to act as a catalyst for social interaction between residents and visitors.

02 Reconfigure the existing plans to accommodate new functions such as commercial, student, senior and private housing.

03 Improve indoor environmental quality and well-being

04 Recycle and reuse materials from the existing building blocks to minimize the use of virgin materials.

05 Decarbonize energy mix by introducing active strategies to reduce operational CO2e emissions.

06 New buildings must be designed for disassembly to extend the lifespan of the individual elements further than the buildings own lifespan.

DESIGN CRITERIA /

DESIGN STRATEGIES

MASTERPLAN SCALE

01 → **01** Ensure commercial growth and encourage social interaction between residents and visitors **by relocating commercial functions in a pedestrian circulated area and additon of library**

01 → **02** Provide diversity and a suitable environment for each user group **by organizing the new area in three main zones respectively for elderly residents, families, and businesses**

01 → **03** Prioritize pedestrians over vehicles **by making active outdoor spaces for them to traverse the neighborhood**

03 → **04** Provide outdoor areas with direct sunlight **by liming the height of the S-N oriented buildings**

04 → **05** Avoid demolition as much as possible **by combining strategies for building adaptation and disassembly**

04 → **06** Save CO_2e emissions and materials **by reusing existing foundations and basement**

BUILDING SCALE

02 → **07** Accommodate the individual needs of the user group **by providing row-housing units of different sizes**

02 → **08** Ensure the structural capacity of the floor-slab and the foundation **by placing heavy elements of the row-houses on top of the existing load-bearing lines**

04 → **09** Lower the project's carbon footprint **by maximizing the reuse of rooms, elements and materials disassembled from the existing buildings**

03 → **10** Improve daylight quality **by adjusting existing facade openings**

05 → **11** Reduce the operational emissions **by adding solar panels**

DETAIL SCALE

03 → **12** Improve overall energy performance **by optimizing transmission losses in the preserved structure and buildups**

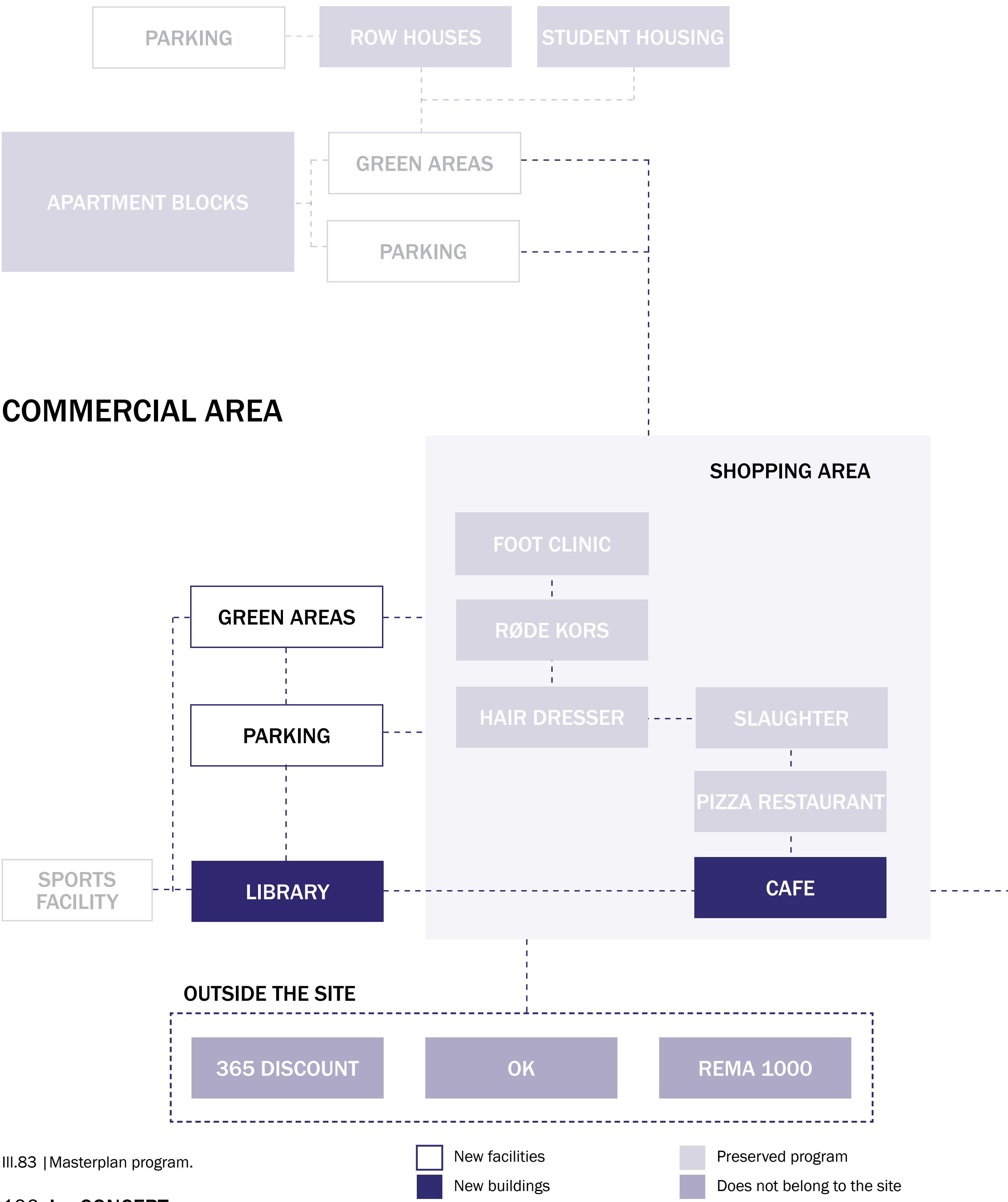
06 → **13** Ease end-of-life disassembly **by designing reversible joints**

06 → **14** Ensure reusability **by introducing enduring materials with a low GWP**

PROGRAM

PRESERVED RESIDENTIAL AREA

COMMERCIAL AREA



Ill.83 | Masterplan program.

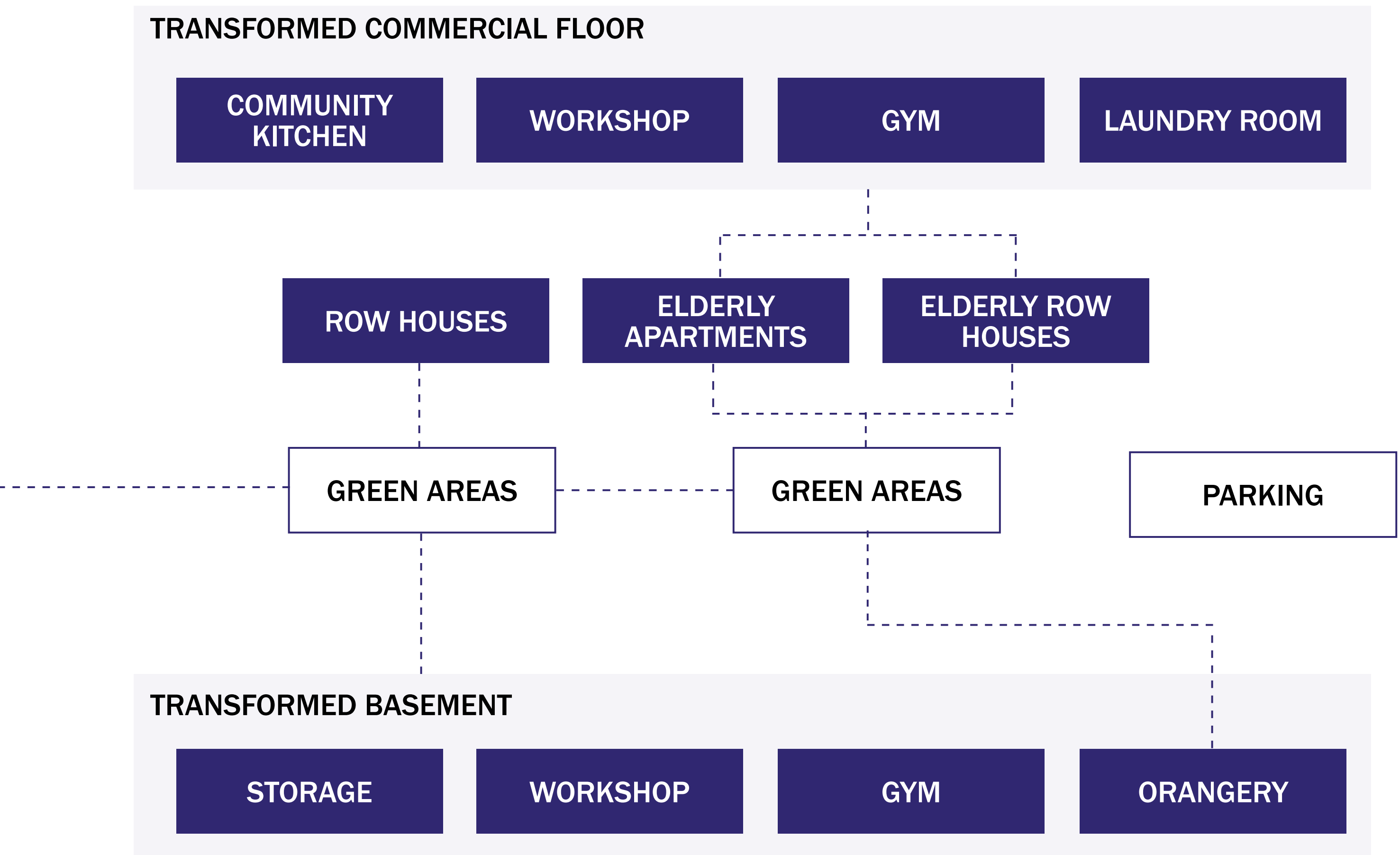
The new proposal for Sundparken is mostly focused in the areas on the south that according to the previous studies are less functioning (See Sundparken Chapter). The area in the north should therefore be preserved as much as possible (Ill. 83).

In order to bring more unity to the site, the commercial area serves as an activated connecting point between the residential blocks and the new houses (Ill. 84, with the intention to become a gathering social point. To encourage the rise of educational levels, this one should be complemented with facilities such as a small coffee place and a library where families have a place where to take their children and do some after school reading activities and students can meet as well. The sports court should be preserved in order to reinforce the quality of a gathering place. In addition, the commercial area should be better connected to existing supermarkets adjacent to the site where residents do their grocery shopping.

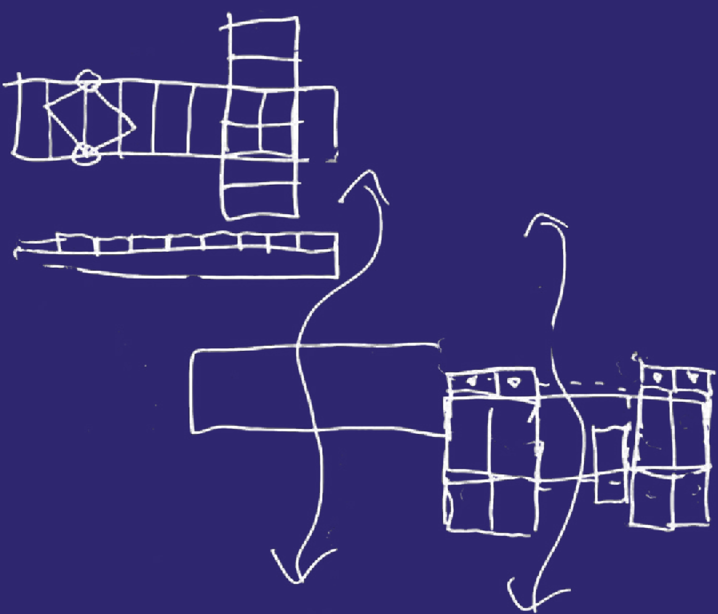
The access to the commercial spot is through connecting paths in the green areas on each residential area.

Regarding the new residential area, to achieve the percentage required by the government, new row houses for property owner families and the elderly should replace the family apartments. There should also be elderly apartments, consisting of the transformation of an existing block. To reduce the CO_2e- emissions, the space occupied by the present basement and the evicted commercial floor in one of the blocks should be transformed. The new purpose should function as common facilities, contributing to the residents health and well-being. The elderly apartments should then supplied with a gym, a multi-purpose workshop for indoor recreative activities, a community kitchen and a laundry room. The row houses basement should be replaced by useful unheated room, such storage, a workshop, a gym, and orangery or bycicle and mobility scooter parking.

NEW RESIDENTIAL AREA

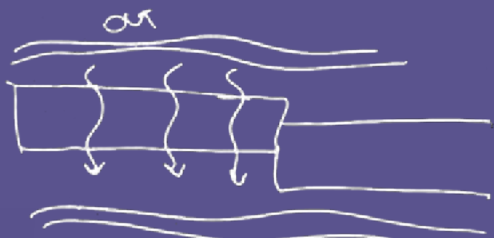


Ill.84 | Masterplan program in new residencial area.



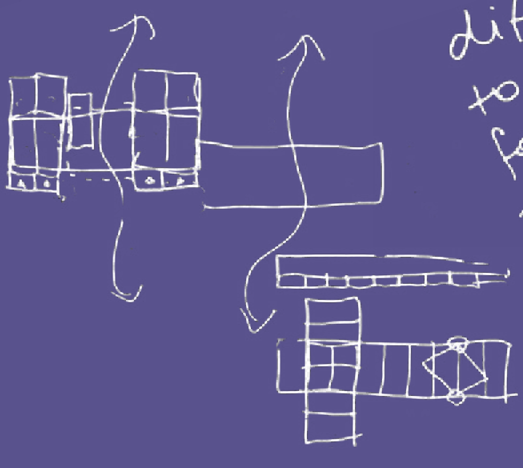
#05 | DESIGN PROCESS.

DATA PROCESSING

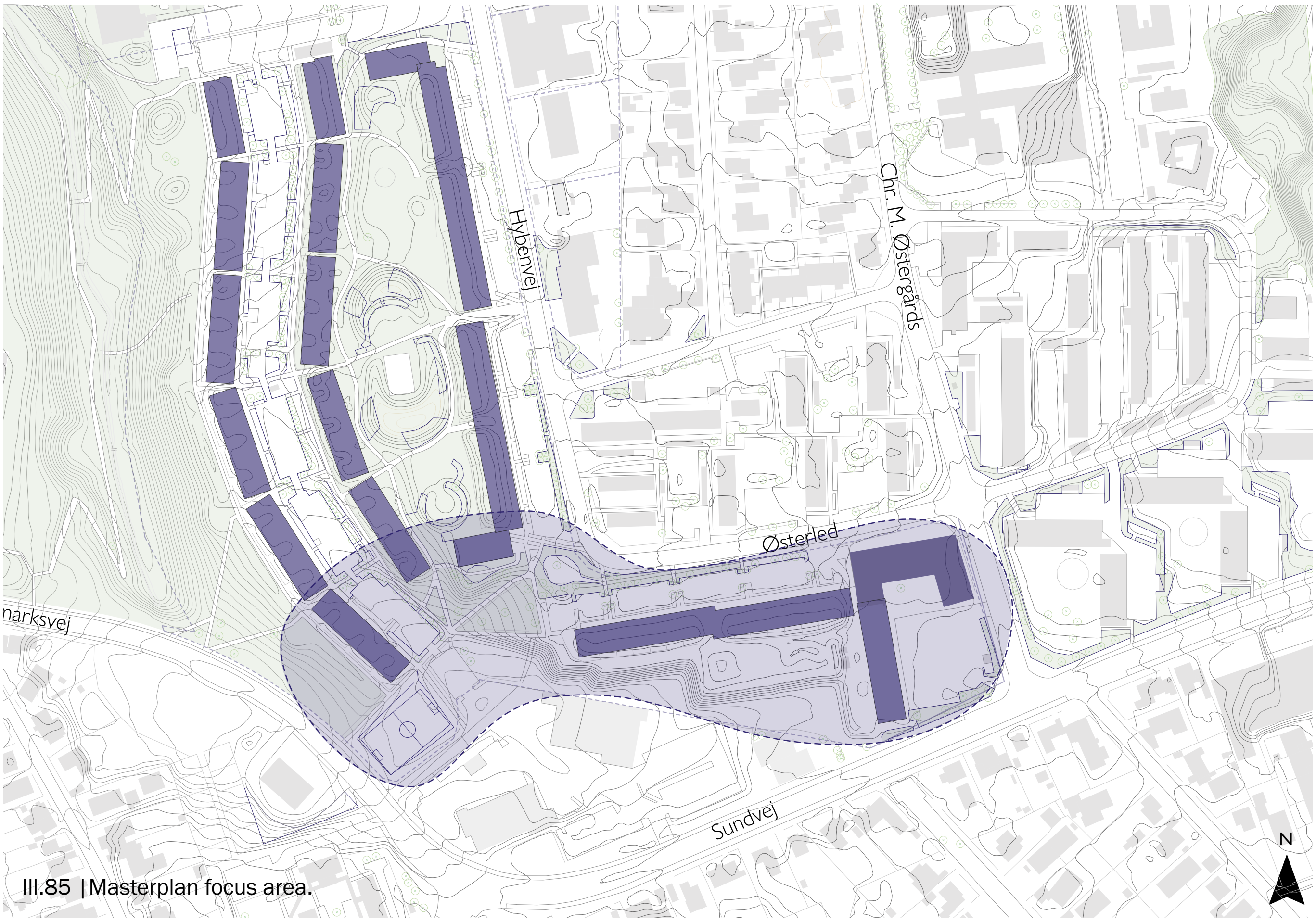


walk through, it's not it's own go around, shorter ways, access commercial area, slows down the pace, reasons to stop

different routes, things to look out, opportunities for interaction, it's part of the city, it's not secluded



THE MASTERPLAN



Ill.85 | Masterplan focus area.

The previous desk study (see sub-chapter: Conclusions on Sundparken) lead to focus the masterplan investigations on the southern area of the site. In the masterplan it is important to define how to comply with the required reduction percentage, what to demolish and what to transform. How to reach the potentials of the recycled elements and provide a high-quality environment that provides a healthy socially balanced life. The criteria named below rules the different studies in this chapter.

MASTERPLAN SCALE / DESIGN CRITERIA

01 Ensure commercial growth and encourage social interaction between residents and visitors **by relocating commercial functions in a pedestrian circulated area and addition of library**

02 Provide diversity and a suitable environment for each user group **by organizing the new area in three main zones respectively for elderly residents, families, and businesses**

03 Prioritize pedestrians over vehicles **by making active outdoor spaces for them to traverse the neighborhood**

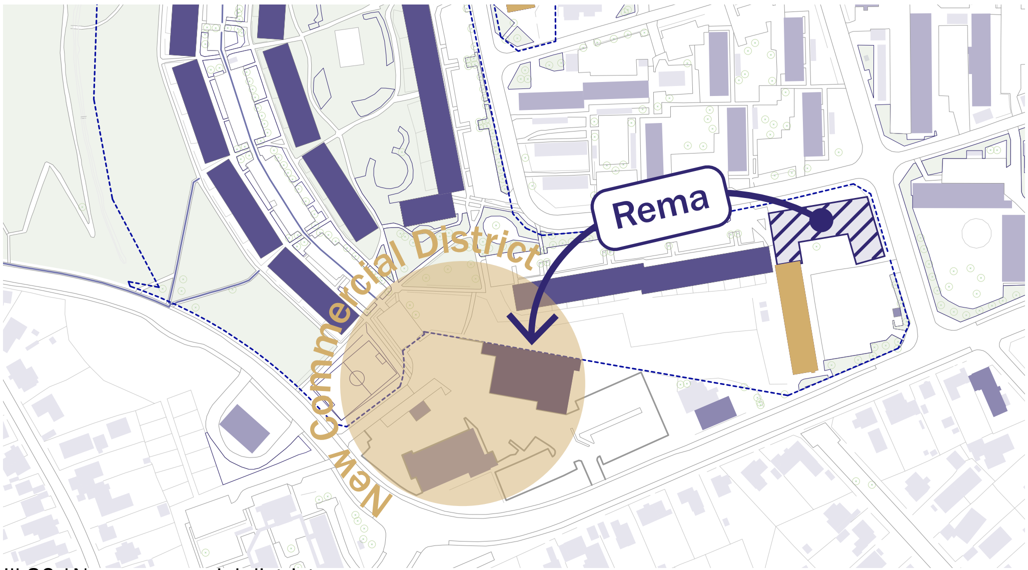
04 Provide outdoor areas with direct sunlight **by liming the height of the S-N oriented buildings**

05 Avoid demolition as much as possible **by combining strategies for building adaptation and disassembly**

06 Save CO_2e emissions and materials **by reusing existing foundations and basement**

MASTER PLAN ZONING

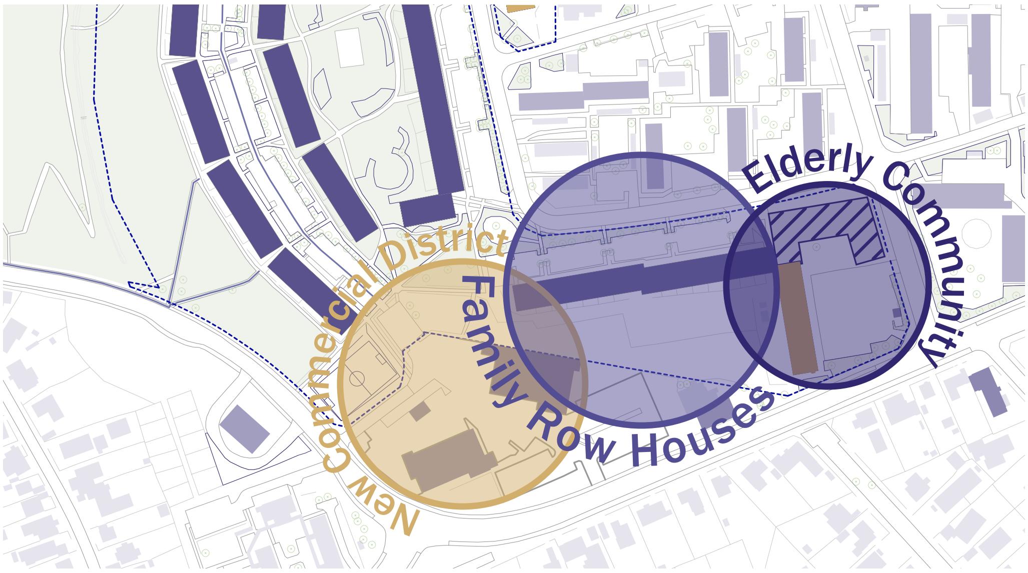
01 Ensure commercial growth and encourage social interaction between residents and visitors **by relocating commercial functions in a pedestrian circulated area and addition of library**



Ill.86 | New commercial district area

Rema 1000 is moving to the old Aldi building. This will reduce the foot traffic to the current shopping district, and it is believed that this will have negative consequences for the smaller stores. The commercial functions should therefore be relocated to an area that can ensure commercial growth and social interaction. The proposed new location is the area next to the football field. The small stores will at this location be in close connection with the two convenience stores, while placing it between Sundparkens main body and the A blocks. The new commercial area is supposed to be a central social gathering spot, that can connect all of Sundparken and Horsens..

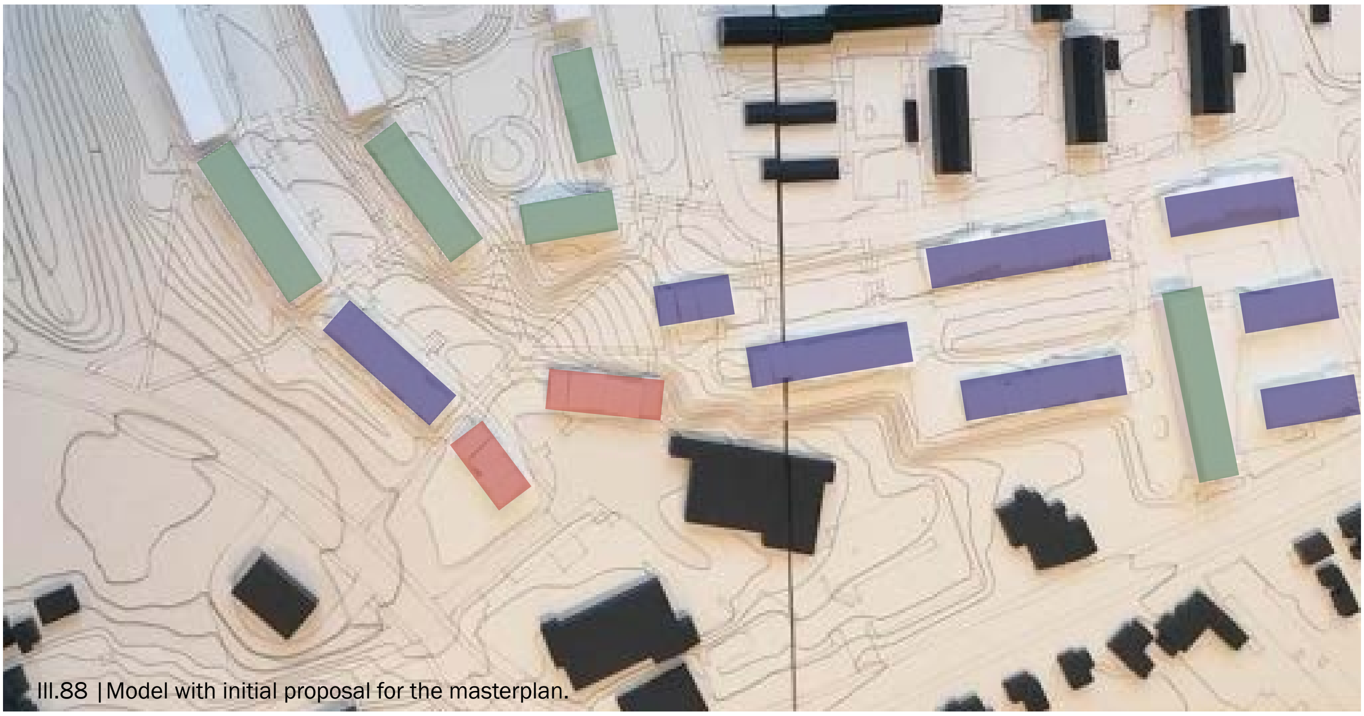
02 Provide diversity and a suitable environment for each user group **by organizing the new area in three main zones respectively for elderly residents, families, and businesses**



Ill.87 | Masterplan zoning of the focus area

The Transformation of Sundparken will provide a suitable area for local businesses in the new commercial district located next to the new Rema and the 365 Discount. The old area will be converted into an elderly living community, since the existing A2 block is ideal for reconfiguration due to its apartments sizes and it being accessible thanks to its elevator. The area between these two will be used for the construction of new family row houses where the current A1 block is located. This block will be strategically disassembled, and its parts will be reused in the new constructions.

MASTERPLAN INITIAL DESIGN



Ill.88 | Model with initial proposal for the masterplan.

INITIAL DESIGN:

The initial design implemented three significant design principles based on the theoretical framework and site analysis. The proposal is visualized on the illustration above. The new row houses are marked in blue, reconfigured blocks in green and commercial functions in red.

Firstly, it relocated the commercial district to what currently is the parking lot next to the football field. that helped guide the design iterations that followed. This gives the shops a direct connection to the convivence stores and great access to the outdoor activities.

Secondly, it implemented the idea of converting some of the existing blocks from family housing to other functions such as elderly apartments.

Thirdly, the orientation of the new row houses faced the same way as the old blocks, allowing some of the existing foundation to be reused.

Critique

The new placement of the commercial district was, according to the external supervision, a suitable placement that could benefit both the current convenience stores and the shopping district as a whole. It was however crucial that people would have more reasons than shopping to interact with the area. This could be to create a meaningful connection to the green areas and add functions that people could use independently from the shops, such as common facilities or maybe a library.

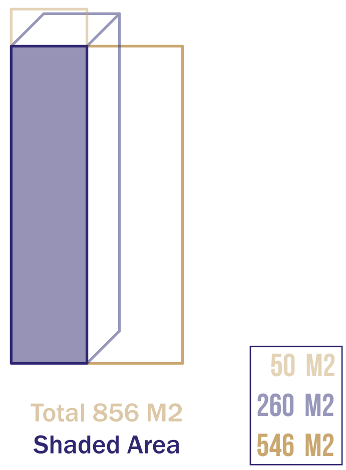
The decision to place the new buildings with the same orientation as in the original design can be strong, since the block placements follow the surrounding landscape quite beautifully, but it is very important than the new design doesn't redo the same mistakes as the original. The horizontal placement on the masterplan can create a long barrier, which would make it hard to connect the area with the surrounding neighborhood. The supervisors proposed different orientations that would allow for more openings along the main road.

An additional remark on the orientation was that most people work from 8 to 16 and would therefore not be home during the middle of the day. Since the buildings orientate themselves to the south, the residents wouldn't be able to enjoy the sun during the afternoon. A Southwest or a western orientation was therefore proposed.

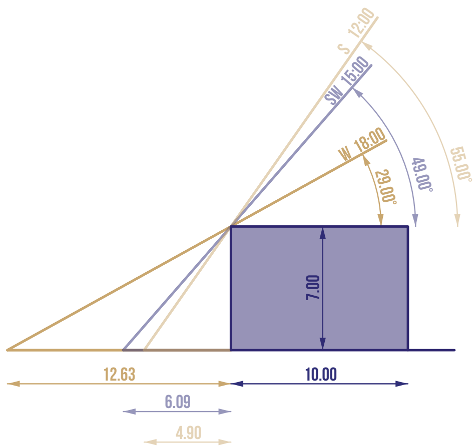
ORIENTATION STUDY

Too decide on which building orientation to work with a simple shadow study was conducted on a simle volume with 40 meters length, 10 meters width and 7 meters tall. Since people are home primarily in the evening hours, the study looked into the shadow area that the volume would cast at three different times during the summer solstice. At 12:00 from the south, 15:00 from southwest and at 18:00 from the west. The shadow areas from the three different times would then be totaled to find the orientation which produced the least amound of shaded area.

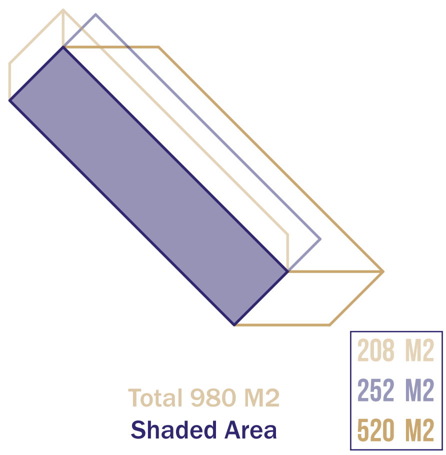
The different angles of the sun during the different times of day are visualized on illustration 89.



Ill.90 | Shaded are of East-West oriented building



Ill.89 | Different angles of the sun along the day during summer



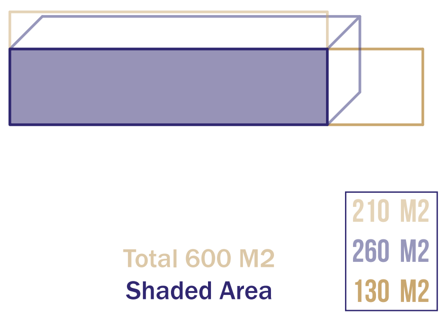
Ill.XX | Shaded are of NE-SW oriented building

Conclusion
The orientation which creates the smallest shaded area during the evening is the south orientation. It only creates a total of 600 m2 of shade, wich is significantly lower compared with the others.

This is the same orientation that the old A1 block used, which was critised in the original sunlight anlysis of Sundparkens current conditions. The reason why it is no longer a problem in this iteration is due to the two-floor reduction that lowered the building height.

The south orientation also allows the builings to be placed closer to eachother since the lenght of the shadow from the south is the shortest.

Consequently, the chosen orientation is north-south, which is beneficial for reusing the foundation as well.



Ill.91 | Shaded are of North-South oriented building

VOLUME PLACEMENT STUDY

1. Teardown of 121 units and 0 conversion

Required new row houses: 64 units
Commercial: 24 units (current number)

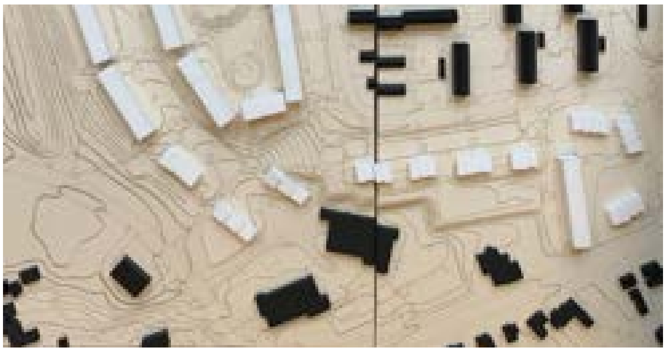
This proposal is close to the current development plan, where conversion isn't included. This plan tears down the A1 block (64 units), the A2 block (33 units) and one the C6 block aswell (24 units).

Ill.92 | Iteration 01. Teardown of 121 units and no

2. Teardown of 88 units and 33 conversion

Required new row houses: 31 units
Commercial: 24 units (current number)

Tearing down has a high Global warming potential and should therefore be used as little as possible. This proposal introduces the conversion of the A2 block into elderly apartments, thus reducing the amount of tear down and global warming potential.



Ill.93 | Iteration 02. Teardown of 88 units and conversion of 33.

3. Teardown of 64 units and 33 conversion

Required new row houses: 71 units
Commercial: 24 units (current number)

This proposal lowers the number of tear down even further. Now it is onlt the A1 block that gets torn down. This will however require the new conctruction of a total of 71 new row house units. This will make the area too compact.

Ill.94 | Iteration 03. Teardown of 64 units and conversion of 33.

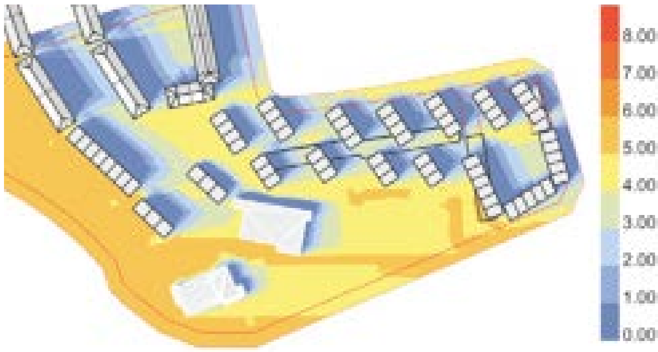
4. Teardown of 88 units and 33 conversion

Required new row houses: 43 units
Commercial: 12 units (Rema leaving)

Rema takes up half of the commercial units and will be leaving the site. The number of commercial units is thus halved and an aditional 12 new row house units most be constructed to replace them. The small D block is getting torn down in this proposal, but conversion could be considered instead.

Ill.95 | Iteration 04. Teardown of 88 units and conversion of 33.

The solar analysis on this proposal clearly shows how the south western orientation casts long shadows on the outdoor areas during the evening hours. The courtyard does however recieve decent sun light, but this is due to the lower building height, since the A2 block is torn down in this variation.

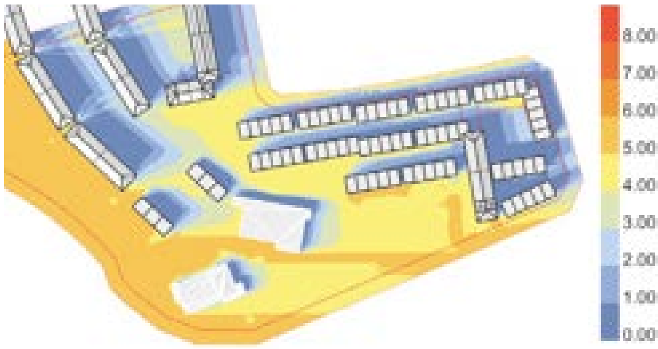


Ill.96 | Iteration 01. Solar studies in equinox from 14.00 to 22.00.

The reduced number og row house units gives a larger sunlit urban area. Most of it recieves around 5 hours of sun light in the time periode. The courtyard is however in the shade, since the A2 block is preserved.

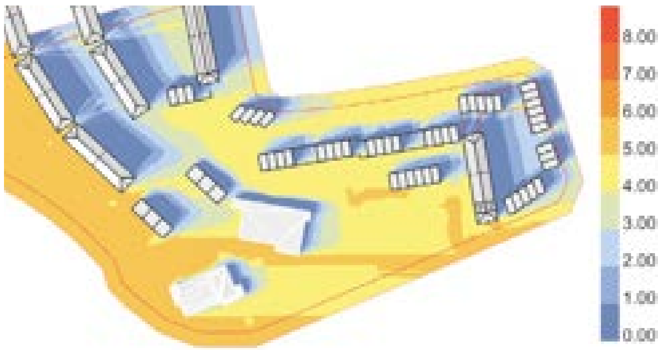
Ill.97 | Iteration 02. Solar studies in equinox from 14.00 to 22.00.

Reducing the number units to be torn down has increased the number of new units and since the plot area is the same, the buildings are placed very compact. This creates a lot of shadow, but the shadow lenght is shorter due to the south orientation.



Ill.98 | Iteration 03. Solar studies in equinox from 14.00 to 22.00.

The fourth proposal seems to find a nice balance between teardown, preservation and building new. The area does't seem emty or too packed and the sunlight conditions seem pleasing with the openings between the buildings.

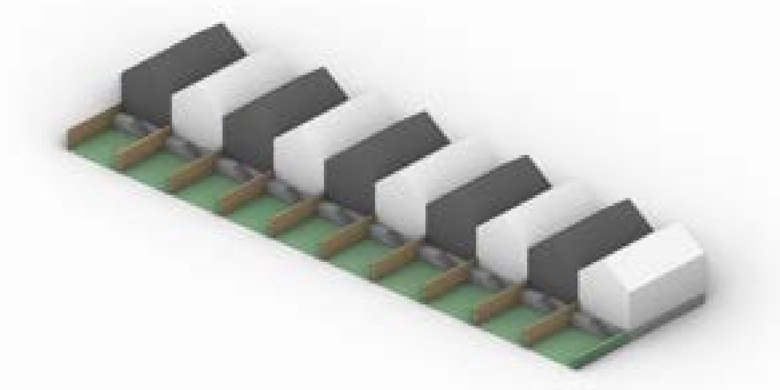


Ill.99 | Iteration 04. Solar studies in equinox from 14.00 to 22.00.

BASEMENT REUSE

PERPENDICULAR

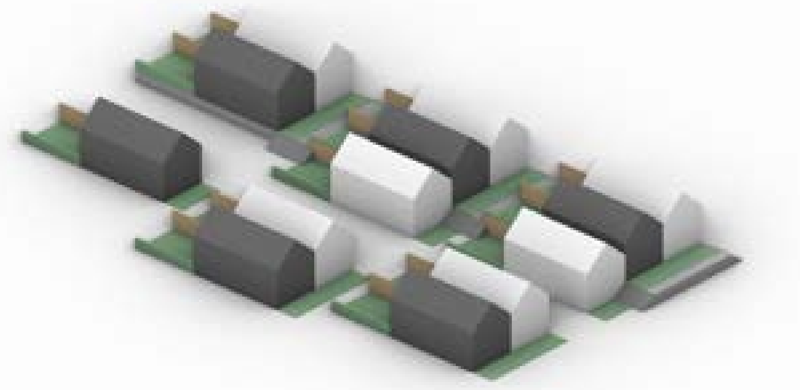
Building perpendicular on the basment will give a high utilization. The volume could be seen as a barrier like the current A1 block, when no openings are added. The backyard will, however, not be on the same level as the house, so stairs will be necessary.



Ill.100 | Visualization of perpendicular placement of houses on top of the all the basement.

PARALLEL

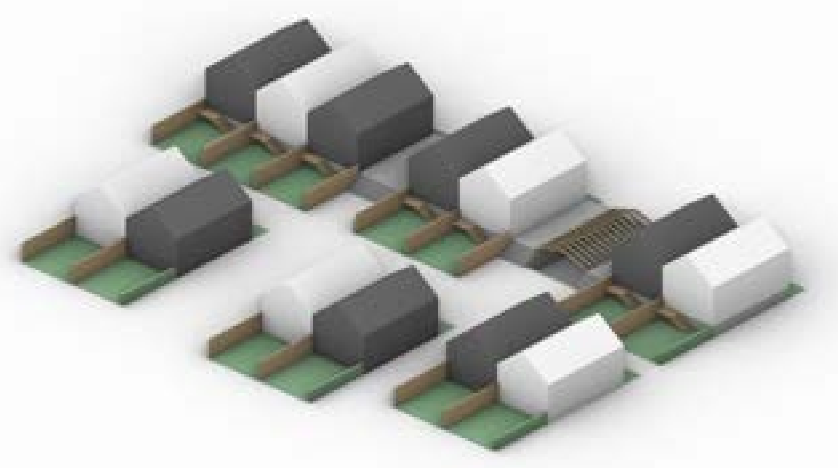
Placing the buildings parallel with the existing basement will allow the backyards to be on the same level as the ground floor. This Will however take up more space on the basement that cannot be used for additional buildings.



Ill.101 | Visualization of parallel placement of houses partially on top of the basement with free spaces in between.

PERPENDICULAR WITH PATHS

By adding openings between the buildings, it will help make the volume more permeable. These openings could be used to add new functions, which will be explored in the illustrations on the page to the right.

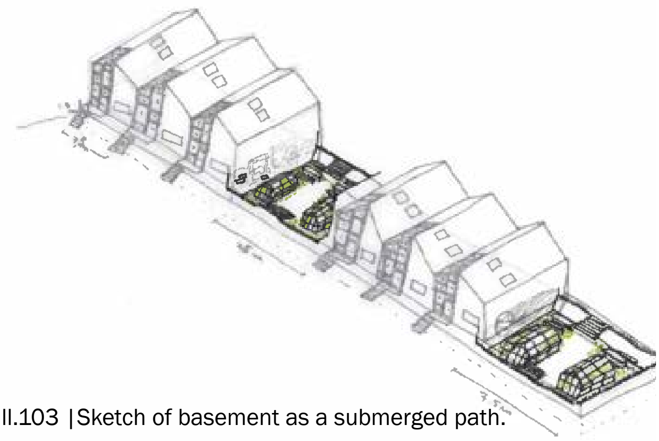


Ill.102 | Visualization of perpendicular placement of houses partially on top of the basement with free spaces in between.

BASEMENT AS PASSAGES

1. Submerged path through the basement

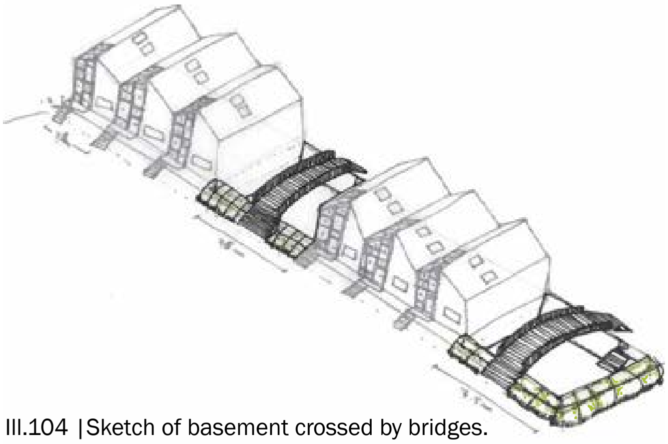
One way to traverse the basement could be to let the path go down to the basement floor level and then back up again on the other side. This would create submerged outdoor areas that could be made green and used as an extension of the surrounding green areas connecting them to each other.



Ill.103 | Sketch of basement as a submerged path.

2. Bridges across the basement

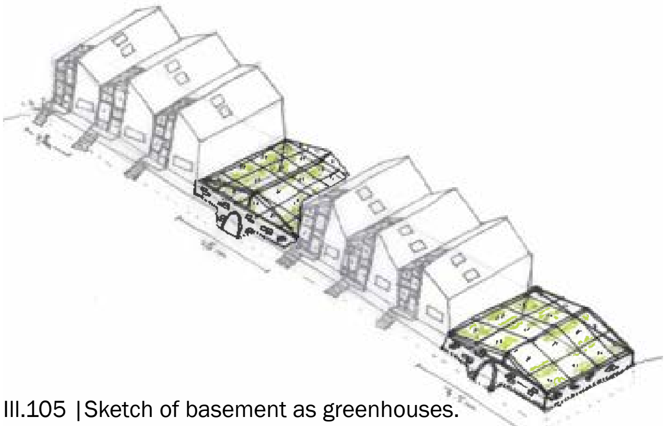
Another way to go across the basement would be by bridge. This would allow for level free access, but that would leave half a floor underneath that could be hard to utilize. The bridges could go in an arch to give more room height beneath the bridge in the basement.



Ill.104 | Sketch of basement crossed by bridges.

3. Greenhouses in the basement

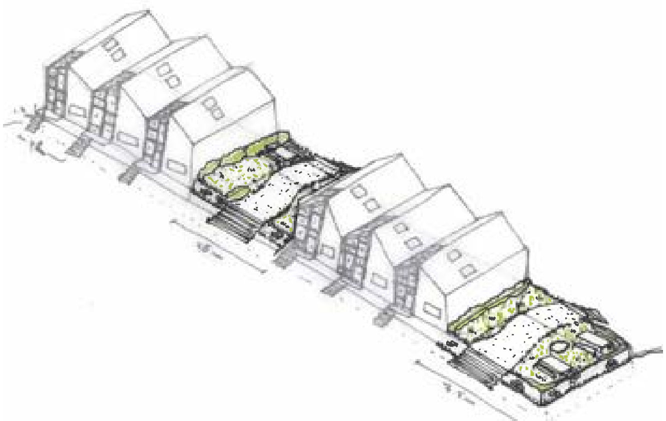
The fourth proposal is most likely the simplest. In this proposal the basement is traversed across the top of the basement. This leaves the basement untouched. The area can still be used as a green area where the path can go through.



Ill.105 | Sketch of basement as greenhouses.

4. Lifted green path on top of basement

The fourth prososal is the most likely the simplest. In this proposal the basement is traversed across the top of the basement. This leaves the basement untouched. The area can still be used as a green area were the path can go through.



Ill.106 | Sketch of basement as a lifted green path.

BASEMENT REPURPOSE

06 Save CO_2e emissions and materials **by reusing existing foundations and basement**

Ill.107 | Possible functions for the basement repurpurpose.

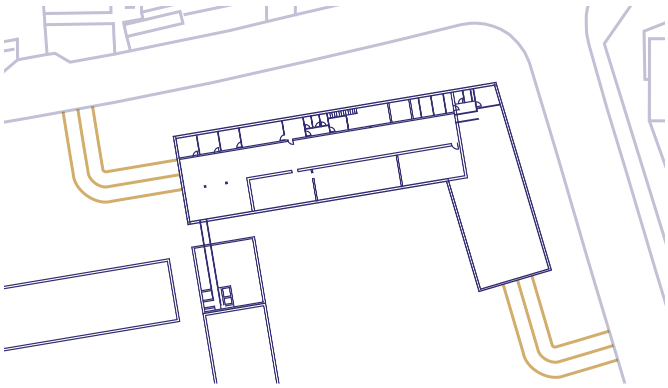
The theoretical framework and the initial LCA calculations indicate that avoiding demolition is the most sustainable approach. Reusing the existing foundation is there for a great start for a sustainable project. This also means reusing the existing basement, which is rather large. Car Parking was as mentioned considered, but it was not feasible. The interviews did however indicate that parking for smaller vehicles such as bicycles and mobility scooters seemed to be needed. This fits with both of the user groups and their needs. The existing blocks are currently equipped with emergency shelters, most likely a product of their time. It has been decided to keep them as is. The text below develops the study of the potential for parking.

BASEMENT AS PARKING

Ramp access

Pro: Utilizing the basement for parking
Con: Requires a considerable amount of space

To utilize the basement under Rema for parking a car ramp will have to be implemented. If the space is narrow and the road has to be one way, an additional ramp is required on the other side.

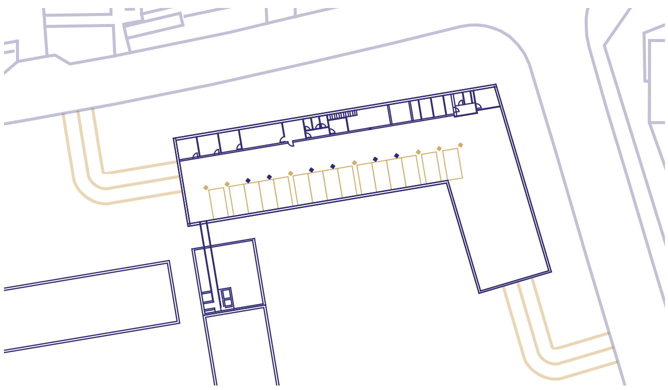


Ill.108 | Proposal for ramp access.

1. Perpendicular basement parking

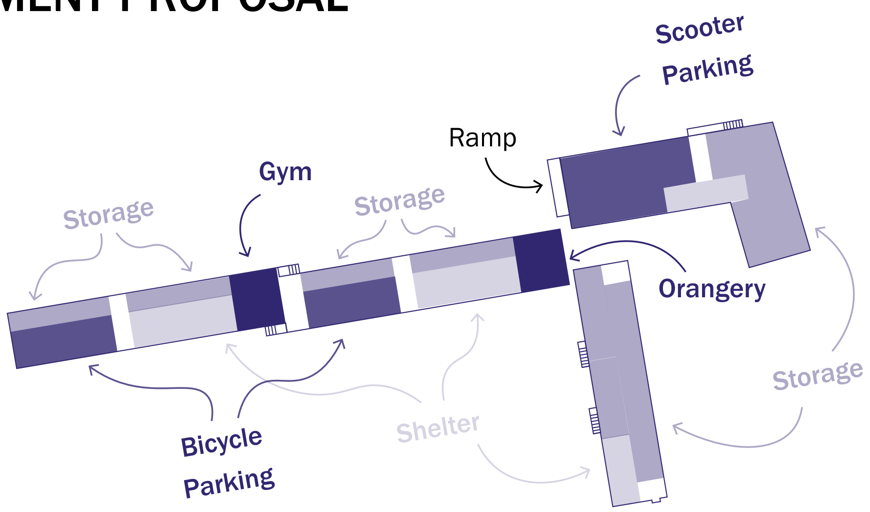
Pro: High density parking
Con: Does not follow the structural system

This perpendicular parking proposal gives 15 parking spaces which all follow the same basement wall. They do, however, not follow the structural system so most of the parking spaces are blocked by columns as illustrated by the blue columns on the drawing to the right.



Ill.109 | Iteration 01. Perpemndicular basement parking.

FINAL BASEMENT PROPOSAL



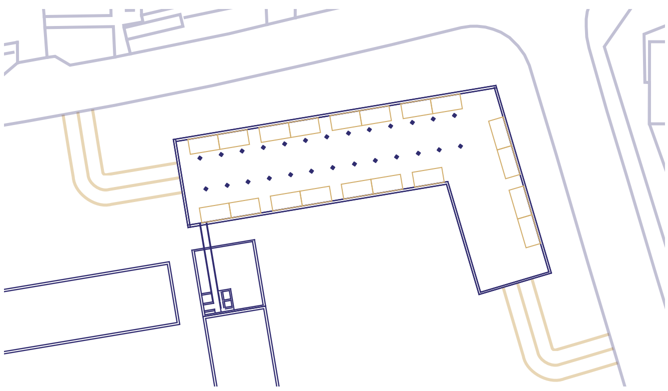
Ill.112 |Sketch of basement as a lifted green path.

The final layout of the basement is shown in the illustration above. The former A1 block will be equipped with bicycle storage with enough room to fit even larger electric bikes. It also has a gym and an orangery that sticks out from the basement to collect sunlight. The A2 block is mostly storage, one half for the residents and the other is storage for the community functions that will replace the commercial functions on the ground floor. The basement under the old Rema building will also have personal storage but is also equipped with a larger parking area for mobility scooters. This is accessed via an external ramp to the west, and the goal is to make it easier for the elderly to have more transportation options.

2. Parallel basement parking

Pro: Allows parking on both sides of the path
Con: Less space efficent

The parallel parking makes it possible to have parking on both sides of the path. The main part of the basement still has 15 parking spaces while the secondary adds 4, which could also be added to the perpendicular parking proposal.

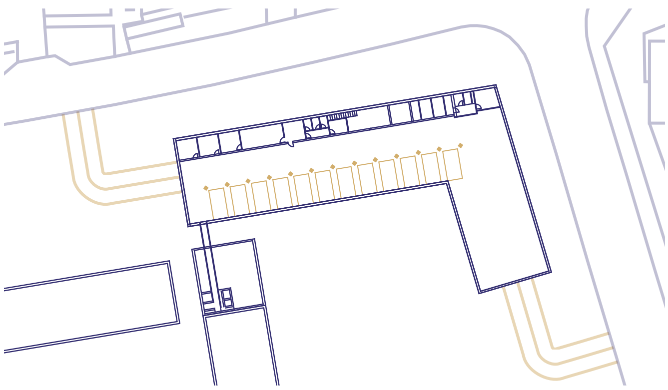


Ill.110 |Iteration 02. Parallel basement parking.

3. Parking following the structural system

Pro: Follows the structural system
Con: Less parking spaces

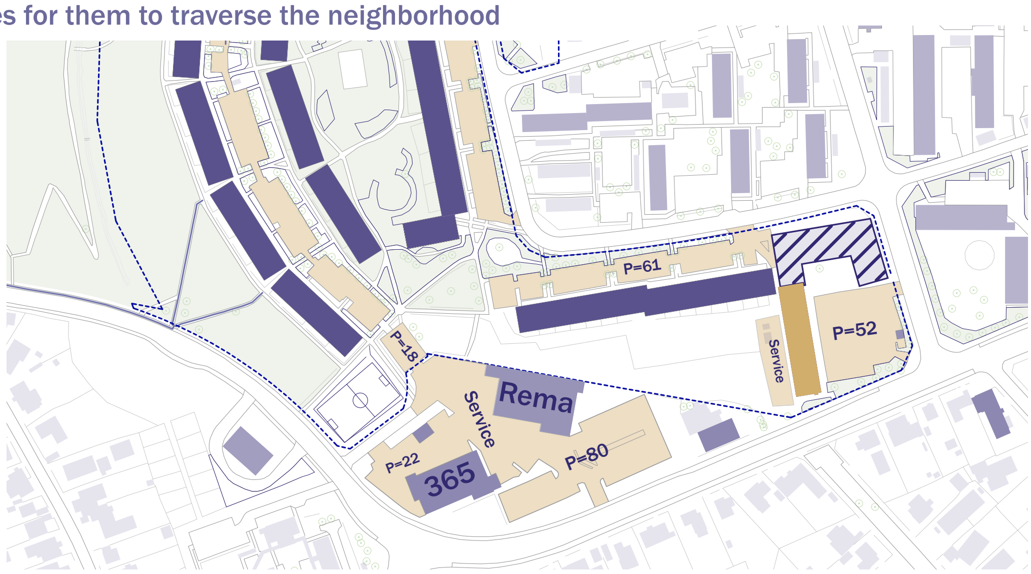
The last proposal iterates on the perpendicular parking and fits it to the structural system. This makes it easier to implement but reduces the number of parking spaces from 15 to 12.



Ill.111 |Iteration 03. Respect of existing structure.

EXTERIOR PARKING CONSIDERATIONS

03 Prioritize pedestrians over vehicles **by making active outdoor spaces for them to traverse the neighborhood**



Ill.113 | Existing parking.

Car parking takes up a substantial amount of area in the current layout and as demonstrated in pages 114-115, the present basement is not suitable for it. The convenience stores have a total of 120 parking spaces, while the A1 block has 61 and the existing shopping district has 52. The new design aims to prioritise pedestrians over vehicles. Four different parking proposals have been examined and evaluated in the text below. The four types are direct parking, parallel parking, Shared parking and reusing the existing parking. The final of these can be seen on the page to the right.

PARKING PROPOSALS

1. Direct parking

Pro: Personal car parking at the front door
Con: Long driveways and space ineficient

This type allows the resident to park their car right next to their front door. It does, however, have a low parking density and since the houses are far from the street the driveways will take up a lot of space. This will make it harder to give the residents front yards and it disrupts the pedestrian flow.

Ill.114 | Iteration 01. Direct parking.

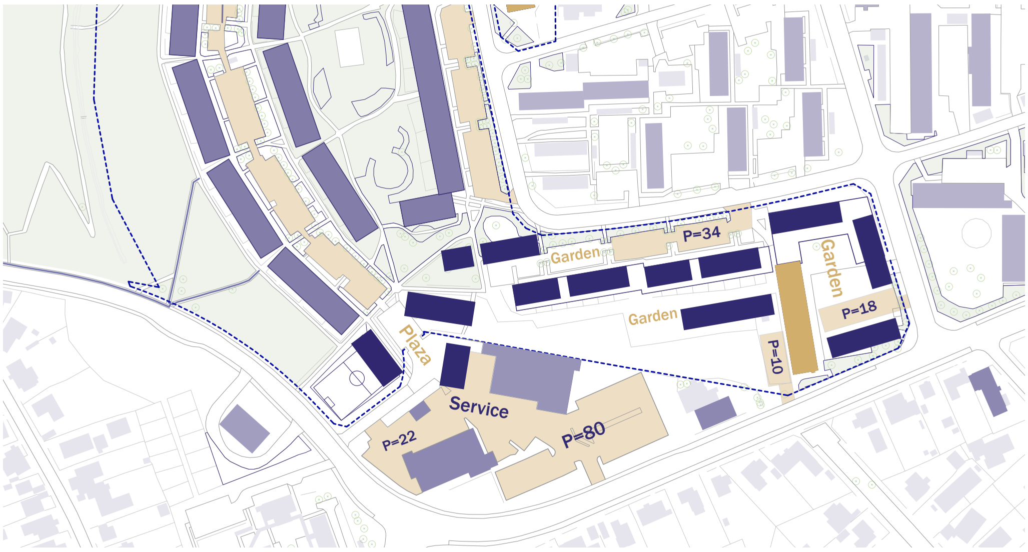
2. Parallel parking

Pro: Personal parking posible on narrow roads
Con: Long roads to connect to the parking.

Direct parallel parking also gives the residents a low walking distance. The width of the parking area is however more compact, which makes it easier to implement on narrow roads. Giving more space to greenery.

Ill.115 | Iteration 02. Parallel parking.

FINAL PARKING PROPOSAL PROPOSAL



Ill.118 | Iteration 01. Perpemndicular basement parking

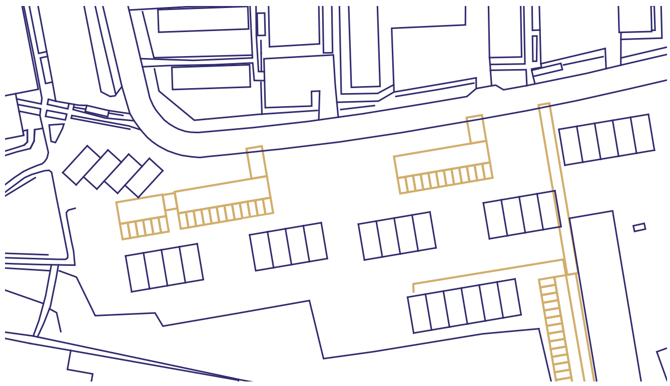
The final parking proposal has lowered the total number of parking spaces to change the focus from cars to people. This is also possible since the total number of residents has been lowered. The option of using the existing basement as car parking was explored, but studies indicated that this would require a significant structural change to the basement and a large access ramp that would take up nearly the same space as regular parking. The new masterplan now provides more recreational spaces to encourage social interaction.

3. Shared parking

Pro: Space effient

Con: Longer walking distance

Shared parking is the most optimal. The ratio of roads to parking area is at its most optimal and the area not used for parking can be used to make greenery instead. The walking distance from the car to the housing units is, however, the longest.



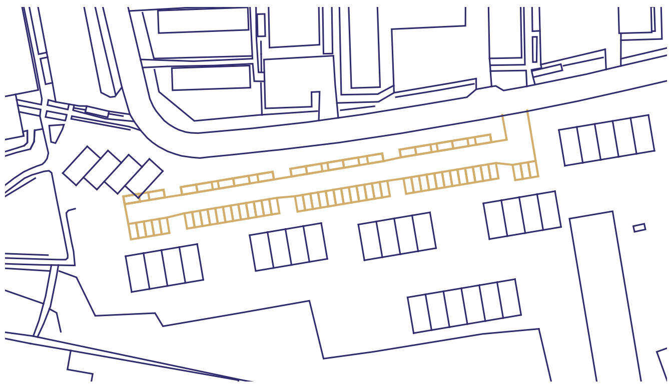
Ill.116 | Iteration 03. Shared parking.

4. Reusing existing parking

Pro: Environmentally sustainable

Con: Design restrictive

Reusing the existing car park in Sundparken would without a doubt be the most environmentally sustainable since no energy would be used on constructing parking spaces. The existing car parking is a shared parking lot so if reused the walking distances would be higher than some of the other

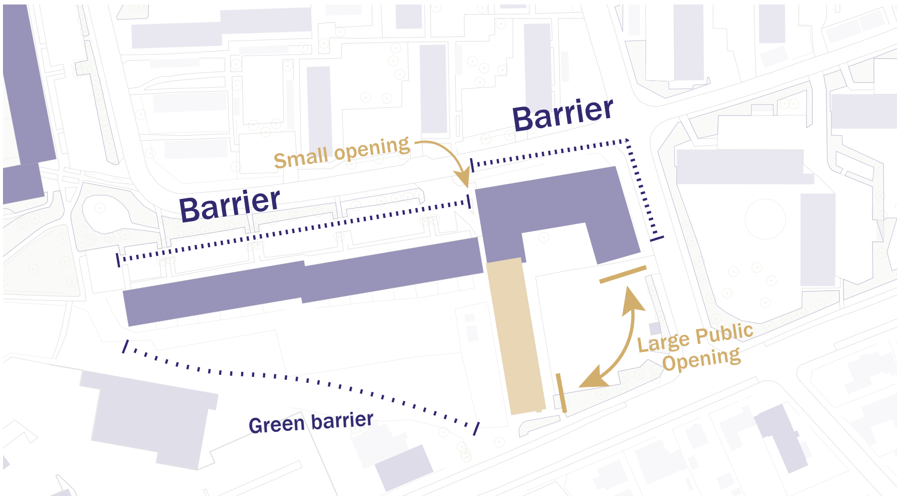


Ill.117 | Iteration 04. Reuse of existing parking.

ROW HOUSE AREA DEVELOPMENT

CURRENT STATE

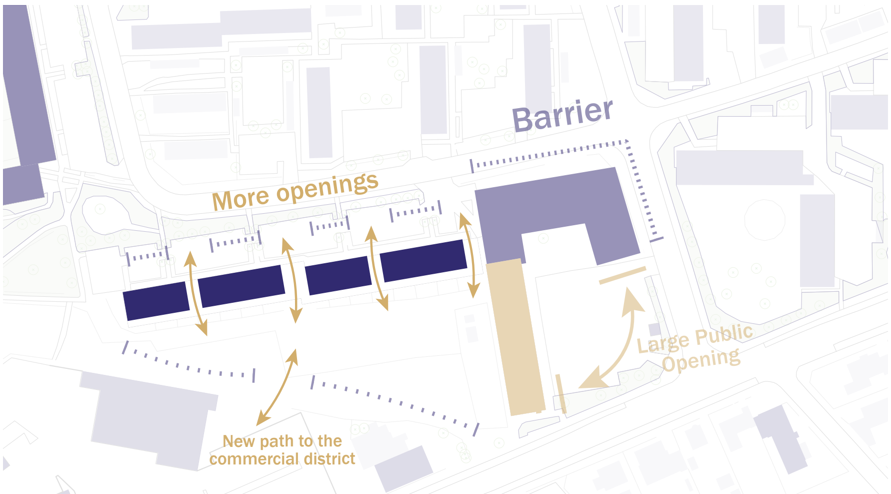
The A1 block and Rema acts as barrier dividing north from south. The only opening is small and uninviting. The current shopping district has a large public opening to the Southeast, while the trees to the south block any connection to the area below the A1 block.



Ill.119 | Sundparken's current situation.

PERMEABILITY

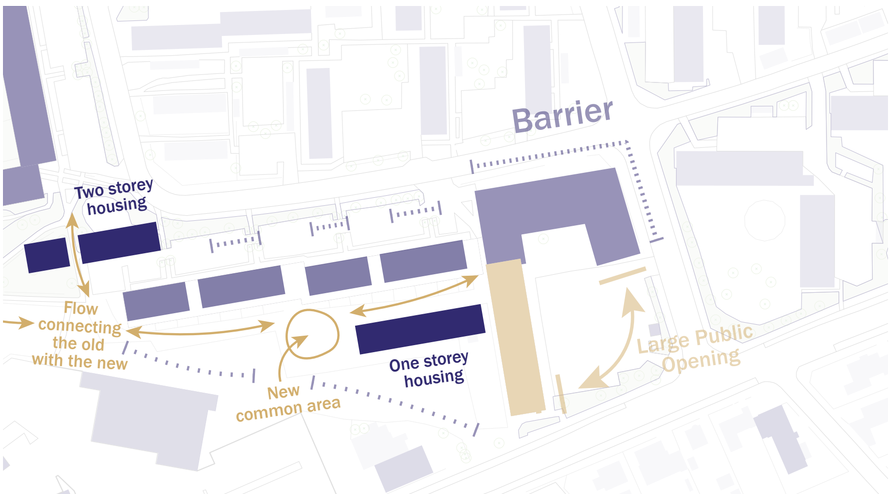
The A1 block is remodeled, and the new openings break down the former barrier. This, in addition to a new path through the green barrier, will connect the area with the neighborhood to the north and the stores to the south.



Ill.120 | Proposal increasing the permeability of the block.

CONNECTIONS

New housing units are added to the south and north creating areas between the buildings where a main path will connect the new area with the new commercial district and the old areas of Sundparken. These paths meet at a common area where people can interact.

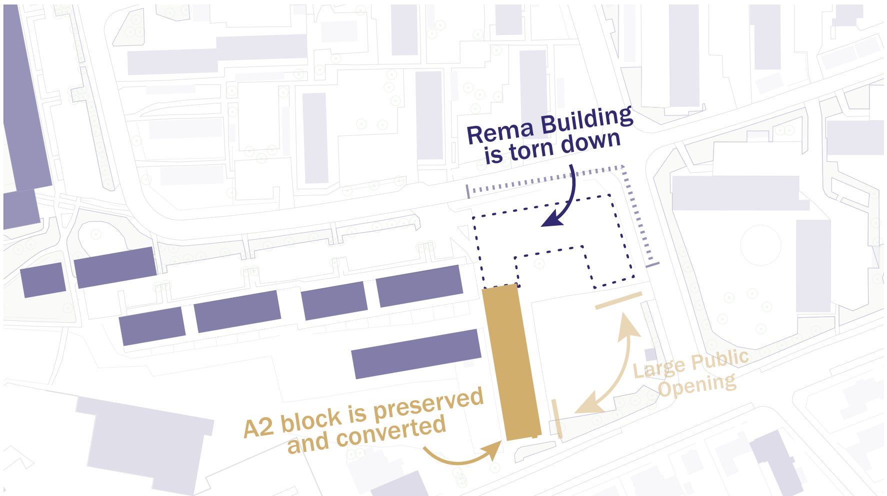


Ill.121 | Proposal increasing the density and the connectivity inside the site.

ELDERLY COMMUNITY AREA DEVELOPMENT

REPROGRAMING

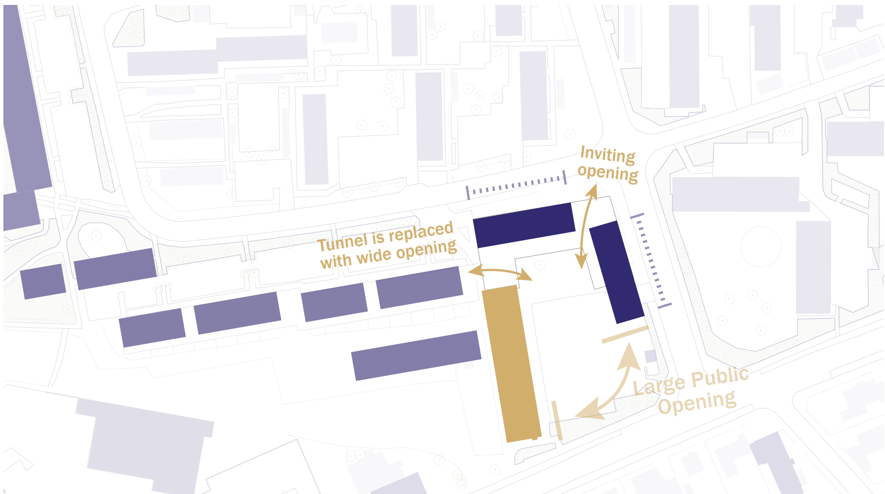
The old Rema building is torn down to make room for new housing units, while the A2 block is preserved and reconfigured into elderly apartments. The stores on the ground floor are transformed into common functions such as a gym, workshop, laundry and a community kitchen.



Ill.122 | Proposal to repurpose the area of Rema and A2 block's ground floor.

OPENINGS

New housing units are placed on top of Rema old basement with new and larger openings to the former shopping district. Especially the old east to west tunnel connection is changed to a wide opening to connect the elderly area with the rest of Sundparken.



Ill.123 | Proposal to reconfigure the access to the area to frame it without blocking the visibility .

PROTECTION

Housing units are also placed in a two storey row to the south to protect the courtyard where residents can participate in community activities from Sundvejs traffic noise and. It reduces the opening to the southeast as well, which is essential as the area is no longer a commercial district.

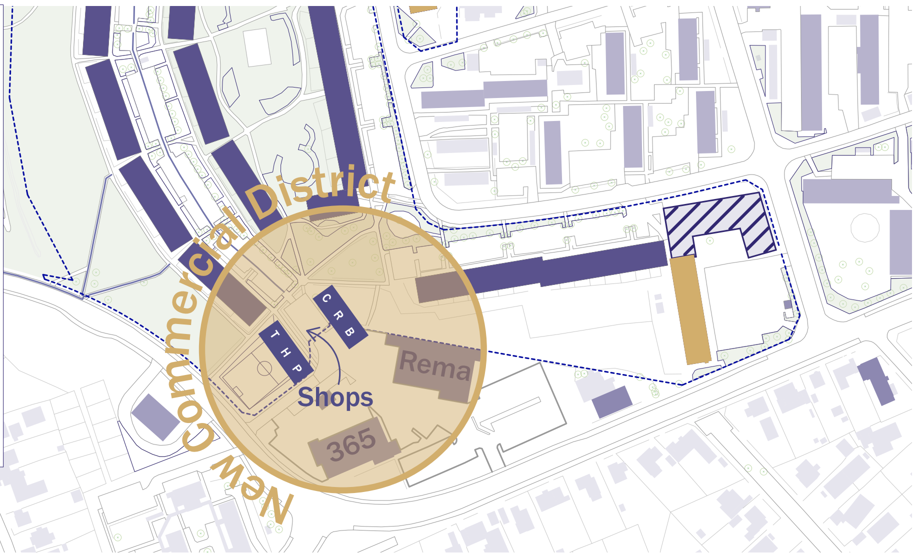
Ill.124 | Proposal to isolate the area from Sundvej's traffic noise on the south.

COMMERCIAL AREA DEVELOPMENT

OVERVIEW

INITIAL RELOCATION

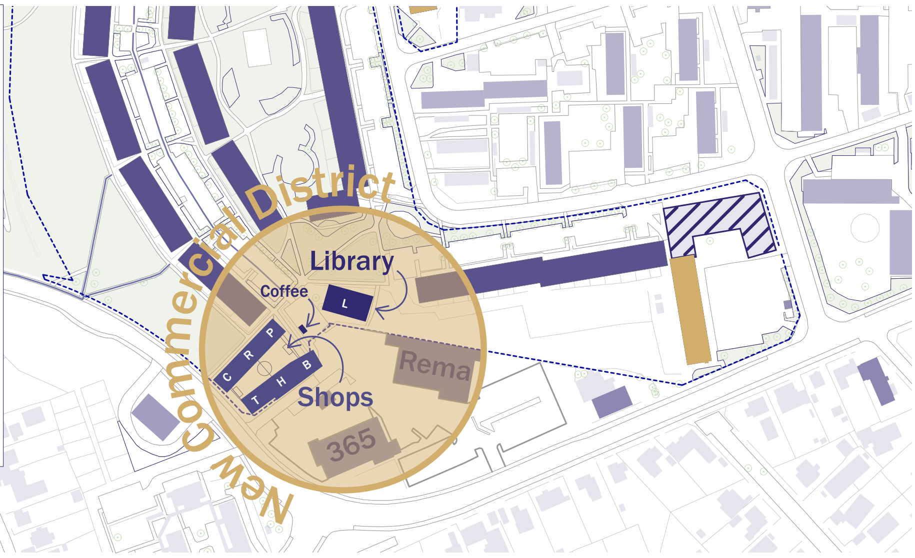
The initial design consisted of two building volumes equivalent to 12 units. These housed the existing commercial functions. The proposal did not seem inviting towards the A-Blocks and community functions were lacking.



Ill.125 | Initial relocation of commercial area.

EXTRA FUNCTIONS

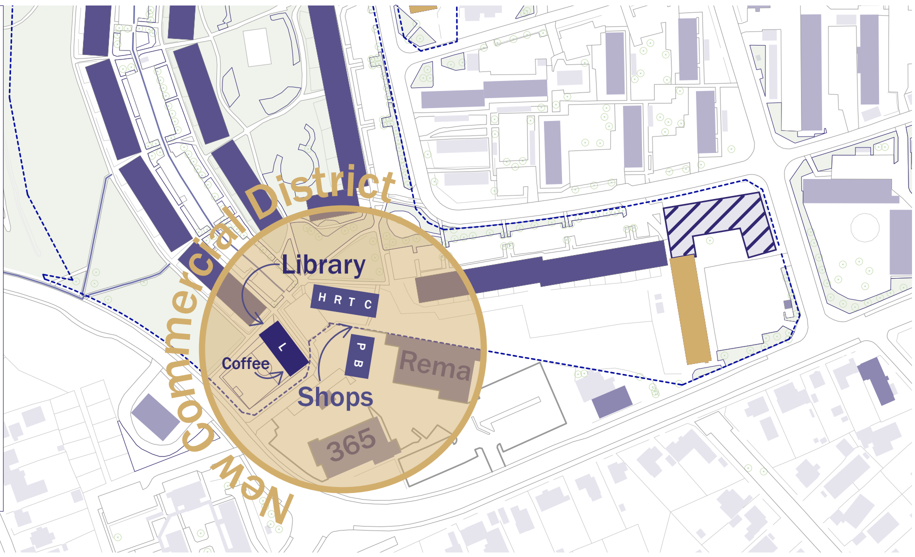
The second proposal introduces a public library with community functions and a coffee shop. The two shop volumes create a small shopping strip that leads to the library. This comes at the cost of removing the football field.



Ill.126 | Addition of extra functions.

CENTRAL PLAZA

The final proposal centers the three volumes around a single plaza to admit the preservation of the sport facility . The library has switched places with the stores. The intention is to use the library to invite people from the outside in, since the volume can interact both

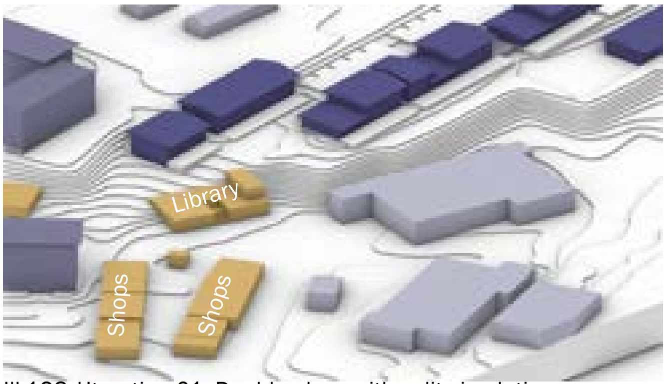


Ill.127 | Final proposal for commercial area with a central plaza.

1. Double-plaza + split circulation

Creating a shopping strip at the current football field and placing the library inside the hill.

This iteration creates two plazas, one in front of the library and a shopping strip between the two rows. A café in the middle splits and regulates the flow. The aim of creating social interaction might be more effective if there was only one plaza. There is additionally a lack of suitable space for a service area.

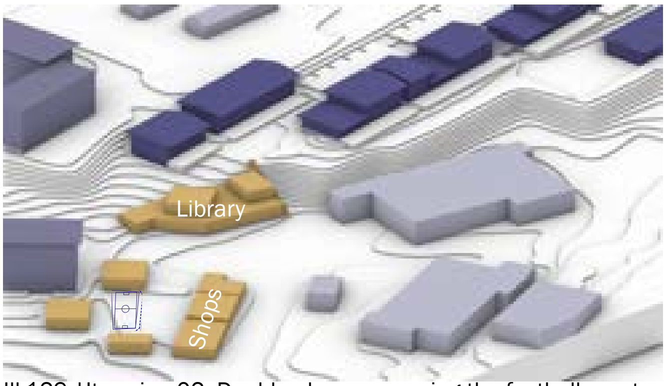


Ill.128 | Iteration 01. Double plaza with split circulation.

2. Double plaza + sport facility preservation

Placing the shops around the current football court and the library inside the hill.

This also creates two plazas, but in this the existing football field is preserved. It faces the same challenges as the first one although the connection to the library is more fluid.



Ill.129 | Iterarion 02. Double plaza preserving the football court.

3. Central plaza + sport facility preservation

Placing the library north of the football field and the stores in the the B block chain.

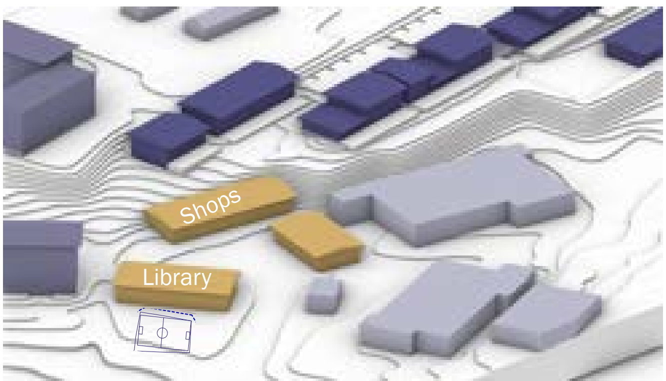
The third iteration focuses on one area instead of two and intruduces a service area next to Rema 1000. The area does however not seem like a plaza, but more like a road leading people in and out of Sundparken.

Ill.130 | Iteration 03. Central plaza preserving the football court.

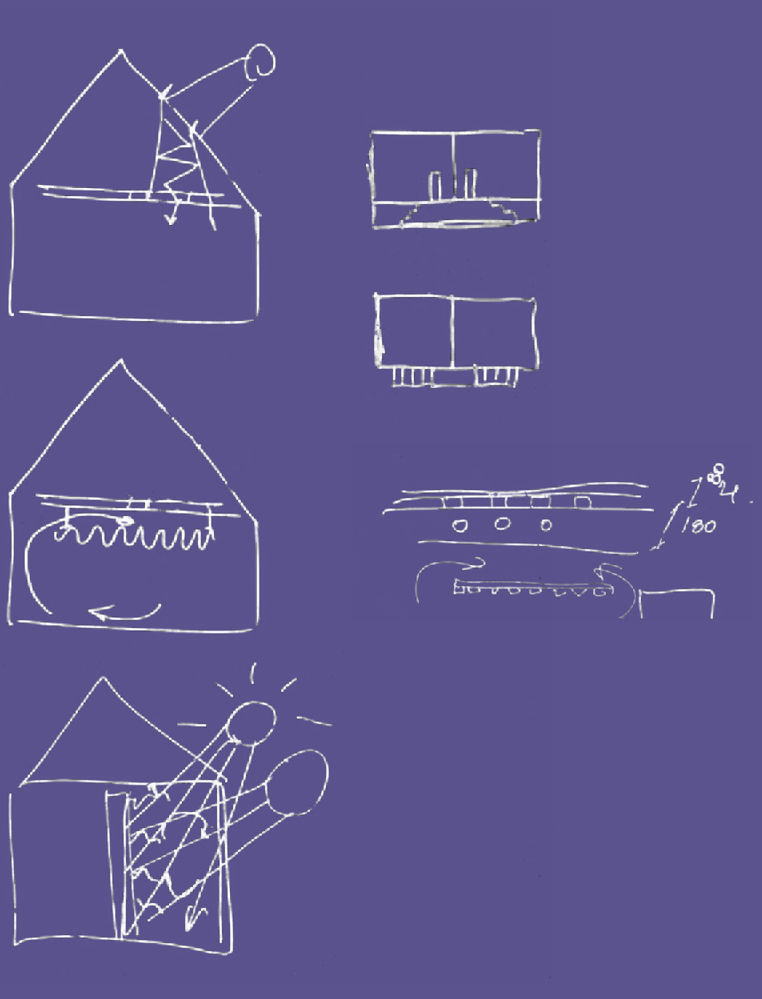
4. Topography considerations

Placing the library north of the football field and the shops in oposing corners to create a plaza.

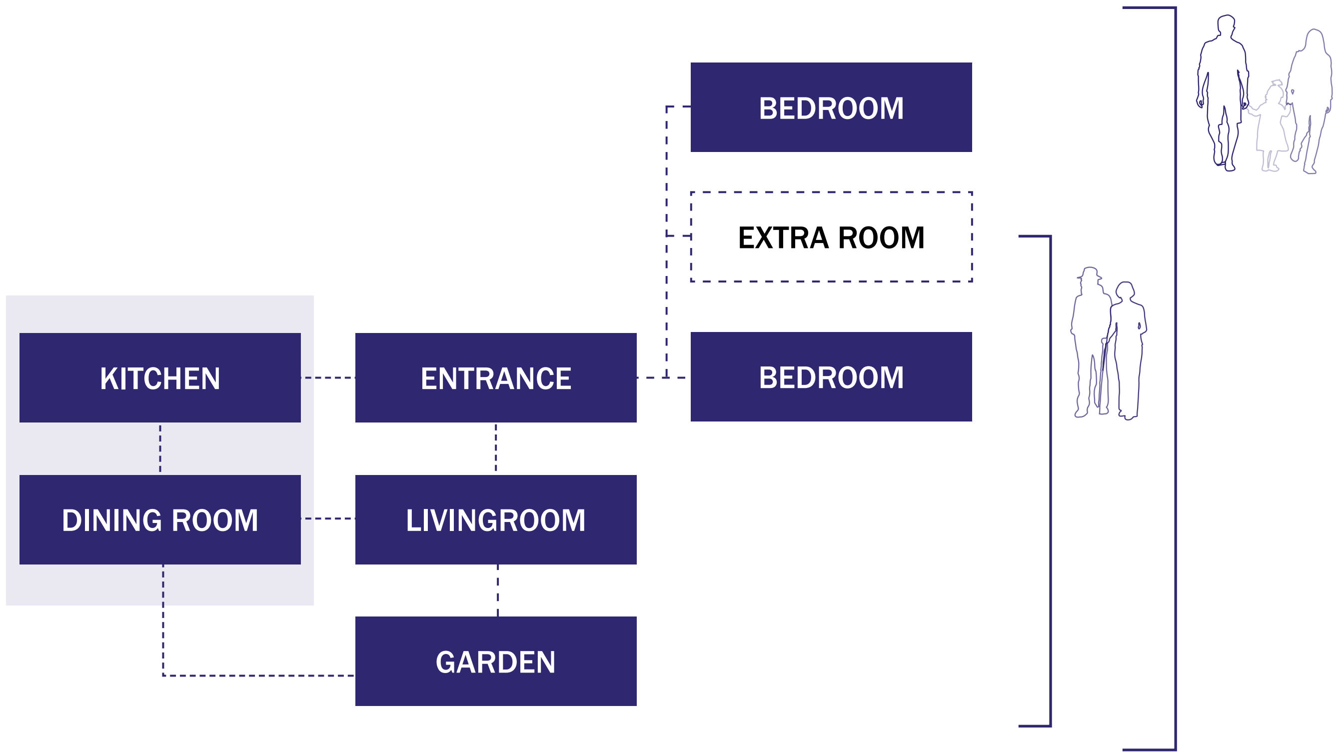
The fourth iteration gives more space to the public plaza integrating the topography and giving space to the service area for the shops. The plaza can now function as a public meeting point with attractive facilities where people can interact with each other.



Ill.131 | Iteration 04. Shops volume follows the topography while having a central plaza and preserving the football court.


180

THE ROW HOUSES



Ill.132 | Program for family and elderly houses.

To design the floorplan, it was important to consider the user group's needs and the indoor environment quality while finding a solution that reuses the materials in the most efficient way. The row houses should then have a private garden, a well-connected kitchen-dining room, and in the case of the family user group have at least two bedrooms and an extra that can adapt to multiple purposes. The elderly residences should have at least one private bedroom separated from common areas and be single-story.
As a principle. the floorplans should be compatible with the existing basement layout to enable its reusability and minimize the number of typologies to unify and simplify solutions (See: Circular Economy).

BUILDING SCALE / DESIGN CRITERIA

07 Accommodate the individual needs of the user group **by providing row-housing units of different sizes**

08 Ensure the structural capacity of the floor-slab and the foundation **by placing heavy elements of the row-houses on top of the existing load-bearing lines**

09 Lower the project's carbon footprint **by maximizing the reuse of rooms, elements and materials disassembled from the existing buildings**

10 Improve daylight quality **by adjusting existing facade openings**

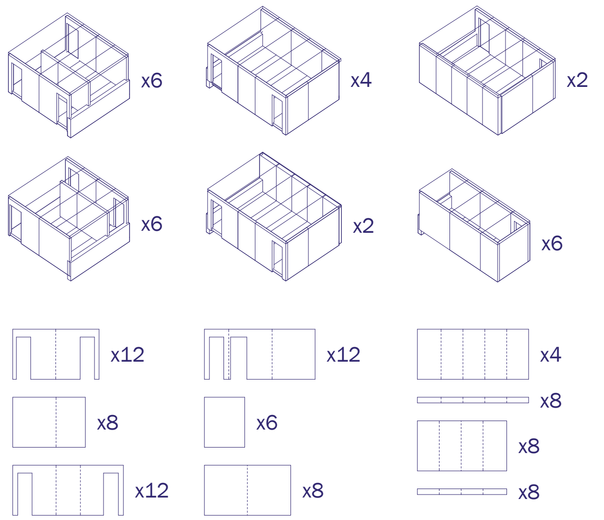
11 Reduce the operational emissions **by adding solar panels**

DISASSEMBLY FOR DESIGN, SELECTIVE DEMOLITION

The disassembly process is one of the most important parts of the design since it is decisive regarding how many units can be built, how these are and how much material can be saved, having great impact on the final LCA results.

1. Maximizing blocks preservation

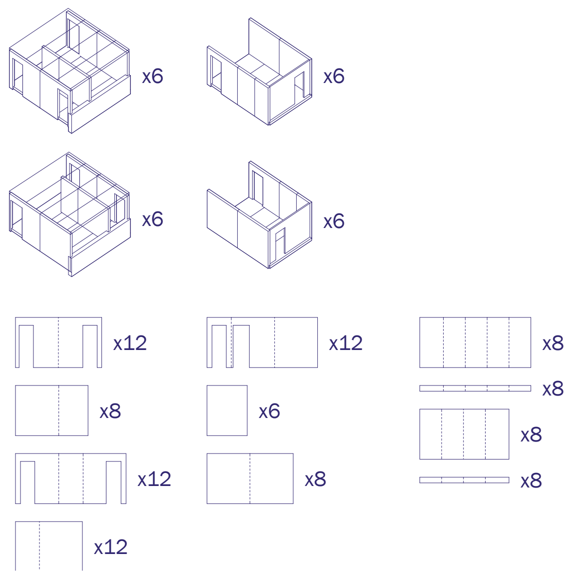
The first iteration focuses on disassembling the building in a way that most of the rooms can be extracted, compromising the material as little as possible. The problem with this porposal is that the resulting inventory is quite varied and the quantity is uneven, meaning that the new row houses would require several unique design solutions that make it unscalable and difficult to predict the final number of housing units.



Ill.133 | Iteration 01. Material atlas of concrete blocks and walls.

2. Minimizing blocks variations

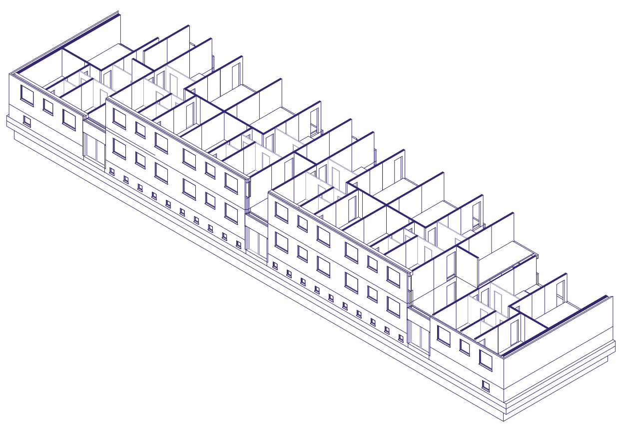
The second iteration prioritizes the restriction of the material atlas variation and the optimization of number of new units. The kitchen-bathroom and the bedroom rooms are preserved, making it possible to reuse the blocks for at least 6 identical new row houses. The remaining concrete walls can be recycled being combined with new materials. (See chapter: Joints).

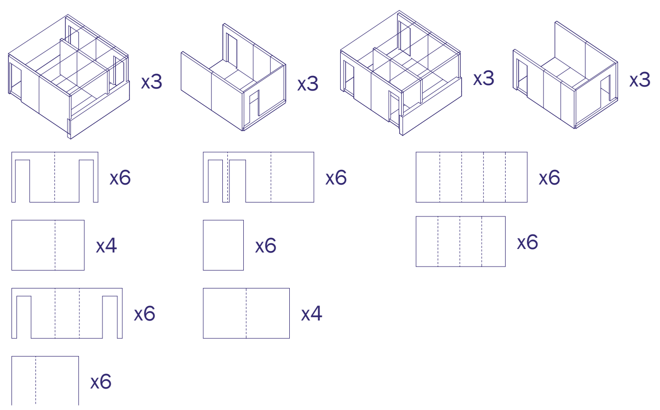


Ill.135 | Iteration 02. Material atlas of concrete blocks and walls.

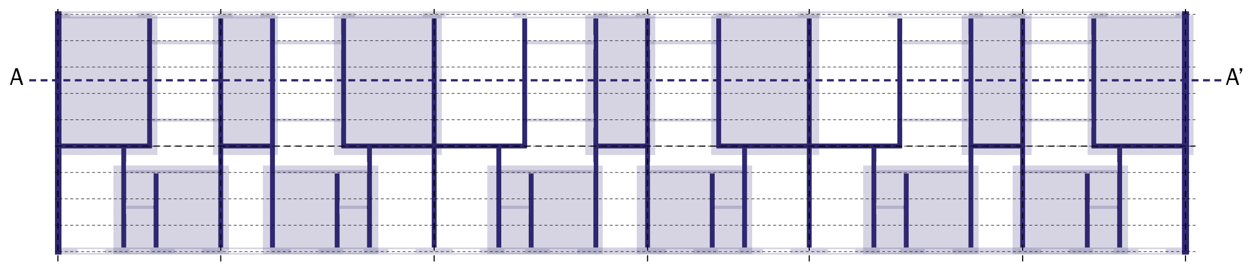
3. Minimizing disassembly

The last iteration studies the possibility of preserving the first stories of the building attached to the basement. In this way, most of the structure can be left intact, meaning that the floorplan layout is untouched and the existing foundation can be easily reused. This proposal reduces the risk of compromising the elements. The remaining storeys can be disassembled as proposed in the second iteration.

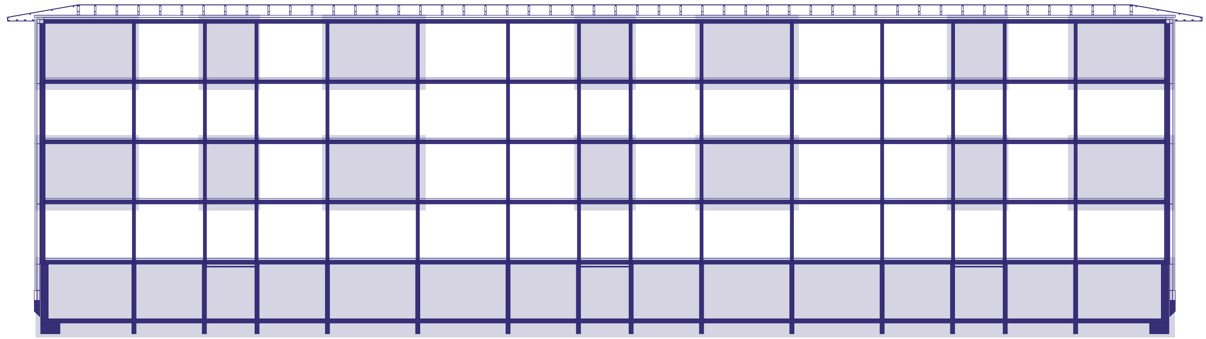




Ill.137 | Iteration 03. Material atlas of concrete blocks and walls.

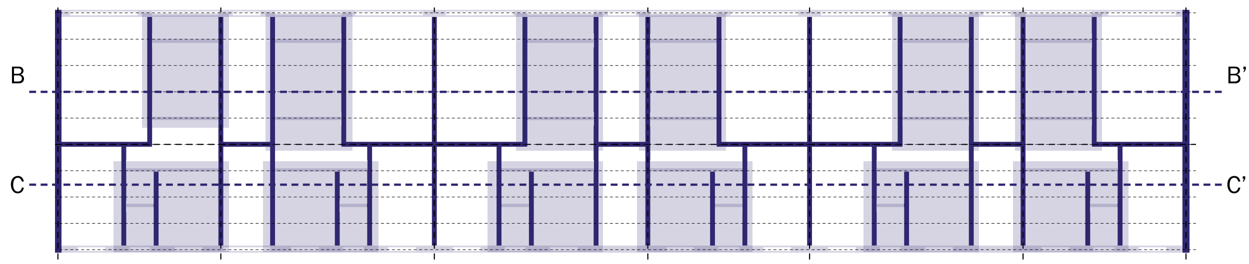


Floorplan of representative block. Typology 1.

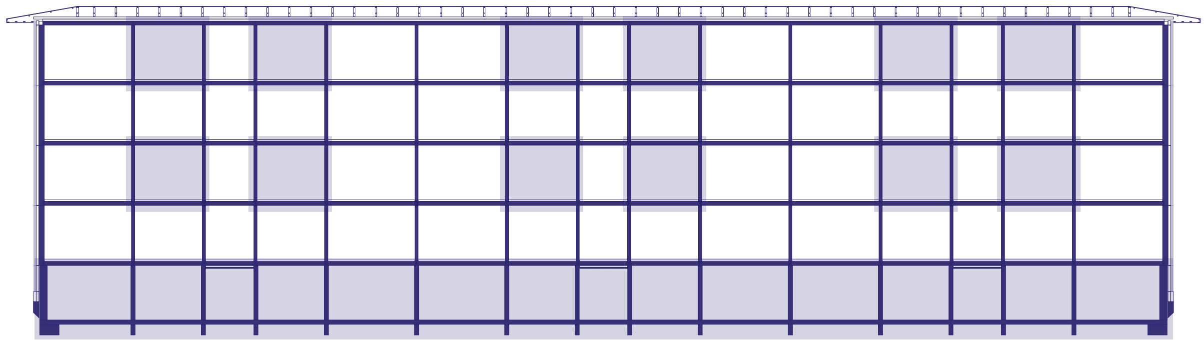


Ill.134 | Iteration 01. Disassembling the building as blocks saving as many rooms as possible. Section A-A’.

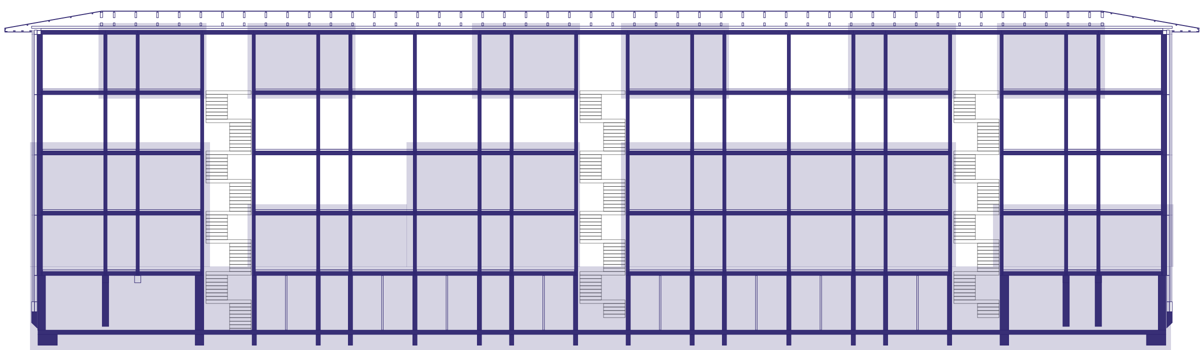
Elements cut as blocks



Floorplan of representative block. Typology 1.



Ill.136 | Iteration 02. Disassembling the building as blocks reducing variability of elements to maximize the number of new equal typologies and simplify diversity of components. Section B-B’.



Ill.138 | Iteration 03. Preserving the building partially to transform into row houses and disassembling the remaining parts as blocks reducing variability of elements to maximize the number of new equal typologies. Section B-B’.

REUSE OF WINDOWS

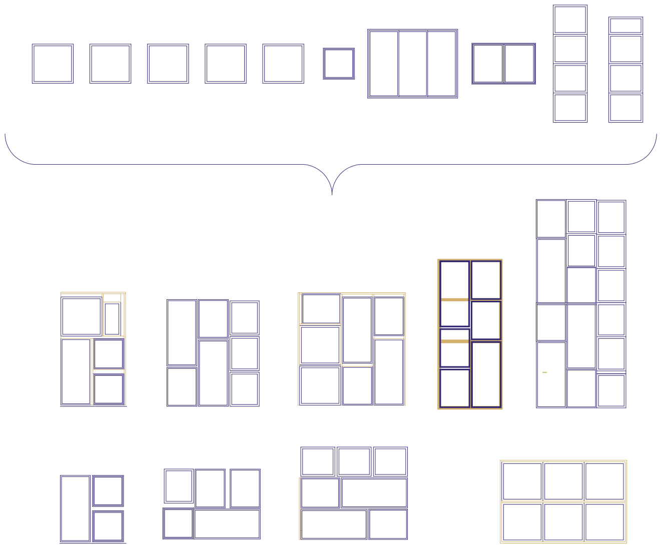
There are 6 different types of windows per apartment, 19 units in total, covering an area of 27.66 m^2. These have been renewed in the late 90s and consist of white plastic frames and two-layer thermal glass. Based on the report results from Energistyrelsen which labels Sundparken as B in a G-A scale, it is assumed that the U-value is 1.6 and the G value is 0.5.

Lendager Group proposes in Upcycle Studios (see sub-chapter: Upcycle Studios) that buildings like Sundparken should not dispose the windows, but instead recycle them, and one possibility is to combine them with another layer of new or recycled windows. In this way, the windows preserve their value and can meet the requirements.

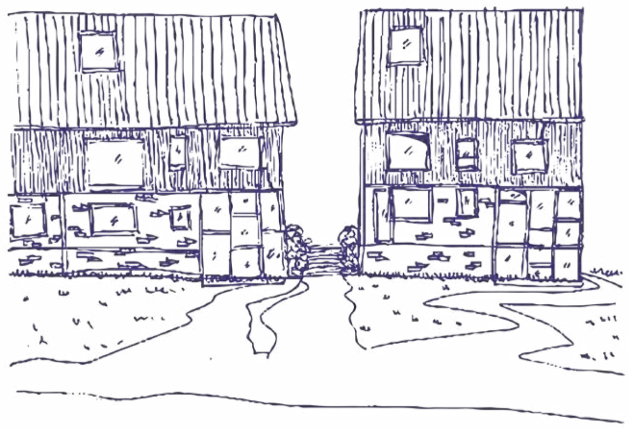
Illustration 139 shows different layouts that the existing Sundparken windows could adopt to create a glazed facade. But when covering large areas, it becomes necessary to include new windows to be able to provide all the 40 new houses with these.

The sketch on illustration 140 shows conceptually the use of recycled windows in the facade, integrated with the house.

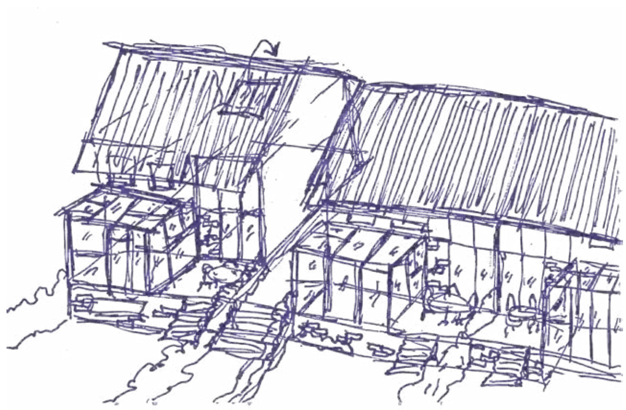
Another proposal (Ill. 141) contemplates the idea of using single layer of recycled windows frame to create a non-heated area between the house and the exterior. This can serve as an orangery, a conservatory or a double-layer facade which functions as a transitional space, similar to Montagerækkerne (see sub-chapter:



Ill.139 | Above: Existing windows per apartment. Below, possible combinations for a glazed facade.



Ill.140 | Sketch of recycled windows glazed facade.



Ill.141 | Sketch of recycled windows conservatory.

MATERIALITY

Sundparken's materiality consists of a mix of bricks on the outside (1), with a non visible roof and facade which strong horizontality is interrupted by a glazing facade on the staircase. The interior has a wooden parquet floor (3), delimited by white walls which colour comes from white painted concrete (4) and white gypsum walls (5).

The criteria for the selection contemplates the principles of design for disassembly (DfD) and their impact on the comfort. The new materials should therefore be durable, non-toxic and pure to ease their recyclability afterward (see chapter: Design for disassembly). It is also considered the availability of the material, the effect on thermal mass, acoustics, light distribution, texture and functionality.

On the outside, brick is preserved but the quantity is limited, thus it is complemented with natural wood cladding. For interior finishes, concrete, gypsum board and plywood are considered (Ill. 142).

Exposing concrete to natural light can bring a lot of texture into the room enhancing its quality of raw and reused. It also contributes to the stability of the thermal comfort in the room (see chapter: The Potential of Thermal Mass). Though, its use must be limited since it increases reverberance, affecting the acoustic comfort, and its dark color absorbs the light in the room. In addition, electric wires and installations would be exposed and its hard surface prevents users from personalizing the wall and owning the room.

Gypsum boards can be placed in front of the concrete hiding the infrastructure and allowing users to decorate walls. Although it is hard to disassemble, Gyproc developed a group of products that makes this possible, but screws are exposed looking unfinished.

Wood cladding and plywood have a better performance acoustically and its color is lighter that concrete. The connections can be hidden and still be reversible. Thermal inercia qualities are not significant but it can be combined with concrete.

As a consequence, the aesthetics of the new buildings have a raw appearance, where textures are exposed and spaces are loaded with material expression.

Ill.142 | Existing materials in Sundparken. Wood cladding as an addition to the palette.

Ill.143 | Exterior and interior materiality test.

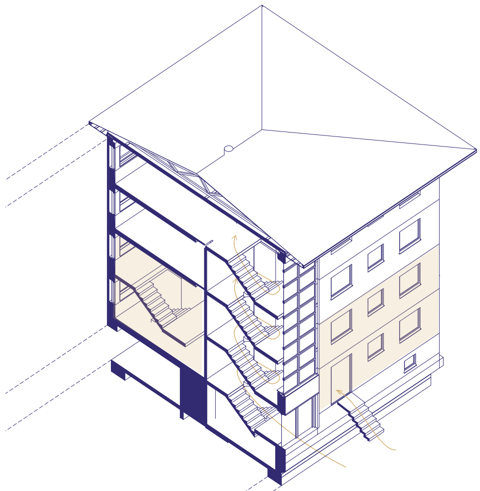
THE BLOCK TRANSFORMATION

The main challenge for the floorplan was to design it assuring that the old materials were reused in an efficient scalable way. In all the cases the entrance to the houses was a problem since the basement elevated the building 1.3 m above the ground. These investigations can be seen in the Appendix 7. Another important aspect was to increase the permeability of the overall block by opening passages to break it down, allow circulation through and integrate the backside with the city.

1. Partial transformation of block A2

Layout adaptation on first 2-storeys

This study focuses on adapting the existing layout of the first two floors to two-storey row houses. There are some issues regarding daylight, structure, permeability and access.
The floorplan creates deep rooms where daylight is insufficient, and when removing load bearing walls required to reorganize the rooms, while keeping the floors above it compromises the structure. In addition, the access to the upper floor apartments is through a 4 storey staircase which has blind accesses on the first two levels. This proposal also lacks passages through the 70-meter-long block. Though, a similar strategy is applied to transform all floors of the Typology 2 into elderly apartments (see sub-chapter: Floorplan Typologies).

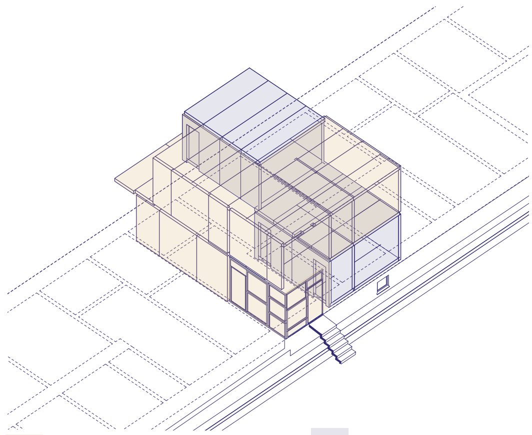


Ill.144 | Iteration 01. Axonometry.

2. Strategic demolition of the block

Reuse of room blocks
Reuse of foundation and basement

The second iteration observes ways to dismantle the building and reuse those elements for the new construction, minimizing waste. In one of the study cases (See Case Study /Montagerækkerne) the elements are disassembled as a group forming blocks where it is possible to build around. In this case, it is fundamental to follow the load-bearing lines, but it is a misuse of energy to remove elements to place them back again on the basement, compromising the joints strength and thicknesses. Regarding the permeability, all the housing units are 7.5 m wide, opening the block every 15 m which seems excessive for the case.

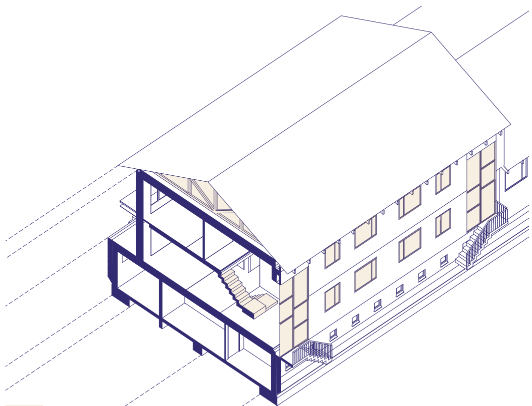


Ill.146 | Iteration 02. Axonometry.

3. Partial transformation + strategic demolition

Layout adaptation
Reuse of room blocks, foundation and basement

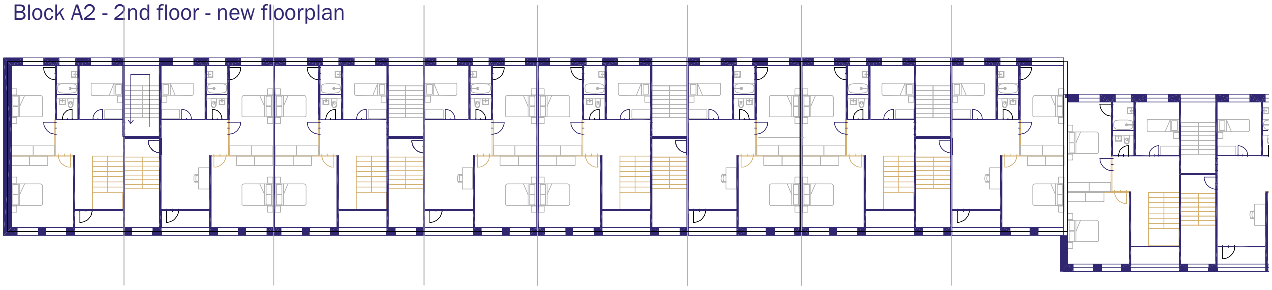
The last investigation combines the former iterations. The first two floors are adapted and the remaining parts are disassembled in a way that they can be recycled. This solution avoids most of the technical problems related to structure and is the one that saves most material, reusing 61% of it 1 to 1. By having two types of units with different widths, the openings through the building are adjustable.



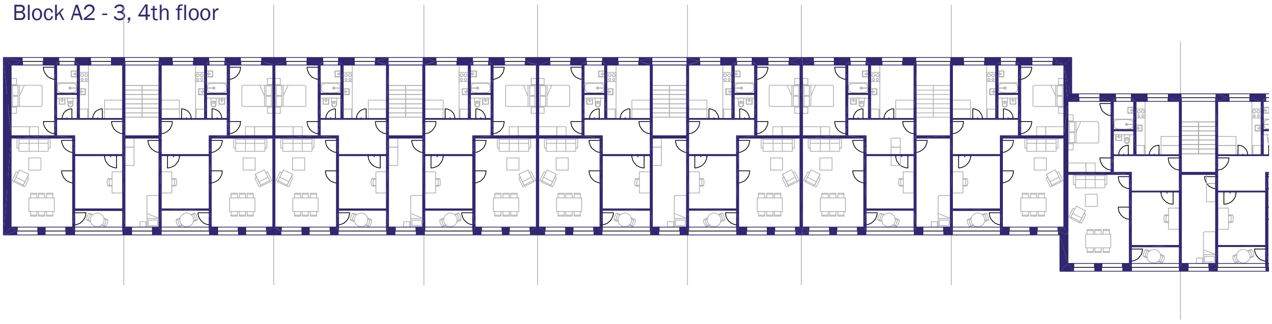
Ill.148 | Iteration 03. Axonometry.

Block A2 - 1st floor - new floorplan

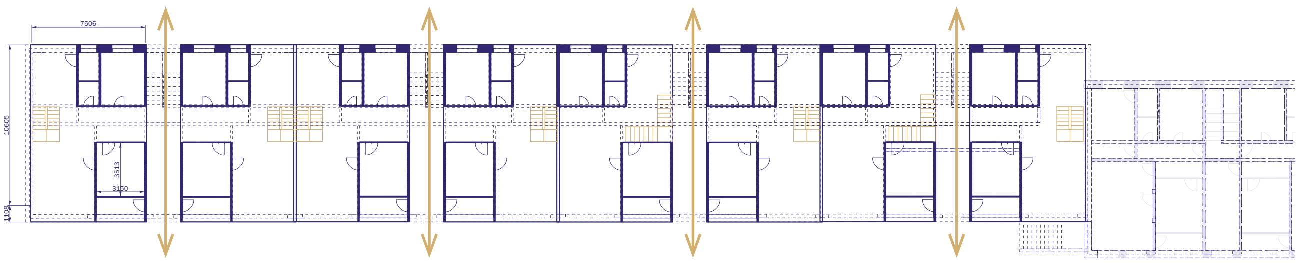
Block A2 - 2nd floor - new floorplan



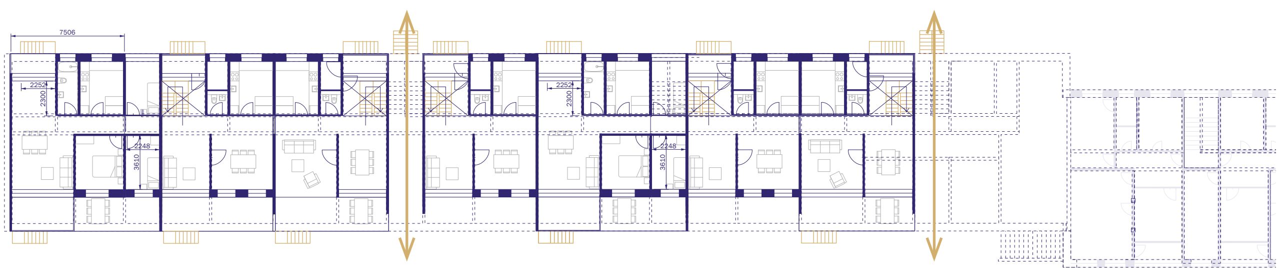
Block A2 - 3, 4th floor



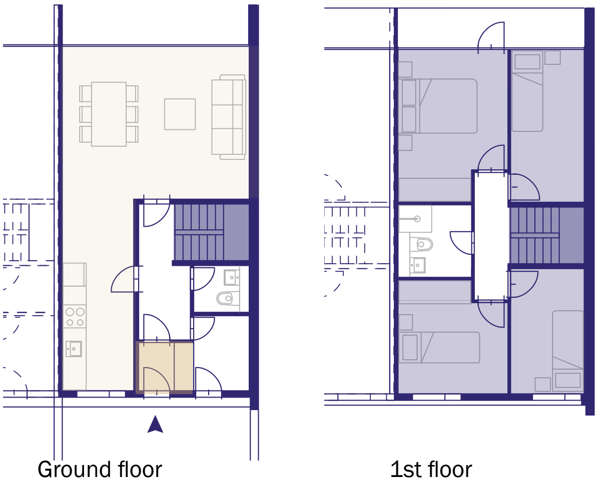
Ill.145 | Iteration 01. Preserving the building as it is, partially transforming into row houses and keeping the last two as apartments.



Ill.147 | Iteration 02. Disassembling the elements as room blocks. These can be placed on the existing basement and build around.There is room for variation due to the regular spans that allow breaking the symmetry between houses when placing the

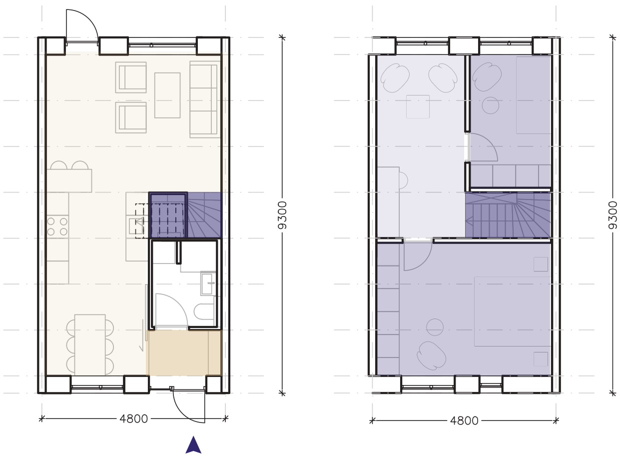


Ill.149 | Iteration 03. Preserving 61% of the the building and disassembling the remaining elements as room blocks.



Ground floor 1st floor

Sundparken, block E1-E2, J. Broch-Christensen. 140 m²



Ground floor 1st floor

Circle House, GXN. 90m²

Ground floor 1st floor

Montagerækkerne, Panum&Kappel. 120m²

Entrance
Common areas
Staircase
Bedrooms
Extra rooms
▲ Main entrance

Ill.150 | Analysis of floorplan in row houses of case studies.

THE FLOORPLANS

The distribution of the rooms is based on an analisys of the existing row houses (See sub-chapter: Floorplan Typologies) and the case studies Circle House and Montagerækkerne. This identifies the principle elements of a house.

The entrance

Sometimes it is preceded by a front garden or a patio and leads to an entry space visually isolated from the common areas.

The common areas

These are placed on the ground floor and the kitchen is integrated to the space, normally centered on the floorplan or close to the entrance. The livingroom is adjacent to the backyard, receiving the evening sun.

The staircase

It stands in the middle, separating the entrance from the rest and minimising the circulation area on the second floor. In some cases it creates a double heigh space that is more permeable to light,it can be better for natural ventilation and it integrates the two floors with an internal balcony between.

The bedrooms

This are separated from the common areas by the bathroom or the staircase, creating a quiet environment around it.

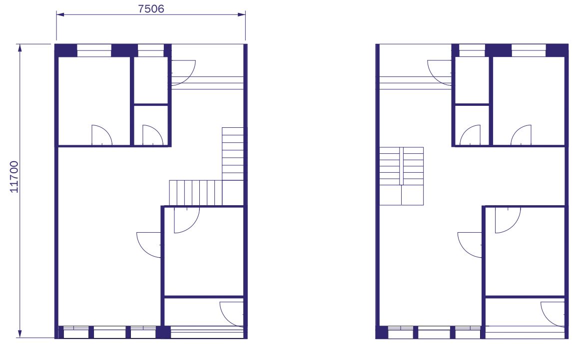
Extra rooms

Circle House and Montagerækkerne have an extra room that can have multiple purposes and give some adaptability to the floorplan. This is suitable both for

The most relevant studies are presented in this section. One of the biggest issue in the floorplan was to fit the staircase between the fixed walls without interrupting the circulation and placing the entrance strategically.

Full depht, different staircases

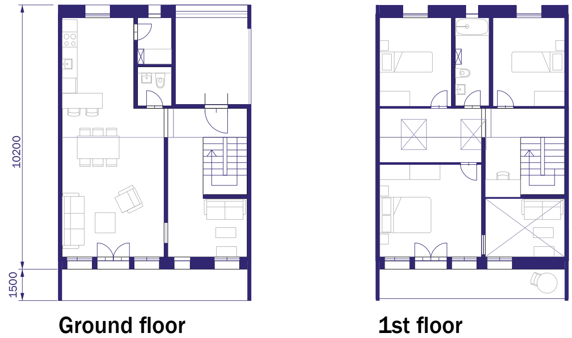
Illustration 151 shows different ways to place the staircase in the original floorplan. Each floorplan is 90m^2, meaning that each house is 180m^2 and must be reduced. The following studies achieve that by decreasing the depht of the plan and pushing the front wall of the entrance.



Ill.151 | First studies.

1. Double-height southern staircase, double skin entrance

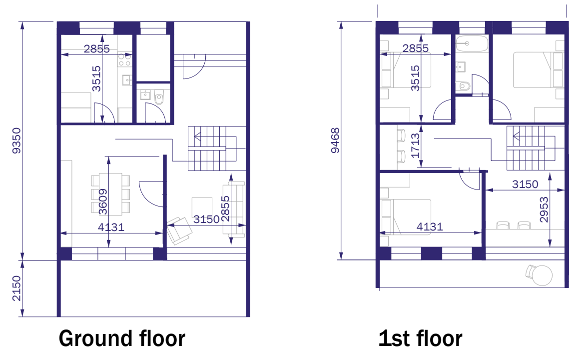
Iteration 02 removes 9 m^2 of heated floor area proposing a double skin access on the north-east corner, but this leaves the room on top of it unsupported. On the south, 1.5m are occupied by a terrace. The saircase creates a double-height space and separated a secondary quiet livingroom. This faces south and risks overheating and visual discomfort due to direct sunlight.



Ill.152 | Iteration 01.

2. Centered staircase, entrance hall

A different study rotates the stairs and removes the double height space, but the circulation is not wide enough. Moreover, the entrance is almost the same size as a room and the space is not efficiently used.



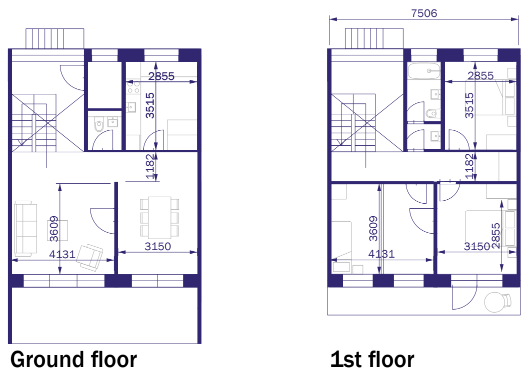
Ill.153 | Iteration 02.

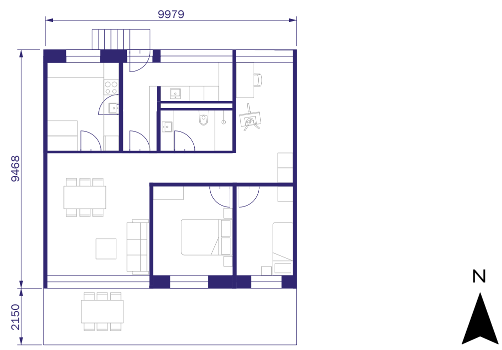
3. Double height northern staircase integrated with entrance

This problem is fixed in the last proposal, where the staircase is moved to the north and combined with the access. In this way, the ground floor has a big indirect source of light. The livingroom is separated from the dining room, adjacent to the kitchen. The terrace is 2.15m deep, and the entrance wall is now aligned with the rest of the facade to avoid thermal bridges or loss of space when insulating the existing reused elements.

In the first floor there are three bedrooms, one of them offering the possibility to be subdivided in two by the placement of the windows.

The single story floorplan has a similar room distribution with the common areas in one side and the private areas towards the east. The entrance is in between, dividing the flow.





Ill.154 | Iteration 03.

ROOM PROGRAM

Room	User group	Area m2	Quantity	Capacity People	Level of activity met Larsen, T. S., 2020
Unit A	First time buyers	120-150		9 units	
Livingroom and Kitchen		40-45	1	3-5	1,5
Bedroom		10-13	1	2	0,8
Bathroom		5-10	2	1	1,2
Rooms		8-10	3	1	1,2
Unit B	Mix	80-100		23 units	
Livingroom and Kitchen		30-35	1	2-3	1,5
Bedroom		10-13	1	2	0,8
Bathroom		5-10	1	1	1,2
Rooms		8-10	2	1	1,2
Unit C	Elderly couples	60-75		8 units	
Livingroom and Kitchen		30-35	1	1-2	1,5
Bedroom		10-13	1	1-2	0,8
Bathroom		5-10	1	1	1,2

(Ill. 155) Room program. The table shows the reference values to study the indoor environment quality in the row houses.

Visual comfort	Thermal comfort		Atmospheric comfort	
Daylight factor	Temperature	CO2	Ventilation strategy	Ventilation rate
%	C	PPM	Natural / Mechanical	l/s pr. m2
Valbjørn et al, 1999	Dansk Standard, 2019	Dansk Standard, 2019	By og bygning 202	Appendix
2-3%	20-26	900	Natural	2,2-3,7
2-3%	20-26	900	Natural	2,2-3,7
-	20-26	900	Natural	2,2-3,7
2-3%	20-26	900	Natural	2,2-3,7
2-3%	20-26	900	Natural	2,2-3,7
2-3%	20-26	900	Natural	2,2-3,7
-	20-26	900	Natural	2,2-3,7
2-3%	20-26	900	Natural	2,2-3,7
2-3%	20-26	900	Natural	2,2-3,7
2-3%	20-26	900	Natural	2,2-3,7
-	20-26	900	Natural	2,2-3,7

ENERGY PERFORMANCE STUDIES

The goal of the study is to examine the point of optimization of insulation in the building envelope, where the saving in operational emissions from reducing heat demand no longer outweighs the embodied emissions of adding insulation to the construction. The optimization point exists because the GWP of the insulation material increases linearly, while the of the U-value of the envelope decreases exponentially, meaning there are diminishing returns on adding more insulation to lower the U-value.

Analysis on generic materials

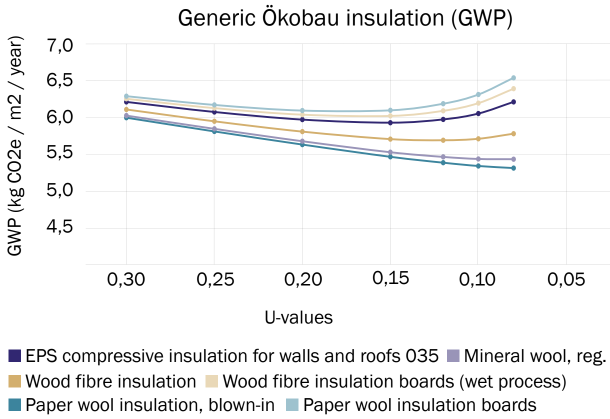
The results indicate that materials with a higher GWP pr kg reach their optimal insulation thickness at a higher U-value than materials with a lower climate impact. The study also indicates that from the generic Ökobau material database the material with the lowest climate impact would be blown in paper-wool insulation and mineral wool, while wood fibre insulation, paper-wool panels and EPS are performing worse. From previous LCA studies the experience is that there are wood fibre insulation products on the market, which should have lower embodied emissions than the generic data. Therefore, the study will expand the amount of insulation materials to consider how product specific material data compares to the generic data.

Analysis on industry- and product specific materials

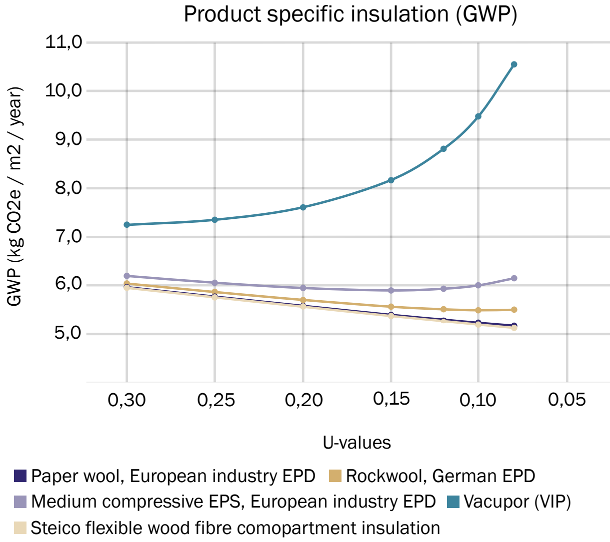
The materials based on industry and product EPDs indicate that the paper-wool and wood fibre insulation have lower emissions than the other materials, while also showing that the EPD and mineral wool materials are in line with the generic data. Lastly, the specialized vacuum insulation panels have such a high GWP pr kg, that the optimization point is reached at a lower U-value than the other materials in the study, while also having a higher overall environmental impact.

Material thickness and final U-values

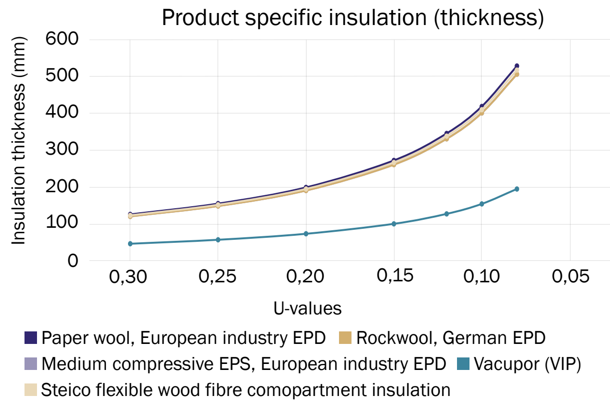
The vacuum insulated panel is made for renovations where there is not much space for insulation in the existing constructions, and figure 158 shows the potential for making a significantly slimmer construction using this material, compared to the others. The final design uses product specific wood fibre insulation due to the results indicating this material would have a lower impact on the final LCA calculation. The material thickness is not determined from the study, as it indicates that a U-value of 0,08 or lower would give a smaller overall climate impact for material. Because there is limited space in the gables,



(Ill. 156) Analysis on generic materials.



(Ill. 157) Analysis on industry and product-specific materials.



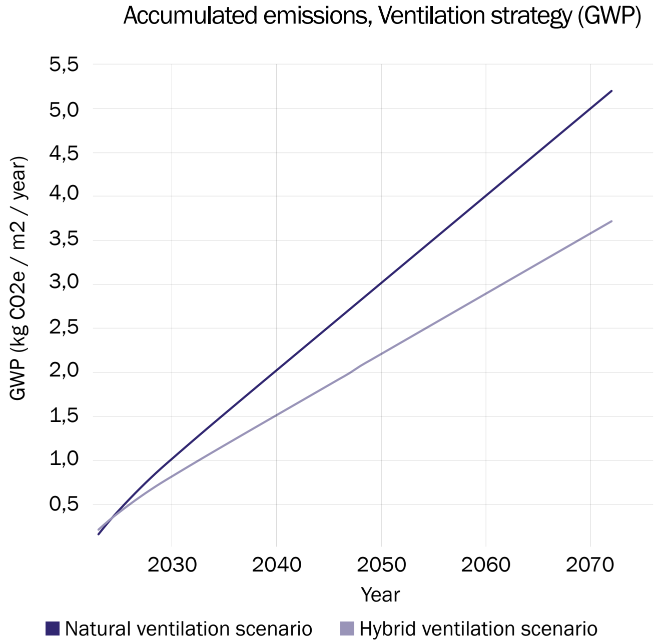
(Ill. 158) Analysis on material thicknesses and final U-values.

and to not reduce the daylight and spatial qualities significantly, the southern wall and gables will have U-values of 0,1 W/m²K and 0,12 W/m²K respectively. From testing in Be18 there is a significant reduction in the amount of energy spent on heating, when introducing a mechanical ventilation system with heat recovery in winter. This study examines if the operational emissions saved in this regard are larger than the emissions from production of the ventilation system.

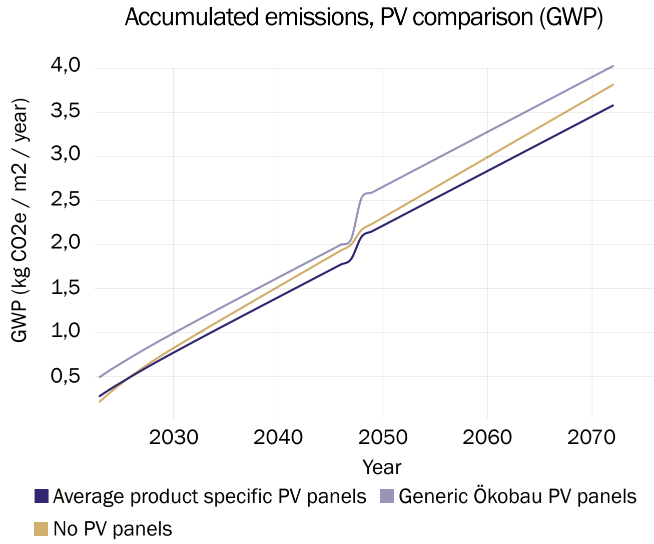
Analysis of ventilation strategy
Figures 159 shows the total emissions of the first year are higher in the hybrid ventilation scenario than in the scenario using only natural ventilation, as the production stage for the ventilation system is accounted for here. The results show a significant saving in operational and total emissions is possible with the implementation of the hybrid ventilation strategy. The embodied emissions in the ventilation system make up less than 0,1 kg CO_2e / m² /year, while saving 1,59 kg CO_2e / m² /year, which is a reduction in operational emissions of 30,5% compared to the natural ventilation scenario.

Analysis of photovoltaic panels
After implementing the hybrid ventilation solution, the overall energy frame is still 47,7 kWh/m2 yearly, and with little room to change façade openings to keep daylight conditions and direct access to the outside, the solution of using photovoltaic panels is a good opportunity to lower the energy demand. This study is performed to examine whether the operational emissions savings makes up for the embodied emissions associated with the production of the PV panels.

It is inconclusive if an overall savings in emissions can be found by using the PV panels, depending on the specific product that is chosen in the design, as the generic Ökobau LCA data has a significantly higher amount of embodied emissions than the average product. The embodied emissions of the generic panels produce 10,6% more embodied emissions than are saved in operational emissions, while the product average indicates a 1,1% reduction in overall emissions. Since the PV panels are required for the building to pass the energy frame requirement, they're implemented assuming the savings indicated by using the specific product average to be true.



(Ill. 159) Analysis of ventilation strategy

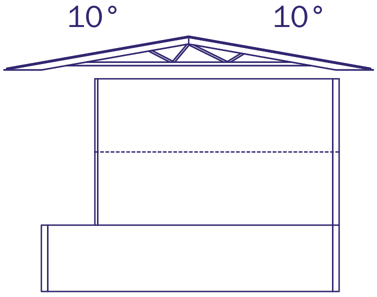


(Ill. 160) Analysis of photovoltaic panels.

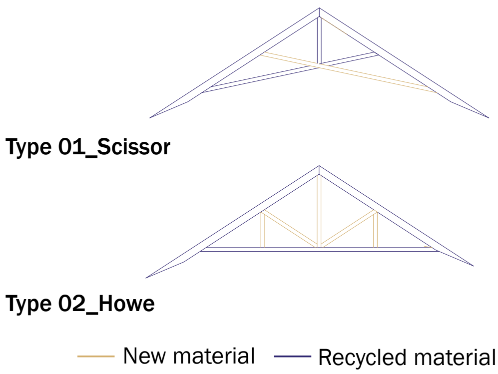
SOLAR PANELS AND ROOF

The intention for the roof is to reuse the metal cladding and recycle the wood rafters by adapting them to a new inclination that is more suitable for solar panels.

Illustration 161 shows that the existing roof does not fit the new building, sing the floorplan has a reduced depth. Two types of wooden trusses have been studied for this purpose, scissors and howe (Ill. 162). Even though the Scissor truss requires less new material, the Howe type fits better to the construction, since the beam lands on the slab reinforcing the connection strength and stability.



(Ill. 161) Existing wood rafter on new building.



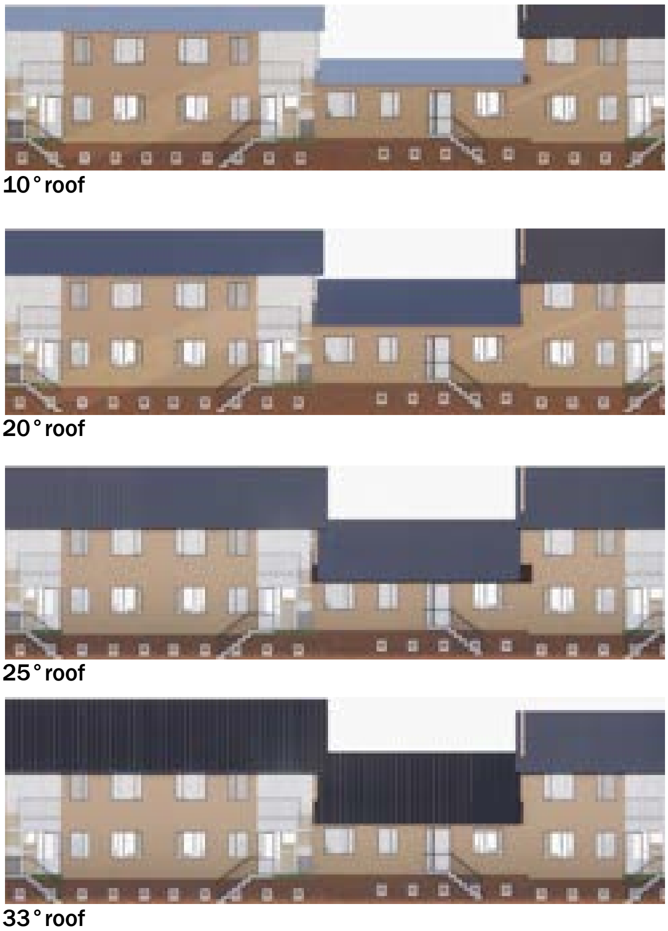
(Ill. 162) New possible trusses.

Different iterations have been conducted to optimize the angle according to the solar panels integrated with the roof, but also the scale of the building. For this, the focus is set on the performance of the photovoltaics during summer and equinox separately. The energy covered by them corresponds to the energy performance studies (See sub-chapter: Energy Performance Studies) and applies to a 130m2 unit.

Illustration 163 shows the appearance of the facade on each iteration and how the height of the row houses affects its scale.

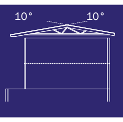
Conclusion

The results show that in general terms, PVs on the roof are more productive during the summer. Specifically, an angle of 25° has an acceptable contribution while the height of the roof does not impact the architectural scale of it. The parapets can be used as an optimization during the equinox, when energy demand for heating is higher, but there is less area available when in fact it requires more.



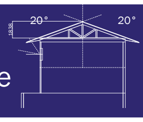
(Ill. 163) Facade for each different angle.

1. **10 degrees**
7.14m^2 of solar panels per house



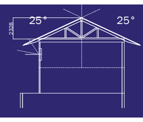
Maintaining the current 10° angle shows to be among the least efficient solutions, demanding more solar panels which have a high GPW (See: Energy Performance Studies). The facade is low and barely precepted as a pedestrian, as in the current case.

2. **20 degrees**
6.75m^2 of solar panels per house



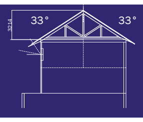
Rising the angle to 20° angle shows some improvement, although it is not significant. The facade does have a human scale. (Ill. 164).

3. **25 degrees**
6.6m^2 of solar panels per house

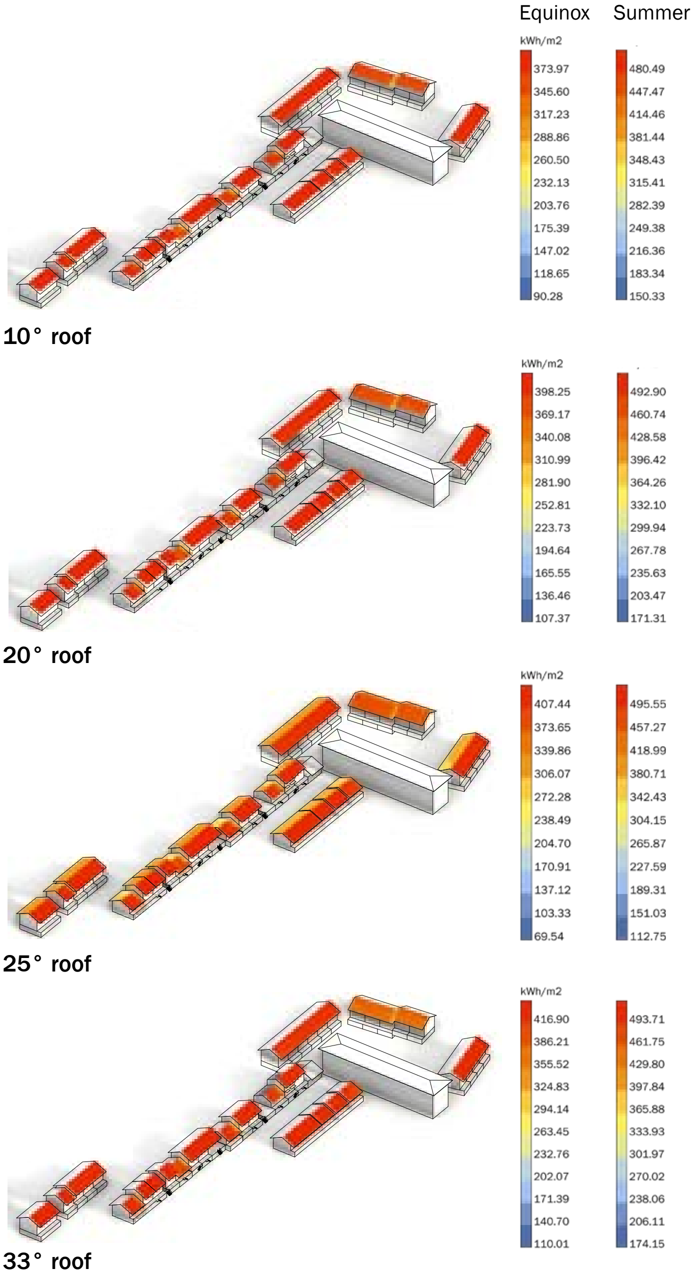


A 25° angle would require 0.45 m2 less of solar panels per house, which indicate bigger savings in the masterplan scale. The facade does have a human scale. (Ill. 164).

4. **33 degrees**
6.5m^2 of solar panels per house



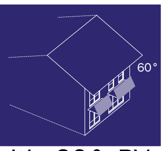
A roof with 33° is the most efficient of the study, but it adds 3.2 meters to the total volume height, interfering with shadows and dissolving the human scale more than the previous iterations. (Ill. 164).



(Ill. 164) Solar radiation during the equinox and summer with different roof angles..

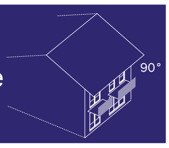
SOLAR PANELS AND BALCONY

1. **60 degrees**
6.7m^2 of solar panels per house

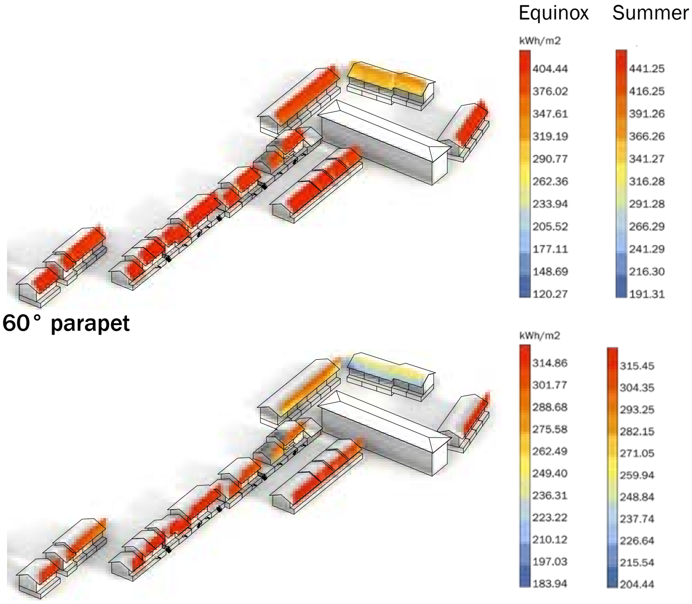


Replacing the parapet of the balcony with 60° PVs shows a higher contribution than a 20° roof and a more stable performance in summer and equinox. Though, it takes away more usable space.

2. **90 degrees**
8.7m2 of solar panels per house



On a 90° parapet, the solar panels have a poor performance both during equinox and summer and it therefore not recommended.



(Ill. 165) Solar radiation during the equinox and summer on the parapet of the balcony.

DESIGNING WITH THERMAL MASS

Transforming an area built with prefabricated concrete elements poses many challenges, but there are also opportunities to be explored. Concrete has, as previously mentioned (See Chapter: The Potential of Thermal Mass), a large carbon footprint, thus giving it a negative reputation when it comes to building sustainable.

A large part of the sourced materials from the A1 block is concrete elements. The design for the new housing units will therefore utilize the same or at least comparable structural system where the loadbearing structure consists of concrete walls and slabs. This means that without any cladding most of the internal walls would be in concrete and the same applies to the floor and the ceiling.

This is therefore a great opportunity to use the concrete heat capacity properties to improve the indoor thermal comfort and the energy frame within the new housing units.

Restrictions when designing with thermal mass
As described in the theoretical section on thermal mass, the concrete has to be exposed directly to the internal air. If the concrete is clad with a material such as gypsum its thermal mass properties would be blocked since it would no longer be in direct contact with the air around it.

Before determining which surfaces and how many should be exposed, it is important to know which heat capacity category to aim for. The four categories consist of: extra light (40 Wh/K m2), medium light (80 Wh/K m2), medium heavy (120 Wh/K m2) and extra heavy (180 Wh/K m2) (Miljøstyrelsen, 2007). Aiming for a medium heavy construction seems quite plausible due to the high amount of concrete in the material atlas. The calculation method and datasheet presented in the Theoretical section on thermal mass is applied in this study.

Choosing the internal surfaces
The exterior walls will be either reconstructed or reinsulated, this means that the potential use of thermal mass on the exterior walls is quite limited. These will most likely be cladded in a material such as gypsum. Gypsum has a heat capacity of 3 Wh/K m2.

The floor in the existing building currently cladded with a wood flooring on joists. This build up will probably be reused to some extent to ensure a higher percentage of reused materials. Wood flooring over concrete has a heat capacity of 10 Wh/K m2.

The loadbearing internal walls will all be in concrete and could easily be exposed, allowing its high heat capacity to be utilized. Exposed concrete on internal walls has a heat capacity of 33 Wh/K m2.

The ceiling has a high potential regarding its heat capacity and to reach the medium-heavy category it is necessary to use this potential to its fullest. The problem is however that it can be a bit restrictive on the aesthetical expression and if any installation is required in the ceiling it would have to be exposed. An exposed light weight concrete ceiling has a heat capacity of 45 Wh/K m2.

Calculating the heat capacity
The heat capacity values from the different components are added together with an additional 10 Wh/K m2 for furniture, using the formula described in the Potential of thermal mass section.

Heat capacity Calculation:
45 + 10 + 3 + 33 + 10 = 101 Wh/K m2

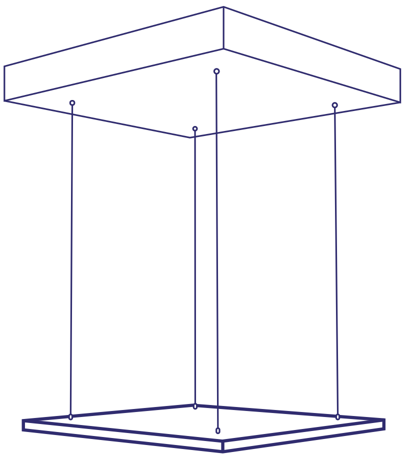
This ensures that the building meets the aim of being categorized as a medium heavy construction. This number will be used in the final BE18 model.

Utilization of thermal mass in the ceiling
It has been decided to utilize the heat capacity of concrete within the ceiling construction. This requires that the concrete surface is exposed to the internal air. Concrete is great at soundproofing between apartments due to its sound reflective properties.

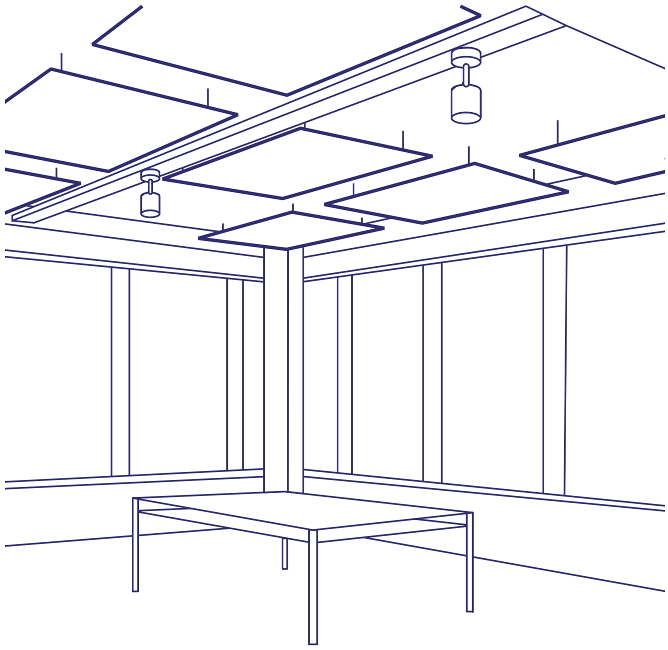
This can however have a negative impact on the acoustic comfort within the building since the sound reflectivity can create echoes (Tie et al., 2020). This design study will therefore explore how a concrete ceiling can be designed so it uses thermal mass without having poor acoustic performance.

OFFICE SPACE INSPIRATION

Office buildings often times have to deal with this exact problem and will thus be used as an inspiration in the design process. One way to solve this issue is with acoustic panels suspended from the ceiling with wires. These panels ensure that the airflow to the surface of the concrete ceiling is unobstructed as long as there is a reasonable air gap between the panels and the walls (Rockfon, 2023). The panels are shown on the illustrations 166 and 167.



(Ill. 166) Sketch of suspended acoustic ceiling panel.

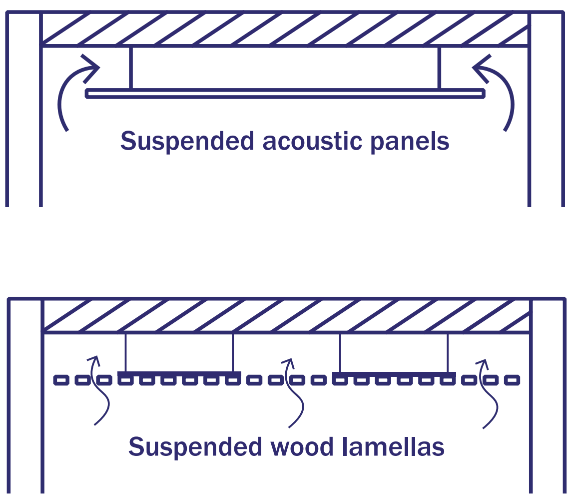


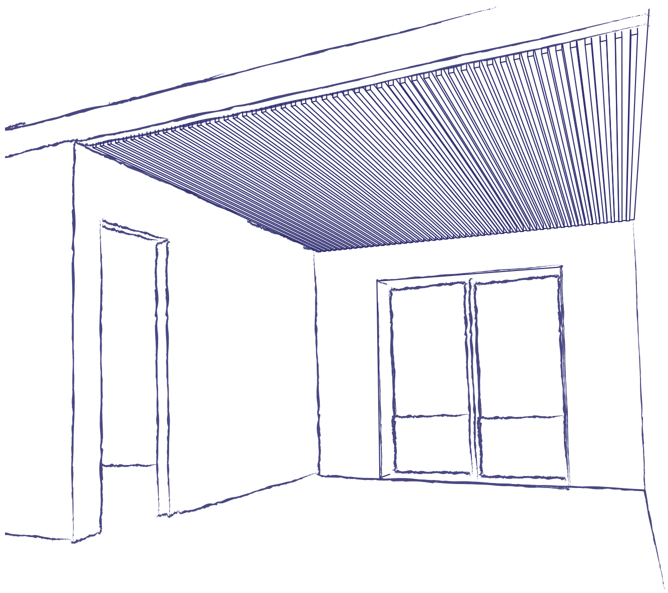
(Ill. 167) Sketch of suspended ceiling.

RESIDENTIAL IMPLEMENTATION

The suspended acoustic ceiling panels both improve the acoustics and still allow for air to circulate to the surface of the concrete slab (Ill. 168). It does however have a distinct aesthetic that fits in an office workspace but could seem out of place in a Livingroom.

A similar solution could be to add a layer of wooden lamellas. They would create a more uniform expression in the ceiling, while still allowing air through in the space in between the lamellas. The solution shown on the illustration below will be further explored and implemented in the final design.





(Ill. 168) Sketch of wooden lamellas as souspended ceiling.

INDOOR ENVIRONMENT DESIGN STUDIES

Objective
It is not enough that the new housing units have a low Carbon footprint, they have to be comfortable to live in as well. The design will, therefore, implement design solutions that improve the indoor environmental quality, by studying the effects of certain design variations on multiple factors such as indoor temperature, daylight and energy consumption.

There is no right answer, but some solution will be preferable compared to others.

Simulation basis
The initial design proposal has at this stage achieved a desirable energy frame through calculations done in BE18 and an initial façade expression and window placement have achieved adequate daylight results, as illustrated in the daylight studies within the design process.

The BSim model is based on the construction build ups that were picked based on our energy frame and LCA calculations.

Required benchmark
The expectation regarding the results of the BSim analysis, is that they should be close to meeting the requirements set by the Danish building regulation regarding indoor thermal comfort. The regulation states that there in a housing unit can be a maximum of 100 hours above 27 degrees and 25 hours above 28 (BR18, 2023).

The calculation is based on the living room/dining area within a type A unit located on the existing foundation furthest to the west. This should be one of the critical units when it comes to overheating since it is exposed to the south with little external shading.

The room is deemed critical due to its orientation, internal loads and glazed area.

Settings
The information within the room program is used in the Bsim system settings, such as set points for heating and venting.

RESULT OVERVIEW:

	Unit	0: Initial	1: Glazing	2: Thermal	3: Overhang	4: Final
Hours above 27 ˚C	[h]	165	102	101	81	79
Hours above 28 ˚C	[h]	88	46	37	28	24
Q Heating	[kWh]	1312	1600	1452	1506	1511
Q Sun	[kWh]	2982	2353	2353	2135	2105
Q Transmission	[kWh]	-2561	-2659	-2434	-2397	-2389
Q Venting	[kWh]	-2682	-2252	-2342	-2218	-2201
KW/h/m2 Heat	[kWh/m2]	29,2	35,6	32,3	33,5	33,6

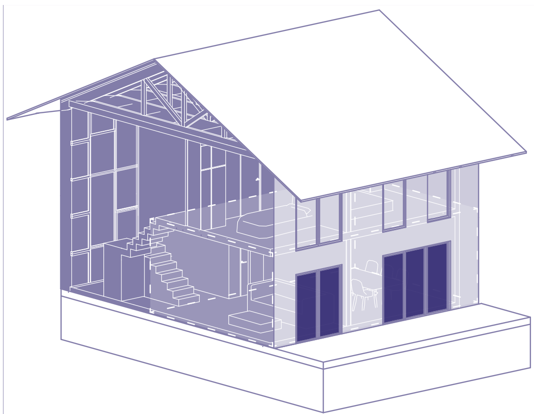
Ill.169 | Table with result overview of indoor environment studies.

Initial Model:

Hours above 27 degrees Celsius:	165	X
Hours above 28 degrees Celsius:	88	X

The initial model complies with the daylight requirements described in the room program, but the thermal comfort is inadequate.

It does however have a low heating demand due to high sun radiation as seen on the ledger above.

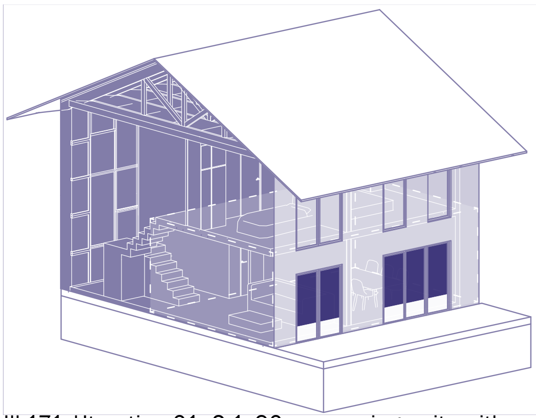


Ill.170 | Initial model. 2.1x90cm opening units fully glazed.

1. Reduzed Glazing:

Hours above 27 degrees Celsius:	102	X
Hours above 28 degrees Celsius:	46	X

The high overheating was reduced significantly by reducing the glazed area of windows from 90% to 71%. This design solution changes the daylight conditions, but the impact is determined by the placement of the subtracted glazed area. To retain the best daylight conditions, it was decided to change the lower part of the windows. This ensured adequate daylight and less overheating.

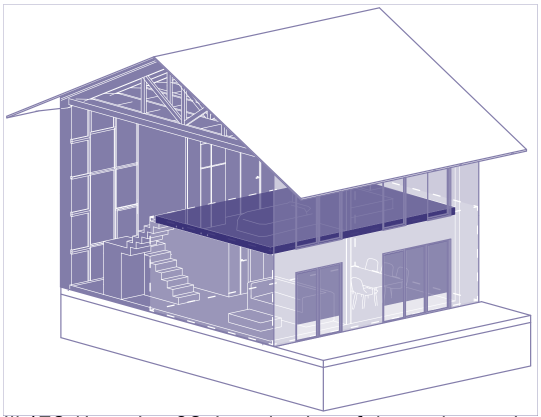


Ill.171 | Iteration 01. 2.1x90cm opening units with an opaque panel on the bottom taking 29% of the area.

2. Introducing Thermal Mass:

Hours above 27 degrees Celsius:	101	X
Hours above 28 degrees Celsius:	37	X

As investigated in the theoretical framework, thermal mass can have an influence on a building's energy performance and indoor environmental comfort, since a higher thermal mass can help stabilize temperature fluctuations. This property is utilized in the design proposal by exposing the reused hollow core slabs in the ceiling and the load bearing internal walls. This gives the building a heat capacity of 107 Wh/K pr.m^2.

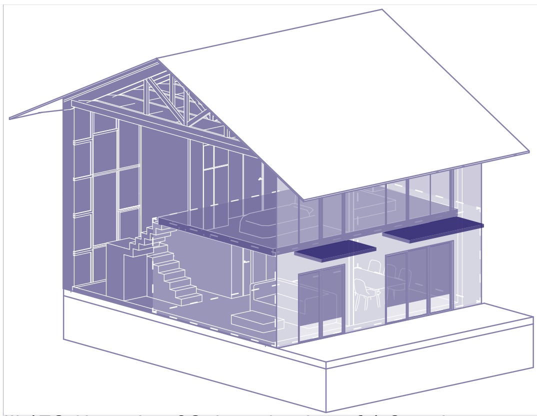


Ill.172 | Iteration 02. Introduction of thermal mass in the ceiling: concrete exposed in the room.

3. Introducing Overhang:

Hours above 27 degrees Celsius:	81	OK!
Hours above 28 degrees Celsius:	28	X

The design proposal is close to achieving the thermal comfort requirements. An 1,2-meter overhang with a distance of 0,44 meter from the window top is added. This overhang can also act as a balcony, thus giving the shading system a practical function for the residents.

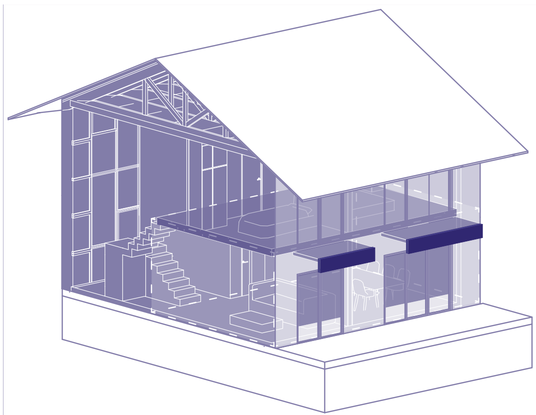


Ill.173 | Iteration 03. Introduction of 1.2 m deep overhangs.

4. Final Model:

Hours above 27 degrees Celsius:	79	OK!
Hours above 28 degrees Celsius:	24	OK!

The overhang ensured that the hours above 27 degrees stays within the BR18 regulations, but the proposal is still 4 hours too many above 28. This is reduced by lowering the distance from the window top to the edge of the balcony from 0,44 to 0,3 meters. This change can be implemented when designing the structural system and the railing system.



Ill.174 | Iteration 04. Vertical extension of overhangs to approach the window edge.

DAYLIGHT ANALYSIS

Natural light in indoor spaces is important for humans' physical and psychological health, and openings create a connection to the outside conditions. It also contributes to energy efficieny by reducing the need for artificial light (Steemers, 2015).
The Danish Building Regulations demand a minimum of 300 lux on at least 50% relevant floor area for 50% of the sun hours that can be accomplished when the glazed area without shading equals at least 10% of the relevant floor area (Bygningsreglementet, 2018).

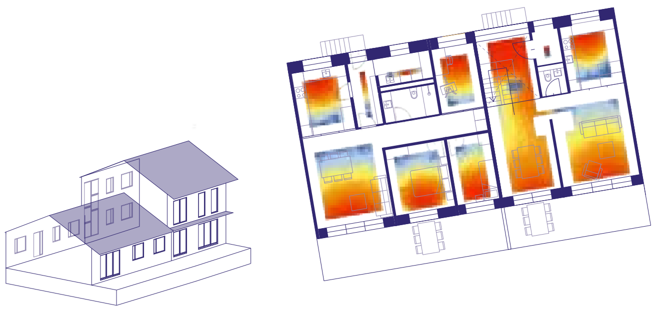
There are two main restrictions related to the openings in the project.
- the preservation of the existing facade with concrete elements in the north limits the vertical dimension. Otherwise, these would need to cut.
- the north-south orientation risks of overheating.

The variable parameters for this daylight study are external shading elements and opening sizes (WxH). The LT value is fixed on 0.7 due to the chosen windows.

1. 1st floor

Overhang N: X
Windows N: 1.5x1.3
Overhang S: 0.8 m
Windows S: 0.9x2.1
1.5x1.3

The first iteration proposes windows of similar dimensions to the exiting ones on the north and sliding windows on the south in connection to the garden. The overhang dimensions corrispond to Be18 initial studies that suggest that 0.8m is enough to avoid overheating. Daylight conditions are enough.

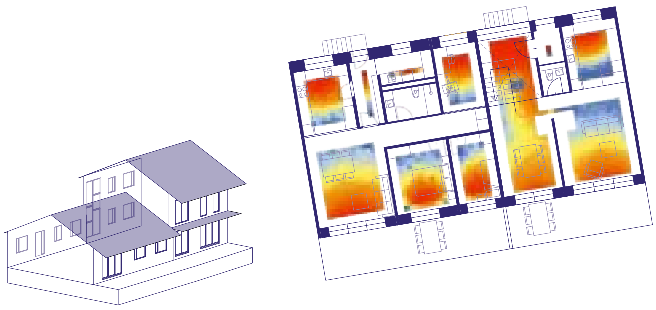


(Ill. 175) Iteration 01. Daylight provision on 1st floor of single and 2-storey houses.

2. 1st floor

Overhang N: 0.5 m
Windows N: 1.5x1.3
Overhang S: 1.5 m
Windows S: 0.9x2.1
1.5x1.3

Due to resulting overheating problems on the Bsim simulations, in the second iteration the overhang is extended to 1.5m, reducing daylight in the south oriented rooms significantly.

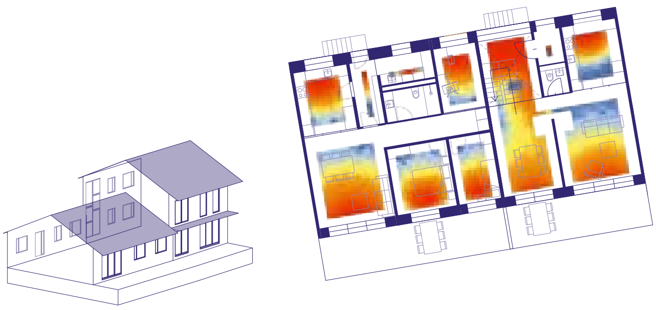


(Ill. 176) Iteration 02. Daylight provision on 1st floor of single and 2-storey houses.

3. 1st floor

Overhang N: 0.5 m
Windows N: 1.5x1.3
Overhang S: 1.2 m
Windows S: 0.9x2.1
1.5x1.3

A reduction of 0.3m in the lenght of the southern overhang improves the results while allowing it to function as a balcony in the 2-storey house. Though it still is insufficient.



(Ill. 177) Iteration 03. Daylight provision on 1st floor of single and 2-storey houses.

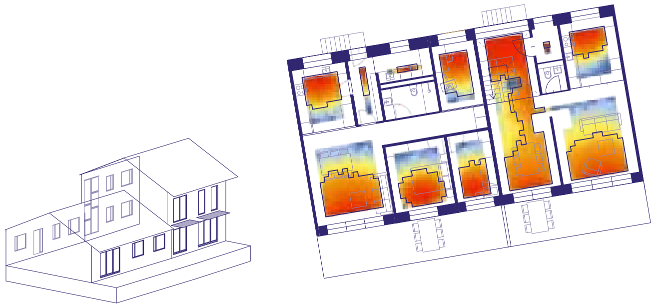
N

4. 1st floor

Overhang N: X
Windows N: 1.5x1.3

Overhang S: 1.2 m
Windows S: 0.9x2.1
1.5x1.3

In the fourth iteration the balcony is split into two letting more light to access the rooms. The violet line in the illustration indicates the area that has over 300 lux for at least 50% of the daylight hours. At this point, overheating is still a problem.



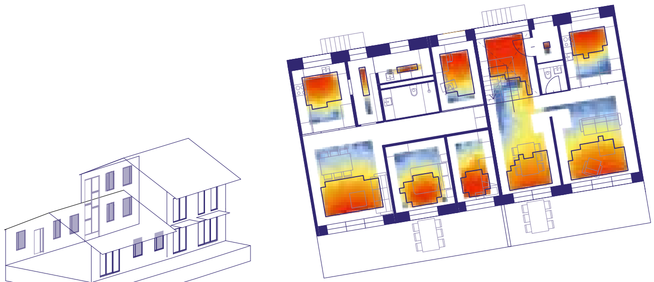
(Ill. 178) Iteration 04. Daylight provision on 1st floor of single and 2-storey houses.

5. 1st floor

Overhang N: X
Windows N: 1.2x1.6

Overhang S: 1.2 m
Windows S: 0.9x2.1
1.2x1.6

To decrease overheating, a new proportion of windows with a similar total area is studied. Since it is taller, it was expected for the light to get further in the room, but the presence of the overhang and width reduction affected notably the area covered by enough illuminance. In addition, this solution involved cutting the concrete of the facade.



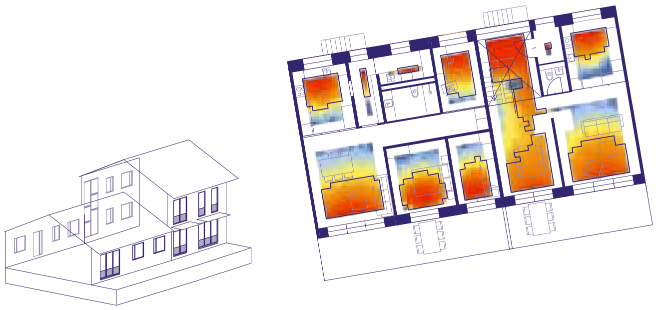
(Ill. 179) Iteration 05. Daylight provision on 1st floor of single and 2-storey houses.

6. 1st floor

Overhang N: X
Windows N: 1.5x1.3

Overhang S: 1.2 m
Windows S: 0.9x1.5
1.5x1.3

In this iteration a third of the 2.1m tall windows is replaced by an opaque material at the bottom. This had a big positive impact on the thermal comfort without affecting the daylight results considerably.



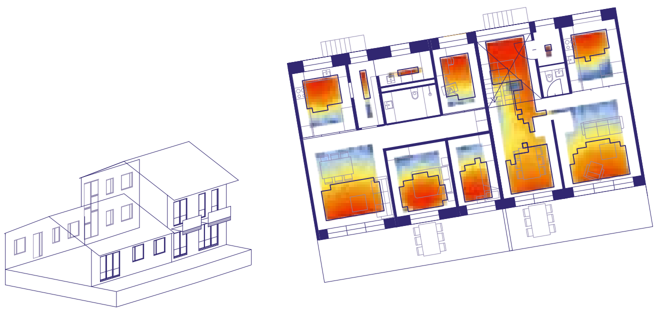
(Ill. 180) Iteration 06. Daylight provision on 1st floor of single and 2-storey houses.

7. 1st floor

Overhang N: X
Windows N: 1.5x1.3

Overhang S: 1.2 m
Windows S: 0.9x1.5
1.5x1.3

To eliminate the last extra hours above 27°, an opaque railing has been aded on the balcony of the 2-storey house, overpassing the slab in the bottom by 0.3m to approach the border of the windows of the floor below. The daylight results are acceptable.



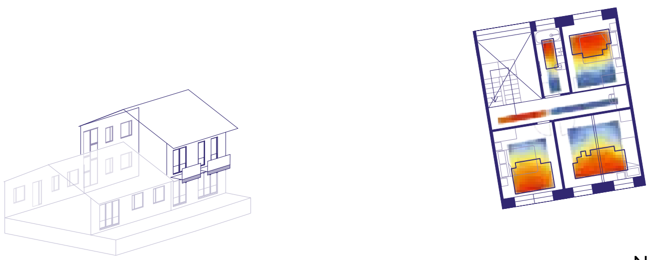
(Ill. 181) Iteration 07. Daylight provision on 1st floor of single and 2-storey houses.

2nd floor

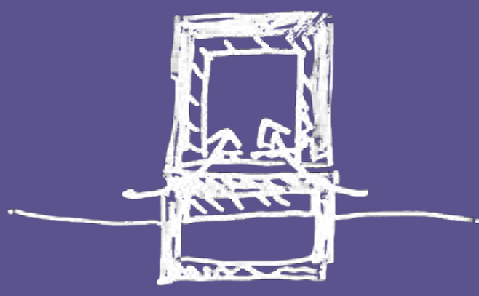
Overhang N: X
Windows N: 1.5x1.3

Overhang S: 1.2 m
Windows S: 0.9x1.5

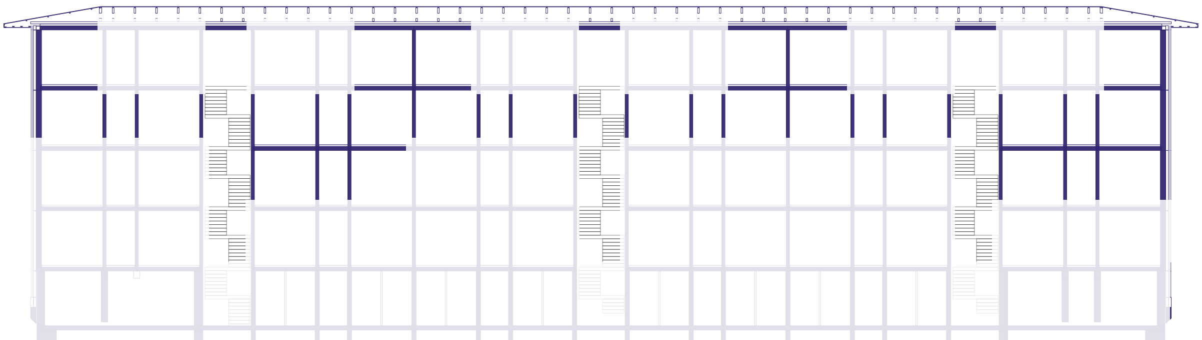
The opaque 0.8m tall railing impacted negatively the amount of daylight on the upper floor bedrooms. This can be replaced by a more permeable solution. Appendix 8 shows the results according to the 10% rule.



(Ill. 182) Iteration 08. Daylight provision on 1st floor of single and 2-storey houses.



THE JOINTS



Ill.183 | Remaining building elements.

This sub-chapter studies the thermal bridges on joints due to the preservation of the basement and the connections between the remaining elements removed from the existing building, used on the row houses built directly on the terrain. This topic is developed on a conceptual level.
Illustration 183 shows the leftover material from the transformation of a block. These should be recycled, but as explained on the study cases (See sub-chapter: Hybrid trækonstruktion and Montagerækkerne) load-bearing concrete walls and slabs can be structurally compromised during the sawing process. Therefore, these should be combined with new materials to recover its value, and the link between them should follow the principles of design for disassembly. In other words, it should be reversible.

DETAIL SCALE / DESIGN STRATEGIES

12 Improve overall energy performance **by optimizing transmission losses in the preserved structure and buildups**

13 Ease end-of-life disassembly **by designing reversible joints**

14 Ensure reusability **by introducing enduring materials with a low GWP**

THERMAL CONDUCTIVITY OF TERRACE SLAB

The envelope is one of the biggest aspects in this project since the reuse of the basement leads to thermal bridges and a higher demand for operational energy (See: Foundations' Second Life). In the design proposal, the southern wall is moved two meteres away from the existing foundation line, in order to create shallower rooms with a greater opportunity for daylight quality. This, however, means that there is a direct thermal bridge from the, now exposed, existing floor slab going into the row-houses. This joint is a point of concern and will be analyzed using THERM, to explore how to minimize heat loss through the detail.

1. Existing terrace slab

Line loss U-value: 0.114 W/m^2K

The existing floor slab does not have any insulation, and this is shown is the temperature gradient lines which are packed closely together, meaning that the heat travels fast through the construction due to the overall lack of materials with a low thermal conductivity. The well-insulated outer-wall helps limit the transmission loss through the joint, and as such the U-value on the inside of the construction is calculated to be 0,114 W/m^2K

2. Vacuum insulated panel terrace slab

Line loss U-value: 0.094 W/m^2K

To keep the existing floor height inside the row-house, 25mm vacuum insulated panels are examined for insulating the outside of the terrace floor slab, insulating the thermal bridge while keeping the construction thin. This reduced the U-value through the joint to 0,094 W/m^2K. While the construction is impressively thin, the LCA results indicate that this is a material that should be used sparingly, due to its high level of embodied emissions.

3. Build-up terrace slab

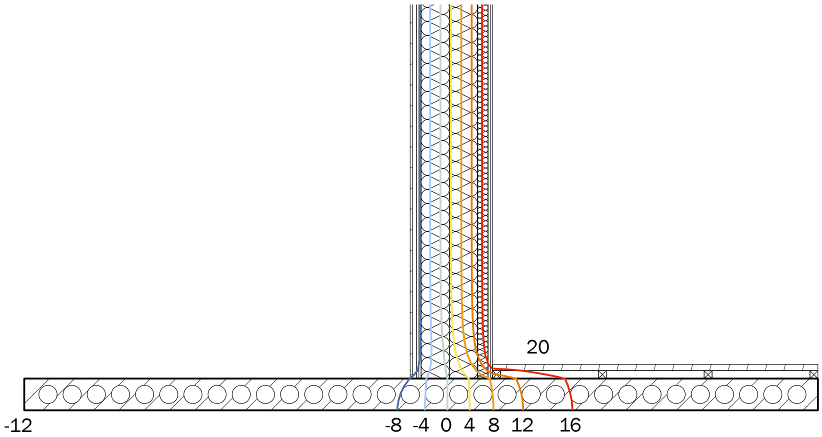
Line loss U-value: 0.095 W/m^2K

An alternative build-up for the slab is examined, using 80mm of compressive EPS insulation to achieve a similar U-value of 0,095 W/m^2K. The LCA study indicates this would have a significant climate impact reduction compared to the vacuum insulation panels, however, the construction is thick and the transition from inside to outside now has

4. Build-up floor slab

Line loss U-value: 0.085 W/m^2K

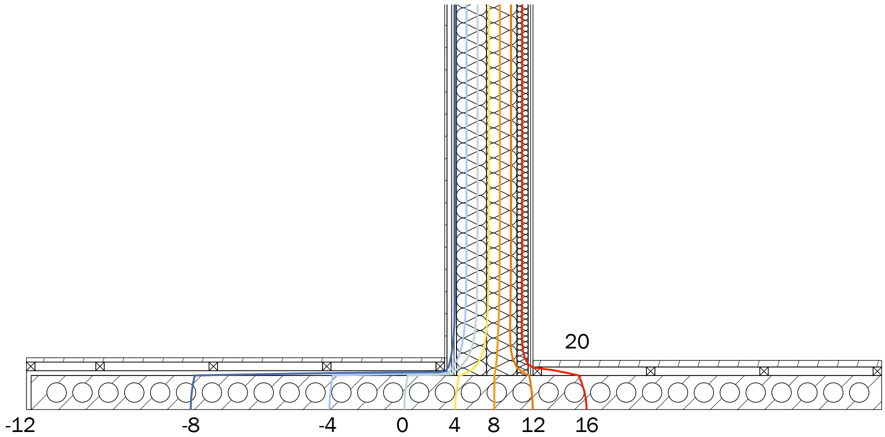
To solve this step the interior floor is raised and insulated 120mm of wood fibre insulation on wooden joists. This allows for a more level free access while also lowering the U-value in the joint further to 0,085 W/m^2K. This is the floor slab build-up chosen in the project.



(Ill. 184) Iteration 01.

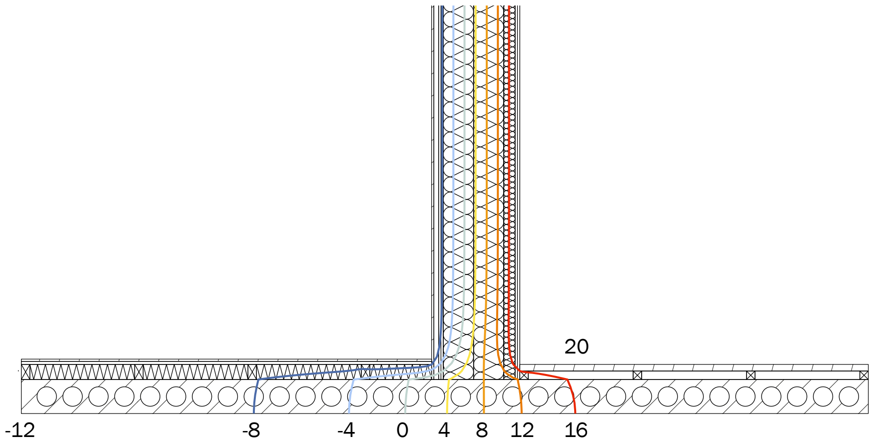
Light wall construction
25 mm - Plywood
60 mm - Wood Fibre insulation, class 36
00 mm - PE-foil
320 mm - Wood fibre insulation, class 36
10 mm - Wind gipsum
37 mm - Ventilated air gap

Existing floor slab
12 mm - Pine cladding
35 mm - Parquet floor boards
45 mm - Floor joists
180 mm - Hollow-core concrete slab, PE



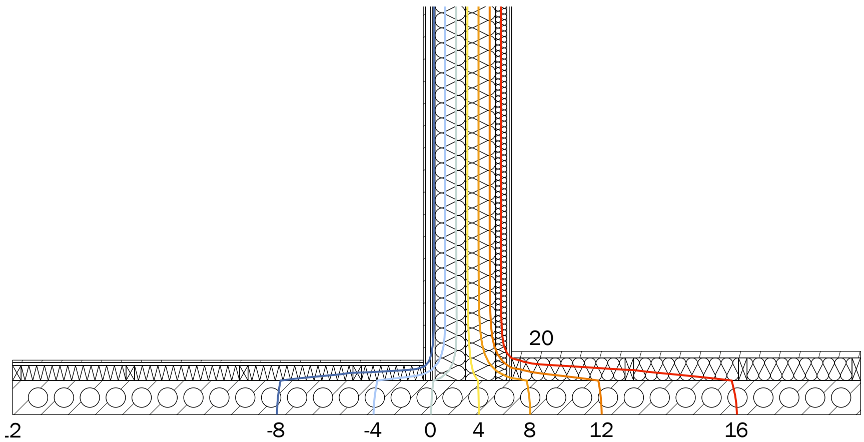
(Ill. 185) Iteration 02.

Vacuum insulated terrace slab
12 mm Wooden terrace boards
20 mm Ventilated air gap w. Wood joists
25 mm Vacuum insulated panel
180 mm Hollow-core concrete slab, PE



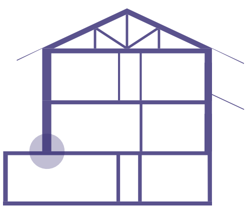
(Ill. 186) Iteration 03.

Build-up terrace slab
12 mm Wooden terrace boards
20 mm Ventilated air gap w. Wood joists
00 mm PE-foil / Bitumen-membrane
16 mm Plywood
20 mm Stationary air gap w. Wood joists
80 mm Compressive EPS, class 32
180 mm Hollow-core concrete slab, PE



(Ill. 187) Iteration 04.

Build-up floor slab
12 mm Wooden terrace boards
20 mm Ventilated air gap w. Wood joists
120 mm - Wood Fibre insulation, class 36
180 mm Hollow-core concrete slab, PE



THERMAL CONDUCTIVITY OF BASEMENT CEILING SLAB

Another point of concern is the joint between the unheated basement walls going into the floor slab of the living room. In the existing building the basement ceiling is not insulated, an earlier analysis (see sub-chapter: Designing with thermal mass) showed an energy- and LCA performance increase in implementing 150mm insulation to the basement ceiling. Likewise, there is an interest in exploring how to minimize the heat loss through this construction further.

1. Existing basement ceiling slab

Line loss U-value: 1.183 W/m²K

The existing floor slab has no insulation between the unheated basement and the inside of the row-house. The semi-heavy construction using the hollow-core slab had a U-value along the inside of 1,183 W/m2K.

2. Insulated basement ceiling floor

Line loss U-value: 0.461 W/m²K

In order to reduce the heat loss through the construction, 130mm of insulation will firstly be applied to the cold site of the construction, which provides a U-value of 0,461 W/m2K.

3. Build-up floor slab

Line loss U-value: 0.206 W/m²K

As mentioned earlier the existing floor construction is raised and insulated to provide better access to the outside, the same applies to the floor for this joint. This reduces the U-value to 0,206 W/m2K. The temperature gradient lines still show a strong heat loss through the concrete walls connecting to the hollow-core slab.

4. Adding thermal bridge insulation

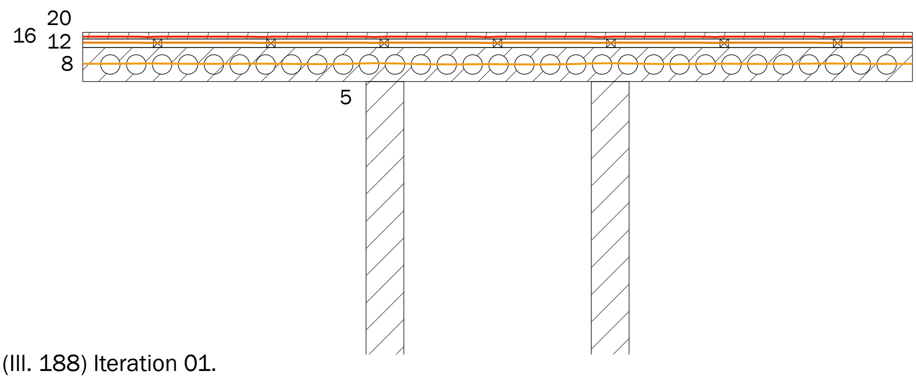
Line loss U-value: 0.189 W/m²K

To reduce this heat loss, 520mm of the basement walls get insulated, this means the hallways retain a height of 1,9m before the insulation starts. This reduces the U-value to 0,189 W/m2K and shows the heat flow slowing down through the construction. This is the solution chosen in the project.

5. Increasing thermal bridge insulation

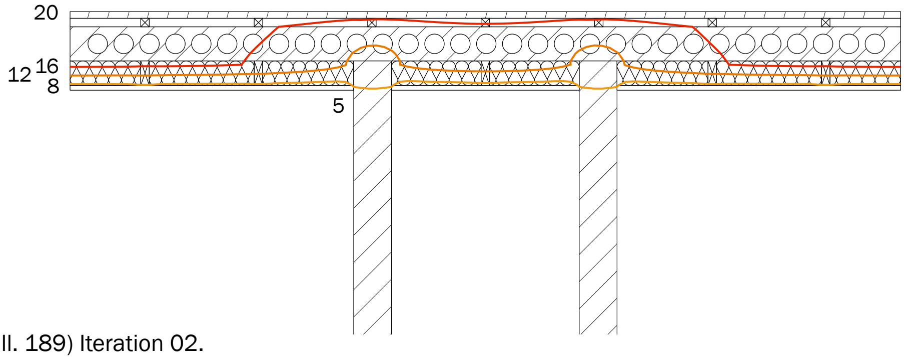
Line loss U-value: 0.184 W/m²K

The insulation around the basement walls is extended to cover a 1 meter from the hollow-core slab, and while it gives a slight reduction of the U-value, the added insulation lowers the room height in the hallways to 1,55m which is not sufficient in the already compact space.



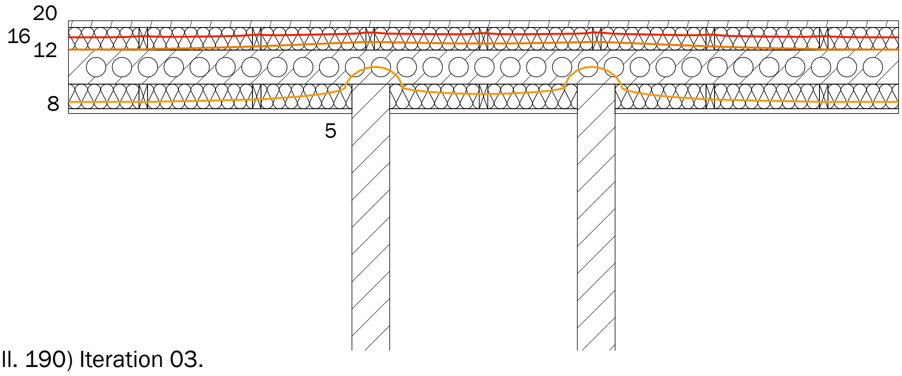
Existing floor slab
35 mm Parquet floor boards
45 mm Wooden floor joists
180 mm Hollow-core concrete slab, PE

(Ill. 188) Iteration 01.



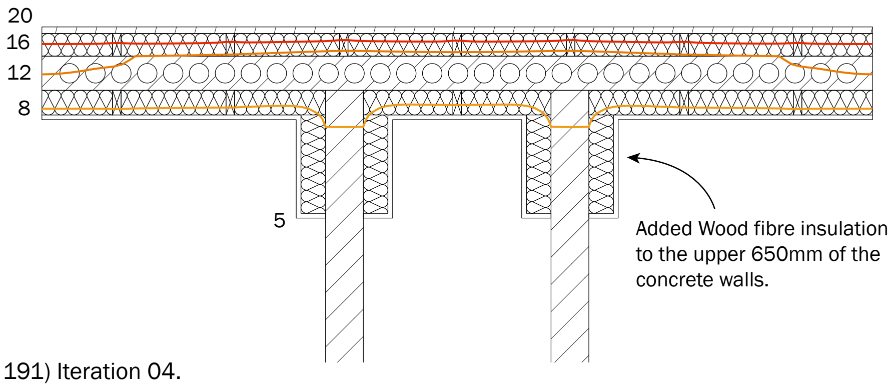
Insulated basement ceiling
35 mm Parquet floor boards
45 mm Wooden floor joists
180 mm Hollow-core concrete slab, PE
130 mm - Wood Fibre insulation, class 36
25 mm Gypsum boards

(Ill. 189) Iteration 02.

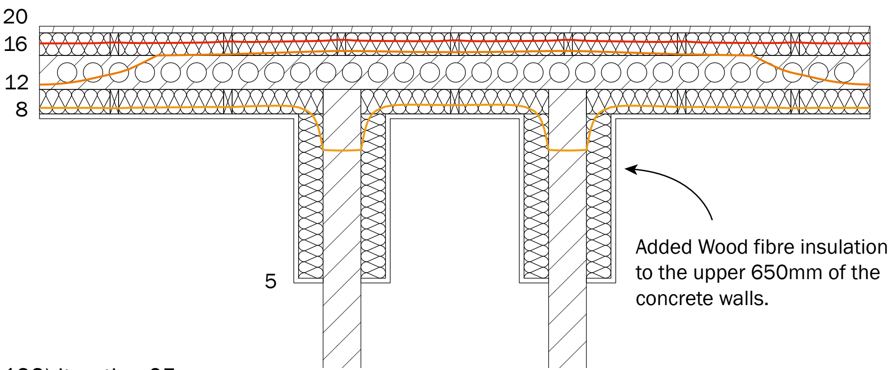


Insulated floor and basement ceiling
35 mm Parquet floor boards
120 mm - Wood Fibre insulation, class 36
180 mm Hollow-core concrete slab, PE
130 mm - Wood Fibre insulation, class 36
25 mm Gypsum boards

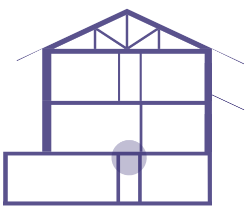
(Ill. 190) Iteration 03.



(Ill. 191) Iteration 04.



(Ill. 192) Iteration 05.

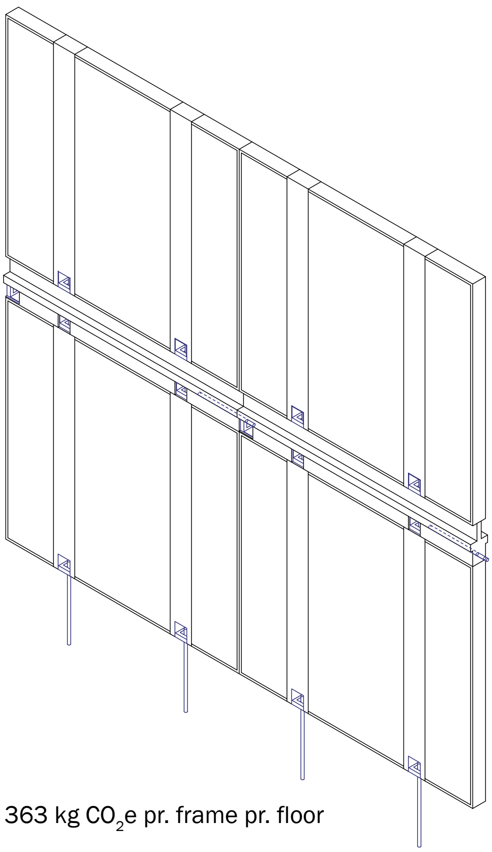


DESIGN FOR DISASSEMBLY CONSTRUCTION SYSTEM

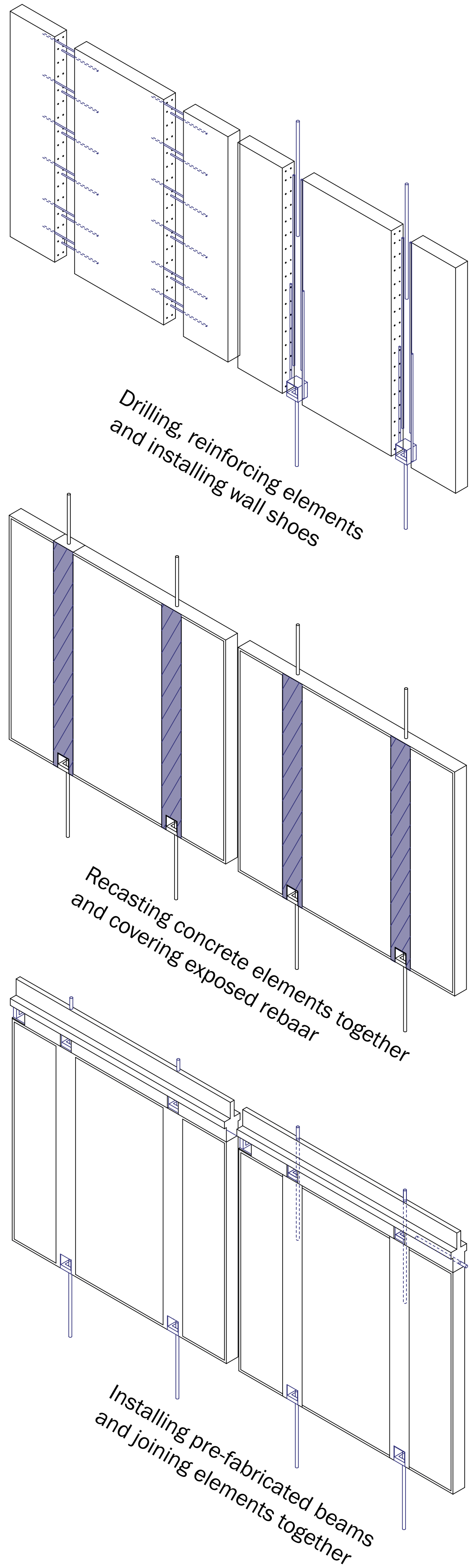
The concrete elements in the interior walls are investigated as a proof of concept for design-for-disassembly in the new row-houses. When reusing the concrete walls, the elements are first cut on either side of the joint connecting them, as seen in figure xx. These cuts mean that it is not possible to cast the wall elements together as normal, instead a different system must be developed.

This investigation showcases two iterations for reusing the concrete wall elements. The wooden system is partially based on concepts from Ressourcerækkerne while the concrete system is based on solutions in Circle House, both are mentioned in further detail in their respective case studies.

When reassembling the concrete walls for reuse using the concrete system, as displayed on the illustration 193, the walls will first be cut into smaller pieces, holes will have to be drilled for installing reinforcement, ensuring stiffness throughout the elements, and lastly equipped with a wall shoe. The wall shoe allows the wall elements to attach to foundations and other elements using threaded bars and nuts. To connect the elements to one another, a pre-cast beam is placed on top of the elements, these beams are connected via the same wall shoe system (Ill. 194).



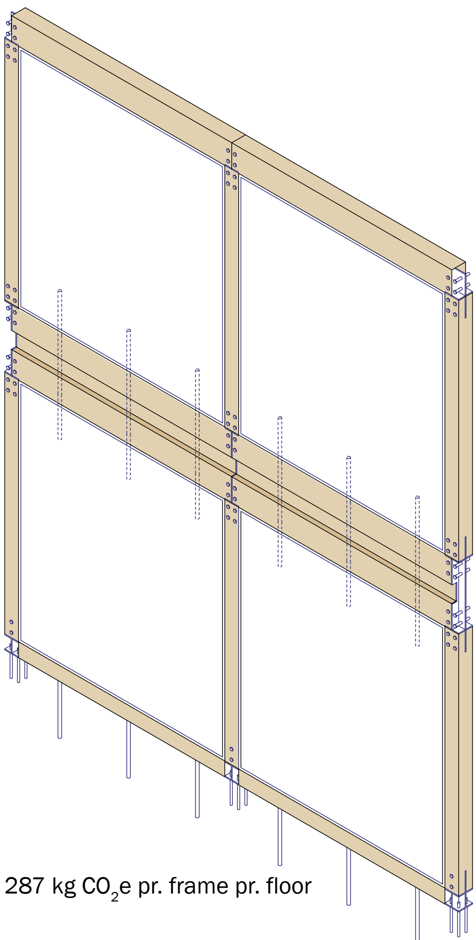
(Ill. 193) Iteration 01. Concrete walls combined with precast beams and shoes.



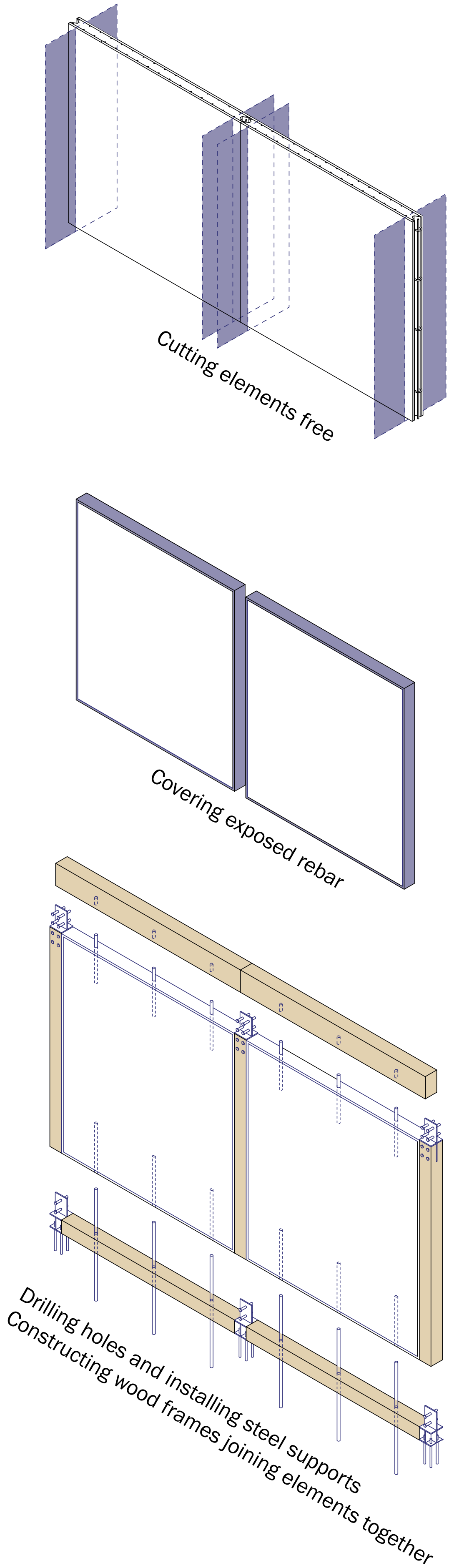
(Ill. 194) Step-by-step description of iteration 01 proposal and its components.

The wooden system allows for keeping the elements intact, the sides of the elements are covered by a 25mm layer of concrete to protect the exposed rebar from corrosion, then holes would be drilled in the top and bottom to install reinforcement bars connecting the slab to the element above and the foundation below, this is illustrated in figure 196. Lastly the concrete elements are inserted into a system of glulam frames joined together with steel plates, bolts and nuts. To ensure an even transfer of loads between the concrete and wood elements all edges will be connected with lime mortar.

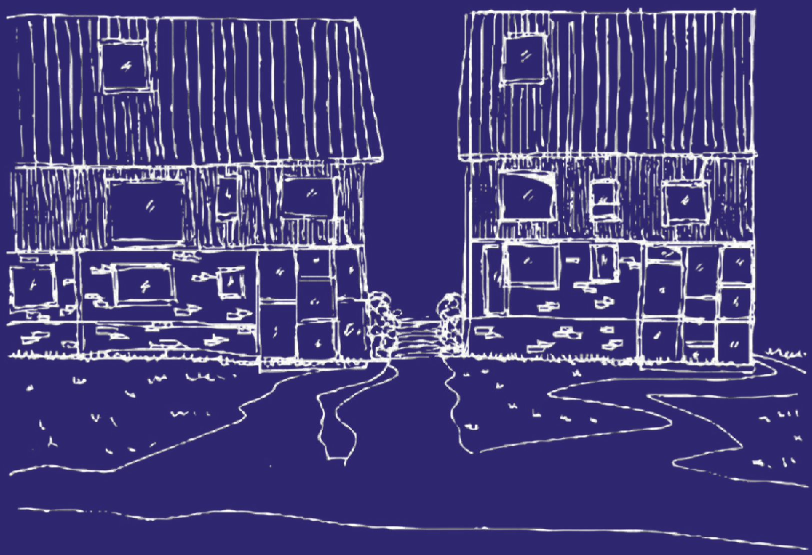
The goal of reusing elements in the project is ultimately to save materials and embodied CO_2e emissions. The wood frame system for two concrete panels would produce 287kgCO_2e and the concrete frame would generate 363kgCO_2e emissions. For comparison using two new virgin concrete elements would produce 322kgCO_2e. The wood system provides a potential 7,1% reduction in environmental impact, not including the waste of cutting the walls, while using the concrete frame system would increase embodied emissions by 12,6% compared to virgin concrete elements. For this reason, the wood framing system is chosen in the final design.



(Ill. 195) Iteration 02. Concrete walls combined with glulam frameand metal mechanical joints.



(Ill. 196) Iteration 02. Concrete walls combined with glulam frameand metal mechanical joints.

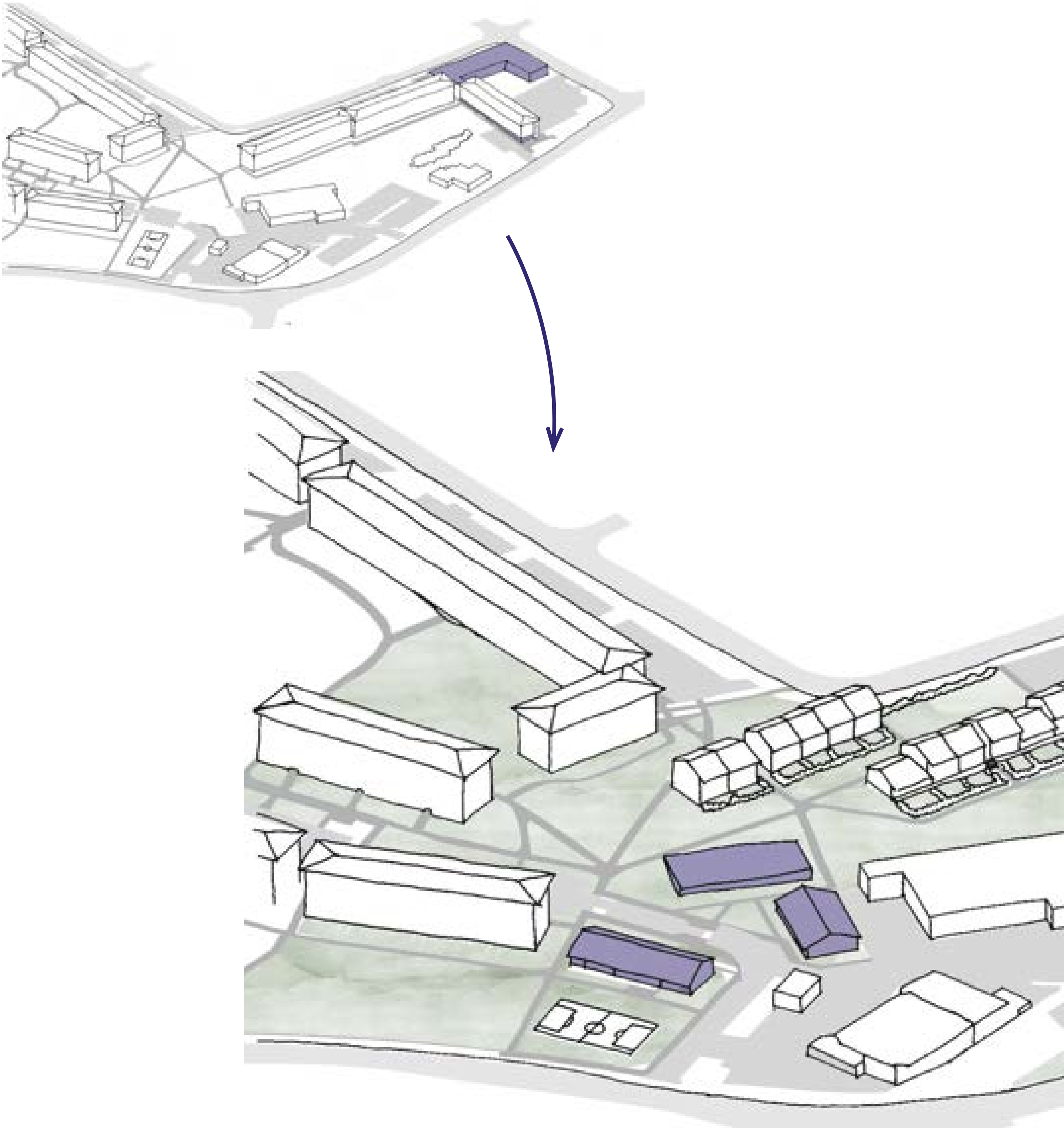


#09 DESIGN PRESENTATION.

(Ill. 197) Masterplan. 1:1000.

THE MASTERPLAN

The Sundparken's southern Masterplan proposes a mixed diverse neighbourhood with new ways to transit the area and a greater potential for interaction between residents and the surrounding city. The family and elderly areas are provided with parking, outdoor and indoor facilities for extra activities. The addition of new paths connect the different residential areas with the new commercial district in the corner adjacent to Sundvej. This acts as a connector between the existing buildings and the row houses.



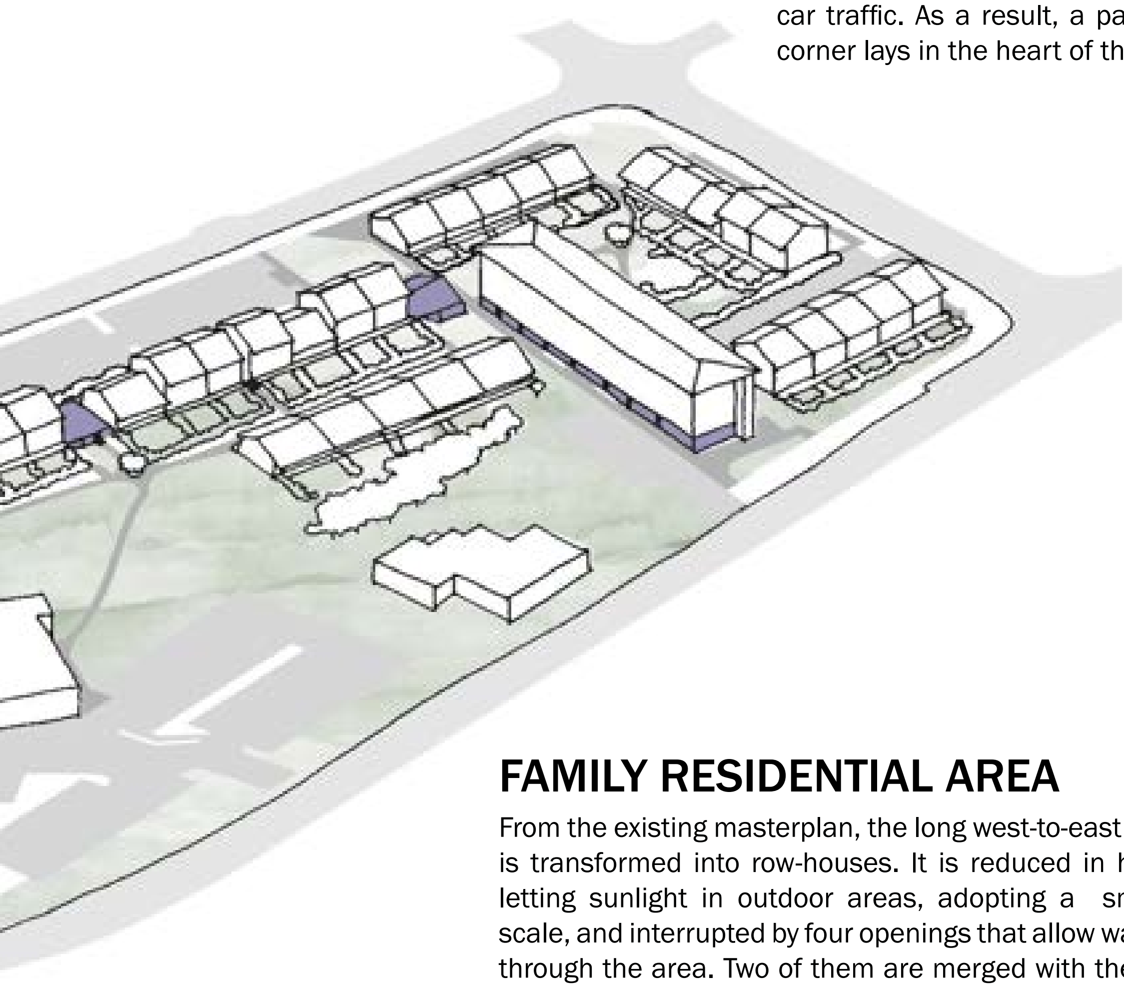
THE CULTURAL DISTRICT

The exising commercial functions are moved to the west corner, creating an active high-traffic and gathering spot together with the sports facility and a library. In this way, the shops are in closer dialogue with the existing supermarkets visited by the residents and neighbours, the sports court brings opportunity for a healthier life and the library stimulates cultural and didactic activities.

(Ill. 198) Sketch of Sundparkens current setting and the design proposal.

ELDERLY RESITENCIAL AREA

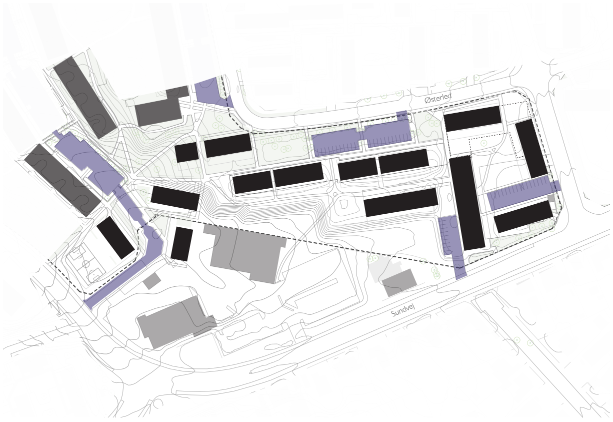
The existing block is transformed into elderly apartments and the foundations of Rema are reused for single-storey row houses. Two-storey family houses act as a barrier from the noise coming from Sundvej's car traffic. As a result, a park accessible from every corner lays in the heart of the area.



FAMILY RESIDENTIAL AREA

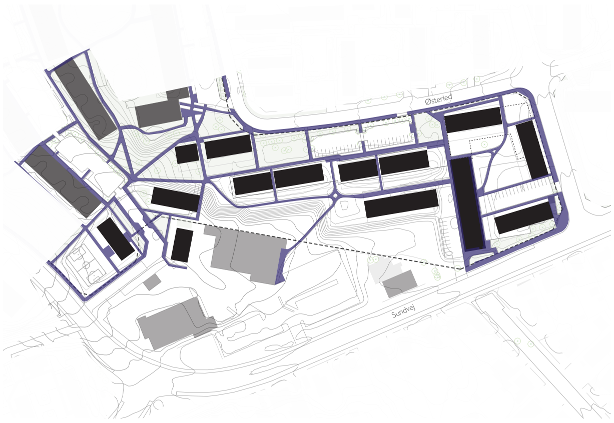
From the existing masterplan, the long west-to-east block is transformed into row-houses. It is reduced in height letting sunlight in outdoor areas, adopting a smaller scale, and interrupted by four openings that allow walking through the area. Two of them are merged with the gym and the orangery. Additional row houses parallel to the old block increase the density in the site, framing the paths that go across culminating in the green areas.

(Ill. 199) Visualization of passage between two-storey row houses.



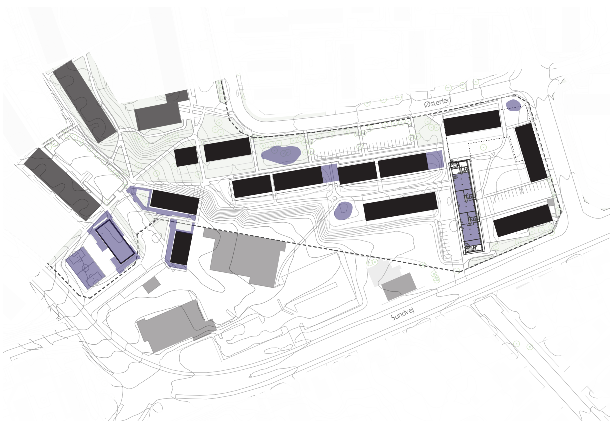
(Ill. 200) Plan of parking.

The masterplan prioritizes pedestrians by organizing **parking** on the perimeter of the site so that residents can park close to the entrance of their home without affecting the human scale.



(Ill. 201) Plan of paths.

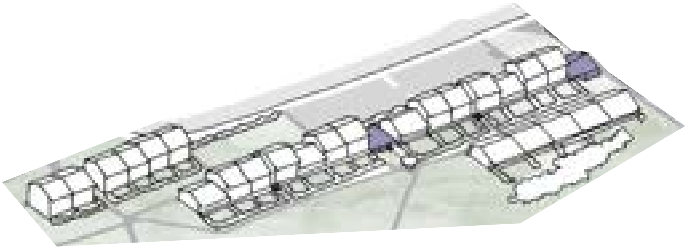
The **paths** increase the permeability of the area without compromising privacy. There are exposed and sheltered long routes and shortcuts between the residential areas and the cultural district to fit different paces and ways to transit.



(Ill. 202) Plan of indoor and outdoor recreative facilities.

The **recreative facilities** are placed along the paths as reasons to stop or contemplate, incrementing the opportunities for interaction among users. The activities are qualified according to the progam and the user group in the zone.

(Ill. 203) Family residential area

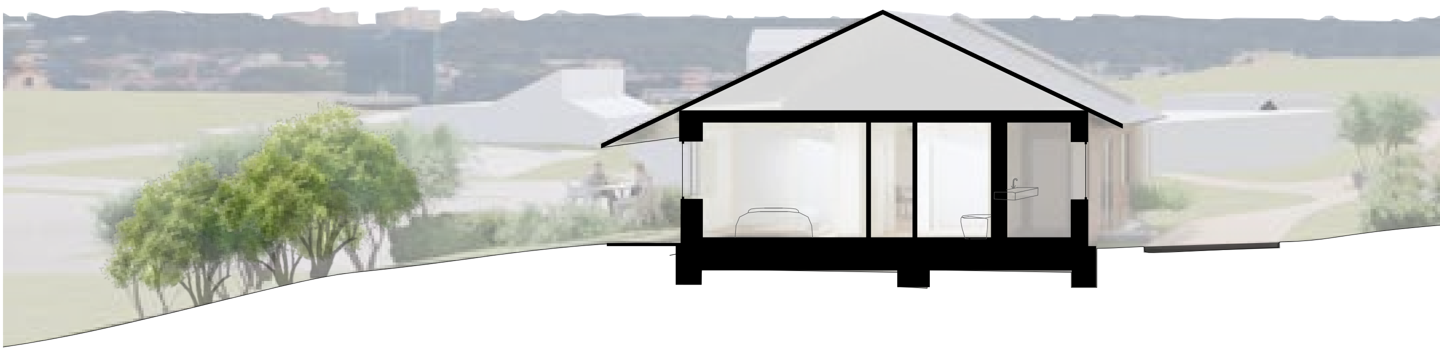


FAMILY RESIDENTIAL AREA

The family residential area consists of three rows of houses with a south-north orientation following the existing foundation and the terrain.

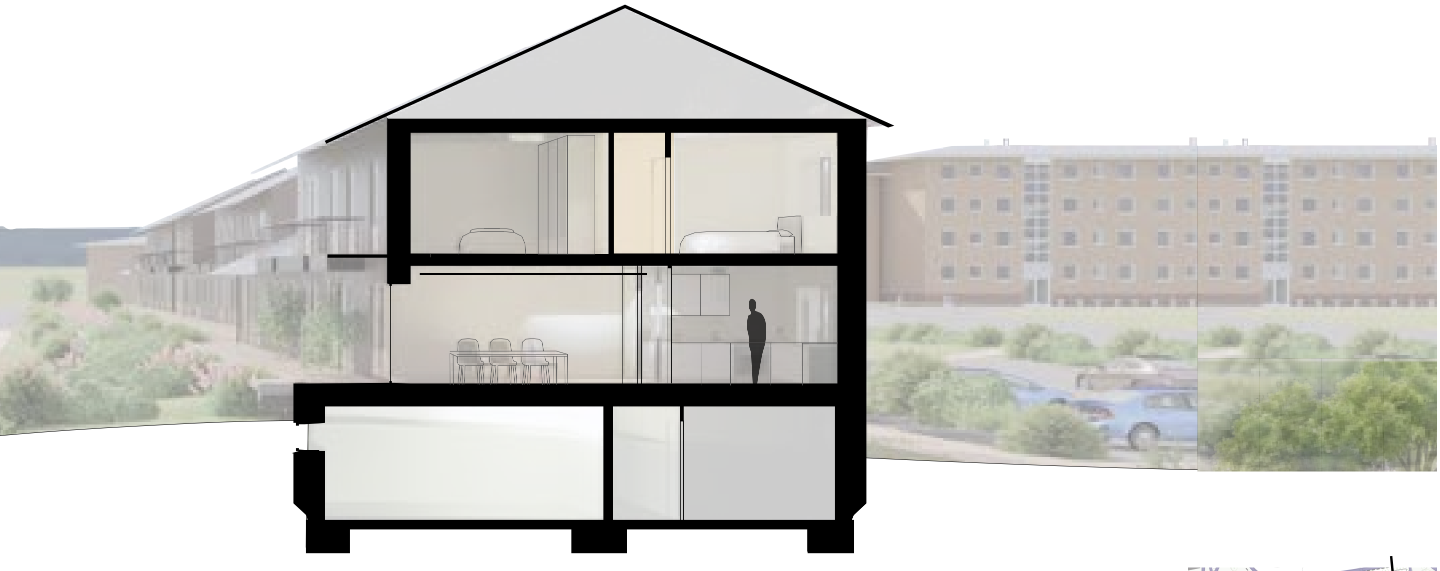
The area contains 25 family row houses separated by private gardens and different types of paths. The units on the south are single storey to let direct sunlight on the gardens of the following row. (Ill. 204)

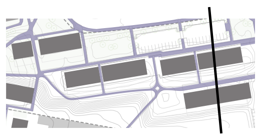
56% of these are built on top of existing basement, which is repurposed for communal functions such as a local gym, a shared orangery, mobility scooter and bike parking, a workshop and storage. These are accessible from the southern facade where the path is separated from the public and sheltered between the two rows of houses (Ill.205).



(Ill. 204) Section of family residential zone. 1:200

(Ill. 205) Visualization of entrance from the north-east corner to the park in the center.





(Ill. 206) Visualization of slow-pace path in family residential area.

The slow-pace path between the houses is separated from the public front facade and the height of the houses provide an intimate scale in which the front yard and the backyard of different houses face each other, increasing the opportunity for interaction and community formations. The basement functions are accessible from this path.

The site is delimited by a path in the north that separates them from the parking and leads to the entrance. On its end where it connects to the elderly area, the current tunnel to Rema 1000 is removed increasing its visibility and sunlight.


(Ill. 207) Photograph of tunnel to Rema 1000 today.

(Ill. 208) Visualization of exposed path between parking and family row houses. This path used to be the passage to Rema 1000


(Ill. 211) Visualization of entrance from the north-east corner to the park in the center.

(Ill. 210) Section of elderly residential zone. 1:200

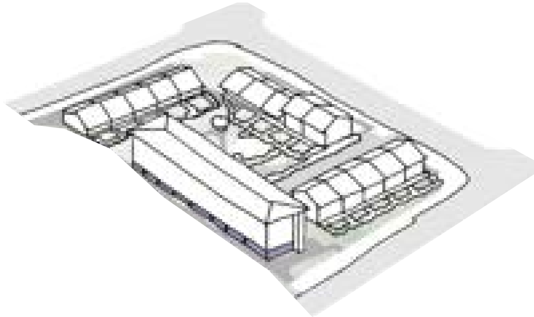
ELDERLY RESIDENTIAL AREA

The elderly residencial area consists of four volumes that frame a park in its center and shelter it from the surrounding noise (Ill. XX).

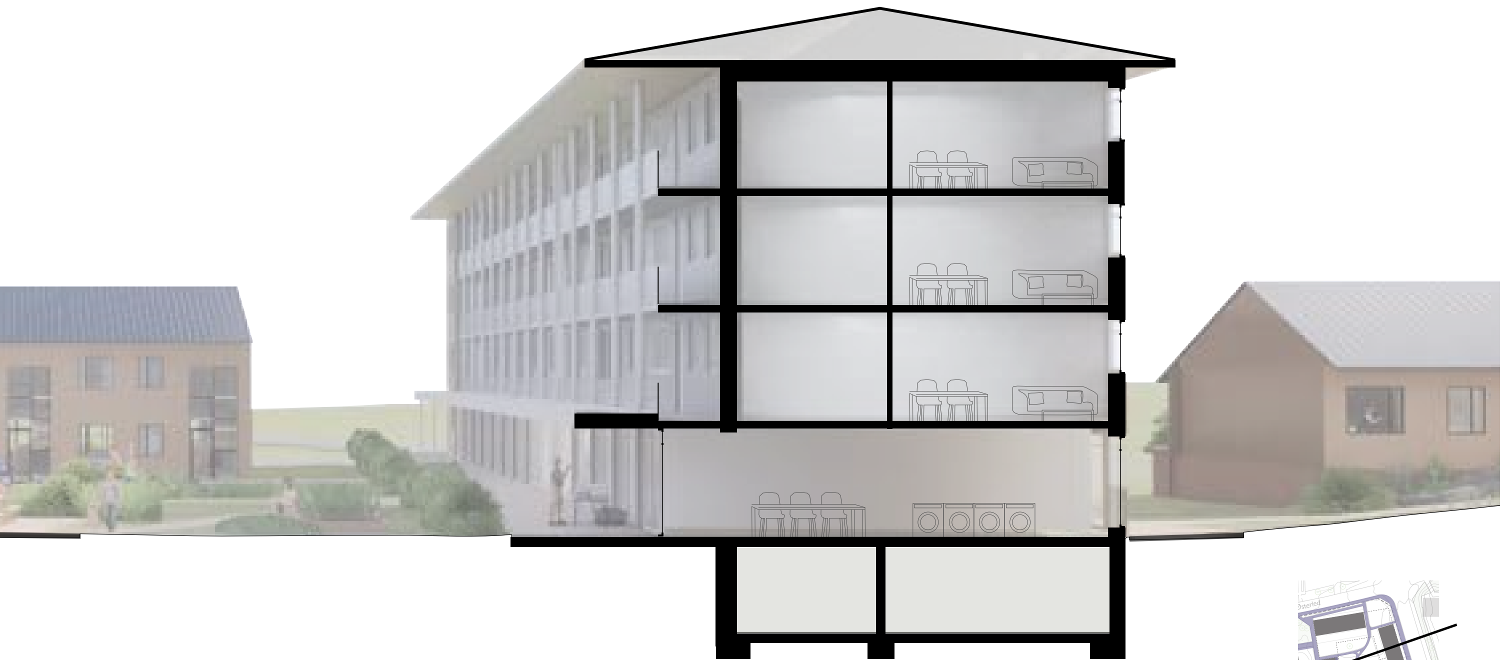
The area contains 27 apartments and 7 single-storey houses for the elderly, but there are also 7 family row houses to encourage exchange between different types of users.

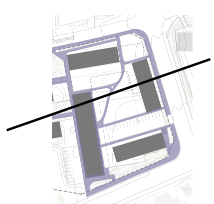
50% of these are built on top of existing foundation, while the existing apartment building is transformed into living units for the elderly. The ground floor is now occupied by community functions such as a workshop, a gym, a community kitchen and a shared laundry. To contrast the separation created by this four-storey building, the floor is mostly glazed, allowing a visual connection with the family residencial area and the orangery adjacent to it (Ill. 210). In addition, it also establishes a closer connection with the park in the center, creating bigger opportunites to extend the activities to the outside.

The park is accessible from all corners of the area (Ill. 211), which are narrowed by the houses to provide some privacy.



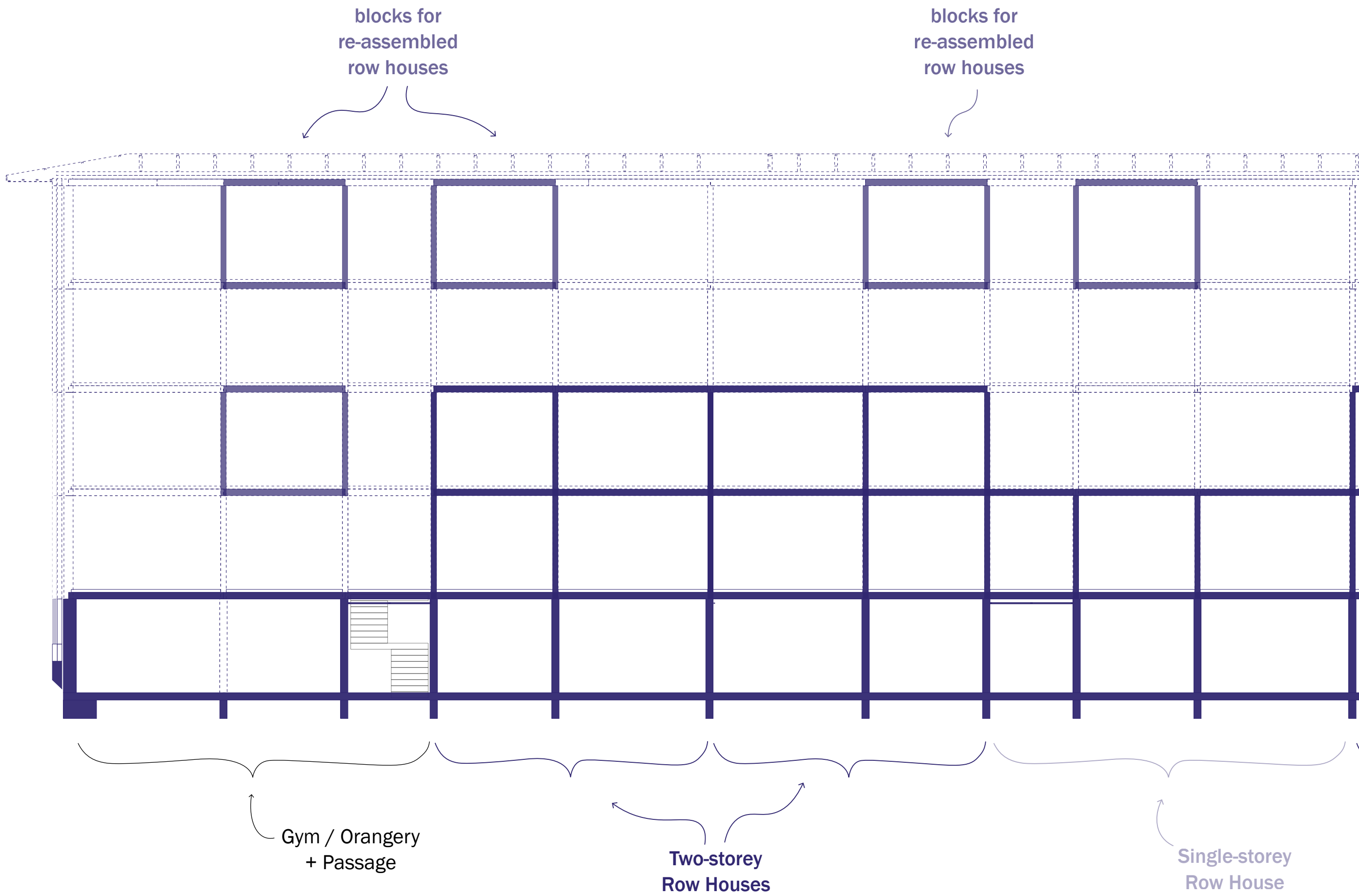
t(Ill. 209) Elderly residencial area






(Ill. 212) Visualization of elderly residential area.

The site is visited by mixed types of user profiles that live in the area bringing opportunity for higher positive interaction between them regardless of age and ethnicity.



(Ill. 213) Partial reuse of A1 block and cutting strategy of remaining elements.

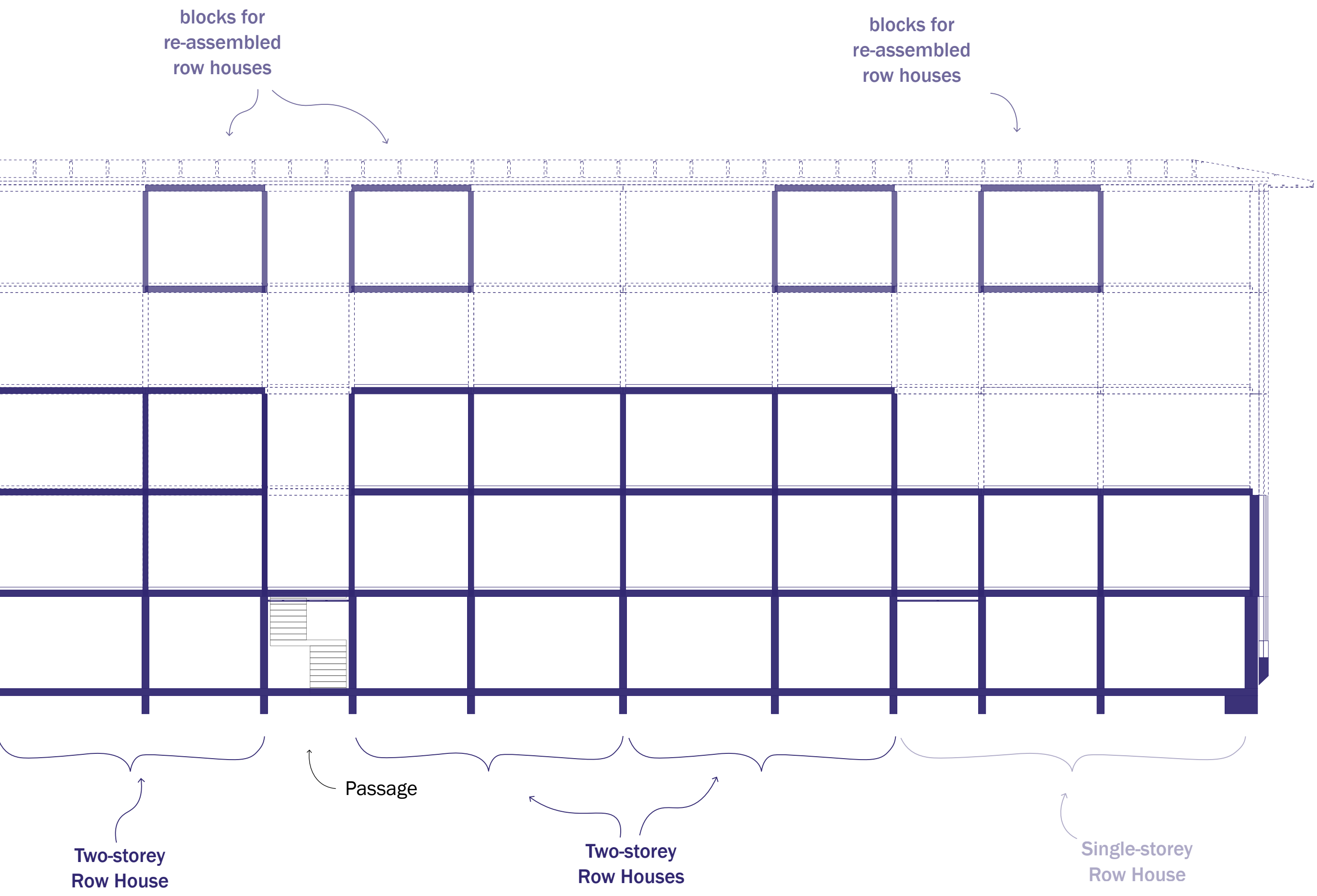
BUILDING CIRCULARITY

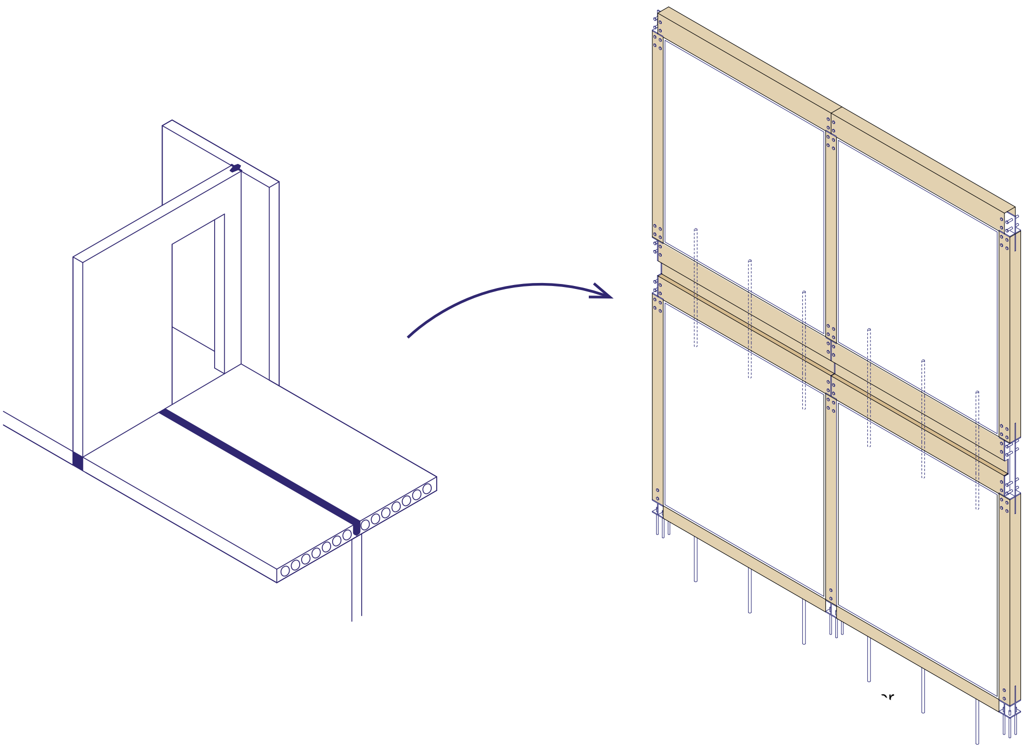
With the circular principles as main design drivers the small scale becomes fundamental for the definition of the bigger scale. Wheather an element is preserved, recycled or repurposed determines the spacial configuration of the apartments, the heights and the thicknesses of the build-ups.

The A1 block is partially preserved, reusing the foundation, the basement, the first floor and some of the second floor. The houses follow a very similar floorplan as the existing one (Ill. 213).

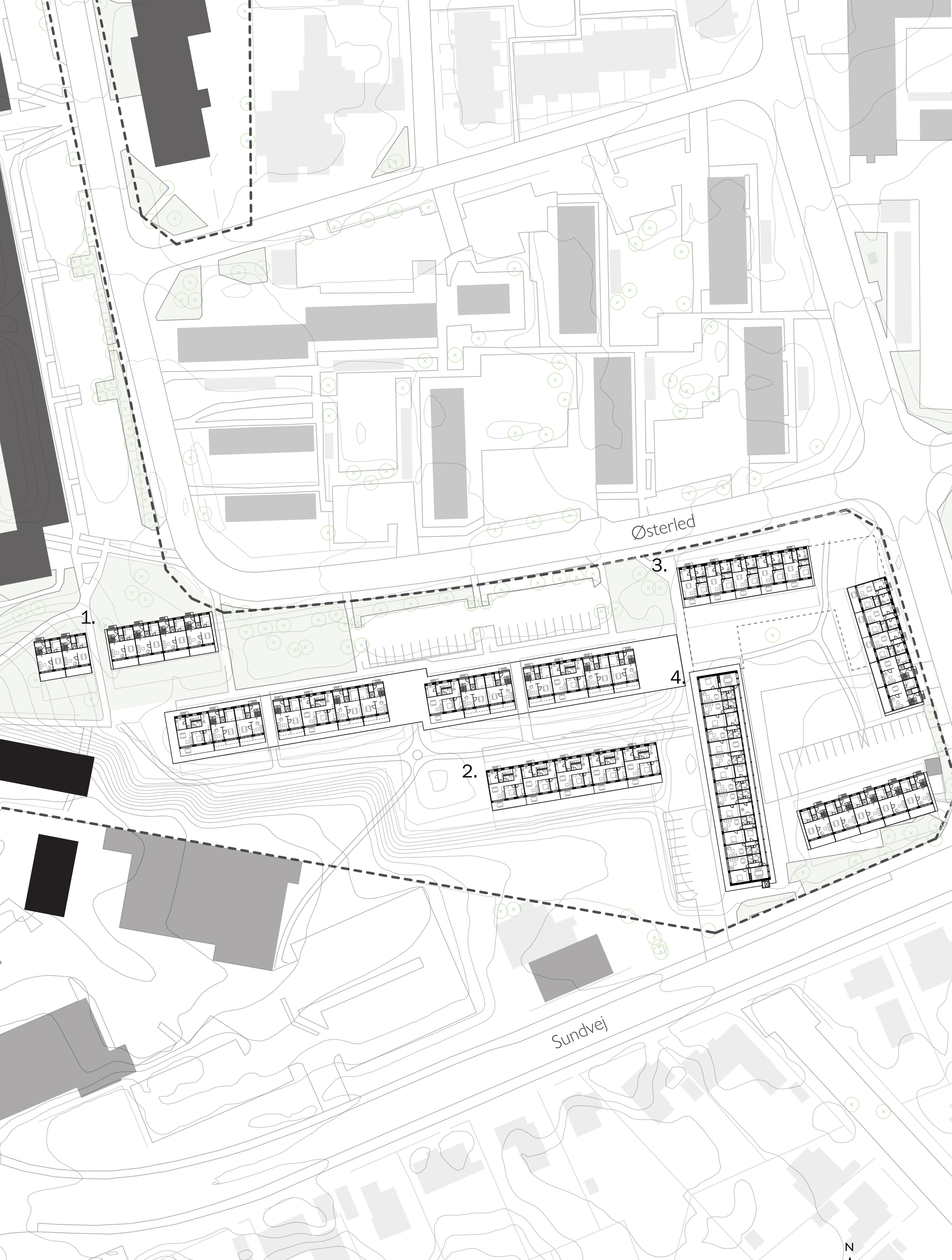
The remaining parts are cut as blocks constituing a room and individual elements. These are enough to build 18 more houses that use them as a core and build around.

The individual wall elements and slabs are cut apart and combined with a glulam frame. This technique is present on the houses standing on top of the ex-Rema 1000's basement and new foundation (Ill. 214).





(Ill. 214) Recycling technique of indivivual elements.



(Ill. 215) Residencial area with different housing types. 1:1250.

FLOORPLAN TYPES

The floorplans are characterized by the adaptation from previous buildings and yet offer different possibilities fitting the individual needs of every user.

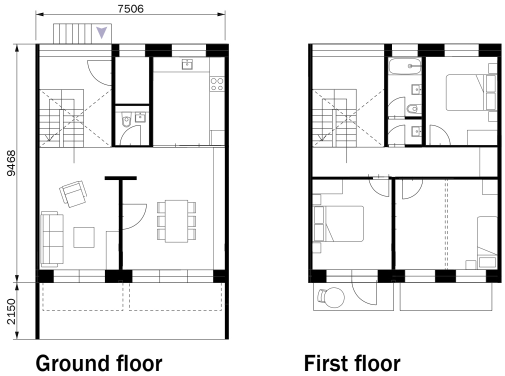
The two-storey house type separates common areas and private rooms in two storeys allowing one of the bedrooms to be subdivided in case of need.

The single-storey row house for families is a smaller unit that fits all functions on the ground floor, placing common areas on the east side and private quiet rooms on the east. It initally presents two bedrooms and an extra multi purpose room that can be transformed into a bedroom.

The single storey row house for the elderly follows the same program distribution concept. The kitchen, dining room and living room are connected and there is one undefined room in the north-east corner that can adapt to different purposes.

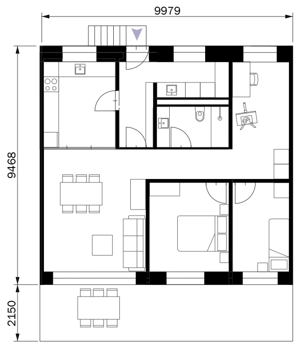
The partially preserved block is transformed by applying the least possible changes. Single room apartments are merged in a way that all the living units have a minimum of one dining-living room, a kitchen and a bedroom. As a result, these have two to three rooms, where the third one can serve different functions according to the individual user's needs, as shown on Ill. 219.

1.



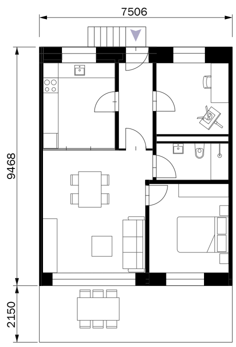
(Ill. 216) Floorplan of two-storey row houses for first-time-buyer families. 130 m². 1:400

2.



(Ill. 217) Floorplan of single-storey row houses for first-time-buyer families.95 m². 1:400

3.



(Ill. 218) Floorplan of single-storey row houses for the elderly. 70 m². 1:400

4.

(Ill. 219) Floorplan of transformed elderly apartments. From 40 m² to 65 m². 1:400

FACADES

The overall elevation matches visually the current project while bringing diversity to it (Ill. 220). The individual facades change according to weather it is the transformation of a partially preserved existing building or a recycled construction.

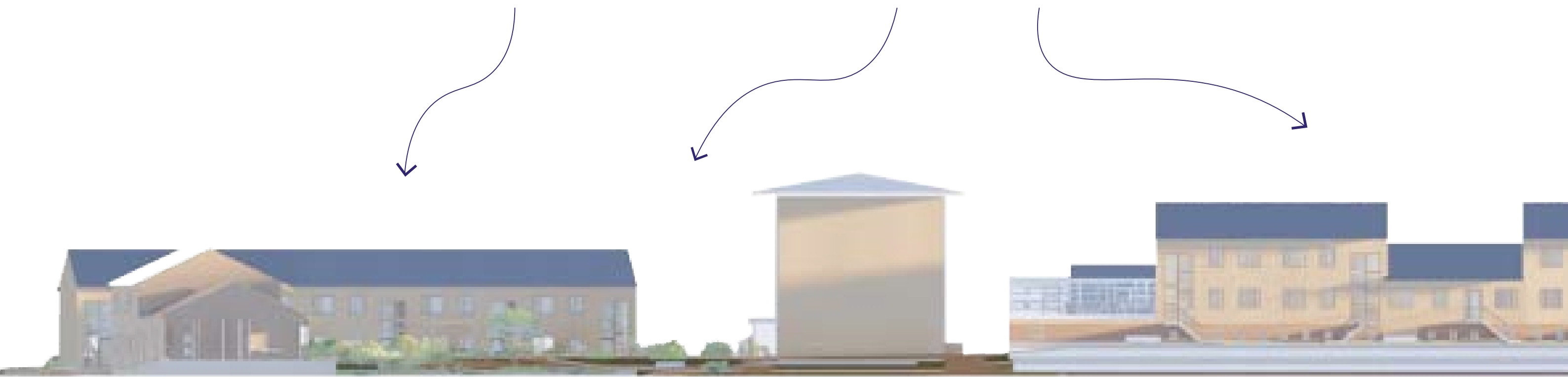
In all cases, the north side is finished with bricks, while the others have wood cladding due to most cases reusing the basement. The northern facade is aligned with the supporting wall underneath and therefore can have a heavier material, giving the opportunity to reuse the old bricks as well. On the contrary, the southern facade is displaced from the loadbearing line to give space to the terrace, hence it requires a light construction. Wood is chosen due to its low GWP and great potential for reuse in the future (Ill. 222).

The construction that is partially preserved reuses the existing facade one-to-one, showing the remains of the pre-existing apartments (Ill. 223). These facade is only on the family residential area.

The recycled bricks facade has a stronger expression in this matter due to the brick tiles that change direction combined with the recycled windows. This one can be found both in the elderly and the family residential area (Ill. 221, Ill. 224).

(Ill. 221) Recycled brick facade facing north in a two-storey house. 1:200

(Ill. 222) Wooden facade facing south with solar panels in a two-storey house. 1:200



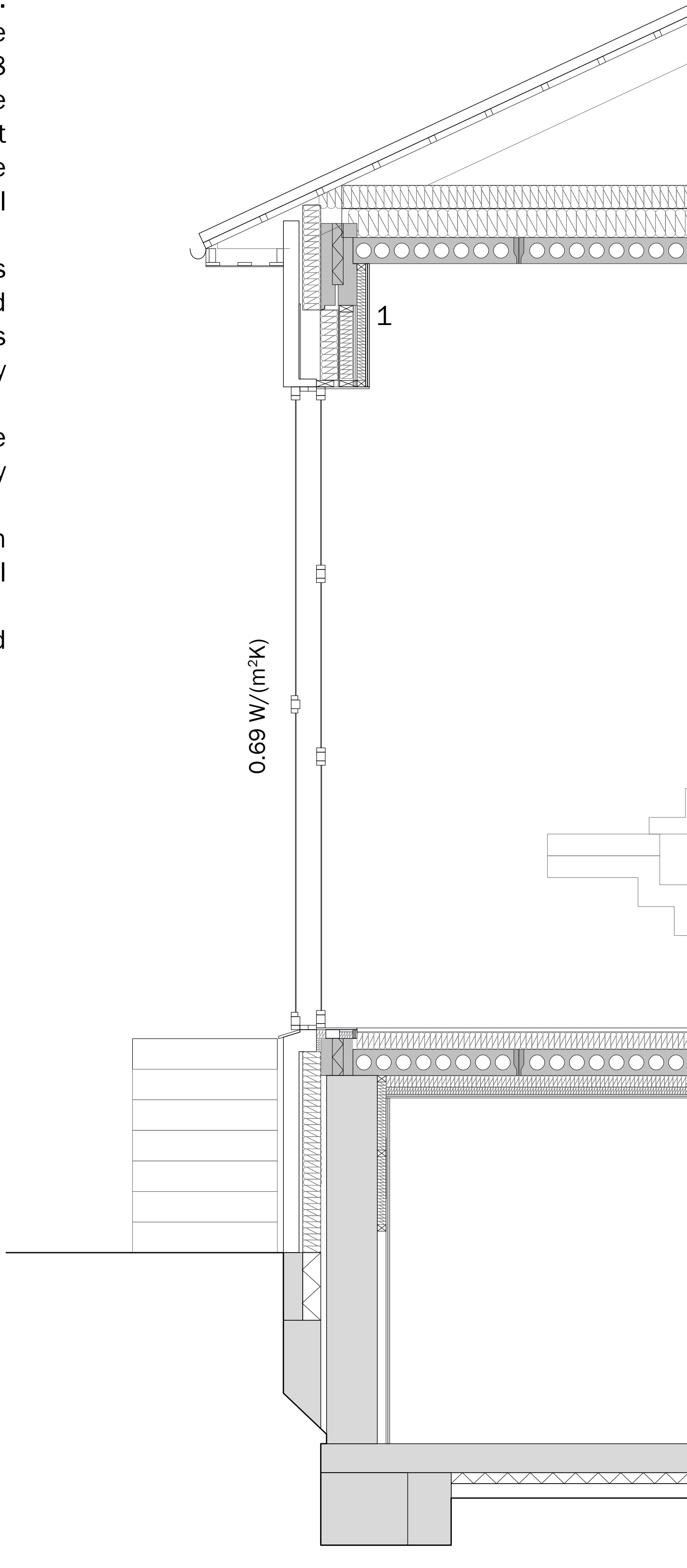
(Ill. 220 South elevation of the masterplan.

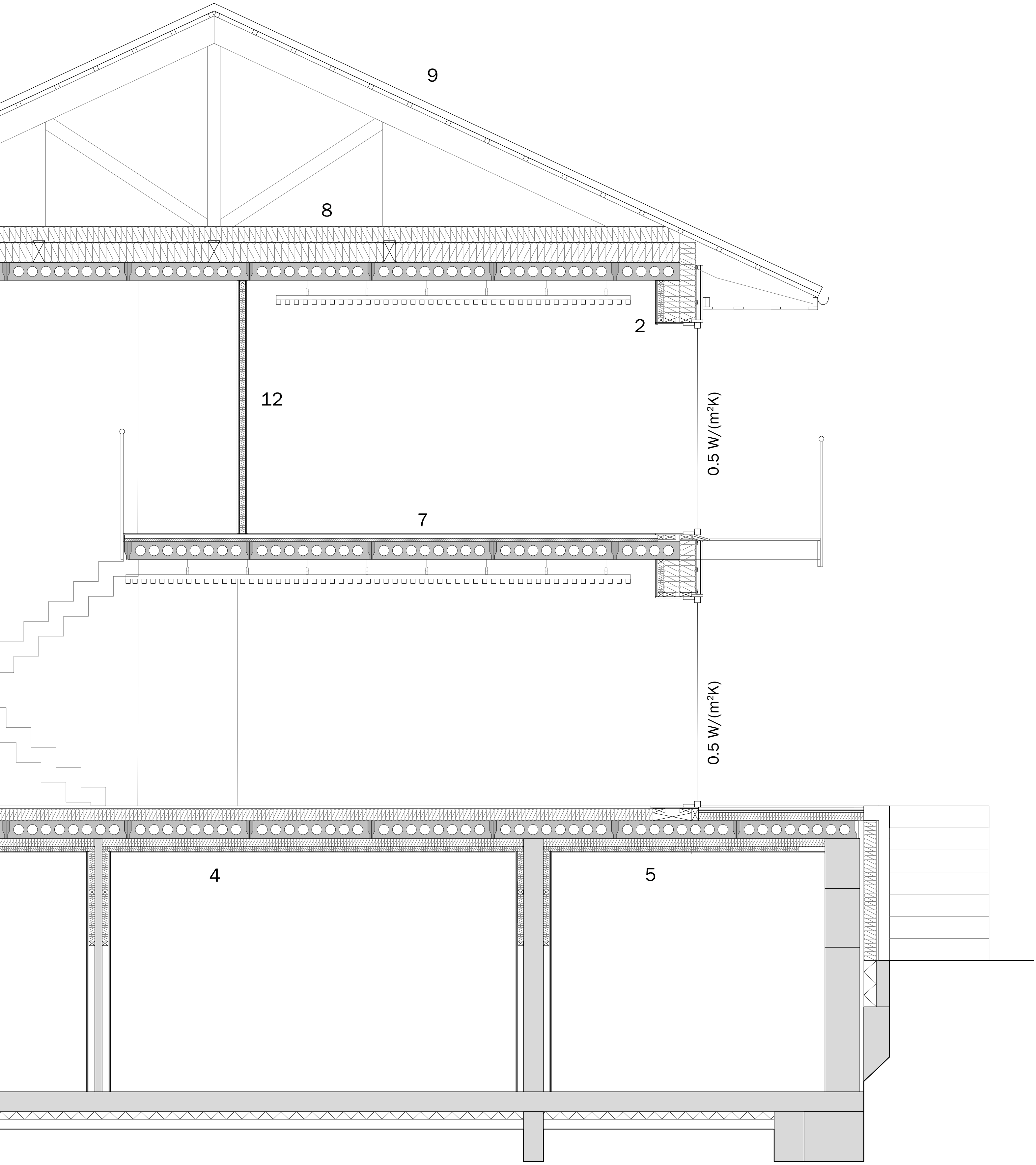
(Ill. 223) Reused brick facade facing north in a two-storey house. 1:200

(Ill. 224) Recycled brick facade facing north in a single-storey house. 1:200

CONSTRUCTION SECTIONS

The detail shows the different build-ups of the envelope. These are marked with a number and listed with the components, the thickness and the U-value from page 178 to 181. The houses on top of the existing basement are the ones with higher risk of thermal bridges. Thus, the present basement is insulated in the ceiling and a meter down the walls. The terrace slab is less insulated to avoid interstitial condensation. The detail can be seen on page 180.
The wall in the north is preserved, hence it is the same as the existing building. It has a an extra layer of new wood fiber and plywood to improve the U-value. In the section it is visible the recycled double-frame layer windows inspired by the case studies as well.
The south has a less thick light wall construction. The details of the connection with the terrace and the balcony can be seen on page 181.
The roof has a similar solution as the one before but in wood fiber and 16cm thicker. Page 181 presents the detail of the connection with the walls.
The window U-values are referenced in the illustration and wall build-ups are listed below.

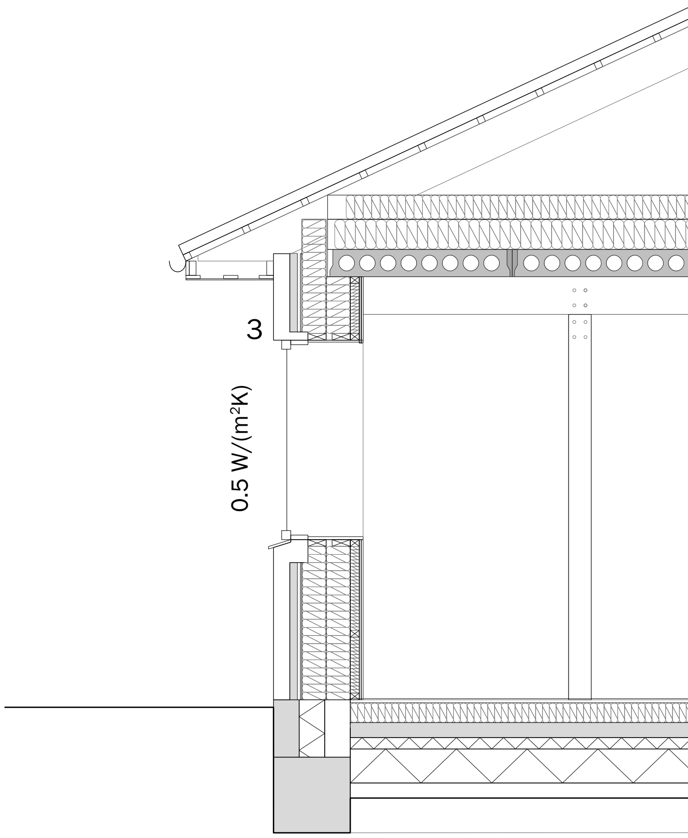




(Ill. 225) North-south section of partially preserved two-storey row houses. 1:50.

CONSTRUCTION SECTION

The row-houses that are not built on top of existing foundation have a more simple envelope solution.
The terrain slab insulation is continuous and the build-up in the south is the same in the north, except for the recycled bricks cladding. The roof is defined as in the previously mentioned houses.



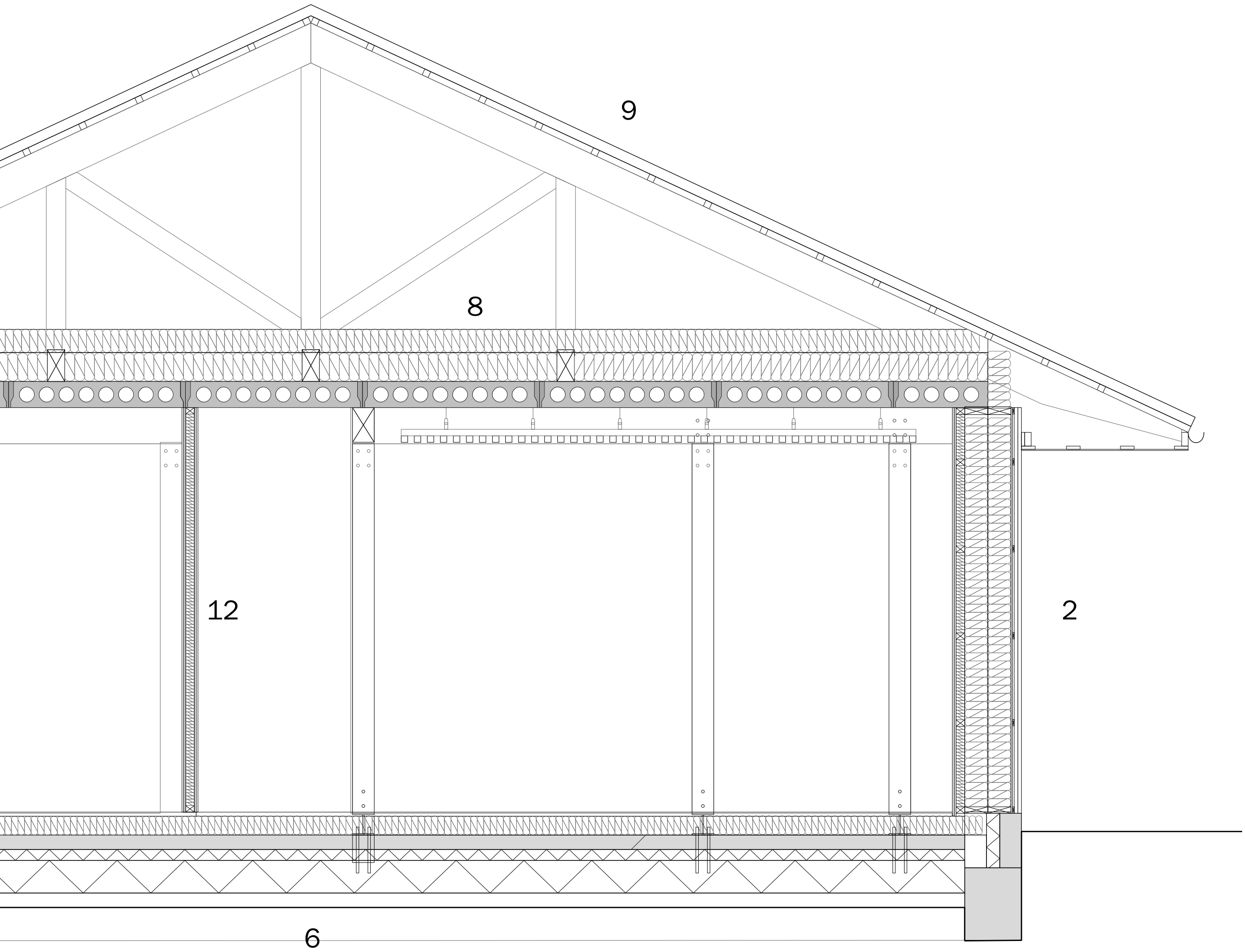
BUILD-UPS DESCRIPTION

1- Preserved exterior wall North

593 mm	**U-value: 0,15 W/(m²K)**
108 mm	Clay bricks
25 mm	Ventilated airgap with rafters
125 mm	Rockwool insulation
75 mm	Concrete
75 mm	Rigid EPS insulation
100 mm	Concrete
60 mm	Wood fibre insulation 36 with laiths
12,5 mm	Plywood mounting layer
12,5 mm	Plywood wall cladding

2- New exterior wall south

464 mm	**U-value: 0,10 W/(m²K)**
12 mm	Vertical wood cladding
25 mm	Ventilated airgap with rafters
12 mm	Spacing
10 mm	Rigicell wind barrier
160 mm	Wood fibre insulation 36 with studs
160 mm	Wood fibre insulation 36 with studs
0 mm	Vapour barrier PE foil
60 mm	Wood fibre insulation 36 with laiths
12,5 mm	Plywood mounting layer
12,5 mm	Plywood wall cladding



(Ill. 226) North-south section of single-storey row house with recycled materials.

3- New exterior wall north	
464 mm	**U-value: 0,10 W/(m²K)**
158 mm	Recycled bricks
25 mm	Ventilated airgap with rafters
12 mm	Spacing
10 mm	Rigicell wind barrier
160 mm	Wood fibre insulation 36 with studs
160 mm	Wood fibre insulation 36 with studs
0 mm	Vapour barrier PE foil
60 mm	Wood fibre insulation 36 with laiths
12,5 mm	Plywood mounting layer
12,5 mm	Plywood wall cladding

4- Basement slab	
490 mm	**U-value: 0,15 W/(m²K)**
20 mm	Reused wood flooring on joists
15 mm	Air gap
120 mm	Wood fibre insulation class 36
180 mm	Reused concrete hollow core slabs
80 mm	Wood fibre insulation 36 with laiths
50 mm	Air gap
12,5 mm	Plywood mounting layer
12,5 mm	Plywood cladding

BUILD-UPS DESCRIPTION

5- Terrace slab

490 mm	**U-value: 0,20 W/(m²K)**
20 mm	Wood planks 20 x 125 mm
62 - 18 mm	Ventilated air gap with laths
4 mm	Waterproof mebrane layer
16 mm	Plywood
56 - 100 mm	Riggid EPS insulation
180 mm	Reused concrete hollow core slabs
80 mm	Wood fibre insulation 36 with laiths
50 mm	Air gap
12,5 mm	Plywood mounting layer
12,5 mm	Plywood cladding

6- Terrain slab

580 mm	**U-value: 0,11 W/(m²K)**
20 mm	Reused wood flooring
30 mm	Rigid insulation
30 mm	Screed concrete
100 mm	Reused concrete element
75 mm	Reused EPS
225 mm	EPS
100 mm	Gravel

7- Floor slab

410 mm	**U-value: 0,69 W/(m²K)**
20 mm	Reused wood flooring on joists
30 mm	Air gap
30 mm	Wood fibre insulation class 36
180 mm	Reused concrete hollow core slabs
150 mm	Air layer with acoustic lamellas

8- Roof Ceiling

690 mm	**U-value: 0,11 W/(m²K)**
160 mm	Wood fibre insulation class 36
200 mm	Wood fibre insulation class 36
180 mm	Reused concrete hollow core slabs
150 mm	Air layer with acoustic lamellas

9- Roof

381 mm	**U-value not relavant**
70 mm	Reused Kal Zip aluminium roof
35 mm	Laths 35 x 70 mm C.C 600 mm
12 mm	Spacing
4 mm	Water proof membrane
12 mm	Plywood
250 mm	Recycled wood rafters

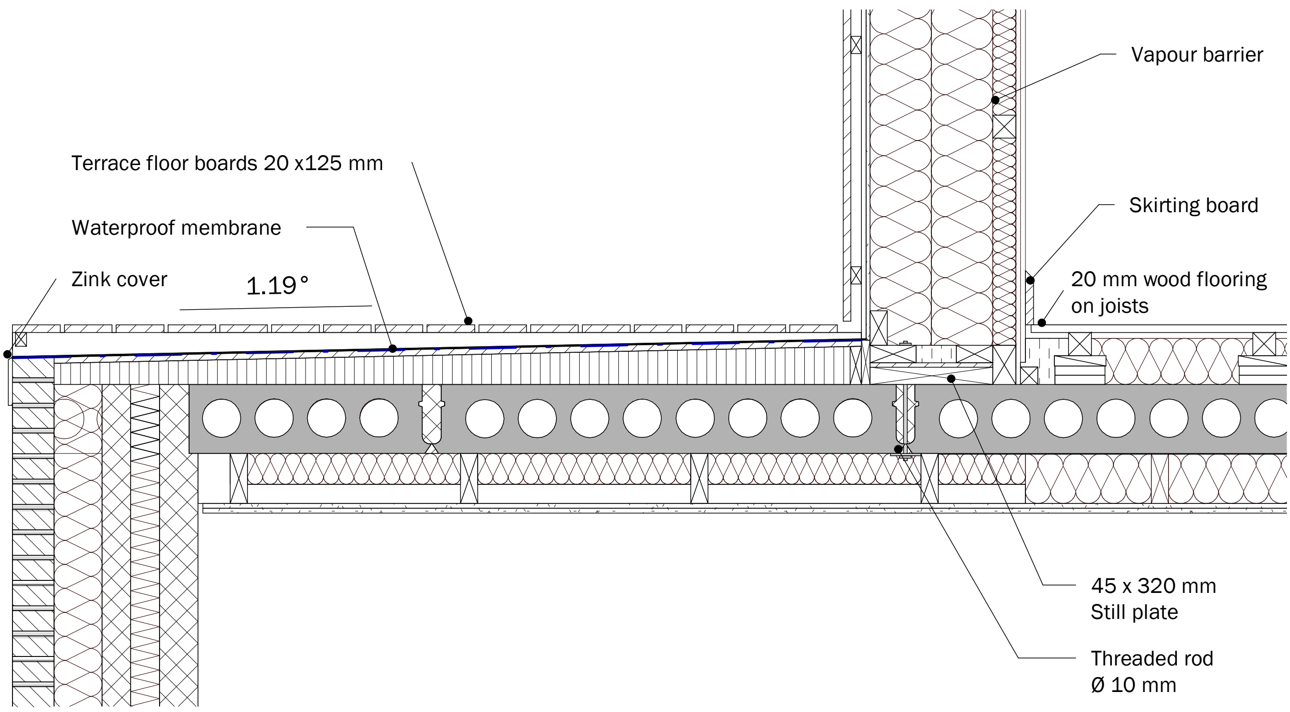
10- Gable wall

534 mm	**U-value: 0,12 W/(m²K)**
12 mm	Vertical wood cladding
25 mm	Ventilated airgap with rafters
12 mm	Spacing
10 mm	Rigicell wind barrier
240 mm	Wood fibre insulation
150 mm	Reused Concrete element
60 mm	Wood fibre insulation 36 with laiths
12,5 mm	Plywood mounting layer
12,5 mm	Plywood wall cladding

11- Internal load bearing walls

150 mm	**U-value: 4,35 W/(m²K)**
150 mm	Reused concrete elements

DETAILS



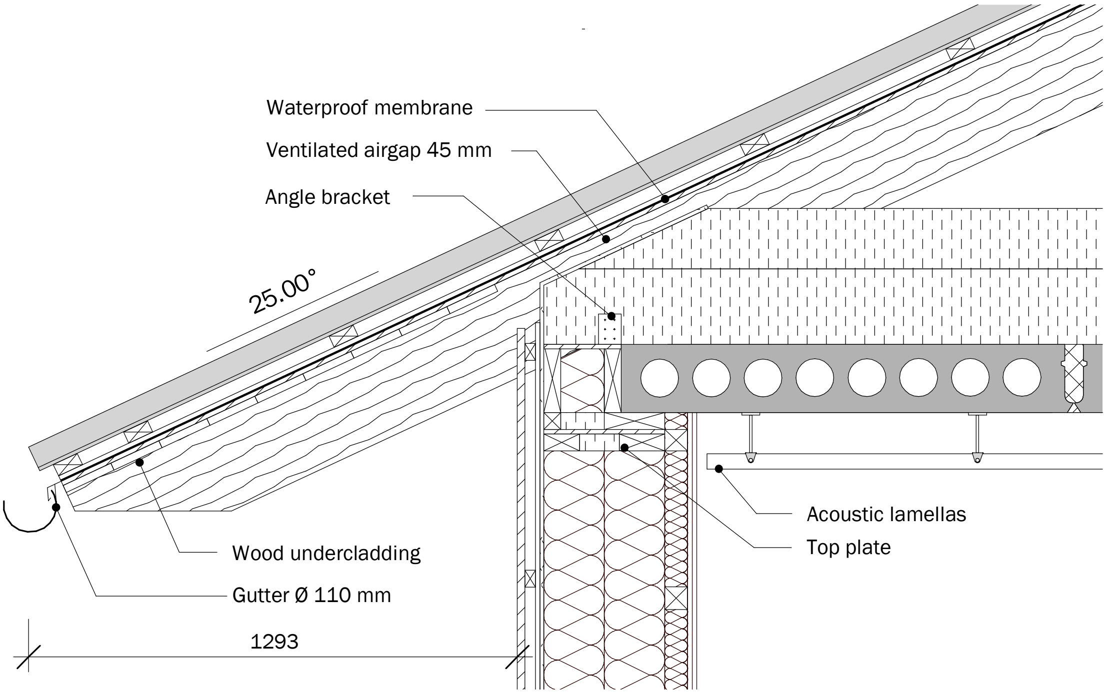
(Ill. 227) Detail of connection between basement and terrace. 1:20.

12- Internal non load bearing walls

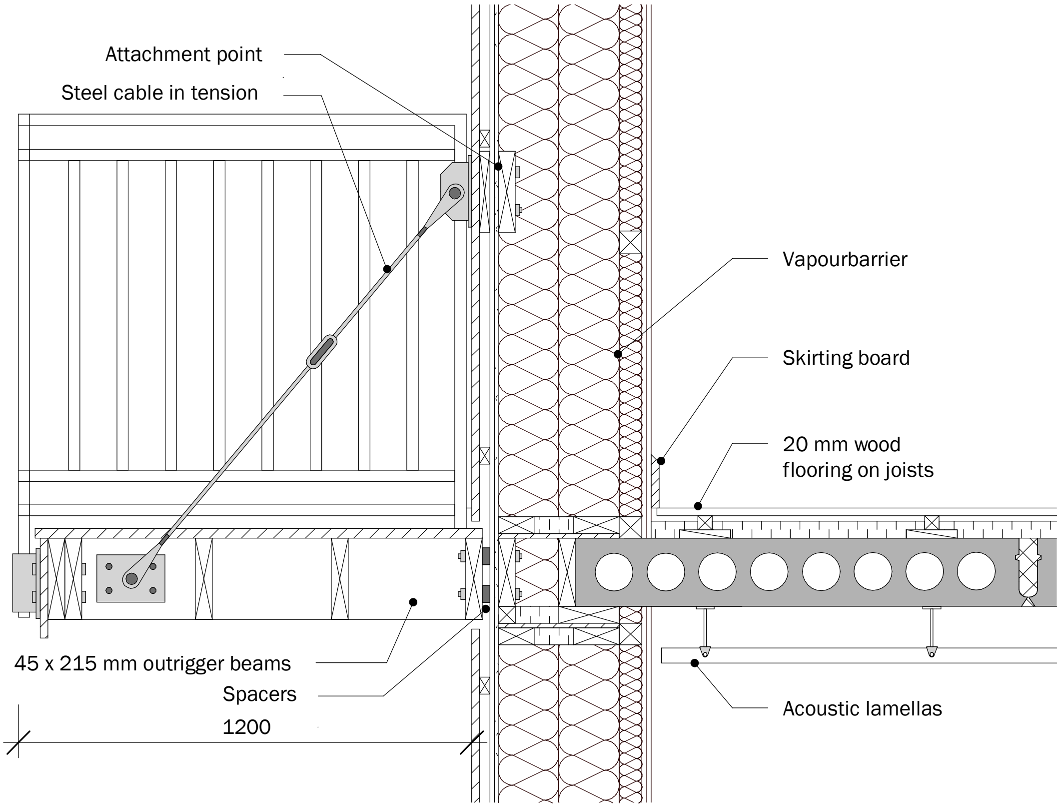
110 mm	U-value: 0,55 W/(m²K)
12,5 mm	Plywood wall cladding
12,5 mm	Plywood mounting layer
60 mm	Wood fibre insulation 36 with studs
12,5 mm	Plywood mounting layer
12,5 mm	Plywood wall cladding

13- Internal wall between units

320 mm	U-value: 0,30 W/(m²K)
12,5 mm	Plywood wall cladding
12,5 mm	Plywood mounting layer
60 mm	Wood fibre insulation 36 with laiths
150 mm	Reused Concrete element
60 mm	Wood fibre insulation 36 with laiths
12,5 mm	Plywood mounting layer
12,5 mm	Plywood wall cladding



(Ill. 229) External wall-to-roof detail. 1:20.



(Ill. 228) External wall-to-balcony detail. 1:20

(Ill. 230) Visualization of materiality inside the row houses on top of the reused foundation. View from the kitchen to the living-dining room.

MATERIALITY

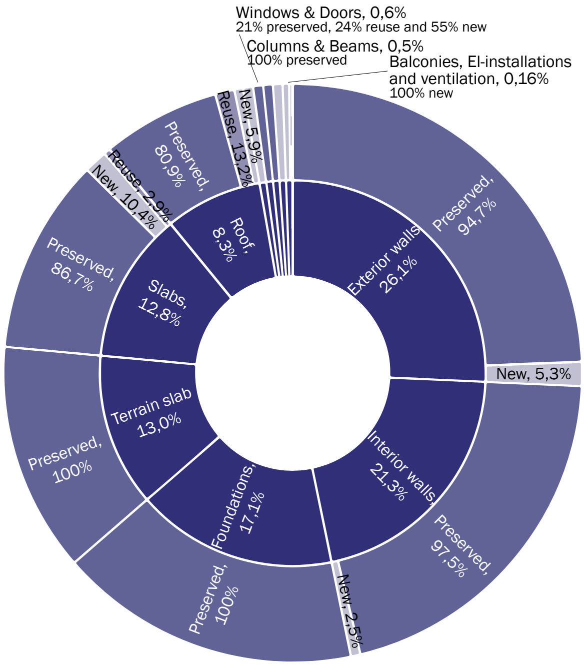
In the interior of the row houses the construction is exposed, giving a raw expression (Ill.230). When it is not necessary to add extra material, for instance between rooms of a single unit, the concrete is exposed. In the facade and the separating walls between different houses which require insulation are finished with plywood since it is easier to disassemble without harming the element, its bright color helps to distribute the light in the room and it gives a warm appearance. The floor follows a similar logic while reusing the available wood parquet from the existing construction, and the ceiling has suspended wood lamellas to improve the acoustic comfort while facilitating the thermal mass performance of the concrete slabs.

The houses that are not build on top of the foundation with a direct reuse of the concrete structure have a higher degree of honesty, in the sense that connections between the recycled elements are exposed, constituing the tectonic expression.

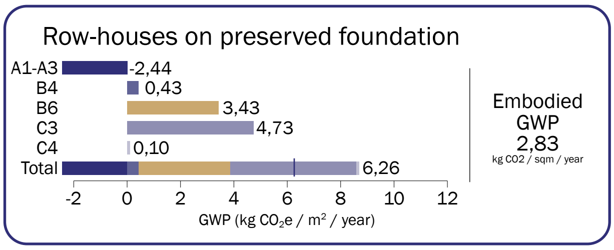
(Ill. 231) Material palette of the interior of the houses.

(Ill. 232) Visualization of materiality inside the row houses with recycled concrete elements View of living-dining room.

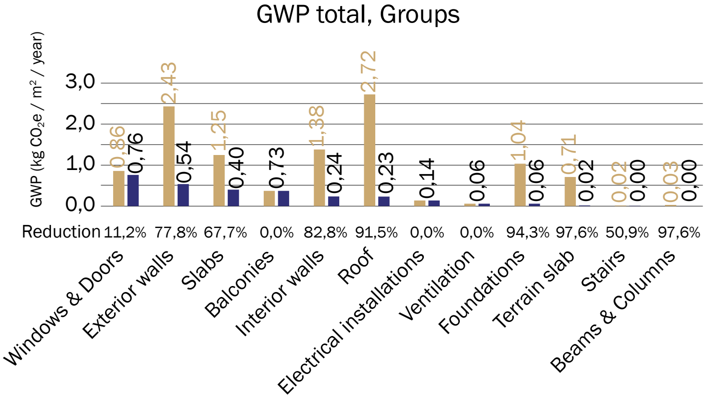
LCA RESULTS
PRESERVED ROW-HOUSES



(Ill. 233) LCA material amount in weight percentage in preservation.



(Ill. 234 LCA result of a row house preserved structure per phase.



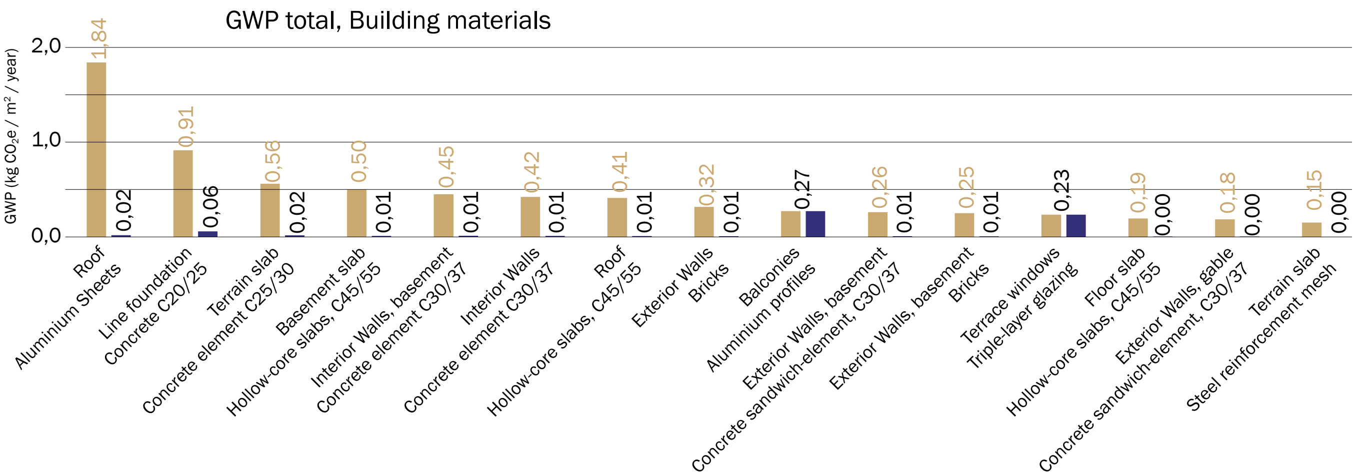
(Ill. 235) GWP per group in a row house preserving structure.

These row-houses are built on the idea of preserving as much of the existing structure as possible, following iteration 3 "minimizing disassembly" of the Disassembly for design chapter. The preserved materials are treated as requiring no refurbishment, giving them a large potential for saving CO_2e compared to the same virgin materials, as seen in figure 236.

While as much of the existing structure as possible is preserved, one construction where this is not possible is the roof. This has to be disassembled in order to cut the wall and slab elements to reduce the building to the desired height and size. As can be seen in figure 235 and figure 236 the roof has great potential for saving embodied emission in reuse because of the aluminium sheet cladding. The truss system is reassembled as described in the chapter for solar panels and roof angles. The same method for reuse is applied in the DfD row-house.

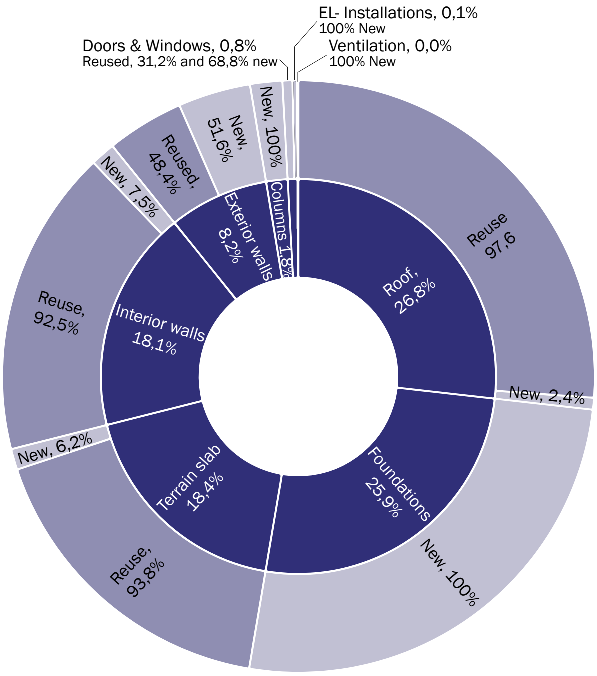
In order to comply with energy performance requirements, wood fibre insulation and complimentary materials are added to reduce heat loss from the exterior walls and basement ceiling slabs. These constructions are light weight, giving them a small impact on the weight% of new materials as shown in figure 233. The impact of the materials is, however, visible in the figure 235, where despite being primarily preserved concrete with a 97% reduction in GWP, as an effect of the added virgin materials, these groups result in 77,8% and 67,7% savings, respectively.

See Appendix 4 for LCAByg Data extraction.

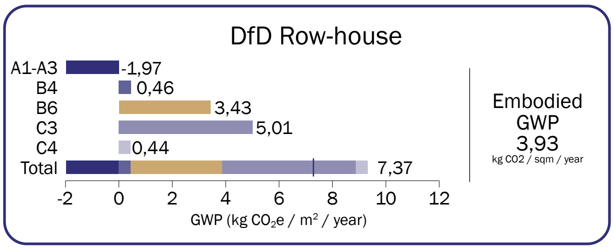


(Ill. 236) GWP per material per group in a row house preserving the structure.

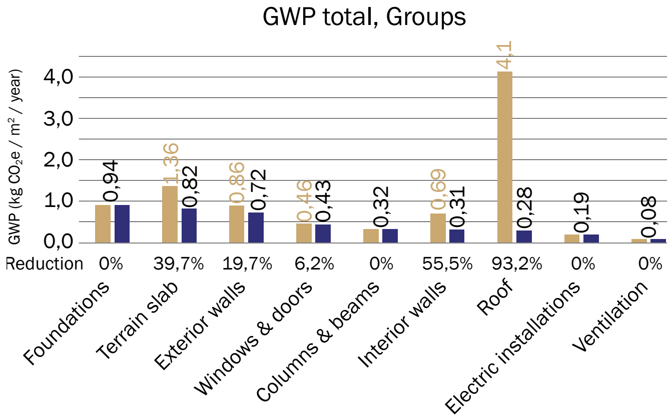
LCA RESULTS
DESIGN-FOR-DISASSEMBLY ROW-HOUSES



(Ill. 237) LCA material amount in weight percentage in DfD.



(Ill. 238) LCA result of a row house DfD per phase.

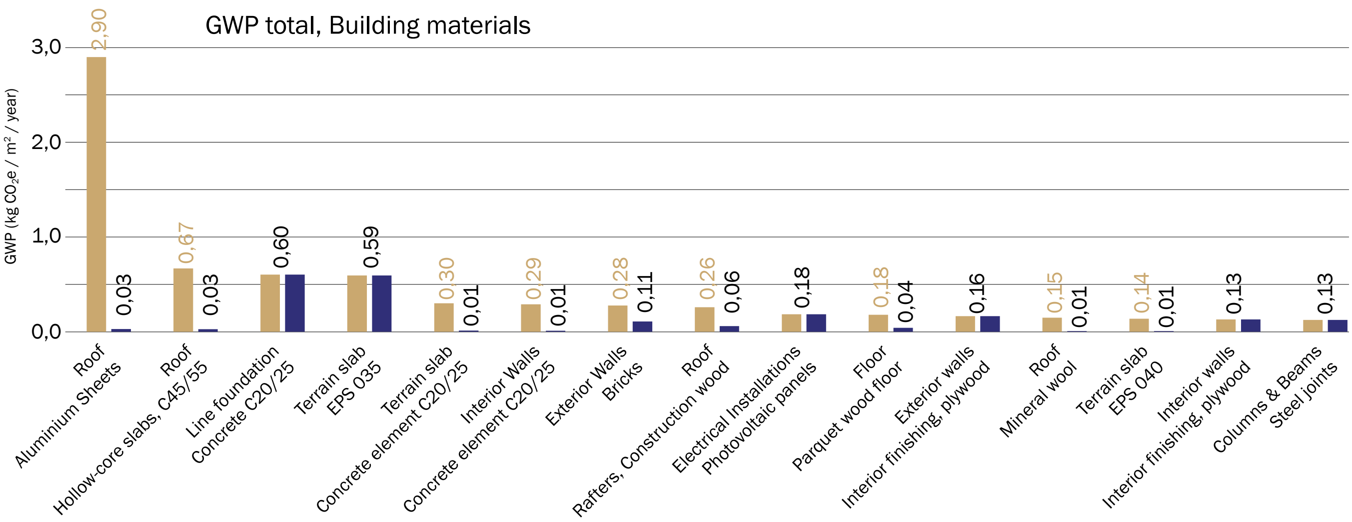


(Ill. 239) GWP per group in a row house DfD.

Figure 239 shows the DfD row-houses have significant potential savings of embodied emissions in reusing the roof, interior walls and terrain slab. The materials are sourced from the existing A1 building, a general overview of the materials available can be found in the Material Atlas chapter.

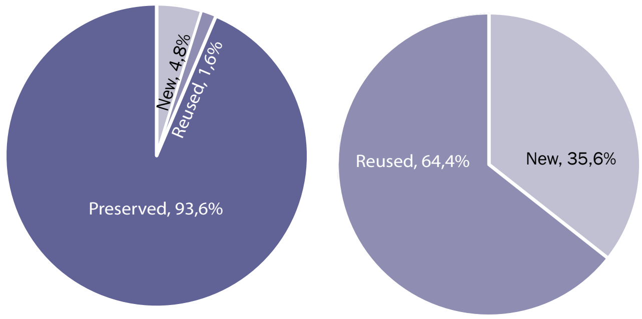
The row-houses work with an idea of reusing sandwich-elements from the original buildings, as part of the terrain slab. The façade elements can be separated into 100mm of concrete and 75mm of EPS insulation, meaning it would be a functioning radon barrier. To further insulate the ground slab an additional 225mm of virgin EPS insulations is added, bringing the final embodied emissions to 0,82kg $CO_2e/m^2/year$ and a 39,7% reduction of GWP compared to using virgin materials.

As mentioned earlier it is necessary to arrange the concrete wall elements in a new system when reusing them. As seen in figure 240 the concrete elements, when reused, have a global warming potential of 0,01kg $CO_2e/m^2/year$, a 96,5% reduction compared to virgin concrete and reinforcement. Reusing these elements along with the wood system, which has a GWP of 0,32kg $CO_2e/m^2/year$, the result is a combined reduction of only 2,2%. This reduction, while small, provides circular value as the concrete elements can more easily be taken apart along with the wood system in the future.
See Appendix 5 for LCAByg Data extraction.

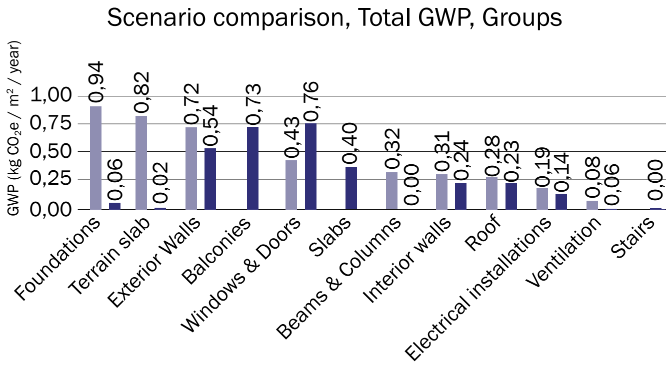


(Ill. 240) GWP per material per group in a row housw designed for disassembly.

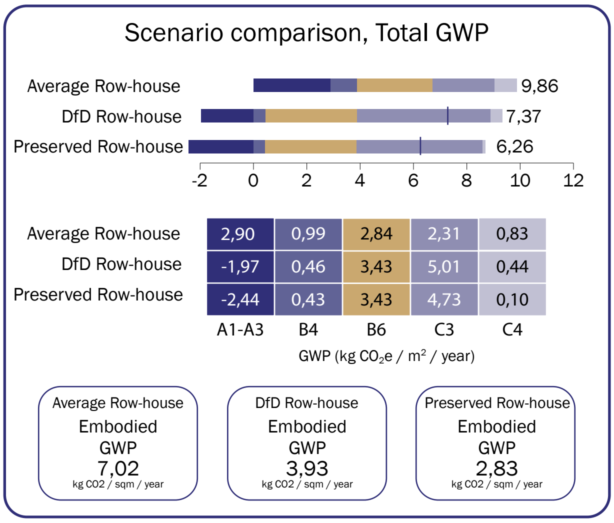
LIFE CYCLE ASSESSMENT RESULTS
COMPARISON OF RESULTS



(Ill. 241) Comparison of reused and new materials distribution by weight percentage in a preserved and a DfD house.



(Ill. 242) Comparison of GWP per group in a preserved and a DfD house.



(Ill. 243) Comparison of totat GWP per phase between a DfD house and a preserved house.

Figure 243 is a summary of the final design proposal results compared with the average row-house benchmark from the early design phase. The results show that the circular row-houses have lower embodied emissions, attributed to the production phase of the life cycle, with –1,97 and –2,44kg CO_2e/m^2/year respectively, compared to 2,90kg CO_2e/m^2/year in the average row-house. This is due to the chosen methodology in which the reduction factor for circular materials is applied to the production phase, while production is omitted for the preserved materials.

Furthermore, the final design proposals have a higher level of emissions in the waste processing phase compared to the average row-house. This is due to the addition of wood fibre insulation, wooden joists and plywood interior finishing, all of which store biogenic carbon in the production phase which is released during the end-of-life.

The circular row-houses have higher operational emissions compared to the average row-house. Considering the strategies of insulating the existing structures and optimizing heat losses throughout the design process, the emissions are likely a result of added heat demand in the final design proposals, compared to the modern house, which assumed to be more air-tight and insulated than was achieved in the reused and preserved constructions.

Figure 241 compares the circular row-houses, according to the weight of materials reused and preserved in each scenario with one-another. For a detailed breakdown at a construction group level see the previous pages. The DfD row-house has a higher number of constructions including new materials, such as the foundations, exterior walls and beams & columns. As mentioned in the results page the terrain slab has a large volume of new EPS insulation, which has a low influence on the reusability percentage, and as can be seen in figure 242, despite the concrete in the terrain slab being reused, this construction has a significantly higher GWP than the terrain slab in the preserved design proposal. It is generally the new constructions that make a significant difference in environmental impact between the two proposals

Both types of row-houses have added virgin materials for insulating reused and preserved constructions, which is why the environmental impact of exterior and interior walls are similar between the two proposals.

LIFE CYCLE ASSESSMENT CONCLUSIONS

It can be concluded that there is a significant potential for environmental impact savings when designing row-houses using preserved constructions and reused building materials, as compared to a standard scenario and similar constructions from virgin materials. Furthermore, it is indicated that there is a potential for further savings when designing using preserved constructions and materials than designing with reused materials only. This discrepancy between the two scenarios is also caused by the inability or lack of materials to reuse certain constructions, such as the foundations in the design-for-disassembly row-house. The final GWP results of the design-for-disassembly houses are 7,37kg CO_2e/m^2/year in total emission and 3,93kg CO_2e/m^2/year for embodied emissions only, while the preserved row-houses have 6,26kg CO_2e/m^2/year in total and 2,83kg CO_2e/m^2/year in embodied emissions. The preserved row-houses have 15,1% lower total emissions and 28,0% lower embodied emissions compared to the DfD row-houses.

Furthermore, it can be concluded from the results of the construction system in the design-for-disassembly row-house, that the environmental impact savings are heavily reduced when the examined elements are not designed for reuse but instead need to additional complimentary structures to enable reuse. Here the concrete elements would ordinarily have a 96,5% reduction potential when reusing but because of the amount of added materials required to enable the reassembly of the elements, the reduction potential was decreased to 7,1% for the generic element and 2,2% in the row-house design proposal.

Throughout the design process multiple optimization studies of embodied emissions against operational emissions have been performed:

In the study of insulation materials and the thickness of this, it can be concluded that as a results of the energy performance of the existing constructions, insulation materials with a lower embodied carbon footprint pr. kg like product specific paperwool and wood fibre insulation products, would not reach the optimal U-value within 0,08W/m^2K. Having a lower U-value would have produced an insulation layer of more than 500 mm. Instead, less optimal U-values of 0,1W/m^2K and 0,12W/m^2K were chosen in the exterior walls, to keep the constructions thinner, allowing for larger outdoor areas and greater daylight quality in the houses.

It can be concluded that implementing a hybrid ventilation strategy with heat recovery in winter indicates a significant saving in emissions, compared to a purely natural ventilation strategy. Ventilation equipment is a small subsection of the final embodied emissions while providing large savings related to operational emissions through lowering heat demand. Implementing hybrid ventilation had an increase in embodied emissions of 0,11kg CO_2e/m^2/year, while saving 1,59kg CO_2e/m^2/year in operational emissions, which was a 30,5% reduction in GWP compared to exclusively natural ventilation.

The study on integrating photovoltaic panels to reduce the energy consumption in order to meet the requirements of the Danish Building Regulation showcased that the operational emissions saved are equal to or less than embodied emissions associated with producing and replacing the photovoltaic panels themselves. The two products included in the study, one generic and one product average, resulted in the embodied emissions of the generic panels being 10,6% higher than the saved operational emissions, while the product average indicated a 1,1% reduction in overall emissions. Therefore, the study was inconclusive as to whether or not implementing photovoltaics to increase the building energy performance would provide a total reduction in CO_2e emissions.


opaque

#09 CONCLUSION.

DISCUSSION

The focus of the project has changed and shifted from what was originally envisioned during the early research phase to what the final design ended up tackling. Energy renovations was supposed to be a major focus throughout the project. Sundparken was chosen because of the lack of a detailed development plan compared to some of the other transformation areas and since the buildings were built in the sixties it seemed like there could be a high potential for energy renovations, which would be a great case for conducting LCA studies comparing embodied carbon emissions with the potential savings in operational emissions.

It did however quickly become apparent that this approach wouldn't be viable. Sundparken had gone through a thorough energy renovation in 2000, which had improved the energy performance quite significantly and improved the architectural quality of the area substantially. We realized that justifying any tear down or major changes to the building envelope would be extremely difficult due to the existing building conditions. This was highlighted even further by visiting the site and speaking to locals, social workers and reading articles from the local newspapers. Sundparken seemed to be an area on a positive trajectory were people liked living, but it was too little too late. Sundparken had been categorized as a tough ghetto too many times in a row, and now has to go through a significant transformation to reduce the percentage of social family housing down to 60% and teardown seemed like the most likely approach.

The building industry usually justifies teardown with the improved energy performance achieved by the new buildings. Sundparken is an example of how this approach will become less viable as time goes on, since the energy performance of the buildings getting marked for teardown today most likely have a better performance than buildings marked for teardown 20 years ago. The question then becomes; how can the construction sector approach these tasks, that normally would entail a regular teardown, with a more environmentally sustainable approach?

The results of the LCA studies conclude that there is a significant potential for environmental impact savings in using preserved constructions and reused building materials. This approach proved time-consuming, since a lot of preliminary building analysis had to be made before the design process could move into the further stages. Building on existing foundation and reusing existing layouts is very challenging and quite restrictive on the design. It requires a substantial amount of building data, that in some cases can be hard to obtain.

One of the biggest challenges is disassembly. Concrete element blocks like the ones used in Sundparken were not made to be taken apart, they were made to last, thus all connections between the elements are cast in concrete. The initial idea was to dissemble whole blocks and then reuse the elements like lego's to create new buildings. The thought was that this would give more freedom in the design process. However, the final design ended up reusing the structural system on both the buildings on the existing foundations and the ones on the new. This happened since it allowed a higher percentage of the existing materials and elements to be reused, and since the new design fits the existing structural system, it was possible to preserve a high potential of the existing building. This approach seems to be ideal when aiming for an environmentally sustainable design solution.

This also highlights the importance of DfD. Most buildings are built with a specific purpose in mind and as time goes on there's a risk that its original purpose becomes obsolete. A typical example of this is factory buildings left empty by a decline in local industry. A similar situation is currently happening in Sundparken. Its current purpose is rendered obsolete, not due to failing industries, but due to governmental regulations. A building that has to be taken apart after it lost its original purpose does not have to be a cumbersome task to solve. Most buildings were relatively easy to disassemble before the industrialization of the construction sector. Bricks held together with lime mortar and timber structures were easy to take apart and reuse, and these building methods stand in stark contrast to the cement mortar and precast concrete elements from the sixties. By ensuring that the buildings are easy to take apart, it extends the lifespan of the building and the elements, and significantly lowers the carbon footprint of future building reconfigurations. Thus, the rowhouses on new foundation has been projected with Design for Disassembly in mind, to ensure easy reconfiguration of the buildings in the future.

LCA DISCUSSION

LCA analysis in Denmark normally has its main focus on GWP, similar to this report, however, also has eight sub-focuses on areas like ozone depletion, acidification and resource depletion. While all these factors are important to consider for a more holistic consideration of measurable sustainability, the available dataset for circular materials and environmental impact reductions used to calculate the impact savings in the project only consider global warming potential. As such these other factors were left out.

Methodology for preserved materials following the 0:100 cut-off method incentivizes direct reuse of most mineral based materials, like concrete, bricks and mineral wool. However, for natural-based materials with biogenic carbon, ones project would be punished for reusing these in a given project. This is due to the absorption of carbon in building materials like construction wood, are only applied to the first life-cycle, while the release of the biogenic carbon is allocated solely to the last life-cycle. This case is not present in the project, as reused wood materials would have to be removed, processed and reassembled due to adding insulation or in order to remove/dismantle construction below the wood "layer". Had there been a large amount of natural materials with potential for reuse, a distributive method could have been beneficial in this case, distributing the emissions of all the life-cycle phases equally amongst the multiple building-life-cycles.

Energy consumption vs. Embodied emissions. We can see in our file results that the embodied emissions are reduced to half or less of the total emissions for the building, meaning that the focus then becomes on energy optimization strategies while reusing existing materials and structures. Furthermore, in the Danish Building Requirement there has for years been a focus on building energy performance as a measure of sustainability, and only with the voluntary sustainability class and the implementation of LCA requirements in the 2023 Building Regulation has the focus shifted to material sustainability. The photovoltaic study shows the potential disconnect between the two methods, in which photovoltaics is a viable way to increase the energy performance, but due to the large number of embodied emissions in the panels, the environmental impact of this implementation is equal to or worse/higher compared to leaving them out.

REFLECTION

The scope of the project became larger than intended as the project moved along. This is due to the mix between the project type and the technical focus we decided to work with. Having LCA as our primary technical focus would from the start require a large amount of calculation work. The LCA results lead us to investigations on preservations, reuse and design for disassembly, while theproject type as a transformation of a ghetto area, lead us to further investigations of urban planning and social sustainability. This resulted in working in a lot of different fields, all the way down to the scale in the individual joint and all the way up to urban scale. It has therefore been difficult to know which area to keep focus on, thus resulting in a number of areas with superficial levels of detail.

An example is the new commercial area has been a major design consideration during the masterplan design process. Its placement is essential for the final design proposal since it's intended to act as a catalyst for social interaction between people from inside and outside of Sundparken. This is also why we decided to call it the cultural district. Due to time limitation, we did not develop it any further.

To achieve the BE18 energy performance requirements the final proposal implements photovoltaics. This is apparently not allowed to do this on social housing areas since the buildings span across multiple building plots. According to the Danish Electricity Supply Act which establishes that solar electricity supply is allowed inside a single plot and the photovoltaic installation must be divided so that each building within the building complex has its own installations. Redistribution between buildings is not permitted. This regulation seems highly arbitrary, and it should be questioned whether or not this regulation belongs in an industry that is a vital part of ongoing green transition.

Circularity involves using either reused or recycled elements, which means they can come in different shapes and conditions. Considering the diversity provided by materials that have such different and often unpredictable origins, it becomes a challenge to achieve a certain level of unity. Consequently, the aesthetics of the building are highly dependent on the skills of the people constructing the project. They must work with a variety of measures, thicknesses, and finish what the architect has limited control over. In this way, carpenters and builders become part of the process since every joint is new and different, and the execution becomes as relevant as the abilities of architects to design them.

LCA REFLECTION

A source of error between the life-cycle assessment results of the existing buildings, the DfD-proposal and the preserved proposal, is the fact that building materials are not always aligned between buildings as they were made by different group members. This means that the build-up of for example, doors and the strength of concrete vary between calculations, leading to inconsistencies when comparing results. The numeric results may change but the overall indications and conclusions should remain the same. The inconsistencies were found shortly before the date of the project hand-in and as such were not corrected due to time restraints.

Similarly, the level of detail in the different calculations is of varying degree. The reason for this is that different group members have conducted different calculations using a higher or lower amount of standard constructions from the LCAbyg database, with a generally higher level of detail including multiple layers of finishes and fasteners. Due to time restraints a last thorough alignment of the different LCA calculations was not possible.

Operational results from Be18 are allowed to go negative, meaning that the excess power produced is sold off to the grid, lowering the energy frame below 0 kWh/m2 yearly for el- operations. This is in part due to the tool running a monthly calculation without considering when the power is used, this is not the case in LCAbyg, in which operational emissions do not go below 0 kWh/m2 yearly, as it is not assumed that the excess energy can be utilized. This affects the study regarding Photovoltaics. However, while Be18 calculates a 4,6 kWh/m2 yearly excess energy production, this does not take into account the energy consumption for lighting, which is around 20 kWh/m2, meaning that the photovoltaic panels do have a function below "just" reducing the energy performance to fit the requirement.

The fact that hardly any energy is accounted for in the collection and processing of the reused and preserved building elements means that the actual reduction factor is likely significantly lower than what is calculated for in the background data and for the results of this report as a whole. This is an area of development that will be interesting to follow, as the field of circularity grows in the building industry.

CONCLUSION

It can be concluded based on the site analysis that Sundparken is a well-functioning housing area, where people like living and enjoy the green areas around it. This does, however, not change the fact that Sundparken has been categorized as a transformation area and must therefore reduce its percentage of social family housing down to 60%.

The design proposal has achieved the reduction to 60% social family housing by strategically disassembling 50 units from the A1 block and converting the remaining 14 into private family housing, while converting the total of 33 apartment units in the A2 block into 30 new elderly apartments. These blocks were chosen based on the analysis of Sundparken and the observations made on site. They concluded that altering these blocks and the old Rema 1000 building could have a high potential for improving the social sustainability of the area. The buildings can currently be interpreted as physical barriers that restrict circulation through the area

Nationwide, 9000 apartment units are currently at risk or in the process of being torn down due to the enactment of the parallel society act. The number of units that will end up getting demolished depends entirely on how the transformation task will be approached. This design proposal provides a transformation approach that showcases the potential of preserving and reusing existing construction elements, which results in the reduction of demolished apartment units from 124, in the original proposed development plan, down to only 50 units that instead of getting demolished will be strategically disassembled.

The strategic disassembly of the A1 block manages to change the architectural qualities of the built environment with the aim of improving social sustainability by creating better visual connections to the surrounding neighborhoods, by creating new openings through the existing building volumes, thus inviting people in, so they can interact with each other at the new cultural district.

It furthermore showcases how materials sourced from the strategic disassembly can be used in new constructions to significantly lower their embodied carbon emissions, thus creating more environmentally sustainable housing units. This is showcased by the final LCA results of 6,26 kgCO2/m2/year and 7,37 kgCO2/m2/year both results comply with the 2029 limit value of 7,5 kgCO2/m2/year for new constructions and the rowhouses built on the preserved basement with preserved materials also comply with the 2025 limit value of 7,0 kgCO2/m2/year for the low-emission class. It can therefore be concluded that this is a more environmentally sustainable approach.

By choosing to preserve as much of the existing constructions as possible, it forces the new design to align itself to the existing structural system. This requires following the loadbearing line and letting the building orientation be defined by the existing foundation. This resulted in keeping the north to south orientation from the original A1 block which was criticized in the site analysis. The new design does, however, work better with this orientation, due to its lowered height and permeable openings.

The design seeks to achieve social sustainability by promoting social interactions within the new cultural district. The district will be a central plaza within Sundparken that connects the main body with the new housing area and Horsens as a whole. The local businesses from the existing shopping district will, in collaboration with the convenience stores and the new library, act as catalysts for social interactions in and around Sundparken. This extra activity and centralization of the public functions around the new cultural district is done to ensure commercial stability and growth for the local businesses by placing them next to the area with the highest foot traffic, thus being in close relation to the convenience stores.

The transformation of the old shopping district into the elderly residential area is a great example of how an existing building can be reconfigured by converting the small apartments within the A2 block, classified as social family housing, into elderly apartments by making the necessary changes to accommodate the new user group, such as ensuring private bedrooms in all the elderly apartments. Social interaction between the residents is encouraged by the community functions placed on the ground floor where the stores used to be located.

The transformation of Sundparken can be used as an example of how the building industry could approach transformation of buildings by preserving, reusing and reprogramming instead of tearing down and building new. Demolition is from an environmental perspective already hard to justify, and it will become even harder to do so in the future, when the future old buildings have the energy performance of today.

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ILLUSTRATION LIST AND CREDITS

Ill. 01 - 06: own illustration.

Ill. 07: Sweco Architects, 2012-2022. Ringparken, Slagelse.

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All illustrations in the forthcoming appendix are own illustrations.

APPENDIX.

APPENDIX 1: BE18 MODEL & RESULTS OF EXISTING BUILDING

The building	
Building type	Multy-story house
Rotation	0,0 deg
Area of heated floor	2487,0 m²
Area heated basement	0,0 m²
Area existing / other usage	0,0 m²
Heated gross area incl. basement	2487,0 m²
Heat capacity	140,0 Wh/K m²
Normal usage time	168 hours/week
Usage time, start at - end at, time	0 - 24

Calculation rules	
Calculation rules	BR: Actual conditions
Suplement to energy frame	0,0 kWh/m² år

Heat supply and cooling	
Basic heat supply	District heating
Electric panels	No
Wood stoves, gas radiators etc.	No
Solar heating plant	No
Heat pumps	No
Solar cells	No
Wind mills	No
Mechanical cooling	No

Room temperatures, set points	
Heating	20,0 °C
Wanted	23,0 °C
Natural ventilation	24,0 °C
Mechanical cooling	25,0 °C
Heating store	15,0 °C

Dimensioning temperatures	
Room temp.	20,0 °C
Outdoor temp.	-12,0 °C
Room temp. store	15,0 °C

External walls, roofs and floors					
Building component	Area (m²)	U (W/m²K)	b	Dim.Inside (C)	Dim.Outside (C)
4_floors_Brick_wall_Gable	261,6	0,21	1,000		
4_Floors_Brick_wall_Facade	607,4	0,21	1,000		
4_floors_GypsumWindows	231,0	0,16	1,000		
Basement_Brick_Wall	129,0	0,21	0,700		
Basement_Plinth_Wall + EPS (regular)	56,0	0,19	0,700		
Basement_Plinth_Wall (Fill-in)	10,0	0,17	0,700		
Roof Slab	571,0	0,18	1,000		

External walls, roofs and floors					
Plinth (No insulation)	100,0	0,46	0,700		
Terrain_Slab (>500mm below terrain)	622,0	0,37	0,700		
Basement_Floor/Ceiling	622,0	0,56	0,700		
Ialt	3210,0	-	-	-	-

Foundations etc.					
Building component	l (m)	Loss (W/mK)	b	Dim.Inside (C)	Dim.Outside (C)
Line_loss_doors	20,0	0,00	1,000		
Line_loss_windows_4Floors	950,0	0,00	1,000		
Line_loss_windows_Basement	210,0	0,00	1,000		
Line_loss_Windows_Stairs	210,0	0,00	1,000		
Foundations	169,0	0,00	1,000		
Ialt	1559,0	-	-	-	-

Windows and outer doors													
Building component	Number	Orient	Inclination	Area (m²)	U (W/m²K)	b	Ff (-)	g (-)	Shading	Fc (-)	Dim.Inside (C)	Dim.Outside (C)	Ext
Windows_(129x123)_WEST	60	270	90,0	1,8	1,60	1,000	0,86	0,75	Default	1,00			0
Windows_(129x123)_EAST	48	90	90,0	1,8	1,60	1,000	0,86	0,75	Default	1,00			0
Windows_(102x102)_EAST	24	90	90,0	1,1	1,60	1,000	0,81	0,75	Default	1,00			0
Windows_Balcony_(259,x297)_WEST	24	270	90,0	7,7	1,60	0,700	0,84	0,75	Default	1,00			0
Windows_Stairs_EAST	3	90	90,0	18,2	1,60	0,700	0,82	0,75	Default	1,00			0
Windows_Basement_(45x45)_EAST	20	90	90,0	0,2	1,60	0,700	0,50	0,75	Default	1,00			0
Windows_Basement_(73x64)_EAST	4	90	90,0	0,5	1,60	0,700	0,71	0,75	Default	1,00			0
Windows_Basement_(59x217)_WEST	6	270	90,0	1,3	1,60	0,700	0,70	0,75	Default	1,00			0
Ialt	189	-	-	467,8	-	-	-	-	-	-	-	-	

Shading					
Description	Horizon (°)	Eaves (°)	Left (°)	Right (°)	Window opening (%)
Default	15	0	0	0	10

Summer comfort	
Floor area	0,0 m²
Ventilation, winther	0,3 l/s m²
Ventilation, summer, 9-16	0,9 l/s m²
Ventilation, summer, 17-24	0,9 l/s m²
Ventilation, summer, 0-8	0,6 l/s m²

Ventilation													
Zone	Area (m²)	Fo, -	qm (l/s m²), Winter	n vgv (-)	ti (°C)	El-HC	qn (l/s m²), Winter	qi,n (l/s m²), Winter	SEL (kJ/m³)	qm,s (l/s m²), Summer	qn,s (l/s m²), Summer	qm,n (l/s m²), Night	qn,n (l/s m²), Night
Kitchens	240,0	1,00	0,30	0,00	0,0	No	0,20	0,00	1,0	0,30	2,00	0,00	0,00
Bathrooms	114,0	1,00	0,30	0,00	0,0	No	0,20	0,00	1,0	0,30	1,50	0,00	0,00
Bedrooms	320,0	1,00	0,00	0,00	0,0	No	0,50	0,00	0,0	0,00	2,00	0,00	0,00
Living rooms	572,0	1,00	0,00	0,00	0,0	No	0,50	0,00	0,0	0,00	5,00	0,00	0,00
Small rooms	266,0	1,00	0,00	0,00	0,0	No	0,50	0,00	0,0	0,00	3,00	0,00	0,00
Oblong rooms	160,0	1,00	0,00	0,00	0,0	No	0,50	0,00	0,0	0,00	2,00	0,00	0,00
Entrance	206,0	1,00	0,00	0,00	0,0	No	0,20	0,00	0,0	0,00	2,00	0,00	0,00
Balconies	84,0	1,00	0,00	0,00	0,0	No	0,20	0,00	0,0	0,00	3,00	0,00	0,00

Ventilation													
Staircase	280,0	1,00	0,00	0,00	0,0	No	0,20	0,00	0,0	0,00	2,00	0,00	0,00

Internal heat supply				
Zone	Area (m²)	Persons (W/m²)	App. (W/m²)	App,night (W/m²)
Kitchens	240	1,5	3,5	0,0
Bathrooms	114	1,5	3,5	0,0
Bedrooms	320	1,5	3,5	0,0
Living rooms	572	1,5	3,5	0,0
Small rooms	266	1,5	3,5	0,0
Oblong rooms	160	1,5	3,5	0,0
Entrance	206	1,5	3,5	0,0
Balconies	84	0,0	0,0	0,0
Staircase	280	0,0	0,0	0,0

Lighting											
Zone	Area (m²)	General (W/m²)	General (W/m²)	Lighting (lux)	DF (%)	Control (U, M, A, K)	Fo (-)	Work (W/m²)	Other (W/m²)	Stand-by (W/m²)	Night (W/m²)

Other el. consumption	
Outdoor lighting	0,0 W
Spec. apparatus, during service	0,0 W
Spec. apparatus, always	0,0 W

Basement car parkings etc.											
Zone	Area (m²)	General (W/m²)	General (W/m²)	Lighting (lux)	DF (%)	Control (U, M, A, K)	Fo (-)	Work (W/m²)	Other (W/m²)	Stand-by (W/m²)	Night (W/m²)

Mechanical cooling	
Description	Mechanical cooling
Share of floor area	0
El-demand	0,00 kWh-el/kWh-cool
Heat-demand	0,00 kWh-heat/kWh-cool
Load factor	1,2
Heat capacity phase shift (cooling)	0 Wh/m²
Increase factor	1,50
Documentation	

Heat distribution plant		
Composition and temperature		
Supply pipe temperature	70,0 °C	Varmepumpe
Return pipe temperature	40,0 °C	
Type of plant	2-string	Anlægstype

Pumps				
Pump type	Description	Number	Pnom	Fp

Heating pipes					
Pipe lengths in supply and return	l (m)	Loss (W/mK)	b	Outdoor comp (J/N)	Unused summer (J/N)
Building, General 2x length	110,0	0,30	0,700	N	N

Domestic hot water	
Description	Domestic hot water
Hot-water consumption, average for the building	250,0 litre/year per m² of floor area
Domestic hot water temp.	55,0 °C

Hot-water tank	
Description	New hot-water tank
Number of hot-water containers	1,0
Tank volume	950,0 liter
Supply temperature from central heating	60,0 °C
El. heating of DHW	Summer
Solar heat tank with heating coil	No
Heat loss from hot-water tank	4,0 W/K
Temp. factor for setup room	0,0

Charging pump	
Effect	0,0 W
Controled	No
Charge effect	0,0 kW

Heat loss from connector pipe to DHW tank			
Length	Loss	b	Description
40,0 m	0,3 W/K	0,00	

Cirkulating pump for DHW	
Description	PumpCirc
Number	2,0
Effect	80,0 W
Number	0,0
Effect	0,0 W
Reduction factor	0,00 [-]
El. tracing of discharge water pipe	No

Domestic hot water discharge pipes			
Pipe lengths in supply and return	l (m)	Loss (W/mK)	b
Pipes inside heated space	50,0	0,25	0,700
Pipes outside heated space	110,0	0,25	0,000

Water heaters	
Electric water heater	
Description	Electric water heater
Share of DHW in separate el. water heaters	0,0
Heat loss from hot-water tank	0,0 W/K
Temp. factor for setup room	1,00
Gas water heater	
Description	Gas water heater
Share of DHW in separate gas water heaters	0,0
Heat loss from hot-water tank	0,0 W/K
Efficiency	0,5

Model: 2023-03-29 Sundparken ENergyFrame	SBi Beregningskerne 10.19.7.22
Be18 key numbers: Existing Sundparken (29-03-2023)	
Transmission loss, W/m²	
Tramission loss frame, normal	13,6
Tramission loss frame, low energy	12,6
Tramission loss, calculated	22,3
Renovation class 2, kWh/m² year	
Energy frame renovation class 2, without addition	70,9
Addition for special terms	0,0
Total energy frame	70,9
Total energy requirement	69,0
Renovation class 1, kWh/m² year	
Energy frame renovation class 1, without addition	53,2
Addition for special terms	0,0
Total energy frame	53,2
Total energy requirement	69,0
Energy frame BR 2018, kWh/m² year	
Energy frame BR 2018, without addition	30,4
Addition for special terms	0,0
Total energy frame	30,4
Total energy requirement	69,0
Energy frame low energy, kWh/m² year	
Energy frame low energy, without addition	27,0
Addition for special terms	0,0
Total energy frame	27,0
Total energy requirement	69,0
Contribution to energy requirement, kWh/m² year	
Heating	66,8
El. for service of buildings	6,5
Excess temperature in rooms	0,0
Net requirement, kWh/m² year	
Room heating	53,5
Domestic hot water	14,3
Cooling	0,0
Selected el. requirements, kWh/m² year	
Lighting	0,0
Heating of rooms	0,0
Heating of domestic hot water	6,1
Heat pump	0,0

Model: 2023-03-29 Sundparken ENergyFrame	SBi Beregningskerne 10.19.7.22
Be18 key numbers: Existing Sundparken (29-03-2023)	
Transmission loss, W/m²	
Tramission loss frame, normal	13,6
Tramission loss frame, low energy	12,6
Tramission loss, calculated	22,3
Renovation class 2, kWh/m² year	
Energy frame renovation class 2, without addition	70,9
Addition for special terms	0,0
Total energy frame	70,9
Total energy requirement	69,0
Renovation class 1, kWh/m² year	
Energy frame renovation class 1, without addition	53,2
Addition for special terms	0,0
Total energy frame	53,2
Total energy requirement	69,0
Energy frame BR 2018, kWh/m² year	
Energy frame BR 2018, without addition	30,4
Addition for special terms	0,0
Total energy frame	30,4
Total energy requirement	69,0
Energy frame low energy, kWh/m² year	
Energy frame low energy, without addition	27,0
Addition for special terms	0,0
Total energy frame	27,0
Total energy requirement	69,0
Contribution to energy requirement, kWh/m² year	
Heating	66,8
El. for service of buildings	6,5
Excess temperature in rooms	0,0
Net requirement, kWh/m² year	
Room heating	53,5
Domestic hot water	14,3
Cooling	0,0
Selected el. requirements, kWh/m² year	
Lighting	0,0
Heating of rooms	0,0
Heating of domestic hot water	6,1
Heat pump	0,0

Model: 2023-03-29 Sundparken ENergyFrame	SBi Beregningskerne 10.19.7.22
Ventilators	0,4
Pumps	0,0
Cooling	0,0
Heat loss from installations, kWh/m² year	
Room heating	5,0
Domestic hot water	1,2
Output from special sources, kWh/m² year	
Solar heat	0,0
Heat pump	0,0
Solar cells	0,0
Wind mills	0,0
Total el. requirement, kWh/m² year	
El. requirement	29,6

APPENDIX 2: BE18 MODEL & RESULTS OF FINAL DESIGN PROPOSAL

The building	
Building type	Nondetached house
Number of residential units for non-detached houses	3
Rotation	350,0 deg
Area of heated floor	300,0 m²
Area heated basement	0,0 m²
Area existing / other usage	250,6 m²
Heated gross area incl. basement	300,0 m²
Heat capacity	100,0 Wh/K m²
Normal usage time	168 hours/week
Usage time, start at - end at, time	0 - 24
Calculation rules	
Calculation rules	BR: Actual conditions
Suplement to energy frame	0,0 kWh/m² år
Heat supply and cooling	
Basic heat supply	District heating
Electric panels	No
Wood stoves, gas radiators etc.	No
Solar heating plant	No
Heat pumps	No
Solar cells	Yes
Wind mills	No
Mechanical cooling	No

Room temperatures, set points	
Heating	20,0 °C
Wanted	23,0 °C
Natural ventilation	24,0 °C
Mechanical cooling	25,0 °C
Heating store	15,0 °C
Dimensioning temperatures	
Room temp.	20,0 °C
Outdoor temp.	-12,0 °C

Dimensioning temperatures	
Room temp. store	15,0 °C

External walls, roofs and floors					
Building component	Area (m²)	U (W/m²K)	b	Dim.Inside (C)	Dim.Outside (C)
Roof slabs	223,7	0,10	1,000		
Floor slab, to the basement	223,7	0,15	1,000		5
Basement walls	197,0	0,18	0,028		
Existing outerwall, North (brick facade)	64,5	0,15	1,000		
Gables (new construction XX)	99,1	0,12	1,000		
Outerwall/Roof joint (New construction YY)	36,7	0,12	1,000		
Outerwall, lightweight, South (New Construction ZZ)	71,0	0,10	1,000		
Ialt	915,8	-	-	-	-

Foundations etc.					
Building component	l (m)	Loss (W/mK)	b	Dim.Inside (C)	Dim.Outside (C)
Terrace Joint	27,3	0,09	1,000		
Basement to floor	99,4	0,19	1,000		5
Windows	183,8	0,06	1,000		
Ialt	310,5	-	-	-	-

Windows and outer doors													
Building component	Number	Orient	Inclination	Area (m²)	U (W/m²K)	b	Ff (-)	g (-)	Shading	Fc (-)	Dim.Inside (C)	Dim.Outside (C)	Ext
Patio windows, 3 doors	3	S	90,0	5,5	0,50	1,000	0,86	0,50	Two-storey, ground floor - patio, 3door	0,90			0
Patio windows, 2 doors	4	S	90,0	3,7	0,50	1,000	0,86	0,50	Two-storey, ground floor - patio, 2door	0,90			0
Tall windows	4	S	90,0	1,9	0,50	1,000	0,85	0,50	Two-storey, 1st floor - tall windows	0,90			0
Wide windows, South	2	S	90,0	1,9	0,50	1,000	0,83	0,50	One storey, ground florr -	0,90			0

Windows and outer doors													
									wide windows				
Wide windows, North	6	N	90,0	1,9	0,50	1,000	0,83	0,50	North windows	0,90			0
Small windows	5	N	90,0	1,3	0,50	1,000	0,80	0,50	North windows	0,90			0
Entrance glazing	2	N	90,0	9,7	0,70	1,000	0,92	0,48	North windows	0,90			0
Entrance Doors	1	N	90,0	1,7	1,00	1,000	0,84	0,50	North windows	0,90			0
Ialt	27	-	-	82,0	-	-	-	-	-	-	-	-	

Shading					
Description	Horizon (°)	Eaves (°)	Left (°)	Right (°)	Window opening (%)
Two-storey, ground floor - patio, 3door	6	30	68	28	16
Two-storey, ground floor - patio, 2door	6	30	67	28	23
One storey, ground florr - wide windows	6	30	67	28	31
Two-storey, 1st floor - patio, 2door	0	30	0	0	23
Two-storey, 1st floor - tall windows	0	30	0	0	44
North windows	15	10	60	45	31

Unheated room: Basement	
Gross area	250,0 m²
Ventilation	0,1 l/s m²
b	0,03

Transmission loss from building		
Building component	Area (m²)	U (W/m²K)
Terrain slab	250,0	4,00
Walls	197,0	0,18

Transmission loss to surroundings		
Building component	Area (m²)	U (W/m²K)

Summer comfort	
Floor area	0,0 m²
Ventilation, winther	0,3 l/s m²
Ventilation, summer, 9-16	0,9 l/s m²
Ventilation, summer, 17-24	0,9 l/s m²

Summer comfort	
Ventilation, summer, 0-8	0,6 l/s m^2

Ventilation													
Zone	Area (m^2)	Fo, -	qm (l/s m^2), Winter	n vgv (-)	ti (°C)	El-HC	qn (l/s m^2), Winter	qi,n (l/s m^2), Winter	SEL (kJ/m^3)	qm,s (l/s m^2), Summer	qn,s (l/s m^2), Summer	qm,n (l/s m^2), Night	qn,n (l/s m^2), Night
Kitchens, two-storey	20,6	1,00	0,30	0,88	0,0	No	0,10	0,00	0,4	0,30	3,00	0,00	0,00
Kitchen, one-storey	9,8	1,00	0,30	0,88	0,0	No	0,10	0,00	0,3	0,30	3,00	0,00	0,00
Bathrooms, two-storey	18,4	1,00	0,30	0,88	0,0	No	0,10	0,00	0,4	0,30	0,40	0,00	0,00
Bathroom, one-storey	4,6	1,00	0,30	0,88	0,0	No	0,10	0,00	0,3	0,30	0,40	0,00	0,00
Bedrooms, two-storey	75,2	1,00	0,30	0,88	0,0	No	0,10	0,00	0,4	0,30	3,00	0,00	0,00
Bedrooms, one-storey	29,6	1,00	0,30	0,88	0,0	No	0,10	0,00	0,3	0,30	3,00	0,00	0,00
Living rooms, two-storey	32,5	1,00	0,30	0,88	0,0	No	0,10	0,00	0,4	0,30	3,00	0,00	0,00
Living room, one-storey	20,7	1,00	0,30	0,88	0,0	No	0,10	0,00	0,3	0,30	3,00	0,00	0,00
Dining rooms, two-storey	22,6	1,00	0,30	0,88	0,0	No	0,10	0,00	0,4	0,30	3,00	0,00	0,00
Entrances and hallways, two-storey	53,7	1,00	0,30	0,88	0,0	No	0,10	0,00	0,4	0,30	2,00	0,00	0,00
Entrance and hallways, one storey	13,3	1,00	0,30	0,88	0,0	No	0,10	0,00	0,3	0,30	2,00	0,00	0,00

Internal heat supply				
Zone	Area (m^2)	Persons (W/m^2)	App. (W/m^2)	App,night (W/m^2)
heated floor area, people load + equipment	300	3,0	3,5	0,0

Lighting											
Zone	Area (m^2)	General (W/m^2)	General (W/m^2)	Lighting (lux)	DF (%)	Control (U, M, A, K)	Fo (-)	Work (W/m^2)	Other (W/m^2)	Stand-by (W/m^2)	Night (W/m^2)
Real Rooms	232,0	1,0	3,0	300	2,00	M	1,00	0,0	0,0	0,0	0,0
Entrances and hallways	68,0	1,0	3,0	300	0,60	M	1,00	0,0	0,0	0,0	0,0

Other el. consumption	
Outdoor lighting	0,0 W
Spec. apparatus, during	0,0 W

Other el. consumption	
service	
Spec. apparatus, always	0,0 W

Basement car parkings etc.											
Zone	Area (m²)	General (W/m²)	General (W/m²)	Lighting (lux)	DF (%)	Control (U, M, A, K)	Fo (-)	Work (W/m²)	Other (W/m²)	Stand-by (W/m²)	Night (W/m²)

Mechanical cooling	
Description	Mechanical cooling
Share of floor area	0
El-demand	0,00 kWh-el/kWh-cool
Heat-demand	0,00 kWh-heat/kWh-cool
Load factor	1,2
Heat capacity phase shift (cooling)	0 Wh/m²
Increase factor	1,50
Documentation	

Heat distribution plant		
Composition and temperature		
Supply pipe temperature	70,0 °C	
Return pipe temperature	40,0 °C	
Type of plant	1-string	Anlægstype

Pumps				
Pump type	Description	Number	Pnom	Fp

Heating pipes					
Pipe lengths in supply and return	l (m)	Loss (W/mK)	b	Outdoor comp (J/N)	Unused summer (J/N)
Outside pipes	55,0	0,15	0,700	N	N

Domestic hot water	
Description	Domestic hot water
Hot-water consumption, average for the building	250,0 litre/year per m² of floor area
Domestic hot water temp.	55,0 °C
Hot-water tank	
Description	Ny varmtvandsbeholder
Number of hot-water containers	3,0
Tank volume	110,0 liter
Supply temperature from central heating	60,0 °C

Hot-water tank	
El. heating of DHW	No
Solar heat tank with heating coil	No
Heat loss from hot-water tank	1,0 W/K
Temp. factor for setup room	0,0

Charging pump	
Effect	0,0 W
Controled	No
Charge effect	0,0 kW

Heat loss from connector pipe to DHW tank			
Length	Loss	b	Description
5,0 m	0,2 W/K	0,70	

Cirkulating pump for DHW	
Description	PumpCirc
Number	2,0
Effect	80,0 W
Number	0,0
Effect	0,0 W
Reduction factor	0,50 [-]
El. tracing of discharge water pipe	No

Domestic hot water discharge pipes			
Pipe lengths in supply and return	l (m)	Loss (W/mK)	b
Domestic hot water, pipe lenghts, inside	121,0	0,15	0,000

Water heaters	
Electric water heater	
Description	Electric water heater
Share of DHW in separate el. water heaters	0,0
Heat loss from hot-water tank	0,0 W/K
Temp. factor for setup room	1,00
Gas water heater	
Description	Gas water heater
Share of DHW in separate gas water heaters	0,0

Gas water heater	
Heat loss from hot-water tank	0,0 W/K
Efficiency	0,5
Pilot flame	50,0 W
Temp. factor for setup room	1,00

District heat exchanger	
Description	New district heating exchanger
Nominal effect	0,0 kW
Heat loss	0,0 W/K
DHW heating through exchanger	No
Exchanger temperature, min	60,0 °C
Temp. factor for setup room	1,00
Automatics, stand-by	5,0 W

Other room heating	
Direct el for room heating	
Description	Suplemental direct room heating
Share of floor area	0,0
Wood stoves, gas radiators etc.	
Description	
Share of floor area	0,0
Efficiency	0,4
Air flow requirement	0,1 m³/s

Solar heating plant		
Description	New solar heating plant	
Type	Room heating	
Solar collector		
Area 100,0 m²	Start 0,8	-
Coefficient of heat loss a1 3,5 W/m²K	Coefficient of heat loss a2 0,0 W/m²K	Anglefactor 0,9
Orientation S	Slope 20,0 °	-
Horizon 0,0 °	Left 0,0 °	Right 0,0 °
Solar collector pipe		
Length 0,0 m	Heat loss 0,00 W/mK	Circuit 0,8
Electricity		
Pump in solar collector circuit 50,0 W	Automatics, stand-by 5,0 W	

Solar cells	
Description	PV Panels

Solar cells		
Area 15,0 m²	Orientation S	Slope 20,0 °
Horizon 0,0 °	Left 0,0 °	Right 0,0 °

Additional	
Peak power 0,170 kW/m²	Efficiency 0,80

Model: 2023-03-29 Sundparken ENergyFrame	SBi Beregningskerne 10.19.7.22
Be18 key numbers: Existing Sundparken (29-03-2023)	
Transmission loss, W/m²	
Tramission loss frame, normal	13,6
Tramission loss frame, low energy	12,6
Tramission loss, calculated	22,3
Renovation class 2, kWh/m² year	
Energy frame renovation class 2, without addition	70,9
Addition for special terms	0,0
Total energy frame	70,9
Total energy requirement	69,0
Renovation class 1, kWh/m² year	
Energy frame renovation class 1, without addition	53,2
Addition for special terms	0,0
Total energy frame	53,2
Total energy requirement	69,0
Energy frame BR 2018, kWh/m² year	
Energy frame BR 2018, without addition	30,4
Addition for special terms	0,0
Total energy frame	30,4
Total energy requirement	69,0
Energy frame low energy, kWh/m² year	
Energy frame low energy, without addition	27,0
Addition for special terms	0,0
Total energy frame	27,0
Total energy requirement	69,0
Contribution to energy requirement, kWh/m² year	
Heating	66,8
El. for service of buildings	6,5
Excess temperature in rooms	0,0
Net requirement, kWh/m² year	
Room heating	53,5
Domestic hot water	14,3
Cooling	0,0
Selected el. requirements, kWh/m² year	
Lighting	0,0
Heating of rooms	0,0
Heating of domestic hot water	6,1
Heat pump	0,0

Model: 2023-03-29 Sundparken ENergyFrame	**SBi Beregningskerne 10.19.7.22**
Ventilators	0,4
Pumps	0,0
Cooling	0,0
Heat loss from installations, kWh/m² year	
Room heating	5,0
Domestic hot water	1,2
Output from special sources, kWh/m² year	
Solar heat	0,0
Heat pump	0,0
Solar cells	0,0
Wind mills	0,0
Total el. requirement, kWh/m² year	
El. requirement	29,6

APPENDIX 3: LCA MATERIAL DATABASE SOURCES

Material name	Ökobau UUID	Version
Triple-layer glaing	fa9f6670-3170-4597-92ab-a2fdec7f1451	20.20.010
Aerated concrete P2 04 non-reinforced	906b4864-0511-480f-a8bc-7b8302efbf0b	20.19.120
Air ventilation duct (zinc coated steel plate)	b24ae8b5-e28a-42f7-a592-05779a347164	20.19.120
Aluminium section	bd6d6d89-b76d-4002-a217-afffbb8aa308	20.19.120
Aluminium sheets	a4c1c27c-53a0-4027-83f6-88c52c758bb1	20.19.120
Application coating water based glaze	1a4a4522-7297-4ae5-a430-689e89ec2159	20.19.120
Application paint emulsion, interior, wear resistant	35be6146-5a80-4a9e-a32d-5d05c03a8d5c	20.19.120
Cement mortar	b2c3f5a3-7858-4644-a49a-2eb883d37c91	20.19.120
Cement screed	0973f221-2284-4892-ae3d-1b8c2986b6dd	20.19.120
Chipboard	60e8b384-adf2-4c3b-b3da-e407df106cf5	20.19.120
Clay plaster	8be785fa-5548-4ea5-a2d7-b962675b9eff	20.19.120
Concrete C20/25	9702d9ab-2af2-4fdc-9d99-225583a9ffb7	20.20.020
Concrete Elements C20/25	d9fd76f0-190d-437d-bb07-549963b32d65	00.02.000
Concrete Elements C30/37	b6096c9c-1248-4ce1-9c2d-f4a48aade80f	00.02.000
Concrete Elements C45/55	a3662e98-9dc9-412f-9603-47f653f3db7f	00.03.000
Construction Wood (15% moisture / 13% H2O)	703eec32-59af-47e1-9c91-4a32afe3187f	20.19.120
Decentralized AHU w. Heat-recovery 60 m3/h	efabdf2d-993e-418c-ba86-85a3a91562a2	20.19.120
Door, Alu, Front door	4d22a515-cfcc-4bcb-bbf9-a6e647bed9ab	00.00.007
EPDM sealing for aluminium section	66094ad5-51d6-45c4-b2e3-451220520cab	20.19.120
EPS for Ceilings / floors / basement / terrain slab 035	ee10b277-07b5-4c0a-8a48-e0412a9630ff	00.07.000
EPS for Ceilings / floors / basement / terrain slab 040	d63926ea-8473-4ea7-b965-a7bae6e5e022	00.07.000
EPS for walls and roofs 040	64564161-a587-47de-b195-b6b13b3bfb07	00.07.000
Expanded clay concrete block inner wall	1b978129-dd5e-45ea-9c82-1c3510e9c965	20.20.020
Expanded clay concrete block outer wall	21a40e8f-3897-4465-975b-81b6370936fb	20.20.020
Facing brick	f74a19da-df9a-4462-a632-3b3dc83377b1	20.19.120
Glass 3mm	1490b480-2c36-43f2-ba8b-4ea49948f7c3	20.19.120
Glulam, pine tree	8041ec07-5885-40dc-bfc9-190013f6749b	20.19.120
Gypsum fibre board (thickness 0.01 m)	6d535792-4351-4d7d-97c6-6d2c3624f3e0	20.20.010
Gypsum plaster board (impregnated, moisture resistant)	07423e99-8c7c-4e93-8311-dcf7ae85c41d	20.20.010
Insulated glazing, double pane	d941f45e-1244-419c-a083-e4a49fb5498e	20.19.120
Lime gypsum interior plaster	70f6e305-e46f-4719-a94f-70267b936029	20.19.120
Lime plaster	d7f4a913-441f-4c21-aae5-42e421737e29	20.19.120
Lime-cement plaster	dea7df16-f59b-4842-a66c-cb9463a58ae3	20.19.120
Mineral wool	fafd5743-0b42-4614-8e3d-5c4eacdfba98	20.20.020
Plywood sheet	cc180aec-8a5c-4e07-b1a0-1ab81dd746ac	20.19.120
Screws and fasteners galvanized steel	b9c775be-d100-4d35-bdf3-c5964e655692	20.19.120
Steel reinforcement mesh	e9ae96ee-ba8d-420d-9725-7c8abd06e082	20.19.120
Stoneware tiles glazed	b4a0e610-e038-47d3-b86e-cef013cd7c83	20.20.010
Strip parquet	88619ce6-c0aa-43bd-9ac6-477b5d6ce442	20.20.010
Structural Steel: Sections and Plates	5cb2c568-76fe-4803-8b46-0084e79800c8	00.06.000
Tile adhesive	78b7cd15-d82a-4ffa-ae08-870b6e5d35d4	20.19.120
Timber larch (12% moisture / 10.7% H2O)	8c47fba4-0e61-48d1-a03f-bf17911f0dae	20.19.120
Timber oak (12% moisture / 10.7% H2O)	7ec1d463-fd99-4b1d-9a57-9a72cac408d2	20.19.120
Timber pine (12% moisture / 10.7% H2O)	aea021e8-7e2f-4f6b-ae3f-a76cba4c5d6e	20.19.120
Vapour barrier, Pe-foil (0,0002 m)	99792cbc-c5f4-4d2d-bc9e-3790509891a0	20.20.010
Window frame, alu	c1cacd2c-d98d-4795-84db-b567d25bb1ed	20.19.120
Window frame, wood	318f08e0-1b04-49eb-ab16-531482cd75da	20.19.120
Window sash PVC-U	91ea177a-e65a-4fe2-ac2d-2f378a03e168	20.19.120
Window Sill, alu	dfa64bbb-dc8d-497b-9557-300416b8448f	20.19.120
Window Sill, wood	4127e60a-3c42-4076-83f5-5232b4ed642e	20.19.120
Product name	EPD Registration number	
Lose Zellulosedämmung	EPD-ECI-20200217-ICG1-DE	-
EPS-Hartschaum - weiß mit mittlerer Rohdichte vorzugsweise für die Flachdach- oder Bodendämmung mittlere Druckbelastbarkei	EPD-IVH-20220130-CBG1-DE	-
ROCKWOOL Steinwolle-Dämmstoffe im niedrigen Rohdichtebereich	EPD-DRW-20180065-IBC1-DE	-
STEICO flex F flexible wood fibre compartment insulation	EPD-STE-20200001-IBA1-DE	-
Vakuum-Isolations-Paneele	EPD-POR-20200138-IBC1-DE	-
MAXEON 3 MONO-CRYSTALLINE PHOTOVOLTAIC MODULE	NEPD-3087-1726-EN	-
Building integrated photovoltaic (BIPV) module, ERS-0191 (130W)	MD-23028-EN	-
Hqjfwqnsj%Kzxnts%ufsjq	S-P-06949	-
Wave, Midsummer	S-P-06692	-

APPENDIX 4: LCA CALCULATION PRESERVED ROW-HOUSES

Description	Name	Total Replacements	Total GWP A1-A3 kg CO_2-eq.	Total GWP A1-A3, circular kg CO_2-eq.	Total GWP b4 kg CO_2-eq.	Total GWP b6 kg CO_2-eq.	Total GWP c3 kg CO_2-eq.	Total GWP c4 kg CO_2-eq.	Total GWP d kg CO_2-eq.	Total GWP sum kg CO_2-eq.	Total GWP sum, circular kg CO_2-eq.	Weight		Reduction%	Reused Weight%
Sum	Building		5,74E+00	-2,44E+00	4,30E-01	3,43E+00	4,73E+00	1,04E-01	-3,67E+00	1,44E+01	6,26E+00				
Sum	Operations		0,00E+00	0,00E+00	0,00E+00	3,43E+00	0,00E+00	0,00E+00	0,00E+00	3,43E+00	3,43E+00				
Operational consumption el	El (Projection 2020-2040)		0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00				
Operational consumption Heating	District Heating (Projection 2020-2040)		0,00E+00	0,00E+00	0,00E+00	3,43E+00	0,00E+00	0,00E+00	0,00E+00	3,43E+00	3,43E+00				
Building process			0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00				
Construction and assembly			0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00				
Construction equipment and machinery			0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00				
Sum	Operations		0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00				
Operational consumption el	El (Projection 2020-2040)		0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00				
Operational consumption Heating	Natural Gas(Projection 2020-2040)		0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00				
Sum	Building Component		5,74E+00	-2,44E+00	4,30E-01	0,00E+00	4,73E+00	1,04E-01	-3,67E+00	1,10E+01	2,83E+00	1127558,66	kg		
Group	Balconies		3,44E-01	3,44E-01	4,47E-03	0,00E+00	2,29E-02	2,19E-05	-2,83E-01	3,72E-01	3,72E-01	1263,44	kg		0%
Sub-group	Balcony floor		3,44E-01	3,44E-01	4,47E-03	0,00E+00	2,29E-02	2,19E-05	-2,83E-01	3,72E-01	3,72E-01	1263,44	kg		
Building Component	Balcony		3,44E-01	3,44E-01	4,47E-03	0,00E+00	2,29E-02	2,19E-05	-2,83E-01	3,72E-01	3,72E-01	1263,44	kg		
Construction	Balcony Floor_Aluminium frame & Wood boards		2,57E-01	2,57E-01	4,47E-03	0,00E+00	1,90E-02	1,74E-05	-2,21E-01	2,81E-01	2,81E-01	733,90	kg		
Building Material	Aluminium section	0	2,72E-01	2,72E-01	0,00E+00	0,00E+00	0,00E+00	1,74E-05	-2,10E-01	2,72E-01	2,72E-01	518,00	kg		
Building Material	Screws and fasteners	0	1,29E-04	1,29E-04	0,00E+00	0,00E+00	0,00E+00	2,48E-08	-6,58E-05	1,29E-04	1,29E-04	0,74	kg		
Building Material	Timber larch (12%	1	-1,45E-02	-1,45E-02	4,47E-03	0,00E+00	1,90E-02	0,00E+00	-1,01E-02	8,94E-03	8,94E-03	215,16	kg		
Construction	Balcony_Aluminium railing		6,75E-02	6,75E-02	0,00E+00	0,00E+00	3,86E-03	4,52E-06	-5,58E-02	7,14E-02	7,14E-02	178,54	kg		
Building Material	Aluminium section	0	7,07E-02	7,07E-02	0,00E+00	0,00E+00	0,00E+00	4,52E-06	-5,48E-02	7,07E-02	7,07E-02	134,79	kg		
Building Material	Timber oak (12% moisture	0	-3,19E-03	-3,19E-03	0,00E+00	0,00E+00	3,86E-03	0,00E+00	-1,02E-03	6,74E-04	6,74E-04	43,75	kg		
Construction	Balcony_Fastener profile		1,94E-02	1,94E-02	0,00E+00	0,00E+00	3,18E-05	0,00E+00	-7,13E-03	1,94E-02	1,94E-02	351,00	kg		
Building Material	Structural Steel: Sections	0	1,94E-02	1,94E-02	0,00E+00	0,00E+00	3,18E-05	0,00E+00	-7,13E-03	1,94E-02	1,94E-02	351,00	kg		
Group	Slabs		-1,98E-02	-8,64E-01	0,00E+00	0,00E+00	1,25E+00	1,29E-02	-4,02E-01	1,25E+00	4,02E-01	137131,75	kg		3%
Sub-group	Slabs		-1,98E-02	-8,64E-01	0,00E+00	0,00E+00	1,25E+00	1,29E-02	-4,02E-01	1,25E+00	4,02E-01	137131,75	kg		
Building Component	Basement slab		-1,14E-01	-7,26E-01	0,00E+00	0,00E+00	1,05E+00	2,22E-03	-3,10E-01	9,40E-01	3,28E-01	100381,60	kg		
Construction	Basement slab_Ceiling,		-2,32E-01	-2,32E-01	0,00E+00	0,00E+00	3,33E-01	9,18E-07	-1,29E-02	1,01E-01	1,01E-01	3252,40	kg		
Building Material	Screws and fasteners	0	4,78E-03	4,78E-03	0,00E+00	0,00E+00	0,00E+00	9,18E-07	-2,44E-03	4,79E-03	4,79E-03	27,39	kg		
Building Material	Plywood sheet	0	-1,19E-01	-1,19E-01	0,00E+00	0,00E+00	1,66E-01	0,00E+00	-5,24E-03	4,79E-02	4,79E-02	1612,50	kg		
Building Material	Plywood sheet	0	-1,19E-01	-1,19E-01	0,00E+00	0,00E+00	1,66E-01	0,00E+00	-5,24E-03	4,79E-02	4,79E-02	1612,50	kg		
Construction	Basement slab_Floor tiles		2,97E-02	2,97E-02	0,00E+00	0,00E+00	1,74E-04	1,98E-03	-1,73E-04	3,18E-02	3,18E-02	2871,65	kg		
Building Material	Cement screed	0	2,09E-02	2,09E-02	0,00E+00	0,00E+00	0,00E+00	1,71E-03	0,00E+00	2,26E-02	2,26E-02	2313,60	kg		
Building Material	EPS for Ceilings / floors / basement / terrain slab	0	1,91E-04	1,91E-04	0,00E+00	0,00E+00	0,00E+00	2,17E-04	-1,14E-04	4,08E-04	4,08E-04	1,34	kg		
Building Material	Stoneware tiles glazed	0	7,32E-03	7,32E-03	0,00E+00	0,00E+00	1,74E-04	0,00E+00	-4,86E-05	7,49E-03	7,49E-03	482,00	kg		
Building Material	Tile adhesive	0	1,27E-03	1,27E-03	0,00E+00	0,00E+00	0,00E+00	6,01E-05	-1,05E-05	1,33E-03	1,33E-03	74,71	kg		
Construction	Basement slab_Hollow-core slabs_Preserved		5,56E-01	0,00E+00	0,00E+00	0,00E+00	1,03E-02	6,61E-05	-7,48E-02	5,67E-01	5,67E-01	85682,33	kg		
Building Material	Steel reinforcement mesh	0	6,62E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	6,61E-05	-3,81E-02	6,63E-02	6,61E-05	1972,08	kg	100%	
Building Material	Concrete Elements C45/55	0	4,90E-01	0,00E+00	0,00E+00	0,00E+00	1,03E-02	0,00E+00	-3,67E-02	5,00E-01	1,03E-02	83710,25	kg	100%	
Construction	Basement slab_Insulation,		-1,46E-01	-1,46E-01	0,00E+00	0,00E+00	2,27E-01	8,45E-07	-7,65E-02	8,13E-02	8,13E-02	2721,52	kg		
Building Material	Vapour barrier, Pe-foil	0	4,95E-03	4,95E-03	0,00E+00	0,00E+00	6,88E-03	0,00E+00	-3,40E-03	1,18E-02	1,18E-02	50,40	kg		

Building Material	Screws and fasteners	0	4,40E-03	4,40E-03	0,00E+00	0,00E+00	0,00E+00	8,45E-07	-2,24E-03	4,40E-03	4,40E-03	25,20	kg		
Building Material	Construction Wood (15% moisture / 13% H2O)	0	-7,14E-02	-7,14E-02	0,00E+00	0,00E+00	1,03E-01	0,00E+00	-2,59E-02	3,21E-02	3,21E-02	1199,77	kg		
Building Material	SteicoFlex 036	0	-8,40E-02	-8,40E-02	0,00E+00	0,00E+00	1,17E-01	0,00E+00	-4,49E-02	3,30E-02	3,30E-02	1446,15	kg		
Construction	Basement slab_Insulation,		-1,61E-01	-1,61E-01	0,00E+00	0,00E+00	2,48E-01	8,45E-07	-8,30E-02	8,76E-02	8,76E-02	2972,09	kg		
Building Material	Vapour barrier, Pe-foil	0	4,95E-03	4,95E-03	0,00E+00	0,00E+00	6,88E-03	0,00E+00	-3,40E-03	1,18E-02	1,18E-02	50,40	kg		
Building Material	Screws and fasteners	0	4,40E-03	4,40E-03	0,00E+00	0,00E+00	0,00E+00	8,45E-07	-2,24E-03	4,40E-03	4,40E-03	25,20	kg		
Building Material	Construction Wood (15% moisture / 13% H2O)	0	-7,93E-02	-7,93E-02	0,00E+00	0,00E+00	1,15E-01	0,00E+00	-2,87E-02	3,57E-02	3,57E-02	1333,08	kg		
Building Material	SteicoFlex 036	0	-9,08E-02	-9,08E-02	0,00E+00	0,00E+00	1,26E-01	0,00E+00	-4,86E-02	3,57E-02	3,57E-02	1563,41	kg		
Construction	Basement slab_Wood floor on joists_Reused		-1,61E-01	-2,17E-01	0,00E+00	0,00E+00	2,33E-01	1,66E-04	-6,26E-02	7,15E-02	1,59E-02	2881,61	kg		
Building Material	Screws and fasteners	0	3,27E-03	3,27E-03	0,00E+00	0,00E+00	0,00E+00	6,26E-07	-1,66E-03	3,27E-03	3,27E-03	18,69	kg		
Building Material	Construction Wood (15% moisture / 13% H2O)	0	-2,29E-02	-3,09E-02	0,00E+00	0,00E+00	3,33E-02	0,00E+00	-8,31E-03	1,03E-02	2,37E-03	385,59	kg	77%	
Building Material	Mineral wool	0	1,67E-02	3,93E-04	0,00E+00	0,00E+00	2,98E-04	1,65E-04	0,00E+00	1,71E-02	8,56E-04	220,78	kg	95%	
Building Material	Timber pine (12% moisture	0	-1,58E-01	-1,90E-01	0,00E+00	0,00E+00	1,99E-01	0,00E+00	-5,26E-02	4,08E-02	9,38E-03	2256,56	kg	77%	
Building Component	Floor slab		1,41E-01	-9,12E-02	0,00E+00	0,00E+00	1,25E-01	8,16E-04	-6,45E-02	2,67E-01	3,41E-02	35785,14	kg		
Construction	Floor Slab_Hollow-core		2,16E-01	0,00E+00	0,00E+00	0,00E+00	4,00E-03	2,57E-05	-2,90E-02	2,20E-01	4,02E-03	33253,13	kg		
Building Material	Steel reinforcement mesh	0	2,57E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	2,57E-05	-1,48E-02	2,57E-02	2,57E-05	765,36	kg	100%	
Building Material	Concrete Elements C45/55	0	1,90E-01	0,00E+00	0,00E+00	0,00E+00	4,00E-03	0,00E+00	-1,42E-02	1,94E-01	4,00E-03	32487,77	kg	100%	
Construction	Floor slab_Insulation,		-1,17E-02	-1,17E-02	0,00E+00	0,00E+00	2,46E-02	3,35E-07	-9,26E-03	1,29E-02	1,29E-02	292,49	kg		
Building Material	Vapour barrier, Pe-foil	0	1,96E-03	1,96E-03	0,00E+00	0,00E+00	2,73E-03	0,00E+00	-1,35E-03	4,69E-03	4,69E-03	20,00	kg		
Building Material	Screws and fasteners	0	1,75E-03	1,75E-03	0,00E+00	0,00E+00	0,00E+00	3,35E-07	-8,90E-04	1,75E-03	1,75E-03	10,00	kg		
Building Material	Construction Wood (15% moisture / 13% H2O)	0	-7,08E-03	-7,08E-03	0,00E+00	0,00E+00	1,03E-02	0,00E+00	-2,57E-03	3,19E-03	3,19E-03	119,03	kg		
Building Material	SteicoFlex 036	0	-8,33E-03	-8,33E-03	0,00E+00	0,00E+00	1,16E-02	0,00E+00	-4,46E-03	3,27E-03	3,27E-03	143,47	kg		
Construction	Floor slab_Tiles		1,18E-02	1,18E-02	0,00E+00	0,00E+00	6,92E-05	7,90E-04	-6,90E-05	1,27E-02	1,27E-02	1143,89	kg		
Building Material	Cement screed	0	8,31E-03	8,31E-03	0,00E+00	0,00E+00	0,00E+00	6,80E-04	0,00E+00	8,99E-03	8,99E-03	921,60	kg		
Building Material	EPS for Ceilings / floors / basement / terrain slab	0	7,61E-05	7,61E-05	0,00E+00	0,00E+00	0,00E+00	8,63E-05	-4,54E-05	1,62E-04	1,62E-04	0,53	kg		
Building Material	Stoneware tiles glazed	0	2,92E-03	2,92E-03	0,00E+00	0,00E+00	6,92E-05	0,00E+00	-1,94E-05	2,98E-03	2,98E-03	192,00	kg		
Building Material	Tile adhesive	0	5,08E-04	5,08E-04	0,00E+00	0,00E+00	0,00E+00	2,39E-05	-4,18E-06	5,31E-04	5,31E-04	29,76	kg		
Construction	Floor slab_Wood floor on		-7,46E-02	-9,13E-02	0,00E+00	0,00E+00	9,58E-02	3,02E-07	-2,61E-02	2,12E-02	4,53E-03	1095,62	kg		
Building Material	Screws and fasteners	0	1,57E-03	1,54E-05	0,00E+00	0,00E+00	0,00E+00	3,02E-07	-8,01E-04	1,57E-03	1,57E-05	9,00	kg	99%	
Building Material	Timber pine (12% moisture	0	-7,62E-02	-9,13E-02	0,00E+00	0,00E+00	9,58E-02	0,00E+00	-2,53E-02	1,96E-02	4,52E-03	1086,62	kg	77%	
Building Component	Terrace Slab		-4,70E-02	-4,70E-02	0,00E+00	0,00E+00	7,78E-02	9,82E-03	-2,80E-02	4,07E-02	4,07E-02	965,01	kg		
Construction	Terrace floor_Built-up		-4,00E-02	-4,00E-02	0,00E+00	0,00E+00	5,22E-02	1,41E-07	-1,41E-02	1,22E-02	1,22E-02	597,94	kg		
Building Material	Screws and fasteners	0	7,34E-04	7,34E-04	0,00E+00	0,00E+00	0,00E+00	1,41E-07	-3,74E-04	7,34E-04	7,34E-04	4,20	kg		
Building Material	Construction Wood (15% moisture / 13% H2O)	0	-5,15E-03	-5,15E-03	0,00E+00	0,00E+00	7,47E-03	0,00E+00	-1,87E-03	2,32E-03	2,32E-03	86,65	kg		
Building Material	Timber pine (12% moisture	0	-3,56E-02	-3,56E-02	0,00E+00	0,00E+00	4,47E-02	0,00E+00	-1,18E-02	9,17E-03	9,17E-03	507,09	kg		
Construction	Terrace floor_Compressive		8,67E-03	8,67E-03	0,00E+00	0,00E+00	0,00E+00	9,82E-03	-5,17E-03	1,85E-02	1,85E-02	60,48	kg		
Building Material	EPS for walls and roofs 040	0	8,67E-03	8,67E-03	0,00E+00	0,00E+00	0,00E+00	9,82E-03	-5,17E-03	1,85E-02	1,85E-02	60,48	kg		
Construction	Terrace floor_Insulation,		-1,57E-02	-1,57E-02	0,00E+00	0,00E+00	2,56E-02	1,41E-07	-8,81E-03	9,94E-03	9,94E-03	306,59	kg		
Building Material	Vapour barrier, Pe-foil	0	8,24E-04	8,24E-04	0,00E+00	0,00E+00	1,15E-03	0,00E+00	-5,66E-04	1,97E-03	1,97E-03	8,40	kg		
Building Material	Screws and fasteners	0	7,34E-04	7,34E-04	0,00E+00	0,00E+00	0,00E+00	1,41E-07	-3,74E-04	7,34E-04	7,34E-04	4,20	kg		
Building Material	Construction Wood (15% moisture / 13% H2O)	0	-7,93E-03	-7,93E-03	0,00E+00	0,00E+00	1,15E-02	0,00E+00	-2,87E-03	3,57E-03	3,57E-03	133,31	kg		
Building Material	SteicoFlex 036	0	-9,33E-03	-9,33E-03	0,00E+00	0,00E+00	1,30E-02	0,00E+00	-4,99E-03	3,66E-03	3,66E-03	160,68	kg		
Group	Electrical and mechanical		6,64E-02	6,64E-02	6,90E-02	0,00E+00	2,59E-03	3,77E-05	0,00E+00	1,38E-01	1,38E-01	285,00	kg		0%
Sub-group	Energy production		6,64E-02	6,64E-02	6,90E-02	0,00E+00	2,59E-03	3,77E-05	0,00E+00	1,38E-01	1,38E-01	285,00	kg		
Building Component	Photovoltaic Panels		6,64E-02	6,64E-02	6,90E-02	0,00E+00	2,59E-03	3,77E-05	0,00E+00	1,38E-01	1,38E-01	285,00	kg		
Construction	Photovoltaic Panels		6,64E-02	6,64E-02	6,90E-02	0,00E+00	2,59E-03	3,77E-05	0,00E+00	1,38E-01	1,38E-01	285,00	kg		
Building Material	Product Average PV Panels	1	6,64E-02	6,64E-02	6,90E-02	0,00E+00	2,59E-03	3,77E-05	0,00E+00	1,38E-01	1,38E-01	285,00	kg		
Group	Foundations		9,76E-01	0,00E+00	0,00E+00	0,00E+00	5,93E-02	1,22E-04	-8,86E-02	1,04E+00	5,94E-02	183008,00	kg		0%

Sub-group	Line foundations		9,76E-01	0,00E+00	0,00E+00	0,00E+00	5,93E-02	1,22E-04	-8,86E-02	1,04E+00	5,94E-02	183008,00	kg		
Building Component	Line foundation		9,76E-01	0,00E+00	0,00E+00	0,00E+00	5,93E-02	1,22E-04	-8,86E-02	1,04E+00	5,94E-02	183008,00	kg		
Construction	Line foundation_Preserved		9,76E-01	0,00E+00	0,00E+00	0,00E+00	5,93E-02	1,22E-04	-8,86E-02	1,04E+00	5,94E-02	183008,00	kg		
Building Material	Steel reinforcement mesh	0	1,23E-01	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,22E-04	-7,05E-02	1,23E-01	1,22E-04	3648,00	kg	100%	
Building Material	Concrete C20/25	0	8,54E-01	0,00E+00	0,00E+00	0,00E+00	5,93E-02	0,00E+00	-1,81E-02	9,13E-01	5,93E-02	179360,00	kg	100%	
Group	Interior walls		7,57E-01	-3,87E-01	3,43E-02	0,00E+00	5,90E-01	2,04E-04	-2,18E-01	1,38E+00	2,37E-01	228653,55	kg		0%
Sub-group	Load-bearing interior walls		1,04E-01	-3,17E-01	0,00E+00	0,00E+00	4,57E-01	1,15E-05	-6,07E-02	5,61E-01	1,40E-01	96100,18	kg		
Building Component	Interior walls_150mm		4,22E-01	0,00E+00	0,00E+00	0,00E+00	1,13E-02	1,15E-05	-4,67E-02	4,33E-01	1,13E-02	91782,90	kg		
Construction	Inner walls_150mm concrete		4,22E-01	0,00E+00	0,00E+00	0,00E+00	1,13E-02	1,15E-05	-4,67E-02	4,33E-01	1,13E-02	91782,90	kg		
Building Material	Steel reinforcement mesh	0	1,15E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,15E-05	-6,62E-03	1,15E-02	1,15E-05	342,90	kg	100%	
Building Material	Concrete Elements C30/37	0	4,10E-01	0,00E+00	0,00E+00	0,00E+00	1,13E-02	0,00E+00	-4,01E-02	4,21E-01	1,13E-02	91440,00	kg	100%	
Building Component	Interior walls_Finishing		-3,17E-01	-3,17E-01	0,00E+00	0,00E+00	4,46E-01	0,00E+00	-1,40E-02	1,28E-01	1,28E-01	4317,28	kg		
Construction	Inner walls_Finishing		-3,17E-01	-3,17E-01	0,00E+00	0,00E+00	4,46E-01	0,00E+00	-1,40E-02	1,28E-01	1,28E-01	4317,28	kg		
Building Material	Plywood sheet	0	-3,17E-01	-3,17E-01	0,00E+00	0,00E+00	4,46E-01	0,00E+00	-1,40E-02	1,28E-01	1,28E-01	4317,28	kg		
Sub-group	Load-bearing interior walls		6,88E-01	1,14E-02	3,43E-02	0,00E+00	1,55E-02	1,77E-04	-1,20E-01	7,38E-01	7,38E-01	129196,35	kg		
Building Component	Interior basement		5,45E-01	9,94E-03	3,00E-02	0,00E+00	1,20E-02	1,55E-04	-9,93E-02	5,87E-01	5,21E-02	100440,34	kg		
Construction	Basement Walls_200mm Concrete		5,35E-01	0,00E+00	0,00E+00	0,00E+00	1,20E-02	9,80E-05	-9,91E-02	5,47E-01	1,21E-02	100363,20	kg		
Building Material	Steel reinforcement mesh	0	9,82E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	9,80E-05	-5,65E-02	9,83E-02	9,80E-05	2923,20	kg	100%	
Building Material	Concrete Elements C30/37	0	4,37E-01	0,00E+00	0,00E+00	0,00E+00	1,20E-02	0,00E+00	-4,27E-02	4,49E-01	1,20E-02	97440,00	kg	100%	
Construction	Paint		9,94E-03	9,94E-03	3,00E-02	0,00E+00	0,00E+00	5,69E-05	-1,64E-04	4,00E-02	4,00E-02	77,14	kg		
Building Material	Application paint emulsion, interior, wear	3	9,94E-03	9,94E-03	3,00E-02	0,00E+00	0,00E+00	5,69E-05	-1,64E-04	4,00E-02	4,00E-02	77,14	kg		
Building Component	Interior basement		1,43E-01	1,44E-03	4,36E-03	0,00E+00	3,48E-03	2,25E-05	-2,06E-02	1,51E-01	9,31E-03	28756,01	kg		
Construction	Basement walls_400mm Concrete		1,41E-01	0,00E+00	0,00E+00	0,00E+00	3,48E-03	1,42E-05	-2,06E-02	1,45E-01	3,50E-03	28744,80	kg		
Building Material	Steel reinforcement mesh	0	1,43E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,42E-05	-8,20E-03	1,43E-02	1,42E-05	424,80	kg	100%	
Building Material	Concrete Elements C30/37	0	1,27E-01	0,00E+00	0,00E+00	0,00E+00	3,48E-03	0,00E+00	-1,24E-02	1,30E-01	3,48E-03	28320,00	kg	100%	
Construction	Paint		1,44E-03	1,44E-03	4,36E-03	0,00E+00	0,00E+00	8,27E-06	-2,38E-05	5,81E-03	5,81E-03	11,21	kg		
Building Material	Application paint emulsion, interior, wear	3	1,44E-03	1,44E-03	4,36E-03	0,00E+00	0,00E+00	8,27E-06	-2,38E-05	5,81E-03	5,81E-03	11,21	kg		
Sub-group	Non-load-bearing Interior		-8,13E-02	-8,13E-02	0,00E+00	0,00E+00	1,17E-01	5,23E-08	-3,75E-02	3,54E-02	3,54E-02	1398,62	kg		
Building Component	Interior wall_lightweight built-up constructions		-8,13E-02	-8,13E-02	0,00E+00	0,00E+00	1,17E-01	5,23E-08	-3,75E-02	3,54E-02	3,54E-02	1398,62	kg		
Construction	Interior wall_wooden built-		-8,13E-02	-8,13E-02	0,00E+00	0,00E+00	1,17E-01	5,23E-08	-3,75E-02	3,54E-02	3,54E-02	1398,62	kg		
Building Material	Vapour barrier, Pe-foil	0	3,06E-04	3,06E-04	0,00E+00	0,00E+00	4,26E-04	0,00E+00	-2,10E-04	7,32E-04	7,32E-04	3,12	kg		
Building Material	Screws and fasteners	0	2,73E-04	2,73E-04	0,00E+00	0,00E+00	0,00E+00	5,23E-08	-1,39E-04	2,73E-04	2,73E-04	1,56	kg		
Building Material	Construction Wood (15% moisture / 13% H2O)	0	-3,88E-02	-3,88E-02	0,00E+00	0,00E+00	5,62E-02	0,00E+00	-1,41E-02	1,75E-02	1,75E-02	651,94	kg		
Building Material	SteicoFlex 036	0	-4,31E-02	-4,31E-02	0,00E+00	0,00E+00	6,00E-02	0,00E+00	-2,31E-02	1,69E-02	1,69E-02	742,00	kg		
Sub-group	Non-load-bearing Interior		4,59E-02	0,00E+00	0,00E+00	0,00E+00	6,41E-04	1,50E-05	-1,96E-04	4,66E-02	6,56E-04	1958,40	kg		
Building Component	Basement wall_80mm		4,59E-02	0,00E+00	0,00E+00	0,00E+00	6,41E-04	1,50E-05	-1,96E-04	4,66E-02	6,56E-04	1958,40	kg		
Construction	Basement walls_80mm lightweight		4,59E-02	0,00E+00	0,00E+00	0,00E+00	6,41E-04	1,50E-05	-1,96E-04	4,66E-02	6,56E-04	1958,40	kg		
Building Material	Aerated concrete P2 04	0	4,57E-02	0,00E+00	0,00E+00	0,00E+00	6,41E-04	0,00E+00	-1,96E-04	4,64E-02	6,41E-04	1938,00	kg	100%	
Building Material	Lime gypsum interior	0	2,21E-04	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,50E-05	0,00E+00	2,37E-04	1,50E-05	20,40	kg	100%	
Group	Columns and beams		2,93E-02	0,00E+00	0,00E+00	0,00E+00	7,09E-04	2,11E-06	-3,74E-03	3,00E-02	7,11E-04	5823,10	kg		0%
Sub-group	beams		2,35E-02	0,00E+00	0,00E+00	0,00E+00	5,91E-04	1,98E-06	-3,25E-03	2,41E-02	5,93E-04	4859,14	kg		
Building Component	Beams_Basement,		2,35E-02	0,00E+00	0,00E+00	0,00E+00	5,91E-04	1,98E-06	-3,25E-03	2,41E-02	5,93E-04	4859,14	kg		
Construction	Beam_Concrete KB		2,35E-02	0,00E+00	0,00E+00	0,00E+00	5,91E-04	1,98E-06	-3,25E-03	2,41E-02	5,93E-04	4859,14	kg		
Building Material	Steel reinforcement mesh	0	1,99E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,98E-06	-1,14E-03	1,99E-03	1,98E-06	59,14	kg	100%	
Building Material	Concrete Elements C30/37	0	2,15E-02	0,00E+00	0,00E+00	0,00E+00	5,91E-04	0,00E+00	-2,10E-03	2,21E-02	5,91E-04	4800,00	kg	100%	
Sub-group	Columns		5,75E-03	0,00E+00	0,00E+00	0,00E+00	1,18E-04	1,33E-07	-4,97E-04	5,87E-03	1,18E-04	963,96	kg		
Building Component	Columns_Basement,		5,75E-03	0,00E+00	0,00E+00	0,00E+00	1,18E-04	1,33E-07	-4,97E-04	5,87E-03	1,18E-04	963,96	kg		
Construction	Columns_Basement		5,75E-03	0,00E+00	0,00E+00	0,00E+00	1,18E-04	1,33E-07	-4,97E-04	5,87E-03	1,18E-04	963,96	kg		

Building Material	Steel reinforcement mesh	0	1,33E-04	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,33E-07	-7,65E-05	1,33E-04	1,33E-07	3,96	kg	100%	
Building Material	Concrete Elements C45/55	0	5,62E-03	0,00E+00	0,00E+00	0,00E+00	1,18E-04	0,00E+00	-4,21E-04	5,74E-03	1,18E-04	960,00	kg	100%	
Group	Roofs		1,52E+00	-9,75E-01	1,55E-02	0,00E+00	1,19E+00	2,17E-04	-1,82E+00	2,72E+00	2,32E-01	88573,79	kg		13%
Sub-group	Roofs		1,52E+00	-9,75E-01	1,55E-02	0,00E+00	1,19E+00	2,17E-04	-1,82E+00	2,72E+00	2,32E-01	88573,79	kg		
Building Component	Roof_Aluminium cladding		1,61E+00	-2,84E-01	1,55E-02	0,00E+00	3,40E-01	1,20E-04	-1,48E+00	1,96E+00	7,14E-02	6898,13	kg		
Construction	Roof_Aluminium cladding construction_Reused		1,61E+00	-2,84E-01	1,55E-02	0,00E+00	3,40E-01	1,20E-04	-1,48E+00	1,96E+00	7,14E-02	6898,13	kg		
Building Material	Aluminium sheets	0	1,84E+00	1,82E-02	0,00E+00	0,00E+00	0,00E+00	1,20E-04	-1,45E+00	1,84E+00	1,84E-02	3572,86	kg	99%	
Building Material	Vapour barrier, Pe-foil	1	6,47E-03	6,47E-03	1,55E-02	0,00E+00	9,00E-03	0,00E+00	-8,89E-03	3,09E-02	3,09E-02	65,92	kg		
Building Material	Construction Wood (15% moisture / 13% H2O)	0	-2,07E-02	-2,79E-02	0,00E+00	0,00E+00	3,01E-02	0,00E+00	-7,52E-03	9,34E-03	2,15E-03	348,72	kg	77%	
Building Material	Plywood sheet	0	-2,14E-01	-2,81E-01	0,00E+00	0,00E+00	3,00E-01	0,00E+00	-9,46E-03	8,65E-02	1,99E-02	2910,63	kg	77%	
Building Component	Roof_Hollow-core slab		2,66E-01	-2,34E-01	0,00E+00	0,00E+00	3,34E-01	9,68E-05	-2,11E-01	6,00E-01	1,00E-01	75676,80	kg		
Construction	Roof_Hollow-core		5,00E-01	0,00E+00	0,00E+00	0,00E+00	8,46E-03	9,68E-05	-8,59E-02	5,08E-01	8,56E-03	71647,92	kg		
Building Material	Steel reinforcement mesh	0	9,70E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	9,68E-05	-5,58E-02	9,71E-02	9,68E-05	2887,92	kg	100%	
Building Material	Concrete Elements C45/55	0	4,03E-01	0,00E+00	0,00E+00	0,00E+00	8,46E-03	0,00E+00	-3,01E-02	4,11E-01	8,46E-03	68760,00	kg	100%	
Construction	Roof_Insulation		-2,34E-01	-2,34E-01	0,00E+00	0,00E+00	3,26E-01	0,00E+00	-1,25E-01	9,19E-02	9,19E-02	4028,88	kg		
Building Material	SteicoFlex 036	0	-2,34E-01	-2,34E-01	0,00E+00	0,00E+00	3,26E-01	0,00E+00	-1,25E-01	9,19E-02	9,19E-02	4028,88	kg		
Building Component	Roof_Wood rafters		-3,57E-01	-4,57E-01	0,00E+00	0,00E+00	5,17E-01	0,00E+00	-1,29E-01	1,61E-01	6,05E-02	5998,86	kg		
Construction	Roof__Wood		-2,89E-01	-3,89E-01	0,00E+00	0,00E+00	4,19E-01	0,00E+00	-1,05E-01	1,30E-01	2,99E-02	4856,22	kg		
Building Material	Construction Wood (15% moisture / 13% H2O)	0	-2,89E-01	-3,89E-01	0,00E+00	0,00E+00	4,19E-01	0,00E+00	-1,05E-01	1,30E-01	2,99E-02	4856,22	kg	77%	
Construction	Roof_Added wood for		-6,80E-02	-6,80E-02	0,00E+00	0,00E+00	9,86E-02	0,00E+00	-2,46E-02	3,06E-02	3,06E-02	1142,64	kg		
Building Material	Construction Wood (15% moisture / 13% H2O)	0	-6,80E-02	-6,80E-02	0,00E+00	0,00E+00	9,86E-02	0,00E+00	-2,46E-02	3,06E-02	3,06E-02	1142,64	kg		
Group	Terrain slab		6,95E-01	0,00E+00	0,00E+00	0,00E+00	1,66E-02	1,51E-04	-1,46E-01	7,12E-01	1,67E-02	139376,00	kg		0%
Sub-group	Terrain slab		6,95E-01	0,00E+00	0,00E+00	0,00E+00	1,66E-02	1,51E-04	-1,46E-01	7,12E-01	1,67E-02	139376,00	kg		
Building Component	Terrain Slab		6,95E-01	0,00E+00	0,00E+00	0,00E+00	1,66E-02	1,51E-04	-1,46E-01	7,12E-01	1,67E-02	139376,00	kg		
Construction	Terrain slab_200mm		6,95E-01	0,00E+00	0,00E+00	0,00E+00	1,66E-02	1,51E-04	-1,46E-01	7,12E-01	1,67E-02	139376,00	kg		
Building Material	Steel reinforcement mesh	0	1,51E-01	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,51E-04	-8,68E-02	1,51E-01	1,51E-04	4496,00	kg	100%	
Building Material	Concrete Elements C25/30	0	5,44E-01	0,00E+00	0,00E+00	0,00E+00	1,66E-02	0,00E+00	-5,91E-02	5,61E-01	1,66E-02	134880,00	kg	100%	
Group	Stairs and ramps		-4,71E-03	-1,24E-02	0,00E+00	0,00E+00	1,98E-02	1,31E-08	-6,08E-03	1,51E-02	7,42E-03	2539,59	kg		
Sub-group	Stairs and ramps		-4,71E-03	-1,24E-02	0,00E+00	0,00E+00	1,98E-02	1,31E-08	-6,08E-03	1,51E-02	7,42E-03	2539,59	kg		
Building Component	External staircases		7,71E-03	0,00E+00	0,00E+00	0,00E+00	2,11E-04	0,00E+00	-7,53E-04	7,92E-03	2,11E-04	1718,64	kg		
Construction	External		7,71E-03	0,00E+00	0,00E+00	0,00E+00	2,11E-04	0,00E+00	-7,53E-04	7,92E-03	2,11E-04	1718,64	kg		
Building Material	Concrete Elements C30/37	0	7,71E-03	0,00E+00	0,00E+00	0,00E+00	2,11E-04	0,00E+00	-7,53E-04	7,92E-03	2,11E-04	1718,64	kg	100%	
Building Component	Internal staircase		-1,24E-02	-1,24E-02	0,00E+00	0,00E+00	1,96E-02	1,31E-08	-5,33E-03	7,21E-03	7,21E-03	820,95	kg		
Construction	Interior staircase_Wood		-1,24E-02	-1,24E-02	0,00E+00	0,00E+00	1,96E-02	1,31E-08	-5,33E-03	7,21E-03	7,21E-03	820,95	kg		
Building Material	Screws and fasteners	0	6,81E-05	6,81E-05	0,00E+00	0,00E+00	0,00E+00	1,31E-08	-3,47E-05	6,81E-05	6,81E-05	0,39	kg		
Building Material	Clay plaster	0	3,05E-03	3,05E-03	0,00E+00	0,00E+00	9,18E-05	0,00E+00	-1,27E-04	3,14E-03	3,14E-03	599,04	kg		
Building Material	Timber pine (12% moisture	0	-6,13E-03	-6,13E-03	0,00E+00	0,00E+00	7,71E-03	0,00E+00	-2,04E-03	1,58E-03	1,58E-03	87,36	kg		
Building Material	Timber pine (12% moisture	0	-5,80E-03	-5,80E-03	0,00E+00	0,00E+00	7,29E-03	0,00E+00	-1,93E-03	1,49E-03	1,49E-03	82,68	kg		
Building Material	Timber pine (12% moisture	0	-3,61E-03	-3,61E-03	0,00E+00	0,00E+00	4,54E-03	0,00E+00	-1,20E-03	9,31E-04	9,31E-04	51,48	kg		
Group	Ventilation and cooling		3,53E-02	3,53E-02	2,20E-02	0,00E+00	3,32E-03	3,72E-05	-2,59E-02	6,07E-02	6,07E-02	55476,10	kg		0%
Sub-group	Air handling unit		1,87E-02	1,87E-02	2,20E-02	0,00E+00	3,31E-03	3,72E-05	-1,72E-02	4,40E-02	4,40E-02	55365,00	kg		
Building Component	Ventilation AHU		1,87E-02	1,87E-02	2,20E-02	0,00E+00	3,31E-03	3,72E-05	-1,72E-02	4,40E-02	4,40E-02	55365,00	kg		
Construction	Ventilation AHU		1,87E-02	1,87E-02	2,20E-02	0,00E+00	3,31E-03	3,72E-05	-1,72E-02	4,40E-02	4,40E-02	55365,00	kg		
Building Material	Decentralized AHU w. Heat-recovery 60 m3/h	1	1,87E-02	1,87E-02	2,20E-02	0,00E+00	3,31E-03	3,72E-05	-1,72E-02	4,40E-02	4,40E-02	55365,00	kg		
Sub-group	Ventilation shafts		1,66E-02	1,66E-02	0,00E+00	0,00E+00	8,94E-06	0,00E+00	-8,66E-03	1,66E-02	1,66E-02	111,10	kg		
Building Component	Ventilation Shafts		1,66E-02	1,66E-02	0,00E+00	0,00E+00	8,94E-06	0,00E+00	-8,66E-03	1,66E-02	1,66E-02	111,10	kg		
Construction	Ventilation Shafts		1,66E-02	1,66E-02	0,00E+00	0,00E+00	8,94E-06	0,00E+00	-8,66E-03	1,66E-02	1,66E-02	111,10	kg		
Building Material	Air ventilation duct (zinc	0	1,66E-02	1,66E-02	0,00E+00	0,00E+00	8,94E-06	0,00E+00	-8,66E-03	1,66E-02	1,66E-02	111,10	kg		
Group	Windows, doors, curtain		2,76E-01	1,80E-01	2,48E-01	0,00E+00	3,15E-01	1,80E-02	-1,73E-01	8,57E-01	7,61E-01	6114,40	kg		24%
Sub-group	Doors		-8,10E-02	-4,06E-02	0,00E+00	0,00E+00	1,58E-01	2,77E-05	-2,58E-02	7,71E-02	1,17E-01	1945,56	kg		
Building Component	Exterior door		2,17E-02	2,17E-02	0,00E+00	0,00E+00	1,40E-03	1,55E-05	-1,23E-02	2,31E-02	2,31E-02	126,90	kg		

Construction	Door Front Door		2,17E-02	2,17E-02	0,00E+00	0,00E+00	1,40E-03	1,55E-05	-1,23E-02	2,31E-02	2,31E-02	126,90	kg	
Building Material	Door, Alu, Front door	0	2,17E-02	2,17E-02	0,00E+00	0,00E+00	1,40E-03	1,55E-05	-1,23E-02	2,31E-02	2,31E-02	126,90	kg	
Building Component	Interior doors		-4,51E-02	-6,34E-02	0,00E+00	0,00E+00	6,88E-02	5,35E-06	-5,92E-03	2,37E-02	5,40E-03	798,44	kg	
Construction	Interior doors Reused		-4,51E-02	-6,34E-02	0,00E+00	0,00E+00	6,88E-02	5,35E-06	-5,92E-03	2,37E-02	5,40E-03	798,44	kg	
Building Material	Screws and fasteners	0	3,14E-03	3,08E-05	0,00E+00	0,00E+00	0,00E+00	6,03E-07	-1,60E-03	3,15E-03	3,15E-05	18,00	kg	99%
Building Material	Application paint emulsion, interior, wear	0	8,29E-04	8,29E-04	0,00E+00	0,00E+00	0,00E+00	4,74E-06	-3,42E-06	8,34E-04	8,34E-04	6,44	kg	
Building Material	Chipboard	0	-3,64E-02	-4,91E-02	0,00E+00	0,00E+00	5,29E-02	0,00E+00	-1,22E-04	1,65E-02	3,79E-03	594,00	kg	77%
Building Material	Timber pine (12% moisture	0	-1,26E-02	-1,51E-02	0,00E+00	0,00E+00	1,59E-02	0,00E+00	-4,20E-03	3,25E-03	7,49E-04	180,00	kg	77%
Building Component	Interior doors Basement		-5,76E-02	1,06E-03	0,00E+00	0,00E+00	8,79E-02	6,83E-06	-7,57E-03	3,03E-02	3,03E-02	1020,22	kg	
Construction	Interior		-5,76E-02	1,06E-03	0,00E+00	0,00E+00	8,79E-02	6,83E-06	-7,57E-03	3,03E-02	3,03E-02	1020,22	kg	
Building Material	Screws and fasteners	0	4,02E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	7,71E-07	-2,05E-03	4,02E-03	4,02E-03	23,00	kg	100%
Building Material	Application paint emulsion, interior, wear	0	1,06E-03	1,06E-03	0,00E+00	0,00E+00	0,00E+00	6,06E-06	-4,37E-06	1,07E-03	1,07E-03	8,22	kg	
Building Material	Chipboard	0	-4,65E-02	0,00E+00	0,00E+00	0,00E+00	6,76E-02	0,00E+00	-1,56E-04	2,10E-02	2,10E-02	759,00	kg	100%
Building Material	Timber pine (12% moisture	0	-1,61E-02	0,00E+00	0,00E+00	0,00E+00	2,03E-02	0,00E+00	-5,36E-03	4,16E-03	4,16E-03	230,00	kg	100%
Sub-group	Curtain walls		-5,68E-03	-5,68E-03	1,73E-02	0,00E+00	2,29E-02	1,11E-04	-7,92E-03	3,46E-02	3,46E-02	407,53	kg	
Building Component	Interior doors Glazed		-5,68E-03	-5,68E-03	1,73E-02	0,00E+00	2,29E-02	1,11E-04	-7,92E-03	3,46E-02	3,46E-02	407,53	kg	
Construction	Interior doors Glazed		-5,68E-03	-5,68E-03	1,73E-02	0,00E+00	2,29E-02	1,11E-04	-7,92E-03	3,46E-02	3,46E-02	407,53	kg	
Building Material	Screws and fasteners	1	2,13E-03	2,13E-03	2,13E-03	0,00E+00	0,00E+00	4,09E-07	-2,17E-03	4,26E-03	4,26E-03	12,20	kg	
Building Material	Glass 3mm	1	8,87E-03	8,87E-03	8,98E-03	0,00E+00	0,00E+00	1,09E-04	0,00E+00	1,80E-02	1,80E-02	135,42	kg	
Building Material	Application paint emulsion, interior, wear	1	2,27E-04	2,27E-04	2,28E-04	0,00E+00	0,00E+00	1,30E-06	-1,87E-06	4,56E-04	4,56E-04	1,76	kg	
Building Material	Chipboard	1	-8,35E-03	-8,35E-03	3,77E-03	0,00E+00	1,21E-02	0,00E+00	-5,61E-05	7,55E-03	7,55E-03	136,15	kg	
Building Material	Timber pine (12% moisture	1	-8,55E-03	-8,55E-03	2,21E-03	0,00E+00	1,08E-02	0,00E+00	-5,69E-03	4,41E-03	4,41E-03	122,00	kg	
Sub-group	Windows		3,63E-01	2,26E-01	2,30E-01	0,00E+00	1,35E-01	1,79E-02	-1,40E-01	7,46E-01	6,09E-01	3761,31	kg	
Building Component	Reused Windows		6,15E-02	-4,02E-02	3,59E-02	0,00E+00	2,64E-02	3,31E-03	-2,85E-02	1,27E-01	2,54E-02	674,98	kg	
Construction	Window Glazing Thriple-		3,42E-02	-2,32E-02	3,59E-02	0,00E+00	1,40E-03	3,02E-04	-1,30E-03	7,18E-02	1,44E-02	385,40	kg	
Building Material	Insulated glazing, double	1	3,42E-02	-2,32E-02	3,59E-02	0,00E+00	1,40E-03	3,02E-04	-1,30E-03	7,18E-02	1,44E-02	385,40	kg	80%
Construction	Window		2,74E-02	-1,69E-02	0,00E+00	0,00E+00	2,50E-02	3,01E-03	-2,72E-02	5,54E-02	1,11E-02	289,58	kg	
Building Material	EPDM sealing for	0	3,09E-03	-4,20E-03	0,00E+00	0,00E+00	3,01E-03	3,01E-03	-3,26E-03	9,11E-03	1,82E-03	19,54	kg	80%
Building Material	Window Sill, alu	0	1,21E-02	1,99E-03	0,00E+00	0,00E+00	5,30E-04	0,00E+00	-7,28E-03	1,26E-02	2,52E-03	22,26	kg	80%
Building Material	Window Sill, wood	0	-9,80E-04	-8,76E-03	0,00E+00	0,00E+00	1,07E-02	0,00E+00	-4,30E-03	9,72E-03	1,94E-03	113,85	kg	80%
Building Material	Window frame, alu	0	1,36E-02	2,34E-03	0,00E+00	0,00E+00	4,68E-04	0,00E+00	-8,29E-03	1,40E-02	2,81E-03	24,44	kg	80%
Building Material	Window frame, wood	0	-3,76E-04	-8,31E-03	0,00E+00	0,00E+00	1,03E-02	0,00E+00	-4,11E-03	9,92E-03	1,98E-03	109,48	kg	80%
Building Component	Terrace Windows		1,67E-01	1,67E-01	1,17E-01	0,00E+00	5,77E-02	7,19E-03	-6,19E-02	3,50E-01	3,50E-01	1770,72	kg	
Construction	Window Glazing Thriple-		1,11E-01	1,11E-01	1,17E-01	0,00E+00	5,82E-03	9,41E-04	-5,39E-03	2,35E-01	2,35E-01	1170,00	kg	
Building Material	Triple-layer glaing	1	1,11E-01	1,11E-01	1,17E-01	0,00E+00	5,82E-03	9,41E-04	-5,39E-03	2,35E-01	2,35E-01	1170,00	kg	
Construction	Window		5,68E-02	5,68E-02	0,00E+00	0,00E+00	5,19E-02	6,25E-03	-5,65E-02	1,15E-01	1,15E-01	600,72	kg	
Building Material	EPDM sealing for	0	6,40E-03	6,40E-03	0,00E+00	0,00E+00	6,25E-03	6,25E-03	-6,76E-03	1,89E-02	1,89E-02	40,54	kg	
Building Material	Window Sill, alu	0	2,50E-02	2,50E-02	0,00E+00	0,00E+00	1,10E-03	0,00E+00	-1,51E-02	2,61E-02	2,61E-02	46,18	kg	
Building Material	Window Sill, wood	0	-2,03E-03	-2,03E-03	0,00E+00	0,00E+00	2,22E-02	0,00E+00	-8,92E-03	2,02E-02	2,02E-02	236,17	kg	
Building Material	Window frame, alu	0	2,81E-02	2,81E-02	0,00E+00	0,00E+00	9,70E-04	0,00E+00	-1,72E-02	2,91E-02	2,91E-02	50,70	kg	
Building Material	Window frame, wood	0	-7,79E-04	-7,79E-04	0,00E+00	0,00E+00	2,14E-02	0,00E+00	-8,52E-03	2,06E-02	2,06E-02	227,12	kg	
Building Component	Window 45x45		1,21E-02	0,00E+00	2,10E-03	0,00E+00	5,87E-03	1,12E-03	-4,60E-03	2,12E-02	9,09E-03	91,06	kg	
Construction	Basement Glazing Preser		2,00E-03	0,00E+00	2,10E-03	0,00E+00	8,20E-05	1,77E-05	-7,60E-05	4,20E-03	2,20E-03	22,55	kg	
Building Material	Insulated glazing, double	1	2,00E-03	0,00E+00	2,10E-03	0,00E+00	8,20E-05	1,77E-05	-7,60E-05	4,20E-03	2,20E-03	22,55	kg	100%
Construction	Basement Plastic		1,01E-02	0,00E+00	0,00E+00	0,00E+00	5,79E-03	1,10E-03	-4,52E-03	1,70E-02	6,89E-03	68,51	kg	
Building Material	EPDM sealing for	0	1,13E-03	0,00E+00	0,00E+00	0,00E+00	1,10E-03	1,10E-03	-1,19E-03	3,32E-03	2,20E-03	7,13	kg	100%
Building Material	Window sash PVC-U	0	8,99E-03	0,00E+00	0,00E+00	0,00E+00	4,69E-03	0,00E+00	-3,34E-03	1,37E-02	4,69E-03	61,38	kg	100%
Building Component	Window 59x217		2,27E-02	0,00E+00	5,15E-03	0,00E+00	1,04E-02	1,97E-03	-8,14E-03	4,02E-02	1,75E-02	175,76	kg	
Construction	Basement Glazing Preser		4,91E-03	0,00E+00	5,15E-03	0,00E+00	2,01E-04	4,34E-05	-1,86E-04	1,03E-02	5,40E-03	55,35	kg	
Building Material	Insulated glazing, double	1	4,91E-03	0,00E+00	5,15E-03	0,00E+00	2,01E-04	4,34E-05	-1,86E-04	1,03E-02	5,40E-03	55,35	kg	100%
Construction	Basement Plastic		1,78E-02	0,00E+00	0,00E+00	0,00E+00	1,02E-02	1,93E-03	-7,95E-03	2,99E-02	1,21E-02	120,41	kg	
Building Material	EPDM sealing for	0	1,98E-03	0,00E+00	0,00E+00	0,00E+00	1,93E-03	1,93E-03	-2,09E-03	5,84E-03	3,86E-03	12,53	kg	100%
Building Material	Window sash PVC-U	0	1,58E-02	0,00E+00	0,00E+00	0,00E+00	8,24E-03	0,00E+00	-5,86E-03	2,40E-02	8,24E-03	107,88	kg	100%

Building Component	Windows		9,92E-02	9,92E-02	6,96E-02	0,00E+00	3,42E-02	4,26E-03	-3,67E-02	2,07E-01	2,07E-01	1048,81	kg		
Construction	Window Glazing_Thriple-		6,56E-02	6,56E-02	6,96E-02	0,00E+00	3,44E-03	5,57E-04	-3,19E-03	1,39E-01	1,39E-01	693,00	kg		
Building Material	Triple-layer glaing	1	6,56E-02	6,56E-02	6,96E-02	0,00E+00	3,44E-03	5,57E-04	-3,19E-03	1,39E-01	1,39E-01	693,00	kg		
Construction	Window		3,36E-02	3,36E-02	0,00E+00	0,00E+00	3,07E-02	3,70E-03	-3,35E-02	6,80E-02	6,80E-02	355,81	kg		
Building Material	EPDM sealing for	0	3,79E-03	3,79E-03	0,00E+00	0,00E+00	3,70E-03	3,70E-03	-4,00E-03	1,12E-02	1,12E-02	24,01	kg		
Building Material	Window Sill, alu	0	1,48E-02	1,48E-02	0,00E+00	0,00E+00	6,52E-04	0,00E+00	-8,94E-03	1,55E-02	1,55E-02	27,35	kg		
Building Material	Window Sill, wood	0	-1,20E-03	-1,20E-03	0,00E+00	0,00E+00	1,32E-02	0,00E+00	-5,28E-03	1,19E-02	1,19E-02	139,89	kg		
Building Material	Window frame, alu	0	1,67E-02	1,67E-02	0,00E+00	0,00E+00	5,75E-04	0,00E+00	-1,02E-02	1,72E-02	1,72E-02	30,03	kg		
Building Material	Window frame, wood	0	-4,62E-04	-4,62E-04	0,00E+00	0,00E+00	1,26E-02	0,00E+00	-5,05E-03	1,22E-02	1,22E-02	134,53	kg		
Group	Exterior walls		1,07E+00	-8,23E-01	3,68E-02	0,00E+00	1,25E+00	7,28E-02	-5,08E-01	2,43E+00	5,39E-01	279313,94	kg		0%
Sub-group	Basement exterior walls		9,28E-01	0,00E+00	0,00E+00	0,00E+00	2,14E-02	4,02E-02	-1,07E-01	9,90E-01	6,16E-02	142333,05	kg		
Building Component	Basement, Exterior wall_150mm Concrete		1,13E-01	0,00E+00	0,00E+00	0,00E+00	3,01E-03	3,08E-06	-1,25E-02	1,16E-01	3,02E-03	24571,80	kg		
Construction	Basement, Exterior wall		1,13E-01	0,00E+00	0,00E+00	0,00E+00	3,01E-03	3,08E-06	-1,25E-02	1,16E-01	3,02E-03	24571,80	kg		
Building Material	Steel reinforcement mesh	0	3,08E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	3,08E-06	-1,77E-03	3,09E-03	3,08E-06	91,80	kg	100%	
Building Material	Concrete Elements C30/37	0	1,10E-01	0,00E+00	0,00E+00	0,00E+00	3,01E-03	0,00E+00	-1,07E-02	1,13E-01	3,01E-03	24480,00	kg	100%	
Building Component	Basement, Exterior wall_Brick construction		3,02E-01	0,00E+00	0,00E+00	0,00E+00	6,50E-03	8,06E-03	-5,10E-03	3,16E-01	1,46E-02	19442,41	kg		
Construction	Basement, exterior walls_Added		2,23E-02	0,00E+00	0,00E+00	0,00E+00	3,99E-04	2,21E-04	0,00E+00	2,29E-02	6,20E-04	295,31	kg		
Building Material	Mineral wool	0	2,23E-02	0,00E+00	0,00E+00	0,00E+00	3,99E-04	2,21E-04	0,00E+00	2,29E-02	6,20E-04	295,31	kg	100%	
Construction	Basement, exterior walls_Bricks_Preserved		2,64E-01	0,00E+00	0,00E+00	0,00E+00	6,10E-03	9,52E-04	-1,87E-03	2,71E-01	7,05E-03	18096,70	kg		
Building Material	Tile adhesive	0	2,02E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	9,52E-04	-1,66E-04	2,11E-02	9,52E-04	1183,90	kg	100%	
Building Material	Facing brick	0	2,44E-01	0,00E+00	0,00E+00	0,00E+00	6,10E-03	0,00E+00	-1,71E-03	2,50E-01	6,10E-03	16912,80	kg	100%	
Construction	Basement, exterior walls_Plinth_leca		7,76E-05	0,00E+00	0,00E+00	0,00E+00	1,52E-06	0,00E+00	-4,63E-07	7,91E-05	1,52E-06	4,60	kg		
Building Material	Expanded clay concrete	0	7,76E-05	0,00E+00	0,00E+00	0,00E+00	1,52E-06	0,00E+00	-4,63E-07	7,91E-05	1,52E-06	4,60	kg	100%	
Construction	Basement, exterior walls_Plinth_polystyrene		1,52E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	6,88E-03	-3,23E-03	2,21E-02	6,88E-03	1045,80	kg		
Building Material	EPS for walls and roofs 040	0	5,42E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	6,14E-03	-3,23E-03	1,16E-02	6,14E-03	37,80	kg	100%	
Building Material	Lime-cement plaster	0	9,81E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	7,43E-04	0,00E+00	1,06E-02	7,43E-04	1008,00	kg	100%	
Building Component	Basement, Exterior wall_Sandwich concrete		5,14E-01	0,00E+00	0,00E+00	0,00E+00	1,19E-02	3,21E-02	-8,94E-02	5,58E-01	4,40E-02	98318,85	kg		
Construction	Basement, Exterior wall_Facade		4,06E-01	0,00E+00	0,00E+00	0,00E+00	9,58E-03	2,59E-02	-6,71E-02	4,41E-01	3,55E-02	79042,30	kg		
Building Material	Steel reinforcement mesh	0	1,43E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,42E-05	-8,20E-03	1,43E-02	1,42E-05	424,80	kg	100%	
Building Material	Steel reinforcement mesh	0	1,94E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,94E-05	-1,12E-02	1,94E-02	1,94E-05	578,20	kg	100%	
Building Material	Concrete Elements C30/37	0	2,54E-01	0,00E+00	0,00E+00	0,00E+00	6,97E-03	0,00E+00	-2,48E-02	2,61E-01	6,97E-03	56640,00	kg	100%	
Building Material	Concrete Elements C30/37	0	9,52E-02	0,00E+00	0,00E+00	0,00E+00	2,61E-03	0,00E+00	-9,31E-03	9,79E-02	2,61E-03	21240,00	kg	100%	
Building Material	EPS for walls and roofs 040	0	2,28E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	2,59E-02	-1,36E-02	4,87E-02	2,59E-02	159,30	kg	100%	
Construction	Basement, Exterior wall_Gable		1,08E-01	0,00E+00	0,00E+00	0,00E+00	2,30E-03	6,22E-03	-2,23E-02	1,17E-01	8,52E-03	19276,55	kg		
Building Material	Steel reinforcement mesh	0	1,37E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,37E-05	-7,87E-03	1,37E-02	1,37E-05	407,52	kg	100%	
Building Material	Steel reinforcement mesh	0	5,13E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	5,12E-06	-2,95E-03	5,14E-03	5,12E-06	152,82	kg	100%	
Building Material	Concrete Elements C30/37	0	6,09E-02	0,00E+00	0,00E+00	0,00E+00	1,67E-03	0,00E+00	-5,95E-03	6,26E-02	1,67E-03	13584,00	kg	100%	
Building Material	Concrete Elements C30/37	0	2,28E-02	0,00E+00	0,00E+00	0,00E+00	6,27E-04	0,00E+00	-2,23E-03	2,35E-02	6,27E-04	5094,00	kg	100%	
Building Material	EPS for walls and roofs 040	0	5,48E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	6,21E-03	-3,26E-03	1,17E-02	6,21E-03	38,21	kg	100%	
Sub-group	Exterior walls		1,41E-01	-8,23E-01	3,68E-02	0,00E+00	1,23E+00	3,26E-02	-4,01E-01	1,44E+00	4,77E-01	136980,88	kg		
Building Component	Exterior wall_Gable		-1,50E-01	-3,64E-01	2,23E-02	0,00E+00	5,46E-01	6,02E-04	-1,69E-01	4,18E-01	2,05E-01	47962,53	kg		
Construction	Exterior wall, gable_150mm concrete		2,13E-01	0,00E+00	0,00E+00	0,00E+00	4,93E-03	3,36E-05	-3,69E-02	2,18E-01	4,96E-03	41069,70	kg		
Building Material	Steel reinforcement mesh	0	3,36E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	3,36E-05	-1,93E-02	3,37E-02	3,36E-05	1001,70	kg	100%	
Building Material	Concrete Elements C30/37	0	1,80E-01	0,00E+00	0,00E+00	0,00E+00	4,93E-03	0,00E+00	-1,76E-02	1,85E-01	4,93E-03	40068,00	kg	100%	
Construction	Exterior wall,		-3,02E-02	-3,02E-02	0,00E+00	0,00E+00	5,17E-02	3,73E-07	-1,81E-02	2,15E-02	2,15E-02	617,70	kg		
Building Material	Vapour barrier, Pe-foil	0	2,18E-03	2,18E-03	0,00E+00	0,00E+00	3,04E-03	0,00E+00	-1,50E-03	5,23E-03	5,23E-03	22,26	kg		

Building Material	Screws and fasteners	0	1,94E-03	1,94E-03	0,00E+00	0,00E+00	0,00E+00	3,73E-07	-9,90E-04	1,94E-03	1,94E-03	11,13	kg		
Building Material	Construction Wood (15% moisture / 13% H2O)	0	-1,58E-02	-1,58E-02	0,00E+00	0,00E+00	2,29E-02	0,00E+00	-5,71E-03	7,09E-03	7,09E-03	264,95	kg		
Building Material	SteicoFlex 036	0	-1,85E-02	-1,85E-02	0,00E+00	0,00E+00	2,58E-02	0,00E+00	-9,93E-03	7,28E-03	7,28E-03	319,36	kg		
Construction	Exterior wall,		-9,44E-02	-9,44E-02	0,00E+00	0,00E+00	1,35E-01	3,73E-07	-5,25E-03	4,09E-02	4,09E-02	1321,62	kg		
Building Material	Screws and fasteners	0	1,94E-03	1,94E-03	0,00E+00	0,00E+00	0,00E+00	3,73E-07	-9,90E-04	1,94E-03	1,94E-03	11,13	kg		
Building Material	Plywood sheet	0	-4,82E-02	-4,82E-02	0,00E+00	0,00E+00	6,76E-02	0,00E+00	-2,13E-03	1,95E-02	1,95E-02	655,25	kg		
Building Material	Plywood sheet	0	-4,82E-02	-4,82E-02	0,00E+00	0,00E+00	6,76E-02	0,00E+00	-2,13E-03	1,95E-02	1,95E-02	655,25	kg		
Construction	Exterior wall, gable_Wood cladding construction		-9,96E-02	-9,96E-02	2,23E-02	0,00E+00	1,47E-01	5,67E-04	-4,19E-02	7,02E-02	7,02E-02	2476,64	kg		
Building Material	Screws and fasteners	0	2,92E-03	2,92E-03	0,00E+00	0,00E+00	0,00E+00	5,60E-07	-1,49E-03	2,92E-03	2,92E-03	16,70	kg		
Building Material	Gypsum plaster board (impregnated, moisture	0	6,12E-03	6,12E-03	0,00E+00	0,00E+00	0,00E+00	5,66E-04	0,00E+00	6,69E-03	6,69E-03	767,97	kg		
Building Material	Construction Wood (15% moisture / 13% H2O)	0	-7,29E-03	-7,29E-03	0,00E+00	0,00E+00	1,06E-02	0,00E+00	-2,64E-03	3,28E-03	3,28E-03	122,64	kg		
Building Material	Application coating water	3	5,69E-03	5,69E-03	2,23E-02	0,00E+00	1,74E-03	0,00E+00	-2,17E-03	2,97E-02	2,97E-02	42,29	kg		
Building Material	Timber pine (12% moisture	0	-1,07E-01	-1,07E-01	0,00E+00	0,00E+00	1,35E-01	0,00E+00	-3,56E-02	2,76E-02	2,76E-02	1527,04	kg		
Construction	Exterior wall_Insulation,		-1,39E-01	-1,39E-01	0,00E+00	0,00E+00	2,07E-01	3,73E-07	-6,72E-02	6,76E-02	6,76E-02	2476,87	kg		
Building Material	Vapour barrier, Pe-foil	0	2,18E-03	2,18E-03	0,00E+00	0,00E+00	3,04E-03	0,00E+00	-1,50E-03	5,23E-03	5,23E-03	22,26	kg		
Building Material	Screws and fasteners	0	1,94E-03	1,94E-03	0,00E+00	0,00E+00	0,00E+00	3,73E-07	-9,90E-04	1,94E-03	1,94E-03	11,13	kg		
Building Material	Construction Wood (15% moisture / 13% H2O)	0	-7,00E-02	-7,00E-02	0,00E+00	0,00E+00	1,02E-01	0,00E+00	-2,54E-02	3,15E-02	3,15E-02	1177,55	kg		
Building Material	SteicoFlex 036	0	-7,35E-02	-7,35E-02	0,00E+00	0,00E+00	1,02E-01	0,00E+00	-3,93E-02	2,89E-02	2,89E-02	1265,93	kg		
Building Component	Exterior wall_Light		-3,28E-01	-3,28E-01	1,46E-02	0,00E+00	4,74E-01	3,71E-04	-1,24E-01	1,60E-01	1,60E-01	5950,63	kg		
Construction	Exterior wall,		-2,02E-01	-2,02E-01	0,00E+00	0,00E+00	2,89E-01	1,30E-07	-9,29E-02	8,78E-02	8,78E-02	3469,65	kg		
Building Material	Vapour barrier, Pe-foil	0	7,60E-04	7,60E-04	0,00E+00	0,00E+00	1,06E-03	0,00E+00	-5,22E-04	1,82E-03	1,82E-03	7,74	kg		
Building Material	Screws and fasteners	0	6,76E-04	6,76E-04	0,00E+00	0,00E+00	0,00E+00	1,30E-07	-3,44E-04	6,76E-04	6,76E-04	3,87	kg		
Building Material	Construction Wood (15% moisture / 13% H2O)	0	-9,62E-02	-9,62E-02	0,00E+00	0,00E+00	1,40E-01	0,00E+00	-3,49E-02	4,33E-02	4,33E-02	1617,31	kg		
Building Material	SteicoFlex 036	0	-1,07E-01	-1,07E-01	0,00E+00	0,00E+00	1,49E-01	0,00E+00	-5,72E-02	4,20E-02	4,20E-02	1840,73	kg		
Construction	Exterior wall, light_Interior		-6,16E-02	-6,16E-02	0,00E+00	0,00E+00	8,84E-02	2,44E-07	-3,43E-03	2,67E-02	2,67E-02	863,27	kg		
Building Material	Screws and fasteners	0	1,27E-03	1,27E-03	0,00E+00	0,00E+00	0,00E+00	2,44E-07	-6,47E-04	1,27E-03	1,27E-03	7,27	kg		
Building Material	Plywood sheet	0	-3,15E-02	-3,15E-02	0,00E+00	0,00E+00	4,42E-02	0,00E+00	-1,39E-03	1,27E-02	1,27E-02	428,00	kg		
Building Material	Plywood sheet	0	-3,15E-02	-3,15E-02	0,00E+00	0,00E+00	4,42E-02	0,00E+00	-1,39E-03	1,27E-02	1,27E-02	428,00	kg		
Construction	Exterior wall, light_Wood cladding construction		-6,51E-02	-6,51E-02	1,46E-02	0,00E+00	9,60E-02	3,70E-04	-2,74E-02	4,59E-02	4,59E-02	1617,71	kg		
Building Material	Screws and fasteners	0	1,91E-03	1,91E-03	0,00E+00	0,00E+00	0,00E+00	3,66E-07	-9,70E-04	1,91E-03	1,91E-03	10,91	kg		
Building Material	Gypsum plaster board (impregnated, moisture	0	4,00E-03	4,00E-03	0,00E+00	0,00E+00	0,00E+00	3,70E-04	0,00E+00	4,37E-03	4,37E-03	501,63	kg		
Building Material	Construction Wood (15% moisture / 13% H2O)	0	-4,76E-03	-4,76E-03	0,00E+00	0,00E+00	6,91E-03	0,00E+00	-1,73E-03	2,15E-03	2,15E-03	80,11	kg		
Building Material	Application coating water	3	3,71E-03	3,71E-03	1,46E-02	0,00E+00	1,14E-03	0,00E+00	-1,42E-03	1,94E-02	1,94E-02	27,63	kg		
Building Material	Timber pine (12% moisture	0	-6,99E-02	-6,99E-02	0,00E+00	0,00E+00	8,80E-02	0,00E+00	-2,33E-02	1,80E-02	1,80E-02	997,44	kg		
Building Component	Exterior wall_Sandwich &		6,20E-01	-1,31E-01	0,00E+00	0,00E+00	2,11E-01	3,16E-02	-1,08E-01	8,63E-01	1,12E-01	83067,72	kg		
Construction	Exterior wall, Sandwich & Brick_Insulation, inside		-3,18E-02	-3,18E-02	0,00E+00	0,00E+00	5,44E-02	3,92E-07	-1,91E-02	2,27E-02	2,27E-02	649,89	kg		
Building Material	Vapour barrier, Pe-foil	0	2,30E-03	2,30E-03	0,00E+00	0,00E+00	3,20E-03	0,00E+00	-1,58E-03	5,50E-03	5,50E-03	23,42	kg		
Building Material	Screws and fasteners	0	2,05E-03	2,05E-03	0,00E+00	0,00E+00	0,00E+00	3,92E-07	-1,04E-03	2,05E-03	2,05E-03	11,71	kg		
Building Material	Construction Wood (15% moisture / 13% H2O)	0	-1,66E-02	-1,66E-02	0,00E+00	0,00E+00	2,40E-02	0,00E+00	-6,01E-03	7,46E-03	7,46E-03	278,76	kg		
Building Material	SteicoFlex 036	0	-1,95E-02	-1,95E-02	0,00E+00	0,00E+00	2,72E-02	0,00E+00	-1,04E-02	7,66E-03	7,66E-03	336,00	kg		
Construction	Exterior wall, Sandwich & Brick_Interior finishing		-9,93E-02	-9,93E-02	0,00E+00	0,00E+00	1,42E-01	3,92E-07	-5,52E-03	4,30E-02	4,30E-02	1390,49	kg		
Building Material	Screws and fasteners	0	2,05E-03	2,05E-03	0,00E+00	0,00E+00	0,00E+00	3,92E-07	-1,04E-03	2,05E-03	2,05E-03	11,71	kg		
Building Material	Plywood sheet	0	-5,07E-02	-5,07E-02	0,00E+00	0,00E+00	7,12E-02	0,00E+00	-2,24E-03	2,05E-02	2,05E-02	689,39	kg		
Building Material	Plywood sheet	0	-5,07E-02	-5,07E-02	0,00E+00	0,00E+00	7,12E-02	0,00E+00	-2,24E-03	2,05E-02	2,05E-02	689,39	kg		

Construction	Exterior			3,84E-01	0,00E+00	0,00E+00	0,00E+00	7,71E-03	5,35E-03	-2,16E-03	3,97E-01	1,31E-02	28654,37	kg		
Building Material	Lime-cement plaster	0		3,65E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	2,76E-03	0,00E+00	3,92E-02	2,76E-03	3747,20	kg	100%	
Building Material	Lime plaster	0		1,57E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,04E-03	0,00E+00	1,67E-02	1,04E-03	1405,20	kg	100%	
Building Material	Lime gypsum interior	0		2,29E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,55E-03	0,00E+00	2,44E-02	1,55E-03	2107,80	kg	100%	
Building Material	Facing brick	0		3,09E-01	0,00E+00	0,00E+00	0,00E+00	7,71E-03	0,00E+00	-2,16E-03	3,16E-01	7,71E-03	21394,17	kg	100%	
Construction	Exterior wall_Mineral			1,75E-01	0,00E+00	0,00E+00	0,00E+00	3,45E-03	5,12E-04	-3,01E-02	1,79E-01	3,97E-03	22840,36	kg		
Building Material	Steel reinforcement mesh	0		3,54E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	3,53E-05	-2,04E-02	3,54E-02	3,53E-05	1053,90	kg	100%	
Building Material	Concrete Elements C30/37	0		9,45E-02	0,00E+00	0,00E+00	0,00E+00	2,59E-03	0,00E+00	-9,24E-03	9,71E-02	2,59E-03	21078,00	kg	100%	
Building Material	Screws and fasteners	0		1,02E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,96E-07	-5,21E-04	1,02E-03	1,96E-07	5,86	kg	100%	
Building Material	Mineral wool	0		4,42E-02	0,00E+00	0,00E+00	0,00E+00	8,61E-04	4,77E-04	0,00E+00	4,55E-02	1,34E-03	702,60	kg	100%	
Construction	Exterior wall_sandwich-element, inside_Preserved			1,92E-01	0,00E+00	0,00E+00	0,00E+00	3,46E-03	2,57E-02	-5,08E-02	2,21E-01	2,92E-02	29532,62	kg		
Building Material	Steel reinforcement mesh	0		4,25E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	4,24E-05	-2,44E-02	4,25E-02	4,24E-05	1264,68	kg	100%	
Building Material	Concrete Elements C30/37	0		1,26E-01	0,00E+00	0,00E+00	0,00E+00	3,46E-03	0,00E+00	-1,23E-02	1,29E-01	3,46E-03	28104,00	kg	100%	
Building Material	EPS for walls and roofs 040	0		2,27E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	2,57E-02	-1,35E-02	4,83E-02	2,57E-02	158,09	kg	100%	
Building Material	Screws and fasteners	0		1,02E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,96E-07	-5,21E-04	1,02E-03	1,96E-07	5,86	kg	100%	
Building Material	EPS for walls and roofs 040	0		2,27E-02	0,00E+00	0,00E+00	0,00E+00	0,00E+00	2,57E-02	-1,35E-02	4,83E-02	2,57E-02	158,09	kg	100%	
Building Material	Screws and fasteners	0		1,02E-03	0,00E+00	0,00E+00	0,00E+00	0,00E+00	1,96E-07	-5,21E-04	1,02E-03	1,96E-07	5,86	kg	100%	

APPENDIX 5: LCA CALCULATION DFD-ROW-HOUSES

Description	Name	Total Replacements	Total GWP a1_3 kg CO_2-eq.	Total GWP A1-A3, circular kg CO_2-eq.	Total GWP b4 kg CO_2-eq.	Total GWP b6 kg CO_2-eq.	Total GWP c3 kg CO_2-eq.	Total GWP c4 kg CO_2-eq.	Total GWP d kg CO_2-eq.	Total GWP sum kg CO_2-eq.	Total GWP sum, circular kg CO_2-eq.	Weight		Reduction%	Reused Weight%
Sum	Building		3,12E+00	-1,97E+00	4,57E-01	3,43E+00	5,01E+00	4,35E-01	-4,10E+00	1,25E+01	7,37E+00	125482,82	kg		64,4%
Sum	Operations		0,00E+00	0,00E+00	0,00E+00	3,43E+00	0,00E+00	0,00E+00	0,00E+00	3,43E+00	3,43E+00				
Operational consumption el	El (Projection 2020-2040)		0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00				
Operational consumption Heating	District Heating (Projection 2020-2040)		0,00E+00	0,00E+00	0,00E+00	3,43E+00	0,00E+00	0,00E+00	0,00E+00	3,43E+00	3,43E+00				
Building process			0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00				
Construction and assembly			0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00				
Construction equipment and machinery			0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00				
Sum	Operations		0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00				
Operational consumption el	El (Projection 2020-2040)		0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00				
Operational consumption Heating	Natural Gas(Projection 2020-2040)		0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00				
Sum	Building Component		3,12E+00	-1,97E+00	4,57E-01	0,00E+00	5,01E+00	4,35E-01	-4,10E+00	9,03E+00	3,93E+00				
Group	Electrical and mechanical installations		8,90E-02	8,90E-02	9,25E-02	0,00E+00	3,46E-03	5,05E-05	0,00E+00	1,85E-01	1,85E-01	95,00	kg		0%
Sub-group	Energy production		8,90E-02	8,90E-02	9,25E-02	0,00E+00	3,46E-03	5,05E-05	0,00E+00	1,85E-01	1,85E-01	95,00	kg		
Building Component	Photovoltaic Panels		8,90E-02	8,90E-02	9,25E-02	0,00E+00	3,46E-03	5,05E-05	0,00E+00	1,85E-01	1,85E-01	95,00	kg		
Construction	Photovoltaic Panels		8,90E-02	8,90E-02	9,25E-02	0,00E+00	3,46E-03	5,05E-05	0,00E+00	1,85E-01	1,85E-01	95,00	kg		
Building Material	Product Average PV Panels	1	8,90E-02	8,90E-02	9,25E-02	0,00E+00	3,46E-03	5,05E-05	0,00E+00	1,85E-01	1,85E-01	95,00	kg	0%	
Group	Foundations		8,28E-01	8,28E-01	0,00E+00	0,00E+00	4,22E-02	3,40E-02	-7,73E-02	9,04E-01	9,04E-01	32463,13	kg		0%
Sub-group	Line foundations		8,28E-01	8,28E-01	0,00E+00	0,00E+00	4,22E-02	3,40E-02	-7,73E-02	9,04E-01	9,04E-01	32463,13	kg		
Building Component	Foundations		8,28E-01	8,28E-01	0,00E+00	0,00E+00	4,22E-02	3,40E-02	-7,73E-02	9,04E-01	9,04E-01	32463,13	kg		
Construction	Line foundations		8,28E-01	8,28E-01	0,00E+00	0,00E+00	4,22E-02	3,40E-02	-7,73E-02	9,04E-01	9,04E-01	32463,13	kg		
Building Material	Steel reinforcement mesh	0	8,10E-02	8,10E-02	0,00E+00	0,00E+00	0,00E+00	8,08E-05	-4,66E-02	8,10E-02	8,10E-02	600,00	kg	0%	
Building Material	Concrete C20/25	0	5,64E-01	5,64E-01	0,00E+00	0,00E+00	3,92E-02	0,00E+00	-1,20E-02	6,03E-01	6,03E-01	29500,00	kg	0%	
Building Material	EPS for Ceilings / floors / basement / terrain slab	0	2,98E-02	2,98E-02	0,00E+00	0,00E+00	0,00E+00	3,39E-02	-1,78E-02	6,37E-02	6,37E-02	51,80	kg	0%	
Building Material	Expanded clay concrete block inner wall	0	2,98E-02	2,98E-02	0,00E+00	0,00E+00	6,60E-04	0,00E+00	-2,02E-04	3,05E-02	3,05E-02	497,71	kg	0%	
Building Material	Expanded clay concrete block outer wall	0	1,23E-01	1,23E-01	0,00E+00	0,00E+00	2,40E-03	0,00E+00	-7,34E-04	1,25E-01	1,25E-01	1813,62	kg	0%	
Group	Interior Walls		-6,22E-02	-4,46E-01	6,56E-02	0,00E+00	6,88E-01	3,11E-04	-1,25E-01	6,92E-01	3,08E-01	22771,33	kg		93%
Sub-group	Load-bearing Interior walls		2,28E-01	-1,55E-01	6,56E-02	0,00E+00	2,79E-01	3,11E-04	-9,12E-02	5,74E-01	1,90E-01	21737,41	kg		
Building Component	Inner Walls Load-bearing		2,28E-01	-1,55E-01	6,56E-02	0,00E+00	2,79E-01	3,11E-04	-9,12E-02	5,74E-01	1,90E-01	21737,41	kg		
Construction	Brick in-fill Reused		8,65E-02	3,23E-02	0,00E+00	0,00E+00	2,09E-03	2,59E-04	-5,84E-04	8,89E-02	3,47E-02	1529,60	kg		
Building Material	Cement mortar	0	3,05E-03	1,03E-03	0,00E+00	0,00E+00	0,00E+00	2,59E-04	0,00E+00	3,31E-03	1,29E-03	89,60	kg	61%	
Building Material	Facing brick	0	8,35E-02	3,13E-02	0,00E+00	0,00E+00	2,09E-03	0,00E+00	-5,84E-04	8,56E-02	3,34E-02	1440,00	kg	61%	
Construction	Concrete elements Reused		3,32E-01	2,59E-03	0,00E+00	0,00E+00	9,47E-03	5,16E-05	-6,34E-02	3,42E-01	1,21E-02	19535,04	kg		
Building Material	Steel reinforcement mesh	0	5,17E-02	4,66E-04	0,00E+00	0,00E+00	0,00E+00	5,16E-05	-2,97E-02	5,17E-02	5,17E-04	383,04	kg	99%	
Building Material	Concrete Elements C20/25	0	2,80E-01	2,13E-03	0,00E+00	0,00E+00	9,47E-03	0,00E+00	-3,37E-02	2,90E-01	1,16E-02	19152,00	kg	96%	
Construction	Load-bearing walls finishes		-1,90E-01	-1,90E-01	6,56E-02	0,00E+00	2,68E-01	0,00E+00	-2,72E-02	1,43E-01	1,43E-01	672,77	kg		
Building Material	Construction Wood (15% moisture / 13% H2O)	0	-1,26E-02	-1,26E-02	0,00E+00	0,00E+00	1,83E-02	0,00E+00	-4,58E-03	5,69E-03	5,69E-03	52,90	kg	0%	
Building Material	Plywood sheet	1	-1,62E-01	-1,62E-01	6,56E-02	0,00E+00	2,28E-01	0,00E+00	-1,44E-02	1,31E-01	1,31E-01	549,47	kg	0%	
Building Material	SteicoFlex 036	0	-1,54E-02	-1,54E-02	0,00E+00	0,00E+00	2,15E-02	0,00E+00	-8,26E-03	6,06E-03	6,06E-03	70,40	kg	0%	

Sub-group	Non-load bearing interior walls		-2,91E-01	-2,91E-01	0,00E+00	0,00E+00	4,09E-01	0,00E+00	-3,35E-02	1,18E-01	1,18E-01	1033,92	kg		
Building Component	Inner Walls_Non-load-bearing		-2,91E-01	-2,91E-01	0,00E+00	0,00E+00	4,09E-01	0,00E+00	-3,35E-02	1,18E-01	1,18E-01	1033,92	kg		
Construction	Inner Walls_Light Construction		-2,91E-01	-2,91E-01	0,00E+00	0,00E+00	4,09E-01	0,00E+00	-3,35E-02	1,18E-01	1,18E-01	1033,92	kg		
Building Material	Construction Wood (15% moisture / 13% H2O)	0	-2,28E-02	-2,28E-02	0,00E+00	0,00E+00	3,30E-02	0,00E+00	-8,25E-03	1,02E-02	1,02E-02	95,22	kg	0%	
Building Material	Plywood sheet	0	-2,40E-01	-2,40E-01	0,00E+00	0,00E+00	3,38E-01	0,00E+00	-1,06E-02	9,73E-02	9,73E-02	814,40	kg	0%	
Building Material	SteicoFlex 036	0	-2,73E-02	-2,73E-02	0,00E+00	0,00E+00	3,80E-02	0,00E+00	-1,46E-02	1,07E-02	1,07E-02	124,30	kg	0%	
Group	Columns og Beams		-2,44E-01	-2,67E-01	0,00E+00	0,00E+00	5,66E-01	0,00E+00	-1,88E-01	3,22E-01	3,22E-01	2198,38	kg		0%
Sub-group	Beams		-2,22E-01	-2,67E-01	0,00E+00	0,00E+00	3,39E-01	0,00E+00	-8,49E-02	1,18E-01	1,18E-01	978,88	kg		
Building Component	DfD frame system_Beams		-2,22E-01	-2,67E-01	0,00E+00	0,00E+00	3,39E-01	0,00E+00	-8,49E-02	1,18E-01	1,18E-01	978,88	kg		
Construction	DfD_Beams		-2,22E-01	-2,22E-01	0,00E+00	0,00E+00	3,39E-01	0,00E+00	-8,49E-02	1,18E-01	1,18E-01	978,88	kg		
Building Material	Glulam, pine tree	0	-2,22E-01	-2,22E-01	0,00E+00	0,00E+00	3,39E-01	0,00E+00	-8,49E-02	1,18E-01	1,18E-01	978,88	kg	0%	
Sub-group	Columns		-2,26E-02	-2,26E-02	0,00E+00	0,00E+00	2,27E-01	0,00E+00	-1,03E-01	2,04E-01	2,04E-01	1219,50	kg		
Building Component	DfD frame system_Columns		-2,26E-02	-2,26E-02	0,00E+00	0,00E+00	2,27E-01	0,00E+00	-1,03E-01	2,04E-01	2,04E-01	1219,50	kg		
Construction	DfD_Columns & Connections		-1,48E-01	-1,48E-01	0,00E+00	0,00E+00	2,27E-01	0,00E+00	-5,67E-02	7,87E-02	7,87E-02	654,30	kg		
Building Material	Glulam, pine tree	0	-1,48E-01	-1,48E-01	0,00E+00	0,00E+00	2,27E-01	0,00E+00	-5,67E-02	7,87E-02	7,87E-02	654,30	kg		
Construction	DfD_Metal Joints		1,26E-01	1,26E-01	0,00E+00	0,00E+00	2,06E-04	0,00E+00	-4,61E-02	1,26E-01	1,26E-01	565,20	kg		
Building Material	Structural Steel: Sections and Plates	0	1,26E-01	1,26E-01	0,00E+00	0,00E+00	2,06E-04	0,00E+00	-4,61E-02	1,26E-01	1,26E-01	565,20	kg	0%	
Group	Roofs		3,04E+00	-9,06E-01	0,00E+00	0,00E+00	1,10E+00	1,72E-03	-2,69E+00	4,14E+00	1,93E-01	33607,26	kg		98%
Sub-group	Roofs		3,04E+00	-9,06E-01	0,00E+00	0,00E+00	1,10E+00	1,72E-03	-2,69E+00	4,14E+00	1,93E-01	33607,26	kg		
Building Component	Roof		3,04E+00	-9,06E-01	0,00E+00	0,00E+00	1,10E+00	1,72E-03	-2,69E+00	4,14E+00	1,93E-01	33607,26	kg		
Construction	Roof_Aluminium Cladding_Reused		2,90E+00	2,88E-02	0,00E+00	0,00E+00	0,00E+00	1,89E-04	-2,29E+00	2,90E+00	2,90E-02	1403,78	kg		
Building Material	Aluminium sheets	0	2,90E+00	2,88E-02	0,00E+00	0,00E+00	0,00E+00	1,89E-04	-2,29E+00	2,90E+00	2,90E-02	1403,78	kg	99%	
Construction	Roof_Hollow-core slabs_Reused		7,44E-01	1,38E-02	0,00E+00	0,00E+00	1,38E-02	8,84E-05	-1,00E-01	7,58E-01	2,77E-02	28510,72	kg		
Building Material	Steel reinforcement mesh	0	8,85E-02	7,98E-04	0,00E+00	0,00E+00	0,00E+00	8,84E-05	-5,09E-02	8,86E-02	8,86E-04	656,21	kg	99%	
Building Material	Concrete Elements C45/55	0	6,55E-01	1,30E-02	0,00E+00	0,00E+00	1,38E-02	0,00E+00	-4,90E-02	6,69E-01	2,68E-02	27854,52	kg	96%	
Construction	Roof_Wood Truss_Reused		-5,76E-01	-7,76E-01	0,00E+00	0,00E+00	8,36E-01	0,00E+00	-2,09E-01	2,60E-01	5,97E-02	2412,24	kg		
Building Material	Construction Wood (15% moisture / 13% H2O)	0	-5,76E-01	-7,76E-01	0,00E+00	0,00E+00	8,36E-01	0,00E+00	-2,09E-01	2,60E-01	5,97E-02	2412,24	kg	77%	
Construction	Roof_insulation_New		-1,76E-01	-1,76E-01	0,00E+00	0,00E+00	2,45E-01	0,00E+00	-9,41E-02	6,91E-02	6,91E-02	802,03	kg		
Building Material	SteicoFlex 036	0	-1,76E-01	-1,76E-01	0,00E+00	0,00E+00	2,45E-01	0,00E+00	-9,41E-02	6,91E-02	6,91E-02	802,03	kg	0%	
Construction	Roof_insulation_Reused		1,45E-01	3,42E-03	0,00E+00	0,00E+00	2,60E-03	1,44E-03	0,00E+00	1,49E-01	7,45E-03	478,49	kg		
Building Material	Mineral wool	0	1,45E-01	3,42E-03	0,00E+00	0,00E+00	2,60E-03	1,44E-03	0,00E+00	1,49E-01	7,45E-03	478,49	kg	95%	
Group	Terrain slab		1,58E-01	-3,81E-01	0,00E+00	0,00E+00	8,09E-01	3,90E-01	-5,02E-01	1,36E+00	8,18E-01	23074,37	kg		94%
Sub-group	Terrain slab		1,58E-01	-3,81E-01	0,00E+00	0,00E+00	8,09E-01	3,90E-01	-5,02E-01	1,36E+00	8,18E-01	23074,37	kg		
Building Component	Floor		-5,30E-01	-5,95E-01	0,00E+00	0,00E+00	7,99E-01	0,00E+00	-2,31E-01	2,69E-01	2,69E-01	2160,86	kg		
Construction	Floor_Insulation and joists		-2,14E-01	-2,14E-01	0,00E+00	0,00E+00	3,04E-01	0,00E+00	-9,75E-02	8,97E-02	8,97E-02	938,42	kg		
Building Material	Construction Wood (15% moisture / 13% H2O)	0	-9,86E-02	-9,86E-02	0,00E+00	0,00E+00	1,43E-01	0,00E+00	-3,57E-02	4,44E-02	4,44E-02	412,62	kg	0%	
Building Material	SteicoFlex 036	0	-1,15E-01	-1,15E-01	0,00E+00	0,00E+00	1,61E-01	0,00E+00	-6,17E-02	4,53E-02	4,53E-02	525,80	kg	0%	
Construction	Floor_Parquet floor boards_Reused		-3,16E-01	-3,81E-01	0,00E+00	0,00E+00	4,95E-01	0,00E+00	-1,34E-01	1,80E-01	1,14E-01	1222,44	kg		
Building Material	Strip parquet	0	-3,16E-01	-3,81E-01	0,00E+00	0,00E+00	4,95E-01	0,00E+00	-1,34E-01	1,80E-01	1,14E-01	1222,44	kg	77%	
Building Component	Terrain Slab		6,88E-01	2,14E-01	0,00E+00	0,00E+00	9,85E-03	3,90E-01	-2,71E-01	1,09E+00	6,14E-01	20913,51	kg		
Construction	Terrain Slab_New Insulation		2,78E-01	2,78E-01	0,00E+00	0,00E+00	0,00E+00	3,17E-01	-1,67E-01	5,95E-01	5,95E-01	483,55	kg		

Building Material	EPS for Ceilings / floors / basement / terrain slab	0	2,78E-01	2,78E-01	0,00E+00	0,00E+00	0,00E+00	3,17E-01	-1,67E-01	5,95E-01	5,95E-01	483,55	kg	0%	
Construction	Terrain Slab_Reused Constructions		4,10E-01	-6,35E-02	0,00E+00	0,00E+00	9,85E-03	7,31E-02	-1,04E-01	4,93E-01	1,95E-02	20429,96	kg		
Building Material	Steel reinforcement mesh	0	5,37E-02	4,84E-04	0,00E+00	0,00E+00	0,00E+00	5,36E-05	-3,09E-02	5,38E-02	5,38E-04	398,00	kg	99%	
Building Material	Concrete Elements C20/25	0	2,92E-01	2,21E-03	0,00E+00	0,00E+00	9,85E-03	0,00E+00	-3,51E-02	3,02E-01	1,21E-02	19920,00	kg	96%	
Building Material	EPS for walls and roofs 040	0	6,45E-02	-6,62E-02	0,00E+00	0,00E+00	0,00E+00	7,31E-02	-3,84E-02	1,38E-01	6,88E-03	111,96	kg	95%	
Group	Ventilation and cooling		4,32E-02	4,32E-02	2,95E-02	0,00E+00	4,44E-03	4,98E-05	-3,26E-02	7,72E-02	7,72E-02	18,46	kg		0%
Sub-group	Air handling unit		2,50E-02	2,50E-02	2,95E-02	0,00E+00	4,43E-03	4,98E-05	-2,31E-02	5,90E-02	5,90E-02	18,46	kg		
Building Component	Ventilation_AHU		2,50E-02	2,50E-02	2,95E-02	0,00E+00	4,43E-03	4,98E-05	-2,31E-02	5,90E-02	5,90E-02	18,46	kg		
Construction	Ventilation_AHU		2,50E-02	2,50E-02	2,95E-02	0,00E+00	4,43E-03	4,98E-05	-2,31E-02	5,90E-02	5,90E-02	18,46	kg		
Building Material	Decentralized AHU w. Heat-recovery 60 m3/h	1	2,50E-02	2,50E-02	2,95E-02	0,00E+00	4,43E-03	4,98E-05	-2,31E-02	5,90E-02	5,90E-02	18,46	kg	0%	
Sub-group	Ventilation shafts		1,82E-02	1,82E-02	0,00E+00	0,00E+00	9,79E-06	0,00E+00	-9,49E-03	1,82E-02	1,82E-02	30,30	kg		
Building Component	Ventilation_Shafts		1,82E-02	1,82E-02	0,00E+00	0,00E+00	9,79E-06	0,00E+00	-9,49E-03	1,82E-02	1,82E-02	30,30	kg		
Construction	Ventilation_Shafts		1,82E-02	1,82E-02	0,00E+00	0,00E+00	9,79E-06	0,00E+00	-9,49E-03	1,82E-02	1,82E-02	30,30	kg		
Building Material	Air ventilation duct (zinc coated steel plate)	0	1,82E-02	1,82E-02	0,00E+00	0,00E+00	9,79E-06	0,00E+00	-9,49E-03	1,82E-02	1,82E-02	30,30	kg	0%	
Group	Windows, doors, curtain walls		6,55E-02	3,70E-02	1,62E-01	0,00E+00	2,25E-01	6,36E-03	-8,62E-02	4,59E-01	4,30E-01	994,01	kg		31%
Sub-group	Doors		-4,32E-02	-7,18E-02	9,79E-02	0,00E+00	1,78E-01	6,56E-04	-3,52E-02	2,33E-01	2,04E-01	707,70	kg		
Building Component	Doors		-4,32E-02	-7,18E-02	9,79E-02	0,00E+00	1,78E-01	6,56E-04	-3,52E-02	2,33E-01	2,04E-01	707,70	kg		
Construction	Door_Exterior/Terrace_Front Door		1,18E-02	1,18E-02	2,43E-02	0,00E+00	1,23E-02	1,62E-04	-4,83E-03	4,85E-02	4,85E-02	83,41	kg		
Building Material	Triple-layer glaing	1	1,90E-02	1,90E-02	2,02E-02	0,00E+00	9,98E-04	1,61E-04	-9,24E-04	4,03E-02	4,03E-02	49,95	kg	0%	
Building Material	Screws and fasteners galvanized steel	1	1,05E-03	1,05E-03	1,05E-03	0,00E+00	0,00E+00	2,02E-07	-1,07E-03	2,11E-03	2,11E-03	1,50	kg	0%	
Building Material	Application paint emulsion, interior, wear	1	1,12E-04	1,12E-04	1,13E-04	0,00E+00	0,00E+00	6,41E-07	-9,25E-07	2,25E-04	2,25E-04	0,22	kg	0%	
Building Material	Chipboard	1	-4,12E-03	-4,12E-03	1,86E-03	0,00E+00	5,99E-03	0,00E+00	-2,77E-05	3,73E-03	3,73E-03	16,74	kg	0%	
Building Material	Timber pine (12% moisture / 10,7% H2O)	1	-4,23E-03	-4,23E-03	1,09E-03	0,00E+00	5,32E-03	0,00E+00	-2,81E-03	2,18E-03	2,18E-03	15,00	kg	0%	
Construction	Door_Exterior/Terrace_Glazed		2,36E-02	2,36E-02	4,85E-02	0,00E+00	2,46E-02	3,25E-04	-9,67E-03	9,71E-02	9,71E-02	166,81	kg		
Building Material	Triple-layer glaing	1	3,80E-02	3,80E-02	4,03E-02	0,00E+00	2,00E-03	3,23E-04	-1,85E-03	8,06E-02	8,06E-02	99,90	kg	0%	
Building Material	Screws and fasteners galvanized steel	1	2,11E-03	2,11E-03	2,11E-03	0,00E+00	0,00E+00	4,04E-07	-2,14E-03	4,21E-03	4,21E-03	3,00	kg	0%	
Building Material	Application paint emulsion, interior, wear	1	2,24E-04	2,24E-04	2,25E-04	0,00E+00	0,00E+00	1,28E-06	-1,85E-06	4,51E-04	4,51E-04	0,43	kg	0%	
Building Material	Chipboard	1	-8,25E-03	-8,25E-03	3,73E-03	0,00E+00	1,20E-02	0,00E+00	-5,54E-05	7,46E-03	7,46E-03	33,48	kg	0%	
Building Material	Timber pine (12% moisture / 10,7% H2O)	1	-8,45E-03	-8,45E-03	2,18E-03	0,00E+00	1,06E-02	0,00E+00	-5,62E-03	4,36E-03	4,36E-03	30,00	kg	0%	
Construction	Door_Interior_Glazed		-8,23E-03	-8,23E-03	2,51E-02	0,00E+00	3,32E-02	1,60E-04	-1,15E-02	5,02E-02	5,02E-02	146,98	kg		
Building Material	Screws and fasteners galvanized steel	1	3,09E-03	3,09E-03	3,09E-03	0,00E+00	0,00E+00	5,93E-07	-3,15E-03	6,18E-03	6,18E-03	4,40	kg	0%	
Building Material	Glass 3mm	1	1,29E-02	1,29E-02	1,30E-02	0,00E+00	0,00E+00	1,58E-04	0,00E+00	2,60E-02	2,60E-02	48,84	kg	0%	
Building Material	Application paint emulsion, interior, wear	1	3,29E-04	3,29E-04	3,30E-04	0,00E+00	0,00E+00	1,88E-06	-2,71E-06	6,61E-04	6,61E-04	0,63	kg	0%	
Building Material	Chipboard	1	-1,21E-02	-1,21E-02	5,47E-03	0,00E+00	1,76E-02	0,00E+00	-8,13E-05	1,09E-02	1,09E-02	49,10	kg	0%	
Building Material	Timber pine (12% moisture / 10,7% H2O)	1	-1,24E-02	-1,24E-02	3,20E-03	0,00E+00	1,56E-02	0,00E+00	-8,24E-03	6,39E-03	6,39E-03	44,00	kg	0%	
Construction	Door_Interior_Reused		-7,04E-02	-9,90E-02	0,00E+00	0,00E+00	1,07E-01	8,36E-06	-9,25E-03	3,70E-02	8,45E-03	310,50	kg		
Building Material	Screws and fasteners galvanized steel	0	4,91E-03	9,82E-04	0,00E+00	0,00E+00	0,00E+00	9,43E-07	-2,50E-03	4,91E-03	9,83E-04	7,00	kg	80%	

Building Material	Application paint emulsion, interior, wear	0	1,30E-03	1,30E-03	0,00E+00	0,00E+00	0,00E+00	7,41E-06	-5,35E-06	1,30E-03	1,30E-03	2,50	kg	0%	
Building Material	Chipboard	0	-5,69E-02	-7,75E-02	0,00E+00	0,00E+00	8,26E-02	0,00E+00	-1,91E-04	2,57E-02	5,15E-03	231,00	kg	80%	
Building Material	Timber pine (12% moisture / 10,7% H2O)	0	-1,97E-02	-2,38E-02	0,00E+00	0,00E+00	2,48E-02	0,00E+00	-6,56E-03	5,08E-03	1,02E-03	70,00	kg	80%	
Sub-group	Windows		1,09E-01	1,09E-01	6,41E-02	0,00E+00	4,73E-02	5,71E-03	-5,10E-02	2,26E-01	2,26E-01	286,31	kg		
Building Component	Windows 1500X1300		8,70E-02	8,70E-02	5,13E-02	0,00E+00	3,78E-02	4,57E-03	-4,08E-02	1,81E-01	1,81E-01	229,04	kg		
Construction	Window Frame wood/alu		3,87E-02	3,87E-02	0,00E+00	0,00E+00	3,53E-02	4,16E-03	-3,85E-02	7,81E-02	7,81E-02	101,84	kg		
Building Material	EPDM sealing for aluminium section	0	4,26E-03	4,26E-03	0,00E+00	0,00E+00	4,16E-03	4,16E-03	-4,49E-03	1,26E-02	1,26E-02	6,71	kg	0%	
Building Material	Window Sill, alu	0	1,71E-02	1,71E-02	0,00E+00	0,00E+00	7,50E-04	0,00E+00	-1,03E-02	1,78E-02	1,78E-02	7,84	kg	0%	
Building Material	Window Sill, wood	0	-1,39E-03	-1,39E-03	0,00E+00	0,00E+00	1,51E-02	0,00E+00	-6,08E-03	1,38E-02	1,38E-02	40,09	kg	0%	
Building Material	Window frame, alu	0	1,93E-02	1,93E-02	0,00E+00	0,00E+00	6,64E-04	0,00E+00	-1,18E-02	1,99E-02	1,99E-02	8,64	kg	0%	
Building Material	Window frame, wood	0	-5,32E-04	-5,32E-04	0,00E+00	0,00E+00	1,46E-02	0,00E+00	-5,82E-03	1,40E-02	1,40E-02	38,57	kg	0%	
Construction	Window Glazing		4,84E-02	4,84E-02	5,13E-02	0,00E+00	2,54E-03	4,11E-04	-2,35E-03	1,03E-01	1,03E-01	127,20	kg		
Building Material	Triple-layer glaing	1	4,84E-02	4,84E-02	5,13E-02	0,00E+00	2,54E-03	4,11E-04	-2,35E-03	1,03E-01	1,03E-01	127,20	kg	0%	
Building Component	Windows 985X1300		2,18E-02	2,18E-02	1,28E-02	0,00E+00	9,46E-03	1,14E-03	-1,02E-02	4,52E-02	4,52E-02	57,26	kg		
Construction	Window Frame wood/alu		9,67E-03	9,67E-03	0,00E+00	0,00E+00	8,82E-03	1,04E-03	-9,61E-03	1,95E-02	1,95E-02	25,46	kg		
Building Material	EPDM sealing for aluminium section	0	1,06E-03	1,06E-03	0,00E+00	0,00E+00	1,04E-03	1,04E-03	-1,12E-03	3,14E-03	3,14E-03	1,68	kg	0%	
Building Material	Window Sill, alu	0	4,27E-03	4,27E-03	0,00E+00	0,00E+00	1,88E-04	0,00E+00	-2,57E-03	4,45E-03	4,45E-03	1,96	kg	0%	
Building Material	Window Sill, wood	0	-3,47E-04	-3,47E-04	0,00E+00	0,00E+00	3,79E-03	0,00E+00	-1,52E-03	3,44E-03	3,44E-03	10,02	kg	0%	
Building Material	Window frame, alu	0	4,82E-03	4,82E-03	0,00E+00	0,00E+00	1,66E-04	0,00E+00	-2,94E-03	4,98E-03	4,98E-03	2,16	kg	0%	
Building Material	Window frame, wood	0	-1,33E-04	-1,33E-04	0,00E+00	0,00E+00	3,64E-03	0,00E+00	-1,45E-03	3,51E-03	3,51E-03	9,64	kg	0%	
Construction	Window Glazing		1,21E-02	1,21E-02	1,28E-02	0,00E+00	6,35E-04	1,03E-04	-5,88E-04	2,57E-02	2,57E-02	31,80	kg		
Building Material	Triple-layer glaing	1	1,21E-02	1,21E-02	1,28E-02	0,00E+00	6,35E-04	1,03E-04	-5,88E-04	2,57E-02	2,57E-02	31,80	kg	0%	
Group	Exterior walls		-7,91E-01	-9,67E-01	1,07E-01	0,00E+00	1,58E+00	3,17E-03	-3,94E-01	8,95E-01	7,18E-01	10260,88	kg		48%
Sub-group	Exterior walls		-7,91E-01	-9,67E-01	1,07E-01	0,00E+00	1,58E+00	3,17E-03	-3,94E-01	8,95E-01	7,18E-01	10260,88	kg		
Building Component	Exterior Walls Light		-7,91E-01	-9,67E-01	1,07E-01	0,00E+00	1,58E+00	3,17E-03	-3,94E-01	8,95E-01	7,18E-01	10260,88	kg		
Construction	Exterior Wall_Wooden Construction		-8,68E-01	-8,68E-01	8,20E-02	0,00E+00	1,26E+00	1,81E-03	-3,15E-01	4,76E-01	4,76E-01	4221,34	kg		
Building Material	Vapour barrier, Pe-foil (0,0002 m)	0	4,89E-03	4,89E-03	0,00E+00	0,00E+00	6,81E-03	0,00E+00	-3,36E-03	1,17E-02	1,17E-02	12,40	kg	0%	
Building Material	Gypsum fibre board (thickness 0,01 m)	0	3,84E-02	3,84E-02	0,00E+00	0,00E+00	0,00E+00	1,81E-03	0,00E+00	4,02E-02	4,02E-02	610,00	kg	0%	
Building Material	Construction Wood (15% moisture / 13% H2O)	0	-2,15E-01	-2,15E-01	0,00E+00	0,00E+00	3,12E-01	0,00E+00	-7,79E-02	9,68E-02	9,68E-02	899,30	kg	0%	
Building Material	Construction Wood (15% moisture / 13% H2O)	0	-6,95E-03	-6,95E-03	0,00E+00	0,00E+00	1,01E-02	0,00E+00	-2,52E-03	3,13E-03	3,13E-03	29,10	kg	0%	
Building Material	Plywood sheet	1	-2,03E-01	-2,03E-01	8,20E-02	0,00E+00	2,85E-01	0,00E+00	-1,79E-02	1,64E-01	1,64E-01	686,84	kg	0%	
Building Material	SteicoFlex 036	0	-2,55E-01	-2,55E-01	0,00E+00	0,00E+00	3,55E-01	0,00E+00	-1,36E-01	9,99E-02	9,99E-02	1160,50	kg	0%	
Building Material	Timber pine (12% moisture / 10,7% H2O)	0	-2,32E-01	-2,32E-01	0,00E+00	0,00E+00	2,92E-01	0,00E+00	-7,71E-02	5,98E-02	5,98E-02	823,20	kg	0%	
Construction	Exterior Wall_Wooden Construction w. brick		7,66E-02	-9,96E-02	2,52E-02	0,00E+00	3,16E-01	1,36E-03	-7,85E-02	4,19E-01	2,43E-01	6039,55	kg		
Building Material	Vapour barrier, Pe-foil (0,0002 m)	0	1,39E-03	1,39E-03	0,00E+00	0,00E+00	1,93E-03	0,00E+00	-9,54E-04	3,32E-03	3,32E-03	3,52	kg	0%	
Building Material	Gypsum fibre board (thickness 0,01 m)	0	1,11E-02	1,11E-02	0,00E+00	0,00E+00	0,00E+00	5,21E-04	0,00E+00	1,16E-02	1,16E-02	176,00	kg	0%	
Building Material	Construction Wood (15% moisture / 13% H2O)	0	-6,95E-02	-6,95E-02	0,00E+00	0,00E+00	1,01E-01	0,00E+00	-2,52E-02	3,13E-02	3,13E-02	290,95	kg	0%	
Building Material	Construction Wood (15% moisture / 13% H2O)	0	-3,79E-03	-3,79E-03	0,00E+00	0,00E+00	5,50E-03	0,00E+00	-1,37E-03	1,71E-03	1,71E-03	15,87	kg	0%	
Building Material	Plywood sheet	1	-6,23E-02	-6,23E-02	2,52E-02	0,00E+00	8,75E-02	0,00E+00	-5,51E-03	5,04E-02	5,04E-02	210,96	kg	0%	
Building Material	SteicoFlex 036	0	-8,14E-02	-8,14E-02	0,00E+00	0,00E+00	1,13E-01	0,00E+00	-4,36E-02	3,20E-02	3,20E-02	371,25	kg	0%	
Building Material	Cement mortar	0	9,91E-03	3,35E-03	0,00E+00	0,00E+00	0,00E+00	8,42E-04	0,00E+00	1,08E-02	4,19E-03	291,00	kg	61%	
Building Material	Facing brick	0	2,71E-01	1,02E-01	0,00E+00	0,00E+00	6,78E-03	0,00E+00	-1,90E-03	2,78E-01	1,08E-01	4680,00	kg	61%	

APPENDIX 6: GENERIC RENOVATION SYSTEM DATA FOR ENERGY PERFORMANCE CALCULATION

Infiltration Data

In the assignment for the miniproject it is stated that all dwellings are very leaky. In the renovation process we strive to improve the building envelope and building tightness.

In your calculations, you'll need to assume the infiltration flow rates, in order to reach certain level of confidence in your models.

Here are the assumptions to use in your models, which are based on following reference:

http://vbn.aau.dk/files/63094400/Beskrivelse_af_Casehuse.pdf

For the building **before renovation**: 0.45-0.6 l/s per m2

For the building **after renovation**: 0.1 l/s per m2

Internal Loads Data

The size of the internal loads is already defined in the miniproject, as following:

Energy neutrality including the energy use for appliances and lighting, which cannot be higher than 1725 kWh/year per apartment (it corresponds to a heat gain of 1.71 W/m^2)

Pay attention that this is a combined load, which includes the electricity and lighting. The only way this value can be fulfilled is if the daylight in your dwellings is good (DF= 2-3%).

Provided values are valid only for the renovated building, for the building before renovation, you shall use the values advised in BE10.

In BSim, however, it is not good enough to use an average value for the whole year, as we are working with higher level of detail. You can generate your own profiles, using an excel file, which can find in General course information, on Moodle: Person- VBV- og elprofiler_UK.xlsm. It is enough to assume 4 profiles when open sheet "El -profil", you only need to provide yearly energy use for your apartment and press CONVERT. Necessary profiles will be generated

Summer- weekday

Summer weekend

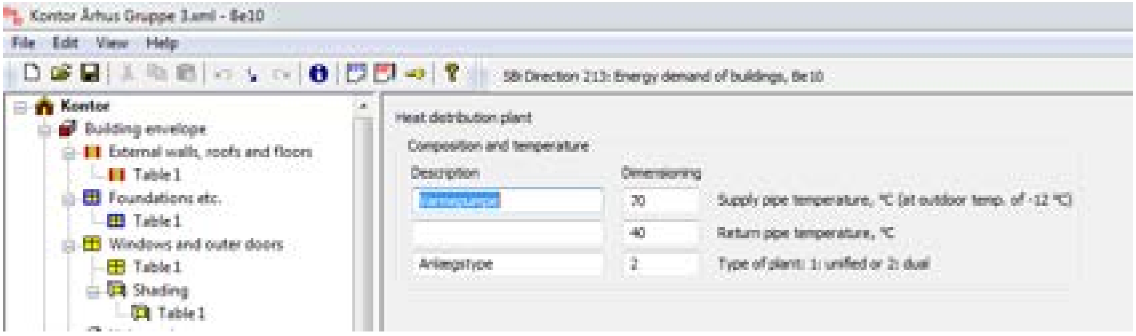
Winter weekday

Winter weekend

The rest of the information in this file can also be used for your BSIm models.

Systems Data

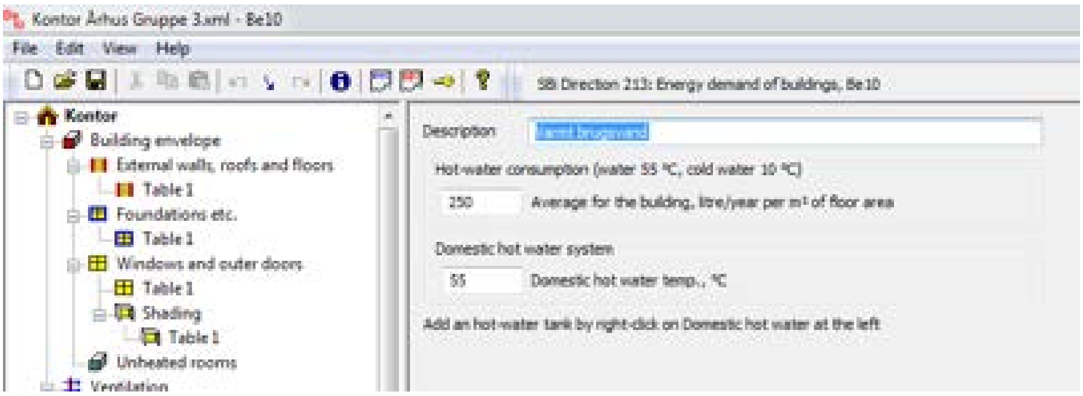
1. Heat distribution plant



Heating pipes
These are the pipes outside of heated space. Approximate length: 2*building length.
Loss =0.45 W/m
b=0.7

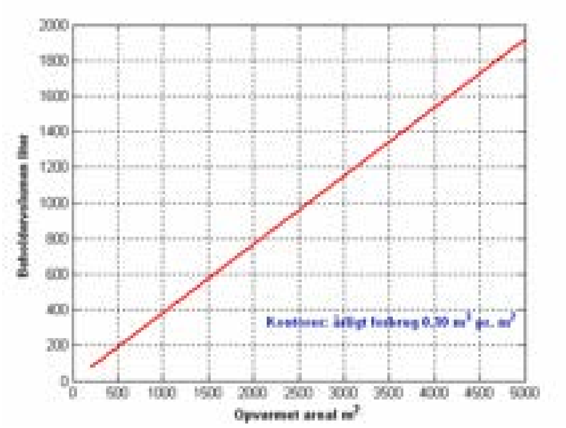
You do not need to define pumps in that section

2. Domestic hot water



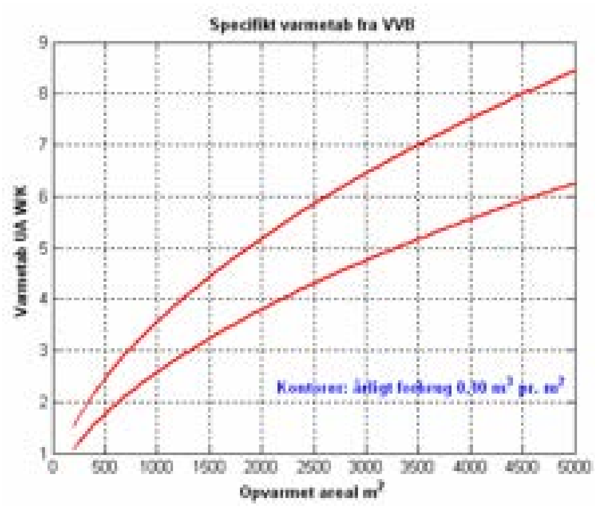
In the assignment you want to add a hot-water tank. Right click in the tree menu on “domestic hot water”. A menu will appear and you press “Add new tank”

Hot-water tank, size

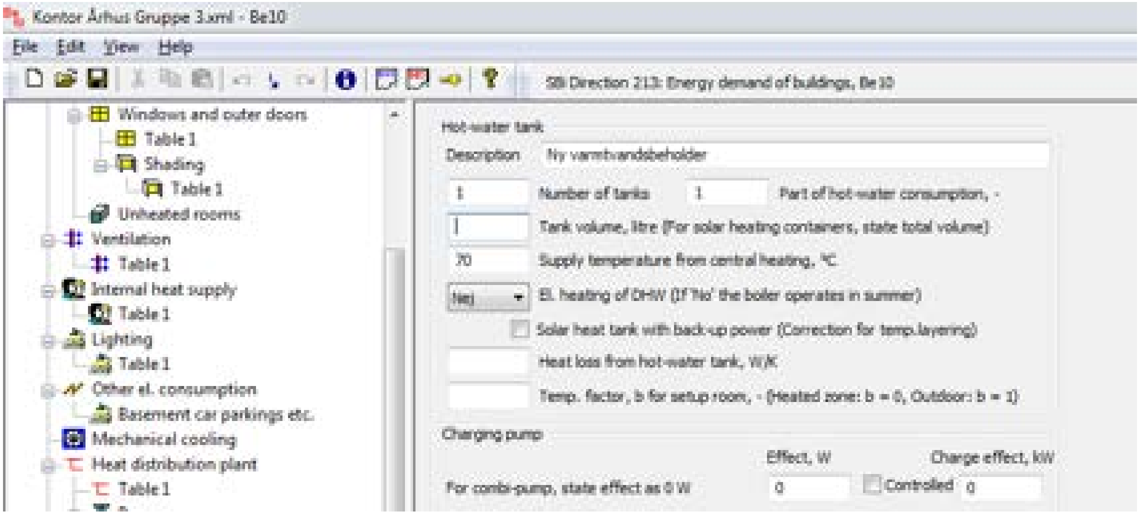


x-axes: Heated floor area, m2
y-axes: size of hot-water tank, in liters

Heat loss from hot-water tank



x-axes: Heated floor area, m2
y-axes: Heat loss, W/K
This is the data for an isolated hot-water tank, thus for an old system reasonable values will be at the upper curve, at least.



Heat loss from connector pipe to hot water tank

Pipe length= apx. 40 m
Loss =0.45 W/m
b=0

Circulation pump for domestic hot water

Number=2
Effect= 80W

Domestic hot water discharge pipes:

Loss =0.45 W/m
Here you must include length of all pipes for domestic hot water (distribution pipes and circulation pipes), including the pipes within the heated space.
Aproximate length of pipes within the heated space can be calculated as :
L=n*2*(e-1)*h
n- number of entry-pipes (upward going distribution pipe)
e – number of floors
h- height of 1 floor

Aproximate length of pipes outside the heated space can be calculated as : 2*length of the building

b=0.7 (within heated space)
b=0 (within unheated space)

APPENDIX 7: ENTRANCE TO ROW HOUSES
HOW TO LEVEL THE BASEMENT

Staircase to door
Terrace only in the back of the house
Parking on the side. Ground level.
*Volume is not integrated

Stair interrupted by elevated terrace.
*Requires ground movement.

Staircase in front of terrace
Terrace underground
No parking
*water drainage and cleaning could be problematic.
Circulation is compromised.

Staircaise in front of terrace
Terrace above the ground
Parking grouped outside the area.
Human scale paths with a width that allows access to cars on special occasions (health emergency, fire, moving out).
Path expands to give space to disposal station, playground, sitting areas, micro-gardens and other common facilities.

Starcaise entrance
Terrace on the back above the ground on top of garden.

Starcaise entrance
Terrace on the back above the ground blends with topography.
*Requires ground movement.

Starcaise entrance
Terrace on top of parking
Parking underground
*Requires significant amounts of space and water drainage could be problematic.

Starcaise entrance
Starcaise entrance
Terrace above the ground
Parking underground
*Requires significant amounts of space and water drainage could be problematic.

APPENDIX 8: DAYLIGHT ANALYSIS
10% RULE CALCULATION - BEDROOMS

Beregning 1

Type:	Forudsætninger						
Bolig	Beskrivelse	Gulvareal [m²]	Vinduesareal [m²]	Glasareal [m²]		Glas/gulv-forhold [%]	
Rumtype	St. 1 tv. i	72.9	17.2	10.4		14.2%	
Beboelsesrum	Kitchen	9.9	2.0	1.6		16.4%	

Vinduesegenskaber								LT-værdi		Vægtyk.		Omgivelser						Udhæng 1				
Nr.	Type	Antal	Orient. [°]	Hældn. [°]	Areal [m²]	Ff [-]	Glasareal [m²]	LT-værdi	F_{LT}	Vægtykk.	$F_{væg}$	Middel Afstand [m]	Middel Højde [m]	Vh, beregnet	Vh, overskriv	V_h	F_{omg}	Vinkel,α	Vinkel,β	Dybde [m]	Afstand [m]	V_{OH}, beregnet
1	V1	1	350	90	1.95	0.83	1.62	0.70	0.93	0.59	0.90						1.00					

Soverum	Bedroom south	11.4	2.0	1.6		14.2%	

Vinduesegenskaber								LT-værdi		Vægtyk.		Omgivelser						Udhæng 1				
Nr.	Type	Antal	Orient. [°]	Hældn. [°]	Areal [m²]	Ff [-]	Glasareal [m²]	LT-værdi	F_{LT}	Vægtykk.	$F_{væg}$	Middel Afstand [m]	Middel Højde [m]	Vh, beregnet	Vh, overskriv	V_h	F_{omg}	Vinkel,α	Vinkel,β	Dybde [m]	Afstand [m]	V_{OH}, beregnet
1	V1	1	170	90	1.95	0.83	1.62	0.70	0.93	0.46	0.98	16.6	4.3	15		15	0.95	79	74	1.00		

Soverum	Bedroom north	8.0	2.0	1.6		20.3%	

Vinduesegenskaber								LT-værdi		Vægtyk.		Omgivelser						Udhæng 1				
Nr.	Type	Antal	Orient. [°]	Hældn. [°]	Areal [m²]	Ff [-]	Glasareal [m²]	LT-værdi	F_{LT}	Vægtykk.	$F_{væg}$	Middel Afstand [m]	Middel Højde [m]	Vh, beregnet	Vh, overskriv	V_h	F_{omg}	Vinkel,α	Vinkel,β	Dybde [m]	Afstand [m]	V_{OH}, beregnet
1	V1	1	350	90	1.95	0.83	1.62	0.70	0.93	0.59	0.90						1.00					

Soverum	Bedroom south	8.0	2.0	1.6		20.3%	

Vinduesegenskaber								LT-værdi		Vægtyk.		Omgivelser						Udhæng 1				
Nr.	Type	Antal	Orient. [°]	Hældn. [°]	Areal [m²]	Ff [-]	Glasareal [m²]	LT-værdi	F_{LT}	Vægtykk.	$F_{væg}$	Middel Afstand [m]	Middel Højde [m]	Vh, beregnet	Vh, overskriv	V_h	F_{omg}	Vinkel,α	Vinkel,β	Dybde [m]	Afstand [m]	V_{OH}, beregnet
1	V1	1	170	90	1.95	0.83	1.62	0.70	0.93	0.46	0.98	16.6	4.3	15		15	0.95	82	47			

Soverum	2nd floor - north	9.8	2.0	1.6		16.5%	

Vinduesegenskaber								LT-værdi		Vægtyk.		Omgivelser						Udhæng 1				
Nr.	Type	Antal	Orient. [°]	Hældn. [°]	Areal [m²]	Ff [-]	Glasareal [m²]	LT-værdi	F_{LT}	Vægtykk.	$F_{væg}$	Middel Afstand [m]	Middel Højde [m]	Vh, beregnet	Vh, overskriv	V_h	F_{omg}	Vinkel,α	Vinkel,β	Dybde [m]	Afstand [m]	V_{OH}, beregnet
1	V1	1	350	90	1.95	0.83	1.62	0.70	0.93	0.59	0.90						1.00					

Soverum	2nd floor - south	11.2	3.7	2.3		20.3%	

Vinduesegenskaber								LT-værdi		Vægtyk.		Omgivelser						Udhæng 1				
Nr.	Type	Antal	Orient. [°]	Hældn. [°]	Areal [m²]	Ff [-]	Glasareal [m²]	LT-værdi	F_{LT}	Vægtykk.	$F_{væg}$	Middel Afstand [m]	Middel Højde [m]	Vh, beregnet	Vh, overskriv	V_h	F_{omg}	Vinkel,α	Vinkel,β	Dybde [m]	Afstand [m]	V_{OH}, beregnet
1	V2	1	170	90	3.73	0.61	2.28	0.70	0.93	0.46	1.00	16.6	4.3	15		15	0.95					

Soverum	2nd floor - south 2 w	14.7	3.7	2.3		15.4%	

Vinduesegenskaber								LT-værdi		Vægtyk.		Omgivelser						Udhæng 1				
Nr.	Type	Antal	Orient. [°]	Hældn. [°]	Areal [m²]	Ff [-]	Glasareal [m²]	LT-værdi	F_{LT}	Vægtykk.	$F_{væg}$	Middel Afstand [m]	Middel Højde [m]	Vh, beregnet	Vh, overskriv	V_h	F_{omg}	Vinkel,α	Vinkel,β	Dybde [m]	Afstand [m]	V_{OH}, beregnet
1	V3	2	170	90	1.86	0.61	1.13	0.70	0.93	0.46	0.95	16.6	4.3	15		15	0.95					

Source: MOE's 10% Dagslys, 2023. Based on Building regulation's guide on correction for 10% rule for daylight. Danish Transport, Construction and Housing Authority, 2019.

Korrektion		Resultat			Evaluering	
Resulterende korrektionsfaktor	Korrigeret glasareal [m²]	Korrigeret glas/gulv-forhold [%]	Krav [%]	Krav overholdt (Ja/Nej)	Nødv. glasareal for overholdelse [m²]	Relativ overholdelse af krav
0.99	10.21	14.0%	10.0%	Ja	9.06	40%
0.84	1.37	13.9%	10.0%	Ja	1.17	39%

		Udhæng 2								Fremspring, h			Fremspring, v			Afskærmning			Atrium				Rum-dybde		Ovenlys		Fl. vinduer		Samlet	
V_{OH}	$F_{udhæng}$	Jdstrækning [m]	Afstand [m]	Vα, beregnet	Vα, overskriv	Vinkel,α	Vinkel,β	V_{OH}	$F_{udhæng}$	V_{SF}	Vinkel,h	$F_{fremspring}$	V_{SF}	Vinkel,h	$F_{fremspring}$	Farve	Hældning	F_{AFS}	LT-værdi	F_{LT-tag}	Tagkonst.	F_{TAG}	Rumdybde	F_{RUM}	Ovenlys	$F_{Ovenlys}$	Unikke orient.	F_{FL}	Samlet korrektion, $F_{G,kor,i}$	Korrigeret glasareal [m²]
	1.00								1.00			1.00			1.00			1.00		1.00		1.00	3.4	1.00	Nej	1.00	1.00	1.00	0.84	1.37

0.79	1.28	11.2%	10.0%	Ja	1.45	12%

		Udhæng 2								Fremspring, h			Fremspring, v			Afskærmning			Atrium				Rum-dybde		Ovenlys		Fl. vinduer		Samlet	
V_{OH}	$F_{udhæng}$	Jdstrækning [m]	Afstand [m]	Vα, beregnet	Vα, overskriv	Vinkel,α	Vinkel,β	V_{OH}	$F_{udhæng}$	V_{SF}	Vinkel,h	$F_{fremspring}$	V_{SF}	Vinkel,h	$F_{fremspring}$	Farve	Hældning	F_{AFS}	LT-værdi	F_{LT-tag}	Tagkonst.	F_{TAG}	Rumdybde	F_{RUM}	Ovenlys	$F_{Ovenlys}$	Unikke orient.	F_{FL}	Samlet korrektion, $F_{G,kor,i}$	Korrigeret glasareal [m²]
34	0.90								1.00			1.00			1.00			1.00		1.00		1.00	3.7	1.00	Nej	1.00	1.00	1.00	0.79	1.28

0.84	1.37	17.1%	10.0%	Ja	0.95	71%

		Udhæng 2								Fremspring, h			Fremspring, v			Afskærmning			Atrium				Rum-dybde		Ovenlys		Fl. vinduer		Samlet	
V_{OH}	$F_{udhæng}$	Jdstrækning [m]	Afstand [m]	Vα, beregnet	Vα, overskriv	Vinkel,α	Vinkel,β	V_{OH}	$F_{udhæng}$	V_{SF}	Vinkel,h	$F_{fremspring}$	V_{SF}	Vinkel,h	$F_{fremspring}$	Farve	Hældning	F_{AFS}	LT-værdi	F_{LT-tag}	Tagkonst.	F_{TAG}	Rumdybde	F_{RUM}	Ovenlys	$F_{Ovenlys}$	Unikke orient.	F_{FL}	Samlet korrektion, $F_{G,kor,i}$	Korrigeret glasareal [m²]
	1.00								1.00			1.00			1.00			1.00		1.00		1.00	3.4	1.00	Nej	1.00	1.00	1.00	0.84	1.37

0.78	1.26	15.8%	10.0%	Ja	1.02	58%

		Udhæng 2								Fremspring, h			Fremspring, v			Afskærmning			Atrium				Rum-dybde		Ovenlys		Fl. vinduer		Samlet	
V_{OH}	$F_{udhæng}$	Jdstrækning [m]	Afstand [m]	Vα, beregnet	Vα, overskriv	Vinkel,α	Vinkel,β	V_{OH}	$F_{udhæng}$	V_{SF}	Vinkel,h	$F_{fremspring}$	V_{SF}	Vinkel,h	$F_{fremspring}$	Farve	Hældning	F_{AFS}	LT-værdi	F_{LT-tag}	Tagkonst.	F_{TAG}	Rumdybde	F_{RUM}	Ovenlys	$F_{Ovenlys}$	Unikke orient.	F_{FL}	Samlet korrektion, $F_{G,kor,i}$	Korrigeret glasareal [m²]
34	0.89								1.00			1.00			1.00			1.00		1.00		1.00	3.7	1.00	Nej	1.00	1.00	1.00	0.78	1.26

0.84	1.37	13.9%	10.0%	Ja	1.16	39%

		Udhæng 2								Fremspring, h			Fremspring, v			Afskærmning			Atrium				Rum-dybde		Ovenlys		Fl. vinduer		Samlet	
V_{OH}	$F_{udhæng}$	Jdstrækning [m]	Afstand [m]	Vα, beregnet	Vα, overskriv	Vinkel,α	Vinkel,β	V_{OH}	$F_{udhæng}$	V_{SF}	Vinkel,h	$F_{fremspring}$	V_{SF}	Vinkel,h	$F_{fremspring}$	Farve	Hældning	F_{AFS}	LT-værdi	F_{LT-tag}	Tagkonst.	F_{TAG}	Rumdybde	F_{RUM}	Ovenlys	$F_{Ovenlys}$	Unikke orient.	F_{FL}	Samlet korrektion, $F_{G,kor,i}$	Korrigeret glasareal [m²]
20	1.00								1.00			1.00			1.00			1.00		1.00		1.00		1.00	Nej	1.00	1.00	1.00	0.84	1.37

0.80	1.83	16.3%	10.0%	Ja	1.39	63%

		Udhæng 2								Fremspring, h			Fremspring, v			Afskærmning			Atrium				Rum-dybde		Ovenlys		Fl. vinduer		Samlet	
V_{OH}	$F_{udhæng}$	Jdstrækning [m]	Afstand [m]	Vα, beregnet	Vα, overskriv	Vinkel,α	Vinkel,β	V_{OH}	$F_{udhæng}$	V_{SF}	Vinkel,h	$F_{fremspring}$	V_{SF}	Vinkel,h	$F_{fremspring}$	Farve	Hældning	F_{AFS}	LT-værdi	F_{LT-tag}	Tagkonst.	F_{TAG}	Rumdybde	F_{RUM}	Ovenlys	$F_{Ovenlys}$	Unikke orient.	F_{FL}	Samlet korrektion, $F_{G,kor,i}$	Korrigeret glasareal [m²]
34	0.90								1.00			1.00			1.00			1.00		1.00		1.00		1.00	Nej	1.00	1.00	1.00	0.80	1.83

0.77	1.74	11.8%	10.0%	Ja	1.92	18%

		Udhæng 2								Fremspring, h			Fremspring, v			Afskærmning			Atrium				Rum-dybde		Ovenlys		Fl. vinduer		Samlet	
V_{OH}	$F_{udhæng}$	Jdstrækning [m]	Afstand [m]	Vα, beregnet	Vα, overskriv	Vinkel,α	Vinkel,β	V_{OH}	$F_{udhæng}$	V_{SF}	Vinkel,h	$F_{fremspring}$	V_{SF}	Vinkel,h	$F_{fremspring}$	Farve	Hældning	F_{AFS}	LT-værdi	F_{LT-tag}	Tagkonst.	F_{TAG}	Rumdybde	F_{RUM}	Ovenlys	$F_{Ovenlys}$	Unikke orient.	F_{FL}	Samlet korrektion, $F_{G,kor,i}$	Korrigeret glasareal [m²]
34	0.90								1.00			1.00			1.00			1.00		1.00		1.00		1.00	Nej	1.00	1.00	1.00	0.77	1.74