A TALE OF LAYERS

EXPLORING ADAPTABLE SKINS WITHIN A CRADLE TO CRADLE CONTEXT

OMAR ZALLOUM

Chalmers University of Technology
Department of Architecture and Civil Engineering

Examiner: Paula Femenias
Supervisor: Magnus Persson

Author: Omar Zalloum
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Chalmers University of Technology
Department of Architecture and Civil Engineering
Master's Program Architecture and Planning Beyond Sustainability

Supervisor: Magnus Persson
Examiner: Paula Femenias

omar.zalloum.93@gmail.com

CHALMERS
UNIVERSITY OF TECHNOLOGY

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ABSTRACT

Due to the dynamic lifestyle we are currently living, our needs are changing accordingly. However, the majority of the buildings are not designed to adapt with the continuous changes. The buildings' capacity of change is limited to the rigidity of its walls and the interlocked building systems; causing more demolition, loss of assets, materials and historical values. Moreover, the physical adaptability of buildings, such as renovation and expansion, usually requires high costs, time, and labor work.

This thesis research question is 'How can the design of the skin make buildings more adaptable and respond to the changing demands in a sustainable way?' It is an exploration to design the skin as layers that can be disassembled for more adaptability and easy materials reclamation. The aim is to develop some design strategies that architects can follow to create adaptable skins, and to create a design proposal based on the design strategies. Research for design is the main method of this thesis. Relevant topics like buildings adaptability, systems separation, materials consumption from a Cradle to Cradle perspective, and Design for Disassembly are explored to create general design strategies that can be used in different contexts.

The context of the thesis is Ronneby municipality, south of Sweden, where it has adopted Cradle to Cradle as a method for its sustainable development and change towards Circular economy. The design proposal is applied to the currently on-going extension project of Snäckeback School in Ronneby. Also, the role of the architect in the design process and the change towards Circular economy is discussed.

The adaptability of the buildings' skin system is crucial as it holds, with the structural system, the higher value of the buildings and determine the buildings' capacity of change. The concept of the design proposal is to separate the building systems and to design the skin system as layers that can be disassembled, allowing buildings to be seen as 'easy-to-change' products according to the different situations. With the freedom this concept provides for the different skin layers, waste of materials is minimized and even buildings can become a source of materials. One extra advantage is optimizing the buildings energy performance by altering the insulation layer, as presented in the design proposal, to create variable U-Value skins; since the optimal U-Value varies for cold climates and buildings with a high heat load. The collaboration among the different actors in the design process like architects, material manufacturers, and entrepreneurs is crucial since the early design stages to achieve more circular products and shift towards Circular economy.

Keywords: Skin system, Circular economy, Adaptability, Cradle to Cradle, Design for Disassembly, Ronneby.

THANK YOU

Without the help of others, I wouldn't have reached here. I would like to thank every person who contributed to this thesis for their valuable inputs. I would like to thank my examiner Paula and my supervisor Magnus for their efforts and time. Special thanks to the municipality of Ronneby and Cefur for their kindness and cooperation. I appreciate the endless support from my family and friends that cannot be described in words. And finally, I am grateful to the Chalmers Foundation for awarding me the Avancez scholarship that helped me do my master's studies.

ABOUT THE AUTHOR

Omar Zalloum graduated from the University of Jordan in 2015 with the Bachelor's degree in Architecture Engineering. He worked as a junior architect for more than one year in Amman before starting his master's studies focusing on sustainable architecture.

PERSONAL MOTIVATION

From my childhood, I remember when my family and I were frequently going to a construction site. It was our dream house under construction. We were just dreaming about the day we move in. It is not the perfect house, but we had an emotional bond to each piece of stone in the building.

Just a few years of inhabiting the house, some construction works took place. We added pitched roofs on the terraces to have better protection from the summer sun and the winter rain. We maintained the roof parapets because they let rainwater in. And when I started going to Architecture school, we glazed the terrace connected to my room and made it my working studio. My two elder brothers got married so we decided to take advantage of the rarely-used basement and divide it into two apartments for them.

The two apartments became small as they got children. There was a need for an extra room. One of the apartments had the chance to expand from one side and add an extra toilet as well. The other was stuck among a retaining wall, the adjacent apartment, and two outer walls of concrete and stone. The only feasible solution was to rearrange the interior partitions. However, the layout of the apartment was hard to adjust that lead to a temporary solution of adding a wall creating a room with bad daylight and ventilation.

Despite the fact that the regulations allowed for more floors and wider footprint than the already built, the building itself did not allow us to change. The way it was designed and constructed generated rigid, inflexible walls made the adaptability of the building limited and highly expensive. And the structural system cannot tolerate extra floors on top. Our house has been in a continuous state of change through twelve years, but at this point, it reached a dead end of adaptation.

That made me wonder, what would have been done to make this building living, growing, and adapting to us as much as possible? How can the building at least keep its economical value if it comes to this point? In this thesis, I am trying to see buildings not as artifacts freezing in time once they are built, rather than a continuous tale of layers that facilitate change.

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1 INTRODUCTION

BACKGROUND & CONTEXT

Buildings change regularly

Location of Ronneby

Almost all buildings are in continuous change. The decay of building components is one of the reasons to change, but it can be to adapt to the changing needs or even fashion. Responding to the reasons of change is crucial to allow the built environment serve its purpose and satisfy the needs. However, in most cases, the buildings' capacity of change is limited to the rigidity of its walls and the interlocked building systems making change a challenging step to do.

With the scarcity of resources on the planet and the current overconsumption in the linear manners, there is a need to adopt new ideas to tackle these problems. What if buildings' skins are designed in a way that allows change to happen easily? Disassembling layers and recycle instead of demolishing and disposing, being more responsible towards the natural resources instead of being a burden.

Architects play a major role by their design decisions. But designing and constructing the built environment is a complex multi-disciplinary task that requires collaboration.

CONTEXT:

Ronneby municipality, in Blekinge län, Sweden. Ronneby has a vision to become an internationally renowned, innovative promoter of sustainable development in business and society, with Cradle to Cradle as a method. It has already some Cradle to Cradle inspired projects mainly in the educational facilities. This thesis is relating to the project of Snäckeback school , which is being designed during the writing of the thesis.

THESIS OVERVIEW

	THEORY	PRACTICE
Problem area	Buildings continuous change and the corresponding waste of materials. Shifting towards Circular design in architecture.	Buildings limited physical adaptability. Implementation of circular design in the skin systems.
Research area	Cradle to Cradle view towards materials and Circular design as a potential solution. The design process and the contribution of different stakeholders.	Creating the assemblies and the connections between the elements.

PURPOSE

- To develop a set of design strategies that architects can follow to create skin that can be disassembled for more adaptability and easy materials reclamation.

- To create a design proposal of adaptable skins for Snäckeback school extension based on the design strategies.

-To explore the role of the architect in the process of change towards circular economy, where the Snäckeback school is considered as an example.

RESEARCH QUESTIONS

How can the design of the skin make buildings more adaptable and respond to the changing demands in a sustainable way?

- How can Cradle to Cradle influence the choice of the skin materials and minimize materials waste?

- How can designing the skin as layers influence the insulation layer and contribute for more optimized building energy performance?

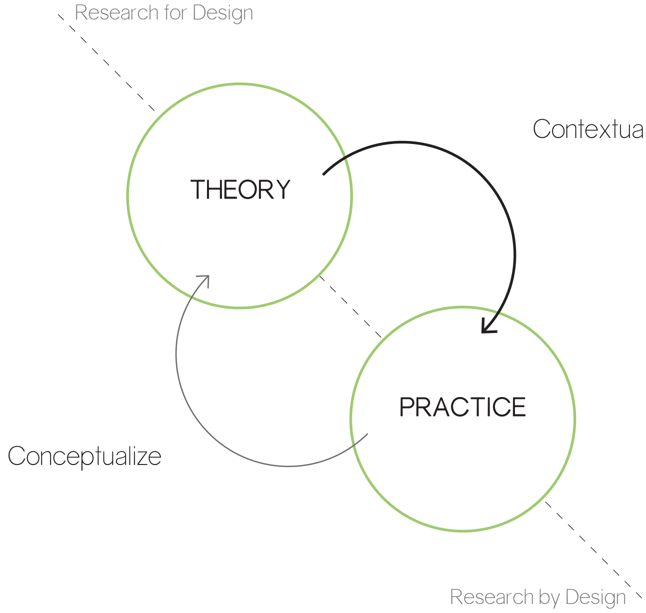
RESEARCH QUESTIONS RELATED TO THE CONTEXT

- What is the process of buildings design in Ronneby and how can it promote the application of Cradle to Cradle in architecture?

-What is the architect's contribution in changing towards circular economy?

METHODS

The main method used is Research for Design. Relevant theories and examples like buildings adaptability, systems separation, materials consumption from a Cradle to Cradle perspective, and Design for Disassembly are explored to define the theoretical framework through readings, case studies, and own-interpretations. Then to develop a set of design strategies for adaptable skins. The design strategies are used in the design proposal. Research by Design is used during the design process to reflect on the design strategies developed in iterative way.



The main Method followed in this thesis

SUPPORTIVE METHODS

Literature studies: of selected books to gain knowledge within related topics to extract conclusions and design strategies.

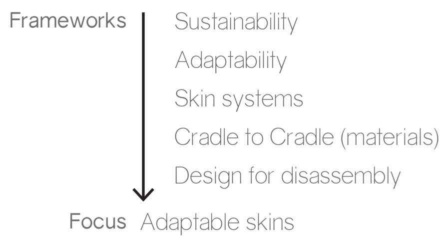
Case studies: related to the reading process to learn from practical examples.

Study trips: To Ronneby city, to see and have better understanding of the site and context. To the Netherlands, was done before the thesis, However it inspired the thesis.

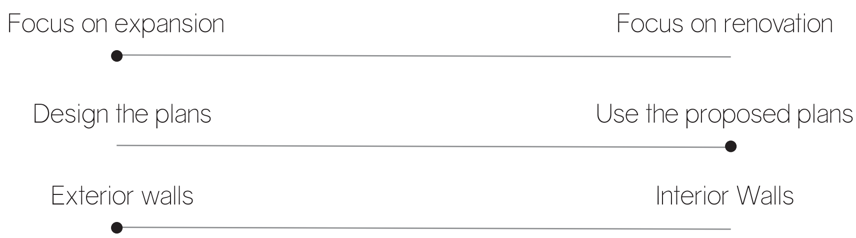
Interviews: with professionals in related topics (check page 71).

DELIMITATION

The main focus of this thesis is the physical aspect of adaptable skins and the relation to the materials of the skin. Therefore, the view of Cradle to Cradle towards materials is explored in the research and in the design. The adaptability of the skin system is considered because it can open more possibilities for the building's overall adaptability, and because the skin design process is related more to the architects (Check pages 22, 34).The project of Snäckeback school is taken as an example to contextualize and implement the design proposal in a Cradle to Cradle driven municipality. The thesis uses the proposed plans by the architect in Ronneby as a base for the skins design. The investigations about pedagogy are very limited as it is not the main focus.



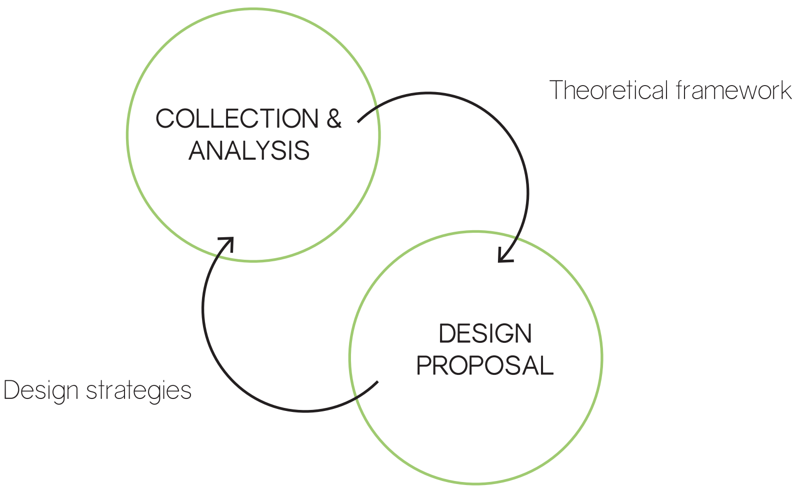
Delimitation diagram



Focus areas in the design proposal of Snäckeback school

DESIGN PROCESS

An iterative process between collection, analysis and design is followed to develop both the design strategies and the design proposal. The outcome of the design is presented in Chapter 4 (Design proposal).



GLOSSARY

CIRCULAR ECONOMY:
Unlike the traditional linear model of ‘extract, use, and discard’, Circular economy is a restorative and regenerative model as it aims to create ‘closed loops’ of products and services with less or no waste.

CRADLE TO CRADLE® (C2C):
A philosophy that does not accept the human existence to be negative on the environment rather than encouraging practices that leave no pollution or waste, and contribute positively in the planet. Cradle to Cradle® is a trademark of McDonough Braungart Design Chemistry, LLC.

MATERIAL RECLAMATION:
When a material is detached from the building to be reused or recycled.

SKIN SYSTEM:
The exterior walls or the facades of a building that create that creates separates the indoor from the outdoor and creates ‘the climate shell’.

U-VALUE:
A measure of the heat transmission through a building part or a given thickness of a material. The lower values indicating better insulating properties.

READING INSTRUCTIONS

As mentioned in the ‘methods’, the literature overview is not only extracts from literature, it also includes conclusions from study visits, case studies and the author’s interpretations, which are presented in both written or graphical form. The chapters are divided according to their focus:

CHAPTER 2: THEORETICAL FRAMEWORK
Summary of the author’s readings and reflections for better understanding of the topic and seeking the thesis general research question. Summarized at the end of the chapter and includes the design strategies developed.

CHAPTER 3: THE CONTEXT
Exploring the municipality of Ronneby and their process in applying C2C as a method for their sustainable development. It includes information about the Snäckeback school project from the municipality’s perspective as well.

CHAPTER 4: DESIGN PROPOSAL
It includes the author’s contribution to the Snäckeback school project.

CHAPTER 5: DISCUSSION & CONCLUSIONS
It includes comments and reflections on both the topic of the thesis a as a whole and the specific context of Ronneby and the Snäckeback school project.

-All images and diagrams, , illustrations and images are by the author unless a source mentioned.

2 THEORETICAL FRAMEWORK

CHANGE & ADAPTABILITY

BUILDINGS CHANGE & ARCHITECTS ROLE

Change is constant in everything; in the solid rocks by the sea and in the delicate plant leaves. The rocks crush into smaller particles in thousands of years and leaves grow and fall within months. And so is architecture changing as Brand (1994, p.2) mentioned that "Architecture, we imagine, is permanent. And so our buildings thwart us. Because they discount time, they misuse time." Change in buildings is continuous throughout their lifetime. It is a natural thing to happen as they are a part of a continuous changing world. Change of needs, usage, and developing technology.

Future is uncertain and the timing when change is needed can be unpredictable. However, there are many drivers that can rise the necessity of change. Schmidt III and Austin (2016) mentioned some of the change drivers.

Physical	Economic	Functional
Weathering	Market fluctuations	Ownership/ user needs
Wear and tear	Budget shifts	Organizational expansion/ shrinkage
Vandalism	Ownership	Type of work
Incompatibility factors	Reduction in lease lengths	Quality of workplace
	Global competition	Flexible employment arrangement

Technological	Social	Legal
Information technologies	Fashion	General legislation
Construction methods	Demographics	Building ordinances
Material performance	Lifestyle – mobility, density	Construction standards
Product life cycles	Social agendas, trends	Government grant incentives
Transport facilities	Skills	Planning
		Environmental controls

Change drivers
(Based on Schmidt III and Austin, 2016).

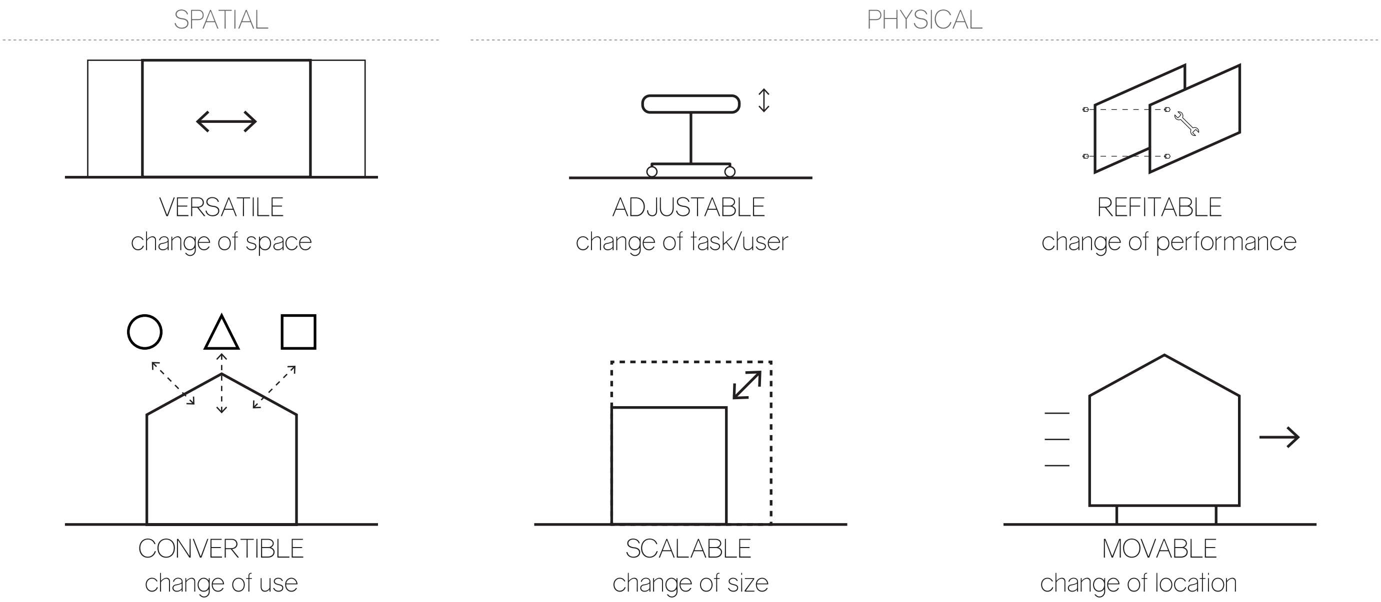
Despite that buildings are changing, almost no buildings adapt well. They're designed not to adapt; also budgeted and financed not to, constructed not to, even remodeled not to. But all buildings (except monuments) adapt anyway, however poorly, because the usages in and around them are changing constantly (Brand, 1994, p.2). The capacity for buildings to respond to these changes are highly determined through design decisions early on resulting in the building's design structure – what it is, how it is constituted (Baldwin et al., 2000). The architect's role in allowing buildings to respond to the change is challenging and sometimes hard to achieve. It is because of the complexity of design for the current circumstances and considering the uncertain various future scenarios. Time as a design contingency relies on placing architecture in context, making it susceptible to its temporal reality and biggest fear - change. Designers tend to ignore these temporal aspects focusing on an aesthetic fixation and functional performance, freezing out time in pursuit of a static idealized object of perfection (Schmidt III, et al. ,2010, p.2).

ADAPTABILITY DEFINITION

'The capacity of a building to accommodate effectively the evolving demands of its context, thus maximizing value through life'. (Schmidt III et al., 2010,p.3)
This definition does not only focus on changing to satisfy the evolving demands, rather than it shows the importance of seeing the consequences of the change in a longer perspective; to maximize the value through life. Therefore, achieving higher level adaptability and sustainability.

ADAPTABILITY TYPOLOGIES

Schmidt III and Austin (2016) proposed six adaptability types and defined them as a classification for a particular change objective that shares a subset of characteristics and tactics under the umbrella of adaptability.



Adaptability types
(Based on Schmidt III and Austin, 2016).

The spatial types – versatile and convertible were found to be much more prevalent than physical types. In addition, spatial and physical types of adaptability behave differently – e.g. spatial types are spread through-out the building layers, while physical types are more concentrated in one or two building layers.

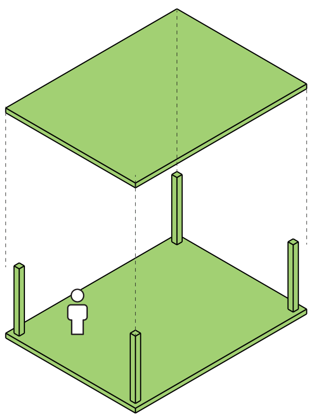
BUILDINGS AS SYSTEMS

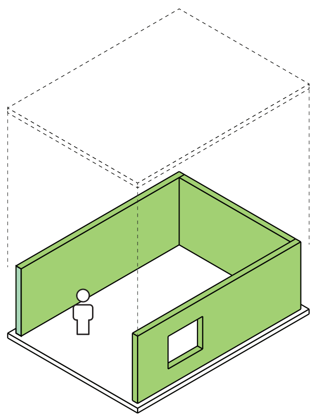
As a way to explore how can architects add the dimension of time to their designs and promote adaptability, it is essential to understand how the buildings function and what are the components that make the whole.

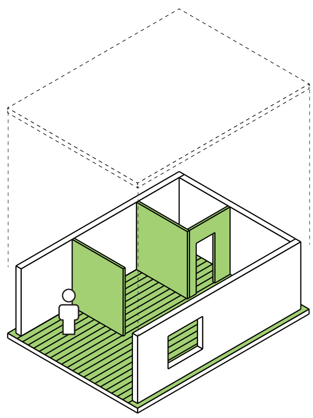
A building is no longer a single object, but a combination of systems, each system with its own design process, production process and lifetime (Leupen, 2005). They can be seen as a combination of four main systems. Where each system serves a specific function; A structural system that makes the building stand and acts as a skeleton, a skin system that creates a climate shell, a space plan system that shapes the interior spaces, and a services system that contributes to makes a building comfortable and functional.

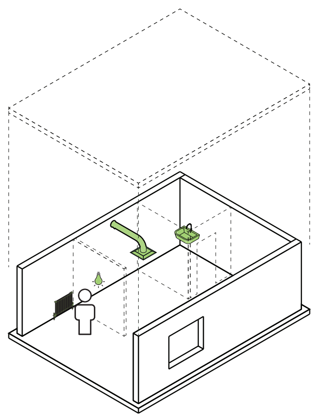
The building systems, in many cases, are combined and interlocked with each other. Structural systems, for instance, can also be parts of the skin system and services systems can be part of the skin system as well. This fusion makes change complicated and expensive and some cases impossible.

Furniture and equipment can also be seen as the fifth system, but it is not directly affecting the building. Moreover, the architect's role in this system is limited to a great extent compared to the other systems in the building. The architect can contribute by proposing a furniture layout, but does not have to choose the items directly and decide their qualities unless assigned for this task.


1. Structural system

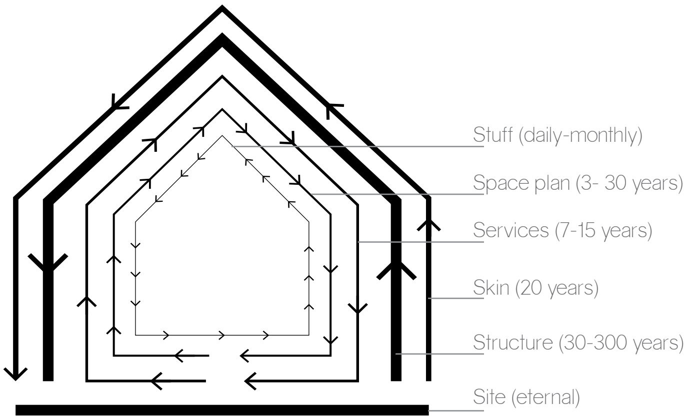

2. Skin system


3. Space plan system


4. Services system

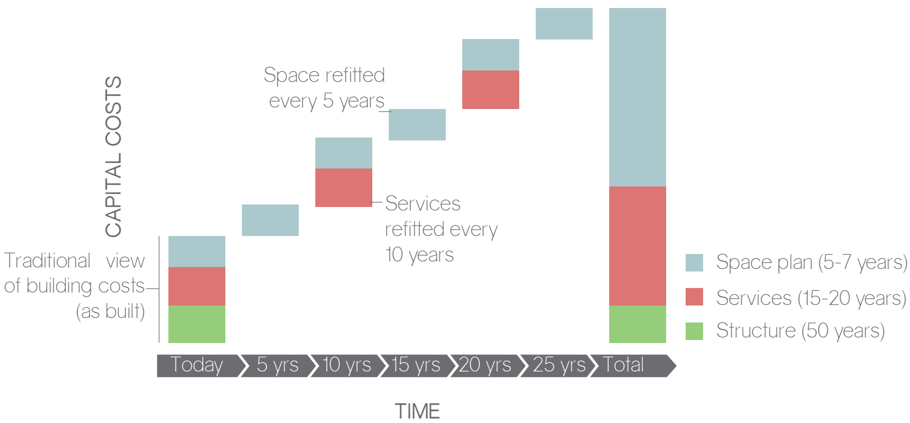
SLOW VS. QUICK

The layers concept acknowledges that building elements have different lifespans that should be constructed distinctly. The term was coined by Frank Duffy who argued that buildings should not be measured in material terms, but in terms of time (Schmidt III and Austin, 2016, p.36).



Shearing layers of change (Brand,1994).

Brand (1994) suggests that slow changing components control and constrain the quick changing ones. Site dominates the structure, which dominates the skin, which dominates the services which dominate the space plan, which dominates the stuff. Meaning that in the long term, it is the structure and the skin that have the biggest role in the determining the capacity of change; whether as a facilitator or as an obstacle. Therefore, designing them with qualities that can open the possibilities to change is essential. However, building systems in many cases are interlocked and combined with each other, where if one system, or an element, needs maintenance or fails, it leads to change in the other well-performing systems. The more layers are connected, the greater difficulty and cost of adaptation.



Cumulative capital costs over time.
Duffy and Henney (1989)

SYSTEMS SEPARATION

A strategy called ‘System Separation’ developed by the Office for Real Estate and Public Buildings of the Swiss Canton of Bern has a high potential in increasing the buildings’ capacity of change and reducing the associated costs. It sees the buildings according to their hierarchy of lifespans and categorizes the building into a Primary System including the structure and the skin; a Secondary system including the internal elements like building services; and a Tertiary System consisting of equipment and furniture.

Geiser (2004) clarified the systems as the following:

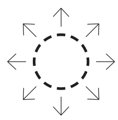
THE PRIMARY SYSTEM
must be as open as possible for the different (and unforeseeable) activities in the secondary system, so the scope for adaptation must be as wide as possible. It must be assumed that the primary system will accommodate various secondary systems in different cycles during its service life.

THE SECONDARY SYSTEM
Subsequent install-ability, disassembly and reassembly are the key focal points for this system level.

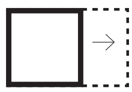
THE TERTIARY SYSTEM
is a short-term investment that can be changed without any major structural work. It is subject to rapid change and is least predictable.

PRINCIPLES OF SYSTEM SEPARATION (Based on Macchi,2017).

Replacement or modification of shorter life elements does not affect or damage those of greater durability.



Flexibility, assured by the Primary and Secondary Systems being designed for openness.



Area-availability, assured by the Primary System being designed in such a way that the building can be extended to the maximum over time.

Design with the buildings systems lifespans in consideration.

EXAMPLE: INO- UNIVERSITY HOSPITAL OF BERN
SWITZERLAND

Purpose of example: The first project guided by System Separation.
Building scale: Large.
Location: Bern, Switzerland
Completed 2012

Geiser (2004) mentioned that the west surgery wing was not planned for variable use. It was tailor-made for the use concept envisaged at the time of its construction and it was no longer meeting the modern standards of building services and safety and major renovation was needed. However, despite the fact that the structural system was intact, the building was impossible to adapt to the changing needs because the dividing walls between the operating theatres were designed as load-bearing walls. Consequently, the building was demolished.

The west surgery department Change timeline

The planning process of the project was divided according to the System Separation hierarchy. An international competition was held for the planning and design of the Primary System (building structure and shell) involving architects not necessarily specialized in hospital planning. It was concerned instead with the urban and architectural challenge of creating a robust Primary system- attractive, well positioned and designed for openness. The subsequent competition for the Secondary System – in other words, for the interior organization fit-out – was open exclusively to highly experienced hospital planners. The Tertiary System designers were directly appointed on the basis of their expertise, as were the project managers (Macchi, 2017).

Primary system designers:
HKK Architekten Partner, Hegi Koch Kolb + Partner Architekten, and Kamm Architekten.
Secondary system designers:
Itten+Brechbühl AG.
Tertiary System designers:
HWP Planungsgesellschaft.

Interior view
© Sandra Stampfli, Bern / by courtesy of Itten+Brechbühl AG, Switzerland (www.ittenbrechbuehl.ch

The structural system is made concrete frame that has columns on a grid of 8.4 x 8.4 m2 with zone of 3.6 x 3.6 m2 in the center of each structural bay that can be knocked out to introduce daylight, for vertical access, or to make visual connections. INO has become a pioneering medical institution and because of its adaptability can continue to retain its cutting edge (Macchi, 2017).

EXAMPLE: HSB LIVING LAB

Purpose of example: Demountable facade components
Building scale: Medium
Location: Gothenburg, Sweden
Years of Commission 2013-2023
Architects: Tengbom

Exterior view

HSB Living Lab is a research and demonstration arena which also includes homes for students and guest researchers. The house is built in modules and on a temporary construction permit. Then after ten years, the whole building will be moved elsewhere (HSB,2015). The structure is based on modules to ensure flexibility of the structure and facilitate mounting and dismounting.
12 demountable components 1.5x3m were integrated on the exterior walls to allow for different wall assemblies testing. They are designed to be taken out from the interior to the exterior but never been done so far. A change happened only in the cladding layer to mount some PV panels as Shea Hagy, the Project manager, mentioned in an interview (2018).

DECOUPLE STRUCTURAL ELEMENT FROM NONSTRUCTURAL ELEMENTS

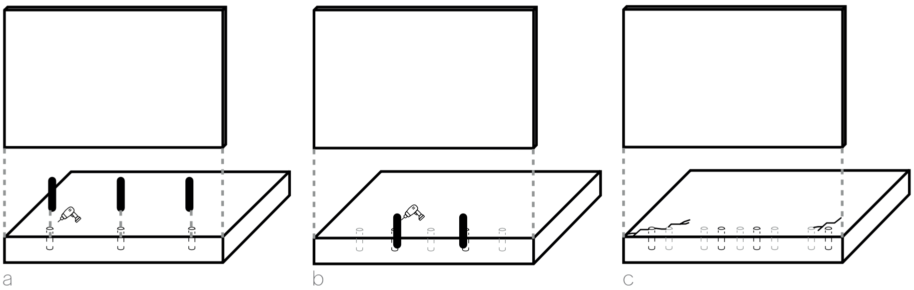


Figure 1 **Degradation of structural elements** Inspired from the interview with Shea Hagy (2018).

a. Connecting the skin to the structural element for the first fixing after making penetrations in the structural element.

b. Creating new penetrations in the structural element to fix the changed skin to ensure stability.

c. After multiple changes, the structural element degrades due to many perforations.

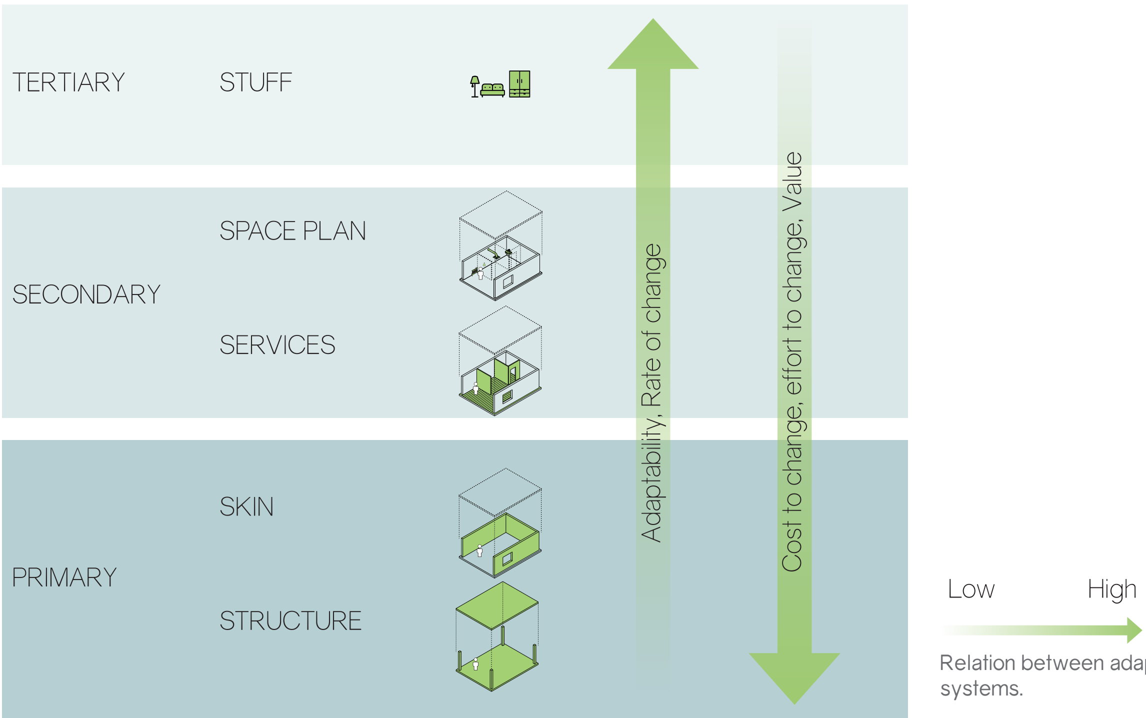
It is important to avoid connection methods that degrade the quality of the structural elements with the repetition of mounting and dismounting the skin. For instance, if penetrations are made in the structural element for each time the skin is changed, the structural elements will degrade over time because of the multiple penetrations.

CHALLENGING THE CONVENTIONAL CONSTRUCTION INDUSTRY

The design of HSB Living Lab challenged the conventional construction industry to estimate and implement the new proposal. Therefore, increased the process time and cost to ensure that the project will be economically feasible for the different stakeholders despite that the building technology used is already existing.

ADAPTABILITY AND BUILDING SYSTEMS

This diagram shows the relation between the building systems and the level of adaptability. One important aspect of adaptability in buildings is to have the adaptability qualities embedded in all the building systems. Especially to the primary systems as they have the final call in critical situations whether the whole building will adapt-physical adaptability, or come to an end. The primary system is the base that should be solid and durable yet adaptable.



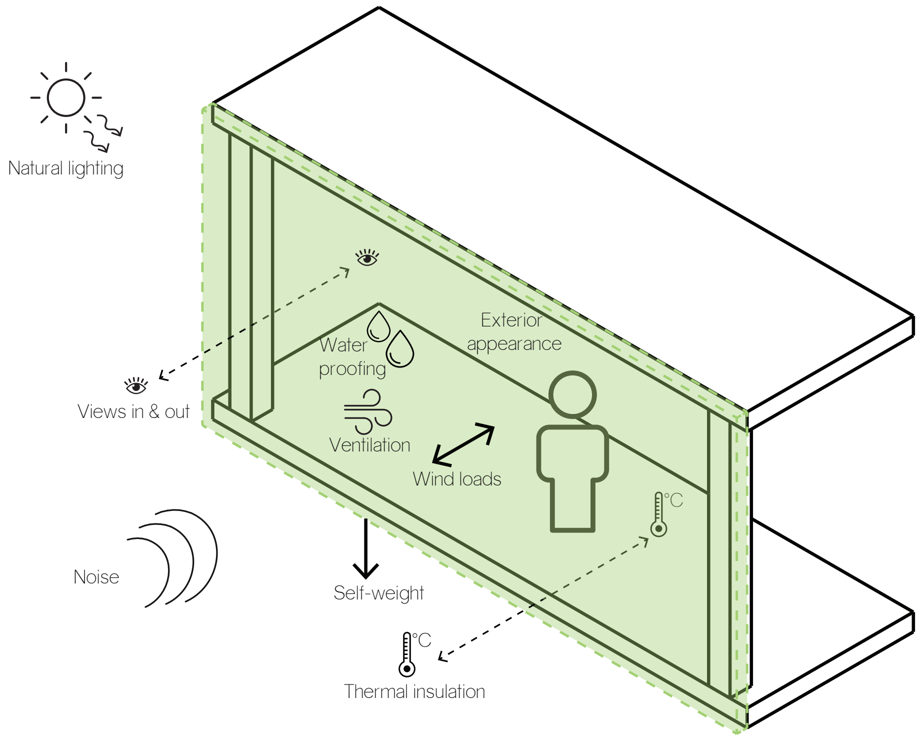
Relation between adaptability and building systems.

Because that the primary systems hold the higher value of the building and require high efforts and cost to change, their level of adaptability should be higher to ensure better, longer and more sustainable life of the building. Designing the primary system is an interdisciplinary task between architects and structural engineers. Architects are more engaged in the design and details of the skin than the design of structure. Therefore, this thesis is focusing on the skin system from the architect's perspective.

UNDERSTANDING FACADES

FACADE

The term 'facade' derives from the Latin 'facies' (face),which was used in antiquity to describe the publicly visible side of a building – especially of prestigious buildings(sacral as well as secular). A structure built by the hand of Man symbolises the interaction between the individual, the outside space and society. This encompasses the climate and topographic contexts on one hand, the reflection of societal forms, political intent, religious provenance and ethnic grouping on the other, and even the availability of local resources. A building serves as a store of information, and is at the same time a witness of different epochs (Herrmann, Krammer, Strum, Wartzeck,2015, p.12).



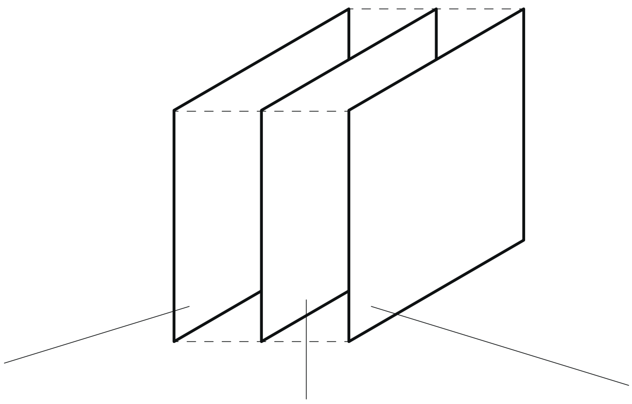
Facade functions

Different functions that a façade serves: it defines the architectural appearance of the building, provides views to the inside and outside, absorbs push and pull forces from wind loads, bears its self-weight as well as that of other building components. The facade allows sunlight to penetrate into the building while usually providing protection from the sun at the same time. It resists the penetration of rainwater and has to handle humidity from within and without. The façade provides insulation against heat, cold and noise and can facilitate energy generation. In addition, it must be long-lasting, easy to maintain and to clean (Knaack, Klein, Bilow, Auer,2014, p.36).

3 LAYERS

The facade can be separated into three layers to provide protection against different environmental factors.

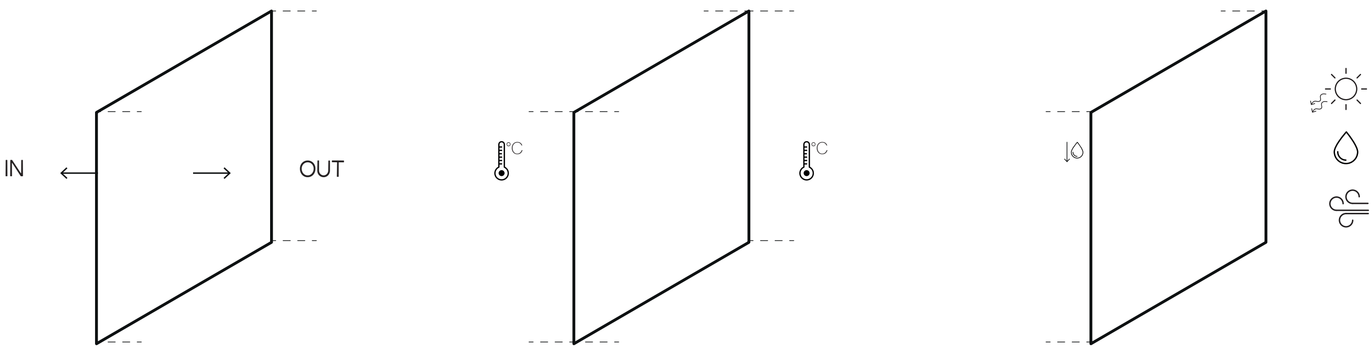
(Illustration by author inspired from Knaack et al, 2014)



INNER LAYER

INTERMEDIATE LAYER

EXTERNAL LAYER



INNER LAYER

Separates the interior space from the facade or from the external space.

- Functions as wind and vapour barrier.

INTERMEDIATE LAYER

Provides insulation against heat and cold in both directions.

- To prevent or minimise the direct transmission of heat, this layer should be thermally isolated from the outer weatherproofing layer.
- Provides sound insulation if sufficiently solid.
- If the facade has load bearing function, this is performed by this layer.

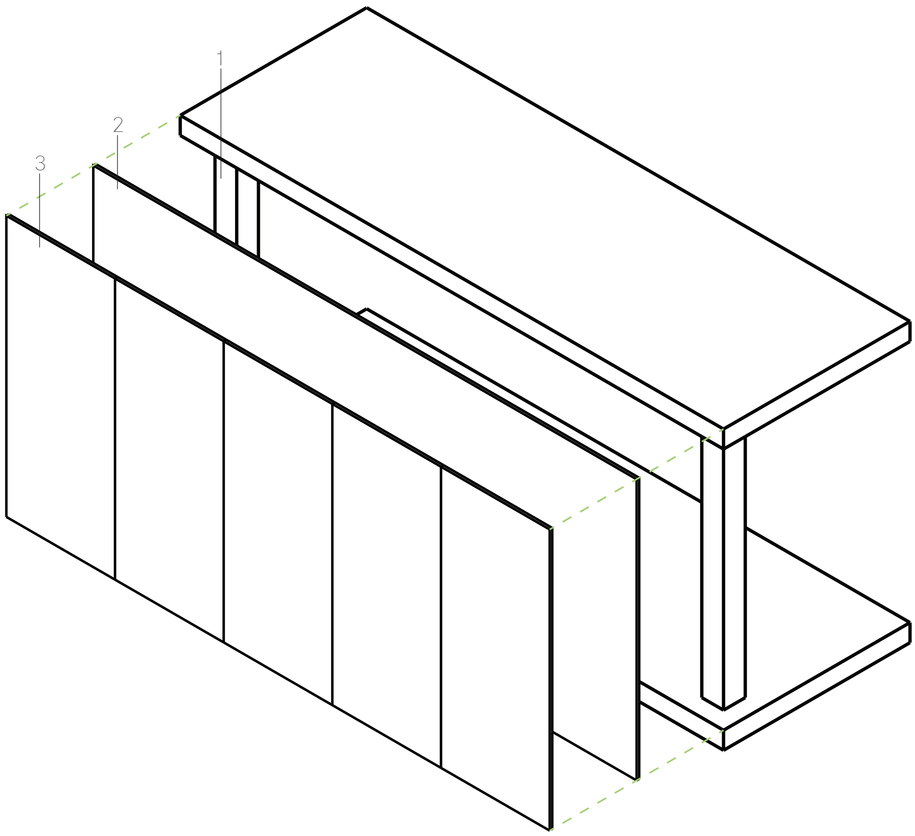
EXTERNAL LAYER

Weatherproofing against rain, wind and solar irradiation.

- Means for solar radiation protection can be added to this layer.
- Water should be drained out from the building to avoid damage caused by it through adding a second drainage behind this.

FACADES CONSTRUCTION

Knaack, et al., (2014) mentioned that three main areas of construction can be defined within the facade; primary structure, secondary structure, and infill elements.



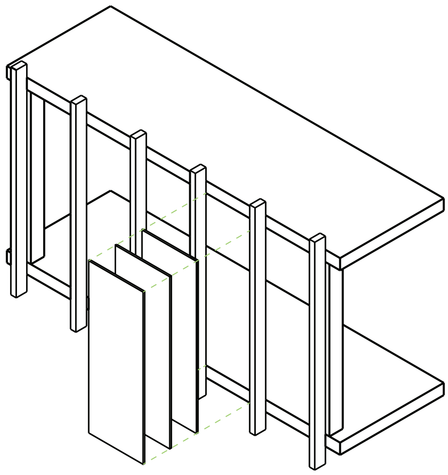
Schematic representation of the elements of facade construction

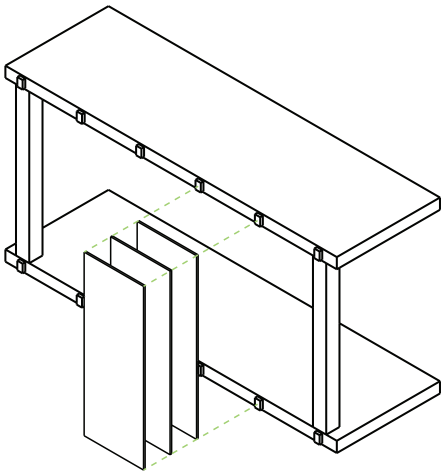
1. PRIMARY STRUCTURE
Forming the main load bearing structure of the building.

2. SECONDARY STRUCTURE
The load bearing structure for the facade and constitutes the connecting element between levels one and three.

3. INFILL ELEMENTS
Such as glazing, panels etc. are mounted on the secondary structure.

POST AND BEAM VS PANEL SYSTEMS





POST AND BEAM FACADE

ADVANTAGES
- Allows adjustments and flexibility in sudden changes
- Economic
- Reliable

DISADVANTAGES
- More site activities
- Slow assembly
(Kawneer, 1999).

PANEL SYSTEM FACADE

ADVANTAGES
- Factory assembly
- Fast construction

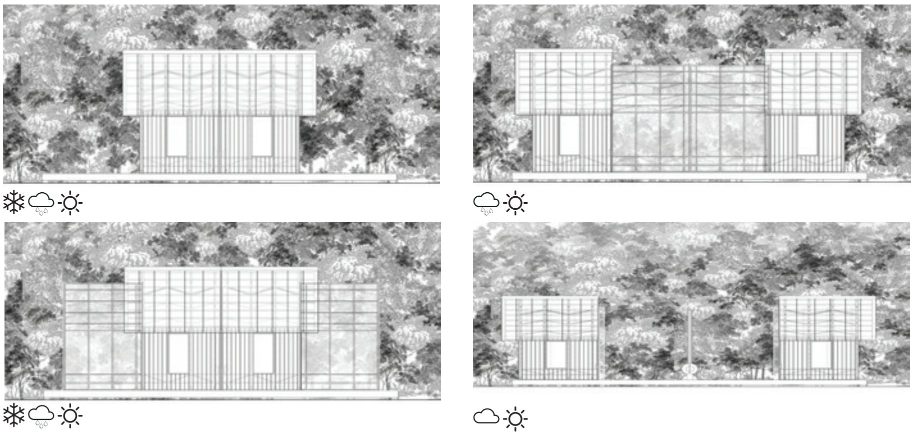
DISADVANTAGES
- Storage and shipping costs
- Cost for lifting equipments on site.
(Kawneer, 1999).

VARIABLE U-VALUE

One of the functions that the skin serves is the insulation against heat and cold. In conventional buildings, the insulation is sandwiched in the layers of the skin with fixed thickness despite the difference of heat and cold throughout the year, or even the day in some climates. To overcome this issue, changes often happen in the HVAC system. However, one of the adaptive solutions to optimize the building energy performance is allowing the U-value of the skin to alter. "For cold climates and buildings with a high heat load, the optimal U-value varies. When the heat load peaks, there is a need for cooling while heating still is needed cold days and when the activity is low. A low U-value would help to keep the warmth indoors when heating is needed while a high U-value would help to cool the building when the outdoor temperature is lower than the indoor temperature." (Berge, Hagentooft, Whalgren, and Adl-Zarrabi, 2015, p.376). Variable U-value can be achieved on a micro level relying on the materials behavior under different circumstance as Berge, et. al (2015) showed in their paper. Another way can be seen with the naked eye and it is often associated changing the configuration of the wall layers, specifically the insulation layer.

EXAMPLE: GARDEN HOUSE

Purpose of example: Building physical adaptability, Variable U-Value
Building scale: Small
Location: Eindhoven, The Netherlands
Completed 2016
Designed and built by: Caspar Schols



The different changes of the house
Images source: www.archdaily.com

The idea is that the house can be easily adjusted to any weather type, mood or occasion. Mainly built in Douglas wood, it contains an inner shell of double glass and an overarching roof of steel. The space is heated by a small but efficient Norwegian wood stove. The whole project gets its stability from a traditional timber truss structure and is built on 18 pillars of reinforced concrete (150*20*50cm)(Archdaily, 2016).

Provides protection in extreme weather (Timber frames, wood wool insulation, and metal roof)
Provides transparency (Timber frames and glass)

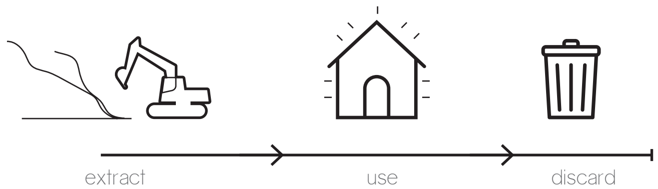
The Skin layers

Images source: www.archdaily.com

CRADLE TO CRADLE

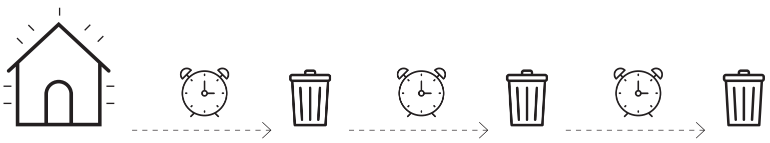
LINEAR ECONOMY

No matter how long each layer of the building served, short or long, at the end it will reach to a point where it cannot fulfill its task. In the conventional linear use of materials; the raw materials are extracted, manufactured, used, and then discarded leading to a definite end as waste. This does not only create bigger and bigger landfills on the planet and discards the value of material, but also makes buildings a burden to the planet. As we are currently on average use more the 1.5 times the resources that the planet can provide (World's footprint 2015).



Linear use of resources

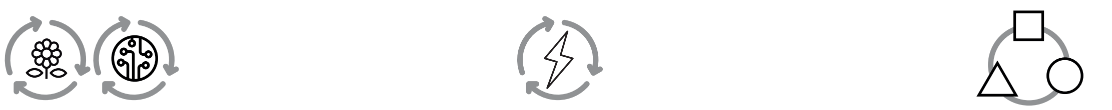
The building industry is responsible for the use of up to 40% of the materials produced globally and about 35% of the world's waste (Jensen and Sommer, 2016, p.182). Designing within the framework of the materials lifespans provides a good start for a sustainable future. However, it does not provide a solution for the linear consumption as it is only reducing the need for new materials. Reduction as McDonough and Braungart (2009) mentioned does not halt depletion and destruction- it only slows them down, allowing them to take place in smaller increments over a longer period of time.



Reduction is only delaying

CRADLE TO CRADLE: THE PHILOSOPHY

Cradle to Cradle as elaborated by McDonough and Braungart (2009) is a philosophy that does not accept the human existence to be negative on the environment rather than contributing positively in it. *Being less bad is not good* - Cradle to Cradle encourages practices that leave no pollution or waste, but contribute to improve the quality of life on the planet.



WASTE = FOOD
Everything is a nutrient for something else.

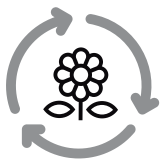
USE CURRENT SOLAR INCOME
Energy that can be renewed as it is used.

CELEBRATE DIVERSITY
Species, cultural, and innovative diversity.

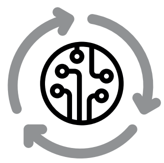
CRADLE TO CRADLE: THE TWO METABOLISMS

To eliminate the concept of waste means to design things- products, packaging, and systems- from the very beginning on the understanding that waste does not exist. It means that the valuable nutrients contained in the materials shape and determine the design: form follows evolution, not just function (McDonough & Braungart, 2009, p.104).

From the principle waste equals food, the products can be integrated into two types metabolisms; Biosphere metabolisms and Technosphere metabolisms.



BIOSPHERE METABOLISMS
for products designed to support biological processes.



TECHNOSPHERE METABOLISMS
for products designed to provide a technical service and whose materials are continuously recycled.

The two metabolisms
(Based on Cradle to Cradle)

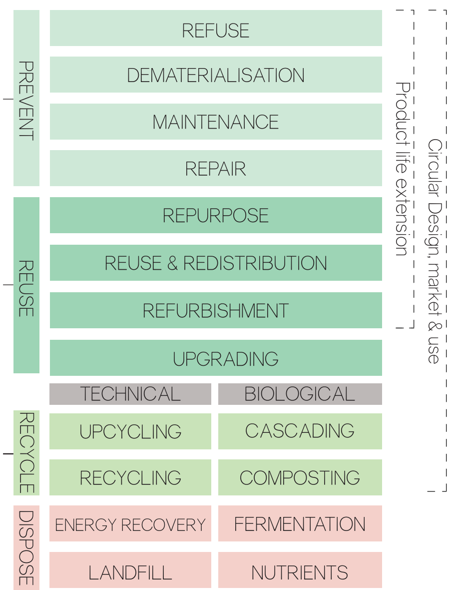
WASTE HIERARCHY

Avoid unnecessary use initially and prolong the life of service.

Repeated use for the same original purpose.

To return materials into use again after modification.

The last step when the material cannot return to the circular system.



Circular Ladder for resources use in a circular economy
(Based on De Groene Zaak, 2016)

WHAT IS A CRADLE TO CRADLE BUILDING ?

A Cradle to Cradle building contains defined elements that add value and celebrate innovation and enjoyment by: measurably enhancing the quality of materials, biodiversity, air, and water; using current solar income; being deconstructable and recyclable, and performing diverse practical and life-enhancing functions for its stakeholders (Mulhall and Braungart, 2010, p.7).

EXAMPLE: VENLO CITY HALL

Purpose of example: Cradle to Cradle building
Building scale: Large
Location: Venlo, The Netherlands
Completed 2016
Architects: Kraaijvanger Architects

The building is not merely sustainable 'less bad', but delivers a positive contribution to man, the environment and economy. It exploits water, makes energy from sunlight and groundwater, and purifies air by the green facade.
The green facade and the trees purify the air from the road and railway line alongside the building. More than 100 varieties of flora & fauna. Combats heat stress and forms part of the insulation layer.
The material manufacturer of the aluminum , Kawneer, designed their products in such a way that they are easy to disassemble and can be melted down for future applications at the end of their lifecycle (archello,2018).

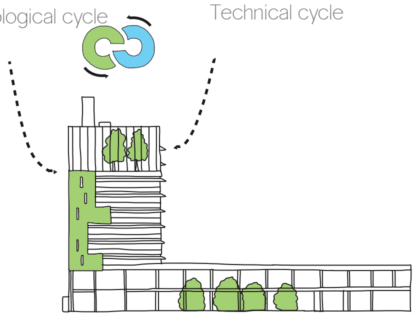


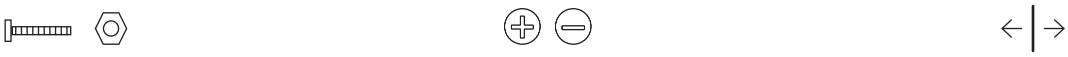
Diagram retrieved from City Hall Venlo Infografic English. www.c2c-centre.com

Venlo City hall
Image source: www.Archdaily.com

DESIGN FOR DISASSEMBLY

'Design for disassembly' is a holistic design approach where the intention is to make any given product easy to disassemble into all its individual components. The approach is a cornerstone of the circular economy because it allows the different components to fit into a closed material cycle, where they can be reused, reassembled and recycled to new products of similar or higher quality. (Jensen and Sommer, 2016, p. 41).

STRATEGIES FOR CONNECTIONS



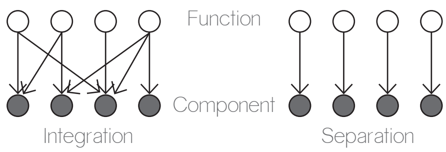
Use screws, pins, nuts and bolts. Use common and similar fasteners. Use easy dissolvable binders.

Strategies for connections
(Based on Jensen and Sommer, 2016).

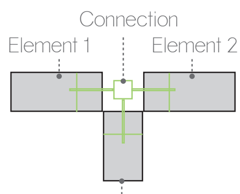
FUNCTIONAL SEPARATION AND DEPENDENCE IN ASSEMBLY

Design for disassembly favours total separation between different functions, on all building levels. A building component can be taken from a building, if it is defined as an independent part of the building's structure. The first step that must be made is to subdivide the building into different sections that have different performances and different life cycles (Durmisevic, 2006, p.163)

Durmisevic (2006) also discussed the aspect of design of connections between components and their assembly. She showed seven principles of connections ranged from fixed to flexible connections. Where the most flexible connection is "indirect with additional fixing device" that with the change of one element another stays untouched, and it allows all elements to be reused or recycled.



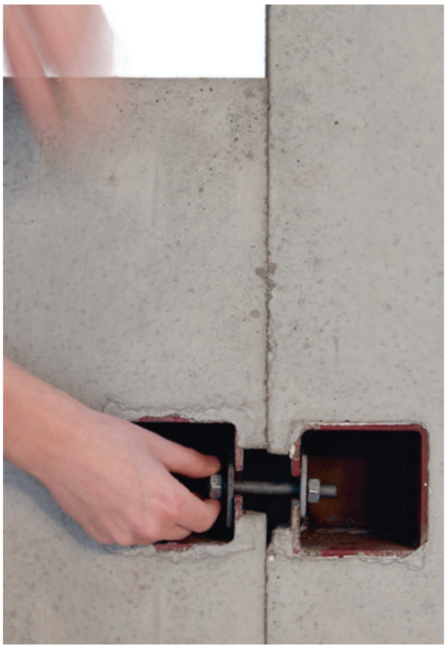
Separation vs. integration of functions
(Based on Durmisevic, 2006).



Flexible connection
(Based on Durmisevic, 2006).

DESIGN FOR DISASSEMBLY: CONNECTION EXAMPLE

Martin Ravnsvbæk and Hans Nicolai Søndergaard in 2015 developed a mechanical connection prototype that allows disassembly and reuse.



Corner using mechanical connections
(Image copyrights to GXN)

The prototype shows a typical connection between two precast concrete corner elements, as well as two wall elements side by side using the same connection technology. These connections between elements are based on accessible load transferring bolts placed in embedded anchor boxes in precast recesses. The bolted joints are accessible from the external side of the element, protected against fire due to insulation and external cladding. This concept is primarily targeting buildings of up to four stories (Jensen and Sommer, 2016, p.99-100).

EXAMPLE: CIRCL PAVILION

Purpose of example: Circular design
Building scale: Medium
Location: Amsterdam, The Netherlands
Completed 2017
Architects: de Architekten Cie.

The project architect Hans Hammink explains: "We selected wood as the main material. The life cycle of the supporting structure is estimated to be thirty years. This means that the supplier must be able to pick up the timber after three decades in order to use it again. Therefore we need to create a design which makes it easy to dismantle the components of the Pavilion." In fact, in a circular way of thinking the wood supplier is no longer a mere 'supplier', but a 'co-creator'. The supplier should benefit from being able to re-use his wood again after thirty years (http://en.cie.nl/projects/174#).
The structural timber elements were oversized to keep greater value of the material for the next life cycle.

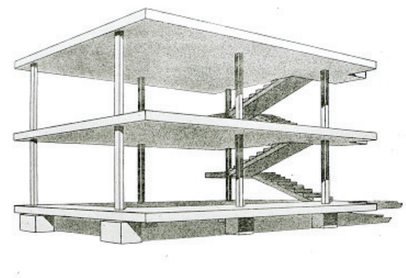

Circl Pavilion, Amsterdam.

The concept of 'Products of service' has been implemented in the project where the elevators will remain the property of the manufacturer, Mitsubishi, and the users are charged for the service. The manufacturer services the lift and will ensure that the parts are recycled at the end of service life in thirty years' time.

POSSIBILITIES FOR THE SKIN

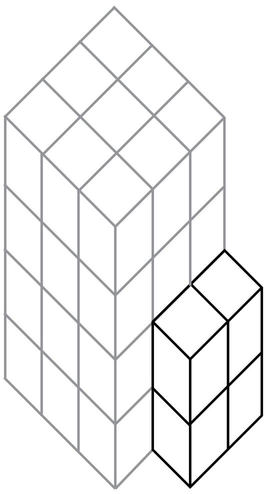
If the exterior walls of a building are load-bearing that means that the structural system is interlocked with the skin system. Thus the dependency of the systems on each other causes limited capacity for change and might lead to a quick end of the building's life.

The distinction of the structure from the skin within the Primary System provides higher freedom and flexibility in the design, and brings a better setting for the building's adaptability. In 1914 Le Corbusier designed Maison Domino, a two-floor concrete structure (slabs, columns and stairs) plus partitioning. This design distinctly separates the structure from the skin; allowing the exterior walls to be free from the structural function. This concept of a structural frame and an infill wall is not only limited to concrete but can be implemented in wood or steel frames as well.

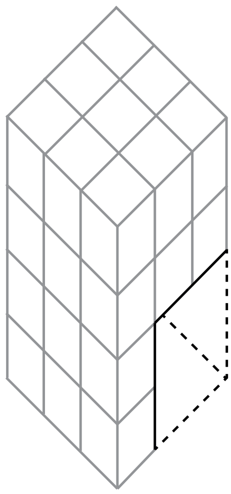


Maison Domino, Le Corbusier.
Image source: http://thecityasaproject.org

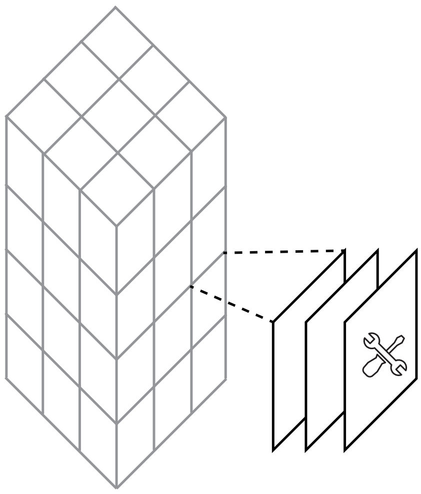
Possibilities of physical change in the exterior walls without affecting the structure:



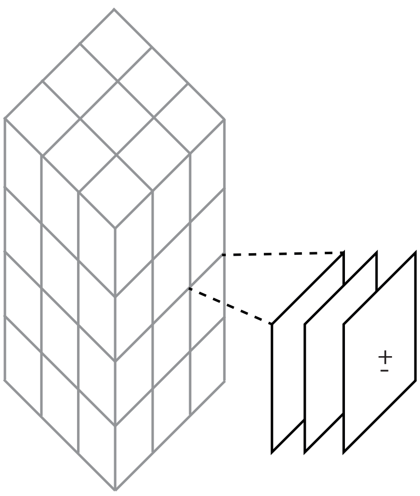
Expand



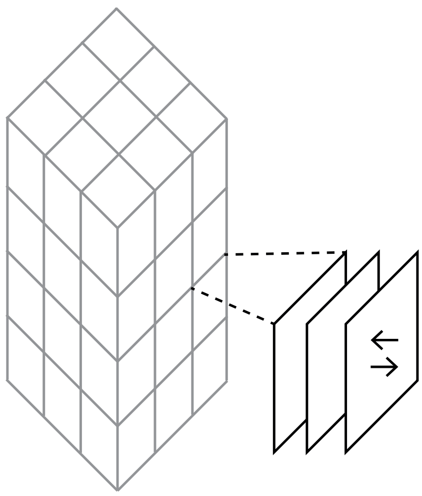
Shrink



Repair



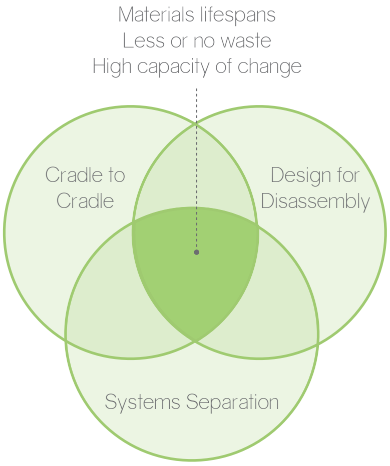
Add or remove layers



Change layers

SUMMARY & DESIGN STRATEGIES

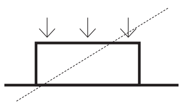
SUMMARY



Shared principles

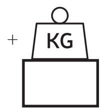
-The primary systems; structure and skin, have the final call in the critical situations that demand major physical changes in the building. Hence, according to the primary system's capacity of change, the whole building adapts, or come to an end.
- Cradle to Cradle, Design for Disassembly, and Systems Separation complement each other and share many principles. They take the materials lifespan in consideration, aim for less or no waste, and as a result, they can provide products with a high capacity of change.
-Separate functions to different components for easier material reclamation.
- The construction technology and material manufacturers impact the realization of circular design.

DESIGN STRATEGIES



Systems Separation

Separate the structure system from the skin system; Avoid load-bearing walls.

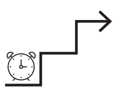


Oversize structural elements

Allow for expansion, and to earn future value of the materials when reclaimed.

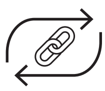
Avoid materials damage

Replacement or modification of shorter life elements does not affect or damage those of greater durability.



Hierarchy of lifespans

Take in consideration the rate of change and materials excepted lifespans

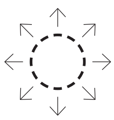


Reversible connections

That does not need customized tools for easy separation of the different layers.

Accessible connections

Place the connections to be easily accessed.

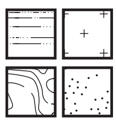


Open possibilities

Design in a way to create more possibilities to correspond to the unexpected future needs.

Modularity

Design to standard dimensions to reduce materials waste and increase reuse possibilities.



Select reusable, recyclable materials

Materials that can be integrated into the technosphere or biosphere metabolisms.

3 THE CONTEXT

RONNEBY
SNÄCKEBACK SCHOOL PROJECT

RONNEBY

RONNEBY AND CRADLE TO CRADLE

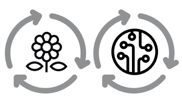
Ronneby in Blekinge county, Southeast of Sweden

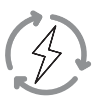
Ronneby is located on Southeast of Sweden in Blekinge county. The area of Ronneby is 825 km^2 and has 29,207 inhabitants (SCB, 2016). In the first decade of the 21st century, Ronneby experienced a downward economic spiral and politicians started to argue how the future of Ronneby had to be guided by sustainability. Ronneby lost the local university of technology; a huge business park was looking for new tenants and the local government commissioner became firmly convinced of how sustainable development was to be the new "guiding star" (Mellqvist, Kristensen, and Van Den Bosch, 2016, p. 79-80). During that period one politician was interested in the philosophy of Cradle to Cradle and then it was adopted by the municipality as a method for its sustainable development visions and to change towards circular economy. In 2011, the city of Ronneby founded a Center for Research and Development in Ronneby [Cefur] which is responsible for Ronneby Municipality's commitment to sustainable development. The long-term goal is circular economy and the method they have chosen to get there is to be inspired by Cradle to Cradle (www.ronneby.se).

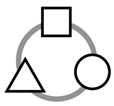
After some years of population decline in the municipality, the population started growing again in 2013. It is mainly because of inflow immigrants from abroad. The population structure is also changing. The proportion of children and youth as well as the elderly will increase the most. To ensure growth, high quality investments are being made in the educational environments of preschools and elementary schools (Ronneby 2035, 2017). In 2014, Backsippan preschool was opened, which is considered ,at the time, as the healthiest preschool in Sweden (Ronneby). Many other projects followed with the focus on C2C, and Snäckeback School, which this thesis is relating to, is one of them.

Main events in Ronneby in the process of change towards C2C as a method. By the author.

RONNEBY'S APPLICATION OF CRADLE TO CRADLE IN THE BUILT ENVIRONMENT


Manage resources


Use renewable energy


Diversity

In order to apply the C2C philosophy in the built environment, Ronneby & Cefur gave some tools and strategies to facilitate and ensure the implication of C2C principles in planning and constructing the built environment in the municipality. The strategies create a framework that can be used for both the municipality's work and the private businesses. The framework consists of three basic principles (Ronneby 2035, 2017):

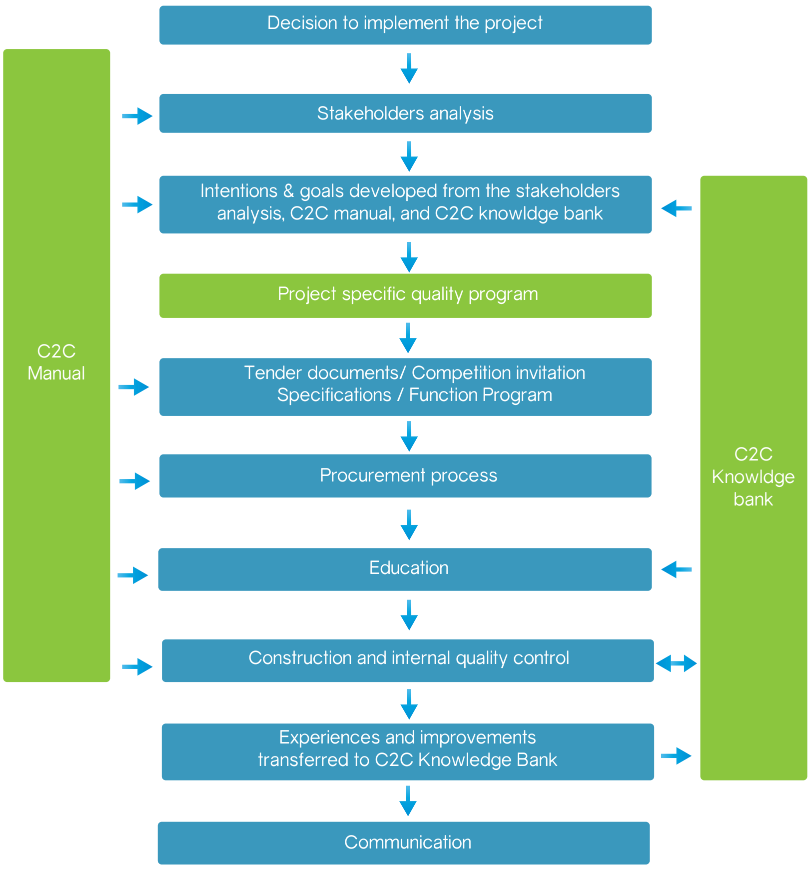
- Manage resources: Biological materials should be able to go back to nature as nutrition and technical materials can be recycled as raw materials for industry.

- Use renewable energy: to drive the necessary processes.

- Achieve resilience through diversity: Biological, cultural, and economic diversity helps everyone to be resilient against different threats.

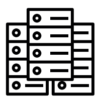
CRADLE TO CRADLE PRJOECTS PROCESS IN RONNEBY

Ronneby municipality in collaboration with Cefur published a beta version of a "Cradle to Cradle manual for the built environment in Ronneby municipality" describing how technical administrations can use C2C as a method in the projects. Generally it describes the overall process of a project. Where it shows how to identify the interests of the different stakeholders related to the project and develop a project specific program based on the stakeholders analysis,C2C manual, and C2C knowledge bank that documents the experience from previous projects. It also suggests educating people who are related during the different project steps about C2C, sustainability and using a material database. As Ronneby municipality has high goals of sustainability, the manual suggests communicating about the projects to promote and increase the attractiveness of the municipality.



Process for a project with C2C as a method (Ronneby Cradle to Cradle manual for the built environment in Ronneby municipality beta version). translated by the author.

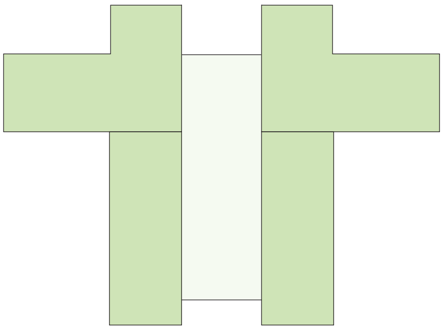
As a method to measure and assure the quality of materials in the built environment, Ronneby suggests referring to SundaHus material database. It provides support in making environmentally conscious material choices, i.e., to avoid products containing hazardous substances and to document product choices. SundaHus Material Data provides the opportunity to monitor the contents of a building over time through reliable product documentation (www.sundahus.se).



Material Database

EXAMPLE FROM RONNEBY: HULTA PRESCHOOL

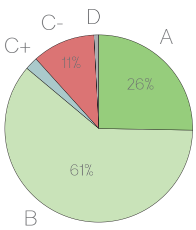
Purpose of example: Same context
Building scale: Small
Location: Ronneby, Sweden
Completed 2017
Architect: Zijad Bico, Ronneby municipality



The modular plan layout

Image taken by Author

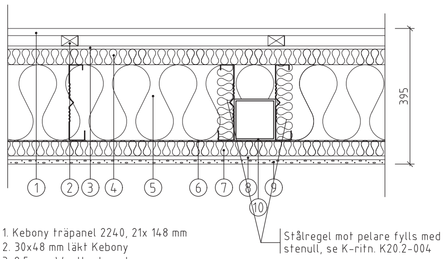
- Designed in modules to increase the building's adaptability; it can be changed in the future to senior housing.
- The structural system is pillar-slab system (Steel pillars and concrete slabs)
- It is better example than Backsippan preschool; More healthy materials used.



Distribution of materials assessments according to SundaHus material Data

Assessments for the products mainly over their contents into five categories where (A) category is for products that give minimal health or environmental impacts. (Check page 72 for details).

Exterior walls details



1. Kebony träpanel 2240, 21x 148 mm
2. 30x48 mm läkt Kebony
3. 9,5 mm Weatherboard
4. 45 liggande stålregel s 600 och 45 mm isolering
5. 220 stående stålregel s 600 och 220 isolering, system Danogips el. likv.
6. 0,2 Plastfolie
7. 45 liggande stålregel s 450 och 45 isolering
8. 11 OSB-skiva
9 12,5 mm Gipsskiva
10 Stålpelare enl. K-ritning, placering enligt K-ritning

SNÄCKEBACK SCHOOL PROJECT

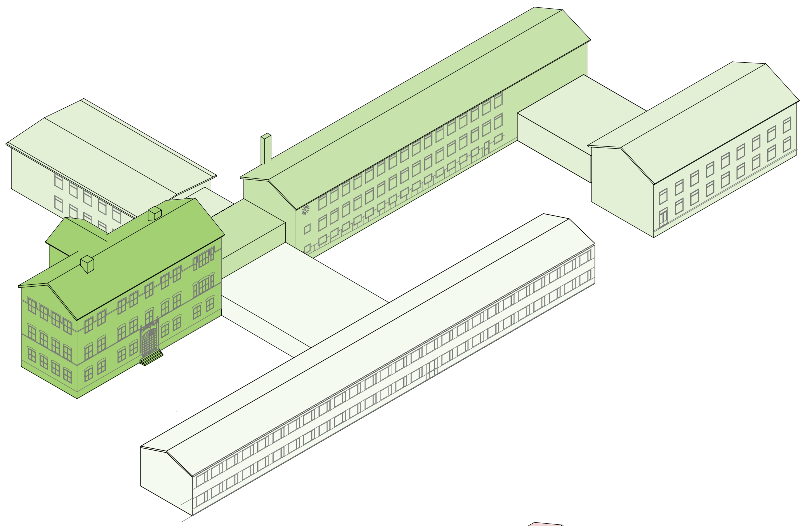
THE SCHOOL

Snäckeback was established in 1913 in one building and expanded on different since then to become a complex of 5 connected buildings. Currently the school is for grades from 4-6 and it will be expanded to be from grades 4-9.
Project phase: design phase.
Architect: Zijad Bico, Ronneby municipality
Area extension: 5,725 m^2
Area renovation: 3,145m^2

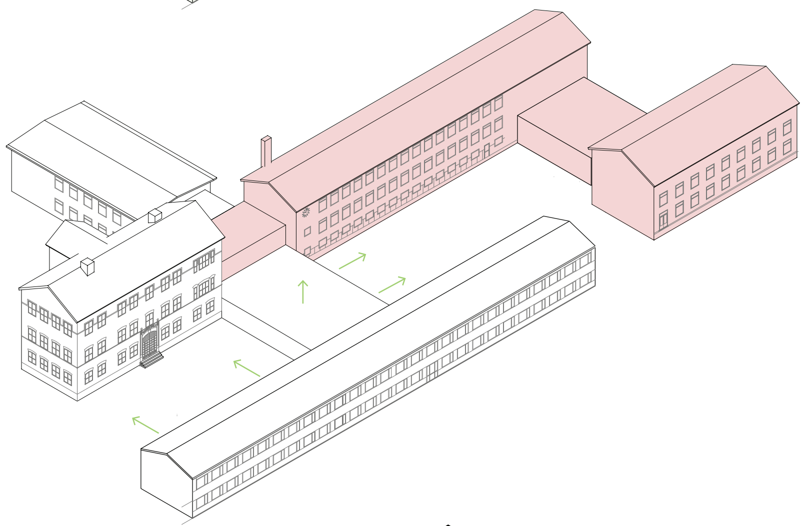
The first building.
Ronneby central square
Image source: Ronneby Municipality

Ronneby central square
The Current school buildings.
Image source: Ronneby Municipality

CHANGE TIMELINE

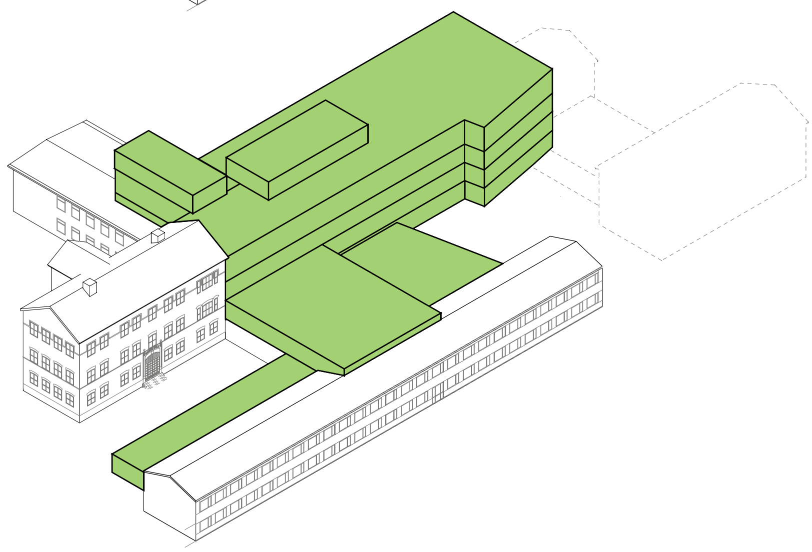


1913
1952
1961
1972



The city decided to deconstruct two of the school buildings and build a new expansion.

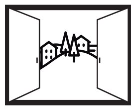
Demolish
Expand



The proposed changes by the city

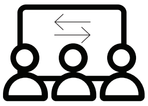
THE SCHOOL DESIGN GOALS

The city wants the school to have some main features:



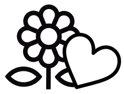
OPEN TO THE CITY CENTER

Create the feeling of 'openness' in the school.



FLEXIBLE CLASSROOMS

Not assigning a room to a specific group of students, so it is decentralized in the way that students does not always have classes in the same room.



OUTDOOR CLASSROOMS

To bring students closer to nature. For instance, by providing a setting where students can sit and learn outside.

LEARNING FROM THE BUILDING

Use the building to educate the students about Cradle to Cradle philosophy, for instance using solar energy in the school. Other aspects can be a green house to show the biological cycles.

BRICKS FROM DECONSTRUCTED BUILDINGS

Even though the bricks of the buildings that will be deconstructed are in good condition, not all of them will be reused because of the high efforts and time needed to separate the bricks and therefore, not so feasible economically. However, the city will reuse some of the bricks in the new extension.

Construction year : 1952
Bricks area: 690 m^2

Construction year : 1961
Bricks area: 412 m^2

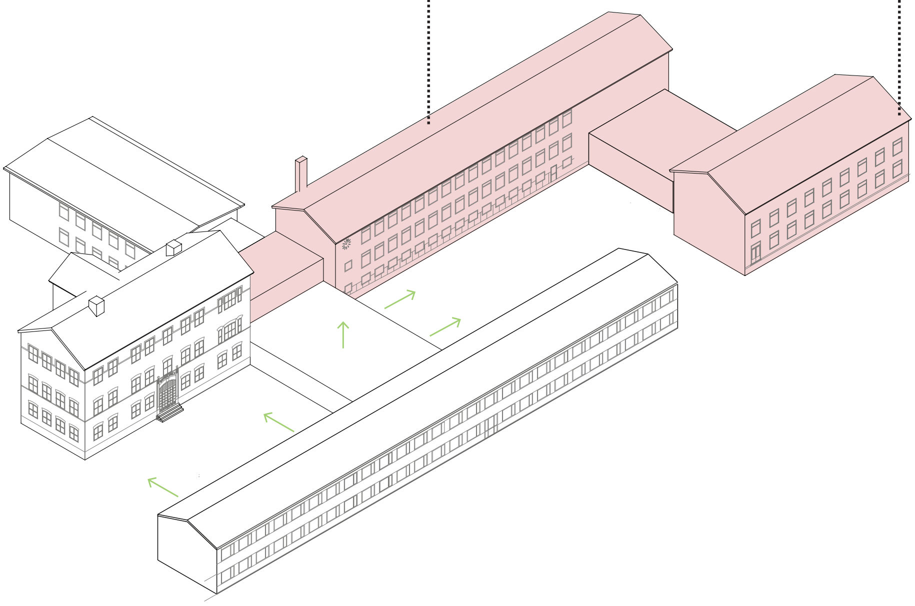


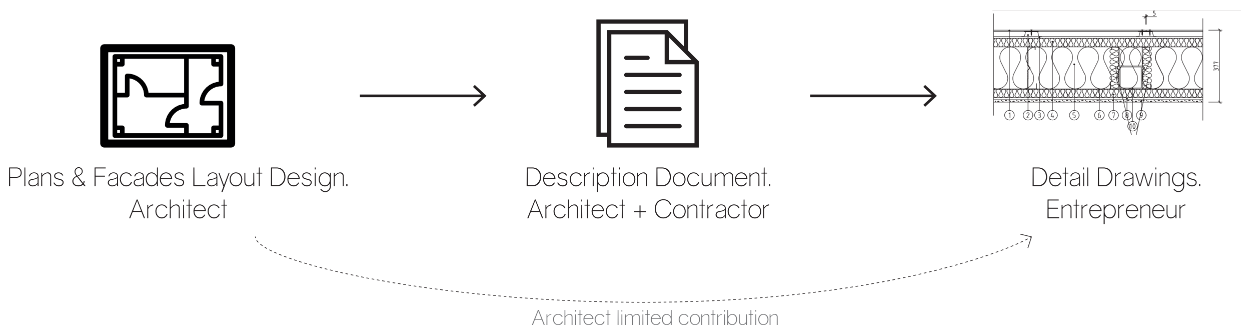
Illustration highlighting the buildings that will be deconstructed.

THE DESIGN PROCESS OF THE SCHOOL BY THE MUNICIPALITY

- The designer architect of Snäckeback school project does not develop the project to the details level. His tasks are limited to design the layout of the plans and facades without developing the construction details.

- When the design is approved, a selected contractor in cooperation with the architect develop a description document of what the building is expected to be. The documents has a separate page for each room with description of the different aspects that were not developed in the architectural drawings; for instance, the interior finishing look and color, the desired room temperature, and lighting conditions, etc.

- The drawings and the documents are then handed to an entrepreneur who develops the design details. The entrepreneur in that case chooses the different building systems to use, materials, etc on their own unless stated clearly in the description and drawings to use a specific material.



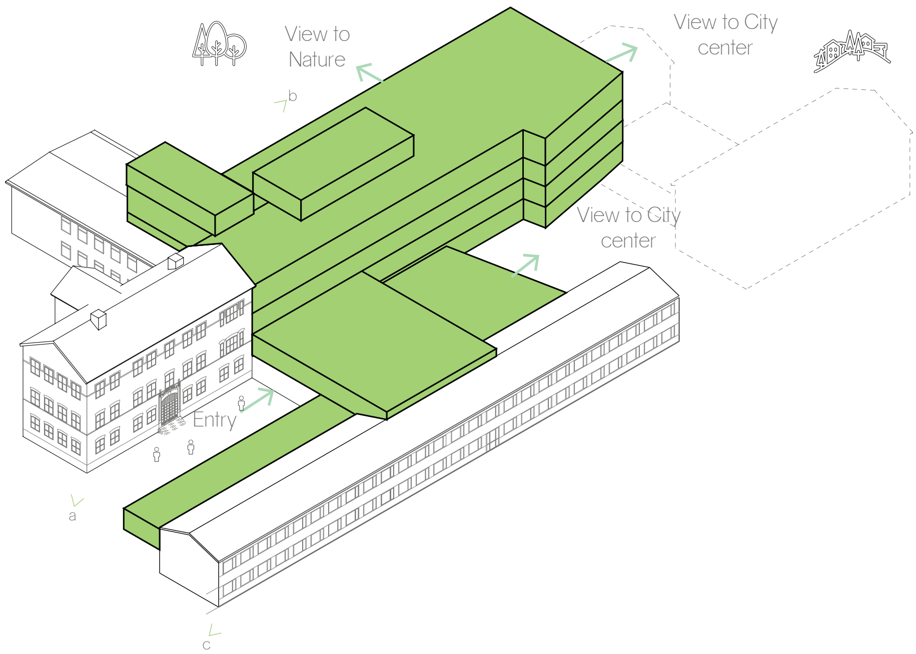
The design process of snäckeback school by the municipality

4 DESIGN PROPOSAL

ANALYSIS & SKETCHING
DETAILING

ANALYSIS & SKETCHING

THE ARCHITECTURAL CHARACTER



a. The oldest building in the school, Eye catching, big windows, Bricks and white plaster on the highest floor.

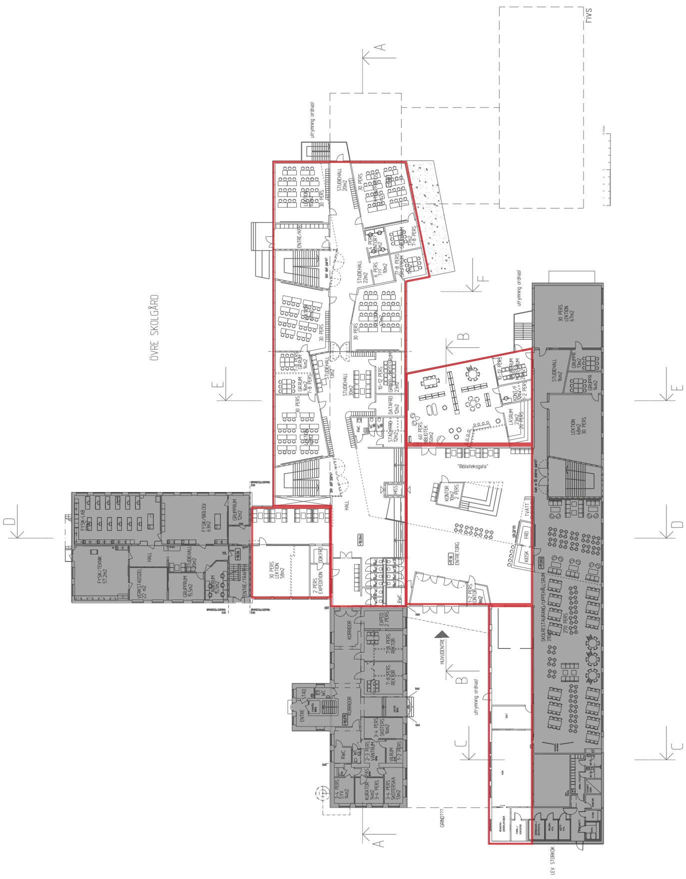
b. Rhythm and repetition, bricks, big windows, white frames.

c. Rhythm and repetition, horizontality, bricks and greenish metal cladding.

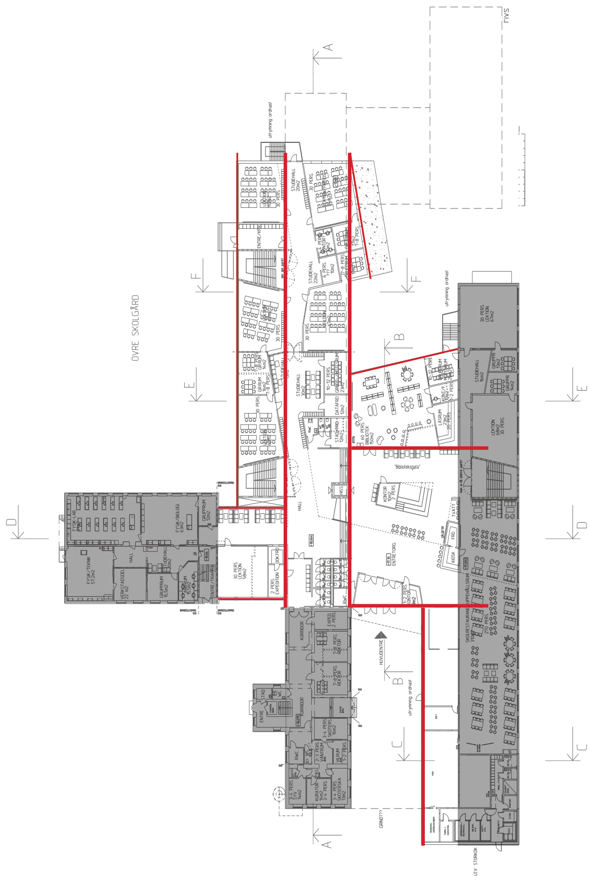
THE COMPOSITION SKETCHING

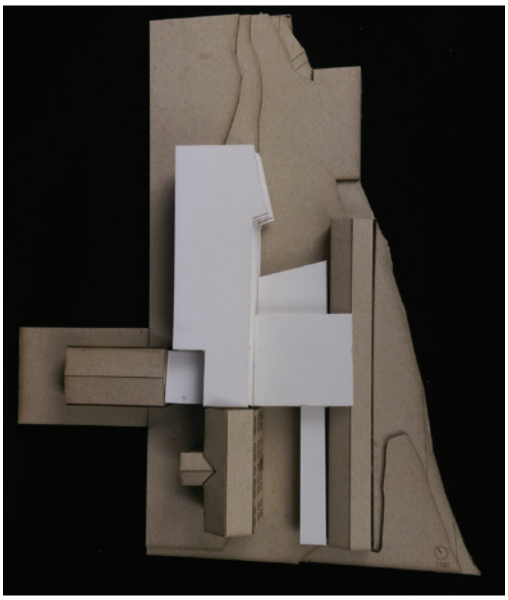
As a method to explore different alternatives for the extension composition; sketch models of horizontal planes and vertical planes were built and studied.

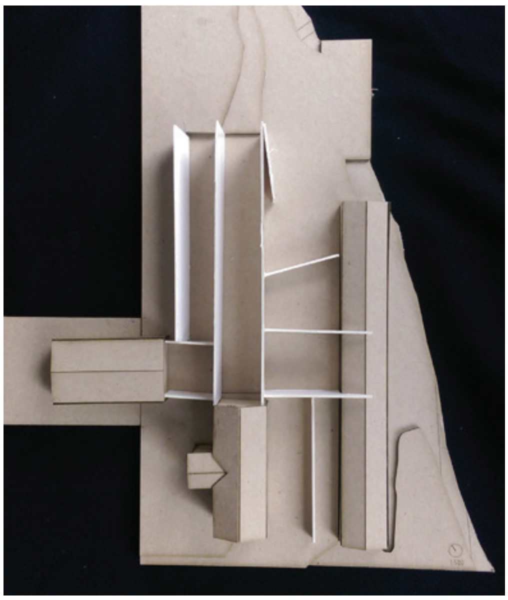
HORIZONTAL PLANES



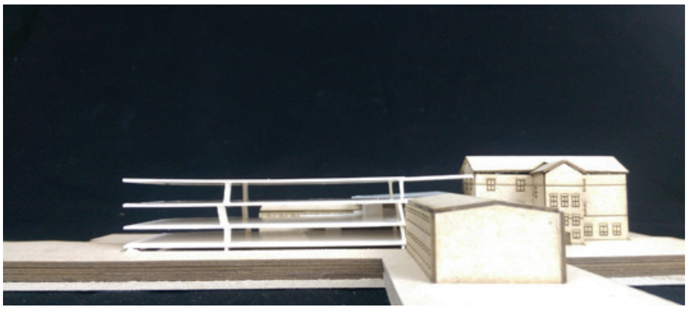
VERTICAL PLANES

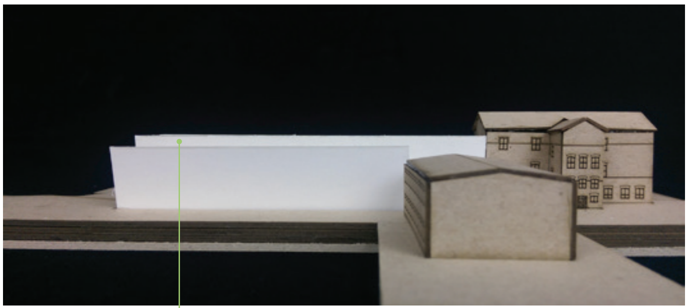




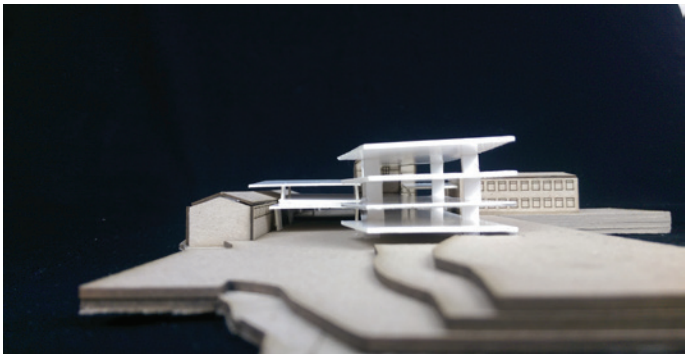


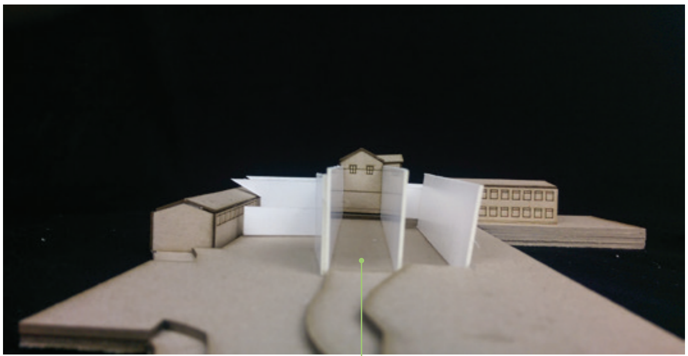
THE COMPOSITION SKETCHING - HORIZONTAL VS. VERTICAL PLANES



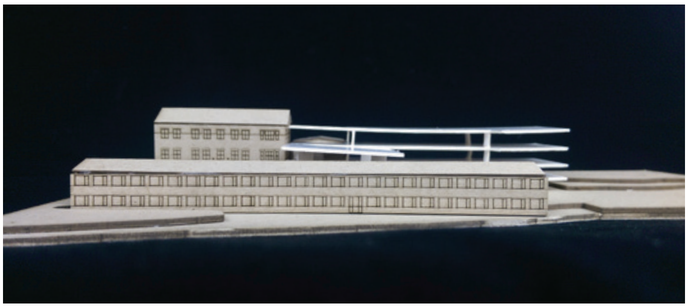


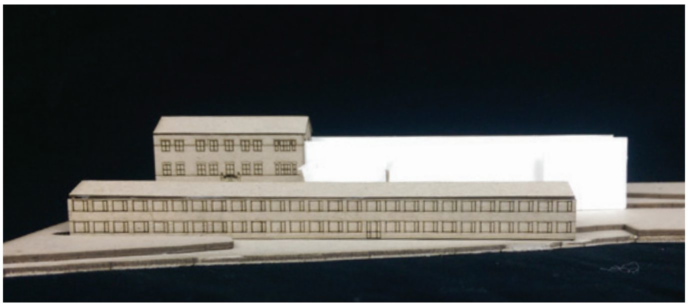
Shows traces of the demolished building



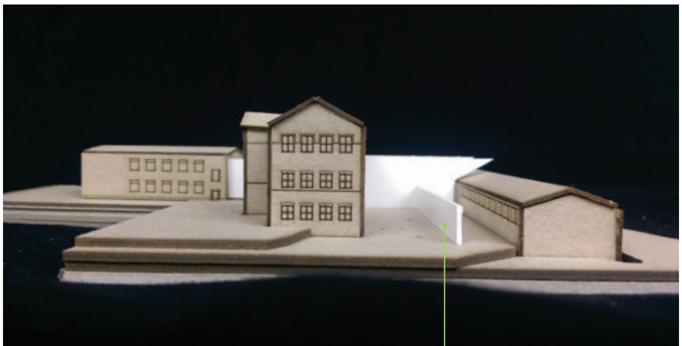


Shows the lines of the demolished building



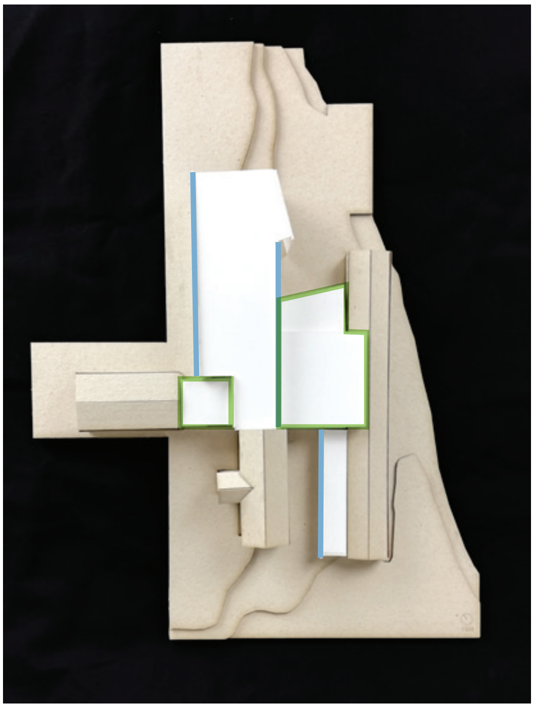


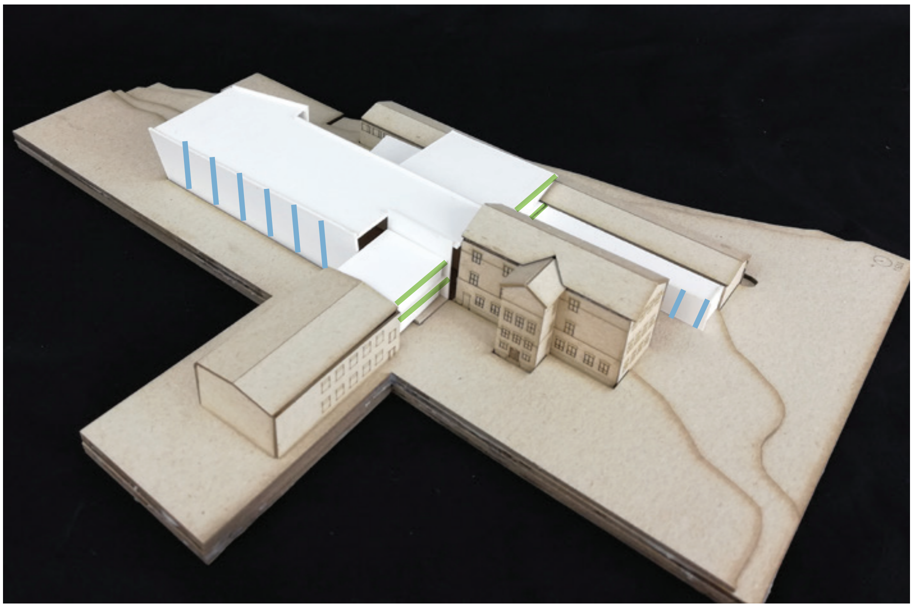
Creates a welcoming entrance



Creates guidance to the entrance

THE COMPOSITION SKETCHING - A COMBINATION OF HORIZONTAL AND VERTICAL PLANES



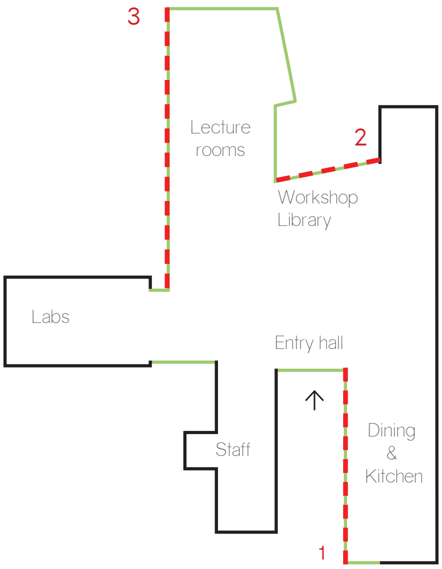


Emphasize horizontality in the facade lines

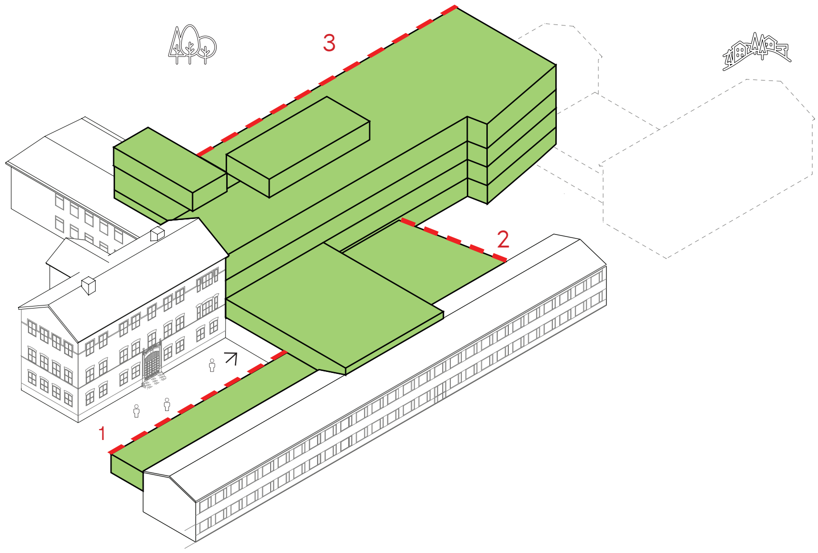
Emphasize verticality in the facade lines

THE SELECTED FACADES

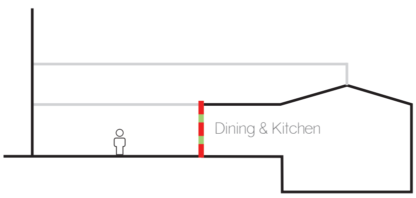
FUNCTIONS AND FACADES



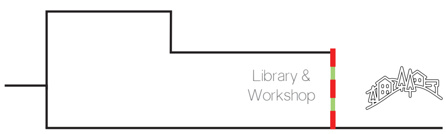
Main functions in the different floors according to the proposed plans by the municipality



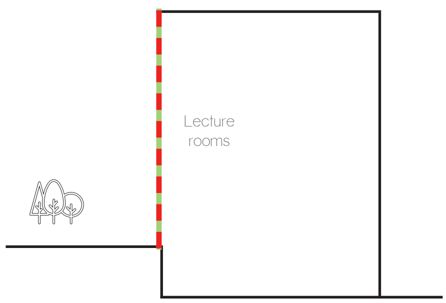
These three facade are selected to apply the design strategies and presented in the following pages.



1. BY THE ENTRANCE

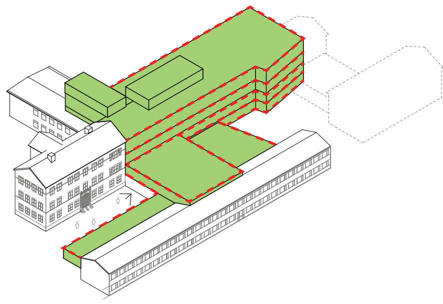


2. SCHOOL TO CITY



3. SCHOOL TO NATURE

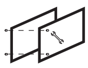
DETAILING



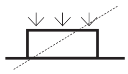
THE CONNECTION

An element made of timber that acts as a joint between the skin and the structure. It keeps the structure that has a long lifespan (+50 years) unaffected by the changes that can happen to the skin that has a shorter lifespan (+20 years). It also allows for easy accessibility for the layers of the skin. It can be applied to the school extension.

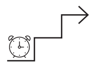
ADAPTABILITY TYPOLOGIES

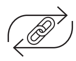

Refitable

DESIGN STRATEGIES

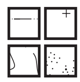

Systems Separation


Avoid materials damage

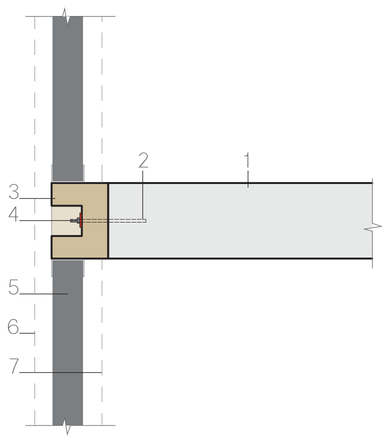

Hierarchy of lifespans


Reversible connections


Accessible connections

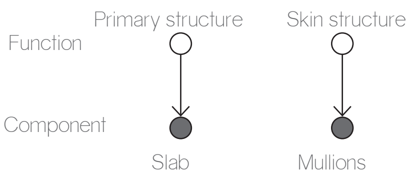

Select reusable, recyclable materials

SECTION 1:20

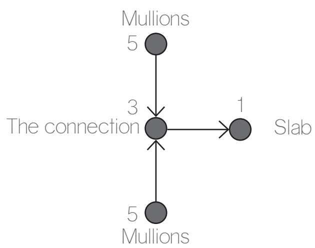


1. The slab (Primary structure).
2. Built-in hole in the slab.
3. The connection (timber).
4. Stainless steel bolt and nut.
5. Mullions (skin structure).
6. Exterior layer of the skin.
7. Interior layer of the skin.

FUNCTIONAL SEPARATION



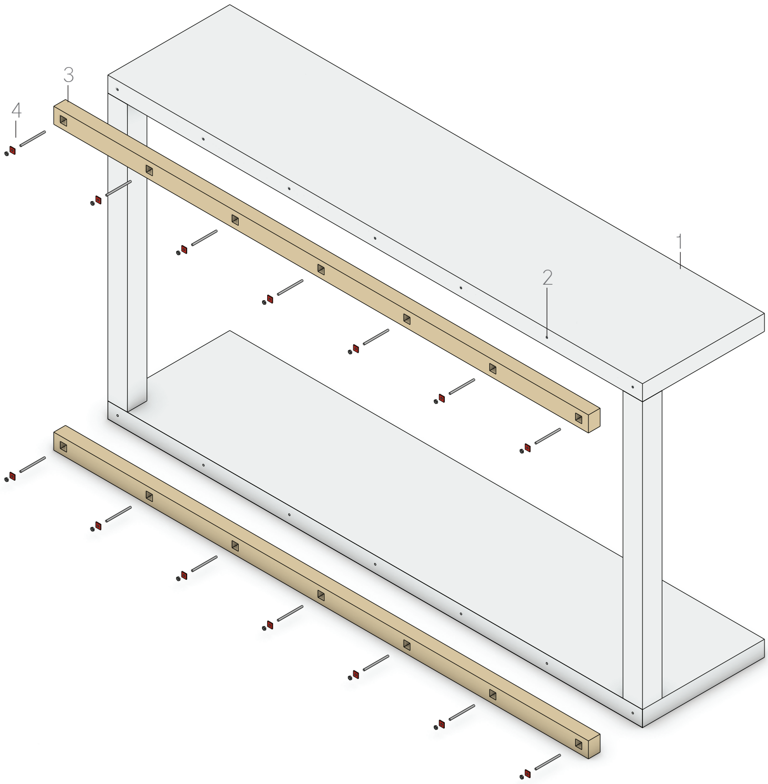
DEPENDENCE IN ASSEMBLY



COMPONENTS LIFESPANS

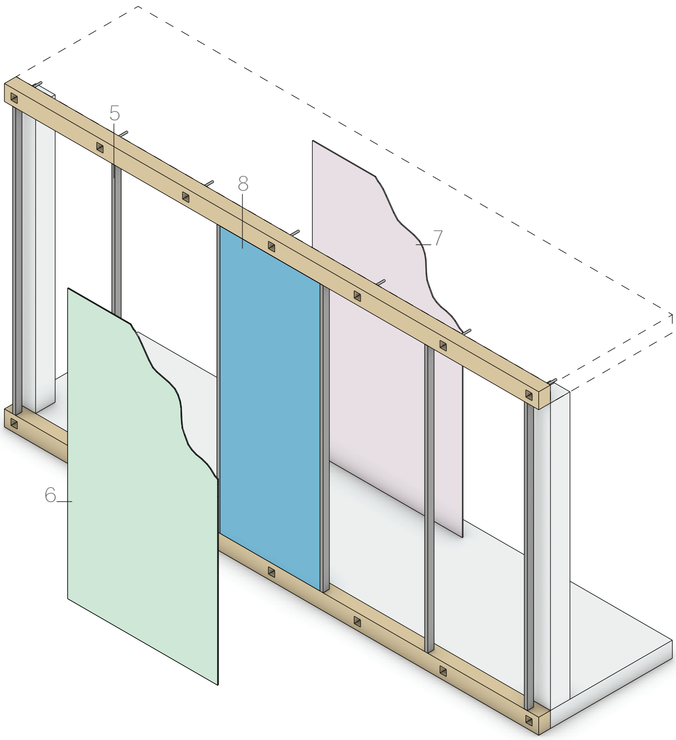
The slab (1): +50 years
The connection (3): +30 years
The skin (5+6+7): 20 years

ASSEMBLY OF THE CONNECTION



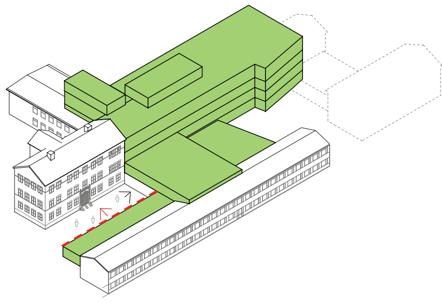
The connection extends along the slabs, in lengths matching the structural span. The dimensions and material of the mullions vary according to the skin layers.The distance between the mullions is multiplications of standard dimensions, i.e. 600, 900, 1200 mm, etc.

ASSEMBLY OF SKIN LAYERS



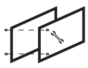
1. The slab (Primary structure).
2. Built-in hole in the slab.
3. The connection (timber).
4. Stainless steel bolt and nut.
5. Mullions (skin structure).
6. Exterior layer of the skin(Add-on).
7. Interior layer of the skin(Add-on).
8. Middle layer of the skin (Fill-in).

1. BY THE ENTRANCE



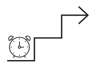
This facade is facing the Snäckeback school oldest building that has a distinctive character. It also extends along the way to reach the school's new entrance. From the interior, it is the dining area and the kitchen.

ADAPTABILITY

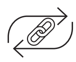


Refitable

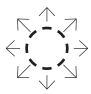
DESIGN STRATEGIES



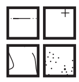
Hierarchy of lifespans



Reversible connections



Open possibilities

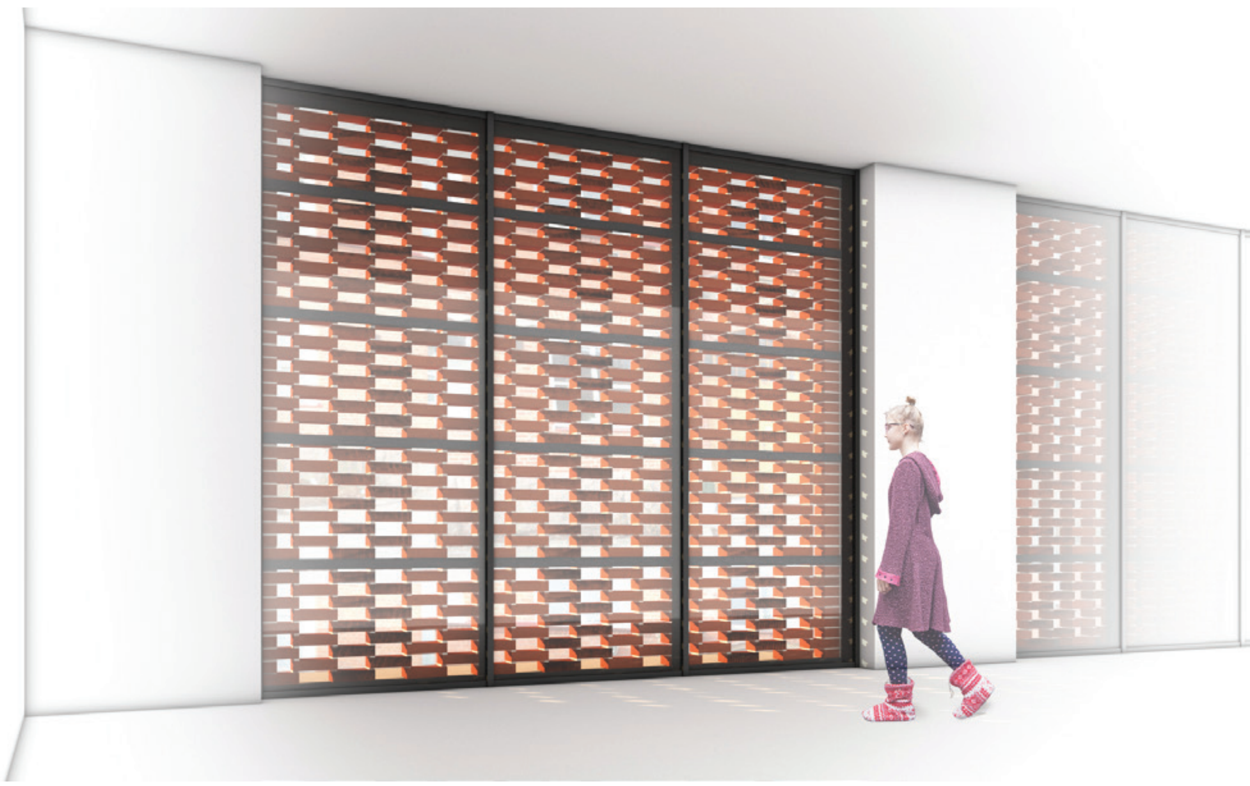


Select reusable, recyclable materials

SCHOOL DESIGN GOALS

Learning from the building

INTERIOR VIEW OF THE SKIN FROM THE DINING AREA

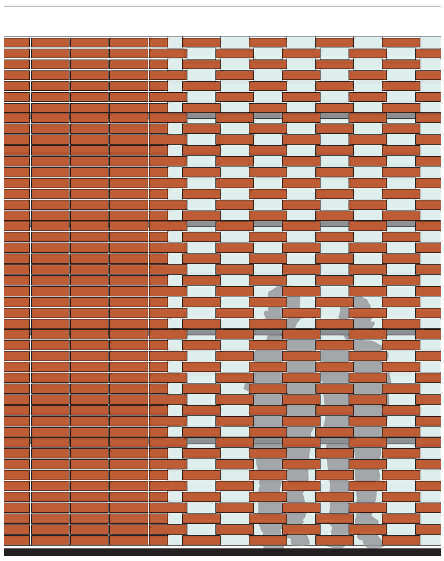


MATERIALS

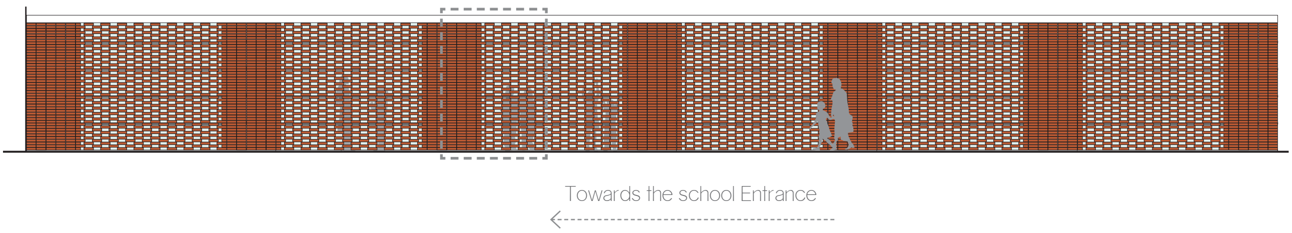
One of Snäckeback school brick facades that will be deconstructed.

Reused bricks from the deconstructed buildings is chosen to be the exterior layer of the skin, to be a neutral surface facing the oldest school building, and to expose the bricks from the deconstructed buildings as a resemblance of change and example of reusing.

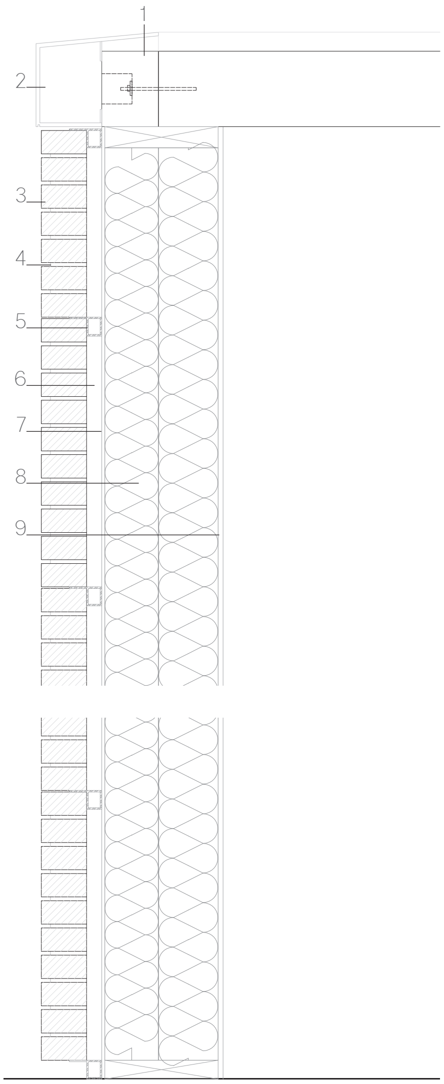
FACADE 1:200 AND 1:50



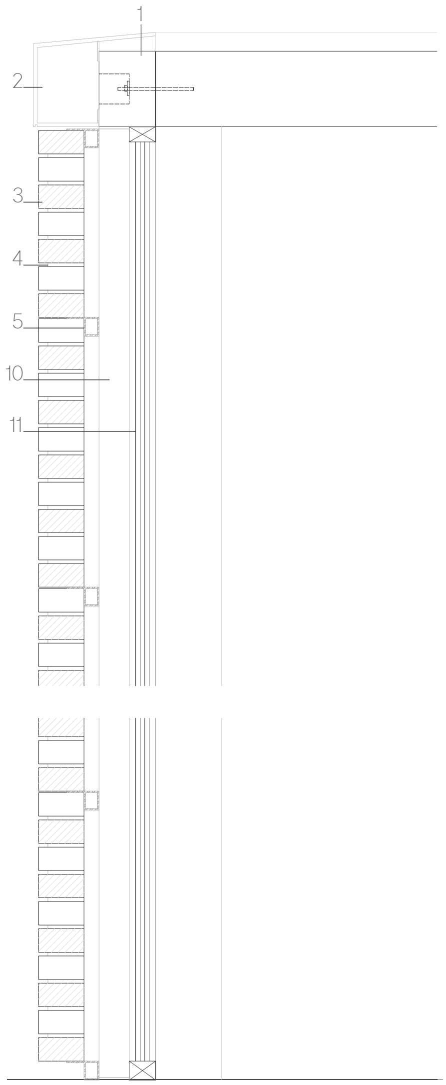
Since the amount of bricks is unknown; two modules of different patterns for the bricks are proposed. One is closed covering the whole module, and the other is perforated using less number of bricks. The layout of the facade can alternate between the two modules according to the bricks quantity. This alternation, creates a visual sense of guidance towards the school entrance while walking along the facade.



SECTION AA 1:20

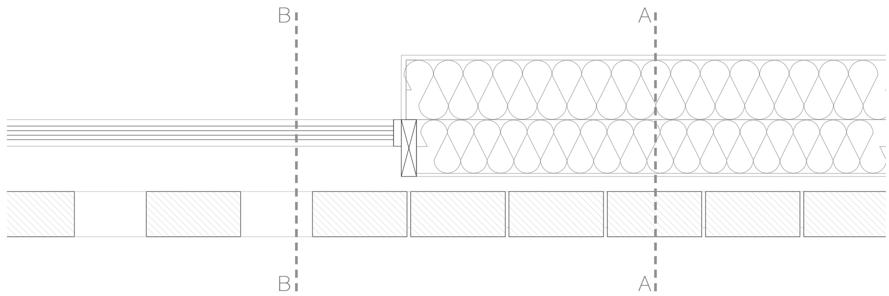


SECTION BB 1:20



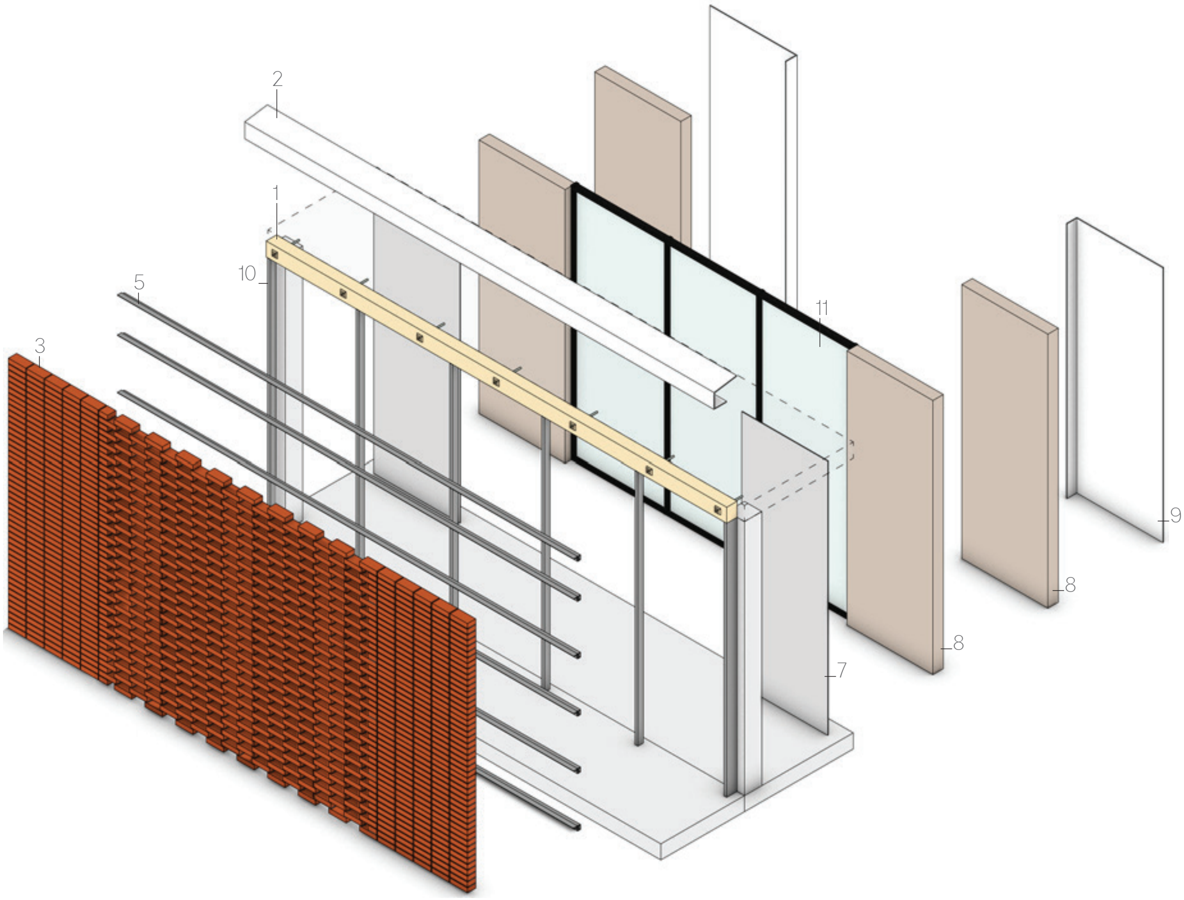
1. The connection (timber).
2. Covering.
3. Reused Bricks.
4. Lime Mortar.
5. Stainless steel support.
6. Ventilated cavity .
7. Rain/ Wind stopper.
8. Thermal insulation 300mm.
9. Interior finish 12mm.
10. Mullions.
11. Glazing.

PLAN 1:20



ASSEMBLY OF SKIN LAYERS

The assembly of the of structure that holds the bricks layer is separated from the other layers in the skin, due to the different lifespans. Lime mortar is used to bind the bricks together to make it easy to separate the bricks for further reuse.



1. The connection (timber).
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8. Thermal insulation 300mm.
9. Interior finish 12mm.
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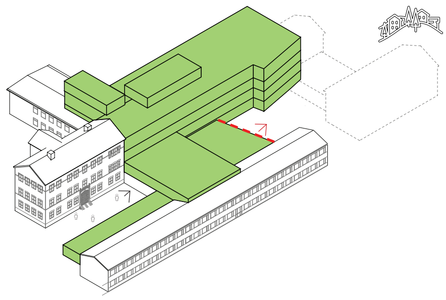
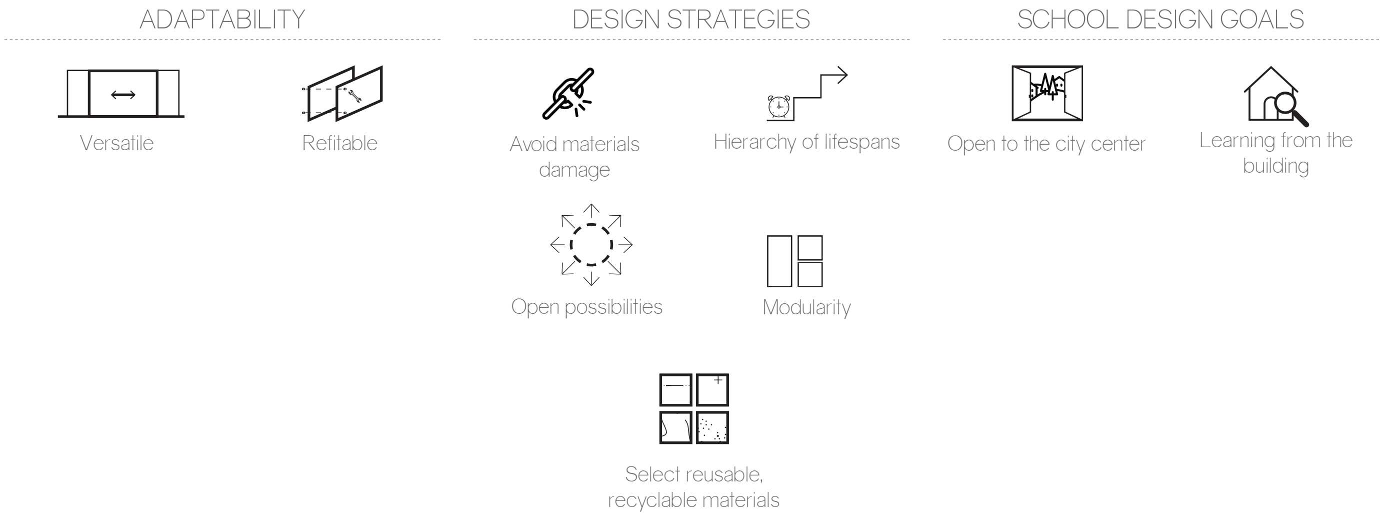
11. Glazing.

2. SCHOOL TO CITY



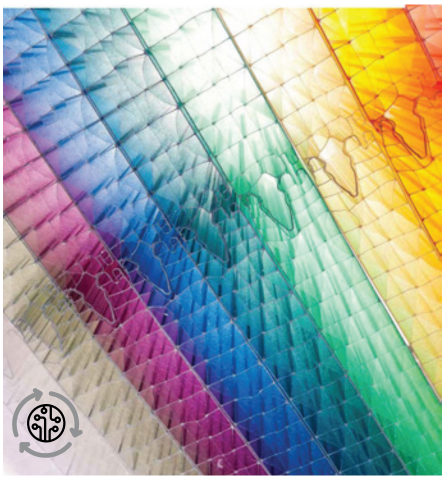
This facade is facing the city center and has the workshop and library from the interior. It is meant to be open to the city center by the use of light translucent materials and to 'communicate' what the students are learning in the school.



INTERIOR VIEW OF THE SKIN FROM THE WORKSHOP

MATERIALS

Polycarbonate panels



- Translucent
- 100% recyclable
-Lighter than glass
-Guarantee for 10 years at least
-SundaHus material database: B

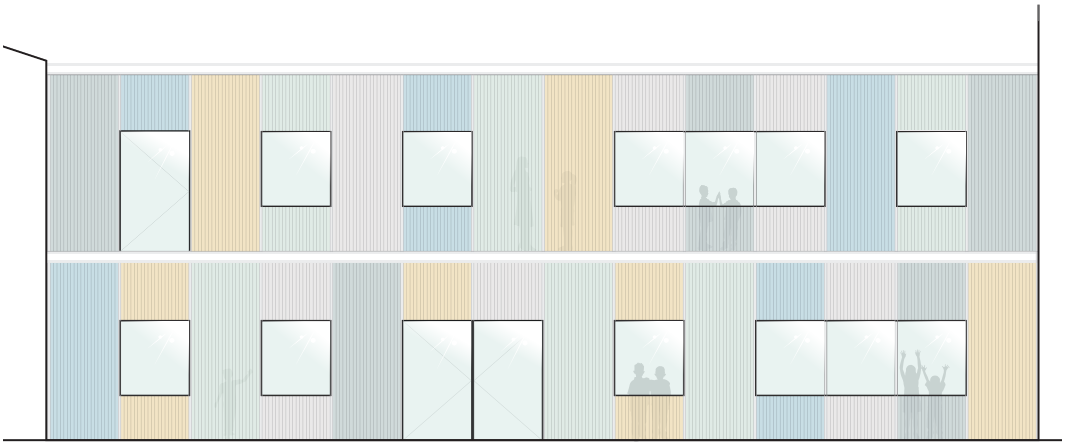
(http://sfs.sabic.eu)

Mycelium

- Biomaterial.
- Good insulation properties with thermal conductivity at 10c (W/mK): 0.039
- Cradle to Cradle Gold product.

Adding and removing the thermal insulation layer in the different seasons can be an extra advantage of the easy accessibility to the different skin layers. In this skin system, an empty air gap between two polycarbonate panels can be filled by the thermal insulation when needed. As a way of making students learn from the building, mycelium can be used as the insulation layer. By introducing cleaned agricultural byproducts to mycelium, it grows binding the particles according to the mold shape within few days. In the next month, it becomes solid. Growing the material can be done by the students in the workshop. When the insulation is taken away, it can be integrated into the biosphere cycle as it is a biodegradable material.(http://mushroomtinyhouse.com/) (www.ecovativedesign.com)

FACADE 1:150

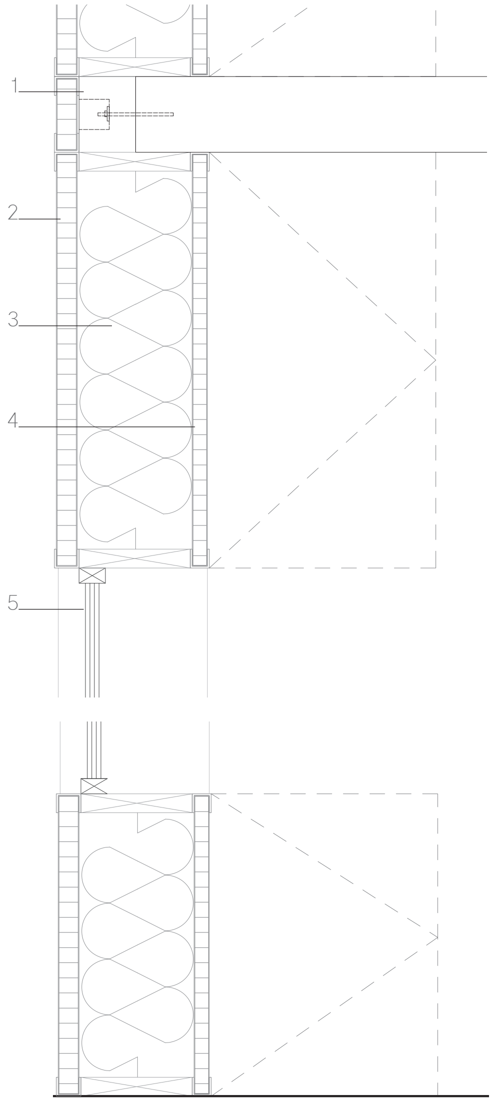


No insulation layer
U-Value: 0.3 w/(m^{2}k)

Growing mycelium

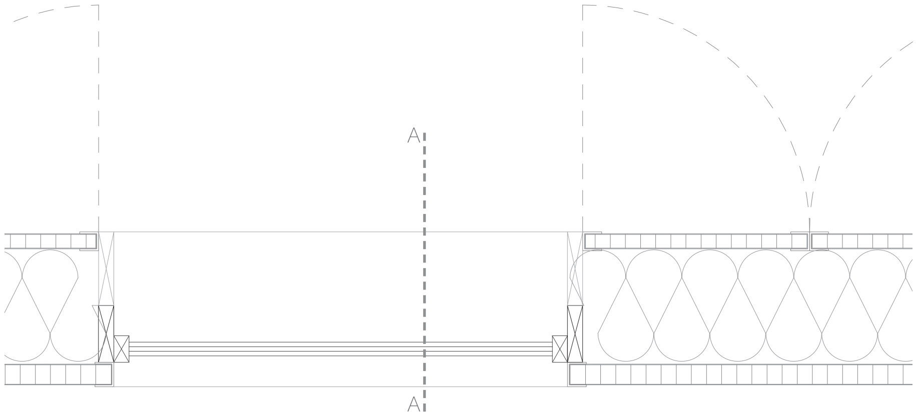
With fully grown mycelium
U-Value: 0.1 w/(m^{2}k)

SECTION AA 1:20

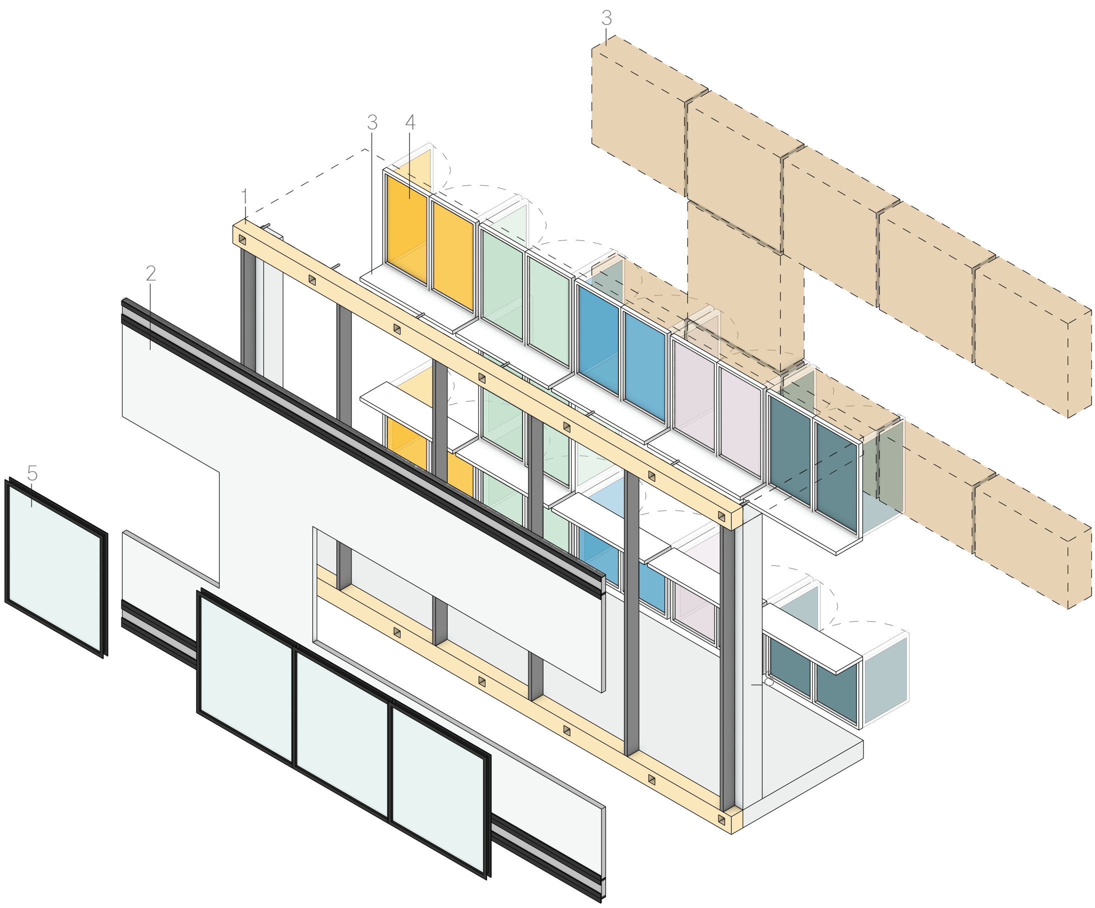


1. The connection (timber).
2. Uncolored polycarbonate panels 55mm.
3. Air gap can be filled with thermal insulation 300mm.
4. Colored polycarbonate panels 40mm(openable).
5. Window.

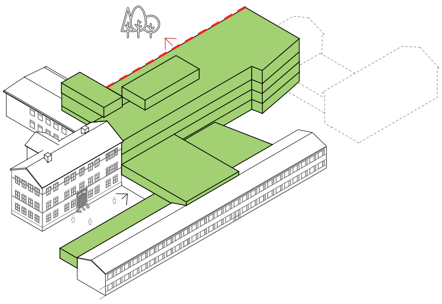
PLAN 1:20



ASSEMBLY OF SKIN LAYERS



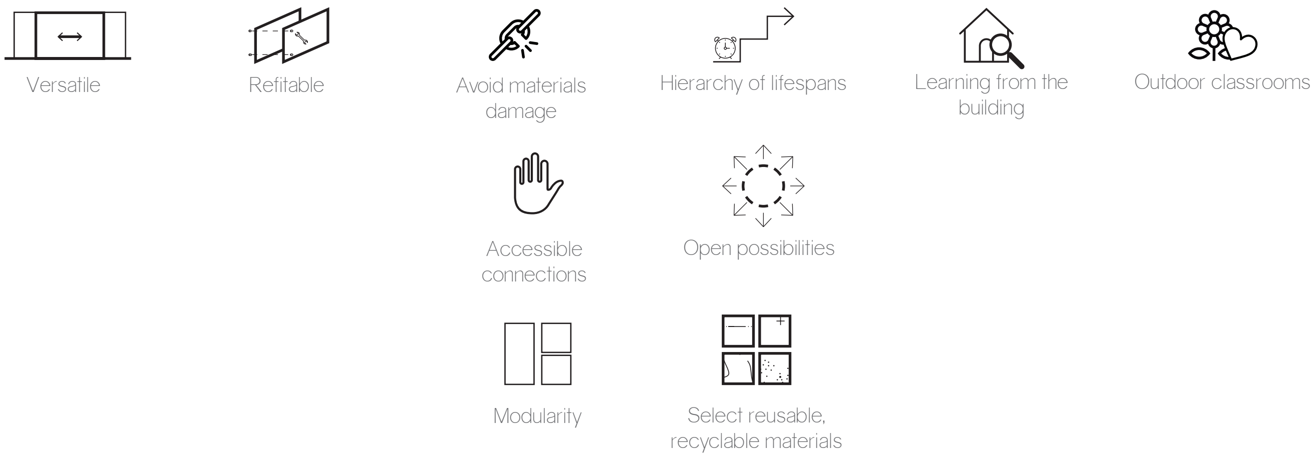
1. The connection (timber).
2. Uncolored polycarbonate panels 55mm.
3. Air gap can be filled with thermal insulation 300mm.
4. Colored polycarbonate panels 40mm(openable).
5. Window.



3. SCHOOL TO NATURE

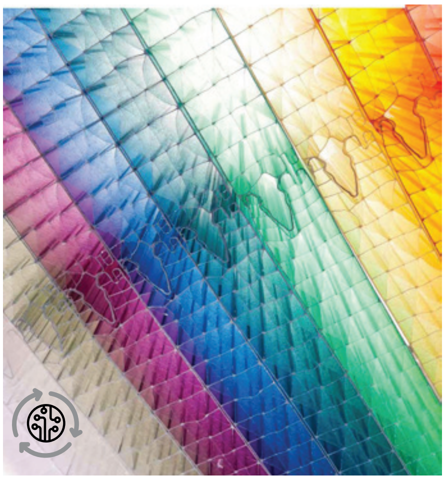
This facade is facing the forest with North West orientation of low direct sunlight. To bring the students closer to nature a highly translucent facade is used to emphasis the visual connection to the forest.

ADAPTABILITY | DESIGN STRATEGIES | SCHOOL DESIGN GOALS



MATERIALS

Polycarbonate panels



- Translucent
- 100% recyclable
-Lighter than glass
-Guarantee for 10 years at least
-SundaHus material database: B

(http://sfs.sabic.eu)

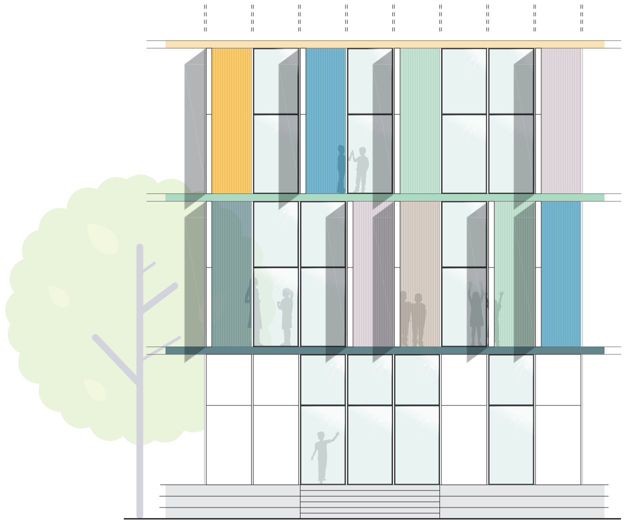
Vacuum Insulation Panels (VIP)

- Highly efficient light insulation with thin thicknesses; 2-3 cm corresponds to 10-15 cm of mineral wool insulation.
- 90% recyclable.
- Lifespan of 30-50 years.
- Should be protected from direct sun, moisture, and should not be penetrated.

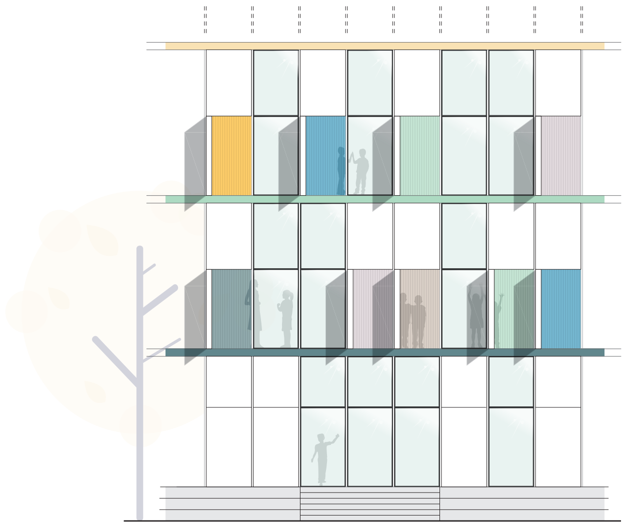
(www.byggahus.se) (www.kingspan.com)

To create more notable difference in the U-value of the skin and keeping the openness towards the forest, the highly efficient thermal insulation is put on the exterior of the skin and the translucent polycarbonate panels are in the interior. The thermal insulation panels are dynamic that can open and close according to the surrounding context. When Opened they give more daylight to the interior through the translucent polycarbonate panels and give stronger connection to the nature. When closed they create more compact skin with high thermal insulation.

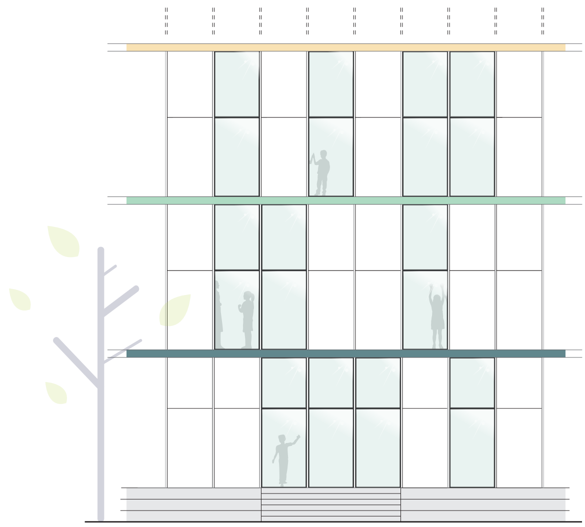
FACADE 1:200



Open insulation layer
U-Value: 0.75 w/(m²k)

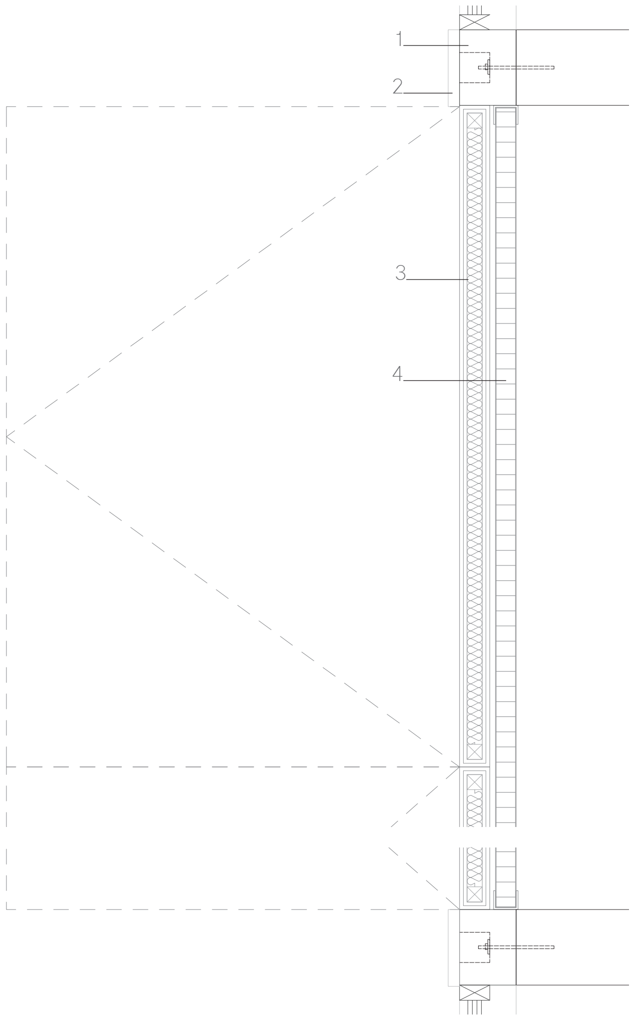


Semi-open insulation layer



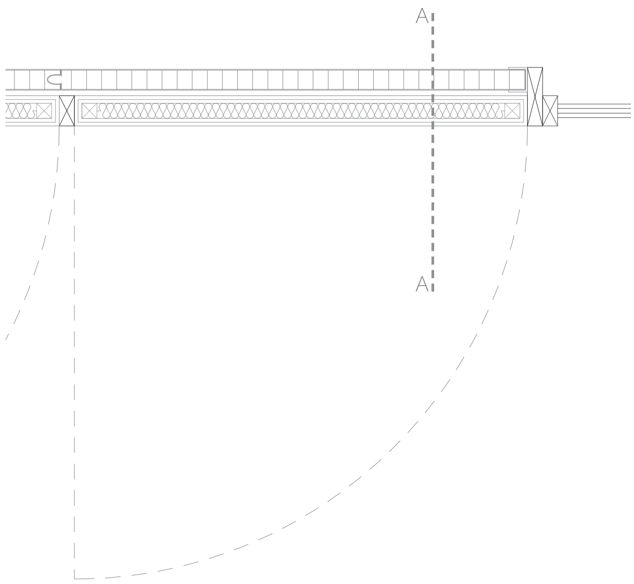
Closed insulation layer
U-Value: 0.1 w/(m²k)

SECTION AA 1:20

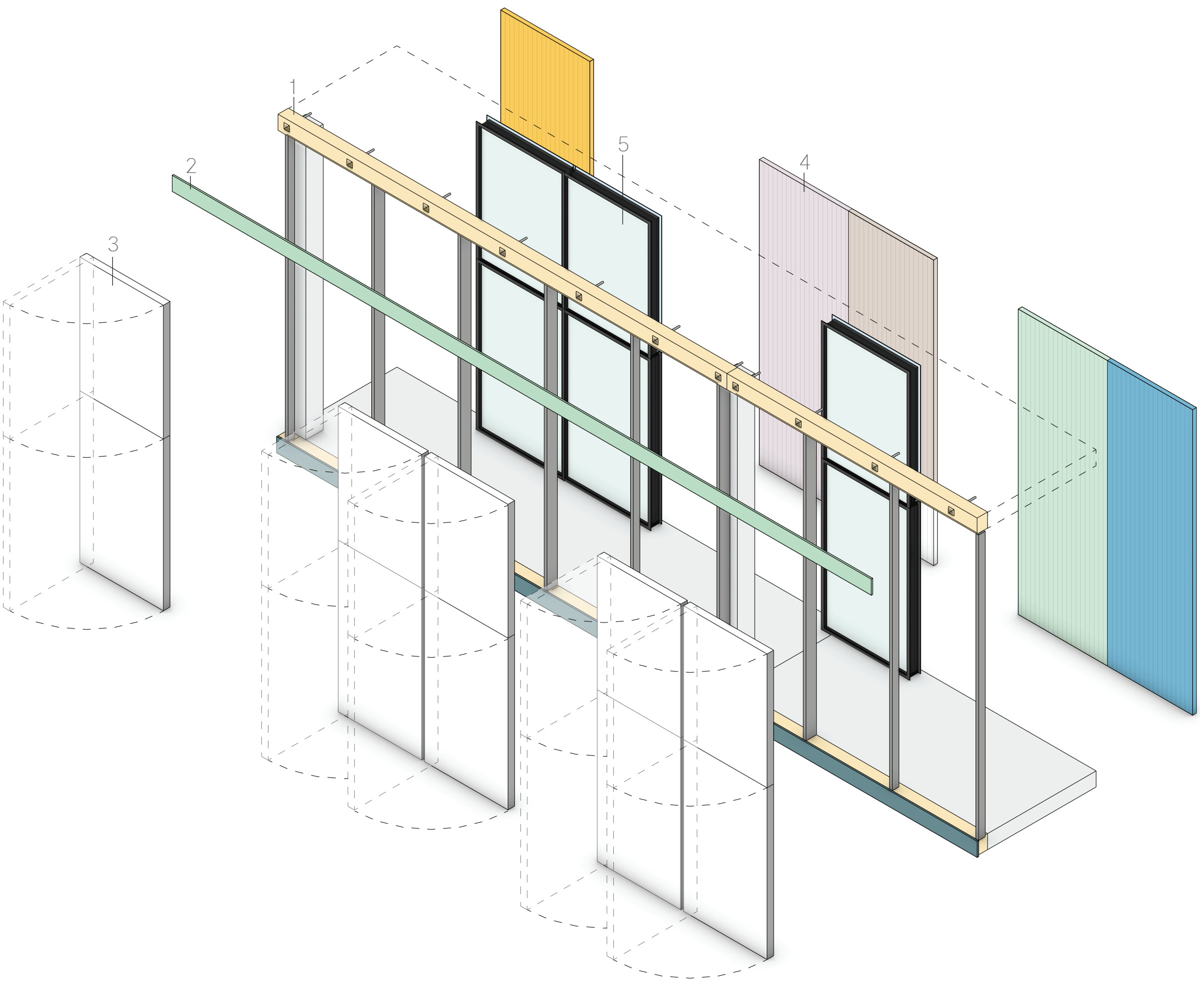


1. The connection (timber).
2. Covering
3. Vacuum insulation panels covered 50mm with wind and rain stopper 2mm (openable).
4. Colored polycarbonate 55mm.

PLAN 1:20



ASSEMBLY OF SKIN LAYERS



1. The connection (timber).
2. Covering
3. Vacuum insulation panels covered 50mm with wind and rain stopper 2mm (openable).
4. Colored polycarbonate 55mm.
5. Glazing.

5 DISCUSSION & CONCLUSIONS

DISCUSSION & CONCLUSIONS

ON THE THESIS DELIMITATIONS

-Adaptability is an important aspect of sustainable design and it should be considered in all building systems, not only the skin, because of the uncertain future and changing demands. In other words, the importance of having high capacity of change in buildings can bring rewards whenever the building changes; if changes happen after a short period operations like maintenance, physical adjustments, and materials reuse become easier and faster. If change was not needed until the end of service, then materials reclamation and disassembly become simpler and cheaper.

- This thesis focused on the skin system and their materials. Therefore, the research in Cradle to Cradle, building construction, and examples presented are limited to the skin system and materials.

- Only the materials of the main elements in the proposed design are specified because the material of the other elements depend on the main materials, for instance, their weight, strength and construction method. This is a point that can be further studied with other professionals like structural engineers.

ON THE DESIGN STRATEGIES

- Reversible connections embrace the fact that buildings are not fixed artifacts, rather than continuously changing. The connections should keep the materials undamaged, and the materials should be easy to disassemble, because the higher efforts and cost needed to reclaim material, the higher the opportunity they get into landfills; as the example of the bricks in the deconstructed buildings in Snäckeback School.

- Modularity and binding to the standard dimensions make the construction process simpler and leave less or no waste of materials. Also, materials reuse becomes simpler and cheaper, because no major modifications are needed. On the other hand, modularity can limit the architectural design putting boundaries for the architect to do more with less.

ON THE DESIGN PROPOSAL

- The design proposal in the thesis as not a final design, it is only a first step in exploring the possibilities of the connections among the elements, and the skin systems. It is a starting point for more engagement between architects engineers, material manufacturers and entrepreneurs during the design process.

- Designing the skin as layers opens many possibilities:

. Easy access to the different building layers allow the building for continuous change and adapting to the new demands, development of technology, and sustainability solutions.

. Provides the possibility to optimize the energy performance of the building through changing the configuration of the insulation layers resulting in variable u-value.

. Provides a good setting for some materials to be used more easily like Vacuum Insulation Panels.

- The different examples of the design proposal show the importance of collaboration between architects, engineers, and material suppliers during the design phase to benefit from the different expertise not only to create new innovative circular designs, but to explore more options for new building materials and new circular economy models.

- ‘School to City’ and ‘School to Nature’ are explorations to achieve variable U-value skins, by changes in the insulation layer, as one more possibility to optimize buildings energy performance.

- To optimize the building’s energy performance, a variable U-value skin system should be considered in relation to the HVAC system and the building as a whole.

- If the whole building comes to the end of service, ‘The connection’ allows for easy separation of the skin from the structural elements without damaging the strucuture, bringing both environmental and economic gains.

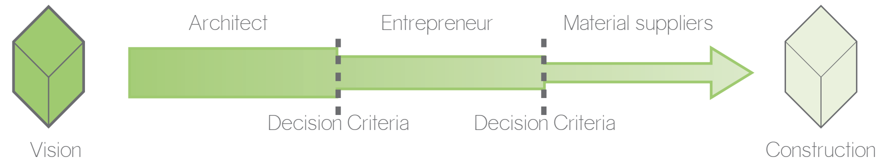
IN THE BIGGER SCALE

- A network of materials can be established when different buildings replicate the same modules and connection types. Making each building as a source of materials that can feed the other buildings in the network in the case of change. For instance, if a building is going into renovation and changing its facade, the materials of the facade that are still in good condition can be reused in other buildings with the same modular system, as they will fit easily. However, other factors that are unknown in the beginning must be tackled to make this network function. These factors can be the quantity of materials needed, or when are they needed, where to store them, and who will be responsible for handling them. The concept ‘products of service’ can provide a solution to make this network function. The material suppliers provide the building with materials as a service and be able to handle the material at the end of its life cycle- as the example the aluminum facade in Venlo city hall and the elevators in the Circl pavilion. It does not necessarily mean that the material supplier needs to recycle the materials if they are still in good condition. The material supplier can lease them again for other buildings in the network as used materials. With the spread of a unified modular system, buildings consequently become with high capacity of change and act as a source of materials. One crucial point for the success of such kind of network is developing a modular system with connection types that can fit various materials for different functions, yet in a similar way. Collaboration among architects, engineers, entrepreneurs, and material suppliers is needed to develop this modular system and connections. In the beginning, it can be costly to develop it and adapt the building industry to it, but on the long-term with the spread of these modular systems, the builders will develop their skills in working with them for assembly or disassembly resulting in faster operations and lower costs. ‘The connection’ presented in the chapter 4 (Design proposal) is a proposal of a connection system that has the potential to be a starting point.

- Ronneby is in a strong position in the transition towards circular economy, as it is closely engaged in designing the different school projects in the municipality, and at the same time, has the power of decision making with support from Cefur. This can be a great opportunity to experiment such a kind of network in the project of Snäckeback School and other projects owned by the municipality. One way can be to establish an open circular system, where they create a modular system that allows material reclamation so that it attracts material suppliers or entrepreneurs who are interested in circular economy.

ON THE DESIGN PROCESS OF SNÄCKEBACK SCHOOL:
ACHIEVING THE VISIONS AND SHIFTING OF DECISION CRITERIA

Shifting from visions to construction



The overall process in Ronneby can bring the C2C into the built environment, as it is a comprehensive process and aims to include the different stakeholders and their interests since the very beginning. The project specific program, the drawings, and the description document can direct the entrepreneur to develop the design details to respond to these different 'instructions'. However, dividing the design development process into clear steps where different stakeholder(s) are responsible can shift the final result from the initial vision as every stakeholder has different decision criteria. For instance, the architect has to respond to the client wishes, the functional program, building regulations, while the entrepreneur is concerned about the economic feasibility of the project, easier and faster construction methods. This puts pressure on the entrepreneur in finding the suitable solutions to build a C2C inspired building, which can be challenging within the limitations of the existing building technology that is not based on circular economy principles yet.

Collaboration to achieve the visions

The engagement of the different stakeholders in the design is recommended to push the process further towards achieving the vision. If the architect, the entrepreneur, and material suppliers are involved together in the design process under one decision criteria (the project specific program), more solutions will be created allowing for the maximum adaptability, materials reuse, and recycling. Therefore, the vision will be easier and more likely to be achieved. Accordingly, change towards circular economy will happen in the different sectors creating a solid base of circular economy with the continuous partnership one project after another.

REFERENCES

Baldwin, C. Y. and Clark, K. B. (2000) Design Rules: *The Power of Modularityvol. 1*. Cambridge, MA: MIT Press.

Berge, A., Hagentoft, C., Wahlgren, P., Adl-Zarrabi, B., Chalmers University of Technology, Institutionen för bygg- och miljöteknik, Byggnadsteknologi, . . . Department of Civil and Environmental Engineering, Building Technology. (2015). Effect from a variable U-value in adaptive building components with controlled internal air pressure. *Energy Procedia*, 78, 376-381. doi:10.1016/j.egypro.2015.11.677

Durmisevic, E. (2006). Transformable building structures: *Design for disassembly as a way to introduce sustainable engineering to building design & construction* , Delft University of Technology, Delft, The Netherlands.

Brand, S. (1994). *How buildings learn: What happens after they're built*. Great Britain: Viking.

Geiser , S. (2004). Open Building in Health Care Architecture: The Case of the INO Project in Bern, Switzerland. In *Open Building and Sustainable Environment. The 10th Annual Conference of the CIB W104 Open Building Implementation*, 2004, United States.

Herrmann, E. M., Krammer, M., Strum, J. Wartzeck, S.(2015). Scale: Enclose | Build. Basel: Birkhäuser.

Jensen, K., Sommer, J.(2016), *Building a Circular Future*. Denmark: GXN.

Knaack, U., Klein, T., Bilow, M., Auer, T., (2014). *Façades: Principles of Construction*. Basel: Birkhäuser.

Kawneer. (1999). Principles of curtain walling.

Leupen, B. (2005) '*Towards Time Based Architecture*', in B. Leupen, R. Heijine and J. V. Zwol (eds), Time-based Architecture. Rotterdam: 010 Publishers.

Macchi, G. (2017). *System Separation: A Fitting Strategy for Future Development. Architectural Design special issue Loose-Fit Architecture: Designing Buildings for Change*, Volume (87), 76-83.

McDonough, W., Braungart, M.(2009) Cradle to cradle : remaking the way we make things. London: Vintage.

Mellqvist, H., Kristensen, L. S., Van Den Bosch, C. K. (2016). Participatory Green Structure
Planning For Linking Urban And Rural Landscapes – A Case Study From Ronneby, Sweden. Nordisk Arkitekturforskning Nordic Journal Of Architectural Research, Issue (3), 79-80. Retrieved from http://arkitekturforskning.net/na/article/view/855/797

Mulhall, D., Braungart, M. (2010). *Cradle to Cradle® Criteria for the built environment*. The Netherlands: Duurzaam Gebouwd / CEO Media BV.

Schmidt III, R., Eguchi, T., Austin, S. and Gibb, A. (2010), *"What is the meaning of adaptability in the building industry?"*, Proceedings of the 16th International Conference on Open and Sustainable Buildings, May 2010, CIB 104, Bilbao, pp. 227-236.

Schmidt III, R., Austin, S. *Adaptable Architecture: Theory and practice*. London: Routledge.

Statistiska centralbyrån (SCB), 2016. http://www.scb.se/hitta-statistik/sverige-i-siffror/kommuner-i-siffror/#?region1=1081&region2=

WEBSITES

www.Archdaily.com
Garden House / Caspar Schols" 25 Oct 2016. ArchDaily. Accessed 9 May 2018. <https://www.archdaily.com/797991/garden-house-caspar-schols/> ISSN 0719-8884

Stadskantoor Venlo / Kraaijvanger Architects" 27 May 2017. ArchDaily. Accessed 9 May 2018. <https://www.archdaily.com/872129/stadskantoor-venlo-kraaijvanger-architects/> ISSN 0719-8884

http://www.c2c-centre.com/library-item/city-hall-venlo-more-merely-sustainable

footprintnetwork.org
World Footprint, October 2015

INTERVIEWS

Unni Johannesson
The school project leader
22/12/2017 In Ronneby (Introduction to the school project and the municipality's process to the date)
23/2/2018 In Ronneby (Understanding the design process of the school. The author introduced the initial design ideas)

Helena Revelj
Urban planning director
22/12/2017 In Ronneby (Talk about Ronneby's vision as a municipality. Site visit to the school)

Martina Lindgren
Cefur
22/12/2017 In Ronneby (Cefur background, visions and achievements)

Zijad Bico
Architect in Ronneby Municipality
23/2/2018 In Ronneby (Understanding the design process of the school. The author introduced the initial design ideas)

Shea Hagy
HSB Living Lab Project Manager
29/1/2018 in Gothenburg (Talk about his experience the HSB LL and some recommendations for the thesis work)

Raed Wahbeh
Founding Architect- Minimalist Architects, Amman.
20/2/2018 Via Skype. (Discussion about the initial design proposal of the connection)

Paula Whalgren
Associate Professor, Architecture and Civil Engineering, Building Technology, Chalmers University of Technology.
27/3/2018 in Gothenburg (Discussion about the possibilities of a Variable U-Value)

APPENDIX 1

SundaHus assessment

Source: https://www.sundahus.se/en/services/material-data/

A

Products that

1. Give minimal health or environmental impacts associated with the PRIO properties defined in the Swedish Chemicals Inspectorate priority guide PRIO (e.g. carcinogenic, toxic to reproduction, endocrine disruptors, allergens etc.)
2. Are not classified as hazardous for health or the environment during the construction phase
3. Do not affect the indoor environment negatively through high emissions of volatile organic compounds
4. Give minimal contribution to smog formation
5. Do not emit excessive levels of formaldehyde (according to the E1 standard)
6. Provide a minimal strain on natural resources and less to landfill mountains
7. Have a long service life (for selected product groups)
8. Are not likely to contribute to unsustainable forestry
9. Have poor transparency regarding the product contents

B

Products that do not qualify for A and do not match the criteria for C+ and/or C-.

C+

Products for which workers, nearby communities and the environment risk exposure to substances of very high concern used for the manufacture of polymers.

C-

Products that

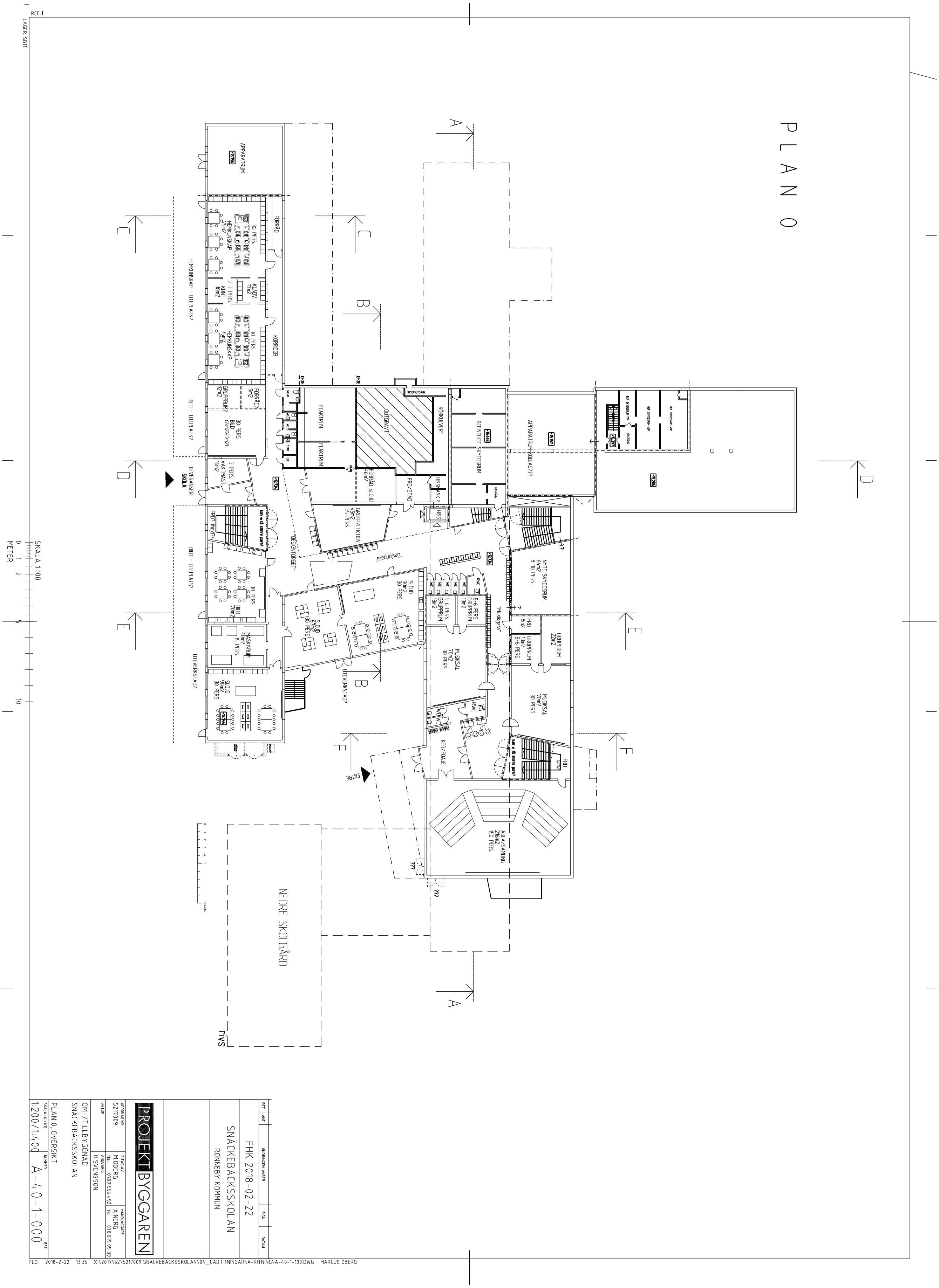
1. Could lead to an exposure to substances with PRIO properties (e.g. carcinogenic, toxic to reproduction, endocrine disruptors, allergens)
2. Could lead to exposure to substances with other toxic properties
3. Risk affecting the indoor environment negatively through high emissions of volatile organic compounds
4. Contribute to smog formation through emissions of volatile organic compounds with high photochemical ozone creation potentials
5. Contain substances or are produced with substances that at very low emissions can have a big impact on the climate
6. Risk contributing to unsustainable forestry

D

Products with insufficient documentation for an assessment.

APPENDIX 2

The plans of the school designed by Ronneby municipality



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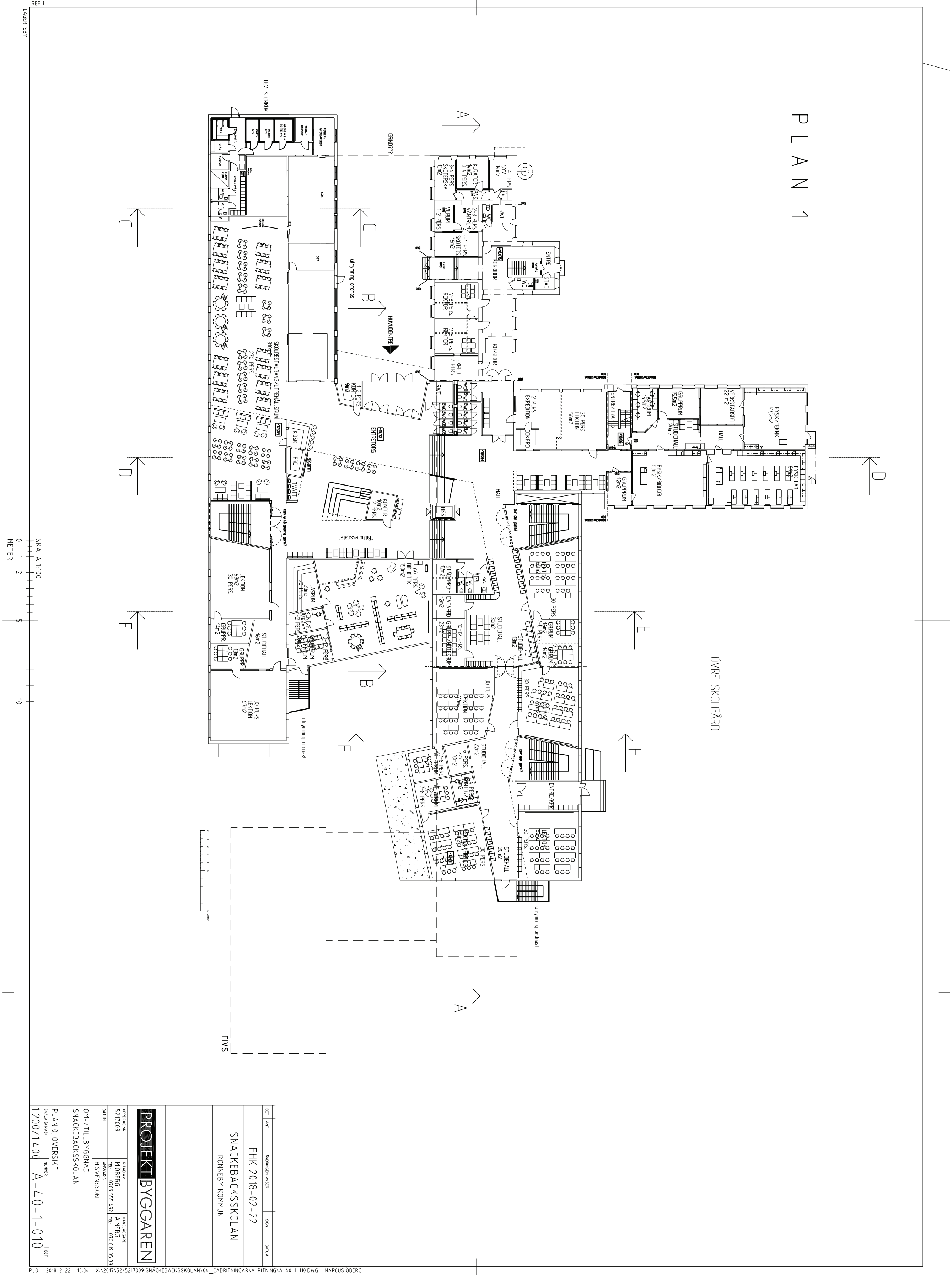

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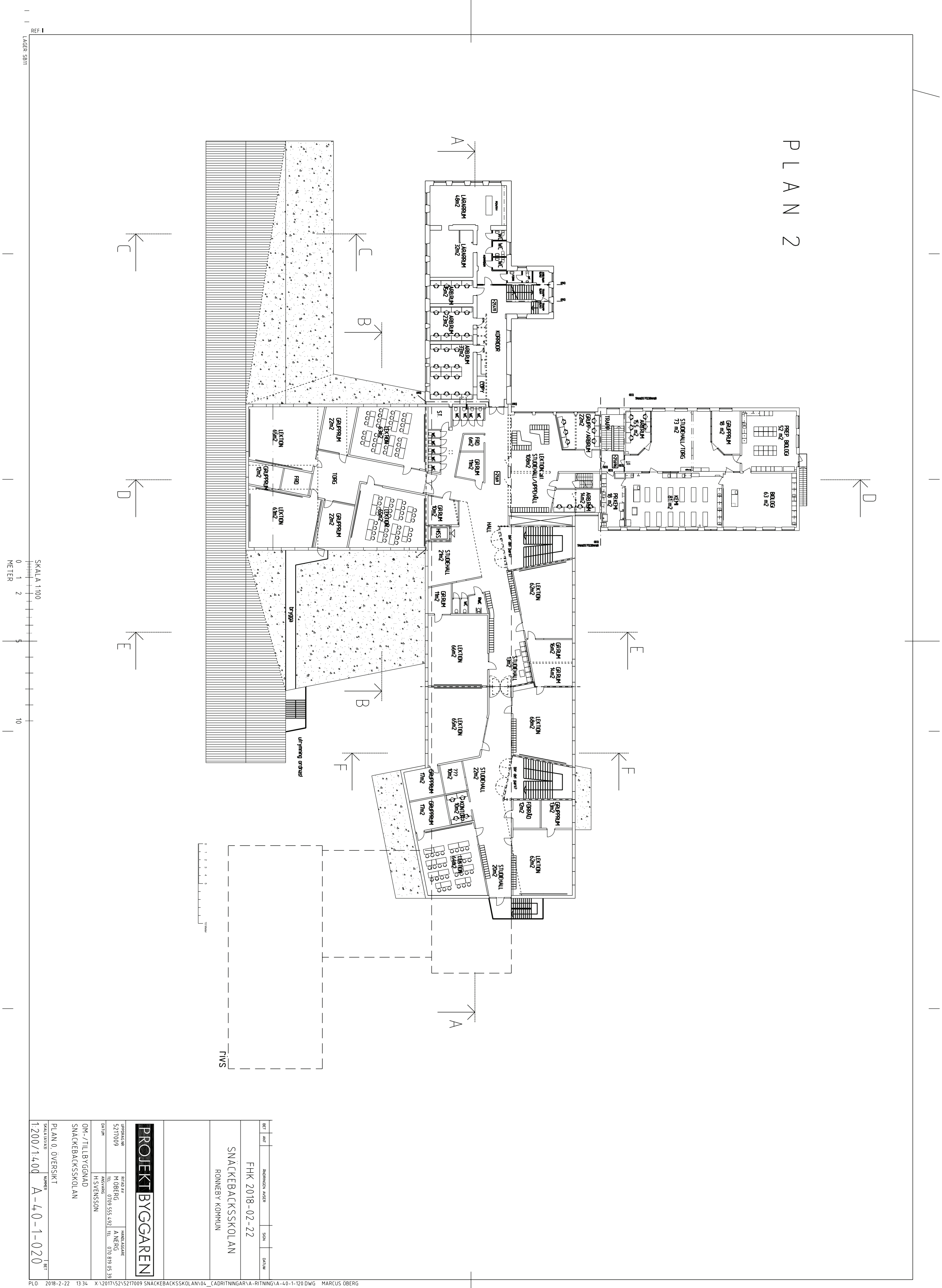

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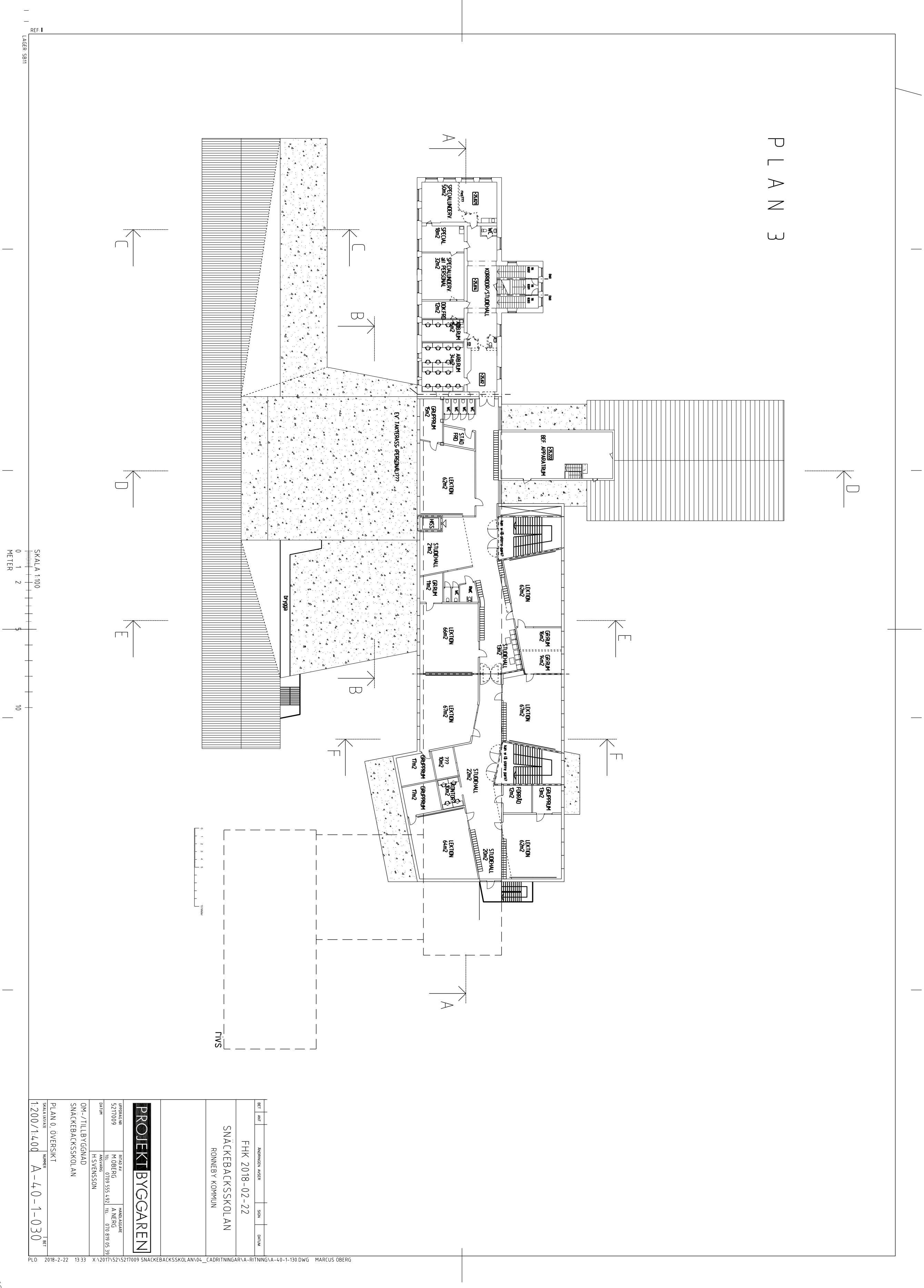

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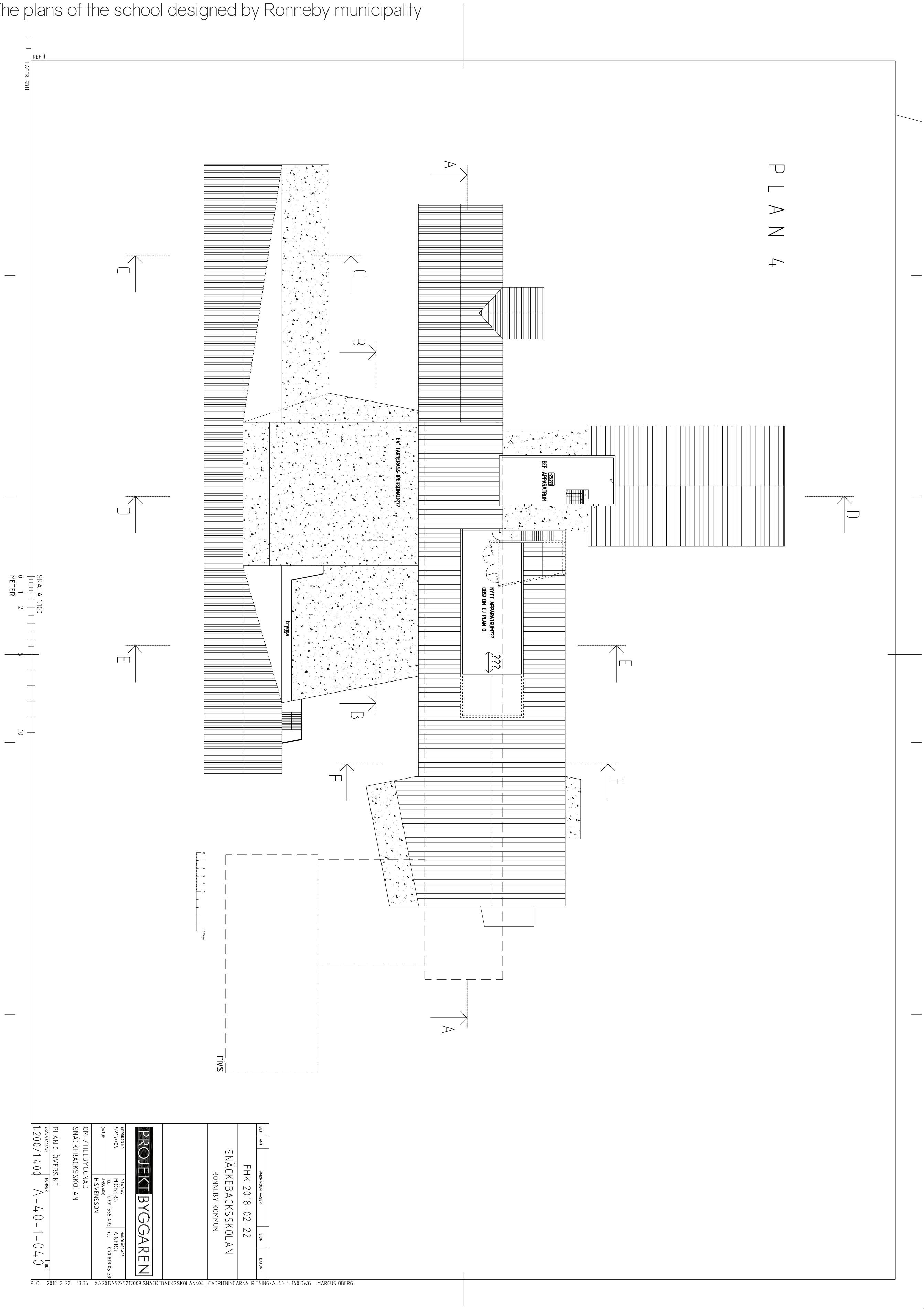
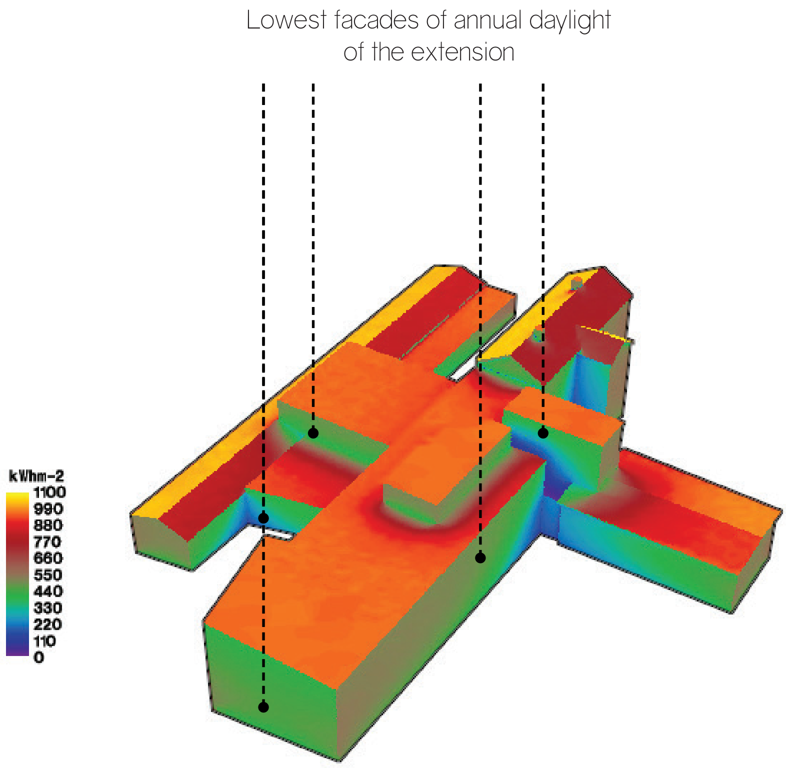
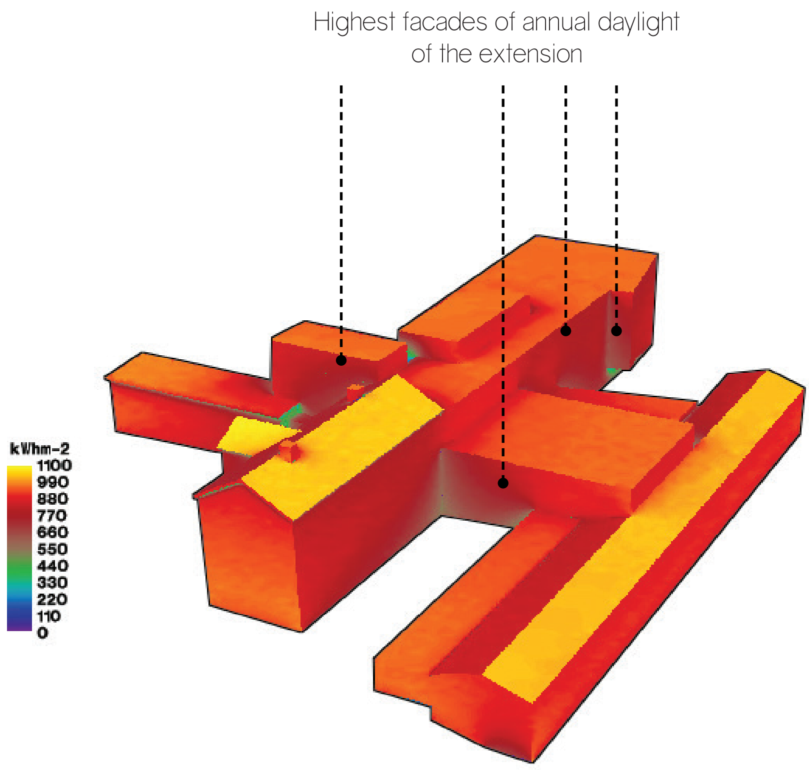


APPENDIX 3

Annual daylight studies by the author



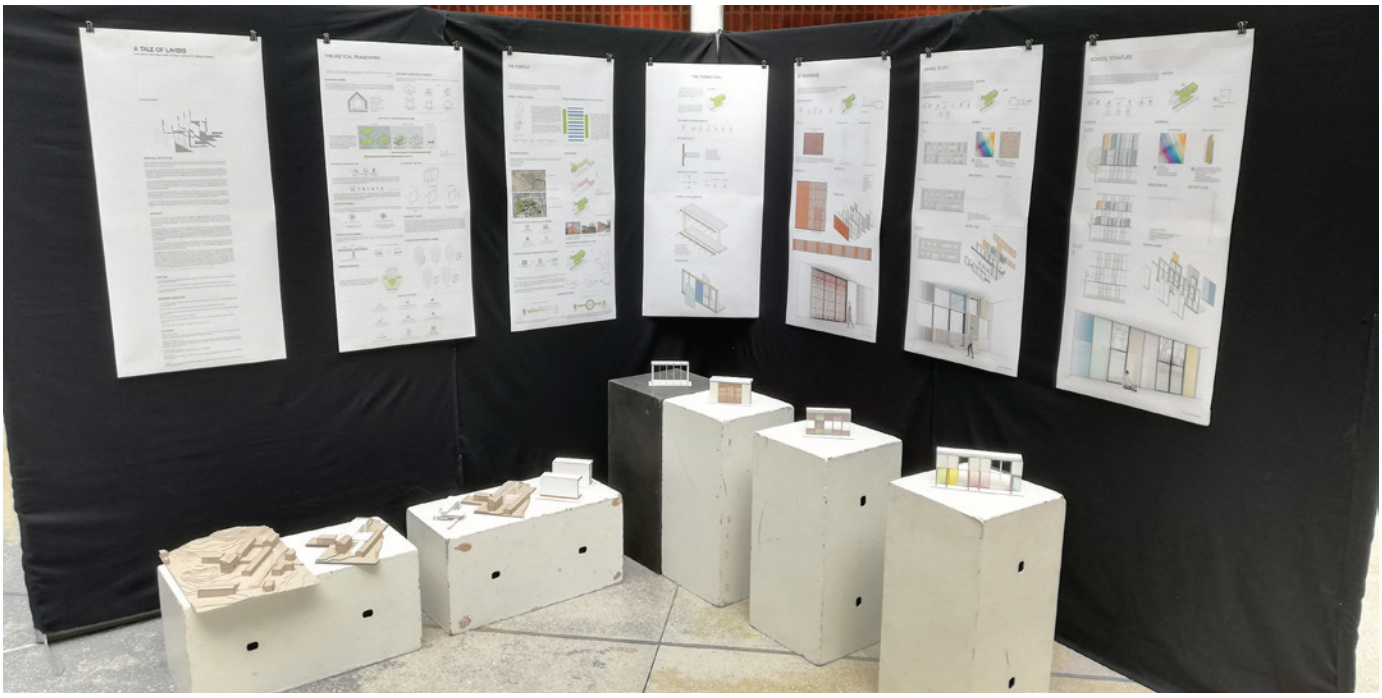
View from North



View from South

APPENDIX 4

Open seminar 31/5/2018



Design proposal models