FORM FOLLOWS MATERIAL

design with local resources

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Form Follows Material - Design with local resources
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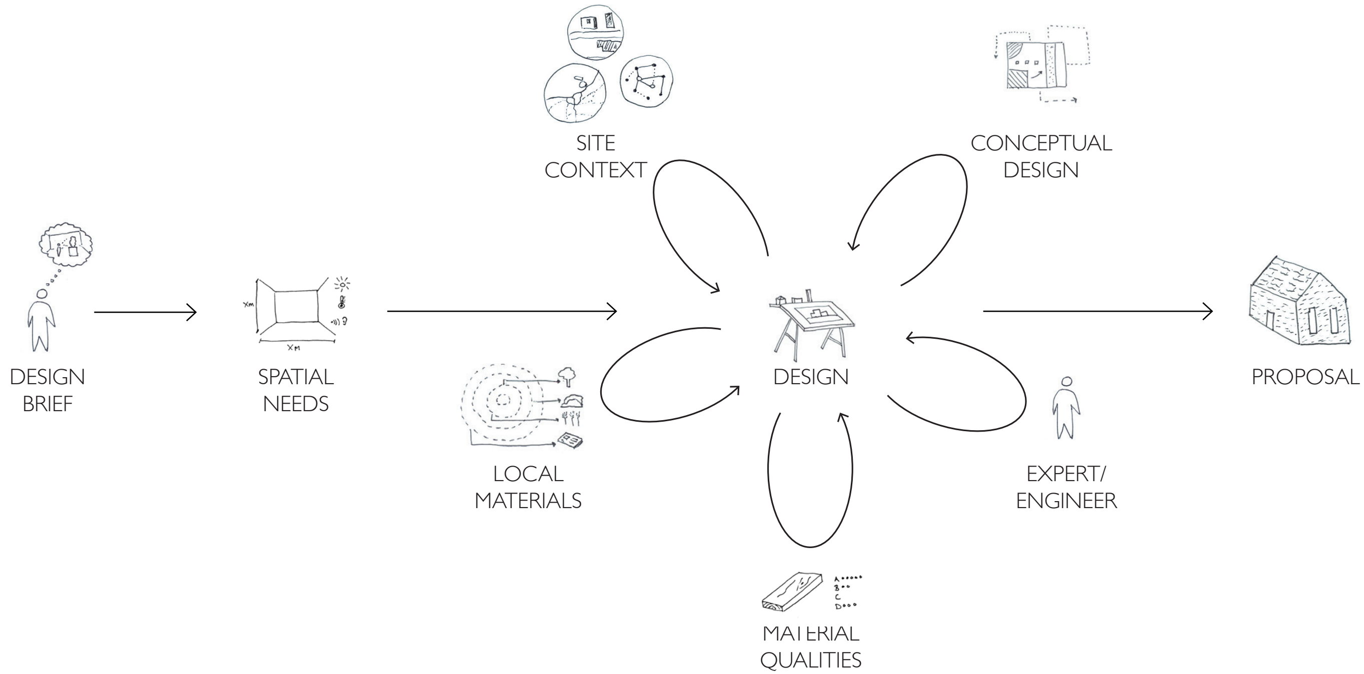
CHALMERS


DESIGN
BRIEF
SPATIAL
NEEDS
SITE
CONTEXT
CONCEPTUAL
DESIGN
LOCAL
MATERIALS
DESIGN
EXPERT/
ENGINEER
MATERIAL
QUALITIES
PROPOSAL

ABSTRACT

Approximately 40% of the world's energy and resource consumption is used within the construction industry. There have been many innovative solutions in regards to energy efficiency and cyclic service systems, however although there is an increasing interest in the embodied energy of materials little attention is still given to the wider environmental and social impacts of the material process. In a world that is facing the overhanging threats of climate change and globally diminishing resources this should not be the general practice.

This thesis has aimed to define a holistically sustainable material and a design process that uses locally available resources in order to promote a more responsible use of materials. Literature and reference projects have been used to frame the problem and explore alternatives by looking at models such as circular economy and different criteria for a sustainable use of materials. The notion of local has also been expanded from simply geographical distance to economical supply chains and mental connections. The design process has been investigated in a case study set in Mariestad through the proposal of a Material Centre, a program that enables local communities to utilise local resources as building materials. Resource and material opportunities were mapped and identified in this local context and these materials were then used in the development of the design proposal by setting the parameters of form.

The main outcomes of the thesis have been the reflection and definition of an alternative material and design process that have a holistically positive impact on communities, showcasing the potential for local societies and communities to fight the global threats the world is facing today.

SAMMANFATTNING

Ungefär 40% av världens årliga energi- och resurskonsumtion används inom byggnadsindustrin. Det har skett mycket innovation rörande energieffektivitet och cykliska servicesystem och man kan även se ett ökat intresse för den inbyggda energin i material. Det är dock fortfarande lite fokus på de större miljömässiga och sociala påverkningarna som orsakas av materialprocesser. I en värld som står inför hotet om klimatförändring och resursbrist så man inte råd att låta detta fortgå.

Målet med denna rapport är att identifiera en holistiskt hållbar material och designprocess. Rapporten har tittat på användandet av lokala resurser för att visa på för ett mer ansvarsfullt användande av material. Litteratur och referensprojekt har använts för att bättre förstå problemet och utforska alternativ som bland annat cirkulär ekonomi samt olika kriterier för hållbart materialanvändande. Konceptet för lokal producerat har utvecklats från ett geografiskt avstånd till ekonomisk och social påverkan. Själva designprocessen har testats och utvecklats genom ett designförslag för ett Material Center, ett program som uppmuntrar ett hållbart användande av lokala resurser och material. I designprojektet så kartlades potentiella material som användes som en stark drivkraft i formutvecklingen.

Resultatet av denna rapport är en definition och reflektion över en alternativ materialprocess som har en holistiskt sett positiv påverkan på samhället. Det är en process som genomsyrar många lager, från lokalsamhällsutveckling till arkitektens process och visar på potentialen i en omställning till ett hållbarare samhälle.

ABOUT THE AUTHOR

Ida Röstlund grew up in a small village 20 km north of Örebro. She lived in Brighton UK for six years, where did her bachelor in architecture and worked at a practice before returning to Sweden to start at the master program Design for Sustainable Development.

"The topic of sustainable materials is something that I have been touching upon from my first term in Brighton when I designed a pavilion out of crushed aluminum cans. In the third year I wrote my dissertation on the topic of how waste could be used as building materials and how design could transform waste into something new.

During the master program I was introduced to the concept of Design System and this new tool allowed me to explore and develop thoughts that I had been carrying with me for years. Thoughts of how everything is connected and how our design choices creates ripples into society.

Now I have been given the chance to take on this topic of sustainable materials with a new set of tools and explore it further in my thesis."

THANK YOU

First of all thank you to all the amazing people that took the time to talk and meet with me this spring. I have been so lucky to have met you and your input has been essential. Special thank you to all the great people I met in Mariestad.

Secondly thank you for all the support I have received from Chalmers University, especially to Lena Falkheden, Nils Björling and Lisa Bomble. Your enthusiasm and passion has been a strong inspiration.

I also owe thanks to the amazing "third floor thesis group" it was a pleasure to work alongside you this spring. Thank you Petra and Erika for your support and input, without you this term would only have been half as great!

Lastly thanks to my family and friends who have put up with my endless talk about materials and especially to Matt; thank you for keeping me together.

TABLE OF CONTENT

INTRODUCTION

BACKGROUND

Approximately 40% of global materials and energy consumption is used within the construction industry (Goodbun & Jaschke, 2012). Many innovative solutions to promote more sustainable lifestyles have been developed and energy efficient houses with cyclic service systems are becoming a standard. The embodied energy that goes into the construction of a building or the impact of the material extraction and production are still however not widely considered. This could be due to a tradition within architecture where materials are secondary to form (Lloyd, 2007). The modernist movements use of form follows function is one example of a notion that strengthens the idea's value over the physical material.

This disconnection has been reinforced by the global post-industrial society where we no longer have to consider the inherent properties of natural materials, or be restricted by local availability (Ingold, 2011). Since materials are so accessible they also lose economical value and are disposed of fairly early in relation to their potential lifespan.

PURPOSE

In a time with the growing threat of climate change and diminishing global resources the construction industry can no longer justify this linear use of materials, high level of resource extraction and excessive emission rates. A more efficient use of local resources could be a key cornerstone when fighting these threats. A locally focused approach could also support the development of more resilient societies both environmentally as well as social and economical (Hopkins, 2012).

The focus of the thesis has been to explore the opportunity of building with local resources in order to promote a more sustainable and efficient use of materials in the construction process. The thesis has investigated a design process where locally available materials set the parameters of form.

AIM

The aim of this thesis is to explore and define a **material process** that uses materials in a sustainable way that could have a **holistic positive impact** on local communities. The thesis focuses on the **architect's role** in this alternative process, where form follows materials as well as sustainable use of materials.

The material process is approached on the scale of the industry rather than as a bespoke self-build project. This has been in order to find key arguments to change a fundamental process in the industry that supports an unsustainable use of resources.

QUESTIONS

? What is an holistic sustainable material process?

? How can architects work with a sustainable material process?

? What material opportunities can local resources generate?

METHOD

In order to better understand the alternative material process and how architects can work with it this thesis has been developed through theoretical research as well as by the development of a design proposal. By being forced to go through the process a greater understanding has been achieved since more problems have been faced. It has been an iterative process, shifting between theories and design work using them as a driver for one another, see fig 4.

It is important to make it clear that the design proposal in the case study is not the result of the thesis but it has been a way to develop the project in parallel to academic theories.

Overview

The diagram below in fig. 5 tries to show how theory and design will run parallel, informing the result. In this way the project has been developed by ***Research for design*** and ***Research by design*** in parallel.

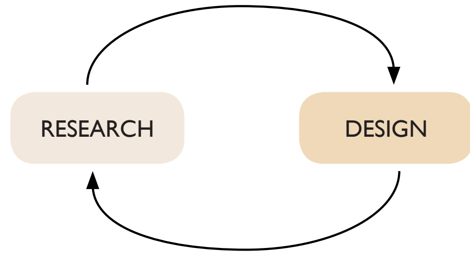


Fig 4. The thesis has had a iterative relationship between theory and design where these aspects have acted as a driver for one another.

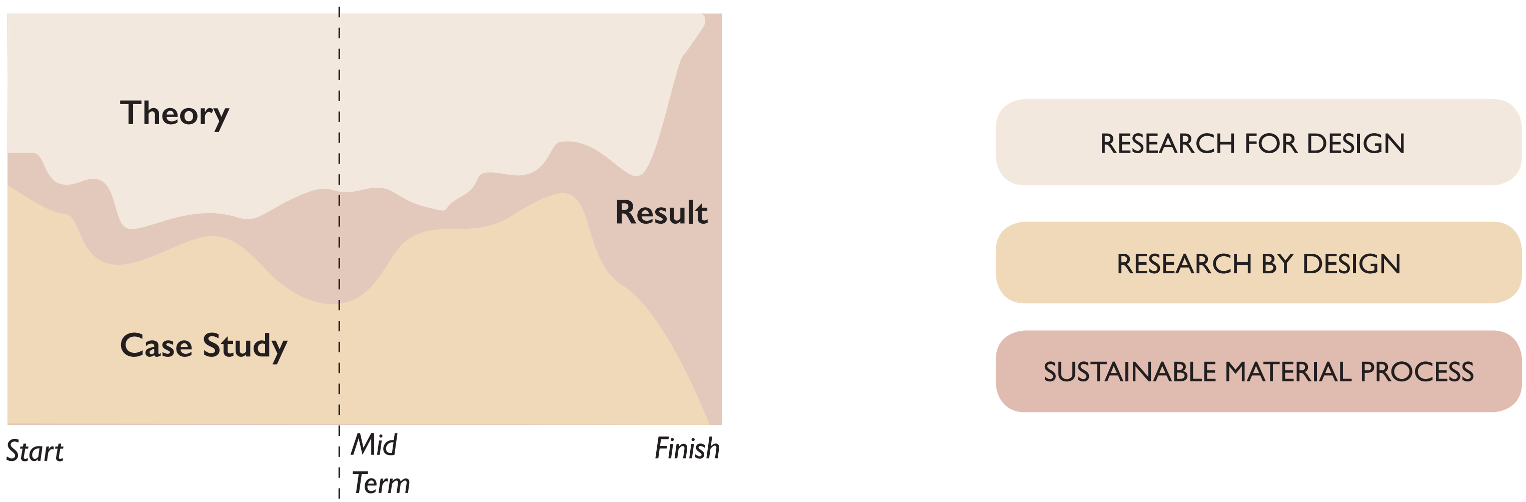


Fig 5. The concept for an alternative material process has been developed through both the approach of research for design and research by design. Working with theory and a more practical exploration in the case study has allowed for the topic to be investigated from two different directions.

DELIMITATIONS

The thesis has been developed in two parts that has looked at the material process from two directions. The first three chapters are theoretical studies relating to three main topics and the fourth presents the case study.

Broader context of sustainability:

This chapter has been used to get an overview of general sustainable models in regards to consumption and materials e.g. circular economy and definition of locality.

Materials in practice

The second chapter is focused on understanding the architects relationship to material and form. It looks back at historical development in order to try to understand the tradition of materials subordinate role in relation to form. It also relates to concepts of locality and architecture through texts such as Frampton's *Critical Regionalism* (1983).

Materials and Construction

The last theoretical chapter zooms in and looks more closely on sustainable materials and their use. Traditional building techniques are viewed as good inspiration for environmentally sustainable material use. The thesis does not however discuss the cultural heritage value of the use of these materials and techniques.

Case Study

The case study has been a way to approach the topic from another angle, by testing the principles in a design proposal. The focus for the proposal has been the one of material use and exploration of the design process. This means that other parts have not been developed as much as they would normally in a design proposal, e.g. site plan or spatial relationship. More time has been used to instead try to understand potential detail solutions and how material qualities can contribute to form.

READING INSTRUCTION

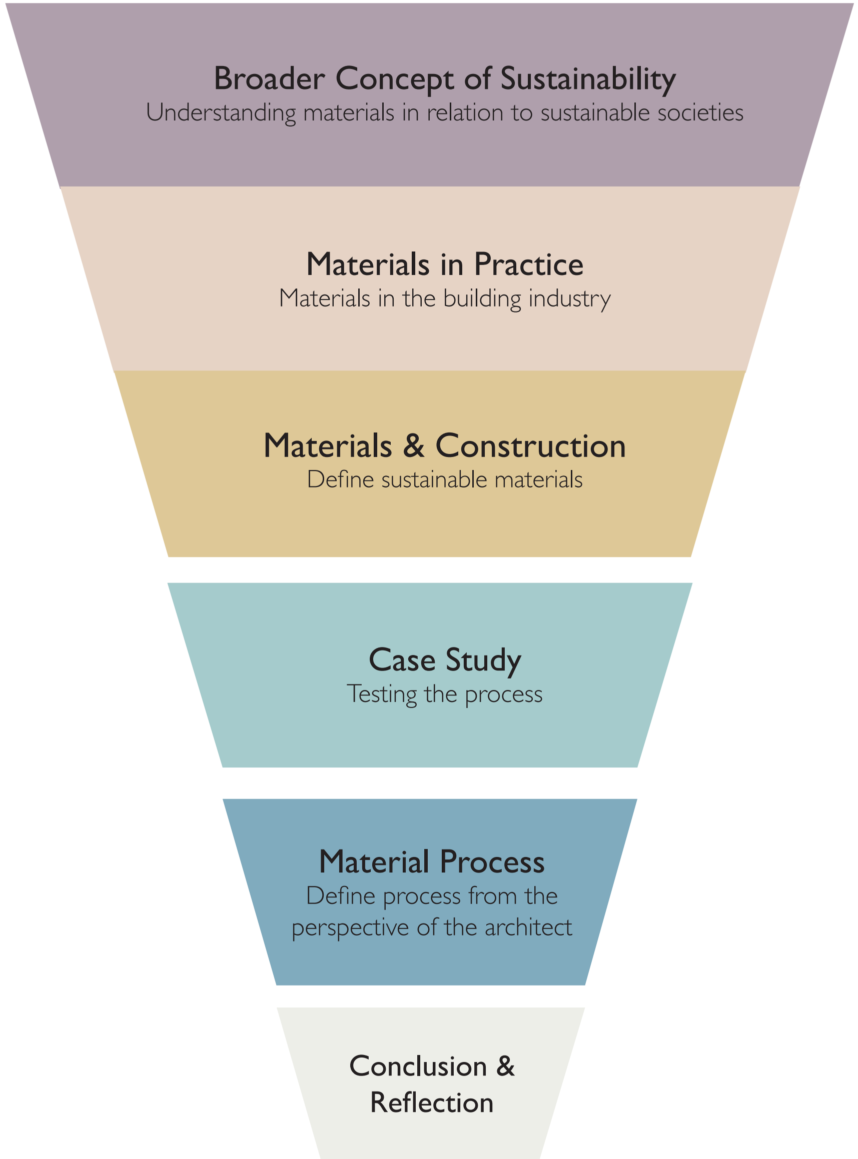
This thesis explores a sustainable material process which has been done in three steps:

Chapter 1-3 - Theory
The first three chapters explore a sustainable material process through literature studies. This begins in chapter one with the broad ideas of sustainability. In the second chapter the focus is brought onto materials and the architects relationship with these. While chapter 3 looks at sustainable materials and sustainable material use in closer detail.

Chapter 4 - Case Study
In the fourth chapter the process has been explored in a case study located in Mariestad. In this chapter concepts from the previous parts have been used.

Chapter 5 - Material Process
This chapter contains the result of the thesis. It outlines ideas for sustainable material process which has a holistic positive effect in society.

Chapter 6 - Conclusion & Reflection
In this chapter conclusions and reflections of the thesis are made and its topic as a whole. The thesis questions are also answered within this chapter.



TERMS

Downcycling
When a product is recycled but loses quality in the process.

Form
Shape and configuration of a building.

Leverage Point
Place in a system where a small change can create a large impact.

Materials
Elements or products that can be used as building components and for construction of a building.

Recycling
When a product/material is modified to be used again for the same way or different purpose.

Resources
Stock or supply of matter that can be turned into materials through refinement, recycling, reconfiguration or reuse.

Reuse
When components or products are reused with none or minor modifications.

BROADER CONCEPT OF SUSTAINABILITY

Materials in a sustainable society

1

Fig 7. Chino mine, an open copper mine in Silver City, N.M. Showcases land impact of mining.

On the 8th of august 2016 the threshold for the earth's annual biocapacity (how much resources the world can generate and waste is can absorb in one year) was reached. This means that any resources consumed or waste generated during the rest of the year has been chipping away at the earth's reserves. This consumption impact can be calculated as an Ecological footprint, which means the area of land needed to sustain the impact caused by the human societies consumption and waste habits (footprintnetwork.org).

Since 1970 the Ecological Footprint has been larger than the biocapacity of the earth, this is showcased in fig. 8. Not only is the Ecological Footprint steadily increasing, but this is also done at the expense of the biocapacity by example high exploitation of land. TThis is like spending all of your salary earlier and earlier every month. In 2016 this was the equivalent of spending your salary by the 18th of every month and then living on savings and an overdraft for the rest of the month.

A big contributor to the high ecological footprint is today's linear society see fig 9, where resources are extracted, refined, used and then discarded. There is also a skewed justice in who it is that uses the global resources. The average footprint per person in the world is around 1.6, compared to the footprint of Sweden which is 7.3 (footprintnetwork.org, 2012).

The earth's capacity to deal with overconsumption and waste has a limit and today modern society is pushing the overdraft boundaries and soon the earth wont be able to grant any more loans but will react with heavy fines in the form of global warming and depletion of resources (Tedex, 2010).

An example of landscape impact can be seen in an article by Jon Mooallem in a New York Times Magazine (oct. 22, 2015) where he writes about the phenomenon of the open mine industry which is captured by the photographer Edward Burtynsk, fig. 7. Moollem reflects on how human societies have always been extracting resources from the earth but how the scale in which this now occurs becomes intangible and how we can now feel threatened by the force of our own society. Burtynsk said that "If you feel revulsion to this landscape, you should have a revulsion to your whole life." since we all are a complicit in the development through our lifestyles and choices.

Like other industries the construction industry plays an essential role in this development since approximately 40% of the global materials and energy consumption is used within the construction industry and around 10% of that becomes waste (Goodbun & Jaschke, 2012).

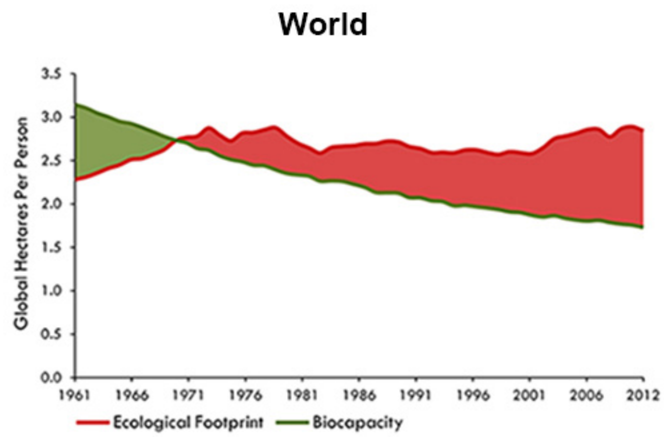


Fig 8. Diagram from the footprint network shows that the annual global ecological footprint has been larger than the annual capacity since the 19070's.

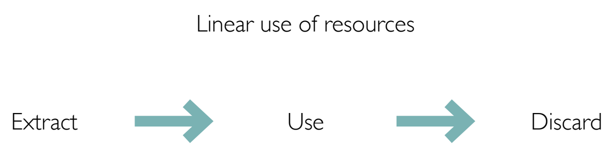


fig 9. Diagram showcase how resources are used within a Linear economy.

ENERGY EFFICIENCY AND EMBODIED ENERGY

In sustainable architecture the main focus has been to lower the operating energy of buildings. A lot of developments have been made in this area and it is today possible to build very energy efficient houses. Søren Nielsen from Vandkunsten architects in Copenhagen is one of many who now promotes that the next step is to turn the focus to the embodied energy of the building materials used in construction (lecture Chalmers, 2017).

Embodied energy considers all the energy used in the materials process. It can be very hard to measure but should in theory account for all energy used, from extraction and refinement, to transportation and construction at the building site. Looking at fig. 10 , this shows an example of the relationship between operating energy and embodied energy. Line B (normal efficiency) meets the embodied energy after 20 years, this means that after 20 years half of the energy used in the building is built into the materials (energy.mit.edu).

Steel and concrete are two materials that are widely used within the construction industry, favoured both by architects and engineers they are also both examples of materials with high-embodied energy and connected to high levels of CO^2 emissions.

THREE PILLARS

Low embodied energy would fall under the category of environmental sustainability, since this would generally mean less emissions. Environmental sustainability is however only one of three pillars outlined for sustainable development. In the *Brundtland Report* economical growth and social equity were also outlined as two vital aspects for sustainability. These three aspects have been defined as vital in achieving sustainable development and have set the framework for several organisations when outlining sustainability goals, fig 11.

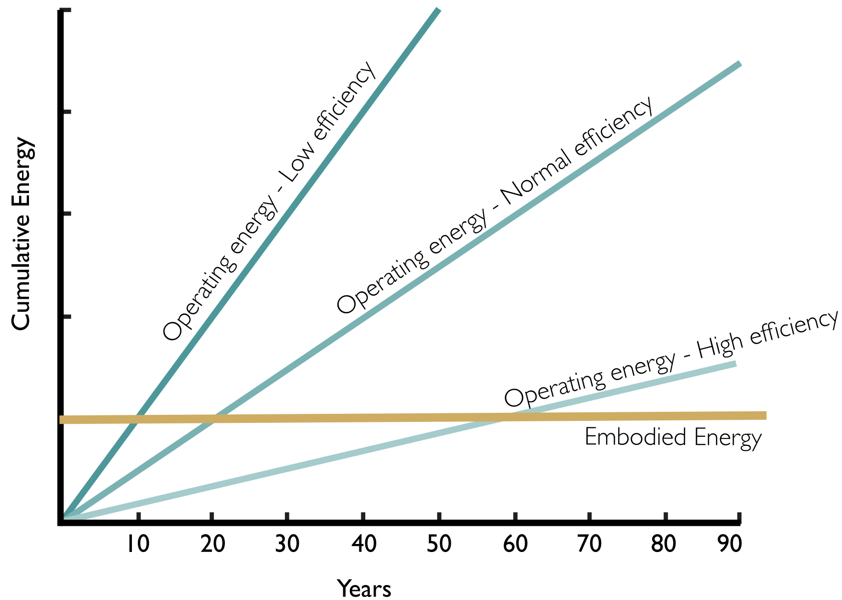


Fig. 10. Diagram from MIT Energy Initiative regarding embodied energy compared to operation energy by years.

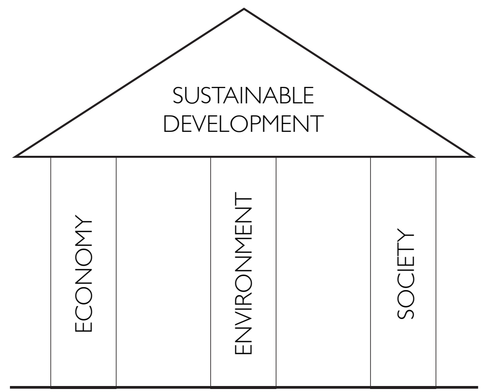


Fig. 11. The three pillars of sustainable development

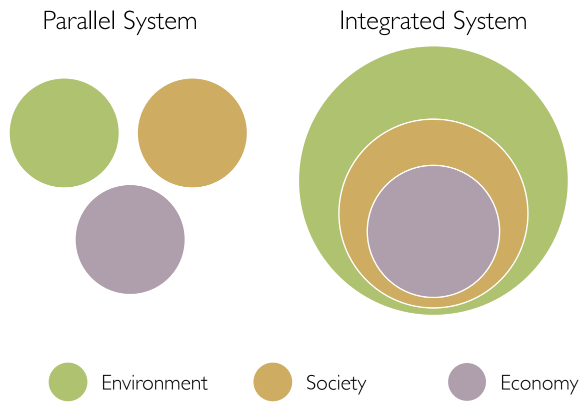


Fig. 12 Diagram illustrates the concept for a parallel approach versus an integrated and holistic idea.

"Like the building they make, materials themselves are cultural artifacts, constructed in social and political context and subjected to the same critical analysis."

Katie Lloyd Thomas - Material Matters p. 7

The natural steps' 'Future-Fit' business benchmark highlights the disconnection between these areas and how today business is favoured in a way that allows it to fail both environmental and social needs. (futurefitbusiness.org)

This could be due to either lack of interest or to the fact that it is easier to deal with issues as parallel and sometimes overlapping systems rather than the complexity of considering them as one integrated system, containing the three areas. Looking at materials it is however vital to consider the social and economical impacts of a material process just as much as the impacts on the environment. Fig 12 illustrates an integrated system approach rather than a parallel. Bjorn Berge who is a practicing architect and researcher (2009) supports this notion in his book '*The ecology of building materials*'. In this book he also mentions that the social and economical footprint surrounding a product or material can be just as important as the environmental one. Katie Thomas Lloyd a professor in architectural theory (2007) agrees with this notion and argues that designers and architects have to take wider material impacts in consideration since these too are a part of social and economical systems.

Sand as an example

Sand is an essential resource in the construction industry, the documentary director Denis Delestrac describes in his tedtalk (2013) that this industry accounts for around 80% of the annual global sand consumption. It is used as aggregate in concrete, asphalt, mortar and so on. Sand might seem like a resource that exists in abundance but due the rate at which it is being used has caused it to deplete in many places. In many cases sea-floors are now being dredged and sand is pumped up from the oceans. This excessive extraction is disrupting marine life at the seabed and by extension fishing opportunities. Due to the dynamic movement of the sand and gravity beaches are also disappearing in places, effecting both local tourism and habitats for wildlife. Since there is still a vast market for sand, illegal sand mining has become a large business for organised crime in e.g. India.

This example gives an idea of how interlinked the systems are and how ripple-impacts move through all of the areas creating new effects and impacts. In order to advocate change towards more sustainable societies, a holistic view of social, economical and environmental factors is needed.

Circular Economy

The Cradle to Cradle model divides resources into technical and biological systems. Biological nutrients are resources and products made from biological resources that can be returned to the ecological cycle. Technical nutrients on the other hand are resources that have been modified (without gaining toxic properties) and that can no longer be decomposed by natural systems. The model advocates to strengthen the biological cyclic system and for the technical to mimic this cyclic process, through the concept "waste equals food", fig 13. By encouraging refined matter to circulate as many times as possible through the process of reuse, recycling or upcyling, less resources will become waste which will minimize the need to extract raw resources from nature would. (McDonough & Braungart, 2003)

In the Ellen Macarthur foundation (2017) the relationship between resources and products is highlighted as the core to a circular economy; to see beyond raw natural resources and broaden the view for a more efficient use of the supplies that are available in society. The model of a circular economy also highlights the importance to consider the future life of products and goods already in the design stage and to design for future reuse.

Circular ladder

In fig. 14 the circular ladder is shown which is a development of the EU waste hierarchy which gives a priority of how resources should be used to prevent the creation of waste. This can with ease be applied to building materials. The first priority is to ***Prevent*** which can be done by avoiding excessive use from the start and prolonging the life through maintenance and repair. Next step is ***Reuse,*** to at the end of a materials life try to reuse it with no or small modifications. The third level is ***Recycle,*** through larger modifications an old material can be processed to become a new material. For biological nutrients this can be also be done by returning the nutrients to the biosphere through cascading or composting.

The last resort is ***Dispose*** where in the best case energy is extracted in an incineration or fermentation process. All of these actions in the last step however mean that the materials have exited the system.

CIRCULAR ECONOMY

Fig 13. Circular flow of matter in a circular economy.

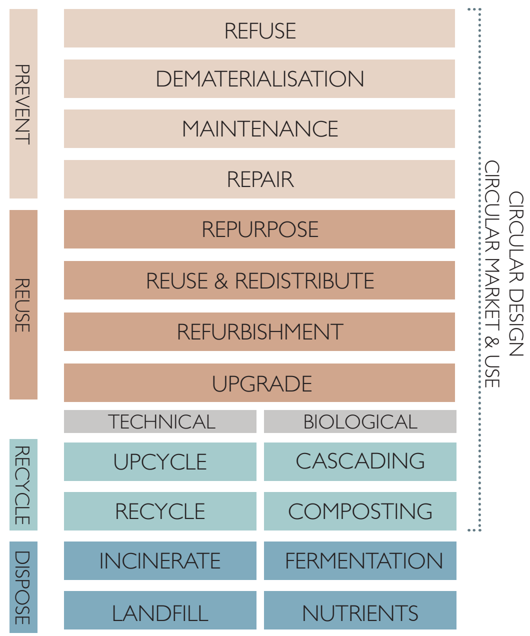


Fig 14. Circular Ladder over how to prioratise use of resources in a circular economy from De Groene Zaak, 2016

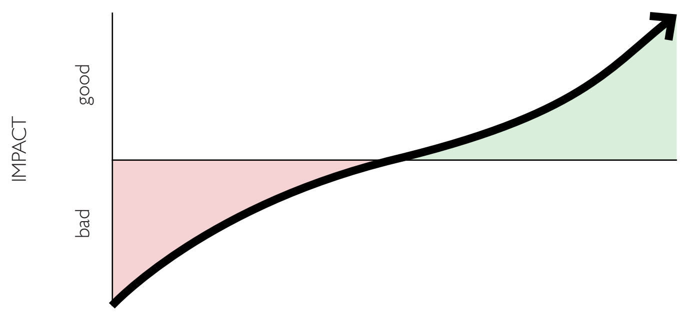


Fig 15. Diagram based on Cradle to Cradle's concept of having a positive impact rather than less bad.

Biobased Economy
In a report from Formas (2012), biobased economy is defined as a move from fossil fuel dependence in relation to transport and production towards a more sustainable relationship to ecosystem services. This is achieved through a more efficient use of renewable resources that are cultivated in a sustainable way. It also accounts for the social and economical impacts alongside as well as ecological.

Regenerative Design
Lyle (1996) described regenerative economy as a system that continues to replace the materials and energy used as a part of its own process. The main thought was to mimic nature and how it renews and restores itself constantly.

In the book *Upcycle* (2014) McDonough and Braungart also highlight the notion of limiting development to doing less bad to instead doing good. They make a comparison to a tree that in fact has a "positive" emission rate and question why human design does not strive for this rather than zero emissions. How future society can not only limit the negative impact but use economy, design and business as a way to do good.

Resilience
This is a way to estimate how vulnerable a society is to negative impacts, also called shock or disturbance. (Pearson, Newton & Roberts. 2014) This could be environmental ones e.g. flooding events. It could also be social or economical crises like the great recession in 2008 or the current refugee situation in Europe. The concept can also be applied on different scales from countries to small societies.

In the book *Resilient Sustainable Cities* (Pearson et al. 2014) the authors write about qualities that make a society more resilient. It is important to have a holistic approach and work with people and the places as a point of departure. Green space should be valued and changes made in just ways, considering social cohesion. By building up many small connections rather than relying on a few large-scale systems societies can become less vulnerable.

In circular and sustainable models not only is the use and reuse of matter important but also where and how resources are sourced and used. One of the principles in Blue Economy is: "Nature only works with what is locally available. Sustainable business evolves with respect not only for local resources, but also for culture and tradition."

Some of the green certification systems such as LEED also take locality of the resources into account. By using locally available materials, transportation distances can be shortened considerably leading to less emissions being released (buildings.com, 2013).

By using local resources it could also build a stronger awareness of the environmental impacts the societies consumption patterns are causing. For example, if a new neighborhood would be built mainly out of pine, the physical impact would be apparent in the shape of large clear-felled areas in the forest.

There are also other benefits in the use of local resources and materials. In his article *'Peak oil and transitions towns'* (2012) Rob Hopkins writes about how local communities from a grassroots' level can work in a way that mitigates global issues the world is facing today. One of the principles that the Transition Town Network works with is the New Economic Foundations 'leaky bucket'. This principle puts focus on the importance for capital to circulate within the local community as many times as possible and in that way create work and business opportunities in the local society.

A study made at the University of Minho in Portugal (Fernandes, Mateus & Braganca, 2014) makes the same conclusion when looking at the use of vernacular materials in sustainable construction. Like Hopkins they reflect on the holistic impact this can have in the form of work opportunities, education and skills, how a fairer distribution of income within a society creates a more durable system where more stakeholders benefit. In the report they also suggest that this decentralised system looks at sustainability in a way that challenges the cities and could favour regeneration of rural areas.

Bjorn Berge (2009) also writes about the benefits of shifting focus from large-scale rationalised industries to networks of local producers. Small-scale companies have other opportunities to work with quality in a closer relationship to the user. Berge also explains that smaller companies have more opportunity to be more sensitive when it comes to resource extraction due to their scale. A shift towards decentralisation could therefore contribute to a more sensitive use of resources as well as more economically empowered and resilient local societies.

What is local?

So what is a local material then? According to the environmental certification system LEED, regional materials are defined as "building materials or products that have been extracted, harvested or recovered as well as manufactured within 500 miles (approx. 800 km) of the project site for a minimum of 10% or 20%, based on cost of the total materials value" (Buildings.com, 2013).

In fig 16. this guideline has been applied for the case study site of Mariestad. According to LEED, materials could be sourced from almost the whole Baltic area, the south west part of Finland, north Poland and Germany, the whole of Denmark, almost half of Norway and two thirds of Sweden.

Fig 16. Map showcasing the area of 800 km distance from LEED certification applied from the location of the case study in Mariestad.

Some materials could however of course be sourced much closer to site. Especially if part of the goal with the use of local resources is to strengthen local communities and build on cultural values.

One thought is to use the boundaries of the municipal system that is in place in Sweden today. These political boarders could support a local focus since the municipalities have a strong interest in strengthening their areas. However, these borders are rather abstract when it comes to resource flow and availability and although some materials could be sourced within these areas it could become limiting. Even the regional scale is abstract, especially when working in the edge zones. Although regardless of this regional and municipal areas still have the potential to influence and support a local focus.

Consider Local Food

Local food production is a topic that has become increasingly popular over the last few years. In a report from SLU (Ljungberg et al. 2012) the distribution routes of locally produced food were investigated. In this report it is noted that in Sweden local food should be produced and refined within a 250 km distance (though there is no official certification in regards to this), while in the UK a distance of 160 km is used. These two concepts have been illustrated in fig. 17.

In a briefing from the EU (Augère-Granier, 2016) the issue of locality was instead viewed in the form of supply chains, this briefing also brought attention to how local food producers' benefit from short supply chains. An imbalance has been discovered within food supply chains as it is an industry that is complex with many stakeholders. Large companies can put high pressure on small-scale business and co-operatives that might be forced to sell at a loss. By shortening the distance between the producer and consumer the farmers can take a greater part of the products market value.

When defining local food systems the briefing relates to geographical distance that depending on product could vary from approx. 20-100km. It however also states that the notion of locality is more complex and relates to the context of the area; population density, landscape character and accessibility. The closeness of the relationship between the producer and consumer can also be a big part in the definition of local.

Perhaps the same complex factors apply when considering locality of building materials. Geographical distance being one aspect and the economical closeness in the form of supply chains another, as well as the social or mental relationship.

Different areas have different conditions where some materials may be easier or harder to extract and refine. The definition of a local sustainable material is most likely more fluid and context specific than a set geographical distance.

Local materials and architecture

The use of local or vernacular materials also has the potential to contribute to a sense of place making. This point will be explored further in the next chapter.

Fig. 17. Geographical distance defining local according to local food market for Sweden (250 km) and UK (160 km) set from Mariestad.

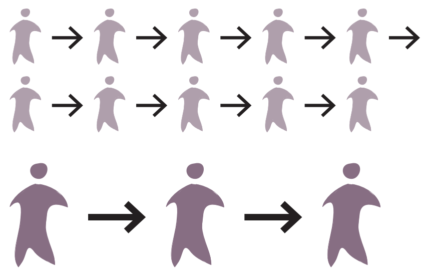


Fig. 18. Local focus can contribute to shorter Supply chains.

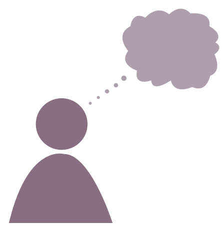


Fig. 19. When using local materials there is a chance for a mental connection between user and material.

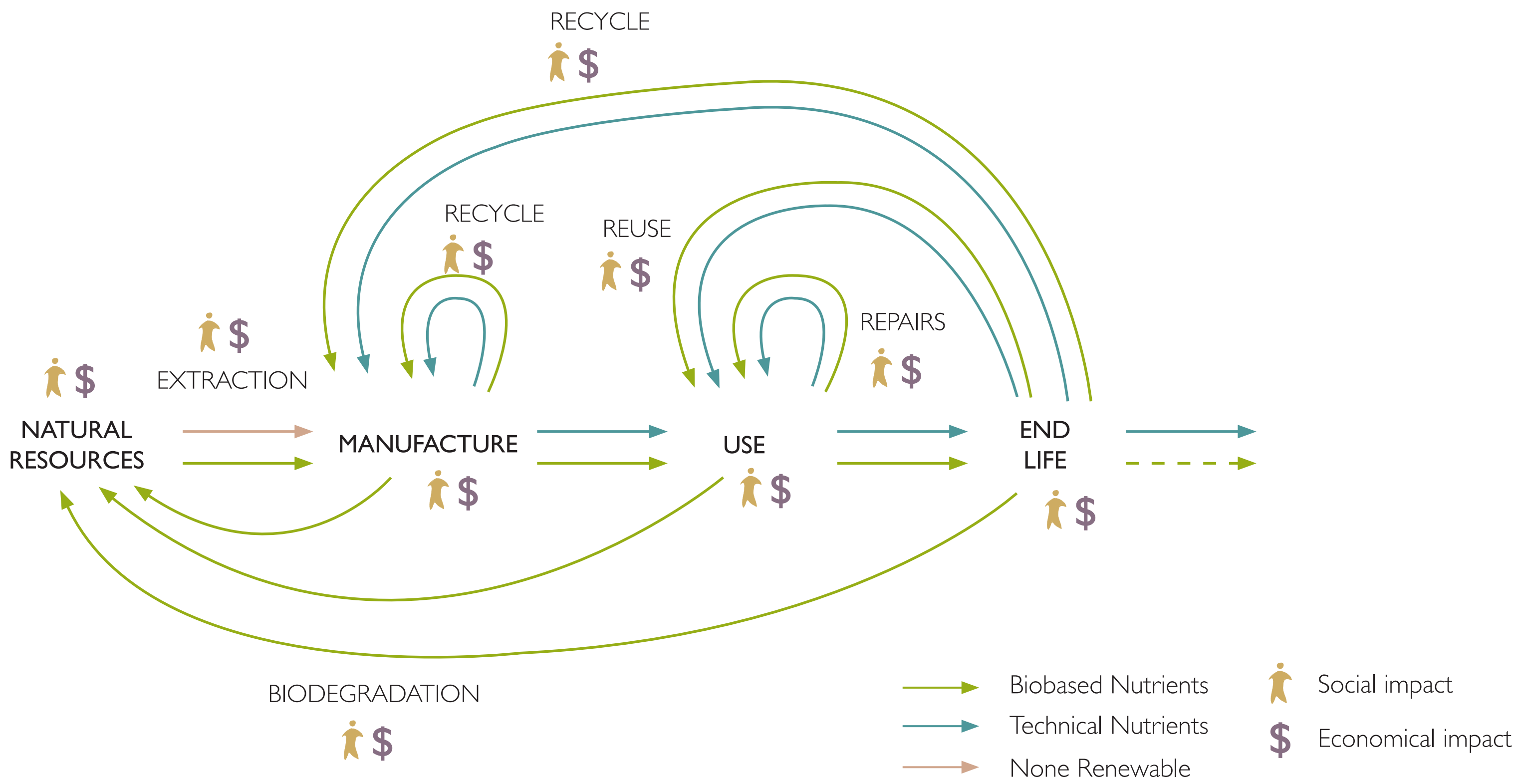
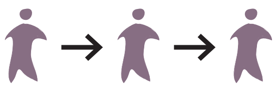


Fig. 20. In this diagram material flow in a circular economy is explored according to lifetime steps. Loops should preferably be kept as small as possible throughout the chain. This system also showcases that material flow has social and economical effects as well.


Short Transports


Short Supply Chains


Potential Mental Connection

SUMMARY

HOLISTICALLY SUSTAINABLE PROCESS

Today there is an increased focus in the environmental impact that material processes have. To be able to achieve a real positive change in this system it is however important to also consider the social and economical impacts that materials have in modern society. By viewing economy, society and the environment as an integrated system one can begin to outline the interdependence between the areas. In this way a holistical sustainable process can begin to be explored.

CIRCULAR SOCIETY

According to the Cradle to Cradle model, there are two systems that matter can be a part of: the biological and the technical. The biological contains matter that can be a part of natural ecosystems. The technical on the other hand contains matter that has been modified in such a way that it no longer can be returned to the biological system.

Fig. 20 is an adapted version of the Rioch Comet Circle Model, instead of looking at the system from the users point of view this system is showing it from the perspective of resource use in construction. One of the corner stones in models for circular societies is keeping materials looping within the systems as many times as possible. There is no waste in nature as matter is simply transformed. It is also desirable to keep the loops as short as possible in order to preserve energy and materials. The dollar sign and human are a reminder of the holistic system, that behind each step there are people and money involved.

LOCAL

An increased local use of materials could support local communities by strengthening the local market. It could contribute new work opportunities, which is also empowering to local residents. A local focus could begin to counteract the on-going trend of centralisation and rationalised industries that leave communities vulnerable with low resilience.

The geographical boundary set for local materials seems rather generous, with its 800 km distance. In the concept of local food the geographical dimension shifts depending on local conditions such as population density and landscape character. According to a briefing from the EU there are also two other important aspects that define local food: supply chain distance and mental connection between product and consumer. Taking this into account it makes the definition of a local material more fluid.

2

MATERIALS IN PRACTICE

Materials place in the building industry

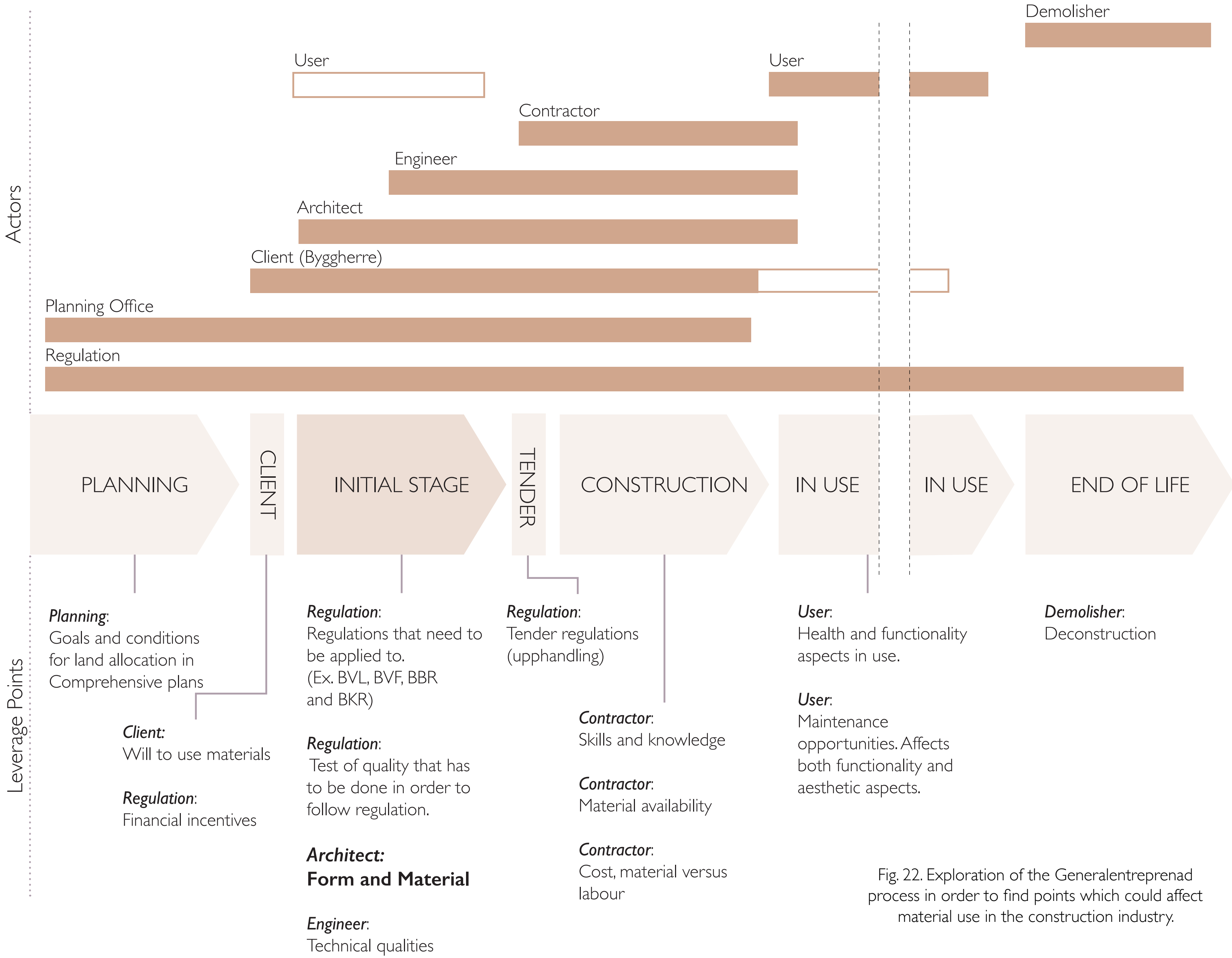


Fig. 22. Exploration of the Generalentreprenad process in order to find points which could affect material use in the construction industry.

The diagram fig. 22 to the right is an exploration of one of the most common construction processes in Sweden called 'Generalentreprenad' (Nordstrand, 2008). The section at the top indicates the actors that are involved in different stages along the process. In the bottom section points of opportunity or leverage points have been noted since these could influence the selection of materials. As shown in the diagram there are many actors who have the power to impact this selection:

Planning
Annika Kjellqvist, the director of the Bygg och miljö department at Mariestad municipality, thinks that there could be good opportunities to introduce demands of local materials at the planning stage and in land allocation documents. She believes that this could be a way for the municipality to encourage a more localised market.

Client
The wishes of the client are of course of big importance for the material selection. It will be easier to make "better" material choices if the client has an interest in sustainability. If this is not the case, different incentives from a political level could be a way to encourage clients to make sustainable material choices. Green certification systems are also ways that have the opportunity to encourage this.

Initial Stage
Materials have to apply to certain standards in order to be used and covered by insurances (Nordstrand, 2008). Linda Lindblad at Craft Laboratory (part of Gothenburg University) explains that it can be a very expensive process to get new materials certified, which favors large scaled manufacturers.

Engineers and technical consultants might require new ways to evaluate new materials that do not fit the standardised systems in place today. Linda Lindblad makes an example of the traditional timber frame construction that has been used widely all over Sweden over hundreds of years which proves its suitability for construction. It is however very hard to calculate structural values according to todays standardised models since the quality of the timber is not homogeneous but can vary depending on the tree or even between different parts of the same tree.

In Germany a certification system has been developed which allows for bales of straw to be tested to assure the quality. This certification makes the material available to more people.

The architects role in the selection of materials is essential since there is a key leverage point in the relationship between form and materials which will be discussed further in this chapter.

Tender
Since Sweden is a part of the European Union, the free market needs to be considered. Björn Ohlén from Västarvet in Göteborg can see that there could potentially be problems in the tender stage in regards to a localised focus. He makes a comparison to a municipality in Sweden that uses biogas buses and a local company could have provided these buses with gas produced within the municipality. However at the tender stage a French company could supply the ga s cheaper who then won the biding process.

Construction
Rob Hopkins mentions (2012) that a use of local material might require what he calls "re-skilling", where local contractors might need to learn new techniques in order to be able to work with another range of materials.

Currently there is not a strong market for localised materials on an industry scale in Sweden which limits the selection. The ones that are available are mainly used by self-builders and for bespoke projects. The move towards a larger change would have to be a long term transitional process, growing from small scale initiatives until it reaches lager companies.

In use
Fig 18. fails to show that the 'In Use' phase actually is the longest of them all.
By allowing for a building to be easily maintained and repaired by the users or owners the life of a building can be prolonged, the same applies if its adaptable to users changing needs, remaining functional as well as keeping aesthetic value through e.g. favorable weathering.

Demolition
By changing the demolition process to deconstruction more material can be reused or recycled. According to Vasakronan, a large property company in Sweden who has recently worked with a pilot project with a selective demolition process, there is a lack of companies who deal with deconstructed materials. They have also found the highest resistance of reuse of materials has been from clients and architects.

GxN, the research branch of 3xN are encouraging the concept of material passport which acts as a material reference list to the building where all material data is logged. This means that it will easier to reuse components in the future since more information will be available.

This was a very short description of a few potential points that could impact the material use. It felt important to contextualise the problem within the industry before proceeding to explore the architects potential role in an alternative process.

There has been an ongoing trend amongst architects to prioritise form over material, both in theoretical work and in practice. This can be observed in general practice when in tender packages form is illustrated in drawings while materials are marked in words and mainly discussed from construction practicalities. Has the architects craft shifted from building to drawing? (Lloyd Thomas, 2007)

The disconnection between matter and form has been an ongoing discussion since the roman times. Vitruvius considered form finding as the main point of invention and creativity while the material was merely chosen for its constructional properties, regional tradition and availability as well as economical factors. During the renaissance this view continued to be the norm with the addition of now also being selected for its aesthetic and beautifying properties. During the industrialisation in the 19th century this relationship started to be questioned with the introduction of new materials such as glass, iron and concrete. Gottfried Semper was one of the great spokespersons for the materials value in itself and how each material had its appropriate form. This notion of materials new status as form giver was reinforced by the developments in architecture at the time in the shape of delicate iron-and-glass creations where materials set the boundaries of form (Jeska, 2008).

The architects Frank Lloyd Wright and Adolf Loos shared this view that each material had its own form language. There were however critics to this technical-material approach. Alois Riegl and Adolf von Hildebrand were art historians who argued that materials must be subordinate to form. This is because form originates from the spiritual to then being materialised, and that material is an effect of form (Jeska, 2008).

Though the discussions and change of opinions have been fierce throughout history it might be the industrial revolution, globalisation and modernisation that have had the largest impact on the development of architecture and its relationship to form and material.

Susannah Hagan writes in an essay in *Material Matters* (2007) about how in the pre-industrialised society there had been a tradition of 'new-and–renew' as she calls it. New was a stage that was repeated over and over, to create and handcraft new objects was labour intensive so things that decayed were repaired or components reused. This tradition was however challenged in the early 20th century by the totalising effect of industrialisation and the notion of the new-and-renewed was swept away by the assembly line to be replaced by 'new-as-novelty'. This new notion stood for everlasting, resurrection, never decaying, never ending. This set the foundation for the ideology of modernist architecture, to be complete and permanently new. The same applied to the built fabric, renewal was replaced by the modern movements tabula rasa.

Alongside this theoretical development the industrial revolution kept running like a steam train. This social and economical development further reinforced the notion of materials as secondary to form. Due to the development of technologies such as steel and concrete, together with the growth of transport infrastructures and trade opportunities, materials were no longer bound to local availability or regional tradition. This development created an illusion of endless resources. (Borden and Meredith, 2012)

The economist E. F. Schumacher writes in his book *Small is Beautiful* (1974) how this illusion of the misconception of the quantity of resources contributed to materials losing their value further. Since it was now easier and cheaper to both extract and refine resources.

Tim Ingold, anthropologist, mentions in his book *The Perception of the Environment*, (2011) the relation between the detachment from matter with the growth of mechanics. He notes that while machines provide a level of precision that the artisan may lack, they remove the creative part of the physical engagement in the process of making, the relationship between man and material. Ingold goes on to reflect on the architect's relationship with matter and states that the architect has become a creator of structures. He writes "…and significantly, the process by which the architect or theoretical scientist arrives at novel ideas, as distinct from their subsequent implementation or testing, is often described more akin to art…"(p. 295). This suggests that the interaction with material has fallen under the category of technology thus is becoming a mechanical execution of predetermined decisions. This makes the material detached from the process of the design and enforces it's role as a tool to realise form.

Standardised Materials

With the industrialisation there was a move away from craftsmanship which required great material knowledge. Berge (2009) writes about how the growing power of the engineers lead to automatisation and workers lost control over the manufacturing process, making material knowledge less valuable. New standardisation models for steel surpassed timber construction since steel of certain dimensions will always perform the same way.

This standardisation is of course not only a bad thing. Through regulations and certifications, quality and safety of users can be assured (Bygganadsmaterial, 2001). It is however causing a problem for materials that are less suitable for standardisation, where craft knowledge is a higher requirement. Talking with Linda Lindblad, she explains that timber cannot be standardised since the models used today can not consider the different qualities of different parts of the tree or type of tree. It requires skill and knowledge to understand this material. Previously wood workers owned their own material process while now products are being bought from large companies.

Ingemar Widheden, who is a retired construction teacher, agrees with this and

"Whereas steel components of certain dimensions always have the same properties, the properties of timber joints are complex and often verified through experience rather than calculations."

Bjorn Berge -
Ecology of building materials p. 50

tells a story about a company that used to produce wooden timber frames. These should traditionally be made in dense heartwood of pine that is rich in resin to avoid rot. When the company bought new machines these could however not process this dense wood since the resin clogged the machines. So they started using lighter wood in their process, producing windows of lesser quality and which would most likely rot a lot sooner.

There are however signs of a potential stir in the waters. Björn Frodin and Stefan Jonasson, two craftsmen working with mainly traditional techniques explain how the Swedish Stolpverks society (Svenska stolpverksföreningen) is trying to attain certifications for timber and joints which could help to level the playing field. Björn Ohlén at Västarvet who has worked a lot with traditional building techniques and sustainable buildings can also see clear benefits in using the knowledge of materials qualities from traditional techniques. Historically materials were worth more and more care was given to maintenance and flexibility. There are also many techniques in regards to natural and renewable materials since these were the ones locally available. He believes that the future of sustainable construction is a marriage between the old knowledge and new developments.

Digital developments

Computers and digital tools are today essential for architects. This could mean that materials are further deprived of their importance since in a digital world material restraints can be overlooked (Jeska, 2008).

However new digital tools and simulation platforms also bring back focus to the materials and give more opportunities for designers to work with materials. An example of this is Arvid Söderholm's thesis '*Reincarnation of a building*' from 2016. In his thesis he used materials salvaged from a large shed to build a new smaller boat workshop. In order to minimise waste he worked with Rhino and Grasshopper to use a code script so that he could tweak the model to get an optimal form that would minimise waste materials. In the program Revit 3D models are built with material components, which makes the materials very present in the design. In practice, versions of the models are shared between different consultants such as the architect, structural engineer, electric engineer and so on. This could make it easier for trans-disciplinary work, where people get a better insight into each other's tasks.

LOCALITY AND MATERIALS

In his text 'Towards a critical regionalism' Kenneth Frampton (1983) writes about how the tabula rasa approach of the modernist movements strive towards an universal civilisation, a kind of 'one size fits all' methodology, has contributed to a global phenomenon of placelessness, especially in the western world.

In a material study from Portugal it is noted that the use of local and traditional building techniques could have an impact on local heritage and cultural legacy. (Fernanders, Mateus and Braganca, 2014) Frampton stresses however the importance of not confusing this increased local focus with populism or sentimental regionalism. The aim is in no way to glorify and revert back to the past or that "our local is better". It is about breaking the notion of the universal civilisation, that instead of leveling a site completely and raising a standardised structure one should work with the local conditions and instead use the sites topography and work with the local climate and materials.

The use of local materials could potentially make people feel more connected to their local environment. By knowing the forest from which the timber came or that the foam glass is a result of the recycling that you handed in could strengthen a mental connection between building and user.

The environmental architect Jason F. McLennan wrote in an article about how in the future anything 'heavy' such as materials, products and resources will become more localised due to energy prices for transportation and this will be a way to strengthen local economies. While anything 'light' like information and knowledge will be increasingly shared globally (2011). This notion could lead to a new localised architecture, where new and traditional local materials are used together with global knowledge.

DESIGN PROCESS

There are practices who work with materials close to their design process:

Rural Studio

This studio is a part of the Auburn University that offers courses for architecture students to get hands on experience in design and construction. The architect and founder Samuel Mockbee felt that architects have a strong ethical responsibility and the students chose projects for the community or individuals in the deprived area of Hale County, Alabama. In the beginning the studio was relying on donations both in the form of funds and materials. This usually meant that students were working with unconventional materials such as: cardboard, carpet tiles, tires or even parts of an old barn (Oppenheimer Dean, 2002).

Mockbee had a very experimental approach to design and construction, and a lot of the design was developed through experiments on the site. This was necessary

Fig. 23. The Manson Bend Glass Chapel by Rural studio with layered glass facade made of thrown away car windscreens. The shape of Rural Studios project usually grow from experiments with materials at hand.

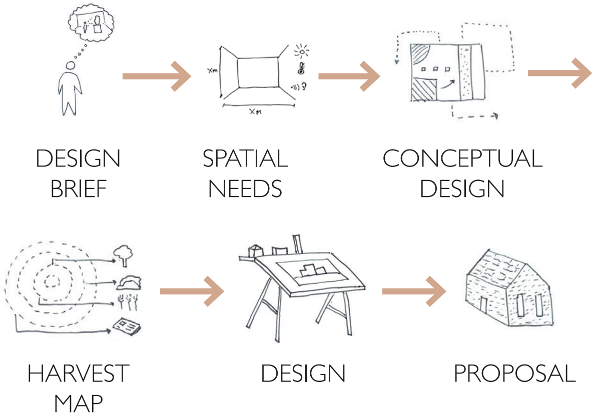


Fig. 24. Diagram illustrating the design process of Superuse Studios, in the process locally available materials set the parameters for the design proposal.

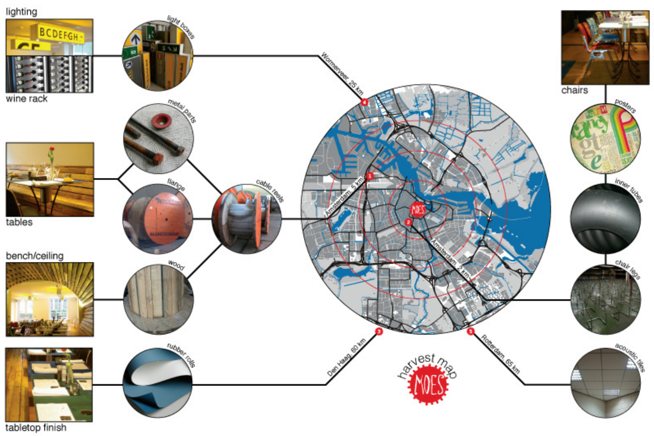


Fig. 25. Example of Superuse Studios harvest map for the Moes project, a tool in which the practice map local materials.

in order to understand the potential qualities of the materials that were relatively unexplored (Oppenheimer Dean and Hursley, 2005).

Superuse Studios

This Dutch practice was started in -97 and has been focused on using waste materials and products as materials in architecture. In order to do so they developed a design process that allowed for materials to become a bigger parameter.

The process is illustrated in fig. 24: they start with an abstract sketch of the design proposal to understand important qualities. In the next step they use a tool that they have developed called a 'harvest map' (fig. 25) where locally available waste products and materials are mapped. The needs from the abstract sketch are then connected to the materials that are available, letting the materials design the project instead of transforming them. By allowing the qualities of the materials to drive the design a new aesthetic logic starts to take shape.

Spatial needs and material qualities

Perhaps rather than discussing material and form, the discussion should be about space and materials. Because is it not spaces humans need and desire? Space to work, live or experience. These needs are then connected to material qualities, allowing them to become a bigger driver of the design – like in the examples above.

IN USE

In the construction process the user phase is easily overlooked. This is however the longest of the phases and the purpose of it in the first place. It is important to allow for easy repairs and maintenance in regards to materials during the user phase. The materials are however also connected to functionality and the aesthetics of the building which is also essential for the building's potential lifetime.

NOT SENTIMENTAL

The reason for using local materials should not be grounded in populist opinion, but rather as a way to connect back to the local context. To challenge the tabula rasa approach and instead embrace local conditions.

TRADITION AND DEVELOPMENT

In the case of a sustainable material process the use of traditional techniques are not used for their heritage values. There are cases when the heritage value of these techniques are essential but for the material process, tradition and technical development should not been viewed as two opposing teams but rather two tools that can be used together.

STRONGER PARAMETER

It seems beneficial to introduce the materials earlier in the design process as in the example of Superuse Studios. By letting them become stronger parameters of the design, the materials can generate an aesthetic of their own rather than being transformed to follow a preset form that risks compromising both aesthetic and material value.

DESIGN WITH MATERIALS

To be able to work with the material as a stronger parameter of form it is important to design with the materials from an early stage. By modeling physically or digitally it might be easier to consider qualities and restrictions of the materials,

PLACE MAKING

By taking more consideration to the local conditions of the site and context it is more likely that a proposal will be created which ties in with the place. There is also the potential of building a mental connection between user and materials if these are locally sourced. Strengthening the sense of place and awareness building.

MATERIALS & CONSTRUCTION

Defining sustainable materials

3

There are many aspects to consider when aiming to select a sustainable material. According to the *Whole Building Handbook* (Bokalders & Block, 2010) the two main aspects in regards to sustainable materials are health (emission's effect on humans and ecosystems) and environmental impact (mainly in the form of extraction of resources or green house gas emissions).

Health

There are issues both when materials containing hazardous chemicals are in use as well as when they are disposed of. Today there are many regulations in place in regards to chemicals and substances that are deemed dangerous for humans and ecosystems. Such as the EU regulatory framework for chemicals REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) or the Swedish database PRIO that is in the environmental code (Bokalders & Block, 2010). There are also private companies who work within the construction industry who help with phasing out hazardous chemicals such as SundaHus AB.

Environmental Impact

There are numerous methods used to calculate the environmental impact or ecological footprint of a material component or a whole building. These studies are usually collected in databases. Life-Cycle Analysis or LCA is one of the most common methods in evaluating materials. This method analyses the environmental impact caused during a materials life time, from land to energy and water requirements. It is a complex model that requires a lot of effort. Each evaluation is very linked to the specific material since it relates to its particular manufacturing process and conditions (Bokalders & Block, 2010).

Health and environmental impact are very important aspects to consider when selecting materials. In the search for a holistic sustainable material process it might however be useful to go one step further to better understand aspects of the process. This can be done by observing the material chain in fig 27 which illustrates a materials lifetime and factors to consider during the different stages (Bokalders & Block, 2010).

Interlinked

In a linear society this is a fairly straightforward process, however in circular societies these steps become more interlinked. As outlined in the first chapter a big part of the cradle to cradle methodology is to design with the materials future life in mind. This can be considered both in the production of the actual material as well as how it is being used in the design of a building. The latter is probably the most common for architects unless it is a bespoke project where the architects could influence the configuration of the material.

Resources and Materials

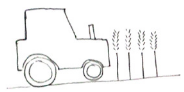
In this project a distinction has been made between resources and materials in order to break down the material process into two parts: matter used to produce materials and matter in the form of finished products.

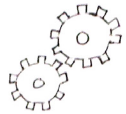
Resources have been defined as a stock or supply of matter that can be turned into materials through refinement, recycling, reconfiguration or reuse. The word raw materials has not been used since it gives a limited view of what could be turned into a material and excludes many opportunities. Resources are primarily relating to the first two steps in the materials chain: *Cultivation and Extraction*.

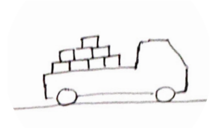
Materials have then been defined as elements or components that can be used in the construction of a building. Relating to steps three to eight: *Production Process, Distribution, Construction, Use, Demolition and Surplus Products.*

RESOURCES

MATERIALS







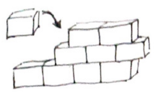
1. CULTIVATION
- Risk of mono-culture
- Pesticides needed
- Emissions or hazardous waste
- Total energy needed for cultivation (inc. what type of energy, renewable or fossil fuels)

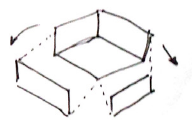
2. RESOURCE EXTRACTION
- Which resources
- Amount
- Additives needed
- Emissions or hazardous waste
- Extraction or recycling
- Transportation
- Total energy needed for extraction/recycling (inc. type of energy, renewable or fossil fuels)

3. PRODUCTION PROCESS
- Energy consumption (inc. type of energy)
- Waste/surplus created
- Emissions or hazardous waste

4. DISTRIBUTION
- Distance
- Means of transportation
- Type of packaging

MATERIALS





5. CONSTRUCTION
- Equipment or machines needed
- Emissions or hazardous waste
- Waste/surplus materials created

6. IN USE
- Maintenance/repairs (surface treatments, worn out parts)
- Cleaning
- Emissions released
- Health impacts
- Impact on surrounding materials (ex. corrosion)

7. DEMOLITION
- Ease of disassembly
- Equipment or machines needed
- Emissions/hazardous waste

8. SURPLUS PRODUCTS
- Opportunity for reuse
- Opportunity for recycling
- Biodegradable
- Energy extraction (Incineration)
- Transportation and distance

Fig. 27 Material chain highlighting points to be considered in a sustainable material and in material use.

In the *Whole Building Handbook* materials have been divided into three categories: renewable, minerals and synthetic (Bokalders & Block, 2010). The two first categories are also applicable for resources, the third could however be revised to instead become 'circular'. This would encompass products and materials that have already been refined/modified for a purpose but have fulfilled their first life and can now be reused or recycled into a new material.

Renewable Resources

This is organic matter that uses photosynthesis e.g. straw, wood or flax. The way that these are managed is however essential, e.g. the need for pesticides, water consumption, mono-agriculture. There is also an issue of potential competition between food resources and material resources. If these instead could correspond to one another and the surplus in the form of straw and other agriculture waste could be used, the two sectors would instead strengthen each another (Berge, 2009). In regards to forestry there are many different management styles that have varied impacts on biodiversity in the affected areas e.g. the Lübeck model (Silvaskog.se)

Minerals

These resources are non-renewable (or generated extremely slowly) and are extracted from the crust of the earth e.g. sand, clay or metals. While some of these are becoming depleted there are still many that exist in large quantities. Energy required at extraction as well as transportation should be considered. (Bokalders & Block, 2010). Attention should also be paid to potential negative impacts on landscape, biodiversity and the potential leakage risk of hazardous substances.

Circular

These are resources that has already been refined and that through reuse or recycling can become a new product e.g. used brick. This is a big category within a circular economy where natural resources should be preserved and kept in balance. The system should then strive to keep resources circulating as many times as possible rather than extracting new natural resources (ellenmacarthurfoundation.org, 2016).

Fig. 28. Timber is an example of a renewable resource.

Fig. 29. Sand is an example of a mineral resource.

Fig. 30 Used bricks are an example of a circular resource.

RESOURCE HIERARCHY

When considering the principles in the sustainable models discussed in the first chapter, a priority guideline can be established in regards to the use of resources. The main function of this guideline would then be to inspire resource use that corresponds to the ideas of circular economy. The real impact of a material will however very much depend on the specific production process and use in construction.

When selecting circular resources or materials it is favorable to chose the option of reuse over ones that need to be recycled since modifying resources will usually require more energy. There is also a higher risk for a highly processed material to lose future recyclability by e.g. losing homogeneous qualities.

Below follows a proposal for a resource use hierarchy:

1. Reuse of Structures
The most sustainable use of material is most likely the one where no material is needed. This relates to the concept of prevention in the waste hierarchy - to avoid use of new materials. Instead perhaps an existing structure could be used, as a whole or in parts (this has to be weighed against spatial needs as well as other sustainability aspects such as energy efficiency).

2. Reuse of construction components
3. Recycling of construction components
The category of construction components has been separated from other circular materials due to the clear suitability for reuse. It also seems appropriate to strive to take responsibility and close loops within the construction industry.

4. Reuse circular materials bound for downcycling
5. Recycle circular materials bound for downcycling
In these categories surplus from consumption or production which would normally be downcycled should be used. Downcycling means that a product or a material decreases in value after it has been recycled. Steel from cars is an example of this, where good quality steel is used in the production of cars and when recycled it is mixed with other metals and results in a weaker product. (McDonough & Braungart, 2003)

6. Refine renewable biobased surplus
Straw is a good example of a renewable biobased surplus resource. This is a surplus product from the food industry where straw is often chopped up and left on the fields. This byproduct could instead be used to make materials creating a win-win situation.

7. Refine renewable resources
This group contains materials such as trees or reed. These resources are renewable but these could be left as part of the local ecosystems and could potentially be carbon sinks and contribute to biodiversity.

8. Refine semi-renewable minerals
There are some minerals such as clay or sand which exist in abundance in Sweden and are renewable. The extraction of these resources will require mining and a higher land impact.

9. Reuse circular materials part of recycling or upcycling systems
These are products and materials that are part of systems that allow them to keep their value or even increase it. Newspaper is an example of this kind of resource since it can keep circulating within a recycling system. By extracting resources from these systems other sectors are forced to extract new resources from other groups, just pushing the issue elsewhere.

10. Refine minerals
This group contains minerals such as stone, sand, metals and oil. These resources are finite and will usually require an impact on the local landscape that can vary in size. The environmental impacts also vary considerably between different minerals.

As mentioned in the beginning of this section this is merely a guideline of how to prioritise in the selection of resources. The most important point that has been made is to expand the view of resources that can be turned in to materials.

MATERIAL STRATEGIES

Considering the criteria outlined in the material chain and ideologies regarding sustainable construction, there are a number of aspects that should be explored in relation to sustainable use of materials. Here follows a list of aspects that should be considered, these have then been dissected into strategies in an attempt to understand some of the core values behind them.

LIFETIME

Søren Nilesn from Vandkunsten talked about the idea of lifetime layers in his lecture this spring (chalmers, 2017) which relates to the notion of sheering layers. This concept encompasses the notion that different parts of a building can be seen as having different lifetimes. By allowing the building to have flexible layers the building can stay current and usable for longer, instead of being demolished. Stuff such as interior and the space plan are aspects that might want to be changed fairly often depending on function and trends. Services and the skin of the building could however be expected to have a longer life time, while the structure should be able to be used for a long time. This can justify using materials with higher energy levels for long term layers while the ones with shorter lifetimes should be kept as low as possible.

Adaptable: The design should be able to be adapted for future needs or changes.

Layers: By thinking in layers it will be easier to "peel" off components that are no longer required and allow for parts of the structure to live on.

EMISSIONS

Emission rates are something that should be considered at all stages of the material chain. This could be CO_2 emissions or other toxic substances that are released during transportation, extraction or in the refinement process. It is also important that emissions are minimised in the construction and usage stage. Many materials given off gas when heated during use which can effect the users negatively.

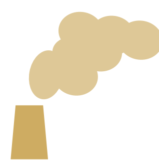
Healthy: Healthy materials don't have a negative impact on workers, users or the environment.

CO_2 : In threat of global warming CO_2 emissions should be considered. Both the amount that is released at different stages but also the one locked into renewable materials, making buildings act as CO_2 sinks.

Lifetime

Adaptable / Layers

Emissions



Healthy - CO_2

Waste

Resourceful - Closed loops - Prefabrication

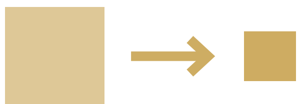
WASTE
The minimisation of waste is a big part of circular economies. It is important that matter, especially technical products, are circulated as many times as possible.

Resourcefulness: It is important to push the boundaries of what the concept of a material is and how it can be used. People are very good at this in times of need and crisis. The same innovative mindset should be encouraged in normal times.

Closed loops: This is the core of circular models, to think in closed looped systems where everything should be able to circulate.

Prefabrication: Prefabricating components off site is a way to minimise waste since the process can be done with a higher level of control. There is also less risk of stock being damaged by weather which could also make work on site faster.

Reduce



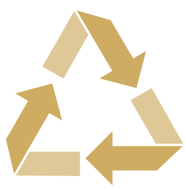
Love-ability - Adaptable

REDUCE
Reducing the need and use of materials is probably one of the most environmentally sustainable methods. This means less extraction, less energy in production and in the long term less waste.

Adaptability: *See Lifetime*

Love-ability: This is an idea that Søren Nilesn from Vandkunsten also talked about in his lecture where he made the point that liked buildings tend to live longer. By trying to design buildings that people will like for a long time, the life expectancy should increase. This means that both aesthetics and function could be tied to the concept of loveability.

Reuse/Recycling



Homogeneous - Disassemblable

REUSE/RECYCLING
These are two ways to keep materials circulating either through reuse with none or minor modifications or recycling with large modifications.

Homogeneous: To ensure recycling, it is easier if the material is homogeneous. Aluminum cans are relatively easy to recycle while composite materials (where materials are mixed) can be a lot harder.

Disassemblable: In order to both be able to reuse and recycle materials it is important that structures can be taken apart with relative ease. Brick laid with lime plaster is for example easier to clean and reuse since the bond is softer than cement plaster. This requires both less effort in the cleaning process and less waste of broken bricks.

MAINTENANCE

In order to keep the building in a good working condition maintenance is an important aspect that is very relevant for materials. To be able to exchange damaged parts or design with durability in mind is important.

Repairable: It is important to consider future ability to repair parts of the building., Both foreseen vulnerable points for wear-and-tear but also for less foreseeable events such as e.g. water leaks.

Layers: See *lifetime*

Disassemblable: See *lifetime*

LEVEL OF PROCESSING

The level of processing required for different products varies greatly. Low processed materials do generally require less energy than highly processed products. For example three different uses of straw: a packed bail of straw is a very low processed product. While a panel made of compressed and heated straw requires more energy and machines. To cut up the straw and use the fibers on a molecular level, mixing it with resins and other fibers requires an even higher level of energy. This is not to say that all low processed products are better but that materials have their requirements and functions.

Low-energy: It is important to strive to keep energy requirements as low as possible to avoid emissions. Increased use of renewable energy could however change the circumstances for this strategy.

Homogeneous: See *reuse/recycling*

HEATING QUALITIES

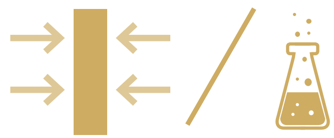
Heating is a big part of the operating energy when buildings are in use. Some materials have different inherent properties that can effect heating of buildings. Insulation is of course one, where the U-value varies depending on material and thickness. Another quality is a materials ability to store heat or its thermal mass e.g. a stone floor will stores heat when it is exposed to the sun and slowly release it during the night.

Thermal: Utilise the inherent thermal qualities of different materials.

Maintenance

Repairable - Layers - Disassemblable

Level of Processing



Low Energy - Homogeneous

Heating Qualities

Thermal

People

Healthy - Ethical

Industry

Small Scale - Local

PEOPLE

It is important to remember that there are people behind every step in the material chain. Are conditions humane and safe? Who is it that is working and for how long? Are they being paid fairly and is the process effecting people not working in the actual supply chain? These are hard questions to answer in a world with endless global supply chains. It is however vital to consider these aspects when selecting materials from a catalogue and not push them to the side as someone else's problem.

Healthy: *See Emissions*

Ethical: Chose materials with a material process that treats people fairly throughout the chain. This might be one of the hardest strategies since it lies beyond the architects control. It is only in the selection of a material that the designer can effect the process. It is not about going down to micro-level but simply gaining enough knowledge to make an informed choice.

INDUSTRY

Large scale and rationalised industries are most often unable to be as resourceful as small scaled companies due to the volume and efficiency required to be economically profitable. There is also a link between large scale industries and the growing disconnection between the producer and the user as well as the producers and architects. (Berge, 2009)

Small Scale: Small scale industries can afford to be more resourceful and careful. Supporting networks of small scale industries can contribute to more resilient societies. (Berge, 2009)

Local: By bringing production and manufacturing closer to people the disconnection between producer and consumer can be bridged. There is also potential for a stronger relationship and trust when trading with local companies. There is also the benefit of shorter transportation. (Berge, 2009)

REFERENCE PROJECTS

Here follows three different examples of projects that have been built with local resources and materials. The architects have been very different in their approaches and choice of materials.

At the bottom of each project the recourse type has been noted as well as any of the material strategies that could be connected to the project.

Superuse Studio - Villa Welpeloo

2009, Netherlands

Fig 32.

This was the first building that Superuse studio designed with their waste use approach. The architects first made an abstract design based on the clients needs. In the next step the studios harvest map tool was used, a way to map locally available waste materials and products which set the base of what can be worked with. This approach lets the materials drive the design, allowing it to keep evolving depending on their qualities.

Materials

The whole scheme is made with circular materials from the facade made out of cable reel slats to light armatures made of broken umbrellas. The structure was created by machine steel profiles from the textile industry .

(superuse-studios.com)

Reflection

There is immense potential in the use of waste from the production and consumption industry as building materials.

Resource:

Circular

Material Strategies:

Disassemblable / Low Energy / Resourceful

Architype - Enterprise Centre
2015, UK

Fig 33.

The whole project is focused on sustainable impact, being a passive house primarily built with local renewable materials. It has been designed with a 100-year life span and was rewarded with both Passivhouse and BREEAM Outstanding rating. The aim has been to achieve both low embodied energy and carbon construction. The thatch panels were prefabricated and provided local thatchers with work during the winter which is usually low season.

Materials
The facade is mainly clad in prefabricated thatch panels, with lime render and a timber frame.

(architype.co.uk)

Reflection
The use of local materials can generate new form expressions. It is also interesting how in this project a traditional technique like thatching was used to make prefabricated panels. Making the traditional technique very current and efficient.

Resources:
Renewable / Local

Material Strategies:
CO_2 / Healthy / Thermal / Love-ability

Vandkunsten - Modern Seaweed House
2013, Denmark

Fig 34.

In this project an old vernacular technique was used in the production of the facade. On the island of Læsø building with seaweed has been a long tradition. Vandkunsten used this local technique in a new way when they combined this unconventional material with a classic form. The project included prefabricated elements that meant for a quicker assembly, it has also been designed to allow easy disassembly so the materials can be used again.

Materials
The facade is made of seaweed which is rolled into 'pillows' and used to clad the building. The structure, some of the cladding and the interior is made of larch, spruce and pine, there is no note if the timber was sourced locally.

(Vandkunsten.com, 2011)

Reflection
This project also makes a traditional technique current. It is interesting how one can look back in history to find "new" potential materials locally.

Resources:
Renewable / Local

Materials:
CO_2 / Healthy / Thermal / Love-ability / Disassemblable

SUMMARY

MATERIAL CHAIN

By considering the material chain many factors that might seem obvious but which are often overlooked are brought back to light. The chain shows the complex network that lies within a material process and indicates critical moments in regards to a sustainable use of materials.

The distinction was made between resources and materials in order to be able to discuss the two groups without risk of confusion. Resources are mainly related to the first two steps in the chain, while materials relate to the last six steps.

RESOURCES

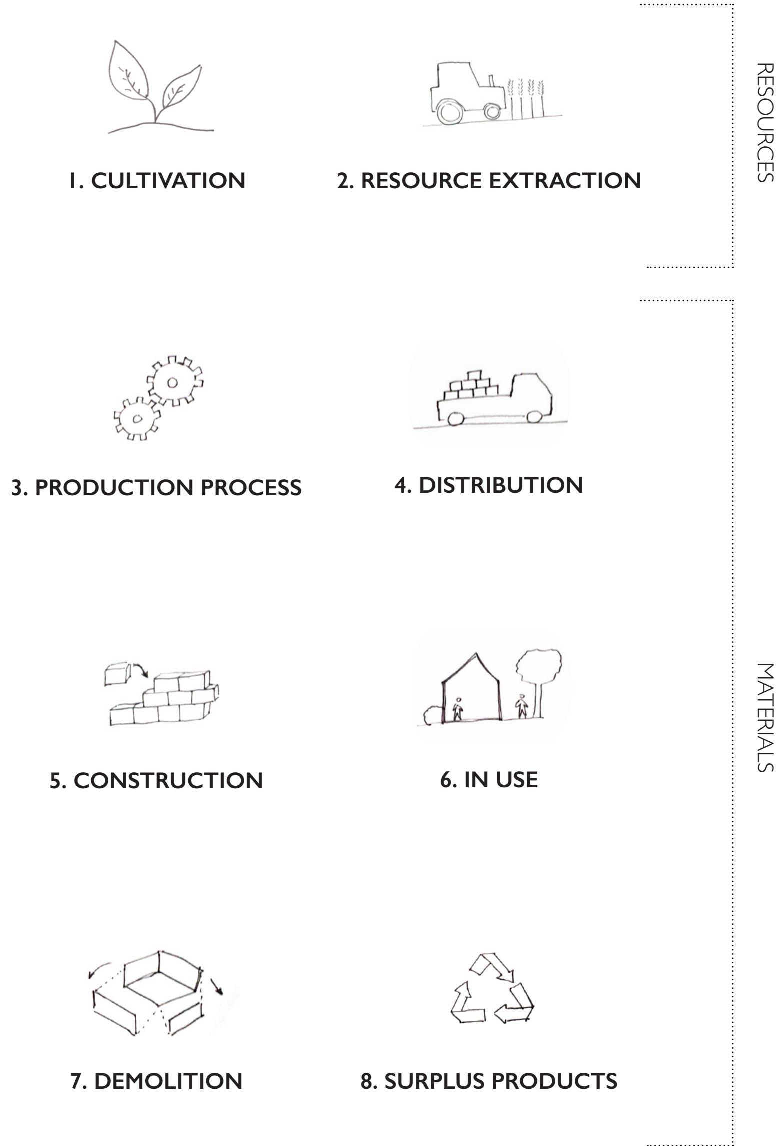
Usually this category might be called raw materials, matter that can be refined into materials. This would then include renewable and mineral assets such as forest and quarries. By instead calling this group resources it opens up for the group of circular products (surplus from consumption or production) to be considered valuable matter that can be transformed into new materials.

Considering the principles in the sustainable models discussed in the first chapter, a set of priority guidelines can be established in regards to the use of resources. This list has been compiled to the right with examples of resources. Again, this is just a guideline of how one could prioritise resources within a circular economy.

MATERIALS

The two aspects that are usually considered most vital in regards to sustainable materials are health and environmental impact. In this thesis a third aspect has been applied, circular use of materials. In a circular society it is important to consider the future lives of the materials that are to be used. This is important to keep in mind through all the steps of the material chain.

The summary of material strategies on the following page relates to features within sustainable production and construction. The strategies are an attempt to find the core in this feature to establish what architects can use as guidelines when designing.



1. REUSE STRUCTURES

2. REUSE CONSTRUCTION COMPONENTS
E.g. Window, door, timber

3. RECYCLING CONSTRUCTION COMPONENTS
E.g. Rubble

4. REUSE CIRCULAR MATERIALS BOUND FOR DOWNCYCLING
E.g. Car windscreens

5. RECYCLED CIRCULAR MATERIALS BOUND FOR DOWNCYCLING
E.g. Some plastics,/paper/glass

6. REFINED RENEWABLE BIOBASED SURPLUS
E.g. Straw, Wood Fibers

7. REFINED RENEWABLE RESOURCES
E.g. Thatch, Timber

8. REFINED SEMI-RENEWABLE MINERALS
E.g. Clay

9. REUSE/MODIFY CIRCULAR RESOURCES PART OF RECYCLING/UPCYCLING SYSTEMS
E.g. Newspaper,

10. REFINE MINERALS
E.g. Stone, Sand

HOMOGENEOUS	LOW ENERGY
DISASSEMBLABLE	REPAIRABLE
ADAPTABLE	LOVE-ABLE
RESOURCEFUL	CLOSED LOOP
CO_2	THERMAL
LAYERS	HEALTHY
ETHICAL	LOCAL
SMALL SCALE	PREFABRICATED

CASE STUDY - MARIESTAD

Investigating opportunities and testing the process

4

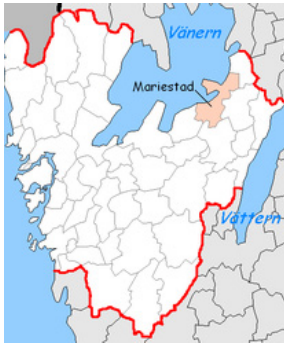


Fig 36. Mariestad's location in Västragötaland

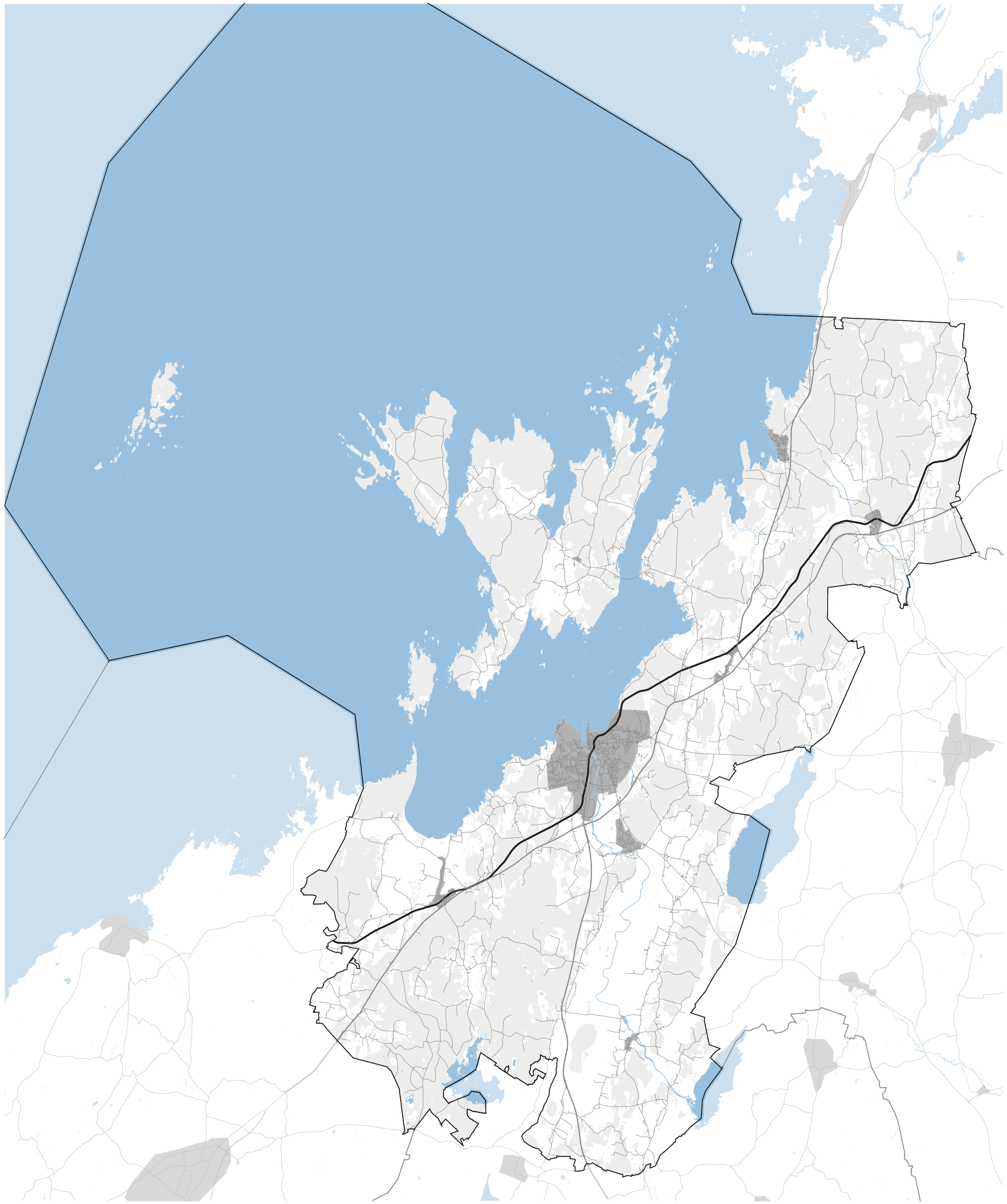


Fig 37. Map of Mariestad Municipality

Mariestad municipality is a medium-small sized municipality (approx. 24000 inhabitants) that is located in the north east part of the Västra Götaland region. The main town, also called Mariestad, is located on the south east bank of the lake Vänern by the inlet of the river Tidan.

Challenges

Mariestad is facing the same challenges as many smaller municipalities in Sweden are today such as an elderly population and problems with young people moving for work or education opportunities (Mariestads municipality, 2017).

In a conversation with Björn Ohlén at Västarvet he says that Mariestad is at risk of losing people. He makes a comparison to Lidköping where people have another sense of pride and a different attitude, when someone moves its seen rather as "when are you coming back?" which is missing in Mariestad.

In their comprehensive plan (2017) the trend of uneven geographical development has been identified as the main threat. Rationalisation and centralisation has contributed to investments being channelled to larger and denser urban areas contributing to a downward facing spiral that is happening/taking place all over Sweden. By centralising capital to nodes it weakens smaller areas, leading to less opportunities which tend to lead to less inhabitants which in turn leads to less investments, see fig. 38.

Fig 38. Diagram illustrating downward facing spiral of uneven geographical development.

Opportunities

Natural resources

There is a wide variety of renewable resources available in the surrounding area.

Rurban planning talks

This was a conference that took place in Mariestad this spring is a part of the trend to challenge current systems. It challenges the urban sustainability norm, advocating the less urban areas potential/importance in a sustainable society.

Local actors

There are a number of actors in Mariestad who are very relevant when considering the implementation of a local material process.

- Municipality

The municipality has the opportunity to encourage a local market through planning documents and incentives. They also have the power to lead by example in pilot projects that could both become the start of a local market and showcase the opportunities.

- Institution of Cultural heritage (Gothenburg university):

Gothenburg university has a branch in Mariestad, a part of the institution of cultural heritage. The courses within the programe are focused on construction and craft (Bygghantverksprogrammet) that uses traditional materials and techniques (utbildning.gu.se, 2017).

- Hantverkslaboatoriet:

This organisation at Gothenburg university is a national hub for construction heritage and craft, that works in collaboration with the private sector. They can offer research opportunities in material and construction techniques that relate to traditional methods (craftlab.gu.se).

- Biosfärområdet:

This organisation works with sustainable development and works under Unesco to find local solutions to global challenges. The area spans over three municipalities: Mariestad, Götene and Lidköping. Their main tasks are to inspire people towards sustainable development, facilitate meetings between organistions and people, design and drive initiatives and strive to create opportunities for sustainable development (vanerkulle.org).

- Small construction companies and selfbuilders:

According to Annika Kjellqvist at the municipality these are the two main groups that construct buildings in the municipality (personal communication, 26 jan, 2017).

Purpose
The design proposal will be made for a Material Centre that helps to enable a local material process in Mariestad, fig 39. The idea is that by showcasing opportunities both through the construction itself and as a function in the building it could spark a demand and a market for these localised materials.

Potential Stakeholders
There are a number of local stakeholders that could have an interest and a share in such a project for example: Gothenburg university, the biosfär area, the municipality, the craft laboratory as well as some local companies.

Functions
In order to support the implementation of a local material process it is important to showcase use and build an awareness, see fig. 40. These are the three main functions:

Lecture space 40-60m²
This function enables lectures and further conversations regarding the topic of local material opportunities as well as local cyclic systems.

Showcase 125-250m²
Through a showcase space different techniques and materials can be exhibited to professionals and the general public.

Test space 80-180m²
This space allows for people to interact and get hands-on experience in production or construction with different materials, allowing people to get closer to the materials. This function can be used in different scales from school children spending an afternoon trying out clay construction to university students or companies renting the space for a longer time to test or develop new techniques.

Potential Users
As shown in fig. 41 there are a variety of users for the material centre and some might be using some functions more. Two important groups are construction companies and self-builders since these are the main groups who build in Mariestad. It is however also important to reach out to potential production companies as well as the general public.

Fig 39 Diagram illustrates how a Material Centre could start the process to use local resources.

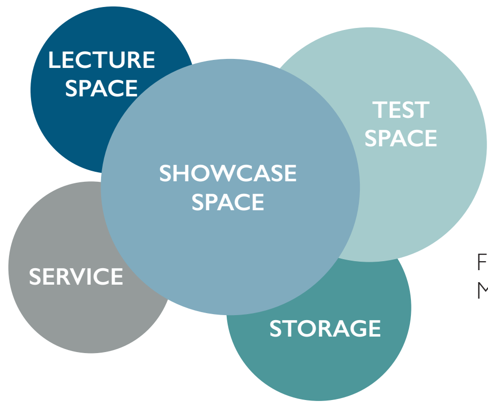


Fig 40 Functions in the Material Centre.

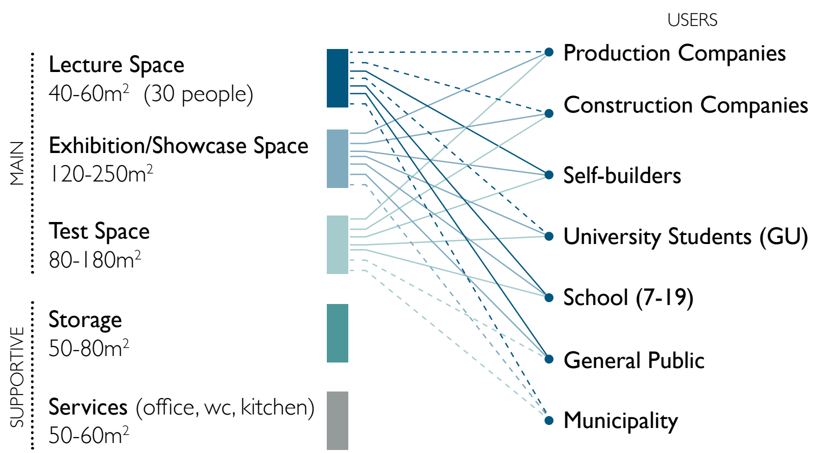
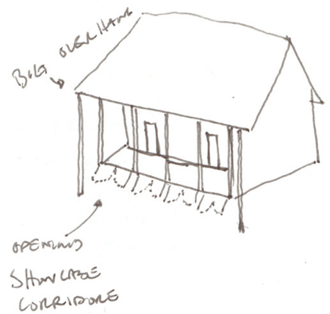


Fig 41. Potential users related to functions.



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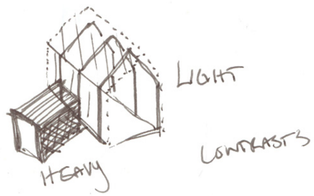

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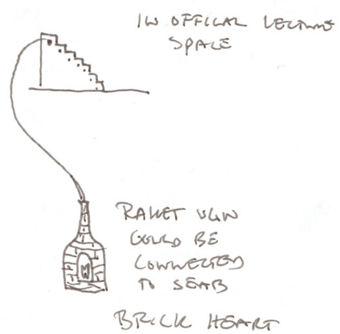

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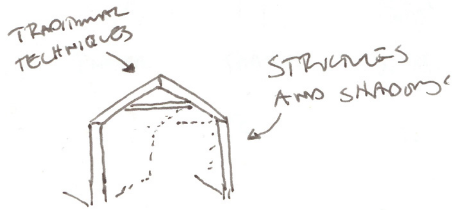


4.

Sketches made after the conversation with GU students.
1. Large corridor that can double as showcase space
2. Contrast between light and heavy construction
3. "Rocket oven" (Raket ugn), could lead smoke through seating to warm seat and room
4. Traditional roof joist techniques to create beautiful details and shadow patterns.

Meeting with Students

In the development of the project I met with Isak Blomster (timber), Anton Bachs (brick) and Freja Gyllenhaks (timber/finishes) who are students at the heritage and construction program in Mariestad. This was to discuss both the potential program and function of the building and how they look at materials in the building process. These conversions have been translated into spatial needs of the program and material qualities that they thought were important to lift.

Spatial Needs

- Test space: This should preferably be a large open space with no columns. It also needs be durable and easy to clean with no direct sunlight, preferably north facing both for better light quality and to avoid over-heating. It will also most likley be a space with a high quite level of noise.

- Showcase space: Easy to transport materials in and out. Could be a hall or series of smaller rooms. Be aware of noise from test space.

- Lecture space: Need to be sure to prevent noise from test space to travel to this space.

Material Qualities

- Stolpverkskonstruktion: This is a traditional building technique that uses thicker joists of timber. The joists are usually joined with plugs rather than nails. The thickness of timber makes it easier to repair and replace parts of the beams. There is also a high level of loveability connected to this type of construction and the structure is usually left exposed.

- Roof joints: These are great opportunities to demonstrate beautiful techniques which could add to the experience of the building.

- Light and heavy: Since the aim of the building is to showcase local material opportunities it would be a nice contrast if one part of the building is lightweight while the other is heavy. This would also give the potential to showcase a wider variety of materials.

- Domes: This is a way to use bricks and tiles as structural elements for roofs.

The site is located in Johannesberg park in the east part of Mariestad town. This park was historically used as an institution for mentally disabled youths and adults from the late 1800's until 1995. Because of its previous function, the park and some buildings have a certain character and in a report by Västragötaland museum (2003) the area as a whole has been deemed to have a high heritage value.

Current conditions

The park is located next to residential areas and lies approx. 10 min by foot from the main square along Stockholmsvägen, one of the town's main roads. Since the area was privatised in the 90's new actors have overtaken most of the buildings and there is now a mix of functions occupying the site.

The garden facilities at the university used to be located in the east side of the park but were moved to the University park closer to the centre a few years ago. The wood yard that is used for the timber courses at the university is however still located in the west part of the park.

Future plans

According to the draft comprehensive plan (2017) there are plans to build a residential area in the north west side part of the park. There are also unofficial talks about building a nursing home just off the park. This could potentially become a pilot project for the municipality to test the use of local materials.

After the completion of this thesis the decision has been made to move the wood yard from Johannesberg.

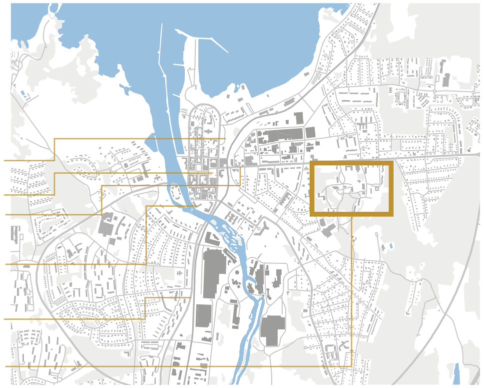


Fig 43. Map over Mariestad Town

Fig. 44. Johannesberg park

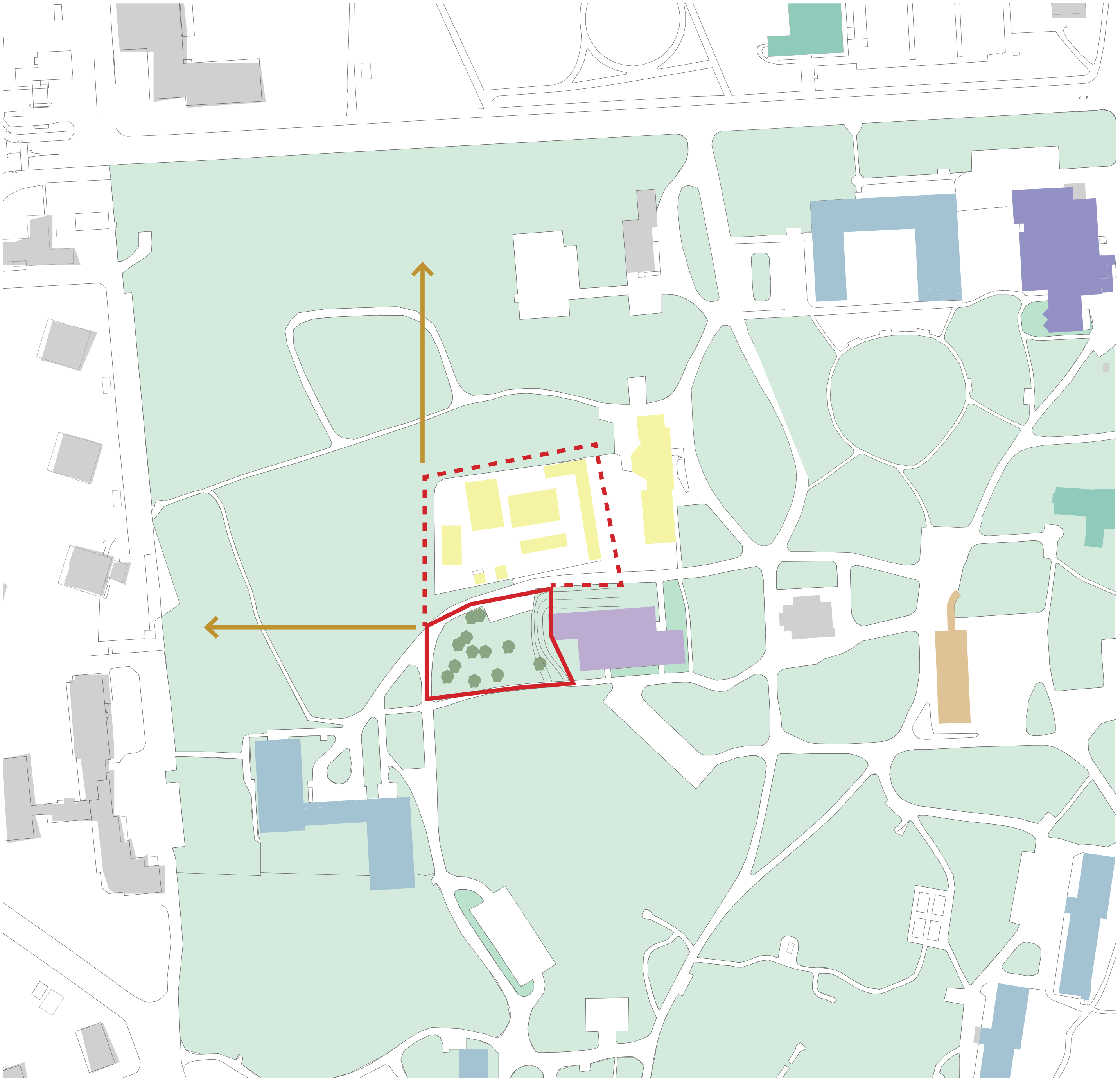


Fig. 45. Site area

- Social Service
- School
- Empty
- Recreation/Sport
- Main Site
- Connected Site

Fig 46. View from west side

Fig 47. View from northwest.

Fig 48. View from southeast.

SITE

The site is located in the west side of the park just south of the university wood yard.

WOOD YARD
Linda Lindblad from the craft laboratory explained that the wood yard is used for approx. 15 weeks during the year. During the rest of the year there are great opportunities for collaborations and for other users to utilise the space.

There are currently a number of temporary structures at the yard which might potentially change now when the decision has been made to keep the wood yard at Johannesberg. (After the completion of this thesis the decision has been made to move the wood yard from the Johannesbergs park.)

POOL AND GYM
To the east there is a public building with mainly recreational activities. There is a pool that is open a few days a week and a gym.

FUTURE CONNECTIONS
There are opportunities to create new paths connecting the site to the new development and the area to west. This would make the site more integrated by breaking up the introverted road structure of the park.

TREES
There are a number of trees on the site which should preferably be kept. If trees need to be removed an attempt should be made to use the timber in the construction.

Fig 49. View from southeast.

AVAILABLE LOCAL RESOURCES

Through conversations with people in Mariestad a number of potential resources have been identified as being available in the area within and around the municipality. This is just a mapping of potential resources which has been categorised according to the resource hierarchy.

2. **Reuse construction components**
   Doors, windows, wc, pipes, bricks, timber

3. **Recycling construction components**
   Rubble, glass,

4. **Reuse circular materials bound For downcycling**
   Car windscreens, rubber tires, glass

5. **Recycle circular materials bound For downcycling**
   Plastics, paper, glass

6. **Refine renewable biobased surplus**
   Straw, wood fibers, thatch

7. **Refine renewable resources**
   Spruce, pine, leafy trees

8. **Refine semi-renewable minerals**
   Clay

9. **Reuse/modify consumption & production Surplus part of recycling/upcycling systems**
   Newspaper, paper, glass bottles

10. **Refine minerals**
    Sand, chalk, Stone (natursten, not been able to specify)

CHOSEN RESOURCES

Below follows a more detailed list of the resources that have been chosen to be used in the proposal, each has a brief explanation and example of a scenario where the resource could be sourced and refined.

Reed

Renewable surplus

Every year large areas of the banks of Vänern are covered in reeds. This poses an issue for the municipality must trim back large volumes of reeds every year, this could be used as a material in the construction industry.

The volumes could be collected and mounted into prefabricated panels during the winter and spring. This could either be done at the wood yard or in the test space building if it is completed first.

Source location:
Banks of Vänern (1)
Refinement location:
Wood yard (A)

Pine and Spruce

Renewable

There are large areas of forest around the main town which are dominated by pine and spruce. The trees could be sourced by the small scale Lübeck technique and there are also a few pine trees on the site that need to be removed due to the proposal. If suitable these could also be used in the construction.

The preparation of the construction parts could also be made at the wood yard.

Source location:
Local forest (2.1) and Site (2.2)
Refinement location:
Wood yard (B)

Straw

Renewable surplus

When harvesting wheat and other grains the straw is usually left in the fields or sometimes collected to be incinerated. Instead these volumes could be collected and used as bales or compressed and used as insulation or even load-bearing panels.

In this project panels would be more suitable than bales due to the difference in space requirement. This would require a higher level of refinement as machines are needed to compress and wrap the panels. This could therefore be done at a vacant space at Katthavet industrial area.

Source location:
Local farm (3)
Refinement location:
Katthavet industrial area (C)

Paper

Production and consumption surplus

Some paper such as newspaper works very well in recycling and can circulate several times while other types such as white office have weaker fibres and are less durable. Some of these volumes could get an extended life time by being used as paper tiles. These volumes could be sourced at Metsä Tissue, one of the largest industries in Mariestad.

Since the process is fairly low-tech this process could also be done in the test space or even in the showcase hall when the external skin have been completed.

Source location:
Metsä tissue (6)
Refinement location:
Test Space (F)

Stone

Mineral

Natural stone has been used in construction for a very long time. Either limestone could be used that is mined at Kinnekulle or another type of local stone could be used. (Unfortunately the mapping has not been able to identify specific types of stone in the area.)

There is a stone cutter approx. 32 km south west of Mariestad that could potentially prepare the stone for the foundation and plinth.

Source location:
Kinnekulle quarry 41 km car (4)
Refinement location:
Thorsberg 32km car (D)

Glass

Production and consumption surplus

Every year approx 411000 kg of glass is handed in for recycling in the municipality. A part of this could be recycled into foam glass. Haspor is a foam glass product often used in infrastructure but also in construction.

To produce foam glass products is a high-tech process. There is a factory in Hammar 60 km linear way (or 97km by car).

Source location:
Hammar 97km car (7)
Refinement location:
Hammar 97km car (G)

Clay

Semi-renewable mineral

The soil conditions in the area are rich in clay and one of Sweden's last active brick yards is located within a 30 km distance from Mariestad.

The clay for the tiles could be sourced there and also refined and burnt.

Source location:
Horns Brickyard 28 km car (5)
Refinement location:
Horns brickyard 28 km car (E)

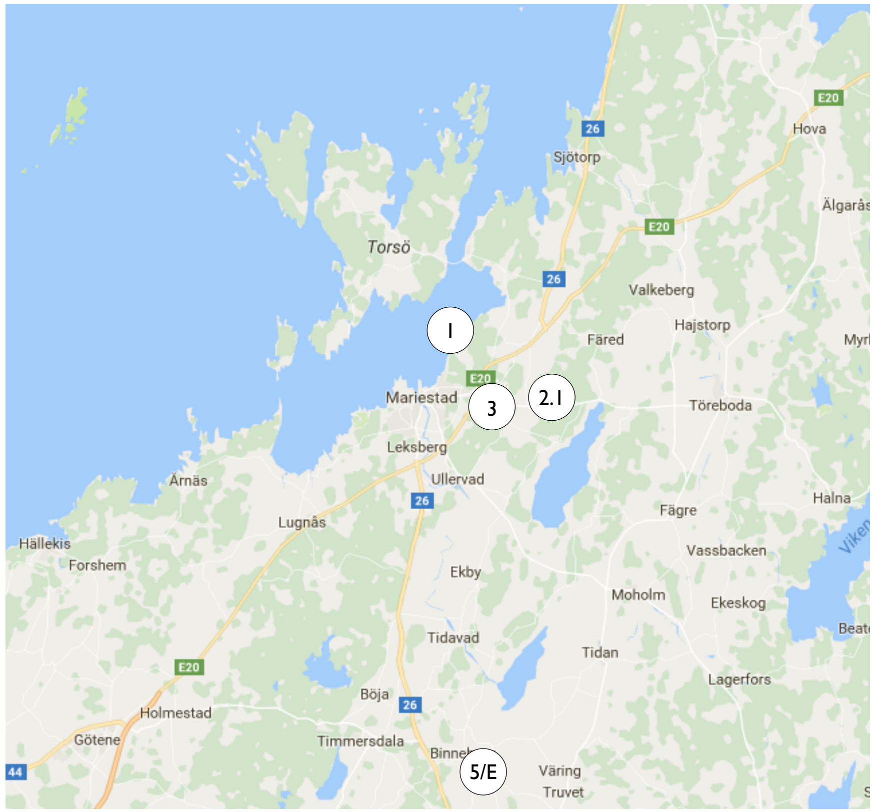
Doors, windows, bricks & insulation

Reuse construction components

Though not much is being demolished in Mariestad there are renovations taking place. From this doors, windows and synthetic insulation can be sourced. The search can also be expanded to other towns or even to Skövde to find a high enough volume of windows.

Mounting and restoring can be prepared at the wood yard.

Source location:
Within 40km
Refinement location:
Wood yard (H)



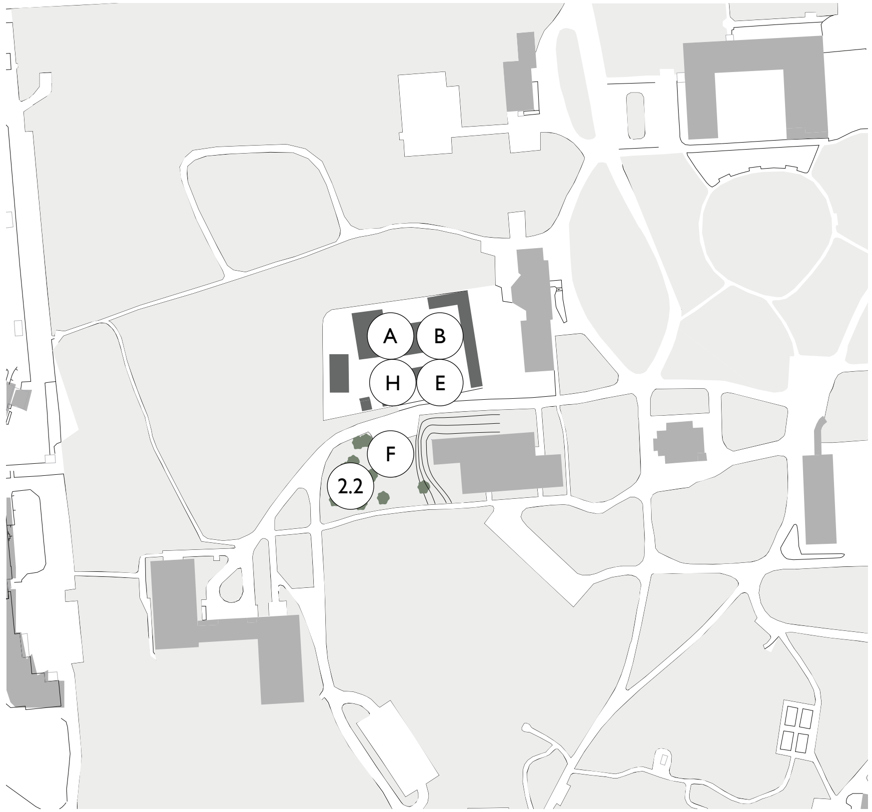
RESOURCES:
4. Kinnekulle quarry - Stone
7. Hammar - Glass

REFINEMENT:
D. Kinnekulle quarry - Stone
G. Hammar - Haspor (Foamglass)

RESOURCES LOCATION:
1. Banks of Vänern - Reed
2. Local Forest - Pine/Spruce
3. Local Farm - Straw
6. Horn Brick factory - Clay

REFINEMENT LOCATION:
F. Horn Brick Factory - Structural Tiles

RESOURCE & REFINEMENT MAP



RESOURCES:
5. Mätse Tissue - Paper

REFINEMENT:
C. Katthavet industrial area - Compressed straw panels

RESOURCES:
2.2 Site - Pine trees

REFINEMENT LOCATION:
A. Wood Yard - Prefabricated thatched reed panels
B. Wood Yard - Timber frame, facade panels
E. Wood Yard - Paper tiles
H. Wood Yard - Adjust fittings and windows

Structural systems

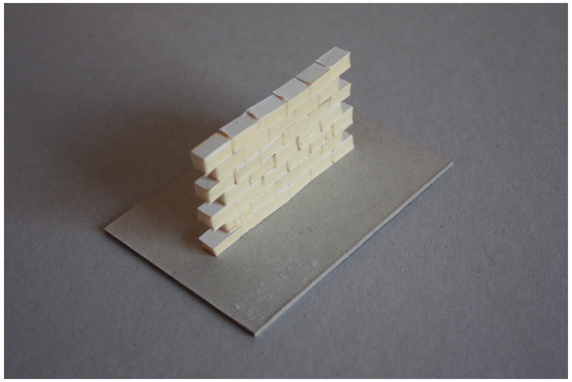


Fig 62. Structural elements - Blocks
Example of potential materials: Clay/straw/bricks

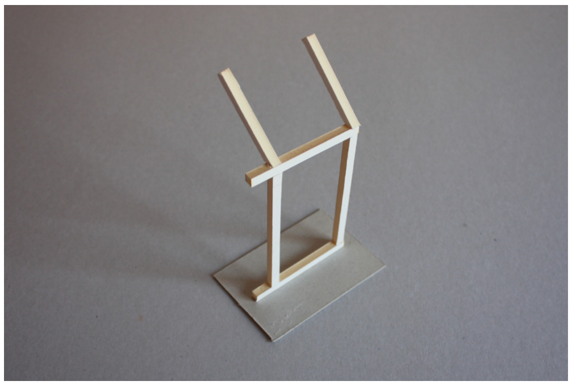


Fig 63. Structural elements - Frame
Example of potential materials: Timber

Structural systems

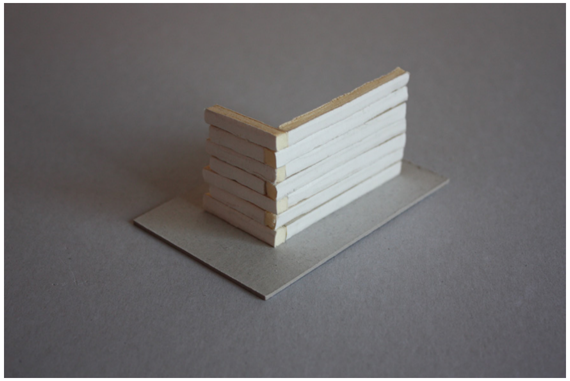


Fig 64. Structural elements - Vertical Elements
Example of potential materials: Straw/timber

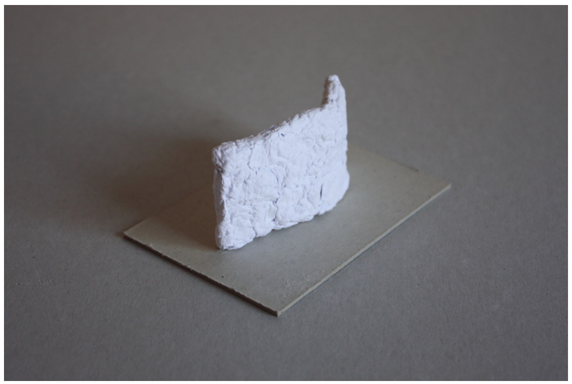


Fig 65. Structural elements - Monolithic
Example of potential materials: Clay/earth

Material Center

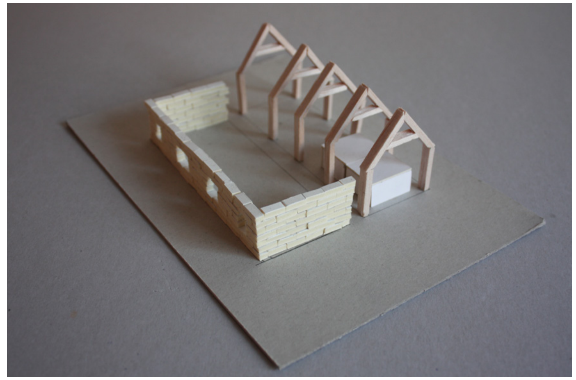


Fig 66. Material Center 1
By making one part in a heavy structural system and one in lightweight, a wider range of materials can be showcased. In this model: Frame and Blocks

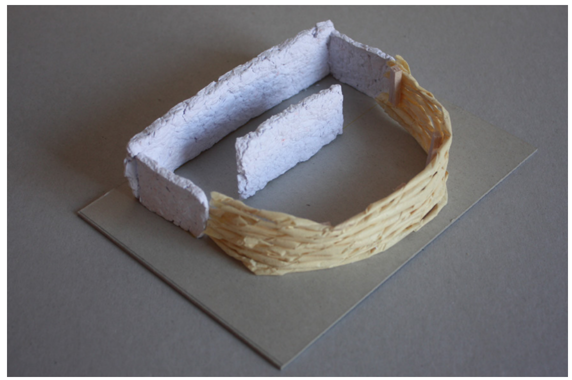


Fig 67. Material Center 2
Second attempt of Material Center in two structural systems. In this model: Vertical and Monolithic

Light Structure

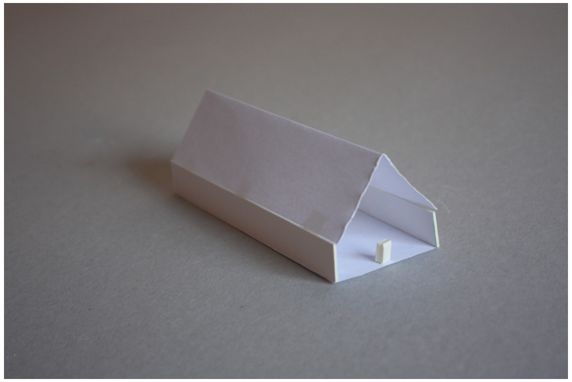


Fig 68. Light Structure 1
Experiment with roof pitch and the relationship between pitch and width of the building.

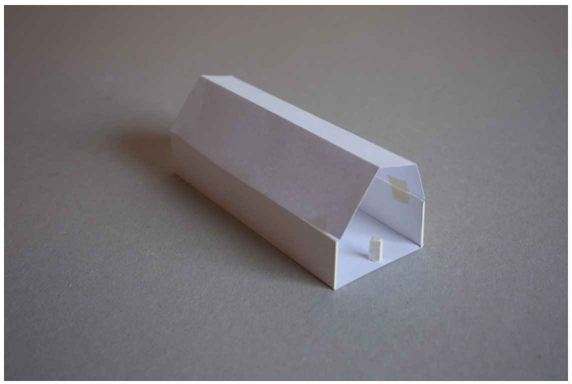


Fig 69. Light Structure 2
Experiment with roof pitch adding an extra kink in the roof structure. Wrong angle for straw.

Heavy Structure

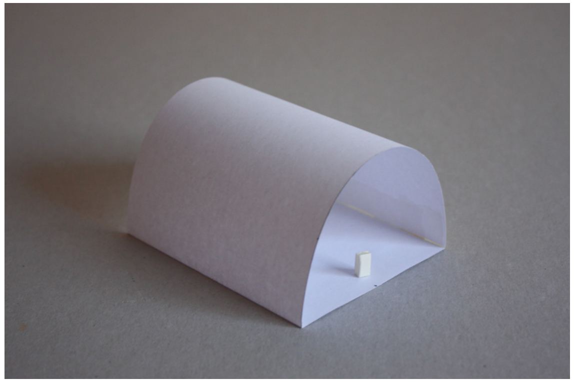


Fig 70. Roman arch
Relationship between height, depth and width for a roman arch.

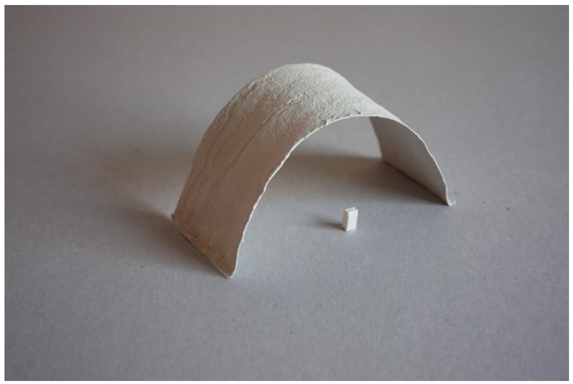


Fig 71. Parabolic shape,
Arch in pure compression which allows for a thinner arch.

Site Configuration

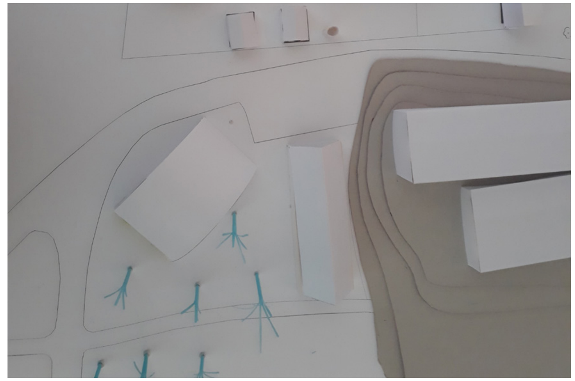


Fig 72. Site orientation 1
By having the arch on the corner it will be in view from both new pathways making a strong corner.

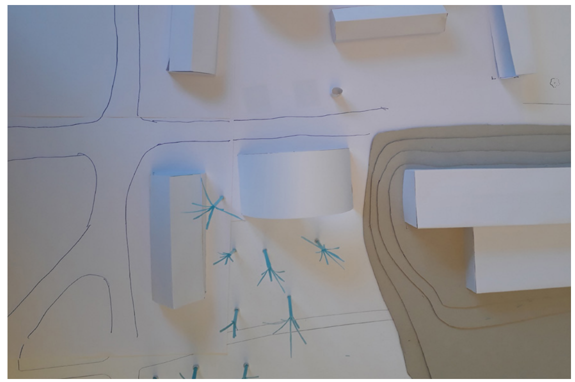


Fig 73. Site orientation 2
By placing the showcase building by the entrance point it creates a transitional step from open to semi-public.

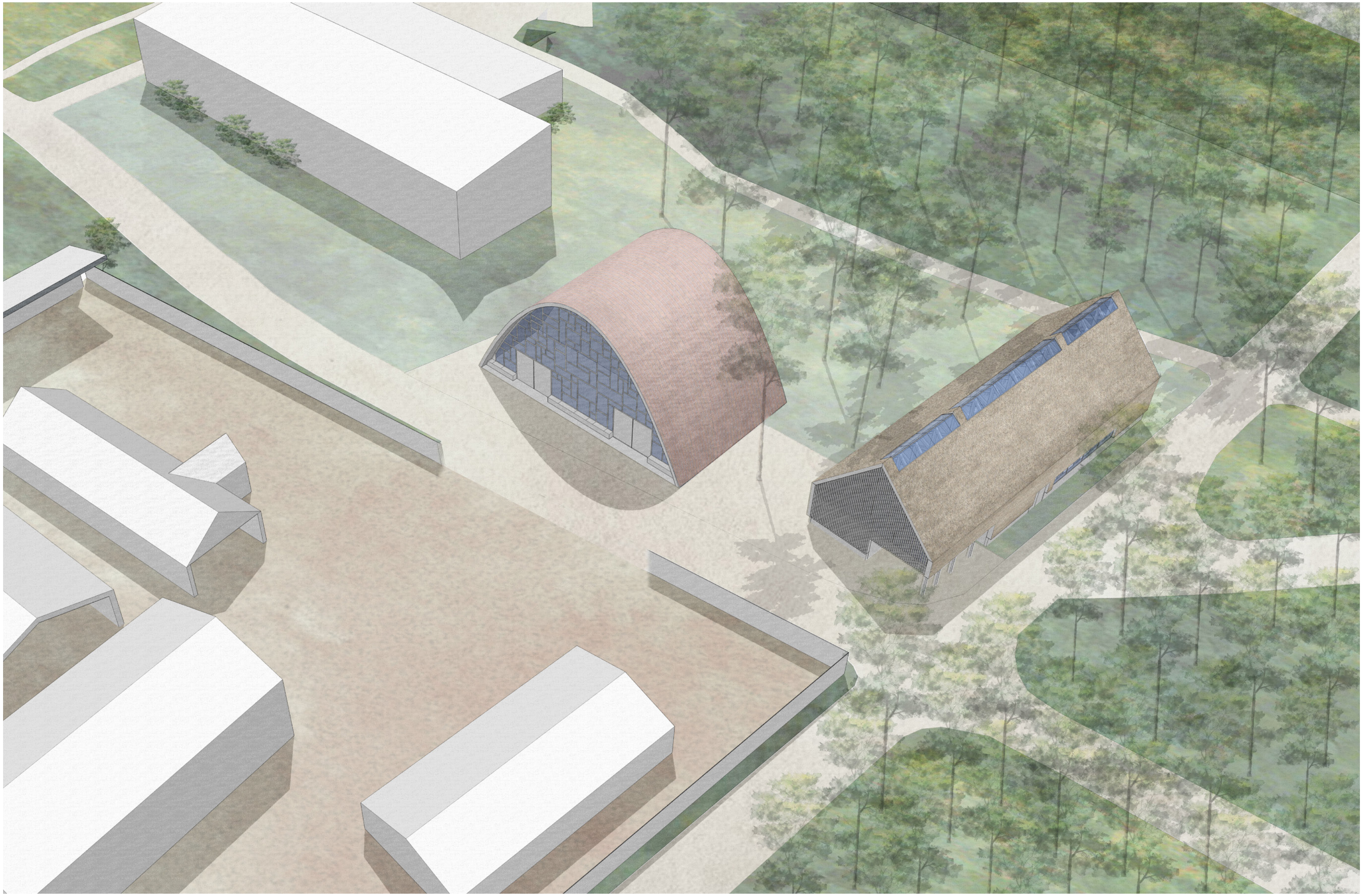


Fig 74. Proposed Material Centre

DESIGN PROPOSAL

The Material Centre has been broken down into two separate structures, the Showcase building and the Test Space.

Showcase
The Showcase building is located in the intersection of the two existing roads and two new paths with the entrance at the northeast corner. With this placement the showcase building meets the two new entrance points.

Test Space
The arch that shelters the test space is faced towards the wood yard and together they form an informal court yard that can be used in collaboration between the university and the Material Centre. By locating the actual test space hall in the north part it provides the space with the right light and prevents overheating.

Material Park
By leaving the south and well kept part of the site this could be used as a park space where activities from the two buildings could spill out during events and similar occasions. It could also become another informal way of showcasing more permanent techniques where street furnitures could be constructed by local materials.

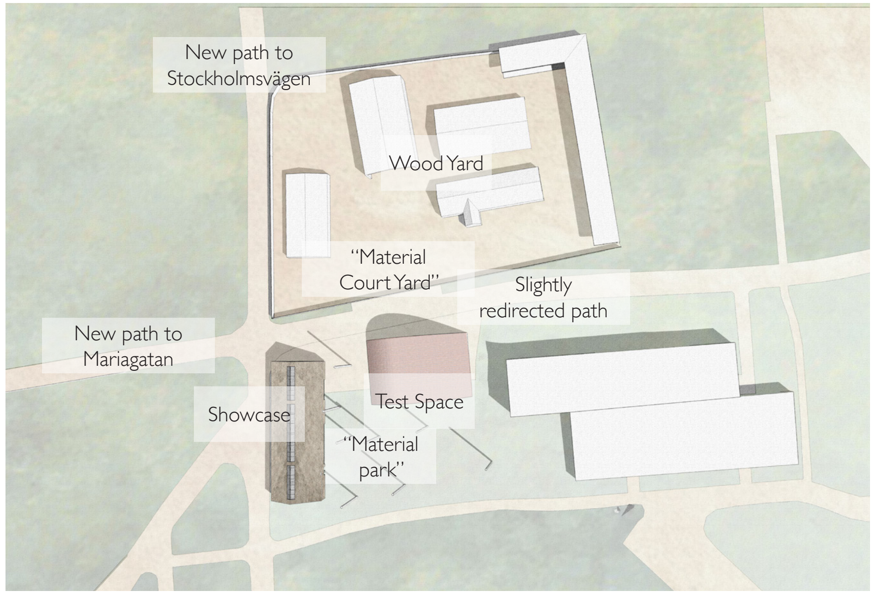


Fig 75. Proposed site plan for the Material Center


Fig 76. Entrance seen from the new path from Mariagatan

SHOWCASE BUILDING

The showcase hall is meant to be the public part of the Material Centre that can be visited by school classes, the general public or other user groups in both formal and informal visits. Here local materials and techniques are exhibited and the lecture hall allows for presentations and discussions regarding the topics of materials, locality, sustainable development or similar.

The main entrance is located in the northeast part of the building and leads to a reception/circulation space. The exhibition hall covers the majority of the ground floor and materials or structures can be taken in through either a two meter wide side door to the east or west, or through a four meter wide door in the south end.

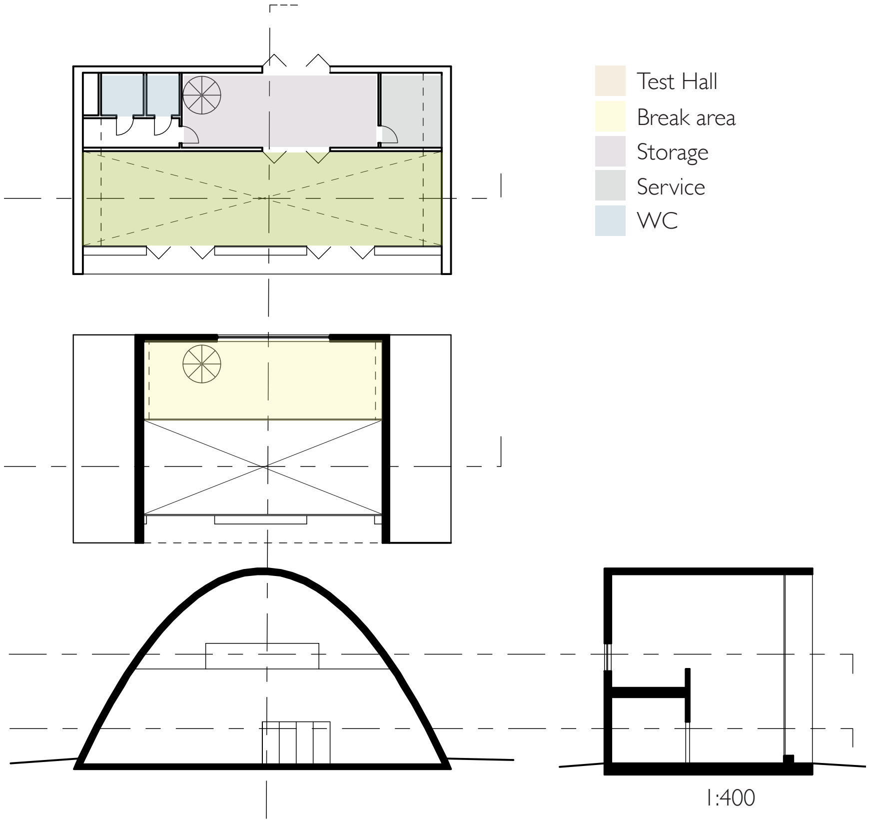
The lecture hall is located above the entrance and can be accessed by a staircase or a platform lift. From the entrance platform outside the lecture hall there is a good view of the exhibition hall and the scissor truss construction.

This building is the lightweight structural system built with stolpverk and cladded in thatched reed panels (see page 74 for more details regarding construction and materials).

SIZES

Showcase hall:	116.7 m^2
Lecture hall:	42.7 m^2
Storage:	20.4 m^2
Services:	31.7 m^2

Fig. 77 View of the showcase space inside the Showcase building.



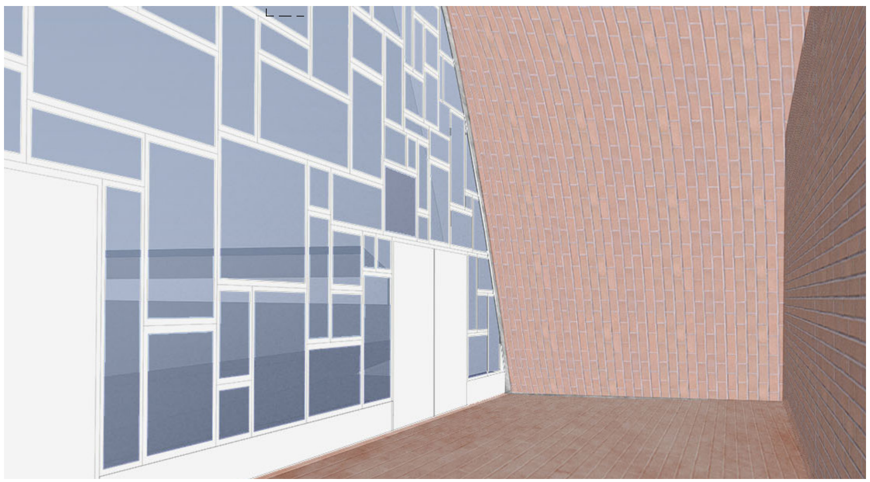


Fig. 78 View of the test space inside the Test building.

TEST SPACE BUILDING

The test space is a semi-public part of the Material Centre where people, professional or the public, can get hands-on experience in working with new materials or traditional techniques relating to local materials and resources. It could be used for varied purposes and timespans, for example a school class could spend an afternoon experimenting with clay, or group of self-builders could spend a weekend testing straw-bale construction or perhaps a small company could rent the space for a month to develop a new technique. The purpose is to give local actors an opportunity to test local material in order to encourage wider use.

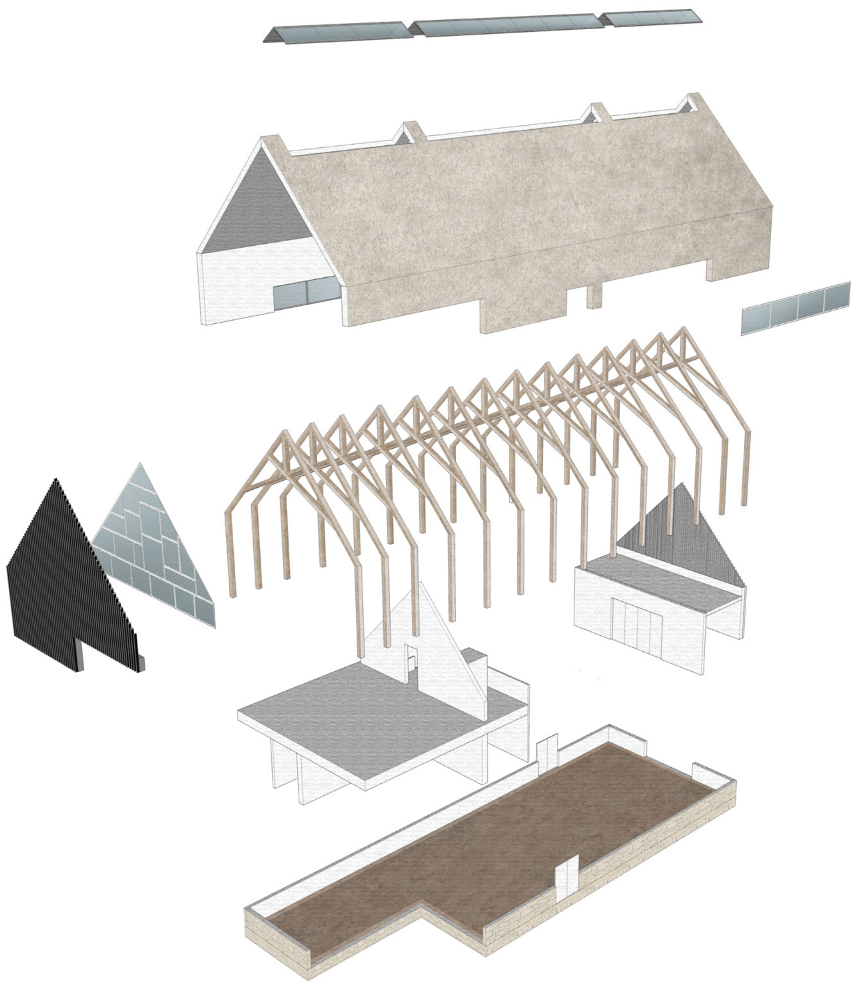
The majority of the Test Space building consists of the actual test hall. The large patchwork window is north facing to allow for good light quality without the risk of over-heating. It also invites people passing by to view the activity inside the Test Space. The rest of the Test Space consists of services, storage and a break area which has a view over the test hall.

The test space is an example of heavier construction made out of structural bricks which forms a parabolic arch over the hall (see page 78 for more details regarding construction and materials).

SIZES

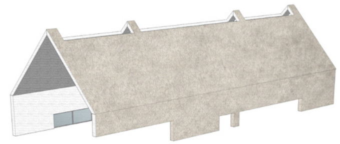
Test hall:	85 m^2	(95 m^2)
Break area:	49.2 m^2	(51.9 m^2)
Service:	8.9 m^2	(12.7 m^2)
Storage:	41 m^2	

SHOWCASE BUILDING



All materials are Small Scale, Local and Ethical

CLADDING & ROOF



Thatched Reed Panels

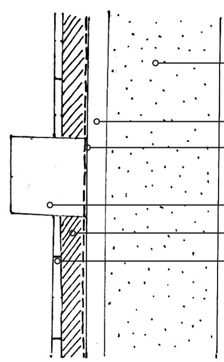
RESOURCE: *Reed (7), and timber (7)*

MATERIAL STRATEGIES:
Healthy, Low energy, Homogeneous, Closed looped, Repairable, Layers, Thermal, CO_2, Disassemblable, Resourceful, Prefabrication, Loveability

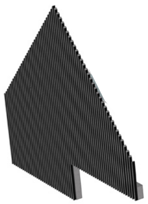
MATERIAL QUALITIES:
Insulating
Water proof

DESIGN PARAMETERS:
Pitch of roof - Thatched roofs have to be set at 45° angle or more
No overhang - Reed turns gray as it weathers, by not having any overhang the fabric will weather more evenly.
High base - The base is 1m high, this is in order to protect the reed panels from splash back from the ground.

DETAIL PRINCIPLE:
By using prefabricated panels time can be saved on site since these can be prepared in a sheltered environment. In order to insulate the building a thick layer of reed is used (approx. 300 mm). There should also be a waterproof membrane between the thatch cladding and the next layer.
(Bonus: solitary bees use reed straws as nests.)



CLADDING



Burnt Timber Cladding

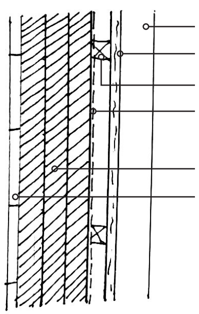
RESOURCE: *Spruce (7)*

MATERIAL STRATEGIES:
Healthy, Low energy, Homogeneous, Closed looped, Repairable, Layers, CO_2 Disassemblable, Loveability

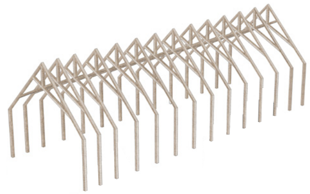
Material Qualities:
Water proof
Maintenance free up to 80-100 years

Design parameters:
No specific parameters

Detail principle:
This a traditional Japanese technique called 'Shou-Sugi-Ban' which is used to preserve wood by burning it. Due to forest management (issues with elk), spruce is more common than pine. Pine is also more suitable for the structure therefore spruce has been chosen as cladding material.



STRUCTURE



Stolpverk

RESOURCE: *Pine (7)*

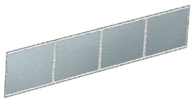
MATERIAL STRATEGIES:
Healthy, Low energy, Homogeneous, Closed looped, Repairable, CO_2, Disassemblable, Prefabrication, Loveability

Material Qualities:
Load bearing
Repairable

Design parameters:
Thicker beams and joists

Detail principle:
This a traditional technique that uses larger timber joists and the components can be prefabricated off-site. The components should be made of pine heartwood it's especially important that the ones which will be placed externally should be dense and resin-rich to avoid rot.
There are also many techniques to use plugs instead of nails at joints.

WINDOWS 1



Windows

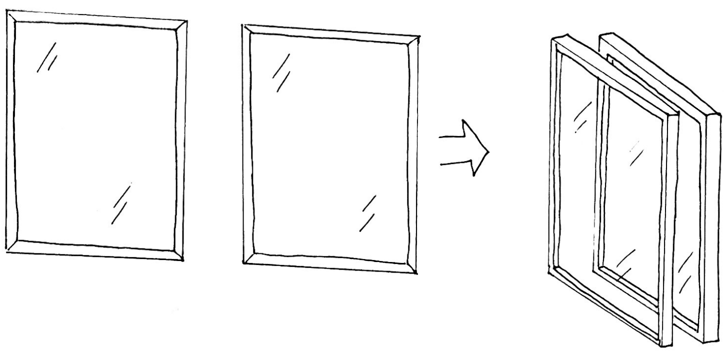
RESOURCE: *Reuse windows (2)*

MATERIAL STRATEGIES:
Healthy, Low energy, Closed looped, Thermal, Disassemblable, Resourceful, Prefabrication

MATERIAL QUALITIES:
Waterproof
Transparent

Design parameters:
The dimension of the window will have to be adjusted to fit sourced windows.

DETAIL PRINCIPLE:
Windows can be sourced from renovation or demolition projects. Old windows can be doubled up in order to achieve a higher U-value.



WINDOWS 2

Skylights

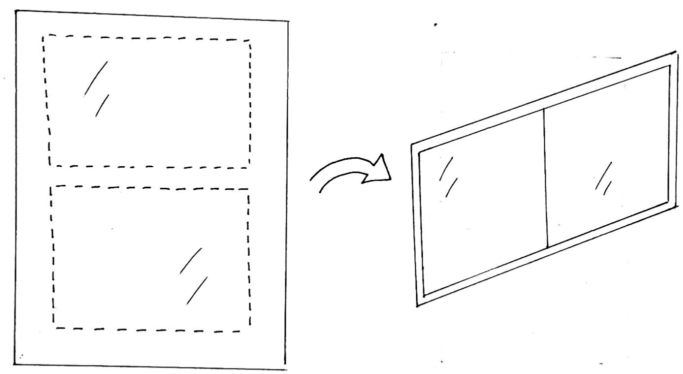
RESOURCE: *Reuse glass facade (2)*

MATERIAL STRATEGIES:
Healthy, Low energy, Closed looped, Repairable, Disassemblable, Resourceful, Prefabrication, Loveability

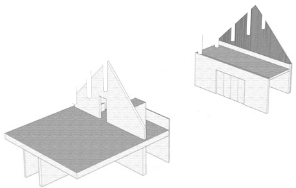
MATERIAL QUALITIES:
Waterproof
Transparent

Design parameters:
No specific parameters

DETAIL PRINCIPLE
Glass facades from renovations or demolitions are usually hard to reuse. For these bespoke windows glass facades are cut to specific dimensions and remounted.



INTERNAL WALL



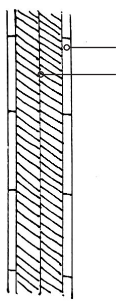
RESOURCE: *Waste paper (9), Straw (6), Reuse vinyl billboards (4)*

MATERIAL STRATEGIES:
Homogeneous, Closed looped, Repairable, Layers, Thermal, Adaptable, CO_2, Disassemblable, Resourceful

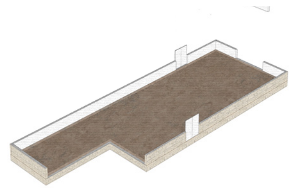
Material Qualities:
Tiles can be coloured

Design parameters:
No specific design parameters.

Detail principle:
The vinyl billboards are used as a damp proof membrane between the thatched reed cladding and the rest of the structure. Compressed straw panels then sit between the timber structure. These panels are dressed with paper tiles as an interior finish.



FLOOR AND FOUNDATION



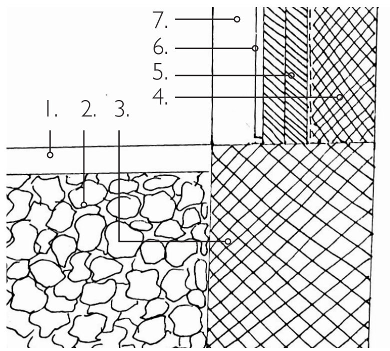
RESOURCE: *Clay (8), Glass (9) and Stone (10)*

MATERIAL STRATEGIES:
Healthy, Closed looped, Repairable, Layers, Thermal, Disassemblable, Resourceful

Material Qualities:
Clay has thermal mass

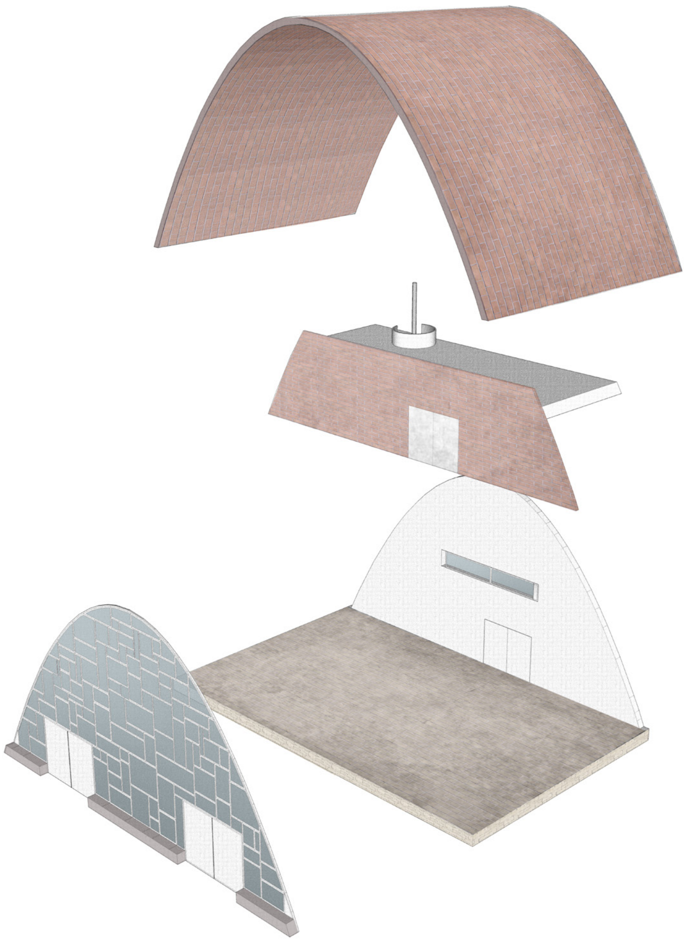
Design parameters:
No specific design parameters.

Detail principle:
The foam glass material hasopor is most frequently used as filling for infrastructure but can also be used in foundations. Natural stone makes up the base for the foundation.



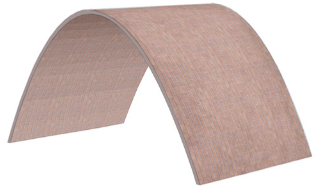
1. Hasopor (Foamglass) 2. Clay 3. Stone foundation 4. Stone base 5. Straw panels 6. Paper tiles 6. Timber structure

TEST BUILDING



All materials are Small Scale, Local and Ethical

CLADDING & ROOF



Parabolic Arch

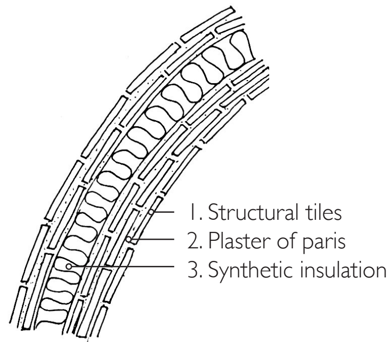
RESOURCE: Clay (8), Reused Polystyrene (2)

MATERIAL STRATEGIES:
Healthy, Homogeneous, Closed looped, Repairable, Thermal, Resourceful, Loveability

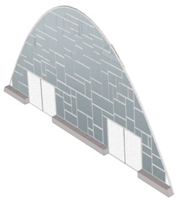
MATERIAL QUALITIES:
Insulating
Waterproof

DESIGN PARAMETERS:
Parabolic arch - The parabolic arch needs to be in pure tension, the relationship between height and width will therefor set the form.

DETAIL PRINCIPLE:
Parabolic arches are an traditional technique from the Catalan region. These arches are made in pure compression which means that they require a much thinner layer of materials than the roman arches. It will be constructed by clay tiles bound with plaster of paris. Polystyrene blocks will be sandwiched within the arch as insulation.



WINDOW



Window

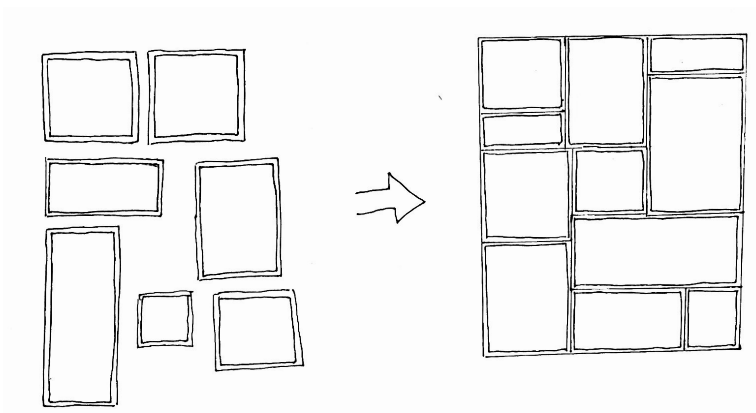
RESOURCE: *Reused Windows (2)*

MATERIAL STRATEGIES:
Healthy, Low energy, Closed looped, Repairable, Disassemblable, Resourceful

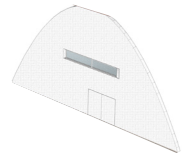
MATERIAL QUALITIES:
Waterproof
Transparent

DESIGN PARAMETERS:
Parabolic arch - The window will become a patchwork that depends on the dimension of the windows that can be sourced.

DETAIL PRINCIPLE:
Windows sourced from renovation or demolition projects will be joined together to create a large patchwork window.



CLADDING



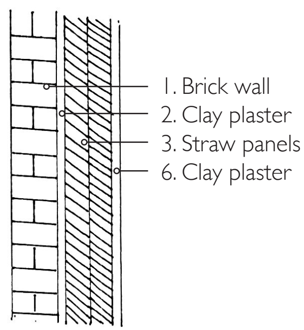
RESOURCE: *Clay (8), Straw (6), Reuse vinyl billboard (4), Timber (7)*

MATERIAL STRATEGIES:
Healthy, Homogeneous, Repairable, Layers, Thermal, Adaptable, CO_2, Disassemblable

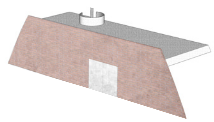
MATERIAL QUALITIES:
Waterproof
Insulating

DESIGN PARAMETERS:
No specific parameters

DETAIL PRINCIPLE:
The facade is dressed in the same finish tiles as the arch. The load bearing elements are a combination between doubled up straw panels (which then become load bearing) and (due to the height) timber beams.



INTERNAL WALL



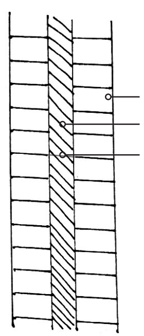
RESOURCE: *Reused bricks (2), Lime (10)*

MATERIAL STRATEGIES:
Healthy, Low energy, Homogeneous, Closed looped, Repairable, Disassemblable, Resourceful

Material Qualities:
Waterproof

Design parameters:
No specific design parameters.

Detail principle:
Since there will be water in the test space for experiments, cleaning it will be important so that the wall wont suffer from moisture problems. The wall will therefore be constructed with reclaimed bricks and lime mortar, with a lime render.



FLOOR AND FOUNDATION

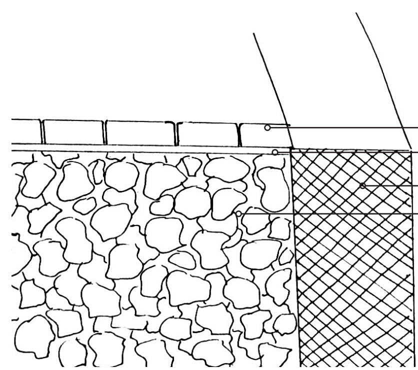
RESOURCE: *Reused bricks (2), Sand (10), Glass (9) and Stone (10)*

MATERIAL STRATEGIES:
Healthy, Low energy, Homogeneous, Closed looped, Repairable, Disassemblable, Resourceful

MATERIAL QUALITIES:
Insulating (foam glass)
Thermal mass (Bricks)
Load bearing (Stone)

DESIGN PARAMETERS:
No specific design parameters.

DETAIL PRINCIPLE:
The foam glass material hasopor is most frequently used as filling for infrastructure but can also be used in foundations. Natural stone makes up the base for the foundation. Reclaimed bricks will be cut in half and used as flooring for higher durability. The thermal mass of the bricks will not be used due to the north facing windows.



SUMMARY

MATERIAL CENTER

Though there were vacant buildings in the Johannebergs park which could have housed the function of the material center the decisions was made design two new buildings. This was justified since the construction of the buildings could be used as a pilot project to explore materials and techniques derived from local conditions. It would also make the buildings themselves a way to showcase the potential in local materials.

By working with the concept of one light and one heavy structural system a wider range of material and techniques could be explored in the case study.

DISTANCE

All the resources used in the proposal for the Material Centre could be sourced within 100 km driving distance. The case study has to be considered as a bespoke projects since there currently is hardly a market for local materials. This means that in the case for the industry and market needs the distance is likely to be longer.

WAYS OF WORKING: MODELS

When working with materials which are a strong component I found it beneficial to work with models, both physical and digital, since that allowed the materials to be a part of the design decision.

WAYS OF WORKING: INFORMATION

The conversations with both the GU students and local craftsmen were invaluable in understanding materials qualities and techniques that could be used with less standardised materials.

TRADITIONAL TECHNIQUES

Traditional techniques were a great inspiration since these usually only work with less conventional renewable materials and are usually meant for easy maintenance and repairs, even disassembly, since materials used to have a higher economical value than in todays society.

ALTERNATIVE MATERIAL PROCESS 5

WHAT AND HOW

In this chapter the result of the thesis will be defined, which means outlining the idea of a holistic sustainable material process and how architects can work with this process, in short what to do and how an architect can do it. This chapter is my personal reflection of the process based on the literature studies and case study performed during this thesis.

HOLISTIC SUSTAINABLE MATERIAL PROCESS

As described in the first chapter it is important to view the environment, society and economy as an integrated system where in fact the earth's capacity sets the parameters in which societies and economical systems need to operate within. Therefore it is important to start with sustainable resource use as a basis for the system. Based on the literature studies I propose that the material used in this process should mimic natures circular systems, or circular economy. This can be through reduction, reuse, recycling or for biological matter biodegradation.

According to the ideas of Björn Berge and Rob Hopkins a change towards a localised material process that is performed by small scale networks of industries leads to a more sensitive use of resources. This network system would also create societies with a higher economical resiliance in communities. By strengthening local economies there is a chance for a more even geographical development where smaller local societies are empowered.

There could be potential for new jobs that require a variety of different new skills. For example in order to reduce the need for materials buildings should become a part of a service society rather than consumption, where buildings are maintained and adaptable with a long lifetime expectancy. This would be an economical model that supports a sustainable use of resources.

A localised material process could also bridge the connection between materials and users, contributing to a strengthened sense of placemaking.

This is my interpretation of an holistic sustainable material process; circular use of materials and resources that is supported by a circular service economy and empowered local societies. It might seem like I believe that this process is the answer to everything but it is of course not. This is only one piece of the puzzle in sustainable development, but it begins to frame how material use in the construction industry can have a positive impact in this development.

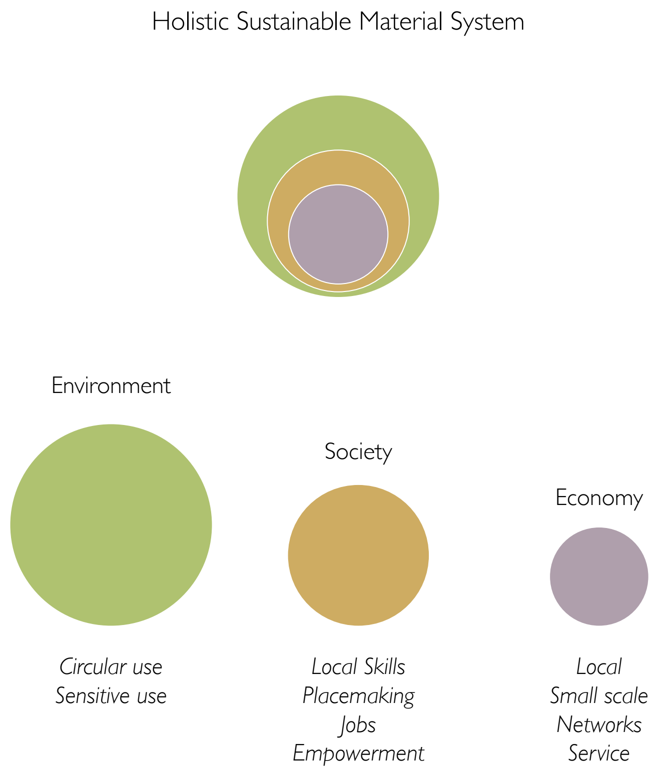


Fig.86 Illustrates how a holistic sustainable material process needs to work within the frame of the earth's capacity while being supported by social and economical systems and what impact this would have within the three areas.

USE MATERIALS

In fig 87 I have tried to describe matters movement in a sustainable material process. In this I have merged the concept of circular material fig 20 in the first chapter with the idea of the material chain in chapter 3. By combining the diagrams it turns the linear concept of the material chain into a circular system.

Like previously mentioned it is important to consider both the past and future life of the material. Design for future reuse is vital but this process can start today. By expanding the concept of what material is or could be, a wider selection of resources can be made available. In a world of depleting resources we have to be more resourceful. The resource hierarchy from chapter 3 is a way to rethink the priority of resource use according to circular economy.

It is also important to ensure future circulation of the materials, preferably in as small loops as possible since that generally will require less energy and waste. Some of the material strategies that were outlined in the third chapters relate to this notion such as: homogeneity, disablement and layers. These factors need to be considered in the design stage.

The diagram in fig 87. also bring is the concept of location and proximity between the different loops by adding the step of distribution.

Traditional techniques

From both talking to people during the process and applying it to the case study I found it very beneficial to look at traditional building techniques to find new (or old) design solutions. These techniques were developed to work with local resources in a way that would allow for adaptation and repairs to prolong the life of the buildings. I worked Jason F. McLennan concept that materials and resources were sourced locally while the techniques of working with them are sourced globally. This was important to create the opportunity to go beyond timber which is the main material used in Sweden traditionally.

For the purpose of the sustainable material process I have not considered cultural or heritage values connected to the traditional techniques since the main function of the techniques is to use local resources and prolong the life of the building. When selecting a traditional technique it is however important to consider the local climate compared to where it originate from especially if the materials are exposed to the weather.

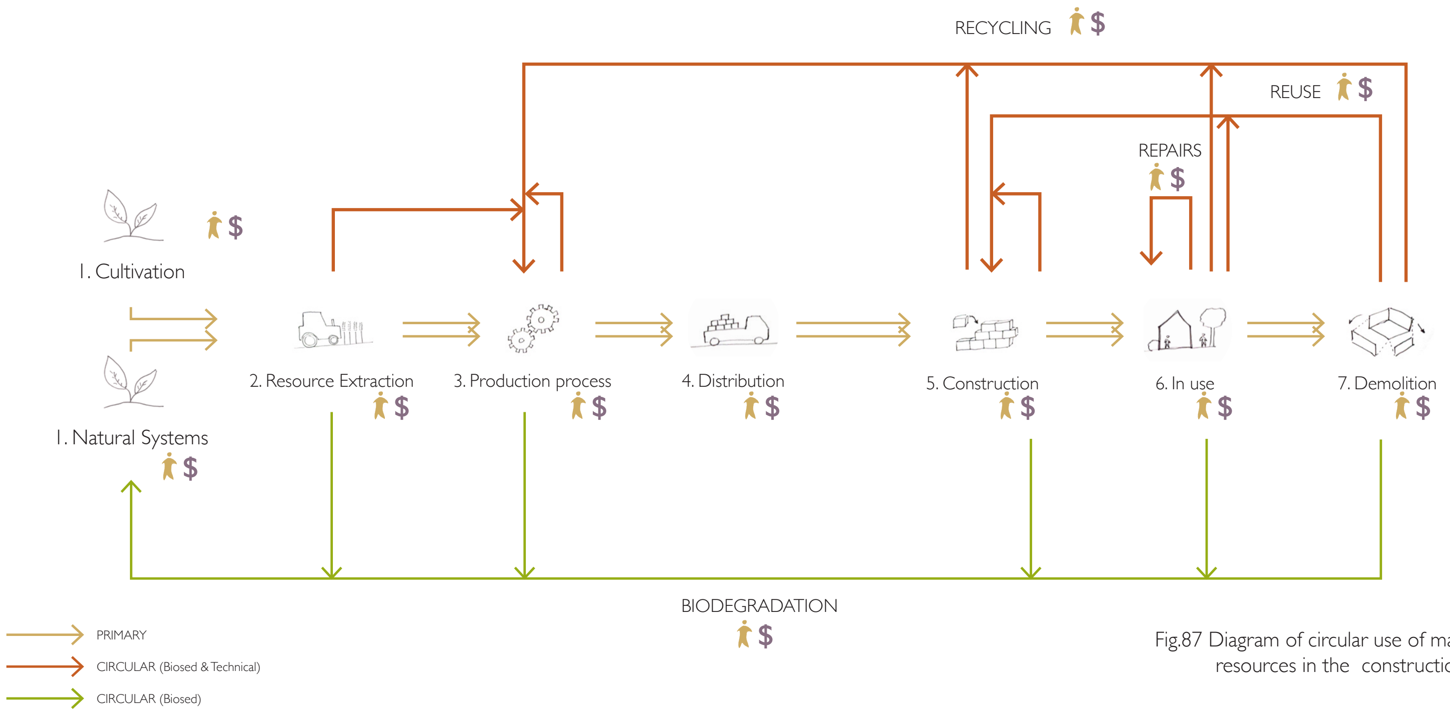


Fig.87 Diagram of circular use of materials and resources in the construction industry.

In the case study I worked with a design process similar to the one of Superuse Studios. Allowing the materials to be a more influential parameter in the design process by using their qualities as form generating.

In fig 88 I have tried to demonstrate the process I began to work with and that I believe is important when working either with a smaller selection of material or with less standardised materials and techniques.

The two first steps ***Design Brief*** and ***Spatial Needs*** are the same as in Superuse Studios. This is to understand the function and needs of the client and proposal. The next step is an iterative design process that loops through the different steps:

Site Context - Kenneth Frampton emphasises the importance of working with the local site conditions in order for the design to become an integrated part of the local fabric. This is also important to fully utilise the qualities of the materials such as thermal mass or avoid bad weathering conditions.

Conceptual Design - This is a step to test anything from the program, spatial needs or materials qualities. It is an experimental step where qualities can be extracted to influence the design.

Local Materials - One stage is to identify potential resources and materials. For the case study I did this research through conversations with local actors and online research.

Material qualities - This stage is essential in order to use the full potential of a material e.g. in the case study, the thatch panels are both thermal and water resistant if used at certain angles. Different materials qualities and constrictions were identified through reference projects and discussions with experts.

Experts - As noted in fig. 88 communication with other experts is an important point. Since the parameters of the materials are vital for a successful project it is important that detailing corresponds to the overall form of the proposal. This makes trans-disciplinary work an important part of the process.

John Ochsendorf who is an associate professor of building technology at MIT, explained in an interview how hard it can be to make corrections in later stages once the design has been set. He also talks about the concept of "Whole life design", to design a building while keeping the future life of the material in mind. In order to do this he stresses the importance of trans-disciplinary work, where more consultants are involved at an earlier stage. Rather than the waterfall model approach where one discipline follows another (traditionally used), a more iterative design process would be favorable. (Stauffer, 2009)

Design - During this process the design starts to take form. I found it very beneficial to work with models since I could design more easily with the qualities of the materials. Something that I found easier to do in 3D rather than two dimensional drawing. It was also useful to change between scales, to model the whole building, elements and details.

Prototyping would have been a good way to test details, meetings and to better understand material qualities which is how Rural Studio approach a new unconventional material.

This was unfortunately not an option for me due to time and scale, though I did some small-scale experiments with straw as reed panels. Instead I did extensive studies of reference projects as well as discussing material solutions with Stefan Jonasson and Björn Frodin, craftsmen who work with traditional methods, and with Isak Blomster, Anton Bachs and Freja Gyllenhak, the students from GU.

All in all I would say that this has been a very inspiring design process and though it has been hard at times I would in no way describe it as limiting. The process is also likely to become easier with time once one has gained better understanding.

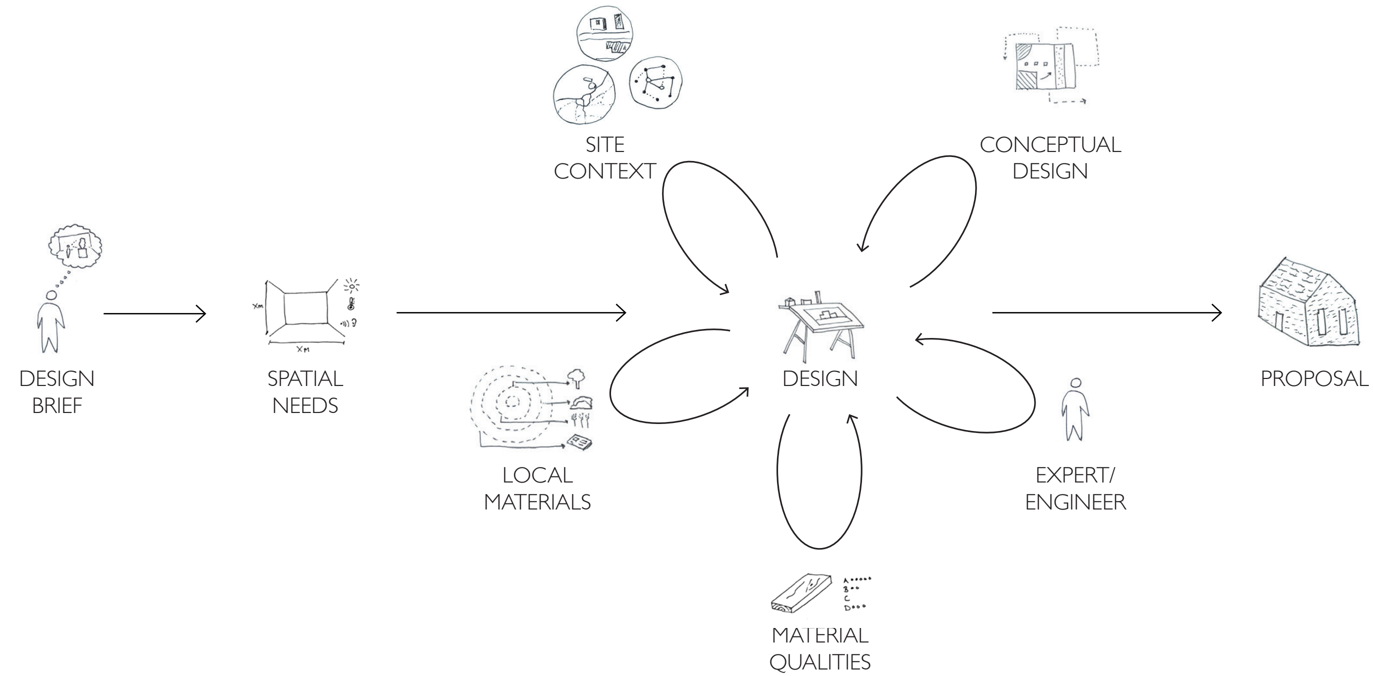


Fig.88 This diagram showcases my design process in my work with local available materials. Since the selection of materials will in some way will be restricted it is favourable to introduce them early in the design process to utilise their full potential.

CONCLUSION & REFLECTION

CONCLUSION

This project has strived to answer three research questions:

What is a holistic sustainable material process?

A holistically sustainable material process considers not only the environmental impact of a material's process but also the social and economical ripples that this process generates in the world. By considering this process as an integrated system there is a greater chance of accomplishing a larger change.

In this project local materials are a big part of achieving this holistic process. Because in todays society with ever growing supply chains is it quite hard to understand the ripple effects that a material process can have and who it is that really pays for the material. Bringing the process to a local level offers a higher level of control of these ripples.

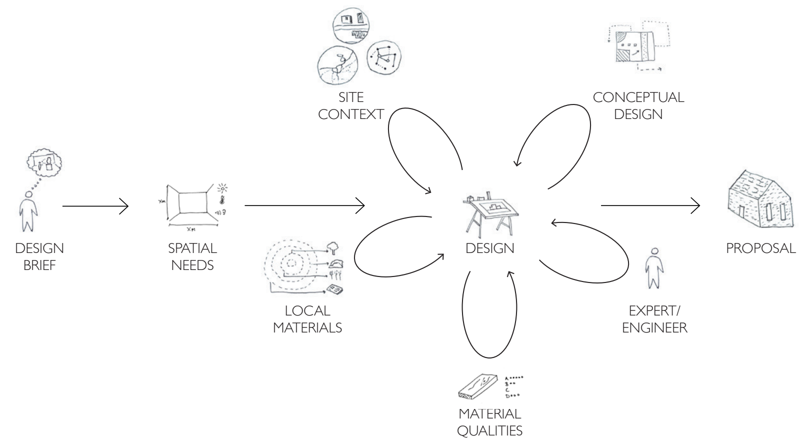
According to the literature studies, supporting networks of small-scale industries can start to counteract the trend of large scale rationalised companies. Smaller local production companies are more likely to be resourceful and sensitive in the use of resources. Especially since extraction impacts and waste streams will become more apparent for producers and users. A localised material process would then support the local market by encouraging capital to circulate within the local society. This strengthening of the local economy could lead to new job opportunities, having an empowering effect on inhabitants. This decentralising approach could potentially strengthen rural areas and smaller towns by lifting the importance of them in a sustainable development.

The project has also attempted to define ways resources and materials could be used in a sustainable way. Circular models show the importance in considering a material's past and future life when using it in the present. Circular resources and materials are an important part in breaking the linear model that is in place today. This means challenging the norm of 'new-as-novelty' discussed by Susanna Hagan which in extension also means breaking the norm of the consumption society. This is vital in a move towards a circular and biobased economy.

How can architects work with a sustainable material process?

At first it might seem limiting to work with a restricted selection of materials, especially since common and form forgiving materials such as concrete and steel are excluded due to both the environmental impact and local availability. This is due to the normative design process where a building's form is a primary step in the design process and then realised by suitable materials. If the process is adapted and allows for the inherent qualities of materials to become a larger parameter of the form giving of a design, then it becomes a lot easier rather than forcing them to perform according to a predetermined form.

The design process explored in the case study was very much inspired by the one of Superuse Studios with the core notion of working with the materials, allowing them to inspire the design and play at their strengths. This was done through an iterative design process where the materials are a strong driver in the design. This requires deeper knowledge in material qualities and construction which can be obtained through increased trans-disciplinary work. Where other experts are invited earlier in the project to influence the design at an early stage.



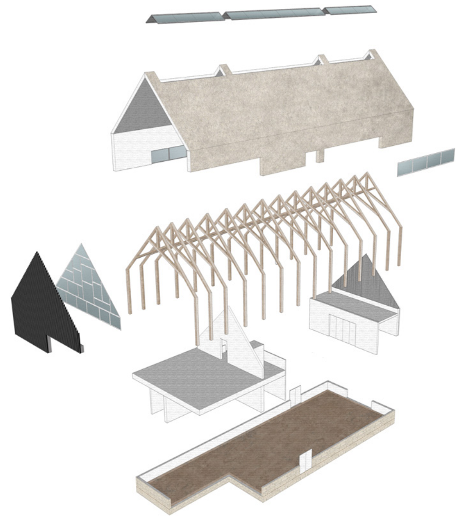
What material opportunities can local resources generate?

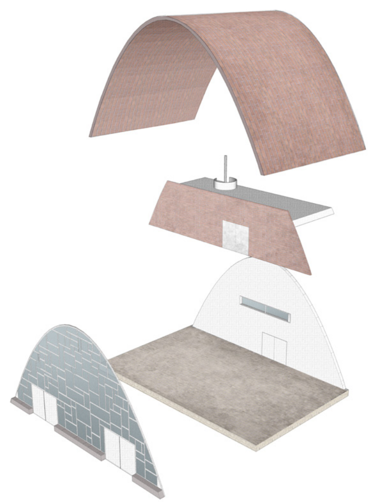
The short answer is - lots! For a more extended answer the case study has hopefully showcased that there is immense potential in local resources. In the case study twelve resource opportunities sourced within 100 km by car have been explored. This is 700 km shorter than what would be awarded points for locality according to the LEED certifications. These resources can also in theory be refined or modified within the same area.

The case study was however an example of a one-off bespoke design, but by comparing the findings of the case study and the theoretical sources an educated guess would be that the distance would have to be larger than 100 km to correspond to market demands on an industrial scale. The specific geographical distance is on the other hand less important. It should instead be considered a tool in order to achieve short supply chains which strengthen local economies and potentially generate a mental connection between user and resource.

It is also important to note that many material opportunities are from circular resources of less widely used renewable resources. The reed panels used as cladding are an example of this where large volumes of reed are cut and wasted every year. However by using an updated version of the traditional technique of thatching a win-win situation is created where the reed instead becomes a valuable material.

Most of the materials used in the case study are not produced locally today but showcase the potential of local resources. One important aspects in turning these resources into feasible materials are product certification to guarantee quality. This is important to ensure quality for e.g. insurance reasons. Today this is a quite rigid system but there are examples of ways to certify the quality of less standardised materials like straw construction in Germany. This would benefit both new circular materials as well as traditional techniques through the implementation of certified: products, producers and constructors.





Problem Framing and Potential

The aim of this thesis was to identify a holistic sustainable material process on the scale of the construction industry and how architects can work within this process. The answers proposed in the thesis have not been a tool box or set of strategies for architect offices to work with today. It has rather begun to frame the problem of the wider impact caused by material choices and by that emphasise their potential role in a sustainable development.

Holistic material process

The concept of a holistically sustainable material process has been a vital part of this master thesis. I believe that by considering materials social and economical impacts, a more environmentally sustainable use of material can be achieved.

At the core it is our value models that need to be changed, because today we have a system in place where everything in measured according to economical value. Other aspects such as security, pride and wellbeing are harder to measure and like the environment they become secondary to relatively short-term economical profits.

It is easy to say in a theoretical work how things should be done, when one doesn't have to fight against the beasts of systems that we have created around us. While globalisation and industrialisation have contributed to great developments for human societies, we now seem to have lost control. Long supply chains that criss-cross over the world makes it hard to understand the true effects of our material choices.

Transition - Obstacles

By considering the process on the scale of the industry more obstacles are discovered and it connects the materials to social and economical impacts. In this thesis that has meant to challenge an underlying structure of rationalisation and acknowledge it's impact on the construction industry and society.

Fig 90. illustrates how the thesis has begun to frame a holistic sustainable material process and related it to today's conditions. This process would require a transition from a rationalised consumption economy to a circular service economy. In the diagram some obstacles that have been touched upon have been marked along the line, while there are of course plenty of others have not been discovered yet.

Knowledge

There is a lot of knowledge and skills that are needed in many steps in the move towards a sustainable material process. Some of them are outlined in the diagram in fig 90 and most of them have been considered in the beginning of chapter two. There is new knowledge needed both in how materials are produced and from what resources as well as new skills to construct and use these materials.

Another part is increased knowledge regarding maintenance in order to prolong a buildings lifetime, it could be beneficial to consider a building as a service rather than a product. To build a market around this service by making it cheaper and easier to maintain and adapt rather than demolish and rebuild. In regards to demolition there is also a great opportunity to increase skills in regards to deconstruction to preserve materials for reuse and recycling.

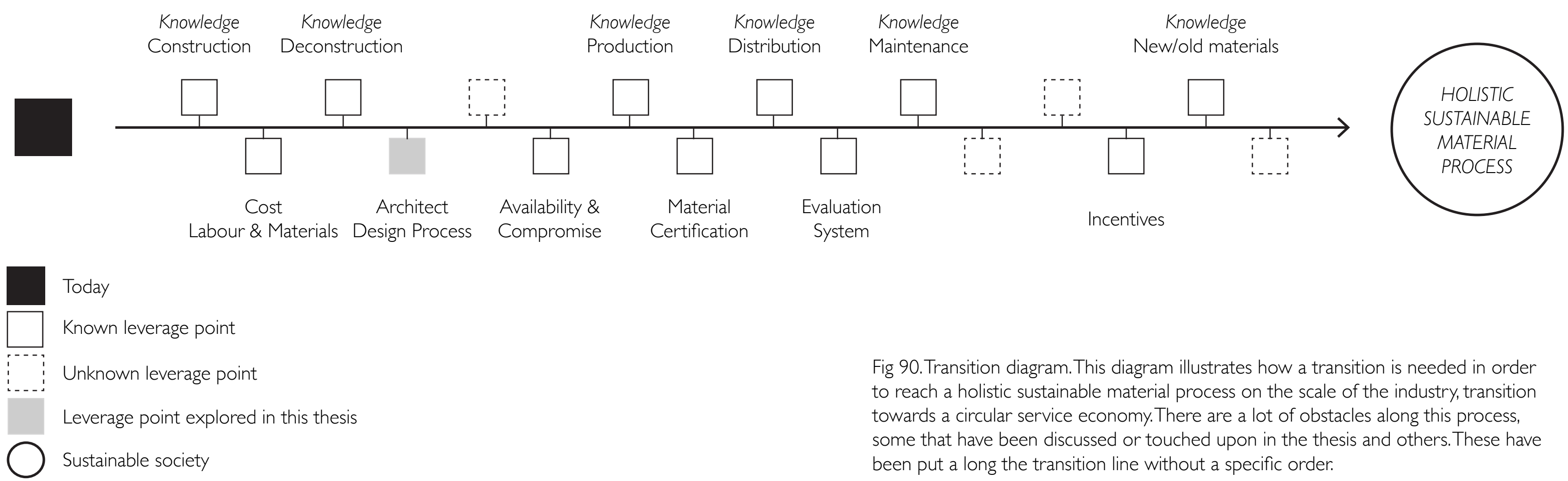


Fig 90. Transition diagram. This diagram illustrates how a transition is needed in order to reach a holistic sustainable material process on the scale of the industry, transition towards a circular service economy. There are a lot of obstacles along this process, some that have been discussed or touched upon in the thesis and others. These have been put a long the transition line without a specific order.

The last two points are connected to the architects role since both aspects can be greatly influenced by the design choices made in regards to materials. This will be discussed further in the section *Form and Materials* on the next page.

Cost

The cost of a project is a vital part in any business' decisions. No calculations were unfortunately made regarding cost for the case study, my guess would be that considering the material cost for the material center as a bespoke building it would probably be similar to a conventional building. If considered from an industry scale it would more than likely be more expensive but this is an investment back into our societies. It would also represent a more true cost in regards to salaries and environmental impact, where the real cost for resources is paid and humans are being compensated fairly.

Another aspect regarding cost is the relationship between labour and materials. In Sweden today the labour is usually more expensive than the materials, therefor prefabricated and standardised processes are preferred in order to save money. This relationship has to be adapted or reevaluated since it contributes to a greater use of resources.

The quality and cost of buildings are sometimes valued in how fast a return can be made on the investment rather than assuring a long lifespan to save resources. Today we can build adaptable and robust houses that should be able to last hundreds of years, but who pays the increased initial cost for this?

Incentives

One way to counteract the trend of the linear use of resources and building with short lifespans are economical incentives to support a decentralised market which uses sustainable materials and resources. For example by supporting refurbishments of kitchens rather than exchanging it for a new one or by making it harder to use unsustainable materials instead of circular and renewable ones.

Municipalities have the opportunity to steer materials use in some ways through land allocations and detail plans. However some issues may occur in regards to the tender process within the free EU market.

Material Certification

A high level of resistance in the use of circular and unstandardised materials is due to a limited level of certification and assured quality control. This means that our evaluation systems needs to be updated to go beyond rationalised materials like what has been done in Germany with the use of a certification system and quality control of straw bales. Certified constructors are also a way to assure a higher level of quality control.

Availability and Compromise

Working with a local material selection can set certain restrictions that we have worked hard to avoid in todays consumption society. Restrictions such as seasonal availability or how it might fluctuate from year to year depending on local conditions e.g. crop yields or number of refurbished houses. This would demand a higher level of organisation and compromising that we are not used to today. It could make it very hard to predict volumes of materials in advance depending on the resource.

Evaluation systems

LCA could be a good way of evaluating and comparing different materials to one another. The evaluation should also be compared to it's estimated lifetime, e.g. a structure that is predicted to be used for 100 years would be allowed a higher LCA value than a cladding with a life-expectancy of 30 years.

Unfortunately I was unable to make a LCA analysis of the material center. It would have been very interesting to compare the circular and traditional materials to a conventional building. It could also be beneficial for the holistic sustainable material process to introduce new evaluation models that track soft values such as empowerment as well as being able to record economical impact.

Material center

The need for a new building could be discussed. The functions of the material centre could have been located in one of the empty buildings within the park. There is however a few major advantages to constructing the two new buildings. Firstly it's an incredible opportunity for local craftsmen to get experience of these materials so the creation becomes a test bed in itself, both in the form of the construction and material production. This could lay a base for a future market. Then the buildings themselves will be a part of the showcase element, displaying the vast potential in local and sustainable materials. This has also been the main function in developing the proposal, to test and showcase the potential in local and sustainable materials and techniques. It is not a finished proposal and no attention has been paid to other sustainable aspects e.g. water use, operating energy or heating.

It would have been interesting to follow the project to the next step and discuss the design with a constructor and people with greater material knowledge to better understand the detailing and how this would affect the overall design. For example though the principles behind the detailing are meant to enable easy deconstruction this would have to be looked at more closely in regards to the design.

Locality

Although the concept of local material has been explored in this thesis, more research is needed in order to understand the relationship between the potentials in local networks and market needs in Sweden on an industrial scale.

The theories have also discussed how small-scale and localised networks of industries would be more environmentally sustainable than centralised and rationalised industries. This highlights the importance of rural areas in a sustainable development, which could help in breaking the urban norm's prerogative in defining concepts of sustainability.

Hierarchy and Strategies

The hierarchy and strategies defined in the third chapter are rather ambiguous. It is for example hard to judge if the proposal is adaptable since it can work on many layers, such as for a specific material or the space plan. Or for example how easy must it be to repair a material in order to consider it repairable? A brick wall can be repaired but it requires a lot more effort than re-plastering a clay floor.

These are however useful as a tool to break down the concept of a sustainable material. In a proposal they have to be weighed against each other and LCA.

Architects Role

Another aim of the thesis was to understand the architects relationship to a sustainable material process. In order to work with a holistic sustainable material process we might have to adapt our working process and values.

Priorities

In the development of a design proposal there are many aspects that have to be weighed against each other. In the development of the material center the focus was mainly on the materials but in a professional project more would need to be accounted for, especially a harder time restriction. It might be easy to lose track of the material value amongst all other priorities, however if we are working in a system where we don't have time to do everything right, maybe we are doing it wrong?

Learn new materials

From the little experience I have of working practice I would say that architects do design with materials in mind, especially structure wise. The only problem is that these are in general materials such as steel and concrete, which have a high ecological footprint. These materials are also in many cases hard to source locally.

Starting to use alternative materials is a process where one needs to learn how these materials function. Once the first hurdle is overcome the resistance decreases. In this case study the material process has been angled towards self-builders and small construction companies since this was the most suitable for the local context. It also offered a good comprehensive scale to engage with, while not getting lost in the complex system. In the original plan I was going to contact a construction company to discuss their material use and their opinions on a local material process. Due to a lack of time I was however unable to do this. Still, at a presentation regarding reuse and recycling of building materials (from the old Sweco building in Gothenburg) made by Vasakronan, they spoke of how they perceived the highest resistance towards these which was materials coming from the architects and sometimes the clients. This would indicate that parts of the construction side of the industry is about to change.

Form, Function and Material

The topic of form and its relation to materials is something that has interested me for a long time. My personal belief after making this thesis is that materials are a realiser of form but that this in no way makes them inferior, however neither **is/ does** form. Together they create what I believe an architect's main design task is: spaces.

I can see how in a world where resources seemed endless and with the development of advanced techniques to manipulate materials it seemed like only the imagination of form would set the limits of a design. These ideas and the increased disconnection between architects and the act of making have most likely reinforced this ideal. When I have spoken to people working with craft and construction the materials are an obvious part of their design process. Perhaps the relationship between material and form derives from the profound philosophical question regarding mind and matter. It could also have been rooted or reinforced over history by different roles within the social classes or maybe it all boils down to man's perceived superiority over nature. It is more than likely a combination of many aspects and this topic requires much further research to outline the underlying structures that have created the situation we see today.

The new process intends to challenge the conception of new-novelty and instead use local conditions as a layer to strengthen a proposal, and by doing this it breaks away from the trend that has come about from the modernist movement and consumption society.

It is then easy to make the misconception that the new material process should replace all the old values of architecture such as function and aesthetic. This is however far from the case, I can see that especially these two aspects are essential parts of the new material process since both functionality and loveability (aesthetic) have been deemed vital in ensuring a long lifetime for a building. This in turn relates to one of the key features of a circular society, the prevention of need for new resources.

Then the proposed material process is not reverting back to a time before industrialisation but building on the old values rather than replacing them. It is adapting the process by acknowledging the real conditions of the world and not in an illusion caused by the delay in ecosystem's reaction.

Though the title of this thesis may give the impression of materials value over form this is not the case in the proposed material process, it was only used to emphazise the materials role in the design process. What I do know is that there is a limit to the earth's resources and behind each material there are people who have worked with extraction and manufacturing. By accepting this reality it then seems irresponsible to value form over materials in our profession. Just as we have to take responsibility for the impacts created by our designs, we have to take responsibility for the impact caused by their creation.

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PEOPLE

During the process of this thesis I have been fortunate to meet with many different people to discuss materials potential impact, role of traditional building techniques, notion of local and much more.

Björn Ohlén
Developer at Västarvet in Västragötland focused on sustainable business development

Linda Lindblad
Head of operations at the craft laboratory in Mariestad

Annika Kjellqvist
Head of the department for construction and environment at Mariestad municipalty.

Isak Blomster, Anton Bachs and Freja Gyllenhak
Bachelor students at the heritage and craft program at Gothenburg university that is located in Mariestad.

Björn Frodin and Stefan Jonasson
Craftmen in Mariestad who works with traditional building techniques.

Karin Hedén
Works at the environmental branch at White Architects and have worked with issues regarding reuse and recycling of construction components.

Ingemar Widheden
Retired upper secondary school construction teacher.

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IMAGES

Figure 1 (Cover and back):
Thatch Texture
Image After (2017). *Thatch Texture* [Electronic]. Retrieved from http://www.imageafter.com/image.php?image=b19roof013.jpg

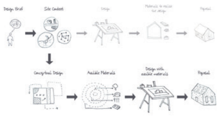


Figure 2:
Process Diagram
Authors own image

Figure 3:
Clay Texture
iHitokage (2017). *Dry clay/soil free texture* [Electronic]. Retrieved from http://ihitokage.deviantart.com/art/Dry-clay-soil-free-texture-557779563

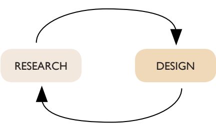


Figure 4:
Process Diagram 1
Authors own image

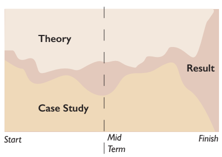


Figure 5:
Process Diagram 1
Authors own image

Figure 6:
Thatch Texture
Pixnio (2017). *Reed, Rush mat* [Electronic]. Retrieved from https://pixnio.com/textures-and-patterns/reed-rushmat-rush-mat-pattern

Figure 7:
Copper Mine
Edward Burtynsky/Howard Greenberg Gallery, *Chino Mine, Silver City, N.M.* by Retrieved from http://www.nytimes.com/interactive/2015/10/25/magazine/25mag-copper.html?_r=0

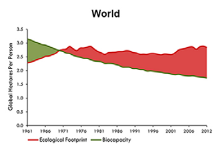


Figure 8:
Global ecological footprint
Footprint network (2012). *Global ecological footprint* [Electronic] http://www.footprintnetwork.org/our-work/

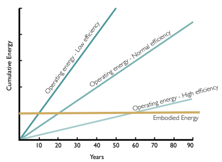


Figure 10:
Embodied Energy
MITei (2017). *Energy use in buildings* [Electronic]. Based on image from http://energy.mit.edu/news/innovative-buildings-prudent-use-of-energy-and-materials/

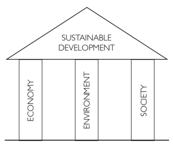


Figure 11:
Three pilars of Sustainability
Authors own image

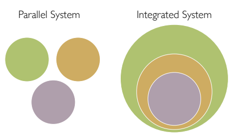


Figure 12:
Process Diagram 1
Authors own image

Figure 13:
Circular Economy
Authors own image

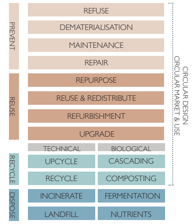


Figure 14:
Waste Laddes
Edward Burtynsky/Howard

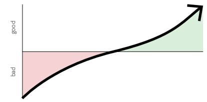


Figure 15:
Good Impact
Based on Cradle to Cradles design process (2012). *Cradle to Cradle Design process* [Electronic] http://www.braungart.com/en/content/c2c-design-concept

Figure 16:
Local according to LEED
Made by author

Figure 17:
Local Food Distances
Made by author

Figure 21:
Timber Texture
Blogspot.com (2013). [Electronic] Retrieved from http://3.bp.blogspot.com/-RRfjMk8XEk/UY8DSLHslwI/AAAAAAAAAFU/b4gOw1Xnmjk/s1600/wildtextures-old-wood-original-file-1280x853.jpg

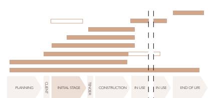


Figure 22:
Building Process
Authors own image

Figure 23:
Glass Chapel
Rural Studios (2012). *Manson Bend Glass Chapel* [Electronic]. Retrieved from http://modosdehabitar.blogspot.se/2010/06/la-otra-arquitectura.html

Figure 24:
Superuse Design Process
Authors own image

Figure 25:
Harvest Map
Superuse Studios (2012). *Harvest Map - Moes* [Electronic]. Retrieved from http://superuse-studios.com/index.php/2012/05/moes/

Figure 26:
Timber Texture
Houzz (2017). *Wood Wallpaper, Brown, Roll* [Electronic]. Retrieved from https://www.houzz.com/photos/19263720/Wood-Wallpaper-Brown-Roll-contemporary-wallpaper

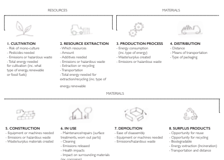


Figure 27:
Material Chain
Authors own image

Figure 28:
Timber
Sveriges Radio (2010) Retrieved 2016-11-28 from http://sverigesradio.se/sida/artikel.aspx?programid=83&artikel=4202996

Figure 29:
Sand
Forsters Landscape Supplies (2013) Retrieved 2016-11-28 from http://forsterslandscapesupplies.com.au/building-supplies.html

Figure 30:
Bricks
Blocket (2016) Retrieved 2016-11-28 https://www.blocket.se/skaraborg/tegelsten__gammal_69121944.htm

Figure 31:
Strategy Diagrams
Authors own images

Figure 32:
Villa Welpeloo
Csustentavel (n/a). *Villa Welpeloo* [Electronic]. Retrieved from http://www.csustentavel.com/en/villa-welpelo-i-casa-reciclada/

Figure 33:
Enterprise Centre
Architype (2017). *The Enterprise Centre* [Electronic]. Retrieved from http://www.architype.co.uk/project/the-enterprise-centre-uea/

Figure 34:
Seaweed House
Dezeen (2013). *Seaweed House* [Electronic]. Retrieved from https://www.dezeen.com/2013/07/10/the-modern-seaweed-house-by-vandkunsten-and-realdania/

Figure 35:
Straw Texture
123RF (2017). *Straw* [Electronic]. Retrieved from https://it.123rf.com/archivio-fotografico/texture_paglia.html

Figure 36:
Mariestad in Västragötaland
Wikipedia (2017). *Region Map* [Electronic] Retrived 07.01.17 from https://sv.wikipedia.org/wiki/Mariestads_kommun

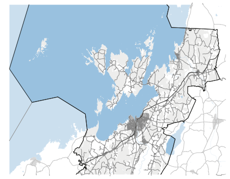


Figure 37:
Mariestad Municipality
Municipality (2017). *Municipality Map* [Electronic] Retrived 20.01.17 from Mariestad Municipality

Figure 44:
Mariestad Town
Municipality (2017). *Town Map* [Electronic] Retrived 20.01.17 from Mariestad Municipality

Figure 45:
Johannesbergpark
Municipality (2017). *Johannesbergpark Map* [Electronic] Retrived 20.01.17 from Mariestad Municipality

Figure 46:
Site 1
Authors own image

Figure 47:
Site 2
Authors own image

Figure 48:
Site 3
Authors own image

Figure 49:
Site 4
Authors own image

Figure 50:
Reed
Gangaochrurikt (2017). *Reed* [Electronic]. Retrieved 2016-11-28 from https://gangaochrurik.com/tag/giftigt/

Figure 51:
Timber
Sveriges Radio (2010) Retrieved 2016-11-28 from http://sverigesradio.se/sida/artikel.aspx?programid=83&artikel=4202996

Figure 52:
Straw
Sveriges Radio (2011). *Straw* [Electronic]. Retrieved from 2016-11-28http://sverigesradio.se/sida/artikel.aspx?programid=442&artikel=4852249

Figure 53:
Kinnekulle Quarry
Stefan Sjöö (2006) *Stenbrottet, Kinnekulle* [Electronic] Retrieved from http://www.nytimes.com/interactive/2015/10/25/magazine/25mag-copper.html?_r=0

Figure 54:
Clay
Grysmdyke Farm (2014) *Clay* [Electronic] Retrieved from http://www.grymsdykefarm.com/index.php?/community/samantha-oswald/

Figure 55:
Paper Recycling
Shutterstock (2017). *Waste paper - 81638668* [Electronic]. Retrieved from https://www.shutterstock.com/search/paper+waste

Figure 56:
Glass Recycling
Junkrescue (2017). *Glass* [Electronic]. http://www.junkrescue.com/materials/glass.html

Figure 57:
Bricks
Blocket (2016) Retrieved 2016-11-28 https://www.blocket.se/skaraborg/tegelsten__gammal_69121944.htm

Figure 58:
Resource/refinement map 1
Google maps (2017) [Electronic] Retrieved from https://www.google.se/maps/@58.7845085,13.7907663,9z

Figure 59:
Resource/refinement map 2
Google maps (2017) [Electronic] Retrieved from https://www.google.se/maps/@58.6915785,13.8094974,11z

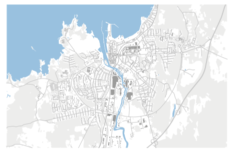
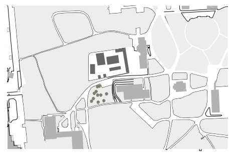


Figure 60:
Mariestad Town
Municipality (2017). *Town Map* [Electronic] Retrived 20.01.17 from Mariestad Municipality



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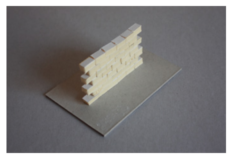


Figure 62:
Structure model 1
Authors own image

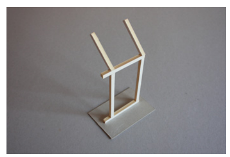
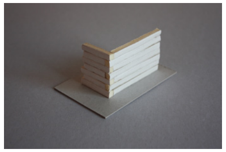


Figure 63:
Structure model 2
Authors own image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Structure model 3
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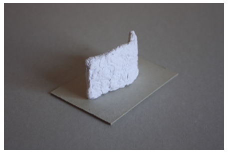
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Structure model 4
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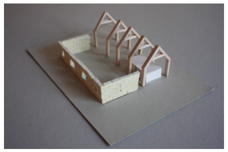
Figure 66:
Center Model 1
Authors own image

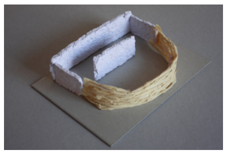
Figure 67:
Center model 2
Authors own image

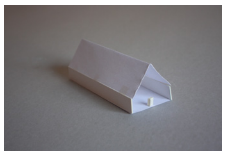
Figure 68:
Thatched Roof Model 1
Authors own image

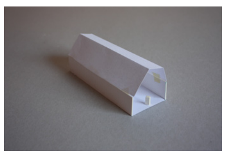
Figure 69:
Thatched Roof Model 2
Authors own image

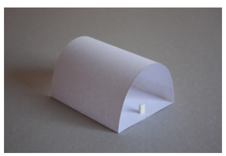
Figure 70:
Arch model 1
Authors own image

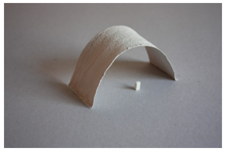
Figure 71:
Arch model 2
Authors own image


Figure 72:
Site model 1
Authors own image

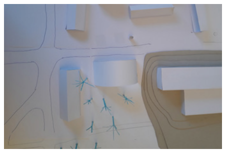
Figure 73:
Site model 2
Authors own image

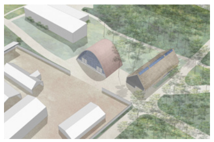
Figure 74:
Site proposal view
Authors own image


Figure 75:
Site plan
Authors own image


Figure 76:
View 1 - Entrance
Authors own image

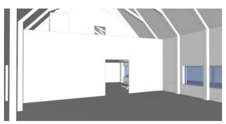
Figure 77:
View 2 - Exibithon Space
Authors own image

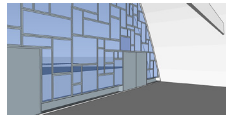
Figure 78:
View 3 - Test space
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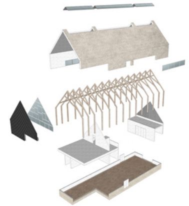


Figure 79:
Showcase building
Authors own image


Figure 80:
Modular thatch panel
Adream (2012). *Modular thatch panel* [Electronic] Retrived from http://www.adream2012.eu/en/node/1237


Figure 81:
Burnt timber panel
Tree.nu (2016). *Shou sugi ban test på gran* [Electronic] Retrived from http://tree.nu/2016/02/22/shou-sugi-ban-test-pa-gran/


Figure 82:
Stolpverk
Elsies Päron (2013). *Växthus* [Electronic] Retrived from https://blogg.loppi.se/elsiesparon/2013/08/03/det-finaste-vaxthuset/


Figure 83:
Clay Floor
Görlinge Norrgård (2015). *Lergolv* [Electronic] Retrived from http://gorlinge.blogspot.se/2015/05/lergolv.html

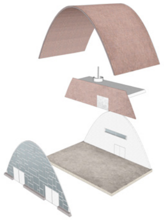


Figure 84:
Test space building
Authors own image

Figure 85:
Parabolic arch
Pintrest (2012). *Timbrel Vault* [Electronic] Retrived from http://crossway.tumblr.com/post/50218727/

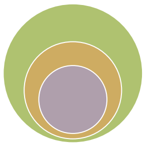


Figure 86:
Holistic process
Authors own image

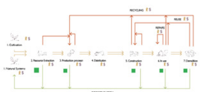


Figure 87:
Circular material chain
Authors own image

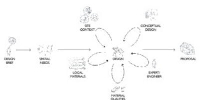


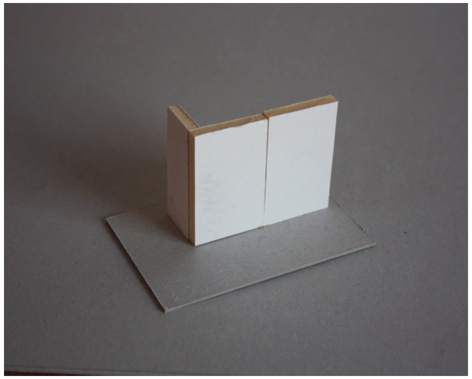
Figure 88:
New design process
Authors own image

Figure 89:
Brick Texture
LuGher 3D (2017). *European bricks wall* [Electronic] Retrived from http://www.lughertexture.com/bricks-walls-textures-free-hires/bricks-new-clean/european-bricks-wall-1672

Figure 90:
Plaster Texture
FoamLine (n/a) *Single-layer mortar with fine scraped finish.* [Electronic] Retrived from http://www.foamlime.com/en/finishes/rendering

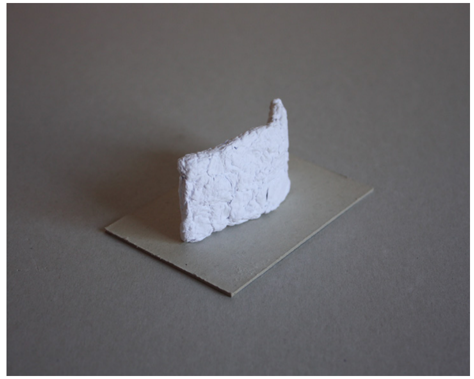
APPENDIX: Model Study

Structural Systems



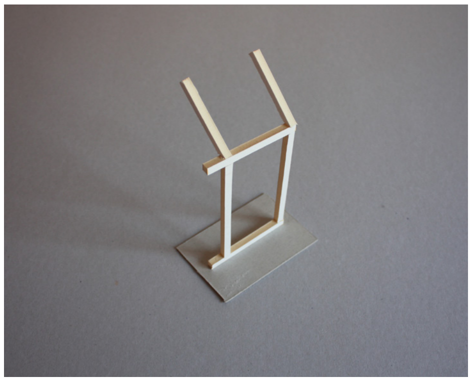
PANELS
Potential Materials: Straw
Model Scale: 1:50

Structural Systems



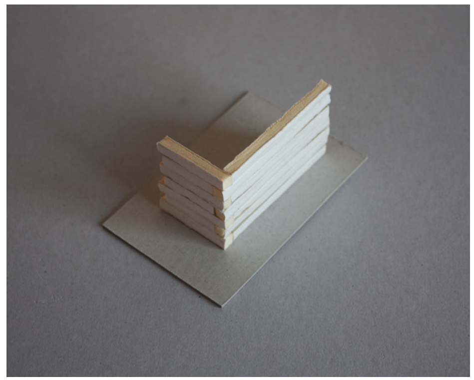
MONOLITHIC
Potential Materials: Clay, Rammed Earth
Model scale: 1:100

Structural Systems



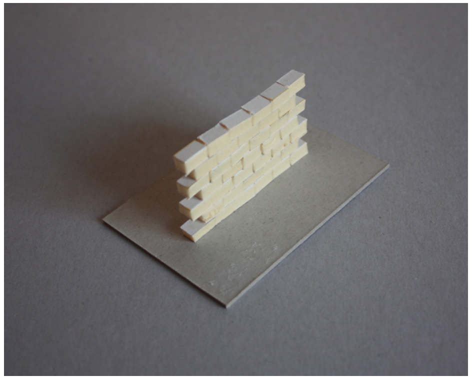
FRAMES
Potential Materials: Timber
Model scale: 1:20

Structural Systems



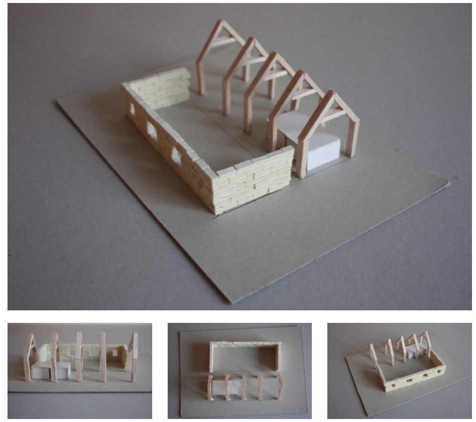
HORISONTAL ELEMENTS
Potential Materials: Timber, Strawjet
Model scale: 1:100

Structural Systems



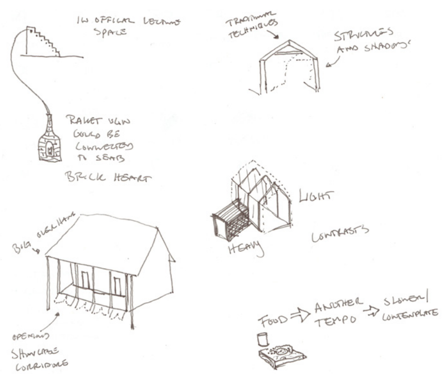
BLOCKS & BRICKS
Potential Materials: Bricks, Straw bales
Model scale: 1:20

Structural Systems



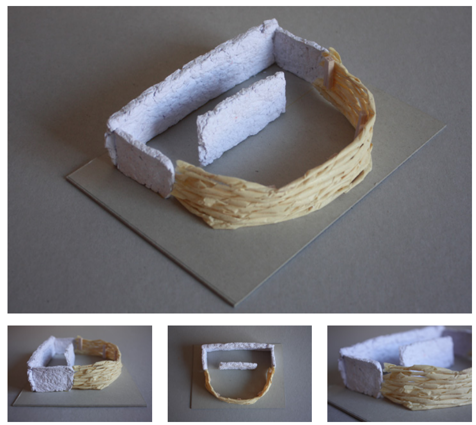
MATERIAL CENTER 1
Potential Materials: Timber frame, Blocks and Straw panel
Model scale: 1:200

Workshop with GU Students



CONCEPT IDEAS
Sketches form meeting
Heavy and light part, use expression of details from traditional techniques

Structural Systems

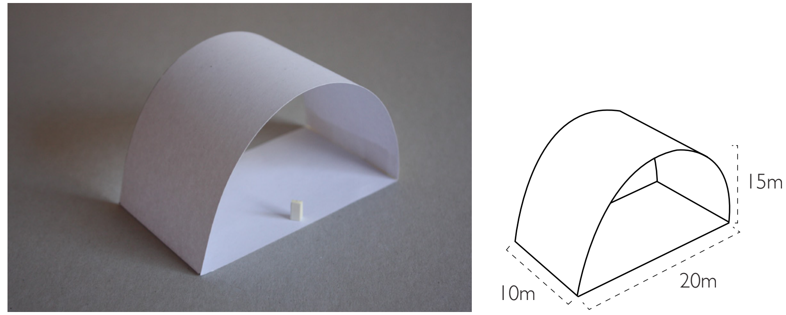


MATERIAL CENTER 2
Potential Materials: Rammed earth and Strawjet quads
Model scale: 1:200

Material Exploration

THATCH 1
Material: Reed
Model scale: 1:10

Material Center - Test Space

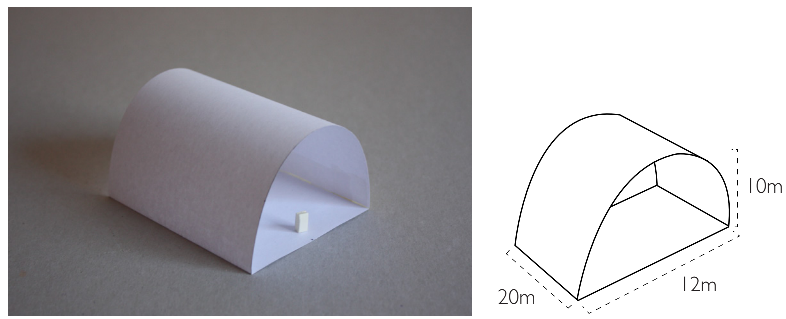


ROMAN VAULT 1
Material: Clay tiles and plaster of paris
Model scale: 1:200

Structural Systems

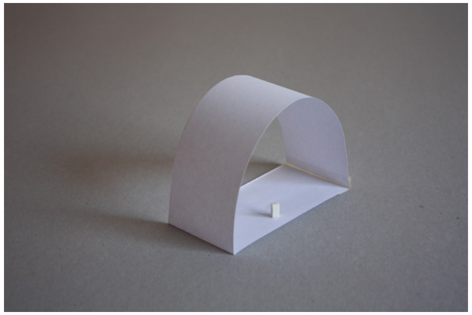
THATCH 2
Material: Reed
Model scale: 1:10

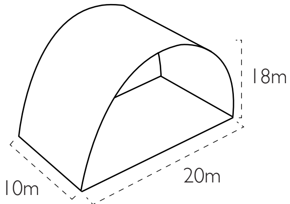
Material Center - Test Space



ROMAN VAULT 2
Material: Bricks
Model scale: 1:200

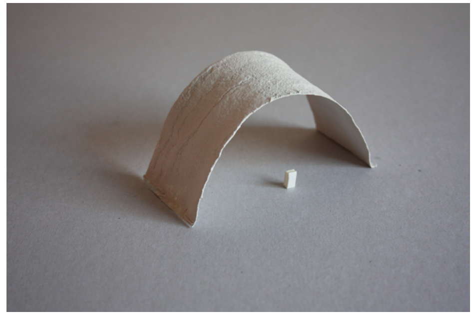
Material Center - Test Space

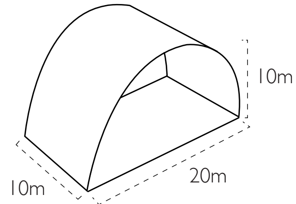




ROMAN VAULT 3
Material: Bricks
Model scale: 1:200

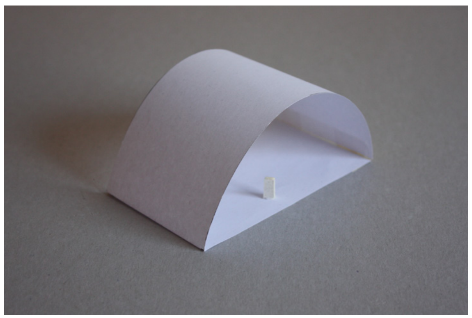
Material Center - Test Space

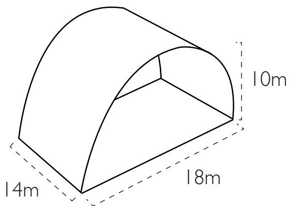




PARABOLIC VAULT 1
Material: Clay tiles and plaster of Paris
Model scale: 1:200

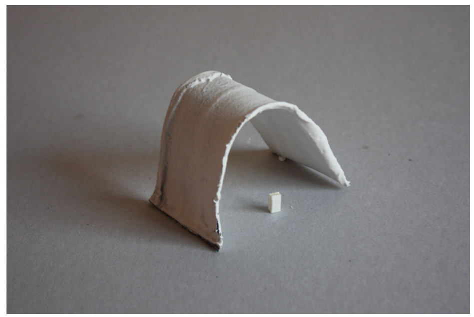
Material Center - Test Space

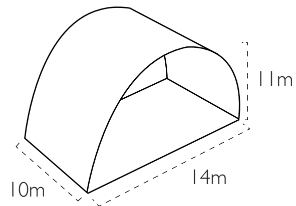




ROMAN VAULT 4
Material: Bricks
Model scale: 1:200

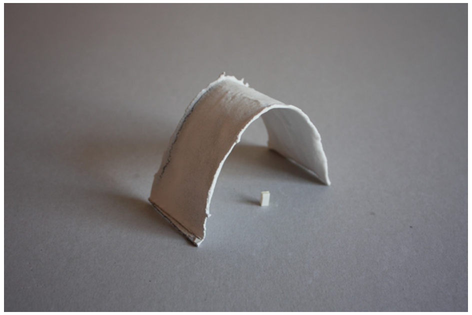
Material Center - Test Space

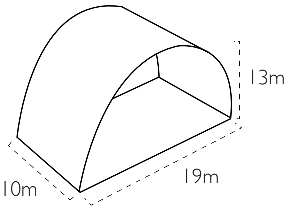




PARABOLIC VAULT 2
Material: Clay tiles and plaster of Paris
Model scale: 1:200

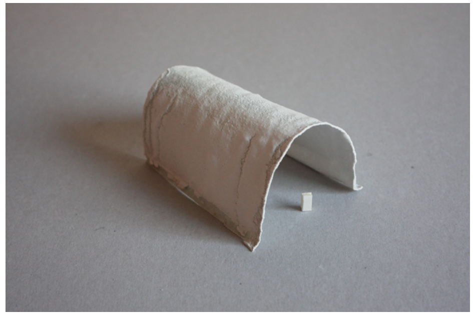
Material Center - Test Space

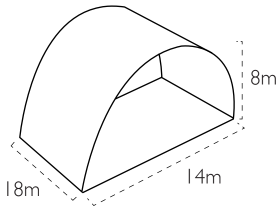




PARABOLIC VAULT 3
Material: Clay tiles and plaster of Paris
Model scale: 1:200

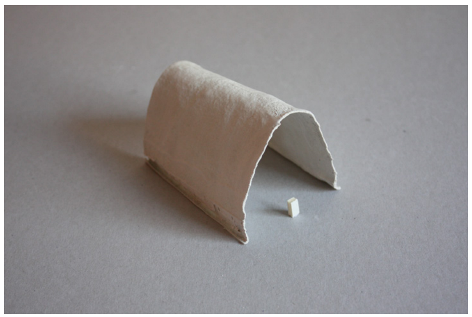
Material Center - Test Space

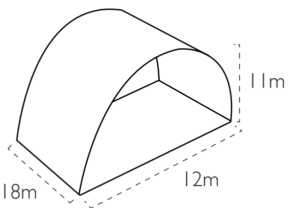




PARABOLIC VAULT 5
Material: Clay tiles and plaster of Paris
Model scale: 1:200

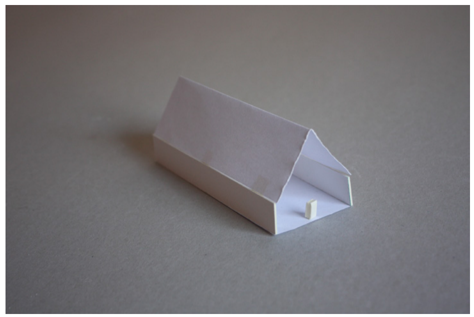
Material Center - Test Space

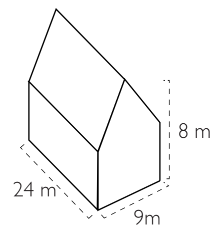




PARABOLIC VAULT 4
Material: Clay tiles and plaster of Paris
Model scale: 1:200

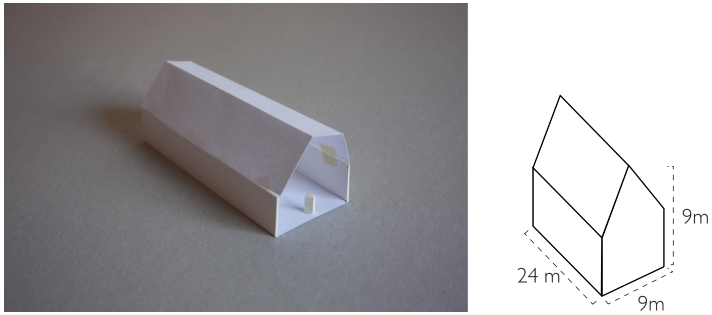
Material Center - Showcase Space





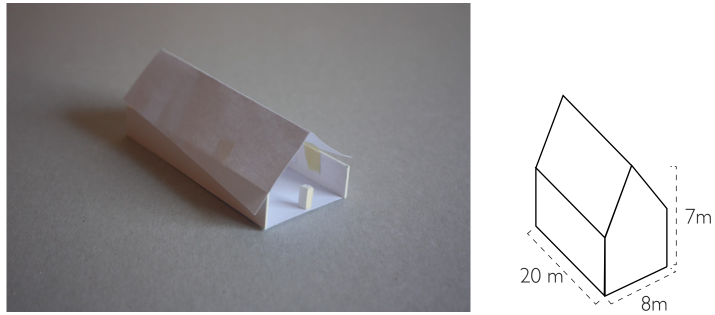
GABLE ROOF 1
Material: Timber frame and Thatch cladding
Model scale: 1:200

Material Center - Showcase Space



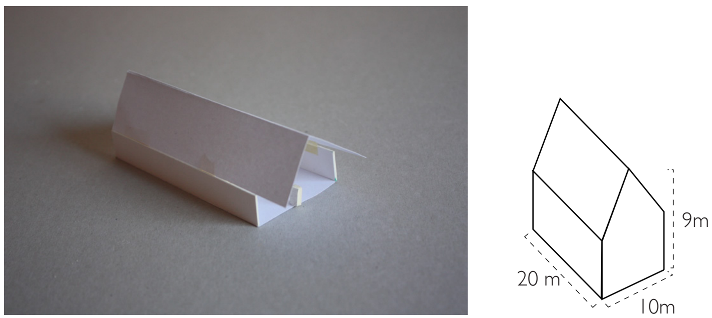
GABLE ROOF 2
Material: Timber frame and Thatch cladding
Model scale: 1:200

Material Center - Showcase Space



GABLE ROOF 4
Material: Timber frame and Thatch cladding
Model scale: 1:200

Material Center - Showcase Space



GABLE ROOF 3
Material: Timber frame and Thatch cladding
Model scale: 1:200

CHALMERS

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