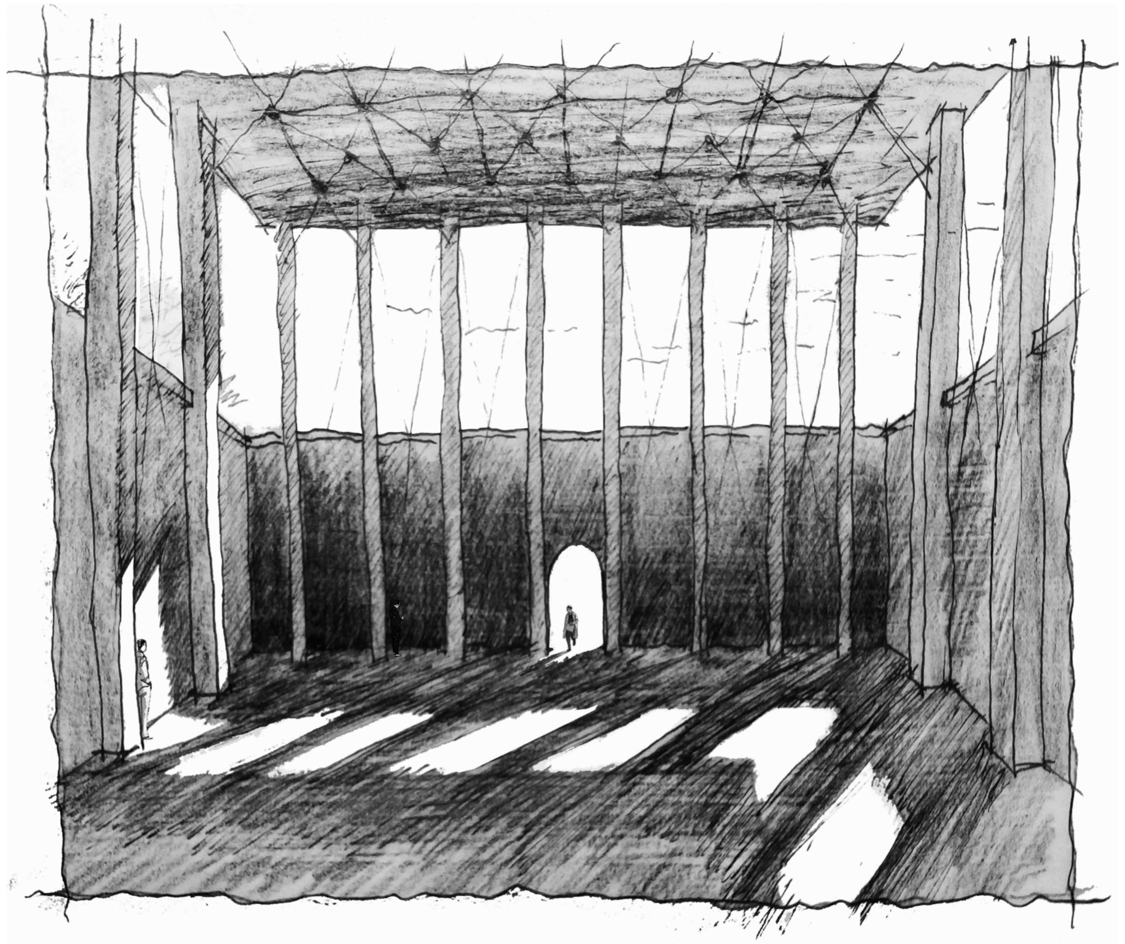

MONUMENT FOR A SUSTAINABLE CITY

NILS BEHRNDT EBBESEN

GROUP 16. MAY 2022

00 TITLE PAGE

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00.2 ABSTRACT

This thesis is an exploration of visionary realism with a focus on what to improve in a sketching phase by showcasing that life cycle assessment, LCA, can be implemented into an iterative and integrated design process. To this avail, it is tested if it is still possible to build monumental spaces with low global warming potential, GWP, scores.

A sustainability center with a focus on humble monumentality, democracy, tectonics, and time was consequently designed, and to assess it a main component of a LCA tool was developed in collaboration with C.F. Møller architects. This will allow for an integrated workflow between rhino and LCAByg. LCA will become a requirement in the Danish building regulations as of 2023, and the tool will therefore have practical significance. The result is a building for people to assemble with a strategy integrated into the structure that allows it to be disassembled.

The LCA script is applied along with a focus on monumentality in a sustainable future and concludes that it is still possible to build large and monumental spaces within the GWP limits of building regulation rules and the Danish sustainability class. However, it requires strategy and significant optimization to achieve the lower scores since GWP is measured in m^2. Furthermore, design for disassembly, DfD, is integrated to show the lack of motivation for circular incentive in an LCA, and to demonstrate its potential to improve the lifetime of a building and its materials further.

00.3 READING GUIDE

The thesis will start with an introduction to the topic and its methodology followed by what theory is used and in what context it is applied. A resulting program is then displayed followed by a rendition of the design process and a presentation of its results. Lastly there is a reflection on the project and some thoughts on what the process has revealed.

The thesis can be viewed in double spread with a single front page.

All Illustrations are original unless specified otherwise in the illustration list.

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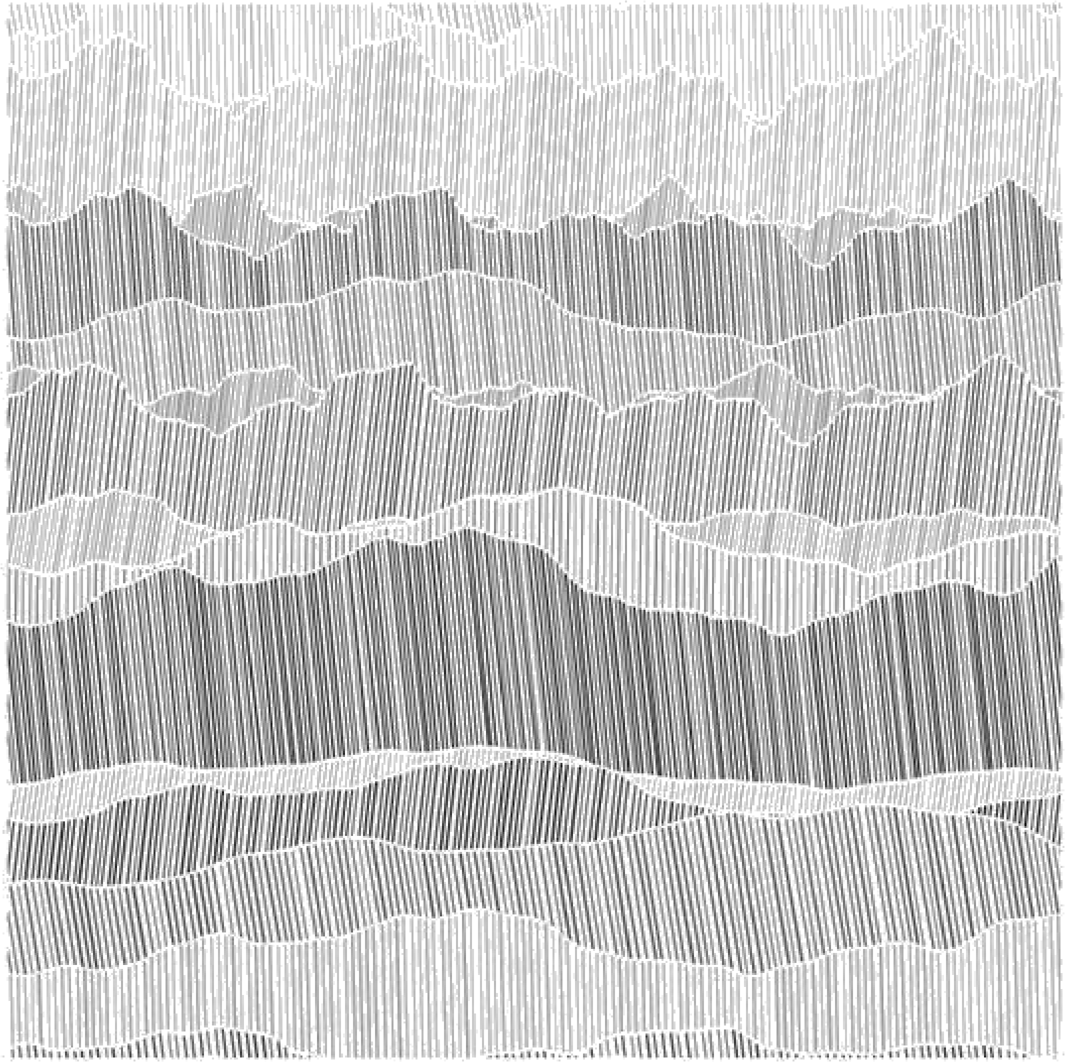


Fig 1:

01 INTRODUCTION

01.1 PROBLEM

How to create a space that tunes the mind and promotes a democratic and sustainable development where a new sustainable community can thrive in their shared values of a greener future.

01.2 A SUSTAINABILITY CENTER

The best way to promote sustainability is by example. A sustainability center is therefore both a culture house incorporating aspects of social sustainability for its local environment and a building that employs state of the art and experimental environmental efforts to decrease c02 emissions and reduce waste. The building should house functions that work as a binder for the local community and have the capacity and scope to inspire and house a larger national or international crowd. The locals will therefore play a role in everyday use and life in the building juxtaposed by the display and interaction from a more global scene. This is mirrored by how climate change is global problem that requires local solutions (Linkov and Bridges, 2011). These two aspects can inherently sustain one another by way of a multifunctional design. The strength of multifunctionality is for example a lesson observed in biology, were one main factor responsible for the persistence of a biological organ is its multifunctionality (Lakhtakia and Johari, 2015). This multifunctionally is another sustainable endeavor and is an argument for investing in a distinctive building that is a place for seeking knowledge as well as reverence which can be used by a diverse group of people.

There is an urban aspect to this problem as well. In ancient Greece the Agora functioned as a public space for meeting and debating and in a similar sense an open urban space could turn into a form of Ecclesia. Ecclesia being the ancient Greek word for an assembly or gathering of those summoned (Ecclesia | ancient Greek assembly | Britannica, 2013). Serving as both the living room for the local community and a place where larger groups of people gather for various pursuits. The building consequently held the capacity for large public lectures, debates, electoral voting and so on. The program of the sustainability center should therefore not be too specific as that could tamper with flexibility and hinder future use, but still be mindful of existing functional applications. In other words, there is longevity in spaces not too specific. The greatest longevity however is not only found in utilitas but stems also from a refined venustas (De Botton, 2014, p. 60). The pantheon is the ultimate sustainable structure as it has stood for almost 2.000 years. Inspired by this gesture the main multifunctional chamber should therefore also be striking to behold.

Design for disassembly will be incorporated since it encompasses action to reduce waste and emission and allows for a choice of adaption. It therefore aligns with the concepts of sustainability and democracy. However, the building will need extra arguments to stay standing if it can be neatly packed down and reused. Its merits as a structure should be apparent as it otherwise could potentially be a short-lived one. That is not the goal, but the building will nevertheless stand as a material bank in times of need.

Fig 2: Close up of the idealised The School of Athens by Raphael (Raphael, 1511). Where the architecture depicted is designed to set the stage for philosophical debate.

02 METHODOLOGY

02.1 APPROACH

Throughout this thesis there is an emphasis on mixing the digital with the analog as they are inherently symbiotic (Jonson, 2005, p. 623).
Working high-tech with programming and simulations but also using the lessons from the past to not design something fleeting. In essence having a methodology that allows for a low-tech solution elucidated with high tech processes.

Scripting can solve old problems in new ways. An example is how coding can be used as a method to solve existential problems. Here depicting the code used for breaking the enigma code in world war 2 as a holy text, ill. 3, (Gamwell, 2015, p. 355). Similarly, scripting will used to speed up the processes that try to solve contemporary problems but there will also be an awareness on its limitations.

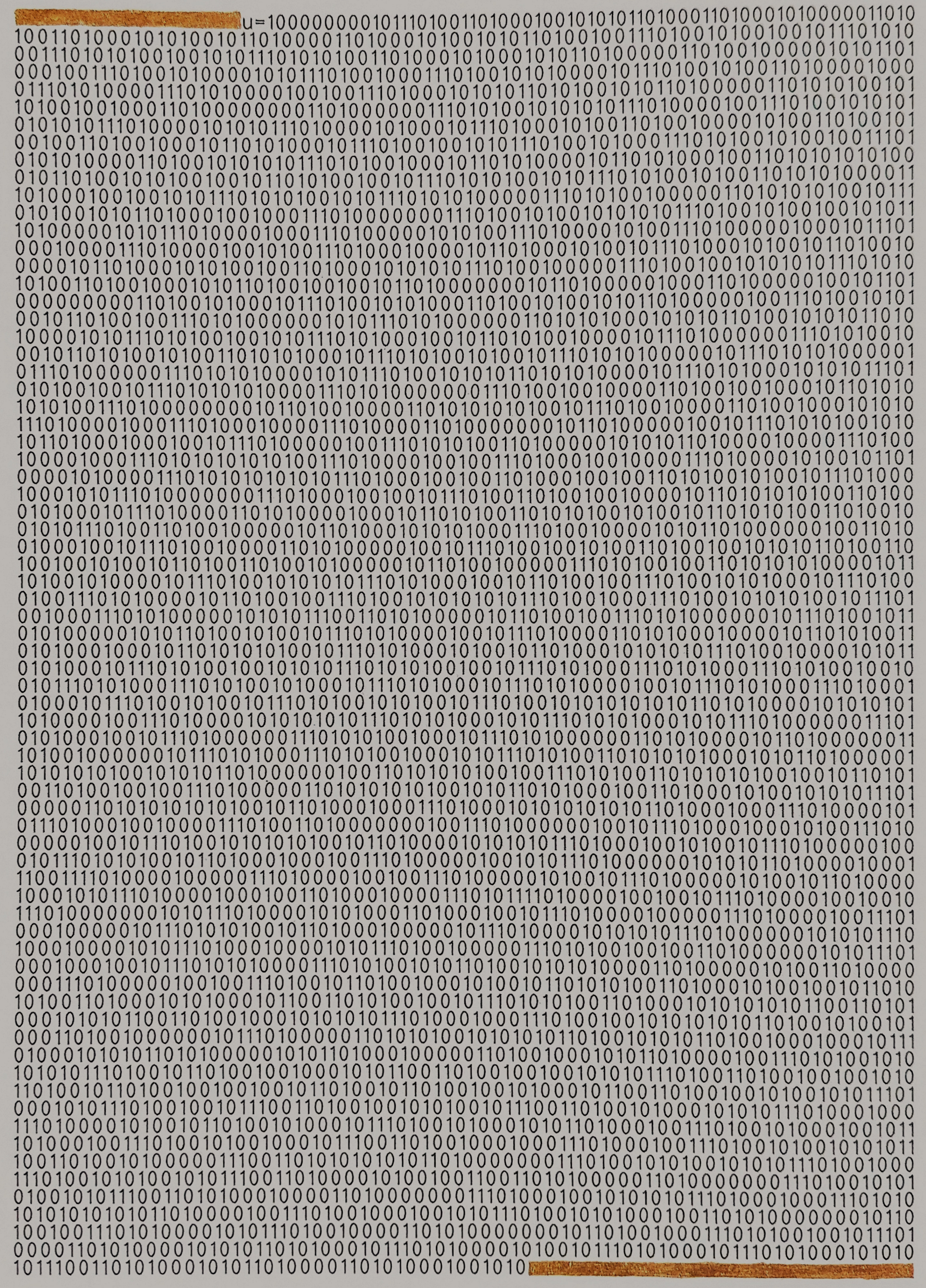


Fig 3: Roman Verostko "the macnchester Illuminated Universal Turning Machine" (Verostko, 1998).

02.1.1 INTEGRATED DESIGN PROCESS

Fig 4: Modified integrated design process

Having a clear problem and analysis to build from gives direction to a sketching process, however sketching in the digital age should be integrated into the problem and analysis phase. A problem is not needed to start sketching and truly integrated analysis tools are also sketching tools. An intuitive quality is important to the final design as successful integrated design is a synthesis of the intuitive and logical. Sketching is therefore placed first in this rendition of the integrated design process as it facilitates a more honest approach of how this thesis played out in practice (Knudstrup, 2004).

02.1.2 SKETCHING AND PARAMETRIC DESIGN

Parametric modelling and sketching as a combined tool. Working from a quick sketch to a more investigative adjustable model and back again. This iterative process allows quick testing and integration with other toolsets.

Parametric modelling and sketching are inherently similar in nature. It is about adding new lines on top of previous lines. However, the parametric method allows backtracking and testing of different combinations with existing lines.

02.1.3 SIMULATIONS AND CALCULATIONS

Spatial daylight autonomy, SDA, simulations as state-of-the-art quantitative assessment and iterative design tool.
Back of the envelope structural calculations for quick testing of element sizes.

02.1.4 INTEGRATED VIRTUAL REALITY AND DIGITAL TWIN

Having a digital twin of the project that allows troubleshooting as well as enabling the ability to virtually approach and walk through the project. It gives the ability to assess if the design is solving design parameters with desired effect from the human perspective it in reality will be perceived from (Portman, Natapov and Fisher-Gewirtzman, 2015).

02.1.5 SITE ANALYSIS

Mapping out the area to understand potential problems and possibilities in the area.

Visiting the to try to catch sensory and atmospheric values of the area. In essence exploring the area as a space instead of a place. Further analysis of the observations to establishes the architectural principles of area.

02.1.6 LITERATURE REVIEW AND CASE STUDIES

Evaluating relevant sources through a thorough literature review and sparing with professors, colleagues, and fellow students.

Case studies for getting inspiration and seeing how others have tried to implement theoretical ideas into practice. What problems have they tried to solve and were where they successful or unsuccessful in their efforts.

02.1.7 MOOD BOARD AND COLLAGES

Visualizing and comparing different moods and solutions with relevant elements to find a suitable combination.

02.2 ITERATIVE AND INTEGRATED LIFE CYCLE ASSESSMENT

02.2.1 WHY LCA AND WHY NOW

LCA is a central tool for quality assessing a building. The building sector has increasingly focus on the impact of projects throughout their lifecycle. LCA is established as a method for doing analysis and supplying documentation to prove a buildings impact on the environment or lack thereof (Zimmermann et al., 2020, p. 5).

In 2023 LCA requirements will become mandatory in the Danish building regulations. The voluntary sustainability class, Den Frivillige Bæredygtighedsklasse, will subsequently become more integrated (Butera, et al., 2021, p. 15). This means that all buildings over 1000 m^2 will require a LCA and are required to reach specific benchmarks.

In Denmark LCAbyg Is the software mainly used for assessments of buildings and creates a shared baseline for how to create, document and combine data (lcabyg.dk | Hjem, 2022). The software is unfortunately completely disconnected from integrated design tools as it is a separate entity that requires manual input. Despite its easier application and simpler way of producing data sheets compared to manual calculations, it is nevertheless a linear process that inherently is not suited for an iterative design process (Knudstrup, 2004).

Currently its usefulness is mainly to assess a building that is already designed, because in practice it would be too time intensive to justify the use of it in a sketching project. LCAbyg is great for a traditional engineer who needs to supply documentation as required in the end of a projection phase or building project, but at this point it is already too late to make fundamental adjustments without adding heavy expenses. It is in the Sketching phase that LCA could have the largest impact (Kanafani and Birgisdottir, 2021, p. 12).

The Danish transport, construction and housing authority even makes the division between the early design phase and final LCAs themselves and recognize that different approaches are needed (Kanafani and Birgisdottir, 2021, p. 16).

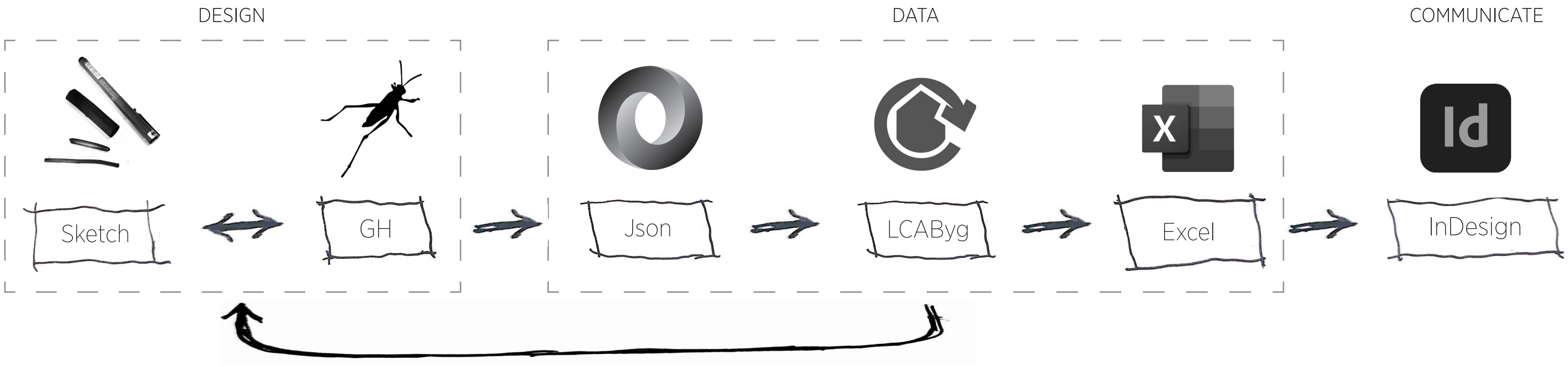


Fig 5: The illustration shows the process of automating LCA results into an iterative and integrated workflow. Json is the programming language LCAbyg is based on. GH stands for the visual programming software grasshopper.

Fig 6: Visual programming quickly becomes a tangle of branches as depicted here by Emilio Perrier (Perrier, 1880).

02.2.2 PROGRAMMING LCA INTO THE SKETCHING PHASE

It is a missed opportunity to not have LCA in the early stages because if it could be integrated this early it could produce more informed initial parameters. This is because it is in the sketching phase where the overall materials strategies and mass modelling is done, and these are vital to the results of an LCA.

There is an interplay between geometry and materials. The geometry's role ranges from where what materials are used and in what quantities and that factor is in essence multiplied by the values of the products that make out the building. A building is a combination of products supplied by different subcontractors and it is therefore important to not only look at the product properties of the subcontractors, but also the product that they combined produce.

Not every architect needs or wants to be a programmer, but this methodology will allow regular professionals to have the benefits of advanced coding with relative intuitive accessibility (Santos, Lopes and Leitão, 2012, p. 95). Similar to how daylight analysis has been integrated into CAD software's through visual programming tools, it is possible to establish a link to LCAbyg that automates the process of pushing data between different software.

This is something C.F. Møller is currently establishing, and this thesis is playing a role in development and testing of these toolsets. This thesis is therefore collaborating with C.F. Møller's sustainability department and developing on the established scripts created by the sustainability engineers.

Optimizing this workflow means to: Code the transition of data, establishing required outputs and inputs from grasshopper to LCAbyg and making the geometry readable on different levels of complexities, testing on different scenarios and combinations. Furthermore, it is a demonstration that a tool like this can be used in a fast and iterative process.

03 THEORY

03.1 MONUMENTALITY, DEMOCRACY AND TIME

03.1.1 WHY MONUMENTALITY

What kind of building can create a space that tunes the mind and promote a democratic and sustainable development? According to the 1943 paper “the nine points of monumentality” the first point gives credence to monumentality being a key parameter.

> *“1. Monuments are human landmarks which men have created as symbols for their ideals, for their aims, and for their actions. They are intended to outlive the period which originated them, and constitute a heritage for future generations. As such, they form a link between the past and the future.” - (Sert, and Giedion, 1943, p. 1)*

Monuments are cultural symbols and the main point of a building that promotes sustainability and democracy is to inspire action. Ideals, aims, and actions are at the core of what a sustainability center should communicate. Furthermore, democracy and sustainability are both concepts that will either falter or strengthen over time. The reminder of the collective ideals of a community is therefore important to realise the aims that actions can achieve. Being a landmark that can stand and adapt to time is consequently paramount to the success of the building. Perhaps it should not be corporate monuments of concrete on the skyline but rather symbols of a more holistic nature that should humbly dominate in a new sustainable city. As Louis Kahn notes:

> *“Have we yet given full architectural expression to such social monuments as .. the community or cultural center?” (Kahn, 1944, p. 1)*

But even a social monument is subject to change and constant revision is the fate of even the most institutional and high-end buildings (Brand, 1994, p. 128). It is therefore important that a building and the space it forms inherently have some flexibility and aesthetic value. Stripping an interior of functional applications and furniture leaves only its essential components such as its load bearing construction. The tectonics of a building is the bastion of its longevity since when conditions change the load bearing structure can only be altered with substantial interventions. Not all constructions are created equal as there is a reason why some buildings are teared down and disliked and why others are restored and revered. The construction should consequently perform as a spatial statement of experiential architectural value to the people who engages and inhabit it (Sekler, 1965).

One of these factors is the fabric of the structure and arguably more importantly its connections. This feeds into the concept of design for disassembly, DfD, as that concept requires a thorough investigation and strategy of a construction’s kit of parts and their points of interaction (Jensen et al., 2016, p. 23). These connections will therefore be part of the design parameters as they provide both a sustainable metric as well as an aesthetic quality. Over time and through continuous use of the building the people it inhabit will come to appreciate how the building is put together, and It is important to establish principles for connections early as it is not a linear process (Christensen, Christensen and Damkilde, 2016).

Fig 7: Depiction of the interior of the pantheon by Giovanni Paolo Panini (Panini, 1734).

03.1.2 THE MEASURABLE AND THE UNMEASURABLE

However, simply stating something is sustainable and showcasing a form of Venustas is not enough. Main aspects should also be proven and inform the final design (Vitruvius Pollio et al., 1999, p. 150) . An integrated design process in the early sketching phase using life cycle assessment will provide direction to a concept by providing an early indication on how materials are used in the building and to what environmental impact (C.F. Møller Architects, 2022). Thereby making important choices and discoveries earlier in the design process and not later when large investments of time has already been done. In a sense this is not life cycle assessment, but a more integrated and iterative form of life cycle designing. The scale needed to evoke the qualities of monumentality makes this point even more apparent.

Another important aspect of validity is the use of light. Light creates form, and how it plays with a construction is where shapes come to life (Rasmussen, 2012, p. 52). Qualitative daylight investigations are therefore vital as it is a primordial and superior light and wavelength compared to artificial lighting. Quantitative daylight should also be measured and simulated to provide a base of validity for where sunlight will penetrate the building and interact with its interior space and the people inhabiting it.

The goal of integrating these aspects into the design process is to create a building that solves the problem with intuition as well as logic. It provides both the unmeasurable and the measurable (Stockli, 1992).

> *"A great building, in my opinion, must begin with the unmeasurable, must go through the measurable means when being designed, and in the end must be unmeasurable." - Louis Kahn (Kahn, 1931, 11)*

Interactions between parts of the building which it encompasses should retain the unmeasurable after the assessments and analysis have been done. It would be a loss if the unmeasurable was erased by the measurable. That is unfortunately what can be observed in practice when key facets of a building project are postponed for later resolution. When finally addressed, they end up removing the unmeasurable qualities which the design had earlier in the process. Integrating these facets is therefore, both a way of adding onto the current design, but also a way to defend it towards future revision and erosion.

Fig 8: The biblical tale of the tower of babel is the ultimate case of vanity. Depicted here above by Athanasius Kirch (Kircher, 1679).

Fig 9: Rebar infested concrete rubble is unusable after a demolition.

03.1.3 SYMBOLS AND THE PILLAR

The second point of "the nine points of monumentality" argues that symbols are interlinked with monuments and are key component to translate collective forces (Sert, and Giedion, 1943, p. 1). Sustainability and democracy are complex concepts with various definitions and examples and they both inhabit symbols from history that create associations to the concepts. These associations could provide some of these unmeasurable aspects.
Pillars are a staple in Greek architecture where the philosophy behind modern democracy has its origins (Athenian Democracy, 2022). Similarly, pillars are used to describe the framework for what is sustainable and what is not through the three pillars of sustainability (Purvis, Mao and Robinson, 2019). Sustainability as a concept is arguably better visualized by intersecting circles, but the name sticks and representations of the pillars has nevertheless stuck round (Nasrollahi et al., 2020, p. 1109). The column as an architype therefore holds symbolic value in both the sustainable and the democratic. Fundamentally a column carries vertical loads, and we intuitively understand that concept which we can project onto other aspects that similarly need to be carried (Bjørn, Eggen and Cruevellier, 2011, p. 180). Furthermore, columns in unison are analogies for a group of people standing and carrying the necessary load. Columns should therefore be used to reference the past and provide a basis for reverence.

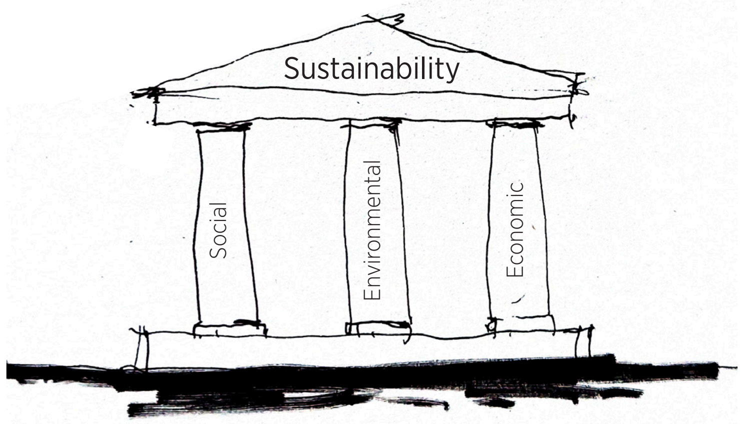


Fig 12: Three pillars of sustainability in the style of a Greek temple.

More practically a column and beam system in a grid allows for easy rearrangement of rooms and for risers to run cables, conduits and other services along (Brand, 1994, p. 191). It is also structurally effective in the amount of material it consumes compared to a more massive load bearing systems.

Monumentality signifies the importance of a pursuit. However, a sensitivity to the history of monumentality and the context of the building is important. Post-World War 2, most architects in the Modernist movement carried the notion that monumentality was undemocratic and immoral

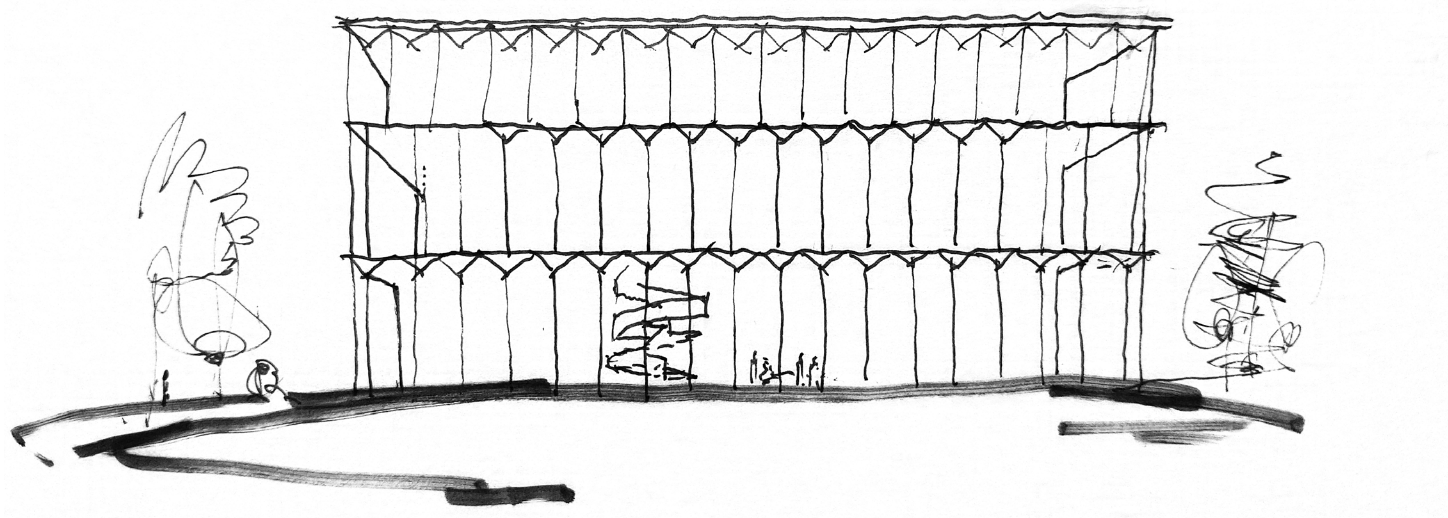


Fig 10: Modern rendition by Gilles Retsin. Nuremberg concert hall proposal. Used as a case study (Retsin, 2022).

Fig 11: Columns made of people on the temple Erechtheion, Athens (Erechtheion, Athens 406 BC).

because it was a celebration of the past and its regimes which had led them to ruin. Lewis Mumford famously argued this in his essay "the death of the monument" from 1937 that:

> *"... If it is a monument it is not modern, and if it is modern it cannot be a monument." - Lewis Mumford (Mumford, 1937, p. 2)*

In the 1960s this notion was challenged by Louis Kahn as he did not perceive monumentality as a tool for fascism, but a product of order. Order in the sense of his definition as an underlying order of all things (Lobell, 2013). This is epitomized in the Bangladesh assembly building which in its scale and play with order and light has become a symbol of democracy and independence for the Bangladeshi people (Kahn, 2017) (AD Classics: National Assembly Building of Bangladesh / Louis Kahn, 2010). Monumentality is in this sense not inherently, bad but can be depending on what it celebrates.

How can monumentality and order be used in the age of sustainability in a democratic country? Counterintuitively a hierarchy might be needed to differentiate normality of a context to the importance of a cause. In a sense creating a democratic order by way of showcasing a clear hierarchy of spaces. Similarly, to how a Greek temple has a clear direction and main entrance to the room of the god it inhabited (Fazio, Moffett and Wodehouse, 2014, p. 35). It should be clear where people need to go to vote or to participate in any case of assembly.

03.1.4 PREDICTIONS, LONGEVITY, AND SCALE

Hierarchy of spaces might provide guidance, but in the end an architect cannot control how a building is used. Buildings are a predictions of the future and Architects cannot force people to use a building the way it is intended (Brand, 1994, p. 178). A more sensible goal is to try and create a framework that sets the stage for use and growth over time. In this case the framework that the building needs to create should give space for interaction and debate. That is a more democratic approach since user profiling can be authoritarian in nature because it is a fallacy to rely heavily on user predictions. This is an error since a designer's current angle and focus on the future is a projection of current trends and problems. Trends and problems which will not persist. No one knows what will happen tomorrow or furthermore in 20 or 200 years. It is arguably arrogant to try and control how people use a building. In reality a building will learn with the user over time and people will similarly learn from the building (Brand, 1994, p. 12).

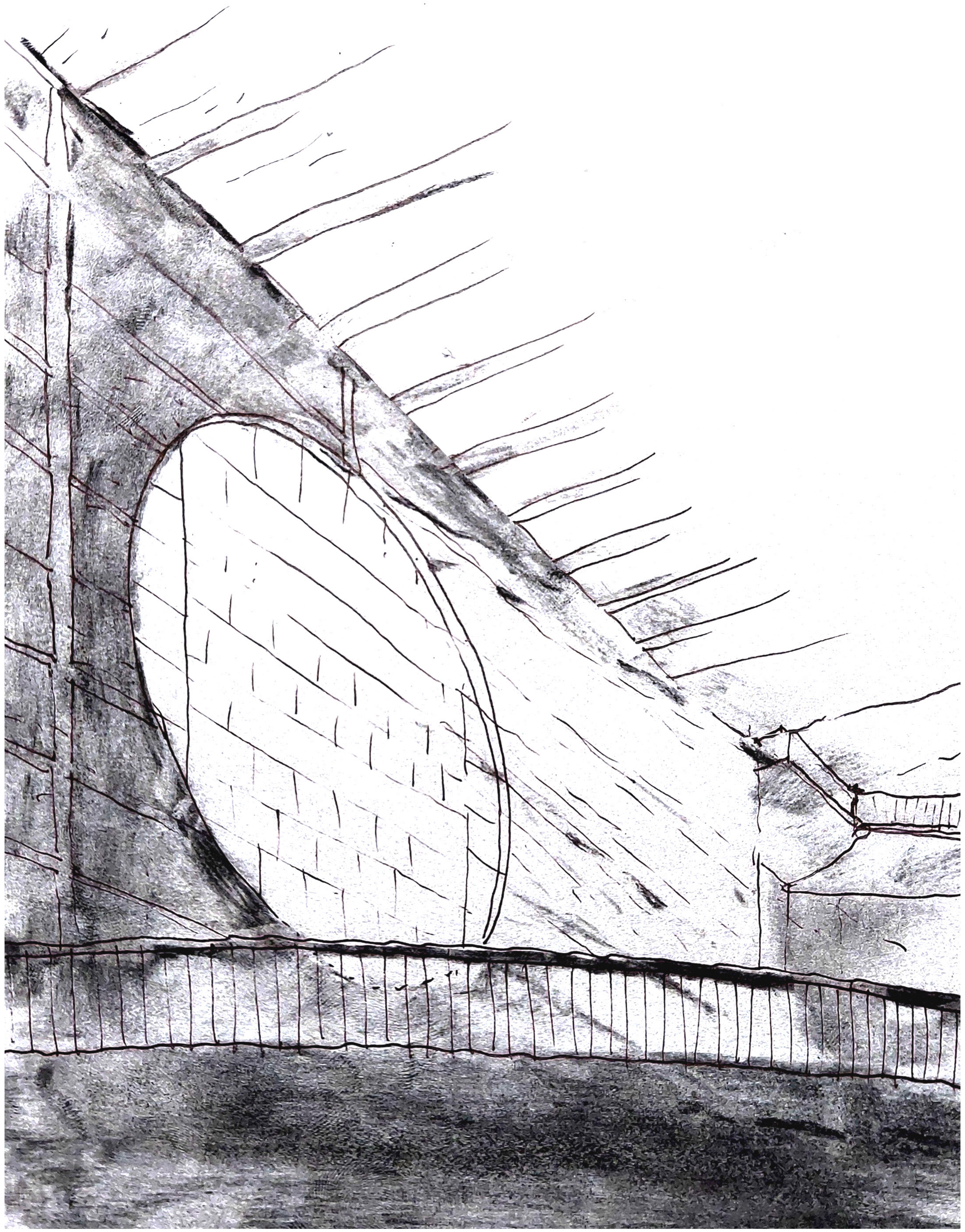


Fig 13: Bangladesh assembly building, Dhakar. 1965-A1987.

“All buildings are predictions. All predictions are wrong” - Stewart Brand (Brand, 1994, p. 178)

However, one cannot ignore the past when designing with a focus on time. Different scenarios and multifunctional options will still prepare a building for future scenarios. Multifunctionality should therefore be incorporated to improve the chance of a less wrong prediction.

Further supporting this point, Aldo Rossi argues that monumentality attracts functions as urban artifacts (Rossi, 1966, p. 59). Making the monumental aspect multifunctional could give it validity or as Rossi says prove its validity as seen with the Palazzo della Ragione in Padua, Italy. The point of attracting function is to increase public participation since it is the crucible for lasting change (Lakhtakia and Johari, 2015, p. 2).

Brand notes that all buildings change except monuments (Brand, 1998). Monumentality is similarly a characteristic which archaeologist observe to play a major role in creating and maintaining an ecosystem for local communities to thrive.

“As slow changing components of these landscapes, monuments appear to have been highly successful as faciliatory mechanisms for repeated region-scale interaction, creating and maintaining highly stable locational systems within which large groups had time and space to form.” - (Buccellati et al., 2019, p. 184)

A monumental center of sustainability could hence be a mechanism that creates region-scale interaction. A monumental core with changeable surroundings could perhaps have both the longevity and attraction of people and functions that monumentality potentially creates, and the adaptability and sensitivity of the everyday adjustment which standard scale buildings allow. Perhaps this combination could help erode the harsh division between scales.
Brand similarly argues that monumentality belittles people. Such as the French architect Étienne-Louis Boullée sketches of grandeur that show what he describes as architecture that wants to make people awed, tiny and powerless (Brand, 1994, p. 188). But Kahn reasons that large scale and skylight rooms are not oppressive but the very opposite. Standing in the main chamber of the Pantheon is not an oppressive state, but one that opens the mind for introspection and respite.

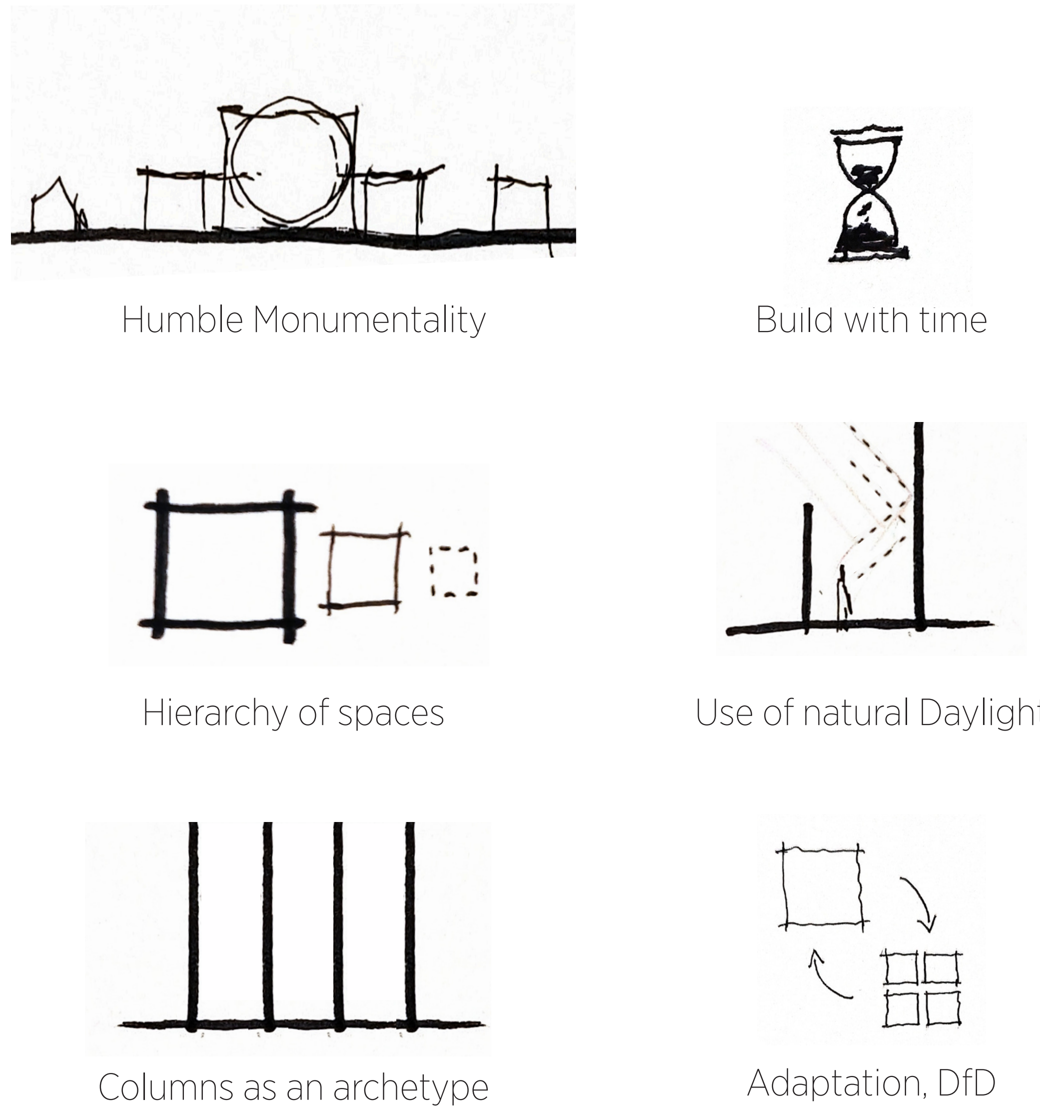


Fig 14: Resulting design parameters

03.1.5 CONCLUSION

A sustainability center should have a humble monumentality about it with a clear order and focus on the use of daylight. This humbleness should express a sensitivity between the scale needed for such a building and its context. It should be adaptable with time around its core of stable monumentality. This core should be multifunctional as it will attract functions. A hierarchy of spaces and layout with views through the building should be mixed with archetypes carrying symbolic value, such as the column. Furthermore, design for disassembly should allow for future adjustments in the surrounding system.

03.2 SUSTAINABLE ARCHITECTURE

03.2.1 WHY AND WHAT

With increasing population, world economy, urbanization and global emissions It is seems apparent that changes are needed to sustain a future devoid of varies problems produced by climate change and waste mitigation (Friedman, 2008, p. 28)(UNEP, Christensen and Burgon, 2015, p. 27). But how can architecture and the building sector adapt and how will it affect the architecture it produces?

Sustainability is many things and can manifest itself in different ways. The economic, social, and environmental pillars carry different loads in different scenarios which can be more of less holistic. However, in this case the focus is on a longer scope as the building should be a visionary example for current and future generations. Longevity, reuse, and a general focus on life cycles is therefore paramount (Butera, et al., 2021, p. 25). The construction and integration with a context will therefore be a main focus points as they are the buildings aspects with the longest lifecycle as described by Brand with his 5 layers of a building (Brand, 1994, p. 13).

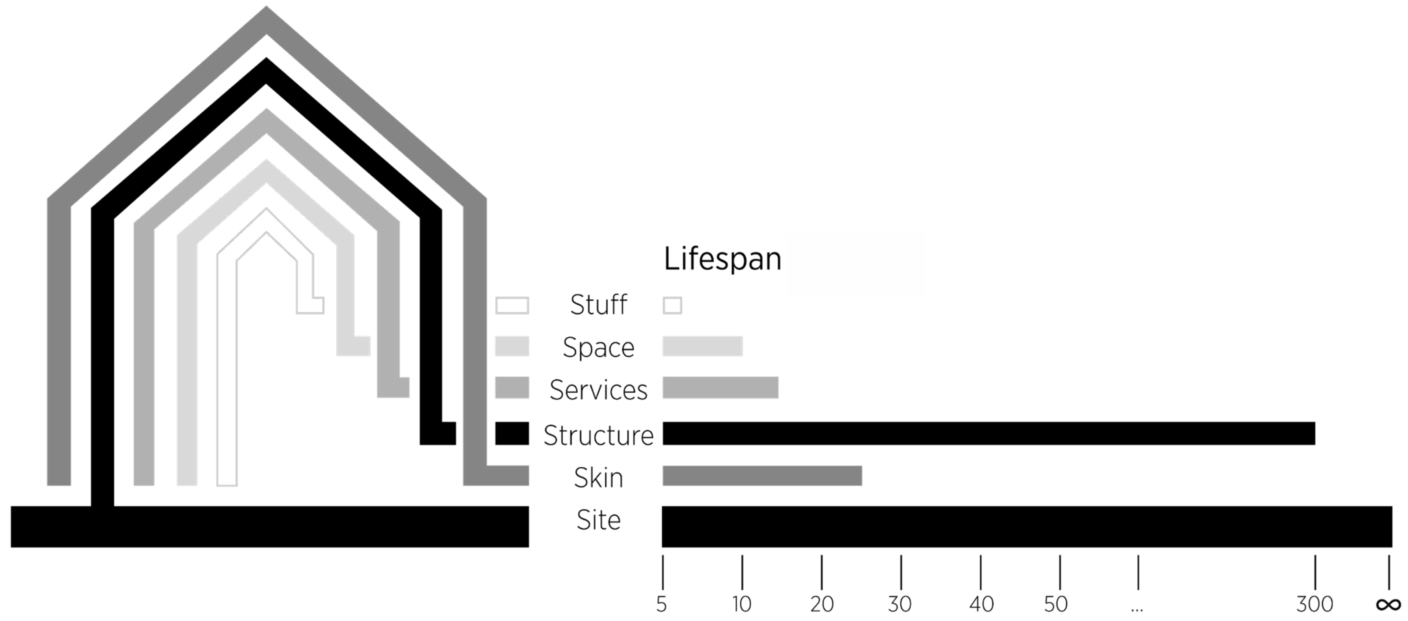


Fig 15: Lifetime of building layers (Brand, 1994, p. 13).

03.2.2 SCOPE AND STANCE

Currently the building sector in Denmark produces 40% of all national waste (Jensen et al., 2016, p. 23) and the amount of construction waste is only raising globally with projections displaying that the volume of construction waste will grow by 85% as of 2030 (PricewaterhouseCoopers, 2022).

Taking the stance of a point of visionary realism a focus will be set to reduce c02 emissions as an impact estimation, use social sustainability in the case of sensitivity to the local pretext and community and the economic inventive with design for disassembly in essence making the building a material bank besides also reducing C02 emissions (Eberhardt, Birgisdóttir and Birkved, 2019, p. 9).

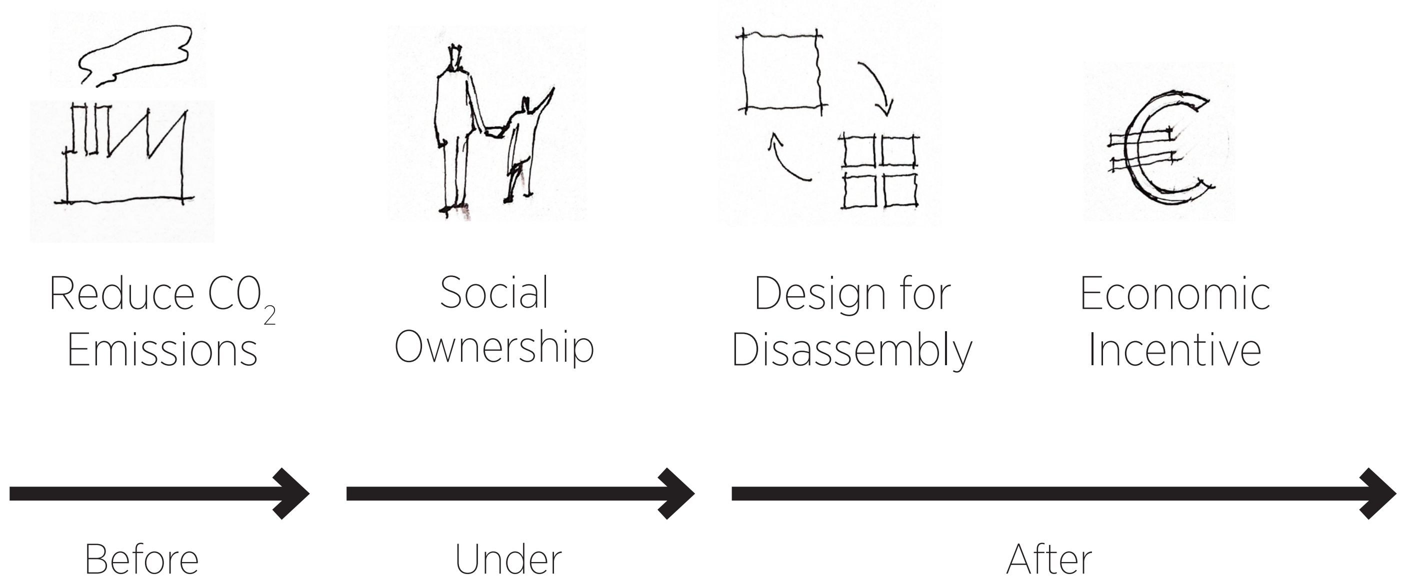


Fig 16: Timeline of sustainable strategies.

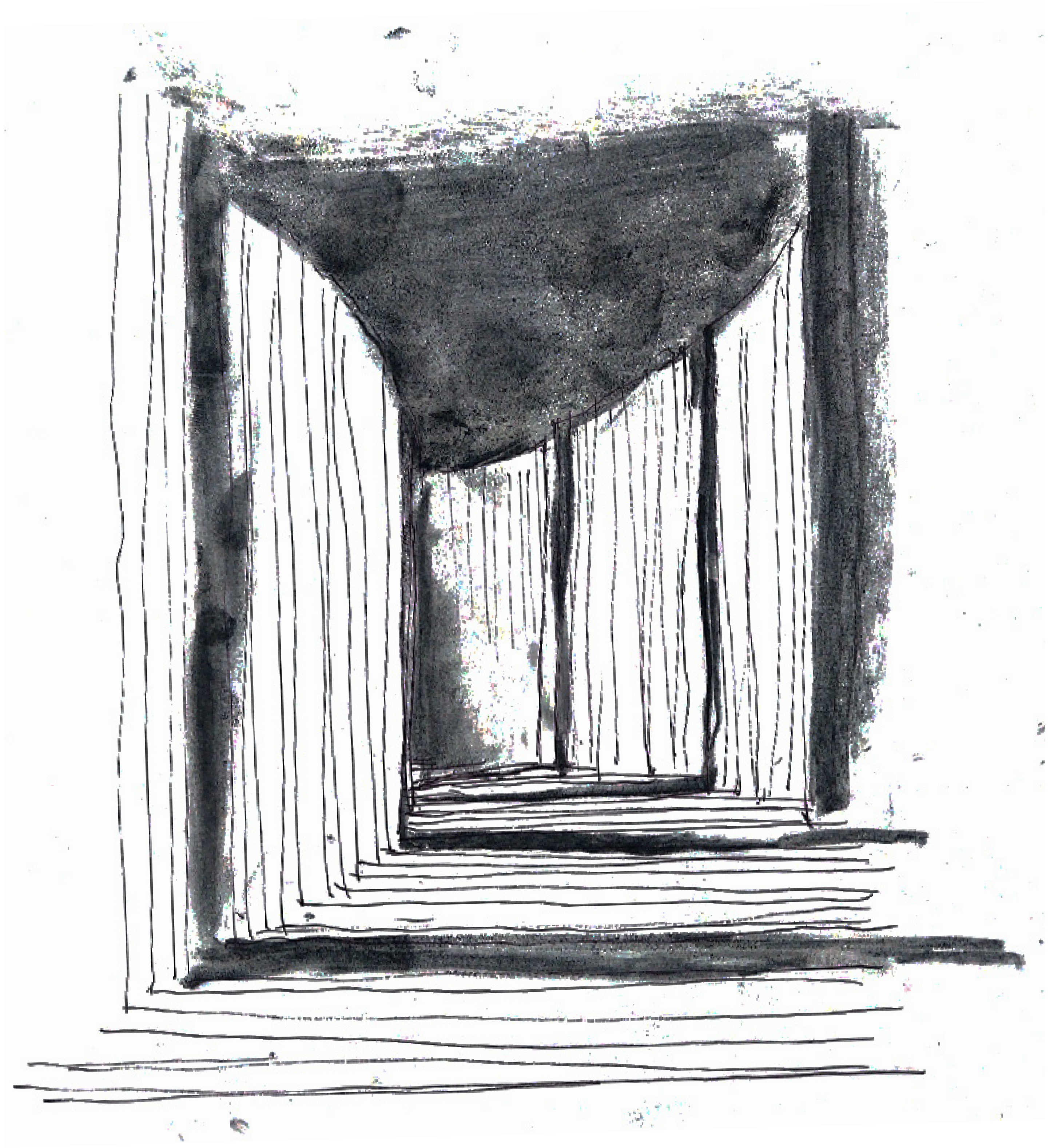


Fig 17: The Chapel of Reconciliation, 2000, Berlin, Germany. by Rudolf Reiterman and Peter Sassenrath in collaboration with Martin Rauch.

Despite not being the main focus, the stage will still be set for other aspects to develop such as biodiversity. These, however, are not the main parameters.

Sustainability should not and does not need to be at the cost of architectural quality. Vitruvius' three points of to balance in architecture Venustas, Firmitas and Utilitas still apply but they have newfound expressions in the anthroposphere age (Vaughan, 2016). Utility is still utility, but the problem has changed. As the French writer Stendhal eloquently put it "Beauty is the promise of happiness", but what is being promised has changed and it ought be reflected in architecture (De Botton, 2014, p. 98). Old and new material and their mechanical and aesthetic properties should be explored.

03.2.3 CONCLUSION

C02 emissions, social ownership, longevity, and reuse with some economic incentive will be the aspect focused on as they allow for every pillar of sustainability to be involved for a more holistic view. A sustainability center should also reflect the time of its inception by showcasing what promises it can solve by informed materials choices.

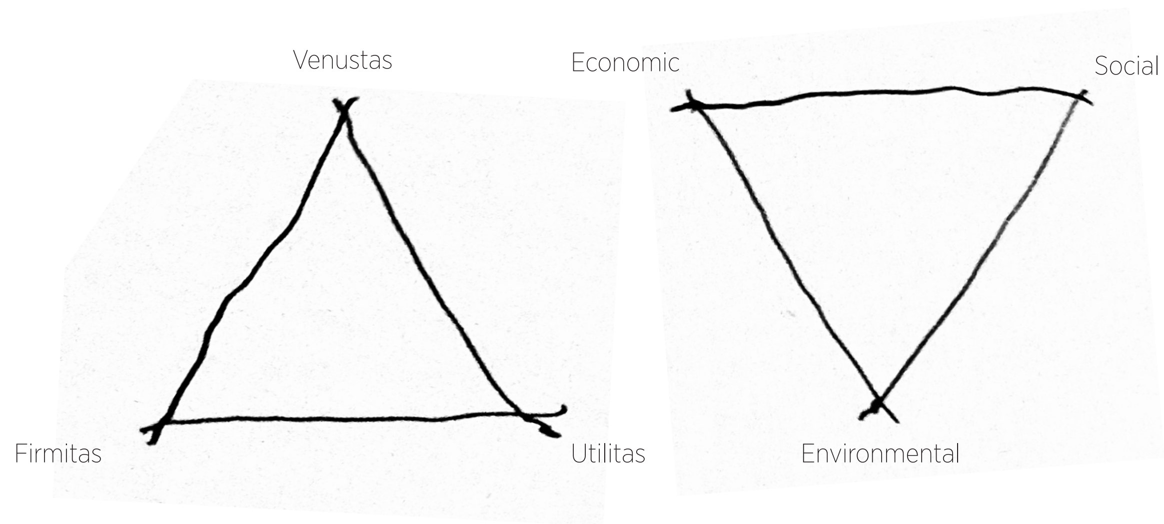


Fig 18: The Vitruvian triad and a sustainability triad.

03.3 LIFE CYCLE ASSESSMENT AND DESIGN FOR DISASSEMBLY

03.3.1 REGULATIONS AND RESTRICTIONS

Optimizing building performance has come a long way since the 1970s, with energy optimizations to the point where modern buildings use more energy and recourses before and after they are built compared to when in use, B1-7. Production, A1-3, building process, A4-5, and end of life, C1-4, is therefore more important to optimize now. To achieve the best results of low climate impact in these phases, LCA should be incorporated as early as possible as stated in the methodology chapter (Kanafani and Birgisdottir, 2021, p. 14). If integrated into the sketching phase, it would allow for variant studies where different generic solutions are compared to decrease the effect of most taxing building parts.

LCA is currently not subject to regulation in Denmark. This means that if assessments are done at all, then in practice these calculations are often postponed and mainly done to achieve different sustainability certifications, such as DGNB or LEED (DGNB: LCA-beregninger og dokumentation, 2021). It should be noted that rarely all aspects in the 5 stages of a life cycle assessment are counted in an LCA, and different certifications required different aspects to be included.
The lack of implementation will not continue in Denmark as of 2023 LCA will be integrated into the building regulations and will require a GWP of 12, which is measured in kilo C02 pr. m^2 pr. year (C02 -eq./m^2/år). To get a credential of the sustainability class, it will be required to hit a GWP under 8.5. The GWP required by the building regulations and the sustainability class will continue to fall up to 2030 where the sustainability class is planned to require a GWP of under 5 (Dyck-Madsen and Pedersen, 2020).

Interestingly the potential for reuse, reduction and recycling, D, is not directly counted in the result of an LCA. These potentials are often negative numbers that have inherent uncertainty which makes it unclear who these negative numbers should benefit. If counted after first use and counted again after second use, the material has in effect been counted twice and therefore inflated results – or in this case deflating GWP results. As an example, it means that wood performs worse since it is estimated to be burned at the end of a building's lifetime even though the wood will be reused later. In effect this means that Design for disassembly does not improve a score of LCA directly, but it is nevertheless shown in the D category.

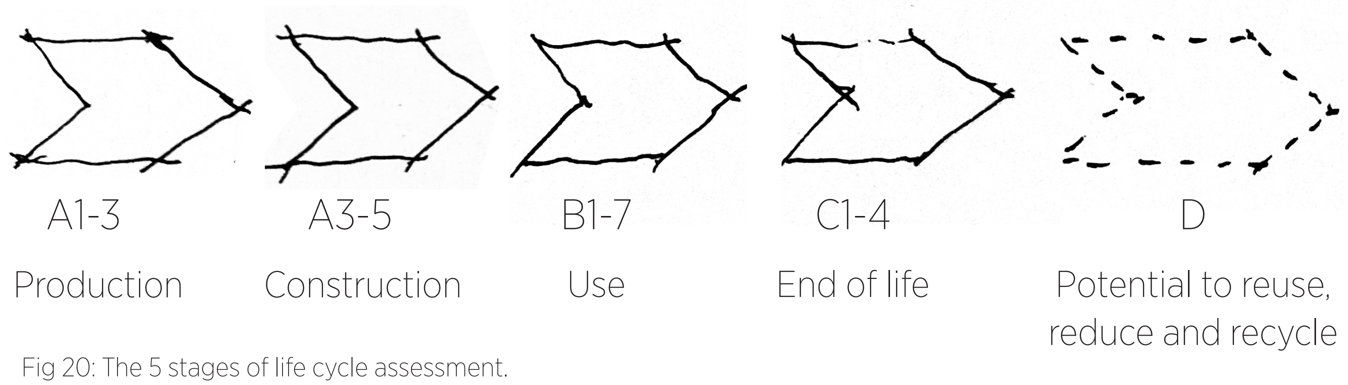


Fig 20: The 5 stages of life cycle assessment.

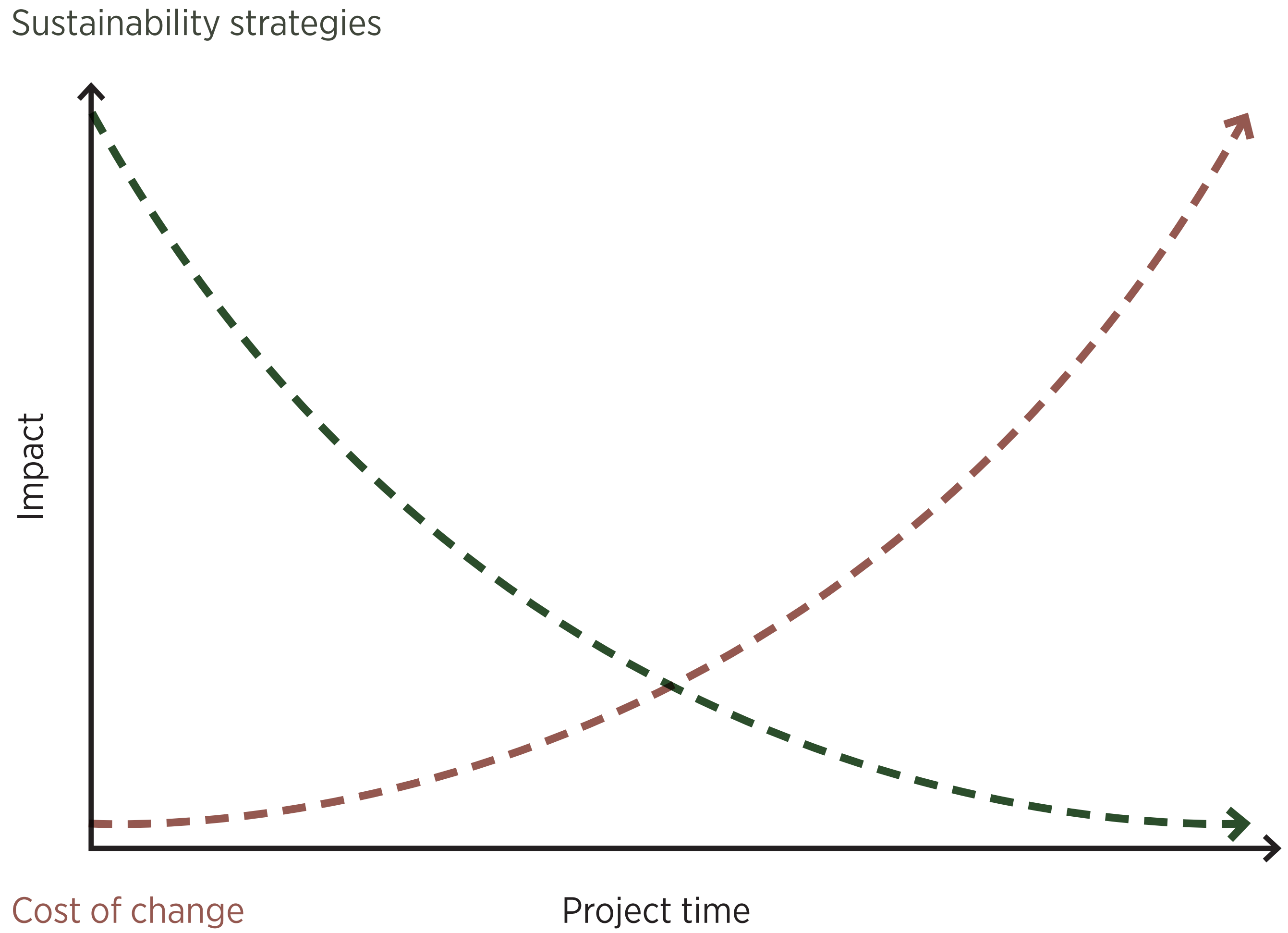


Fig 19: Inspired by C.F. Møller Grow course on LCA and the "LCA in praxis" by the Danish transport, construction and housing authority (Kanafani and Birgisdottir, 2021, p. 12).

Learning to manoeuvre and understand what these new regulations will entail is therefore a worthwhile investment since it will give a competitive edge in the coming years. In worst case it can result in heavy costs since changes late in the design or construction phase rise exponentially with time as seen on fig. 19.

03.3.2 RISING COMMODITY PRICES

There has been a trend of rising prizes for commodities in general in the 21th century compared to the 20th century. Materials such as metals and wood as well as energy and food has seen a significant global and European increase (Dobbs et al., 2013). As seen on the fig. x this is not a new phenomenon (Nominal price index: Jan 1980 = 100, 2022)

This trend has been further developed in the past 10 years due to covid 19 pandemic waves, inflation, and geopolitical tensions (Global Economics Intelligence executive summary, January 2022 | McKinsey, 2022)

The economic incentive to be less wasteful of materials is therefore more prevalent than ever as there are indications that the trend of rising prizes will continue. Using acquired building materials to their full potential is an investment in future resources if handled correctly, as a dismantlable structure is a material bank, and furthermore the skills to build and deconstruct in this fashion will increasingly be in demand. There is therefore not only an environmental argument to reduce downcycling but also an economic motivation (Besenbacher, 2017, p. 14). By rethinking the Danish building industries approach with an effort to reduce, reuse and recycle it is estimated that materials could yield 24% more output then today (Besenbacher, 2017, p. 17).

In the end, if the goal is to improve significantly on these parameters, then the goal should be to move towards a circular economy as it aims to decouple economic growth and development from the consumption of finite resources (Jones et al., 2022, p. 4).

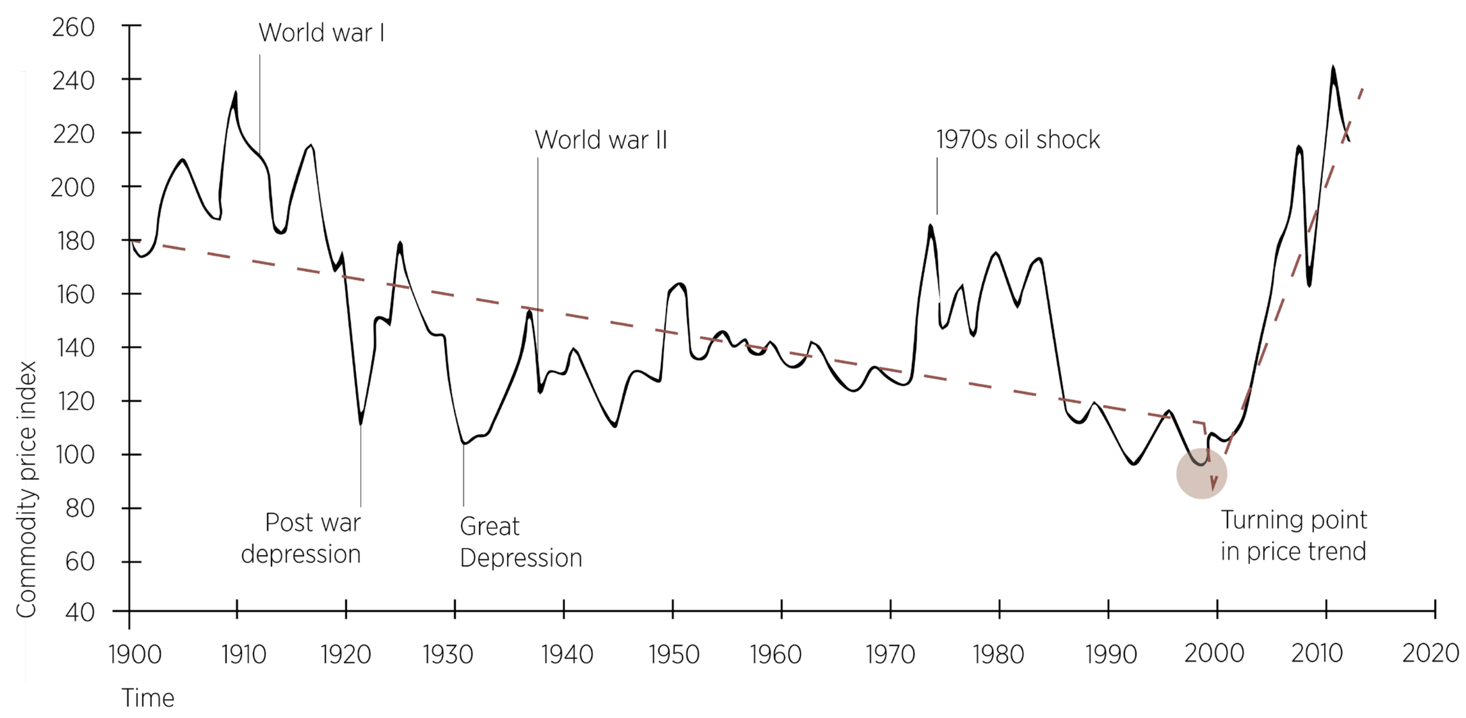


Fig 22: Mckinsey global commodity price index (Nominal price index: Jan 1980 = 100, 2022).

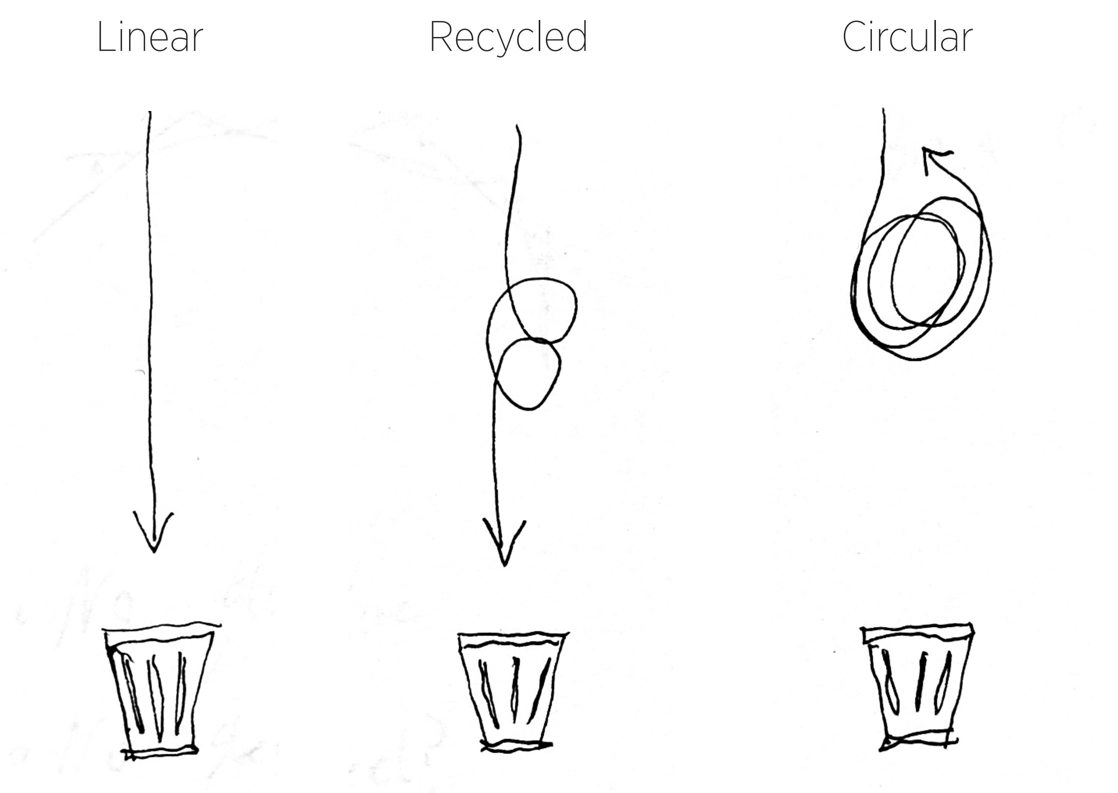
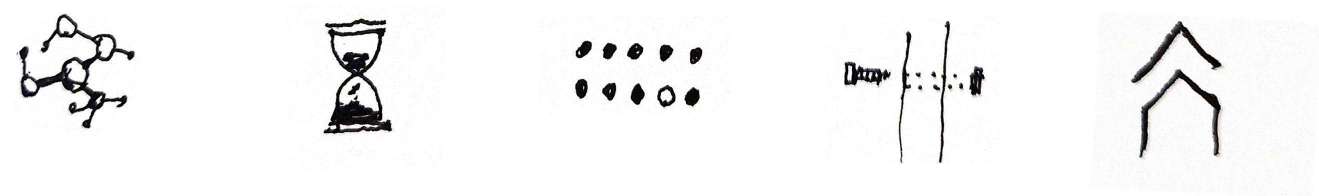


Fig 21: Circular systems.

03.3.3 A FUTURE DESIGNED FOR DISASSEMBLY

How do you design for disassembly? Some Danish architecture firms are forerunners in trying design for disassembly in practice. GXN has published a guidebook with lessons from their projects. They boil it down to 5 main parameters (Jensen et al., 2016, p. 44).



Materials Service Life Standards Connections Deconstruction

Fig 24: The 5 DfD principles.

Chose materials that allow for reuse and with long service life. They should also be non-toxic and pure to allow for easier reuse and recycling.

Design with the whole lifetime of the building in mind with long lasting elements that are flexible and allow for short term elements to be changed and replaced.
Use simple standardized systems that fit into a larger context of modularity. This will also allow for replacement of prefabricated elements with quicker and safer assembly and disassembly. When complexity rises a new module should be created of the elements.

Use reliable connections that tolerate being assembled and disassembles several times and they should be accessible to minimize time and complexity of disassembly. Mechanical joints will further allow for assembly and disassembly without damaging the materials. Binders should be avoided but made dissolvable if they are necessary.

Similarly, to how a project has a construction sequence, then it should also have a deconstruction sequence. It should be simple and clear to ensure structural stability and ease of deconstruction.
It should also be respectful of the context's buildings, people, and its nature (Jensen et al., 2016, p. 46).

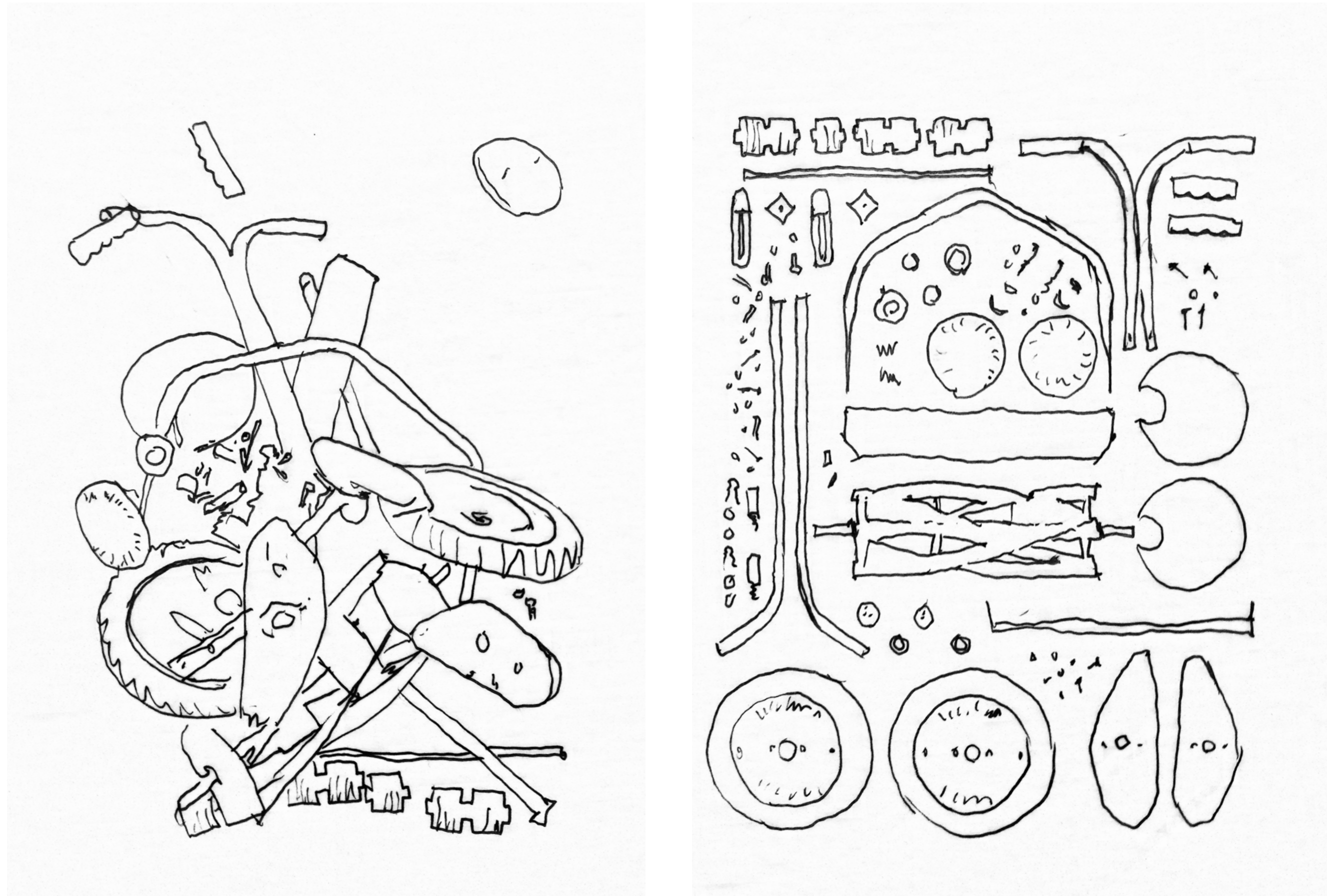


Fig 23: Inspired by "Disassembled" by Todd Mclellan (Mclellan, 2012).

03.3.4 CONCLUSION

In essence now is the right time to learn how to design holistically and implement it into practice. LCA is on the rise which is a good start but to make meaningful changes DfD should be implemented as well if the building industry is serious about achieving long lasting reductions in emissions and waste.

Practically to design constructions with the potential for DfD then long material lifespans are needed and a visible load bearing construction for ease of access and disassembly. Standardization and modularity will increase simplicity which is key and mechanical joints with bolts and charnier connections allow for less strain on the materials under and after construction. Lastly, a strategy of a deconstruction should be integrated.

03.4 THEORY CONCLUSION

A sustainability center should dare to be monumental but offset it by showing contextual and environmental sensitivity. Is it even possible and sensible to build something monumental in a sustainable paradigm and to what extend is order, scale, and light required to achieve the qualities of something monumental? This questioning cannot find its answer solely in theory as it is subject to a design process and the context is it based on.

The contextual sensitivity will take shape differently according to the scale and character of its context. The scale is important because it will attract functions and that will be the bastion of the building's firmness over time. Since most predictions are wrong a willingness to adapt should be integrated into the design. A contextual sensitivity could come from a supporting structure to the main monumental one. Mixing the high flexibility of the surroundings with a stable core of lower rate of change. The supporting functions should allow for DfD since it is an invitation for change and adaptation.

Sustainable materials and their longevity should be showcased in a more circular approach, and it should be a defining aspect of the architectural expression of a building that inhabits values for a more sustainable future. LCA as a holistic method should address the building industry from a standpoint of visionary realism since the building should be an example of the sustainable promises and values of its time and how to solve them. The unmeasurable symbols and aspects will therefore be integrated into the measurable metrics that assess and showcase sustainable development.

A center dedicated to sustainability should be a place for people to assemble and built to allow for disassembly.

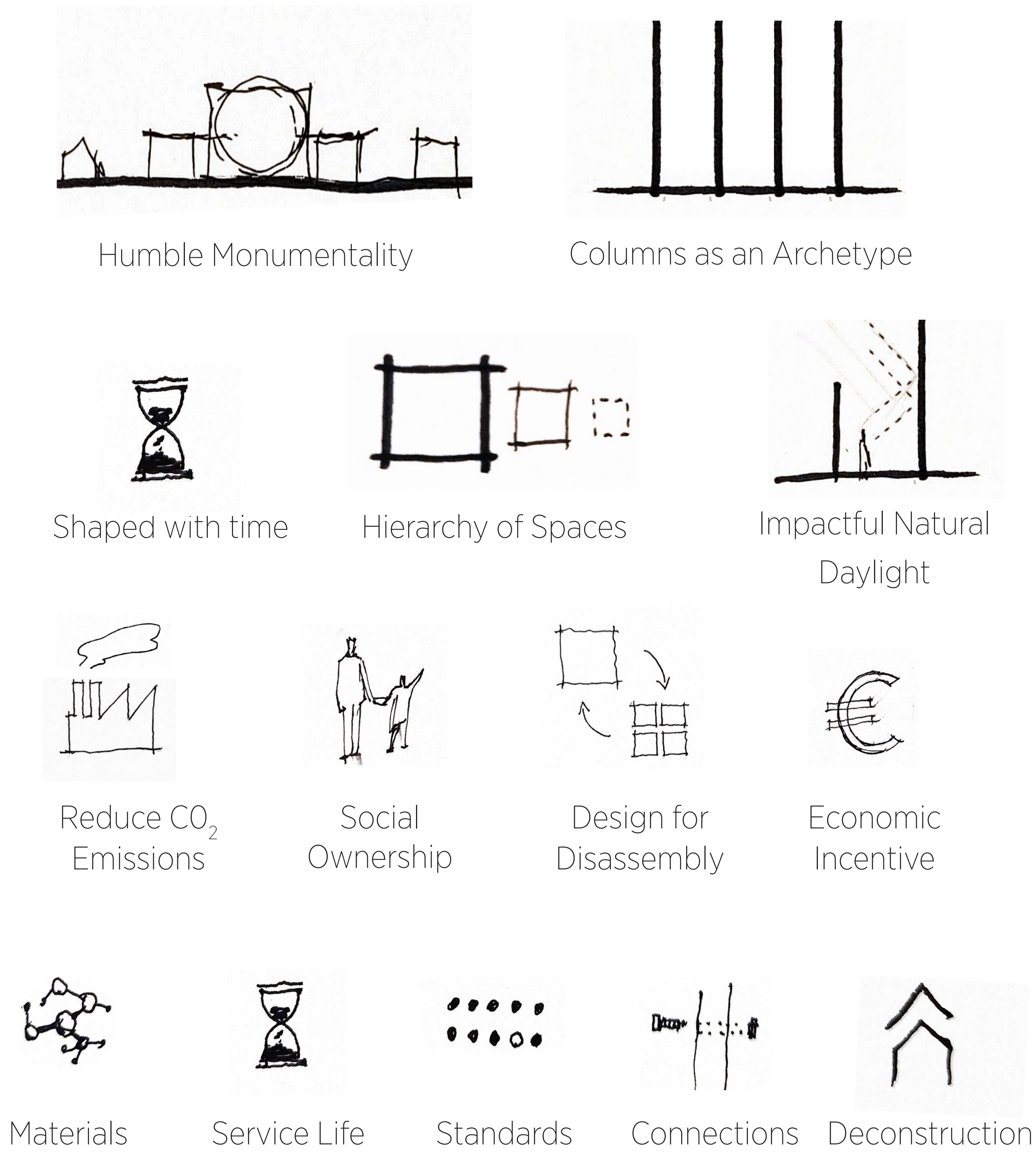


Fig 25: Theory based design parameters.

04 CONTEXT

04.1 DENMARK - AARHUS – NYE

Nye is a relatively new suburb north of Aarhus placed up against and just south of the existing suburb Elev. The town started properly being developed in 2013 when it was politicly decided to establish 650 houses/apartments inside the area (Center for Byudvikling og Mobilitet and Aarhus Kommune, 2016, p. 6). The concept of developing the area has been around since 2007 when it was first established as a potential future suburb due to population growth in Aarhus was predicted to be by 75000 people over the next 25 years (Tekker group, CEBRA, and Rødgivende Ingeniører A/S, 2007, p. 4).

Tekker group has played a major part in the development from its origins and currently most established Danish architecture firms are either building projects in the area or are planning to ('Historikken', 2016). The first phase of four is currently under construction.

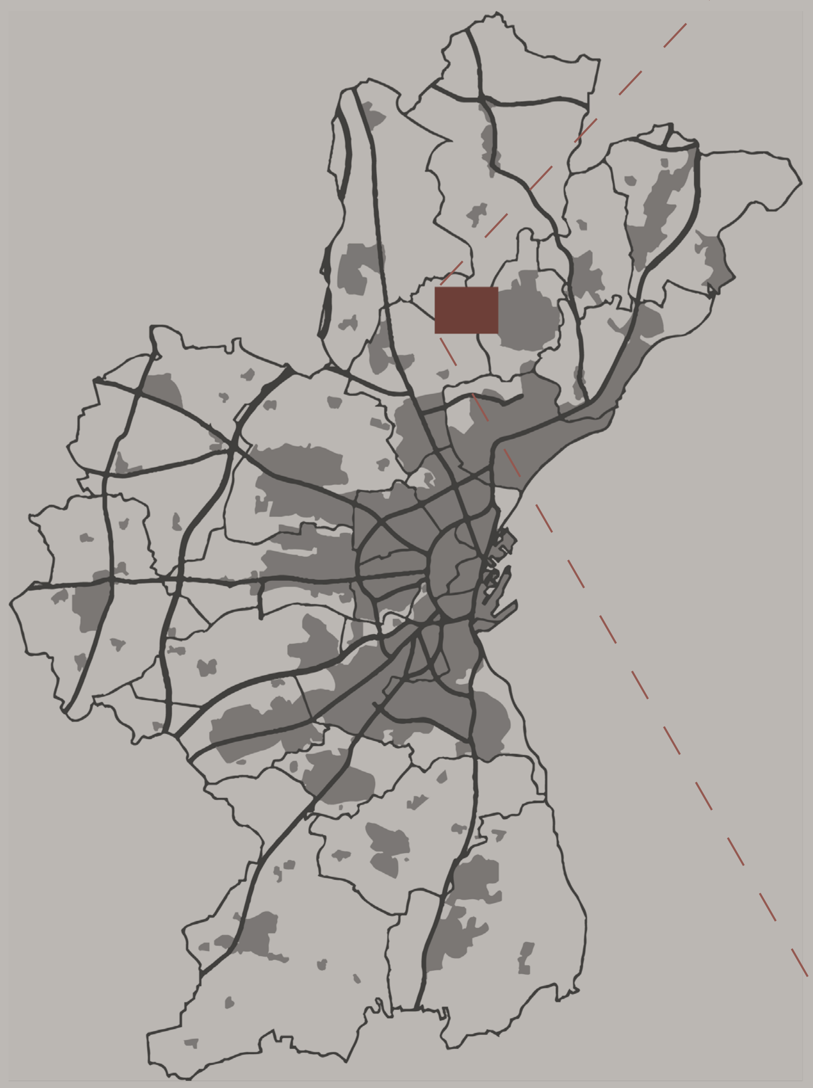


Fig 26: Aarhus municipality

Fig 27. Nye aerial view

04.2 SUSTAINABLE CUTY

"A green city with and active city life " - (Nye, 2021)

The vision of the area is to combine the best from the city, landscape, and nature (Center for Byudvikling og Mobilitet and Aarhus Kommune, 2016, p. 6). Living and being invested in Nye is therefore branded as a sustainable way to live both connected to the city and culture and be intwined in nature and its many benefits. The people choosing to live there are therefore likely to be interested in the values behind sustainable measures more than the general population.

In practice sustainability is mainly realized through wood constructions in the area and surface water treatment that uses the contour of the landscape to capture runoff rain water, filter it, and reuse it for appliances (Regnvandet i Nye bruges til toiletskyl og tøjvask - Aarhus Vand, 2022).

Nye and its surrounding suburbs are disconnected from Aarhus due to the Egå Lake and the highway south of the site. Actions have been done to try and remedy this, such as building a bicycle highway and "Letbane" tram to shorten the distance in time to Aarhus and allow for transportation without a car. The travel time to the center is 33 min on bike and 28 min with the Letbane ('Infrastruktur', 2016)

Fig 28: Nye Development plan.

04.3 SITE LOCATION


Fig 29: Site of 6000 m^2.

04.3.1 WHY THIS SPOT

The next stage of development will be on this plot and is currently planned to more housing as most things in nye. Located on a moderate high point in the area with connection to a lake, it has the potential to blend into the middle of the area as a cultural center but remain connected to nature and be visible.

It is also next to the water refinery which could interact with a sustainability center. The road next to the refinery will receive a minor adjustment.


Fig 30: Current state of site and the glass facade showing the systems inside the water refinery.

04.4 CULTIVATED NATURE

04.4.1 GREEN AND BLUE STRUCTURES

Being on the outskirts of Aarhus the area is Rural in nature with some lakes and woods. But how is this landscape perceived? Based on Hans Finks seven definitions on what nature is, the modern person living in downtown Aarhus and moving to Nye will properly perceive the rural landscape as nature compared to the city (Fink, 2003, p. 2). Therefore, subscribing to the definition of "The Rural" or "the Green" is appropriate since that is how the area is being promoted.

However, looking at the area at large there are no untouched or wild nature to be found. Someone from a more fundamental naturalistic mindset might perceive the area as heavily cultivated. Furthermore, from a more sustainable angle these farmlands are barren in terms of biodiversity.

The Rural is therefore marked in a stripped pattern and the cultivated lakes, meadowlands and woods which provide better biodiversity are marked blue and green respectively.

Cultivated zones

More biodiverse zones

Lakes and streams

Fig 31: Nye nature.

m. 100 250 500

04.5 LACK OF CULTURE

04.5.1 FUNCTIONS IN THE AREA

Nye and the surrounding suburbs inherently contain very limited cultural institutions. Lisbjerg library being the sole facility open to the public that is not connected to religious or educational establishments. There is therefore potentially several thousand people within biking range of the Nyes phase one, with 1.000 inhabitants in Elev and 10000 in Lystrup (Statistics Denmark - Population, 2022),and that is not counting Nyes future development which will be at about 10.000 - 15.000 inhabitants (Aarhus får ny folkeskole, 2022). Up to 26.000 people are potentially within close walking or biking distance to each other without a space to interact.

Locally Nye likewise does not contain any options for assembly other than in its inhabitants' own living rooms. Many of these early settlers in Nye are families desiring the symbiosis of the city and nature, and currently it is only the nature aspect that is represented. There is therefore a demand for a space that can function as a center of culture in the area.

During the development of this thesis, a school was announced in the western part of Nye that should provide some multifunctional activities (Aarhus får ny folkeskole, 2022).

Fig 32: Nye functions.

Nyma, a temporary cafe and ecological store.


Surface water collection.


Playgrounds in nature..


Fields.


Nyes kindergarden viewed from the site.


A focus on bikes and shared cars.


Close vicinity to forests.

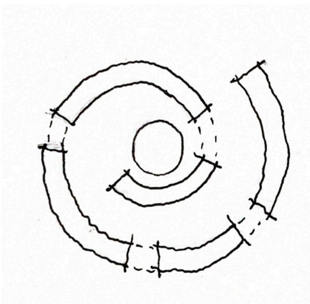
Fig 33: Photos of Nye and its surroundings.

04.6 ARCHITECTURAL PRINCIPLES

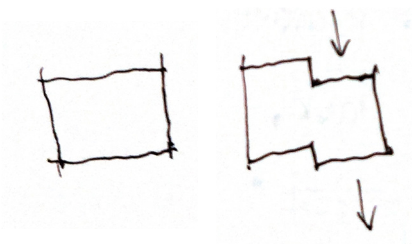
Geometric shapes in Nye are similar to what ancient Greeks depict, despite not being a traditional grid layout (Vitruvius Pollio et al., 1999, p. 206).

The city will and already contain buildings from 1 to 4 stories (Center for Byudvikling og Mobilitet and Aarhus Kommune, 2016, p. 6). Their volumes are broken up into shorter facades and follow the natural height differences in the terrain.

Untamed growth is deliberately being nurtured to interact with the facades of the area, which are mostly comprised of wood cladding.

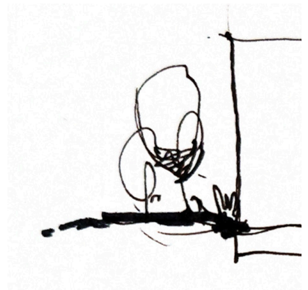


Geometric Systems

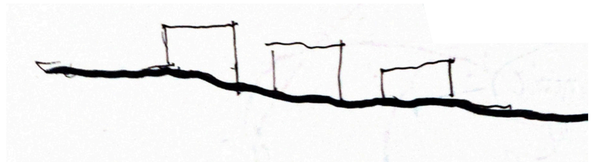


Breaking Up Volumes

Fig 34: Architecture principles in Nye.



Close contrast and interaction between nature and



Active use of Terrain

Wood constructions and cladding

04.7 SITE POTENTIAL OVERVIEW

Fig 35: Main roads in the area. Where people will see and arrive at the building from in car

Fig 36: Letbane as main public transportation infrastructure.

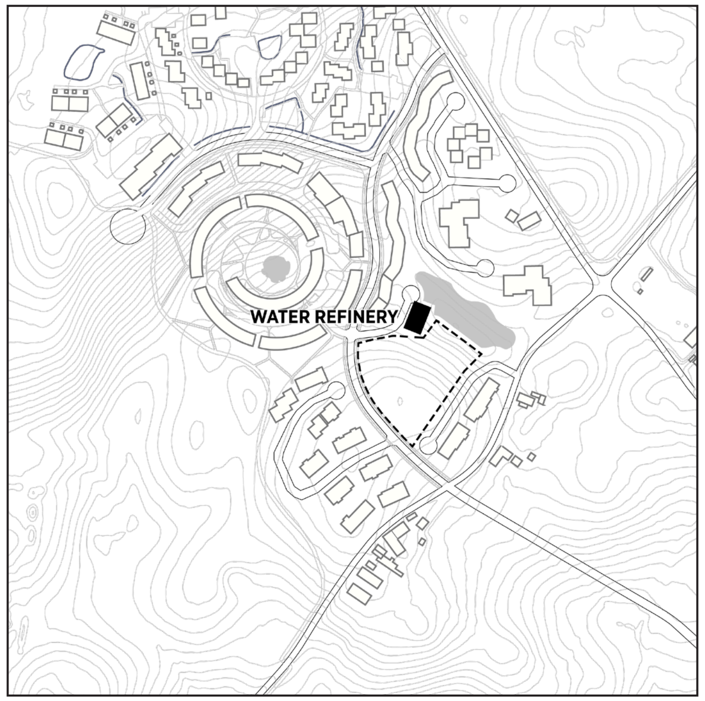


Fig 37: The water refinery and treatment facility that is situated next to the site,

Fig 38: Kindergarten located on the other side of the lake.

Fig 41: Good possibilities for parking in close vicinity to the site.

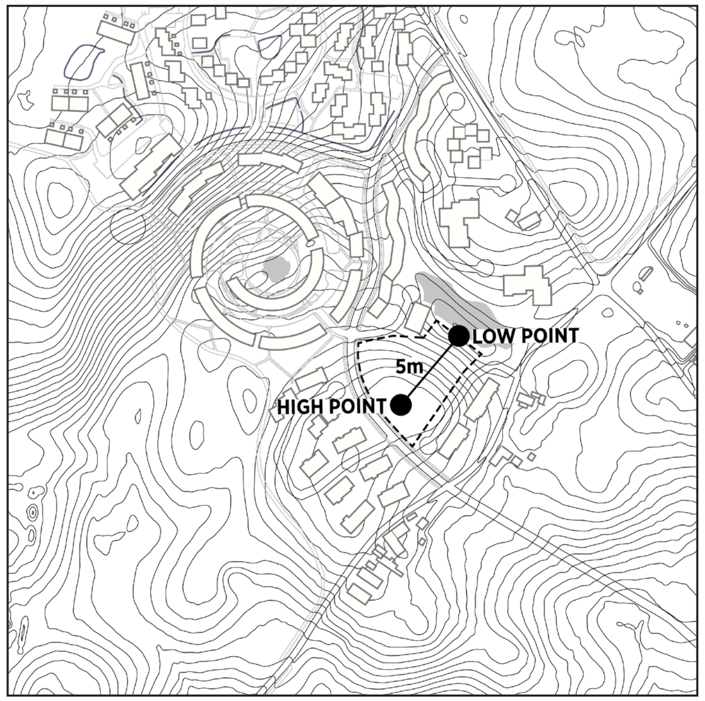


Fig 40: There is a 5m hight difference from top to bottom on the site. 0.5m between the contour curves.

Fig 39: Potential to use the view and connection to the lake or at least take into account the flow around it.

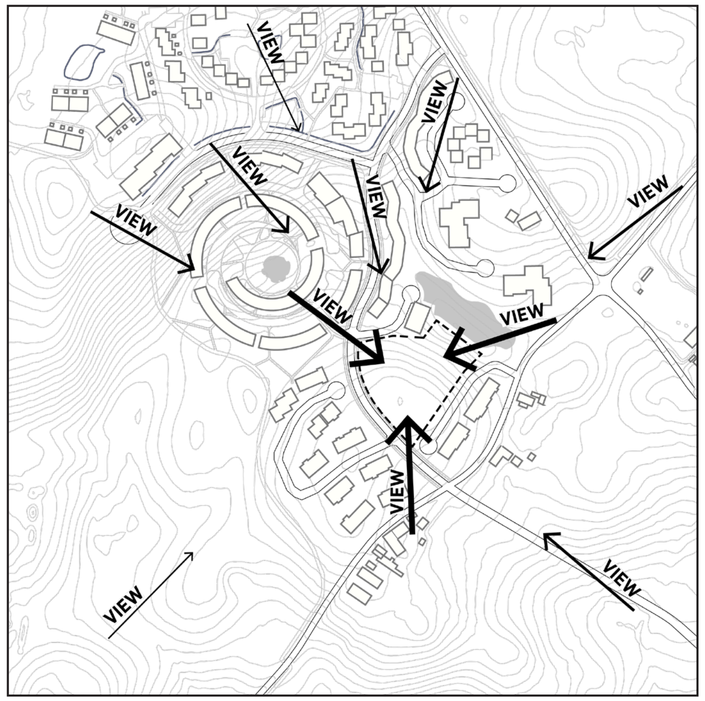


Fig 42: The local highpoint on site allows for a visible building that simultaneously is integrated into the area.

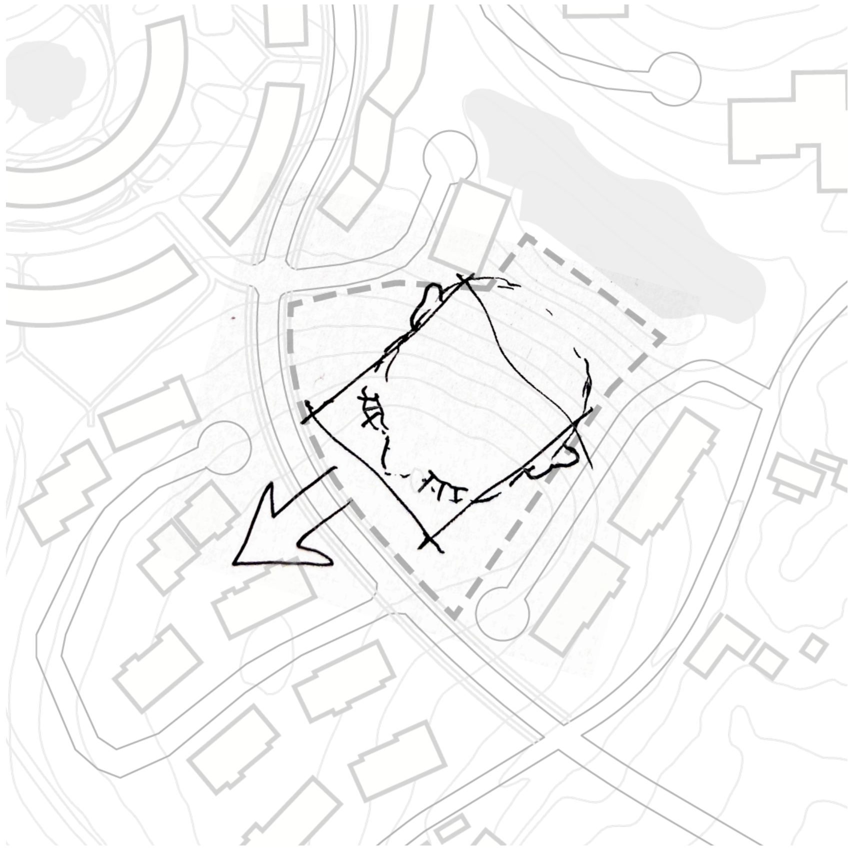
04.8 THE PEOPLE AND ORIENTATION

Nye tries to appeal to people with an interest in preserving nature and an interesting in communal activities (NYE, Aarhus N - Byen i forhaven og naturen i baghaven, 2021). Currently this primarily means families with young children who want to move away from the busy city life and let their kids grown up in a greener and safer environment. This is reflected in the types and sizes of apartments available for purchase ('Sneglehusene - Boligvælger kort', 2022).

As Nye develops, the children of the area will be teenagers and a more diverse area will emerge. The rituals of a human lifecycle such as a confirmation/ non-formation, a wedding or other traditions should have a local space to unfold which will embody the values of the area.

Furthermore, they should have a physical forum for establishing new ideas and continuing the focus on circularity that the area wants to inhabit.

Fig 43: Current primary demographic in Nye.



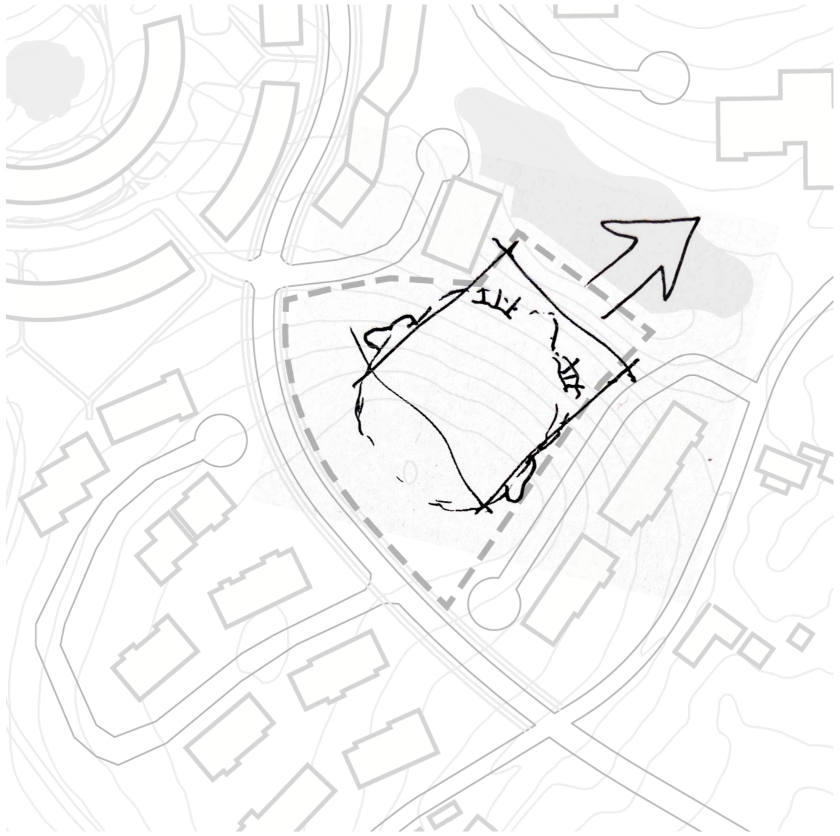


Fig 44: "Facing" of the building. Inspired by orientated otherwise by David Leatherbarrow. Where should the building face?

04.9 CONTEXT CONCLUSION

The people who chose to live in Nye share the potential to use and care about a sustainability center. And there is currently a lack of places to express man's highest cultural needs, as Louis Kahn puts it.

The new city has a visionary plan that is already an established example for suburb development projects not just in Denmark but also globally. A typology that is increasingly common with the ever-growing urbanization.

It is easy to criticize an area while it is being developed, and the people there are arguably more invested in the promise of the area then its current state as a construction site. There should therefore be a continuation of the architectural principles already established as design parameters, but the monumental and multifunctional gathering place established by the theory could break the ruleset to achieve notoriety. The surrounding systems of the building should nevertheless conform more neatly into the context.

The values of the community, the environment and sustainable architecture in restricted scale is the catalyst for a sustainability center with engagement and promise.

Fig 45. Picture of site.

05 PROGRAM

To establish a design solution for a sustainability center with humble monumentality the emphasis will be on LCA, tectonics and integration into the context while having an overall balance of functionality, utility and beauty that provides a grand space as a stable base for organic growth and expansion through time.

05.1 DESIGN CRITERIA

The building will be divided into three parts. The main multifunctional chamber, surrounding supporting and adaptive functions and an outdoor Agora inspired plaza. These three parts lay the groundwork for delivering on the established design criteria.

The supporting functions of office landscape, café, workshop space and shared spaces will be connected by the foyer, which in sequence should be connected to the main chamber and the plaza. The supporting functions should bring some local activity to the everyday use of the building.

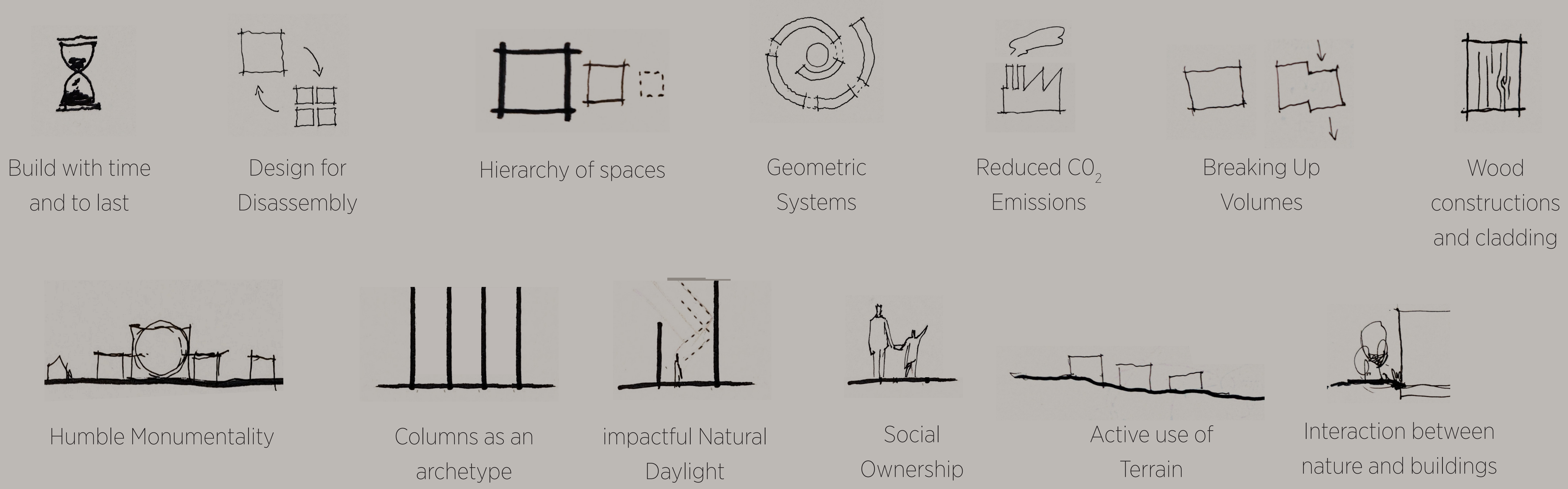


Fig 46: Program main design parameters.

05.2 ROOM PROGRAM

Function	nr.	m²	nr. People
Large main room	1	735	300
Foyer	1	280	75
Office landscape	1	250	40
Workshop Space	1	40	15
Seminar rooms	2	35	10
Exhibition space	1	85	20
Shared space	1	50	20
Kitchen	1	40	4
Cafe/bar	1	160	55
administration office	2	15	2
Storage / Stock delivery	n	150	x
staircase cores	2	115	x
toilets	7		x
toilet handicap	2		x
tech core	2		x
Plaza	1	645	200
Total		2650	

Fig 47: Room program.

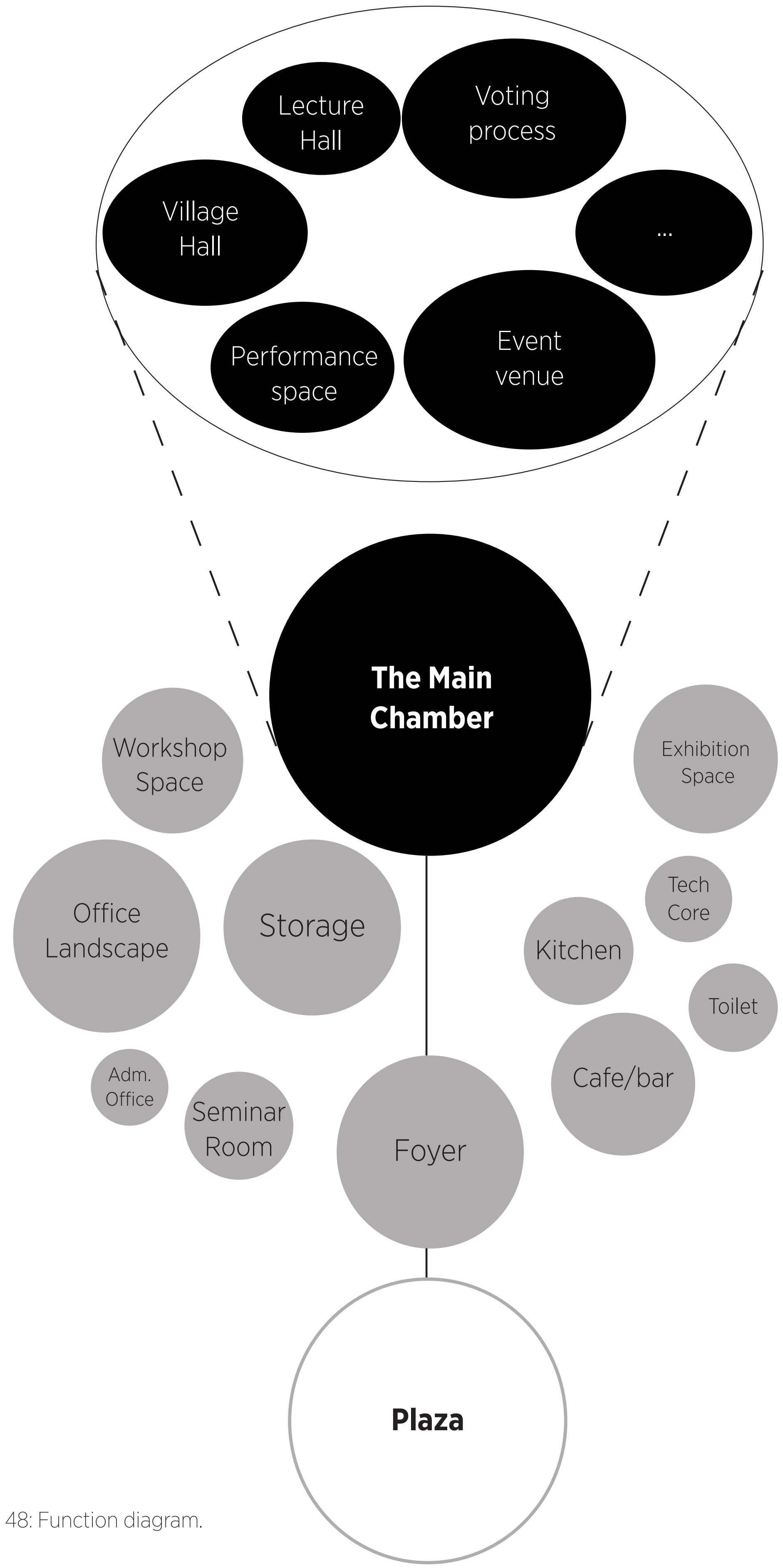


Fig 48: Function diagram.

06 PROCESS

06.1 WHERE TO START

The early process of sketching ideas happened organically parallel with the theory and context exploration. A point of exploration was how should a building that tries to fulfil some of the current promises of the future be realized?

This culminated in varies initial investigations that tried to solve the program and its design criteria in different ways.

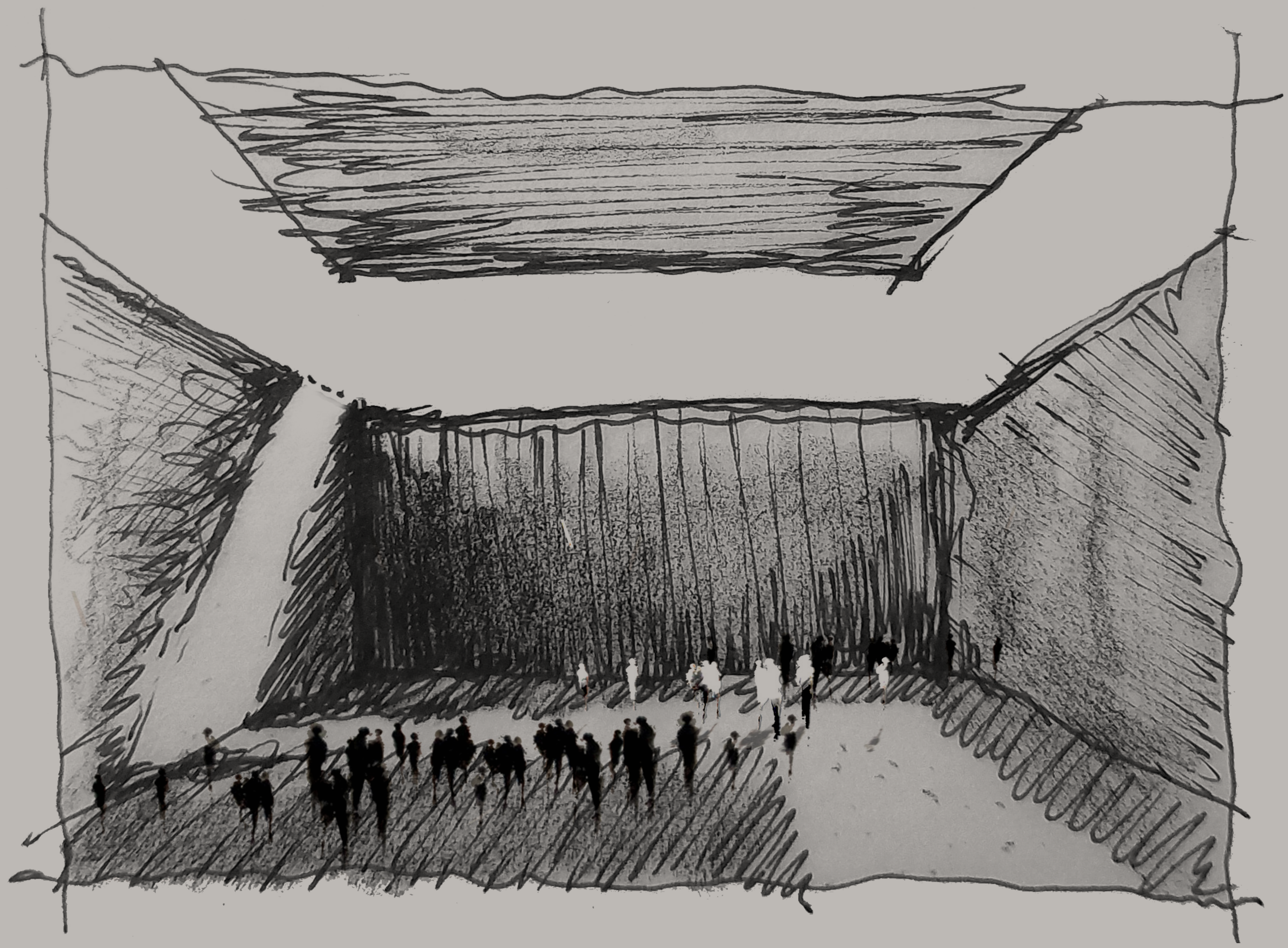


Fig 49: Initial sketch of a monumental place to tune the mind.

06.2 INITIAL SKETCHING

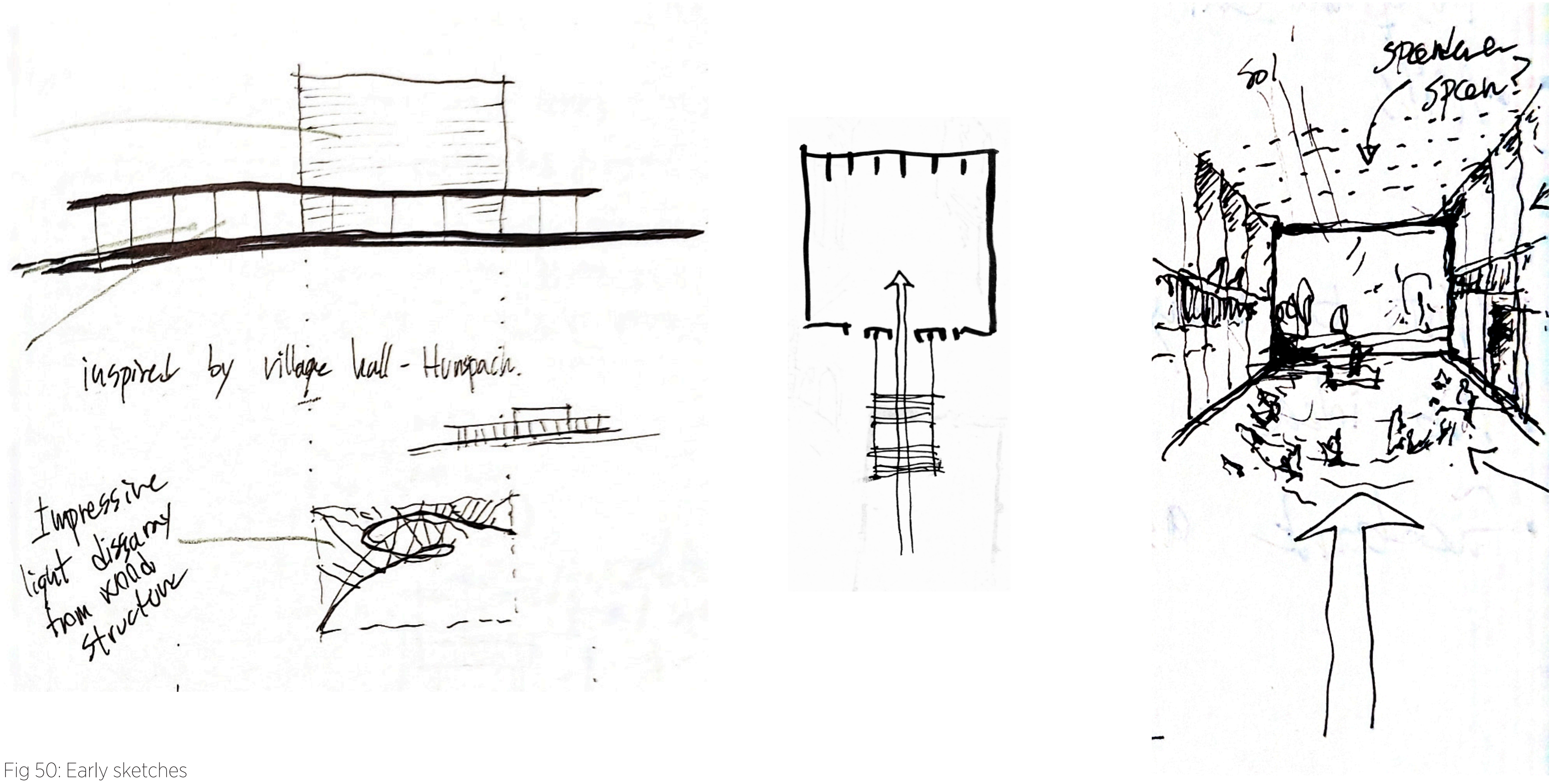


Fig 50: Early sketches

Early in the process it was established that scale and contextual sensitivity would play a role in the design. The first sketches mixing something low and tight with the grand and scenic.

The large space found the alias of the main chamber.

06.3 SECTIONS AND MASSING

Different sizes and layouts of the function diagram was tested in section and in mass models.
It was clear that a more fragmented geometry was needed to fit into the established composition of the context. It also became clear from the 3D model interaction that height had a potential to play a role in the hilly landscape.

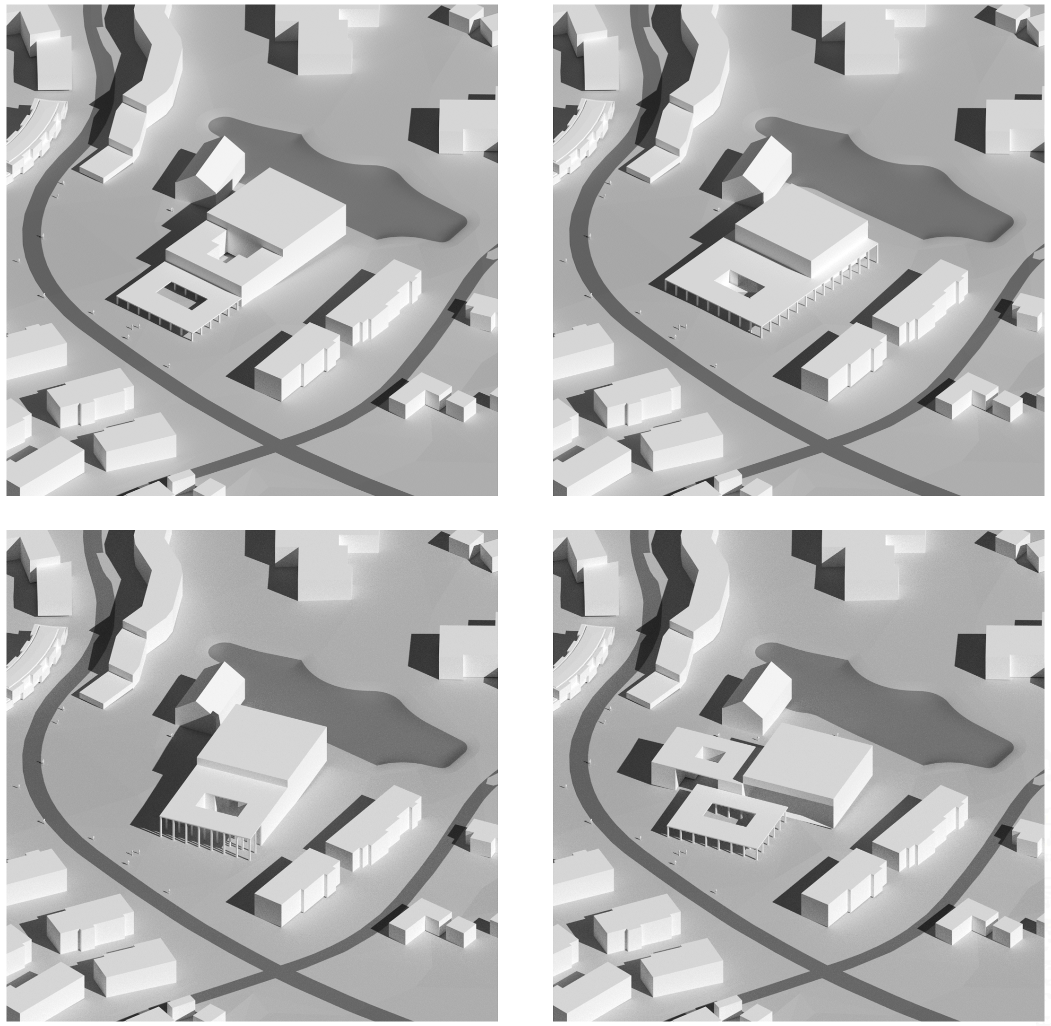


Fig 51: Mass models based of function diagram.

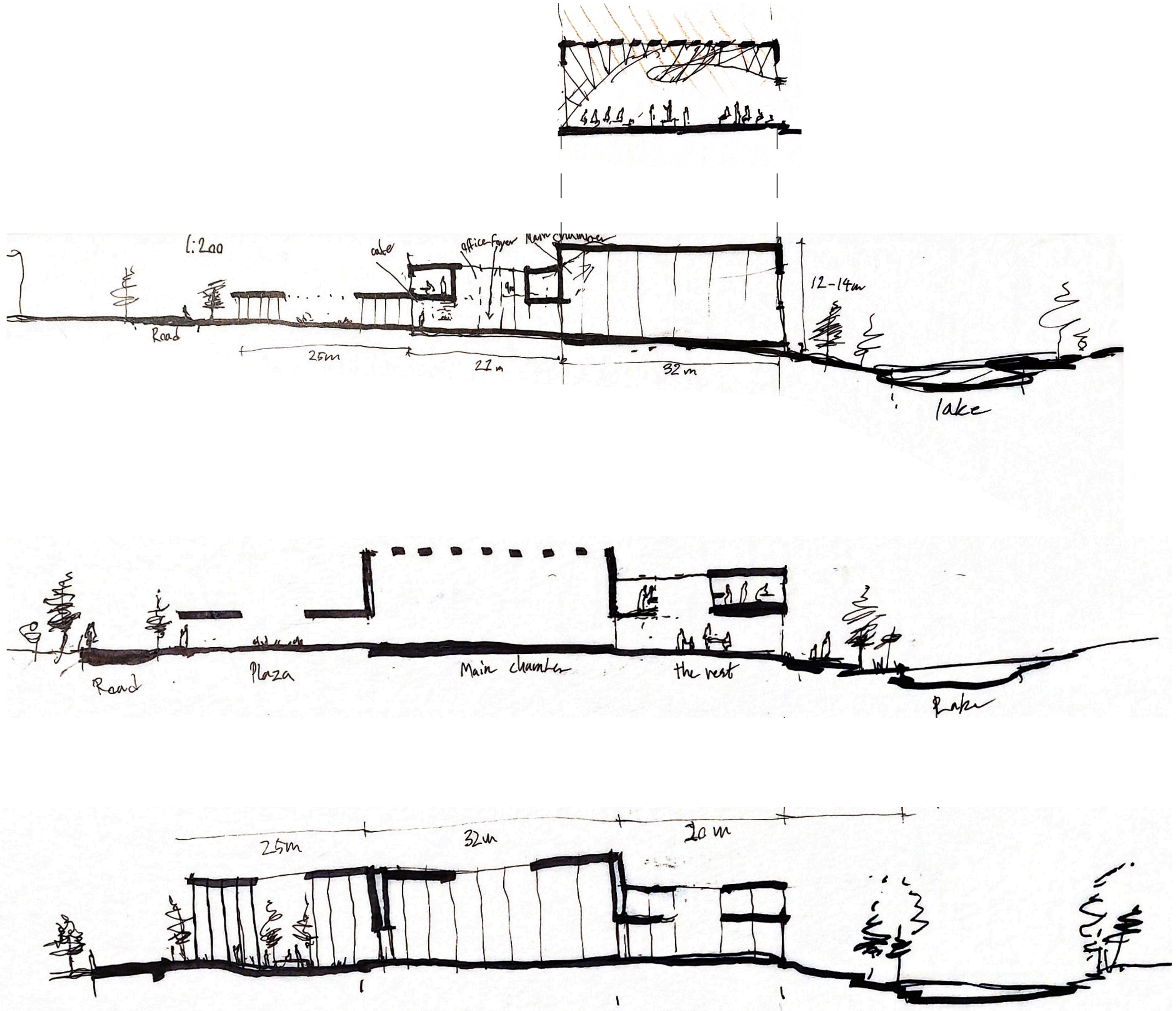
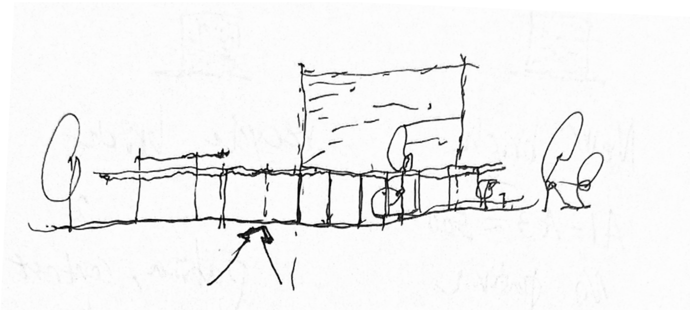
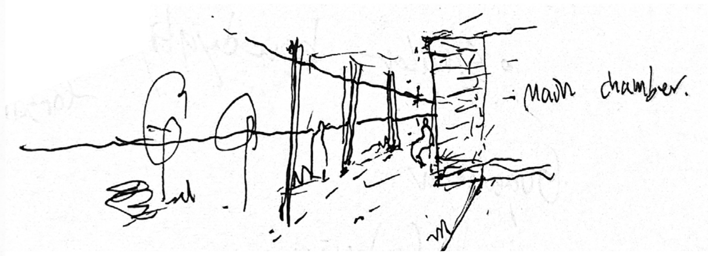


Fig 52: Sections sketches in scale based on function diagram.

06.4 VIRTUAL REALITY WALKTHROUGHS AND MATERIALS

It was clear that the main chambers surrounding functions should speak to the materiality of the area, which is primarily wood based. The question was then if the main chamber itself should be integrated into the same system or if and how it should differentiate itself.





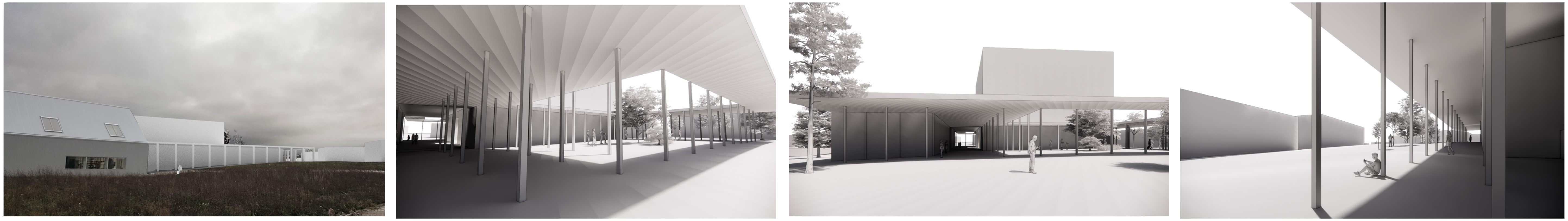


Fig 55: VR walkthrough screenshots from a layout iteration.

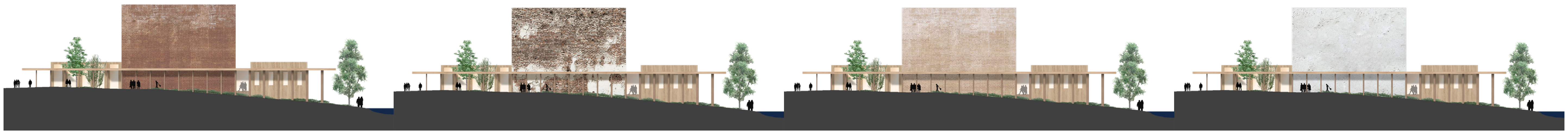


Fig 54: Main chamber material tests.

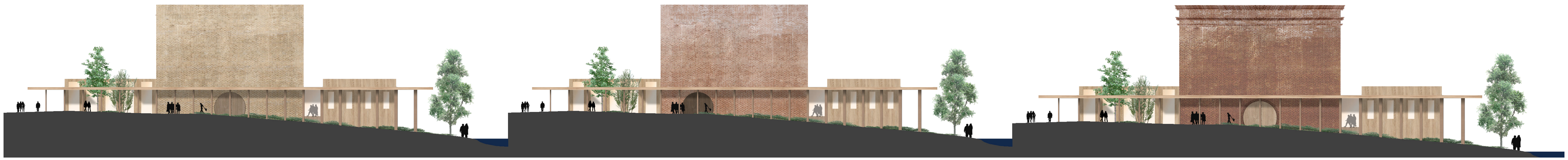


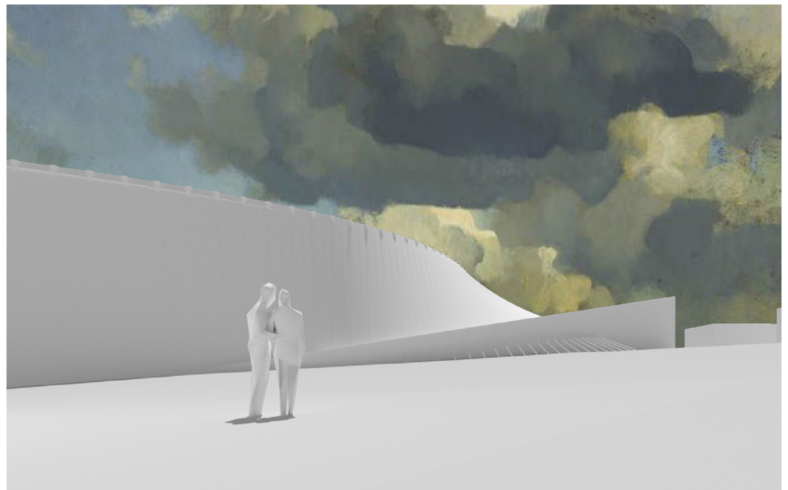
Fig 53: Main chamber opening tests.

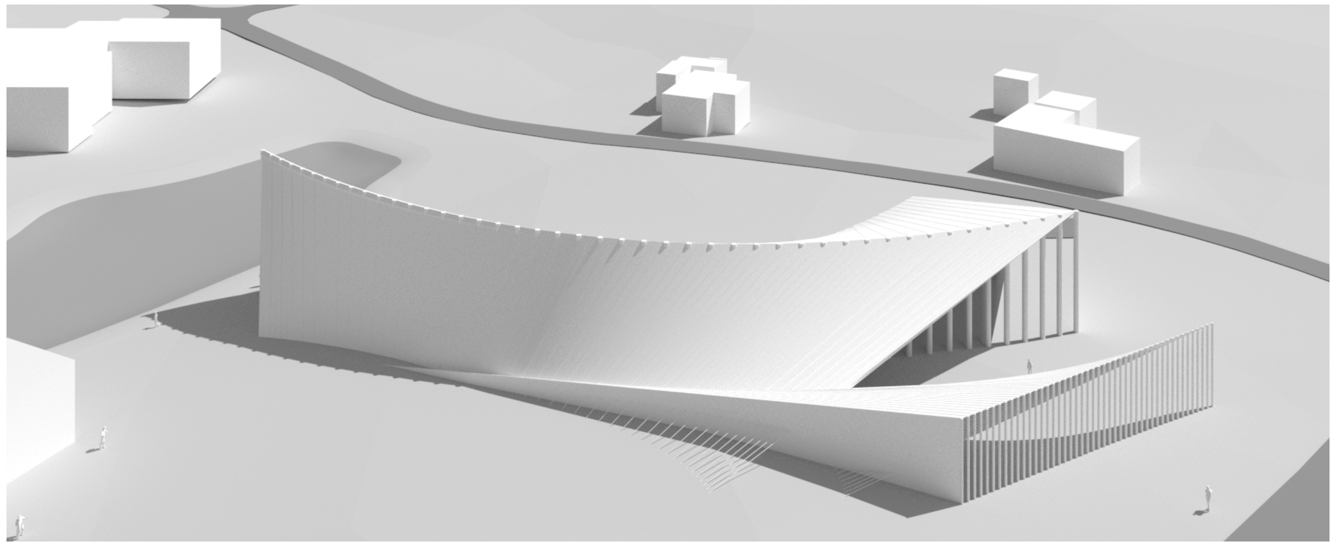
06.5 ALTERNATIVE PATHS

06.5.1 COLUMNS AND ORGANIC SYSTEMS

Several more or less geometric systems were explored. Most failed to achieve a simple enough system suitable for DfD and required material use that would inhabit the results of an LCA significantly, such as concrete shell structures or large tensile systems that require a lot of steel.

The shapes, even though appealing, also didn't integrate well into the architectural principles established in the area and would give too strong of a contrast combined with the advanced structural systems.





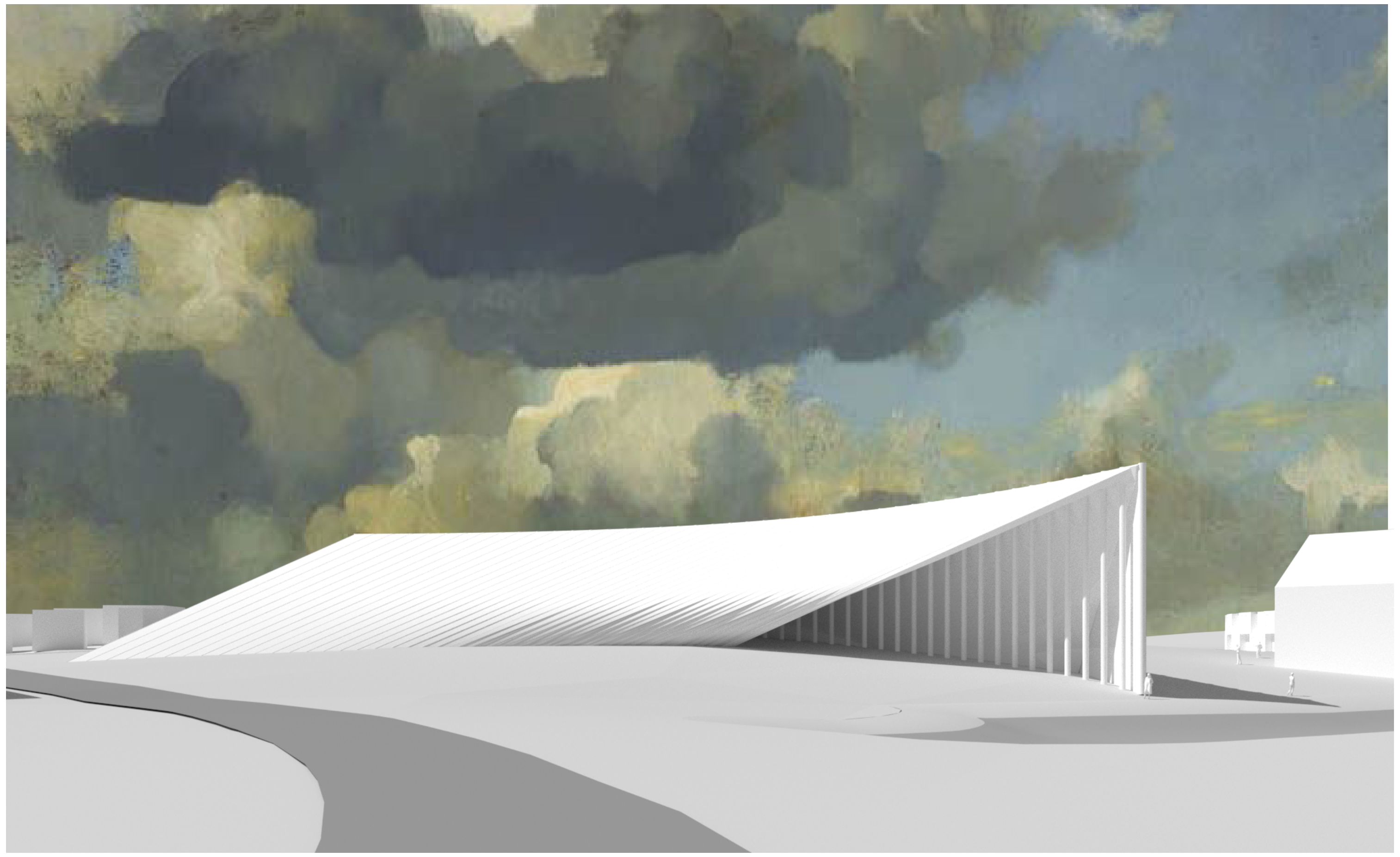


Fig 56: A generated iteration inspired by Richard Sweeney wire sculptures.

06.5.2 COLUMNS IN THE MAIN CHAMBER

Several structural systems in wood inspired by case studies were tested to find a system that had the desired mix of a revering effect, structural efficiency, and use of sustainable materials.

Walking through the spaces showed that a plan uninterrupted by large columns would be optimal. The columns inside the main chamber should therefore be pushed to the perimeter of the space .

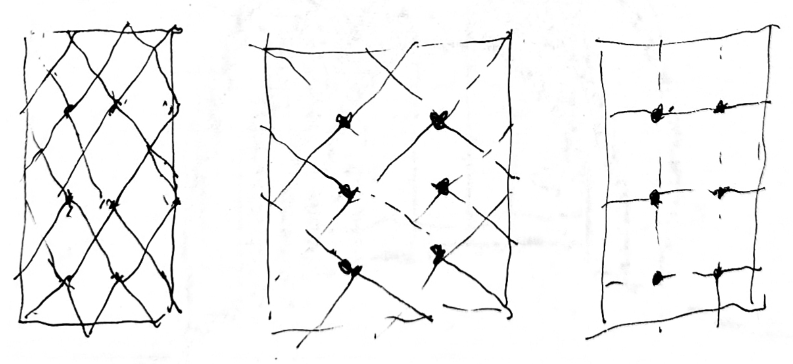


Fig 57: Different plan layouts with columns inside the main chamber.

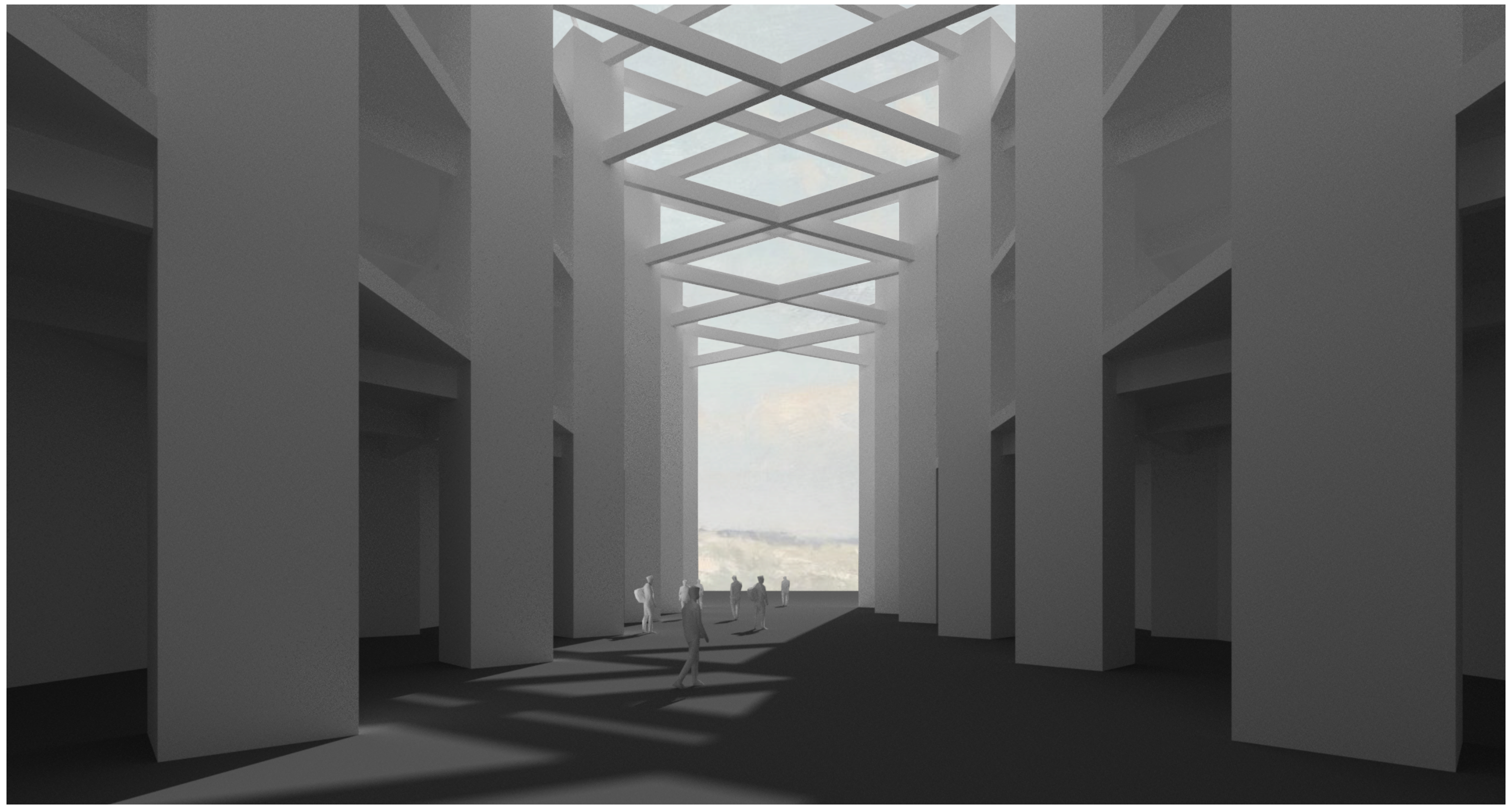


Fig 58: An generated iteration inspired by Richard Sweeney wire sculptures.

Fig 59: A building system based on reused wooden planks used as acoustic cladding.

06.6 LCA TOOL DEVELOPMENT AND TESTING

At this point in the process the programming that was being established allowed for testing of mass models. Building on the established work in the sustainability department, the methodology described earlier in the report was established.

A significant time investment was therefore placed in development of the toolset for applying the iterative LCA script on the sustainability center. After being established it allowed for fast testing of different material combinations based on a set of mass models with different values.

The role of the lack of environmental product declarations, EPD's, showcased the importance of further development on the marked as the current options for different building components are severely limited. EPDs are files a manufacturer supplies to allow for assessment of their product and a LCAByg EPD file is required to make a reliable assessment.

Fortunately, C.F. Møller Architects had an internal course on LCA to spread knowledge in the firm (Grow-kurser i C.F. Møller Architects er i gang, 2022). This allowed for a deeper understanding of the interplay between different professions and the building industry as a whole and showcased why a more integrated tool was necessary to meet and be competitive in the new LCA requirements past 2023.

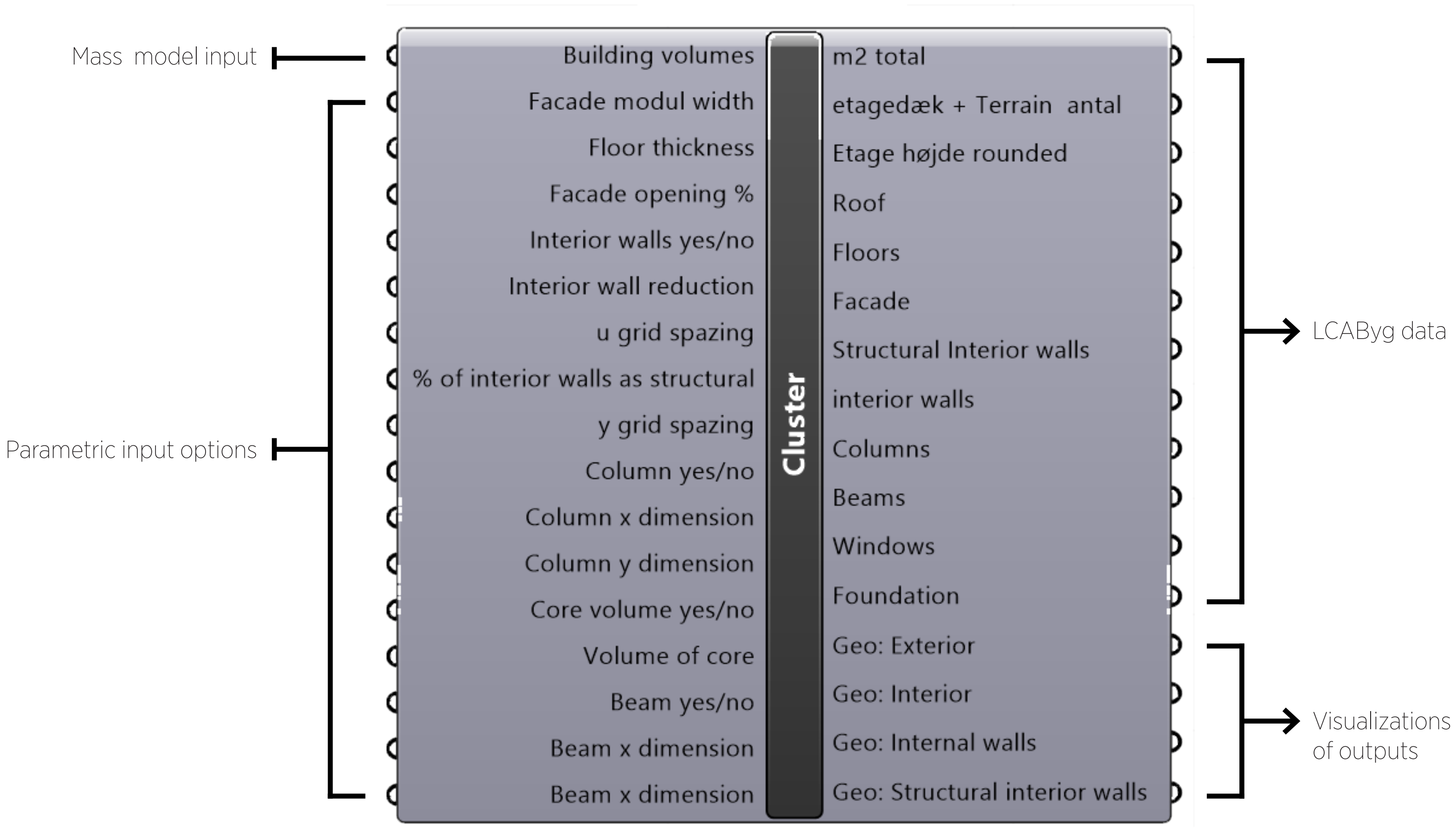


Fig 60: Custem developed grasshopper component with various inputs and outputs.The user will simply need add a building volume and pick different materials and sizes from lists.

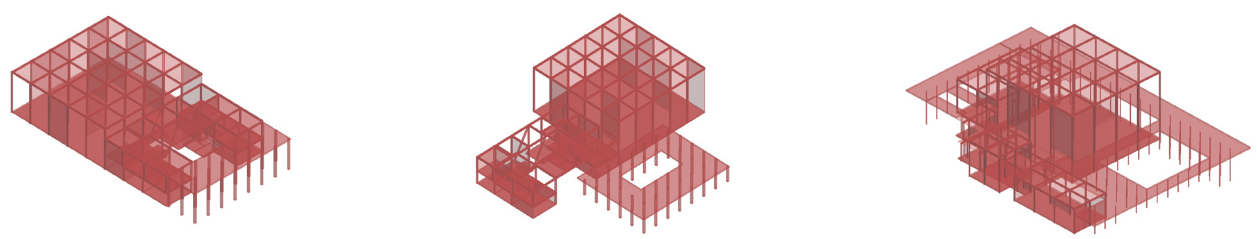


Fig 61: Exaples of geometry generation on different mass models. The red colour is the preview function in rhino grasshopper and show that they are generated and not yet baked out into rhino.

06.6.1 LCA SCRIPT MASS MODEL EXPLORATION

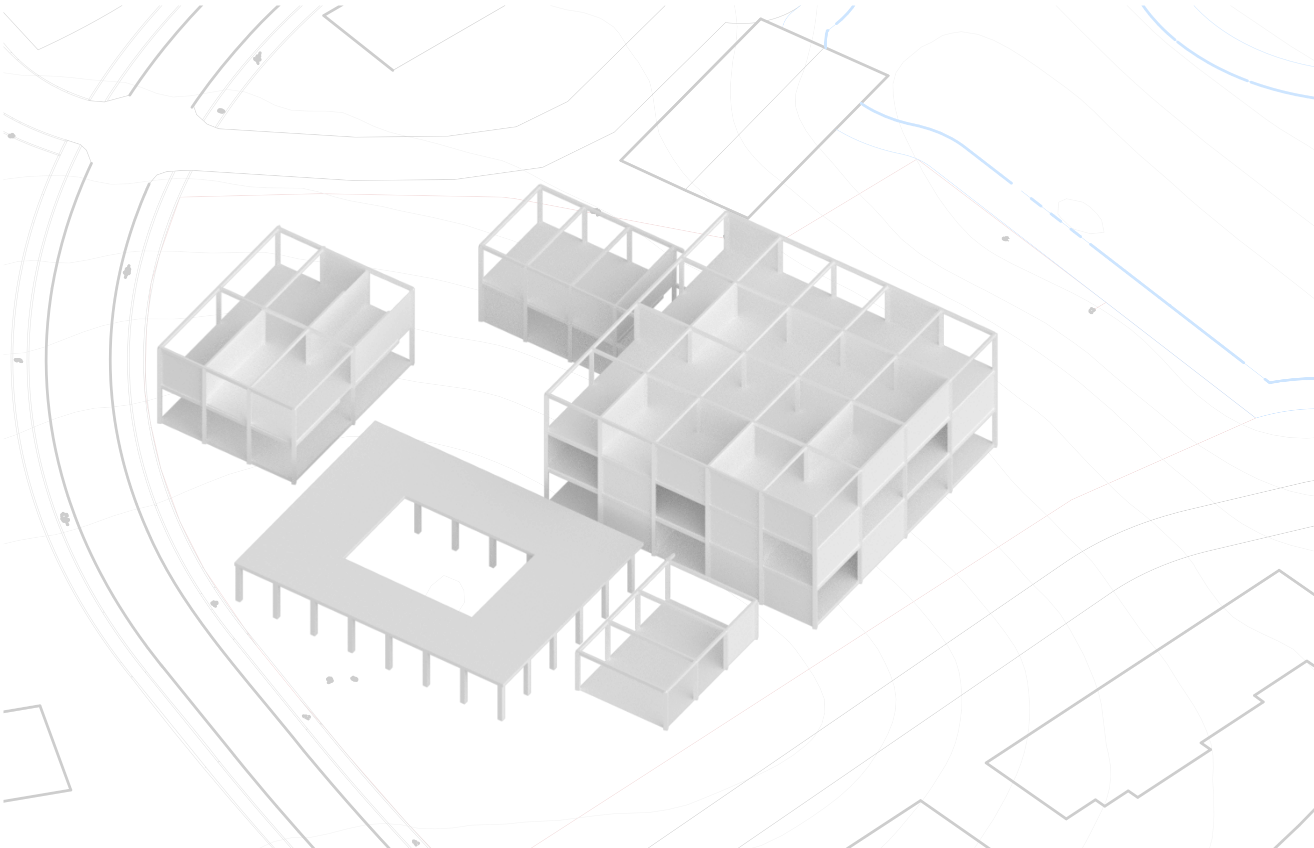
Using the baseline of LCAbyg's internal EPD's several iterations of testing parameters was explored. The biggest factor for this program seemed to be the overall clustering of the masses. Clustering the geometries together reduces the area of exterior wall and to some extend also other factors. This reduces the factor of an outer wall layer and its windows significantly. In this analysis reducing the GWP from 12.1 to 9.9 while both instances having the same m^2.

It is also noteworthy that the plaza can be disconnected because it does not have a climate screen.

Another major factor showed to be the decks and the infrastructure it needs. Reducing number of levels and sticking to few floors is therefore also a priority.

The assessment was done with a prestressed hollow concrete deck, with linoleum flooring. Concrete load bearing columns and beams with internal walls with gypsum wall cladding. Line concrete foundation. Roof of concrete and EPDM covering. Exterior of 3-layer energy glass windows and load bearing concrete elements with brick cladding. Not too different from the standard concrete offices or housing blocks in Denmark of recent years.

GWP: 12.1 - Spread out



GWP: 9.9 - Clustered

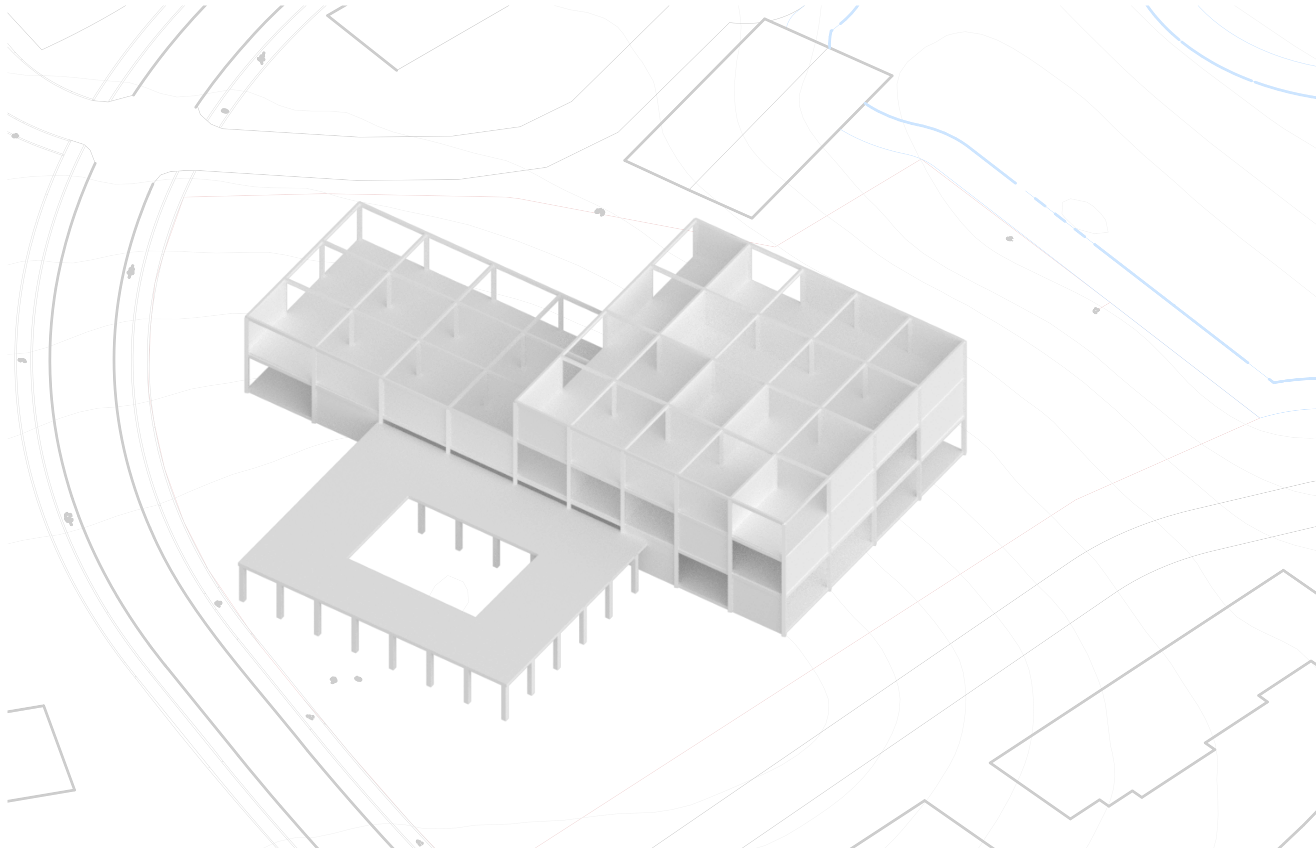


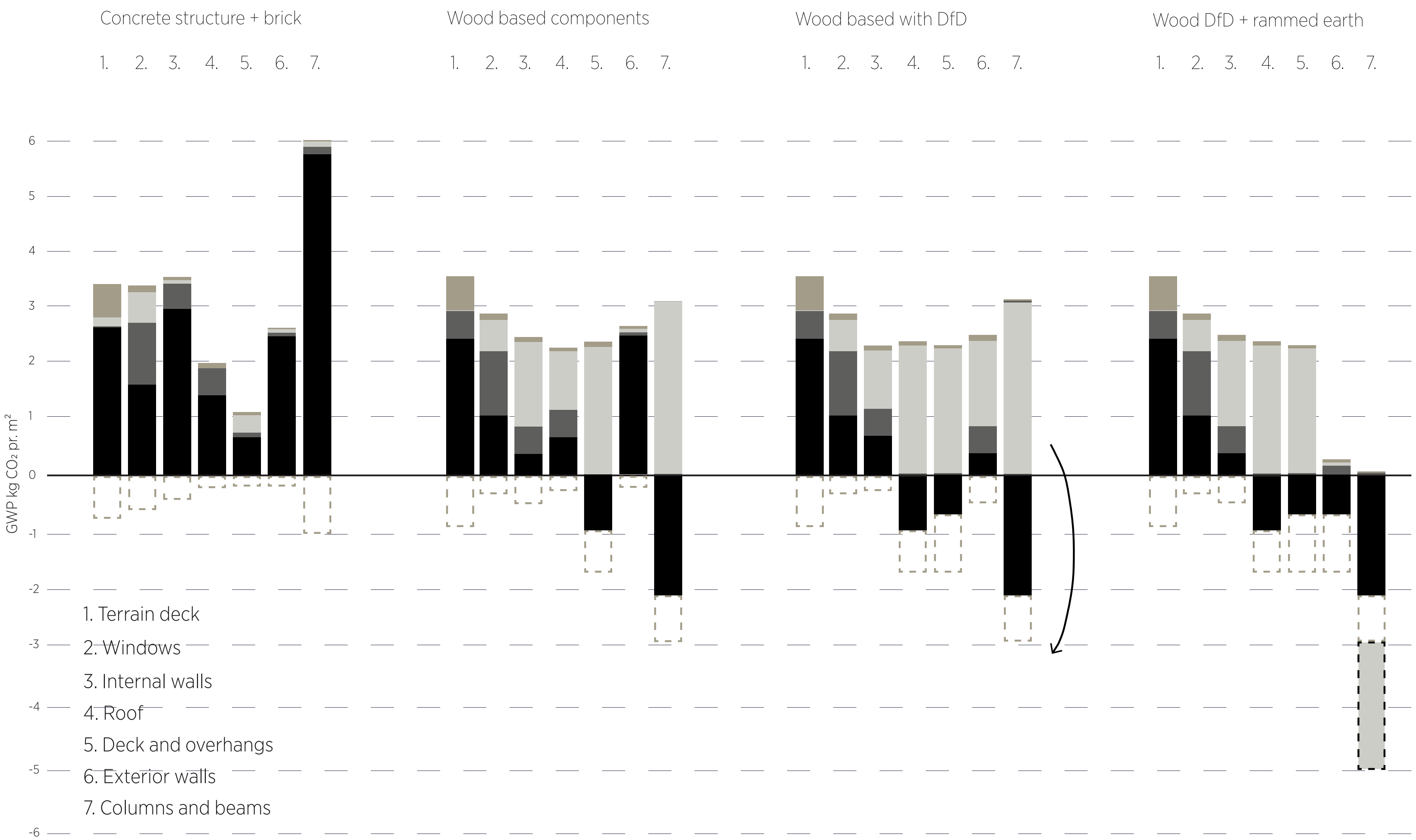
Fig 62: Mathematical representation of load bearing columns, beams and load bearing interior walls used for calculation based on standards.

06.6.2 EXPLORING THE OPTIONS

Moving from products that had a large production cost, A1-5, in C02 is the single largest improvement of an LCA. From brick and concrete to timber-based components makes a big difference, however the actual impact is surprisingly low due an LCA counting the woods whole lifecycle from growth to releasing its inherent carbon storage again at the end of its lifecycle.
DfD should therefore be used to reduce waste of wood, C3, as it would make the construction outperformed the concrete system significantly more.

Furthermore, making the outer wall RE reduces waste as well, but does increase the transport emission due to the weight of the elements because they are a lot thicker than the brick base (Fernandes et al., 2019, p. 16).
Since 80% of the C02 emission of RE is from transportation then it would be preferable to obtain supplies from a small or medium enterprise closer to the site. The sustainability center could perhaps be the catalyst for a rammed earth-based company to establish itself in Nye.

These factors of low impact and high potential for reuse make it more justifiable to create a large, monumental building.



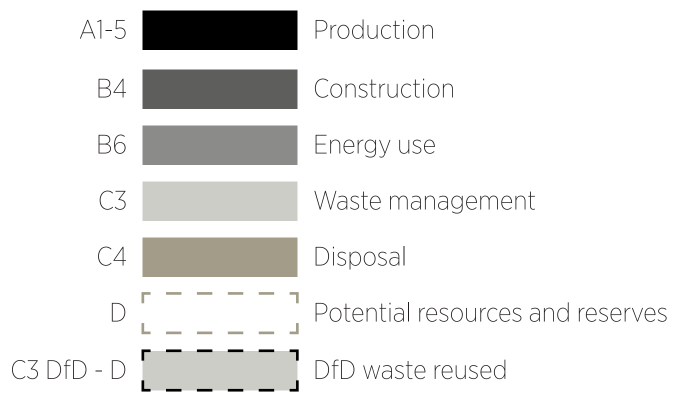


Fig 63: LCA investigation of material combinations.

06.6.3 LCA SCRIPTING CONLCUSION:

The first main step is to move away from a prefabricated concrete panel system to a less dense organic wood system. DfD will not increase LCA scores directly but will nevertheless potentially decrease waste, C3, and increase the D stage.

A clustering of volumes will decrease the area to the exterior and reduce the amount of climate screen needed, which will also increase energy performance.

Rammed earth is introduced as a custom EPD to decrease the emission of the main chambers outer wall materials in the production phase (Fernandes et al., 2019, p. 16). Furthermore, a lack of sustainable deck elements makes it a main contributor and multiple levels should be minimized. A screw foundation will further decrease the footprint of the whole foundation, despite perhaps using concrete floor tiles because of their mechanical properties of their high durability.

Glass will therefore be the main contributor as it is a facet heavily reliable on indoor climate testing which this thesis does not go into detail about. Standard 3-layer energy glass is therefore used.

In the end, the results are not surprising and general sustainable strategies are the most important but nevertheless confirms the theoretical notions.
The big difference being that the numbers could in practice give architects some leverage in negotiating and not simply relying on strategies to argue for more sustainable materials based on a project specific basis.

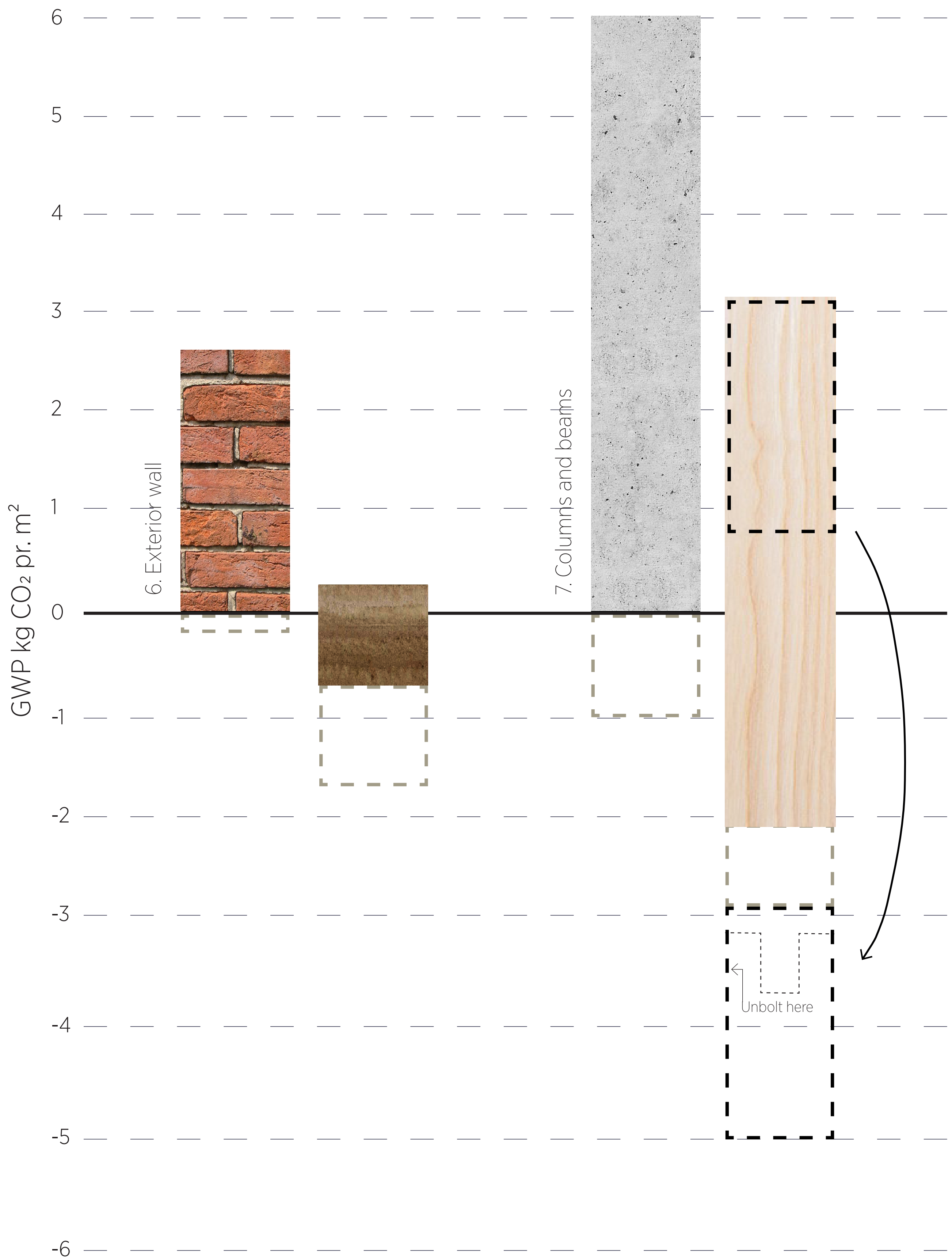


Fig 64: Conclusion of two building layers with the longest lifespan.

06.7 SCALE AND EXPRESSION

The LCA investigations introduction of rammed earth and a new understanding of the impact of scale showed the importance of the main chambers need to have an expression to justify itself.

Different sketches displayed here trying to capture a balance between establishing a system and breaking it in spots like the roof.

It Became clear that a strict and clear system was needed and that the structural system of the main chambers roof could be shown if opened up the big box.

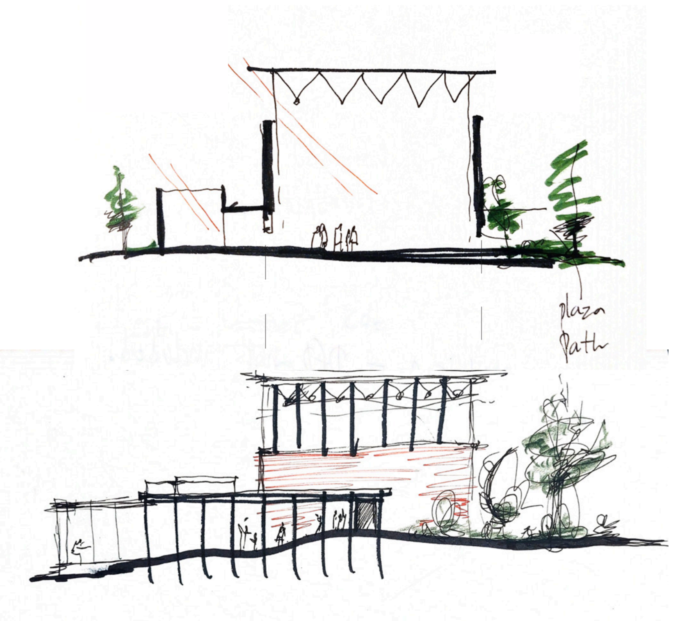


Fig 65: Opening up the main chamber box for the inside and the outside.

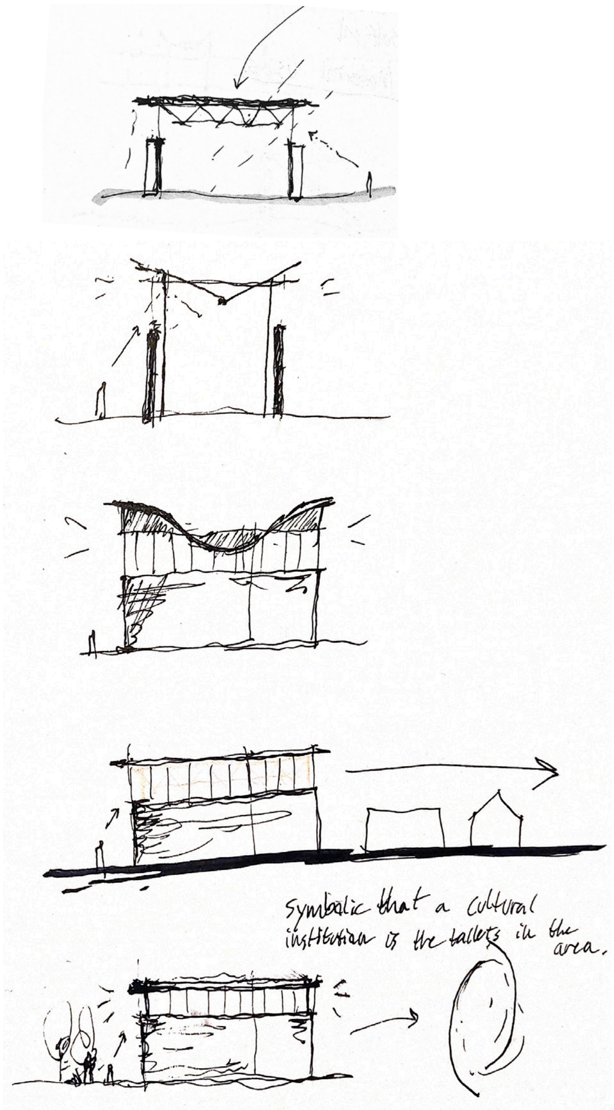
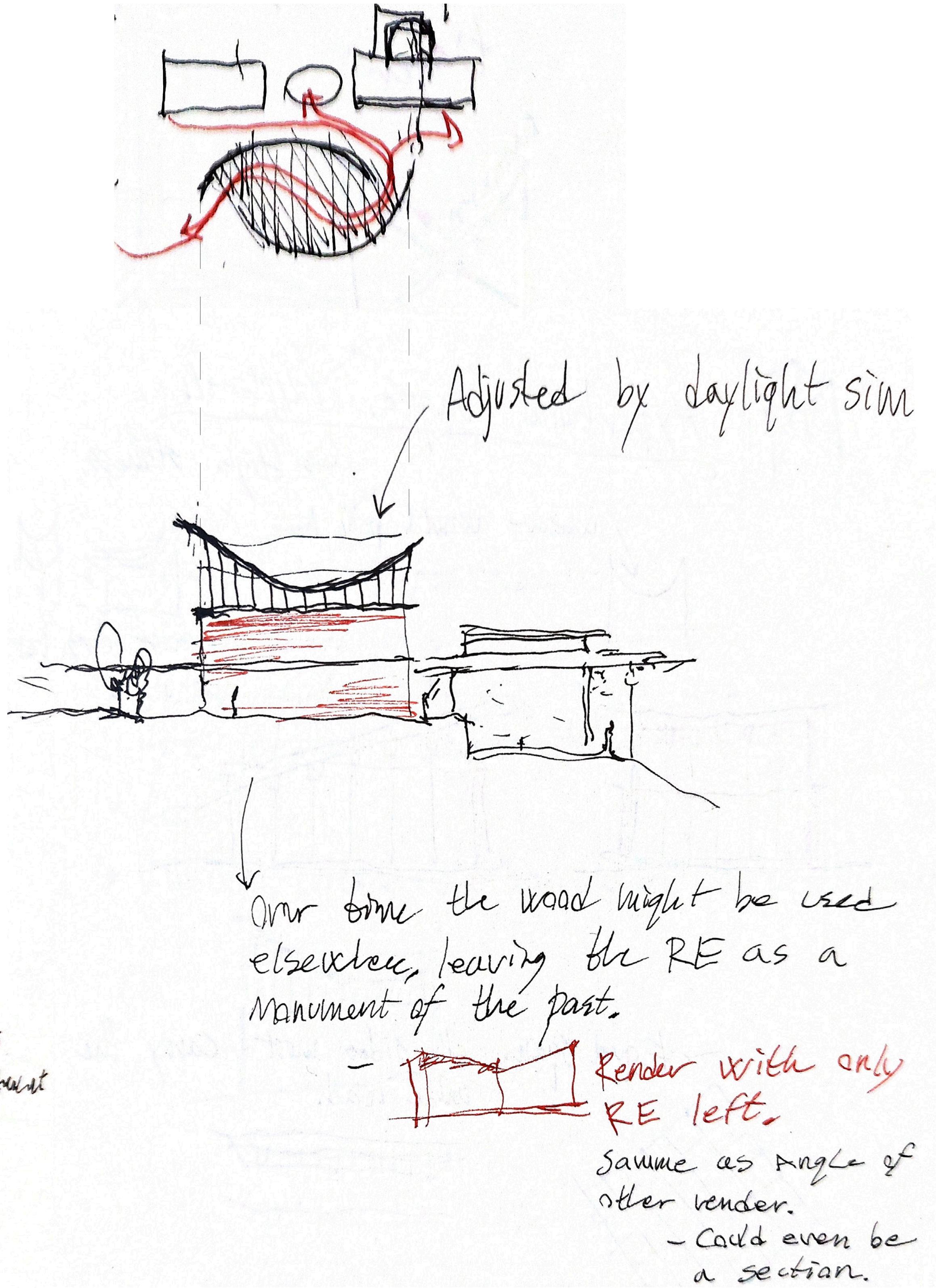


Fig 67: How to open up the main chamber



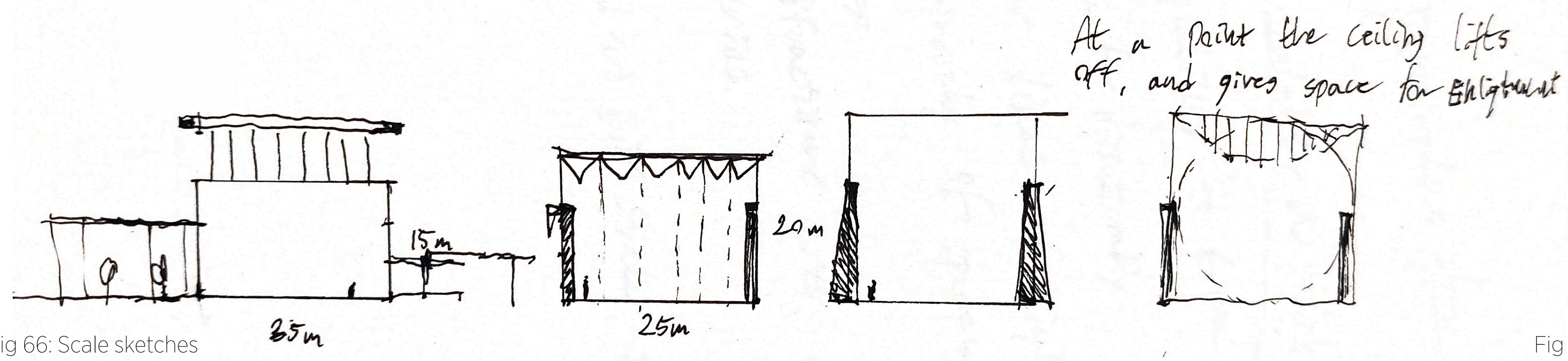


Fig 66: Scale sketches

Fig 68: Possibilities of Rammed earth integration and simulations that was tested.

06.8 ORDER OF RELATIONS

06.8.1 PRINCIPLES USE FOR PLANS

A 3x3m was introduced to conform to some building standards and use modularity and standardization to achieve a simpler overall construction system and layout that would allow for easier prefabrication and replacement.

The main chamber founds it form in a 25x25m square that the rest of the building could be constructed from.

Inspiration from Luis Kahn and to some degree Frank Lloyd Wright was used to establish a ruleset that would allow for integration into the design parameters without reinventing the wheel.

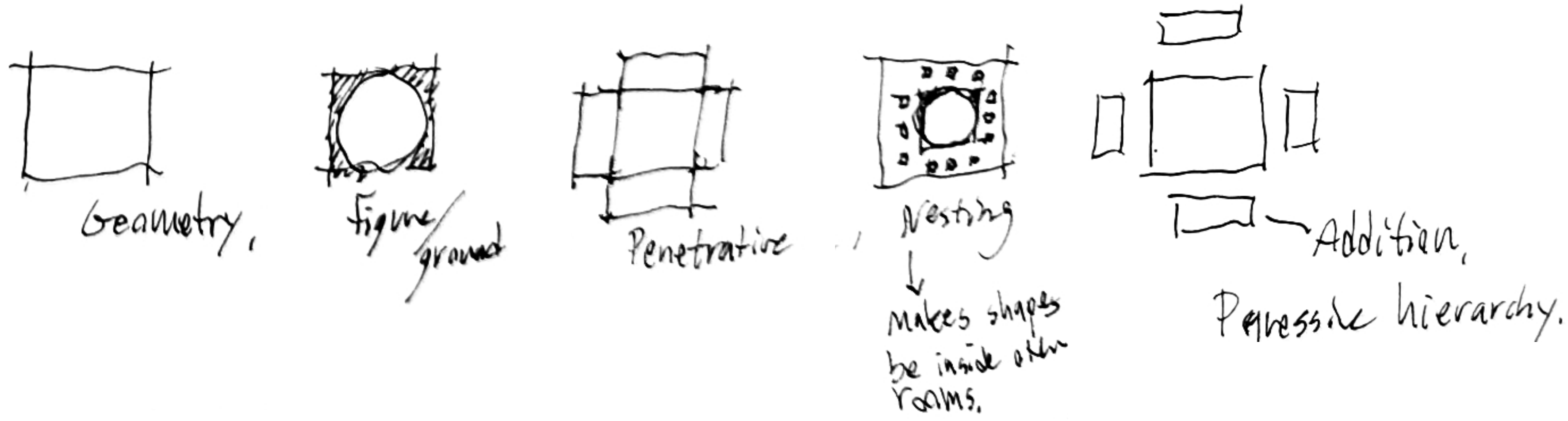


Fig 69: Louis Kahn and Frank Lloyd Wright inspired plan principles.

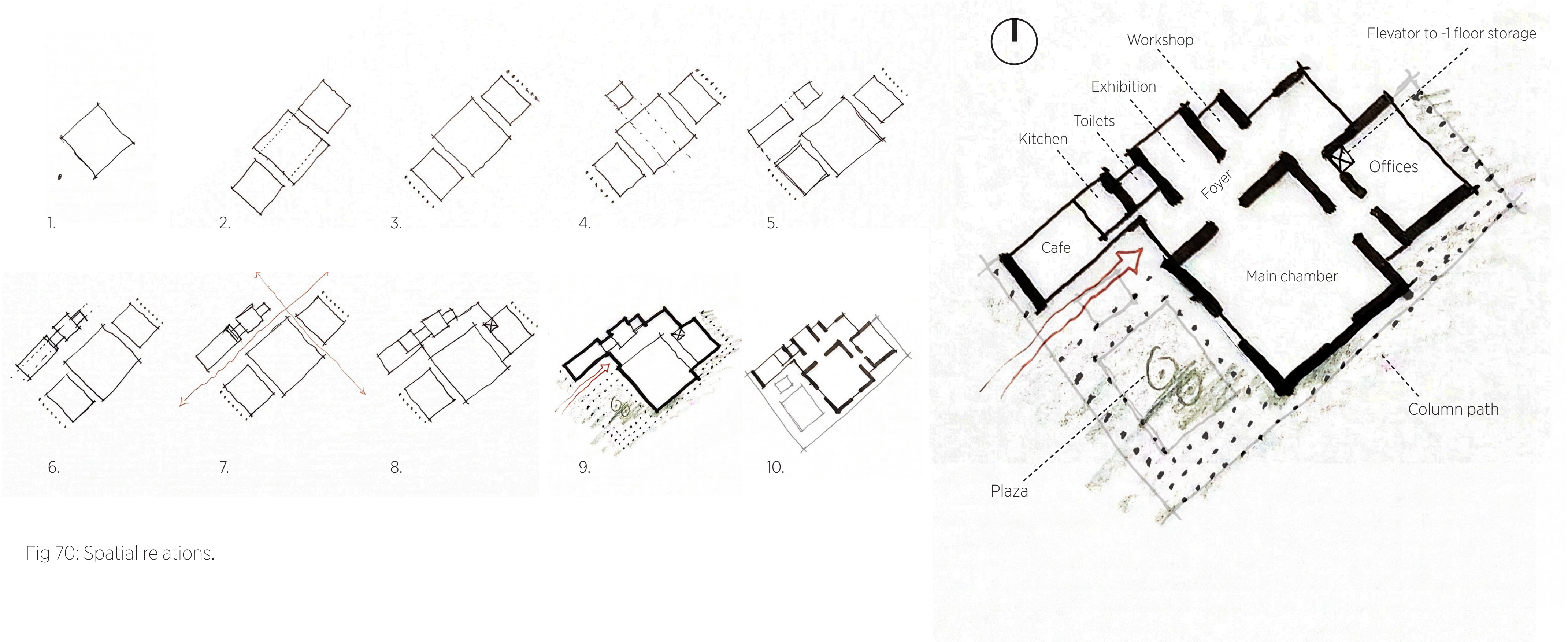
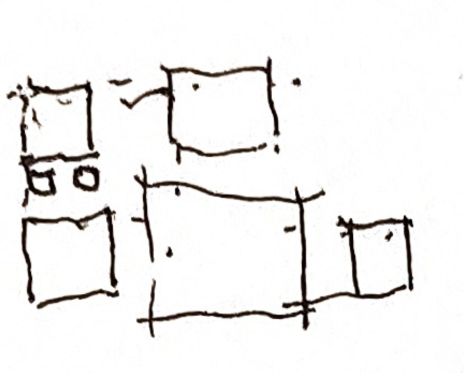


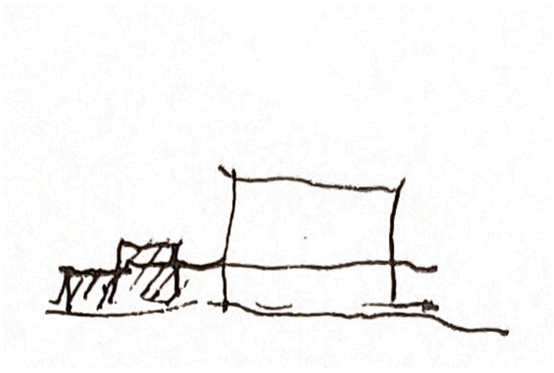
Fig 70: Spatial relations.

06.8.2 DESIGN PARAMETERS FROM SKETCHING

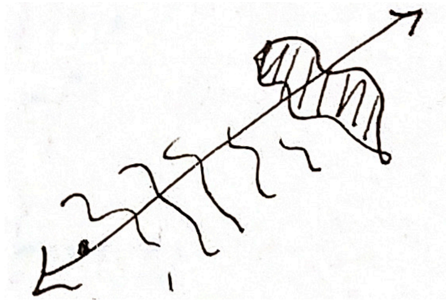
At this point on the design process several parameters and rules were established based on analysing varies different iterations.



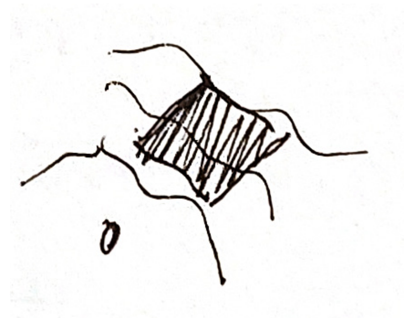
A. Order of relations



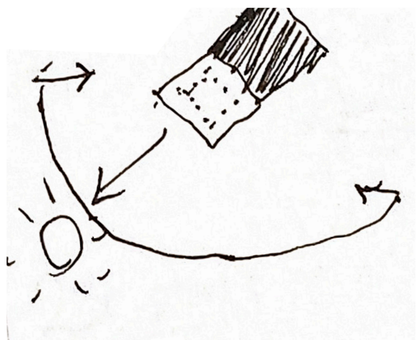
B. Vertical variation



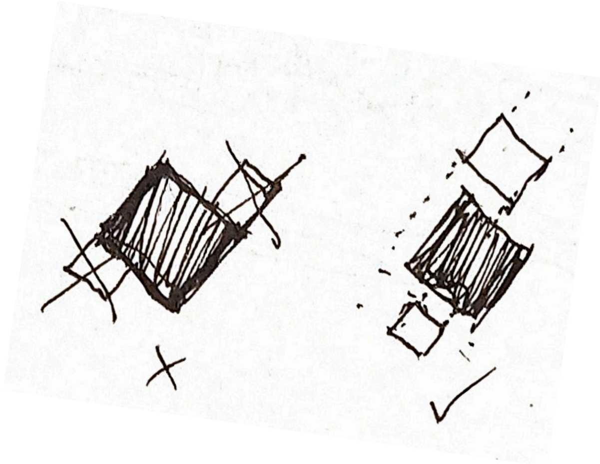
C. Use slope axis



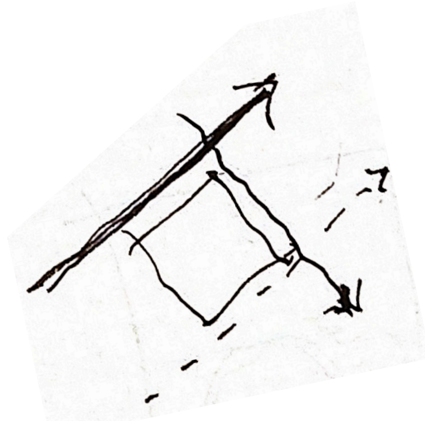
D. Main chamber near highest point



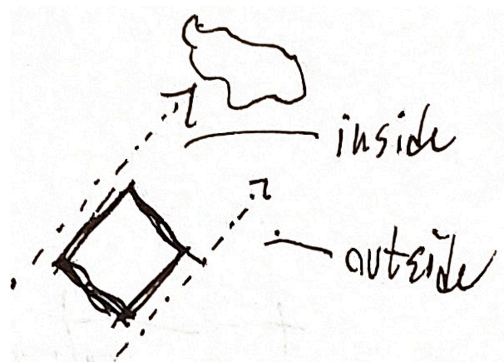
E. Plaza towards south-west



F. No aligned edges



G. Transparent layout



H. Interior and exterior use

Fig 71: Rules as conclusions from analysis various iterations.

06.9 DAYLIGHT AND SCENARIOS

Different scenarios were tested in the layout. It confirmed that the rational square main chamber with no columns would allow for a high amount of multifunctional flexibility.
A place where public lecturers, village gatherings or election voting could be performed and result in a versatile building.

Everyday use of the main chamber could be as a mix of exhibitions and an open office landscape with support from the café. Dividing doors can easily be rolled into the storage area on the same floor, or other larger events could be prepared with supplies directly to the door.

Quantitative daylight analysis was also performed and proved that plenty of daylight punctured the climate screen. The large overhang for the café was not a problem since the tall ceiling height allows a lot of daylight to enter deep in the spaces.

If anything, it showed that the main chamber should have the option of blinds to reduce daylight if the event taking place would require it even though the tall rammed earth walls shade most of the floor area.

The hallway area is darker on purpose to give a sense of scale different between the main chamber and foyer. Furthermore, the darker area is more private which is showcased in the less natural daylight such as the hallway down to the offices.

Fig 75: SDA analysis showing plenty of light due to the many large openings and high ceilings.

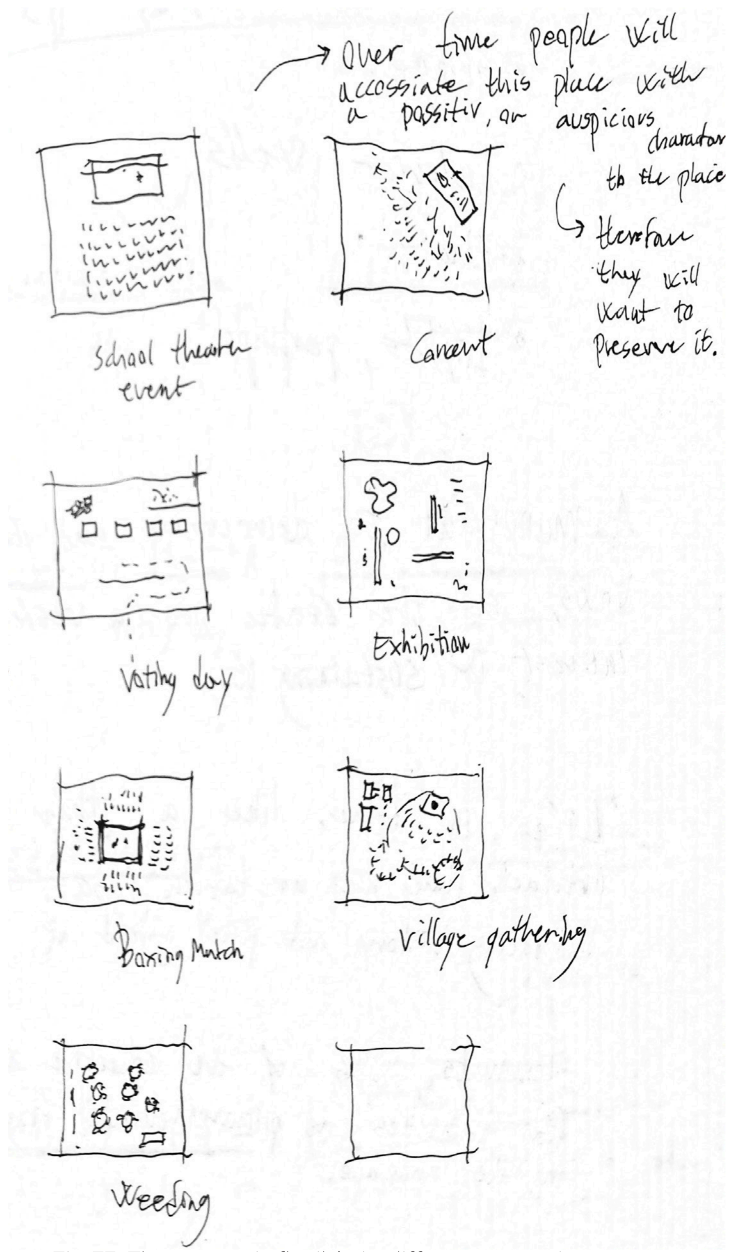


Fig 73: The square is flexible in different scenarios.

Fig 74: Different multifunctional activities.

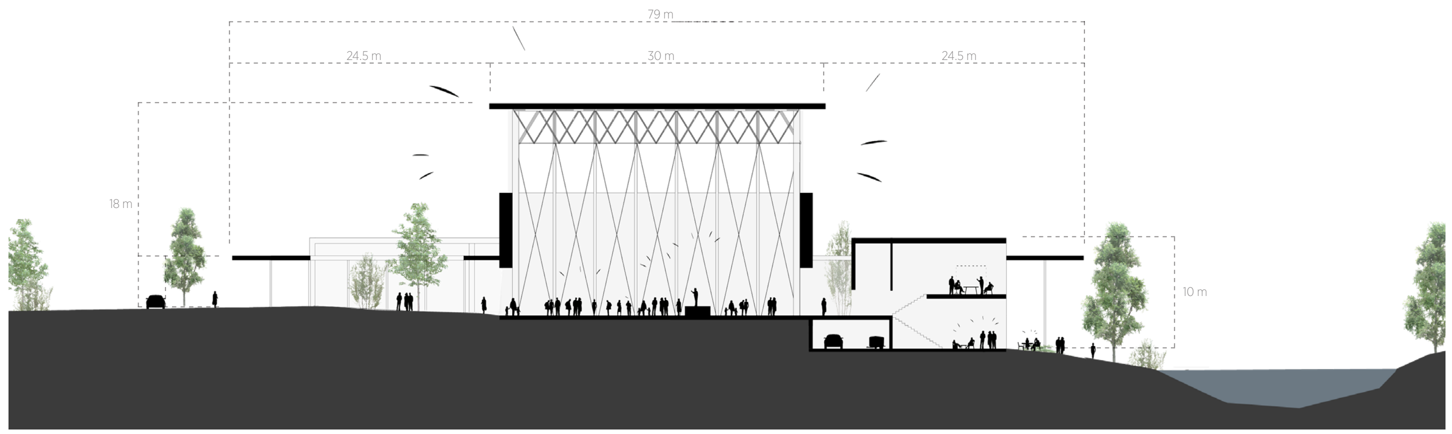


Fig 72: Section shown at the midterm presentation.

06.10 MAIN CHAMBER TRUSS AND COLUMN SYSTEM

The 3x3m grid in the main chamber could be solved in two ways. Either following the grid or offsetting it by 1.5m to hit the corners of the space. A space truss was introduced in the roof because if its good stiffness in the lateral direction and significant torsional stiffness (Bjørn, Eggen and Cruevellier, 2011, p. 230).

The offset system is the more traditional system since it has a column in the corner that can support the windows in that point. However, following the gird system and using a space truss system in the roof that was offset 1,5m showcase a dynamic system with an equal number of columns. The unequal number of columns in the purely offset system made the opening of the main chamber divided between a column.

Since the intent was to establish an association to the ancient geometric system, then the equal number of columns with the opening in the middle was the coherent option (Unwin, 2014, p. 44). Structurally the square space truss plan has a the high degree of statical indeterminacy allowing an irregular pattern of supports (Macdonald, 1997, p. 81).

Walkthroughs in VR also showcased that following the system had a stronger experiential effect when entering the space. The window corners would require a special connection, but the effect was worth it.

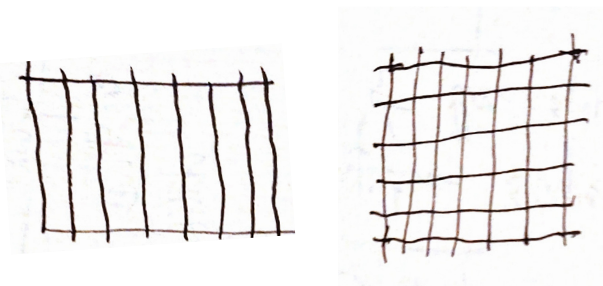


Fig 78: Left, plane truss plan. Right, space truss plan.

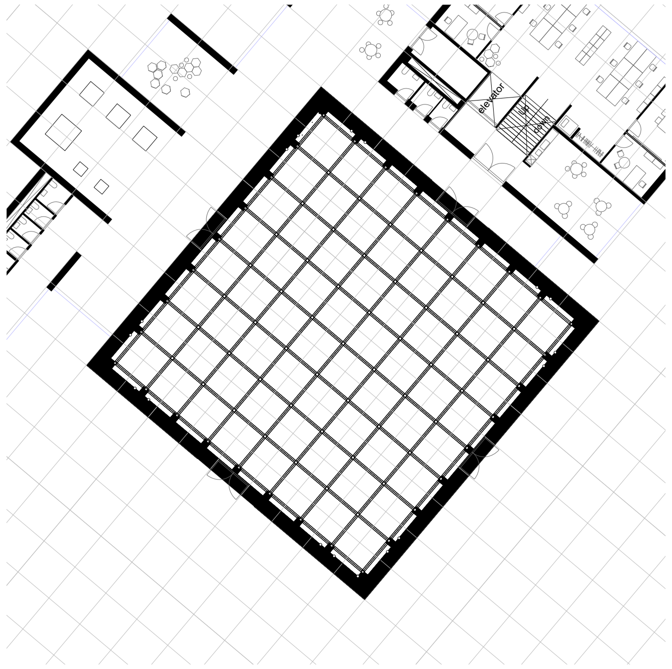
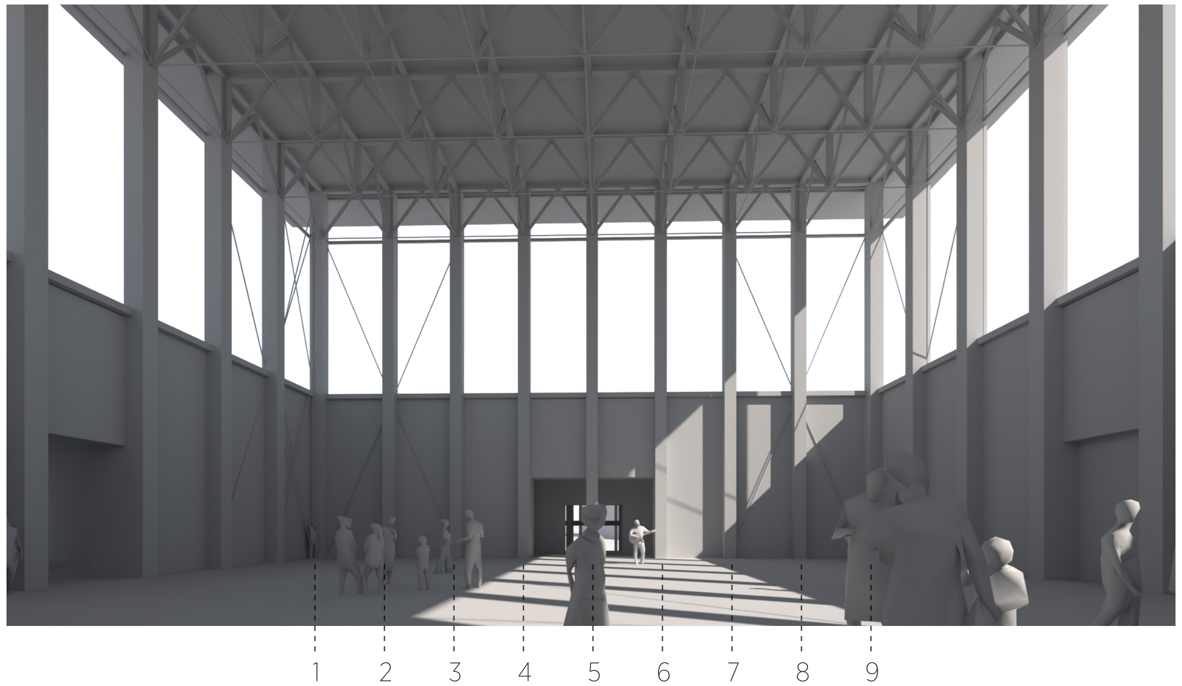


Fig 77: Space truss plan disjointed from the 3x3m grid.



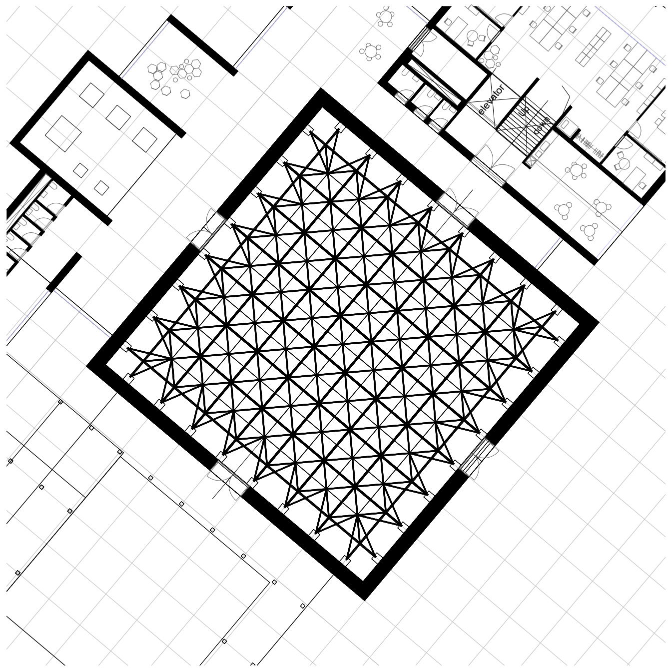
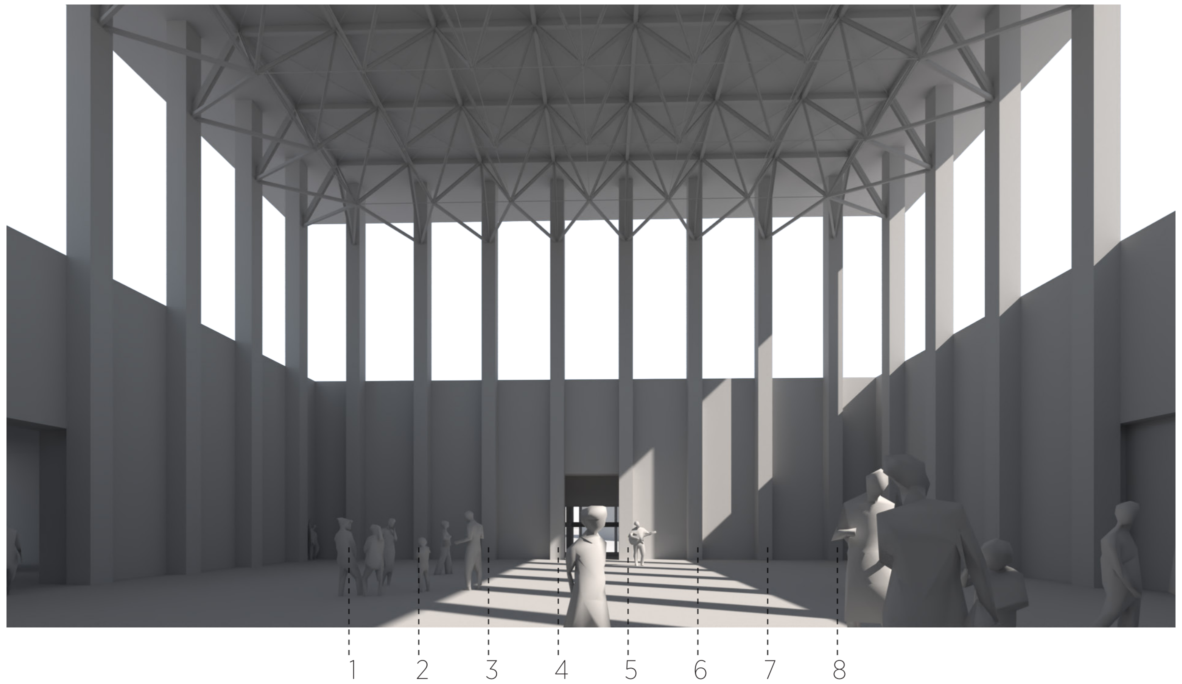


Fig 76: Space truss system integrated into the 3x3m grid.



06.11 STRATEGY OF STRUCTURAL STABILITY

After establishing the space truss in the roof as a viable option the structural stability and bending of the lower section of the main chamber was still in question.

Since the rammed earths mechanical properties are suited for compressive forces it cannot take horizontal loads and provide a base of stability (Ávila, Puertas and Gallego, 2022, p. 3). It can mainly carry itself and the large glass elements above it. A wire system is therefore introduced to stabilize underneath the space truss.

Rammed earth elements are incased in the top and bottom by ring beams, often in wood. The top ring beam is integrated into the columns to increase their efficiency when bending under vertical loads. Notably the space truss also stabilizes in all horizontal directions and is comparatively a light structure solution which reduces the load on the long main chamber columns prove to bending.

The load bearing wood construction is otherwise a column and beam system based on standards (Lilleheden A/S, 2017, p. 15).

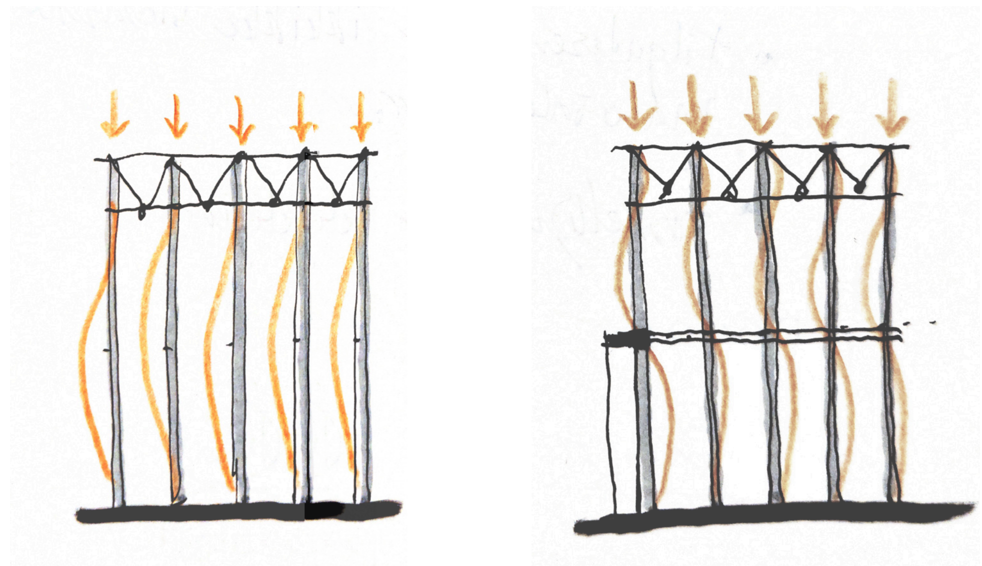


Fig 79: Vertical loads. Using the ring beam of the rammed earth to reduce the effective length of the long columns.

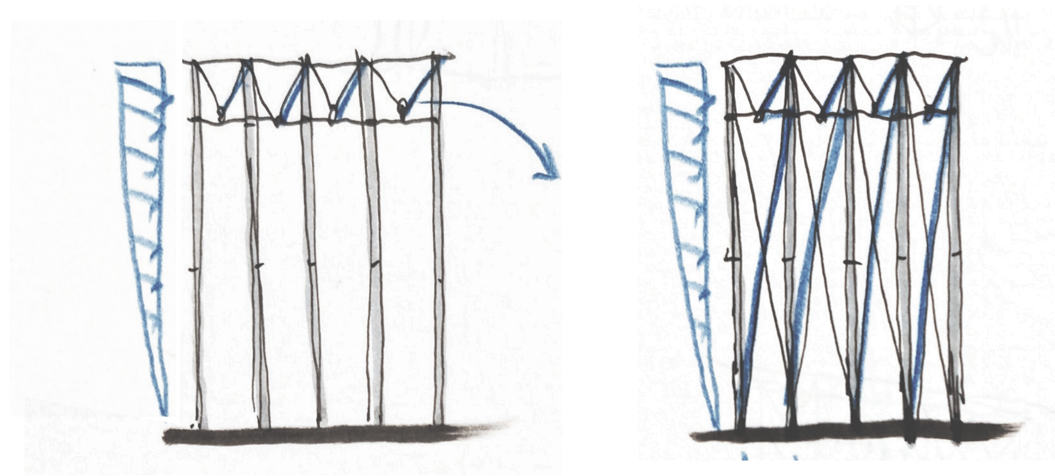


Fig 80: Horizontal loads. 3D truss for high horizontal stability and wires to transfer forces and give further stability.

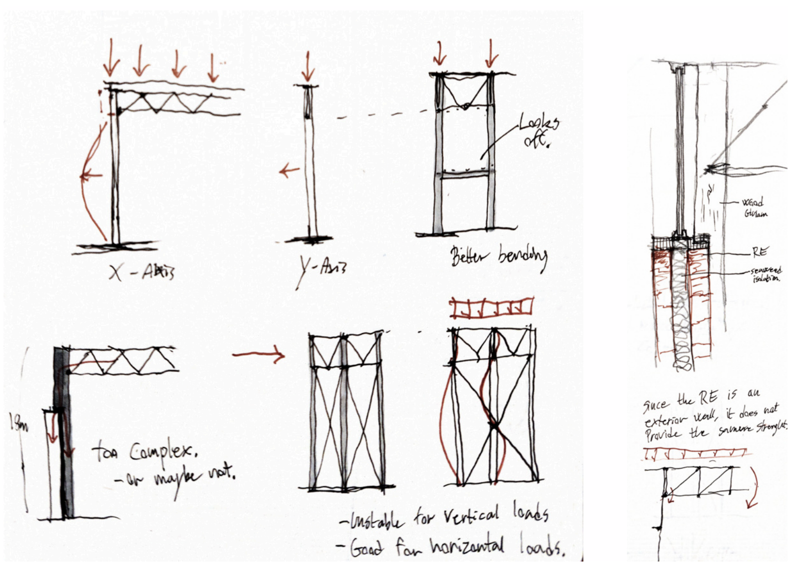


Fig 82: Sketches of identifying structural problems.

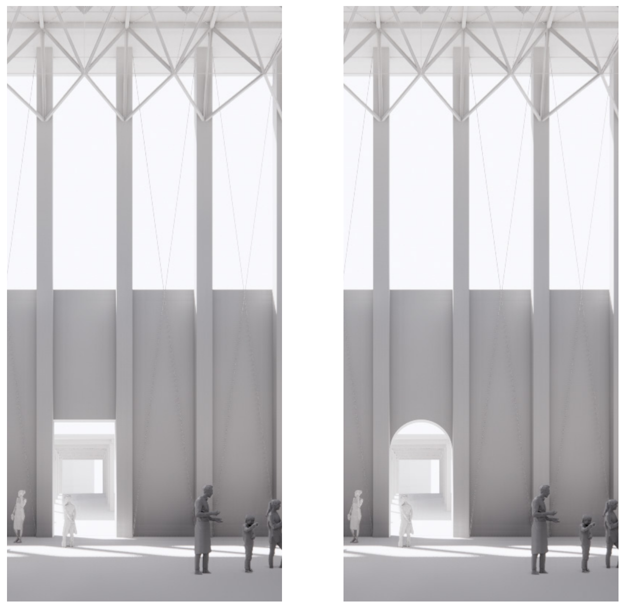


Fig 83: Adapting the rammed earth openings to work in compression by introducing a suitable arch opening.

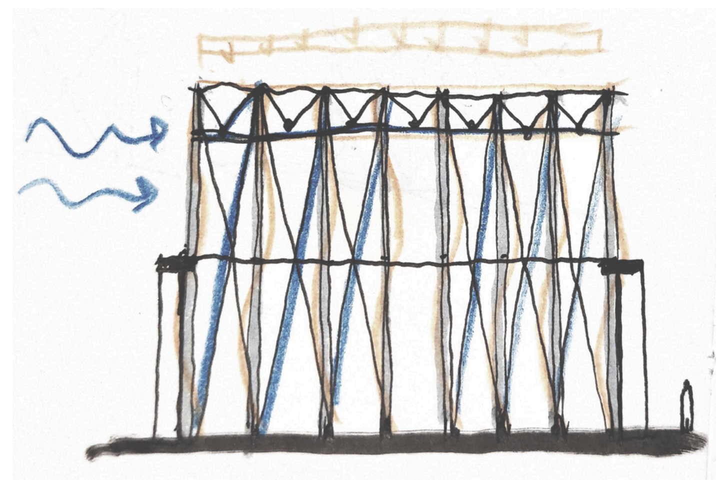
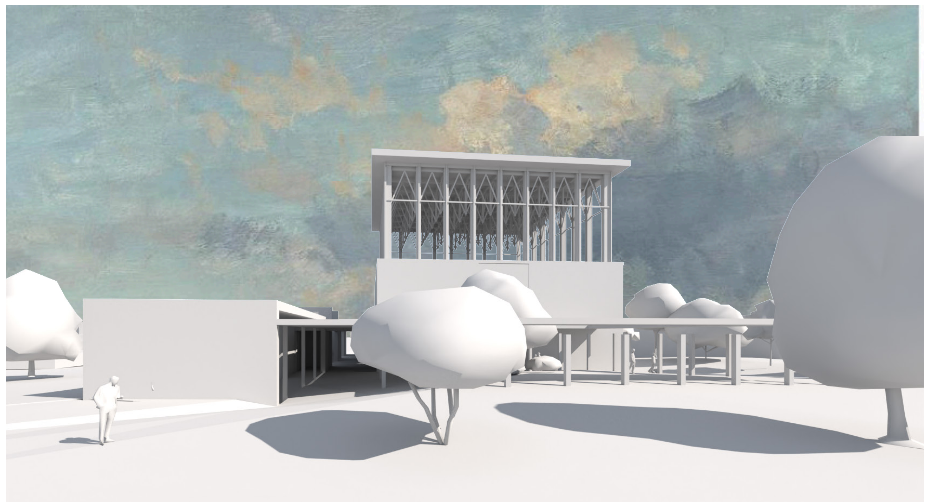


Fig 81: Structural system of the main chamber that allows for high stability from horizontal and vertical loads.

06.12 COMPOSITION

Too much glazing in the main chamber would create problems of excessive daylight and poor energy performance despite the rammed earths stabilizing thermal mass.
A balance had to be reached between the opening in the main chamber and the rammed earth. The solution was to divide it equally and provide an overhang of the roof to reduce solar gains of the summer months. Otherwise, the building should be offset into smaller parts as seen throughout Nye.



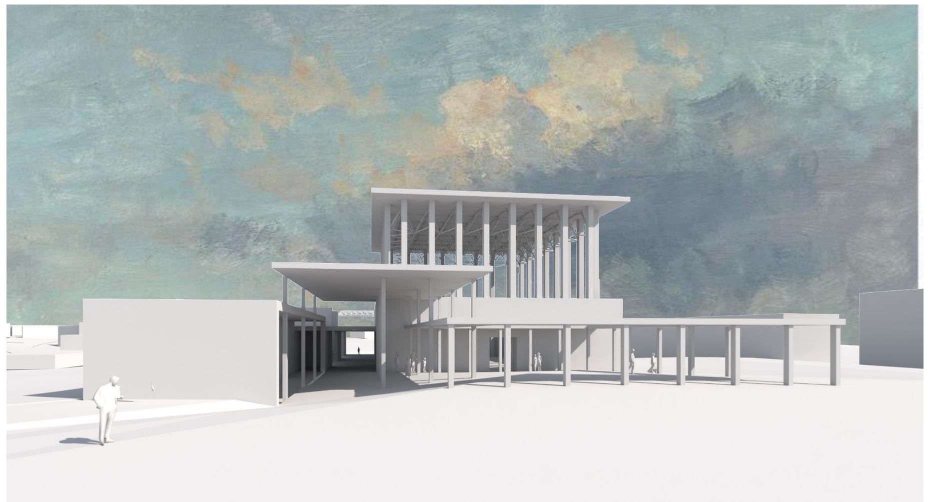
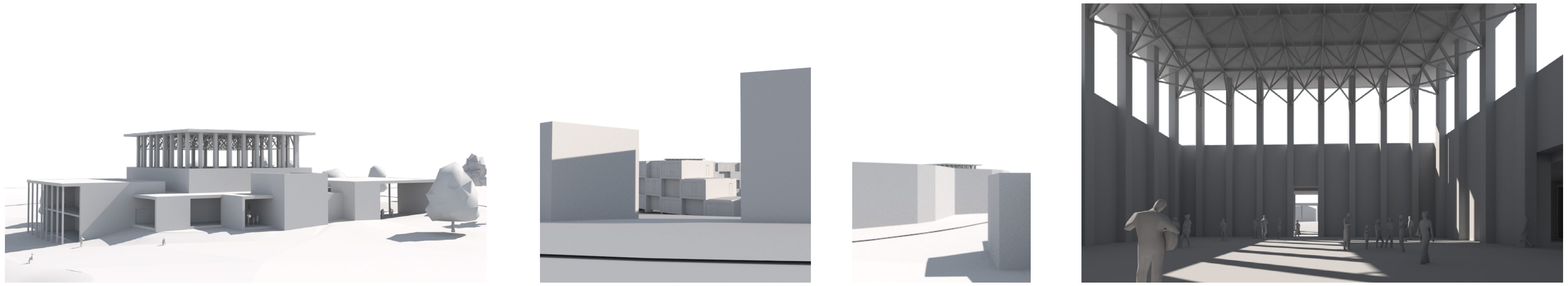


Fig 84: Comparison of different vertical system of the three elements; the plaza, the main chamber and the surrounding system.

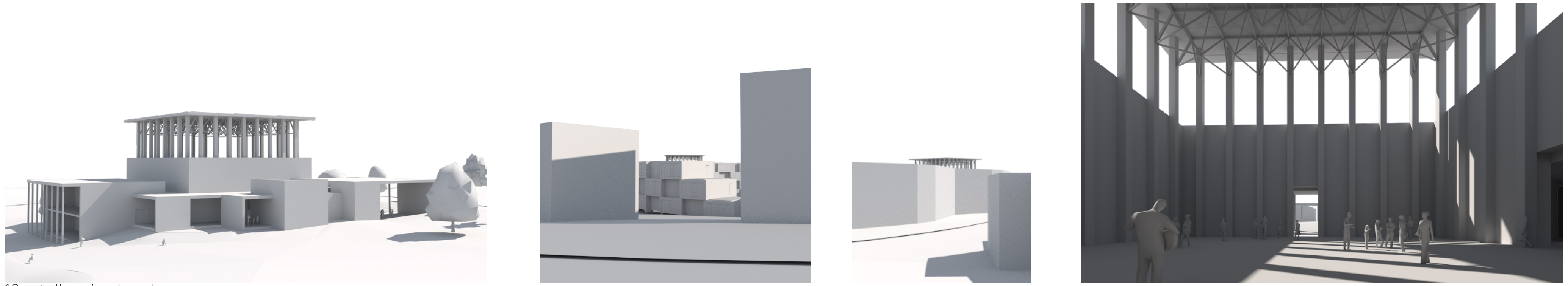
06.13 HOW HUMBLE IS TOO HUMBLE?

A balance subsequently had to be reached with the height of the main chamber and its context. Too low or too tall would both have detrimental effects to either the monumentality or the sensitivity to the context.

After several investigations it was clear that lower then 19m would not suffice since the building disappeared into the skyline of the city. In a humble gesture the main chamber was consequently set at 19m tall.



16m tall main chamber



19m tall main chamber

Fig 86: Analysing the minimum required scale to achieve a landmark height in the context.

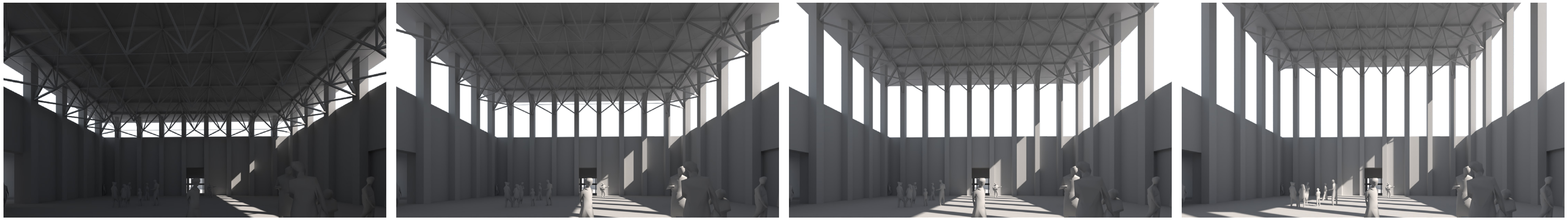


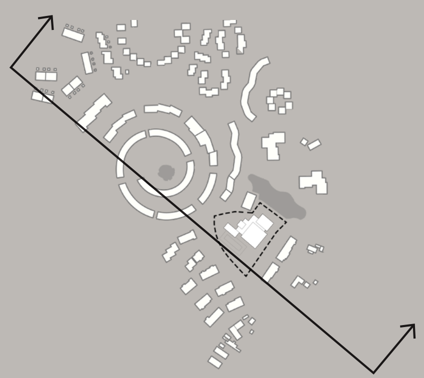
Fig 85: Main chamber height and daylight investigations.

07 PRESENTATION

07.1 PAST, PRESENT AND THE FUTURE

The presentation chapter is the conclusion of the design process.

In essence the sustainability center should weave the principles of integrated architecture, sustainability theory and a promise for a greener future in a democratic context.



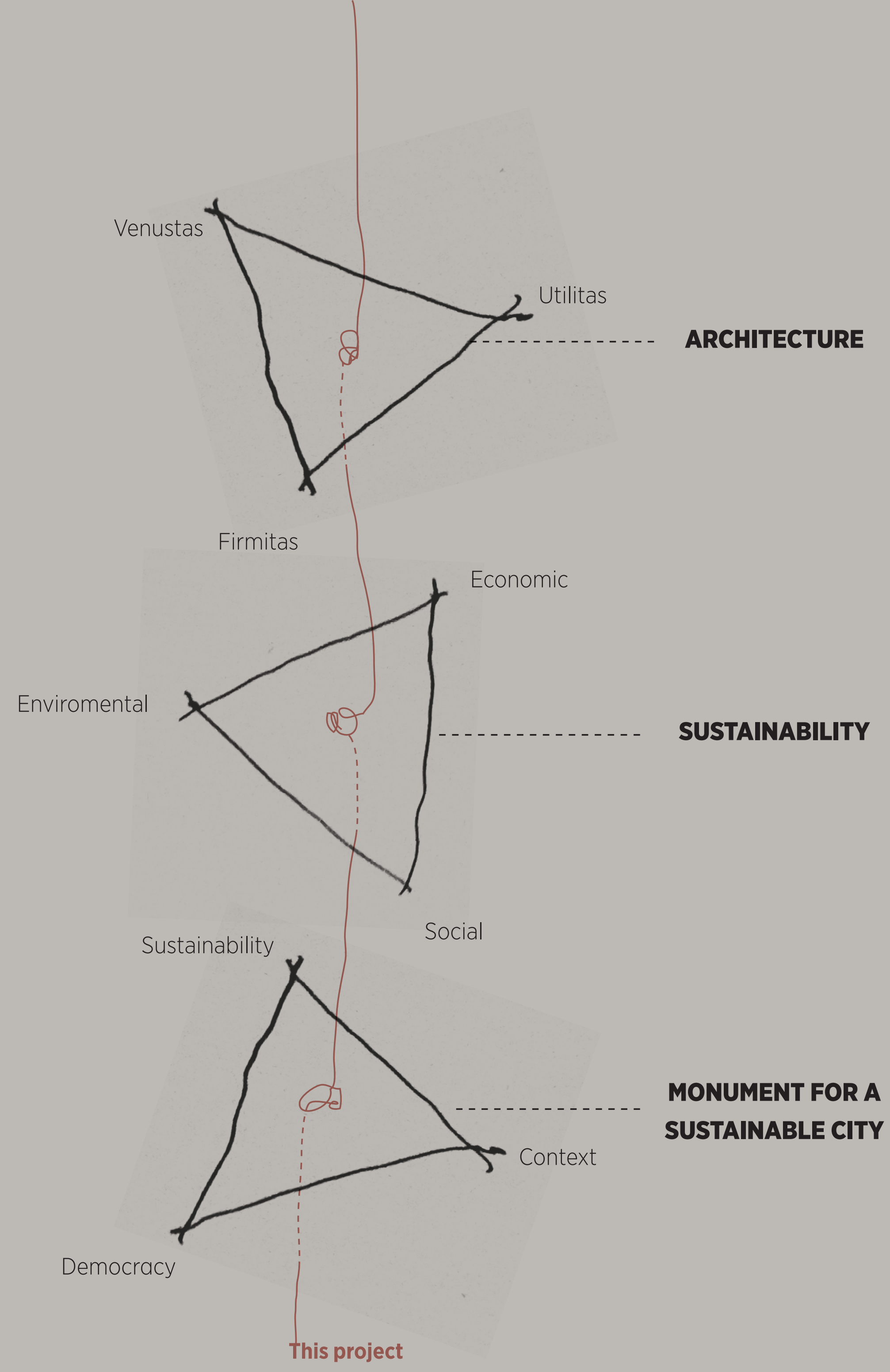


Fig 88: The balance and weaving of concepts.

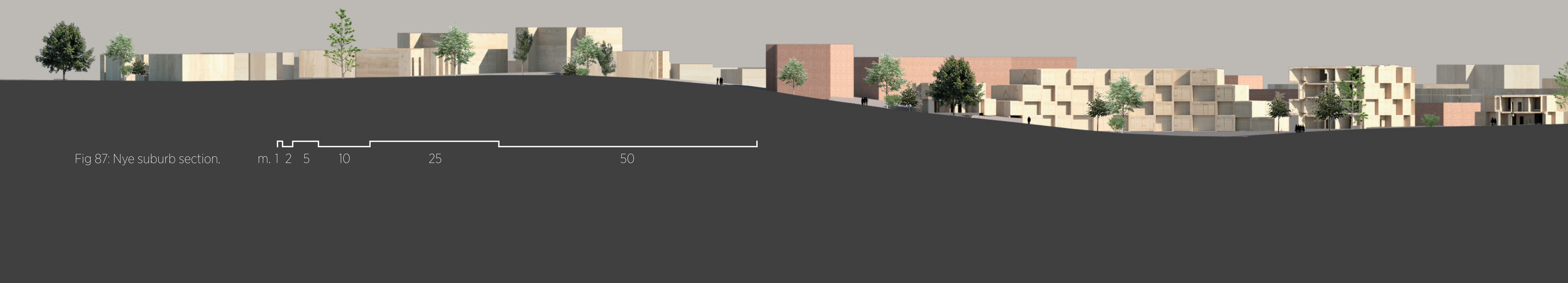


Fig 87: Nye suburb section.

07.2 AN URBAN ARTIFACT

07.2.1 A CULTURAL LANDMARK

The main chamber protrudes slightly above the context. A clear but humble landmark in Nye that showcases where activity is brewing.

The structural system in wood inside the main chamber gives a warm and inviting glow in the evening when cultural activities take place.

As an urban artifact the building will be a defining character in the environment and will be a marker for further development of the area over time.

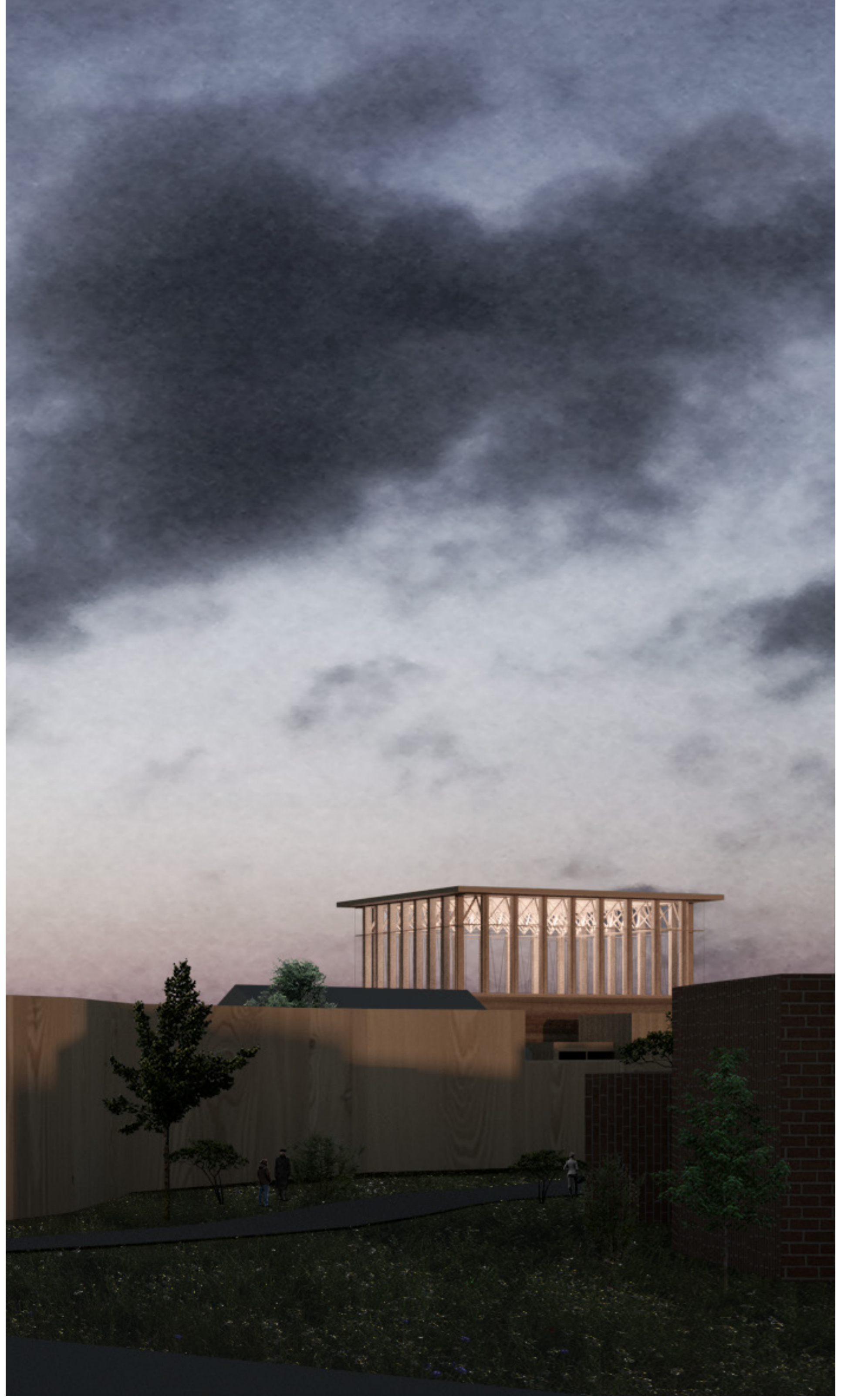


Fig 89: Exterior view of the main chamber lighting up in the evening.

07.2.2 ELEVATIONS

The base of the building and the supporting functions blend into the context.

The plaza follows the natural curvature of the landscape and functions as a meeting place in the warmer months and funnels people into the rest of the building.

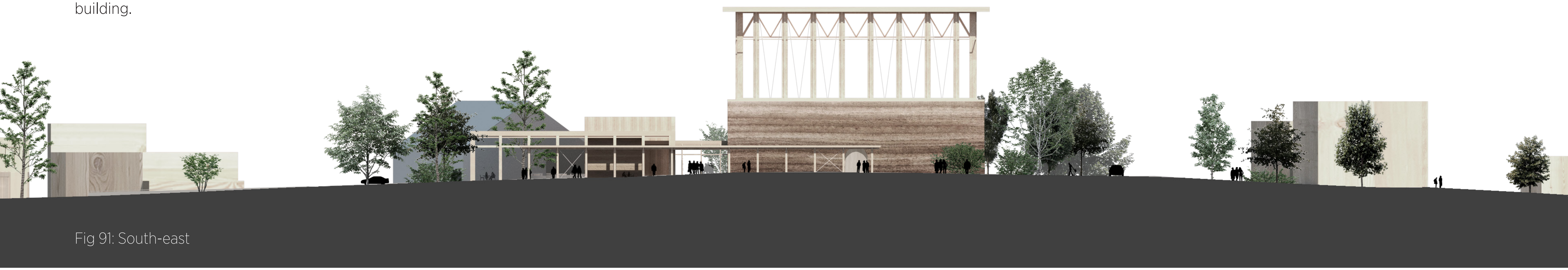


Fig 91: South-east

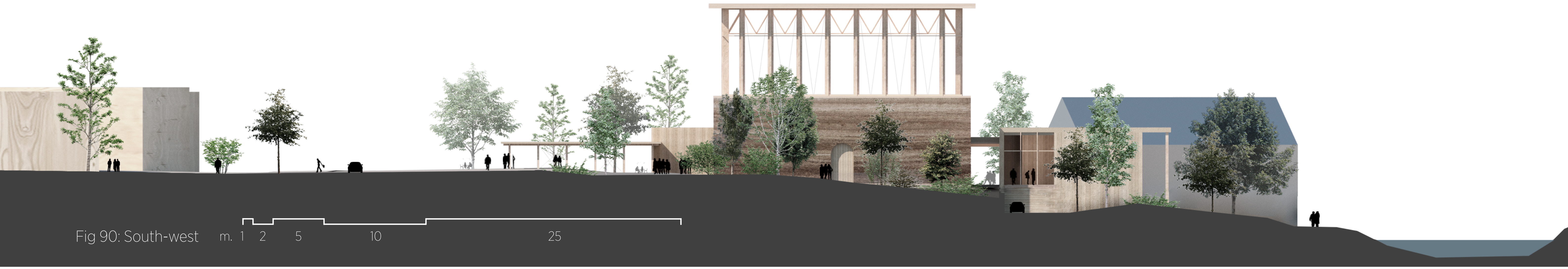


Fig 90: South-west

The different volumes of the building protrude up or down to create a subdivided shape readable from the exterior. Columns and direct lines of sights through the building makes the base blend into the landscape.

Fig 92: North-east

Fig 93: North-west

07.2.3 SITE PLAN 1:500

Fig 94: Situation plan 1:500.

Fig 95: The agora inspired plaza is what people physically meet first. Following the landscape it provides shelter in a more human scale compared to the main chamber

07.2.4 MEETING THE BUILDING

Walking in the hilly landscape with the view of the top of the main chamber will lead people to the plaza at the highpoint in the area.

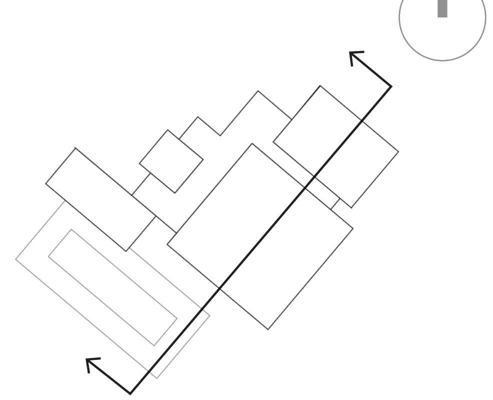
The plaza is directly integrated into the café, which over time will replace the temporary café in the area and be a casual way to pull people to the plaza.

Walking the paths of the plaza will either guide people into the Foyer or directly into the main chamber.

The plazas overhang makes it structurally more efficient since its beams are continues along their short axis. This creates a negative moment at the points of the columns which in effect reduce the bending moment on the beams.

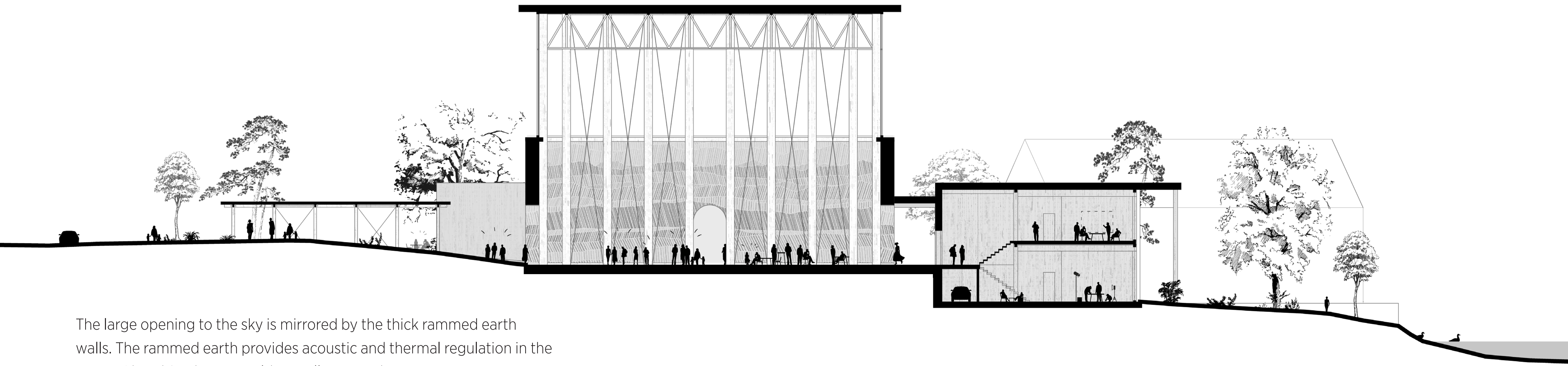
07.3 A SPACE TO FOSTER REVERENCE

07.3.1 SECTION 1:250



Entering the main chamber people meet a strong contrast between the monumental space and the restrained characteristic of the suburbs.

A distance of 1.5m under the rammed earth arch of the door and in between the wood columns framing it let people free in a large uninterrupted space with the large columns that is a defining feature of the building.
The offset space truss in the ceiling and the lack of a column in the corner creates some drama of a space without a defined end.



The large opening to the sky is mirrored by the thick rammed earth walls. The rammed earth provides acoustic and thermal regulation in the space. Absorbing heat or cold as well as sound.

Fig 96: 1:250 section.

Fig 97: The School of athens debating in the main chamber.

07.4 LAYOUT AND INTENT

07.4.1 LVL 0 1:250

1. Main chamber
2. Plaza
3. Foyer
4. Cafe
5. Kitchen
6. Exhibition space
7. Workshop space
8. Open office landscape
9. Adm. Office
10. Storage
11. Toilets
12. Elevator
13. Shared working space / Backstage

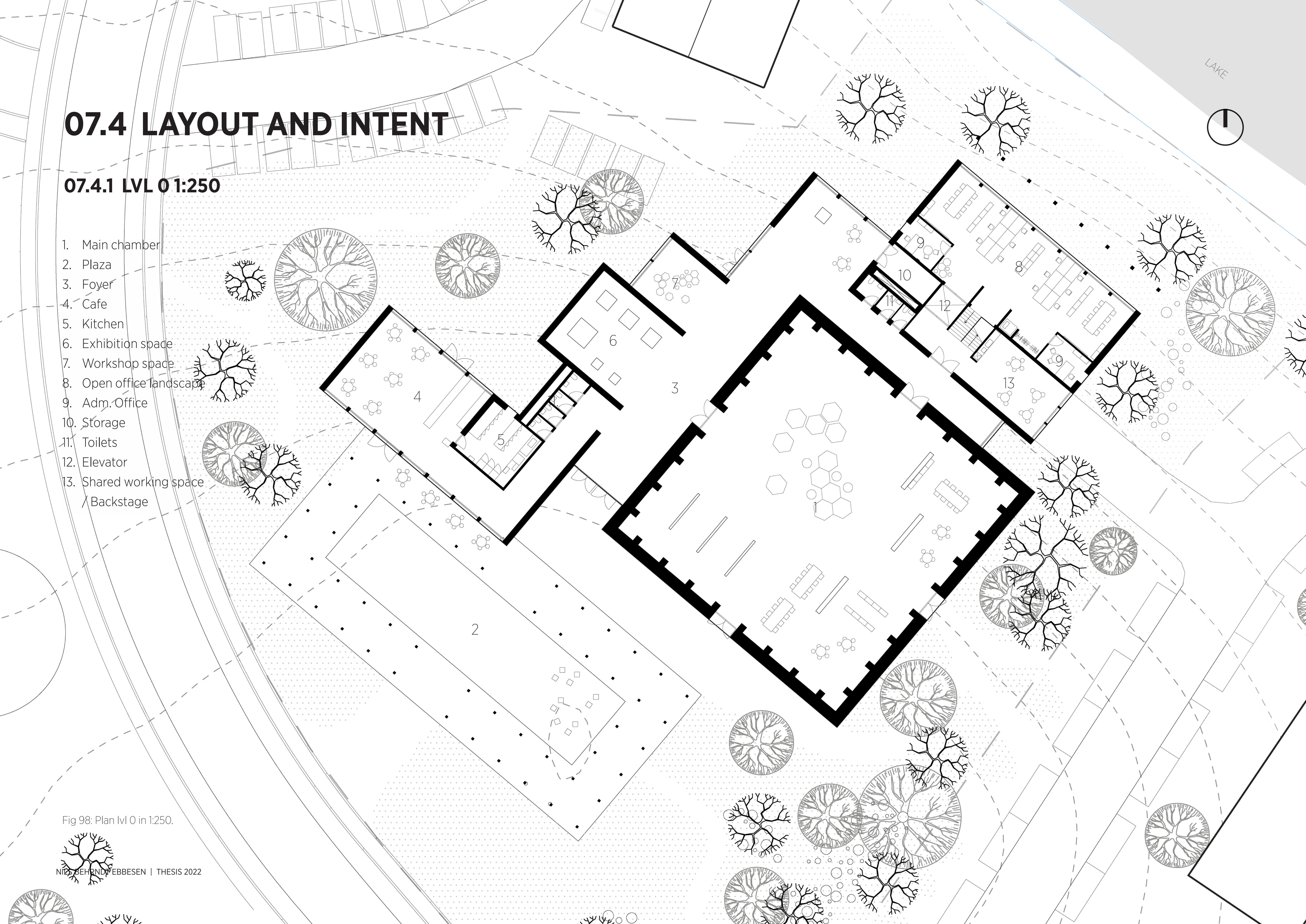
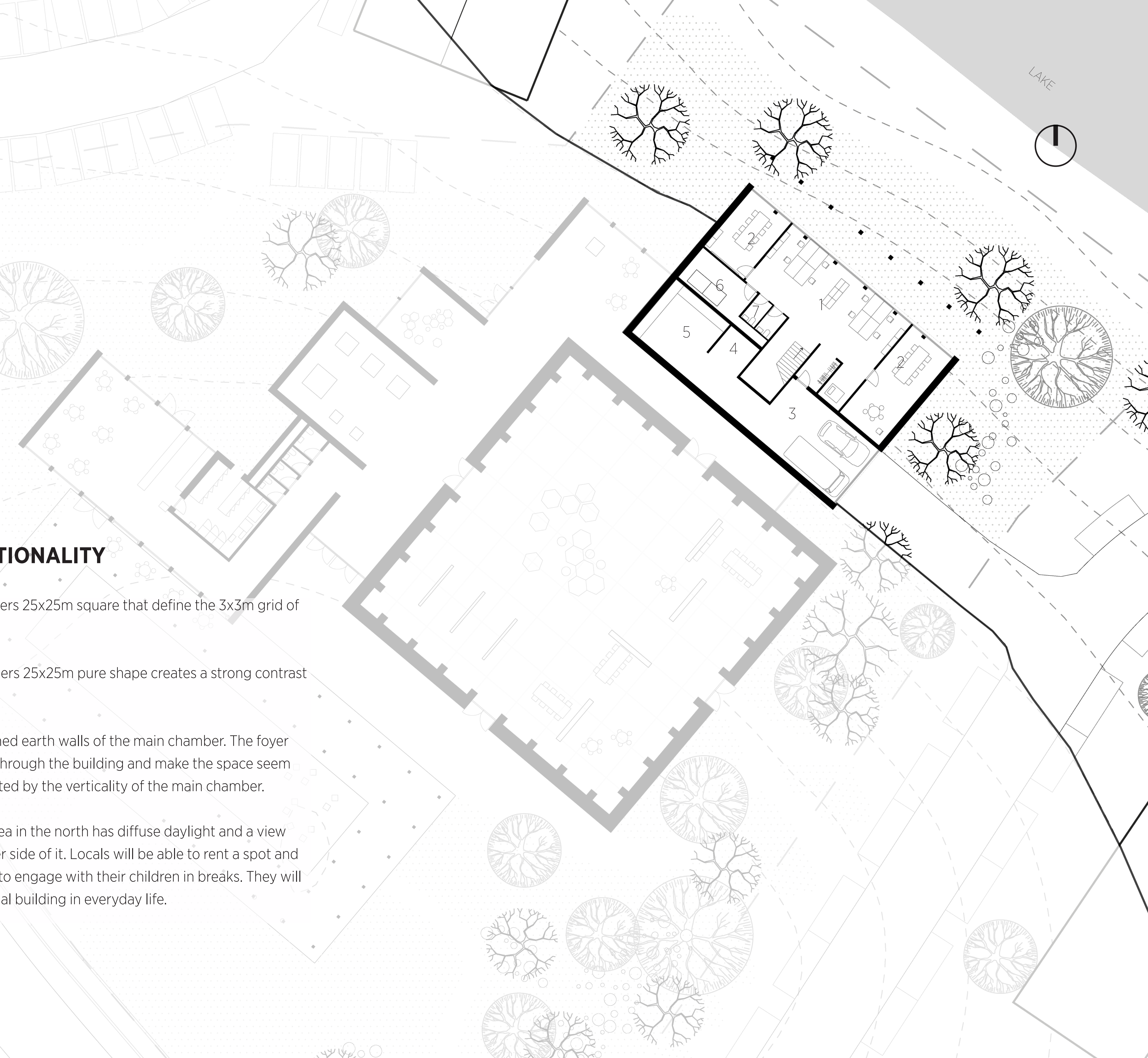


Fig 98: Plan lvl 0 in 1:250.

07.4.2 LVL -1 1:250

1. Open office landscape
2. Seminar rooms
3. Stock delivery
4. Elevator
5. Storage
6. MEP room
7. Toilets



07.4.3 RELATIONS AND RATIONALITY

The plan is developed form the main chambers 25x25m square that define the 3x3m grid of the rest of the building.

The wild growth up against the main chambers 25x25m pure shape creates a strong contrast of nature meeting culture.

All functions lead to the characteristic rammed earth walls of the main chamber. The foyer and its spaces along it have direct views to through the building and make the space seem longer and more horizontal in scale, contrasted by the verticality of the main chamber.

The rational system of double floor office area in the north has diffuse daylight and a view to the lake and the kindergarten on the other side of it. Locals will be able to rent a spot and work close to home and potentially be able to engage with their children in breaks. They will also bring more activity to the multifunctional building in everyday life.

Fig 99: Plan lvl -1 in 1:250

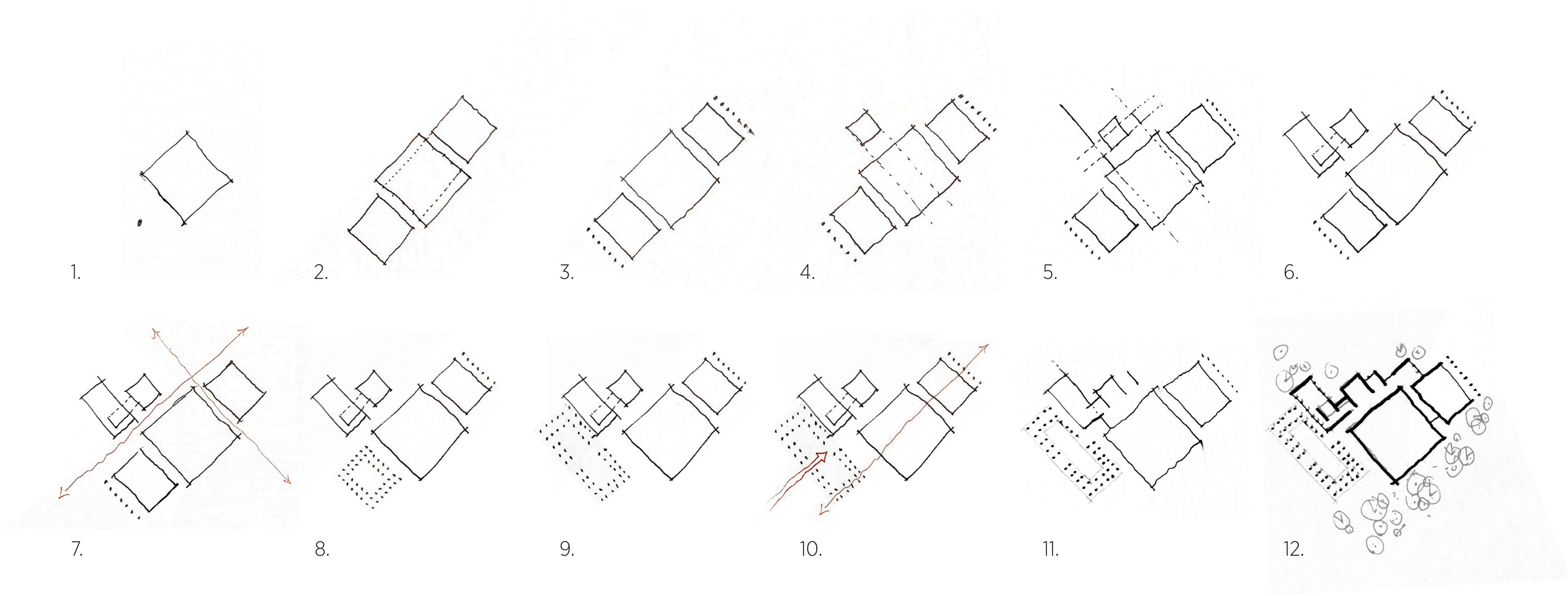


Fig 100: Sequence of how the building is generated from the relation with the main chamber as a starting point.

07.4.4 CLEAR LINES OF CONNECTION

The system of relation to the main chamber results in an interlinked and transparent layout.

Transparency is important for an institution created to inspire debate and action. People go where other people are and their visibility is therefore important for creating the framework for a chance to share ideas.

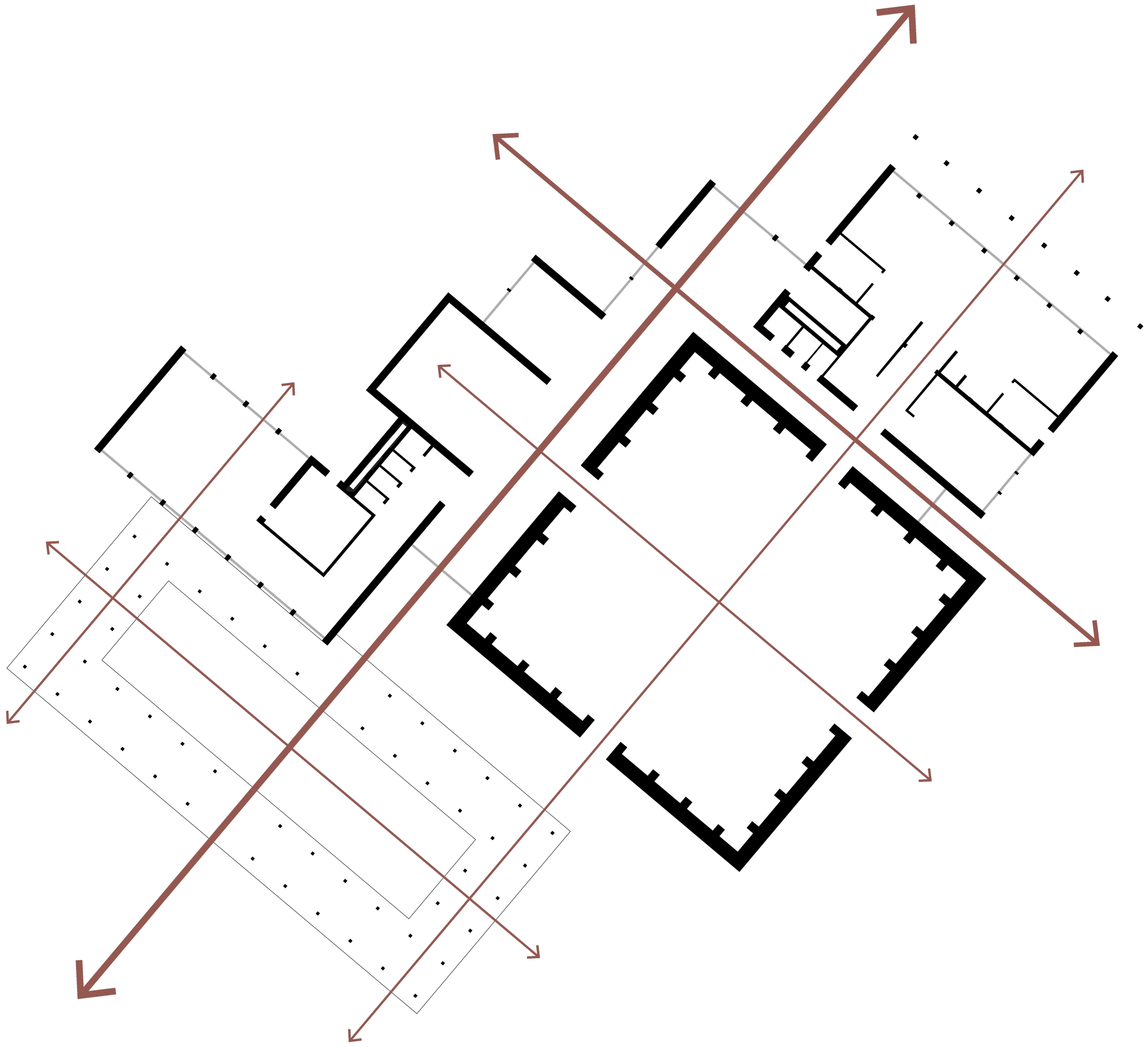


Fig 101: Hierarchy of the lines of sight.

07.5 MULTIFUNCTIONAL COMBINATIONS

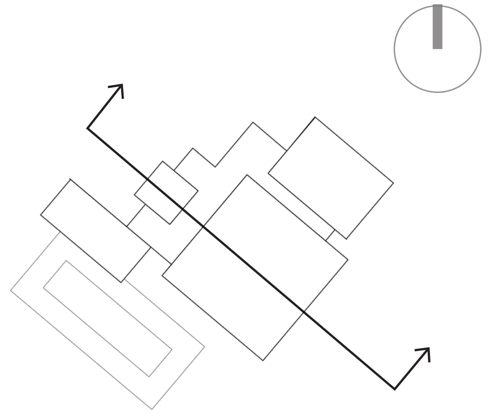
The system of clear lines of connections is deliberately broken at the exhibition space as it should be a place to stop and wonder.

It is therefore designed with a roof opening to allow for thoughts to wonder and daylight to enter with a characteristically different effect. The space is well suited for sculptures and other installations that require one directional natural lighting.

On occasion the exhibition space can be integrated into a larger exposition in combination with the main chamber.

Blinds or large curtains are integrated in the main chamber if an event needs less or no sunlight, even though the direct sunlight hitting the floor of the space is limited because of the tall rammed earth walls.

The two southern side can potentially be shaded of and still allow for diffuse daylight from the two northern facades.



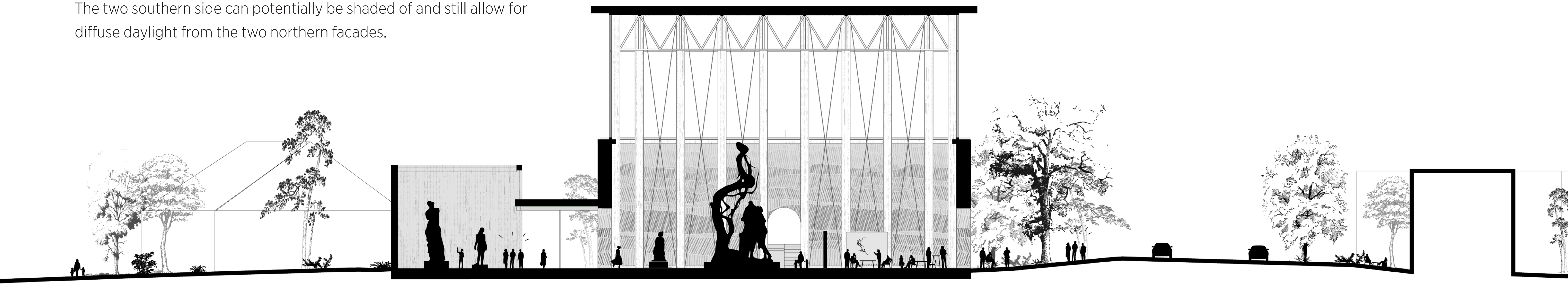


Fig 102: 1:250 Showcasing an art exhibition and event.

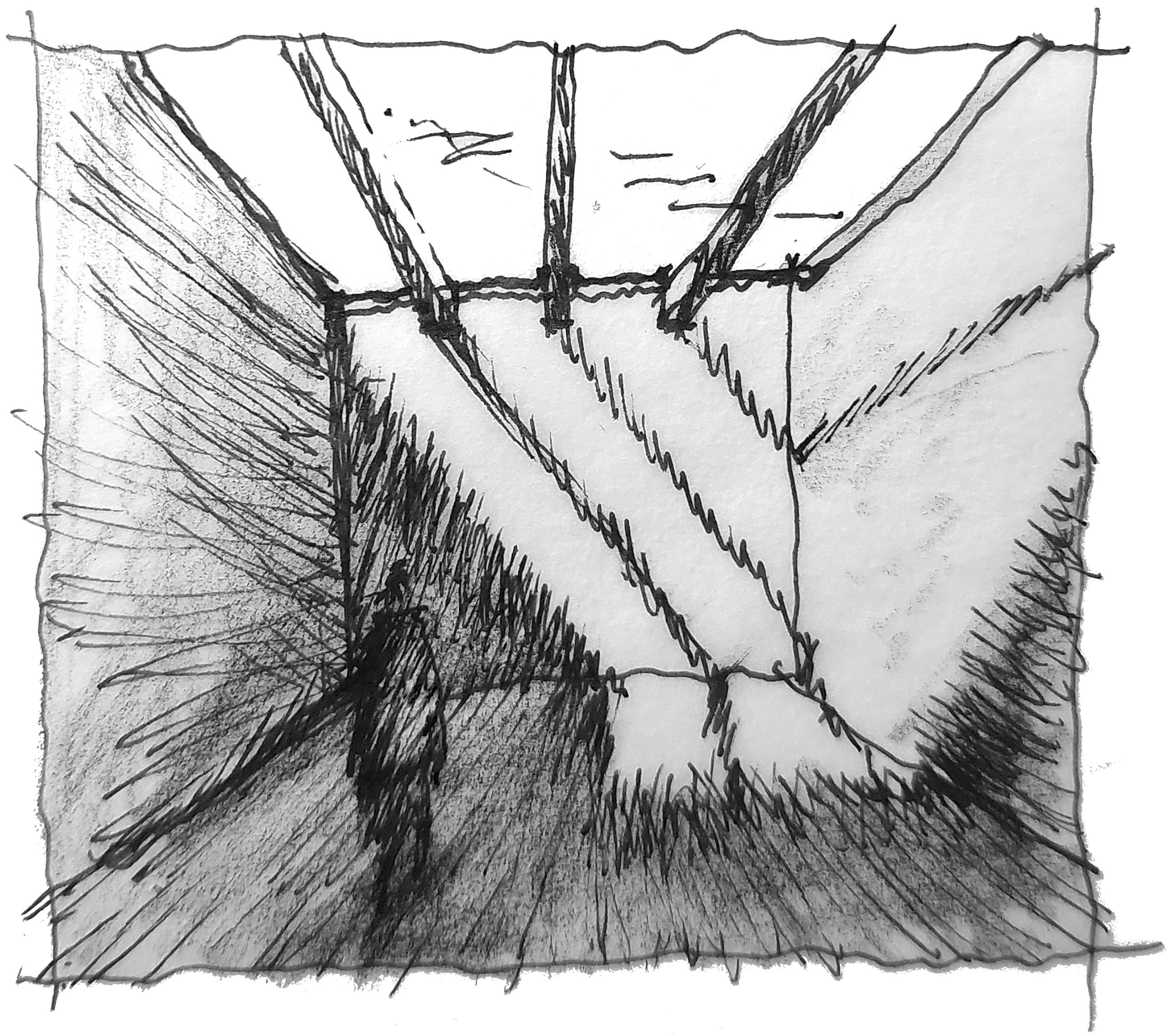


Fig 103: Exhibitions space light and shadow gesture.

07.5 ADAPTABILITY

07.5.1 RATE OF CHANGE

Functions melt form unless designed to adapt and institutional buildings are therefore often mortified by change. Here change is allowed and designed into the system and offset by the stability of the monumental space in the main chamber. Whereas the commercial setups such as the offices and café are persistently metamorphic.

In this way the building can learn from the people using it and they will subsequently learn something in return (Brand, 1994, p. 128).

This sets the framework for an organic development. Scale matters for attracting functions and the surrounding area can adapt to support the functions that the main chamber attracts.

The low rate of change zone is in therefore further stabilized by the continues evolution of the higher rate zones surrounding it.

The column and beam system allows for high flexibility. Perhaps over time the plaza will be integrated into a closed structure behind a climate screen. It nevertheless is a structural basis for imagination and implementations.

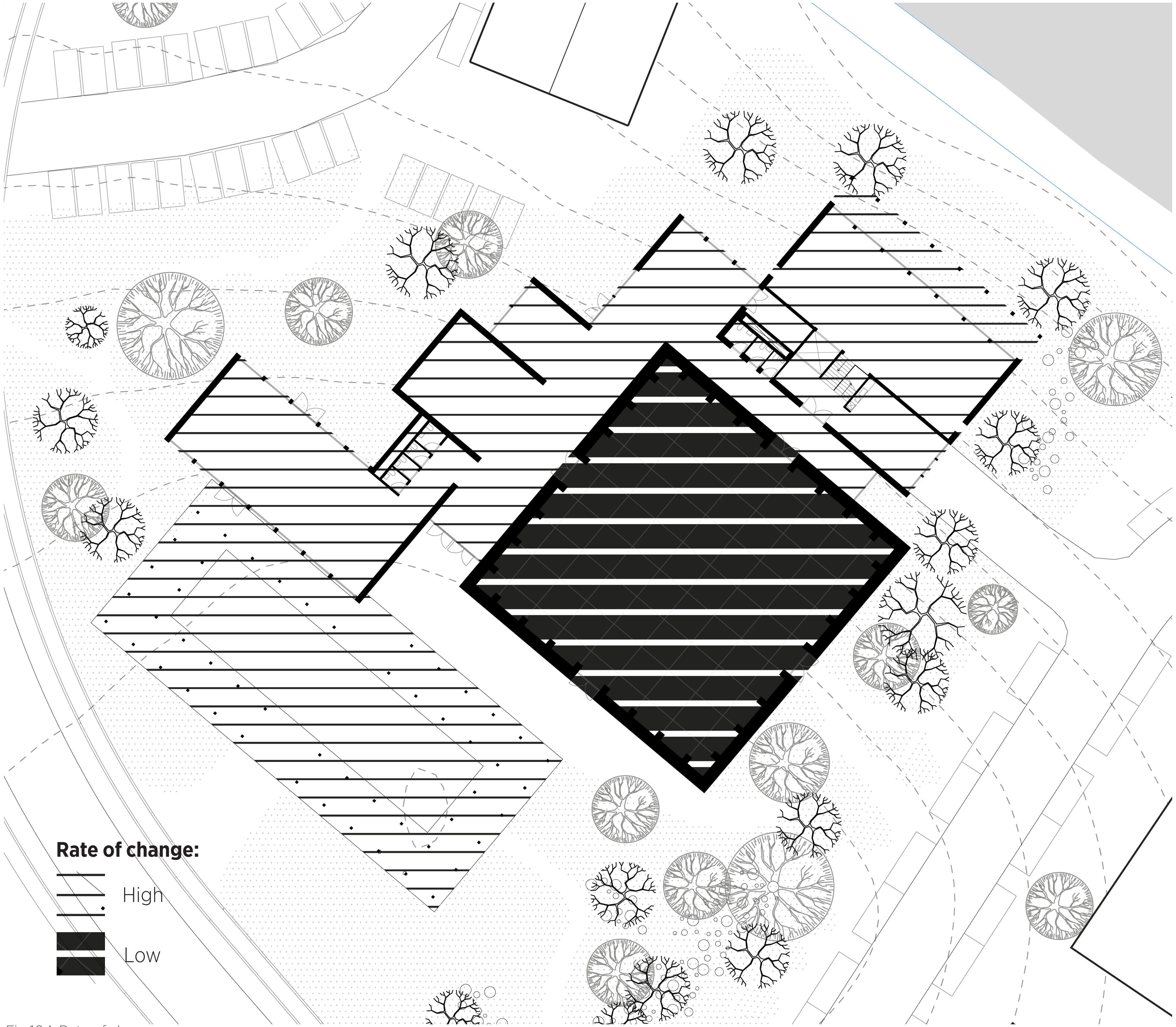


Fig 104: Rate of change.

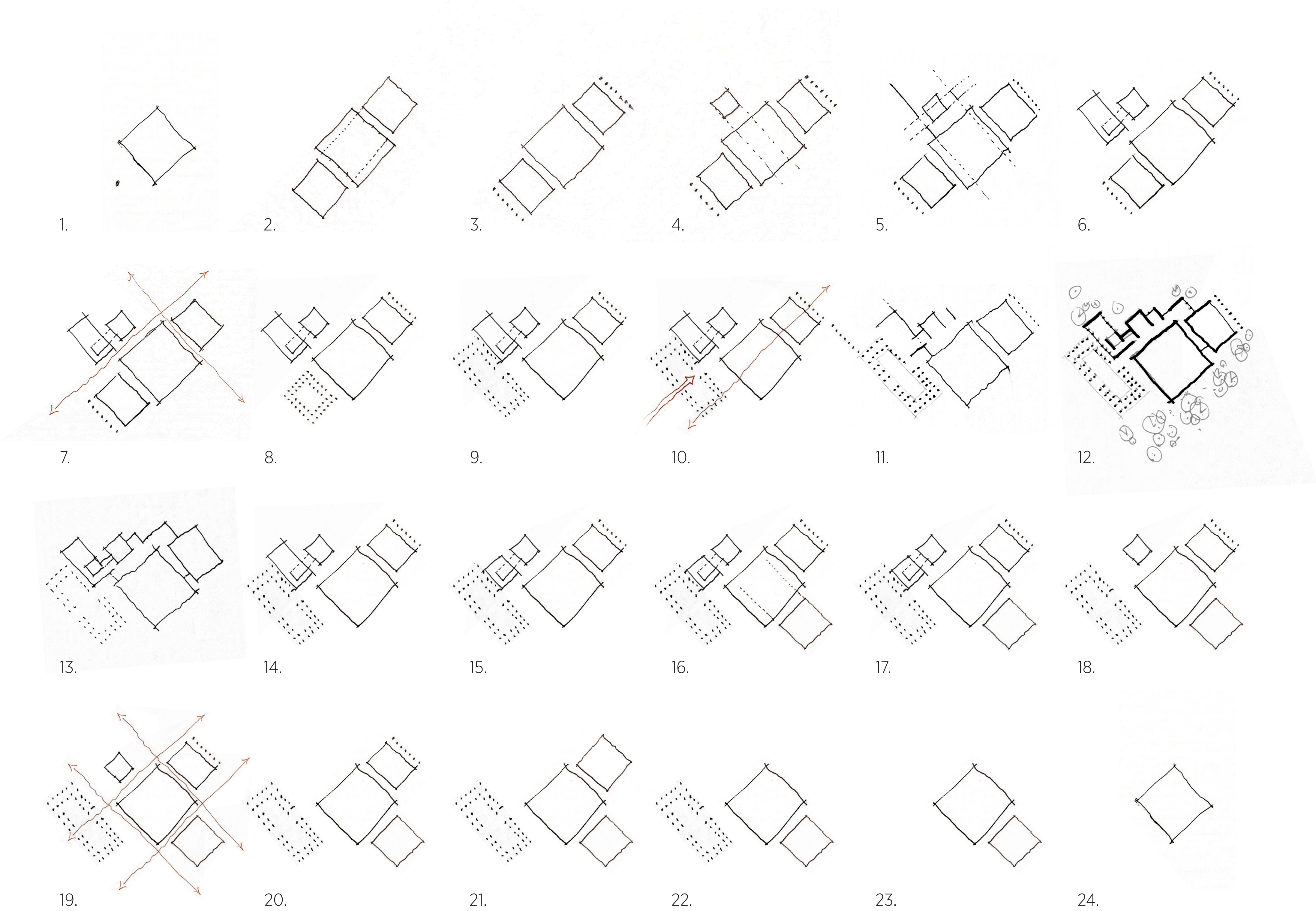
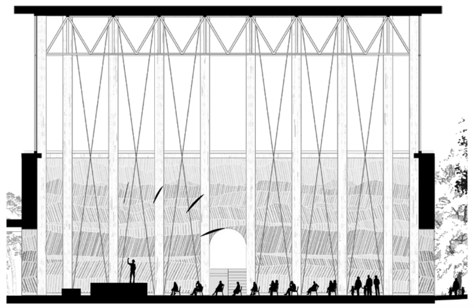


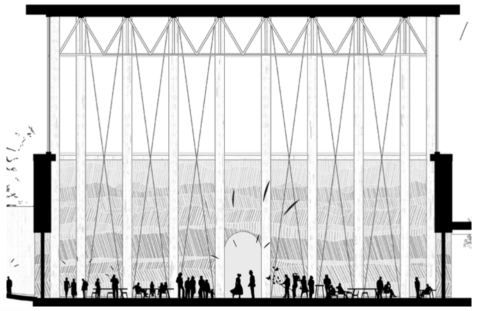
Fig 105: Geometric lifecycle from assembly to disassembly displaying possible outcomes over time within the system.

07.5.2 MULTIFUNCTIONAL MONUMENTALITY.

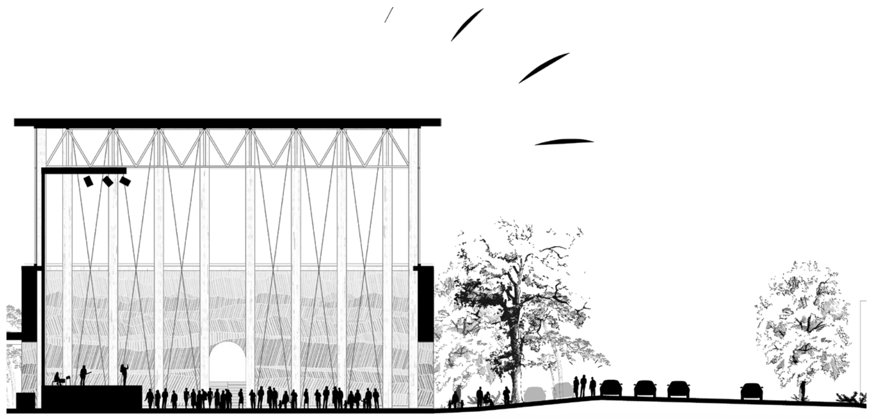
Fig 106: The framework for large gatherings. In this case an informal visit from Greta Thunberg. An example of multifunctional monumentality.



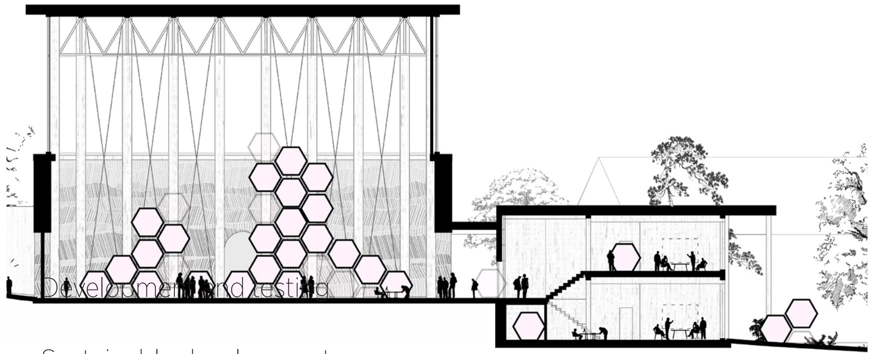
Lectures



Large private gatherings.

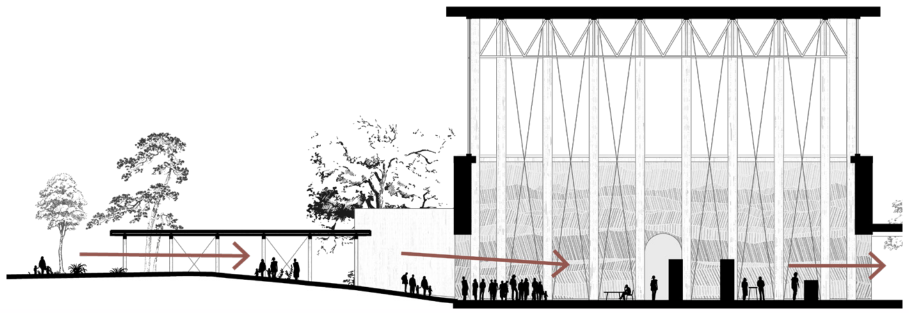


Concerts

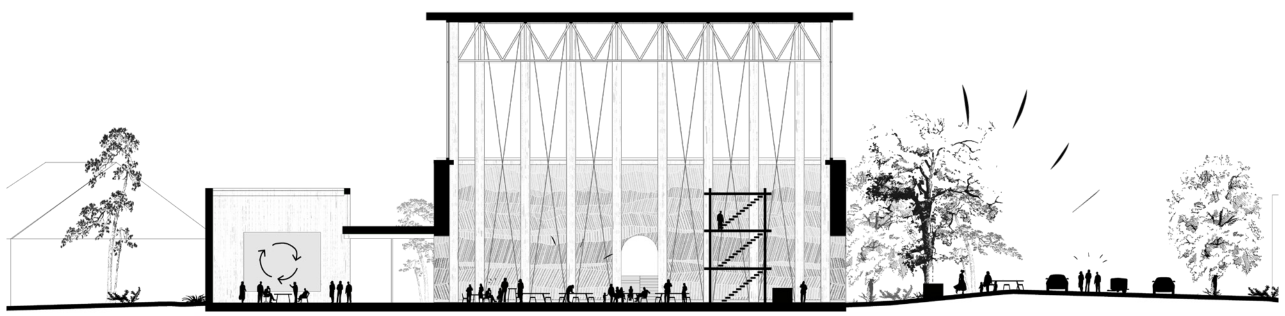


Sustainable development

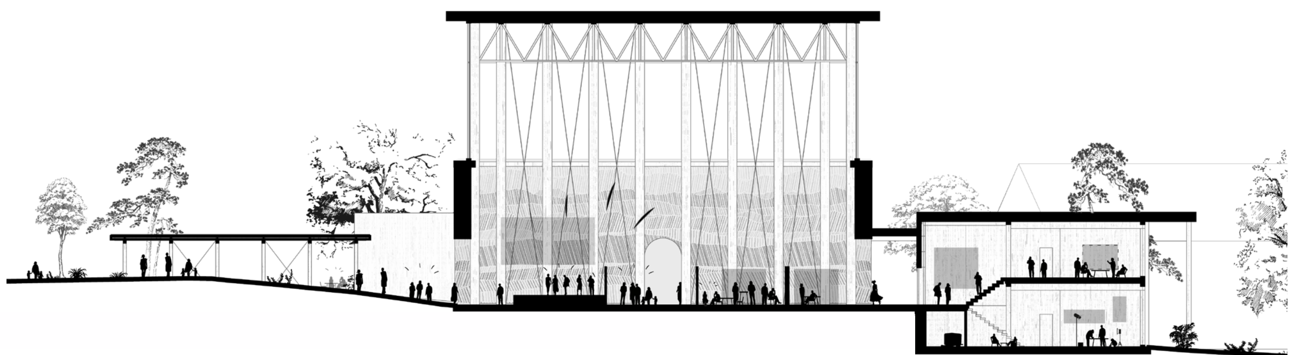
Exhibitions



Voting days



Community gatherings



Conferences

Fig 107: Monumental Multifunctional stability.

07.5.3 A PLACE TO LEARN FROM

The adaptable nature of the building layout will allow for change in 5, 20 or any other amount of years that the people using the building find necessary.

The process will allow them to engage with the building and get involved with its process. That will create a sense of ownership and pride in its development.
It should be up to time to develop the building as a building is not something that is finished but something that is started.

The people using the building know best what functions it is required to fulfill. It is therefore a democratic gesture to give them the responsibility to act on and adjust the building.

Fig 108: View of the foyer, the workshop space and the views through the building.

07.6 SUSTAINABLE TECTONICS

07.6.1 MATERIALITY AND MASS

Sustainable material use requires pure materials that can be reuse or recycled. All the structural building components follow that principle. The base material is wood; however, steel wires and rammed earth has been introduced to solve other more specific tasks requiring other mechanical properties.

The introduction of steel wires and rammed earth create a strong contrast in mass. The thin wire suitable for tension and the thick rammed earth for compression.

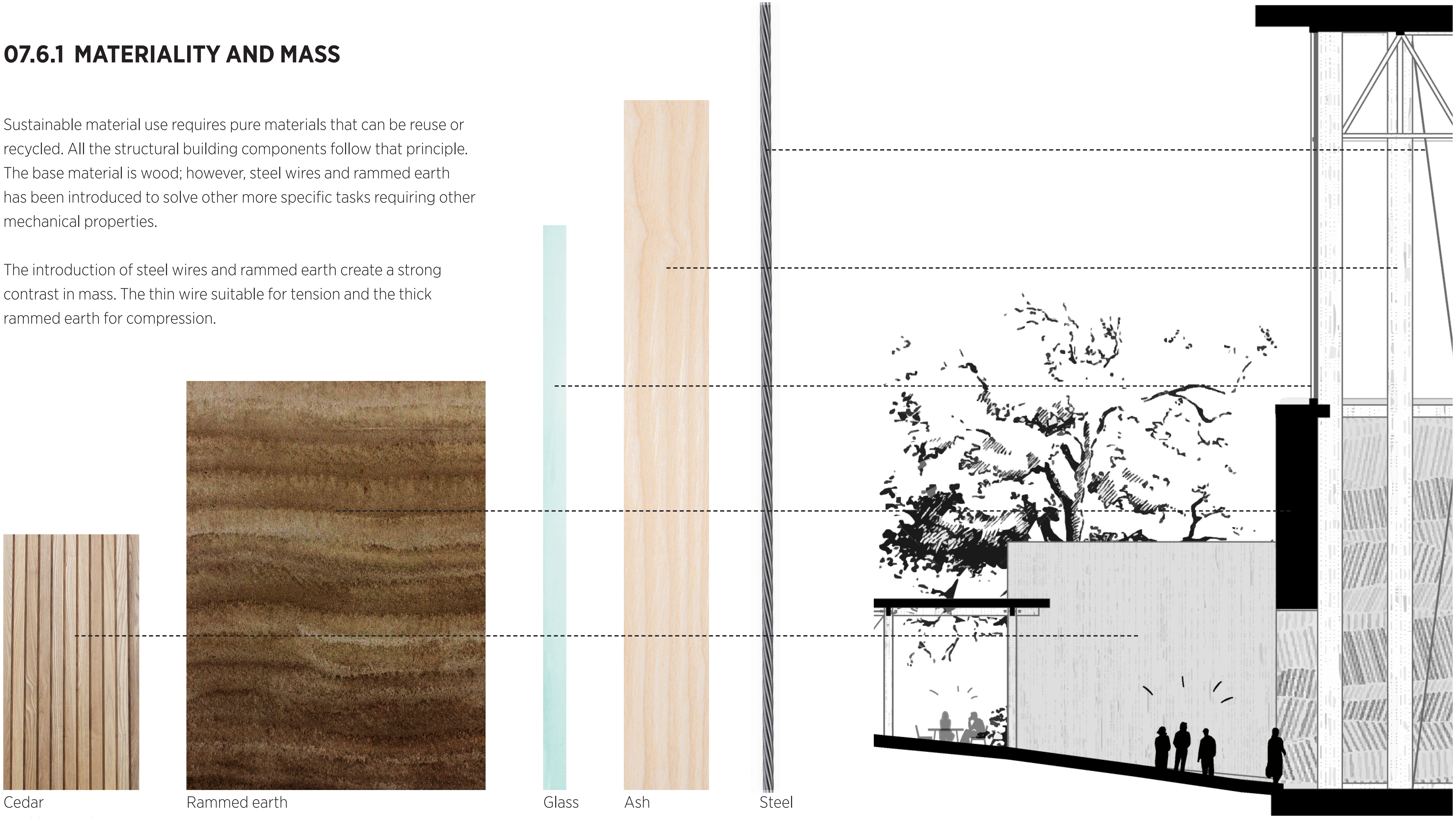


Fig 109: Materiality.

07.5.2 STRUCTURAL SYSTEM

As showcased in the process chapter the focus was to establish a strategy for an effective structural system with great LCA properties to counteract the tall spaces being counted in m^2 and not m3.
The space truss in the roof of the main chamber being a characteristic and particularly efficient solution to a square plan of large spans. It also provides a geometry to bounce light on that ends the tall space in an informed complexity.

The introduction of screw foundation significantly reduced what at one point was the biggest contributors to the LCA iterations, the concrete foundation. When the key performance indicators are low C02 emission and DfD then it is the best option available (Skruefundamenter - den optimale fundering, 2020).

Concrete tiles of 3x3m were nevertheless introduced in the main chamber because of their high durability, but the amount of concrete used to get the same effect is negligible in the LCA compared to a whole foundation of concrete.

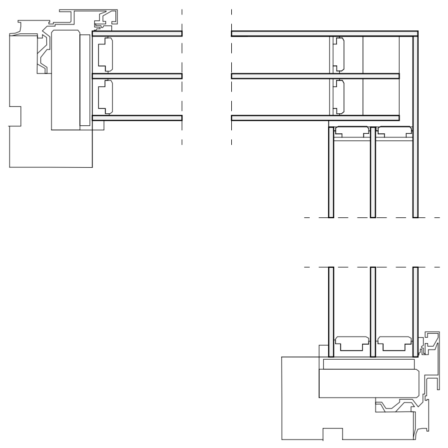


Fig 110: Following the grid in the main chamber results in freestanding corners. The detail allows for slimmer mullions at the corner to open up the end of the space.

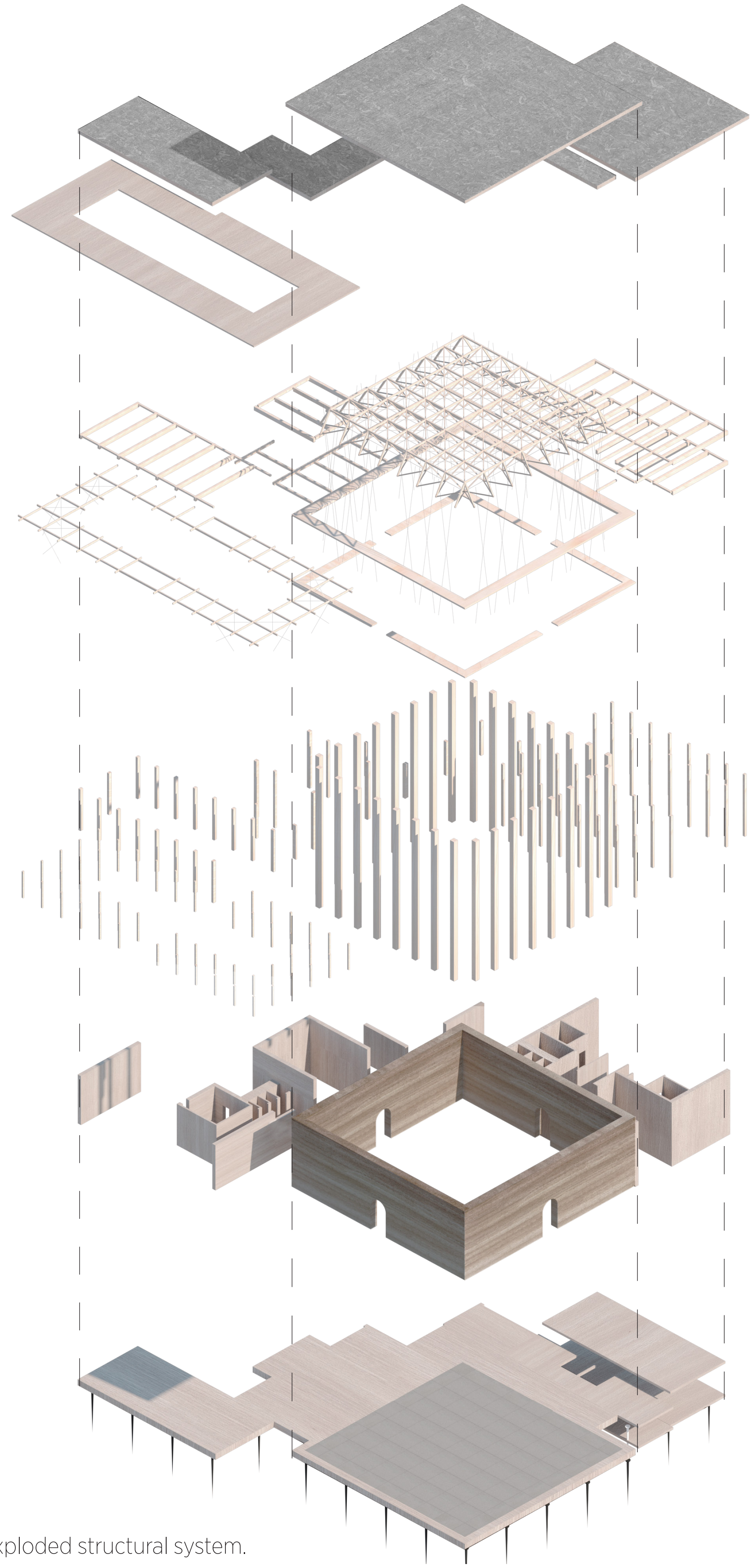


Fig 111: Exploded structural system.

07.6.3 ADAPTABLE KIT OF PARTS

The following system of column and beams allows for reuse and works if 4 beams meet one another, which is quite common in the design of the supporting functions around the main chamber. It similarly works if 3 beams meet in a column, however then one of the beams it is simply not divided into 2 parts as seen on the top column.

The regular and standardized 3x3m grid allow for simple principles of standard DfD systems to take shape. Some complexity is introduced because of the different heights of the building, but they are nevertheless also modularized. The beams and columns of the building are therefore suitable for disassembly and reuse.

07.6.4 BOLTS, DECONSTRUCTION, AND STANDARDS

Bolts are superior when working with DfD since they minimize damage to the wood and can be easily assembled and disassembled.

They will also mark clearly to the people using the building that this structure can be disassembled if need be. The strategy of having a visible construction and all the tectonic benefits it brings with it allow for this possibility.

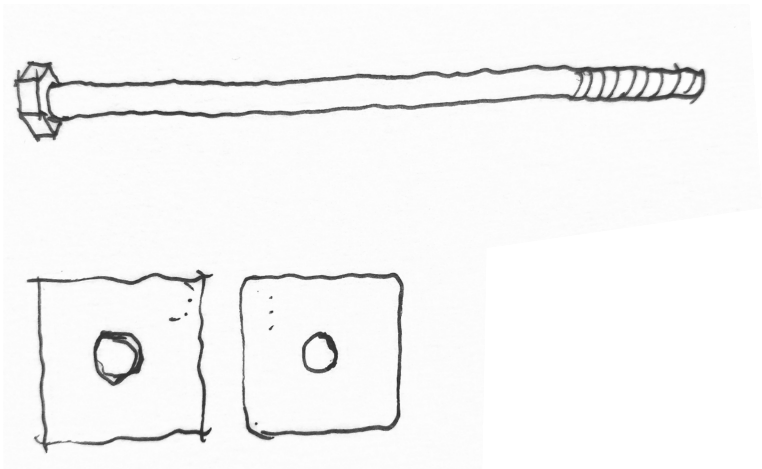


Fig 112: Bolts used for DfD.

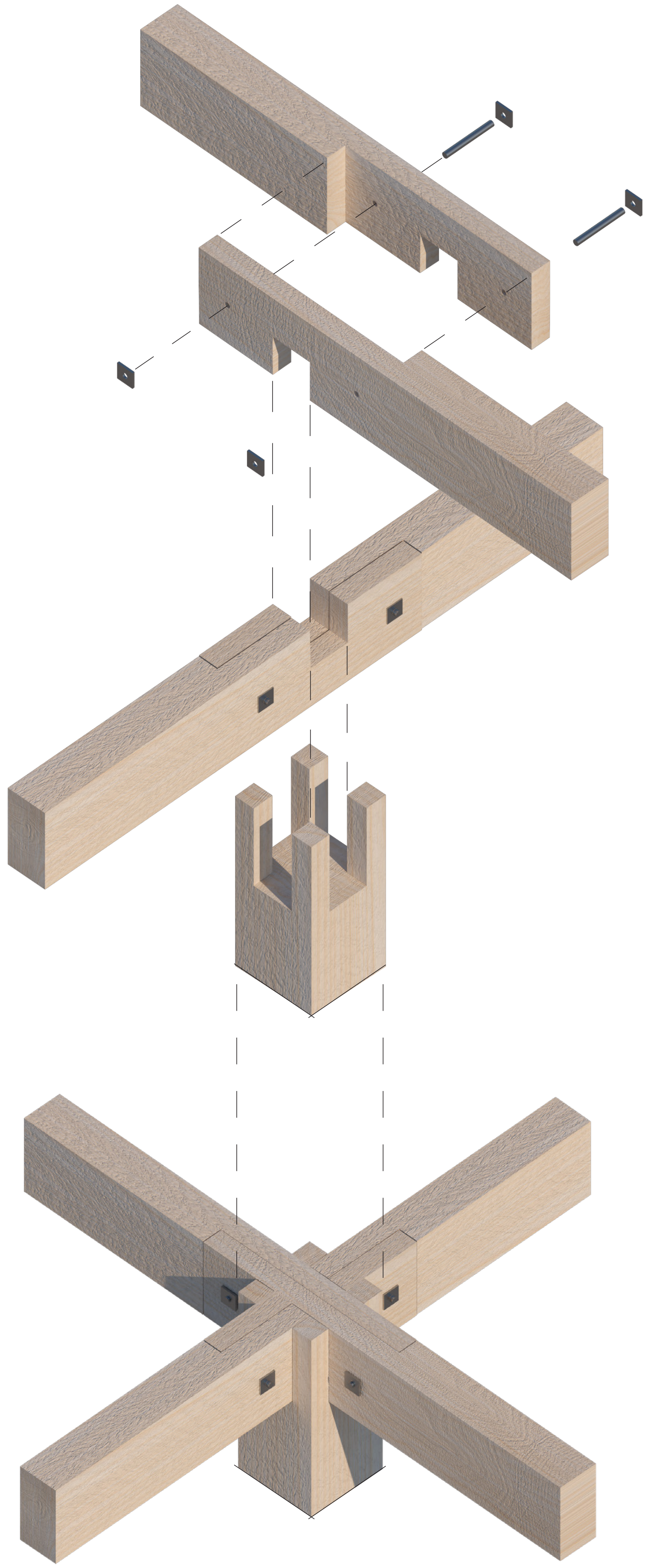


Fig 113: DfD column and beam principle.

07.7 MONUMENTALITY AND LCA

07.7.1 GWP: 7.7 - Counting waste of DfD elements, C3.

Humble monumental architecture in a sustainable future is not dead even though the fact that GWP is counted in m^2 makes it significantly more demanding to make large spaces. However, the large amount of wood used allows for more c02 storage in the structure and the negative numbers counteract the increase in m^2 to some degree. Production, A1-5, is therefore slightly in a negative number because the carbon storage in wood is counteracting the production of the rest of the building products.
Using rammed earth to encase the space reduces one of the normal big LCA contributors of the exterior wall. Lastly having the surrounding building with even lower LCA score also help neutralize the extra impact of the main chamber's height and mass.
The resulting GWP puts the building well within the sustainability class where a score lower then 8.5 is needed in 2023. The lower score allows for some adaptation since the GWP threshold will lowered further in the near future.

It is assumed that the building hits the energy frame just below 30 kWh/pr.m^2 (BR18, 2022, p. 18). The energy use, b6, is therefore 1.6 GWP of the calculation.

Otherwise, the biggest contributor of the LCA is the windows followed by the roof and the rest of the climate envelope. The waste of the columns and beams, despite being wood, comes close after the climate screen. Smaller factors are the screw foundation, interior walls, and the mechanical ventilation systems in office and café.

07.7.2 GWP: 5.9 - Not counting waste of DfD elements.

If the building is assessed with the presumption that elements designed for reuse will be reused, then the GWP is 1.8 lower. That is in effect a reduction higher than the projected GWP of the energy use, B6, of the building through a 50-year period at 1.6 GWP. The GWP would comparatively be even lower if the cost of dismantling the building, C1, was counted since it is currently ignored in LCA (Livscyklusvurdering - Krav, 2022).

The 7.7 GWP is however the value that would be employed in practice.

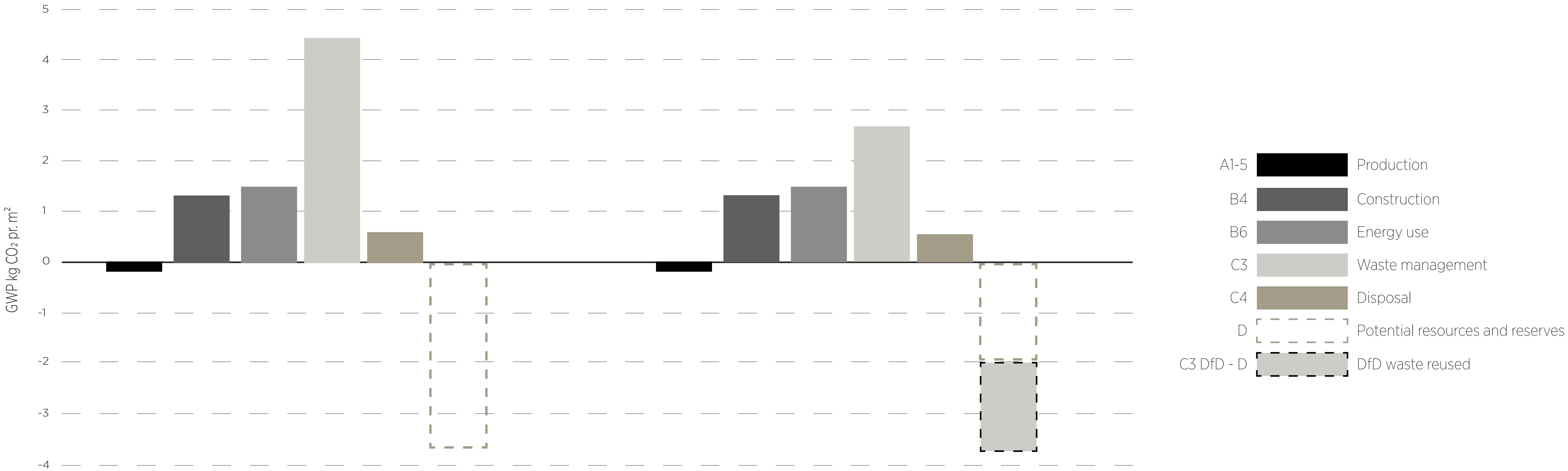


Fig 114: GWP phase distribution from LCAByg.

Fig 115: GWP phase distribution DfD from LCAByg.

07.7.3 BUILDING SET OF A SUSTAINABILITY CENTER

Mixing sustainable components in reasonable amounts results in the combination becoming sustainable. The building products for a monumental sustainability center are therefore the backbone of its LCA metric. A LCA does not care if the products are well put together and it is in the purest sense the measurable, as described by Louis Kahn.

These components contain the material bank that this humbly monumental sustainability center carry with it in time. It should be up to the people who use it to determine how it should be facilitated further. Economically, this could be feasible if the project was executed as a public-private-partnership.

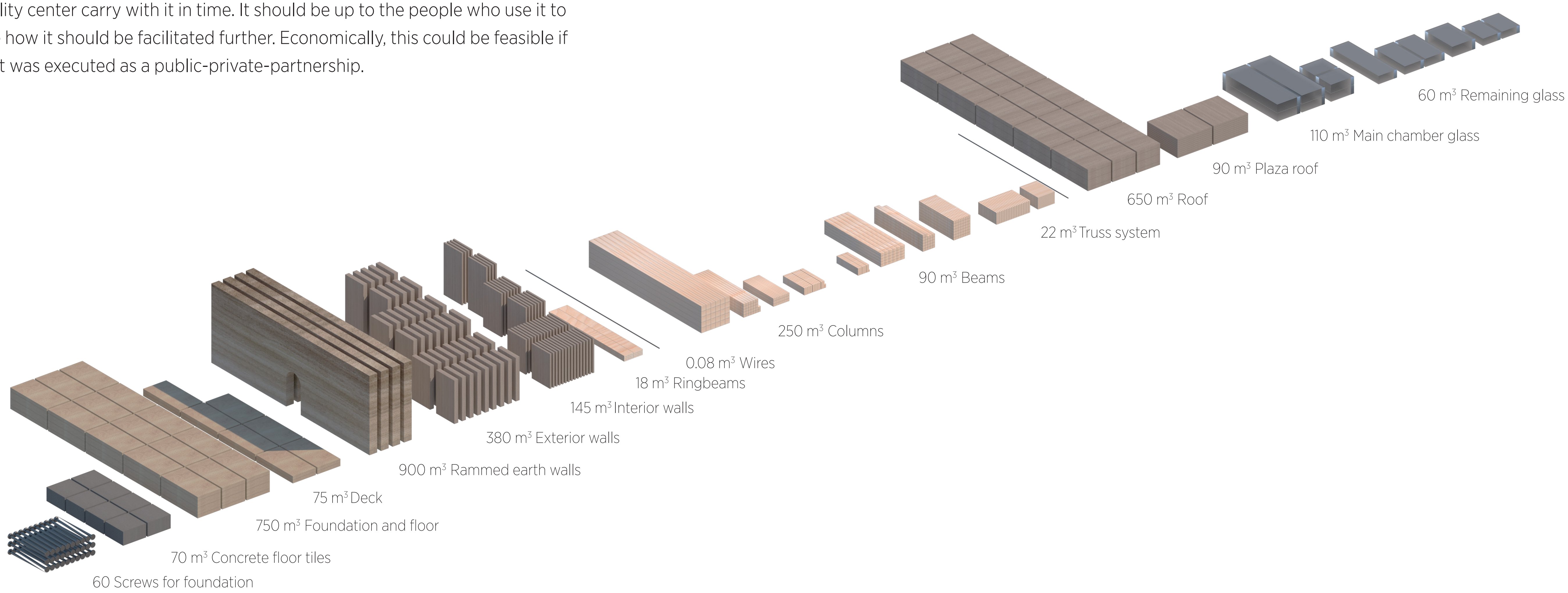


Fig 116: Building components of a sustainability center. The m^3 are rounded up.

07.7.4 THE FRAMEWORK FOR DEVELOPMENT

Over time the sustainability center could develop into a proper monument but that will require that some facet of building outlive its contemporary setting and become established as a piece of heritage for future generations.

The layers in the rammed earth walls are analogies to layers of the past. A similar argument can be said for the grains of the wood.

These patterns are available for the tactile sense because the materials are kept raw and untreated and not hidden behind a wall of gypsum or plaster.

Fig 117: Grundtvig and co. at the danish constitutional assembly of 1848 in the main chamber.

07.8 VENTILATIONS STRATEGY

Using passive strategies is a feature where the high-tech assessments methods meet the tried and tested solutions of the low-tech solutions from the past. They are implemented by way of passive shading, thermal mass, and natural ventilation.

The high ceiling with glass in the upper half of the main chamber allows the use of thermal buoyancy as an effective ventilation strategy. The chimney effect created in the space makes natural ventilation a viable strategy since it has clear access to the outside on all orientations.
Potentially colder air can be ventilated through the base of the openings.
The heat generated of a large gathering of people will accelerate the effect.
The large thermal mass of rammed earth walls in the main chamber will help regulate fluctuating temperatures in the space.

The foyers clear layout allows natural ventilation to be employed as well but having the pressure difference between the closely related spaces being the main driver.

In the Kitchen and office area a mechanical ventilation system is implemented which allow for a hybrid system. A hybrid system is more flexible for these spaces that require a more stable temperature and reliably higher rate of air change throughout the year.

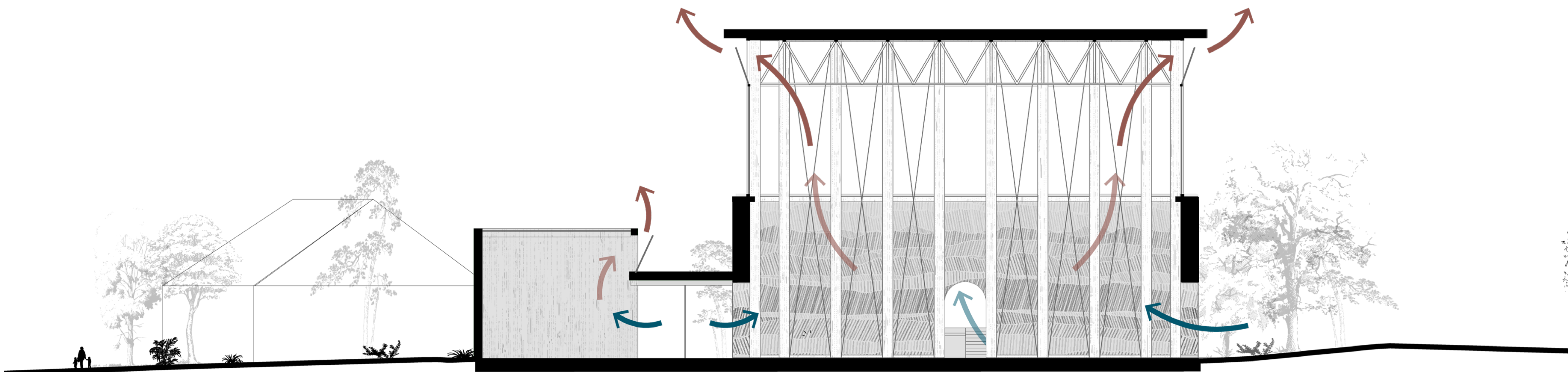


Fig 118: Thermal buoyancy ventilation strategy.

07.9 SCALE AND CONTEXT MATTER

The smaller scale of Nye and its context makes the scale needed to achieve a landmark less demanding and more reasonable material wise.
The main chamber would not have a humble monumentality if placed in Rome next to the pantheon with its height of 44m and chamber diameter of 43m (Sparavigna and Dastrr, 2018, p. 5). The main chamber is even further dwarfed by the Lighthouse skyscraper in Aarhus Ø which is within biking distance from Nye (Lighthouse - Danmarks højeste boligbyggeri, 2022).

However, the sustainability center still towers over the lower suburb areas with significant posture. The hilly landscape of the area cements this gesture further since future development in Nye will be mainly towards the south down the hill.

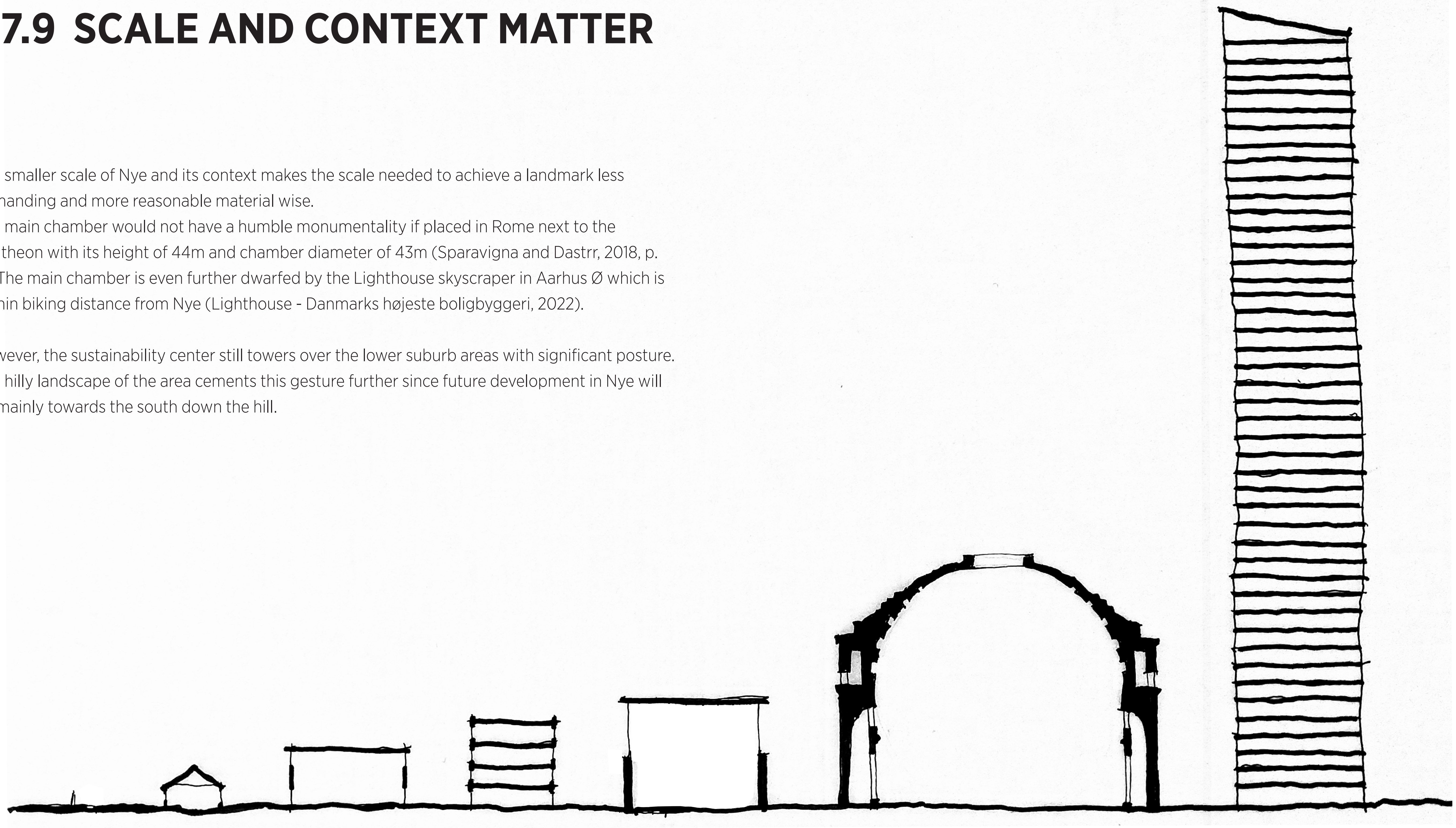


Fig 119: Scale comparison.

07.10 PRESENTATION CONCLUSION

The sustainability center has the components needed to evolve into a monument for a sustainable city. In the end sustainability is about resilience, action, and adaptation and that is directly reflected in the architecture. The promise is meet with the use of both measurable and unmeasurable measures.

Over time the building might in the most sustainable fashion change from a sustainability center into a new mix of functions. But the framework of the structure and the systems should endure with its symbolic and tectonic qualities.

The people of Nye can also rest easy that the buildings itself adheres to the sustainable values that they strive to implement with the low assessment of its life cycle cost. Arguably taking the ideals further than the existing or planned housing in the area.
This sets the stage and allow the community at large to share and develop their values of a greener future and export it by democratically promoting it.

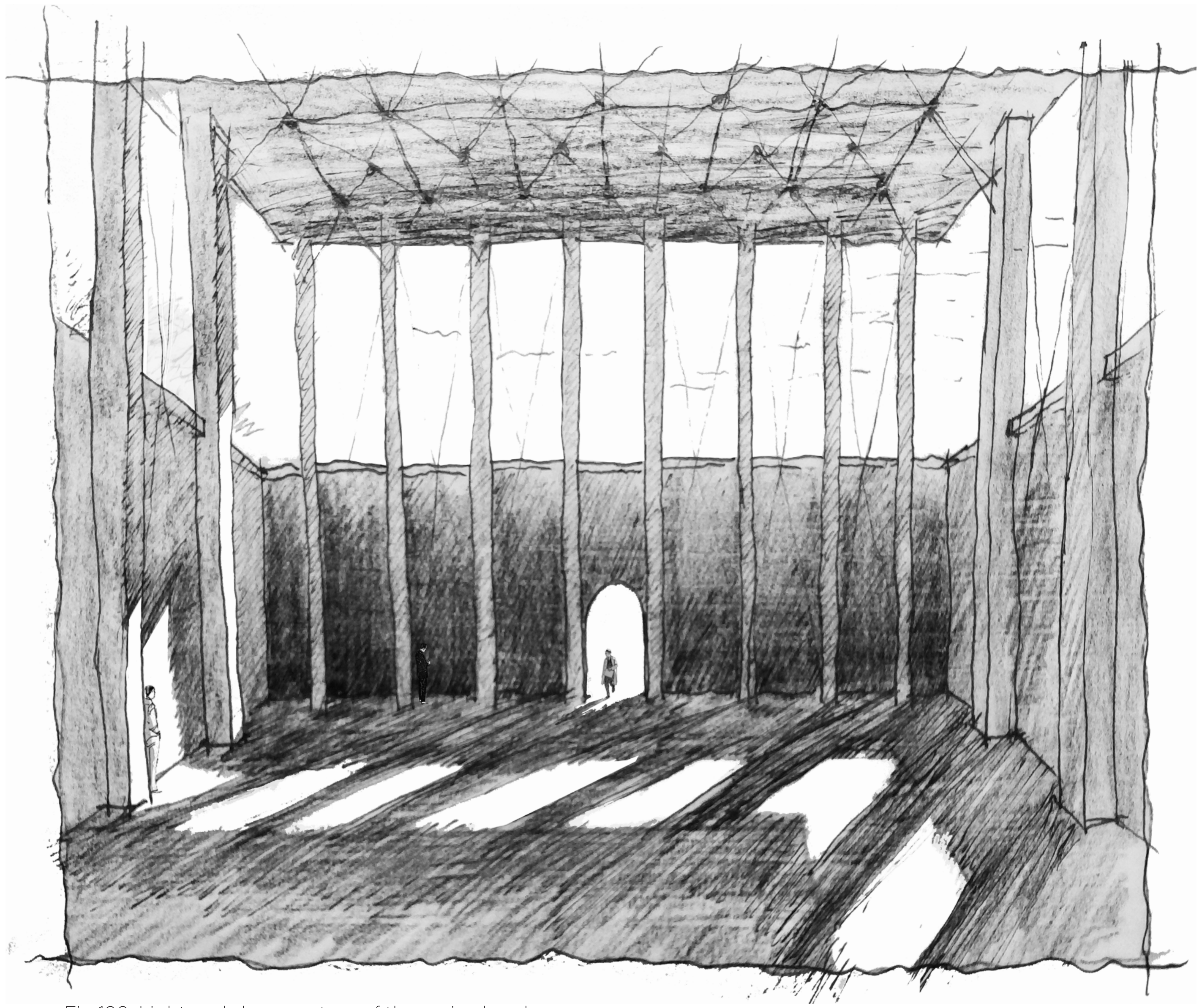


Fig 120: Light and show gesture of the main chamber.

08 REFLECTION

08.1 PROJECT

Humble monumentality is a contradictory term. But it is possible to achieve both a contextual humbleness and a sense of monumentality with composition, order, and light.

Building something monumental in a sustainable paradigm turns out to still be possible. However, an understanding of how a building is assessed is required because a strategy of lowering emissions, and to some degree waste, is needed to maneuver in the world of LCA.

It will become easier to achieve lower GWP in the future when the lower requirements are slowly introduced. A big factor will be the creation of more and better EPDs, which will give more product options to reduce C02 emission and lower the GWP of projects further. Another factor is the increasing use of renewable energy as it will allow for even lower scores. If the energy source was mainly sustainable and some better glass and roof alternatives emerge it would lower this sustainability center well under the projected sustainability class past 2030 of 5 GWP.

The lack of incentive in an LCA for reusable components is a problem with no clear solution. The D category of potential for reuse, reducing and recycling is vague by nature and holds undefined value. Going through the effort to plan and strategies buildings parts, deconstruction, and reuse is a time demanding process with many limitations. Without a clear economic incentive, it is doubtful that the building industry will adopt reuse on a larger scale.

Subcontractors and other manufacturers will improve on the metrics that their products are judge on. The focus on LCA is therefore a step in the right direction, however it is currently more attractive to reduce and not reuse or recycle. As an example, it is arguably easier to produce a product, such as a window, that reduces C02 emission because of high performance with composite materials, but they are very challenging to reuse and recycle (Jensen et al., 2016).
A purer set of materials would allow for recycling and potential upscaling, but it would reduce performance and manufactures would currently be disincentivized for it in an LCA.

The material bank aspect can help, but people generally don't prioritize investments that bear fruit many years into the future. Depending on the contract, the investor, if still around, does not even hold the rights to the material bank at that time. Other types of arrangements might be needed such as private-public-partnerships to truly facilitate the change.
This would leave the material bank to the use of a public institution after a private company develops and leases the building for period. However, such a setup is not traditionally employed in housing or office buildings. A different method might therefore be needed to give incentive for DfD in the building sector.

08.2 TIME

A focus throughout the project has been management of time since the thesis was not the only project done throughout the semester. Parallel was also, work at C.F. Møller, mentoring and a bridge competition.
With more limited time the value of subdividing a planning schedule down into smaller more digestible points became very apparent. It was a big factor in reaching specific goals on a tighter timescale and making the process of doing so more enjoyable. Every morning a plan was set for the day on what goals to reach.

As much as the thesis argues for building with time then it has equally been a focus to be effective with time. Not doing the thesis in a group has given some confidence and experience with coordinating a big project individually that will carry over into a future career.

08.3 TOOLS

Being involved in the process of programming and developing internal tools in a large firm has also given some insight. Tool development, as how in this case a sustainability engineer does it, is a chance to delve deep into subject and solve a problem. As a process this is very rewarding. However, it has also become clear that it inherently holds less recognition compared to using a tool and designing something with it. Close colleges can understand and appreciate the results of development on internal tools, but it seems that in practice most of the credit will come to the design team that will use it to solve and promote an actual project.

In that sense being an internal tool developer does not have scalable recognition and limited feeling of ownership on projects. This becomes clear when most people in the industry require a course to understand what you are working on because development tries to be a step ahead of the curve, which allows them to create tools, so they are ready when they are needed. This thesis could easily have had primary focus on the tool development but in the end it is the design that holds the most individual pride. It is the design that can be shared and debated not some lines or boxes of code.

Recognition and ownership are important, and it consequently can make it less attractive to be the middleman who creates tools for solving problems in the background despite its engaging and challenging process. Mixing development and design would be a more attractive job prospect since it holds both the chance to delve deep into something and follow the outcome. Working integrated with both would allow for a more collaborative digital design process (Santos, Lopes and Leitão, 2012, p. 95).

Fig 121: Texture used in the renders based on edward seago paintings.

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10 APPENDIX

Resultater

Navn	Værdi	Enhed
GWP	5,994e+00	kg CO_2-eq./m²/år
ODP	2,105e-09	kg CFC11-eq./m²/år
POCP	6,369e-03	kg ethene-eq./m²/år
AP	3,257e-02	kg SO_2-eq./m²/år
EP	6,063e-03	kg PO_4^{3-}-eq./m²/år
ADPe	2,474e-04	kg Sb-eq./m²/år
ADPf	1,985e+02	MJ/m²/år
PEtot	4,495e+02	MJ/m²/år
Sek	9,882e-03	MJ/m²/år

LCAByg results with DfD and C3 adjustment.

Resultater

Navn	Værdi	Enhed
GWP	7,691e+00	kg CO_2-eq./m²/år
ODP	2,105e-09	kg CFC11-eq./m²/år
POCP	6,369e-03	kg ethene-eq./m²/år
AP	3,257e-02	kg SO_2-eq./m²/år
EP	6,063e-03	kg PO_4^{3-}-eq./m²/år
ADPe	2,474e-04	kg Sb-eq./m²/år
ADPf	1,985e+02	MJ/m²/år
PEtot	4,496e+02	MJ/m²/år
Sek	9,882e-03	MJ/m²/år

LCAByg results without C3 adjustment.