# TIMBER ROW HOUSE

## Revisiting Traditional Typologies With New Technologies to Address Contemporary Concerns

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*26.05.2020*
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*MA Spatial Design, Thesis semester, Feb - Jun, 2021*
*Number of characters: 44,202 characters*
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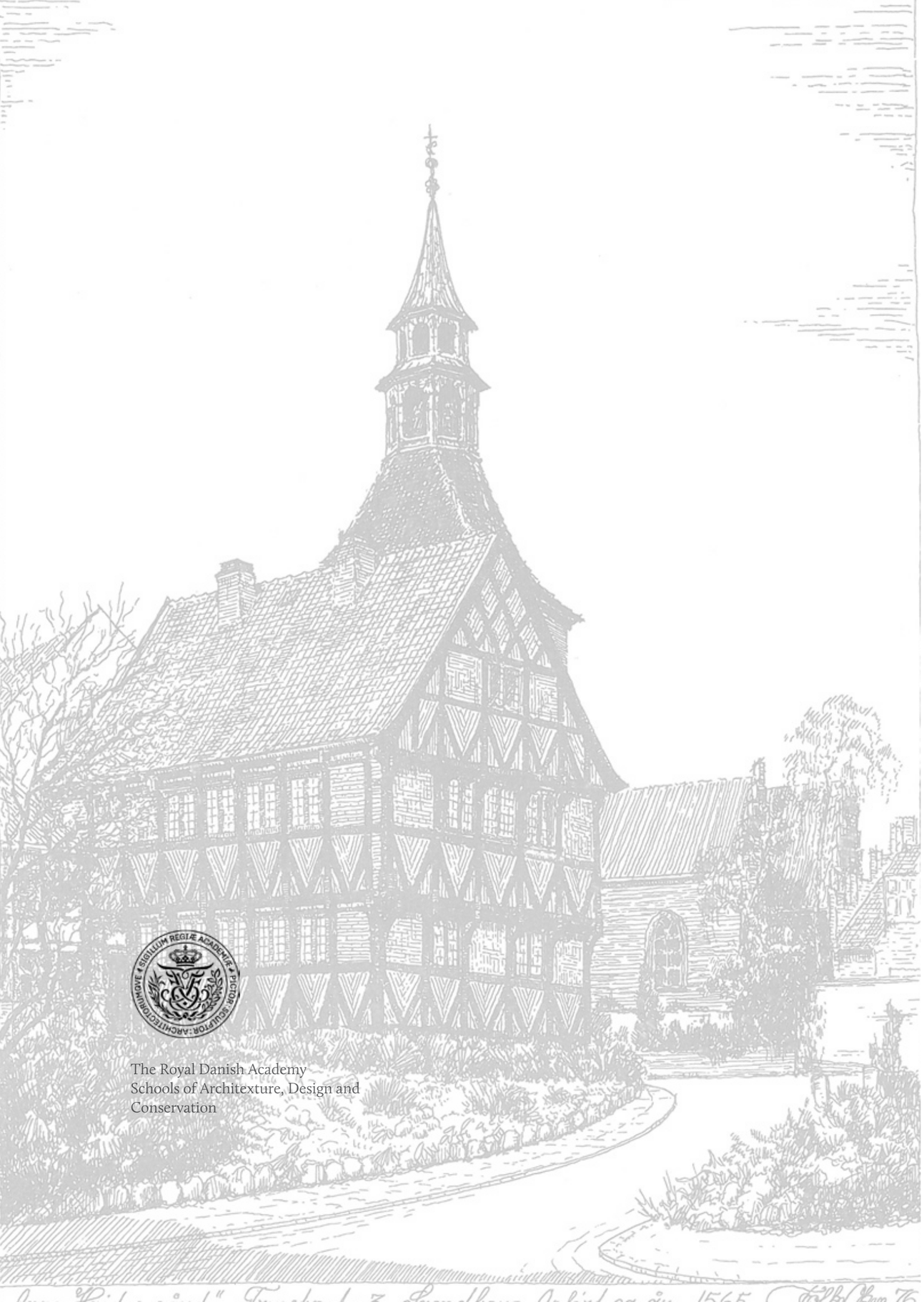

The Royal Danish Academy
Schools of Architexture, Design and
Conservation

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## ABSTRACT

Copenhagen is under constant development in order to keep up with increasing housing demands, exemplified by the future plans to construct Lynnetteholmen; a man-made peninsula to be built in Øresund between Refshaleøen and Nordhavn. Contemporary understanding of the negative impacts that modern building materials and techniques have on the environment require us to re-evaluate conventional building practices in favour of more environmentally friendly alternatives, as we address this trend towards rapid housing development in the near future.

This approach requires us to revisit methods that may have been partly forgotten during the Modernist era, that are viable again with a renewed interest in natural materials and new developments in technology that help us reintegrate these materials and methods into contemporary building practices.

This thesis project aims to design low-rise residential row-housing in natural and environmentally sustainable materials, where viable, as an exploration into alternative housing construction approaches that can rival the appeal of the suburban detached house. Inspired by the future development plans of the area, the housing is designed for a small plot of land on Refshaleøen beside Margretheholm. This is a neighbourhood that despite its positioning in the inner city, is a quiet and green area, attracting many young families looking for space and peace to raise children, who aren't interested in moving to a 1-2 story detached house in the suburbs only accessible by motorcar.

The project leans on theories of Critical Regionalism, drawing inspiration from local-regional approaches that have evolved over centuries to respond to locally available natural materials and demands of regional climate. In-keeping with the teachings of Critical Regionalism, it combines historical references with new and universal technologies and materials, so as to integrate with current development systems, as a viable method in a modern city with high demands.



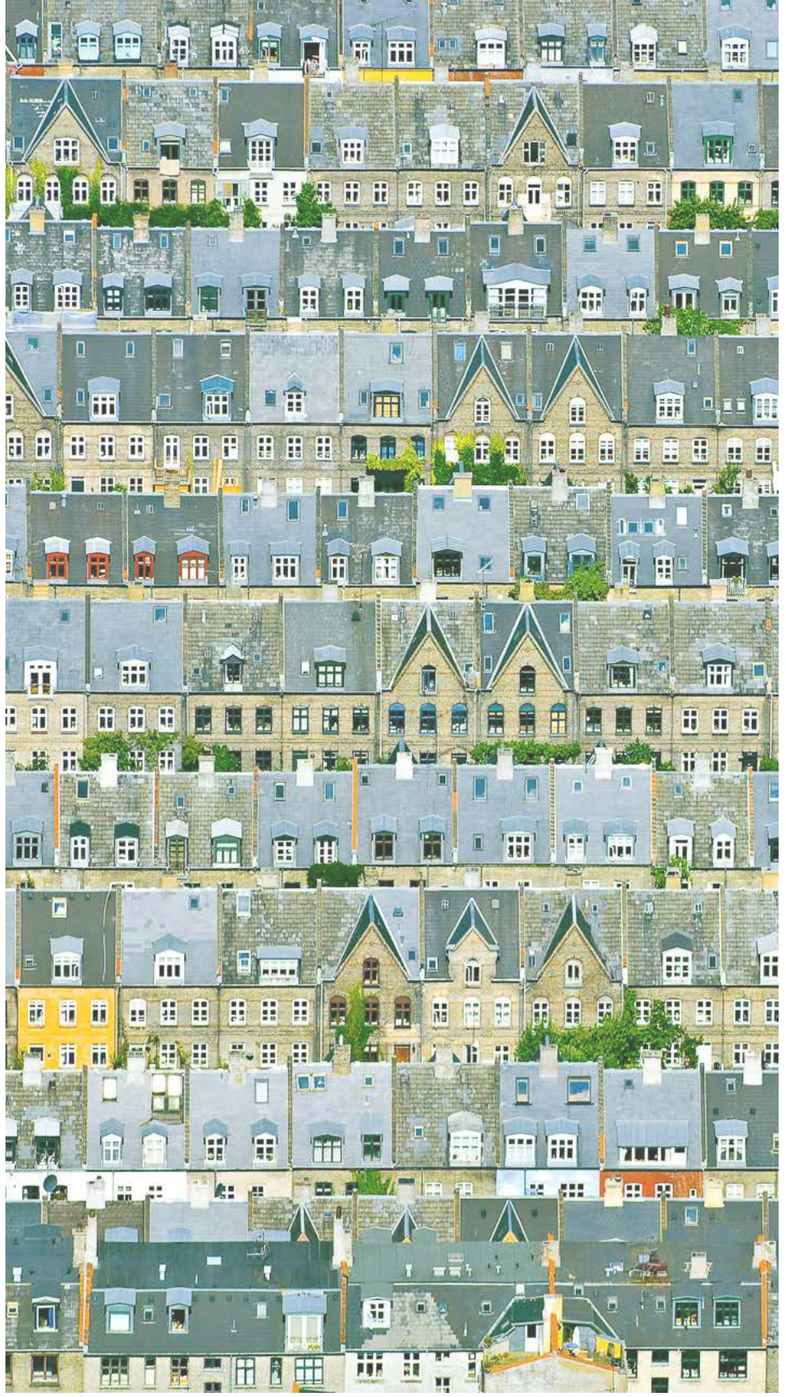
*Front elevation of my final proposal*

## INTRODUCTION & MOTIVATION

"Our society is currently faced with two major challenges: man-made climate change and the need to provide housing for an ever-increasing world population." (Dangel, U). Ulrik Dangel's book 'Turning Point In Timber Construction: A New Economy' details the pressing need for our global construction methods to transition towards relying on renewable resources. He posits that wood is the best example of such a resource, and that combined with "Recent technological advancements in engineering (...) the use of timber for the construction of multi-story structures, (transforms) our buildings and cities into carbon sinks rather than sources of $CO_2$ emissions."

Sustainable building also requires a housing typology that doesn't contribute too heavily to urban sprawl. This sprawl is largely enabled by the twentieth century's prioritisation of the suburban 1-2 story suburban house as the standard family home, accessible primarily by motorcar, which completely transformed the composition of our cities. Previously, our cities achieved density by use of narrow walking streets, row/terrace/ town housing and apartment blocks that were tightly built together (pictured right: density of Kartoffelrækkerne). Modern attempts to address density in cities often involve adding stories to our buildings to the point of building skyscrapers, which can lead to a kind of vertical sprawl, also referred to as vertical cul-de-sacs, which create the same issues of gated communities and monotony as horizontal sprawl does. Jan Gehl points out that, particularly in our Northern positioning on the globe, tall buildings cast vast shadows that requires them to be spaced out to a degree that allows light to reach the street level. This spacing out is often used as an opportunity for 'green space', but as Gehl again explains, often creates windy negative space between buildings of poor spatial quality that come at the cost of potential intimate streetscapes. (Gehl, 2010)

In a more inner-city context, the 5-6 story apartment building would be an appropriate housing typology, but for my site, the row house is an elegant housing typology whose gentle density retains the dignity and comfort of the detached home, while contributing vibrant streetscapes, diversity and to the city's outer neighbourhoods.



*Density of 'Kartoffelrækkerne' - Some of Copenhagen's most sought after properties*

### *PERSONAL MOTIVATION*

I come from a non-architectural background in Set Design, with a degree in Production Design and experience in film and TV, however, I am interested in working with architecture in the future. I aimed to frame this project in way that would allow me to develop an architectural knowledge and experience, so that I could continue to work with wood as a sustainable building material in architecture after graduation. I believe that this is a vitally important change that is to be made in the way we build our homes and cities, and being a part of that change would be a career path that I would be proud to pursue.

## PROBLEM STATEMENT

This project explores how the traditional timber frame construction method can be implemented as a sustainable approach to designing medium density row-housing in natural materials. The design employs innovative materials and currently utilized technologies to present a design proposal that is viable for housing developments planned for Refshaleøen, Copenhagen in the near future.

## BACKGROUND & THEORY

### *DANISH VERNACULAR & TRADITION*

Wood has been a predominant building material in Danish vernacular since the Viking era, used in long houses and Trelleborg houses (Fig. 1), which used timber, mud cladding and thatch roofs, techniques that have stayed with Danish architecture and that have supplemented traditional building techniques, particularly for housing. Timber was the main construction material up until the introduction of the Romanesque and Gothic styles in the 12th and 13th century. This period saw the widespread introduction of granite, limestone and brick, three materials which then became the defining traditional building materials of Denmark, particularly brick, which was the most commonly used of the new materials. In the late Middle Ages, the most common building technique for housing transitioned to half-timbered buildings, which remained as a regional building tradition for centuries after. (Fig. 2: Anne Hvide's House in Svenborg)

The Nordic Modernism movement stood out from the Internationalist movement of the era, with many of its architects drawing inspiration from regional and traditional materials and techniques. This is most apparent in the furniture design of Hans Wegner (Fig. 3: CH36 chair), Børge Mogensen and Kaare Klint, among many others, who drew their inspiration from the American shaker movement in designing wooden furniture. Designers from other countries, Germany and Italy notably, were experimenting with metal and industrial methods. Both styles created beautiful outcomes, but many consider the wooden work of the mid-century Nordic Modernists as timeless classics, and their works are still popular

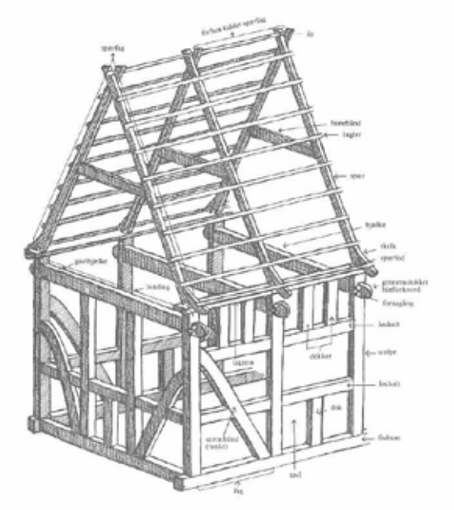


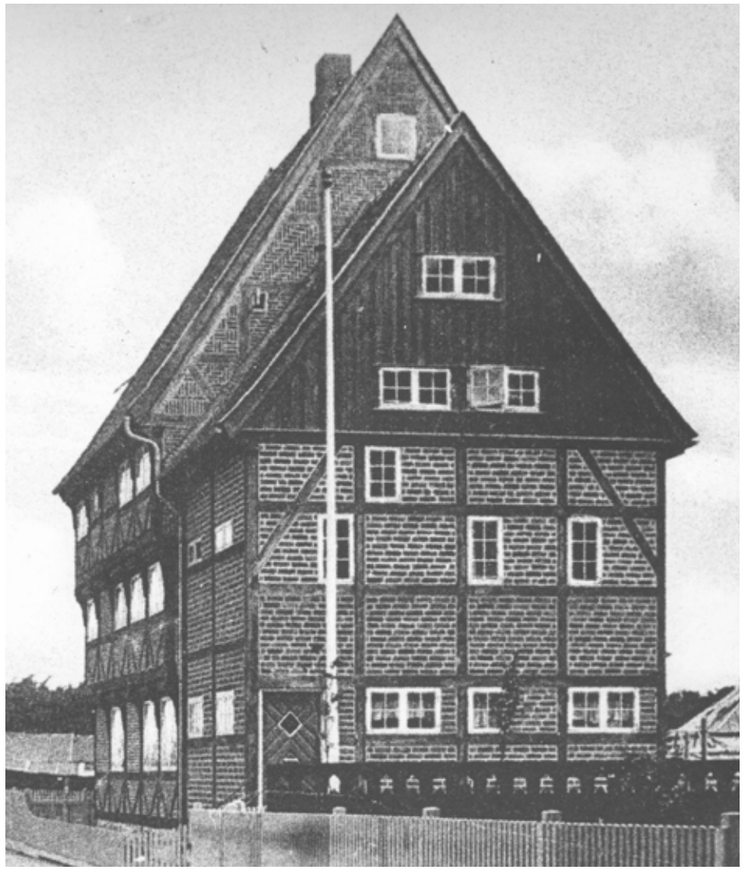
*Fig. 1*

*Fig. 2*

*Fig. 3*

*Fig. 4*





on the market, and commonly featured in design and architecture magazines and publications.

The same applies for Nordic Modernist architects, Jørn Utzon (Fig. 4: Ahm House) and Kay Fisker for example, who insisted on using wood and other regional materials (brick), in a time when reinforced concrete and steel was established as the International Style.

### *TIMBER FRAME*

Timber framing, also referred to as "post-and-beam" construction is a traditional method of building with heavy timbers, creating structures using carefully fitted and joined timbers with joints often secured by wooden pegs. If the structural frame of load-bearing timber is left exposed on the exterior of the building it may be referred to as half-timbered, and in many cases the infill between timbers will be used for decorative effect. The country most known for this kind of architecture is Germany, but many neighbouring countries, including Denmark, also share this building tradition.

The method originates from working directly from logs and trees rather than pre-cut dimensional lumber. Hewing this with broad axes, adzes, and draw knives and using hand-powered braces and augers (brace and bit) and other woodworking tools, artisans or framers could gradually assemble a building's structure, which then allowed versatility for wall and threshold positioning.

Since this building method has been used for thousands of years in many parts of the world, many styles of historic framing have developed. These styles are often categorized by the type of foundation, walls, how and where the beams intersect, the use of curved timbers, and the roof framing details.

### *NEW TECHNOLOGIES IN WOOD ARCHITECTURE*

A rapidly growing understanding and concern towards the impacts our construction methods have on the environment, have seen a return to building with natural materials, most notably wood in the Northern European region. Equal concern is paid toward a growing population, as well as the tendency for the centralisation of populations toward major cities. Progressive innovation has led to

interesting innovations in technology that can lead to replacing problematic materials such as reinforced concrete and steel, with natural materials such as wood, also for large scale builds. “Recent advances in engineered timber have provided us with a range of composite wood materials - like CLT (cross-laminated timber) - that have comparable strength-to-weight ratios to steel and concrete, with far lower emission profiles.” (Gestalten, 2020)

Technological innovation in wood architecture is not limited to new material composites, however, as developments in robotics and digital programming have allowed for new methods of milling, such as the increasingly popular method of CNC milling. This technology allows for machined precision in cuts, allowing for stronger and more complex joinery techniques, with spared labour and specialised expertise. While it would be a shame to replace human mastery in hand-craft, CNC milling allows us to reintroduce the styles of traditionally hand-crafted typologies such as the timber frame, into the digital age as a viable means of construction that meets the mass housing needs of the modern era.

***CRITICAL REGIONALISM***

Critical Regionalism was a concept that arose in the 1980s as a term to contextualise a resistance to the standardised international Modern architecture of the 1960s and 1970s. It described an approach in which regional schools could take influence from global architecture and global ideas, but then personalise and adapt their designs and projects to specific contexts. It recognised a need for some form of regional reference in architecture, but saw the dangers of regressing to romantic pre-modern ideals of a fractal national regionalism. Kenneth Frampton describes “the fundamental strategy of Critical Regionalism as to “mediate the impact of universal civilization with elements derived indirectly from the peculiarities of a particular place.” (Foster, 2002).

This theory informed my approach of drawing material, tectonic and stylistic influences from regional building traditions in order to meet climatic demands and stylistic harmony in the context of the city and local culture, whilst referring to universal techniques, new materials, and international styles (notably Japanese timber frame architecture), to avoid this “regression” to a fractal national regionalism that Frampton warns against in his writings.

*‘Lignum’ - Croatia-based woodworker who combines robotics and old timber crafts in design*

## CONTEXT & DEMOGRAPHIC

The site is located on a level grass plain between the contemporary housing development 'Margretheholm' (2012) and 'Quinti Lynnette' (1800), a timber-frame building built as a part of the old bastions of the Copenhagen fort that protected the city from the 17th to 19th centuries. It is now rented out as office spaces.

The site was chosen as an example of a Copenhagen urban neighbourhood under development. Plans for the development of Holmen and Refshaleøen involve the construction of residential buildings to house 15,000 new residents, including a new metro and motorway connecting the area to greater-Copenhagen, and the future peninsula of Lynnetteholmen, set to be completed in 2070 and house 35,000. Magretheholm serves as an early example of this development that can provide an insight into the demographic of people interested in moving to this neighbourhood. It also serves as an example of a building typology we can critically examine before continuing further wide-spread construction in the area in the same style; a style dependent on synthetic materials such as reinforced concrete and steel and thus the fossil-fuel industry.

The site is also appealing for the development of half-timber housing as it - despite its central location close to the city-centre - feels outside of the city and has potential for nature and culture preservation. The area features many pre-modern buildings that utilize the half-timber construction method, including my site's neighbouring building 'Quinti Lynette'.

Simply put, the point of departure for my project places itself physically and symbolically between Magretheholm and Quinti Lynette, drawing inspiration from Magretheholm's functionality and its demographic, and inspiration from Quinti Lynette's tectonics and architectural style.


*My Site: Located between Quinti Lynnette (left) and Margretheholm (right)*

## ATLASES

After deciding on the theme and site for my thesis project, the process first involved researching the timber frame technique and housing typologies with the help of a series of atlases. These atlases were divided to cover three main categories; joinery, house interiors, and row housing. They reflect the broader resolutions through which I framed my approach; the micro level in the building's joinery, at the macro level its interiority, and then its positioning into its immediate surroundings and as a contribution to the broader context of the city.

### *JOINERY ATLAS*

The joinery atlas first looked at cataloguing traditional joints most commonly used globally, so I could familiarize myself with the most tried and tested methods for post and beam construction. From this I could select those most appropriate for joinery in different circumstances. These techniques have developed over centuries through trial and error across many cultures, boiled down to what could almost be referred to as archetypal methods of wooden joinery.

The next section in the atlas looked at innovative digital joints that have recently become possible with the help of robotic milling technologies. These complex joints appear immensely impressive and are often designed for improved strength in the joint, but in their aesthetic, convey a detachment from the craft of the human hand that the traditional joinery techniques expresses so pleasingly.

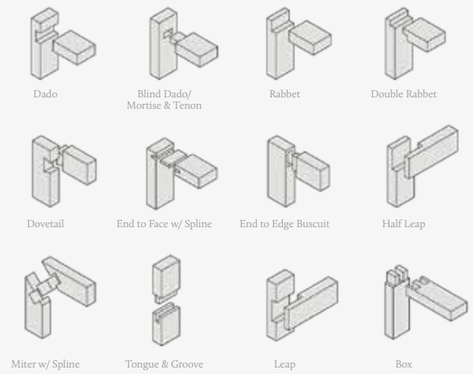
The third section involved me sketching joinery designs that attempted to bridge the gap between the charm and simplicity of the traditional techniques and the innovative complexity of the digital joinery examples.

Attempting to improve upon methods that have been developed over thousands of years in multiple cultures would be an immense engineering task in and of itself, so I concluded that my project will select from the traditional joinery set, and argue for the use of digital technology as a means to simplify the craft of these pieces, prefabricating them for ease of assembly on site.

The last section in the atlas looked at how different joinery methods influence the appearance of post and beam joinery as a spatial and tectonic element, looking at the meeting point between the frame and walls, ceilings and floors.



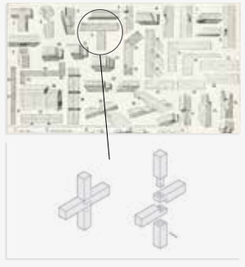





JOINERY: TRADITIONAL

Here is a collection of classic joinery techniques and their names to draw inspiration from. This collection focusses on some techniques specifically for joining beams, and is by no means a comprehensive list.

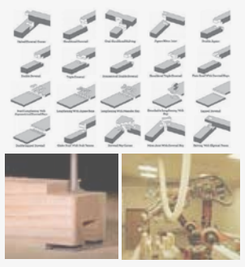
Having a base understanding and catalogue of the classic techniques that have been handed down through traditional craftsmanship for centuries is important, as I can then select techniques that I know will work, as it has been tested by many craftsmen in many contexts. I can also differentiate myself from the classics when trying to create an innovative solution, particularly now that we have access to technology that can machine cut complex joints more quickly and precicely.



TRADITIONAL JOINERY

Studying traditional joinery techniques that have been developed over centuries by hand-tool technology in multiple cultures, but most notably Japanese craftsmanship. Although more complex or elaborate joinery techniques can be achieved through CNC milling, these designs have evolved over time and have an aesthetic that is deeply connected to regional and traditional timber construction.

From studying these joinery styles, I can develop my own designs that serve the purposes I require, and that can be effeciently milled on a CNC machine.

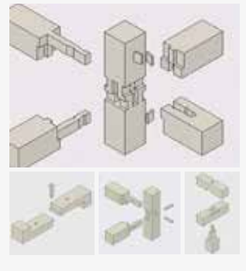


DIGITAL JOINERY

Joinery can be much more elaborate and complex when cut with machinery, allowing for high detail, and many interlocking shapes that create a strong grip between parts.

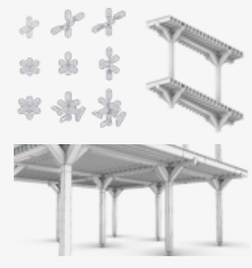
However, when using this create shapes otherwise near-impossible by hand, the resulting style can be very obviously digitally drawn and machine cut, which gives a clinical and cold style.

A balance between this approach and a traditional style could be of interest for my project.



JOINERY ASSEMBLY

Drawing inspiration from the traditional joinery shown previously, and the methods of digital joinery, I created sketches of possible ways to achieve cross-joins for beams and rafters, that reveal their assembly as part of their aesthetic. If these were to be exposed in the ceiling of my building design, rather than hidden behind boards and plaster, they would create a strong characteristic in the interior spaces that honestly expressed the building's construction as an aesthetic quality, adding a level of charm to the interiors.



JOINERY SKETCHING

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SOU FUJIMOTO ARCHITECTS
HOUSE NA (JAPAN)

This metal frame house by Sou Fujimoto Architects allows for the division of space to be extremified on both planes. While the materiality and transparency have little appeal to the intention of my project, the idea of using the house's frame as a grid to divide up the space both longetudely and laterally could allow for an interesting interiority that caters to the timber frame's inate characteristics.

BERNATH + WIDMER (GERMANY)
BÜTTENHARDT HOLIDAY HOME

This timber-frame holiday home designed by Bernath + Widmer is constructed using locally felled wood. The way the construction of the walls exposes the wooden frame on the both the interior and exterior.

This appears to be achieved by a double frame that is then in-filled, which seems to be an inefficient used of building materials. The alternative is however, some kind of wooden paneling as cladding, which may possible require more net wood, but perhaps would be a simpler solution and therefore cheaper.

TSUBAME ARCHITECTS
HOUSE IN KAMIIKEDAI (JAPAN)

This house in Kamiikedai, Japan, uses a timber-frame construction, wrapped in modern materials to meet requirements such as waterproofing, fire protection, heat insulation, view, aesthetics, and use. It follows the process of construction of a wooden structure and keeps this construction exposed as the interior's main personality.

LUKAS LENHERR (GERMANY)
KLEINES HAUS

In the middle of Jonschwil, three turned-off rooms were built on top of each other in a coach house. This stacking opens up a spiral-shaped vertical living space through all three floors.

Today a small house with 99 m 2 of living space stands on the square floor plan . The openings inside connect the rooms and create certain references to the outside. Perspectives arise.

The linked spatial relationships wink at Japanese spatial constellations. The house has no corridors but consists of sequences of rooms. Some of these can be experienced in different sequences and with catamaran nets they can be experienced in a horizontal state of suspension.

PRACTICAL ARCHITECTURE
TIMBER WEAVERS STUDIO (LONDON)

This self build project was designed closely with the client. Shown under construction the monolithic 3 story timber and hempcrete building houses a textiles workshop, two apartments and and a raised internal courtyard.

The sustainable approach to the project was holistic and driven by low embodied carbon and lifecycle analysis. The building is low tech, self-regulating and manually controlled rather than technology driven.

The workshop and apartments were designed to be robust and built by unskilled labour and to celebrate the materials from which it is made creating a richness of character.



***HOUSING INTERIORS ATLAS***

The Housing Interiors atlas looked at different examples from around the world of how timber can be implemented as an aesthetic and spatial characteristic for housing interiors. The collection of references focused of course primarily on examples of timber-frame houses, where the construction of the frame is either exposed, or hinted to, in the nature and character of the building's interior.

In the early stages of the project, I was interested in exposing the timber-frame on the exterior of the building, as this was the common method seen in traditional 'binningsværkshuse' (half-timber houses) built throughout history in the region, exemplified by my site's neighbouring reference, 'Quinti Lynnette'. An early reference in my House Interiors atlas was therefore the 'Büttenhardt Holiday Home' by Bernath + Widmer from Germany, which prefabricated its walls as boxes that were then in-filled, creating a kind of double frame that is exposed on both the exterior and interior. This relies on excess wood consumption, however, and as my project was to prioritise the interior as the project's catalyst, I looked at examples that insulated the frame on the exterior, exposing the frame to the interior, rather than pursuing a double frame solution or prioritising the exterior over the interior.

Several such examples came from Japan, notably the 'House in Kamiikedai' which is wrapped in modern materials on the exterior to meet requirements such as waterproofing, fire protection, and heat insulation, whilst keeping its wooden construction exposed as the interior's main characteristic. The frame is also used to inform the placement of interior walls, stairs and in-built furnishings, an approach I drew much inspiration from later on in the design process.

The atlas extended itself outside of the parameter of timber frame architecture too, including among others a pivotal reference in the form of the 'House NA' by Sou Fujimoto Architects in Japan; a metal frame house that is described in the Architect's own words thusly: "Associated with the concept of living within a tree, the spacious interior is comprised of 21 individual floor plates, all situated at various heights, that satisfy the client's desire to live as nomads within their own home." (Archdaily, 2012). A parallel between this project and the timber frame method was observed in the gridded approach to spatial arrangements. As observed in virtually all timber-frame examples in my Housing Interiors atlas, the division of space in timber frame homes is commonly informed by the grid created by the frame's limited span when using timber.

However, in my research I did not come across timber-frame examples that used this approach vertically, at least not to such a degree as seen in the case of the 'House NA'. This verticality in the grid, along with the metaphorical comparison to the house as a tree, and its rooms as branches, which inhabitants can communicate to one another between, was a key concept that I drew inspiration from throughout the design process.

Other highlights from the Housing Interior Atlas come from the London-based Practical Architecture projects 'Flat House' and 'Timber Weaver's Studio', which feature an exposed timber-frame with hempcrete in-fill on the interiors, which is where I first came across hempcrete as an in-fill material. The 'Kalkhennephuis' by Werkstatt in Holland also uses hempcrete in-fill, but finishes it with a lime plaster to give a cleaner, more contemporary look that creates contrast to accentuate the timber frame structure. This is the technique I used for my final design.

### *ROW HOUSING ATLAS*

The final Atlas series looked at row housing as a building typology. The first reference in my Row Housing atlas comes from Vandkunsten's 'Grønttorvet', which very much resembled my early-process intentions for the project; specifically regarding building scale (3 stories, 11m in depth on the ground floor and 7.2m on the upper stories), the low-rise row-housing layout and the subsequent 'streetscape' created, as well as the approach to providing affordable housing through a simplified construction process. The initial focus of my project was on building economically to provide relatively cheaper wooden housing and 're-democratise' the timber frame typology, as it was my observation that half-timber housing has become rare and therefore attractive and expensive on the housing market. Although my final design still aims to use resources efficiently and economically, my focus transitioned throughout the design process toward prioritising natural building materials for health and environmental benefits, which aren't always the cheapest options. My final proposal is designed as AlmenBolig+ (SocialHousing+), an innovative concept in Danish Social Housing that regulates the market to lower housing costs.

The second notable reference in the Row Housing atlas was Arne Jacobssn's 'Søholm' row housing, where he himself lived. Jacobsen rotates each house and staggers them in relation to one another, creating semi-sheltered exterior niches and orientating the buildings towards the sun for maximal light and potential passive heating. Passive heating is important when working with a climate like Denmark's, especially when working with natural insulation materials such as Hempcrete, which have dynamic thermal and breathable properties; sequestering heat during the day and releasing it again at night. I therefore implemented this approach in my design.





ARNE JACOBSEN
SØHOLM - ROW HOUSING

Arne Jacobsen's row housing rotates each house to allow for more dynamic exterior spaces. it also exposes moreof the house to the outside, allowing for windows in places that would otherwise closed off by a neighbouring unit.

This approach can also be used to orientate front or back faces towards the sun, for maximal light and warmth.

VANDKUNSTEN
GRØNTTORVET (COPENHAGEN)

(Text from Vandkunsten's website)
"The Grønttorvet project features 49 family friendly units in the Copenhagen district of Valby. The 1-3 storey dwellings are built as AlmenBolig+ (SocialHousing+) which is an innovative concept in Danish Social Housing. The rent is 10 percent cheaper than conventionally by combining a new mode of responsibility given to residents, with highly optimized construction processes."

This project has clear parallels to my project, particularly regarding building scale, low-rise row-housing layout and approach of providing affordable housing through a simplified construction process.

VANDKUNSTEN
CO-HOUSING FROM WOOD

(Text from Vandkunsten's website)

...Modern co-housing villages with plenty of shared facilities, and community feeling.

The cohousing concept offers endless variations on a theme and the different spatial-unit designs are used as an architectural tool for providing variation in the village and flexibility for its inhabitants. The formal design creates a separate identity and adds new spatial qualities to the houses. The buildings themselves and life within them promote a special concept for the community.

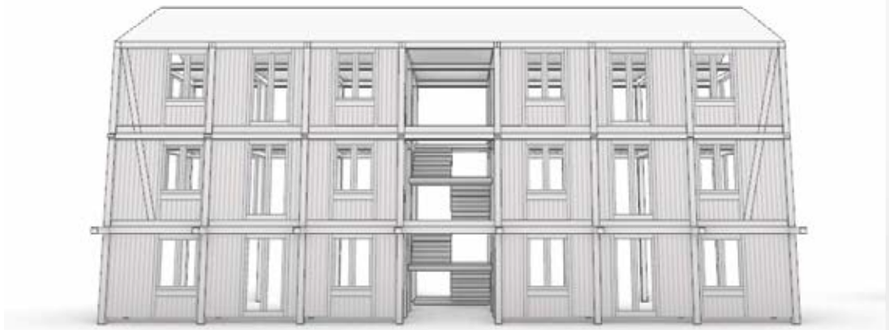
THAM & VIDGÅRD
VERTICAL VILLAGE

Tham & Videgård's Vertical Village is the antithesis of that which I aim to achieve. It's placement of housing creates a lack in privacy between homes, shelter from the weather, and intimacy in the grass spaces provided.

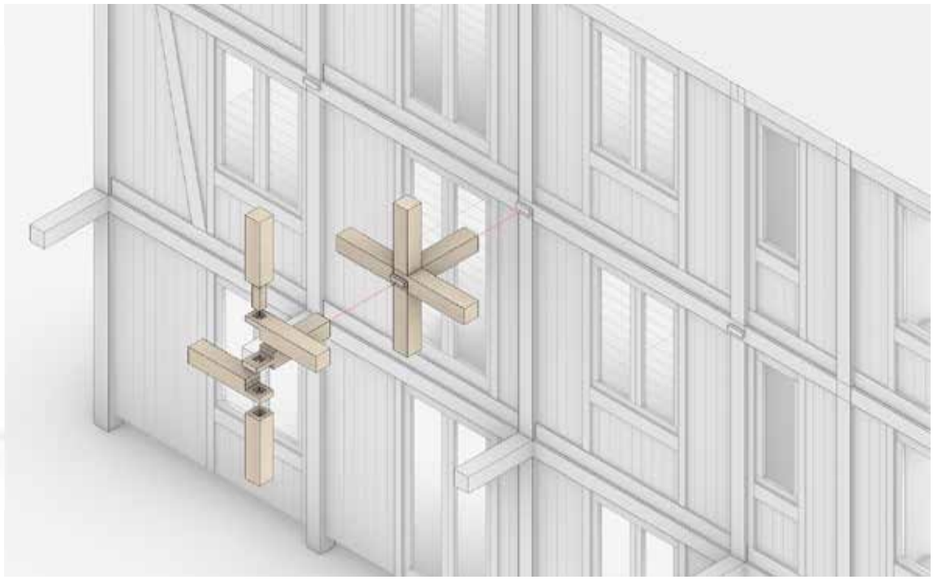
The poor density this housing arrangement provides is ironically made clear on their own website via an arial photo of the site, where it is made clear that their housing is less dense than the 1-2 story detached homes that new urbanists are so against.

PRACTICAL ARCHITECTURE
NAKED HOUSE (LONDON)

Practice Architecture have been working with not-for-profit housing developer Naked House to develop designs for affordable housing within a Community Land Trust model. The homes are designed to be highly adaptable, ensuring that they continue to meet the changing needs of the residents. The designs are developed to provide relatively high density community housing on small to medium publicly owned sites. The buildings are designed to be zero carbon with a bespoke timber frame system.

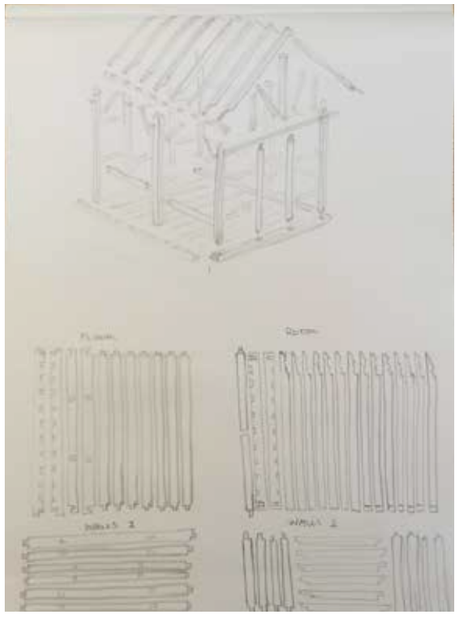


*Sketching - Joinery as point of departure*



*Sketching - Joinery as point of departure*

*1:1 joinery experiments in wood*



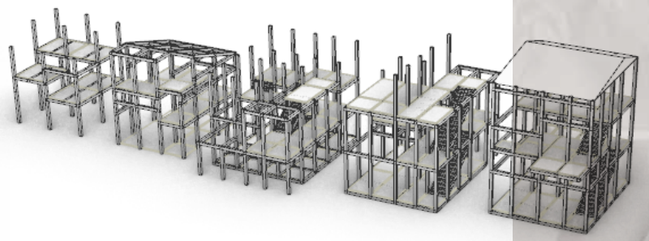
*3D sketching exploring the assembly of a timber frame piece by piece*

## DESIGN METHODS AND PROCESSES

### *JOINERY AS THE POINT OF DEPARTURE*

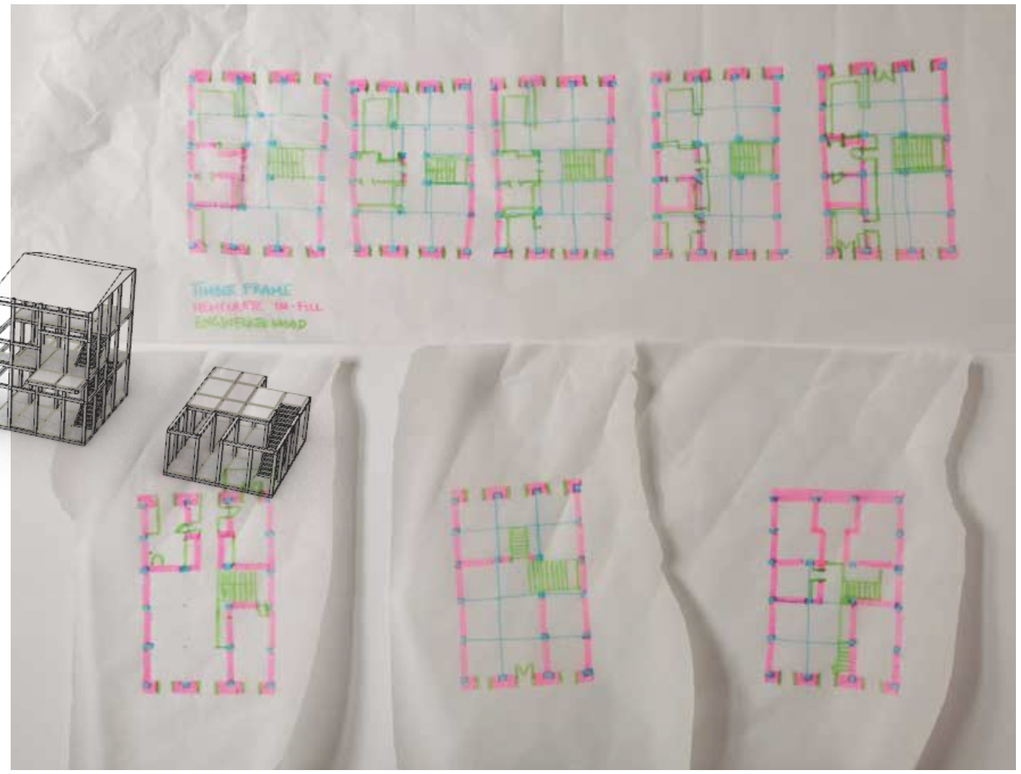
The Atlases described above were not created in a particular order or completed before starting the design process, but rather, were collated alongside the design process, creating an ongoing dialogue between the research and design. The Joinery Atlas was my first point of departure, so the first part of my design process involved sketching a timber frame, inspired by my outcome of the 'Thesis Catalyst Bootcamp' in February; a scale timber frame building constructed in paper which focused on tectonics and construction hierarchy. Following this I digitally 'constructed' a timber frame piece by piece in the 3D drafting program,  Rhinoceros without too much regard for the spatial properties of the structure, allowing the tectonics of the joinery method to inform the layout. The process gave me a basic understanding of how to work with the proportions of a timber frame regarding span of beams, grids created by placement of posts, etc, but it was apparent that I would need to prioritise the interiority of my house as my point of departure, and return to the tectonics later in the process. I referred to my Housing Interiors atlas to begin sketching concepts for the house's structural layout.

*Concept of the 'House NA' as a tree - From 'Sou Fujimoto'*



*3D sketch iterations*

*Sketching in plan on paper*



*Floorplans with focus on material palette*

*Physical model sketching*

*Physical model perspective*

*Volume model 1:500*

### *INTERIOR AS THE POINT OF DEPARTURE*

As mentioned in the above section 'Housing Interiors Atlas', the 'House NA' by Sou Fujimoto Architects was an important inspiration for the spatial organisation concept for my housing design. I combined sketching floorplans and sections on paper and sketching in 3D in Rhino, progressing through grid layouts for the timber frame's beam placement. 2x2, 3x3, 4x4, 3x5, etc (this is counting the 'bays'), raising and lowering the floors as ceilings to create interesting compositions (pictured: '3D sketch iterations). The final design is 3x5, but I worked with other designs for a large portion of the process, which will be apparent in my process imagery, as any adjustments to relationships between spaces meant adjusting the whole plan, in several cases revisiting the grid structure.

### *SKETCH, REFINE, RESET*

A sketch model of an earlier iteration of the timber frame was built in wood at 1:50, into which I positioned inner walls cut from foam-board, to further experiment in 3D with various compositions (pictured: 'Physical model sketching'). Throughout this process, I tested the building's relationship to the context in a 1:500 volume model , observing how the various iterations work when rotated and staggered as done in Arne Jacobsen's 'Søholm' housing (pictured: 'Volume model 1:500).

*Early design iteration interior render*

*Early design iteration exterior render*

Quick renders using Keyshot and Photoshop allowed me to visualize how the building's developing shape would relate to the surroundings, light and shadow, and materiality. Pictured above are a two renders taken for an earlier iteration of the design.

This was the process I implemented for the spatial layout of the house; a progressive cycle of sketching, refining and resetting, that eventually narrowed me down the final design. Adjustments were to be made when introducing furnishing, detailing and cladding.

***KILL YOUR DARLINGS***

A key challenge that greatly influenced my process came from the recognition that my response to working from home saw me relying too heavily on digital sketching in Rhino. This tended to result in a loss of sense of design hierarchy and resolution, preemptively designing details before the gestalt of the project was adequately designed, making flexibility of design changes difficult. My approach to combat this was twofold: (1) To periodically return to paper sketches, particularly plan drawings, attempting to distil the current iteration to its essence, and identify which darlings were to be killed and which were to be preserved, and (2) to utilise perspectival planning techniques by deciding on key perspectives that portray the most important elements of the project and use Photoshop collage and Keyshot renders to visualise different material, joinery and furnishing options.

This approach was very helpful when introducing furnishing to the spaces, whether in-built or loose furniture, as it made the functionality and versatility of each space very apparent. Refinements to the structure had to be made to better accommodate these spatial intentions, which was more easily done when too much time hadn't already been spent on the fine details of the previous design proposal. The results of these refinements and the qualities of each space will be covered later under the section 'The Result'.

*Render from my 3rd crit*

*Render of my final proposal*

***LEGIBILITY***

A pivotal change came when I decided to sharply define the 4 main materials in my palette, and define their typologies so that they contrast legibly to one another in the building's tectonic language. The palette in the final proposal consists of: Solid oak **timber** for the frame, **hempcrete** for the infill, **engineered wood** in the form of plywood for furnishing and reveals and CLT for the staircase, and **cork** for the cladding.

The nature of exposing structural elements to the interior can result in a chaotic visual composition, forcing the designer to consider the positioning and aesthetics of every element. This is evident when comparing my proposal for the third crit (pictured above), and the final proposal (above-right). The simplification of the palette helped distill the various design elements down to a more workable language, so that it was more clear to the viewer how each part contributed to the whole.



If we observe the staircase of the two proposals, we see a development from open threads and balustrade, to a staircase with closed risers and a solid balustrade. In the open staircase design, the balusters clashed with the language of the exposed ceiling joists. The closed staircase design in engineered wood creates more contrast, making the space and these elements more legible and visually pleasing. The final proposal also establishes a clearer division between the front and rear sections of the open plan ground floor, which I ill discuss further under 'The Final Proposal'.

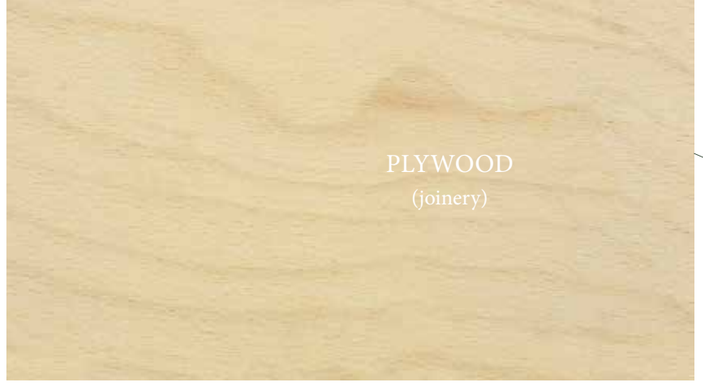
***VISUALISATIONS***

Throughout the process, Keyshot renders and Photoshop collages were used to visualise key perspectives, in order to keep the materiality, lighting and context in perspective whilst designing the building composition. It is easy to lose track of the balance between different materials while working in a digital modeling program, and the visualisations at various stages of design show a refining of this balance, and allowed decisions such as the staircase redesign described in the last paragraph.

## MATERIAL PALETTE

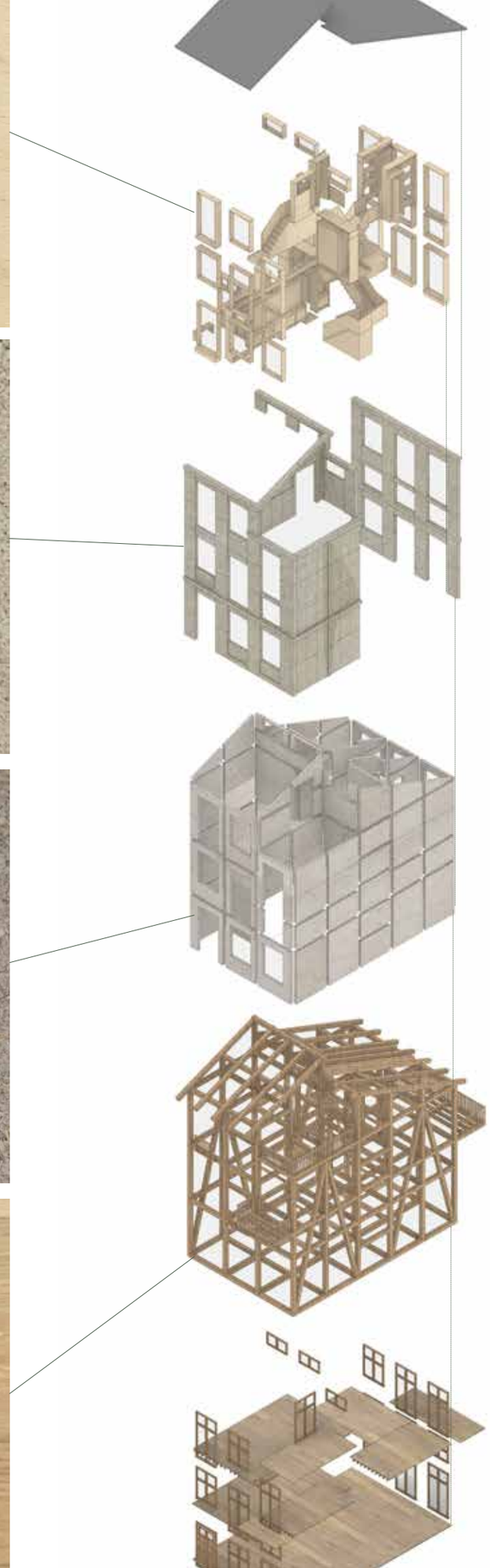
My timber house proposal limits its palette to 4 main materials, each serving their own purpose and designed with their own language, in a way that contributes to the whole. The building's main structure is held up by the hardwood timber-frame and the infill is hempcrete with a lime finish. The stairs, thresholds and joinery use engineered wood such as ply and CLT, and the cladding and roofing are in cork. These 4 materials are all tree or plant based (save for the lime in hempcrete and glue in ply) making the house an almost completely "wooden" construction. There are two extra materials: Rope netting, which is used as a safety barrier in one of the building's more unique spatial features; the opening between the first and second floor, and steel screw piles for the building's foundation. This choice for the foundation is a compromise on the natural material premise, but is chosen for its non-intrusiveness and re-usability at the end of the building's life-cycle.

The four main materials are chosen both for their inherent strengths in the purposes they serve and their sustainable qualities, but also to provide contrast and legibility between these different building elements.









*Exploded axo of my final proposal*

### *FRAME (TIMBER*

As my project revolves around the timber-frame technique, timber is the obvious main-ingredient in my material palette. Although other woods can be used, oak is the most commonly used in timber-frame construction in Denmark, as its hardness is beneficial for load-bearing performance as well as maximum strength and fine precision in complex joinery. In cutting away wood for joinery, the wood around the joint is unfortunately weakened, so hardwood such as oak, mahogany and maple, are best for these situations. Hardwood comes from trees that grow slowly, making them a more expensive material. One is thus motivated to use it sparingly, utilising large spans and a different material for the in-fill, a common approach in timber-frame housing (pictured: 'Timber Frame'). Conversely, a stick-frame construction technique often uses faster-growing and thus cheaper softwood such as pine, cedar or spruce. This method requires a larger volume of wood, in order to evenly distribute the weight of the construction across the many studs in the load-bearing walls (pictured: 'Stick Frame'). For this reason (among others that I will outline in the section 'Atlases' (p.21), I decided to employ the 'post and beam' timber frame method.

*Timber Frame*

*Stick Frame*

### *IN-FILL (HEMPCRETE*

Traditional half-timber construction has used the wattle and daub technique for its infill for at least 6,000 years. The technique entails a woven lattice of wooden strips called wattle, which is daubed with a sticky material usually made of some combination of wet soil, clay, sand, animal dung and straw (pictured top-right). Many historic buildings include wattle and daub construction, and the technique is becoming popular again in more developed areas as a low-impact sustainable building technique. In Europe, when the manufacturing of bricks increased, brick infill replaced the less durable infills and became more common (pictured bottom-right). Stone laid in mortar as an infill was used in areas where stone rubble and mortar were available.

Today, with the increased popularity of working with timber-frame structures, new innovative infill materials are being proposed to combat the prominent use of synthetic materials used for insulation throughout the twentieth and twenty-first century, such as the common combination of fibreglass insulation, foils and plasterboard finish.

*Wattle and Daub technique*

*Timber frame with brick infill*

*Installing fibreglass insulation*

One such material is Hempcrete, the material I've chosen to work with as my infill and insulation material. Hempcrete is a biocomposite material, a mixture of hemp hurds (shives) and lime, sand, or pozzolans, which is used as a material for construction and insulation. Due to its thermal density and permeability to water vapour, it operates as a thermal insulator and moisture regulator in one. It also has high sound insulation performance, fire resistance (Class A2 for a block rendered on both sides. It is inflammable and does not release toxic gases during its combustion), has health benefits due to its 100% natural materiality and zero toxicity, and massive environmental benefits compared to its competitors. The growing of hemp sequesters more $C^{02}$ than the production of hempcrete creates, making it a carbon sink, save for its transportation.

One of its main constructional benefits is - due to the versatile above-stated benefits - that it can be used alone as an insulation material, cutting out the need for foils, vapor membrane or plasterboard finish, which are made of synthetic and toxic materials. Its rough texture also allows for ease in the application of a finish, for example lime or clay, where modern techniques often required wiring or a layer of synthetic material to aid the adhesion.

*Flat House' by Practice Architecture (London): Hempcrete infill exposed to the interior*

*Karl Nørgaard, Magnus Henriques & Mikkel Damgaard Nielsen (right): 'Havnens Hænder'*

I visited Havnens Hænder in Refshaleøen, a newly started company that supplies natural building materials such as hempcrete, cork, lime and plantfiber, in the form of boards, building blocks and insulation. I spoke with Mikkel Damgaard Nielsen (pictured), who showed me samples of the materials and explained the benefits of building with hemprete (and cork), and informed me of what I needed to know regarding construction with these materials.

### *ENGINEERED WOOD*

The building's in-built design elements, including the stairs, threshold frames and cabinetry, employ engineered wood sheeting to differentiate themselves from the building's other elements. CLT is employed in instances such as the stairs where human weight is to be supported safely, and to allow the floating design that will be shown in 'The Final Proposal'.

*'Kalkhennephuis' by Werstatt (Holland): Hempcrete infill with lime finish*

*'Fence House' by Hitotomori Tomoko: Inbuilt plywood furnishing*

***CORK***

During my visit at Havnens Hænder, I asked Mikkel Damgaard Nielsen what materials they used for cladding. He responded with a guided tour of their samples of cork boards, with an explanation of their benefits and applications in exterior cladding, roofing, and insulation. I was skeptical at first, as I hadn't seen or heard of cork as an exterior cladding material. He provided me with reading materials on the performance of the material, and further research lead to many contemporary examples of buildings that employ cork as a cladding material (pictured right).

When used in construction as cladding or insulation, cork can last in excess of 50 years. It is water resistant, highly durable, naturally insulative, and resistant to algal and fungal growth, meaning that it ages well aesthetically. After its lifespan, cork panels can easily be replaced due to their light weight and flexibility. Cork is extremely versatile, as it can be cut or milled into any shape your CNC mill can manage (pictured right).

Cork is harvested by removing bark of cork oak trees without felling or damaging the tree. Bark is harvested from the tree every 9-12 years, and the regeneration of the harvested tree absorbs 3-5 more $CO_2$ than a non-harvested tree. Cork oak trees in Portugal alone help offset 10 million tons of carbon every year. The one downside is transport. Cork that is available in Denmark is farmed in Portugal and Spain, but the environmental benefits of cork out-way those of locally produced synthetic alternatives.



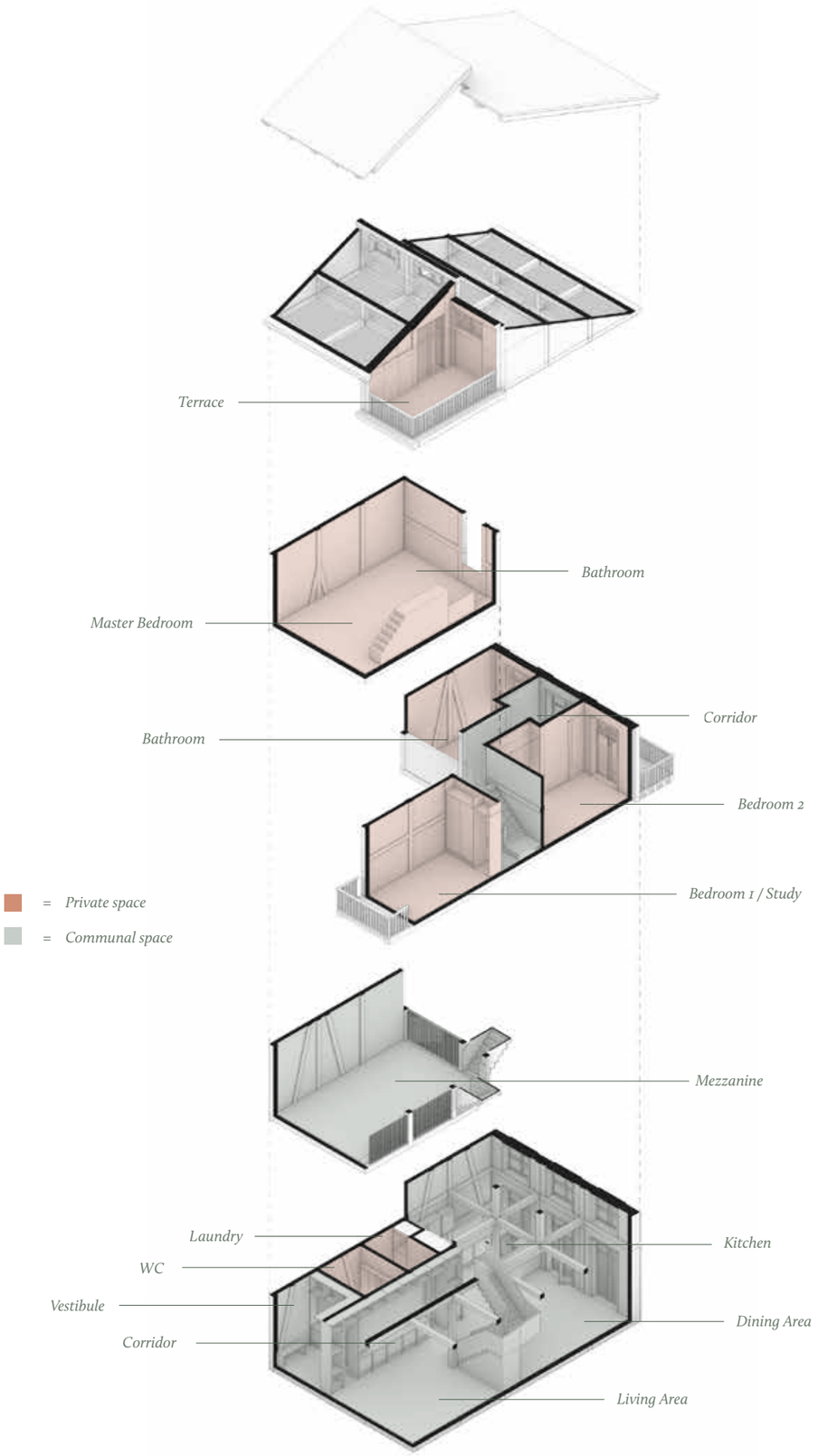
*CNC milled cork samples at Havnens Hænder*



*'Two Cork Houses' by lópez rivera arquitectos: Cork cladding*



*'The House of Wood, Straw and Cork ' by LCA Architetti: CNC milled cork facade*




## THE FINAL DESIGN PROPOSAL

The final design proposal is a multi story row house with a depth of 10.5m, width of 6.7m and a total interior square meterage of 170m2. The floorplan follows the grid structure of the timber frame, but breaks from it in certain instances, pushing some walls into adjacent rooms to create niches for in-built furnishings.

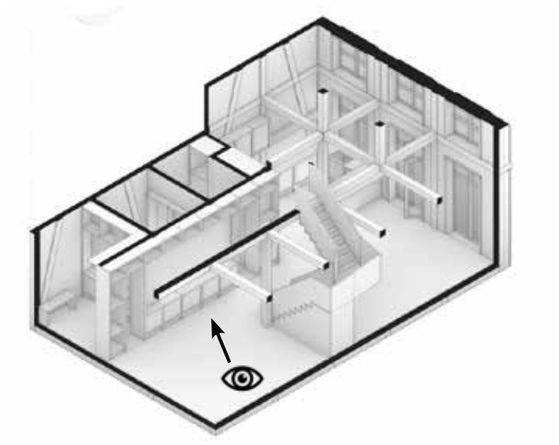
The building's spaces can be roughly divided in two categories; 'communal' and 'private'. The communal spaces follow principles inspired by the 'House NA', which describes the house as a tree and its spaces as branches, separated by elevation and detail but open to one another for sensorial and communicable contact. My design uses this principle more subtly, dividing the open space using differences in ceiling heights and via the timber frame's grid imposed by the posts and beams. This creates communal spaces that are open to one another in a way that allows residents to simultaneously inhabit their own parts of the whole, without closing themselves off from social contact between spaces. The spatial divisions are made clear through layout and design details, to avoid the issues of legibility and underutilized space common to open plan designs.

This open division, or "NA branch principle" we could call it, is also applied on the vertical axis with the opening between the ground and first floor 'mezzanine'. Say a parent is preparing food downstairs and their children are playing in the mezzanine, the parent will be able to signal to the children between the two spaces by calling to them. The children are able to hear, see and also smell activity on the ground floor, keeping them within some kind of contact whilst also providing a semi-private space to play. If full privacy is required, inhabitants can retreat to their own rooms, separated by elevation, allowing the stairs to serve as a transitional space between communal and private.

### *THE 'VESTIBULE'*

The front door is positioned within the left bay on the ground floor, as seen from the southern elevation. It opens to a small 'vestibule', which serves as a coat room and space to comfortably remove and store footwear before entering, sheltered from the weather and with in-built seating and storage. The space functions as a type of transitional space before entering the main ground-floor communal space. The doorway between the vestibule and corridor is built into the joinery using the same birch ply, so they differentiate themselves from the other elements, as I outlined under the section 'Material Palette' (pg. ?)

*Perspective of living space, vestibule, corridor, door to laundry. 1st floor*



***CORRIDOR***

Entering from the vestibule, the ceiling height in the corridor remains the same at 3m, tying the two spaces together as transitional. The 'corridor' which runs down the front middle section of the ground floor, features in-built storage along the left-hand wall to give the space utility, with a doorway to the laundry and wash closet built into the joinery. Although the corridor is open to the living, dining and kitchen areas, ceiling heights and the timber frame differentiate it as its own transitional space that ties the ground floor's 'rooms' together.

***LIVING AREA***

The ceiling is raised to 4.5m in the front living area, accentuating the transition into the space from the corridor. This also opens up contact between the living area and the mezzanine, which is placed above the vestibule, corridor, laundry and WC. It also gives space for an extra window above the ground floor window in the southern façade, letting in more light to the area from above which emphasises the ceiling height as well as providing passive heating. The stairwell separates the area from the dining area and creates a niche against which furniture such as a sofa, shelving system or television can be placed. The space is without in-built furnishing to allow for flexible, personalised living, however, an example of furnishing is shown in my visualisations.

### *LAUNDRY / WC*

Across from the base of the stairwell is a doorway to the laundry, which is embedded into in-built cabinetry along the corridor's western wall. Half of the wall to the right as you enter the room has been pushed into the laundry to allow space for in-built furnishing in the kitchen in the form of a niche with shelving; where a washing machine and dryer can be placed, as well as additional storage above for other cleaning or miscellaneous products. The laundry and WC have been divided into two rooms. This is both so that the laundry can be accessed while the WC is in use, and to add an extra transitional threshold space between the toilet and the corridor. The positioning of the door between the two rooms keeps the toilet out of sight from the living area, stairwell and dining area, if the doors are left open.

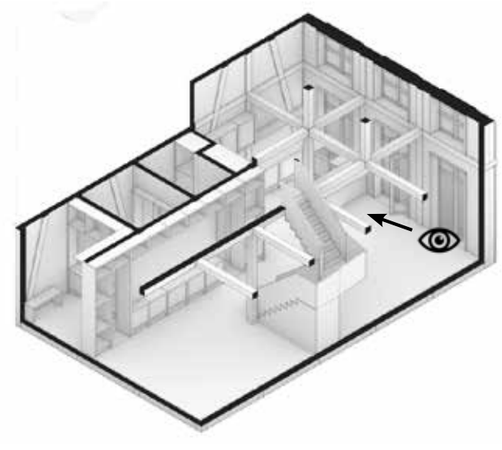
### *DINING AREA*

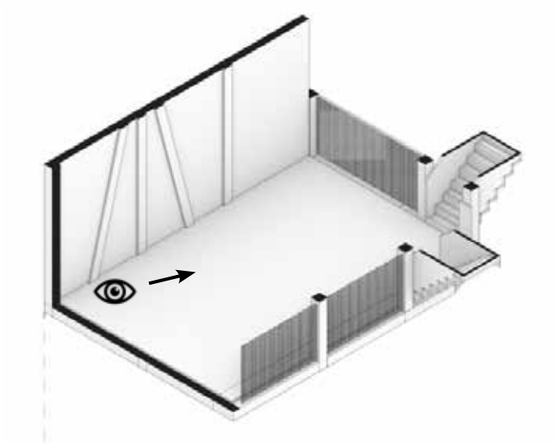
The dining area shares the living area's ceiling height of 4.5m, but is separated from it via the stairwell centered on the building's west-east axis. Like the living area, the ceiling height allows for an extra row of windows to let in light, and to maximise the view out towards Magretheholm's harbour, Refshaløen, Ørsund and importantly, the sky. Two french doors can be opened to create a indoor-outdoor connection to the garden when weather permits, where outdoor seating can also be placed. Like the living area, there is no fixed furniture in the dining area, allowing flexibility and personalisation in the furnishing of the space.

### *KITCHEN*

The kitchen shares the dining area's ceiling height and only subtly differentiates itself spatially through use of the timber frame grid, accentuated by the placement of a kitchen peninsula. The kitchen and dining area are designed to flow together as one functional space, but are to be read as their own separate spatial and functional zones. The kitchen peninsula is designed to accommodate bar seating, to allow for social activities around meal preparation, and as an informal landing point when entering from the rear garden.

*Perspective of dining space and kitchen*





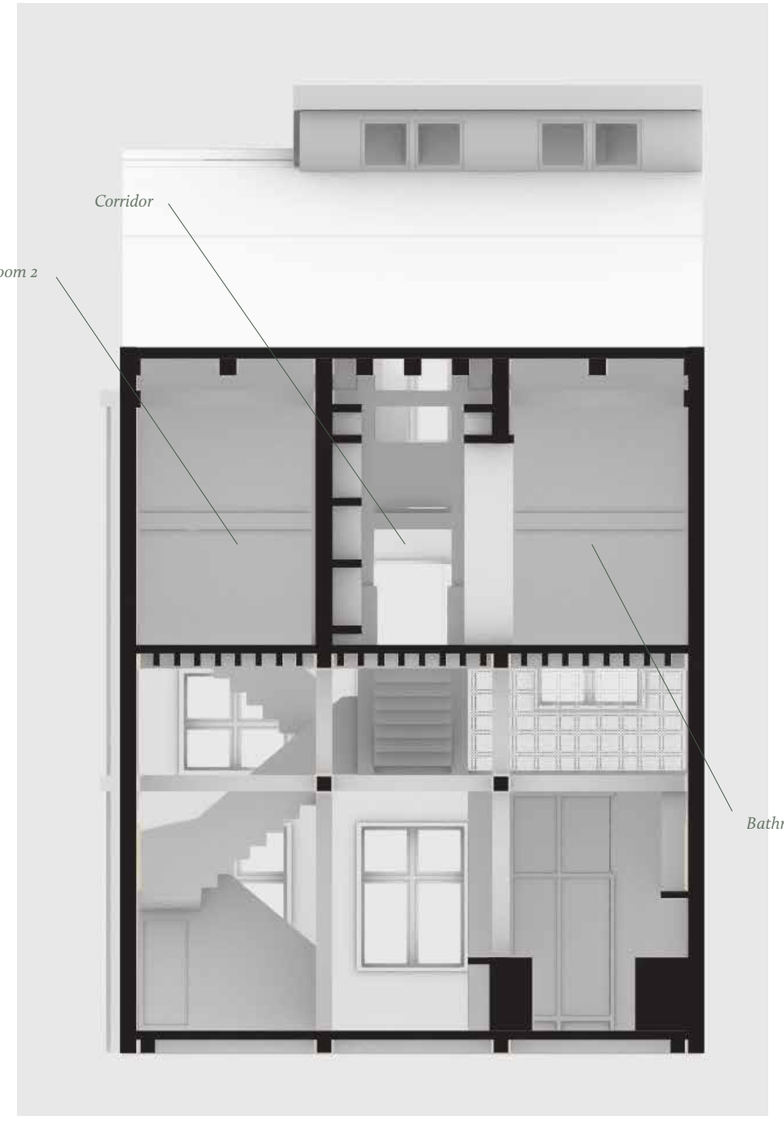
*Perspective of mezzanine*

***SECOND FLOOR - MEZZANINE***

At the top of the first flight of stairs is the last communal space, which I refer to as the second floor or 'mezzanine' as it is partly open to the floors below. This 27m² space is intended as a second living space or recreation room, potentially an area where children or teenagers can play or relax in situations of cross-generational living, or a study/recreational/creative space for other co-living situations. It has windows that face the southern light, and features a small french balcony with a view over the neighbouring lake 'Minebådsgrav'.

The space is unique, in that its opening to the ground floor is via the bottom-half of the interior 'walls', rather than over a waist-high railing like in the case of most mezzanines. This allows increased visibility between spaces due to the angle created by the elevation, but requires a kind of safety precaution in the threshold, which I achieved with a rope netting.

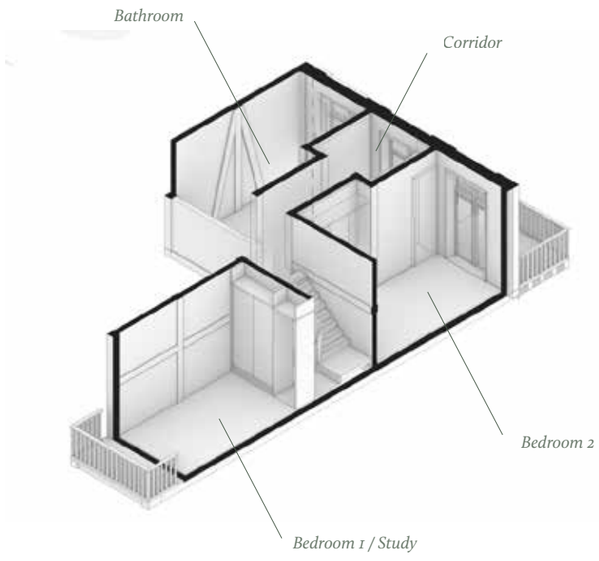
This netting ties in with Refshaleøens local nautical history as a boat production hub for the city throughout the 19th and 20th centuries. Other options were transparent glass or plastic, which i decided against as I was interested in a permeable solution in natural materials. Another option was wooden spindles, but, just as was the case with my early staircase balustrade designs, this clashed with the exposed ceiling joists and contributed to a visually chaotic composition. The netting creates a nice contrast that highlights the opening as a unique element in the building's design, and is in-keeping the building's narrative.




***THIRD FLOOR***

The third floor is made up of two bedrooms and a bathroom, as well as a small corridor at the top of the staircase between the bathroom and 'bedroom 2'. This corridor has access to a small balcony that overlooks Refshaleøen and Ørsund, lets additional light into the mezzanine, and also features in-built shelving for storage. The bathroom has a toilet, sink, shower and cabinets for storage, and is positioned with a window towards the northern façade for ventilation. It's positioning on the 3rd story allows for privacy from the street level without the need for frosted glass. Curtains can be installed if desired. 'Bedroom 2' uses the niche created by pushing the wall out into the narrow hallway space for an in-built wardrobe, and also has a small french balcony overlooking the northern view. The ceiling in both rooms is pitched, 3m at its lowest and 4.6m at its highest, which exposes a beam across the room that accentuates the ceiling height and adds character to the space.

'Bedroom 1' is accessed halfway up the main stairwell, and has a small balcony that faces the southern light, making up for the smaller square meterage (9m²) compared to 'bedroom 2' (10.9m²). Its size and positioning relative to the master bedroom are also suitable for use as a study, in living situations where only two bedrooms are required.



*FOURTH FLOOR*

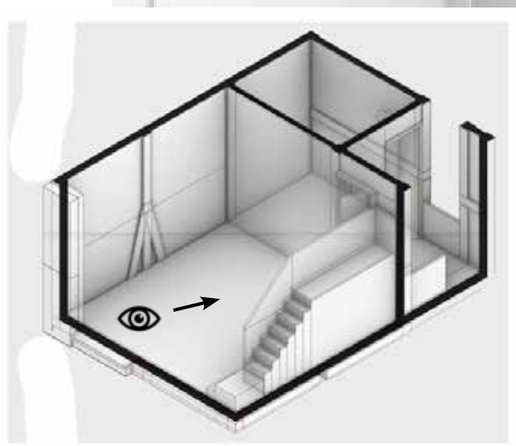
The fourth floor consists of the 'master bedroom', a bathroom, a small hallway at the top of the stairs, and access to the roof terrace. The small hallway allows for the bedroom to be closed off from the stairwell, and also serves as a transitional space between the bedroom and bathroom. The hallway is aligned with the hallway on the third floor, and with skylights, allows for natural light into the central parts of the house furthest from the windows. The bathroom features a toilet, sink, shower, and cabinets for storage, and has a skylight for natural light and ventilation.

The master bedroom is the largest of the three (17.7m$^2$, designed for two inhabitants - for example parents or a couple - with their own bathroom facilities and roof terrace access. The meeting point of the two skillion roofs makes space for windows to let light into the middle of the fourth floor, and as a ventilation point for rising hot air from throughout the house to exit.

A small staircase doubles as access to the roof terrace and as in-built  shelves for storage.

*ROOF TERRACE*

The terrace is placed in the recess in the roof created by the interiors' differentiated ceiling heights, and faces the southern light with a view over the lake. Its balustrade differs from the interior staircase's balustrades, with simple square wooden spindles, newels and hand-railing, that contrast the simple expression of the exterior cork cladding.



*Perspective of master bedroom and roof terrace access*

## REFLECTION & NEXT STEP

This project was conducted during the Covid-19 pandemic, and required working for home for most of the semester. This greatly influenced the approach to the project and the methods I used to achieve my proposal.

This had interesting consequences for the project's scale and framing. Initial plans for the project involved a deeper and more detailed focus on complex tectonics and timber joinery, but as the semester was mostly conducted via computer and paper sketching, my focus shifted towards the interior spatial and living properties of the timber frame approach. This resulted in what I believe is a richer spatial interior exploration into the timber frame's properties, than if I had continued down the path outlined in the section 'Joinery As The Point Of Departure' (p.23).

This project was about the spatial qualities of designing with a timber frame, but moving forward with the project, I would return to the workshop, and zoom into the tectonic details, designing beautiful timber joinery, further accentuating the character of the timber frame to the interior spaces. I would also design the inbuilt furnishings in higher resolution, perhaps working with skilled cabinet makers to create details that harmonize with the joinery of the timber frame

*Rear elevation of my final proposal*

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