MSc04 ARC
Signe Gregers Christensen

ÅSTRUPSKRÆNTEN

a sustainable transformation of the 70th suburban neighbourhood

June 2025

Ill. 1. Bird's eye of Åstrupskrænten, CREDIT base photo: CC BY 4.0 KDS. Modified by the author.

TITLE PAGE

PROJECT TITLE	ÅSTRUPSKRÆNTEN *a sustainable transformation of the 70th suburban neighbourhood*
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Ill. 2. Picture of Åstrupskrænten

ABSTRACT

This project aims to explore a sustainable transformation of suburban neighbourhoods from the 1970s, with a particular focus on Åstrupskrænten and, more specifically, the building at Åstrupskrænten 45. The transformation seeks to increase residential capacity, optimize interior and exterior spaces, and enhance opportunities for social interaction, thereby fostering stronger neighbourly ties.

In contrast to the trend of demolishing outdated suburban homes, this project proposes a future-oriented design strategy based on adaptive reuse. The building is redesigned to be flexible, allowing it to expand or contract in size according to the occupants' needs over time, achieved through minimal interventions that preserve the original structure.

The design process follows Rob Reggema's Research by Design methodology and is divided into three phases. The Pre-Design phase includes site analysis and problem formulation using sub methods such as mapping, sketching, case studies, interviews, and literature review. The Design phase is split into two stages: an exploratory phase where design questions are developed and assessed through pros and cons, and a conclusive phase with site-specific decisions for Åstrupskrænten and Åstrupskrænten 45. Here, sub methods such as LCAbyg, Be18, daylight analysis, and sketching were applied. Finally, the Post-Design phase combines the findings, supported by refined simulations and calculations, while it also reflects and concludes on the project.

The outcome is a replicable design framework for sustainably transforming 1970s suburban neighbourhoods. While the final design is tailored to Åstrupskrænten, the process itself can be transferred to similar sites. Had another site been chosen, the contextual response would differ, but the overall method would remain valid.

The project results in a redefinition of the "good life," where residents can adapt their home to changing needs, and engage with neighbours in shared outdoor spaces. The original architectural language is retained to maintain a sense of connection to the past, while upgrades, particularly targeting energy performance and material emissions, ensure long-term sustainability. The project demonstrates that 1970s suburbs need not be demolished; with modest interventions, they can be reimagined as flexible, socially vibrant, and environmentally responsible communities.

READING GUIDE

The design process has been thoroughly documented throughout this report, which begins with an introduction to the project's motivation and the broader problem statement. The content is structured into six chapters: Methodological Approach, Pre-Design, Design, Post-Design, Final Remarks, and References.

To fully understand the final design, it is important to review the prior chapters. Therefore, it is strongly recommended to read the report in a chronological order.

The **Methodological Approach** outlines the design strategy and highlights the key parameters and considerations that guided the design process.

The **Pre-Design** chapter provides a comprehensive analysis and contextual understanding of both the selected project site and the broader characteristics of 1970s suburban neighbourhoods. This section concludes with the formulation of design drivers, criteria, a vision, and a concept that informs the following design phase.

The **Design** chapter is divided into two parts: an exploratory section that remains open-ended and reflective, and a conclusive section that defines the final design decisions applied to the specific site.

The **Post-Design** chapter presents the final transformation of Åstrupskrænten, with a particular focus on the selected site at Åstrupskrænten 45.

In the **Final Remarks**, the design process and outcome are critically reflected upon, followed by a comprehensive conclusion to the report.

The **References** chapter includes the bibliography, list of illustrations, and appendices. Where all external sources are referenced using the Harvard citation style.

Throughout the project, ChatGPT has been used as a tool to improve grammar and phrasing, ensuring the report is accessible and clearly communicated to all readers. Additionally, ChatGPT has helped estimating some of the emissions in the LCA phases A5 and C1 by providing assumptions to working hours, electricity grid emission factors, and diesel emission rates (see pp. 160-161).

A GLOBAL CLIMATE CRISIS

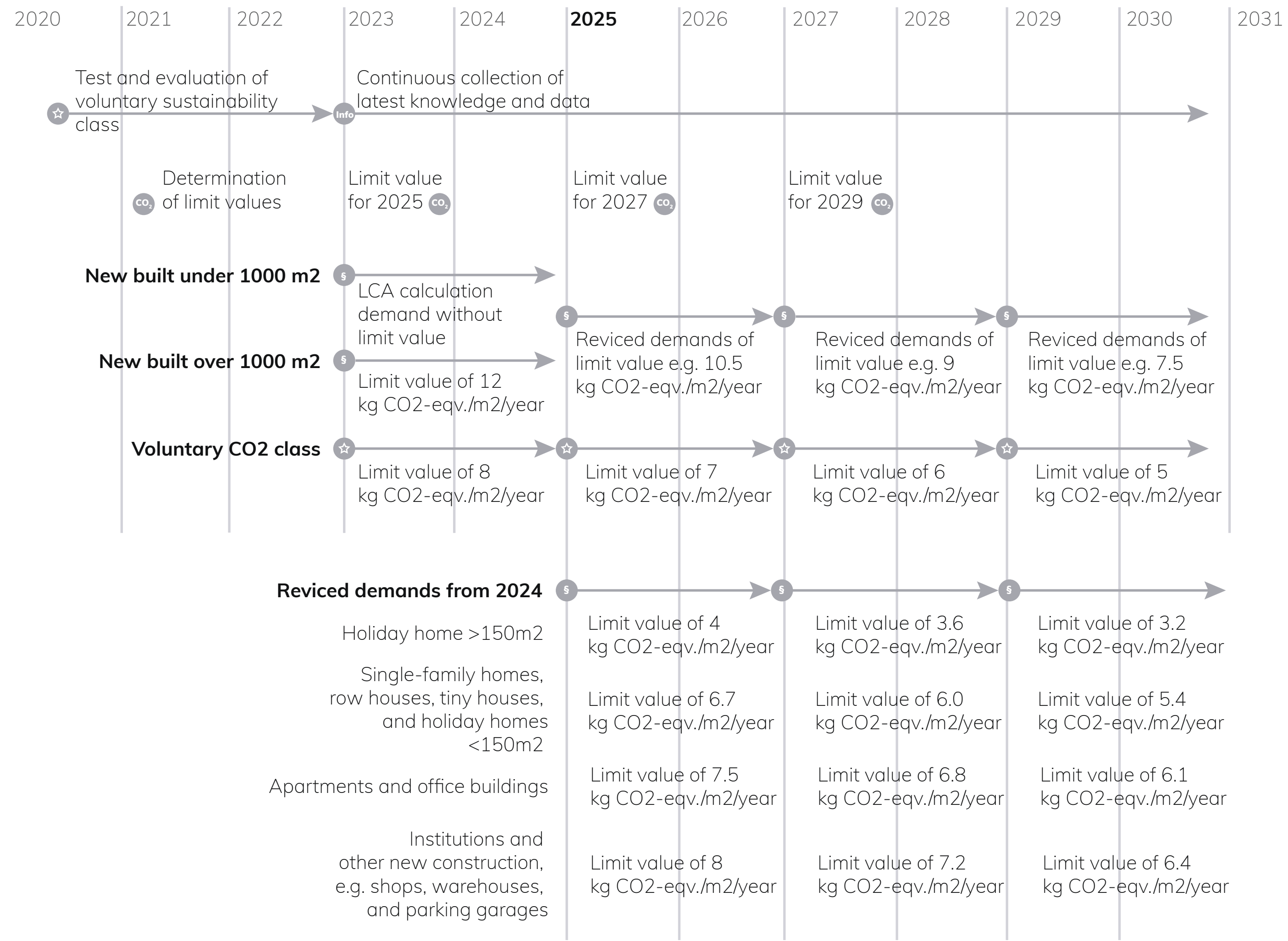
The global climate crisis presents a critical challenge, with the built environment playing a significant role in greenhouse gas emissions. Denmark has one of the world's highest climate footprints per inhabitant (Pedersen). In Denmark, the construction sector accounts for approximately 30% of national emissions, motivating the government to introduce stricter sustainability regulations. Currently, 9% of these emissions stem from the production of new building materials, while 27% result from the energy used to heat buildings. (Laursen) Balancing these two factors is crucial to achieving long-term reductions. Denmark's Climate Act aims to reduce greenhouse gas emissions by 70% before 2030 compared to the levels in1990. Furthermore, Denmark seeks to achieve climate neutrality by 2050 (Klima-, Energi- og Forsyningsministeriet).

To understand the national strategies toward more sustainable building practices, the Danish building sector has developed a roadmap beginning in 2020 and extending through 2031. As seen in illustration 3, the strategies are implemented progressively over the years. (Bolig- and Planstyrelsen, 2021)

Denmark's national strategy for sustainable constructions focuses on five key areas: climate-friendly construction, durable high-quality buildings, resource efficiency, energy-efficient and healthy buildings, and digital support for sustainability. (Regeringen, 2008) These initiatives aim to lower emissions, promote climate-conscious materials, and enhance the longevity of buildings. (Bolig- og Planstyrelsen, 2021)

A key initiative made by the government is the gradual implementation of Life Cycle Assessments (LCA) to measure and regulate the carbon footprint of buildings. Since January 2023, all new buildings under 1,000 square meters must conduct an LCA, while larger buildings must comply with a maximum carbon footprint of 12 kg CO2-eq./m2 year. Additionally, the sustainable CO_2 class was introduced with a stricter threshold of 8 kg CO2-eq./m2 year (Bygningsreglementet.dk). From July 2025, the requirements will become even more tightened, with single-family homes above 150 m2 is required to meet a maximum of 6.7 kg CO2-eq./m2 year (Social- og Boligministeriet, 2024).

This research explores how key elements from Denmark's five national sustainability strategies can be integrated into the built environment, specifically by examining the balance between material-related emissions and the optimization of energy performance in the transformation of an existing building. Furthermore, the study investigates alternative approaches to reducing environmental impact while maintaining architectural quality and ensuring long-term adaptability.



Ill. 3. Requirement roadmap, CREDIT: adapted from National strategi for bæredygtigt byggeri, Bolig- and Planstyrelsen, 2021, pp. 12-13

MOTIVATION

Single-family homes continue to dominate the Danish housing landscape, accommodating over three million residents and significantly contributing to the country's environmental footprint (Eskildsen, 2024). With Denmark's population expected to grow by 167,000 people by 2040, it is essential to explore alternative housing models that can meet future demand, without simply increasing the number of new homes (EFFEKT Architects et al., 2024).

The traditional ideal of "the good life" in Denmark is still closely tied to large, private single-family homes with multiple carports, private gardens, and low-maintenance lawns (Kum.dk, 2024). Today, the average detached home is 154 m², yet approximately 40% of these houses are occupied by just one person. This highlights the potential for subdividing these houses into smaller units to help achieve Denmark's climate neutrality goals. (EFFEKT Architects et al., 2024) Currently, the average Dane lives on 54 m². Research suggests that a comfortable lifestyle can be achieved with just 25–30 m² per person, and potentially even down to 15 m² with optimized design. However, even if everyone lived in homes as small as 15 m² pr. person, there would still not be enough available free space to accommodate the projected population growth. (EFFEKT Architects et al., 2024)

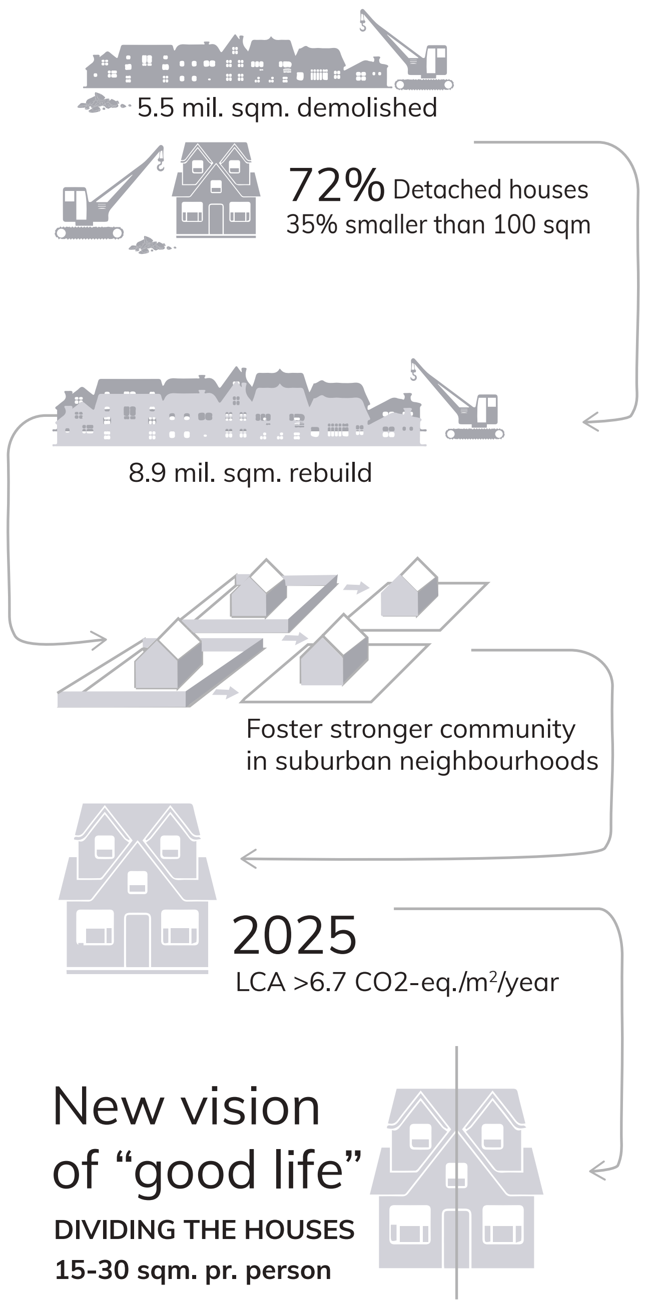
There are currently 1.17 million detached houses in Denmark, many of which are occupied by singles or couples without children. If each of these homes housed just one additional person, and if unused space in offices, apartments, and attics were repurposed, it would be more than enough to meet future housing needs. (EFFEKT Architects et al., 2024) Therefore, it may be time to reframe the current idea of "the good life" by introducing a new vision, one that reimagines the detached single-family home as a flexible structure capable of accommodating multiple households.

To achieve climate neutrality, researchers estimate that 146 million buildings worldwide must be renovated by 2050. This would account for 8.5% of the remaining global carbon budget, underscoring the importance of transforming existing buildings rather than demolishing and rebuilding. (EFFEKT Architects et al., 2024) Between 2010 and 2021, many detached houses, primarily built between 1900 and 1972, were demolished and replaced by new buildings on the same plots (Jensen et al., 2022). (See ill. 4)

"Factoring in the climate impact of demolition could mean that demolishing and rebuilding may not meet the upcoming CO_2 requirements, potentially preventing the redevelopment of sites with substandard buildings."
(Eberhardt et al., 2022, translated from Danish)

Demolitions are often justified by practical factors such as small house sizes, poor orientation, outdated floor plans, and high maintenance costs, where the demolished homes often under 100 m² (Jensen, et al., 2022). (See ill. 4) However, the broader environmental costs of demolition are frequently overlooked by homeowners (Jensen et al., 2022). Therefore, greater emphasis should be placed on renovating existing buildings rather than demolishing and replacing them. In the future the tightened LCA requirements are expected to support a shift. (See ill. 4)

In 2024, the Ministry of Culture launched an architectural competition aimed at reimagining suburban neighbourhoods to promote sustainability. The competition emphasized not just resource minimization, and reuse over new materials, but also the potential to foster stronger community connections through shared spaces and the promotion of biodiversity. (Kum.dk, 2024) One key issue in suburban areas is the social isolation caused by both physical disconnection from urban centres and the demographic uniformity of residents (See ill. 4). Repurposing single-family homes into multi-unit dwellings could help counteract this by renewing urban cores and reducing suburban isolation. (EFFEKT Architects et al., 2024)



Ill. 4. Motivation

RESEARCH QUESTION

The following project explores the sustainable transformation of suburban neighbourhoods developed during the post-war building boom of the 1960s–1980s, with a particular focus on the 1970s. Åstrupskrænten, a typical 1970s suburban neighbourhood located in Grenaa, serves as the primary case study.

The project investigates two central themes: how demolition of existing buildings can be avoided, and how future residents can live well using fewer square meters. Taking a holistic approach to the neighbourhood as a whole, special attention will be given to Åstrupskrænten 45, a 176 sqm single-family home on a 1,655 sqm plot that has not yet undergone any energy optimization. This specific house will be used as a micro-scale case to explore how an individual detached home can be reimagined and retrofitted as a more sustainable dwelling. Through this focused lens, the project seeks to generate insights that can inform broader strategies for transforming similar housing typologies across Denmark. To guide the investigation, the following research question has been formulated:

How can suburban neighbourhoods of the 1970s be sustainably transformed as a housing typology to foster new, visionary, and attractive concepts of “a good life”?

(Inspired by: kum.dk, 2024)

8 KEY FINDINGS

The following eight points outline the most significant takeaways from the transformation of suburban neighbourhoods from the 1970s, with the intention of informing future approaches to suburban retrofitting. For the final conclusion see pp. 192-193.

1. **A SCALABLE AND ADAPTABLE METHODOLOGY**

While Åstrupskrænten serves as the main case study, the design approach is intended as a replicable model for other suburban neighborhoods from the same era. Each site will have its own needs, but the methodology remains applicable and adaptable across contexts. (See pp. 20-23)

2. **A NEW SUBURBAN MODEL**

The typical car-centric 1970s suburban neighborhood can be reimagined into a socially vibrant and future-resilient living environment. By relocating everyday functions into shared spaces, it encourages spontaneous interactions and reduces isolation.

3. **FLEXIBLE HOUSING**

A original detached house from the 1970s can be preserved in size but reconfigured to host multiple households. A flexible wall system allows the layout to change over time, while a shared community house offers extra space during key life events, supporting a more efficient use of square meters without compromising quality of life.

4. **ENERGY EMISSIONS OVER MATERIAL EMISSIONS**

Life Cycle Assessment has revealed that operational energy use has a greater environmental impact than material emissions in a context of non-renovated 1970s detached houses.

5. **PRESERVATION OF THE EXISTING**

Structural changes can be kept to a minimum. The houses should neither be extended nor reduced; instead, the existing square meters should be optimized. In this way demolition is limited, emphasizing a low-impact and preservation-oriented strategy.

6. **LANDSCAPE DESIGN THAT BUILDS COMMUNITY**

The outdoor spaces can be restructured into a clear hierarchy of private, semi-private, and public zones. This spatial strategy encourages movement across shared areas, promoting a sense of belonging and everyday social encounters among neighbors.

7. **MATERIAL STRATEGY**

Both new and reused materials should be carefully chosen based on LCA data, design for disassembly principles, reuse potential, and visual compatibility with the existing architecture. They should age beautifully, allow personalization, so there is a chance that it wont be replaced often.

8. **ENHANCED INDOOR CLIMATE AND SPATIAL QUALITY**

Daylight optimization can improve the interior environment, removing dark areas and enhancing air quality, if thinking of stack ventilation. These changes contribute to both comfort and a higher living standard over time.

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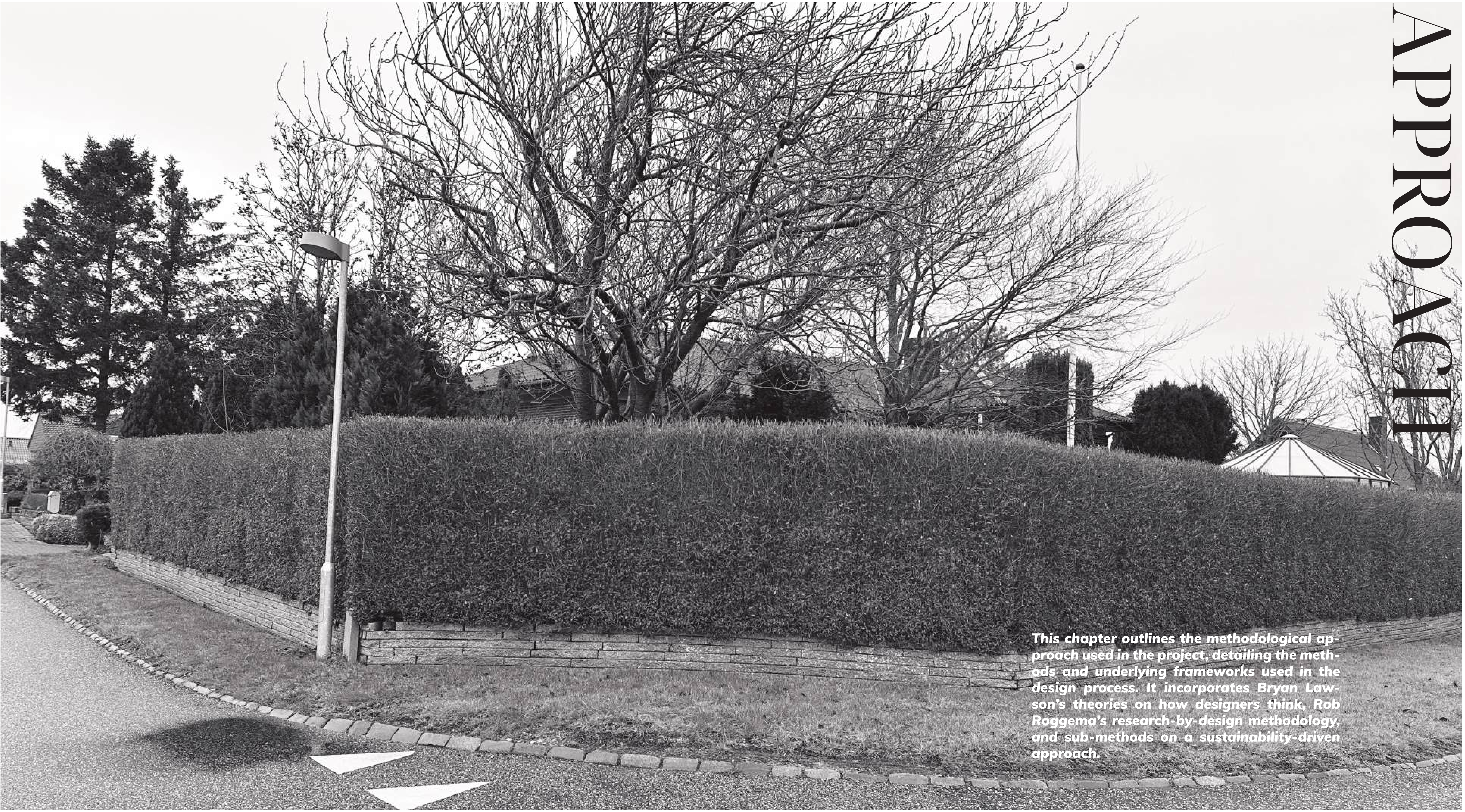
CHAPTER 1

METHODOLOGICAL APPROACH



This chapter outlines the methodological approach used in the project, detailing the methods and underlying frameworks used in the design process. It incorporates Bryan Lawson's theories on how designers think, Rob Roggema's research-by-design methodology, and sub-methods on a sustainability-driven approach.

Ill. 5. Photo of Åstrupskrænten

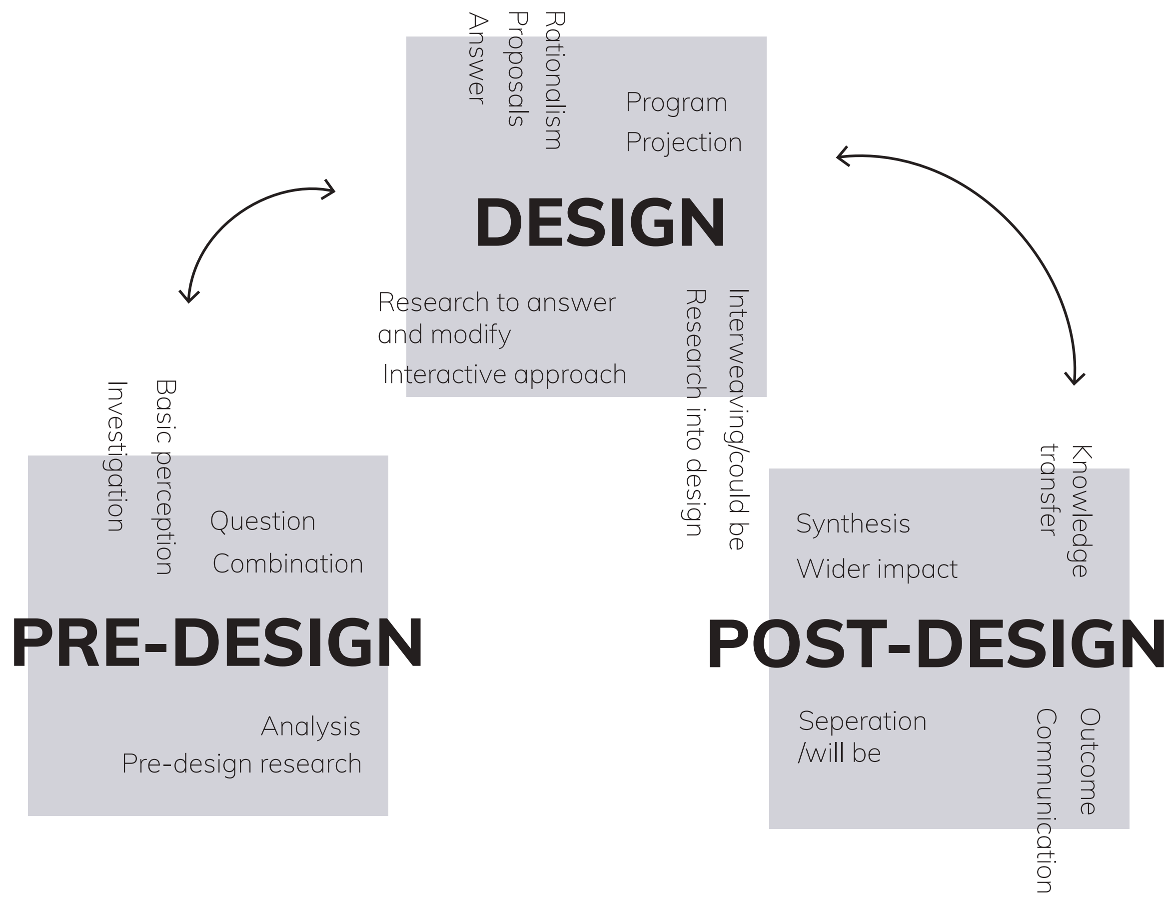
How designers think

Bryan Lawson explores the nature of design thinking, emphasizing that designers deal with *wicked problems*, which he describes as complex problem with multiple possible solutions. (See ill. 6) Seen as the research question in the following project. A key aspect of design thinking, according to Lawson, is the balance between *divergent thinking*, which involves exploring several solutions and alternative approaches, and *convergent thinking*, where the focus narrows to refine a single solution. (Purcell, Patrick, 1980) Lawson explains that a skilled designer must master both, which for this specific project, the design process will begin with *divergent thinking*, allowing for a broad exploration of ideas and possibilities. As the process progresses, it will shift towards convergent thinking, focusing on refining and finalizing the design.

By experimenting with solutions before settling on a final decision, Lawson argues that designers can steer their projects in unexpected and innovative directions. As a result, he claims that there is rarely one single, definitive solution. Instead, the final design is shaped by the decisions made and the theoretical perspectives applied throughout the process. Had different choices been made, the final design could have taken an entirely different form. (Purcell, Patrick, 1980) Therefore, it is crucial in this specific project to reflect upon the decisions and ideas during the design process, but also after having the final design.

The design process will be formed as non-linear process. This means that there is involved a continuous cycle of investigations, reflections, and adjustments to the design. This iterative approach enables what Lawson describes as *emergent thinking*, where new ideas develop spontaneously rather than being strictly preplanned. The design process will therefore be planned to a degree, where changes can be made every day. Sketching, modelling, and prototyping plays a crucial role in this process, serving as tools to explore and refine ideas. (Purcell, Patrick, 1980)

Ill. 6. How designers think

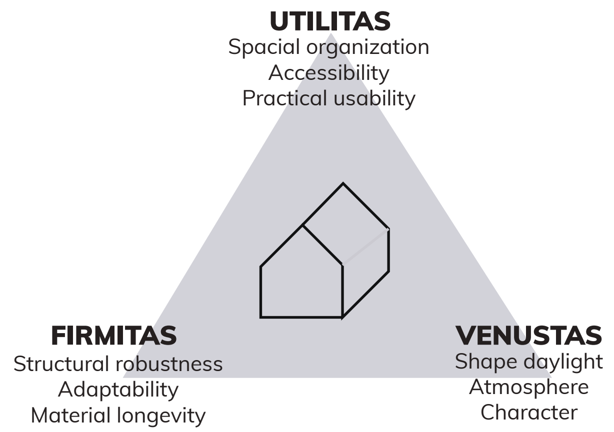


Ill. 7. *Research by design method*

Research by design

The approach to addressing the *wicked problem*, as described by Bryan Lawson, is reflected in Rob Roggema's *Research by Design* method. This method is an experimental and iterative design process in which solutions are developed, tested, and refined through continuous feedback loops (Roggema, 2017). The process follows three main phases: *pre-design, design, and post-design* (see ill. 7).

In this context, feedback loops are established through a *participatory design* approach involving continuous supervision by a lecturer at Aalborg University, who contributes critical insights with a particular focus on sustainable living. Additionally, collaboration with a fellow student serving as a sparring partner fosters dialogue and exchange of ideas. This supports ongoing reflection, allowing the design solutions to develop and improve.



Ill. 8. *The Vitruvian Triade*

Pre-design phase

The *pre-design phase* of the *Research by Design* method focuses on developing a comprehensive understanding of the problem through early research. Here *Participatory design* played a central role, as a dialogue was initiated with the current owner of the house at Åstrupskrænten 45, while broader insights were gathered from residents across the neighbourhood through a questionnaire. In addition, interviews were conducted with individuals living in alternative housing arrangements to explore new perspectives and approaches to living.

To define a project focus, an initial theoretical investigation into the main theme was conducted. This was followed by a contextual analysis of the case site, which helped establish design objectives and key questions. Furthermore, to guide the exploration of the Pre-Design, the Vitruvian principles, *Firmitas, Utilitas, and Venustas*, served as a compass. These principles ensured that no single architectural element dominated, promoting a balanced and holistic design approach. The Vitruvian principles were then translated into design criteria and drivers, which formed the foundation for addressing the research question (see ill. 8).

Utilitas (Functionality)
Utilitas concerned the spatial organization, accessibility, and practical usability of both the dwelling at Åstrupskrænten 45, and the entire neighborhood of Åstrupskrænten. Spatial considerations involved examining how indoor and outdoor spaces could be proportioned and connected. Accessibility addressed how residents would navigate and utilize both the house and the site. Functionality referred to how effectively the spaces supported daily life and evolved user needs.

Firmitas (Durability)
Firmitas addressed the project's technical performance, including robustness, adaptability, and material longevity. Robustness was assessed by evaluating whether the existing building at Åstrupskrænten 45 could meet current and future demands, functionally. Adaptability explored how the structure could be transformed to meet the changing needs, both in terms of interior reconfiguration and outdoor spatial use. Material longevity was understood as the aging process of materials, contributing to both durability and the aesthetic of the site over time.

Venustas (Aesthetic)
Venustas focused on the sensory and emotional qualities of the built environment. Daylight was studied through its interaction with interior spaces at Åstrupskrænten 45, setting principles that could be adapted across other dwellings in the area. The experience aspect referred to the atmosphere shaped by materials, and spatial flow. Character explored the design's visual identity and the possibility for user personalization, with a particular focus on how this could be expressed at Åstrupskrænten 45.

Design phase

The design phase was divided into two parts: an initial *Design Phase 1*, followed by a more refined *Design Phase 2*. As the core of the *Research by Design* methodology, the design phase integrates insights from the pre-design phase. Here the overarching research question was broken into smaller, more manageable questions, allowing each aspect of the problem to be thoroughly investigated throughout the design phase. (See ill. 9)

To maintain a structured and explorative approach, the three identified design drivers, Utilitas, Firmitas, and Venustas, were each explored systematically over the course of three weeks. A new driver was introduced at the beginning of each week, regardless of whether the previous one had been fully resolved. This ensured a broad investigation in the early stages, allowing for an overview before concluding on a final design.

Throughout the design phase, *Participatory design* could be seen in a critical reflection given by a lecturer at Aalborg University, as well as feedback and discussions with a sparring partner from the same class. A mid-way critique session with the entire graduating class also offered valuable insights from fresh perspectives, highlighting overlooked elements or alternative design explorations.

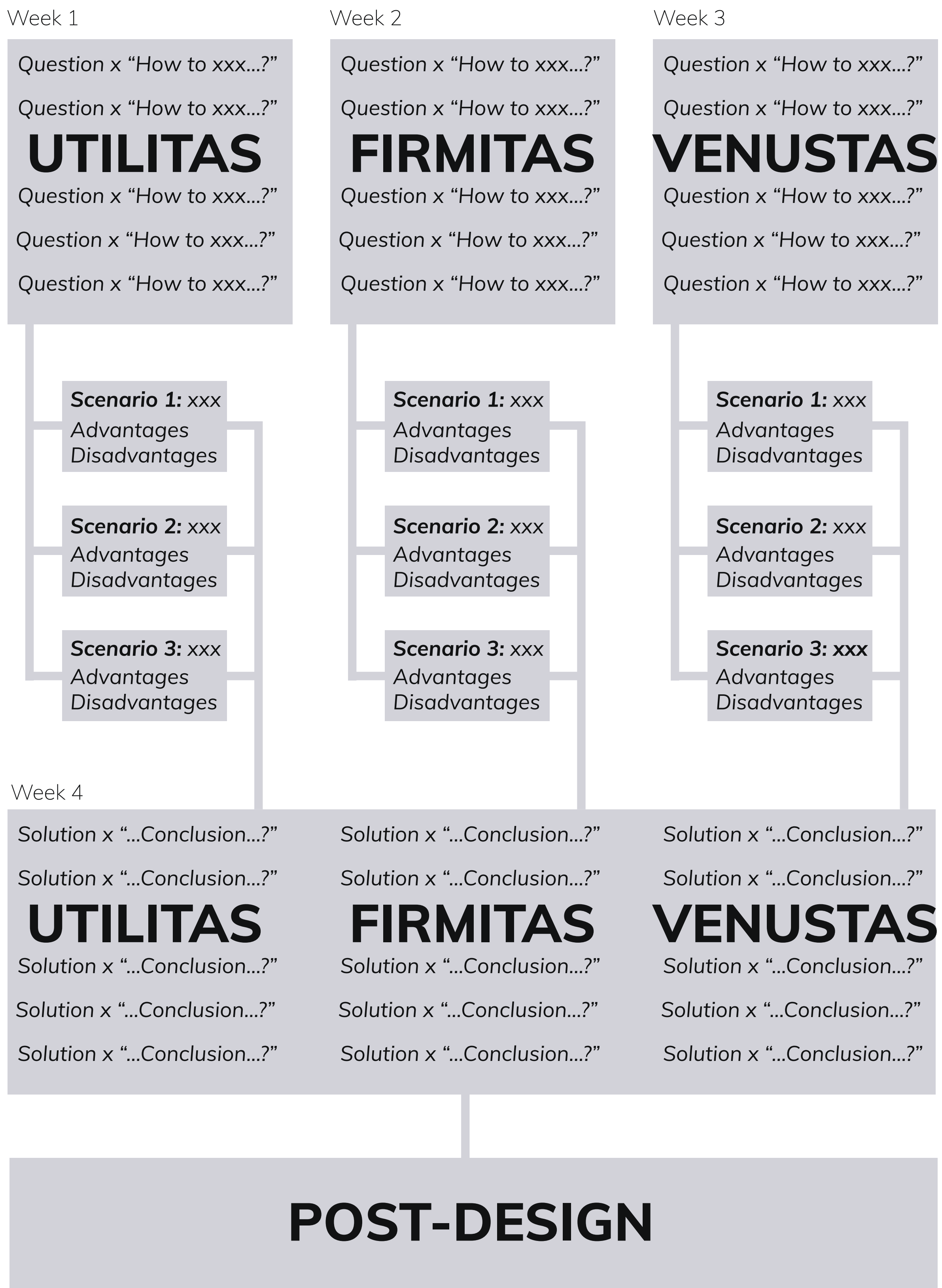
During **Design Phase 1,** the three Vitruvian design drivers were each broken down into key focus areas. For each design driver, a series of questions were formulated, and multiple conceptual scenarios were developed to answer these. The scenarios offered varied approaches, each presenting advantages and disadvantages. This phase was therefore characterized by *divergent thinking*, where no questions were approached with a single solution, but rather explored through multiple possibilities. Feedback from the midway critique seminar informed the transition into *Design Phase 2*, where the most promising ideas from *Design Phase 1* were selected for further development.

In **Design Phase 2,** selected scenarios were further tested and refined through sketching and iterative reflection with the supervisor and sparring partner. This phase aimed to merge the findings from *Design Phase 1*, focusing specifically on what worked best in relation to the case site at Åstrupskrænten. At this stage, the process shifted towards concluding on specific questions, by doing *convergent thinking* and therefore using each answer to inform the next question. This created a step-by-step logic, where answers were shaped by the order in which questions were asked. Asking the questions in a different sequence could potentially have led to entirely different outcomes.

Post-design phase

In the post-design phase, *convergent thinking* played a crucial role, as selected ideas were synthesized into a cohesive outcome, forming the final design. This phase aimed to reflect on the research question and demonstrate the broader relevance of the design.

Before arriving at this stage, it remained essential to continuously challenge the proposed solutions and stay open to the possibility that if there was made a deeper exploration of the research question, it could have led back to earlier phases and another final design outcome.



Ill. 9. The Design Phase Method

Sub methods, developing a sustainable design strategy

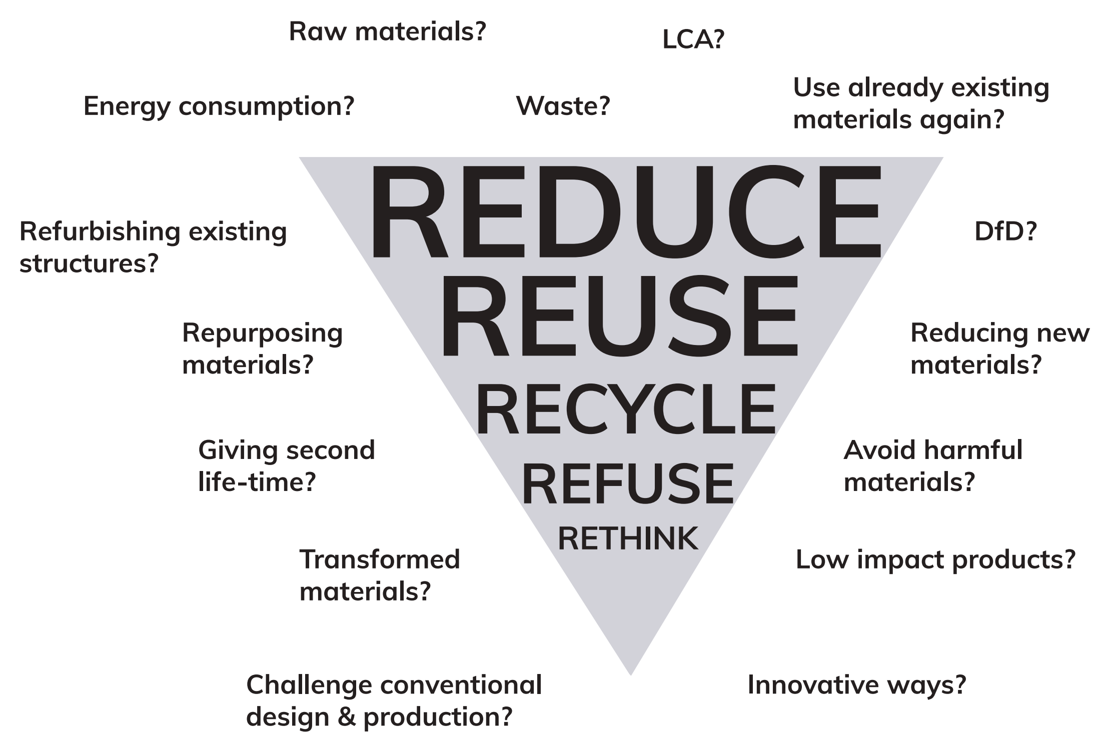
The Five Rs serve as guiding principles in shaping form through a sustainable approach, with a strong emphasis on minimizing environmental impact. By embracing the strategies of Reduce, Reuse, Recycle, Refuse, and Rethink, the design process aims to address, all the sustainable design strategies illustrated in figure 10.

The R: Rethink

The term *Rethink* explores how the design process can be reimagined in new and visionary ways, challenging conventional approaches to construction and ones understanding of how we inhabit and use buildings. In this specific project, *Rethink* serves as a fundamental and overarching principle, guiding the entire design process. It is used as a critical lens to evaluate whether proposed strategies offer genuinely innovative responses to the research question.

Goal
The primary goal of *Rethink* in this project is to question and redefine the function and future needs of the detached house and suburban neighbourhood. This includes identifying which needs the building and entire site must fulfil both now and, in the future, and how these needs can be meet through innovative design methods. Furthermore, the project seeks to challenge the current norms of construction by exploring alternative building methods and questioning emissions and environmental impacts that are not yet fully captured in traditional LCA frameworks.

Scope
The ambition to *Rethink* enters the entire project and is reflected in all the other "Rs", which together aim to push the boundaries of current standards and practices. Each "R" is approached with the intention of offering a forward-thinking, innovative response to the research question, ensuring that the final proposal not only meets functional and environmental goals but also contributes to a broader discourse on sustainable transformation.



Ill. 10. The Five Rs

The R: Reduce

The principle of *Reduce* centers on minimizing the consumption of resources. In this project, the concept of *Reduce* will be addressed through a Life Cycle Assessment (LCA), with a specific focus on evaluating the differences between energy consumption and material emissions. The goal is to determine whether optimizing energy performance or minimizing material-related emissions should be prioritized in the final design decisions.

LCA is a tool used to evaluate the environmental impact of a building across a 50-year period. It should provide a transparent framework that outlines assumptions and supports qualified conclusions. The reliability of an LCA is highly dependent on the quality of the input data (Cays, 2021).

The LCA will include the following phases: A1–A3 (product), A4–A5 (construction), B1–B5 (use), C1–C4 (end-of-life), and D (reuse/recycling) (Birgisdottir, 2015). From 2027, LCA requirements for renovation projects are expected to align with those for new constructions. Under these guidelines, reused materials will be considered zero-impact for CO_2 emissions, if they are not further recycled (Strateginetværk for Bæredygtigt Byggeri, 2023). Additionally, the Danish government is considering denying demolition permits to promote renovation and transformation projects (Social- og Boligministeriet, 2024).

In such a context, LCA becomes an increasingly relevant tool to evaluate the benefits of renovation over demolition. Future regulations may also require energy frameworks to be included in the LCA for renovations. Despite improvements in energy efficiency, Denmark's total residential energy consumption has remained constant since 1990 due to an increase in average dwelling size (EFFEKT Arkitekter et al., 2024). This underlines the importance of evaluating both energy and material impacts when designing sustainable transformations. (Read more about the current LCA regulatory on pp. 6-9)

Goal
The aim is to minimize environmental impact by using LCA to compare the performance of existing versus new building components, informing decisions about what to preserve and what to replace.

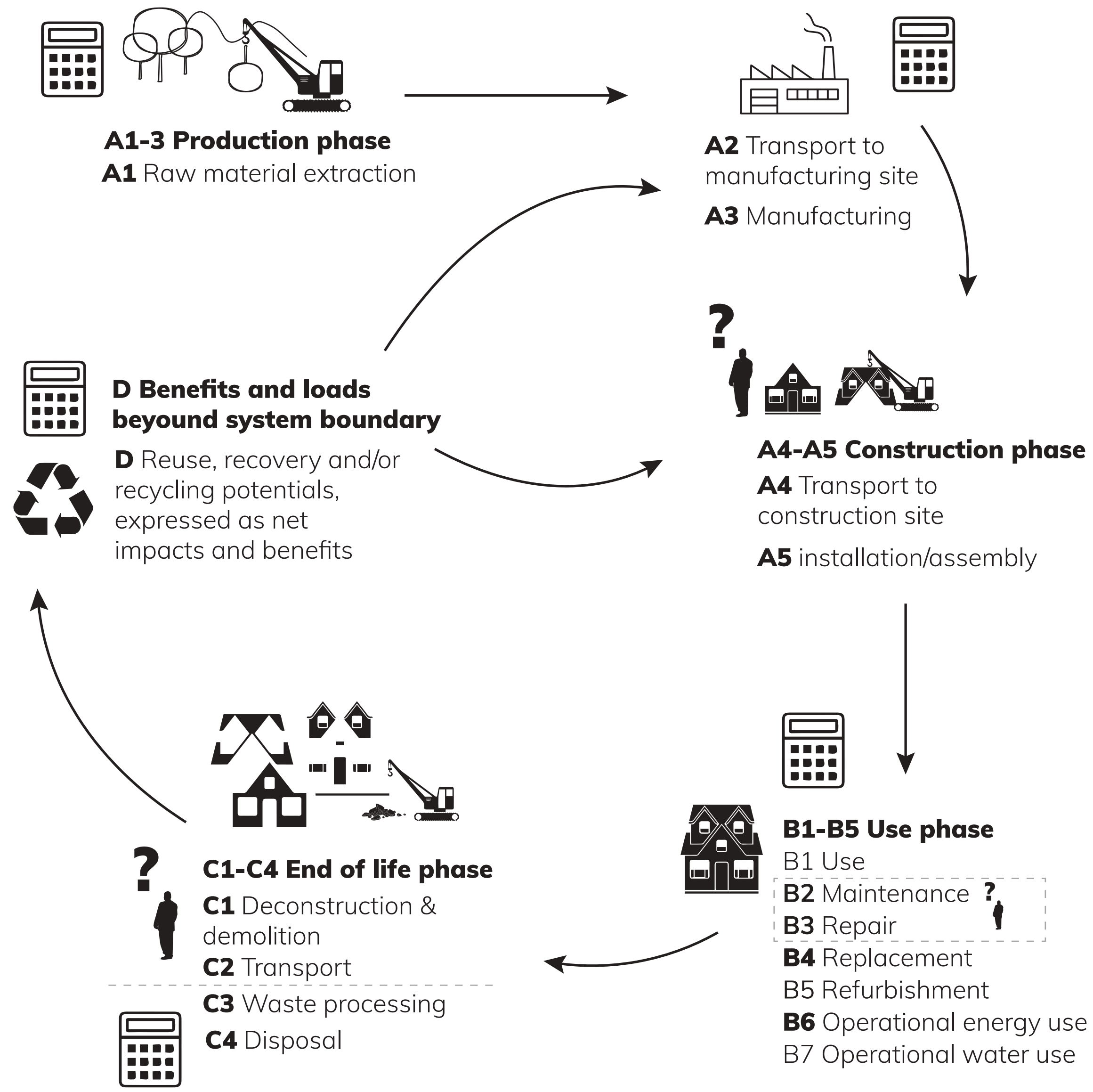
The energy optimization will target improvements in U-values, daylight conditions, and natural ventilation, aiming to achieve Renovation Class 1. This corresponds to a maximum energy use of 63.8 kWh/m^2/year for detached houses, and 71.3 kWh/m^2/year for semi-detached houses. Both passive strategies, e.g., improved insulation and daylight optimization.

Scope
The LCA will calculate impacts for the following phases: A1–A3, B4, B6, C3–C4, and D, using LCAbyg 2023.3 as a calculating tool. Additionally, it will reflect on the phases A4–A5 and C1-C2, incorporating estimated emissions and distances. Furthermore, reused materials will be considered zero-impact in the phases A1–A3.

In the product phase (A1–A3), there will be reflected upon the difference between generic Environmental Product Declarations (EPDs), which use average data, and product-specific EPDs, which reflect actual production data (Birgisdottir, 2015).

The iterative process of the LCA will be documented throughout the design process, and the final LCA will include both calculated results and a reflective analysis of all the mentioned phases. The final LCA will be calculated as followed:
((A1 + A2 + A3 + A4 + A5 + B4 + C1 + C2 + C3 + C4) / (Aref * 50 years)) + (B6 / (A_heat * 50 years)) = Global Warming Potential (GWP)

Here the project aims to meet the 2027 climate target for newly built detached homes over 150 m^2, with a maximum total emission of 6 kg CO_2 eq./m^2/year, where the construction phase (A4–A5) limit is then 1.5 kg CO_2 eq./m^2/year, out of the total of 6. (See pp. 6-7)



Ill. 11. *Life Cycle Assessment (LCA)*

The two Rs: Reuse and Recycle

The principle of *Reuse* and *Recycle* focuses on utilizing materials that have already been produced. In this project, the emphasis will be on preserving existing materials, either for the same or new purposes, with or without altering their original form. Additionally, all newly incorporated materials, as well as reused materials intended for use in a different location, will, as far as possible, be designed allowing for *Design for Disassembly* (DfD) principles.

DfD is a design approach that minimizes resource consumption and material waste in the construction industry by allowing components to be easily disassembled at the end of their life cycle. This allows materials to be reused or recycled while maintaining as much of their original form and value as possible. DfD often involves modular construction and standardized dimensions, which improve the potential for reusing materials elsewhere. It also promotes flexibility and adaptability, allowing future users to reconfigure layouts according to changing needs. (Cutieru, 2020)

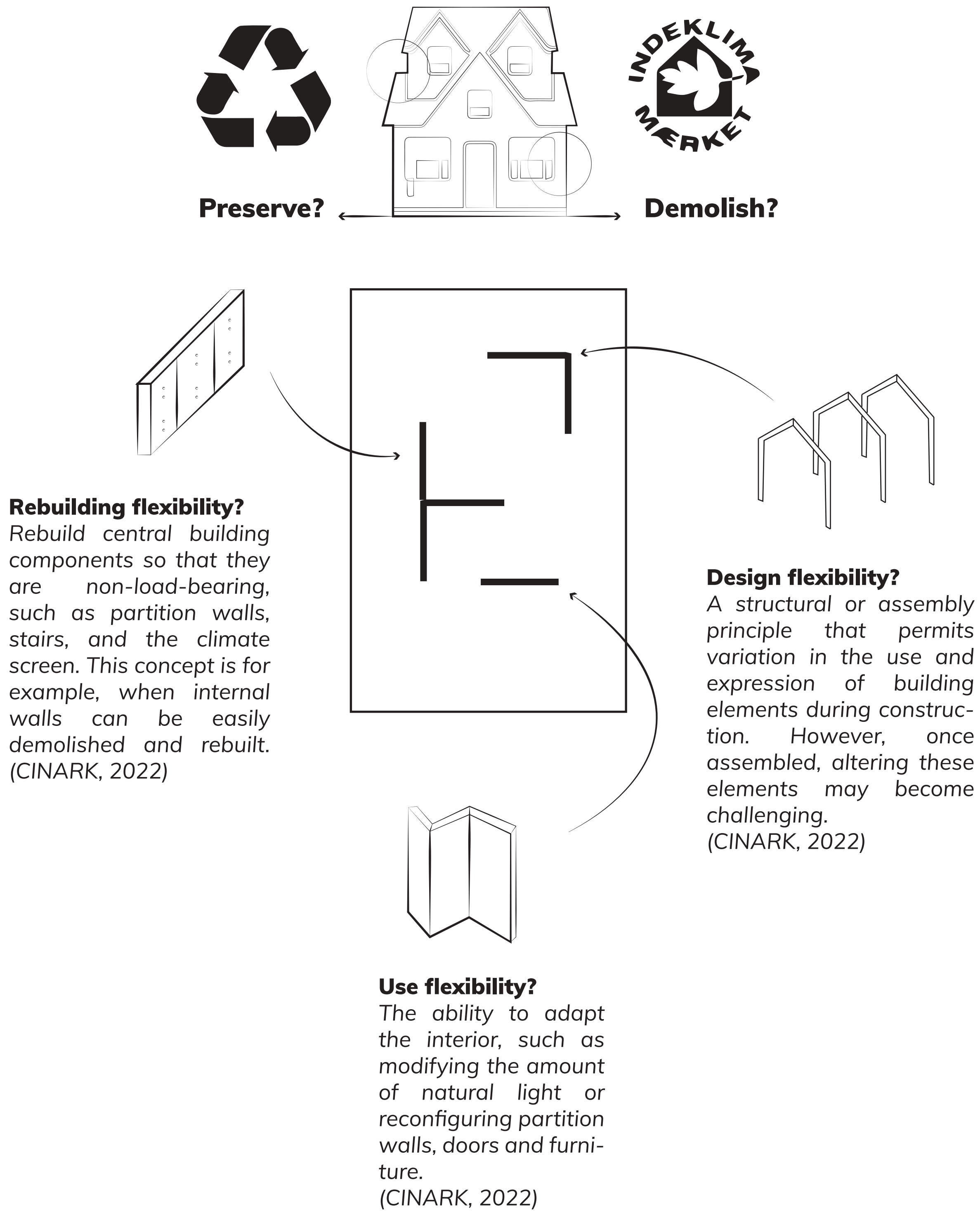
Goal
The primary goal of applying *Reuse* and *Recycle* in this project is to preserve and adjust rather than demolishing existing building elements. Additionally, the project aims to ensure that all new materials or adjusted materials are designed for easy disassembly using DfD strategies. The process will prioritize adaptability to accommodate future use and incorporate adaptable materials where possible.

Scope
When integrating new building elements, the type of connection is crucial (Cutieru, 2020). Mechanical connections, such as bolts, screws, and click systems, will be prioritized over glues or nails, which complicate disassembly and hinder recyclability.

Modular construction techniques, including the use of standardized components, will be explored when designing fixed furniture, enabling individual parts to be replaced without affecting the entire structure.

Wherever possible, lightweight construction will be favored over heavy composite materials, which are often difficult to recycle. Any newly designed components should be easy to remove and reuse for future projects if needed.

Finally, flexibility and adaptability are core principles in the project's DfD strategy (Cutieru, 2020). Interior spaces will be designed to allow for easy reconfiguration, enabling the building to meet future demands without requiring major structural interventions.



Ill. 12. Reuse and Design for Disassembly (DfD)

The R: Refuse

The term *Refuse* involves actively avoiding materials that negatively impact on the environment, including those that are harmful to human health or lack durability. This framework will be applied to assess whether existing materials should be preserved or replaced and to guide the integration of new ones.

In addition to being non-toxic, all new materials introduced into the design should be selected for their durability. This aspect will be evaluated through the lens of materiality, guided by A.K. Bejder's 2012 PhD thesis *Aesthetic Qualities of Cross-Laminated Timber*. Bejder introduces a framework that explores materiality through three dimensions: *Entity* (how a building is experienced as a cohesive whole), *Enclosure* (the elements that mediate between inside and outside), and lastly *Transition* (the way in which materials or elements meet). (Bejder, 2012) (See ill. 13)

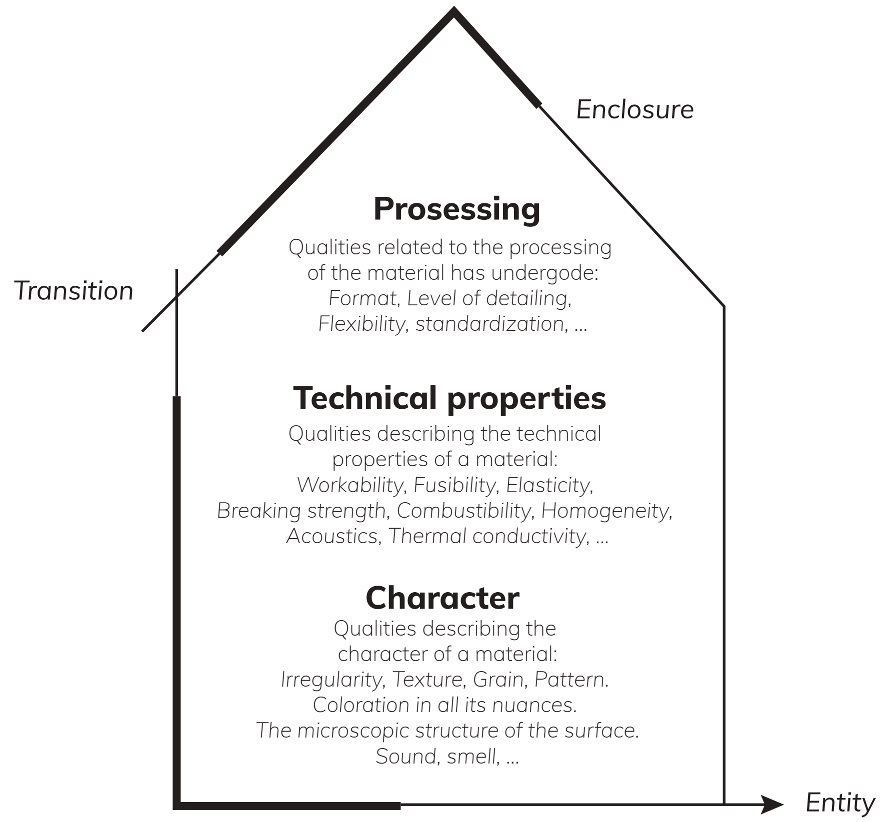
Goal
When incorporating new materials, the aim is to use biobased alternatives or materials certified by Indeklimamærket, a Danish certification label that ensures minimal off-gassing, low fragrance, and no irritation of mucous membranes or headaches (Indeklimamærket.dk). Beyond ensuring good air quality, acoustic properties of materials will be considered to create healthy and comfortable indoor sound conditions. Furthermore, the design should reflect on the materiality of both preserved and newly integrated materials to ensure aesthetic longevity.

In this project, the focus will be on selecting alternative, non-toxic, and long-lasting materials to replace hazardous ones. Attention will also be given to the environmental footprint of new materials, prioritizing those that are biobased and do not release off-gassing. This approach aims to ensure a healthy indoor climate and reduce the need for future material replacements.

Scope
A SAVE registration will be conducted for both the overall Åstrupskrænten neighborhood and the specific site at Åstrupskrænten 45, to identify architectural elements and materials of aesthetic and functional value that are worth preserving. Additionally, a material mapping of the existing building at Åstrupskrænten 45 will be performed to determine which specific materials can be preserved and which require replacement. A material mapping assesses each material's condition, location, quantity, and structural integrity, while also checking for hazardous substances that could harm human health or the environment (Værdibyg, 2020).

Regarding indoor climate, acoustic reflection and absorption will be assessed through qualitative assumptions about each material's density and surface characteristics, though no formal acoustic calculations will be made.

Materiality will further be analyzed through three aspects: *Processing* (exploring sensory interactions with materials, including how "early experiences" shape physical and emotional connections), *Technical properties* (focusing on how materials respond to external influences such as bending, melting, or weathering, as well as fire resistance and structural integrity), and *Character* (evaluating the visual and tactile qualities of materials, their associative meanings, multisensory engagement, and the uniqueness). (See ill. 13)



Ill. 13. Materiality, CREDIT: Own elaboration on Bejder, A.K., 2012, Aesthetic Qualities of Cross Laminated Timber.

CHAPTER 2

PRE-DESIGN PHASE

This chapter provides the theoretical framework for the project by examining key topics to address the research question. It will investigate the suburban housing boom of the 1970s through a historical analysis, while also exploring new approaches to modern living. Additionally, the case site will be contextually analysed to identify potential improvements. Hereby, Åstrupskrænten will serve as a representation of the general 1970s suburban neighbourhood, with a specific focus on Åstrupskrænten 45, a catalogue house from the same period.

Ill. 14. Birds eye of Åstrupskrænten, CREDIT photo: CC BY 4.0 KDS.

Contextual analysis of Grenaa

Grenaa is a Danish city located on the eastern coast of Jutland, facing Kattegat. It is the largest city in Norddjurs Municipality, and serves as the administrative centre, covering 721.18 km2, where it is home to 14,096 residents (as of 2024) (Statistikbanken.dk). The municipality of Grenaa expects a 0.3% population decrease between 2024 and 2028, driven by a decline in younger age groups and a rise in the elderly population. (Norddjurs Kommune) This suggests the need for houses to be adaptable, ensuring they can accommodate different needs.

The municipality aims to maintain the city's educational character, together with its status as the largest city in Djursland. They plan to preserve its industrial area, service area, and harbor area. Although, some industrial areas, such as the former steam weaving mill site and the still-operating paper mill, are expected to be located further away from the city center, to improve city life. (Kommuneplan.norddjurs.dk) Furthermore, the municipality values the city's green areas, which contribute to the city's unique character and are intended to be preserved and enhanced. (Kommuneplan.norddjurs.dk)

Grenaa is a harbor city with ferry connections to Halmstad in Sweden and the Danish island of Anholt. The city is also well connected by road, with main routes such as road 15 to Randers and road 16 to Aarhus. In addition, a light rail service links Grenaa to Aarhus C, and Aarhus Airport is situated midway between the two cities. This connection to larger urban centers suggests that Grenaa could attract individuals working in these cities who commute daily. Consequently, it's likely that families see the potential in relocating to Grenaa in the future, making this group a key consideration in the design process. Furthermore, the city is home to several educational and cultural institutions, which makes it an appealing choice for young families looking for a place to settle.

For over 60 years, Grenaa has sourced its heating from the local district heating plant, Grenaa Varmeværk, which has consistently maintained some of the lowest heating prices in Denmark (Grenaa-varmeværk.dk). This affordability is partly due to the plant's efforts to reduce the number of wood stoves in the area. However, this low pricing also makes it economically unfeasible for homeowners to invest in energy optimization for their properties. (App. 1)

Currently, Grenaa Varmeværk is distributed as followed: 73.4% from wood chips, 14.7% from an electric heat pump, 9.4% from solar heating, 1.3% from an electric boiler, and 1.2% from gas oil. (Grenaa Varmeværk, 2024) Following the Danish Parliament's decision to remove the price cap on additional heat in the summer of 2025, Grenaa Varmeværk has announced a collaboration with the yeast factory, allowing additional heat from the yeast factory to replace a portion of the wood chips currently used for heating. (Nielsen, et al., 2025)

Given the relatively low heating costs, it's understandable that homeowners might not prioritize energy optimization for their homes. However, upon examining the district heating plant, it becomes clear that more than half of the heat is sourced from wood chips. While this will decrease over time due to the shift in energy supply from the nearby yeast factory, it will not reach zero emissions. From an environmental perspective, it still makes sense to prioritize energy optimization to reduce the overall environmental impact.

Ill. 15. Mapping of Grenaa, scale 1:30,000, CREDIT: Base map, CC BY 4.0 KDS. Modified by the author.

PARTIAL CONCLUSION

Grenaa is characterized by its strong educational institutions, green spaces, and strategic connectivity to larger urban centers. The city's population is expected to decrease slightly in the coming years, with a rise in the elderly demographic, highlighting the need for adaptable housing solutions that can meet diverse needs over time. Additionally, Grenaa's strong transport links make it an appealing destination for future families and commuters. As a result, it is essential to consider the needs of young families in the design process.

Grenaa's district heating system has allowed the city to maintain a low heating cost. However, this affordability has also resulted in an unwillingness to invest in energy optimization. Despite the ongoing shift towards a more sustainable heat supply, the environmental impact of heating remains significant. Therefore, from an environmental standpoint, it remains crucial to focus on energy optimization when designing.

Ill. 16. Connections to Grenaa

The suburban neighbourhood

Translation of *the suburban neighbourhood*: *"Residential area with lots of often similar detached houses"*

(Ordnet.dk, translated from Danish)

In 1902, the British urban designer Ebenezer Howard proposed a new vision for the built environment in response to the industrialization of cities, known as *the garden city*. This concept envisioned communities surrounded by open land, where each housing unit had its own garden. Howard imagined these communities as self-sustaining islands within the landscape, with labor, goods, and waste circulating within a closed-loop system. Importantly, the land in these communities was to be held in common ownership (Lind et al., 1996). Although actual garden cities were only built in a few locations, many of their principles have influenced the layout of suburban housing developments, particularly the idea of detached houses with private gardens, typically located on undeveloped land at the periphery of cities.

In Denmark, the industrialization of the late 1950s triggered a significant welfare boom, which doubled the residential space per person between 1960 and 1980 and led to the apperance of suburban neighborhoods, which has some of the same ideas as *the garden cities*. One of the earliest examples is Albertslund, a suburb of Copenhagen, built between 1963 and 1968 by Fællestegnestuen. Albertslund was part of the Finger Plan, a 1947 strategy to structure urban development along the S-train network.

The planning of Albertslund South was characterized by a rational and functionalist approach, emphasizing traffic separation and a clear spatial organization of housing and green areas. The neighborhood was developed on previously open undeveloped land and consisted of prefabricated elements forming atrium houses, and two-story row houses. The primary goal of Albertslund was to create residential environments specifically tailored to nuclear families.

Each atrium house was designed as a self-contained unit with an enclosed private garden, fostering a strong sense of privacy and a family-oriented lifestyle. However, beyond the private homes, schools and public institutions were strategically distributed across the site to serve the local community. Surrounding Albertslund, a large area was designated as a communal green space, featuring lakes and natural landscapes, offering residents access to shared outdoor environments, and reinforcing the suburban ideal of combining nature and urban living (Lauring, 2023).

Ill. 17. Picture of Albertslund, CREDIT photo: CC BY 4.0 KDS. Modified by the author.

Åstrupskrænten

Åstrupskrænten, a planned suburban neighbourhood in Grenaa, shares several characteristics with the suburban development of Albertslund. All houses were constructed between 1974 and 1978 on previously agricultural land with no prior urban development, organized around a central distributing street.

Unlike Albertslund, Åstrupskrænten does not contain its own institutions. However, the neighbourhood was planned to ensure that each dwelling had access to a private garden, alongside a small communal green area and near to a large open agricultural landscape to the east. The area holds potential for remodelling the houses, making them more compact, by introducing a more diverse range of housing typologies. The area includes both catalogue-based prefabricated detached houses and a few individually designed ones. Remodelling the houses could allow for more efficient land use and potentially foster increased social interaction through the creation of shared spaces, much like the integrated communal areas seen in Albertslund.

The following sections include a descriptive analysis of Åstrupskrænten accompanied by an explanatory mapping, highlighting the key characteristics of Åstrupskrænten as a suburban neighbourhood. Furthermore, the mapping will illustrate the site's existing conditions, its potential, and possible interventions that could be implemented to address the research question.

Ill. 18. Bird's eye of Åstrupskrænten, CREDIT: base photo, CC BY 4.0 KDS. Modified by the author.

Flow and social interaction

Jan Gehl identifies in his book *Life Between Buildings* from 2023 that there are three types of activities that shape the quality of a space being: necessary, optional, and social activities. The balance and presence of these activities determine whether a space is perceived as good or bad. (Gehl, 2023)

At Åstrupskrænten, necessary activities include daily routines such as commuting to and from work or running errands using the distributing street or paths (See ill. 19). According to Gehl, these activities take place regardless of weather conditions, and the physical surroundings often go unnoticed, but they contribute to a more vibrant and welcoming environment by ensuring that people can see or hear others nearby, which gives a sense of security in the area (Gehl, 2023).

Optional activities, on the other hand, include recreational activities like walking or cycling for fresh air or sunlight. Since these activities are voluntary, they rely on an inviting and pleasant environment. In Åstrupskrænten, the pedestrian paths and bike-friendly infrastructure support this type of activity by providing safe and accessible spaces away from heavy traffic. (See ill. 19)

Currently, it seems that most social life is taking place inside individual homes rather than in shared outdoor environments. At Åstrupskrænten, the primary social activity is the annual general assembly, where residents gather for a shared meal hosted in one of the private detached houses (App. 3). The only communal area in the neighborhood is an underutilized green space at the beginning of the site towards east alongside the guest parking spots on the main distributing street (see ill. 19).

To strengthen the social character of Åstrupskrænten, additional shared spaces could be introduced. For example, the outdoor underutilized green area could be designed for a specific function encouraging spontaneous interaction among residents, while an indoor communal space could support larger events or meetings amongst the residents. The guest parking area also holds potential for multifunctional use. As Gehl points out, children often prefer playing in informal spaces like parking lots or entrance areas rather than traditional playgrounds (Gehl, 2023).

Furthermore, as shown in illustration 19, an industrial plot is located to the east of the neighbourhood. The Municipality of Grenaa intends to rethink this area, with potential future uses including a cultural district, institutional facilities, green space, or a new suburban development (Kommuneplan.norddjurs.dk). As such, the design process could consider and incorporate this neighbouring plot when addressing the future needs and potentials of the suburban neighbourhood.

Ill. 19. Mapping Åstrupskrænten for flow and social interactions, scale 1:2000, CREDIT base map: CC BY 4.0 KDS. Modified by the author.

Green structures

Each detached house on Åstrupskrænten is situated on a nearly identical-sized plot, generally used to accommodate a house, garage, shed, and private garden space. The layout of the neighbourhood reveals that the houses are strategically placed on their plots to optimize sunlight exposure in the gardens. Moreover, the hedges enclosing the plots serve as effective windbreaks. (See ill.20)

The consistent presence of hedges around each property suggests a strong preference for privacy within the neighbourhood. However, these hedges may also function to clearly separate property boundaries. Most homes are oriented to provide primary views into their private gardens, though some also offer sightlines toward the distributing street. This reinforces the impression that privacy is prioritized not just indoors, but also in outdoor areas. (See ill. 20) Front yards vary in character, some feature small welcoming areas with benches, while others are used mainly for parking or potted plants. The presence of parked cars in the front yards creates a physical buffer between the house and the distributing street, further reinforcing the separation between private and public space.
In terms of greenery, most gardens include a trimmed lawn and hedge, potted plants, together with well-grown trees. In typical suburban neighbourhoods, residents often favor low-maintenance landscapes. However, hedges contradict this preference, as they require regular trimming. An article notes that every seventh Danish garden owner uses a robotic lawnmower (Ban, 2021), reflecting a trend toward automation in garden maintenance. Given the importance of privacy at Åstrupskrænten and the preference for low-maintenance outdoor spaces, it may be worth exploring the potential of wild planting strategies that require less upkeep, while still preserving the degree of privacy that the residents appear to value.

Additionally, the site lies on a north-south slope, where flood risk mapping shows that the area is not vulnerable to flooding or water accumulation (DinGeo.dk), likely due to this natural gradient. As seen at the sections, many houses are integrated into the sloped terrain, either using the natural incline to shape garden spaces or incorporating basements with driveways. This design choice reduces the number of cars visible in front yards and helps maintain the spatial hierarchy between house, garden, and street.

Ill. 20. Mapping Åstrupskrænten for green structures, scale 1.2000, CREDIT base map: CC BY 4.0 KDS. Modified by the author.

Materials

At Åstrupskrænten, there is almost no variation in the materials used on facades and roofs, clearly distinguishing the renovated houses from the original ones due to their distinct appearances (see ill. 21).

Most of the non-renovated houses feature brick facades, making bricks a common material throughout the street. A variety of brick colors are observed on-site, including brown, yellow, red, and white. The white bricks are limestone, while the others are clay bricks, which have been molded to create a characteristic wavy surface texture. The bricks are typically laid in a half-brick bond.

One renovated house stands out with a water-washed finish, contrasting with the otherwise textured brick exteriors. This facade finish, however, requires more maintenance, such as regular cleaning or reapplication to manage algae growth. In comparison, the brick facades demand minimal upkeep, usually limited to occasional changing of the mortar.

Most of the houses at Åstrupskrænten feature wooden cladding on the upper sections of their gables, with the boards installed either horizontally or vertically. These are stained or painted in a range of colors, hereby white, grey, blue, black, red, or brown, to fit in with the house's brickwork. The wooden gable sections do require periodic maintenance, such as repainting or restaining, to maintain their appearance and protect the material.

The non-renovated houses at the site generally have fiber cement roof tiles in the shades of grey, black, or brown, while a few flat roofs are covered with bitumen. The renovated homes at the site generally feature more diverse roofing solutions, including high-gloss ceramic tiles, metal tiles, and in one case, a slate roofing. Most of the roofs are pitched, following a triangular shape with a 30-degree angle, constructed using a truss system.

The window frames across the neighbourhood vary in colour, including white, red, brown, grey, blue, and black. The chosen frame colour generally aligns with either the brick facade or the wooden cladding of the gable, contributing to the overall cohesive appearance of each house.

Ill. 21. Materials at Åstrupskrænten

PARTIAL CONCLUSION

To enhance Åstrupskrænten as an attractive and well-functioning residential area, several improvements can be considered in terms of aesthetics, landscaping, traffic flow, and functionality.

While the use of materials is mostly cohesive, with brick and fiber cement dominating the original homes, renovated houses stand out due to distinct changes in facade or roofing materials. There is an opportunity to strengthen the visual cohesion of the street while maintaining time typical elements, by introducing materials that harmonize with the existing ones and reference to the existing facades by using textures and patterns.

Åstrupskrænten reflects a strong emphasis on privacy, single-story housing, and car-oriented infrastructure. Turning areas, currently function primarily as vehicle zones, these could be reimagined as shared recreational spaces, such as informal play areas, when not in use.

The dominance of hedges highlights the residents' preference for privacy. However, reducing or replacing hedges with more open garden designs could help balance privacy with a greater sense of community. Such changes must be handled with care to preserve the valued sense of privacy. Several of the houses take advantage of the site's sloped topography, incorporating basement levels or stepped garden layouts, which both enhance sense of space in the gardens and reduce parked cars in the front yards. However, removing hedges between houses could unintentionally reduce privacy, especially given the elevation differences across the site. Introducing more wild planting design, while preserving mature trees, could also improve biodiversity and reduce maintenance, aligning with current preferences for low-maintenance outdoor spaces.

While pedestrian and bicycle paths support optional outdoor activities, the lack of shared or communal spaces limits opportunities for spontaneous social interaction. Currently, most social life occurs inside private homes. Given that nearly all homes are single-story, the relationship between indoor and outdoor space is also especially important. Repurposing the underused green space at the entrance to the neighborhood into a shared gathering area could help strengthen the community. Furthermore, with nearby industrial areas undergoing transformation, Åstrupskrænten could be integrated into a broader urban strategy. Repurposing the neighboring industrial site for cultural or recreational use could provide shared facilities and foster greater social interaction among residents. This area could even be imagined as an extension of the neighborhood being a communal zone that supports the changing needs of its residents.

The detached house

Translation of the detached house: *"A detached house with a surrounding garden, intended to accommodate a single household"*

(Ordnet.dk, translated from Danish)

As described in the definition above, the detached house is designed for one family and is situated on its own plot of land with a private garden. Typically they are clad in materials such as clay tiles, brick, and wood (Jensen, 2023).

Detached houses first appeared in the Copenhagen area during the 1850s, particularly in what is now known as Frederiksberg. At that time, only wealthy individuals could afford such homes. This was made possible by a building law passed in 1858, which allowed for the subdivision of land around Copenhagen into villa plots. The law also allowed development beyond the city's soil embankments, which had previously limited urban expansion. These embankments were dismantled due to concerns about the unsanitary conditions of nearby villages, motivating people to secure their own land and build healthier homes. (Lind et al., 1996)

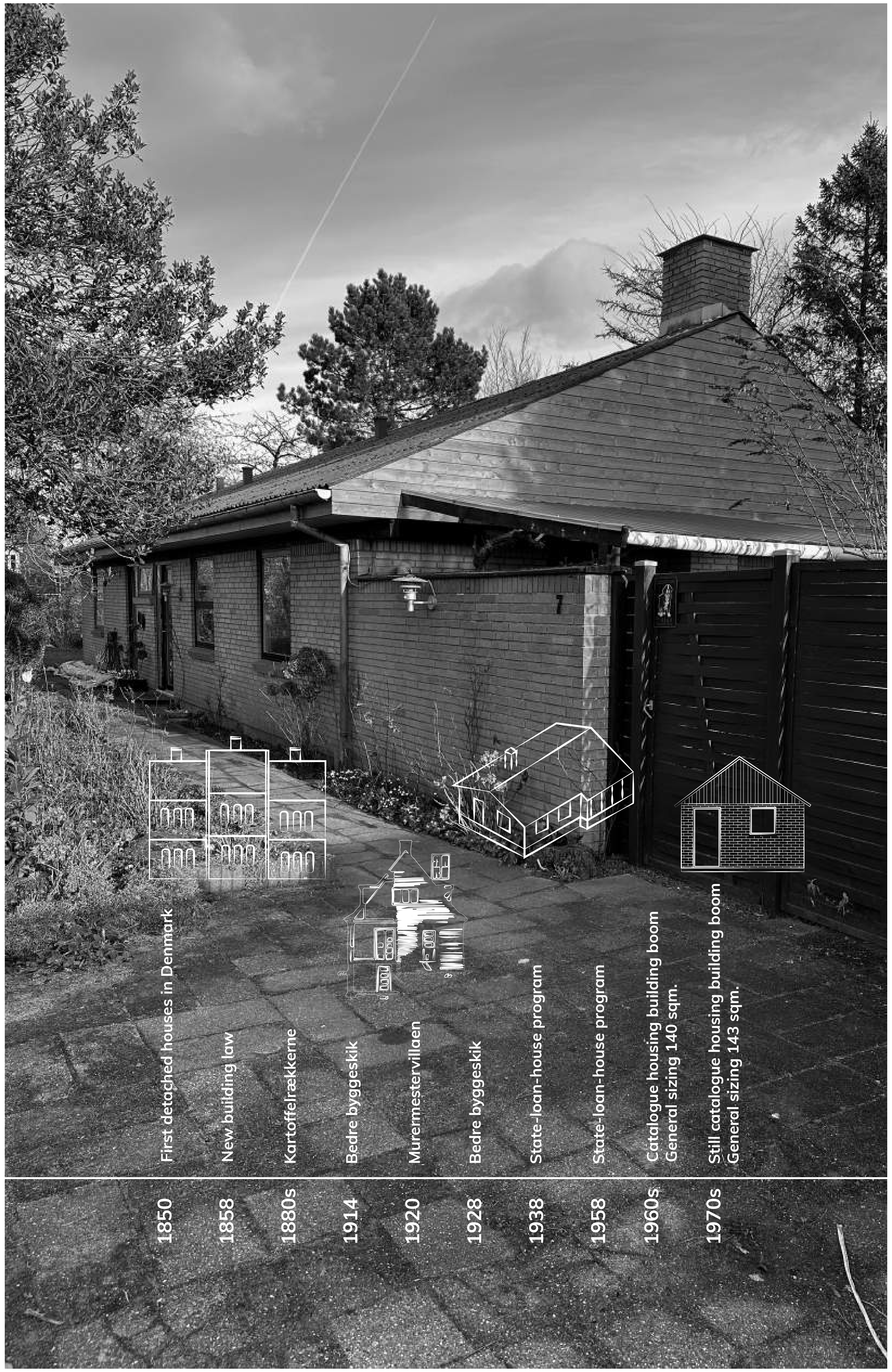
Later, building associations made home ownership accessible to the working class too, which resulted in the construction of rowhouses or semi-detached houses in the larger cities (Jensen, 2023). A notable example from this period is Kartoffelrækkerne, built in the 1880s by the Workers' Building Association in Copenhagen. Kartoffelrækkerne were designed to be affordable and privately owned, financially accessible to workers. Detached houses remained too expensive for most working-class families at the time. (Lind et al., 1996)

Between 1914 and 1928, Denmark saw the emergence of the first catalogue houses in the Grøndalsvænge neighbourhood of Brønshøj. These homes were developed by the architects Poul Holsøe and Jesper Tvede, founders of the Bedre Byggeskik movement. They created a catalogue of five different house types that allowed for variation in location and colour, preventing a uniform look across the neighbourhood. Bedre Byggeskik aimed to standardize architectural quality and technical aspects of detached housing, making it more affordable without compromising on design. In 1920, the first consciously designed catalogue house, Murermesterhuset, was constructed. (Lind et al., 1996)

From 1938 to 1958, the State-loan-house program offered state loans for small-scale home construction, allowing large families to build healthy and functional homes. Detached houses then became accessible to a broader segment of the population. However, there were strict regulations, as homes had to follow specific floor plans and structural principles, which couldn't exceed 110 m². (Jensen, 2023)

A new era for detached houses began in the 1960s. As Denmark experienced increased wealth, the catalogue house market exploded. Initially, the homes were similar in size to the State-loan-house, but as the welfare state developed, homes grew larger up to 140 m² and, by the late 1960s, even 200 m² was not uncommon. By the 1970s, the average size of a detached house had increased to 143 m². Catalogue houses were attractive because they offered pre-designed houses at fixed prices. During this period, the detached house became a symbol of happiness and was a symbol of living "the good life." (Jensen, 2023)

Today, 20% of all detached houses in Denmark are occupied by single individuals, and 36% by couples without children (Laursen, 2020). This shift in demographics highlights the need for more flexible living solutions that allow people to remain in their homes throughout different stages of life. As previously mentioned, the concept of the detached house is rooted in the freedom to customize both its interior and exterior. This type of home provides privacy and a clear separation from the public sphere. However, renovations are common when new owners move in, often to update the aesthetics to a more modern style (Lind et al., 1996). Therefore, when transforming a detached house, it is essential to preserve the potential for personalization.



Ill. 22. House at Åstrupskræntet and timeline for the detached house

Catalogue houses

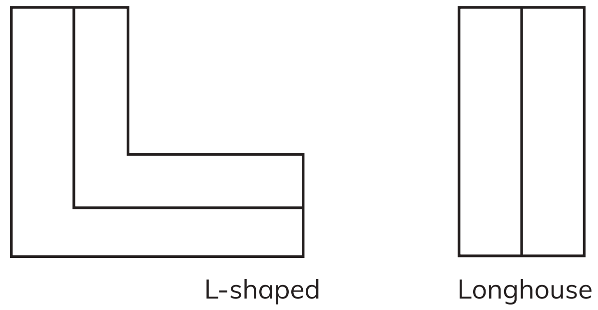
Between the 1960s and 1980s, Denmark saw a building boom in detached house construction, as the wealth of the population nearly doubled. Nearly half of the detached houses that existed in the 1990s were built during this period, as more women entered the workforce, household incomes climbed, which then facilitated homeownership. The catalogue house concept flourished during this period, driven by the belief that housing should be standardized. (Lind et al., 1996)

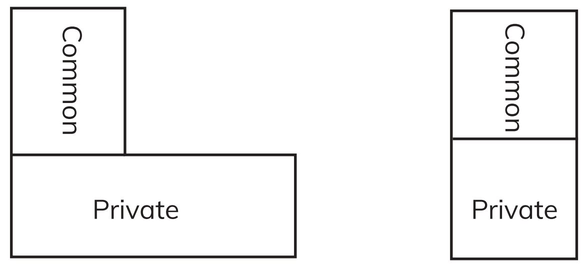
The catalogue houses from the 1970s were typically longhouses or L-shaped designs, all constructed as single-story buildings using prefabricated materials, including lightweight concrete walls and truss roof systems, with the building elements manufactured off-site and assembled on location, (Sode, 2022)

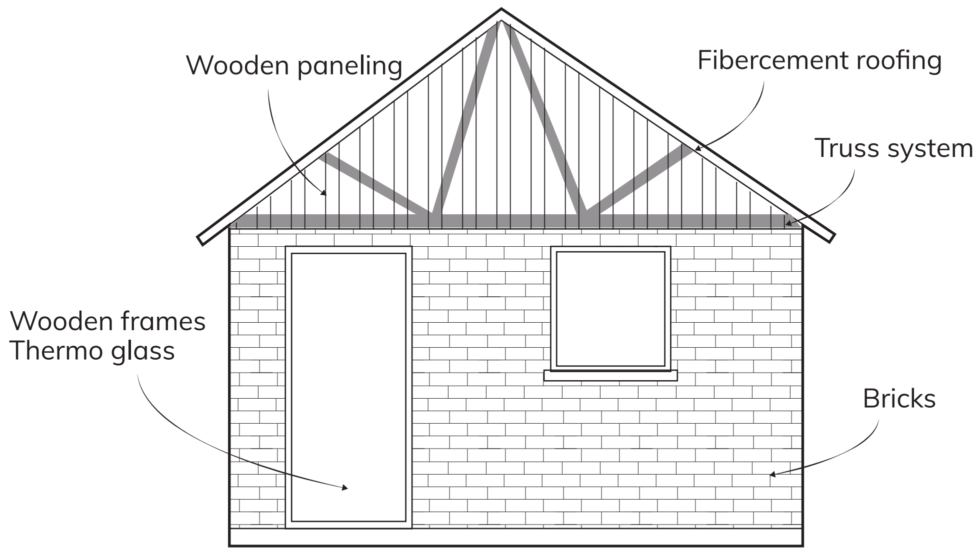
Aesthetic features of the catalogue houses differed from earlier designs, with smooth-surfaced bricks in a variety of colours. Typical structures from that time included a concrete foundation, load-bearing lightweight concrete walls, and fibercement roofing tiles. Wooden-framed thermal windows were used for facades, and floors were made of wood atop a concrete slab. (See ill 23) Interior walls were also made of lightweight concrete, with ceilings clad in wooden panels or gypsum boards. (Sode, 2022)

Most of the houses built during this time included distinct children and adult sections, with a common space at the other end. The common space then offered a combined space for the kitchen, dining area, and living room, designed for family members to gather (Nielsen, 2023). The defining characteristic of catalogue houses was their generic design, which could be selected from a catalogue without considering the specific plot or homeowner. This sometimes led to houses being placed in the centre of plots without regard for the surrounding context. (Sode, 2022)

Today, catalogue houses remain widespread. Open fields are still being developed into suburban neighbourhoods characterized by repetitive variations of the same designs, connected by road networks that feed into larger infrastructure systems. In the *Rundt om Byggeriet* podcast, restoration architect and founder of architectural firm, *Arkoie*, Line Stougaard, critically reflects on the value of these newly built catalogue houses. She argues that many of them remain context-blind and notes a trend of demolishing and rebuilding existing catalogue houses in nearly identical forms. In her view, preserving the original catalogue houses from the 1960s–1980s is essential to remain architectural history, and to make more conscious sustainable design choices. (Christiansen, 2024)







Ill. 23. 1970s catalogue house

Åstrupskrænten 45

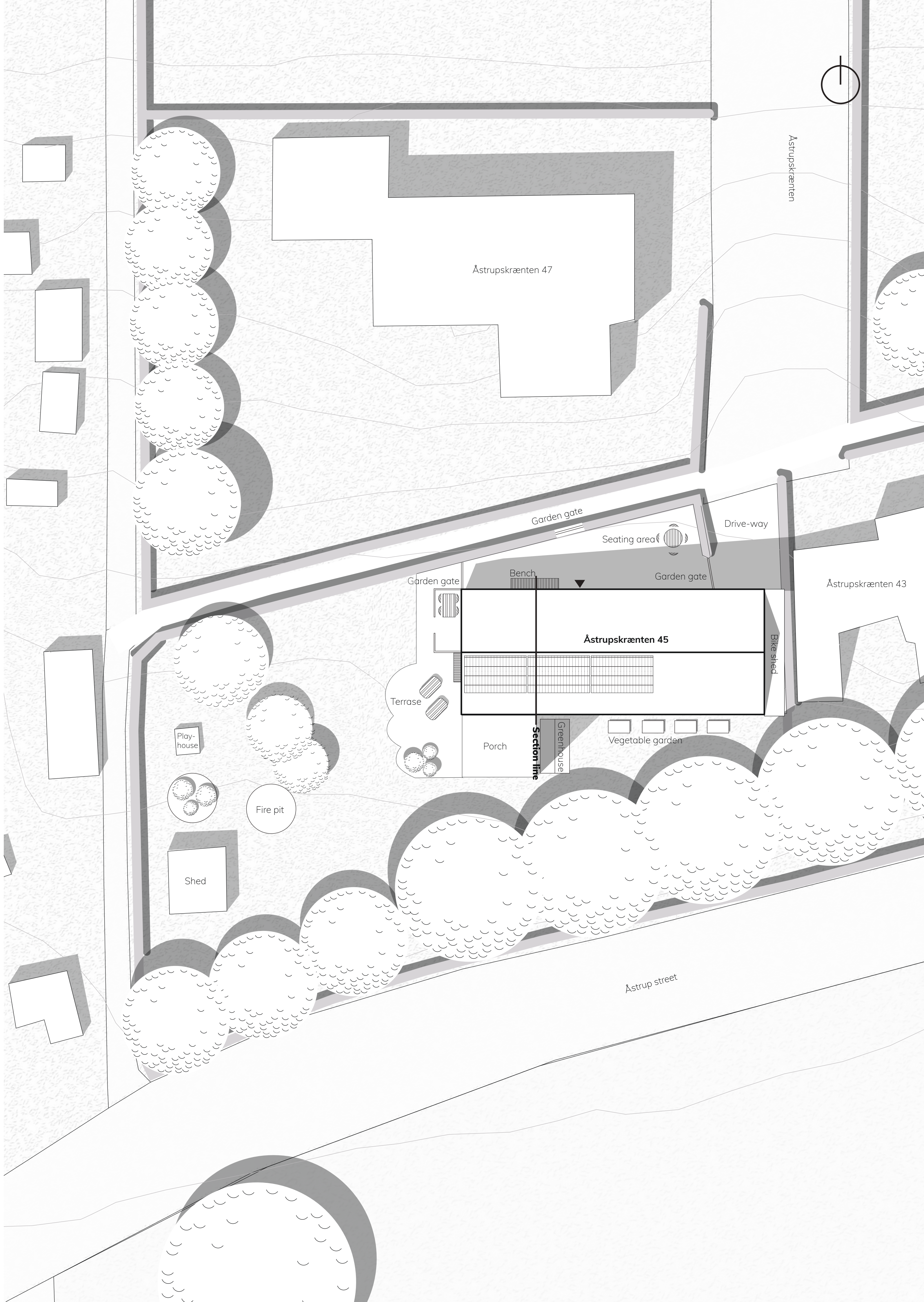
Åstrupskrænten 45 is a detached catalogue house built in 1974, with a total floor area of 146 m², situated on a cadastral plot of 1,655 m², with a building coverage ratio of 8.82% (see ill. 24). This house serves as the specific case study within the project, as it closely reflects the typical size of detached houses from that period and has remained unaltered in terms of footprint since its original construction. Furthermore, Åstrupskrænten 45 was among the first houses to be built in the suburban development of Åstrupskrænten. The current occupants consider the existing size to be more than sufficient for their needs (App. 1), which makes the house relevant for exploring how existing structures can be adapted to new forms of living without expanding their physical footprint.

The house is positioned in the northeastern corner of the plot, allowing for optimal sunlight exposure and maximizing the available garden space. The entry to the house is via the front yard, which is enclosed by a hedge, creating a defined semi-private space. Access is provided either through a gate next to the garage or a smaller entrance gate located directly in front of the house, integrated within the hedge.

Within the front yard, a seating area has been established, which remains private due to the surrounding hedge that shields it from the elevated pedestrian path along the northern edge of the plot. However, this spatial configuration also limits visual and social interaction with passersby.

The backyard offers well-grown trees, plants, and hedges. Inside the backyard there are different spaces, a terrace surrounding the house for different seating options, a shed, and a vegetable garden. Due to the low building coverage ratio, the plot could potentially be subdivided, offering the possibility of building an additional house. (See Ill. 24)

On the western gable, an enclosed terrace features a windbreak wall made from the same brick as the facade cladding, creating cohesion in the design. However, the choice of a different material for the pavement on the terrace makes the space feel less cohesive. The house is almost surrounded by a paved area, with only a small section on the southern side left unpaved, meaning approximately 280 m² of the property is paved. There are loads of terrace space, both in front of the house and towards the west. However, it may not be necessary to have so much, as there are several seating areas available. Furthermore, to the south, a covered porch offers a sheltered outdoor area, allowing the occupants to enjoy the outdoors regardless of the weather.



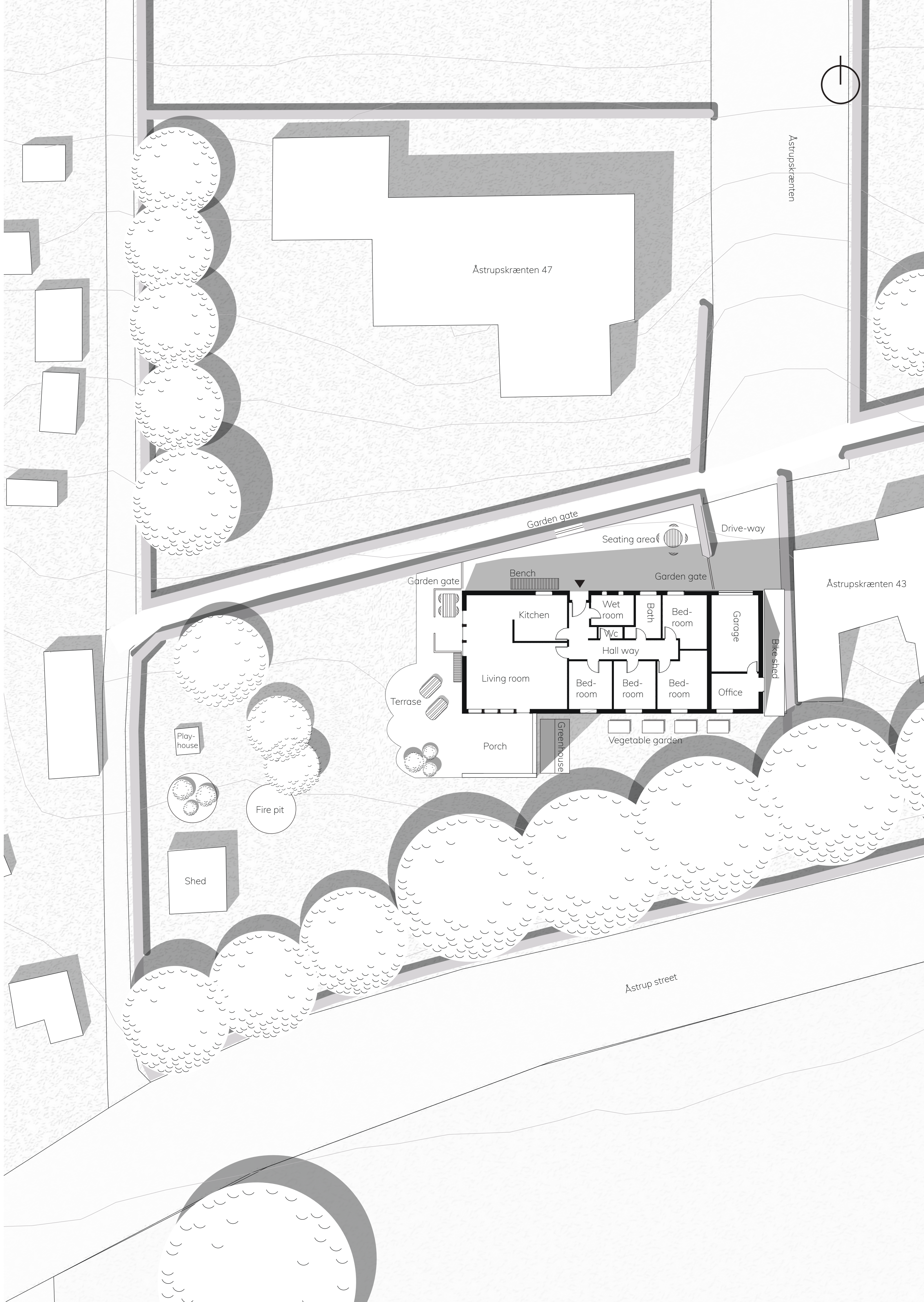
Ill. 24. Current situation plan, scale 1:300, CREDIT based on map from CC BY 4.0 KDS, and the original siteplan of Åstrupskrænten 45, from the local building archive at Norddjurs Municipality. (FilArkiv, Norddjurs Municipality). Modified by the author.

Current interior layout

Åstrupskrænten 45 has undergone minor interior modifications and garden redesigns, primarily reflecting the personal preferences of its occupants. When the house was originally purchased in 1993, it served as a family home (App. 1). The house is currently inhabited by a couple in their late 50s. Before this, it was owned by a married couple, but they got divorced, and later the children moved away from home. At the time that the house was bought in 1993, the kitchen was separated from the living room, which was later opened to get more daylight. Furthermore, the house featured three entrances, one located as shown in illustration 25, and a secondary entrance through the wet room, which was later closed off, leaving only the primary entry in use, and the third one being the office entrance door.

The southern part of the house originally contained bedrooms for each family member. However, following the divorce and the children moving away from home, the function of these rooms changed. Today, they serve as a primary bedroom, a guest bedroom, and hobby spaces. Additionally, an office space in the garage has been repurposed as storage. The current owner also notes that, if it were economically possible, they would have appreciated additional semi-indoor spaces to better support their present lifestyle instead of the spare rooms. (App. 1) This means that in total, approximately 32 m² inside the main house and 8 m² within the insulated garage now function as potential underutilized spaces. This highlights the potential for reconfiguring the house into multiple living units, allowing for a more adaptable housing solution that can respond to changing household needs.

Furthermore, the house is currently organized into a clearly defined private and social zone, allowing for retreat into the private section and potentially encouraging isolation from social life taking place in the shared areas. The social zone is directly connected to the more social-facing parts of the garden, while the private section faces the vegetable garden, and the bicycle shed. Moreover, the office located in the garage is only accessible by exiting the main living space and entering the garage. This spatial disconnection further reduces the occupant's awareness of activity occurring within the rest of the house while working, highlighting the limitations of the existing layout.



Ill. 25. Current floor plan, scale 1:300, CREDIT based on map from CC BY 4.0 KDS, and original floorplan of Åstrupskrænten 45, from the local building archive at Norddjurs Municipality. (FilArkiv, Norddjurs Municipality). Modified by the author.

Current daylight

As illustrated on illustration 26, most rooms in the house receive a satisfactory level of natural daylight. Daylight Autonomy (DA) is used as a tool to measure the daylight percentage of the year, within a room, to see if it is naturally illuminated to 300 lux, without the need for artificial lighting. Assessing DA allows for a more thorough understanding of how well a space performs over time, rather than simply determining whether it meets minimum daylight requirements. The design goal would then typically be to achieve a DA between 40% and 60%, which helps ensure a well-balanced daylight environment with sufficient daylight during the day.

With a DA of 0%, the hallway appears dark, which disrupts the spatial experience of moving through the home. The hallway lacks windows and therefore stands in sharp contrast to the brighter rooms on either side. Since the hallway has no access to exterior walls, the incorporation of skylights could be a valuable strategy to improve daylight conditions and reduce the visual contrast between spaces.

Similarly, the garage lacks windows, making it a particularly dark space. If this space were to be repurposed as part of the living area, it would be essential to address the lack of daylight to ensure comfort and functionality.

Additionally, it appears that the covered terrace towards south has a minimal impact on the daylight conditions in the living room. This suggests that it does not function effectively as a passive shading element and may not significantly influence overheating risks. Therefore, its role in any future passive climate strategy should be carefully evaluated.

Ill. 26. Current Daylight Autonomy (DA), CREDIT based on map from CC BY 4.0 KDS, and original floorplan of Åstrupskrænten 45, from the local building archive at Norddjurs Municipality. (FilArkiv, Norddjurs Municipality). Modified by the author.

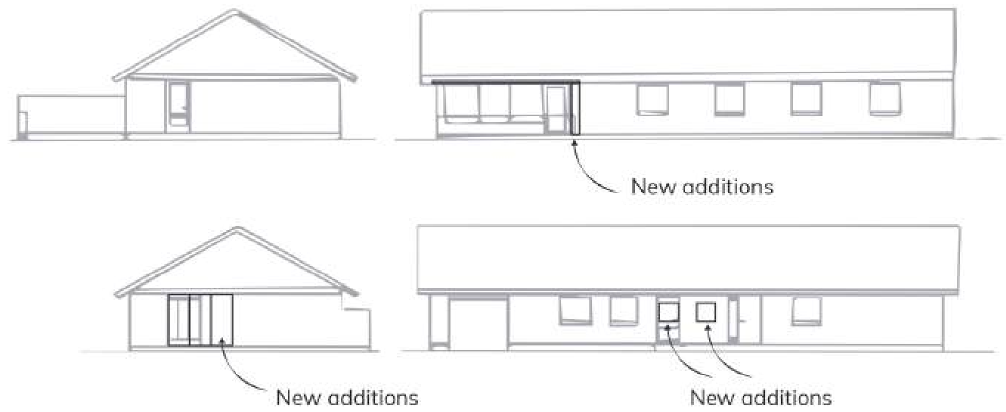
Exterior expression and aesthetics

As shown in illustration 27, the exterior walls primarily feature white limestone bricks, together with a wooden cladding on the upper part of the gables. The windbreak walls on the west and south sides of the house are constructed from the same brick as the main house, emphasizing the consistent use of this material. The combination of wood and bricks are typical for catalogue houses from this period (see pp. 52-53). The wooden part of the gables is white-painted and has a smooth finish, which therefore contrast with the rough, textured brick surfaces below. As illustrated in 27, the sunken mortar joints add depth to the facade but also create conditions that promote algae growth.

Facade
The contrast in the facade is expressed not only through texture but also through temperature and the orientation of the materials in their bonding pattern. This visual contrast could be further enhanced by introducing a colour difference, as originally intended in 1974, when the wooden gables were painted blue. Alternatively, a more cohesive aesthetic could be achieved by cladding the wooden part of the gable with the same brick as below, thereby eliminating the material contrast and creating a more unified facade expression.

The entrance door, made of black-painted wood, displays visible joints and includes a colourful decorative window. In contrast, the other windows and doors are made of white aluminium and plastic, featuring minimal mullions to maximise daylight penetration. Their white frames blend seamlessly with the white brick facade, making the window openings less prominent. These could become more noticeable if painted in a contrasting colour. Furthermore, the windows are generally uniform in size and symmetrically placed. However, a later alteration by the current occupants replaced the original wet room entrance door with two smaller windows, slightly disrupting the symmetry of the northern facade. Restoring this door, if the house is to be adapted for dual occupancy, could help reestablish a more balanced and coherent appearance. (see ill. 27)

Roof
While the covered terrace is roofed with translucent corrugated plastic sheets, the main roof features grey-toned corrugated fibre cement tiles, showing signs of age and patina from exposure to weathering. This roofing material contrasts with the lighter facade and complements the black-painted plinth and entrance door (see ill. 27). According to DinGeo, the roof likely contains asbestos, suggesting a need for replacement (DinGeo.dk). When working with an asbestos-containing roofing material, such as corrugated fiber cement, new Danish regulations taking effect in 2025 state that a complete roof replacement must be carried out by professional workers. However, minor modifications, such as removing a few roofing sheets, installing a skylight, or mounting solar panels, can still be done independently. Additionally, the roofing does not need to be removed unless necessary, but it is important to follow specific maintenance guidelines. High-pressure cleaning is strictly prohibited, as it can release hazardous asbestos fibers into the air. Instead, the roof should be cleaned using a soft brush and a garden hose. Likewise, sanding and repainting the roof are not allowed, as these actions can also cause asbestos particles to disperse. (Jensen, 2025) The design phase could therefore consider both the option to keep and replace the roofing.



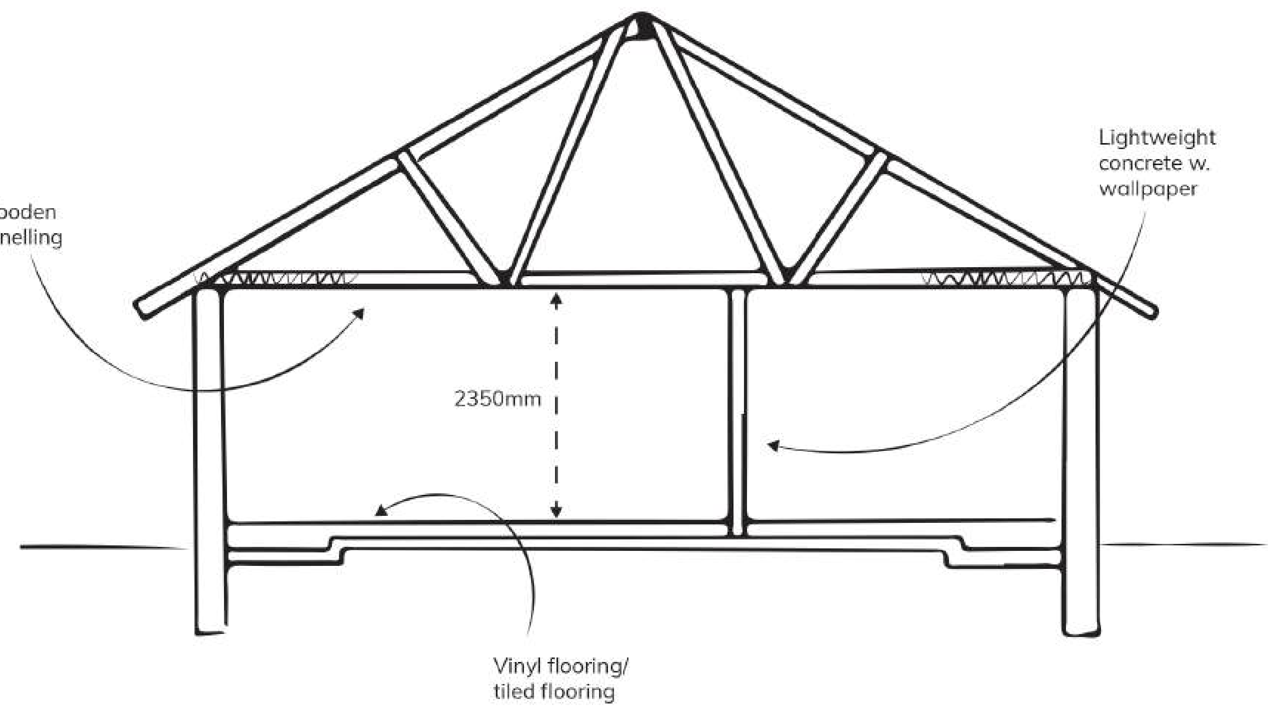
Ill. 27. Current elevations and exterior materials, CREDIT based on original elevations of Åstrupskrænten 45, from the local building archive at Norddjurs Municipality. (FilArkiv, Norddjurs Municipality). Modified by the author.

Interior expression and aesthetics

Flooring
Åstrupskræntn 45 has undergone several interior material renovations over the years, during which the character of the rooms has gradually changed (app. 1). When the house was bought all the flooring was changed. Vinyl flooring was chosen for most rooms in the house due to its durability, as it minimizes visible wear and reduces maintenance requirements (app. 1), but thinking of future needs the floor might need to be replaced with materials that can change character according to personal preference. Across the entire house, three types of tiles have been chosen: one type is used in both the hallway and wet room, while the other two are used separately in the bathroom and toilet. To create a more cohesive and unified expression throughout the home, it would be beneficial to use the same type of tiled flooring in these rooms. (See ill. 28)

Walls
Furthermore, in several areas, the wallpaper on the internal walls has been removed and replaced with a smoother surface finish. However, the remaining walls still feature a mix of wallpaper textures. (See ill. 28) To achieve a more cohesive interior, it could be beneficial to remove all remaining woodchip wallpaper. In the bathroom, the walls are finished with small grey tiles in varying shades, while the bath area is clad in slightly larger grey tiles. Simplifying the material palette in both the toilet and bathroom could contribute enhance the sense of cohesion in these spaces. (See ill. 28) In the toilet, the walls were originally covered with green tiles, which, according to the current owner, contained asbestos. As a result, parts of the tiling have already been removed (App. 1), and therefore it makes sense to remove the rest and replace it with a new surface finish.

Ceilings
Besides this, the ceilings are finished with dark wooden planks, which add warmth and enhance the acoustics of the space. However, the combination of dark ceilings and the relatively low ceiling height at 2350mm may create a somewhat claustrophobic atmosphere for the occupants (see ill. 28). Additionally, the dark ceiling reduces the reflection of natural light. To enhance the sense of space and brightness, the wooden ceilings have in some areas been stained in a lighter color. (See ill. 28) In the living room, it has been replaced with wider, white-painted wood. Therefore, it is evaluated that it would be valuable to explore ways to make the ceilings more cohesive and improve the perception of height. Introducing vaulted ceilings could potentially improve the sense of space. However, it is important to assess whether the existing truss system can structurally support such modifications.



Ill. 28. Cross-section and interior aesthetics, CREDIT based on original section of Åstrupskrænten 45, from the local building archive at Norddjurs Municipality. (FilArkiv, Norddjurs Municipality). Modified by the author.

Energy optimization and structural principle

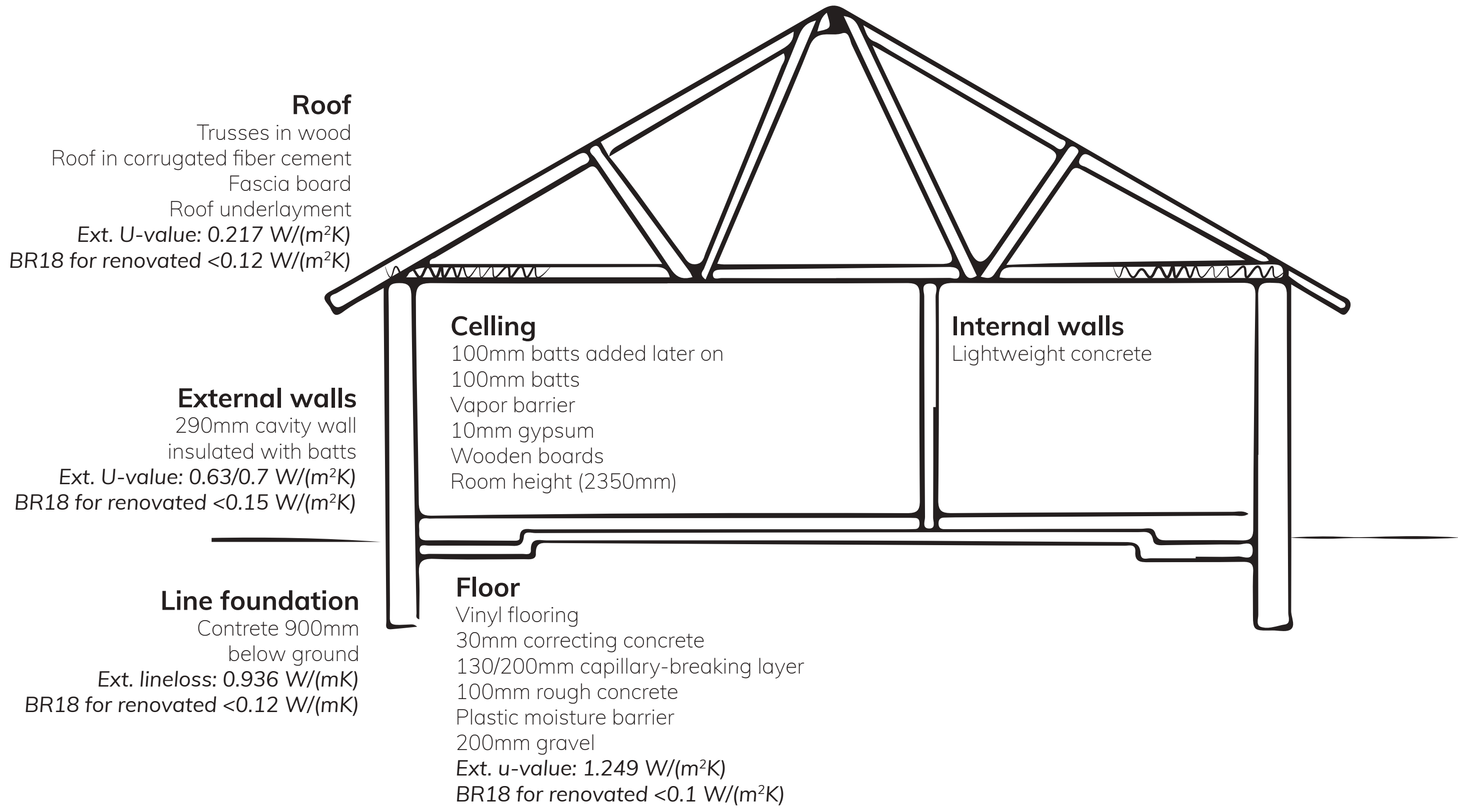
Since Åstrupskrænten 45 was developed in 1974, it can be assumed that energy optimization was not a primary concern at the time (Laursen, 2020). An estimated energy assessment of the house revealed an anticipated consumption of 112.1 kWh/m^2 per year. Furthermore, the house has 6 m^2 of solar cells placed on the top Southwest part of the roof, which makes the operational electricity -3.7 kWh/m^{2}year, and then there is 134.2 kWh/m^{2}year used for heating. (See app. 5)

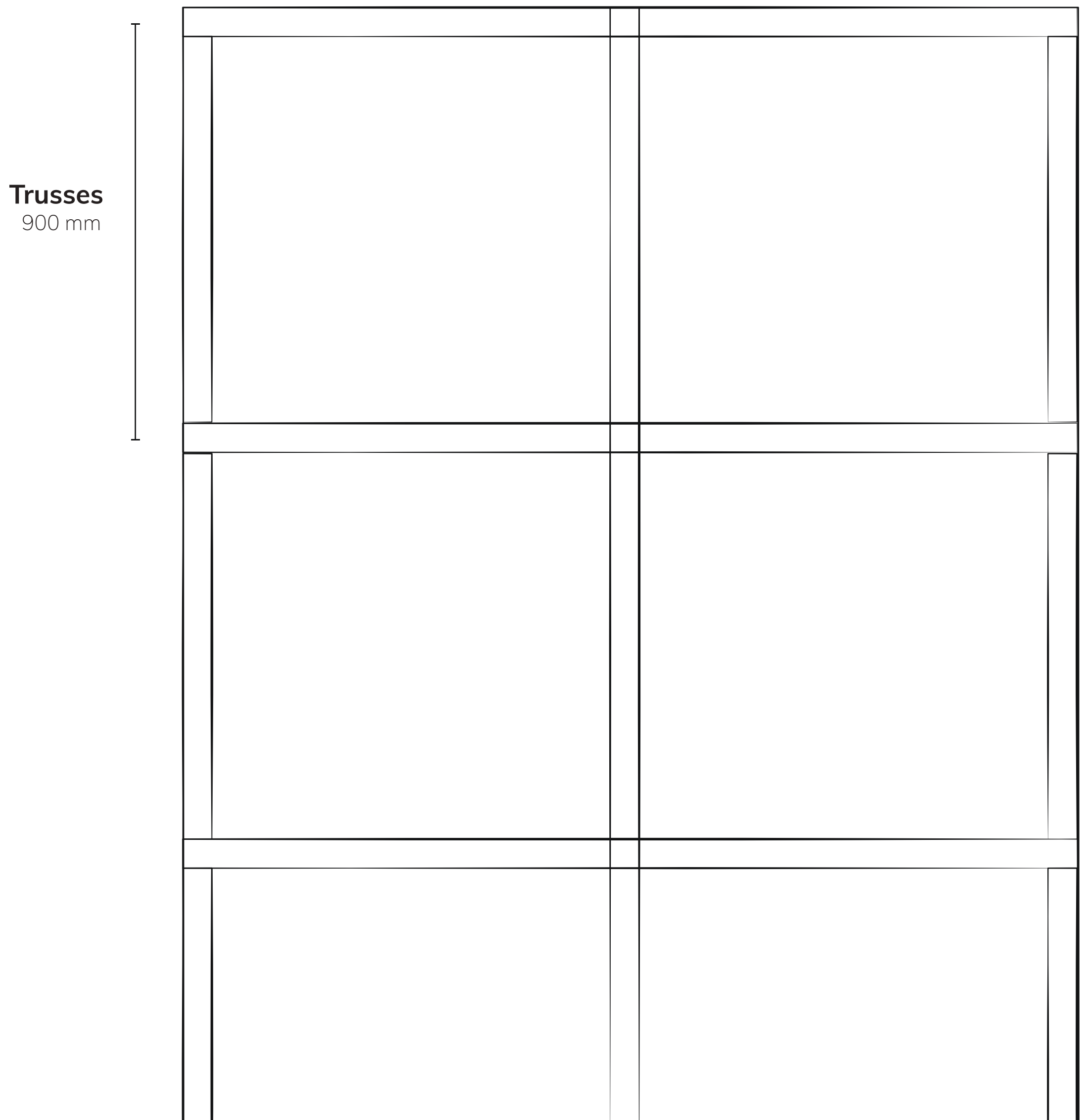
Roof
Åstrupskrænten 45 has a saddle roof supported by wooden trusses with a 30-degree angle made from construction timber for every 900mm (see ill. 29). The roof structure rests on a cavity wall, which is supported by a concrete strip foundation extending 900 mm underground.

Walls
The outer walls consist of a combination of concrete and brick, providing high thermal mass. Furthermore, the cavity walls are insulated in both the main living areas and the garage/office space, which suggests a potential for integrating the garage into the main living area. In addition, both the roof insulation and the insulated floor extend to this part of the house. (See Ill. 29)

Line foundation
The line foundation appears to lack insulation entirely, creating a potential thermal bridge due to its connection with the floor. Since the ground temperature is typically lower than the indoor temperature, this could lead to significant heat loss. Adding insulation to the foundation presents an opportunity to mitigate this issue and enhance the building's overall energy efficiency.

Windows
The windows and doors were mostly replaced during renovation after the owner purchased the house in 1994. As a result, it is assumed that the newer windows and doors have better U-values and G-values compared to those installed in 1974, when the house was originally built. The newer windows are estimated to have a U-value of 1.8 W/m^{2}K and a G-value of 0.63, while the old windows and entry door are assumed to have a U-value of 3.0 W/m^{2}K and a G-value of 0.7. These assumptions are based on typical window performance from the noted eras. To improve the home's energy performance, it could make sense to consider replacing either all windows or the oldest ones.





Ill. 29. Cross-section and placement of trusses, CREDIT based on original section and floorplan of Åstrupskrænten 45, from the local building archive at Norddjurs Municipality. (FilArkiv, Norddjurs Municipality). Modified by the author.

PARTIAL CONCLUSION

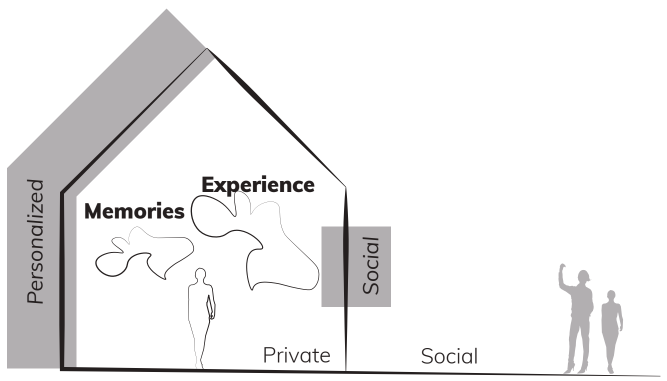
The concept of a detached house circles around the freedom to personalize both its interior and exterior, offering homeowners private space that separates them from the public sphere. Over time, it has become common for these houses to be renovated by new occupants, when the old occupants move out, seeking a more modern aesthetic. This highlights the importance of flexibility, not only in the interior layout, but also in the choice of materials.

Åstrupskrænten 45 presents several opportunities for improvement. The house, built in 1974, has a solid structure but could benefit from aesthetic and functional upgrades regarding daylight entering the living space, but also according to material choices. Here the exterior features, a combination of untreated brick and wooden elements, could also be either emphasized through contrasting colours or unified with a more cohesive material approach. Additionally, the current roofing contains asbestos and should be assessed whether it is most feasible to replace it or keep it.

The interior layout has undergone modifications over the years, adapting to the changing needs of its occupants. However, the house still contains a significant amount of unused space, particularly in the garage and spare rooms. This suggests the potential for repurposing the space to create a more flexible home environment. The house's division into private and common sections also influences social interactions, potentially isolating residents. Adjustments to the layout, such as opening the hallway or modifying the office placement, could enhance connectivity within the home.

The large garden provides opportunities for better land utilization. The property size suggests that it could potentially be subdivided to accommodate an additional house. Additionally, the existing paved areas and terraces might be optimized to create more functional and cohesive outdoor spaces.

Energy optimization is another area of potential improvement. While Grenaa's district heating is relatively inexpensive, the primary energy source, burned wood chips, is not the most sustainable option. Exploring ways to optimize energy consumption within the houses, such as improving insulation could enhance sustainability. Strategies for enhancing insulation could be in the foundation, walls, and floors. Moreover, some of the house's original windows remain in place and may need replacement to improve energy efficiency. Structural adjustments like addressing the asbestos in the roofing and improving ceiling heights could further enhance comfort, and the sense of space.

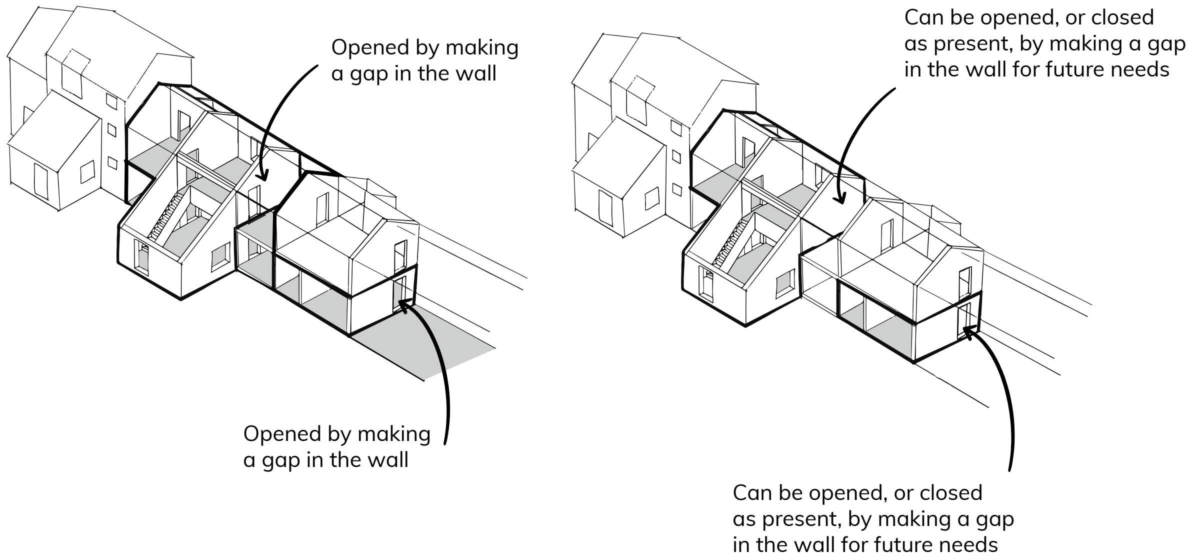


Ill. 30. *The home*

New approaches to housing

Individuals spend an average of two-thirds of their time at home (Lind et al., 1996). Therefore, the home becomes a vital part of our existence. A home cannot be created instantly; it evolves over time through the dweller's adaptation to the world (Pallasmaa, 1995). A home is therefore not only a building or an object, but also a condition, a dynamic relationship between humans and their surroundings. It is not only defined by physical structures but also by actions and is a social and cultural expression of the dweller's lifestyle and values. (Christensen, 2021) Mark Vacher states that the social expression has two forms: people we live with, and people we live above, below or next to. Vacher says, that if it is living with, then certain objects in the home should be able to state this. (Vacher, 1970)

Ill. 31. *Picture of Åstrupskrænten*



Co-living

In the 1980s a rise in co-living arrangements was seen, as people recognized the economic and social advantages of living closer (Lind et al., 1996). Co-housing communities are often based on sustainability and social interaction, as the smaller an individual living space is, the less material use in construction and lower energy demand for heating there can be in total. Moreover, many co-housing projects are situated in repurposed buildings, which contributes to a decrease in resource use. (Andersen, 2021)

For co-housing to thrive, residents must be willing to agree on rules that promote the sense of community. This might include sharing household finances, communal meals, and fostering close relationships. Residents also need to be open to discussing and resolving conflicts, as not everyone in the community may share the same views or desires. (Andersen, 2021)

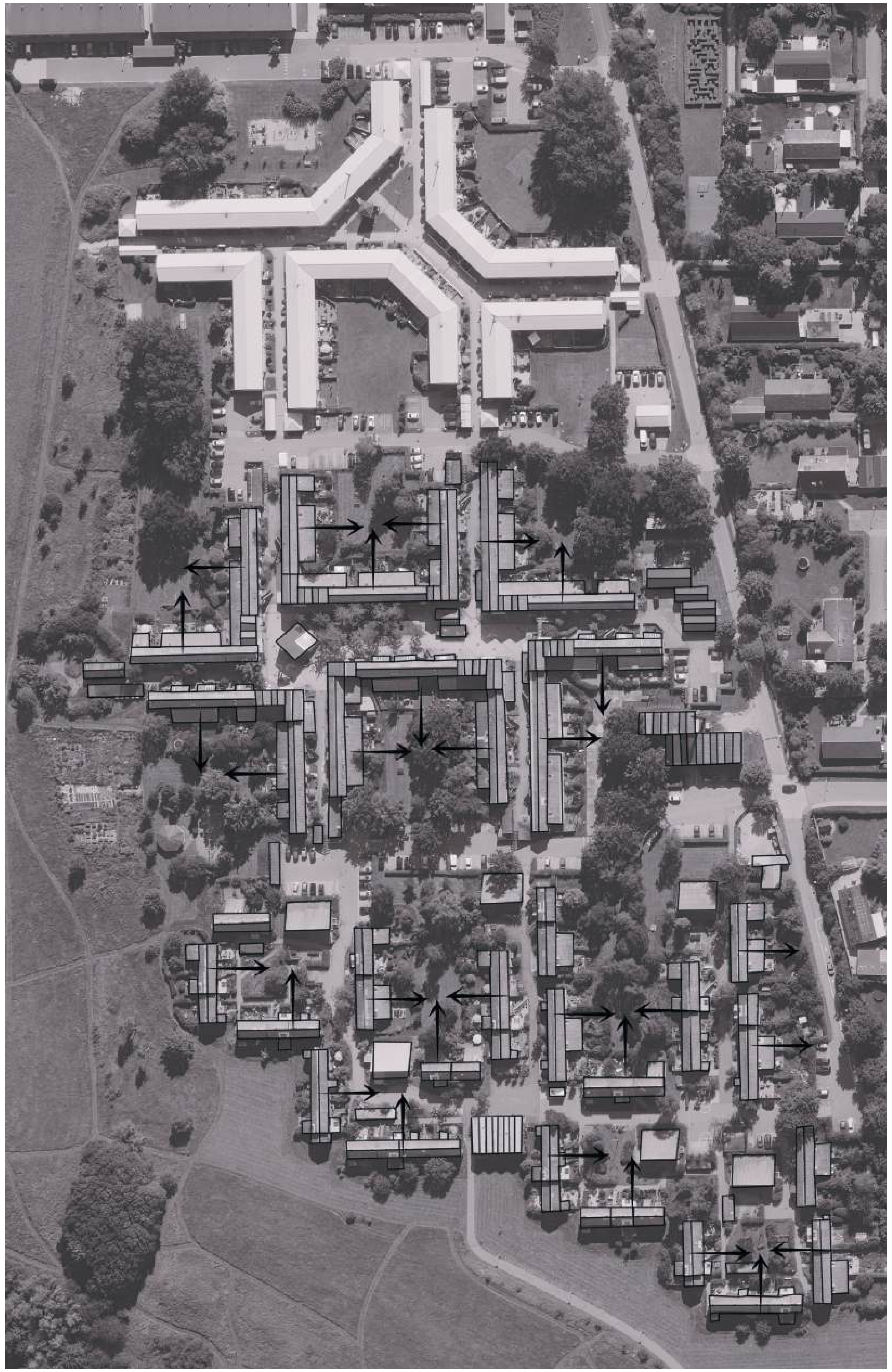
Co-housing communities therefore also vary in structure, with some offering private spaces where individuals can retreat, while others are more communal, sharing all activities and only having private bedrooms. The latter can present challenges in adapting to changing life situations. In most homes, there is a balance between private and communal, where in co-housing communities the communal areas are prioritized higher than the private areas, and does often serve as the central hub for social connections. (Andersen, 2021)

Ill. 32. Tinggårdens flexible walls, CREDIT: Own drawing based on photo by Vandkunsten. Photographer: Tegnestuen, Source: www.arkitekturbilleder.dk /The Royal Danish Academy - Library of Architecture, Design and Conservation.

Tinggaarden, Herfølge

To understand, the benefits from co-living, Tinggaarden in Herfølge has been investigated. Tinggaarden was built in 1978 on an open land as a dense/low housing residential architecture grouped into family clusters. (Vandkunsten.com) As illustrated in 32 and 33, Tinggaarden offers each individual family their own rowhouse, and then as an addition they have a communal house, where they can dine together with the other occupants and host events. They share a semi-public garden with their family cluster, and between the housing units, there are made the flexibility of being able to renovate and give rooms to the neighbouring housing unit. Therefore, the development can be modified and doesn't have to remain as it was originally built. (See ill. 33)

At Tinggaarden, the design concept allows residents to first select from a range of base layouts, each differing in the number of floors and the placement of key functions such as living areas, kitchen, bathroom, and entrance. Once a base layout is chosen, residents can then customize it further by adding or removing separate rooms as needed, these rooms function as flexible modules that can be attached or detached over time. As illustrated, selected walls can be modified with door openings, making the layout even more adaptable. (See ill. 32) This approach offers valuable inspiration for the transformation of Åstrupskrænten. Investigating the potential of flexible wall elements, like those used in Tinggaarden, could inform strategies for creating more adaptable and future-proof homes in the area.



Ill. 33. Tinggården, CREDIT: Based on CC BY 4.0 KDS. Modified by the author.

Multifamily and multigenerational homes

In the latest years it has become more and more common to build multi-generational homes that accommodate children, parents, and grandparents. This includes some of the aspects of co-living combined with the regular living of a detached house. This arrangement often suits families where grandparents may need more assistance and less space, while busy families with children enjoy having their elders nearby, allowing them all to have separate housing units, but still live close. (Arked.dk, 2021)

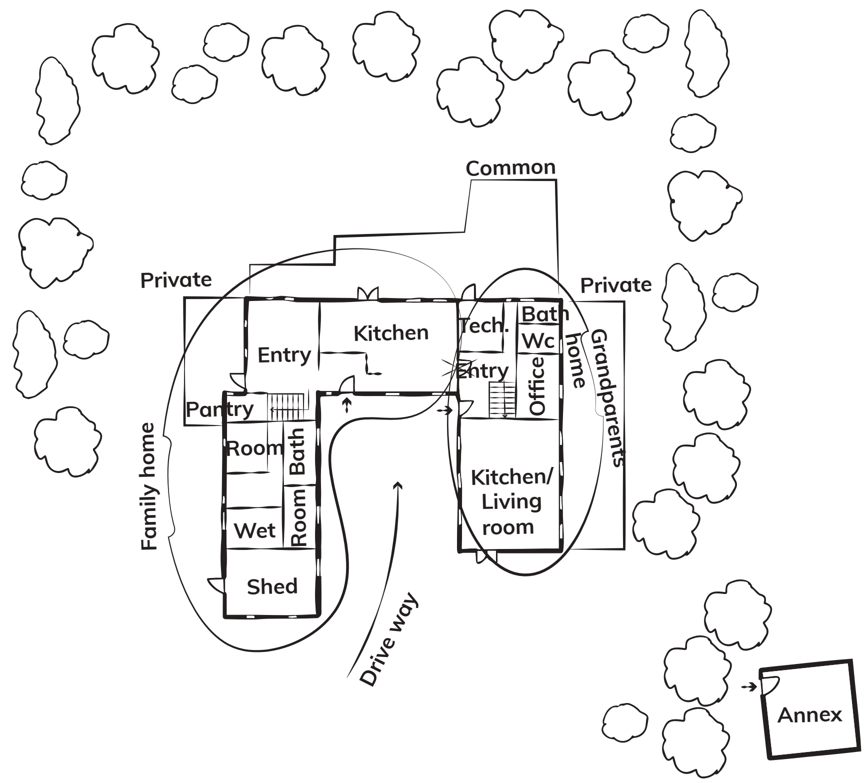
In 2024, data from Statistics Denmark indicated that 232,578 houses in Denmark were considered being a multi-family housing, a very small reduction from the peak in 2019 of 233,819 houses (Statestikbanken.dk). Multifamily homes typically house related families, while multigenerational homes are for unrelated families living together across generations. There are several reasons for choosing this living arrangement, with three key advantages: economic, practical, and social benefits. (Arked.dk, 2021)

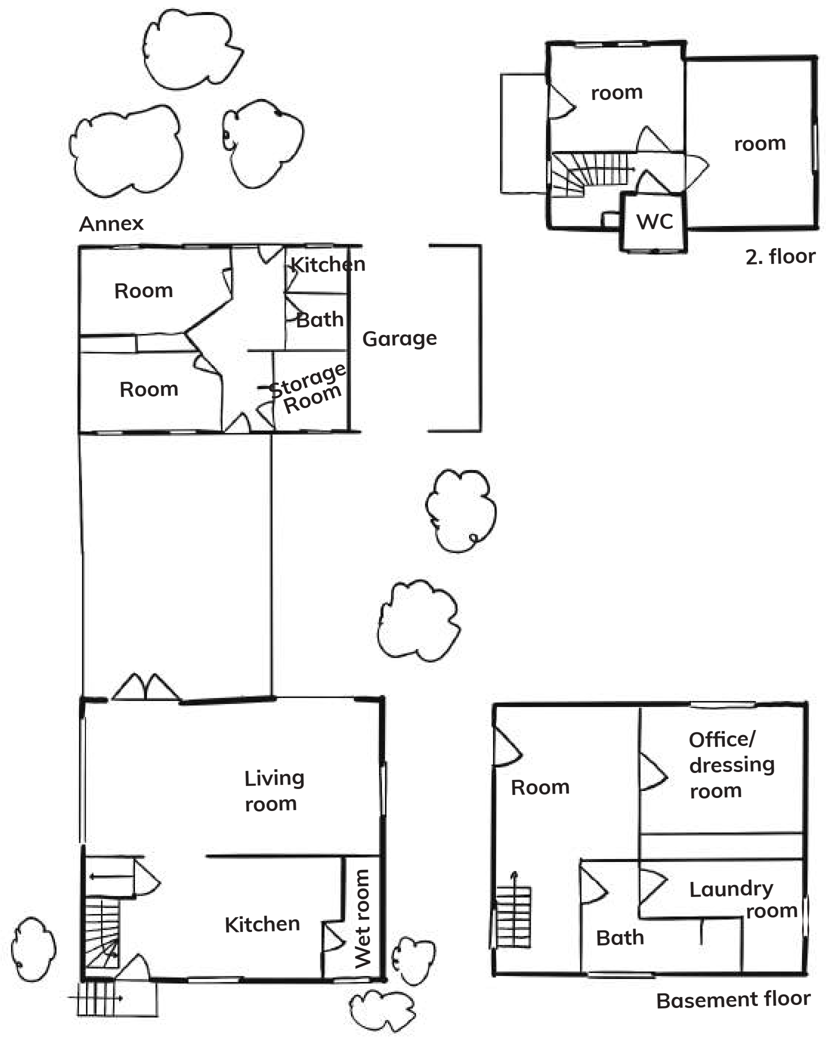
An increasing number of families realize the advantages including shared responsibilities for maintenance, childcare, social activities, and economics (Kristensen, 2022). Transforming single-family homes into multi-family/generational homes could improve the utilization of existing square footage (Berg, Rikke, 2020).

Interviews, multi-generational living
Interviews with residents in multigenerational homes revealed valuable insights into how shared living can evolve over time. In one case, a woman initially moved in with her grandfather. Later, her boyfriend joined them, prompting small renovations to create more private spaces while maintaining a connection to the grandfather. As their family grew, they relocated to a larger, split house where the grandfather had his own annex. While the new setup offered greater privacy, it also reduced the sense of togetherness previously felt when living under the same roof. (App. 2)

Another case involved a couple, their three children, and their grandparents living together. Over time, the house was renovated to include separate kitchens and blocked doorways, increasing privacy. As independence grew, shared dinners declined from daily to weekly, though the family still supported each other in practical ways. (App. 4)

Both cases highlight the importance of flexible housing designs that balance privacy and togetherness. Key features include adaptable layouts, and a mix of shared and private areas. These insights suggest that multigenerational could be a valuable strategy for Åstrupskrænten, as it has diverse households with both couples, families and elderly living alone that may benefit from more flexible and inclusive housing models.





Ill. 34. Casestudies on multigenerational living

Ownership

In general constellations, a detached house is owned by a couple or a single person. When sharing a house with other people, there are different approaches on how to have the ownership. In the following it is investigated how these different ownerships would be, and what the owners should be aware of.

Renting a part of the house
This option targets homeowners with excessive space, allowing them to rent out part of their house. It is particularly relevant for Åstrupskrænten 45, where the home exceeds the current occupants' needs (App. 1). Since this setup does not include separate kitchens or bathrooms, it requires a co-living arrangement, something the occupants should be willing to embrace. In these cases, the homeowner should be mindful of rental regulations and may need separate insurances (EFFEKT Architects et al., 2024).

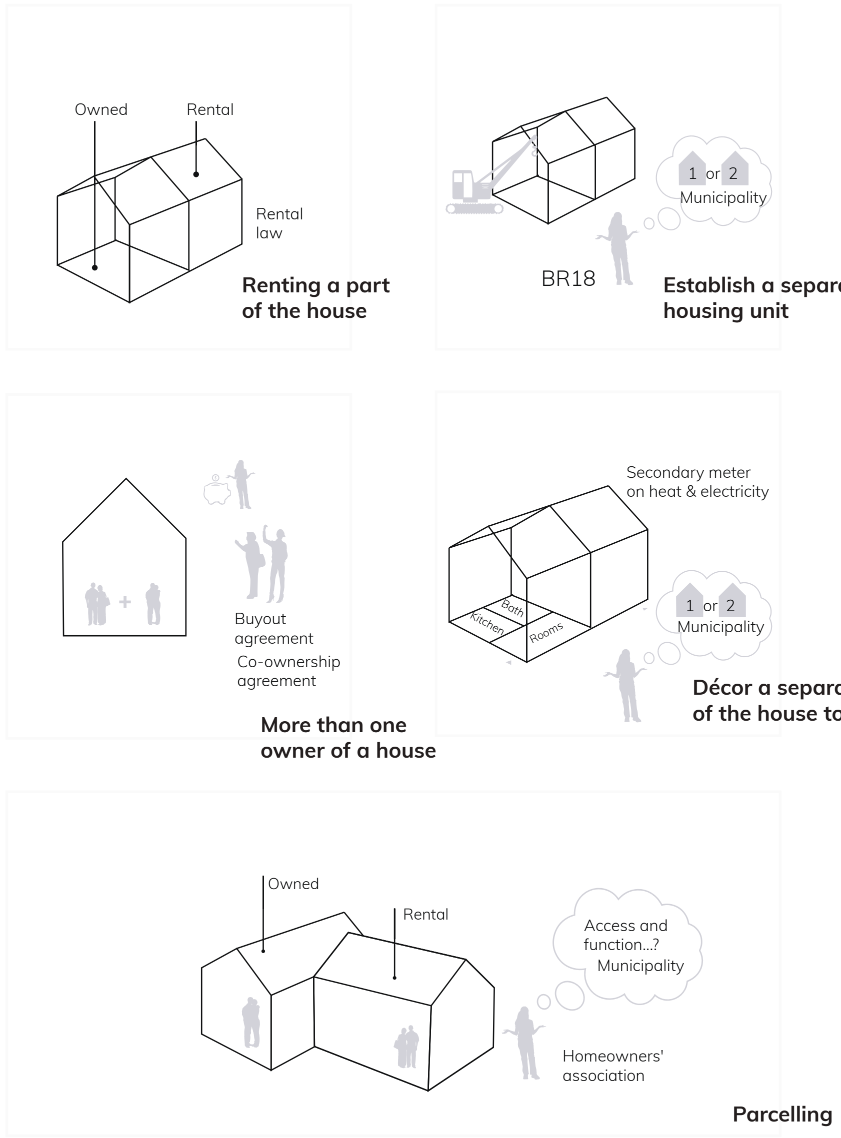
More than one owner of a house
If the excess space in a house is to be shared among multiple owners rather than rented out, a co-ownership agreement should be established to define ownership shares and outline buyout terms in case one party wishes to leave. This arrangement could be particularly relevant for Åstrupskrænten 45, where the house exceeds the needs of its current occupants. Although, this option would primarily apply in cases of the wish for multigenerational living, where shared kitchens and bathrooms are acceptable. However, potential co-owners should be aware that some banks may consider this a high-risk loan, and insurance requirements would also differ from a standard home (EFFEKT Architects et al., 2024).

Décor separate part of the house to rent out
This option applies to homes featuring two bathrooms, separate entrances, and kitchens. However, adding an extra kitchen may prompt the municipality to determine whether the property should be classified as a single dwelling or two separate units. Furthermore, if the additional unit is not officially registered as an independent residence, tenants may be unable to obtain their own insurance (EFFEKT Arkitekter et al., 2024).

In the case of Åstrupskrænten 45, if a distinct section of the house were converted into a new housing unit, it could be challenging to rent out legally, as the plot is currently zoned for only one dwelling. However, since the suburban neighborhood lacks a local development plan, the site is not subject to specific restrictions. This option could therefore be a relevant alternative for homeowners in Åstrupskrænten who are not interested in selling part of their property.

Establish a separate housing unit
If a detached house is to be divided into two separate units, several factors must be considered, such as building regulations, access requirements, fire safety compartments, and sound insulation, as the original design typically only accommodates a single household. In addition, local development plans may restrict properties to one dwelling per lot, meaning a municipal approval would be required (EFFEKT Arkitekter et al., 2024). However, in the case of Åstrupskrænten, no local plan currently limits such conversions, making this option particularly promising. Splitting houses into multiple units could significantly increase the site's capacity to accommodate more residents (see pp. 76-77).

Parcelling
This option would be relevant for detached houses with large plots where owners considered subdividing the property, for example as a semi-detached house or an additional house. However, local development plans would potentially have regulations on access and land use, which could pose challenges (EFFEKT Arkitekter et al., 2024). At Åstrupskrænten, this could be a possible strategy, as many homes have low building coverage ratio, with much of the plot used as garden space. Subdividing plots could increase housing capacity but would also lead to greater density in the suburban neighborhood.



Ill. 35. Types of ownership

Demographics at Åstrupskræntenen

A spatial program of Åstrupskræntenen has been made to see, how the housing units are used. The spatial program reveals that only 7 out of 46 dwellings utilize the optimal space allocation.

1 person = 11% of the houses
2 persons = 37% of the houses
3 persons = 22% of the houses
4 persons = 24% of the houses
5 persons = 4% of the houses
6 persons = 2% of the houses

This highlights a significant potential for optimizing the use of square meters in the neighborhood, as it is also estimated that the area could potentially house 117 additional people compared to its current capacity (see table 36). This estimation assumes that each person has an optimized residential area of 30 m^2 per person (see pp. 6-9).

Additionally, the 10 remodeled houses have not improved their spatial efficiency, suggesting that their renovations may have focused on other aspects, such as energy efficiency. Given that all renovations occurred after 1976, it is reasonable to assume that their energy performance has been improved. However, the remaining houses, built in the 1970s, are likely in need of further energy optimization. (See table 36) When renovating the houses for energy efficiency, it would be worthwhile to also optimize the use of internal square meters and retrofit the existing homes to accommodate more residents.

Moreover, the data shows that all plots have a building coverage ratio below 30%, indicating that a significant portion of the neighbourhood is used as garden space (see table 36). This low density presents an opportunity to subdivide some plots for new developments, thereby increasing housing capacity.

At the site there is only residential housing and nothing else, which indicates that people would probably be at work during working hours on the weekdays, if they are not retired or stay at home. An estimation of the demographics at Åstrupskræntenen is found by investigating how many people are listed on the postal boxes within the neighborhood, hereby it was found that the demography at the site is wide, with both families with children, elderly people, and couples. Given this, it would be valuable to explore how various housing typologies could contribute to the redesign of the area, aiming to increase the overall resident population.

Ill. 36. Spatial program of Åstrupskræntenen

No.	Plot	House	Floors	BCR	Resident count	m^2 pr. person	Optimized resident no. (30 m^2)	Building year	Renovated?
1	1241 m^2	140 m^2	1	11%	3	46.7 m^2	4	1976	No
2	1113 m^2	162 m^2	1	15%	2	81 m^2	5	1976	No
3	972 m^2	156 m^2	1	16%	5	31.2 m^2	5	1975	No
4	889 m^2	155 m^2	1	17%	3	51.7 m^2	5	1975	1993
5	1021 m^2	118 m^2	1	12%	4	29.5 m^2	4	1974	No
6	977 m^2	182 m^2	1	19%	6	30.3 m^2	6	1976	No
7	1360 m^2	138 m^2	1	10%	2	69 m^2	4	1976	No
8	1054 m^2	149 m^2	1	14%	2	74.5 m^2	5	1974	No
9	1351 m^2	182 m^2	1	13%	2	91 m^2	6	1974	1976
10	1175 m^2	147 m^2	1	13%	1	147 m^2	5	1975	No
11	1168 m^2	150 m^2	1	13%	3	50 m^2	5	1976	1991
12	1154 m^2	132 m^2	1	11%	2	66 m^2	4	1976	No
13	1215 m^2	166 m^2	1	14%	4	41.5 m^2	5	1976	1982
14	1043 m^2	135 m^2	1	13%	3	67.5 m^2	4	1976	1987
15	1154 m^2	140 m^2	1	12%	3	70 m^2	4	1975	No
16	949 m^2	195 m^2	1	21%	3	97.5 m^2	6	1976	No
17	1125 m^2	217 m^2	1	19%	3	108.5 m^2	7	1977	No
18	804 m^2	135 m^2	1	17%	1	135 m^2	4	1977	No
19	1132 m^2	163 m^2	1	14%	1	163 m^2	5	1975	No
20	962 m^2	148 m^2	1	15%	4	37 m^2	5	1977	No
21	1163 m^2	137 m^2	1	12%	3	45.7 m^2	4	1975	No
22	1073 m^2	202 m^2	1	19%	2	101 m^2	6	1976	No
23	1195 m^2	144 m^2	1	12%	3	48 m^2	5	1976	No
24	1065 m^2	205 m^2	1	19%	2	102.5 m^2	7	1976	No
25	1208 m^2	138 m^2	1	11%	2	69 m^2	4	1976	No
26	1105 m^2	194 m^2	1	18%	2	97 m^2	6	1976	No
27	1099 m^2	241 m^2	1	22%	3	80.3 m^2	8	1976	1994
28	1014 m^2	200 m^2	1	20%	2	100 m^2	6	1976	2006
29	1050 m^2	165 m^2	1	16%	4	41.3 m^2	5	1976	1996
30	1014 m^2	176 m^2	1	17%	2	88 m^2	6	1977	1995
31	962 m^2	141 m^2	1	15%	2	70.5 m^2	4	1977	No
32	1066 m^2	205 m^2	1	19%	4	51.3 m^2	7	1977	2008
33	1065 m^2	125 m^2	1	12%	4	31.3 m^2	4	1976	No
34	1089 m^2	182 m^2	1	15%	4	45.5 m^2	6	1977	No
35	1105 m^2	150 m^2	1	14%	2	75 m^2	5	1974	No
36	1380 m^2	167 m^2	1	12%	2	83.5 m^2	5	1978	No
37	975 m^2	153 m^2	1	16%	1	153 m^2	5	1978	No
39	1112 m^2	209 m^2	1	19%	5	41.8 m^2	7	1976	No
41	1172 m^2	179 m^2	1	15%	2	89.5 m^2	6	1976	No
43	1264 m^2	132 m^2	1	10%	4	33 m^2	4	1976	No
45	**1655 m^2**	**146 m^2**	**1**	**9%**	**2**	**73 m^2**	**5**	**1974**	**No**
47	1194 m^2	182 m^2	1	15%	1	182 m^2	6	1976	No
49	1066 m^2	135 m^2	1	13%	4	33.8 m^2	4	1977	No
51	1196 m^2	188 m^2	1	16%	2	94 m^2	6	1976	No
53	1066 m^2	261 m^2	1	24%	4	65.3 m^2	9	1976	2009
55	1196 m^2	140 m^2	1	12%	4	35 m^2	4	1976	No

PARTIAL CONCLUSION

Demographically, Åstrupskrænten accommodates a diverse population of families, couples, and elderly residents. However, the spatial analysis reveals a significant underutilization of interior space. The neighborhood could potentially house an additional 117 residents without increasing its footprint, by optimizing existing housing units. The remodeling should be paired with energy optimization, as most houses have not yet undergone substantial energy upgrades.

When transforming the houses, it is important to consider how ownership structures could support more flexible and efficient use of the spaces. While detached houses are typically owned by individuals or couples, shared ownership can take various forms.

In Åstrupskrænten, one of the relevant strategies for increasing housing capacity could be renting out part of a house. For example, in a home like Åstrupskrænten 45, where space exceeds the occupants' needs, this could be a viable option, provided the household is open to a co-living arrangement. Co-living communities like Tinggården illustrate how housing can be designed with shared spaces, flexibility, and adaptability to changing household sizes and needs. A detached house could adopt similar principles in a smaller scale, incorporating features such as movable walls and flexible furniture to better accommodate the evolving lifestyles of its residents.

If the residents are open to multigenerational living, selling a portion of the house might be another solution. This setup would involve shared kitchens and bathrooms and require clear agreements between the co-owners. There is significant potential in transforming single-family homes into multigenerational residences to optimize space and address future housing challenges. When designing a multigenerational home, there should be a focus on both shared and private areas, as well as accessibility and changing needs.

In houses with separate entrances and facilities, it could be possible to rent out a self-contained unit. This allows for more privacy, avoiding a co-living setup, and resembles a semi-detached arrangement where neighbors live closely but independently. This configuration could also be ideal if there is an interest in selling a part of the house, especially since Åstrupskrænten lacks a local development plan that would restrict such a conversion.

For properties with large plots, parceling the land to allow for new dwellings is another potential option. However, this would lead to increased density and higher material consumption, which may conflict with sustainability goals.

Preservability, SAVE

In Denmark, 350,000 buildings are listed as having historical or architectural value. *The Agency for Culture and Palaces* has a database of protected and listed buildings, where the SAVE method (Systematic Valuation of Building Cultural Heritage) is used to assess, which buildings should be preserved, evaluating their historical, cultural, and architectural significance. It is the municipality that designates a building for preservation, caused by its significant value, either architecturally or technically, within a local or regional context. A listed building is considered worthy of preservation primarily for its exterior and, in some cases, specific construction features, materials, or details. (Sode, 2023)

In the podcast *Rundt om Byggeriet*, Line Stougaard, a restoration architect, highlights that buildings from the 1960s to 1980s are significant to cultural heritage, but their value is difficult to recognize due to the number of similar houses. The number of similar houses reduces the perception of their worth, making it harder to appreciate what specifically makes them valuable. Stougaard emphasizes the importance of these buildings not only as part of the suburban neighbourhood's history, but also for their general characteristics, such as material choices, which contribute to their architectural and cultural significance. (Christiansen, 2024)

Ill. 37. SAVE registration

SAVE registration of Åstrupskrænten

The municipality has not conducted SAVE registration for Åstrupskrænten or indicated that it should be preserved, which means that this suburban neighborhood is not considered preservation-worthy. Although, for this project, to register whether to preserve or renovate, there has been reflected upon the SAVE-registration questions.

Typographic characteristics
Åstrupskrænten slopes down towards Åstrupvej and Mellemstrupvej, creating elevated viewpoints for the properties in the northwest, offering views over the town or towards the eastern fields. Most houses are integrated into the landscape, though some are built atop the terrain rather than within it. Structures more adjusted to the landscape hold greater preservation value, as they relates to the site.

Spatial characteristics
While the area is densely built, a small section is dedicated to open grassland. The neighborhood features rich vegetation, including dense bushes and trees, which guide traffic flow and provide visual relief from paved surfaces. Dense vegetation along paths reduces interaction between pedestrians and residents. Homes primarily open toward driveways, with enclosed backyards reinforcing an inward-facing layout. Houses are partially concealed behind greenery, fostering a close connection between residents and nature. However, these elements can also act as barriers, limiting social interaction along the streets.

Settlement pattern & historical characteristics
Plots are laid out in a strictly linear fashion, characteristic of the time, with grid-like parcel divisions carved from former farmland. The houses were constructed within the same timeframe, leading to significant material uniformity, with many homes having near-identical counterparts elsewhere, though a few distinct structures stand out. Houses are positioned at eye level, though some appear lower when viewed from the southern pathways.

Architectural characteristics
Most facades face away from the street and are screened by hedges or fences. Brick dominates the material palette, with colors varying between sand, limestone, and patterned brown, yellow, or red tones. Roads are mostly asphalted, while gardens are allocated by hedges, and pathways are surfaced with either stone or grass.

Ill. 38. Birds eye of Åstrupskrænten, CREDIT: CC BY 4.0 KDS. Modified by the author.

SAVE registration of Åstrupskrænten 45

The municipality has also not declared Åstrupskrænten 45 preservable. However, to assess its potential for preservation or renovation, the project reflects on the SAVE criteria and includes a material mapping that identifies the existing building elements in the current design.

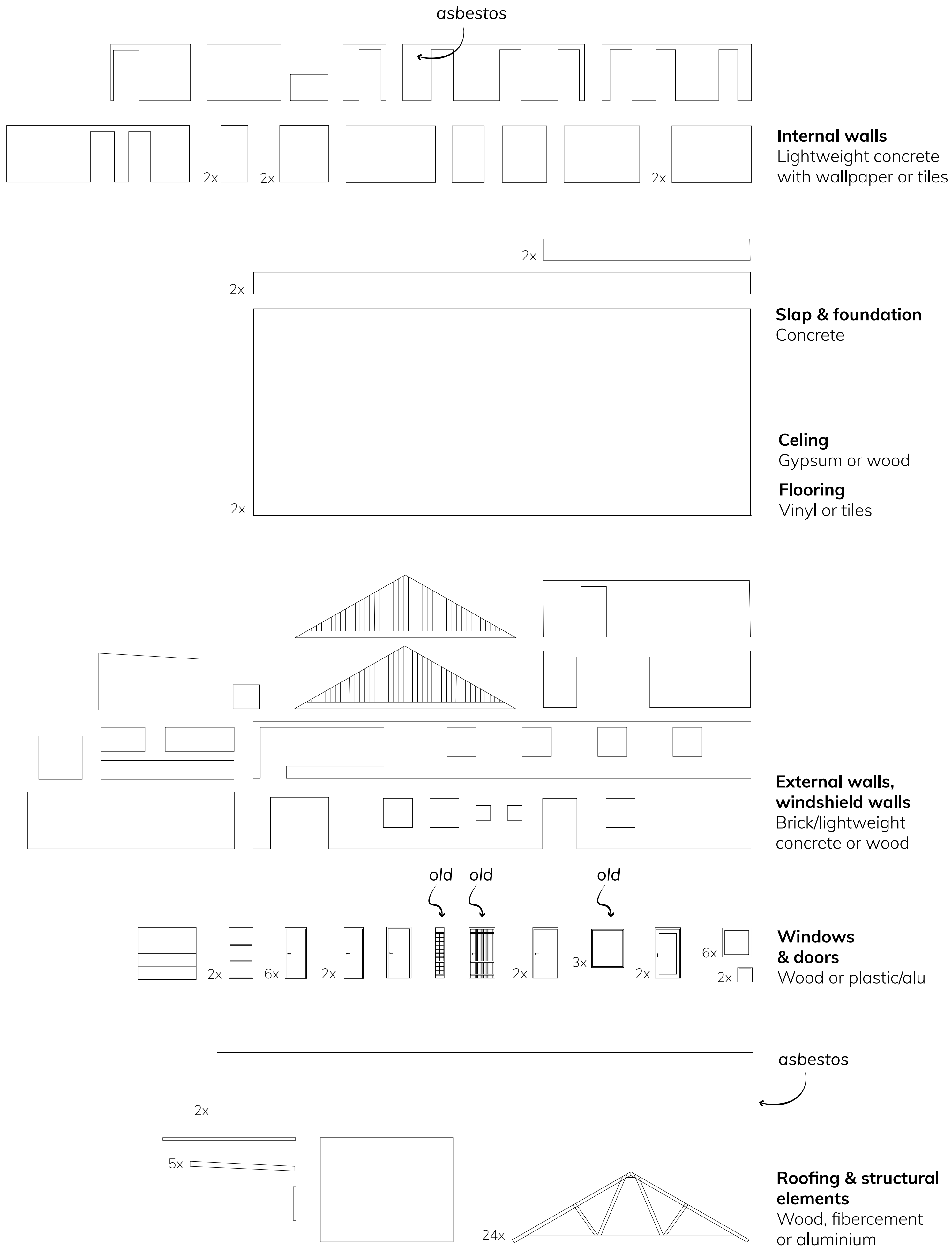
Architectural characteristics
The architectural character of Åstrupskrænten 45 is relatively plain, with a facade that has a rhythmic variation, in the cladding and windows. The uniform placement of almost identical windows around the house introduces a sense of consistency. The building exhibits minimal distinct architectural character as it aligns closely with many others from its era. The rough brick surface adds texture, while the contrast between this and the wooden gable triangles creates a clear distinction between the main living areas and the attic space. (Rating: 9)

Cultural-historical value
From a cultural-historical perspective, the house belongs to a period of "quick" development, when Denmark experienced a welfare-driven housing boom. As a result, the structure is largely a replica of many others in the area, with limited craftsmanship. It represents a typical prefabricated concrete house, making it historically relevant as part of a broader housing trend but not unique. (Rating: 6)

Environmental value
The house does not integrate with the landscape. Therefore, it has no environmental value compared to some of the other homes that are designed to follow the site's natural slopes. (Rating: 9)

Originality
In terms of originality, the house lacks distinctive features and closely resembles many others in the neighborhood. (Rating: 9)

Condition
Despite its architectural limitations, the house is well-maintained and in good condition. Although in an overview of the building elements, it is seen that some of the listed building elements contain hazardous substances that could negatively impact indoor air quality or release harmful particles into the air. Since the house holds many building elements in good condition, it makes sense to reuse or keep these as much as possible during the transformation. The focus should therefore be on preservation rather than demolition. Additionally, as the existing layout already includes multiple entrances, it is worthwhile to explore how minimal interventions could enable the conversion into a multi-dwelling unit. (Rating: 9)



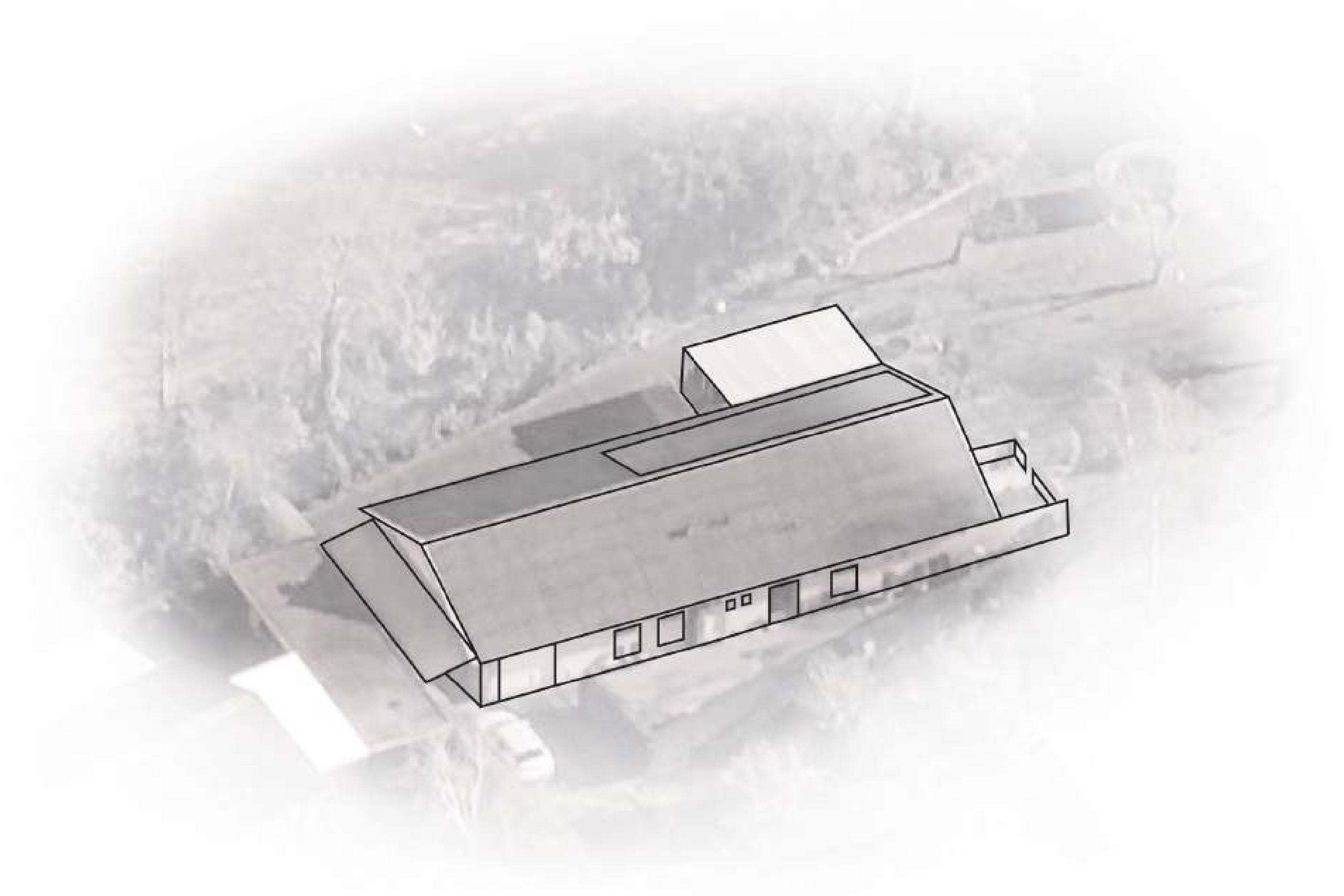
Ill. 39. Material mapping of Åstrupskrænten 45, scale 1:200

PARTIAL CONCLUSION

When evaluating whether to preserve or transform Åstrupskrænten, the SAVE scale is applied. This scale ranges from 1 to 9, where 1 indicates the highest preservation value and 9 the lowest. (Sode, 2023)

Based on the SAVE registrations conducted for the suburban neighbourhood of Åstrupskrænten, the area has a moderate preservation value. The strongest arguments for preservation are its integration with the natural topography. It has historical and architectural worth but lacks exceptional uniqueness or a clear historical narrative that strongly differentiates it from other similar developments. (Final rating: 7)

Overall, Åstrupskrænten 45 also has limited preservation value due to its lack of architectural distinctiveness, no distinct integration with the landscape, and due to its mass-produced design, typical of its era. While it serves as an example of 1970s housing trends, it does not stand out as a significant or unique representation of the period. (Final rating: 8) That said, there should still be a strong focus on preservation rather than demolition, as the building elements are generally in good condition.



Ill. 40. Perspective illustration of Åstrupskrænten 45, CREDIT base photo CC BY 4.0 KDS. Modified by the author.

SUMMATION

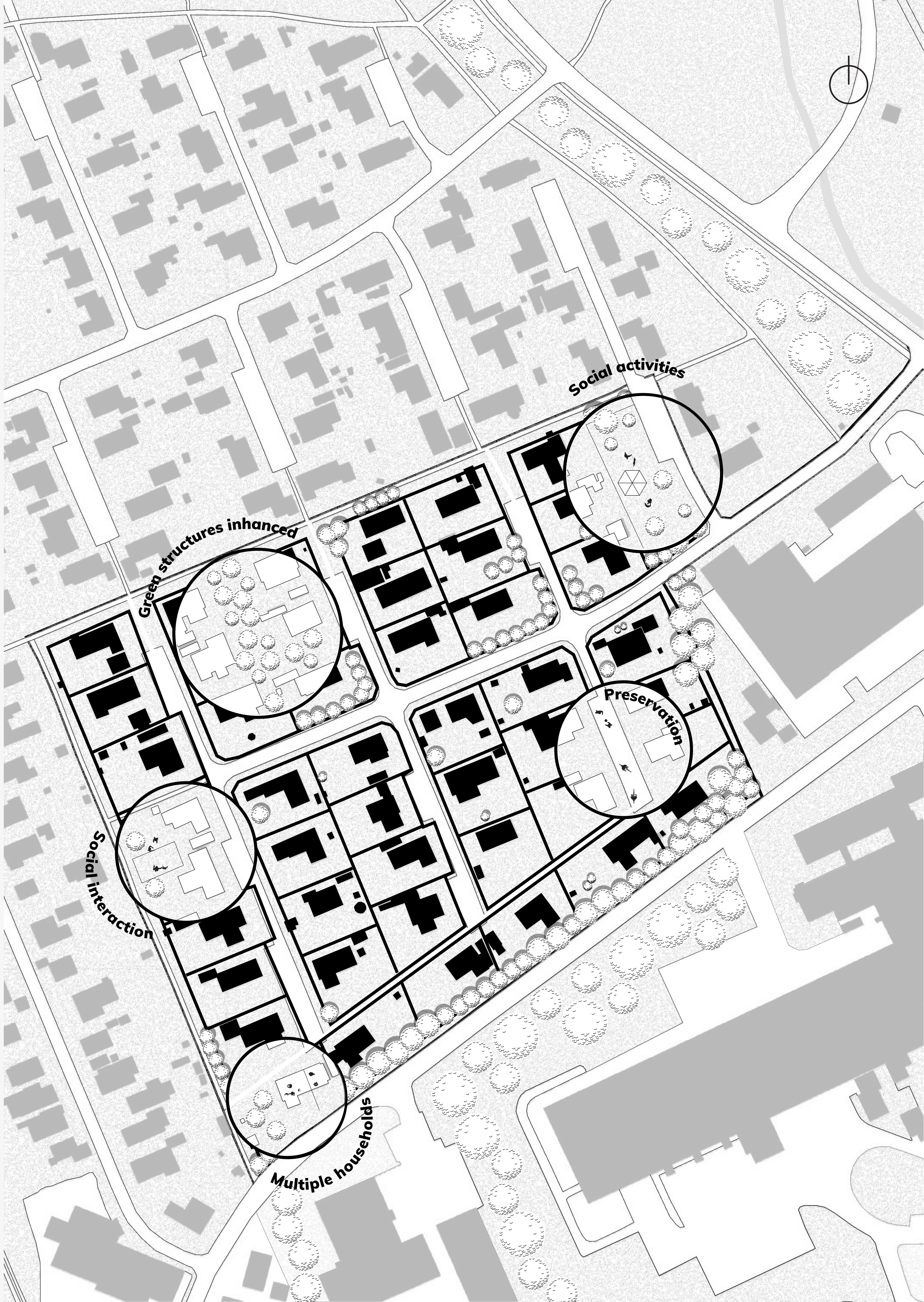
Grenaa is a town defined by strong public infrastructure, green areas, and connectivity to larger urban centers. Although the population is projected to decline slightly, with an increasing elderly demographic, its affordability and strategic location makes it appealing to commuters and young families. This highlights the need for adaptable and intergenerational housing models.

ÅstrupskræNten reflects typical 1970s suburban development, characterized by single-story detached houses, car-centric infrastructure, and a strong emphasis on privacy. However, despite a relatively low architectural preservation value for both the entire Åstrupskrænten and Åstrupskrænten 45 (SAVE rating 7–8), the materials at Åstrupskrænten 45 are in good condition. This supports a transformation strategy focused on preservation over demolition.

Key opportunities for improving Åstrupskrænten include optimizing underutilized interior spaces, which can be done by subdividing large plots, enhancing outdoor areas, and strengthening community ties through shared green spaces. Specific homes, such as Åstrupskrænten 45, show potential for conversion into multi-unit housing with minimal structural changes due to features like multiple entrances, the garage and excess interior space. When considering this, ownership models should be reconsidered to enable flexibility, such as renting out parts of homes or converting them into co-living or semi-detached units. These approaches could accommodate more residents without expanding the physical footprint, while also supporting a wider range of lifestyles and family structures.

While Grenaa's low heating costs have discouraged energy retrofits, future upgrades should prioritize insulation and energy optimization to align with sustainability goals. The neighborhood's design could also benefit from better visual cohesion and landscape improvements, balancing privacy with opportunities for spontaneous interaction.

Ultimately, Åstrupskrænten holds strong potential for renewal. With a focus on flexible spaces, and community-oriented design, the neighborhood can evolve to meet future demands while retaining its suburban character.



Ill. 41. Summation on the Pre-design Phase, CREDIT based on map from CC BY 4.0 KDS. Modified by the author.

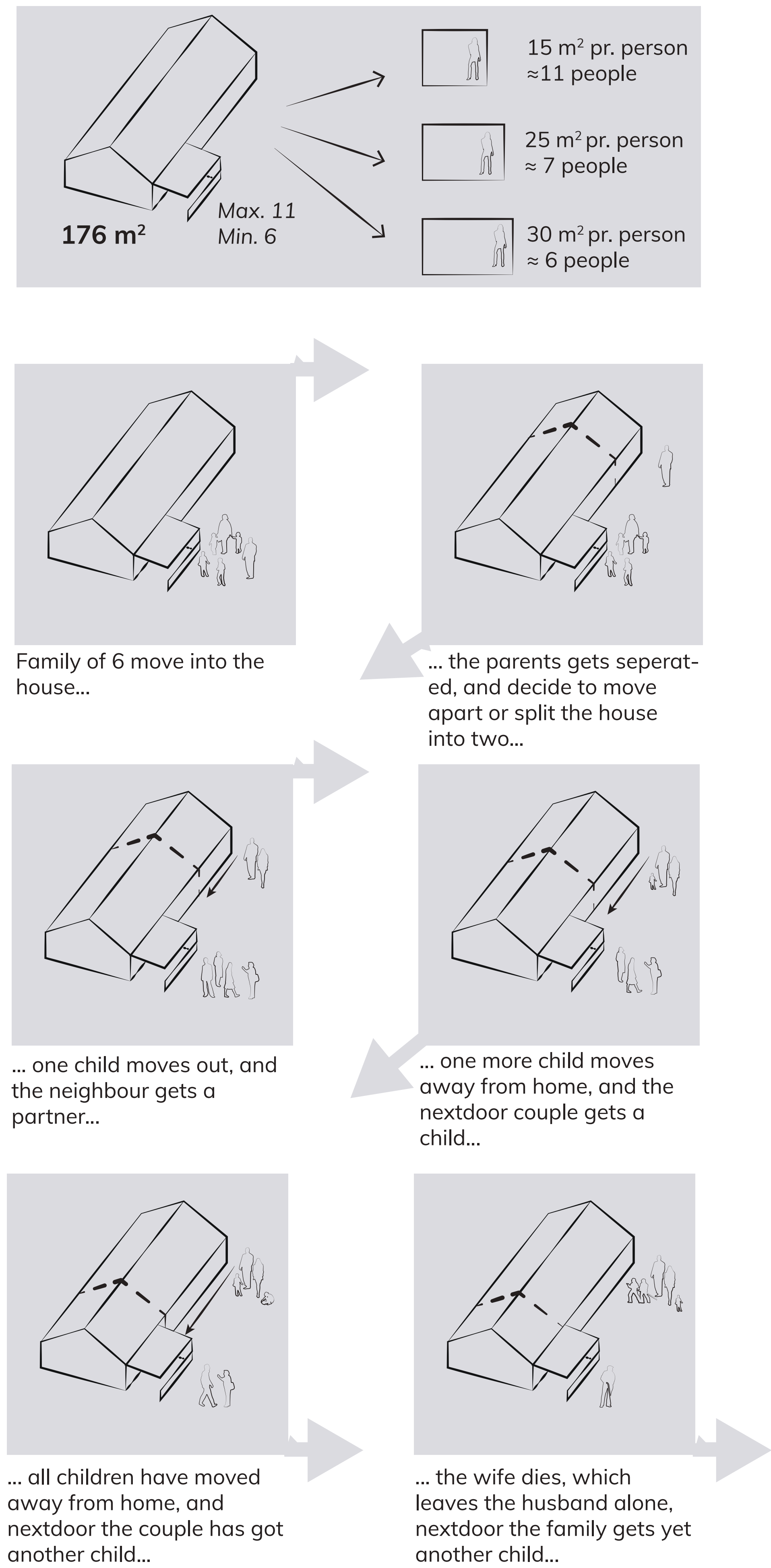
Vision

The vision is to reimagine the 1970s suburban neighbourhood, exemplified by Åstrupskrænten, as a forward-looking model for how “the good life” can be redefined in the 21st century. Central to this vision is a shift from large, underutilized homes to a more compact and thoughtful approach to living. Future homes are envisioned to offer between 15–30 m² per person, promoting adaptable spaces that prioritize quality over quantity and support evolving family dynamics.

The transformation focuses on energy efficiency and material emissions, aligning with climate goals while preserving the architectural identity of the existing homes. Just as vital is the reinvention of outdoor areas, from private, car-centric plots to more nature-rich environments that foster social connection.

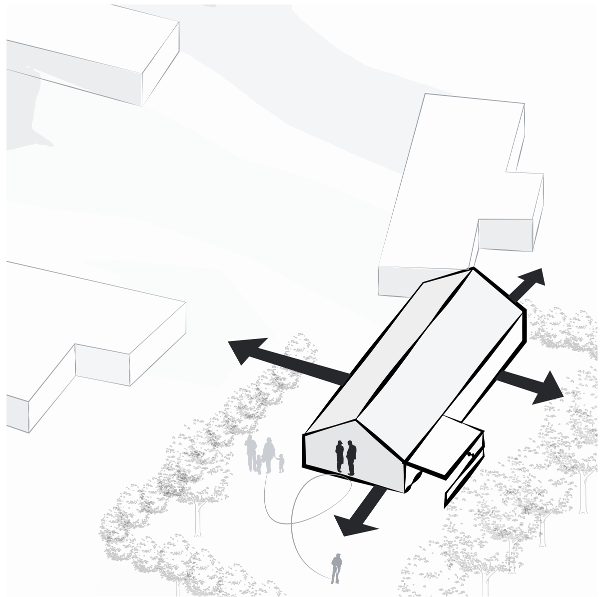
Åstrupskrænten serves as both testing ground and inspiration, demonstrating how the 1970s suburban neighbourhood can be reimagined into sustainable, flexible, and community-oriented places for generations to come.

Åstrupskrænten 45 spans 176 sqm, when including the garage. Based on an allocation of 15–30 sqm per person, this allows space for approximately 6–11 residents (see ill. 42). The design should explore how the house can be divided into multiple units, enabling it to adapt and evolve over time in response to the changing needs of its occupants (see ill.42).

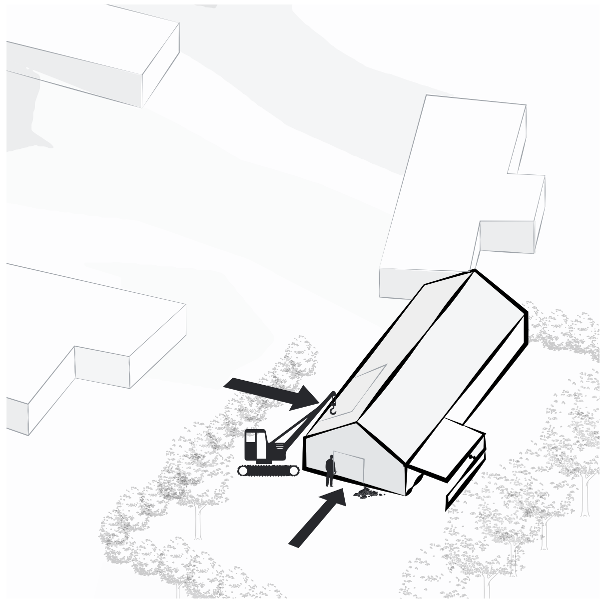


Ill. 42. *Concept*

DESIGN DRIVERS



Ill. 43. Design driver utilitas

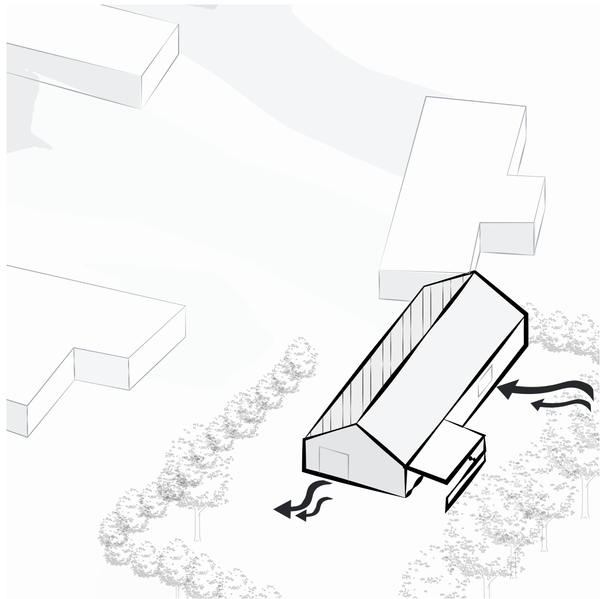


Ill. 44. Design driver firmitas

Utilitas: Space optimization, flexibility and social interaction

To prevent spaces from being unused or underutilized, they should be reimagined to accommodate multiple households with changing life stages, maximizing the efficiency of the available square meters. This requires a design that prioritizes flexibility, allowing spaces to be easily reconfigured as needs evolve.

Outdoor areas, whether shared or private, should foster a sense of belonging, reduce isolation, and strengthen neighbourhood connections. Furthermore, communal spaces should act as transitional zones, balancing the need for privacy with the social benefits of collective living.



Ill. 45. Design driver venustas

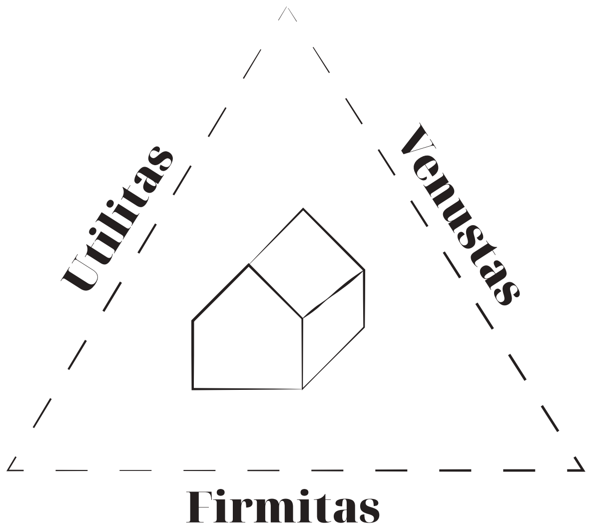
Firmitas: Energy efficiency and sustainability

When transforming detached houses, interventions in the existing structure should be kept to a minimum to reduce emissions. Energy-efficient solutions, such as enhanced insulation and renewable energy sources, should be integrated to lower both energy consumption and carbon footprint.

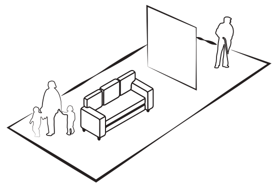
New materials should be carefully evaluated using Life Cycle Assessment principles, prioritizing reuse and locally sourced options. LCA should balance energy efficiency, material emissions, and the overall lifespan of the building. Any new materials introduced should be selected not only for their technical performance but also for their durability and long-term resilience, together with their ability to develop a natural patina over time, ensuring aesthetic and functional longevity.

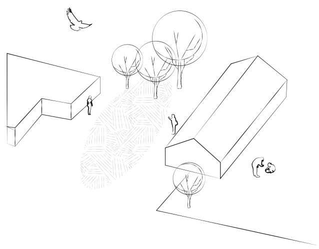
Venustas: Daylight, historical essence and materiality

The design should enhance the indoor climate by carefully optimizing daylight and its interaction with spaces and their functions. The selection and assessment of materials, whether new or existing, should prioritize sensory engagement, ensuring that the architecture feels cohesive. The transformation should retain characteristic elements from the original house, preserving its historical essence while integrating modern adaptations. Additionally, flexibility in the design should focus on the residents being able to personalize their living spaces, fostering a sense of further adaptability.



UTILITAS

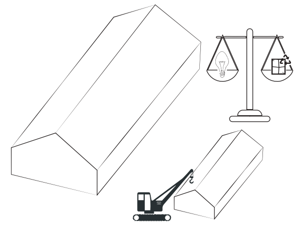


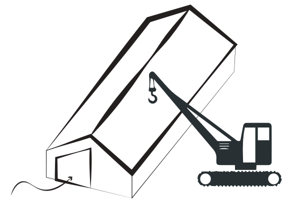


1. Design homes that support multi-unit housing by having flexible spaces through furniture or other elements, offering both shared and private zones to accommodate different age groups while fostering a sense of community.

2. Strengthen the neighbourhood by creating communal spaces that promote social interaction, activity, and a sense of belonging, while carefully designing transition zones that mediate between private and shared areas.

FIRMITAS

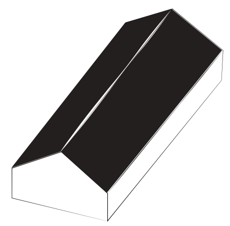


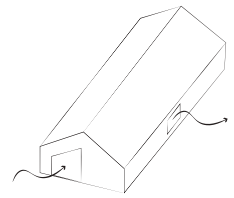


1. Prioritize preservation over demolition, optimizing the use of existing square meters rather than expanding unnecessarily, while applying LCA to balance energy consumption and material emissions, with a preference for reused, locally sourced, and long-lasting materials.

2. Optimize energy efficiency through passive strategies mostly, aiming to achieve Renovation Class 1.

VENUSTAS





1. Maintain and enhance the architectural character of the existing structures while integrating contemporary elements that improve functionality and aesthetics in a way that ensures visible changes contrasts and respects the original design.

2. Improve indoor climate through daylight, and non-toxic materials that age beautifully over time.

Ill. 46. Design criteria

CHAPTER 3

DESIGN PHASE

The following chapter investigates the design phase through a series of studies, each guided by the design drivers and design criteria to address the research question. The design phase is divided into two parts: the first focuses on a broad range of investigations without drawing conclusions, while the second synthesizes these insights to evaluate and determine the most suitable design strategies for the specific context of Åstrupskrænten.

Ill. 47. Photo of Åstrupskrænten 45

Design Phase 1

In the initial design phase, the primary focus is on critically evaluating all prior research, with each finding evaluated through its advantages and disadvantages. This method removes the need for a fixed order of investigation, allowing topics to be explored independently of sequence. Furthermore, this phase is driven by the design drivers, which serve as the foundation for framing key questions when examining various design strategies.

Ill. 48. Design Phase 1

UTILITAS

Programming, dwelling type

Through the investigation of new housing models, including normal living arrangement, co-living arrangements, multi-family, and -generational housing (see pp. 68-77), it becomes clear that Åstrupskræntenin Grenaa offers different design possibilities. Therefore, the question was formed ***"How can the suburban neighbourhood foster a stronger sense of community, while housing more people?"*** To identify the most suitable approach for the suburban context, three scenarios have been developed, serving as frameworks for exploring how different housing typologies may influence the neighbourhood's social dynamics:

1. Status quo
2. Adapt the housing model to support multigenerational living
3. Transform the area into a co-living community

Scenario 1: *Status quo*
Advantages:
- Potential for multigenerational living within one household.
- Low material emissions.

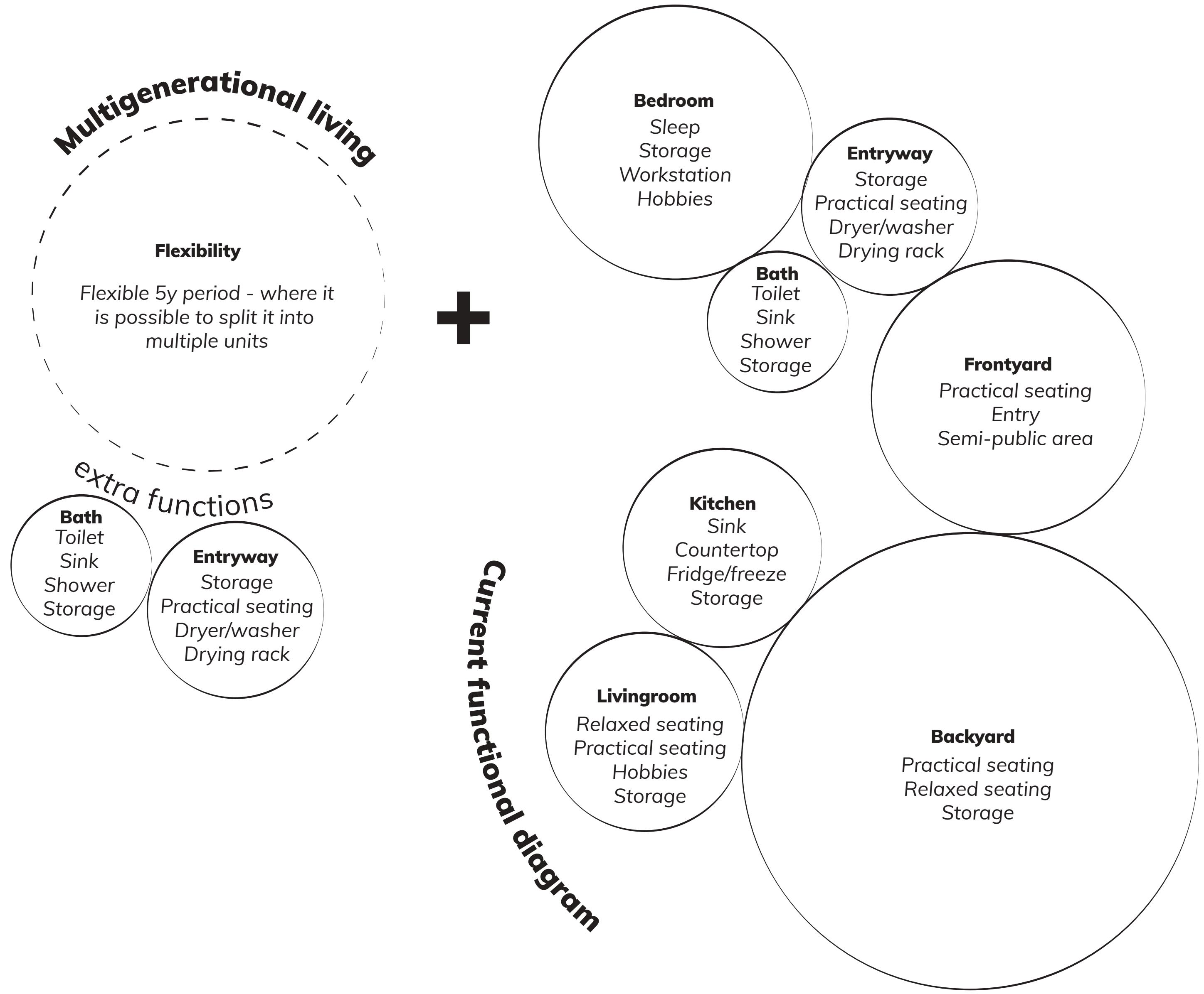
Disadvantages:
- Same level of privacy towards neighbourhood, as in the current design.
- Risk for residents to remain isolated within their own units.
- The interior layout won't be that adaptable.

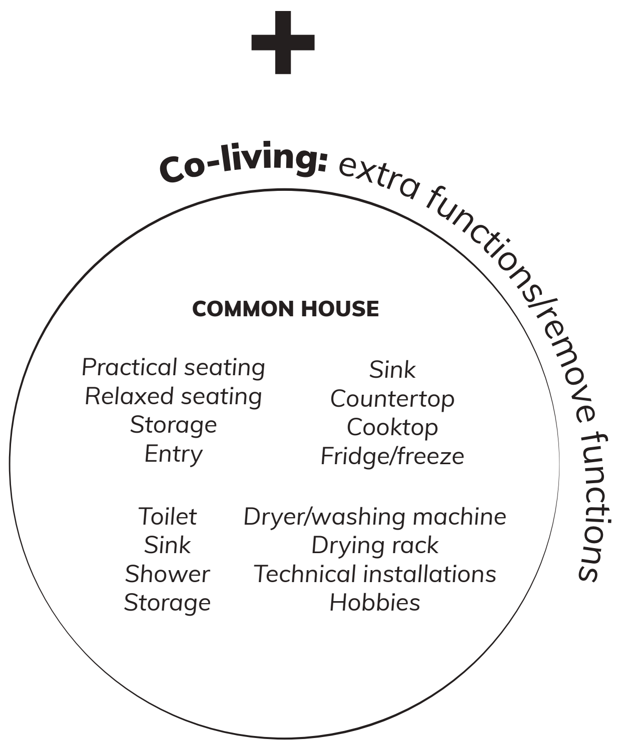
Scenario 2: *Multigenerational living*
Advantages:
- Same level of privacy as in the current design.
- Adaptable interior layout, that can house multiple households.
- Potential for both independent and shared living.

Disadvantages:
- Risk for residents to remain isolated within their own unit.
- Each house may not accommodate enough residents, due to individual functions.

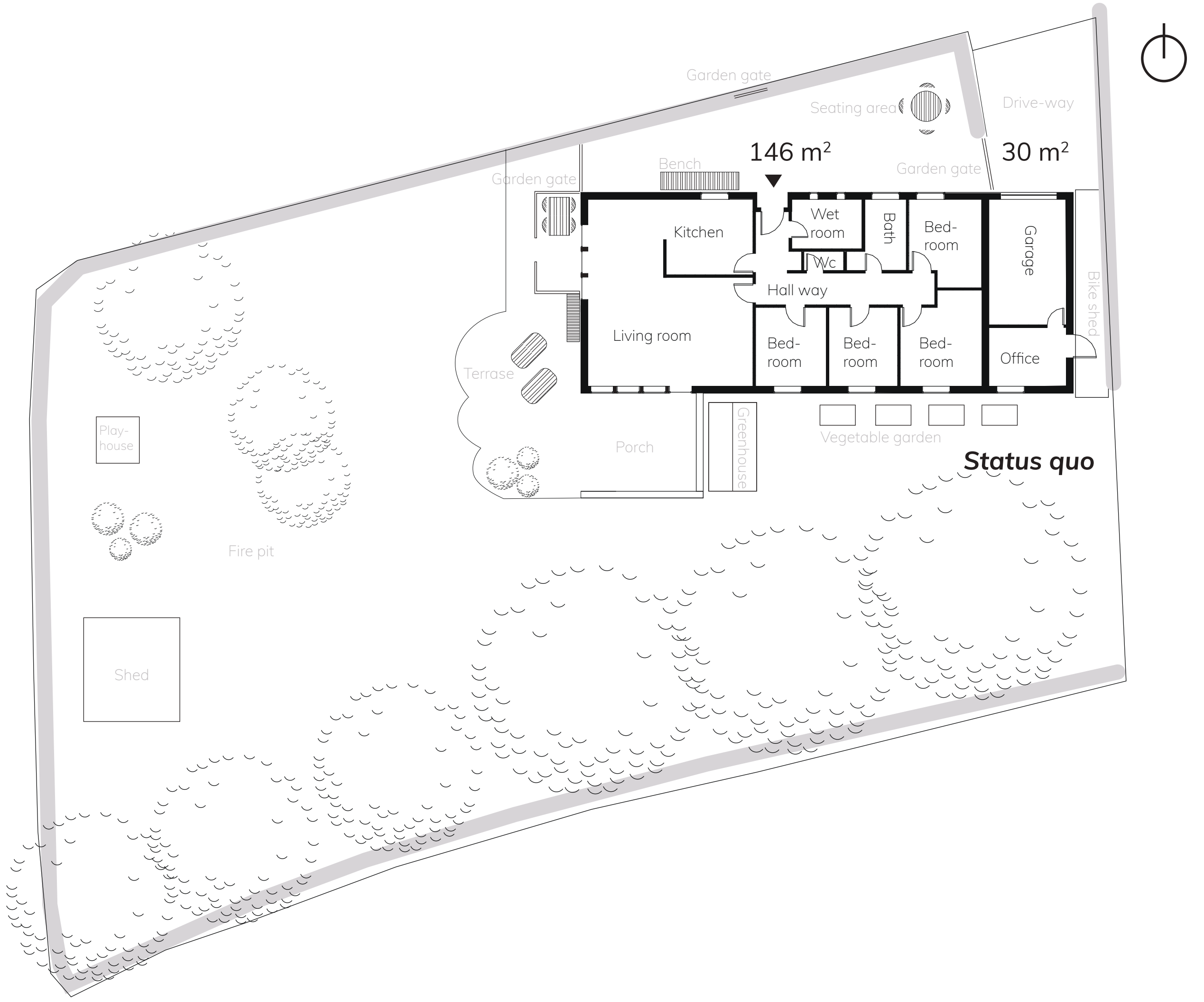
Scenario 3: *Co-living*
Advantages:
- Encouraged to engage with the neighbourhood, due to shared functions.
- Compact design, as each unit doesn't need to include all functions.
- Costs for utilities and maintenance are distributed across multiple households.
- Low energy consumption and material emissions.

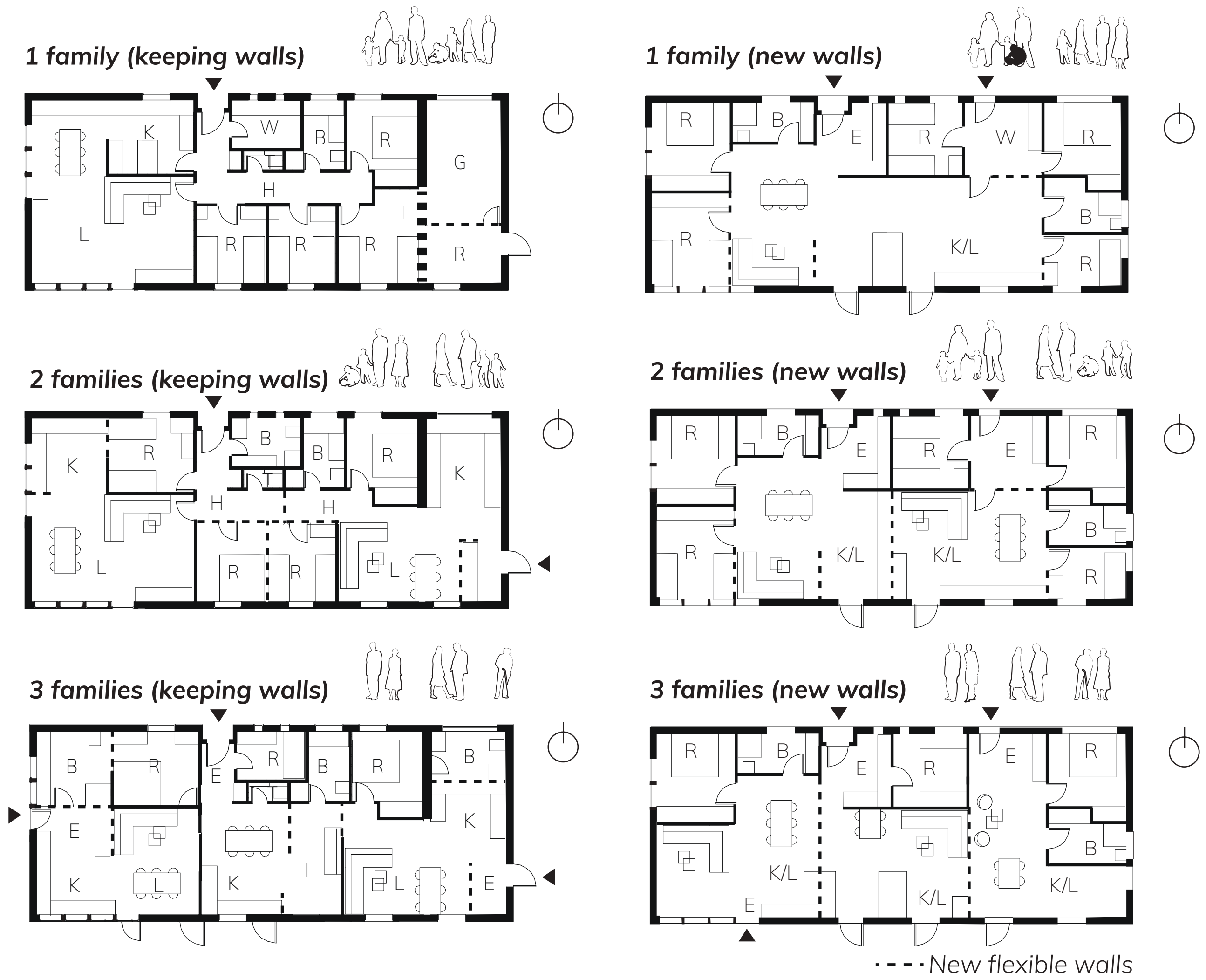
Disadvantages:
- Less personal space. Many people choose suburban areas for privacy.
- Shared spaces and responsibilities can lead to disagreements.
- All households in the neighbourhood should agree to the co-living model.
- Difficult for residents to fully customize their private spaces to their liking.





Ill. 49. Functional diagram





Ill. 50. Spatial planning, scale 1:300, CREDIT current spatial planning based on original floorplan of Åstrupskrænten 45, from the local building archive at Norddjurs Municipality. (FilArkiv, Norddjurs Municipality). Modified by the author.

UTILITAS

Spatial planning, indoor

The house currently has 146 m² of living space, plus a 30 m² garage that could be converted, totalling 176 m². This could accommodate 6–11 residents (see pp. 6-9). To explore how, the question was posed: ***"How can the spatial layout be reconfigured to house 6–11 people?"*** Three scenarios for redistributing the space into 1–3 units have been developed:

1. Status quo
2. Keeping most of the existing internal walls
3. New internal walls

Scenario 1: *Status quo*
Advantages:

- Potential for both independent and shared living within the house.
- Low material emissions.

Disadvantages:

- Relatively large family size to make efficient use of the space.
- Less privacy, due to de potential of multi-generational living, within the one housing unit.
- Not adaptable for future changes.
- The garage and office are considered unnecessary spaces.

Scenario 2: Keeping most of the *existing internal walls*
Advantages:

- Minimal demolition reduces emissions.
- Could retain the historical value of the layout.
- Flexible walls allow for integration between units if desired.

Disadvantages:

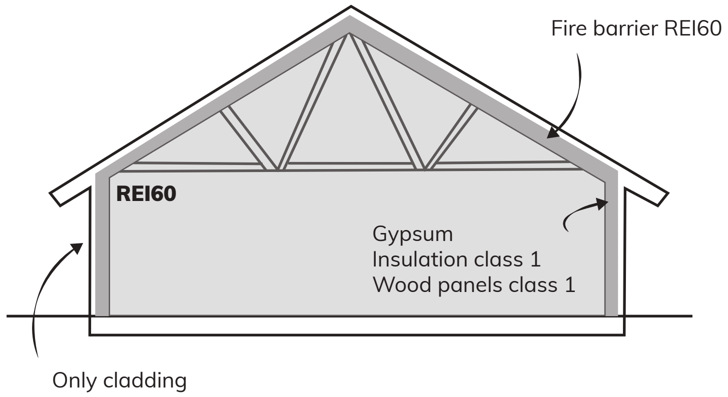
- The home's adaptability for future needs is restricted.
- Some rooms remain poorly connected or impractically sized.
- New additions might not blend seamlessly with the existing structure.

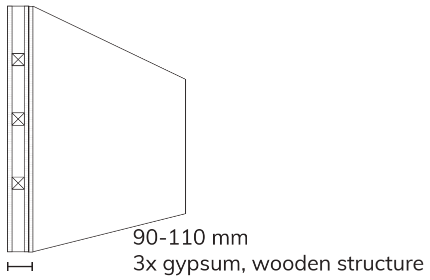
Scenario 3: *New internal walls*
Advantages:

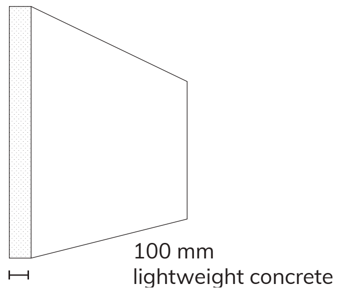
- Designed for adaptability, it can evolve with changing needs.
- Flexible walls allow for integration between units if desired.
- Eliminates unnecessary hallway areas, maximizing usable square meters.

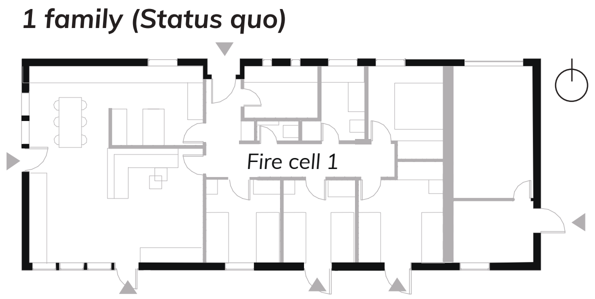
Disadvantages:

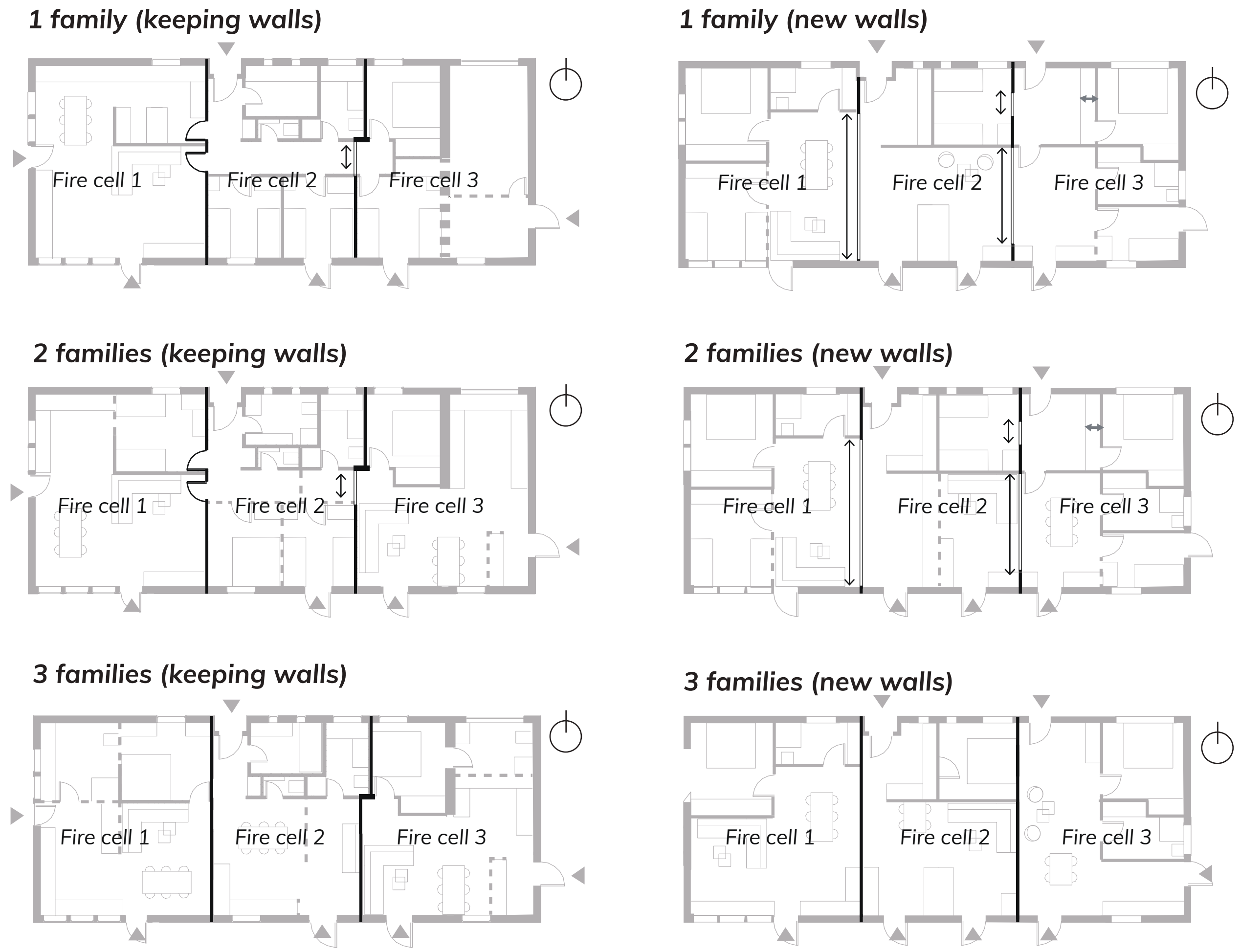
- Removing all internal walls may affect the structural integrity due to "box principle".
- Substantial number of new materials, impacting material emissions.











Ill. 51. Fire safety, CREDIT section and cuurent spatial planning based on original section of Åstrupskræntensen 45, from the local building archive at Norddjurs Municipality. (FilArkiv, Norddjurs Municipality). Modified by the author.

UTILITAS

Fire resistance

According to BR18, fire barriers in REI60 standard must separate each housing unit to prevent fire spread (Bygningsreglementet.dk) (Clasen, 2023), as shown in illustration 51. To explore compliance with Danish fire regulations, the question was posed: ***"How can the building comply with Danish fire regulations for preventing fire spread in attached housing units?"*** The previously assessed spatial layout scenarios were used as a basis (see pp. 102-103):

1. Status quo
2. Keeping most of the existing internal walls
3. New internal walls

Scenario 1: *Status quo*
Advantages:
- Minimized need for additional construction materials, as current internal walls are made of 100 mm lightweight concrete.

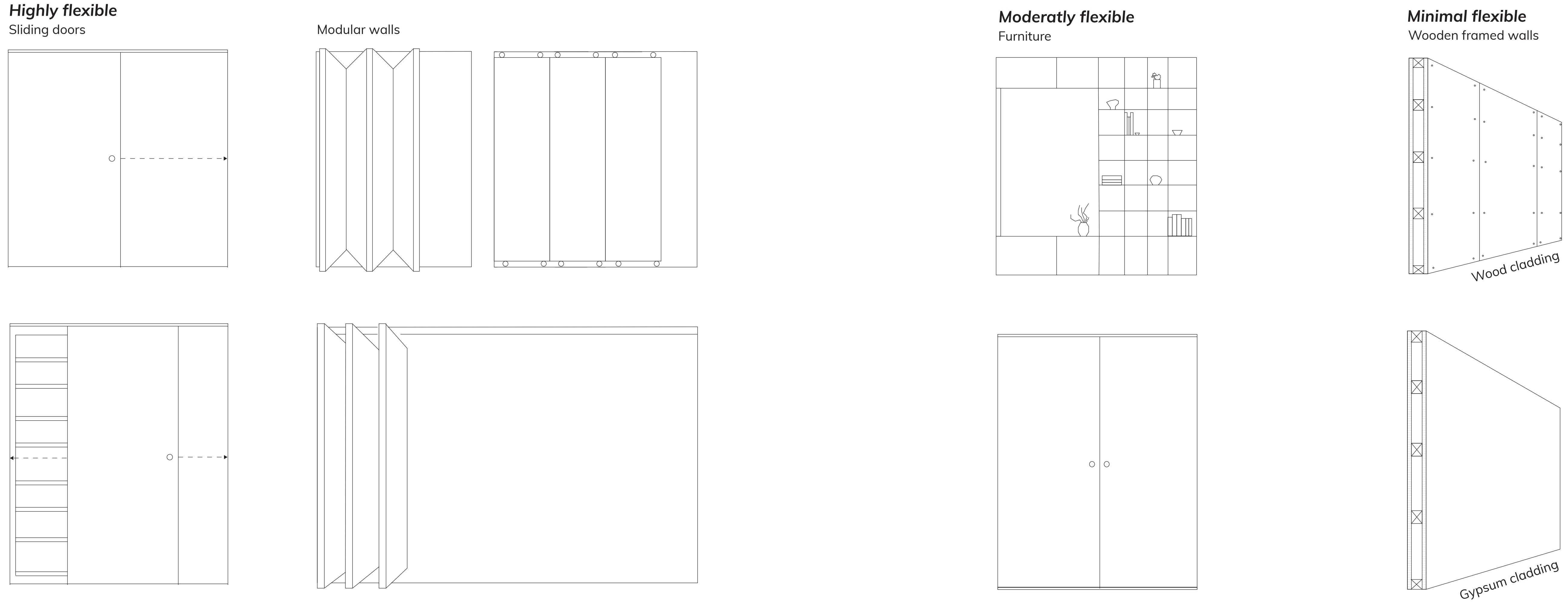
Disadvantages:
- The house can't function as multiple housing units.

Scenario 2: *Keeping the internal walls*
Advantages:
- Minimized need for additional construction materials, as current internal walls are made of 100 mm lightweight concrete.

Disadvantages:
- Replacement of doors with solid walls, when adjusting the number of housing units.
- Fire-rated doors prioritize function over aesthetics, which may affect the overall design.

Scenario 3: *New internal walls*
Advantages:
- The layout ensures a more even distribution of square meters.
- Fire-resistant walls can be constructed using lightweight materials, allowing for customization.

Disadvantages:
- Replacement of doors with solid walls, when adjusting the number of housing units.
- Fire-rated doors prioritize function over aesthetics, which may affect the overall design.
- Fire-resistant walls would be replaced with new ones.



UTILITAS

Ill. 52. *Flexible walls for the interior spatial planning*

Flexibility

The house currently has no flexible internal walls. To support adaptability to changing needs, flexible wall solutions have been explored in the new spatial layout (see ill. 52). To investigate this, the question was asked: **“*What design strategy can ensure a flexible spatial layout?*”** Three scenarios have been examined, based on research in interior spatial planning:

1. A highly flexible solution
2. A moderately flexible solution
3. A minimal flexible solution

Scenario 1: A *highly flexible solution*
Advantages:
- Potential of being opened or closed as needed, allowing for dynamic space usage.
- Can be customized for aesthetics, transparency, fire safety or soundproofing.

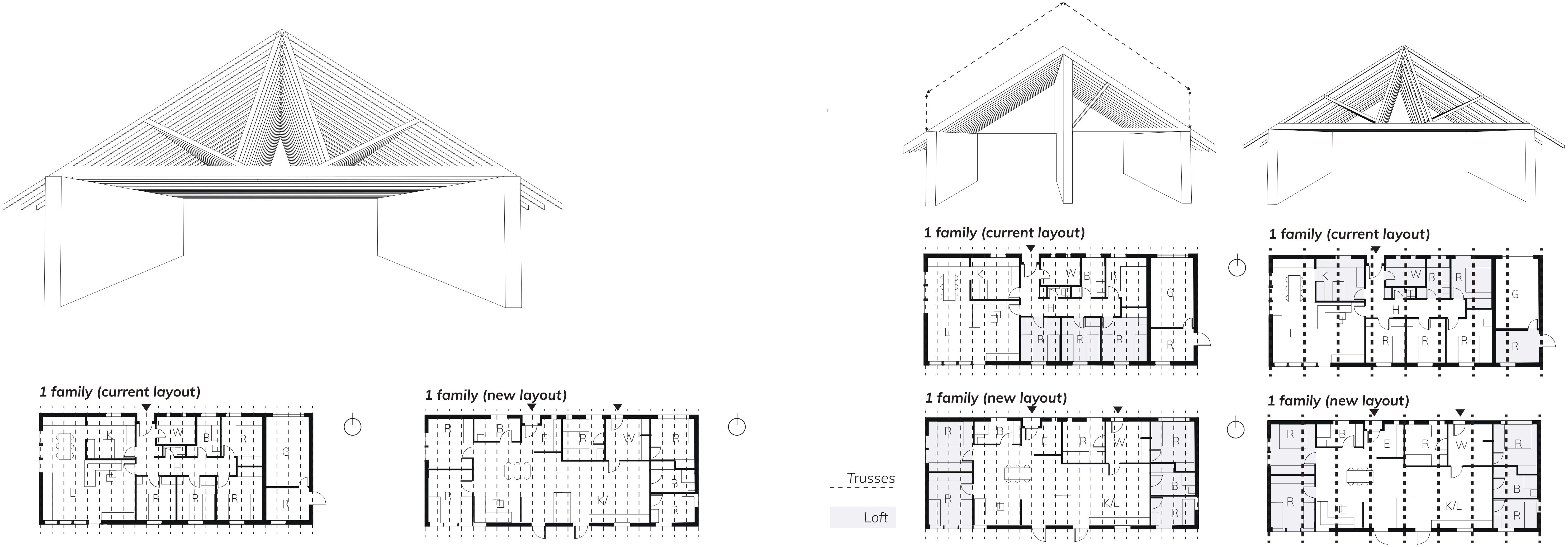
Disadvantages:
- Potential air gap, reducing acoustic insulation.
- Moving mechanisms wear over time.
- Minimal personalization.
- Dedicated space for storing wall elements.
- Reduced sense of privacy.

Scenario 2: A *moderately flexible solution*
Advantages:
- Can be repositioned or replaced to suit changing needs.
- Residents can choose styles, materials, and decorations.
- Does not require permanent changes to the building.

Disadvantages:
- Physical challenging to move.
- Doesn’t provide proper acoustic or fire safety separation.
- Reduces the sense of privacy.

Scenario 3: A *minimal flexible solution*
Advantages:
- Can provide good acoustic separation.
- A durable and sturdy interior wall.
- Can have various finishes and insulation options.
- Can function as a fire-rated element.

Disadvantages:
- Requires disassembly and reassembly to change the layout.
- Reconfiguration takes longer time and requires more labour.
- Will be less flexible if the joints are not visible.



Ill. 53. Structural principles

UTILITAS

Structural principle

To accommodate 11 occupants, none of the current spatial layouts are suitable. The ceiling height in Åstrupskrænten 45 is relatively low, which means that the current design does not allow for the inclusion of a bunk bed system. Therefore, the following question was asked: ***"What structural strategies can support housing 11 people?"*** To evaluate this, three scenarios was tested:

1. Status quo
2. Utilizing existing structure differently
3. New structural principle

Scenario 1: *Status quo*
Advantages:
- Low material emissions.
- Retaining original aesthetic of the building.

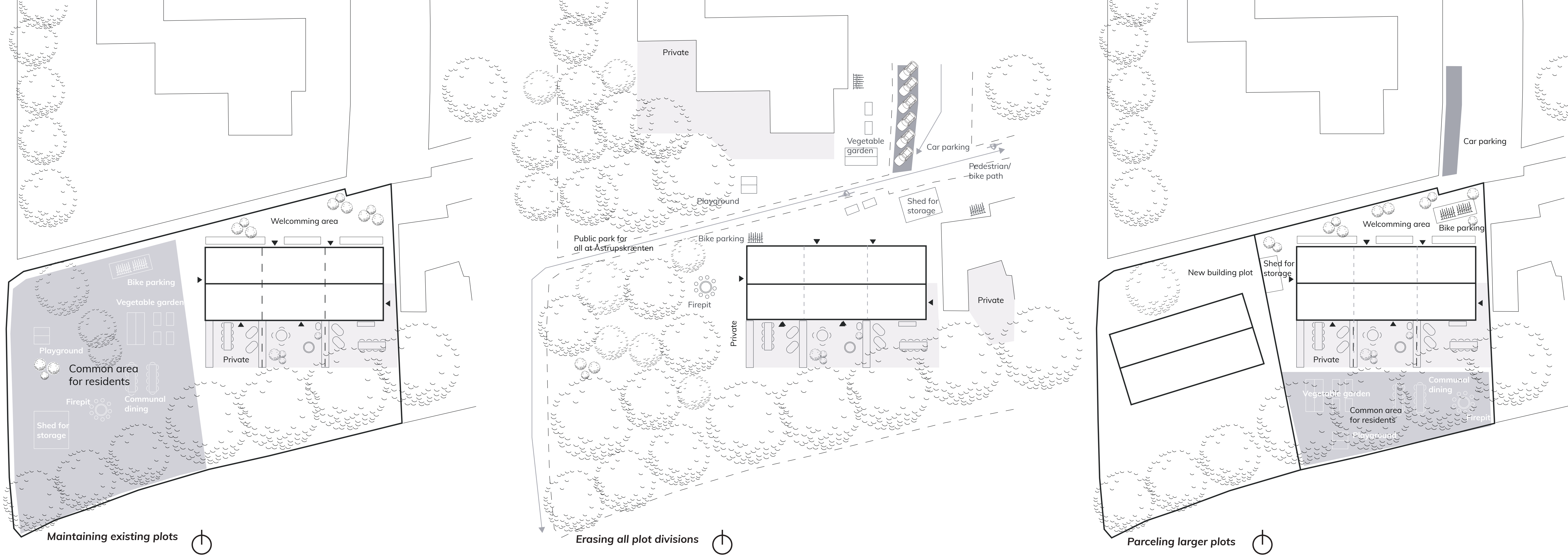
Disadvantages:
- Potential air gap, reducing acoustic insulation.
- Moving mechanisms wear over time.
- Minimal personalization.
- Dedicated space for storing wall elements.
- Reduced sense of privacy.

Scenario 2: *Utilizing existing structure*
Advantages:
- Loft space extended above all rooms gives more usable space.
- Low material emissions.
- The combination of three trusses could provide stability for the larger span.
- Retaining original aesthetic of the building.
- Accommodates 11 occupants.

Disadvantages:
- Low ceiling height, limiting the overall feeling of the rooms.

Scenario 3: *New structural principle*
Advantages:
- Enables higher ceilings or a second floor.
- Reduced material thickness.
- The existing roof contains asbestos; therefore, the roof might need replacement anyways.

Disadvantages:
- High material emissions.
- The layout is constrained by the placement of load-bearing walls.



UTILITAS

Ill. 54. Outdoor spatial layout, CREDIT based on map from CC BY 4.0 KDS. Modified by the author.

Outdoor space planning

Åstrupskrænten 45 is positioned in the plot's northeastern corner, leaving most of the 1,479 m² garden space to the west of the 1,655 m² plot. With 176 m² occupied by the house and 6–11 residents across 1–3 households to accommodate (see pp. 102-103), the outdoor space must support shared living. This leads to the central design question: ***"How can the outdoor spatial layout be adapted to foster a greater sense of community?"*** To investigate this, three scenarios have been developed:

1. Status quo, maintaining existing plots
2. Erasing all plot divisions
3. Parceling larger plots

Scenario 1: *Maintaining existing plots*
Advantages:

- Preserves current garden spaces.
- If each house has three units, there is one parking space per unit.
- Varying garden sizes based on residents.
- Existing hedges remain.
- Semi-public front yards.

Disadvantages:

- Underutilized gardens.
- Transition zones.
- The residents could isolate themselves.

Scenario 2: *Erasing all plot divisions*
Advantages:

- A strong sense of community.
- More natural landscapes.
- Less individual garden maintenance.
- Potential increased biodiversity.

Disadvantages:

- Reduced privacy.
- Challenges in property ownership.
- Shared spaces may suffer from neglect.
- Conflicts over land use.
- Larger parking lot away from the houses.

Scenario 3: *Parceling larger plots*
Advantages:

- Optimized land use.
- Stronger spatial connections.
- Reduced garden maintenance.
- Providing the option for downsizing.

Disadvantages:

- Potential overdevelopment.
- Transitional zones.
- Very dense and trafficked area.

FIRMITAS

Energy optimization, external walls

When planning the energy optimization of the external walls, several options are available. The existing cavity walls are loadbearing and constructed as shown on illustration 55. The construction is presumed based on measurements taken from the existing building, as well as general knowledge of construction practices from this period provided by Sikkerhedsstyrelsen (Sikkerhedsstyrelsen). To meet the Renovation Class 1 standards, the following question was posed: ***"How can the external walls be improved to achieve the BR18 target of <0.15 W/(m²K) for renovated external walls?"*** (Bygningsreglementet.dk) To explore this, three potential scenarios were developed:

1. Status quo
2. Insulated internally
3. Insulated externally

Scenario 1: *Status quo*
Advantages:
- Internal floor area and window recesses preserved.
- Preservation of the exterior appearance.
- Low maintenance requirements.

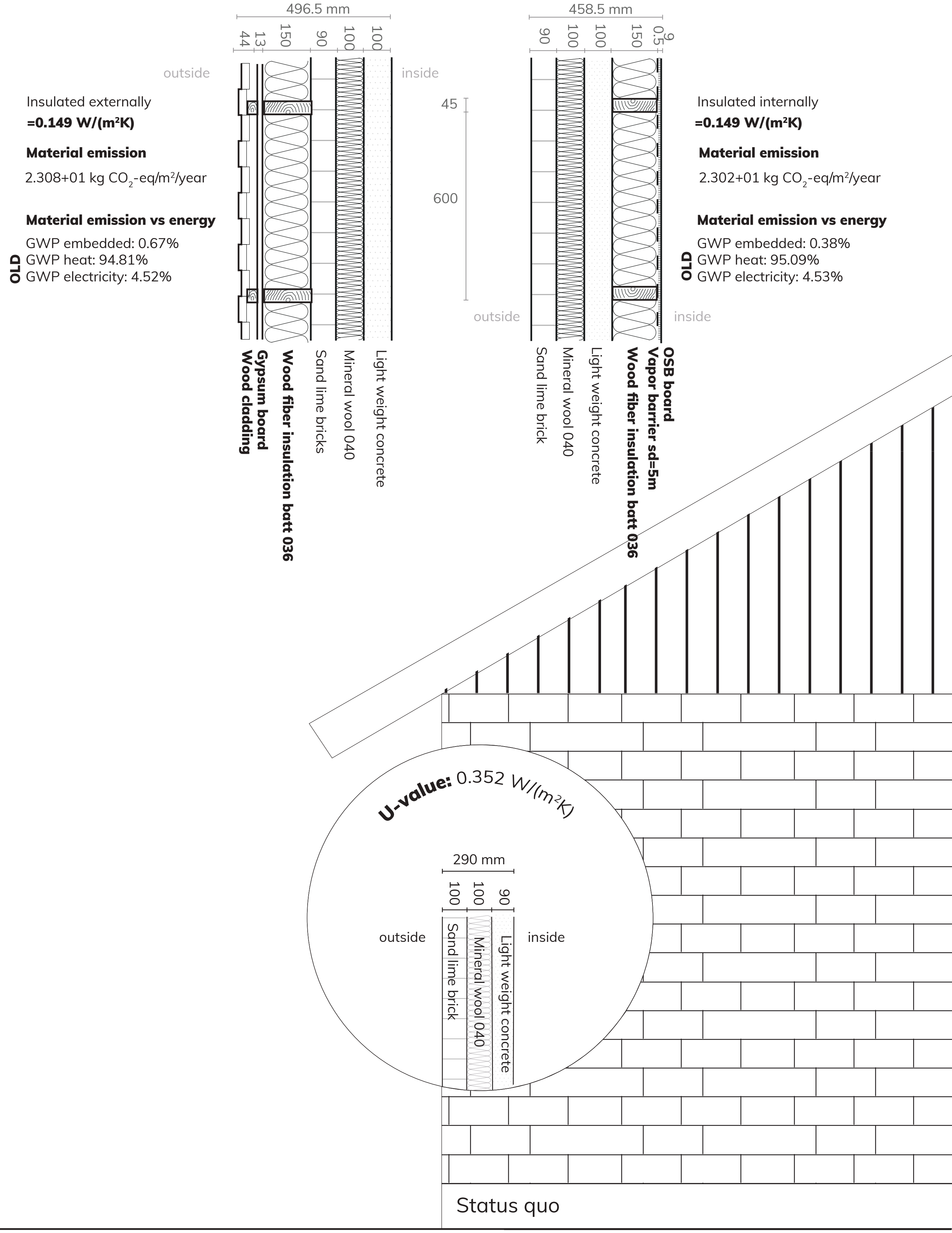
Disadvantages:
- Doesn't meet <0.15 W/m²K.
- Retains a generic aesthetic appearance.

Scenario 2: *Internal insulation*
Advantages:
- 7.74% improvement in energy performance.
- Energy optimization without visible modifications.
- Meets <0.15 W/m²K.
- Low maintenance requirements.
- Designed for easy disassembly.

Disadvantages:
- Retains a generic aesthetic appearance.
- Increased wall thickness, reducing interior space and window recesses.
- The internal walls would need to be replaced.
- If the new internal layer is plastered and painted, disassembly becomes more difficult.

Scenario 3: *External insulation*
Advantages:
- 7.74% improvement in energy performance.
- Building's appearance changes.
- Meets <0.15 W/m²K.
- Designed for easy disassembly.

Disadvantages:
- Increased wall thickness, altering the depth of window recesses.
- If maintaining the original aesthetic is important, changing it is a disadvantage.
- Wood cladding requires more maintenance than brick.
- The material emissions are higher than added insulation on the interior.



Ill. 55. Energy optimization, external walls

FIRMITAS

Energy optimization, roof

As mentioned earlier, when replacing a roof that contains asbestos, the work should be carried out by professional workers, although smaller tasks can be undertaken without professional assistance (Jensen, 2025). The existing attic features a roof and gable constructed as shown in illustration 56. The construction is presumed based on measurements taken from the existing building, along with general knowledge of construction practices from this period, as outlined by Sikkerhedsstyrelsen (Sikkerhedsstyrelsen). To meet the Renovation Class 1 standards, the following question was posed: ***“How can the roof be improved to achieve the BR18 <0.12 W/(m²K) insulation target for renovated roofs?”*** (Bygningsreglementet.dk) To explore this, three potential scenarios were developed:

1. Status quo
2. Insulating the cavity
3. New roof

Scenario 1: *Status quo*
Advantages:
- Preservation of the exterior appearance.

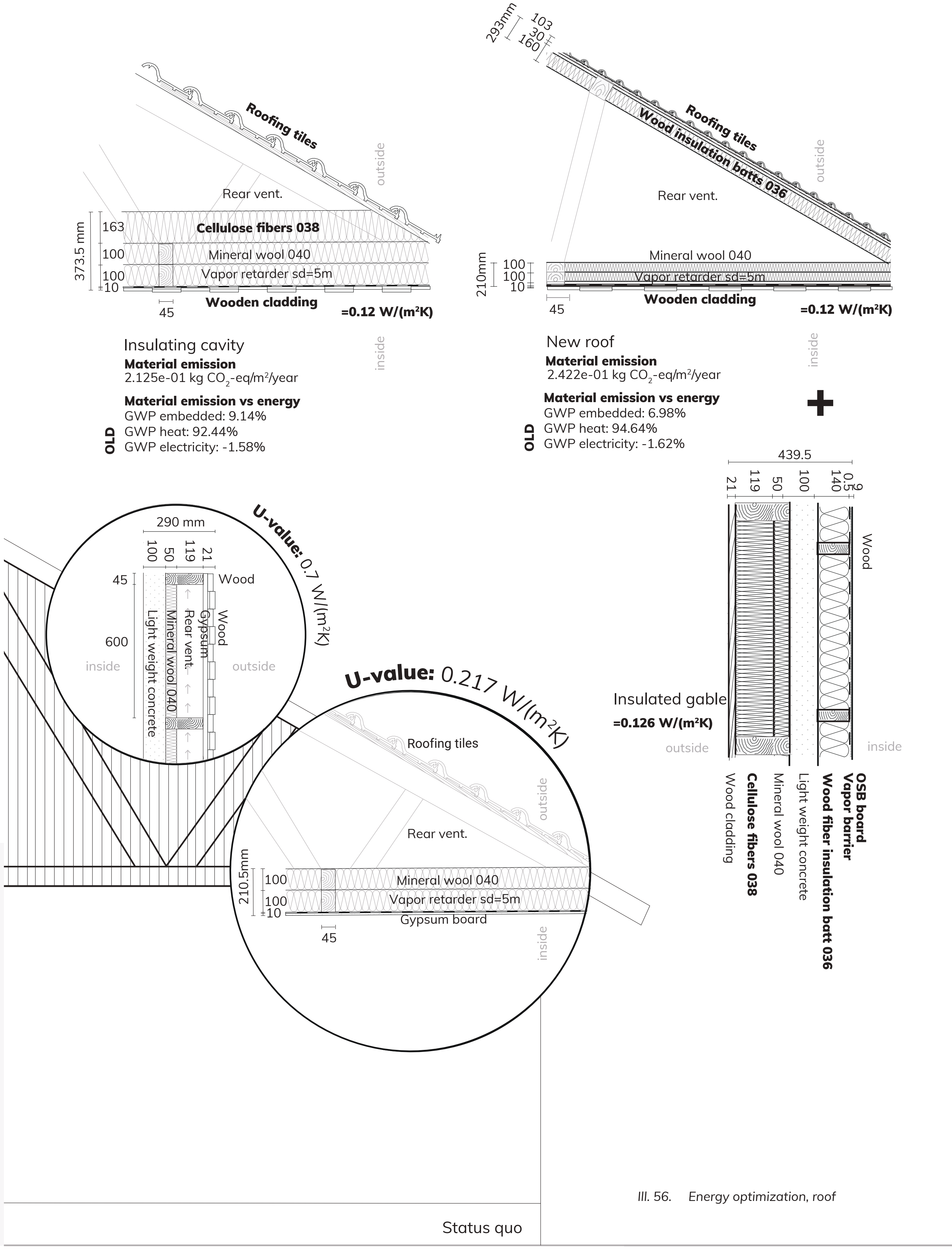
Disadvantages:
- Caution when maintaining roofing or installing a skylight.
- Doesn’t meet <0.12 W/m²K.
- Retains generic appearance.

Scenario 2: *Insulating cavity*
- 4.03% improvement in energy performance.
- Preservation of original appearance.
- Meets < 0.12 W/m²K.
- Low material emissions.

Disadvantages:
- Can’t be implemented if there is a desire to utilize the attic space.
- Low ceiling height.
- Retains generic appearance.

Scenario 3: New roof
Advantages:
- 4.03% improvement of energy performance.
- Meets <0.12 W/m²K.
- Higher ceiling, enable use of attic space, or second floor.

Disadvantages:
- High material emissions.



Ill. 56. Energy optimization, roof

FIRMITAS

Energy optimization, floor

When planning the energy optimization of the floor, several options are available. The existing floor construction is shown in illustration 57. Additionally, the strip foundation appears to lack insulation, which could create a thermal bridge due to its direct connection to the floor. Given that the ground temperature is typically lower than the indoor temperature, this could lead to significant heat loss. Therefore, addressing this issue is crucial during energy optimization but is not part of the current design phase. To meet the Renovation Class 1 standards, the following question was raised: ***"How can the floor be improved to achieve the BR18 <0.10 W/(m²K) insulation target for renovated floors?"*** (Bygningsreglementet.dk) To explore this, three potential scenarios were developed:

1. Status quo
2. Insulating on top of the existing floor
3. Replacing floor with a new one

Scenario 1: *Status quo*
Advantages:
- The thickness of the floor is not increased.

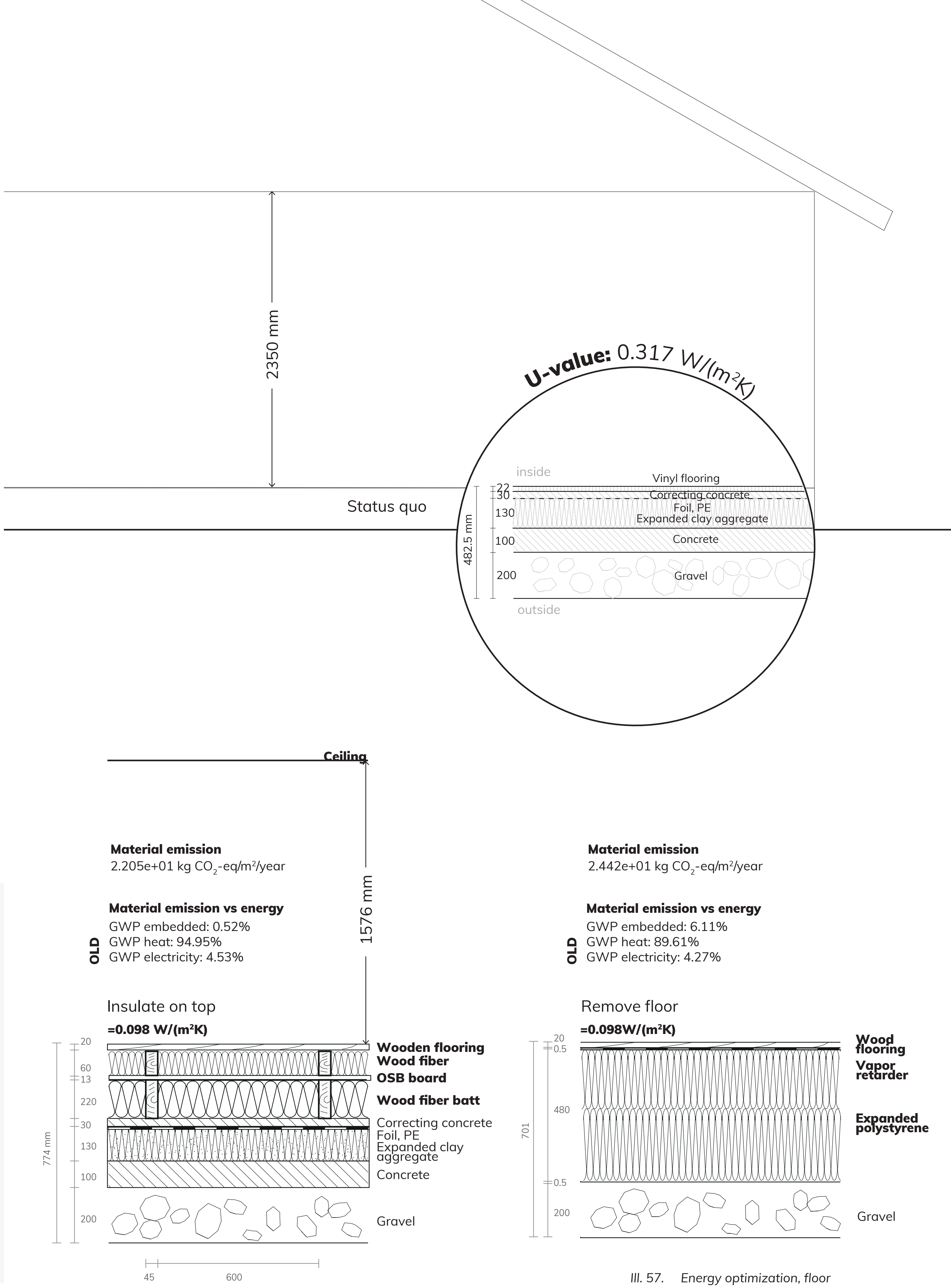
Disadvantages:
- The flooring is inconsistent.
- The floor wouldn't contribute to achieving Renovation Class 1.

Scenario 2: *Insulating on top*
- Energy performance improved by 11.58%.
- Reduced material waste and demolition emissions.
- Meet <0.1 W/(m²K).

Disadvantages:
- High material emissions.
- Additional insulation adds significant height to the floor.
- Internal walls would need to be replaced, due to thermal bridges.

Scenario 3: *Replace floor*
Advantages:
- Energy performance improved by 11.58%.
- Designed for disassembly.
- The room height can be changed.

Disadvantages:
- High material emissions.
- Demolition and reconstruction emissions.



Ill. 57. Energy optimization, floor

FIRMITAS

Energy optimization, windows

The windows and doors were mostly replaced during renovation after the owner purchased the house in 1994. As a result, it is assumed that the newer windows and doors have better U-values and G-values compared to those installed originally. The newer windows are estimated to have a U-value of 1.8 W/m²K and a G-value of 0.63, while the old windows and entry door are assumed to have a U-value of 3.0 W/m²K and a G-value of 0.7, based on assumptions (see ill. 58). To better the energy performance the question was established: ***"How can windows and doors be optimized for better energy efficiency?"*** To explore this, three potential scenarios were developed:

1. Status quo
2. Replace the oldest windows
3. Replace all windows

Scenario 1: *Status quo*
Advantages:
- No material emissions.
- Low maintenance.

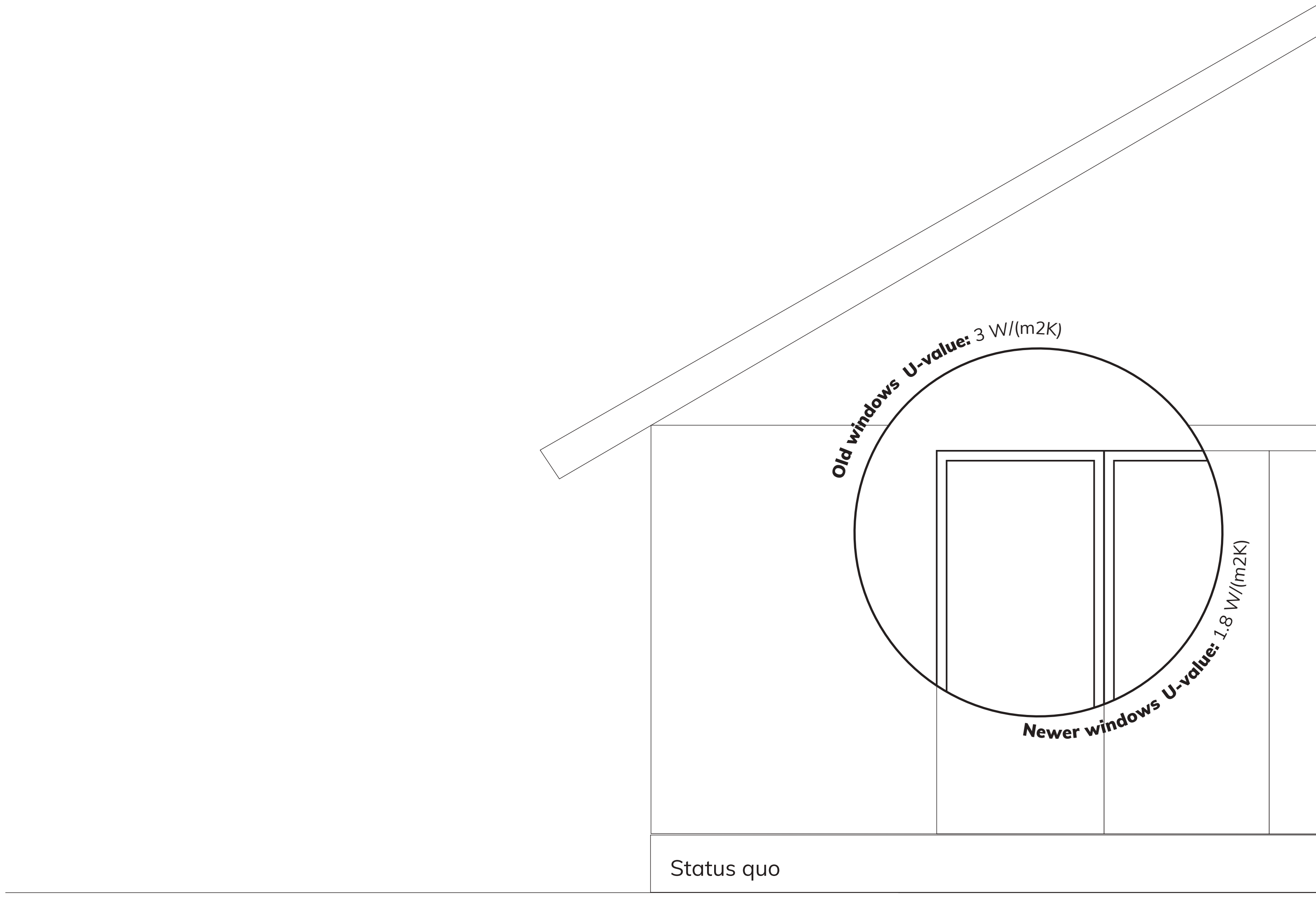
Disadvantages:
- High U-value negatively affects overall energy performance.

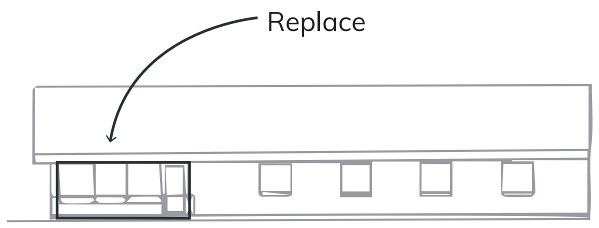
Scenario 2: *Replace oldest*
- Energy performance improved by 6.27%.
- Long-term durability.
- Less emissions than when replacing all windows.

Disadvantages:
- Wood frames require more maintenance.
- The building's appearance may change.

Scenario 3: *Replace all*
Advantages:
- Energy performance improved by 10.8%.
- Long-term durability.
- Potential for an updated aesthetic.

Disadvantages:
- Wood frames require more maintenance.
- High material emissions due to the full replacement.





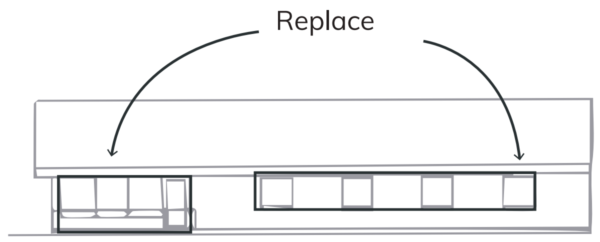
Upgrade the oldest windows

Material emission
1 m² wood 3-layer glass window:
2.294e+01 kg CO_2-eq/m²/year

9.18 m² replaced total:
2.301e+01 kg CO_2-eq/m²/year

Material emission vs energy

OLD
GWP embedded: 0.38%
GWP heat: 95.08%
GWP electricity: 4.53%



Replace all windows

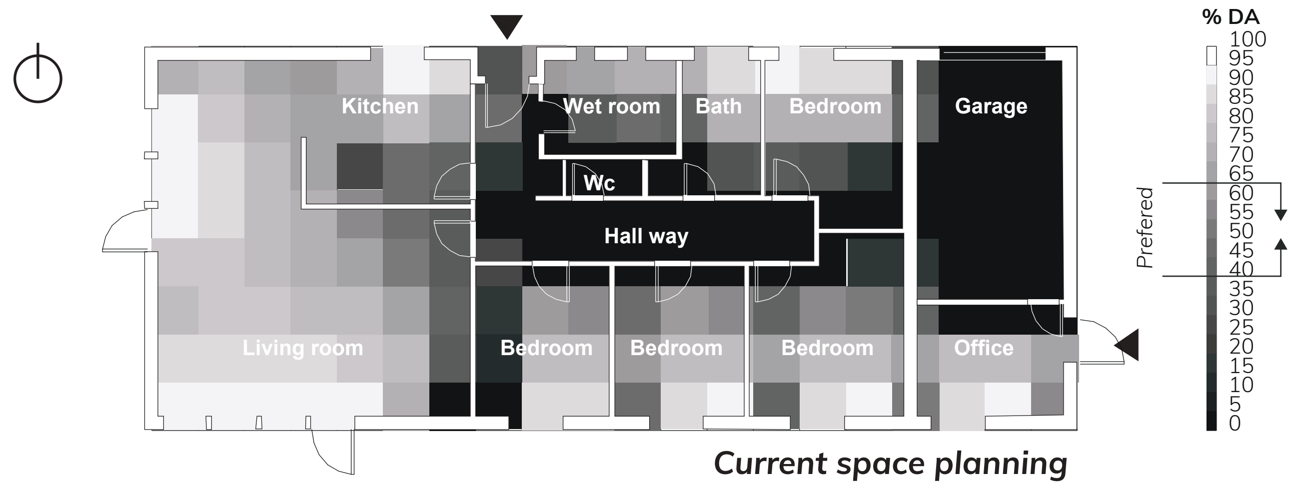
Material emission
1 m² wood 3-layer glass window:
2.294e+01 kg CO_2-eq/m²/year

28.5 m² replaced total:
2.32e+01 kg CO_2-eq/m²/year

Material emission vs energy

OLD
GWP embedded: 1.18%
GWP heat: 94.32%
GWP electricity: 4.5%

Ill. 58. Energy optimization, windows, CREDIT elevations are based on original elevations of Åstrupskrænten 45, from the local building archive at Norddjurs Municipality. (FilArkiv, Norddjurs Municipality). Modified by the author.



VENUSTAS

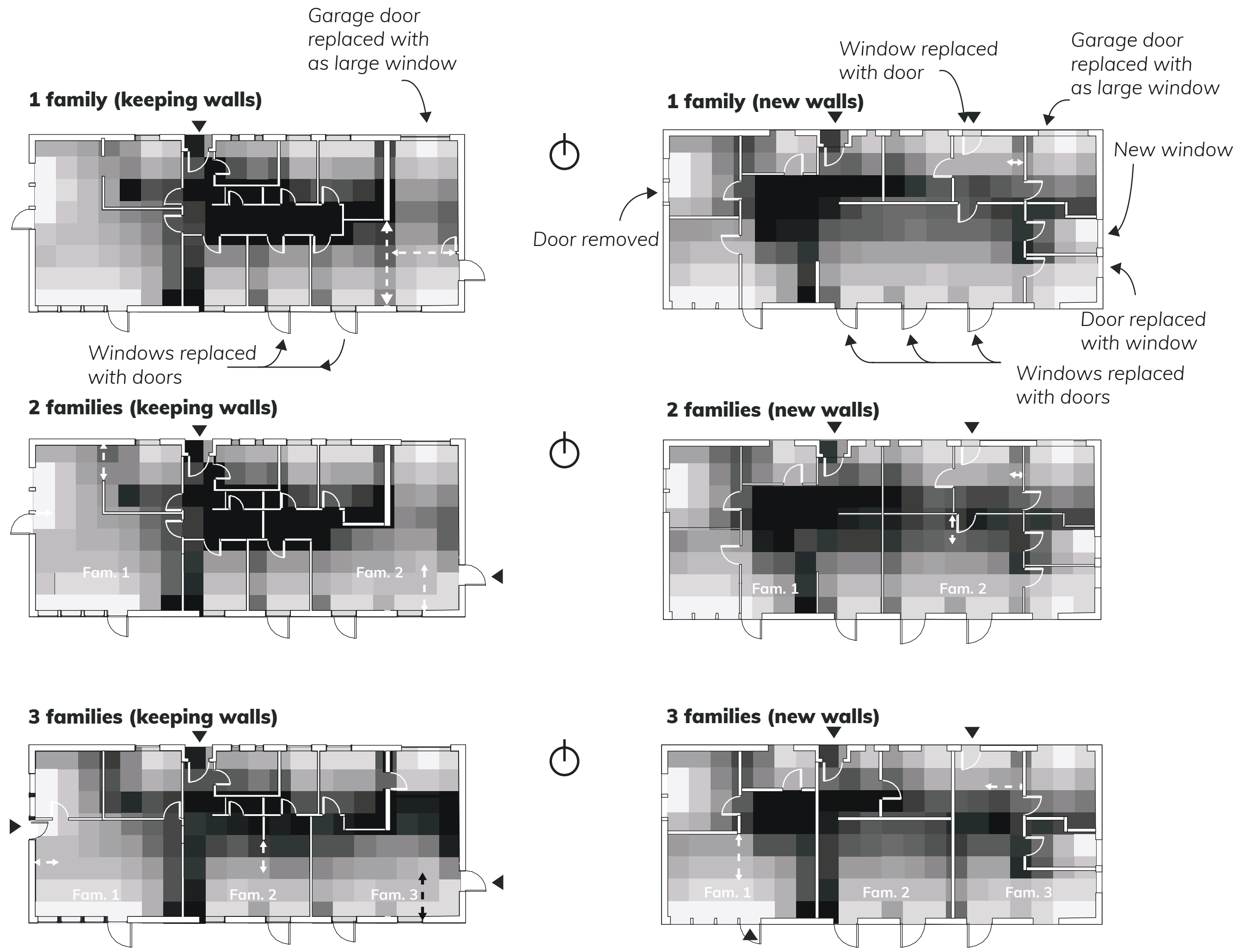
Daylight optimization

Parts of the house currently lack sufficient daylight. To ensure a balanced indoor environment, a Daylight Autonomy (DA) of 40–60% was made. Rearranging walls may reduce daylight access, prompting an analysis of roof window needs, and added window area. This leads to the question: ***"How can daylight be optimized to achieve 40–60% DA while reducing harsh contrasts?"*** Three daylight scenarios have been explored:

1. Status quo
2. Keeping most of the internal walls
3. New internal walls

Scenario 1: *Status quo*
Advantages:
- No additional openings in the exterior walls
- Sufficiently lit in the most frequently used spaces.

Disadvantages:
- Skylights are needed.



Ill. 59. Daylight optimization, CREDIT: current floorplan drawing is based on original architectural drawings of Åstrupskrænten 45, from the local building archive Norddjurs Municipality. (FilArkiv, Norddjurs Municipality). FilArkiv. https://public.filarkiv.dk/707. Modified by the author.

Scenario 2: *Keeping internal walls mostly*
Advantages:
- No additional openings in the exterior walls
- Sufficiently lit in the most frequently used spaces, when one family.
- Three openings need to be altered.

Disadvantages:
- Insufficiently lit in the most frequently used spaces, when 2-3 families.
- Skylights are needed.

Scenario 3: *New internal walls*
Advantages:
- Allow for more natural light.

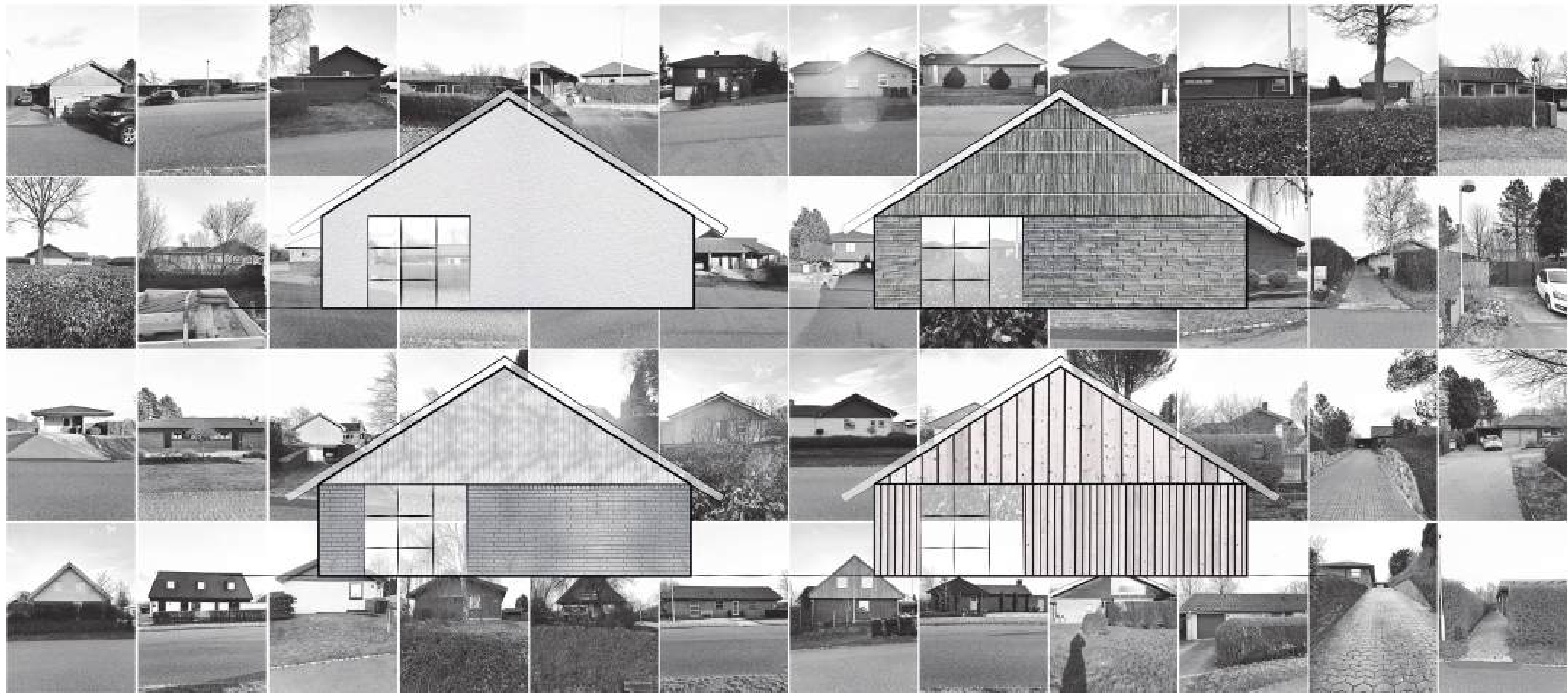
Disadvantages:
- Additional openings have been made.
- Facade cladding needs to be replaced.
- Skylights are needed
- Insufficiently lit in the most frequently used spaces, when 2-3 families.

VENUSTAS

Materiality, external wall

In planning the facade transformation, the focus has been on blending the new cladding with the surroundings. The goal is to give the house a distinct yet not outstanding look that fits the character of both the house and the neighbourhood. The area features varied materials, mainly brick in different colours, plaster, and painted or stained wood. To guide material selection, the key question was: ***"How can facade cladding balance technical performance, durability, and aesthetics?"*** This led to four context-based scenarios:

1. Status quo
2. Introducing a new brick facade
3. Implementing a plastered finish
4. Using wooden cladding



Ill. 61. Materiality, external wall

Ill. 60. Daylight optimization

Scenario 1: *Status quo*
Advantages:
- Aligning with the existing aesthetic of the neighborhood.
- Evokes nostalgia for those who grew up in similar homes.
- Tectonic expression.
- Wood allows for color changes.

Disadvantages:
- Retaining generic facade aesthetic.
- Regular maintenance, due to wood.
- Doesn't explain transformation story from outside.

Scenario 2: *New brick facade*
Advantages:
- Allow for variations in orientation, depth, and bond.
- Minimal upkeep.
- Widely used material in Danish architecture.
- Maintains its original appearance over time.

Disadvantages:
- Less adaptable to personification.
- Less distinctive, due to widespread use of bricks in Denmark.
- 1 sqm. emits 2.293e+01 kgCO2-eq./m2/year.
- Not easy to disassemble.

Scenario 3: *Plastered facade*
Advantages:
- Applied on existing facade.
- Personalization through color choice.

Disadvantages:
- Plain and minimalistic.
- Frequent maintenance.
- 1 sqm. emits 2.714e-04 kgCO2-eq./m2/year.
- Can't resemble the existing facade expression.
- Can't be disassembled.
- Develops an unattractive patina.

Scenario 4: *Wooden facade*
Advantages:
- Varied detail options.
- Allowing for a modern feel.
- Sensory element with its natural smell.
- 1 sqm. emits -2.151e-03 kgCO2-eq./m2/year.
- Design for disassembly.
- Develops a patina that alters the surface character.

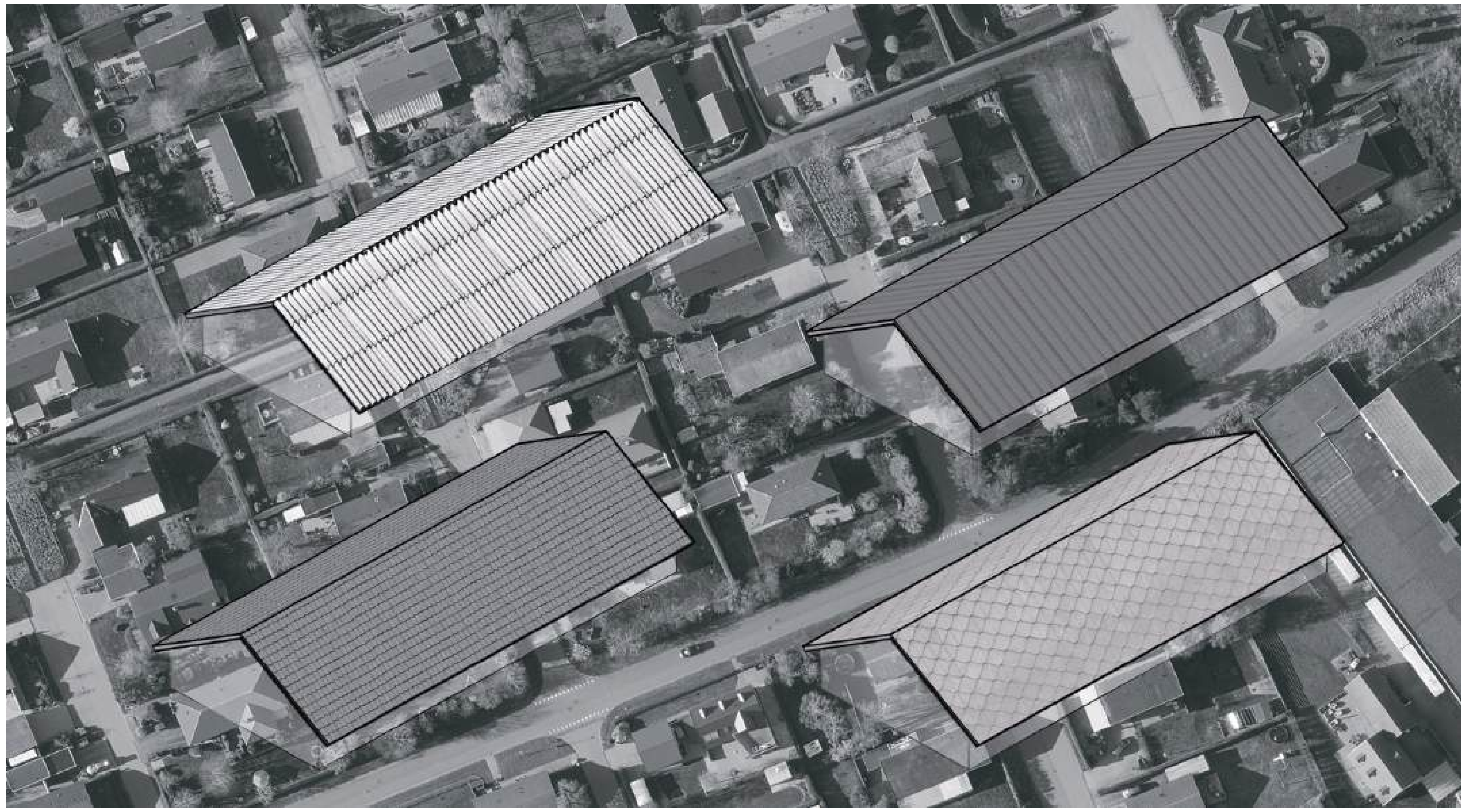
Disadvantages:
- Require more maintenance.
- Wood may evoke a vacation home aesthetic.
- It is likely to wear and get damaged.

VENUSTAS

Materiality, roof

In considering a transformation of the roof's aesthetic, emphasis has been placed on how new materials can integrate with the surrounding context. Roofing in the neighbourhood includes corrugated fiber cement, tiles, metal, bitumen, and slate, varying in colour and finish. As bitumen is only shown on flat roofs, this material is not evaluated. The goal is to give the house a distinct expression without it appearing out of place, but rather in harmony with both the existing building and its surroundings. To guide this process, the question was posed: ***"How can the roofing material balance processing, technical performance, and aesthetic qualities?"*** Based on locally observed materials, four scenarios were developed:

1. Status quo
2. Metal roofing
3. Tiled roofing
4. Slate roofing



Ill. 62. Materiality, roof

Scenario 1: *Status quo*
Advantages:
- Could be cleaned and repainted.
- Maintain the current aesthetic of the house.

Disadvantages:
- Retaining generic aesthetic.
- The roofing is not reusable as it contains asbestos.
- Almost no emissions, just for maintenance.
- Hazard possibility

Scenario 2: *Metal roofing*
Advantages:
- Lightweight compared to heavier materials like tiles or slate.
- Requires minimal upkeep.
- Various colors, finishes, and patterns.
- Design for disassembly.

Disadvantages:
- Loud during heavy rain or hail.
- 1 sqm. zink roof emits 1.781e-04 kg-CO2-eq./m2/year.

Scenario 3: *Tiled roofing*
Advantages:
- Design for disassembly.
- Long lifespan if properly maintained.
- Various colors, textures, and finishes.
- Associated with residential housing.

Disadvantages:
- Can break under heavy storms.
- 1 sqm. emits 1.059e-03 kgCO2-eq./m2/year.

Scenario 4: *Slate roofing*
Advantages:
- Detailed and vibrant surface.
- Design for disassembly.
- Patina is not as obvious.

Disadvantages:
- Slate roofing is heavier than tiled roofing.
- Slate typically comes in a single color.
- 1 sqm. emits 9.635e-04 kgCO2-eq./m²/year.

Design Phase 2

In the following chapter, the design process will be explored through a proposed solution to the research question, derived from the studies and analyses conducted during the Design Phase 1 (pp. 98-125). This solution aims to align with the overall vision and design drivers. It is anticipated that integrating the conclusions from the Design Phase 1 may also raise new questions, opening further opportunities for exploration.

Ill. 63. Design Phase 2

PARTIAL CONCLUSION
ON DESIGN PHASE 1

Utilitas
When evaluating whether the site should cater to multigenerational living versus co-living, multigenerational living emerges as the preferred option. It offers both privacy and social opportunities, allowing residents to choose how much interaction they want while still fostering a sense of community withing each building. While some co-living aspects could be integrated, such as a community house where residents can rent additional space for events like parties, the multigenerational model provides more flexibility in balancing private and shared spaces.

Regarding housing for 6-11 people, research suggests that additional loft space would be necessary to accommodate 11 people with enough beds. However, splitting the house into three units for 11 people would result in very small individual spaces. A more feasible solution might be to treat the third split as a buffer zone, which could be rented by families on either side when needed. Additionally, housing between 6-8 people seems more realistic, as adding a loft would require significant structural modifications to both accommodate the extra space and maintain the house's stability.

In terms of flexibility, the design must consider fire safety by incorporating fire barriers within the walls, and doors must be positioned accordingly to align with these fire regulations. While some internal walls may need to be adjusted, it's important to retain the existing structure as much as possible to preserve the stability of the house. The most practical approach is to keep as many original walls as feasible and make only the necessary walls flexible.

Regarding outdoor spaces, parceling may not be suitable due to fire hazard concerns. Shared facilities without distinct plot boundaries could align better with a co-living arrangement, where garden spaces are more communal. However, given the preference for multigenerational housing, it's best to maintain the plot boundaries. To encourage a greater sense of community, everyday functions like mailboxes, parking, and trash bins could be located near the front yards, ensuring that each house has its daily needs easily accessible in front, rather than hidden behind the building. This approach would also ensure the front yards remain active and interesting. Furthermore, the layout of individual gardens could be designed with flexibility in mind, allowing each housing unit within a building to have more or less garden space depending on residents' preferences and needs.

Firmitas
If the goal is to preserve as many internal walls as possible for structural stability, the most effective approach would be to add insulation externally. This not only maintains the integrity of the house's structural system but also provides an opportunity to redefine its architectural character, differentiating it from neighboring buildings with a facade that has a distinct expression and can be personalized.

Regarding the roof, the best solution might be to retain the existing structure, as suggested in the partial conclusion for Utilitas. However, there is still the possibility of reinforcing certain trusses to allow for a higher ceiling in select rooms. This could improve the spatial experience and daylight conditions, especially if skylights are introduced to bring in more natural light.
As for the flooring, the best option is to remove the existing floor and replace it with a new one. The current floor is compromised due to condensation issues, which could impact durability and indoor climate.

Lastly, in terms of windows, research indicates that the best U-value and the most cohesive aesthetic solution would be to replace all existing windows. However, if only some windows are replaced, careful attention must be given to ensuring facade uniformity, maintaining a harmonious and well-integrated appearance.

Venustas
Research on Venustas indicates that, in terms of daylight, there is no significant difference between retaining the existing internal walls and replacing them entirely, provided no skylights are introduced. This means that Utilitas and Firmitas can determine whether to keep or replace the internal walls based on other factors such as structural integrity and functionality. However, further investigation is needed to optimize daylight conditions while maintaining the internal walls, ensuring a balance between bright and comfortable lighting zones.

Regarding external materiality, the conclusion is that a new facade cladding is necessary. To minimize drastic visual changes, it would be beneficial to select a material that can be treated multiple times without significantly altering its appearance. Wood is an ideal choice, as it not only allows long-term adaptability, are easy to disassemble, but also references the existing building, preserving its architectural narrative and aesthetic continuity. Given that the facade cladding will have a more prominent, expressive material, it makes sense to choose a more subdued roofing material to maintain a balanced overall aesthetic, which is why the metal roofing could be interesting to investigate further.

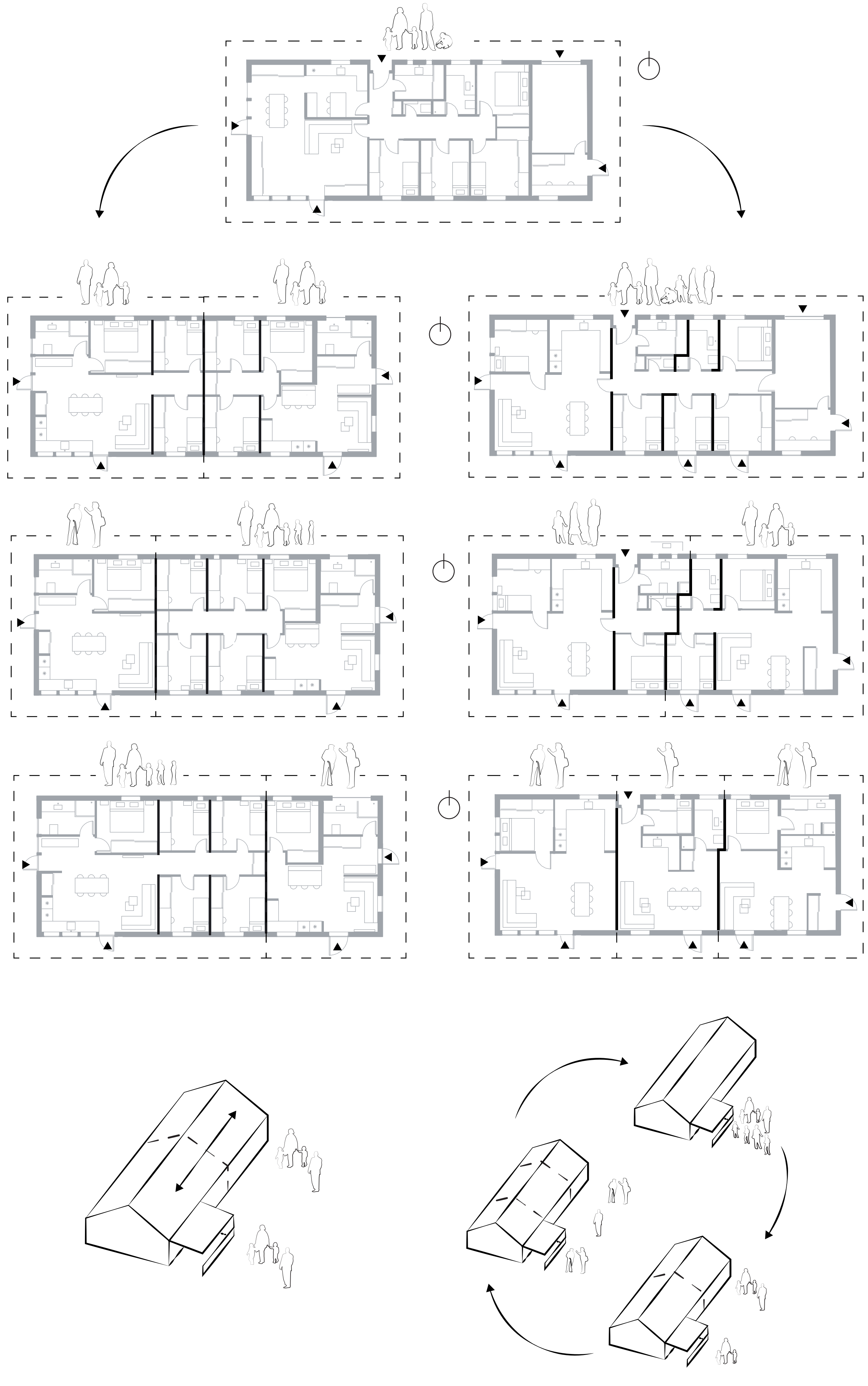
Internal layout and adaptability

When working with the existing internal walls, as concluded from *Design Phase 1*, two distinct approaches can be considered. One option is to design a movable separating wall, allowing for flexibility in the layout over time. The other approach is to envision the house evolving through different stages, initially accommodating a single family, then two, and eventually three.

When examining these two strategies for creating a flexible layout, it becomes evident that accommodating three families simultaneously would require significant changes to room functions. For instance, converting the garage into a livable space with a new kitchen and bathroom would demand extensive renovations. Additionally, the house would become more compact and challenging to navigate. This approach would also require a substantial number of flexible internal walls to accommodate frequent layout changes, making it potentially more suitable to introduce entirely new internal walls instead.

In contrast, the alternative solution involves creating three fire-separating walls, with a central section that can be relocated to different positions within the house. The central section would then need to be dismantled and relocated before being reconstructed at the new place. This allows for a design focused on disassembly, making it easy to adapt the space as needed. Furthermore, this approach maintains a more open floor plan, and no rooms need to change their function.

Therefore, when moving forward, the option featuring a movable boundary wall will be explored in greater detail.



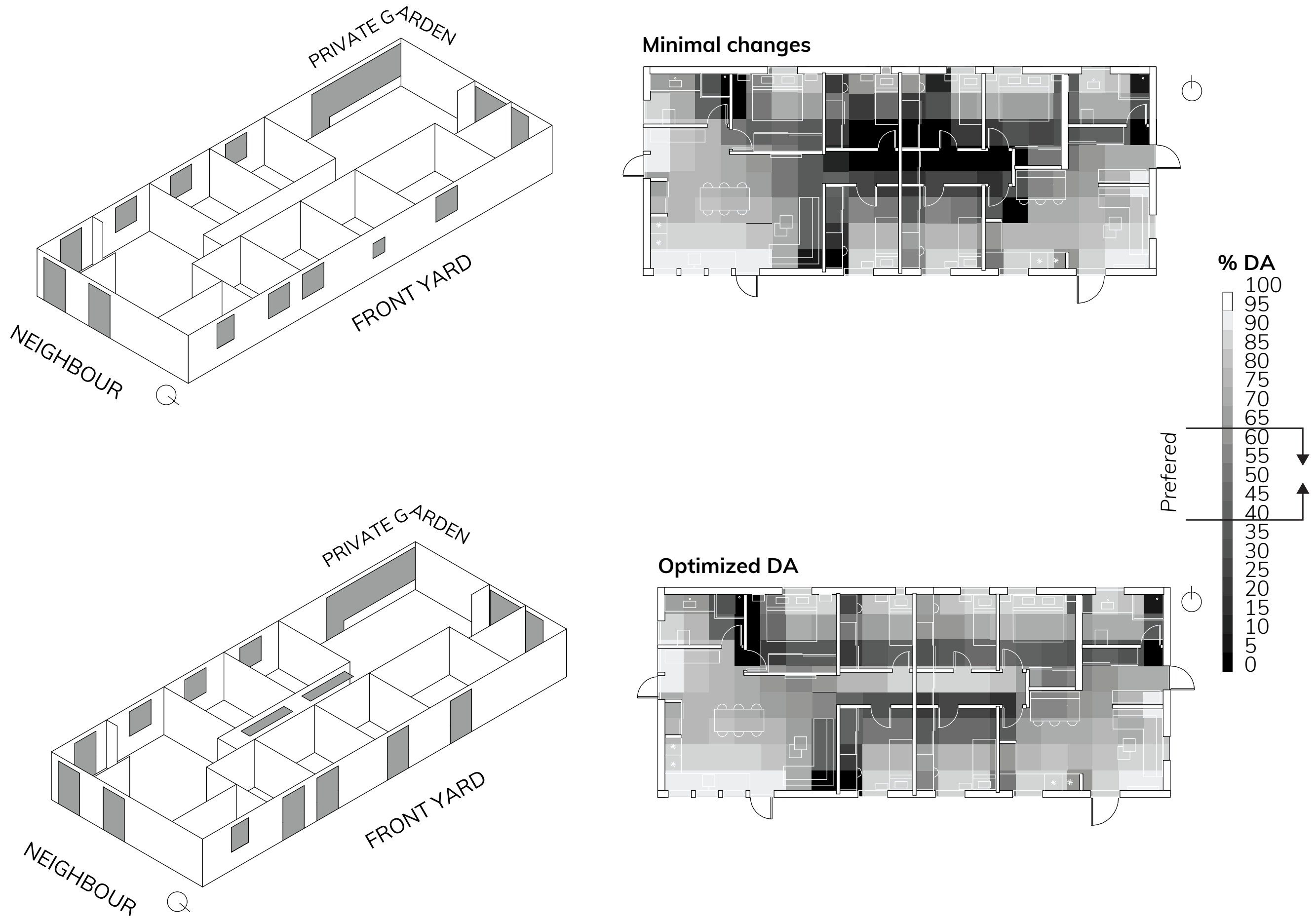
Ill. 64. Interior layout and adaptability, CREDIT current floorplan is based on original floorplan of Åstrupskrænten 45, from the local building archive at Norddjurs Municipality. (FilArkiv, Norddjurs Municipality). Modified by the author.

Daylight optimization

When making minimal adjustments to the windows to accommodate a spatial layout that allows the building to adapt for two housing units, the existing entrance has been removed and replaced with a new exterior wall. Additionally, the garage door has been replaced with a window that matches the existing ones, and a new entrance door has been installed on the eastern facade. However, these minimal modifications do not provide sufficient daylight autonomy (DA) in the desired areas. With this option, the existing roof can be maintained as it is.

To optimize daylight conditions, skylights have been introduced to bring natural light into the previously dark hallway. Furthermore, the northern-facing windows have been extended downward to allow daylight to penetrate deeper into the building. This adjustment not only enhances the indoor lighting conditions but also creates a stronger visual and spatial connection between the interior and the front yard, which faces the communal space at Åstrupskrænten. Furthermore, implementing these changes requires reinforcing the trusses in the hallway to allow for a vaulted ceiling in this area.

Therefore, the design will further explore the integration of skylights and expanded glazing areas, as illustrated in figure 65.



Ill. 65. Daylight Autonomy (DA)

Backyard layout and adaptability

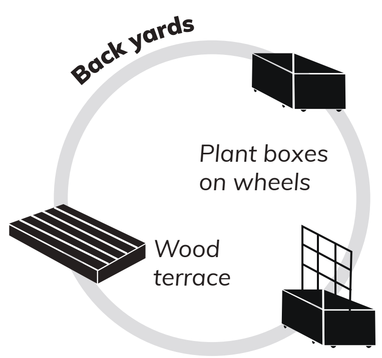
To maintain the existing plot divisions at Åstrupskrænten 45 while improving flow, transitions, and long-term flexibility, several strategies have been considered.

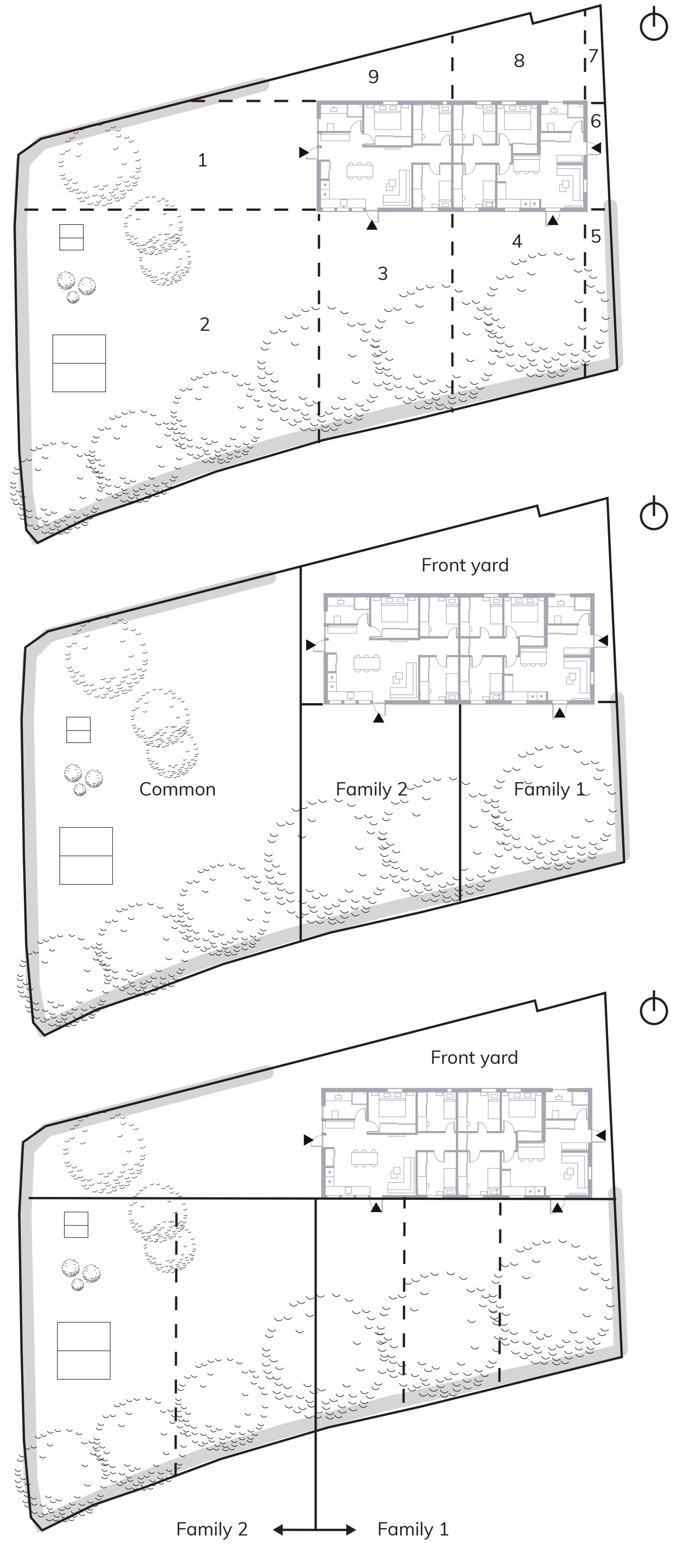
One option involves overlaying a grid and distributing sections to each unit. However, this intervention risks disrupting natural movement patterns, as certain areas must be assigned to specific units due to the house's four exits. Additionally, the need for front yards to remain open and inviting for social interaction further predetermines the allocation of certain grid sections.

Another approach assigns each unit a private garden near its exit, with a shared front garden to the north and a semi-private communal space to the west. While encouraging interaction, this layout may lead to underused communal areas and lacks adaptability.

The third approach is to divide the garden into private and shared sections, with the boundary between them being adjustable. This allows the southern part of the garden to serve as a sheltered, private part, while the remaining space remains open for social encounters among residents. By enabling the garden boundaries to shift, this solution accommodates varying maintenance preferences and evolving spatial needs. Movable elements like raised garden beds and mobile deck platforms can help define spaces and adapt to changing needs.

Moving forward, the project will focus on refining the flexible boundary concept to support both individual and collective use over time.





Ill. 66. Backyard layout and adaptability

Front yard layout

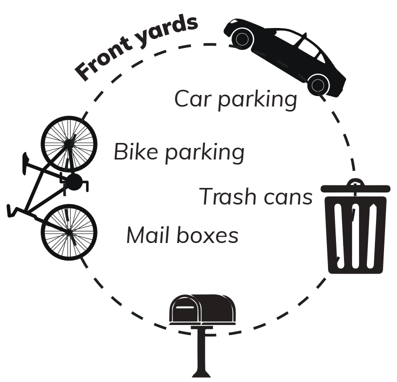
As previously concluded, a clear division between front and back yards supports varied outdoor uses. The front yards can act as semi-public transition zones encouraging casual social interaction, while the more sheltered backyards are shared within each building. Therefore, the front yards should include functions such as bicycle and car parking, trash bins, and mailboxes. By placing these functions in the front, residents are more likely to encounter one another during daily routines.

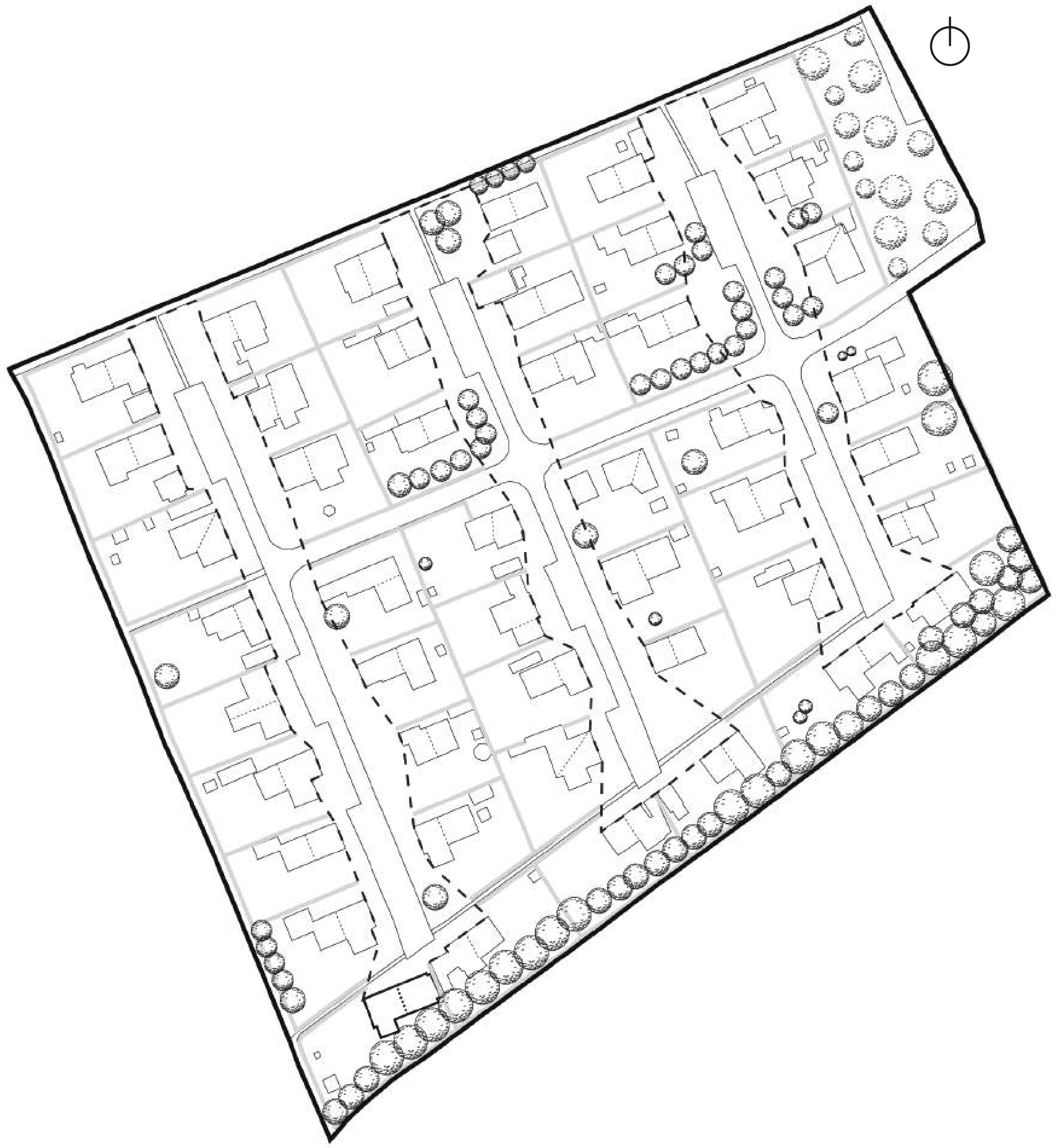
Since Design Phase 1 determined that existing plot boundaries at Åstrupskrænten should be preserved, different strategies can help define front- and backyard zones without redrawing property lines. In the backyards, the current hedges already provide privacy and enclosure and should therefore be maintained.

In contrast, the front yards call for a more open and social character. One approach is to remove the hedges entirely, creating visual openness to the street. However, this could make residents feel exposed and reduce the space's social function.

A compromise is to lower the hedges, preserving some privacy while enabling visual contact across yards. This encourages openness and avoids the need for new planting. To ensure coherence, a hedge height limit could be added to the homeowners' regulations.

Moving forward, the project will focus on adapting the existing front-yard hedges to a lower height and integrating shared everyday functions to naturally promote neighborly encounters.





Ill. 67. Front yard layout, CREDIT based on map from CC BY 4.0 KDS. Modified by the author.

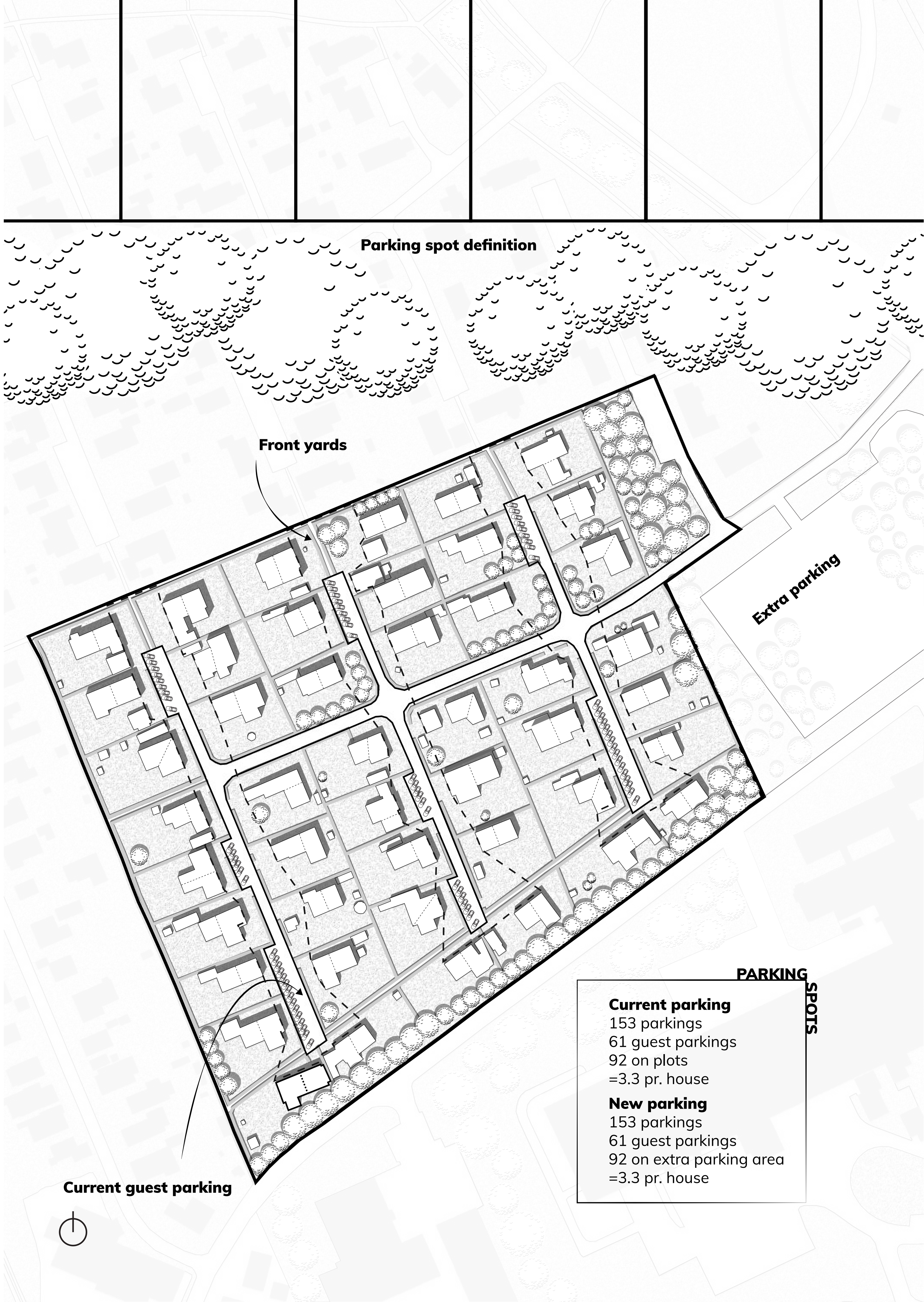
Parking layout

In relation to the masterplan, the current parking situation must be reassessed, particularly considering potential household growth. If all housing units on the street need at least one parking space, the neighborhood layout should accommodate this need in a thoughtful and future-oriented way.

One option is to maintain the existing parking spaces. This approach could accommodate the current number of residents. However, if additional people move into the area, the number of spaces would become insufficient. Furthermore, as noted in Design Phase 1, cars parked directly in front of houses obstruct sightlines and interfere with opportunities for social interaction.

A second option involves repurposing the existing guest parking as the primary parking area, while introducing additional spaces at the current industrial site located at the entrance of the neighborhood. This approach removes vehicles from the front yards, preserving these spaces for more social and recreational use, while it also allows the parked cars to be screened more effectively, improving the overall visual experience. Clustering cars in designated areas can additionally support community interaction, much like the shared placement of mailboxes and waste stations, by creating natural points of encounter.

Moving forward, centralized parking zones will be introduced to promote social interaction and free up front yards, with planting used to define and organize the layout.



Ill. 68. Parking layout, CREDIT base on map from CC BY 4.0 KDS. Modified by the author.

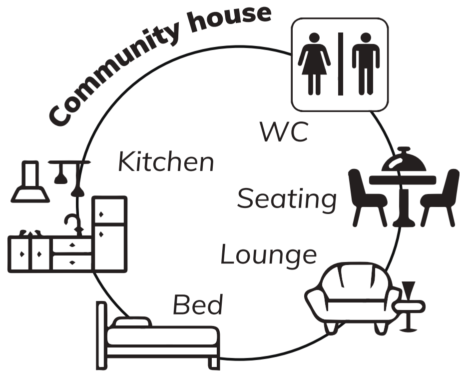
Community house

Design Phase 1 identified the inclusion of a community house as a valuable addition to the neighborhood, particularly considering the reduced size of individual housing units. Such a shared facility would offer a venue for larger gatherings, celebrations, and communal activities that may not be feasible within private homes.

On the eastern edge of the site, a former industrial plot is currently occupied by a large existing building. By repurposing and downsizing this structure to suit its new function, it could serve as an ideal location for the community house. Positioned at the neighborhood's entrance, it would be easily accessible and visible to all residents. The surrounding area offers further potential for enhancement through the introduction of new greenery, increasing biodiversity while also creating a functional outdoor space, perhaps for walking paths or a dog training ground.

An alternative option would be to locate the community house at the center of the neighborhood. This would ensure strong visibility and a clear awareness of its use among residents. However, placing it centrally could also introduce challenges related to noise during events and celebrations, potentially disturbing those living nearby.

After evaluation, it is recommended to utilize the former industrial site for the new community house. Its peripheral location ensures daily visibility, since all residents would pass by it, while minimizing disturbance to nearby homes.



Ill. 69. Community house, CREDIT based on map from CC BY 4.0 KDS. Modified by the author.

External cladding, details

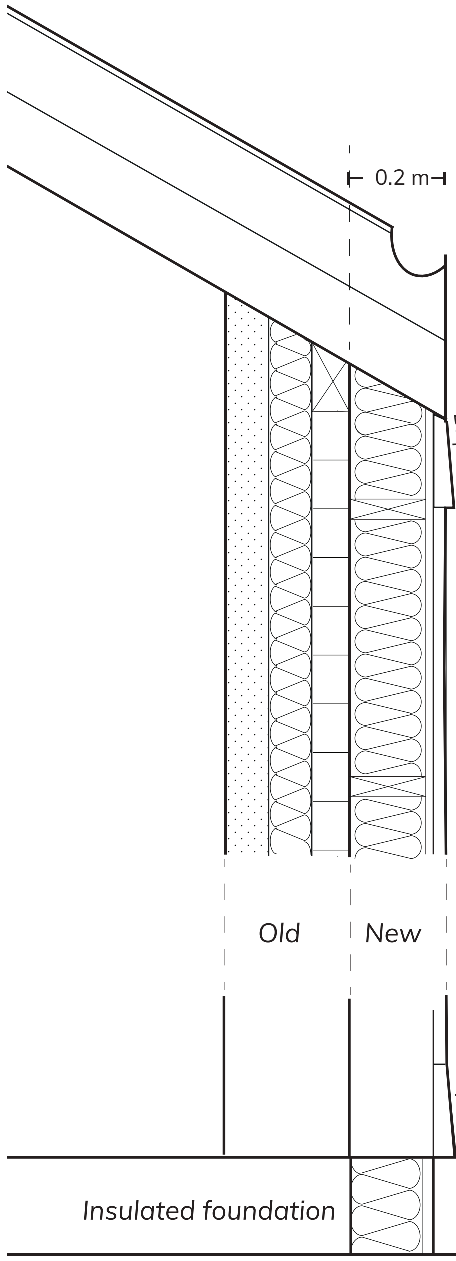
Following the decision in Design Phase 1 to insulate the external walls from the outside, the wall depth increases, requiring careful consideration of how materials meet and transition.

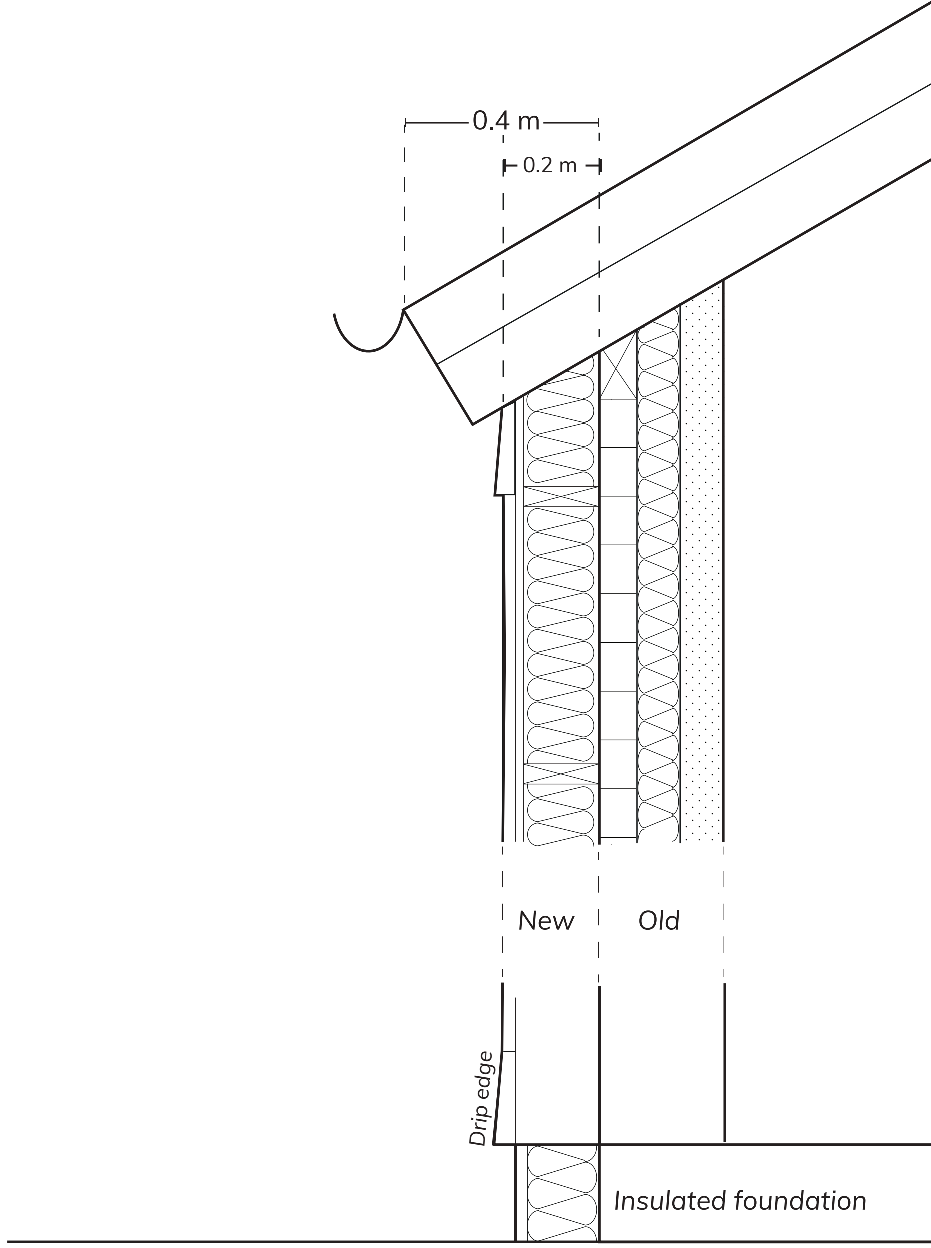
One approach is to retain the existing roof overhang, even though there is a slightly reduced depth. This preserves the architectural rhythm of the original building and protects the new cladding from direct weather exposure. Retaining the overhang also allows the wood to develop a natural patina in varied ways, slower near the overhang and faster further down, adding visual depth and aging character to the facade.

Alternatively, the overhang could be removed, and the gutter repositioned on top of the roof, creating a cleaner, more seamless intersection between roof and wall. However, this solution would require a drip edge to prevent water damage and rot. Wood cladding in particular benefits from being shielded by an overhang, as it reduces weathering and extends material longevity.

Given that the house still reflects its original two-part composition, where the attic is not used as living space, it makes architectural sense to maintain this narrative through material transitions. Retaining the overhang supports this identity and provides essential weather protection for the wooden facade.

Moving forward, the overhang will not be preserved, as there is almost none left, which would then require a new structure.





Ill. 70. External cladding, details

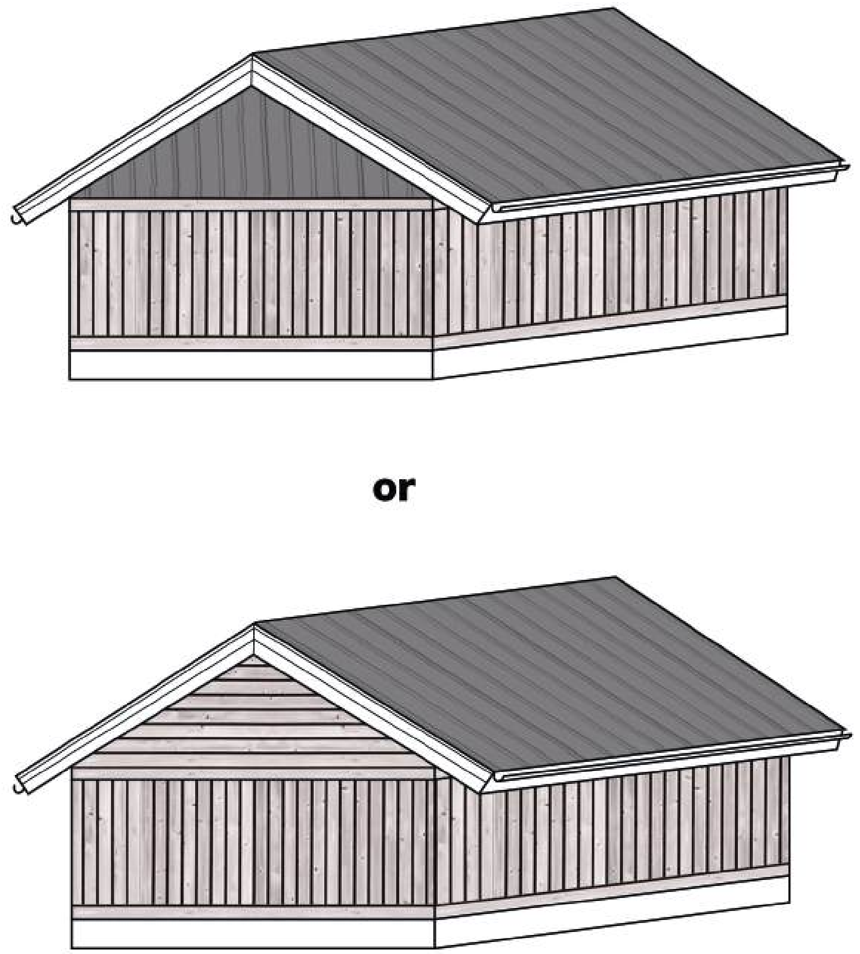
External cladding, materiality

In Design Phase 1, wood was chosen as exterior cladding due to its low emissions, durability, and design for disassembly for future replacements. Thermowood, specifically, offers a maintenance-free solution thanks to its heat treatment, which enhances weather resistance without the need for chemicals and ensures that the facade will develop a silver-grey patina over time. This keeps the facade environmentally friendly while still allowing future owners to paint or stain it if desired (Klaumann, Jørgensen). A local sawmill also supplies facade cladding from Danish wood, reducing transport emissions (Arossavvaerk.dk).

For the roof, several options remain under evaluation. However, zinc in a silver tone is considered a fitting choice, as it reflects the natural patina of weathered wood. Maintaining a visual contrast between the upper and lower parts of the house supports the original architectural character and highlights the distinction between heated and unheated zones. This can be achieved through material choice or cladding direction.

The first option would be to retain wooden cladding on the upper part of the gables, with the roofing material only covering the same surfaces as it does currently. The second option involves extending the roofing material to also cover the gables. Choosing the latter creates a clearer visual and material distinction between the upper and lower parts of the house. In contrast, the first option could suggest the presence of a full second storey, but it also offers a more seamless visual transition to the lower part of the building.

To reinforce the house's two-part narrative, wooden cladding will cover the upper gables for a more cohesive and seamless design.



Ill. 71. External cladding, materiality

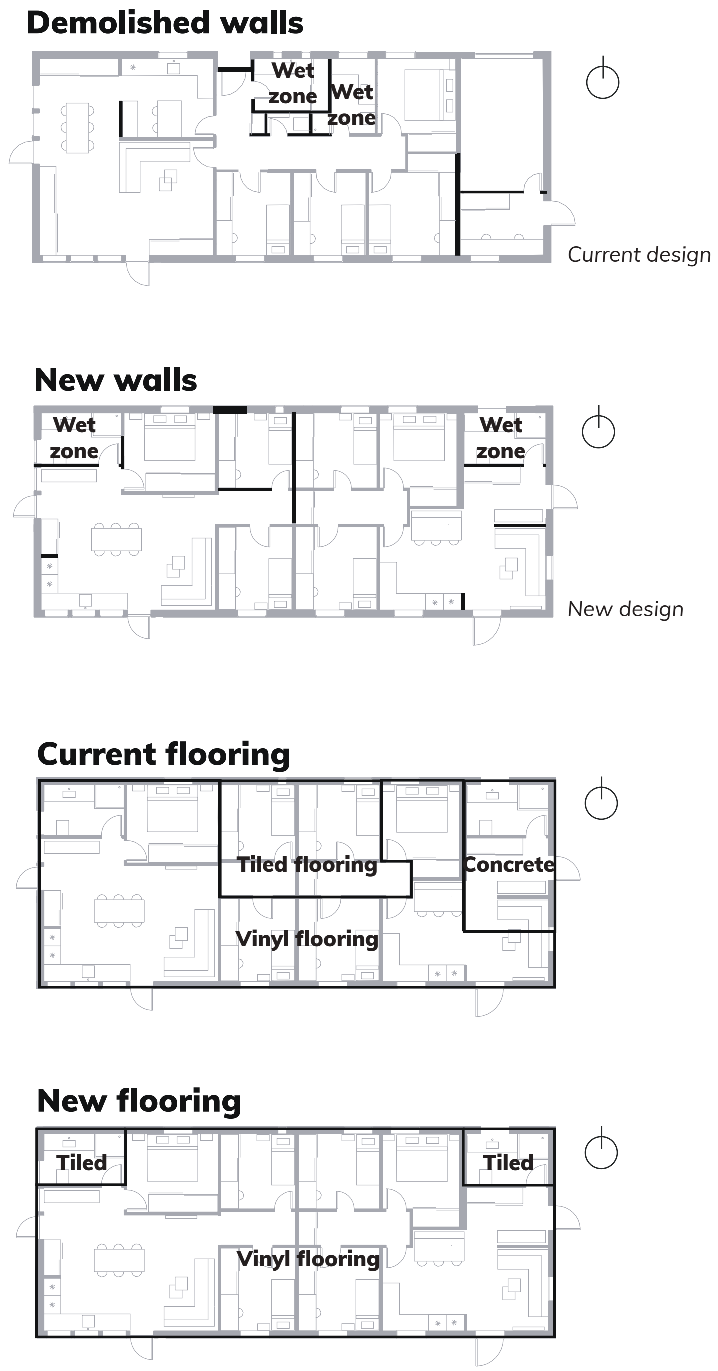
Internal cladding, flooring

Currently, the house features a mix of materials, some rooms have tiles, others have wood-look vinyl, while the garage has exposed concrete (see ill. 72). The flooring strategy aimed to preserve the home's existing character while allowing for future adaptability and personalization. A minimalist approach was chosen, where materials serve as a neutral base for the occupants' own expressions.

One option was to retain the existing flooring and only replace it where necessary, such as in areas with new internal layouts or no current flooring, e.g., the garage. However, the inconsistency of tile types and the lack of cohesion in the vinyl surfaces, particularly between the main living area and office, made this solution less aligned with the minimalist vision.

Instead, wooden flooring was explored as a more coherent and flexible alternative. Unlike vinyl, wood can be sanded, stained, or painted, offering long-term adaptability without full replacement. Individual planks can also be swapped out if needed. Beyond its practicality, wood adds warmth and tactility, enhancing the spatial atmosphere. Furthermore, since the existing tiled areas no longer serve their original function, it was considered appropriate to remove all flooring and start anew. As the tiles are fixed with mortar and cannot be reused, new tiles were proposed for the redesigned wet zones.

Moving forward, the decision is to incorporate wooden flooring for the main areas, offering flexibility and warmth, while introducing new tiled flooring in the wet zones to ensure both functionality and cohesion.



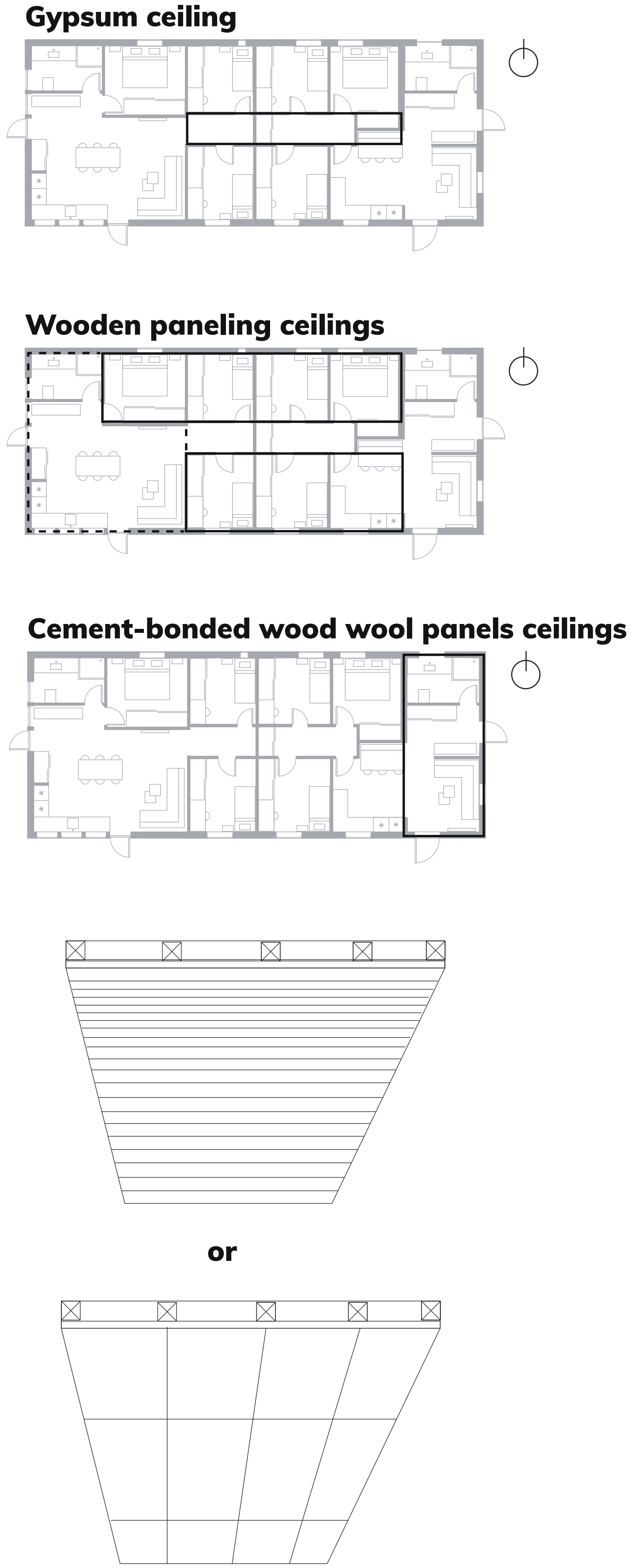
Ill. 72. Flooring, CREDIT "demolished walls" floorplans are based on original floorplan of Åstrupskrænten 45, from the local building archive at Norddjurs Municipality. (FilArkiv, Norddjurs Municipality). Modified by the author.

Internal cladding, ceiling

This analysis explores two ceiling options: wooden panelling and gypsum boards. The original 1974 design featured gypsum boards in the hallway and narrow wooden panels elsewhere, while the current living room has wider wooden panels. Both materials can be painted or stained to create a personal aesthetic.

Reintroducing wooden panelling, stained in a light tone, offers a way to honour the home's original character while enhancing tactility. Wood allows for easy replacement of individual panels and potential reuse if dismantled with care. Although gypsum boards may be easier to paint due to their uniform, non-organic surface. From an environmental perspective, wood is the more sustainable choice, emitting significantly less CO_2 per m² (–1.993e-04 kg CO_2-eq) compared to gypsum boards (5.510e-04 kg CO_2-eq). Furthermore, with reuse in mind, the old wooden panelling can be removed from areas where it's no longer needed and reinstalled elsewhere, allowing existing materials to be repurposed within the house.

Moving forward, wooden panelling will be used for all ceilings to ensure material consistency and enable long-term flexibility.



Ill. 73. *Ceiling*

Internal cladding, walls

To reintroduce some of the tactile and visual qualities of the original house, where ceilings featured painted or stained wooden boards, wood has been considered for new internal wall cladding. As only a few new walls are added, the goal is to balance minimalism, personalization, low emissions, and design for disassembly.

Plywood and wooden boards both support circular principles, as they eliminate the need for plastering and can be more easily disassembled. Plywood has the lowest emissions (–3.370e-04 kg CO_2-eq/m^2), but its strong surface pattern can limit personalization. Wooden boards emit slightly more (–1.993e-04 kg CO_2-eq/m^2) but align better with the house's original aesthetic.

Gypsum boards have the highest emissions (5.510e-04 kg CO_2-eq/m^2) and require full plastering and painting, making them less suitable for reuse and more difficult to dismantle.

Given the small scale of new interior walls, using plywood as a base for plaster and paint is the preferred solution. This creates a smooth, neutral surface that aligns with the minimalist vision, emits less than gypsum, and allows future occupants to adapt the spaces.

Moving forward, painted plywood panels will be used for new interior walls, combining low environmental impact with visual cohesion and long-term adaptability.

Ill. 74. Walls, CREDIT "demolished walls" floorplan is based on original floorplan of Åstrupskrænten 45, from the local building archive at Norddjurs Municipality. (FilArkiv, Norddjurs Municipality). Modified by the author.

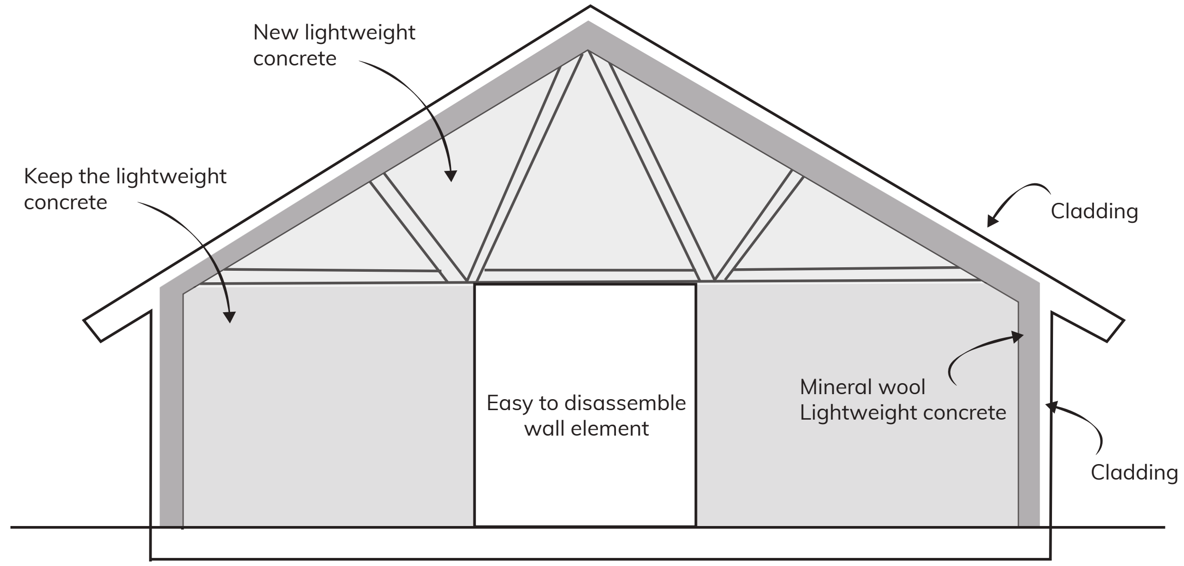
Internal cladding, flexible walls

In the new internal spatial layout, a combination of permanent fireproof walls and a movable fireproof wall element is planned. Since most of the existing walls in this area are already fireproof, it makes sense to retain them in their current state. However, one additional permanent wall is required and must be constructed from scratch. For Åstrupskrænten 45, it makes sense to build it as a gypsum wall, as concluded from *Design phase 1*, due to its ease of disassembly and potential for reuse. The movable wall element, on the other hand, requires a surface that can withstand being repeatedly mounted and demounted without damage. Therefore, it is relevant to investigate which type of material should be used as a cladding.

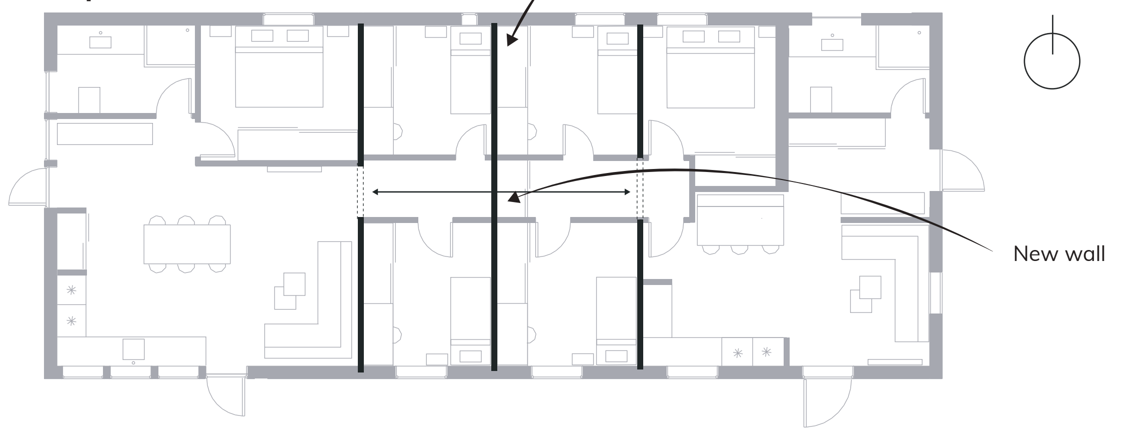
Using wooden panelling boards offers several advantages. The joints and screws can be discreetly concealed between the panels, creating a more refined finish. Additionally, this type of cladding can have sound-reflective properties, which helps reduce echo and improve acoustics in the long, narrow hallway.

Alternatively, using plywood as a cladding would introduce fewer material layers, as it consists solely of wood. However, plywood often brings a strong visual pattern that may result in a bold and overwhelming aesthetic. While the surface could be painted to soften the expression, the joints between the boards would remain visible, which could compromise the overall appearance.

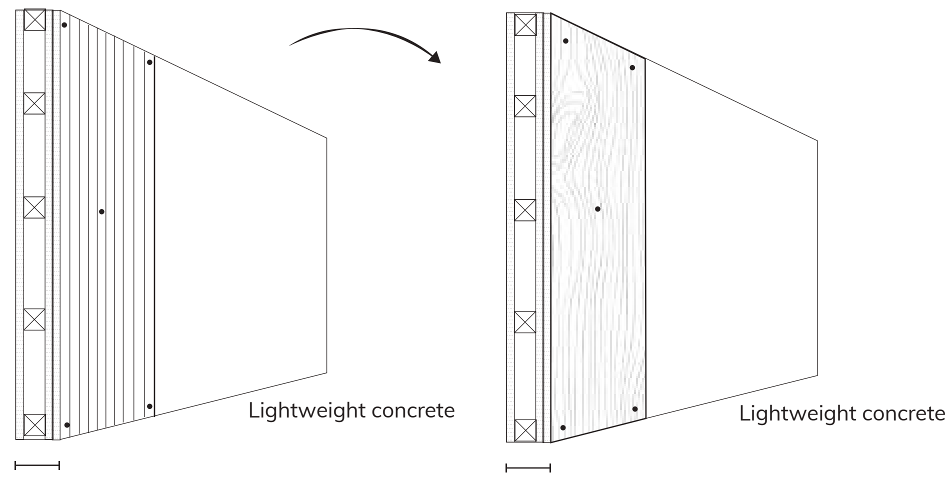
In conclusion, wooden panelling boards are the most suitable solution, as they improve acoustic performance, conceal joints and fixings, and can be easily mounted and removed, making them ideal for a movable wall element in a dynamic interior layout.



Fireproof walls



Easy to disassemble wall element



Ill. 75. Flexible fire resistant walls, CREDIT section drawing is based on original architectural drawings of Åstrupskrænten 45, from the local building archive Norddjurs Municipality. (FilArkiv, Norddjurs Municipality). FilArkiv. https://public.filarkiv.dk/707. Modified by the author.

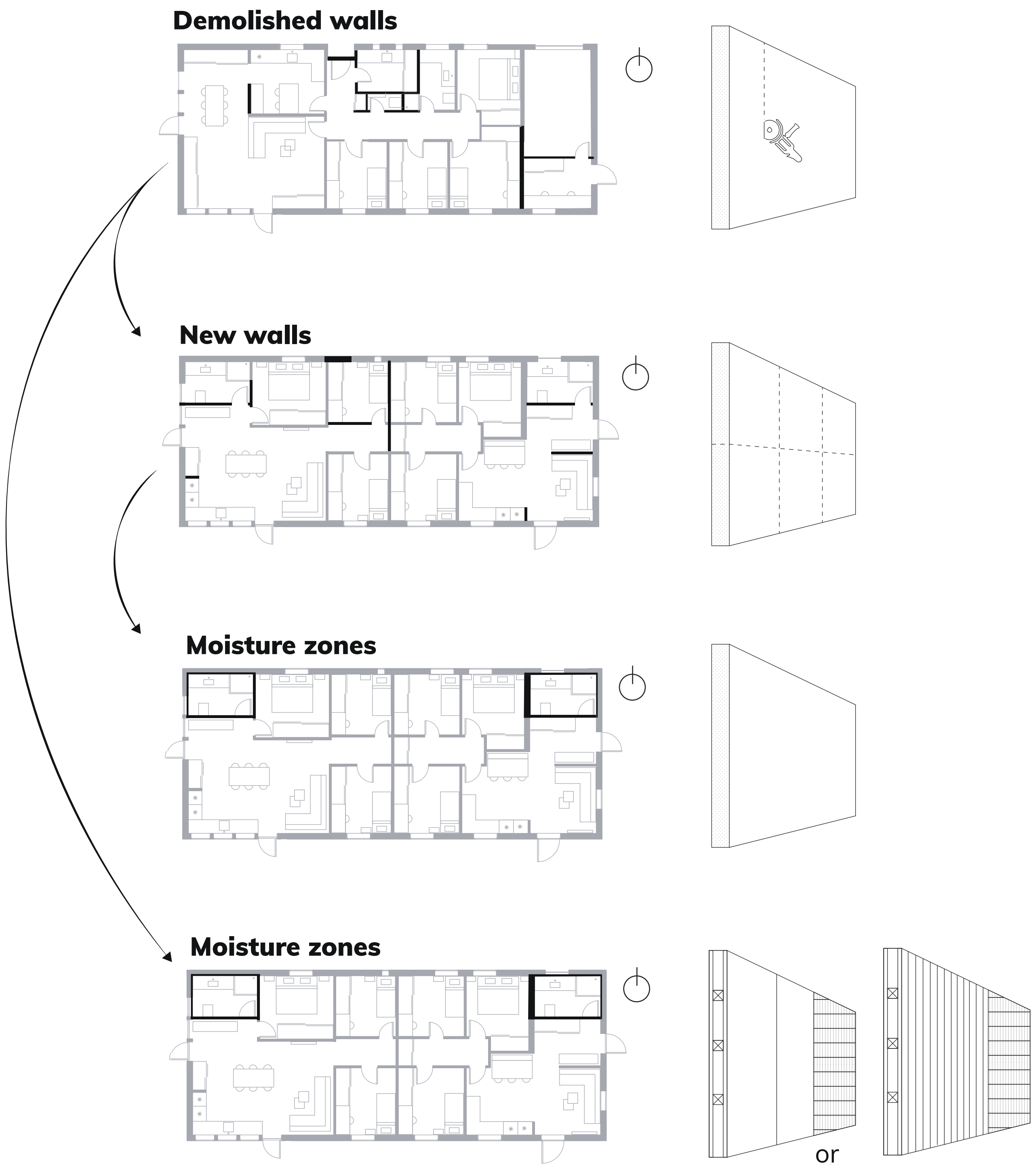
Internal cladding, wet/moisture zones

In bathroom design, two key zones are considered: the wet zone and the moist zone. The wet zone includes the area around the shower (extending 50 cm on each side), the entire floor, and the bottom 10 cm of all walls. Here, full waterproofing is essential, achieved by using wet room gypsum, concrete, or calcium silicate boards covered with a waterproof membrane and finished with water-resistant cladding like tiles (Schjervig, Nielsen, 2024). In the current house, some internal walls must be demolished and rebuilt. To reduce waste, reuse of the existing lightweight concrete walls was investigated. These are suitable for wet zones but offer limited future disassembly potential.

Materials in the moisture zone must be moisture-resistant, such as plywood, particle boards, or wooden panelling (Schjervig, Nielsen, 2024). However, combining large tiles with wood cladding risks introducing too many visual patterns, making the space appear cluttered and harder to personalize.

Since much of the internal wall material will be dismantled and needs to be reused, incorporating it into both wet and moist zones is a practical choice. As these areas are unlikely to change frequently, more permanent solutions are appropriate. Referencing the home's original material palette from the 1970s further strengthens the design narrative.

Moving forward, wet zones will be tiled, while moisture zones will reuse existing lightweight concrete, replastered and painted, creating a cohesive and historically rooted yet contemporary bathroom design.



Ill. 76. Wet/moisture zones, CREDIT "demolished walls" floorplan is based on original floorplan of Åstrupskrænten 45, from the local building archive at Norddjurs Municipality. (FilArkiv, Norddjurs Municipality). Modified by the author.

Energy performance, phase B6

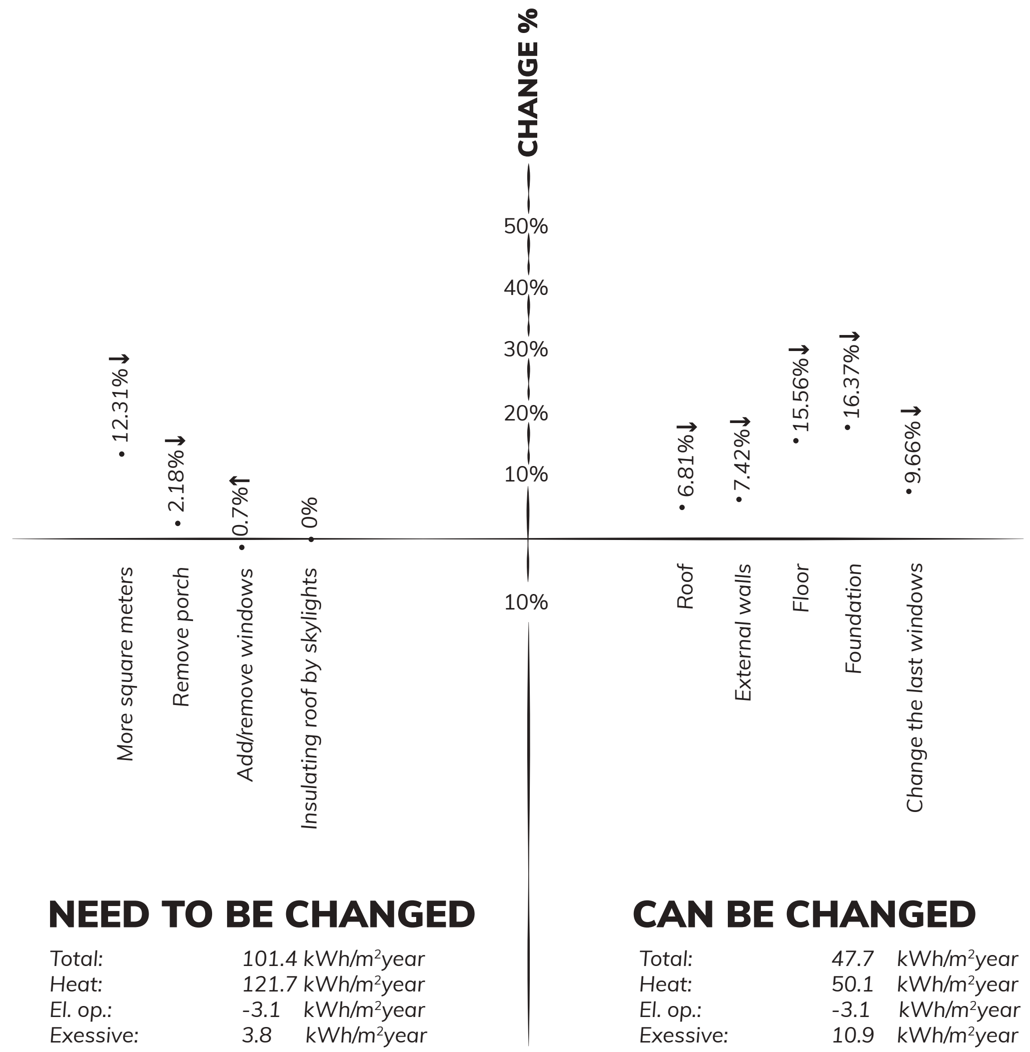
The existing building has an energy use of 112.1 kWh/m²/year, including 134.2 kWh/m²/year for heating and -3.7 kWh/m²/year from operational electricity, with 5.2 kWh/m²/year of overheating (see App. 5). To meet the renovation class, consumption must drop below 71.3 kWh/m²/year. Based on *Design Phase 1*, several elements (see pp. 112-119) are suggested for optimization, while others must be adapted to meet new functional, and occupancy needs. In terms of global warming potential (GWP) the existing building emits 9.171e+00 kg CO_2-eq./m²/year, and when the required changes are made, it emits 8.328e+00 kg CO_2-eq./m²/year. (See ill. 77)

Due to added insulation and larger windows, passive strategies were explored to reduce summer overheating without mechanical cooling:

1. Keeping walls/roof/floor uninsulated = reduced overheating but harmed energy performance.
2. Skipping thermal bridge renovation = had a similar trade-off.
3. Reducing window size = helped but risked poor daylight levels.
4. Shading (external and curtains) = had minor effect.
5. Natural ventilation optimization (cross and stack effect) = showed the most promise, though it relies on user behavior.

Preserving the existing floor was key, limiting structural interventions and maintaining stability, as internal walls likely lack separate strip foundations. Furthermore, the window strategy was refined, so existing windows were reused where possible, and some large floor-to-ceiling windows were replaced with 1.2 × 1.2 m units for better performance and facade coherence. Lastly, the internal doors were thought to be designed to lock open, enhancing natural ventilation throughout the home.

After all proposed changes, the building meets energy class requirements and reduces emissions to 3.343e+00 kg CO_2-eq./m²/year, while mitigating overheating through passive strategies.



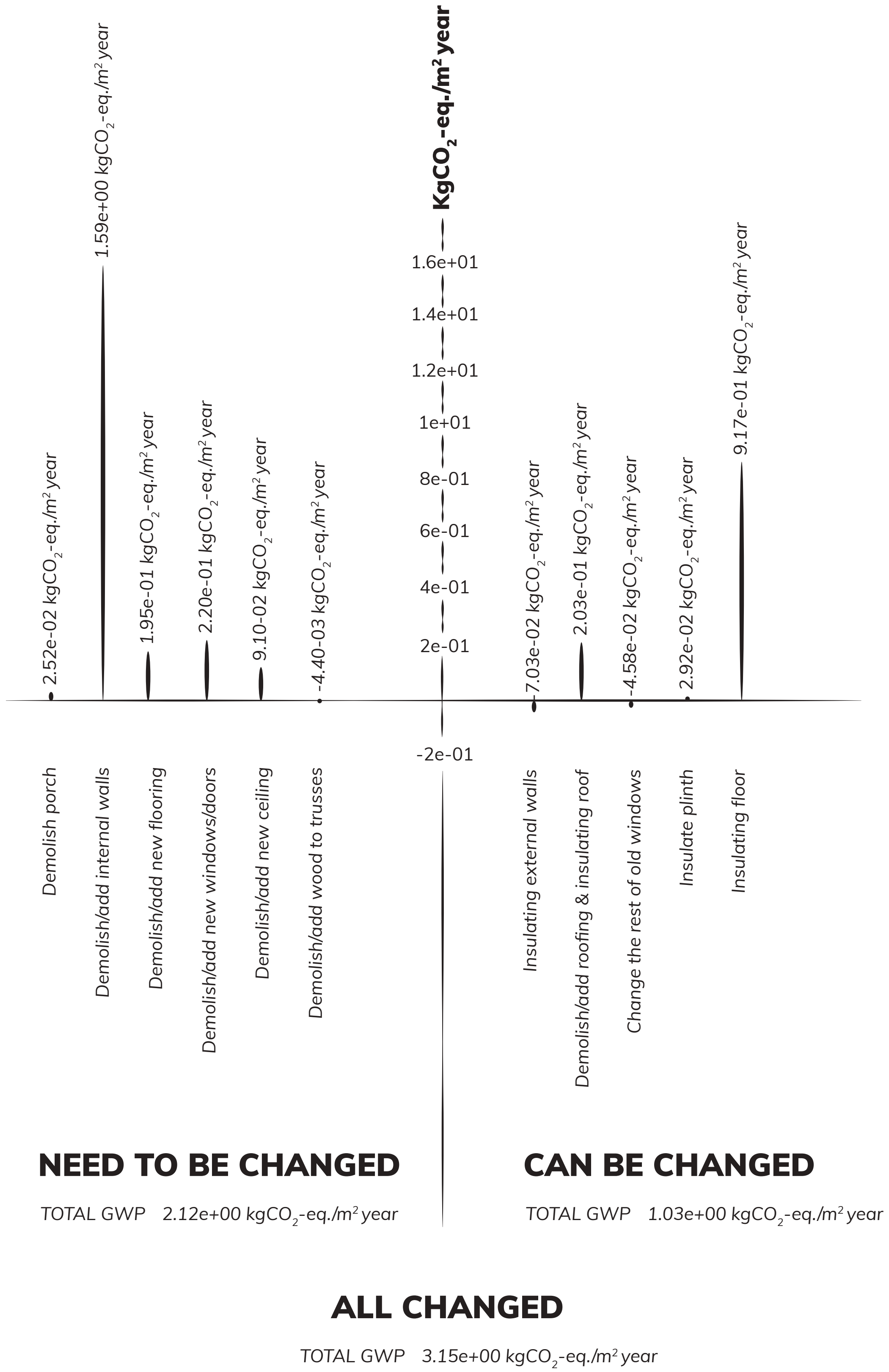
Ill. 77. Energy optimization, phase B6

Material emissions, A1-3, B4, C3-4, D

When conducting an LCA on generic EPDs, of the transformed building, some elements must be modified to accommodate an increased number of occupants, while others are optional improvements. The elements have been evaluated in terms of their impact on the building's energy performance. However, the focus in this section shifts to the environmental emissions associated with those changes. Specifically, this section assesses emissions from four key life cycle stages:

- A1–A3: The production of materials, including raw material extraction, transport, and manufacturing
- B4: The replacement of materials during the building's use phase
- C3–C4: Waste processing and final disposal at the end of the material's life
- D: Potential benefits beyond the system boundary, such as reuse, recycling, or energy recovery

Moving forward, it makes sense to prioritize energy optimization in phase B6, as the other phases do not significantly impact the overall emissions (see ill. 78). Without improvements in phase B6, the annual emissions will remain unacceptably high.



Ill. 78. Material emissions, phase A1-3, B4, C3-4, and D

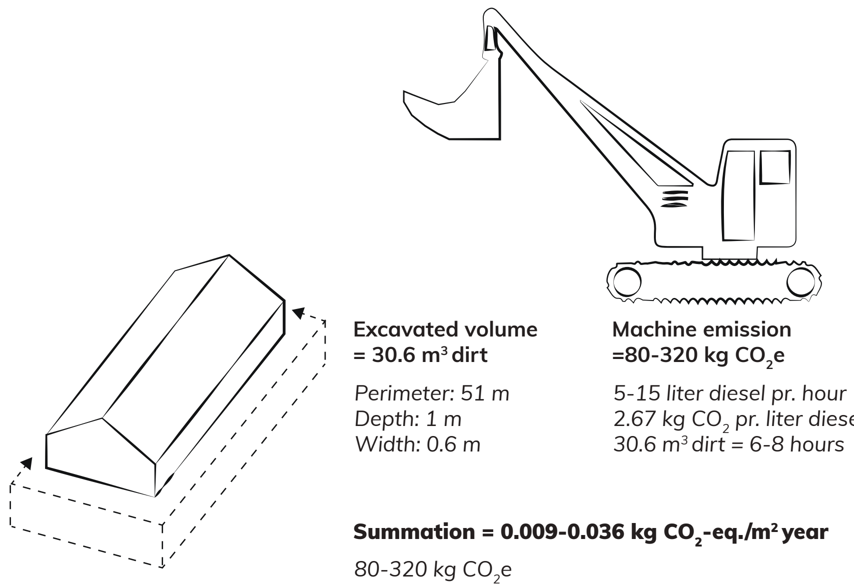
Assembly and demolition, A5 and C1

So far, life cycle assessments have mainly focused on operational energy and material emissions, overlooking impacts from installation and demolition. The following section addresses these aspects, corresponding to life cycle stages A5 and C1.

A5: The installation of a building element.
Most of the new elements, such as the internal walls, floors, ceilings, windows, doors, insulation, and truss reinforcement, can be installed without heavy machinery. Only light power tools like drills, nail guns, and saws are needed. For roof and plinth insulation, specific equipment (e.g., insulation blowers or trench diggers) may be required. (See illu. 79)

C1: The demolition of a building element.
The existing internal walls, floors, ceilings, trusses, windows, doors, and parts of the facade can be removed manually. Reusable elements should be dismantled carefully and stored on-site. Exceptions include the tiled floors, which may need grinding, and the concrete slab, where a demolition hammer and electric wheelbarrow could be necessary. (See illu. 79)

Overall, emissions from A5 and C1 are minimal. Even with all proposed changes, total emissions are estimated at between 1.7e-2 and 4.4e-2 kg CO₂-eq./m²/year.



Excavated volume
= 30.6 m³ dirt

Perimeter: 51 m
Depth: 1 m
Width: 0.6 m

Machine emission
=80-320 kg CO_2e

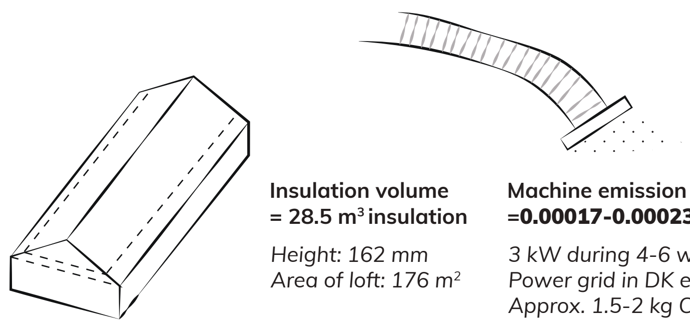
5-15 liter diesel pr. hour
2.67 kg CO_2 pr. liter diesel
30.6 m³ dirt = 6-8 hours

Summation = 0.009-0.036 kg CO_2-eq./m² year

80-320 kg CO_2e

$\frac{80 \text{ kg } CO_2e}{176 \text{ m}^2 \times 50 \text{ year life time}}$ = 0.009 kg CO_2-eq./m² year

$\frac{320 \text{ kg } CO_2e}{176 \text{ m}^2 \times 50 \text{ year life time}}$ = 0.036 kg CO_2-eq./m² year



Insulation volume
= 28.5 m³ insulation

Height: 162 mm
Area of loft: 176 m²

Machine emission
=0.00017-0.00023 kg CO_2-eq./m² year

3 kW during 4-6 working hours = approx. 12-18 kWh
Power grid in DK emits approx. 100–150 g CO₂e/kWh
Approx. 1.5-2 kg CO_2e

$\frac{1.5 \text{ kg } CO_2e}{176 \text{ m}^2 \times 50 \text{ year life time}}$ = 0.00017 kg CO_2-eq./m² year

$\frac{2 \text{ kg } CO_2e}{176 \text{ m}^2 \times 50 \text{ year life time}}$ = 0.00023 kg CO_2-eq./m² year

In total: 0.017-0.044 kg CO_2-eq./m² year

Excavated
= 136 tons

Gravel: 176 m² x 0.2 m =35.2 m³ x 1,600 kg/m³ = 56.3 kg
Concrete: 176 m² x 0.13 m =22.9 m³ x 2,550 kg/m³ = 57,200 kg
Leca: 176 m² x 0.13 m =22.9 m³ x 700 kg/m³ = 16 kg
Vinyl: 176 m² x 0.022 m =3.9 m³ x 1,400 kg/m³ = 5,428.8 kg

Summation =0.008 kg CO_2-eq./m² year

70.5 kg CO_2e

$\frac{70.5 \text{ kg } CO_2e}{176 \text{ m}^2 \times 50 \text{ year life time}}$ = 0.008 kg CO_2-eq./m² year

Machine emission
=70.5 kg CO_2e

Power grid in DK emits around 100–150 g CO_2e/kWh
Approx. 30 kWh
2.67 kg CO_2 pr. liter diesel

25 L diesel × 2.31kg CO_2/L = 66.75 kg CO_2e
30 kWh × 0.125 kg CO_2e/kWh = 3.75 kg CO_2e
3.75kg CO_2e + 57.75kg CO_2e = 70.5 kg CO_2e

Ill. 79. Assembly and demolition, phases A5 and C1

Transport, phases A4 and C2

The transport emissions related to the renovation are estimated based on the assumption that all materials are locally sourced. Therefore, this analysis provides only a simplified and indicative picture of potential emissions. A more accurate calculation could have been made using specific EPDs, but without knowing the exact materials to be used, this could lead to misleading results.

The following is a list of the materials selected for the renovation, along with their production locations and distances to the project site in Grenaa:

- Wooden boards, Aros Savværk, 8400 Ebeltoft (33 km)
- Paint, Promal A/S, 7500 Holstebro (148 km)
- Gypsum boards, Knauf A/S, 9500 Hobro (76 km)
- Mineral wool insulation, ROCKWOOL A/S, 9500 Hobro (76 km)
- Mortar, Vrå Mørtelværk, 9760 Vrå (127 km)
- Wood fiber insulation, Jysk Træfiber, 7900 Nykøbing Mors (142 km)
- Roof tiles, Kambet, 34-340 Jeleśnia, Poland (933 km)
- Waterproof membrane, Danskbitum, 8400 Ebeltoft (39 km)
- Zinc roofing, RHEINZINK GmbH, 45711 Datteln, Germany (575 km)
- Cellulose insulation, ISOCELL, 164 40 Kista, Sweden (532 km)
- EPS insulation, Sundolitt A/S, 3550 Slangerup (118 km)
- Vapor barrier, DAFA Building Solutions A/S, 8220 Brabrand (61 km)
- Windows and doors, GMS ApS, Fannerup, 8560 Kolind (35 km)
- Demolished elements, Grenaa waste facility, 8500 Grenaa (2.5 km)

Mapping the origins of all removed and new materials, transport emissions are estimated at 2.4e-5 kg CO_2-eq./m²/year.

Ill. 80. Transport, phases A4 and C2

CHAPTER 4

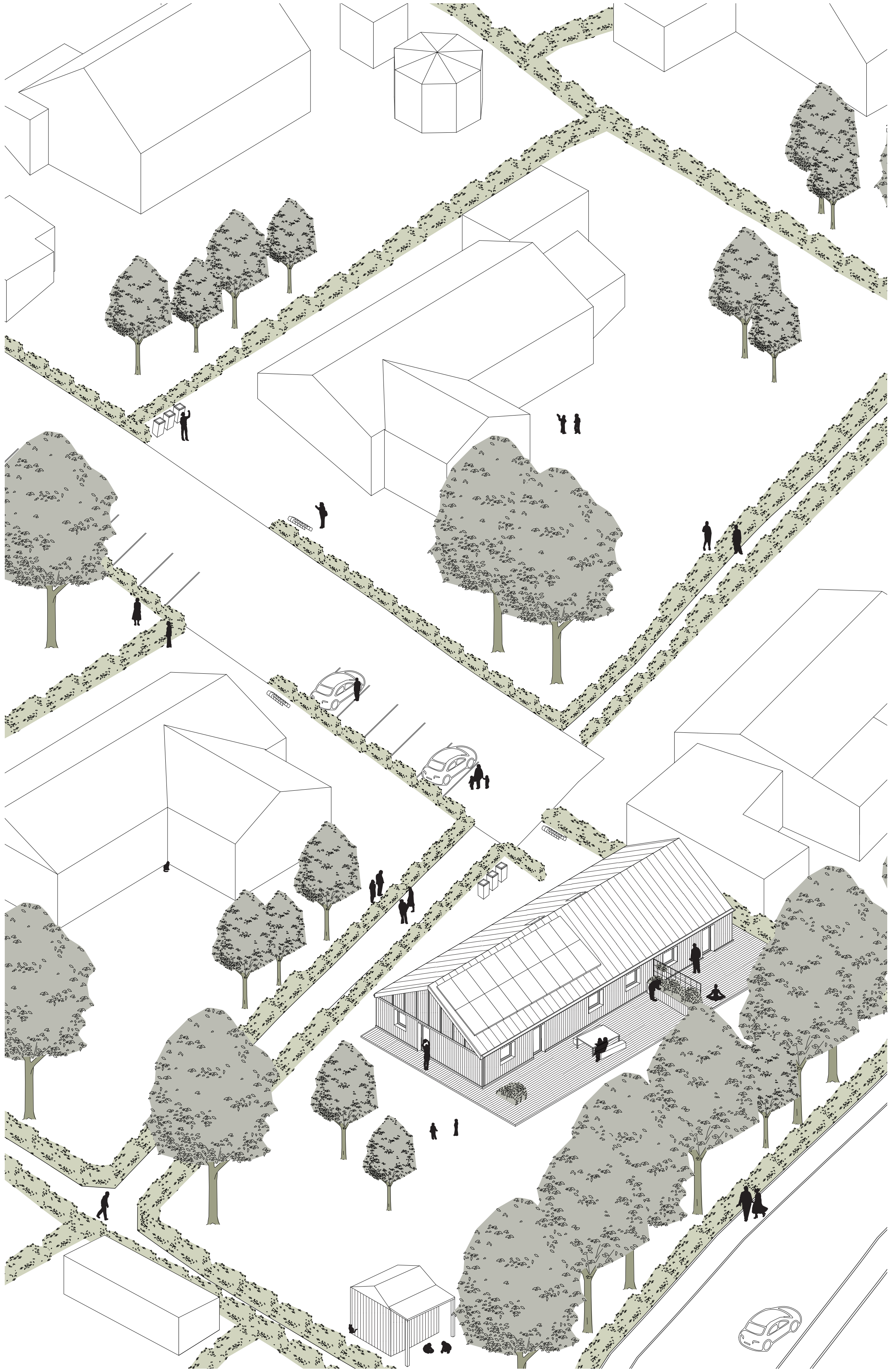
POST DESIGN PHASE

The following chapter presents the final design proposal for Åstrupskrænten as a whole, as well as for Åstrupskrænten 45 specifically. While the *Design Phase* has led to a clear direction, it is important to acknowledge that the outcome could have taken a different form had other priorities or values been emphasized.

Ill. 81. Picture of Åstrupskrænten 45

How can suburban neighbourhoods of the 1970s be sustainably transformed as a housing typology to foster new, visionary, and attractive concepts of “a good life”?

(Inspired by the Kum.dk, 2024)



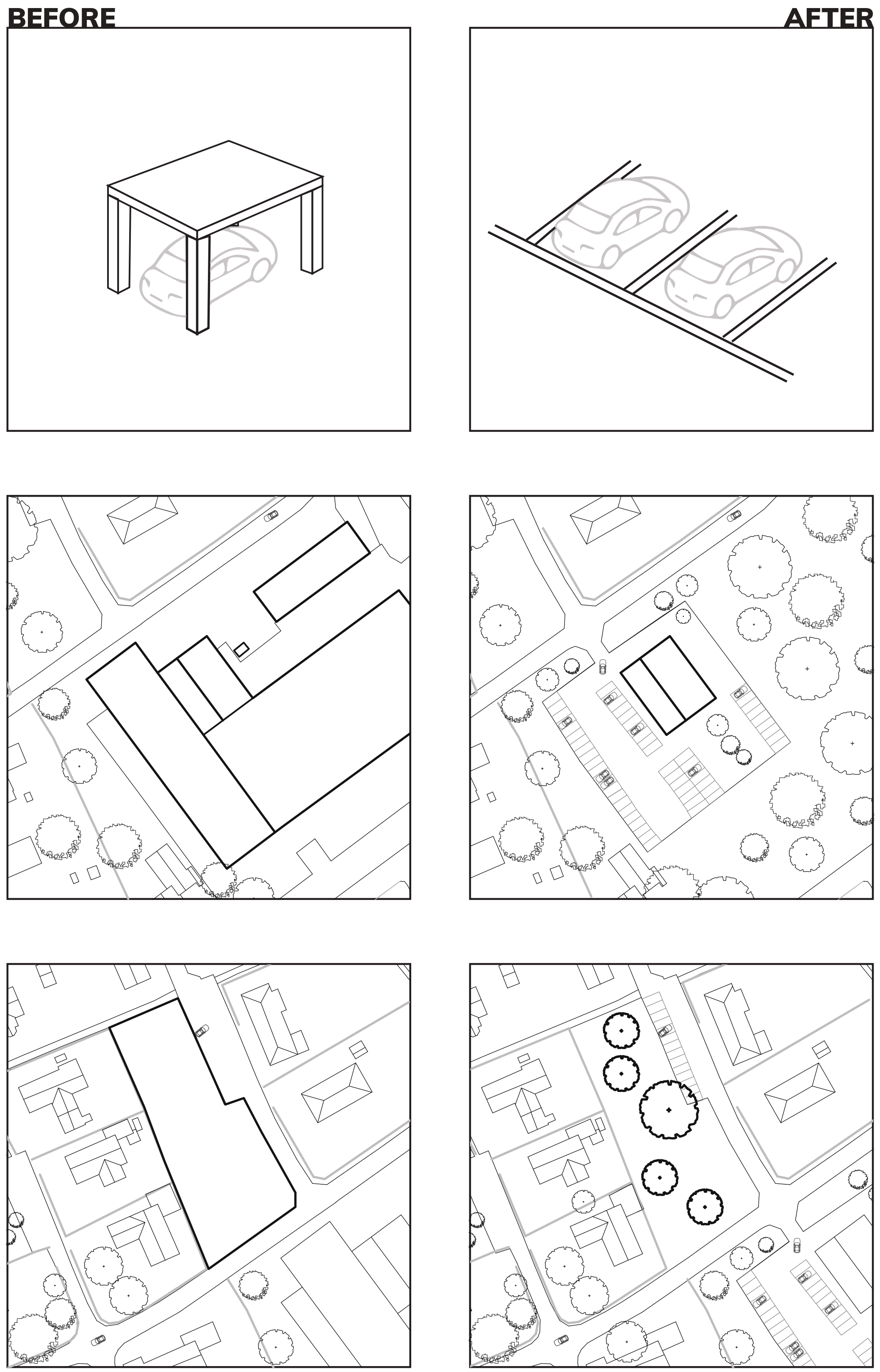
Ill. 82. Isometric of Åstrupskrænten

MASTERPLAN

Åstrupskrænten has been transformed from a typical 1970s suburban neighborhood into a vibrant community that fosters social interaction and a sense of togetherness. The houses have been redesigned to accommodate multiple households, which has increased the demand for parking. As a result, parking has been moved from private plots onto the streets to create shared spaces that naturally encourage neighborly encounters.

In the eastern part of the site, the former industrial area has been cleared, and one of the existing buildings has been repurposed into a community house for hosting larger gatherings, particularly because the new housing units are more compact. Additionally, the previously underutilized grass-area in the northeast has been transformed into a park-like space, designed for social activities, events, and informal outdoor gatherings.

Ill. 83. Future masterplan of Åstrupskrænten, scale 1:2000, CREDIT based on map from CC BY 4.0 KDS. Modified by the author.



Ill. 84. Changes made to the masterplan, CREDIT base map: CC BY 4.0 KDS. Modified by the author.

Ill. 85. Rendering of outdoor areas at Åstrupskrænten

ELEVATIONS

As shown in the elevations (see ill. 86-89), a significant change has been made to the material choices of the building. Instead of the original white brick facade, the building has been externally insulated and clad with timber. This not only allows for future disassembly if needed but also gives residents the opportunity to personalize the facade according to their preferences.

The wooden cladding also helps the building blend into the surrounding natural environment. The vertical boards echo the tall trees on the site, while the horizontal ones reference the hedgerows. Additionally, the gables feature a textured design that reflects the current two-part cladding system, adding depth and visual interest (see next page for reference).

Due to the presence of asbestos in the original roofing, it was removed and replaced with a light grey zinc roof. This new material is intended to harmonize with the timber cladding as it weathers and takes on a silvery patina. The window frames were also replaced, making it possible to use wooden frames that match the new facade material.

Ill. 86. South elevation, scale 1:200

Ill. 87. North elevation, scale 1:200

Ill. 88. West elevation, scale 1:200

Ill. 89. East elevation, scale 1:200

Ill. 90. Lines and patterns in current facade design

To reference the original aesthetic, the new facade reinterprets the house's two-part cladding: vertical above and horizontal below. This concept is retained with a predominantly vertical timber cladding, divided by horizontal panels that act as both visual breaks and functional drip edges. Varying board depths add subtle rhythm and texture.

As shown in ill. 91, the timber will develop a silver-grey patina over time, aligning with the zinc roof and allowing for future personalisation through paint. The natural tones help the house blend more seamlessly into the garden, echoing the site's trees and hedges through its vertical and horizontal lines.

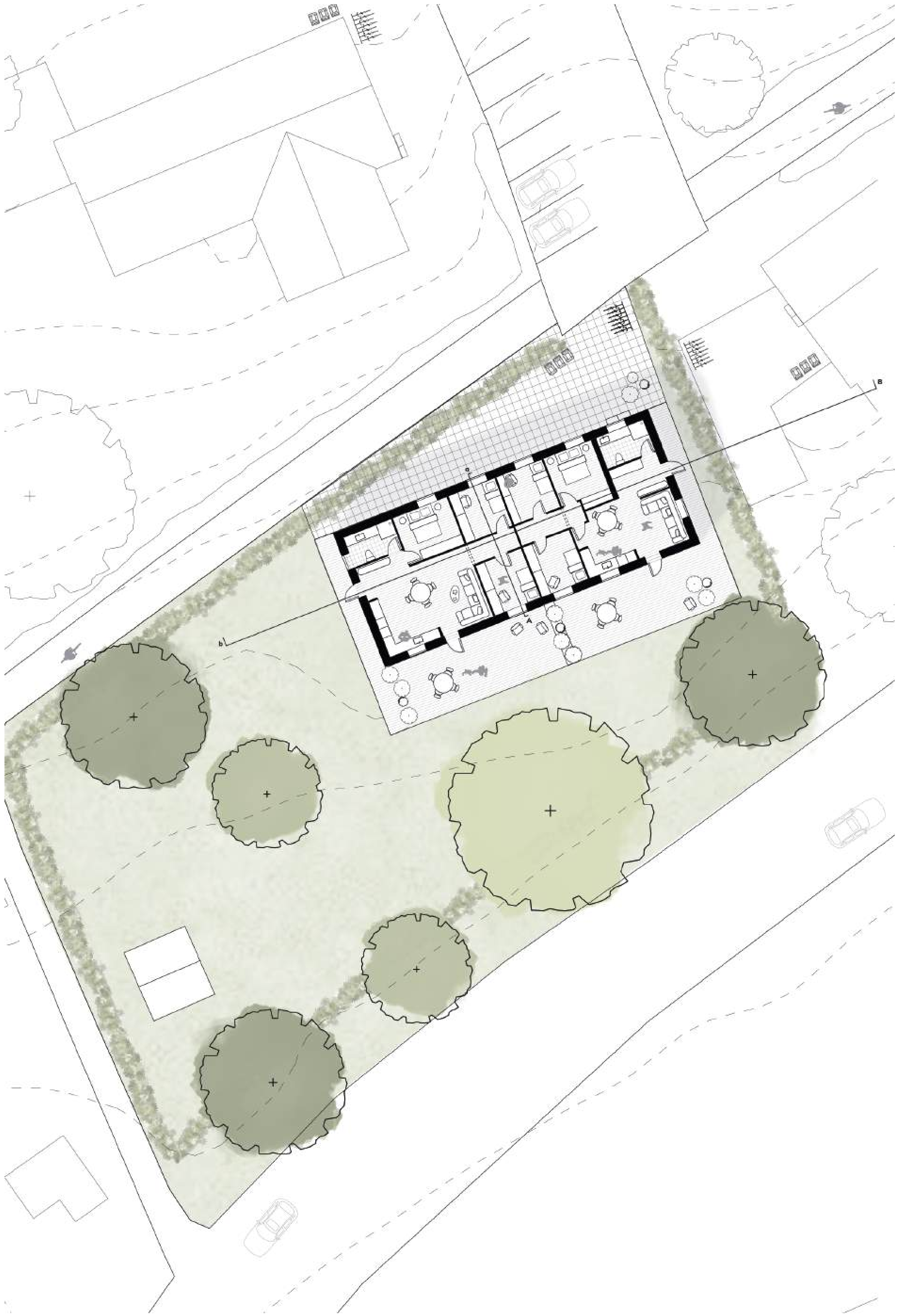
Ill. 91. Rendering of patina in the new facade

FLOORPLAN

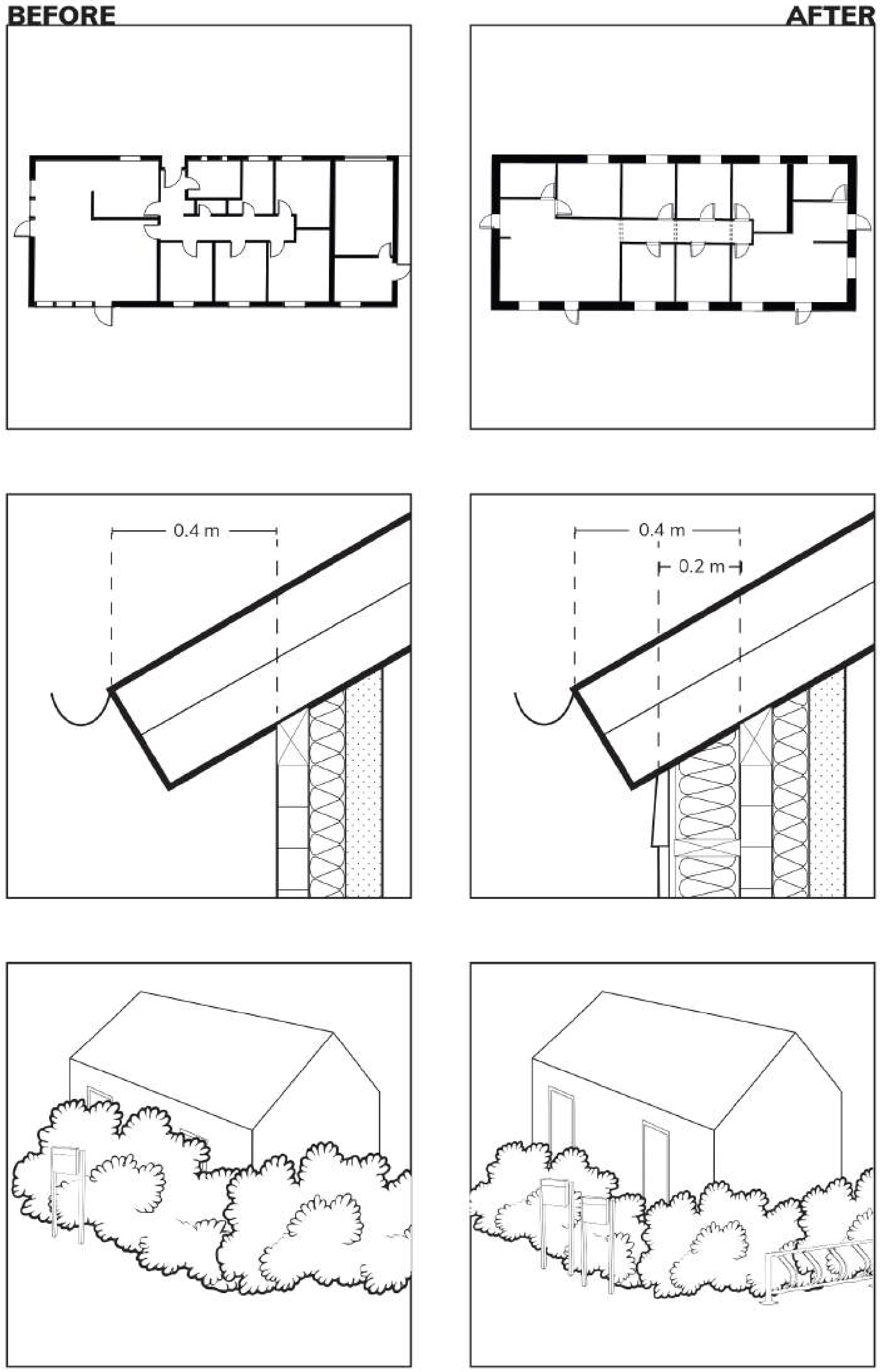
To explore how detached houses from 1970s suburban neighborhoods can be transformed, particular attention has been given to Åstrupskrænten 45, which serves as a case study. The focus has been on creating flexible interior layouts that allow the house to adapt and grow with its occupants over time.

In terms of energy optimization, special emphasis has been placed on the external walls and the architectural expression of the house. To improve insulation performance and support the new aesthetic, insulation has been added externally, resulting in thicker walls and deeper window openings.

Regarding the outdoor spaces, changes have been made to hedge heights to support social interaction. In the front yards, hedges have been lowered to create a more open atmosphere and encourage casual encounters between residents and passersby. Meanwhile, the backyards have been designed to be flexible, allowing residents to divide and organize them according to their own needs.

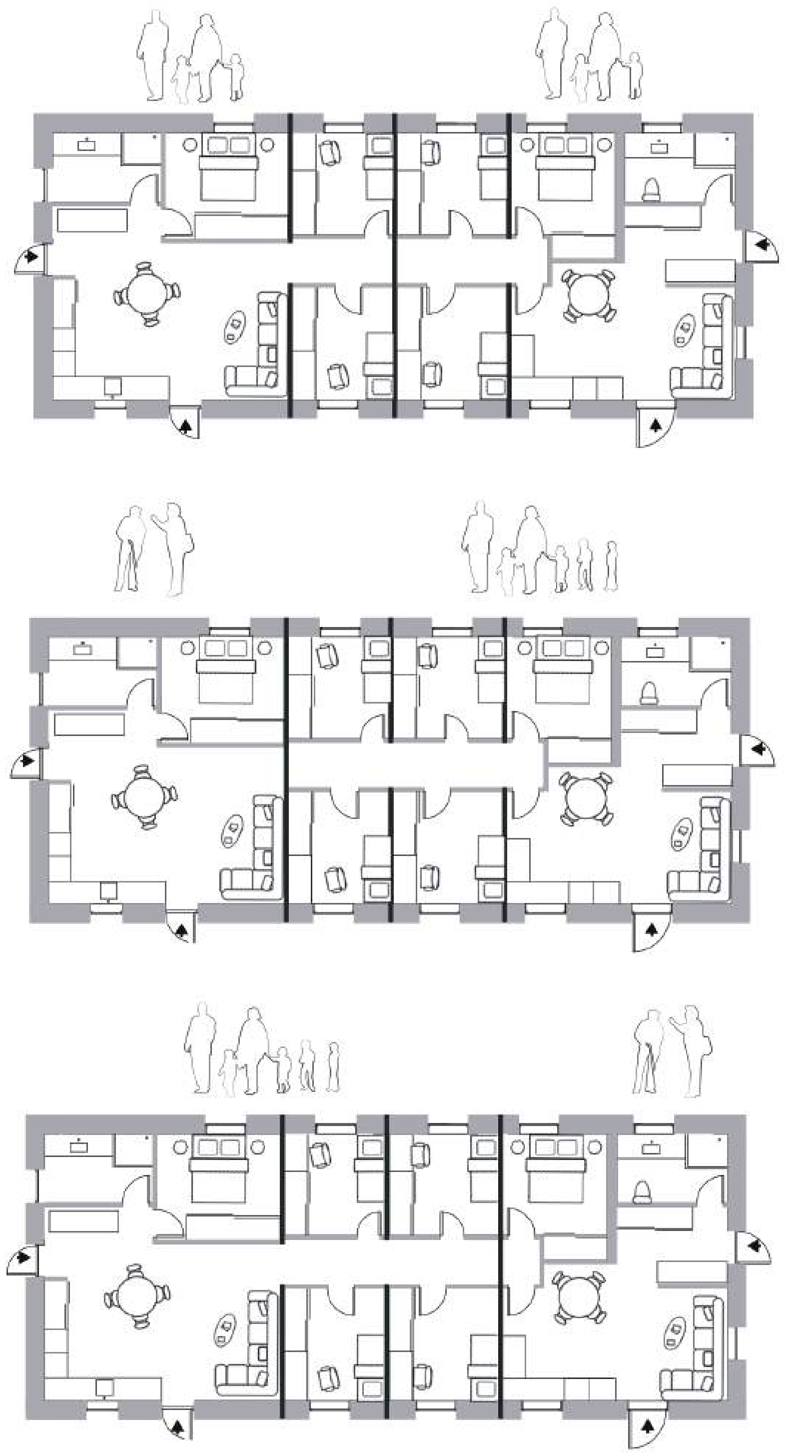


Ill. 92. Floorplan of Åstrupskrænten 45, scale 1:300, CREDIT based on map from CC BY 4.0 KDS. Modified by the author.

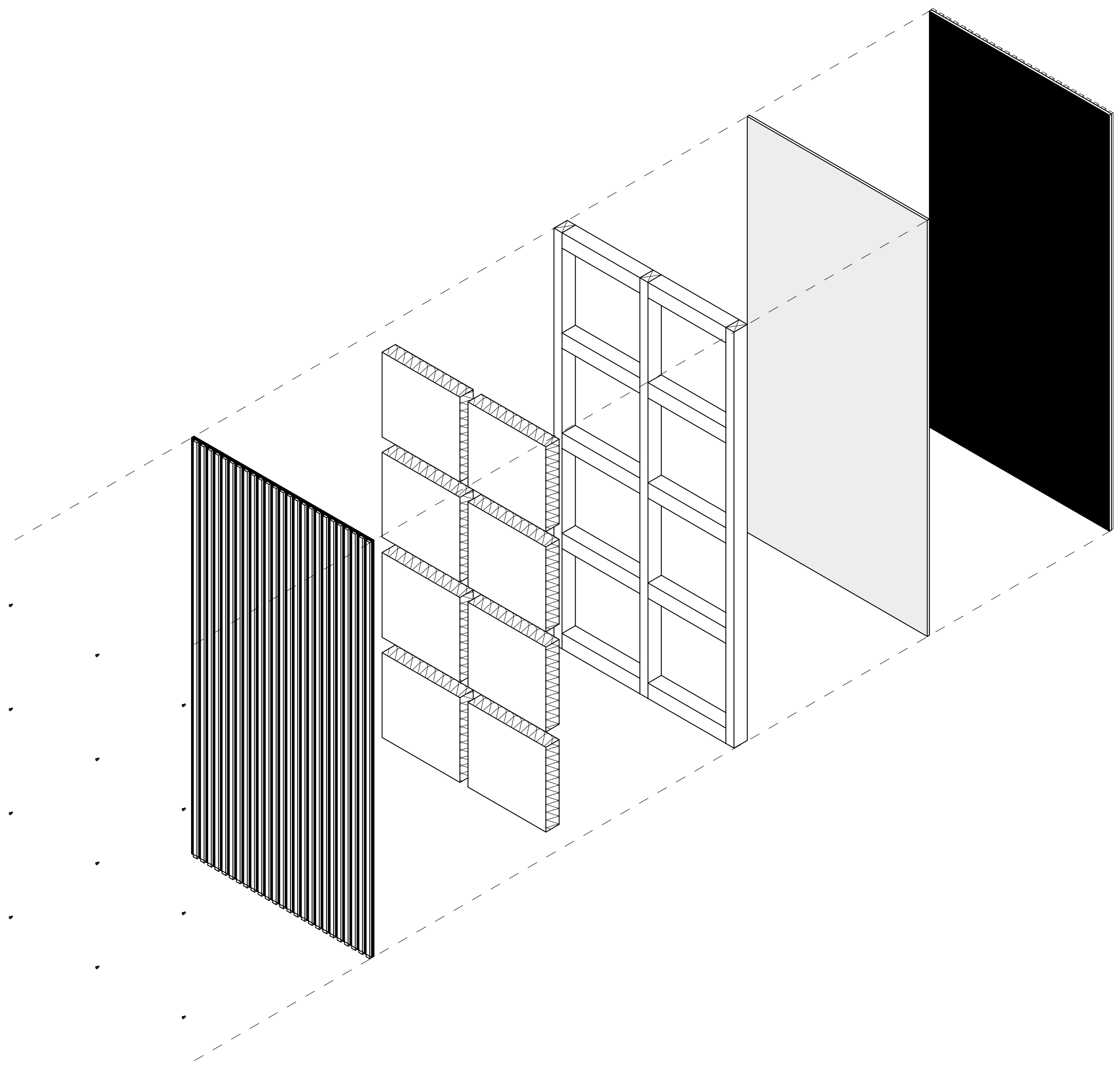


Ill. 93. Changes made to the original floorplan, CREDIT before floorplan is based on original floorplan of Åstrupskrænten 45, from the local building archive at Norddjurs Municipality. (FilArkiv, Norddjurs Municipality). Modified by the author.

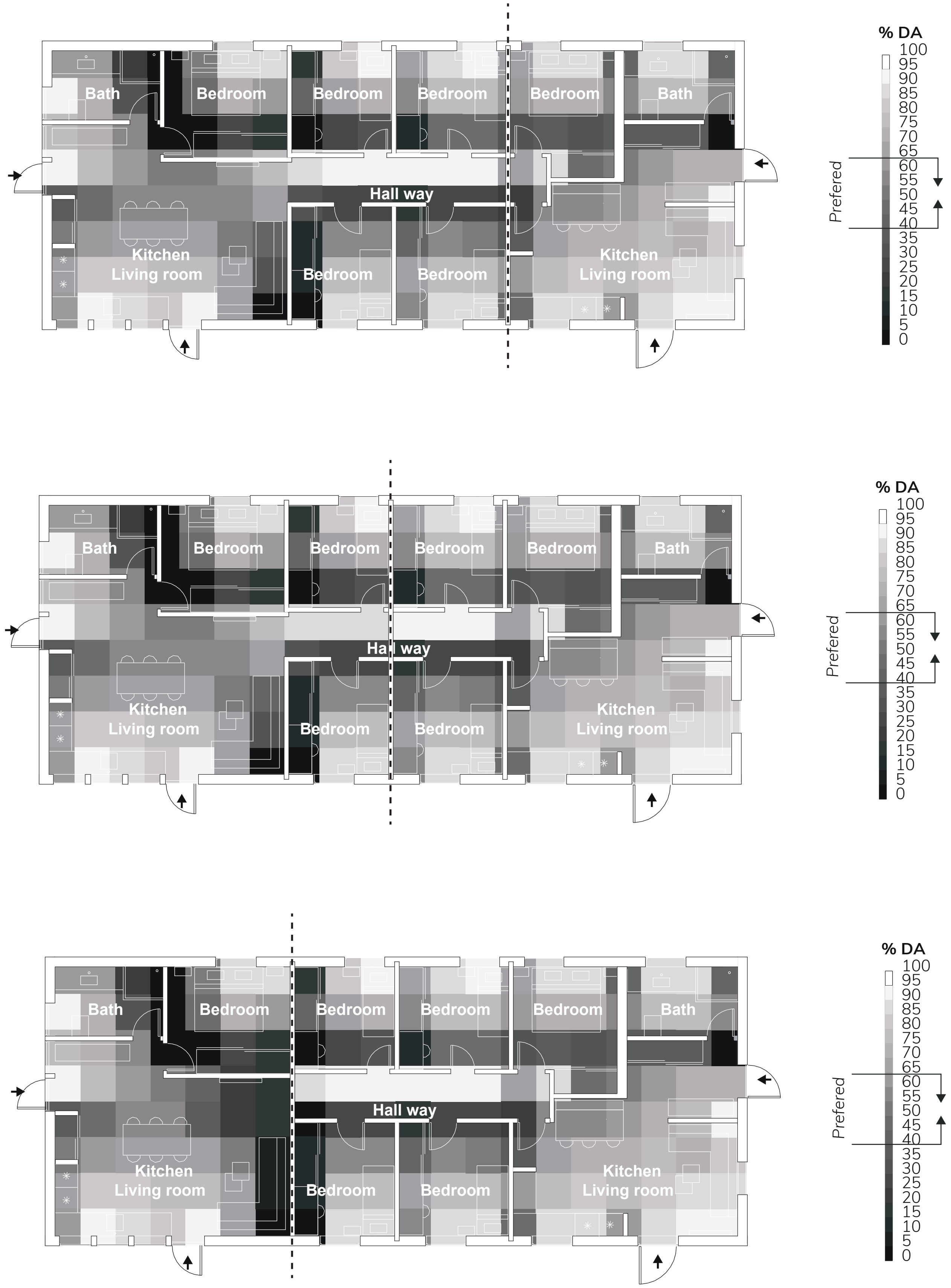
Ill. 94. Rendering from inside Åstrupskrænten 45



Ill. 95. *The flexibility of the house*



Ill. 96. *Flexible wall designed for easy disassembly*



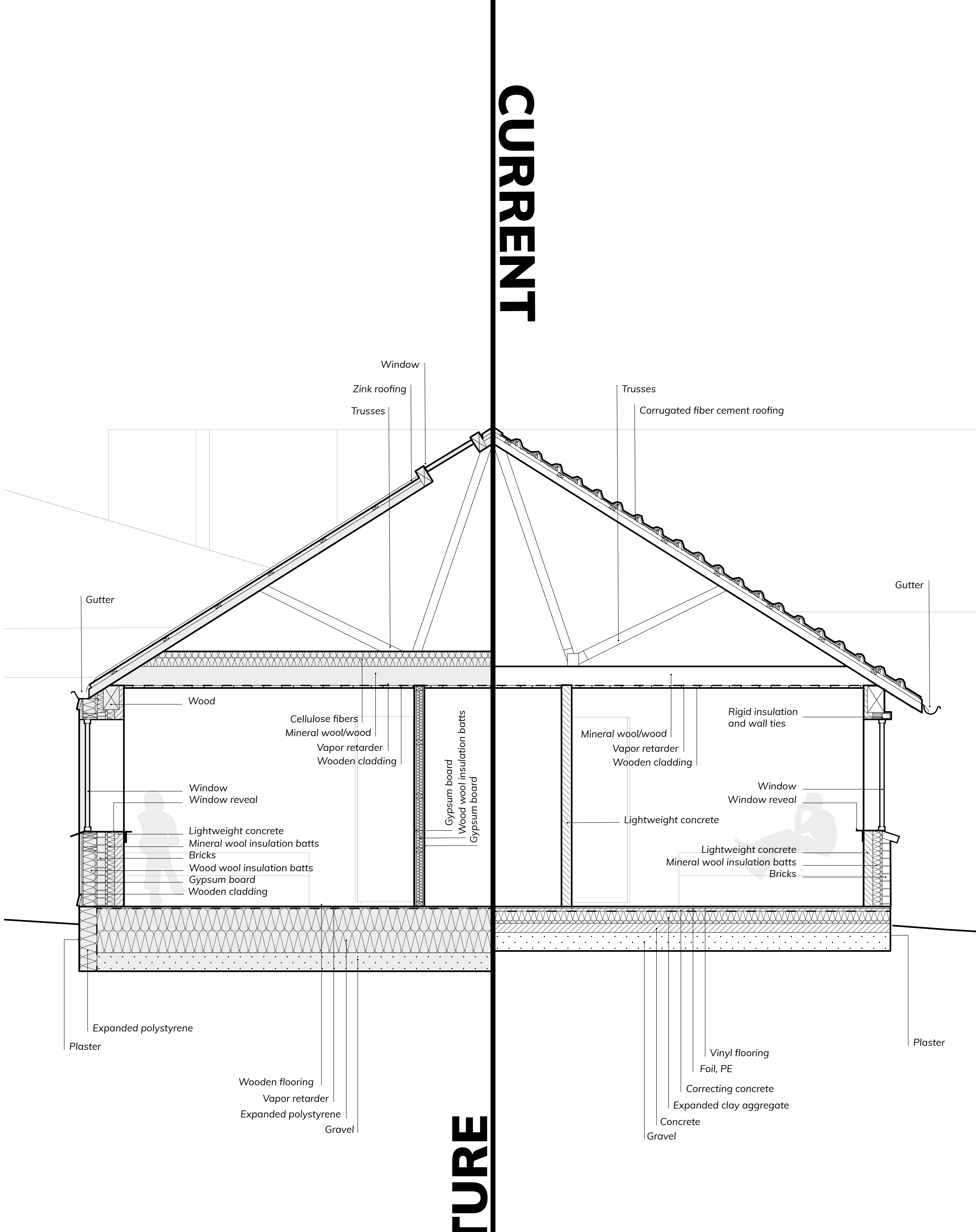
Ill. 97. Future Daylight Autonomy, Åstrupskrænten 45

Ill. 98. Rendering of hallway space

SECTIONS

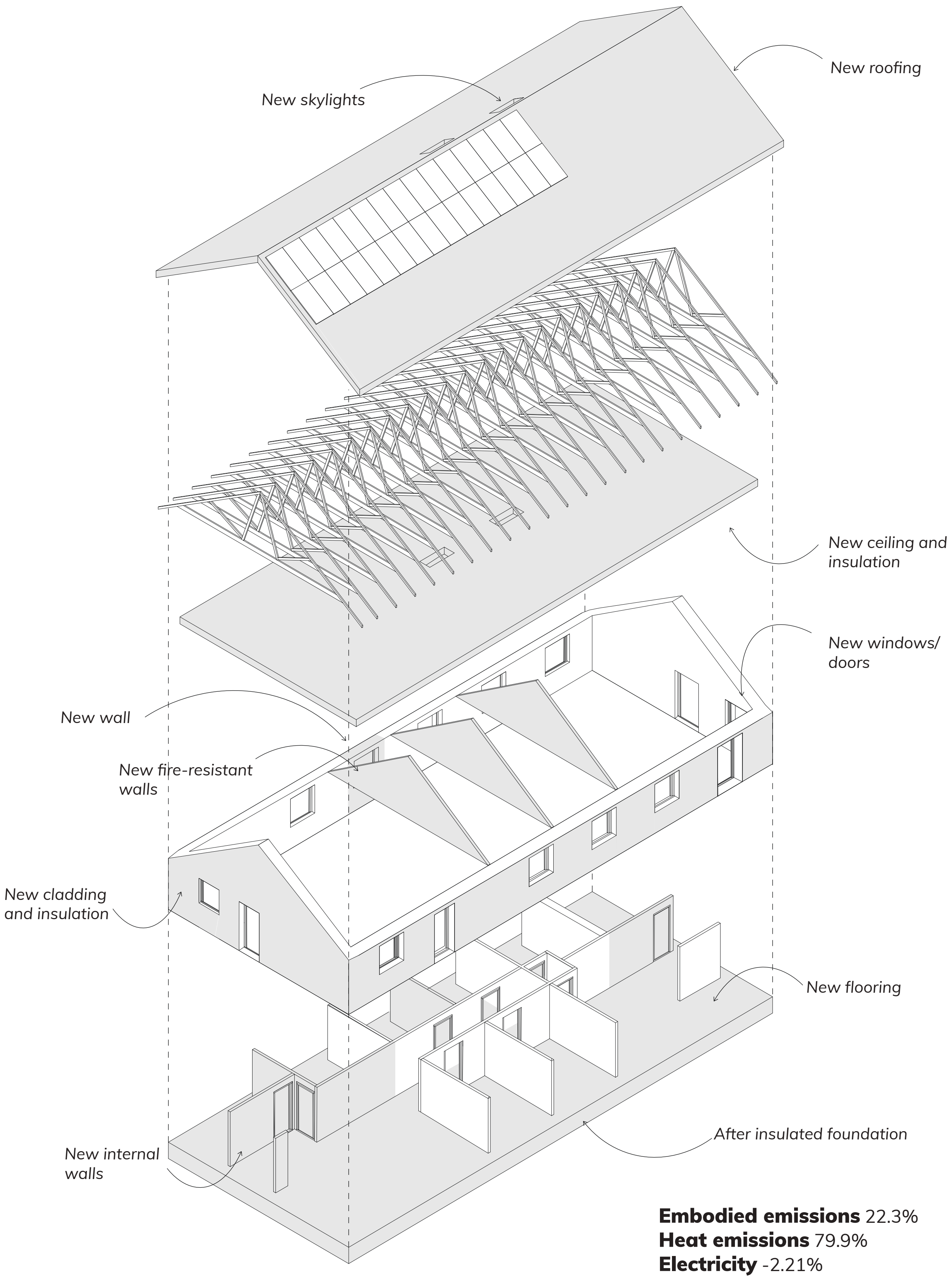
As illustrated in 99, the building envelope has undergone significant changes. The external walls have been externally insulated, and additional insulation has been added to the attic. When constructing new internal walls, lightweight materials were used to allow for easy disassembly in the future if necessary. The same principle applies to the additions on the external walls, including the new cladding and roofing, which are designed for potential removal or adjustment. In addition, the previously uninsulated plinth has now been insulated to improve the building's overall energy performance.

As shown at illustration 100, the house features a movable internal wall that can be adjusted based on the occupants' spatial needs. To ensure fire safety, this wall can only be positioned in three predetermined locations, as it must extend all the way to the roof structure. Lastly, the attic space is maintained for storage purposes only and is not otherwise utilized.

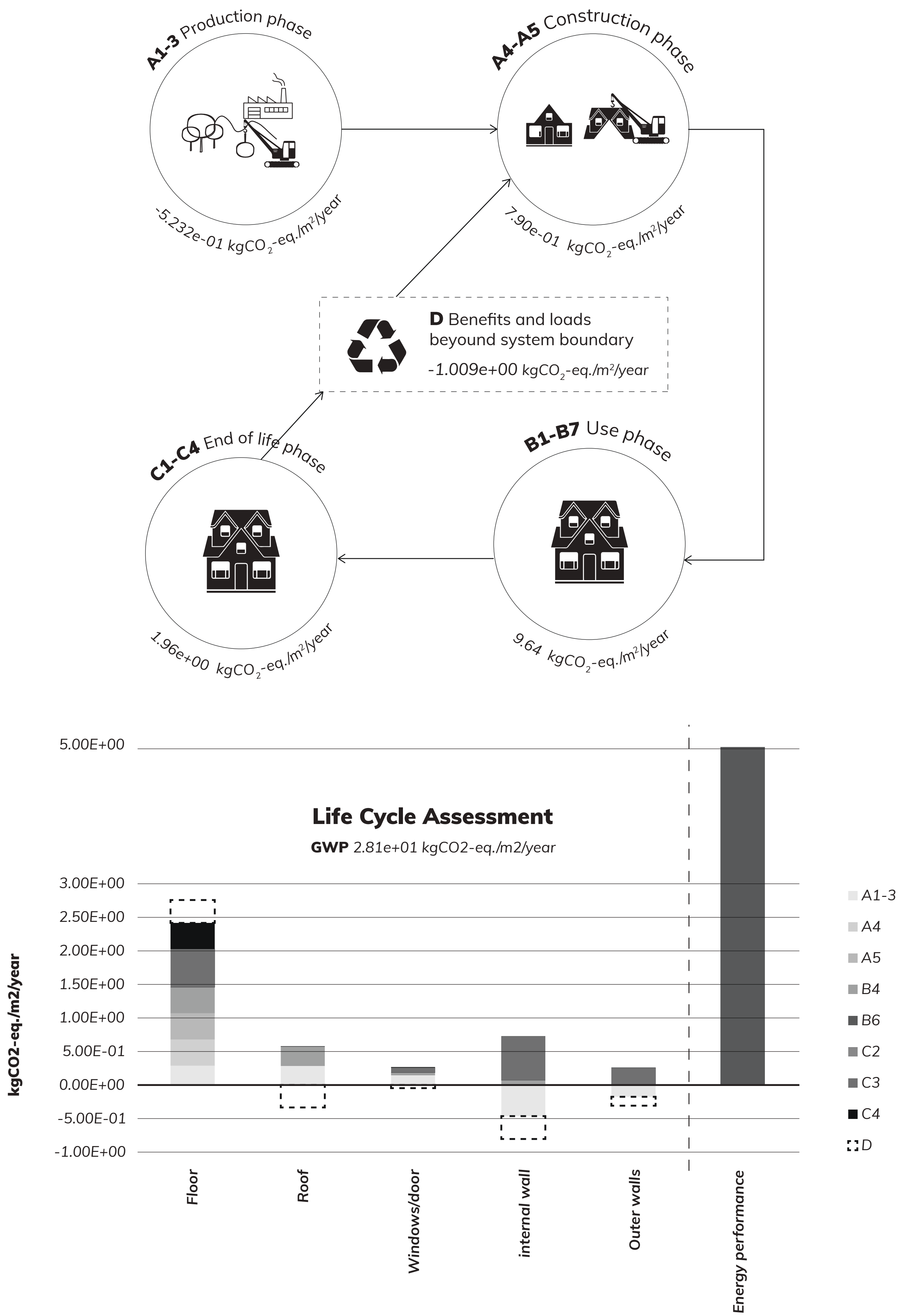


Ill. 99. Section Aa, scale 1:50, of current and future design of Åstrupskrænten 45, CREDIT current section is based on original section of Åstrupskrænten 45, from the local building archive at Norddjurs Municipality. (FilArkiv, Norddjurs Municipality). Modified by the author.

Ill. 100. *Section Bb, scale 1:100*



Ill. 101. Preserved vs. transformed isometric of Åstrupskræntent 45



Ill. 102. Life Cycle Assessment of Åstrupskræntent 45

CHAPTER 5

FINAL REMARKS

The following section will provide a conclusion and reflection on the design process and the final design.

Ill. 103. Picture of Åstrupskrænten

CONCLUSION

How can suburban neighbourhoods of the 1970s be sustainably transformed as a housing typology to foster new, visionary, and attractive concepts of "a good life"?

(Inspired by Kum.dk, 2024)

To evaluate whether the project successfully responds to the research question, the final proposal is assessed against the established design drivers and criteria: Utilitas, Firmitas, and Venustas, as well as the overall project vision.

The transformation of Åstrupskrænten demonstrates how a typical car-centric suburban neighborhood from the 1970s can be reimagined as a socially engaging and future-resilient living environment. By shifting everyday functions into shared spaces, the project fosters spontaneous encounters and strengthens neighbourly relations. The original building at Åstrupskrænten 45 is preserved as much as possible, with selective demolitions made only where necessary to improve functionality and energy performance.
The design follows a low-impact strategy, balancing material reuse and energy upgrades. Life Cycle Assessment reveals that operational energy has a greater environmental impact than material emissions, which led to a focus on reducing energy consumption. The house remains structurally unchanged in size but internally optimized to accommodate multiple households. A flexible wall system enables units to expand or shrink over time, supported by a shared community house that offers additional space during key life events.

In terms of outdoor space, the project introduces a clear hierarchy between private, semi-private, and public zones, supporting both privacy and social interaction. This spatial arrangement encourages movement through shared areas, reducing isolation and promoting a sense of belonging.

Material choices are guided by LCA performance, local sourcing, reusability, and aesthetic compatibility with the existing architecture. New elements are designed for durability, disassembly, and adaptability, extending the building's lifespan while allowing future occupants to make it their own. The existing structure is neither expanded nor reduced, and only essential internal walls were added and removed. The climate screen was comprehensively evaluated to prioritize energy-efficient upgrades with the most significant impact.

Materials were assessed not only for technical properties but also for their adaptability and patina over time. The design allows for easy disassembly, enabling future reuse, a key aspect of futureproofing. Daylight analysis guided major design moves, eliminating dark areas and significantly improving the spatial experience. The redesign also enables natural stack ventilation, enhancing air quality and comfort. New materials were selected to harmonize with the existing architecture, telling a coherent story across time. At the same time, they offer opportunities for future occupants to personalize the aesthetic, ensuring the design remains flexible and meaningful.

The project redefines “the good life” by proving that compact, flexible living does not compromise quality of life. By enabling multiple households to share the same footprint with only 30 m² per person, the design presents a replicable approach to densifying suburban neighbourhoods in a socially and environmentally sustainable way.

While Åstrupskrænten is the main case, the methodology and design strategies are adaptable to other 1970s suburban contexts. Each site may require unique design responses, but the process remains a transferable framework for rethinking how we live together.

REFLECTION

Design proposal

This reflection considers whether the design approach at Åstrupskrænten is transferable to similar 1970s suburban sites, whether greater focus on aesthetics would have been beneficial, and if the proposal effectively addresses future adaptability and low-maintenance living.

Challenging danish norms of space and ownership
A major challenge in implementing this model widely is the cultural perception of the "good life" in Denmark. The average floor area per person remains high, driven by a desire for private ownership and plenty of space. While this project demonstrates that 15–30 m² per person can be liveable when supported by shared facilities, societal transition could potentially require policy change. Regulations could limit demolitions, impose LCA-based renovation targets, or cap floor area per occupant. However, such changes risk public reaction unless reframed as a shift toward shared quality rather than personal sacrifice.

Economically, the motivation to renovate for environmental reasons is weak as long as energy remains cheap. Stronger regulation, such as mandating energy optimization during major renovations, or requiring a balance between embodied and operational emissions, could shift this dynamic.

Architects play a critical role in this transition, not only through design but as cultural translators. When clients seek to demolish and rebuild, architects should advocate for adaptive reuse and highlight the long-term social and environmental benefits of preserving existing structures.

Balancing aesthetics and adaptability
A returning tension in the project was whether to prioritize aesthetic permanence or design for future disassembly. Catalogue houses often aim for timelessness through simplicity, but this can limit personal expression. The final design embraces a middle ground: it allows for personalization (e.g., surface treatments, unit size) while maintaining a coherent architectural language.

Some reuse opportunities were carefully sacrificed to support a more minimalistic expression. Future iterations could explore material systems that allow for aesthetic transformation over time, such as facades with rotatable or reconfigurable panels, combining identity with adaptability. This would reinforce the idea of housing as a living structure, not a static artifact.

The preservation strategy balanced minimalism with flexibility, though at times at the expense of material reuse. More exploration of material layering or adaptable interior finishes could support long-term personalization without sacrificing coherence.

Maintenance and outdoor spaces
Although the house itself emphasizes low-maintenance solutions (e.g., durable materials, minimized interventions), the outdoor areas at Åstrupskrænten remain relatively conventional. Existing hedges and lawns still require regular upkeep. While planting wildflowers can reduce mowing, a more thorough design could have explored maintenance-free vegetation. For instance, replacing hedges with slow-growing plants or groundcovers might better align with the project's low-maintenance ambitions.

Site-specific limits and future opportunities
The house at Åstrupskrænten 45 ends up offering 30 m² per person, double the theoretical minimum of 15 m². While this reflects structural constraints and spatial logic, it also reveals opportunities for deeper transformation. Had the roof structure allowed it, raising ceiling heights could have supported higher occupancy. This points to the importance of structural adaptability in future projects.

Methodology

This section reflects on how the design methodology developed in this project can be applied to similar contexts and how it might be improved or adapted in future design processes. It also critically examines specific sub-methods employed during the design phase, including the decision-making structure and the use of environmental assessment tools.

Transferability to similar suburban sites
The strategic framework employed in this project, containing pre-design, design, and post-design phases, is adaptable to other detached houses and suburban neighbourhoods from the same era. A new pre-design phase should begin with a thorough evaluation of the site's specific typologies, construction methods, and user needs. In the design phase, strategies must be tailored to the context. For instance, while Åstrupskrænten 45 was a catalogue house with a neutral architectural expression, other homes may feature more distinctive facades or interior elements worthy of preservation. As such, design responses should always be reconsidered on a case-by-case basis. The phased design method offers a repeatable process, not a fixed outcome. The first phase helps clarify which things are worth preserving, while the second phase translates those insights into design decisions. This ensures relevance across varying suburban contexts.

Decision-making logic in the design phase
In Design Phase 2, a sequence of weighted decisions was established, where some aspects, such as improving the internal layout to accommodate more occupants, were prioritized over others. This hierarchy of priorities directly influenced the final outcome, and alternative outcomes could have emerged if the priorities had been arranged differently. To support informed design decisions, Design Phase 1 was intentionally left open-ended, with pros and cons mapped rather than conclusions drawn. This type of explorative phase could be beneficial in architectural practice more broadly, especially in design studios, where it could be formalized as a tool for evaluating multiple options without prematurely committing to one direction.

Life Cycle Assessment
The life cycle assessments were carried out using LCAbyg 2023.3, primarily with generic data. While this provides a general picture, it lacks the specificity needed for a fully realistic assessment of a "built project". Location-specific transport emissions were acknowledged but not accurately represented. Product-specific EPDs were avoided due to their tendency to underestimate emissions, especially when comparing reused and new materials.

Moreover, the assumptions around construction and installation emissions were serving to illustrate which building elements are more emissions-intensive than others. A more robust methodology might include deeper investigation into embodied emissions from reused elements, such as the energy required for cleaning, processing, or modifying components.

Additionally, the project assumes a 50-year service life, which may not align with actual building lifespans, particularly for reused elements that may degrade faster. Future research and transformation strategies should incorporate more dynamic life expectancy models and phased maintenance projections.

Energy optimization and indoor climate
The energy performance was assessed using Be18, and daylight was modelled through simulation tools. The design prioritized achieving sufficient daylight first, with energy performance following. This could be reversed in future projects to evaluate the trade-off between optimal daylight and thermal performance.

The final energy calculation revealed over-insulation in parts of the building, leading to excess heat gains. Solar shading strategies or natural ventilation could have been explored in greater depth, possibly using dynamic simulation tools such as BSim. These tools can simulate occupant behavior, window operation schedules, and shading performance over time, providing a more holistic picture of indoor environmental quality.

CHAPTER 6

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Ill. 2 Picture of Åstrupskrænten, photo by author.

Ill. 3 Requirement roadmap. CREDIT: Bolig- og Planstyrelsen. (2021). National strategi for bæredygtigt byggeri. Available at: https://www.sbst.dk/Media/638696001442099861/National-strategi-for-b%C3%A6redygtigt-byggeri-a.pdf.

Ill. 4 Motivation, illustrated by author.

Ill. 5 Photo of Åstrupskrænten, photo by author.

Ill. 6 How designers think, illustrated by author.

Ill. 7 Research by design method, illustrated by author.

Ill. 8 The Vitruvian Triade, illustrated by author.

Ill. 9 The Design Phase Method, illustrated by author.

Ill. 10 The Five Rs, illustrated by author.

Ill. 11 Life Cycle Assessment (LCA), illustrated by author.

Ill. 12 Reuse and Design for Disassembly (DfD), illustrated by author.

Ill. 13 Materiality. CREDIT: Bejder, A.K. (2012) Aesthetic qualities of cross laminated timber. PhD thesis. Aalborg University, Department of Civil Engineering. DCE Thesis, No. 35.

Ill. 14 Birds eye of Åstrupskrænten. CREDIT: Klimadatastyrelsen. (n.d.). CC BY 4.0. Available at: www.skraafoto.dataforsyningen.dk.

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Ill. 16 Connections to Grenaa, illustrated by author.

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Ill. 20 Mapping Åstrupskrænten for green structures, scale 1.2000. CREDIT: Klimadatastyrelsen. (n.d.). CC BY 4.0. Available at: www.dataforsyningen.dk/data.

Ill. 21 Materials at Åstrupskrænten, photo by author.

Ill. 22 House at Åstrupskrænten and timeline for the detached house, photographed and illustrated by author.

Ill. 23 1970s catalogue house, illustrated by author.

Ill. 24 Current situation plan, scale 1:300. CREDIT: Klimadatastyrelsen (n.d.) Map of Åstrupskrænten, Grenaa. CC BY 4.0. Available at: www.dataforsyningen.dk/data. Norddjurs Kommune (1973) Enfamiliehus [PDF], also permission by owner. Available at: www.public.filarkiv.dk.

Ill. 25 Current floor plan, scale 1:300. CREDIT: Klimadatastyrelsen (n.d.) Map of Åstrupskrænten, Grenaa. CC BY 4.0. Available at: www.dataforsyningen.dk/data. Norddjurs Kommune (1973) Enfamiliehus [PDF], also permission by owner. Available at: www.public.filarkiv.dk.

Ill. 26 Current Daylight Autonomy (DA). CREDIT: Klimadatastyrelsen (n.d.) Map of Åstrupskrænten, Grenaa. CC BY 4.0. Available at: www.dataforsyningen.dk/data.

APPENDIX

THESIS TITLE PAGE

This form must be submitted for all theses written in programs under the Study Board of Architecture and Design, and it should be placed at the beginning of the appendix section of the assignment.

A printed copy of the form must be submitted along with the printed copy of the thesis.

The information given in this form must also be available in PURE.

(All fields must be filled out)

Program: **Architecture** ☒	**Industrial Design** ☐	**Urban Design** ☐
This thesis was written by (full name):		
Signe Gregers Christensen		
Title of the thesis: Åstrupskrænten - a sustainable transformation of the 1970s suburban neighborhood		
Supervisor´s name: Michael Lauring		
Submission date/year: 02-06-2025		
Is the project confidential?	**Yes** ☐	**No** ☒
External collaboration*	**Yes** ☐	**No** ☒
External collaboration partner (name of company/organization):		
Contact at external collaboration partner (title, name og email):		

Appendix 1: *Interview with resident of Åstrupskrænten 45*

The questions and answers have been translated from Danish.

Q1: How many people live in each house on Åstrupskrænten, and approximately how old are they?
As far as I know, between 1 and 7 people live in each house.

Q2: Have you built an extension to your house? If yes, what kind and why?
No extension, but I have added a covered bike shelter, and a tool shed.

Q3: Would you like more square meters, or do you think the house is big enough?
I think it's big enough. When we bought it, people were building houses of 100-120 m², which was considered large at the time. It was sufficient, when we had two children and now we fill out the space with hobby spaces.

Q4: Why haven't you carried out an energy renovation of your house?
We installed 6 kW solar panels, but since it has become a financially unviable solution, they will probably be removed again. When we took over the house, an additional 100 mm of insulation had just been added on top of the existing 100 mm, making a total of 200 mm. We haven't done anything further to the attic insulation because of the low price per kWh of district heating compared to the high fixed charge per square meter. The windows have been replaced, and of course, the new glass has better insulation value.

Q5: Has your marital status changed during your time in the house?
Yes, I have been married, divorced, and now I live with a partner.

Q6: Have you made any changes to the floor plan? If yes, where, why, and how?
We opened between the kitchen and the living room and removed the bathtub from the bathroom. Furthermore we changed some materials, such as the vinyl flooring, since it is more resistant to wear and tear. We also recently began to remove the asbestos tiles in the WC.
.

Q7: Were you a first-time homebuyer when you bought the house?
Yes, it was my first house purchase.

Q8: Do you dream of moving to another house? Why?
Not now.

Q9: Have your dreams for the house changed over the years?
Yes, you constantly get new ideas. Today, my dream would probably be to have a larger garage and a smaller house.

Q10: Has life on Åstrupskrænten changed over the years?
There are new young neighbors. Now we are the "old ones," just like our neighbors were when we first moved in.

Q11: What made you buy a single-family house on Åstrupskrænten?
The opportunity to have our own garden, shielded from the outside world.

Q12: Are there any social events throughout the year on Åstrupskrænten?
Yes, for example, the annual general meeting with dinner.

Q13: Are there any social events in Grenaa throughout the year?
Open by Night, Christmas events.

Q14: Do you generally prioritize having a low-maintenance house and property? Has this changed, and why?
Yes, mainly to be able to enjoy outdoor time without spending it on house maintenance.

Q15: What do you use the rooms in your home for? Have their functions changed over the years?
Yes, for example, a room that used to be a children's bedroom has now become more of a hobby room.

Appendix 2: *Interview with resident living in a multi-family home*

The questions and answers have been translated from Danish. The conversation took place on February 19, 2025, and revolved around a woman, her boyfriend, her grandfather, their child, and a friend. During the conversation, I gained insight into how they have lived together over the years. The following will highlight the key points from the discussion. This is not a full transcript of the conversation but rather selected passages that have been adjusted to make the main points clearer. Prior to the conversation, the interviewee shared the floor plans of their current house as well as their previous one. These are displayed in illustration 34.

Q1: How many people have you lived with? And what were the ages of the residents? How many years did you end up living together?
It started with the interviewee and her grandfather living together alone. Later her boyfriend moved in, and they later got a child. It lasted for many years, around eight years or so. Originally, she was 22, and her grandfather was 88.

Q2: How did it all start? How did you end up moving in with your grandfather?
I initially moved in with him temporarily, just planning to stay for a month... but then I ended up living and sleeping there for two years on a sofa in the living room, the long one (see ill. 34). There's a door leading into that room, which I think is quite relevant to your project.

Q3: How did you divide the rooms in the first home you lived in together? And what were the rooms used for before you moved in?
There is a door leading into the long living room, which you can see from the dining room. It had been permanently closed for as long as I could remember. Instead, there was another door across from the staircase, which I used as the primary entrance to my room. The original door was still there, we never covered it up or anything, but it had furniture placed in front of it. That door had never been used in my lifetime. I believe it used to be a bedroom at some point because my grandfather has lived in that house for what feels like a million years, more than 70 years. He raised three children there with his wife, so back then, the space was divided into children's rooms. I know for sure there was at least one, maybe even two, but I can't quite remember. In the beginning, I slept on a sofa that was already there as part of a temporary solution. Then I moved out to live with my then-boyfriend and was gone for about a year and a half before convincing my boyfriend that we could all just move in and live together with my grandfather. When my ex-boyfriend and I moved in, we planned the space a bit more. Since my grandfather was living alone at that point, he wasn't really using all the rooms. The large living room, an extension of the dining room, was left empty and cold. Instead, he mainly used the smaller living room as his TV room, had his bedroom in the back room next to the kitchen, and kept a small office in what used to be a children's room. I suggested that my boyfriend and I moved into the two large living rooms. By closing off the door to the "long living room" and keeping the dining room door shut, we could create our own small section of the house. That way, we had our own space while still being part of the home. The dining room remained as it was, but we mostly ate in the kitchen. The dining room was used more for special occasions, like birthdays, having guests over, or New Year's Eve, which we also celebrated together with my grandfather. It became more of a multipurpose room.

Q4: Did you use the basement, or was it mostly just for extra space?
Yes, it was just for that. I mean, not for living purposes, just for storage.

Q5: When you first moved in with your grandfather, was it simply because you needed a place to live close to Aarhus, or was there another reason?
Yes, I'm from Aarhus, specifically Højbjerg. I had a room in Aarhus that I could have moved into, but I cancelled it because it was nice living with my grandfather. My grandmother had just passed away and everything. After a week, I decided to cancel the place I was supposed to move into.

Q6: Can you describe your relationship with your grandparents?
Yes, but it's one of the things I find so special to our story. We weren't always close. At times, we were very close, and we lived in the same town, which of course created a foundation. But when I was a teenager, I wasn't particularly close to him. However, when we moved in together, we became much closer. I think some people might hesitate to do that because they don't feel particularly close, but for us, that wasn't the case. We became close because we lived together. It's such a gift, the relationship that comes from living together.

Q7: How did you have visitors, just you and your boyfriend, if you lived together and your grandfather didn't necessarily want to be involved?
Well, he was up for everything. People would just come over, and typically we were in our part of the house, where there was plenty of space for us. But it was still the case that the doors were always open, and then Grandpa would wander in and say, 'Hi last name,' he was on a first-name basis with them.

Q8: Have there been any changes in the way you live and your living situation since you moved out to where you live now?
It has changed our social life since we moved to where we are now, in a housing arrangement with two houses, because we have more space for guests. Before, we were more the ones who would go out and visit people. But, you know, that's just how it is, without necessarily thinking about it.
It's not that we never had guests at all. In the summer, we had a big, nice terrace and things like that. I think, unspoken, you end up visiting those who have more space or where it's more practical. Sometimes, I also think that we visit some people if they're a bit more stressed with, like, young kids or something. So, it's at their place, without us planning or giving it much thought.

Q9: Did your life change drastically while you were living together? Your grandfather passed away, and you had a child. Did your living situation change because of that?
Yes, Grandpa passed away.
That was last year, in 2024, and then in 2023, we moved into the new house. I think when we had the baby, we had been so close for so many years, and it only made us closer. Especially during the time when I was younger, it was Grandpa who helped me. He would drive me to work. As he became less mobile and needed my help, the roles started to reverse. He lost his driver's license, so I would drive him to the doctor and take care of all those things. When we moved into our new house, our living spaces were more divided. It was perfect for the stage we had reached because he ended up having a stroke and needing home care, which would have been so difficult in our old setup. It would have been extremely invasive to my and my boyfriend's privacy, I feel. Of course, it would have been for my grandfather as well, if we hadn't moved.

Q10: Having the space to have your own entrance and things like that have made a big difference for you, hasn't it?
Yes, definitely. It's quite an experience to have home care, many different people come. I think around 150 different people, without exaggerating, which is like 1.8 people per week. It was nice that our living spaces were divided. Also, with two bathrooms, for example, and things like aids and equipment. There are different stages in life, right? We all wanted to live together until the end. That was our ultimate dream, and I can see that others might think their grandparents should live with them. But we didn't want my grandfather to go to a nursing home. Others might have preferred to divide it up. I don't know. But if you want to be there for the final stages of life, there are just some practical things to consider. For example, a floor plan that works, having ramps for wheelchairs, and a bathroom where you can move around. Luckily, his part of the house had that. There were even handrails installed, etc.

Q11: What functions did your grandfather have in the annex in the new home?
The house is categorized as an annex. It had a kitchen with a sink, cooktop in the countertop, a small electric oven, and a microwave. So, it had the necessary facilities, but it's not approved for living, so technically you're not allowed to use it as such, and that's the strange part about it. When we lived together, I really helped the community. We helped save a huge amount of money compared to if someone had to take care of my grandfather full-time in a nursing home.

Q12: What do you use the other rooms for in the new house?
In the basement, the ceiling is quite high, so one room is used as an office combined with a dressing area, which works well because there's a bathroom. Then there's a creative space with a little fold-out table and, in the corner, it's kind of a craft room, where we can keep projects out without needing to pack them away because it's time to eat. On the ground floor, we have the kitchen and living room, the common areas, and upstairs are the bedrooms. In our room, there's just a bed. Since there are only two bedrooms, we've thought that we could add an extension with a bedroom from the living room if needed. In the annex, we use one room for storage, and our friend has a room there as well and uses the kitchen and bathroom.

Q13: How do you divide the household tasks now between you and your friend, who now lives in the annex?
Well, our friend mostly helps outside, for example, with building or if something with the sewage system is causing trouble. Or if we need something fixed. He also helps by walking our dog or occasionally helping with babysitting.

Q14: What was the house used for before you moved in?
When we bought the house, it used to be home to a couple who lived there. The people who had the house before didn't have children living at home. They used it as an adult house, which they bought after their children moved out. They also used the annex for renting out, which originally started as a B&B.

Q15: How many square meters was the house? And how many are there in your new house?
115 square meters in the old house, and about 160 in the new one.

Q16: What worked well in the old house, and what didn't work so well?
It worked well that there was an open kitchen, which was really cozy, but there was only one bathroom, and we needed two. Besides that, there wasn't enough space, and it was on two floors, which isn't so smart when you get older. One advantage was that you were kind of forced into having those shared spaces. And having a big, shared dining area, where everyone eats together in the evening. I really think that's lovely. It's where you catch up together, and you sit around the table and have a good conversation.

Q17: What works well in the new house, and what doesn't work so well?
Well, there are two kitchens, although the one in the main house is mostly used, it is more divided because of the physical distance between the houses. However, we've created an outdoor area that is shared between the houses. Additionally, there are two bathrooms, and in the house where Grandpa lived for a short time, there was only one floor.

Q18: Could you have stayed in the old house instead of moving to a new place, now that you became pregnant, and life changed?
Okay, we moved because of the growing family. But we had talked about the small room on the floor plan, which was my grandfather's office, and which he didn't really need. We could have turned it into a nursery, but we just thought it would get a bit complicated having a baby because the kitchen was so small.

Q19: If you were to design the perfect multi-family home in your mind, what would you consider based on the experiences you've had in the two homes?
I really think the dream would be to have something like a "heart of the house" in the middle, where you could have ends on either side. One end could have a bathroom and bedrooms, and the other end the same. Then there would be something shared outdoors, but also private spaces. And then the kitchen in the middle, acting as the connector. I also think it would be good to have some kind of two living areas in each space, because, for example, my grandfather had his own TV room. To have rooms that aren't just for sleeping, apart from the bedrooms in the private end. And then you could also have a shared lounge area in the kitchen section that's communal.

Q20: Could you imagine living in a multi-family home again in the future?
I'm sitting here thinking about my mom and her husband, and then if we were three generations living together. That would just be a dream. But right now, we have my boyfriends friend, or our friend, living over there, so that's really nice. But I've told my mom that if she doesn't want it, she'll never go to a nursing home alone. We'll renovate it or figure something out. It's just so wonderful. I really think we're missing out by not doing it. I think there's so much social joy and relief in different ways. Our friend has the dog over to sleep, and then he comes in here, drops her off, and goes to work, saying goodbye to us. It's cozy and happy, and we go over and grab some sugar or olive oil or whatever you've run out of, or say, 'Hey, come over, we have so much extra dinner today.' It's just lovely, I think.

Appendix 3: *Questionnaire with residents of Åstrupskrænten*

The questions and answers have been translated from Danish. The questionnaire was answered by three residents of Åstrupskrænten, besides from the one specific for the residents of Åstrupskrænten 45. The answers has been divided into these three people answering.

Q1: How many people live in your house? And what is the age of the residents?
No. 1: 2 people: 71 years old and 75 years old
N0. 2: 3 people: 54 years old, 51 years old, and 24 years old
N0. 3: 2 people: (no age mentioned)

Q2: Have you/you made any extensions to the house? If yes, what and why?
N0. 1: No, there has not been an extension.
N0. 2: Carport
N0. 3: No

Q3: Would you like more square meters, or do you think there is enough space in the house? Where and why?
N0. 1: We don't need more square meters. The house is 179 square meters on the ground floor and 149 in the basement.
N0. 2: There is enough space.
N0. 3: Maybe

Q4: Have you energy-optimized the house? If yes, where, how, and why?
N0. 1: We are considering adding 200 mm insulation in the attic on top of the 200 mm that is already there. This will happen in the spring.
N0. 2: No
N0. 3: Extra insulation, up to 300 mm

Q5: Has your civil status changed over the years in the house? If yes, how?
N0. 1: We got divorced 30 years ago but moved back together after 10 years.
N0. 2: No
N0. 3: No

Q6: Have you/you made any changes to the floor plan? If yes, where, why, and how?
N0. 1: There have been no changes to the floor plan - I designed the house myself.
N0. 2: No
N0. 3: No

Q7: Were you a first-time homebuyer when you bought the house? If yes, what were your visions for the house?
N0. 1: This is our first house - I built it myself, and the vision was/is that we would live here for our entire lives.
N0. 2: No
N0. 3: No

Q8: Do you dream of moving to another house? If yes, why?
N0. 1: No - see the answer above!
N0. 2: We have sold and are moving to another house that we have owned since 2018.
N0. 3: No

Q9: Have your dreams for the house evolved over the years? If yes, why and how? And would you change it if you could? How?
N0. 1: We haven't dreamed of changing anything.
N0. 2: No
N0. 3: No

Q10: Has anything changed in Grenaa since you bought the house? If yes, how? And would you change it if you could? How?
N0. 1: Unfortunately, several large companies have closed over the years. However, we were not "really" sad when the Grenaa Paper Mill closed, as we could hear and smell it 24/7 all year round. We wish an electronics factory, or a pharmaceutical company would come to the town.
N0. 2: No
N0. 3: No

Q11: Has life on Åstrupskrænten changed over the years? If yes, how? And would you change it if you could? How?
N0. 1: When we first came to Åstrupskrænten, there were children in all the houses. They have moved out now, and the parents are also moving, but fortunately, new families with children are moving in.
N0. 2: Yes, many new people have come.
N0. 3: No answer

Q12: What made you buy a single-family house on Åstrupskrænten? And is there a difference in how you experienced the home and neighborhood the first time, and how you experience it now?
N0. 1: We bought the plot here on Åstrupskrænten because it was on the sunny side of the hill. There is not much difference in the neighborhood now compared to 45 years ago; some houses have been renovated and had their facades changed. But we have been lucky to have the same great neighbors for many years.
N0. 2: We bought the house because we thought it was a lovely area, and it still is.
N0. 3: No answer

Q13: Are there any social events during the year on Åstrupskrænten/in Grenaa? If yes, which ones? And would you change it if you could? How?
N0. 1: There is only the annual general meeting. For the first 10-15 years, there were street parties where almost all the residents participated.
N0. 2: General meeting in the Homeowners Association
N0. 3: No answer

Q14: Do you generally care a lot about keeping your house and garden maintenance-free? Has this changed, and why?
N0. 1: We try to make the house and garden almost maintenance-free so that it's easy to take care of for older people.
N0. 2: No
N0. 3: No answer

Q15: What rooms do you use in your home? What works, and what doesn't? And have the rooms changed in terms of function over the years?
N0. 1: All rooms are used as intended, but the children's rooms are set up like "hotel rooms" when the children and grandchildren come home.
N0. 2: No answer
N0. 3: No answer

Q16: How is the atmosphere on Åstrupskrænten? What works, and what doesn't? And would you change it if you could? How?
N0. 3: There is a good atmosphere, and we think everything works well.
N0. 2: It is good
N0. 3: No answer

Q17: Is there anything about the surfaces in your home that makes it recognizable?
N0. 1: Our house is the only one with a "real" roof! Red tiles!
N0. 2: No answer
N0. 3: No answer

Q18: Are there any materials in the neighborhood that you associate with safety or discomfort? Which ones and why?
N0. 1: No!
N0. 2: No answer
N0. 3: No answer

Q19: Are there specific sounds in your home that you associate with home? E.g., creaky floors, wind in the trees, echoes in rooms, sounds from neighbors, etc.? Is the neighborhood noisy or quiet? Are there sounds you associate with home?
N0. 1: It's a very quiet neighborhood!
N0. 2: No answer
N0. 3: No answer

Q20: Are there any smells in the neighborhood that you associate with home? E.g., fresh air, trees, grass, asphalt, barbecues in the summer, or similar? Do the smells change with the seasons? Are there certain smells in your home that you associate with home?
N0. 1: No!
N0. 2: No answer
N0. 3: No answer

Q21: How do you experience light in your home? At what time of day, and where in the house, is it best to stay? Is there a specific light you particularly like? How do you experience light in the evening? (Streetlamps, light from windows, etc.)
N0. 1: Our house has a good light influx and is a bright house.
N0. 2: No answer
N0. 3: No answer

Q22: Do you experience Åstrupskrænten changing with the seasons? How?
N0. 1: It can be a problem to get off the hill early on a winter morning when there's snow! But in the summer, Åstrupskrænten is lovely!
N0. 2: It is very dark in the winter.
N0. 3: No answer

Q23: If you/you closed your eyes, how would you describe the feeling of home? Which sensory impressions would be mentioned first? Are there specific places in your home that feel safer? How does it feel to move through the neighborhood? (Do you walk slowly or quickly?) If you had to describe the atmosphere in the neighborhood with words, which ones would you use?
N0. 1: Our entire house feels safe. It feels safe to walk around the neighborhood, and the atmosphere is good – everyone greets each other warmly.
N0. 2: No answer
N0. 3: No answer

Appendix 4: *Interview with resident living in a multi-family home*

The questions and answers have been translated from Danish. The conversation took place on February 20, 2025, and revolved around a woman, her ex-husban, her mom and dad, and their three children. During the conversation, I gained insight into how they have lived together over the years. The following will highlight the key points from the discussion. This is not a full transcript of the conversation but rather selected passages that have been adjusted to make the main points clearer. Prior to the conversation, the interviewee shared the floor plans of their current house as well as their previous one. These are displayed in illustration 34.

Q1: How many years did you live with your family in the multigenerational home? How many people lived together in the multigenerational home, and what were their ages? What was your relationship with those you lived with in the multigenerational home?
She lived there from 2001 to 2020 while she and her husband were still married. The couple moved in when they had a two-year-old son, together with the woman's parents. The couple was in their late 20s and early 30s, and the woman's parents were in their late 50s and early 60s. Later, they had two more children, five years apart. The children were born in 1999, 2004, and 2009.

Q2: What type of housing do you live in now? Do you live with others? Gender, age?
The woman now rents a home after getting divorced. The couple and her parents sold the multigenerational home. When she wanted to live alone, she faced challenges with the bank, as she couldn't afford to buy a place on her own. Instead, she found a master mason's villa in Gilleleje, which she could rent. She now lives there with her two daughters, as her son has moved out. The new house is 214 square meters.

Q3: How did everyday life function in your multigenerational home?
In the beginning, they were very communal. There was an open kitchen, and they shared a single bathroom between the living units. Later, in 2004, they decided to renovate the property to create more privacy. They chose to block off the kitchen doors, which allowed them to utilize the wall space for kitchen elements and also provided more privacy. At first, the family ate with the grandparents every day, but later, this changed to once a week. By then, they each had their own kitchen, and they occasionally organized communal meals in one of the two kitchens. However, they still helped each other with groceries and other errands. After dividing the living spaces in 2004, both households agreed that they would knock before entering each other's homes, allowing them to decide whether they wanted visitors. The couple had found it a bit frustrating when people would just walk in, so they made this arrangement. Initially, they had not established clear rules for such matters.
During the renovation, they converted the garage into additional living space and created private terraces, along with a shared terrace in the middle. This meant that privacy improvements extended beyond the indoors to the outdoor spaces as well. The grandparents had about 20 square meters less than the couple after the renovation. Before the renovation, the family had the smallest living space. Both units placed their bedrooms upstairs, allowing the common areas to be on the ground floor.

Q4: How did you divide household chores and responsibilities?
In their 450-square-meter home, they didn't have shared indoor spaces, but they shared one acre of land. The family and the grandparents divided the outdoor areas, with a shared terrace and private sections on either side of the house, which each household maintained themselves. The terraces were not completely private, as people could pass by, but they still felt private enough. They also had a communal terrace and a shared garden, where they organized workdays to maintain the property. At first, the grandfather mowed the lawn, and later, the children took over this responsibility. In general, they had many communal projects because there was so much maintenance work to be done. However, they also divided responsibilities, ensuring that different areas of the shared outdoor spaces were properly maintained by designated individuals.

Q5: How did living in a multigenerational home affect your daily life? Would you recommend this type of housing to others? Why or why not?
The woman felt that living in a multigenerational home had both positive and negative effects on her daily life. From the children's perspective, she thought it was a paradise. The children did not perceive a clear division between the homes; they simply felt like they had a huge house. This feeling was strongest before they renovated the property, as the homes were later separated, and they had to go outside to visit the neighboring unit. For the adults, it was different. The sense of community was not as strong for the woman's father. It was mostly her husband who carried the responsibility alone, which led to tension between her father and her husband. They previously had a good relationship, but living together strained it. She emphasized that her parents never interfered with raising the children. The relationship with her parents was good initially, but once her father stopped contributing to the household responsibilities, tensions arose. Additionally, financial issues played a role in the later difficulties. Overall, she would recommend this type of living arrangement if all parties agree to share responsibilities before moving in together. However, she reflected that she might not have realized the challenges with her father before they moved in together. Therefore, she suggested that households should establish written agreements to refer back to. She also acknowledged the positives, such as having her parents available to help with the children, pick them up from school, or allow the kids to visit their grandparents freely.

Q6: How did you experience the interaction between generations?
She is confident that she and her family developed a much closer relationship than they would have had otherwise. Back then, their relationship wasn't obligatory. They could spend an hour or two together now and then, making it easier for everyone. There was no need for transportation to visit each other, and they could always pop over next door if they forgot something. The children could also sleep in their own beds when staying with their grandparents.

Q7: Did you find it easier to balance community and privacy in a multigenerational home compared to where you live now? Or the opposite?
After moving, she has not lived in a socially engaging area. In her new home, she has no contact with her neighbors, which she finds pleasant. She did not seek to move into another collective housing situation, as it was not an option when she wanted to move to Gilleleje. However, she also wouldn't want to live in a shared housing arrangement again, as she found it too difficult to establish communal agreements. She reflected on whether it might have been different if everyone had been the same age or if a contract would have helped. Ultimately, she concluded that it had been too difficult and that it didn't work for her. Since leaving the multigenerational home, she has lived in two other places with close living quarters, similar to an apartment setting. In one location, there was a lot of noise between rooms, which she found intrusive, as she hadn't chosen her neighbors. Later, she lived in a place where the upstairs neighbors smoked, which became an issue. She then moved into the master mason's villa, which is more secluded. As a result, she rarely encounters anyone and describes the atmosphere as one where people simply greet each other but don't interact further—which she prefers.

Q8: Did you need more or less space? Why? And for what?
She felt that the old house had too much space, as it was old and constantly required renovations. There was always something that needed fixing or painting. She appreciates having a smaller garden and a lower-maintenance home now.

Q9: How did you use the rooms specifically? Did the use of space change over time?
In the old house, they had a yoga room in the living room. After the father passed away, the mother's section of the house shrank, and they took over her living room for 3-4 years. The mother then moved her living room to the father's old bedroom. She later rented out the former living room to the family for use as a yoga studio since it was 75 square meters. They also built an annex with a yoga studio. When the couple divorced in 2018, the husband moved into this annex, which consisted of two prefabricated modules combined into one large space. He later added a bathroom. When they sold the house in 2020, he moved the annex to a new property and still lives there. The woman lived alone with her mother from 2018 until they moved out in January 2021.

Q10: Were there features you wish the multigenerational home had to make life easier?
It was a fantastic house with great moments and celebrations, offering plenty of space. However, she experiences a lot more noise in her new home and sometimes misses the peace of the old house.

Q11: If you were to design the perfect multigenerational home, what would you consider based on your experience?
She reiterated the importance of knowing each other well and writing down agreements beforehand. The division into separate kitchens worked well. It was beneficial that they could invite each other over rather than always living together, which helped maintain privacy.

Appendix 5: *Energy performance existing building*

The diagram below illustrates the existing energy performance of Åstrupskrænten 45. The calculation is based on estimated U-values derived from archival section drawings available at Norddjurs Kommune (1973) Enfamiliehus (PDF), www.public.filarkiv.dk. In addition, assumptions regarding parts of the building envelope have been made based on similar houses from the same era (Sode, 2022). Lastly, general data on residential buildings has been incorporated, and all calculations follow the guidelines set out in SBi 213.

PASSIVE STRATEGIES

BUILDING

House typology	*Detached house*
Number of units	*1*
Heated floor area	*146 m^2*
Heat supply	*District heating, solar cells*

BUILDING ENVELOPE

External walls			0.352 W/m^{2}K		
Floor	*146 m^2*		0.317 W/m^{2}K		
Roof			0.217 W/m^{2}K		
Foundation				/0.936 W/mK	
Windows 1974	7.08 m^2	/22.4 m	3 W/m^{2}K	/0.2 W/mK	/0.7
Door 1974	2.1 m^2	/6.2 m	2.7 W/m^{2}K	/0.25 W/mK	
Windows 1998	*19.32 m^2*	*/46.3 m*	*1.8 W/m^{2}K*	*/0.12 W/mK*	*/0.63*

Window orientation

S: 54.5%
N: 38.1%
W: 10%
E: 4.2%

SHADING

Porch	*27° horizon*	*6° eaves*	*7° sides*	*6% win. open*
Large windows		*6° eaves*	*7° sides*	*6% win. open*
Small windows		*6° eaves*	*16.6° sides*	*13% win. open*
Terrace doors		*6° eaves*	*9° sides*	*8% win. open*
Coloured window		*6° eaves*	*22° sides*	*20% win. open*

/ACTIVE

SUPPLY

Solar cells	*6 m^2*

RESULT

KEY NUMBERS

Total energy	*112.1 kWh/m^2 year*
heat	*134.2 kWh/m^2 year*
operational el.	*-3.7 kWh/m^2 year*
exessive	*5.2 kWh/m^2 year*

Appendix 6: *Energy performance final building*

The diagrams on the following pages illustrates the future energy performance of Åstrupskrænten 45. The calculation is based on U-values derived from the final design drawings available at pp. 166-189. Lastly, general data on residential buildings has been incorporated, and all calculations follow the guidelines set out in SBi 213.

PASSIVE STRATEGIES

The building

Building type	Nondetached house
Number of residential units	2
Rotation	0 deg.
Area, heated floor	176 m^2
Heated gross area	176 m^2
Heat capacity	100 Wh/K m^2
Normal usage time	168 hours/week
Usage time, start-end	0-24

Heat supply and cooling

Basic heat supply	District heating
Solar cells	Yes

Room temperatures, set points

	Heating	20 deg.
	Wanted	23 deg.
	Natural ventilation	24 deg.
	Mechanical cooling	25 deg.
	Heating store	15 deg.
Dim. temp.	Room temperature	20 deg.
Dim. temp.	Outdoor temperature	-12 deg.
Dim. temp.	Room temp. store	-15 deg.

External walls, roofs, and floors

Building component	Area (m^2)	U-value (W/m^{2}K)	b
External walls	95.6	0.15	1
Floor	176	0.32	1
Roof	176	0.12	1

Foundations etc.

Building component	Area (m^2)	U-value (W/m^{2}K)	b
Line foundation	51.1	0.12	1
Kept windows/doors	46	0.12	1
New/relocated w./d.	31.8	0.03	1
Skylights	6	0.10	1

Windows & outer doors

Building comp.	Nr.	Orient	Inclination	Area (m^2)	U-value (W/m^{2}K)	b	Ff	g	Shading	Fc
Skylights	2	N	30 deg.	0.7	0.8	1	0.9	0.5	-	1
New windows	2	N	90 deg.	1.4	0.8	1	0.9	0.5	Windows	-0.6
Old windows	3	N	90 deg.	1.4	1.8	1	0.9	0.63	Windows	-0.6
Old doors	1	E	90 deg.	2.4	1.8	1	0.5	0.63	Doors	-0.6
New windows	1	E	90 deg.	1.4	0.8	1	0.9	0.5	Windows	-0.6
Old windows	3	S	90 deg.	1.4	1.8	1	0.9	0.63	Windows	-0.6
New windows	1	S	90 deg.	1.4	0.8	1	0.9	0.5	Windows	-0.6
New doors	1	S	90 deg.	2.4	0.8	1	0.9	0.5	Doors	-0.6
Old doors	1	S	90 deg.	2.4	1.8	1	0.5	0.63	Doors	-0.6
Old doors	1	V	90 deg.	2.4	1.8	1	0.5	0.63	Doors	-0.6
New windows	1	V	90 deg.	1.4	0.8	1	0.9	0.5	Windows	-0.6

ACTIVE STRATEGIES

Shading

Description	Horizon	Eaves	Left	Right	Window opening
Windows	0 deg.	6 deg.	46 deg.	46 deg.	42%
Doors	0 deg.	6 deg.	45 deg.	45 deg.	50%

Ventilation

Zone	Area (m²)	Fo	qn W (l/s m²)	qn S (l/s m²)
Whole house	176	1	0.3	1.5

Internal heat supply

Zone	Area (m²)	Persons (W/m²)	App. (W/m²)
Whole house	176	1.5	3.5

Heat distribution plant

Supply pipe temp.	70 deg.
Return pipe temp.	40 deg.
Type of plant	2-string

Pipes	Length (m)	Loss (W/mK)	b
Heating pipes	40 deg.	0.2	0

Domestic hot water

Hot water consumption avg.	250 L/year pr. m² of floor area
Domestic hot water temp.	55 deg.
Type of plant	2-string
District heat exchanger	
Nominal effect	16 kW
Heat loss	1.5 W/K
DHW heating through exchanger	yes
Exchanger temp. min	15 deg.
Automatic standby	5 W

Solar cells

Area (m²)	6
Orientation	s
Slope	30 deg.
Peak power	0.105 kW/m²
Efficiency	75%

RESULT

Key numbers

Total energy	58.2 kWh/m² year
heat	75.4 kWh/m² year
operational el.	-3.1 kWh/m² year
exsessive	0 kWh/m² year

Renovation class 2	95 kWh/m² year
Renovation class 1	71.3 kWh/m² year
Energy frame BR18	41.4 kWh/m² year
Energy frame low energy	27 kWh/m² year