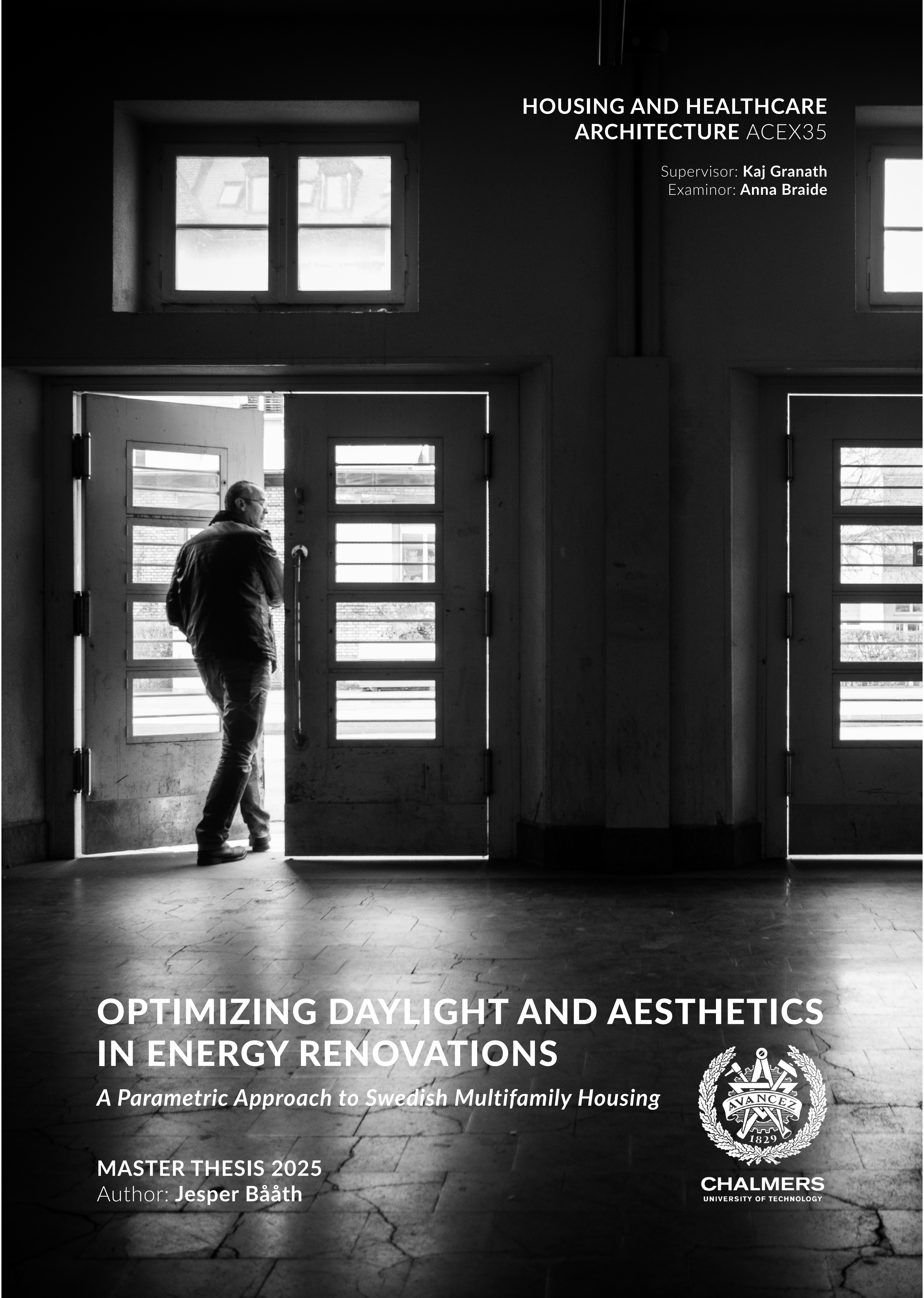

HOUSING AND HEALTHCARE
ARCHITECTURE ACEX35

Supervisor: **Kaj Granath**
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OPTIMIZING DAYLIGHT AND AESTHETICS IN ENERGY RENOVATIONS

A Parametric Approach to Swedish Multifamily Housing

MASTER THESIS 2025

Author: **Jesper Bååth**

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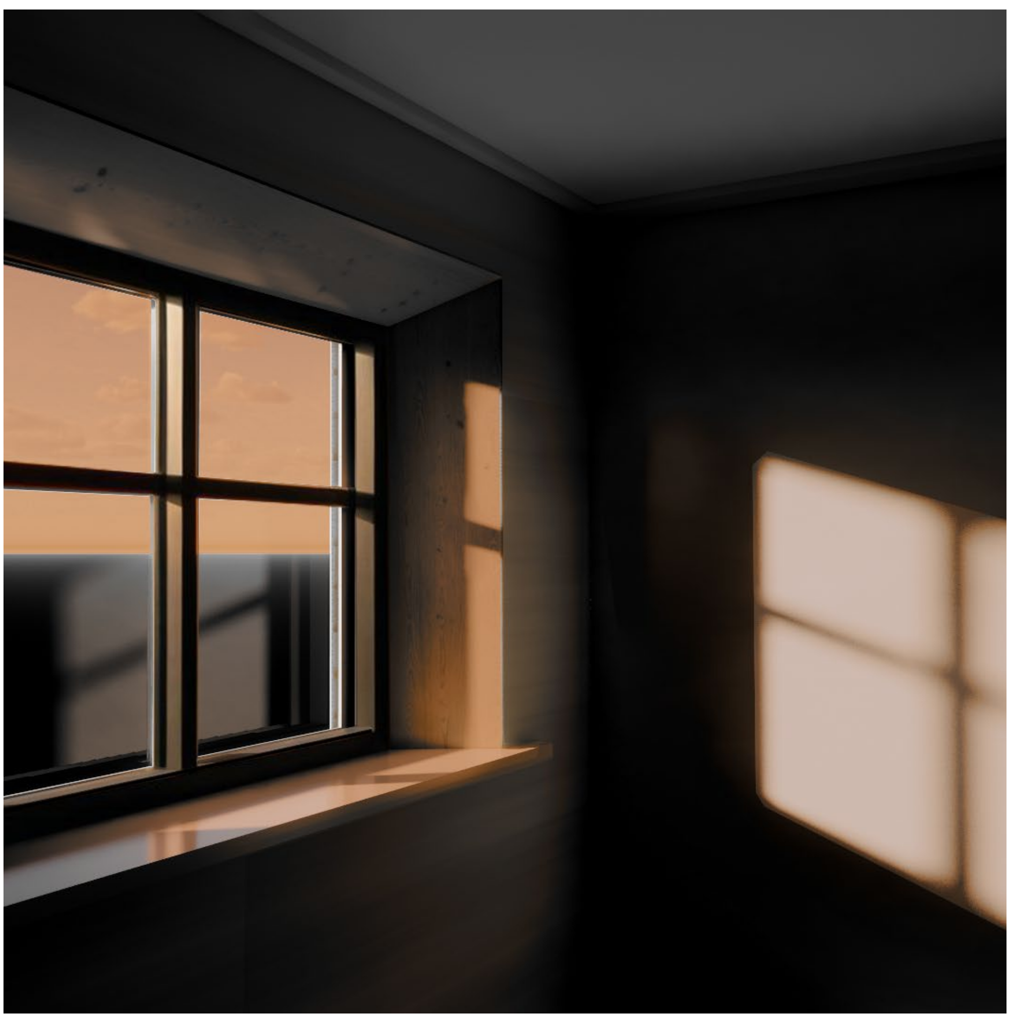

ABSTRACT

This thesis explores how energy renovations of Swedish multifamily residential buildings can be designed to enhance interior daylight quality, thermal comfort, and architectural value, while still meeting upcoming regulatory demands. With the new EU EPBD and the revised Swedish building regulations in BBR coming into force, a large portion of the existing residential building stock will require renovation. However, conventional renovation methods often lead to decreased architectural quality and worse interior conditions. The aim of this thesis is to develop design strategies that balance energy performance requirements with qualitative spatial and aesthetic values.

The methodology combines literature studies, project references, interviews, and simulation-based parametric analysis. Two residential buildings in Gothenburg serve as case studies: Kv. Tuppfjätet, a 1930s landshövdingehus where original character is prioritized, and Siriusgatan, a 1970s million program building targeted for transformation. Through a parametric workflow using Rhinoceros and Grasshopper plugins, daylight and energy performance were assessed using metrics such as Daylight Factor, Useful Daylight Illuminance, Spatial Daylight Autonomy, View-Out, Energy Use Intensity, and overheating risk.

The results show that a combination of minor architectural adjustments—such as improved window niches, optimal window depth, and reflective materials—can significantly enhance daylight access in preservation scenarios. For transformative cases, strategies like optimized window sizes, shading elements, and transparency levels proved effective in improving both energy use and spatial quality. These interventions allowed for better alignment with both daylight regulations and energy targets, without compromising architectural integrity.

The study concludes that integrating simulation-based analyses with architectural design tools can support a more holistic and qualitative approach to energy renovations. It demonstrates that well-informed design strategies can improve interior conditions as well as restore or enhance the architectural identity of aging residential buildings, while still meeting enhanced regulatory energy performance demands. The strategies proposed in this work can be adapted and applied broadly, serving as a methodological guide for architects navigating complex trade-offs in future renovation projects.

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1. INTRODUCTION

1.1 Background

Daylighting plays a crucial role in both energy efficiency and human well-being within built environments. Access to natural light has been widely recognized as a fundamental aspect of architectural design, affecting visual comfort, energy consumption, and overall indoor environmental quality. Research has shown that spaces with well-optimized daylighting reduce the need for artificial lighting, improve occupant satisfaction, and contribute to energy savings by minimizing electrical demand (Dubois et. al.). In the Nordic climate, where the access to daylight varies significantly across the seasons, balancing the daylight performance with the energy performance and risk of overheating is even more important and a big challenge (Verashjerdi Farahani et al., 2021). In order to meet the criteria for higher energy performance, it is often achieved at the expense of the building's aesthetic and cultural value (Femenias et al.) It can also have a direct impact on the daylight performance of the building, since common approaches of renovations includes decreased amount of glazing in the windows, or the windows being placed further into the facade because of the external insulation (Ståhl et al.) With the new initiative from EU, the EPBD, the number of residential buildings in need of renovation for energy efficiency reasons will increase. Meaning a big part of our older residential building stock will most likely alter its appearance.
The architect have an important part to play in this, to ensure that the changes affects the qualities of these buildings positively.

1.2 Terminology

Landshövdingehus: ”Governor's House”. Traditional Swedish building, commonly found in Gothenburg, built between late 19th to early 20th century.
Daylight Factor (DF): The percentage of daylight that reaches an interior space under an overcast sky.
View-Out: Assessment of the visual connection to the outdoors, considering glazing clarity, horizontal sight angles, and perceived layers.
Spatial Daylight Autonomy (sDA): The percentage of occupied hours a space receives sufficient daylight without electrical lighting.
Useful Daylight Illuminance (UDI): The percentage of occupied hours where daylight levels fall within a comfortable range.
Overheating Risk (OR): The percentage of occupied hours where indoor temperatures exceed 26°C, combined with percentage of occupied space achieving too much light.
Energy Use Intensity (EUI): Total energy consumption per square meter annually.
SS-EN: Swedish Standard - European Norm, a national adaptation of European Standards developed by the European Committee for Standardization (CEN).
BBR BFS: Boverkets Byggregler - Boverkets Författningssamling. Swedish building regulations.
LEED: Leadership in Energy and Environmental Design, a certification system for sustainable buildings.
EPBD: EU:s Energy Performance of Buildings Directive.

1.3 Aim & Purpose

This thesis will explore how to avoid the negative consequences explained in the background. It aims to develop new architectural renovation strategies that will have the building's aesthetics and qualities in focus. By completing two case studies, the thesis aims to create design strategies that will be generally applicable and useful for buildings both in need of enhanced and preserved aesthetics. By working parametrically, the study will explore how modifications to windows and facade transformations impacts the buildings' performance in daylight, interior climate and energy use and draw conclusions on which parameters in the renovations are more important to focus on in order to reach better results.

The primary purpose of the thesis is not to produce one perfect renovation design for the selected case studies, but rather to use these as tools to test, evaluate, and refine the developed strategies. The goal is to establish a transferable design approach that can assist architects and planners in future renovation projects, beyond the specific cases studies. By working analytically with different renovation scenarios and design choices combined with interviews and building references, the thesis will illustrate how certain architectural parameters can significantly affect both daylight conditions, interior comfort, as well as architectural expression and spatial quality.

The intention is to shift the focus from solely meeting technical performance standards to incorporating architectural and qualitative values early in the renovation process. Through a combination of simulation-based analysis and architectural design explorations, the thesis aims to demonstrate how these aspects can complement each other rather than compete. With this approach, the aim is to provide guidance on how to prioritize and weigh various design parameters when balancing the energy efficiency requirements stated in regulations such as the EPBD, while simultaneously preserving or enhancing the architectural integrity and daylight conditions of the existing building stock.

Ultimately, the thesis aspires to contribute to a broader understanding of how well-considered design strategies can help ensure that the wave of future energy renovations becomes not only technically successful but also architecturally meaningful.

1.4 Research Questions

The main research question in this master thesis is:

> *How can renovation strategies improve daylight and aesthetics in Swedish multifamily housing while meeting energy efficiency standards?*

Supporting subquestions:

> *What key architectural factors influence daylight performance and aesthetics in energy renovations?*
>
> *How do different renovation strategies balance daylight access, overheating risk, and energy efficiency?*
>
> *How can renovation strategies enhance spatial daylight quality while preserving or enhancing the historical and architectural identity of existing buildings?*

1.5 Delimitations

The study focuses on Swedish multifamily residential buildings in need of energy renovations, excluding other building typologies such as villas, row houses, or buildings undergoing renovation for other reasons.

Financial, constructional, and logistical parameters that would normally influence renovation projects will be briefly discussed but not further investigated, in order to maintain focus on daylighting, indoor climate, and architectural quality.

Daylight performance will be assessed through Median DF and View-Out, in accordance with BBR (BFS 2024:8), and complemented by UDI and sDA metrics to account for seasonal variations, also following international standards such as LEED.

The energy performance analysis will primarily aim to ensure that the results do not decline compared to the current state or post-renovation targets, rather than to optimize energy use in isolation. Metrics used in the analyses will include EUI, Peak Cooling Loads, Hours above 27ºC, and overlit space.

1.6 Methods

The research methodology is structured to achieve a comprehensive approach to analyzing the relationship between daylight performance, energy efficiency, thermal comfort, and architectural quality in energy renovations. A combination of both qualitative and quantitative methods will be used to ensure a well-rounded foundation for the development of new design strategies.

The study will include an initial phase of literature studies and project references to build an understanding of existing research, standards, and strategies within the field. This will be complemented by interviews with professionals involved in relevant renovation projects to gain insight into the practical challenges and architectural considerations in real-world cases. Case studies will also be conducted on two selected multifamily residential buildings in Gothenburg, representing different renovation scenarios.

A significant part of the methodology will consist of parametric modeling and simulation work, using tools in Grasshopper to evaluate how different architectural parameters impact daylight access, indoor climate, and energy use. These analyses will form the basis for the development of two general renovation strategies, one focusing on preserving valuable qualities in the facades, and one a more transformative approach of the facade. The final stage of the thesis will involve testing and illustrating these strategies through design proposals applied to the case studies, with the aim of drawing conclusions on how similar strategies can be applied more broadly in future renovation projects.

While occupant perception and user-centered feedback would be central to evaluating long-term renovation success, this thesis focuses on architectural parameters that influence these experiences indirectly. By grounding design strategies in precedent, regulation, and parametric simulation, the study aims to provide architects with tools to enhance daylight and architectural quality, without requiring direct user feedback.

2. METHODOLOGY

2.1 Literature and Projects Studies

The literature review serves as the foundation for understanding the challenges, opportunities, and best practices within energy renovations and daylight optimization today. It includes sources that address daylight metrics, energy efficiency, indoor comfort, overheating risks, and architectural considerations in renovation processes. Additionally, the review covers current regulatory frameworks, standards, and modern simulation methods to ensure that the research remains relevant and applicable to best practices and the Swedish context.

Beyond the analysis of the selected case study buildings, the research will also investigate additional reference projects in order to identify key parameters that have contributed to their success. These references include: i) a re-renovation of a landshövdingehus in Gothenburg, ii) Kv. Nielsen, a restoration project in Borås, iii) Östra Gårdsten, a large-scale transformation by Liljewall in eastern Gothenburg, iv) Hallonbergen, a transformation of 1970s brick architecture, v) Park Hill in Sheffield, vi) Bijlmermeer in Amsterdam, and vii) various projects where interior niche designs have been used to improve daylight conditions. Together, these projects illustrate a range of renovation strategies, from detail-oriented restorations to large-scale transformations, and provide valuable insight into the balance between technical and architectural goals.

The literature review also includes studies and regulations that evaluate daylight and indoor climate performance, such as BBR BFS 2024:8, SS-EN 17037, and international certification systems like LEED. These sources clarify how metrics like daylight factor, useful daylight illuminance (UDI), spatial daylight autonomy (sDA), and overheating risk are used in the design process and how they influence renovation decisions.

Furthermore, specific focus is placed on literature that explores the relationship between energy renovations and architectural quality, emphasizing how technical upgrades have often resulted in compromised aesthetics. This is complemented by studies that highlight how architectural design choices can directly affect indoor climate and user comfort. These perspectives show the need for new design strategies that address both technical requirements and architectural values.

Finally, the review of project references and literature will not only inform the technical analysis but also provide a foundation for discussing how architectural identity, cultural values, and visual expression have been considered in previous renovations. This combined knowledge will serve as a bridge between the simulation-based analysis conducted in this thesis and the development of generalizable renovation strategies aimed at improving both daylight performance and architectural quality.

2.2 Case Studies

Two buildings located in Gothenburg will serve as both case studies and design objects for the thesis.

I. Kv. Tuppfjätet (Landshövdingehus): Located in Kvillestan and originally built in the early 30s, it underwent renovation in the late 70s and is now subject to potential demolition. The focus of this study will be on restoring original aesthetics while simultaneously enhancing daylight performance and indoor comfort through measures that that does not affect the facade. These strategies include the window niche, the window's depth in the wall, window type and material reflectancy.

II. Siriusgatan (Million Program): Built in the early 70s, Siriusgatan is located in the eastern parts of Bergsjön. On the site, there are several buildings of the same kind, with the majority having undergone renovation recently, and the others are planned to follow suit in the near future (Pettersson, 2025). In contrast to the other case, the focus on this building will be a more extensive transformation of the facade with the aim to provide a new face for the building. The design strategies involves working with window proportions, number of windows, transparancy and shading elements in order to increase daylight performance without negatively impacting energy performance.

The two case studies in this thesis are chosen, not to stand as isolated design projects, but as representative examples to test and illustrate the proposed renovation strategies. Each case reflects a broader category of buildings: one where the architectural expression is considered valuable and should remain as intact as possible, and one where the existing qualities are limited, and a larger exterior transformation is both possible and beneficial. Through these examples, the thesis aims to demonstrate how different levels of intervention — from subtle interior adjustments to major facade transformations — can be used strategically depending on the building's context and character. The case studies are therefore used as practical applications of the general strategies developed in the thesis, highlighting how design choices affect daylight conditions, energy performance, interior conditions and the architectural qualities of residential buildings in need of renovation.

2.3 Interviews and Site Visits

To complement the research and literature studies, a series of interviews and site visits have been conducted to provide additional insights and practical understanding of the topic. These qualitative investigations are intended to complement the quantitative simulation-based analysis, providing a broader perspective on how renovation strategies affect not only performance metrics but also architectural and cultural values as well as design intent and stakeholder perspectives

Interviews were carried out with Fredrik Hjelm, Heritage Officer at Borås Stad, and Christer Johansson, Property and Project Manager at Bostäder i Borås. Together, they were responsible for the window renovation and restoration project in Kv. Nielsen, located in Hestra, Borås. The interview discussions focused on the Kv. Nielsen project itself, their key takeaways from the process, and their views on future renovation projects of a similar nature. In connection with these interviews, a site visit to Borås was conducted together with Fredrik Hjelm. While the main focus of the visit was Kv. Nielsen, it was complemented by additional visits to other building complexes and houses, that were considered relevant examples of successful renovations and restorations. These visits included discussions regarding window types, niches, frames and other important details.

A second interview was held with Camilla Gyllestrand at Liljewall Arkitekter. Camilla was one of the leading architects in charge of the transformation project in Östra Gårdsten, Gothenburg. The interview focused on the project's concept, design strategies, and key takeaways but also included a broader discussion on general approaches to large-scale renovations and specific challenges related to the Swedish Million Program housing stock.

Further site visits were then conducted at the locations of the two case study buildings: Siriusgatan in Bergsjön and Kv. Tuppfjätet in Kvillestan, Gothenburg. These visits aimed to provide a clearer understanding of the facade compositions, the materials and their current conditions, as well as specific architectural details such as window placements and proportions.

2.4 Paramateric Modeling and Simulation

A central part of the thesis is the use of parametric modeling and simulation, to analyze and evaluate how different renovation strategies affect daylight conditions, indoor climate, and energy performance. Parametric refers to a design approach where building components or properties are controlled through adjustable parameters in a digital model. Instead of manually redrawing each design variation, a parametric model allows multiple scenarios to be generated by simply changing input values. These inputs are then evaluated using environmental simulation tools that quantify their impact on performance metrics such as daylight levels or overheating risk. This makes it possible to continuously refine the renovation strategies based on both results and the architectural impact of the design choices. In this thesis, Rhinoceros 8 is used for 3D modeling, while the plugins LadyBug, HoneyBee and Colibri in Grasshopper combined with the Design Explorer 2 software, is used for the simulation and analyses.

The parametric workflow is structured to allow for flexible testing of design variations, with a clear connection to the two case studies and their respective strategies. In the minor intervention scenario, the workflow focuses on adjustments to window details, such as window depth placement, niche angles, and reflectance. In the transformation scenario, the workflow instead targets more comprehensive changes such as window size and placement, the addition of shading elements as well as levels of transparency.

The simulations include the evaluation of both daylight and energy metrics. The daylight analysis is based on Median Daylight Factor (DF_{median}), Spatial Daylight Autonomy (sDA), Useful Daylight Illuminance (UDI), and View-Out quality — selected to align with Swedish regulations (BBR BFS 2024:8 and SS-EN 17037) as well as international certifications such as LEED. In addition, the energy performance is evaluated through Energy Use Intensity (EUI) and overheating risk.

By integrating parametric tools early in the process, the research aims to demonstrate how simulation-based analysis can support more informed and nuanced design decisions in the context of energy renovations — ensuring that architectural quality and daylight conditions are not secondary to technical performance but an integral part of the design strategy.

Simulation outputs will be presented as comparative graphs and spatial analyses in Chapter 6 of the thesis, enabling direct evaluation and comparison of design strategies.

3. CONTEXT & THEORY

3.1 Daylight Challenges in Renovation

Sweden's aging building stock is increasingly subject to stricter efficiency standards, such as the EPBD. However, conventional energy renovations, such as increased insulation thickness and window downsizing (Ståhl et al., 2011), often reduce daylight penetration and negatively impact indoor lighting conditions and the health of residents (Dubois et al., 2025).

Studies indicate that reducing window area to improve energy efficiency leads to lower daylight availability, which in turn affects occupant satisfaction (Bournas et al., 2019). Additionally, the placement of windows further into the facade, due to added insulation, alters light distribution within rooms and affects the overall perception of brightness (Tregenza & Mardaljevic, 2018). But it is not only the the penetration of light that is important to us. The research also shows that visual connection to the outdoors can boost our well-being (Dubois et al., 2025). This makes the balance between daylight access and energy efficiency a key factor in order to achieve sustainable renovations.

While artificial lighting can compensate for lower amount of daylight, it does not replicate the health benefits or our natural preference for natural light (Dubois et al., 2025). It is also simultaneously negating some of the gain of the energy renovation. In fact, in a study that compares energy consumption between old and new buildings, the old buildings tend to have a lower annual electricity consumption (Farahani et al., 2021). This shows a gap in current renovation strategies, where the full picture of the renovation is not fully considered, where energy efficiency is solely viewed as the the wall's performance. Negating its impact on daylight quality, electricity consumption and overheating risk.

In Nordic climates, where access to daylight is already very limited for many months of the year, this consideration is even more important. Energy-efficient renovation strategies must therefore, not only consider reducing energy loss but also consider adequate daylight performance to ensure both environmental and health sustainability. Addressing this balance is essential in developing a new approach to energy renovations.

3.1.1 Research on Strategies Affecting Daylight

In the 2018 master's thesis Sensitivity Analysis of Important Parameters Affecting Daylight, conducted at Lund University, Danai Vogiatzi explores the impact of various design parameters on daylight performance in a typical cellular office in Sweden. Although the building type differs from the residential focus of this thesis, several of the tested parameters are highly relevant across both typologies. While offices and dwellings differ in terms of occupancy patterns and spatial configuration, many of the geometric and material principles that influence daylight remain applicable to residential contexts, where daylight quality is a central concern.

Like this thesis, Vogiatzi's study evaluates performance using both static and dynamic daylight metrics, including DF, UDI, and sDA. However, the study leans more heavily on quantitative outcomes and does not address spatial or experiential aspects of daylight. Still, with over 11,000 parametric design iterations evaluated, it provides a robust technical foundation that helps inform the performance logic of this work.

Several insights from the study are directly relevant. In terms of window placement, a higher position on the wall improves daylight distribution. Window shape also matters — more squared proportions perform better than elongated ones, with aspect ratios of 1:2 and 2:1 shown to deliver slightly weaker results.

One of the most impactful parameters in Vogiatzi's study was surface reflectance, which was the only variable found to simultaneously increase both overall illumination and uniformity of light., highlighting the value of material and finish selection. For this thesis, this is particularly interesting in cases where architectural intervention is limited by the preservation goals.

While the study is rooted in a different typology, its analytical clarity and parametric depth offer a strong reference point. It supports the idea that strategic changes to basic design elements, even smaller ones, can have a measurable impact on daylight quality, making performance an integral part of architectural reasoning.

3.2 Qualitative Light Experience and Spatial Perception

While much of this thesis is based upon performance-based metrics, there are important architectural qualities that fall outside these measurable, quantitative aspects. One such aspect is the perceived experience of daylight, and how architectural detailing, especially in and around windows, contributes to it.

A previous master's thesis here at Chalmers, written by Helena Jacobson in 2008, explored window niches from a qualitative perspective, focusing on how the angles, colors and reflectance affect both the perception of the space and the distribution of daylight on interior surfaces. Unlike performance-based simulations, this work highlights the atmospheric and spatial consequences of design choices that may seem minor, but deeply influence how daylight is felt and acts.

This perspective is especially relevant in the context of preservation-focused renovation strategies, where original details like divided glazing, colored reveals, or splayed niches are often excluded in favor of simplified or standardized solutions. While such choices may slightly improve energy performance or reduce cost, they risk removing a key layer of architectural identity but also the perceived quality of the interior space.

Importantly, the thesis also emphasized how material reflectance, texture, and color can enhance daylight perception, even when quantitative daylight values may remain unchanged. This aligns with findings from other studies that suggest view quality and light distribution are as essential to user comfort as absolute light levels (Dubois et al., 2025).

With this in mind, this thesis aims to show that these types of insights not only strengthen the validation for reintroducing architectural details in renovated facades, but it also helps to argue for a broader definition of "daylight quality" which includes experiential and aesthetic dimensions together with the measurable criteria.

3.3 Current Regulations and Certifications

3.3.1 EU EPBD

The EU EPBD, EU:s Energy Performance of Buildings Directive, is a directive put in place to help achieve the goal of a fully decarbonized building stock by 2050 (Energy Performance of Buildings Directive, 2023). According to their own website, 85% of buildings in the EU were built earlier than 2000 and among those buildings, 75% have a poor energy performance. In the directive it is also mentioned that by 2028, all new buildings owned by public authority should be zero-emission buildings and by 2030, all new buildings in general should meet the requirements of being zero-emission (Boverket, 2024b). According to Boverket, the new points relating to the directive will be a part of Swedish law in the latest as of May 2026.

In addition to the regulations regarding new buildings as well as the reclassification of grading the buildings' energy performance, the new EPBD will have a major impact on the current building stock, and the renovation of it. Different requirements are made depending on the building being commercial or residential. For the residential building stock, the requirements are not on individual buildings, but rather on improving the average energy performance of the building stock in total, with the majority of the efficiency being done on the worst performing part of the stock (Boverket, 2024b). According to the EPBD, the residential building stock needs to reduce its average energy consumption with at least 16% by 2030 and with 20–22% by 2035. However, according to Boverket, these numbers can be slightly more lenient in Sweden, due to the fact that we are far forward in the process of adjusting to fossil-free energy-use. The end-goal of having all buildings being zero-emission in 2050 are still the same.

For architects, the introduction of EPBD a shift where renovations driven by energy performance are expected to increase rapidly over the coming years. This wave of upcoming interventions presents both a challenge and an opportunity. How can buildings be upgraded to meet environmental goals without sacrificing their architectural value? The risk, as seen in many past renovations such as the ones performed in the 70s, is that energy efficiency becomes the only priority, leading to design decisions that neglect cultural and spatial qualities. Within this context, the role of architectural design becomes increasingly relevant. A need for design strategies that respond to the directive's goals while also improving or preserving the character and comfort of our buildings increases.

3.3.2 BBR & SS-EN

In november of 2024, a new version of the regulations regarding hygiene, health and environment was released by Boverket and will come into force as of July 1st, 2025, the BBR BFS 2024:8. In this updated version, the regulations regarding access to daylight has changed. While both versions uses DF_{median} as their unit of measurement, the way it is used differs. Previously, a point halfway into the room, calculated from a window and 1m from an interior wall, should achieve a value of at least 1,0% DF. This would mean that at least haft the room exceeded the daylight aimed for. In the new regulations, the requirement is instead aimed towards the entire, residential area of the apartment, rather than room by room. Within that part, half of the area should achieve at least a 1,0% DF. This means that some of the smaller rooms in the apartment could be under the threshold, as long as one of the bigger rooms had more than enough daylight. Daylight Factor as a measurement considers how much daylight reaches a certain point inside, compared to the light outside under a CIE Overcast Sky - which represents a completely overcast, uniformly diffused sky without direct sunlight (Tregenza & Mardaljevic, 2018), meaning it removes the variability and bases its results on the worst case scenario.

The SS-EN 17037:2018 is the standard in which daylight in buildings are regulated. The standard serves a combination of information, criteria, verifications, assessments, recommendations and calculations of daylight provision. An interesting aspect brought up in this regulation, is the relation between daylight factor and illuminance in local context. According to the SS-EN, in order to reach 300 lux, which is considered good lighting, 2,1% DF is needed in Gothenburg.

However, the part that stands out the most in the SS-EN is the assessment of view-out, especially in the context of a residential building. For most people, the majority of the time spent at home are non-work hours, which translates to time where access to sunlight and daylight are not at the highest. This means that evaluations that also asses daylight as something more than perfect lighting are of high interest. The SS-EN writes the following both the view-out; ”view to the outside provides visual connection with the surroundings to supply information about the local environment, weather changes and the time of day. This information can relive the fatigue associated with long periods of being indoors. All occupant of a space should have the opportunity for the refreshment and relaxation afforded by a change of scene and focus.” The quality of view consists of three distinct layers: sky, landscape, and ground. The ground layer may include activity areas, while the landscape layer typically features buildings, vegetation, or the horizon.

According to SS-EN standards, view-out quality is evaluated at three levels—minimum, medium, and high—each defined by three metrics: horizontal sight angle, viewing distance, and the number of visible layers from at least 75% of the utilized area. It also mentions that rooms deeper than 4m should have window openings of at least 1 x 1.25m (Width x Height).

In terms of of energy performance, table 9:2 in Boverkets regulations states that new buildings require a primary energy number of 75 kWh/m^2, which would acquire a grade C on the scale of A-G. The primary energy number describes the building’s energy performance and constitutes of the building’s energy use, weighted by factors such as location and type of energy. For example, district heating is weighted by a 0.5 value and electricity by 1.6.

3.3.3 LEED

In order for buildings to perform to certain levels, there are two distinct means. The first is the standards and regulations, like the ones described in the previous part. The other is by certifications that can help boost the value prestige of the building. There are both national and international variations of these certifications. In Sweden the most prominent is probably Miljöbyggnad, while the most famous international ones are LEED and BREEAM, developed by the U.S Green Building Council (USGBC) and the UK based Building Research Establishment (BRE) respectively.

What makes LEED especially interesting for this report, is their different approach to evaluate daylight performance, compared to Swedish regulations like Boverket's BBR. LEED uses a point system, giving out different amounts depending on the level of compliance the building reaches. However, these metrics are not based on daylight factor, but rather on spatial daylight autonomy and illuminance (USGBC, 2025), meaning the evaluations are based on local climate conditions, compared to the worst case scenario system used in DF.

Illuminance calculations are based on a schedule, meaning it calculates the performance of a set time frame. This could mean either evaluating certain seasons, or certain times of day. By including both DF and Illuminance calculations in the thesis, it can paint a more complete picture of the building's performance as well as highlight how certain strategies impact residential buildings specifically.

LEED v4.1 gives out 3 points in total for Daylight, which is part of the Indoor Environmental Quality category. There are different ways to simulate the building in order to show the compliance to these metrics, and two of them will be measured in this thesis. The first one is achieving a high enough $sDA_{300/50\%}$ value for the residential space. 300/50% stands for ≥300 lux achieved for 50% of the annual occupied hours. Depending on how much of the area of the room achieves this metric, more points are given. If at least 40% achieves it, 1 points is given out. Then it is 2 points for >55% and 3 points for >75%.

An alternative method of simulation is using UDI, which assesses daylight quality based on a preferred illuminance range, typically between 300 and 3000 lux, to ensure sufficient lighting without causing glare. In the LEED evaluation system, points are awarded based on the percentage of regularly occupied floor area meeting this range: 55% earns 1 point, 75% earns 2 points, and 90% earns the maximum of 3 points.

In this thesis, the points themselves will not be targeted per se, but will work as a way of comparing and understanding the levels of daylight achievable in the buildings.

3.4 Indoor Climate Conditions in Renovation

The increasing demand for higher energy efficiency has led to greater insulation in buildings, which in turn significantly raises the risk of overheating, even in cold climates. Research has identified a correlation between good energy performance and poor interior thermal conditions (Arntsen & Hyrnyszyn, 2021). This research highlights the importance of window design and shading strategies, as they have a direct impact on both thermal comfort and daylight conditions.

Beyond health and well-being concerns, overheating also poses environmental risks, as increased indoor temperatures lead to greater reliance on cooling systems. This will in turn raise energy consumption, contradicting the goal of energy-efficient renovations. Studies indicate that as climate change progresses, heating demands in well-insulated buildings become less critical, while cooling loads increase drastically (Karimpour et al., 2015).

A study conducted in Canada found that highly insulated and airtight new buildings are more prone to overheating than older buildings are (Laouadi et al., 2020), while a similar study in Estonia showed results which indicated that modern buildings without passive solar protections are already regularly overheated (Maivel et al., 2014). These studies emphasized that the operability of windows as well as solar shading measures play a crucial role in reducing the overheating risk. In a Nordic context, these factor are even more important to take into consideration, as cooling systems are more commonly found in commercial or public buildings and less common in residential apartments (Verashjerdi Farahani et al, 2021.). This is a significant issue in current renovation strategies since they have a heavy focus on reducing heating energy demands while neglecting the increasing need for cooling solutions. In the current state of the climate change progressing negatively, heating becomes less and less critical, especially in well-insulated buildings, while the cooling loads become all the more of a challenge (Karimpour et al., 2015). But it is not only environmentally that this is a problem. In Finland, research has found that during heat waves - which become more and more common - urban areas can experience high heat-related mortality risks, which are aggravated by poor ventilation or limited window operability.

Several studies indicate that consideration of the window design - such as size, placement, operability and shading solutions - are very effective strategies to reduce the overheating risk while simultaneously increase the access to daylight. In a Swedish study by Tettey et al. (2017) it was found that window shading significantly reaches the energy consumption, especially under climate change, while Verashjerdi Farahani et al. (2021) suggest that windows that can be opened are crucial in order to regulate indoor temperatures.

Given these challenges, emphasizing the window design is essential in order to develop effective energy renovation strategies that balances both the energy efficiency and thermal conditions ni order to achieve comfortable interior climate conditions.

3.5 Architectural and Aesthetic Considerations

While energy performance is often the driving factor behind renovation decisions, the preservation of architectural and aesthetic values is frequently overlooked. Many Swedish residential buildings constructed during the early 1900s are locally and historically significant and contribute to the identity of their areas. However, typical renovation approaches—such as adding layers of external insulation, changing facade materials, or replacing windows with standardized modern solutions—can diminish the building's original aesthetic qualities (Femenias et al., 2020). In some cases, windows have even been covered up entirely, further impacting both the building's expression and daylight conditions.

The aesthetic value of a building is not solely visual; it also carries cultural, social, and historical significance that connects residents to their built environment. When renovation strategies disregard these aspects, they risk erasing traces of history and reducing the building's architectural integrity. These issues have been evident in much of Sweden's residential building stock, particularly in buildings affected by the energy crisis renovations of the 1970s, where aesthetic qualities were often sacrificed in favor of technical upgrades.

An important consideration today is to avoid repeating those mistakes. This thesis therefore not only takes aesthetic and architectural values into account but also investigates how previously lost qualities can be restored. Renovation projects should not merely comply with energy performance requirements, but should also contribute to the long-term architectural value of the buildings and their surroundings.

During a site visit to Hestra and a meeting with Fredrik Hjelm, heritage officer in Borås, we discussed how to approach buildings of high cultural significance. Fredrik emphasized that when it comes to buildings that still hold their original character, efforts should be made to preserve them as much as possible. According to him, this is often more feasible than one might initially assume—it just requires the right knowledge and care from the right people. He pointed out that small changes, such as alterations to a window's materiality, placement, or detailing, may seem insignificant to the untrained eye. However, when carried out at a larger scale, these small changes accumulate and risk degrading the overall architectural expression, often without being noticed until it is too late.

Preserving aesthetic qualities may seem straightforward when the building's original appearance is largely intact, but it becomes more complex when the building has already undergone alterations, as in the case study example in Kvillestan. In this case, few original materials or details remain. The challenge then instead becomes how to balance the restoration of lost qualities with the current appearance and condition of the building.

In discussions with Fredrik Hjelm, he described this situation as an opportunity rather than an obstacle. If a building is in need of renovation, it provides a chance to bring back as much of its original architectural character as possible. However, this must be done carefully and with attention to detail. Poorly executed attempts to mimic historical details can result in an opposite effect.

A common example is the use of surface-mounted plastic muntins to replicate historic window divisions. While not inherently negative, these solutions frequently fail to recreate the original expression and does not affect the distribution of light inside the building nearly as well. Moreover, they tend to have a limited lifespan and are prone to detaching after only a few years.

Another, more specific example of how technical decisions can undermine architectural quality that was observed during the site visit, was the window side profiles. In this case, a standard technical solution involved extending the metal sheet of the window's side profile nearly all the way to the edge of the niche, with the intention of improving the weather protection. However, this approach drastically alters the visual balance of the facade. What was once a discreetly framed window, became a fully colored niche, totally changing its appearance. Even though there could have been attempts to match the original color, the increased surface area and different material reflectance gives the niche an entirely new expression.

This kind of detailing, often driven by technical or economic reasoning, highlights how small design choices can have large impact on the perceived character of a building. Without architectural consideration, these changes risk becoming standard practice, even though they differ significantly from the building's original qualities.

For these reasons, the aesthetic and architectural considerations in this thesis are treated as essential elements of sustainable renovation strategies. The ambition is to demonstrate how thoughtful and informed design choices can preserve, restore, or reinterpret the architectural identity of residential buildings while supporting technical performance goals.

3.6 The Structural and Financial Aspects of Renovations

This thesis investigates what deciding factors are most relevant for older buildings in need of renovation due to poor energy performance. While the economic parameter may in reality be one of the most influential factors in decision-making, it will be toned down here in order to allow the qualitative aspects to take center stage. Nevertheless, to ensure that the strategies proposed are viable and relevant, financial considerations will not be disregarded entirely. This section briefly explains how the thesis takes these factors into account and how they have informed certain decisions.

The same applies to the structural aspects of the proposed design strategies. Although no structural calculations or technical optimizations will be performed, the constructive aspects will still guide and inform which design interventions are more likely to be realistic and feasible.
Firstly, energy renovations inherently carry an economic dimension. Reducing the energy consumption of a building is not only an environmentally sustainable intervention but can also lower operational costs for the residents. As demonstrated by Skanska in the renovation of Brogården in

Alingsås (Friesen et al.), significant improvements can be achieved when the measures taken are extensive enough. In this case, the renovation to passive house standard reduced the average energy consumption from 215 kWh/m^2 to 86 kWh/m^2.

However, large-scale interventions like this often come with a cost for the tenants, typically in the form of increased rent. In Brogården's case, Alingsåshem—the property owner—negotiated an increase of £25/m^2 per year. This means that the immediate financial gain for the residents was limited, and the actual savings would only be realized in the long term. Alingsåshem estimated that the renovation costs would be offset within 10 to 20 years (Friesen et al.).

Perhaps the most notable finding from the Brogården project was that the total cost of the renovation was comparable to constructing an entirely new residential complex. However, this new complex would likely have had a different spatial and social character, including a different building volume, number of floors, and community composition (Friesen et al.). The decision to renovate was justified by the belief that desirable and high-quality apartments have a longer lifespan, and that longevity is essential for long-term sustainability.

This argument is further supported by the Kv. Nielsen project in Hestra, Borås. It will be discussed in more detail in a separate chapter, but in short, the decision to restore rather than replace the existing windows resulted in significant economic and qualitative benefits. The original renovation budget allocated 15.5 million SEK for replacing all windows (Johansson & Hjelm). Instead, by restoring and repairing the original windows, the total cost was reduced to 10.4 million SEK, while also achieving a better aesthetic and cultural outcome (Johansson & Hjelm).

This leads into the structural considerations of the thesis. Preserving as much of a building's structure and detail as possible is not only an economical approach but also beneficial for maintaining cultural and aesthetic values. The question becomes which elements of a building are worth preserving and which could be altered or replaced to improve energy performance and daylight conditions.

In buildings of high cultural value, such as the landshövdingehus in Gothenburg, the preservation of original elements is generally preferred. However, in cases like the Kvillestan building analyzed in this thesis, previous interventions complicate this approach, and a different strategy may be required. These aspects will be discussed further in the architectural considerations chapter.

Structural integrity becomes even more relevant in projects where a transformative strategy is applied—such as in the Brogården project or the million program case study included in this thesis. More ambitious interventions will often require larger structural modifications to support new facade elements or layouts.

During the interview with Camilla Gyllestrand at Liljewall, it was highlighted that one of the key challenges in renovating Swedish million program buildings—particularly the more recent ones—is that their structure is based on highly optimized concrete elements. These buildings function almost like card houses, where altering one part may affect the stability of others. Therefore, if any structural changes are made, they need to be carefully considered and kept to a minimum.

However, for buildings with non-integrated balconies, there is more potential. In such cases, the balconies are structurally separate from the main building system, which means that interventions targeting these elements may be easier to implement without compromising the overall structural stability. This aspect will be an important consideration when developing the renovation strategies in this thesis.

3.7 The Need for Integrated Design Strategies

The discussion through the previous titles shows the complexity of energy renovations in residential buildings and really highlights the importance of balancing the different performance criteria. Too many renovation projects focus too narrowly on only one or a couple of these aspects, which often leads to unintended consequences that can negate certain results or affect residents negatively. In order to avoid this, new renovation strategies that integrate more of these aspects are required. These strategies should consider daylight access and thermal comfort alongside energy efficiency in the decision-making, preserve or enhance the architectural character of the affected building and, in the best practice case, use a parametric and simulation-based approach to be able to choose optimal design choices.

The previous parts of this chapter have demonstrated how the financial, structural, climatic and architectural considerations are interlinked and cannot be addressed in isolation. Improving one parameter, such as energy efficiency, without considering the aesthetic or social qualities of a building, can risk deteriorating both the residents' well-being and the long-term value of the building. Similarly, neglecting indoor comfort and daylight conditions can result in unintended consequences such as increased overheating risks or reduced usability of interior spaces.

This complexity is further emphasized by the two types of buildings that are explored in the case studies of this thesis—on the one hand, buildings where the original architectural qualities are worth preserving, and on the other hand, buildings in need of a transformative facelift. Both of these require fundamentally different design strategies, but both equally demand an integrated and holistic approach.

By developing design strategies that address these aspects, this thesis aims to contribute to a more holistic approach to energy renovations. One that will facilitate a more long-term sustainable approach which at the same time improves the living conditions of the residents. The goal is not only to demonstrate specific renovation solutions, but to establish a design methodology that can be used in future projects — one that is based on the simultaneous evaluation of daylight, indoor climate, energy performance, and architectural quality. In the context of the increased renovation requirements of the EPBD and national regulations, this type of integrated strategy will be essential to ensure that the architectural heritage and social value of the Swedish housing stock is not lost in the process.

4. PROJECT REFERENCES

Several projects in Sweden and across Europe have shown that it is possible to achieve energy efficient renovations without sacrificing architectural integrity or aesthetic values, or vice versa, enhancing the aesthetic values with compromising the building's energy demand.

4.1 Landshövdingehus Hisingen

The first case study is of another landshövdingehus, also located on Hisingen, very close to Kv. Tuppfjätet. To make the reading easier, this house will be referenced as Brämaregatan. Originally built in 1898, Brämaregatan is older than the design object, however, just as the other one, it was renovated during the national energy saving program in the 70s (Femenias et al., 2020).

Brämaregatan can be viewed as a role model in how it was able to be re-renovated and re-imagined in its design and aesthetic value. The similarities between the two buildings are many and uncanny. The original wooden facade and the detailing in and around the windows with the wooden muntins and frames, which in both cases were removed or covered in the renovation process. The external insulation and the new sheet metal cladding covered the old wooden facade, the windows fell deeper into the facade and the previous aesthetic symmetry was lost with the details around windows and in horizontal and vertical connections in the face being removed. In the Brämaregatan case, the renovation was even more extreme, with two of the windows in the main facade being covered up entirely, affecting the symmetry massively.

During the 2000s, the property was acquired by a construction company with the ambition to refurbish the building (Femenias et al., 2020). The sheet metal on the streetward was replaced with new horizontal wooden panels in order to resonate with the original facade, with the courtyard facade being kept in sheet metal due to risk of moisture.

Fig. 1. Brämaregården in original facade, photographed in 1905 (Göteborg stadsmuseum).

Fig. 2. Building before re-renovation, photographed 2010 (Jesper Hallén).

Fig. 3. Building today.

At the same time, the old external insulation of 50mm was replaced with a new 100m layer. The windows were also replaced with pivot-hung units featuring a false central muntin. The roof was at this point also in need of renovation, however this time, it was carefully executed, with the roof slates being taken down, kept and then reinstated again after the new insulation were done (Femenias et al., 2020).

The company behind the re-renovation claims that with rather small measures, the value of this type of property can rise pretty fast. They do not have concrete proof of this, but have done it to more buildings of this character previously (Femenias et al., 2020)

The residents of the building seems to be proud and care about of the building that they live in. There is an ambition of reinstating the wooden facade towards the courtyards as well, and in the staircases of the building, there are photographs of the original building, which suggest there is a real interest of the history and character of the building (Femenias et al., 2020)

4.2 Kv. Nielsen

Kv. Nielsen, or the Danish houses, is one part of the Hestra Parkstad area in Borås, which was built in 1991 and won the Kasper Salin award in 1992, and are together with Kapellet, the only buildings in the city recognized with the award (Johansson, 2025). The area is very well liked by both its residents and other visitors, who regularly stroll around the green area and admire the houses (Hjelm, 2025). However, in the late 2010s, complaints started to come in regarding the interior climate in the buildings. The wooden windows had started to deteriorate, letting through cold air, and the energy performance of the buildings were the worst of any property handled by the property owners (Johansson, 2025).

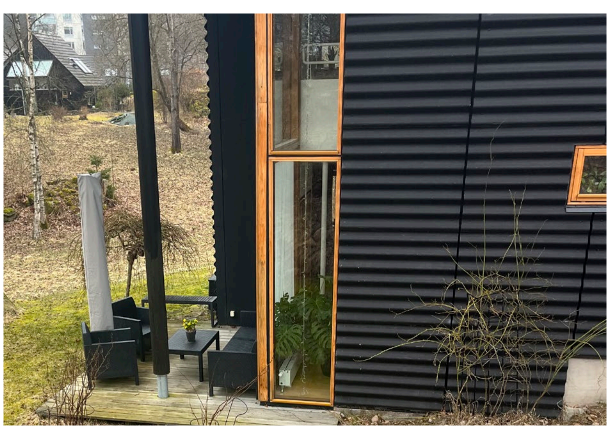

Fig. 4. Bigger window type, with new wooden frames.

Fig. 5. Window detail. Refurbished frames with color-matched sill flashing.

In charge of solving this problem, was Christer Johansson, Property and Project Manager at ”Bostäder i Borås”, and Fredrik Hjelm, Heritage Officer at Borås Stad, who both were more than happy to share the insights to the renovation project.

The area itself had recently been included in the list of parts of the city which need extra careful consideration when worked with. Usually these lists include older areas and properties with high historical and cultural value, but due to the city of Borås lacking other buildings or areas with similarly esteemed reputation, the Danish houses were included anyway. This was the reason behind Fredrik being a part of the early stages of the process.

Christer explained the initial plan of the window amendment was to replace them with aluminum windows, painted in the same color as the original wooden profiles. This would both ease the management of the property and solve the energy performance issue. However, after testing out the new windows on one of the houses, both Christer and Fredrik were not satisfied with the result. The window frames had too much of a flat impression. Instead, they ordered the same windows but with wooden frames. Only this time, Christer explained, the outcome was even worse. To resolve this challenge, Jens Arnfred, the architect from Vandkunsten who designed the houses, was contacted.

Upon arrival, Arnfred shared the concern of the new frames ruining the facades, and instead brought up the idea of renovating the existing frames, rather than swapping them out for new ones. The idea was tested in one of the houses who had the worst conditions. The window panes were swapped out for new double-glazed argon filled windows, that still could fit in the existing frame. A small change were made with the new dropdown that got out in was made in aluminum, but still painted in the same color. The tenant in the building was extremely happy with the results, and the decision to renovate was then made.

The project turned from changing the entire window to basically only swapping the glazing, and the results were very positive, in more ways than just aesthetically. Christer described that the renovation meant less interference for the tenants. Instead of a 3-4 day period of work, both on the interior and exterior side, the renovation could be entirely completed from the outside in just 1-2 days, and the only interference was the cold breezes when the glass was taken down. The vast majority of the existing material could also be kept. Fredrik stated that out of the 700 window unites, only 1.5m of wood had to be discarded.

The success of the project has had a positive impact of the rest of the area as well. Fredrik explained that the Cooperative Housing Association (BRF) of the Norwegian houses in the area decided to work with its front doors, balconies, windows and colors in order to keep the character of the area and its architectural vision intact. The BRF decided to follow suit, and contacted the original Norwegian architect as well.

4.3 Östra Gårdsten

Östra Gårdsten is a renovation project on a million program building in the fringes of Gothenburg, by Liljewall Arkitekter. The project started in 2000 and was finished in December 2005. At the start of the project, around 25% of the apartments stood empty, which is where that transformative approach of creating terraces stemmed from, and took wings from the orientation of the buildings on site, which were placed in a north-south manner with great views towards the sea (Liljewall, 2006.). Apart from visibly scaling down and giving the building a new feel and look, the main concept in the project was to give new hope and admiration to the residents in the area. The people who lived in Gårdsten should feel valued, seen and proud of their residency. To create a sense of ”they are investing in us too” (Gyllestrand, 2025.). To strengthen this concept and optimize the results, people in the area were frequently invited to share their thoughts on what they liked and what they wanted changed (Liljewall, 2006.).

The original facades of the building were made in concrete, with modules made in an overlapping fashion, and had a lake stone finish. The overlaps in the concrete had become sensitive to frostbite and were frequently falling off. This created opening in the structure which in turn exposed it to moisture and energy leakage. If these cavities were to be covered with a new material, such as plaster, it would make the building striped and amplify the sense of verticality. However, redoing the facade too much would make it lose its original concept, which was this solid volume seen as a mound, with windows as cavities. A decision then had to be made, if the appearance of lake stone or the original volume concept was to be retained. In consultation with the city heritage officer, the decision fell on the volume concept, which then opened up the possibility to change the color of the facade. The new color that was chosen was a light gray, which was supposed to coincide with the new project concept of creating something lighter and more open, the color was associated with the architecture around the Mediterranean which the new terraces in the building were similar to (Gyllestrand, 2025).

Fig. 6. Östra Gårdsten before renovation. (Liljewall).

Fig. 7. Volume concept. (Liljewall).

Another part of the building that Gyllestrand mentioned that were up for discussion in terms of being kept or not, were the external balconies and bay windows. They were very appreciated by the residents, however, in order to be able to redo the facade, they had to be dismantled during the process. The decision was made to not reinstate them, since they were not built originally with the house, but instead replace them with other, and a higher amount of balconies. These were supposed to be open balconies that would restrict less light into the apartments.

The windows in the project were at the time English plastic units, that were put in place during a larger renovation in the mid 80s (Boverket, 2007). Having windows in plastic is very rare in Sweden, and is more common down south on the continent, and they were already in the start of the project in need of better insulation. However, Gårdstensbostäder had, and still have, a very strict policy regarding renovation called Hel-o-Ren (Complete-and-Clean). This entails very careful consideration into what could be amended rather than removed or swapped out (Gårdstensbostäder). When asked about it, Gyllestrand also explained that, no matter your opinion on plastic units, the process of swapping out all the units would have been a huge measure. This would have had consequences both economically and administratively, since a lot of residents would have needed to move out or change apartments. This meant that the units were kept in place and instead weatherproofed with new window sealing.

Gyllestrand further explained that keeping the windows in place were also motivated by the building's structure. A lot of million program buildings, especially the ones built later on - in the early 70s, have very optimized concrete wall elements. Removing, changing or cutting out parts of these elements would be very hard and risky, and the stability of the building would be compromised. Gyllestrand equated it to a house of cards, where removing just one part incorrectly would affect its entirety. However, magnifying the window size in a similar building would not be impossible, but it would be a hassle and require good arguments to go through. Gyllestrand also pointed out that the best way to allow for more glazing would be to work in and around the balconies. These elements are already built differently to the rest of the external walls and would be easier to reshape and reconfigure.

Fig. 8. Terracing of the new building. (Liljewall).

Fig. 9. New facade. (Liljewall).

4.4 Park Hill

Park Hill was built between 1957 and 1961 in hilly terrain in Sheffield by architects Jack Lynn and Ivor Smith, coordinated by city architect John Lewis Womersley. The estate was part of a strategy to introduce more high-density housing to the city, to foster a stronger sense of community than the previous ”back-to-back terrace”-housing concept. The policy also fitted well into the city of Sheffield which at the time, had an urgent need for slum clearance and high crime rate (Bryant-Mole, 2017.). The new concept of the building was name ”street-in-the-sky” and the project was seen as one of the boldest, most advanced research experiments in housing of its time, but hade equally many contradictors as fans (Lepratto, 2024).

The background to this project makes it very similar to a typical million program building in Sweden. Built during similar times, with similar issues as the foundation for the new typology. The building itself makes a good reference for Siriusgatan as well, being located on a hill, on the outskirts of a bigger city and having a similar aesthetic to it. The concrete based monolithic building with grid infills of different colors and a very distinct vertical accent.

In 2004, the property developer Urban Splash took on the challenge of rethinking and designing the brutalist complex, with the intention to adapt the living spaces to contemporary standards and to implement a new image of the complex in the eyes of the people of Sheffield (Lepratto, 2024). The developers recruited the the firms of Hawkins//Brown, Studio Egret West and architect Mikhail Riches to lead the architectural design phase, which started in 2008.

The choices made in the initial phase aimed to achieve an impactful change of image, emphasized by the use of bright colors and having the concrete supporting structure as the sole link between past and present, showcased in Figure 12. The concept of a fresh start was achieved through comprehensive facade modifications, visible at a distance. The exposed concrete and brick walls with the white-framed windows were

Fig. 10. Park Hill Flats. (yellow book). CC-BY

Fig. 11. Park Hill, post renovation. (andrewbasterfield). CC BY-SA

removed and new window frames which spanned entire modules were installed. The frames were internally divided into glazing and opaque areas with the opaque parts being painted in colors that would match the original facade.

The second phase of the re-establishment is of a different manor than the first, showcased in Figure 13. Phase 2 starts in 2016 and is led by architect Mikhail Riches, who shifts the attitude of the work. Rather han upgrading and redesigning to create a discontinuity, Mikhail focusing on the reconnection to the building's history and strengthening of its roots (Lepratto, 2024). Similarly to phase one, the concrete grid is preserved, but here the exposed brick is also maintained.

The three nuances in coloring in the facade is re-emerged by simply cleaning up the facade. Instead, the design changes focuses on smaller details, such as window frames. The existing white wood frames are replaced with minimalist design versions in slim, dar metal profiles, coordinated with aluminum flashing. The use of color in the building is now more discreet than in phase one. Now it seeks ro connect the building's image with expressions of Modernist mass housing, recalling tones and positions adopted by Le Corbusier in Unité d'Habitation. Colors such as green, blue and turquoise which are supposed to be soft and match the gray of the concrete and pink and brown of the brick (Lepratto, 2024).

Fig. 12. Park Hill Phase One. (Lepratto, 2024). Reprinted with permission.

Fig. 13. Park Hill Phase Two. (Lepratto, 2024). Reprinted with permission.

4.5 Biljmermeer

The project in the Bijlmermeer district of Amsterdam started in 1966 and was designed by architects Ottenhof, Kromhout & Groet and Rijnboutt. The buildings are made in prefabricated concrete panels and span ten stories high and between 150 and 770 metres in length (Lepratto, 2024).

The neighborhood was intended to be inhabited by the middle class leaving the city centre, but as time passed, the buildings became more and more inhabited by the underprivileged class, often originating from former Dutch colonies. This led to a downward cycle of hardship and social stigma and as early as just a decade later, the area had an entirely different outlook. A debate quickly started on how to adress the social issues, and it swung between correcting the model and demolishing the entire project (Lepratto, 2024).

Just as the Park Hill case, the Bijlmermeer project is in many ways similar to many million program buildings in Sweden. Structurally it is very similar, but maybe even more than Park Hill, the social segregation issues are more evident as well.

In the next 30 years, various modifications were made to the project, varying from extreme to those more respectful to the original design. In the research done by Fabio Lepratto, two buildings are selected for their idea of maintaining the original idea while simultaneously making necessary improvements for the living conditions, which makes them excellent references to the Siriusgatan case. These two buildings are the Florijn completed in 2003, showcased in Figure 16, and Kleiburg completed in 2016, showcased in Figure 17.

The Florijn building was modified by the architects of Studio Vanschagen. In terms of the volume, nearly the entire building was kept in order to preserve the original morphology. The renovation had three main concepts; reconfiguring the ground floor, redesigning the southern blind side and redefining the overall image by replacing most of the components which defined the facade element, with the latter one being the strategy that had the most impact aesthetically. This design strategy involved replacing the previous concrete railings with new white glass ones. The previous elements had over time been repainted in bright colors with the intention to soften up the harshness of the building mass, but failed to do so. Instead the new glass elements would lighten up the galleries in the facade. The previous window rows in the second floor were also switched to bigger elements that fitted an entire facade unit.

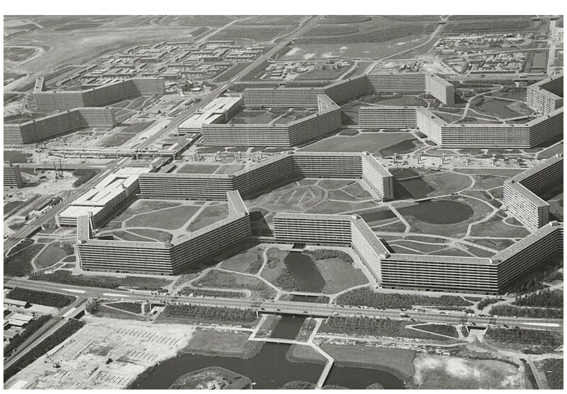

Fig. 14. Biljermeer. (Stadsarchief Amsterdam, 1973). CC0.

Fig. 15. The Kleiburg building, post-renovation. (Alphanille). CC BY-SA

4.6 Light and Niche Consideration

The window niche is often seen as a technical or secondary element in housing renovations, but it can have a significant impact on how light enters a room and how that space feels. In projects where it is not possible to change the size or position of the windows—or where the facade must be preserved—adjusting the niche can be an effective way to improve daylight conditions. Several architectural examples, though not all residential, show how the design of the niche can be used to guide light, reduce glare, and improve spatial quality. In this chapter, three projects are used to show how changes in depth, angle, and materiality can affect daylight and interior comfort.

In *Villa Müller,* designed by Adolf Loos and described in *Adolf Loos: The Life, The Theories and Analysis of the Villa Müller* (Besser & Liebscher, 2005), the windows are often set deep into the walls and placed slightly off-center. The niche around each window is clearly considered as part of the interior space. In many cases, these deep reveals are combined with different materials, such as wood with plaster, which creates contrast with the surrounding walls. These design choices affect both how the window is experienced and how daylight is distributed in the room.

The contrast between materials serves not only an aesthetic function but also influences how light reflects and behaves across different surfaces. Smooth or matte plaster surfaces diffuse light softly, while wooden elements add warmth and subtly shift the tone and direction of reflected light. This layered approach creates a more dynamic lighting condition throughout the day and gives the niche a distinct spatial identity. In renovation contexts, especially when daylight must be optimized without increasing window size, carefully selecting and combining interior materials around the niche offers a simple yet effective method to improve visual comfort.

The depth of the niche allows daylight to enter at a more controlled angle, which reduces glare and creates a more even distribution of light across interior surfaces. In some rooms, the niche creates a small ledge or seating area that gives the window additional function beyond just light or view. While these decisions are part of Loos' spatial planning method—Raumplan—the general approach of treating the niche as an active part of the design

Fig. 16. Biljermeer, Florijn. (Lepratto, 2024). Reprinted with permission.

Fig. 17. Biljermeer, Kleiburg. (Lepratto, 2024). Reprinted with permission.

can be applied in renovation strategies. When the window cannot be moved or resized, adjusting the interior wall thickness, material reflectance or combination of materials can still improve light quality.

In *Therme Vals* by Peter Zumthor, which is analyzed in *A Study on the Sensory Experience Connected to Light...* (Kim, 2020), light is treated as an architectural material. Although the building is not residential, it offers valuable insight into how daylight can be manipulated through surface treatment and spatial composition. The project features a deliberate variation in window placement—some openings are positioned close to the facade surface, while others are deeply recessed within thick walls. This difference in setting causes light to behave in distinct ways depending on depth, orientation, and time of day, resulting in layered transitions between light and shadow and avoiding stark contrasts.

While the use of stone and spatial dramatization is specific to the building's program, similar strategies can be applied in housing renovations to improve the quality of daylight. In Nordic contexts, where sunlight is often low and diffuse, recessed or modulated windows can help control the intensity and spread of natural light. These variations can also improve interior atmosphere without necessarily altering the window size or exterior character of the building.

Materiality further enhances this effect. In Therme Vals, the stone surfaces respond to daylight differently based on texture and finish. In residential settings, this can be translated into practical choices such as matte paint, brighter wall finishes, or timber reveals—each affecting how light is reflected within the room. These principles become especially relevant when increasing glazing areas, where careful surface selection can help mitigate glare and overheating while preserving spatial comfort.
Pumpkällehagen, designed by Ola Nylander and completed in 2008, offers a more directly comparable example in Swedish housing. *The project is presented in the report Interior Climate Conditions in Pumpkällehagen From the Perspective of the Tenants* (Mnela & Mohamed, 2023). The buildings are built to passive house standards, meaning that the walls are thick and well insulated. This could reduce daylight availability if not handled

Fig. 18. Villa Müeller facade. (Hpschaefer). CC BY.

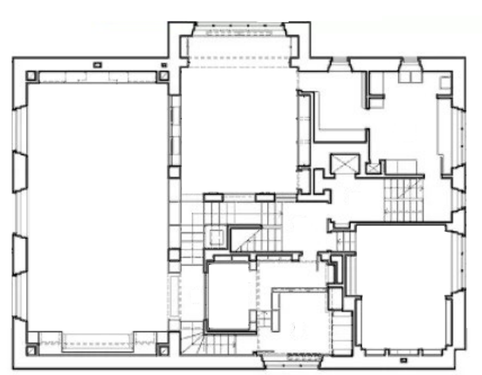

Fig. 19. Villa Müller floor plan.

carefully. However, the project uses angled niches around the windows to bring more daylight into the rooms and improve the indoor environment.
The angled reveals in Pumpkällehagen are designed to help light reach further into the room, improving brightness even with the thick walls. It also improves the view to the outside by increasing the angle at which the sky is visible from inside. These design choices do not affect the exterior appearance of the building, making them well suited for use in buildings where facade changes are not possible.

The results of these strategies are not only theoretical. In a tenant survey included in the report, residents describe their homes as bright and comfortable, and many highlight daylight quality as a key strength of the apartments. This supports the idea that careful niche design can have a real impact on how a space is perceived and used.

These three examples show how niche design can play an important role in daylight performance. By adjusting the depth, angle, and materiality of the reveal, the architect can improve light levels, reduce glare, and add spatial qualities. In renovation projects where the facade must remain intact, the interior side of the window becomes the main area for intervention. This makes niche design a relevant and flexible strategy that can be adapted to different conditions.

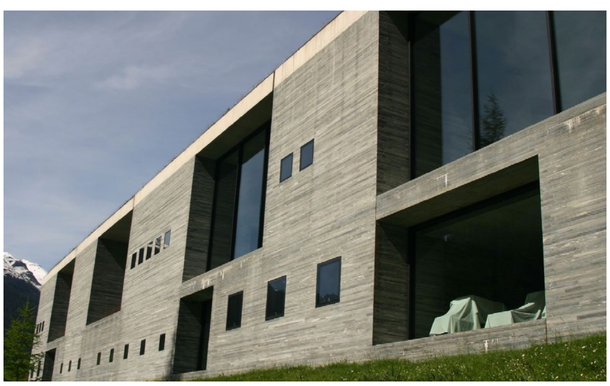

Fig. 20. Therme Vals facade. (p2cl). CC BY-SA.

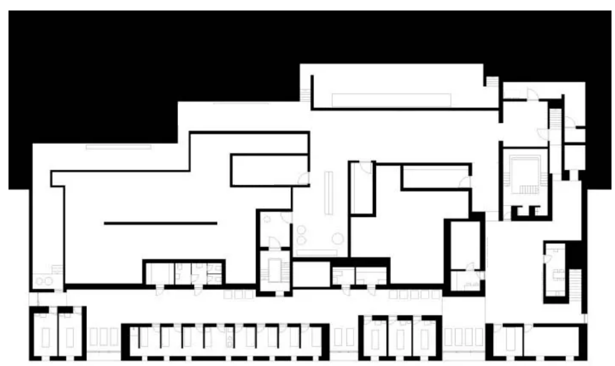

Fig. 21. Therme Vals floor plan.

Fig. 22. Living room of Pumpkällehagen. (E:son Lindman, 2017)

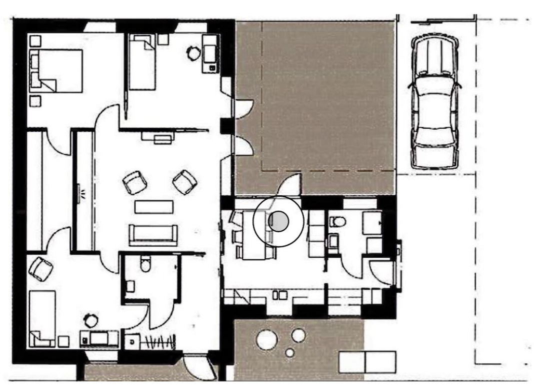

Fig. 23. Pumpkällehagen floor plan.

5. DEVELOPMENT OF DESIGN STRATEGIES

5.1 Current Issues and Key Aspects

The previous chapters have established that energy renovations of existing residential buildings in Sweden often come at the cost of diminished daylight quality, increased overheating risks, and compromised architectural identity. With the upcoming enforcement of the EU EPBD and the revised BBR (BFS 2024:8), a significant number of buildings will require energy upgrades, and architects will have a very impactful task in hand to guide these transitions. As seen in past interventions, particularly those carried out during the latest energy crisis in the 1970s, technical efficiency has too often taken precedence over design quality, leading to worse living environments and the fade of valuable cultural, historical and aesthetic character.

Several key architectural aspects emerge as particularly critical in this context: the size, placement and design of windows and niches, facade articulation, shading elements, and material reflectance. These design factors are directly tied to both quantitative outcomes such as daylight factor, useful daylight illuminance, and overheating risk, as well as to more qualitative aspects like visual comfort, perception of space, and connection to the outdoors. Yet, in many renovation projects, such qualities are either neglected or flattened through standardized technical packages. This disconnection between technical thinking and architectural consequence marks a critical gap in knowledge and ambition in today's development sector.

This thesis aims to address that gap by introducing a framework that connects the technical performance goals to spatial and visual design consequences. It positions the architect not just as a designer, but as a mediator between regulation, lived experience, and built heritage. Rather than proposing a singular design solution, it introduces a structure for reasoning, a set of recurring categories that can help architects recognize what is at stake in renovation projects and act accordingly. These categories are gathered into a comparative framework that maps the renovation process through chronological steps: identifying issues, establishing architectural intention, defining the standard technical approach, exposing its architectural limitations, conducting performance evaluations, reflecting on spatial and visual implications, and finally identifying architectural design measures.

Each of these categories represents a stage of reflection. The identified issues refer to the technical or qualitative reasons why the renovation is considered necessary as well as what the buildings represent. The architectural intention then translates these issues into what the renovation should include and aim for.

In contrast, the standard technical approach outlines what is typically done—such as the application of external insulation and new windows—when aesthetic or contextual values are overlooked. This leads to architectural limitations, where the consequences of such interventions become visible: darker interiors, reduced window proportions, and a lack of spatial or material improvement.

Moving beyond assumptions, the performance evaluation stage quantifies the actual impacts on energy use and daylight metrics, providing architects with concrete arguments for how architectural measures contribute beyond aesthetics. Reflections on spatial and visual implications then highlight which qualities these ambitions and evaluations are aiming to support or restore.

Finally, the last step presents architectural design measures, the specific strategies that can be applied to improve buildings within the constraints of renovation. These are tailored to suit the chosen approach, building type, context, and architectural intent.

As a whole, the framework contributes to the architectural field by offering a structured yet adaptable lens for energy renovations. It places the architect more centrally in the renovation process. Not just as a designer, but as a critical thinker negotiating between performance, heritage, and lived experience.

PRE-RENOVATION ANALYSIS	PRESERVATION STRATEGY	TRANSFORMATION STRATEGY
Identified Issues	Bad energy performance Sensitive, significant design features Fragile building elements	Bad energy performance Uninspiring facades Optimized construction
Architectural Intention	Re-instate original aeshtetic Elevate interior climate conditions	New and/or enhanced aesthetic Elevate interior climate conditions
Standard Technical Approach	Exterior isolation New facade material Standardized window replacements	Exterior isolation New facade material or color scheme
Architectural Limitations	New facade composition Loss of detail Deep window placement Less glazing	Cosmetic changes Lack of qualitative enhancements
Performance Evaluation	Daylight: DF, UDI, sDA View-out: Sky View & General View Energy: EUI Overheating: Overlit Space, Hours above 27 degrees	
Spatial & Visual Consequences	Daylight conditions View out General perception Future overheating risk	General perception Interior climate conditions
Architectural Design Measures	Window placement in wall Window type Niche design Material choice	Window size Window amount Transparency Shading elements

5.2 Development of Performance Evaluation

Performance evaluation in renovation is often reduced to checking whether a building meets updated energy standards. While metrics like EUI are essential for regulatory compliance, they provide little insight into how the renovation affects spatial quality, user comfort, or architectural intent. As previously stated, failing to achieve usability can even lead to the EUI being misleading — for example, if the use of artificial lighting increases due to poor daylight conditions. In the context of this thesis, performance is understood more broadly: as a tool to support design thinking, guide architectural decisions, and reveal the trade-offs between efficiency and experience.

This chapter introduces a performance model tailored to renovation scenarios, structured around four key categories: daylight, view-out, overheating risk, and energy use. These categories are selected not only for their technical relevance, but for their impact on architectural consequence.

Daylight is evaluated using three metrics: Daylight Factor (DF), Useful Daylight Illuminance (UDI), and Spatial Daylight Autonomy (sDA). Together, these provide both static and dynamic perspectives on light distribution, allowing for a more comprehensive assessment of perceived brightness, visual comfort, and compliance with national and international standards. DF is reported as DF_{median}, in line with current BBR requirements. UDI is expressed as UDI Compliance, measuring the percentage of the apartment that meets at least 2 points in LEED's daylight assessment. This helps ensure that the proposed strategy delivers good daylight conditions across the majority of the space, rather than allowing performance to be skewed by isolated areas with high daylight levels.

View-out, often overlooked in technical evaluations, is included through the use of Sky View and General View analysis. Together, these metrics act as a way of checking compliance with the SS-EN view-out regulation. Both are measured as the percentage of the occupied area with a clear view of the specified element. In this thesis, General View measures the ability to see ground or surrounding buildings from a 30-degree angle from eye level. Combined with the Sky View metric, this provides a strong reference point for achieving the "Medium" level of recommendation. Both view metrics use a 2% threshold as the evaluation target, meaning, that any area with a Sky View or General View value above 2% is considered to meet sufficient quality of view, based on SS-EN recommendation.

Overheating risk is measured through the number of hours above 27°C, combined with percentage of overlit space. Measuring overlit space creates a test that evaluates both energy and daylight simultaneously. Here, overlit space refers to the percentage of apartment area that exceeds 3000 lux for more than 15% of the day. While these measurements in isolation do not fully predict future overheating risk, they provide a valuable indication and relate to the theoretical background of the thesis.

Energy performance is represented by EUI, included primarily to contextualize the architectural strategies within regulatory frameworks. The EUI is presented as a primary energy number, converted according to BBR weighting factors, in order to reflect realistic conditions.

By combining these metrics, the evaluation model enables architects to assess not only what works, but why — revealing the spatial, thermal, and experiential consequences of renovation strategies. The performance data generated through simulation offers a way to bridge the gap between technical performance and architectural intent, allowing them to interact in informed, intentional ways.

5.3 The Preservation Strategy

The preserving strategy is developed for buildings where architectural integrity, cultural identity, or historic detailing is worth retaining or carefully reinstating. These are often buildings with recognizable typologies and crafted facades, such as the landshövdingehus, that contribute not only to the character of the city but also to a deeper sense of place and continuity for its inhabitants. In these cases, energy renovations need to balance their performance requirements with architectural sensitivity, avoiding generic or overly technical solutions that often decrease the buildings perception and quality.

This strategy draws from reference projects where small-scale interventions have achieved significant architectural and environmental improvements. The re-renovation at Brämaregatan, demonstrated how reintroducing the horizontal wooden paneling and restoring window detailing could recover lost architectural identity without compromising the building's performance. Similarly, the Kv. Nielsen project showed that by retaining existing window frames and simply replacing the glazing, it was possible to achieve the necessary energy improvements, minimize construction disruption, and preserve both exterior expression and interior daylight character, all while going below the set budget. In both cases, the strategy was rooted in care, detail, and a clear appreciation of original architectural intent.

In this thesis, the preserving strategy takes those lessons into a parametric and performance-based framework. It investigates how variations in window niche geometry, depth placement, surface reflectance, and material detailing affect daylight factor, spatial brightness, and visual comfort. Referencing the spatial thinking found in Villa Mairea and Villa Müller, the strategy argues that windows are not only technical openings, but compositional tools that influence atmosphere, structure perception, and the quality of light across the interior.

The application to Kv. Tuppfjätet focuses on reinstating some of these qualities in a building whose original character has been significantly reduced by 1970s renovations. Here, a full-scale restoration is not a strategy that would fit. Instead, the strategy explores how targeted interventions, such as altering the angle of window reveals, adjusting the reflectance of the niche finish, or adjusting the position of the window in the wall, can lead to meaningful improvements in daylight performance without altering the facade's external expression. The aim is to operate with precision rather than intervention.

The preserving strategy reinforces the idea that even under the pressure of regulatory upgrades, the cultural and architectural value embedded in older housing can be kept. Through performance-based evaluation and design sensitivity, the approach supports long-term sustainability, not just in terms of the energy, but in maintaining the buildings' importance to its urban and social context. It is not resisting the regulations, but offers a method to evolve the building responsibly, using design as an equally important factor.

5.4 The Transformation Strategy

The transformative strategy is designed for buildings where the original architecture offers either limited spatial or aesthetic value, and where renovation is not merely a performative necessity, but an opportunity for architectural improvement. These buildings, often part of the post-war housing boom such as the Swedish million program, are characterized by repetitive facades, minimal detailing, and industrial materials that leave little to no room for identity or spatial quality. In these cases, energy renovations can be the motor for a broader redefinition, such as for light, form, and architectural expression.

This strategy draws on successful precedents where underperforming housing has been reinvented through various façade interventions. The Östra Gårdsten project in Gothenburg is a strong local example. Through a combination of volume reconsiderations such as terracing and facade redesign, the project transformed a monotonous housing block into a bright and more humane environment, where the pride of the residents really improved. Similarly, the Park Hill redevelopment in Sheffield and the Bijlmermeer renovations in Amsterdam demonstrated how targeted architectural interventions, often limited to the facade, can revitalize housing both structurally and socially.

In the thesis, Siriusgatan exemplifies this transformative context. It is a typical million program building constructionally, with a functionally repetitive facade and seemingly random colored sheet metal finish, it presents a great opportunity to test strategic design changes aimed to really optimize the interior qualities and create a refreshing aesthetic to the area at the same time. The transformative strategy evaluates key architectural parameters such as window-to-wall ratio, transparency, passive shading elements and facade patterns. These are explored through parametric models to understand how the combinations of the parameters affect daylight quality, future overheating risk, and facade coherence.

Unlike the preserving strategy, this approach accepts and encourages the visual transformation. However, it does not aim to create decorative solutions or aesthetic trends. Drawing from the logic of the Park Hill renovations, the intent is to work with the building's existing structural grid and modularity to create a new rhythm and identity, an architecture that feels contemporary but is still grounded in the logic of its original system. As seen in the Florijn block in Bijlmermeer, subtle changes in window proportion, color, and patterning can produce significant perceptual improvements without abandoning the original structure. Which aligns with what both Fredrik Hjelm and Camilla Gyllestrand mentioned in their respective interviews.

Ultimately, the transformative strategy offers a way for rethinking energy renovations not as technical obligations, but as design opportunities. It positions the architect to a key role in not only achieving performative goals, but also shaping how these buildings contribute to the context they are in, giving them more clarity, better performance, and pride in the everyday lives of its residents.

5.5 Case Study Selection

To evaluate these strategies, two case studies have been selected, not as ends in themselves, but as representative test environments for different types of interventions. Kv. Tuppfjätet exemplifies a typology with strong historical and architectural identity - a landshövdingehus with cultural value that has been altered through previous renovations. In this case, the strategies focus on preservation through subtle design moves, such as adjustments to window niches, depth, and reflectance, that aim to improve indoor daylight and thermal comfort without impacting the building's outward appearance

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Siriusgatan, on the other hand, represents a Million Program building with limited architectural integrity, offering greater flexibility for exterior transformation. This allows the thesis to explore more expressive and structural interventions, such as changes to window rhythm and proportions, façade patterning, and shading elements, that aim to reframe and enhance the building's identity while simultaneously improving daylight access and mitigating overheating.

Together, these cases are used to test and illustrate two overarching strategic approaches: one that seeks to preserve and refine, and another that seeks to transform and reimagine. The intention is not to present these specific buildings as unique problems to be solved, but rather as examples through which generalizable renovation strategies can be developed. The focus of the thesis remains on the broader applicability of these strategies across Sweden's multifamily housing stock, and on how architects can better navigate the complex trade-offs between regulatory performance and architectural value in future renovation efforts.

6. APPLICATION OF STRATEGIES - CASE STUDIES

6.1 Case Study I - Preservation - Kv. Tuppfjätet

Kv. Tuppfjätet in Kvillestan was built originally built in 1931, but just like Brämaregården, the building underwent renovation during the 70s, which altered its facade.

The building was kept in shape, but was externally insulated and provided with a new facade in sheet metal. The windows were swapped out and kept in its position in the wall. This resulted in all the detailing of the windows, such as the traditional munitions, were lost, and because of the new thickness of the wall, the windows fell further into the facade, losing out on the original expression. The commercial ground floor has also put up advertisement boards in the upper parts of the big windows, which in turn subjected the facade to lose even more character.

However in turns of function, the house remains pretty much exactly the same. Apartments make up the vast majority of the space, with the corner facing the busy street being commercial.

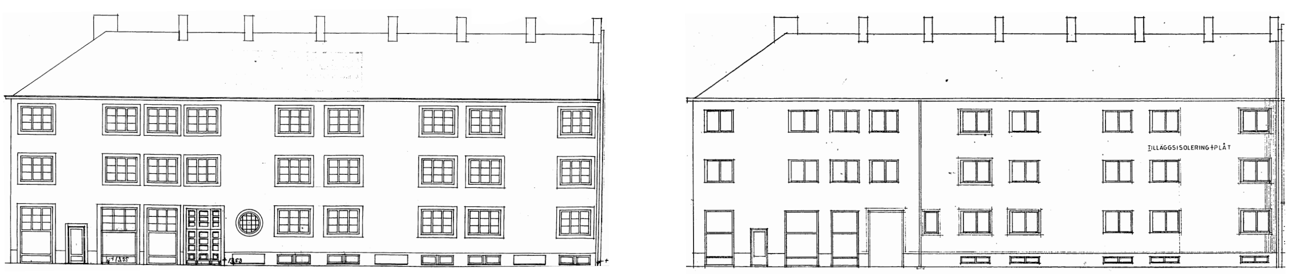

Fig. 24. To the left, drawing of the main facade in 1931, to the right, drawing of the main facade post renovation in 1977.

Fig. 25. To the left, photo of the west facade of Kv. Tuppfjätet, and photo of the north facade to the right, 2025.

6.1.1 Analyses and Inventory of Kv. Tuppfjätet

Current Discourse

The building in Kvillestan is currently subject to potential demolition. On the side that is pushing for the demolition are the property owner, who wants to take down the estate and rebuild an entirely new one, in the same landshövdingehus aesthetic. Backing up this argument is the City Planning Department (Stadsbyggnadsförvaltningen), which writes that the estate ”throughout the years has been distorted by the recent external insulation and window changes. Neither construction nor aesthetic is today especially valuable.” It is believed that the new building would fit in better with the surrounding classic houses (Hela Hisingen, 2023). Stadsbyggnadsförvaltningen continues the reasoning by explaining that the new buildings will have a clear anchoring in the original design principles, and that the department in this case believes that the estate no longer has any particular cultural value and can not be seen as something unique in comparison with other well kept buildings in the area. However, according to the property owner, this does not mean that there is a decision made yet. The verdict merely makes the decision to demolish possible, and no matter what the decision will be, it will be announced to tenants well in advance. (Hela Hisingen, 2023).

On the other side, pushing back on the demolition, are several parties. Among others, Claes Caldenby, professor and president of CfB (centre for building conservation), Paula Femenias, associate professor in sustainable transformation of built environment and Ola Nylander, professor and previous president of CBA (centre of housing architecture), who together wrote a debate article in the newspaper GP.

In the article, they defend the houses by referring to the connection that the city's people have to the classic buildings, and that the City Museum plans to celebrate the 150th anniversary of the houses this year (2025). They elaborate on this by pointing out the fact that the politicians in the city many times have expressed their displeasure with all the new building development themselves, and how why refer to the landshövdingehus as an archetype. The writers also believe that the recent work done to the building is not a motive for demolition and that the general public's interest should weigh more than an individual property owner's. In terms of their own arguments, they push on the sustainability impact of demolishing instead of rebuild and care for existing housing. The social aspect is also an argument, the older houses creates an opportunity for more affordable living which the property most likely would ruin. The finishing argument is that of avoiding being made an example. If this demolition were to go through, future property owners with similar interest could point to Kvillestan as the example of why their rebuild should go through (Göteborgs-Posten, 2023).

Floor Plans & Representative Rooms

4 apartments are chosen as representative for the building according to Figure 25, to simplify the evaluation of the building. The representative apartments are located in different orientations and different sizes to achieve a complete picture of the building's performance, making sure that the strategies are optimized regardless of these factors.

Historical References & Inspiration

Hisingen, and especially the areas of Kvillestan and Brämaregården, have quite a lot of references in terms of landshövdingehus buildings, both past and present houses. The standard landshövdingehus is three stories high, with the first made in brick and the upper floors in wood. When searching through the city archives, all the buildings photographed follow this rule of thumb, with the only major differences between the buildings being if the facade paneling are vertical or horizontal.

However, when examining archived blueprints and drawings as well as what the building looks like in the present, this division seems absent, as visible in Figure 23. The vast majority of the building's facade today is in sheet metal on all three floors, with a minor exception in one part of the facade, made in plaster.

Upon further and deeper review however, there is a document that appears from the modernization and remake of the facade in 70s. In this document, it states that the current exterior facades are 2-layered brick with exterior plaster for the first floor, and wooden construction with vertical paneling in the second and third floor. This means that recreating the classic division between the floors is a viable design strategy for the project.

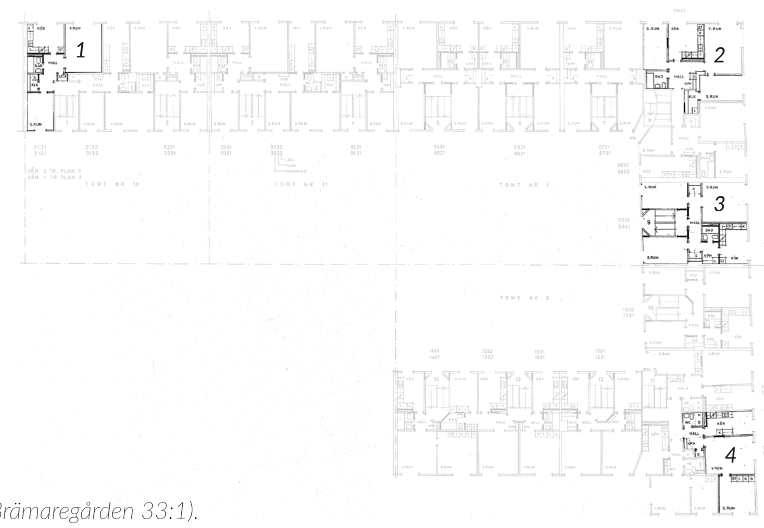

Fig. 26. Floor plan of Kv. Tuppfjätet, 1:1000. (Brämaregården 33:1).

Fig 27. Landshövdingehus in Kvillestan, photographed in 1964. (Hasselgréen).

Fig 28. "Ekenäs" landshövdingehus, located at Brämaregatan. Photo taken 1901 by H. Danielsson.

Energy Performance

Original Measurements

Wall thickness: 0.4m, U: 0.32 W/m²-K
Interior Niche: 0°, 0.2m deep, 0.35 reflectance
Exterior Niche: 0°, 0.2m deep, 0.2 reflectance
Window size (Width/Height): W_1: 1.55m x 1.2m, W_2: 0.8m x 1.2m, U: 2.0 W/m²-K
Sill Height: 1m
Muntin/Divider size (Width/Depth): 80mm x 100mm

The wall thickness is based on archive material and regulatory standards. According to Block & Bokalders, a standard renovation during the 70s added around 100mm of external insulation creating walls of approximately 400mm in total, which is supported by the material from Göteborg Stadsarkiv. Niche depths were measured during the site visit, but slightly rounded for more logical evaluation metrics. Reflectance values are slightly lower than the evaluation standard (0.5 for interior wall and 0.3 for exterior wall) to account for wear, aging and dirt. Window measurements are gathered through a combination of site visit and archive drawing measurements, while the U-value is decided based on a standard triple paned window from the 80s (Elitfönster, 2021).

Current

According to the latest energy declaration gathered from Boverket, Kv. Tuppfjätet has an energyclass of grade E, with the primary energy number in the building listed at 145 kWh/m². In the evaluation made in the digital representative model, this value is calcultaed to 138 kWh/m². The slight variance makes sense since the evaluation is not being made on the entire building, and the exact conductivity performance of the individual wall parts are assumed to be at standard levels.

The resulting cooling needs are currently 3600W during peak loads on the hottest summer day, with the apartments having 500 total hours above 27 degrees over a year.

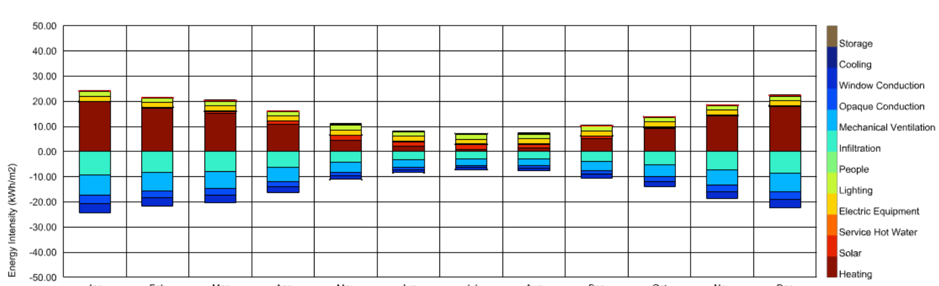

Fig 29. Average energy consumption per every month of the year, per use.

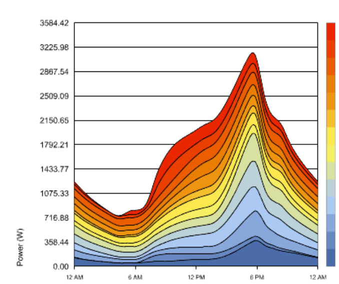

Fig 30. Cooling load profile on the hottest summer day.

Standard Practice Measurements

Wall thickness: 0.48 m, U: 0.17 W/m²-K
Interior Niche: 0°, 0.2m deep, 0.35 reflectance
Exterior Niche: 0°, 0.28m deep, 0.25 reflectance
Window size (Width/Height): W_1: 1.4m x 1.05m, W_2: 0.65m x 1.05m, U: 1.0 W/m²-K
Sill Height: 1m
Muntin/Divider size (Width/Depth): 80mm x 100mm

Using the previous renovation as well as the re-renovation at Hisingen as references, the standard approach assumes an addition of 80 mm external insulation, which would be the middleground between these two. Since the current energy number is quite a lot higher than the 75 kWh/m² that the EPBD sets its limit at, it is also assumed that the windows need to be changed. This is done through both better glazing, a U-value at 1.0 W/m²-K, which is the standard at Elitfönster, and reinforcing the window frame by 75 mm, the standard measurement at Elitfönster. The central divider in the window is assumed to be the same size.

Standard Practice

In the standard renovation scenario, the existing construction is retained and supplemented with 80 mm of external insulation with improved thermal conductivity. This brings the post-renovation wall to a U-value of 0.17, which is slightly above passive house standards. According to the energy simulation, this results in an EUI of 122 kWh/m². While this represents a measurable improvement, it remains well above the target set by the EPBD, indicating that upgrading the wall alone is not sufficient to meet future energy performance requirements. This outcome suggests that more substantial interventions will likely be necessary, either through further enhancement of the building envelope or through modifications to other elements, such as the windows. If a wall with this level of performance cannot bring the building within compliance, the likelihood of pressure to alter more parts of the building increases.

In terms of thermal comfort, the renovated building registers a peak cooling demand of 3100 W during the hottest summer day, with 280 hours annually above 27 °C across the apartments.

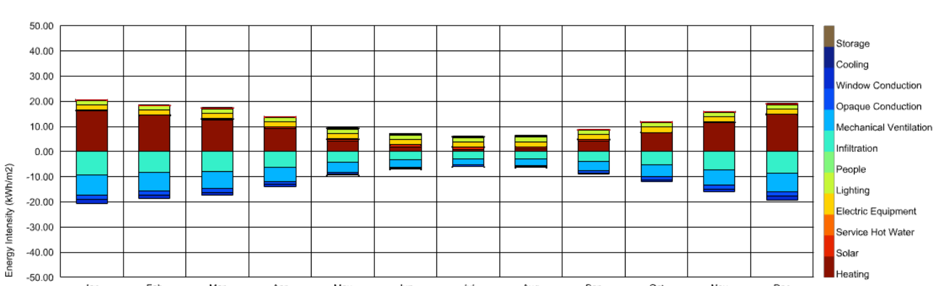

Fig 31. *Average energy consumption per every month of the year, per use.*

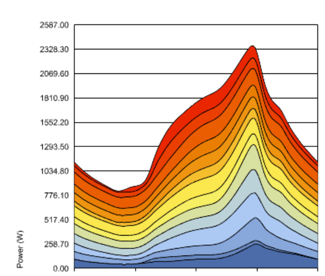

Fig 32. *Cooling load profile on the hottest summer day.*

Daylight Performance

Current

The building today already struggles with daylight levels. Five out of the 14 rooms tested fail to reach the DF > 1.0 standard. Two out of the four apartments do not meet the regulations, while apartment number four only just meets the requirement. Apartment number two, which is the only one clearly above the threshold, is also located in a corner position, benefiting from significantly better daylight potential. This clearly demonstrates the negative impact of the first renovation carried out in the 1970s.

Looking at the dynamic evaluations, the current layout only just meets the minimum threshold for one point (40%) in LEED's assessment and falls well short in terms of compliance, where a minimum of 55% is required to reach the one-point level.

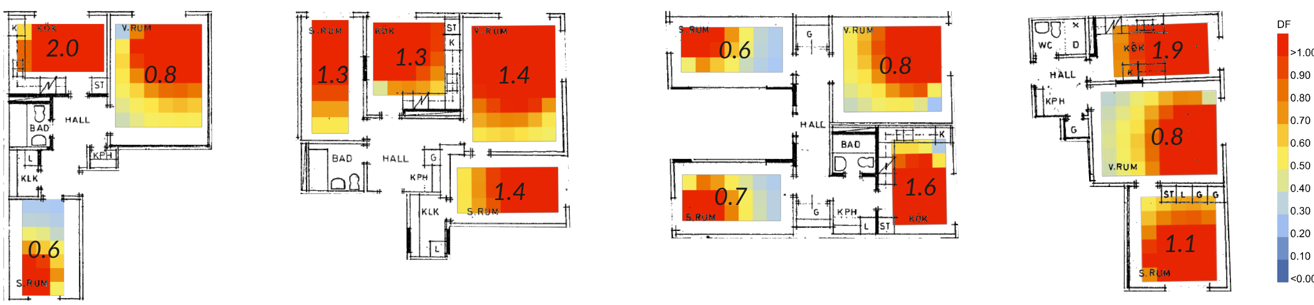

Fig 33. Compliance measured against BBR's DF > 1% target. The DF_{median} is written out for each apartment.

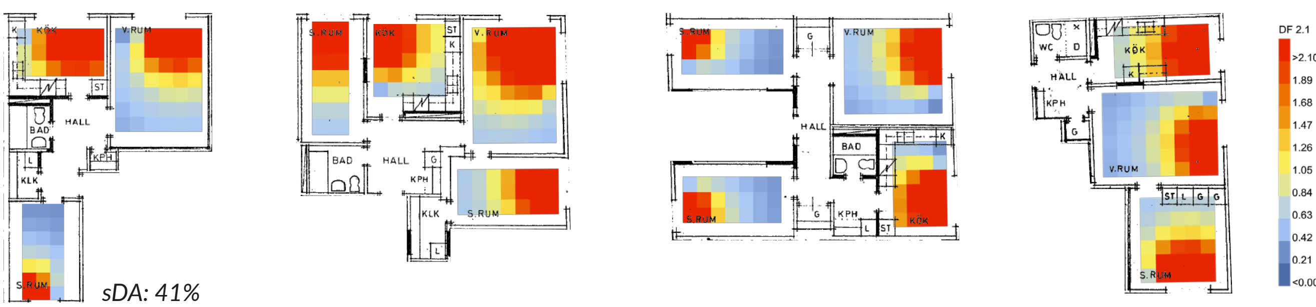

Fig 34. Compliance measured against SS-EN's suggestion of 2.1% DF being sufficient light in the context of Gothenburg. sDA is the average for all apartments combined.

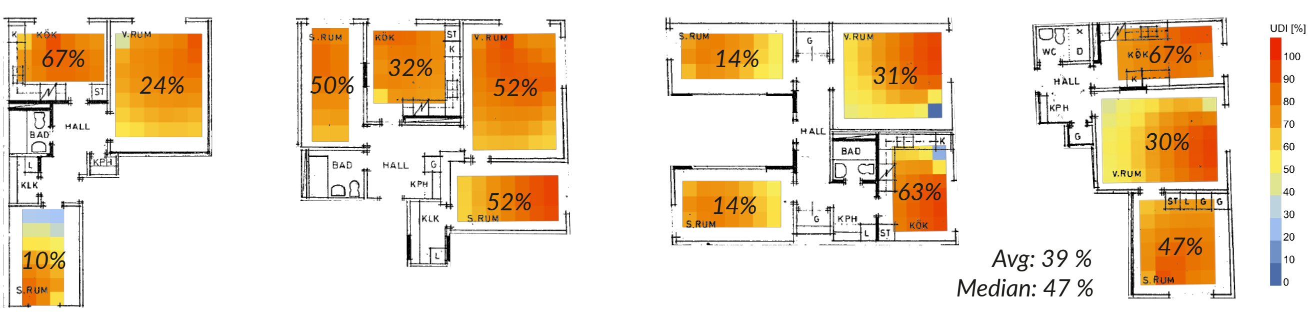

Fig 35. UDI levels in the apartments. Each apartment's compliance towards LEED's 2 point criteria is displayed.

Standard Practice

After undergoing a potential standard renovation, the building's daylight performance declines significantly. None of the apartments meet BBR's regulatory standard, and five rooms now fall below a DF_{median} of 0.5. The dynamic results are equally concerning, with the sDA dropping to just 27% and the median compliance rate falling to 30%.

These outcomes clearly demonstrate that a building of this type cannot sustain another major renovation if interior daylight conditions are not actively considered in the design process.

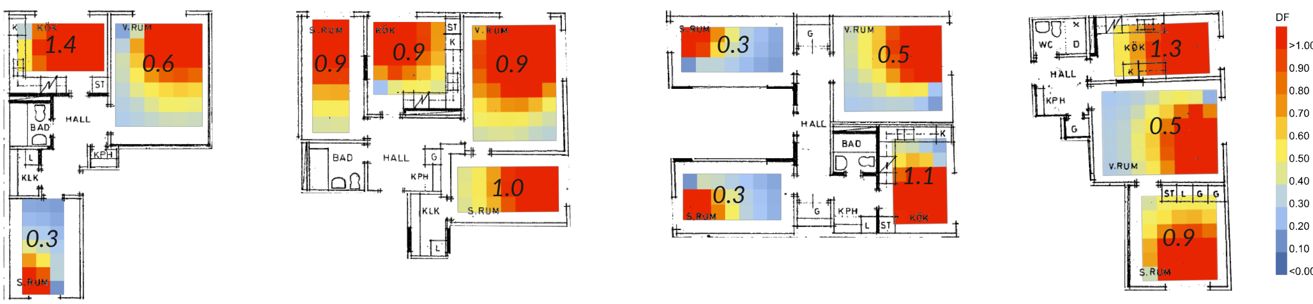

Fig 36. Compliance measured against BBR's DF > 1% target. The DF_{median} is written out for each apartment.

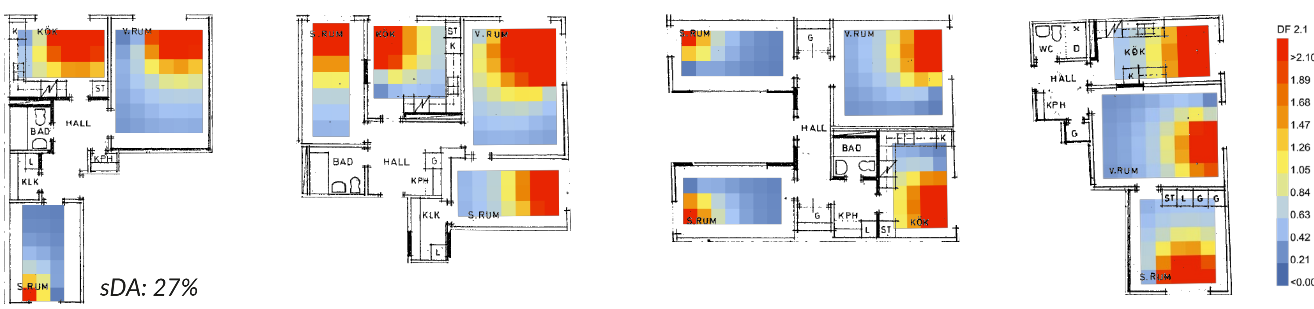

Fig 37. Compliance measured against SS-EN's suggestion of 2.1% DF being sufficient light in the context of Gothenburg. sDA is the average for all apartments combined.

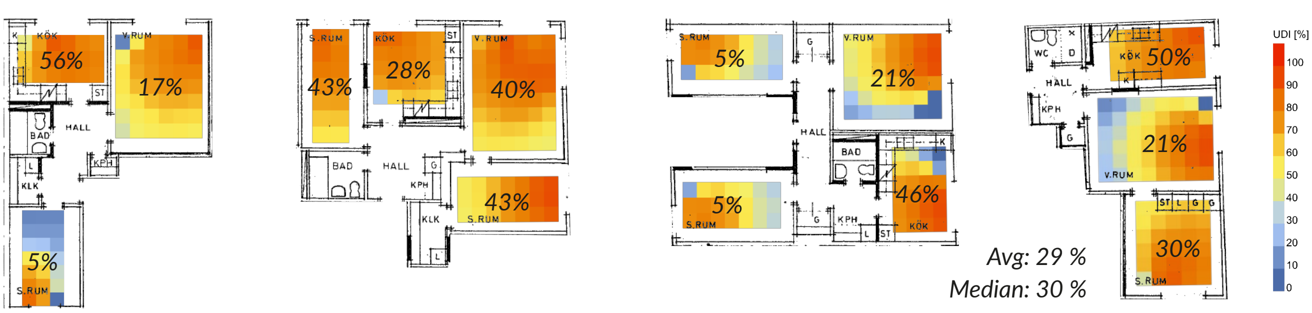

Fig 38. UDI levels in the apartments. Each apartment's compliance towards LEED's 2 point criteria is displayed.

View Performance

Current

The current quality of view is far from optimal. While the window dimensions themselves meet the recommended standards, the deep placement of the windows within the thick walls significantly limits access to high-quality view-out. The depth restricts the visible sky angle and narrows the field of view from the rooms. Combined with the building's location in a densely developed urban context, where nearby buildings are positioned in closely, opportunities for expansive views are limited.

This is clearly reflected in the evaluation results. Both the sky and general view metrics score low, with average and median values closely aligned. The Sky View remains at approximately 25%, while the General View is limited to around 30%. These figures indicate that, despite having adequately sized windows, the placement and surroundings prevent the occupants from experiencing a strong visual connection to the outside environment.

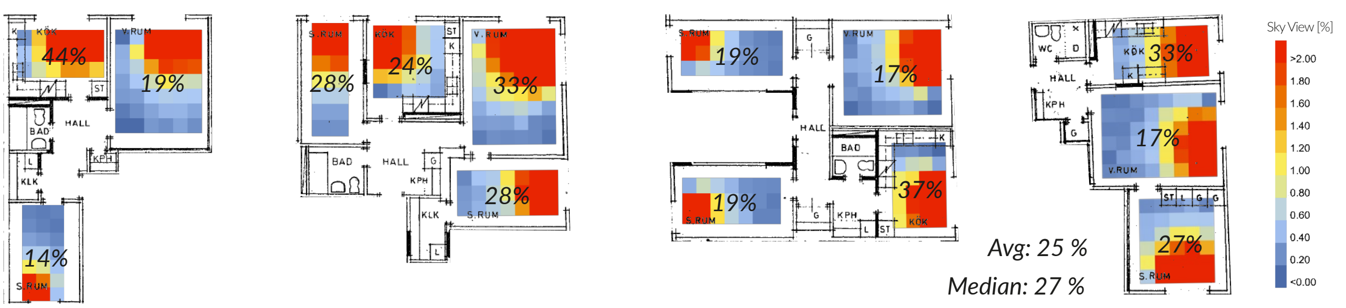

Fig 39. Area of apartments that has sufficient view of the sky.

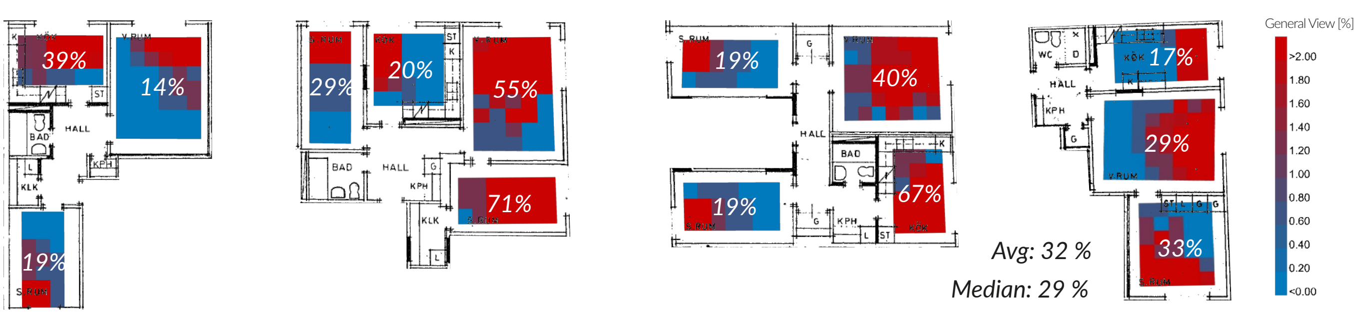

Fig 40. Area in the apartments that has an unobstructed view of the outside.

Standard Practice

The standard renovation approach, which assumes reinforcement around the window frames, further degrades the already limited view quality. What was previously suboptimal becomes even more compromised. The Sky View drops from 25% to just 20%, and the General View declines from 30% to 21%—a reduction of 30%.

This decline is also driven by the increased wall depth surrounding the windows, which reduces the visible angle to the exterior and creates an even more enclosed, tunnel-like effect. In a dense urban settings like this one, where good view conditions are already limited, these changes can meaningfully affect the perception of space and openness. It also reinforces the importance of integrating view-out performance early in the design stage, particularly in renovation projects where wall thickness and structural upgrades are required.

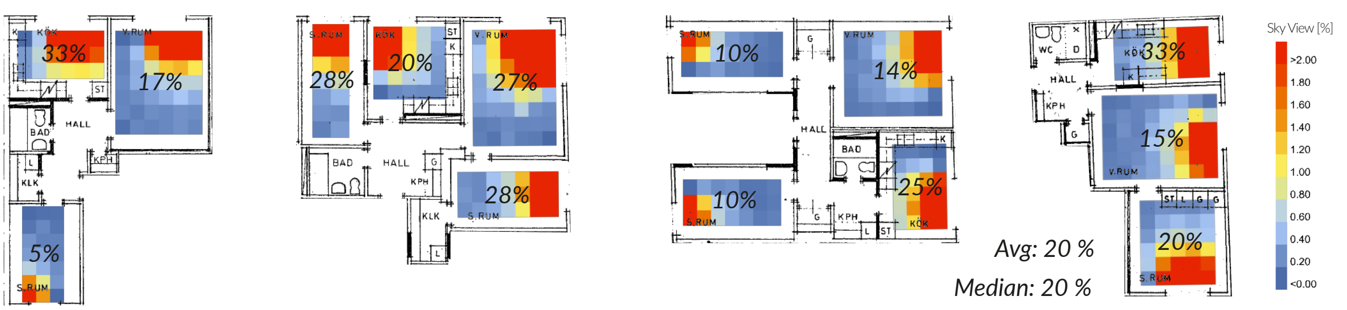

Fig 41. Area of apartments that has sufficient view of the sky.

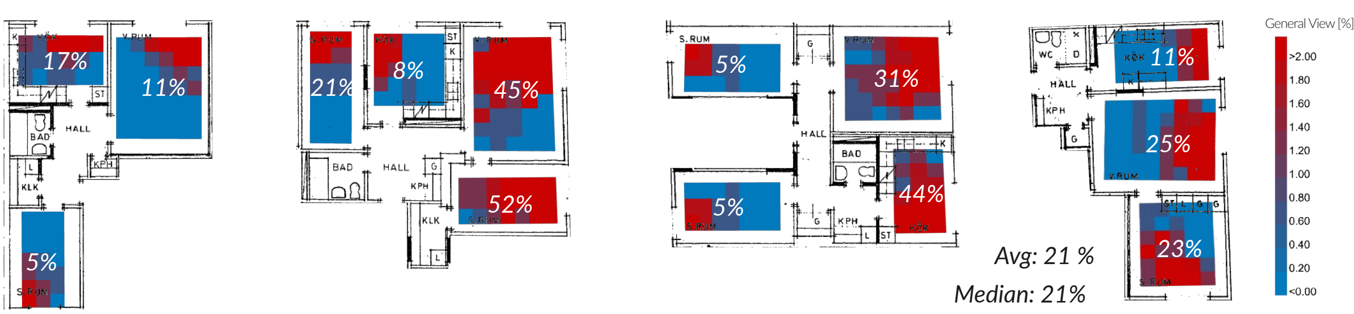

Fig 42. Area in the apartments that has an unobstructed view of the outside.

6.1.2 Iterative Process of Kv. Tuppfjätet

The Parametric Process

In the following section, and in the corresponding part in 6.2.2, a series of parametric iterations have been carried out to test how specific design variables influence the daylight performance and thermal comfort of the two case study buildings. These tests explore a controlled range of design alternatives to uncover trends, trade-offs, and thresholds.

The iterative testing process in this thesis relies on systematically varying one or several parameters at a time to observe how they affect outcome. Each design variant is simulated with the Colibri plugin in Grasshopper, and analyzed for key indicators related to daylight and energy performance. The goal is not to isolate the single best solution, but to understand the performance tendencies associated with different design choices.

Importantly, these evaluations are conducted with their aesthetic impact in mind and within the architectural constraints of each building. For example, certain window placements may not be viable due to structural or preservation limits. As such, the chosen parameters reflect both practical feasibility and architectural intent. For each case study, the tested variables differ based on the renovation strategy: the preservation focuses on subtle internal interventions, while the transformation explores more extensive facade modifications.

The results are displayed as parallel coordinates graphs, showing the correlations between multiple performance metrics at the same time. These graphs are created in the Design Explorer software, which enables the graph to be interactive, helping the user to easier find trends in the results.

The following evaluations should be read not as isolated findings, but as parts of a larger, iterative design investigation. One that reflects how architects can work analytically within creative constraints to improve daylight and comfort in renovation projects.

Metric Correlation Evaluation

The first part of the iterative process focuses on understanding the relationship between key performance metrics.

First, the daylight metrics Daylight Factor (DF) and Useful Daylight Illuminance (UDI). By simulating a controlled series of design variations, with changes in window depth and reflectance, this test evaluates how well DF, the metric currently used in the Swedish daylight regulations, aligns with the more nuanced and climate-responsive UDI. The aim is to identify patterns and correlations in how the metrics respond to the different inputs, in order to make the upcoming evaluations more efficient, only evaluating one of them.

The simulations test variations in window depth (10–30 cm), interior reflectance (0.4–0.8) and exterior reflectance (0.3–0.4).

The results shows a correlation between DF and UDI of (R^2 = 0.92) (Fig. 43) for more shallow window placements (10-20 cm), indicating that high DF values generally align with high UDI compliance in these scenarios. However, the correlation weakened at greater depths (30 cm), where DF starts to overestimate UDI performance, by 10–15%. This discrepancy is largely due to DF's static nature, which does not account for the seasonal and directional variation in daylight that UDI captures.

The findings suggest that while DF may function as a quick analysis tool in simplified or early-stage designs, it lacks the reliability needed for evaluating nuanced daylight behavior, especially in shaded or complex conditions. Because of this, UDI is adopted as the performance metric for all subsequent evaluations in this thesis, to make the process more efficient. Simultaneosuly, this ensures that daylight analysis remains grounded in spatial and climatic relevance, supporting design decisions that prioritize occupant comfort and temporal variability in a Nordic specific context.

Similarly, a correlation analysis was conducted between Sky View and General View to further streamline the evaluation process (Fig. 44). These results show that as Sky View quality increases, General View improves as well. This indicates that assessing only the General View is sufficient to capture the overall view-out quality. As with the daylight metrics, this allows the iterative process to remain both efficient and relevant to architectural performance.

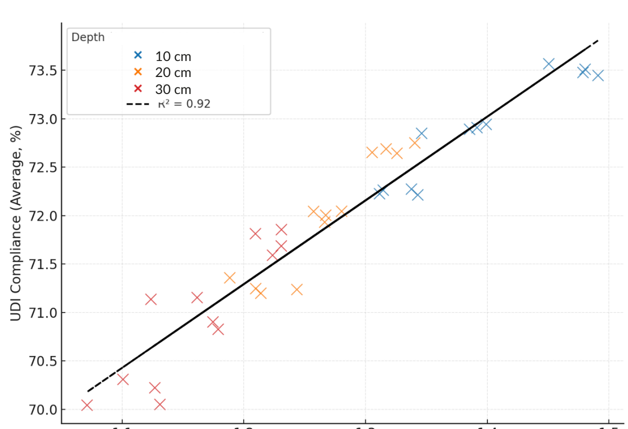

Fig 43. Correlation between DF and UDI.

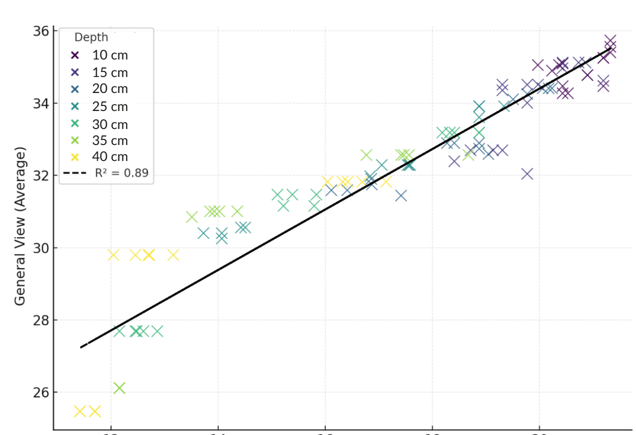

Fig 44. Correlation between Sky- and General View.

Evaluation I

The first evaluation within the preserving strategy focuses on optimizing daylight performance through modifications that targets the idea of not altering the facade expression. Specifically, it investigates how interior and exterior niche angles, window placement depth, and surface reflectance values affect daylight conditions within the apartment.

The angle of the interior niche is tested up to a maximum of 40 degrees. This threshold is set based on spatial constraints, since steeper angles would either conflict with ceiling height or overlap adjacent windows, especially in corner rooms. For the exterior niche, a maximum angle of 20 degrees is tested to preserve the visual integrity of the facade. More aggressive slopes risk compromising the building's cultural and historical character, which is contrary to the aim of the preserving approach.

Window depth is tested in a range from 10 to 40 cm. This allows for the exploration of how recessed placement impacts daylight penetration and interior brightness without visually altering the facade.

Lastly, reflectance values are varied to examine how material choices influence the distribution of light. For interior surfaces, reflectance values of 0.45 and 0.65 are selected to simulate the difference between a more matte and a lighter, more reflective finish. On the exterior, values of 0.2 and 0.4 are used, representing the typical range of facade materials, while still allowing a comparison between more absorptive and lighter finishes.

This first iteration batch uses a relatively small number of options per parameter but spans multiple metrics to establish a foundational understanding of which variables most significantly impact performance. In total, 240 iterations are simulated.

The resulting outputs that these parameters are measured against are: UDI compliance and overlit space. UDI compliance measures how much of the total apartment floor area receives useful daylight for at least 75% of the occupied time, according to LEED's 2-point daylight criteria. A value of 60, for example, means that 60% of the total floor area meets this standard. Overlit space calculates the percentage of apartment area that exceeds 3000 lux for more than 15% of the day. Too much light can cause glare or overheating, so this output is meant to balance the UDI results.

The initial findings indicate a consistent tension between maximizing the UDI compliance, and minimizing overlighting risk. Almost all iterations that reach high UDI values also record elevated levels of overlighting. Conversely, those that succeed in reducing overlighting fall short of achieving top UDI compliance scores.

When isolating the results by window depth, a clear pattern emerges: configurations with shallow placements, closer to the facade, make up the majority of iterations with high UDI performance. Confirming the idea that shallower placements enhance daylight availability (Fig. 45).

Two standout iterations achieve maximum UDI compliance, though through slightly different strategies. The common denominator in both cases is the shallow window placement (Fig. 46). The first iteration reaches peak performance through a combination of maximum angles on both interior and exterior niches, paired with a balanced reflectance strategy—low reflectance on the exterior and high reflectance on the interior. The second iteration uses more moderate niche angles on both sides but compensates with high reflectance values on both interior and exterior surfaces.

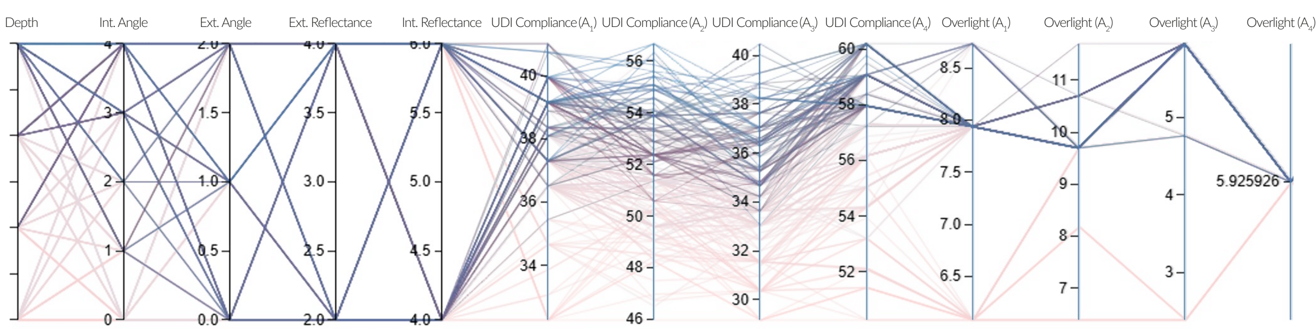

Fig. 45. Iterations when window depth is shallow.

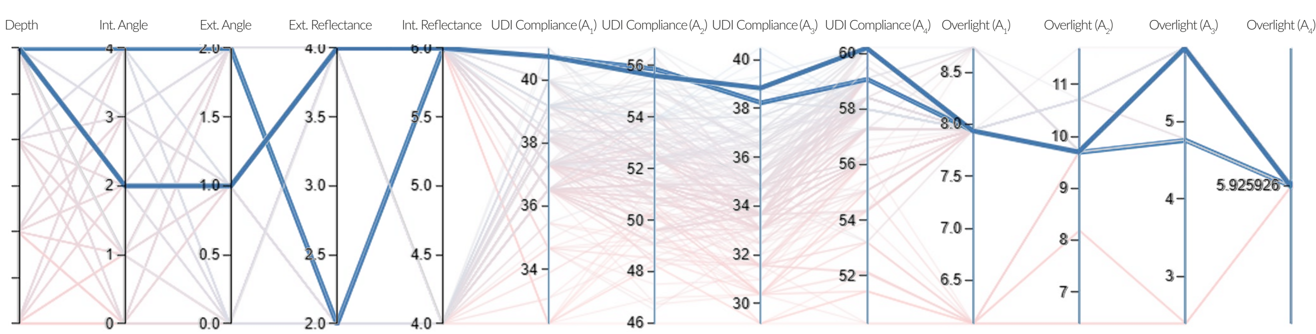

Fig. 46. Iterations with consitently high UDI values.

Evaluation II

Building on the first test, this evaluation examines how reflectance values and interior niche angles affect daylight performance, with the window depth fixed at 10 cm.

Since depth placement proved to be the most influential factor in balancing daylight and overlighting, it is held constant to isolate the impact of surface reflectance and niche geometry, to determine how these factors can be optimized to mitigate overlighting while maintaining adequate daylight levels.

Exterior reflectance is tested at levels of 0.2, 0.3, and 0.4, while interior reflectance ranges from 0.4 to 0.7. This broader spread provides clearer insight into how material finishes affect daylight distribution.

Greater emphasis is placed on the interior niche angle, since the research show strong qualitative effects from these adjustments. The angle is tested between 20 and 40 degrees, enabling assessment of how gradual or steep inclinations impact daylight as well as spatial perception without breaching the spatial constraints. These inouts create 40 different iterations in total.

The results show that these parameters alone cannot significantly reduce overlighting, as indicated by the low spread of overlight risk values in Fig. 47. However, three iterations stands out slightly: one achieved the lowest overlight level with acceptable UDI by combining low exterior and high interior reflectance with a shallow niche angle.

The other two combined maximum exterior reflectance and niche angle, differing only in interior reflectance. This achieves more peaks in terms of daylight, but it is less balanced over the different apartments and fails to achieve a smaller overlight risk.

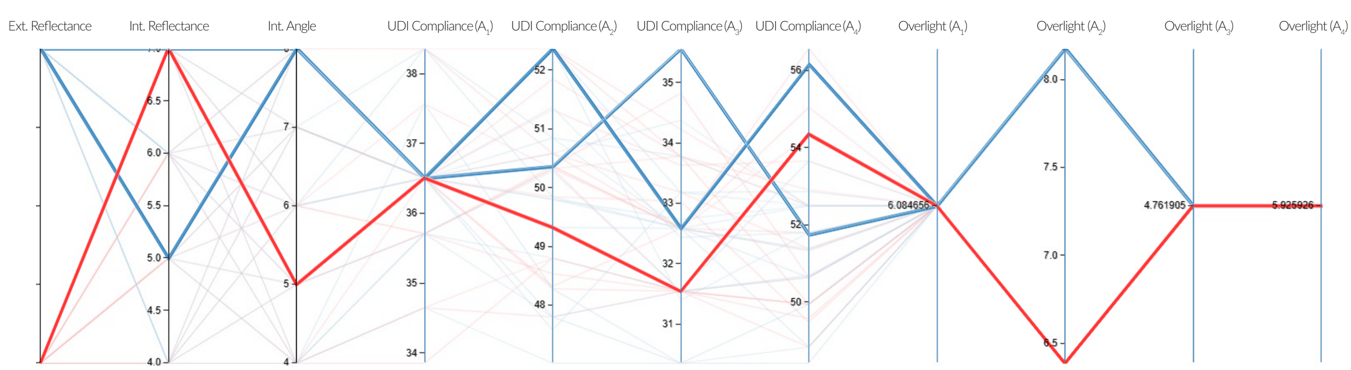

Fig. 47. Lack of consistency when only relying on reflectance and angles for reducing overlight.

Evaluation III

The third test reintroduces window depth and exterior niche angle as variable parameters, combined with the interior angle, to evaluate the relationship between view-out quality and overlighting risk. The goal is to assess whether previously successful daylight configurations also perform well in terms of spatial quality.

Window depth is tested between 5 and 20 cm, since deeper placements have consistently failed to provide adequate daylight. The interior angle ranges from 20 to 40 degrees, while the exterior angle is tested from 0 to 20 degrees. These combination results in 60 different iterations for testing.

The results reveal a clear correlation between high view-out quality and increased overlighting risk, and vice versa. The best balance is achieved in a handful of iterations, most of which combine a high angle on one side, either interior or exterior, with a lower angle on the other. These iterations also tend to prefer a moderate window depth, avoiding placements too close to the facade.

Since the exterior angle has a more significant impact on the building's visual character, the most promising solution is the version that maximizes the interior angle while keeping exterior modifications minimal (Fig. 48).

Evaluation IV

Lastly, the impact of window muntins is evaluated. As a culturally significant detail, muntins add aesthetic value and can enhance the perceived quality of daylight, as desribed in previous research. However, they also reduce the amount of light entering the space.

The test does not aim to show that muntins improve UDI or view-out but rather to identify the threshold at which their impact becomes too obstructive to justify reintroducing them.

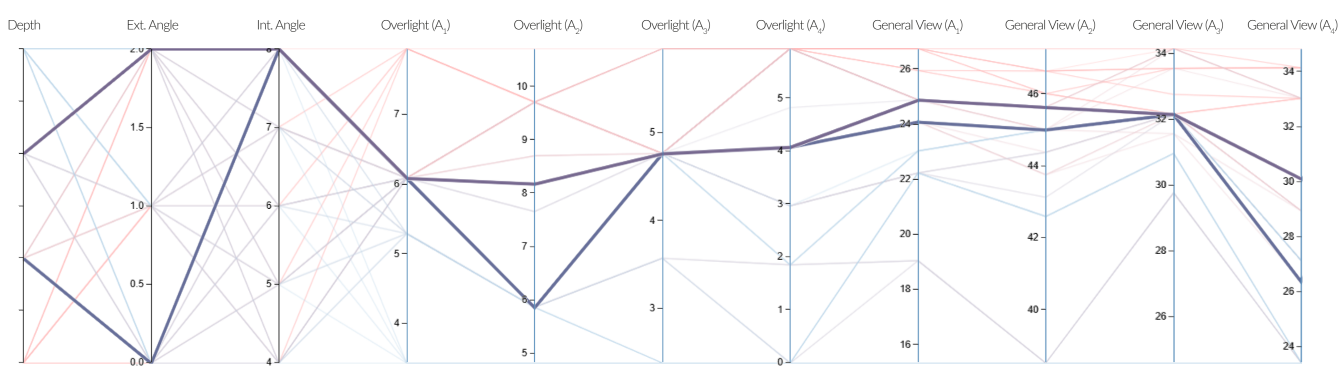

Fig. 48. Balanced, high values.

Muntins are tested in both vertical and horizontal orientations (0–2 in each direction), combined with a shallow window depth near the facade. This results in the evaluation testing 36 total iterations.

Results show that two vertical muntins significantly reduce both UDI and view quality, while one vertical muntin maintains a good balance with minimal impact on view. Horizontal muntins proved more ambiguous; results with 0 and 2 muntins were similar when combined with one vertical muntin and shallow depth (Fig. 49).

This led to a refined test (Fig. 50): fixing both vertical and horizontal muntins at one each, while varying the window depth and the vertical placement of the horizontal muntin, between 30 and 75 cm from the top. Although consistent peak performance was difficult to achieve, see the red line in Fig. 49, two configurations stood out. Placing the window close to the facade with a lower muntin, or placing the window slightly deeper with a higher muntin, with both of these yielding relatively balanced results.

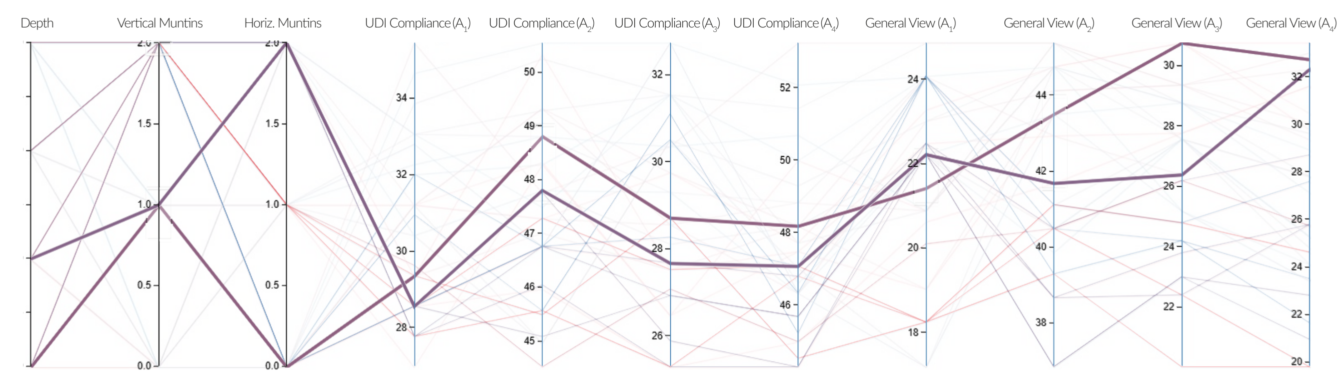

Fig. 49. Comparison of 0 and 2 horizontal muntins.

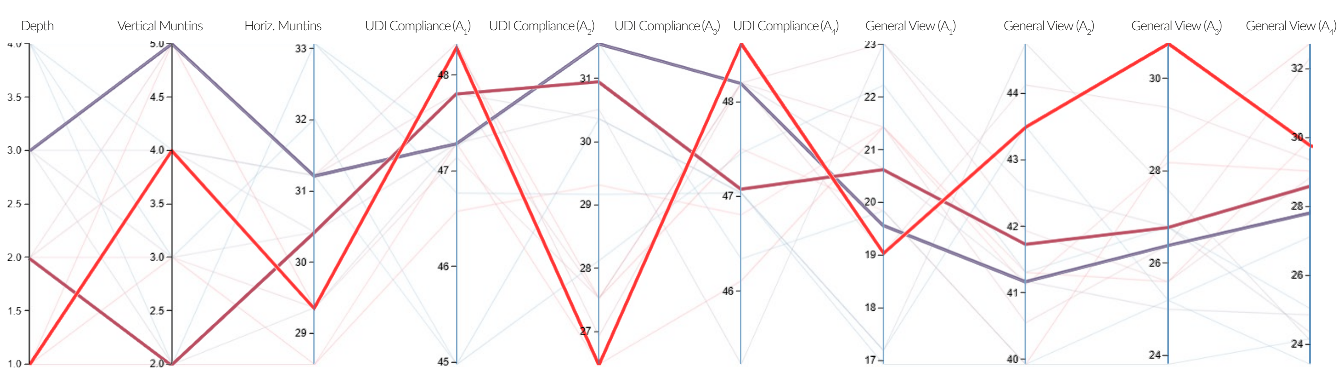

Fig. 50. Fixed number of muntins, with difference in placement.

Conclusive Evaluation

With all previous evaluations in mind, the conclusive test aims to identify the most suitable design solution for the preserving strategy—balancing daylight performance with architectural integrity.

Window depth is tested between 5 and 15 cm. While proximity to the facade consistently performs better in terms of daylight, minor variations in depth have shown potential to reduce overlighting. A balanced combination of exterior and interior niche angles has previously delivered the most favorable results. Since preserving the facade's existing appearance remains a top priority, the exterior angle is fixed at 0 degrees while the interior angle is varied between 30 and 40 degrees to maintain proportionality with the unaltered exterior face. Given that the exterior geometry remains unchanged, interior surface reflectance is prioritized in this test. The reflectance range is set between 0.4 and 0.7 to evaluate how lighter niche finishes influence the light distribution.

For the window detail, one vertical and one horizontal muntin are included. Earlier tests showed that higher quantities significantly diminished daylight performance. However, introducing the detailing in the windows still holds architectural value. Therefore, the vertical muntin is fixed, while the placement height of the horizontal muntin is varied, as this was shown to impact the daylight conditions. The combination of these parameters will test 108 different combinations.

The highest UDI peaks are achieved through deeper window placements combined with steep interior angles and high reflectance. However, these iterations fail to maintain consistently strong results across all apartments and do not achieve the minimum threshold for overlighting.

By contrast, Fig. 51 highlights two more balanced alternatives. While they do not reach the absolute highest UDI values, they maintain better averages across units, with one also achieving the minimum overlighting level. These solutions feature slightly reduced depth, angle, and reflectance values. Additionally, the optimal horizontal muntin placement appears to depend on reflectance—lower placement works best with lower reflectance and vice versa.

Since earlier tests confirmed that shallower window placements also support better view quality, the iteration that achieves the lowest overlighting and a modest facade-adjacent depth is selected as the preferred design.

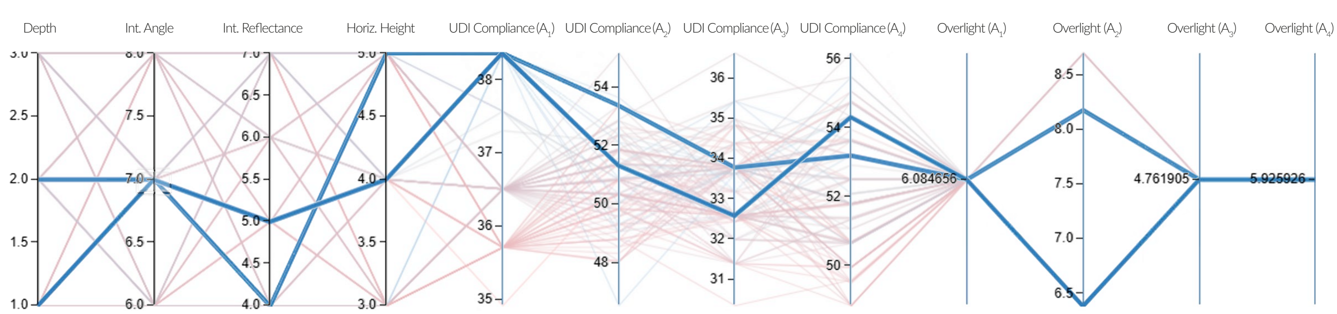

Fig. 51. The final, both high and balanced combiantion.

6.2 Case Study II - Transformation - Siriusgatan

Siriusgatan is a typical million program building located in Bergsjön, in the outskirts of Gothenburg. It is a concrete building built with sheet metal and concrete facade, built in 1971. During 1993 it underwent a smaller renovation.

During the renovation, some parts of the facade was externally insulated and almost all parts where changed in terms of color, however, the main facade material was kept in sheet metal. The window profiles were changed to mostly white aluminum profiles, with a few given color. The floor plans were slightly changed, but have remained similar.

Fig. 52. Top, drawing of west facade from 1969. Bottom, updated drawing of the facade from 1993 with corresponding explanations.

Fig. 53 Photos of the main facades and gable of Siriusgatan, 2025.

6.2.1 Analyses and Inventory of Siriusgatan

The Million Program Discourse

With more than 50 years passing since the majority of Swedish million program housing were built, the discourse around the complexes have remained quite negative. Few people were satisfied at its arrival, and as Fredrik Hjelm reflects over the opinions of the younger generation, the perception does not seem to change. In his own words, this does create a higher acceptance of innovative thinking and design of these type of buildings. Especially if these changes can positively impact the interior conditions of the people living in the buildings.

Fredrik continues to explain that as long as some sense of respect is shown for the original idea and architectural vision of the building, less important parts can be altered, especially in more repetitive facades with a lower level of detail. He also highlights that a lot of actions taken on million program buildings does not necessarily impact the tenants. He exemplifies this with changes such as the color of the facade or making a flat roof into a pitched one, and elaborates by saying that he, in his work as heritage officer, would not mind complying with the idea of making a bit bigger windows in order to improve daylight and interior conditions.

Now, some limitations should still be made to the alterations. Prior to a starting the transformation, an identification of which parts are most important to the building's identity should be made, keeping these parts intact. He does however believe that a majority of the public is in an understanding of these buildings needs to take a bit of a beating in order to improve, and that a focus probably needs to be to keep a smaller amount of the buildings completely intact to show the progression and the past.

Floor Plans & Representative Rooms

5 apartments are chosen as representative for the building according to Figure 54, to simplify the evaluation of the building. The representative apartments are located in different orientations and different sizes to achieve a complete picture of the building's performance, making sure the design strategies will be efficient no matter its placement or size.

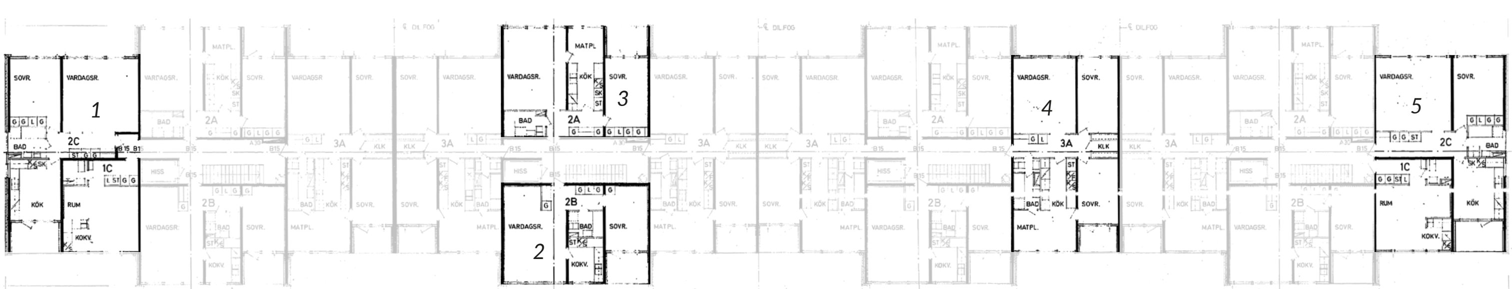

Fig. 54. Floor plan of Siriusgatan, with representative apartments 1:500. (Bergsjön 39:8).

Reference Inspiration

A big part of the buildings' character at Siriusgatan are the colors. Unlike many other million program housing in the city, the gray concrete elements are mostly hidden, by the colorful sheet metal cladding.

The first phase of the renovation in the area chose to keep the color between the buildings, but separate them. The buildings are now mainly light gray, with half of the buildings incorporating blue elements and the other half green elements (Fig. 55). These elements include the balcony fronts and regular facade patches between windows and floors. The colorful concrete slab gables are changed in materiality and the previously more random coloring is swapped for more apparent artwork in the same color way as the facade patches of the respective buildings.

Successful design strategies from England ans Sheffield included making the most apparent changes to the entrance floor, while letting the repeating upper floors keep most of its original character intact. Both Park Hill and Bijlmermeer however, found success in slightly altering the glazing of the upper floors. Bijlmermeer used an especially relevant strategy of including glazed railings to lighten up the facade.

Worth noting from the Swedish reference in Gårdsten, is the consideration of where the changes should take place structurally. Altering the concrete slabs in the facades too could turn out to be a lot of work for little effect. However, focusing more on the balconies and its surroundings could prove an easier and more efficient task.

Fig 55. The recently renovated million program buildings in the area.

Energy Performance

Original Measurements

Wall thickness: 0.4m, U: 0.25 W/m²-K
Interior Niche: 0°, 0.3m deep, 0.35 reflectance
Exterior Niche: 0°, 0.1m deep, 0.2 reflectance
Window size (Width/Height): W_1: 1.15m x 1.05m, W_2: 0.75m x 1.05m, U: 1.5 W/m²-K
Sill Height: 0.9m
Railing transparency: 0%

Siriusgatan was also externally insulated, albeit in the 90s. The Block & Bokalders approximation of 100mm added insulation fits together with the drawings available through Göteborg Stadsarkiv, creating a 0.4m thick wall in this case as well. The depths of the niches were measured during site visit, but somewhat rounded to create more logical evaluation metrics. The reflectance values are a small downgrade from evaluation standard (0.5 for interior wall and 0.3 for exterior wall) to account for wear, aging and dirt. Window measurements are gathered through a combination of site visit and archive drawing measurements, while the U-value is decided based on a standard triple paned window from the 90s (Elitfönster, 2021).

Current

According to the latest energy declaration gathered from Boverket, Siriusgatan has an energyclass of grade E, with the primary energy number in the building being at 124 kWh/m². In the evaluation made on the digital representative model, this number is 136 kWh/m². The small discrepancy between the official energy declaration and the simulated result suggests that the digital model provides a reasonably accurate representation of the building's energy performance. The slight difference is likely due to variations from the standard input assumptions, such as internal loads, user behavior, or system efficiencies not fully captured in the simulation. While not identical, the values are close enough to validate the model for use in evaluating design strategies and estimating their potential impact on energy use.

The resulting cooling needs in the current building are 10.400W during peak loads on the hottest summer day, and the apartments have 1400 total hours above 27 degrees over a year.

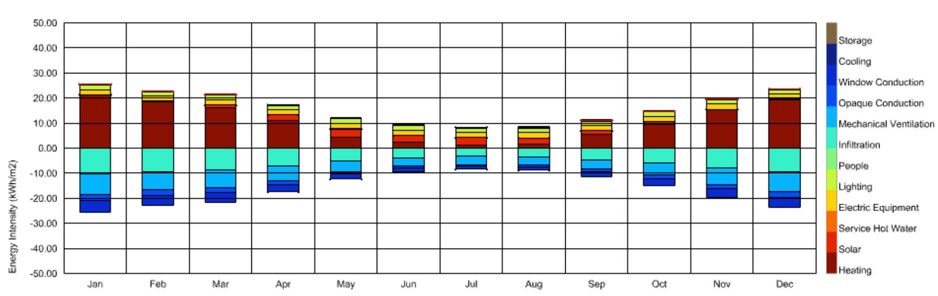

Fig 56. Average energy consumption per every month of the year, per use.

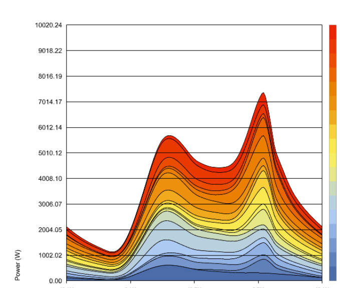

Fig 57. Cooling load profile on the hottest summer day.

Standard Practice Measurements

Wall thickness: 0.48 m, 0.14 W/m²-K
Interior Niche: 0°, 0.3 m deep, 0.35 reflectance
Exterior Niche: 0°, 0.18 m deep, 0.2 reflectance
Window size (Width/Height): W_1: 1.1 m x 1.0 m, W_2: 0.7m x 1.0 m, U: 1.0 W/m²-K
Sill Height: 0.9m
Railing transparency: 0%

As in the previous study, the external insulation is assumed to be 80 mm in thickness. The resulting U-value at 0.14 1.0 W/m²-K is slightly higher, due to the recency of the building being built and renovated. Since there is local references of what a renovation would look like, that is taken into account when assuming how the windows are treated. The placements differ depending on orientation, some being placed in the same depth as previously and some deeper. Therefore, an in-between of 150 mm is chosen. The glazing size is barely changed, which also translates into the standard values. Again, an Elitfönster standard of 1.0 1.0 W/m²-K is chosen.

Standard Practice

With the proposed renovation, the updated wall construction achieves a U-value of 0.14. Combined with the new window, the building's Energy Use Intensity (EUI) is reduced to 126 kWh/m², representing an improvement of approximately 7% compared to the original model. While this marks a measurable gain in energy performance, it remains well above the targets set by the EPBD, indicating that this type of intervention alone is not sufficient to meet upcoming regulatory demands. This highlights the need for additional measures—such as further improving window performance or undertaking a more comprehensive upgrade of the external wall assembly. Both options reinforce the central argument of this thesis: that energy renovation efforts must be guided by integrated design strategies.

The resulting cooling needs in after the renovation are 8.700W during peak loads on the hottest summer day, and the apartments have 850 total hours above 27 degrees over a year.

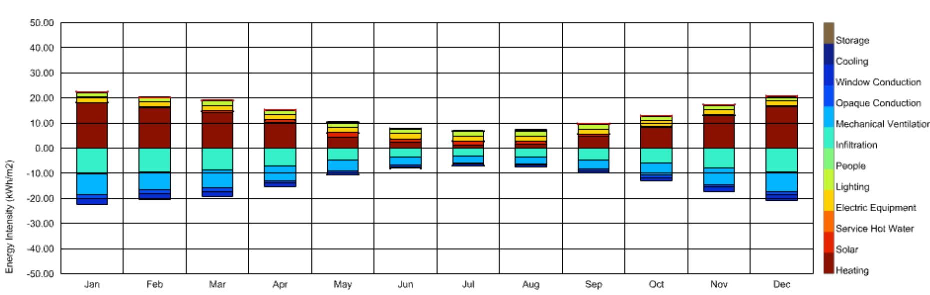

Fig 58. Average energy consumption per every month of the year, per use.

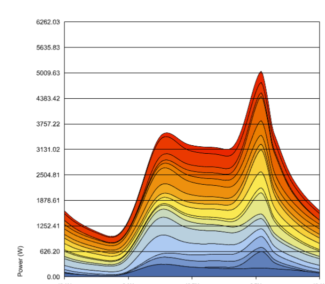

Fig 59. Cooling load profile on the hottest summer day.

Daylight Performance

Current

The average daylight conditions in the current climate are generally good. Across all apartments, only two rooms fall below the BBR requirement of a median DF greater than 1.0. However, there is still room for improvement, as six additional rooms only slightly exceed the threshold, with DF values around 1.2. In terms of dynamic metrics, the sDA reaches 60%, which meets the LEED threshold for two points (≥55%). However, the second metric of UDI Compliance value only narrowly surpasses the lower one-point threshold, indicating that daylight performance is good but not great.

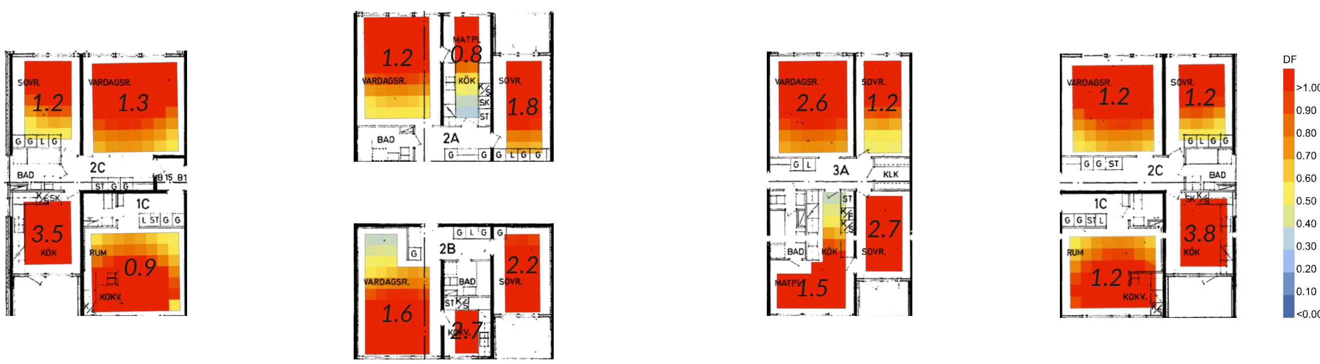

Fig 60. Compliance measured against BBR's DF > 1% target. The DF_{median} is written out for each apartment.

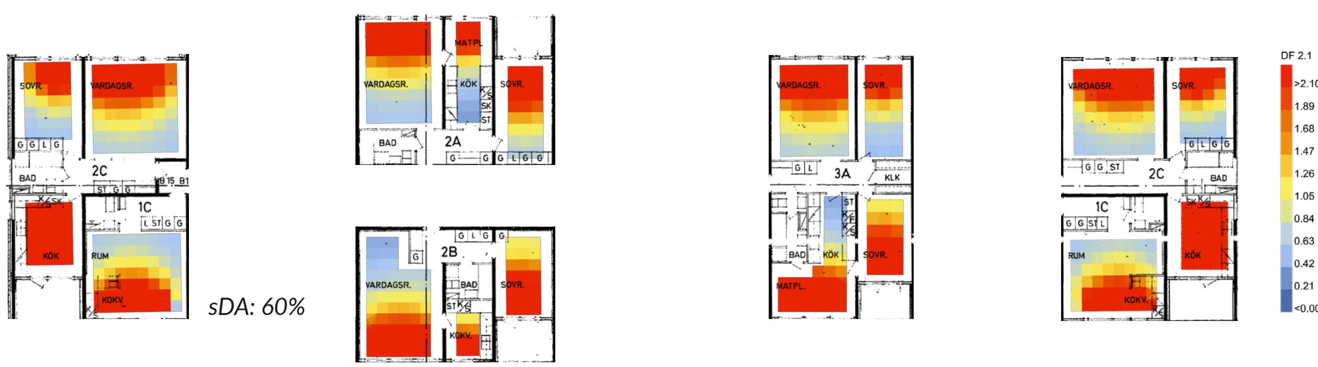

Fig 61. Compliance measured against SS-EN's suggestion of 2.1% DF being sufficient light in the context of Gothenburg. sDA is the average for all apartments combined.

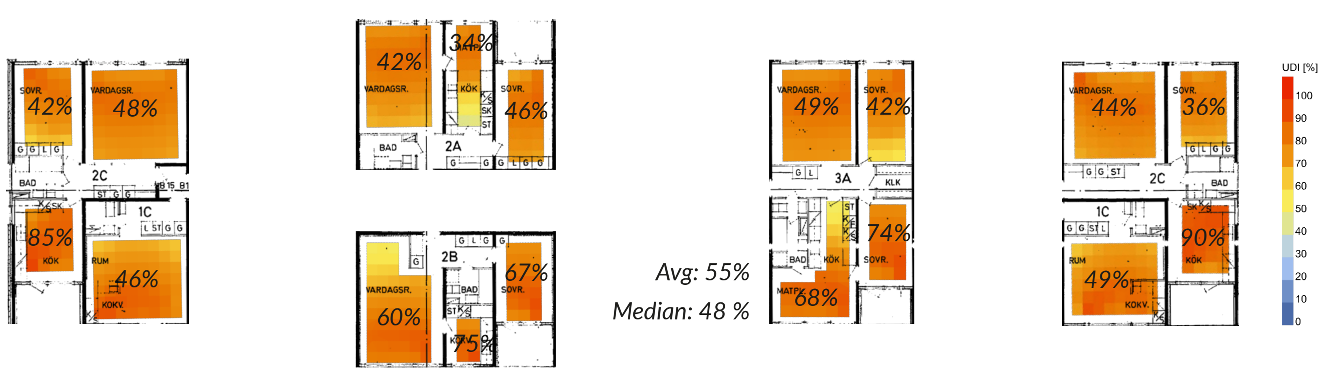

Fig 62. UDI levels in the apartments. Each apartment's compliance towards LEED's 2 point criteria is displayed.

Standard Practice

The evaluation of the standard renovation approach clearly highlights the risks associated with excluding architectural daylight strategies from the design process. In this scenario, ten rooms fail to meet the DF > 1.0 threshold, resulting in three out of five apartments falling below the acceptable compliance rate. Also, apartment 4 further highlights the challenge posed by the updated BBR regulations: two out of its four utilized rooms do not meet the minimum daylight requirement. However, since the revised guidelines assess daylight performance at the apartment level rather than per room, this unit may still qualify, despite the uneven daylight conditions. Additionally, the sDA value has dropped to just above LEED's one-point threshold (40%), with a compliance rate of only 45%. Confirming that the apartments perform poorly also within a Nordic daylight context

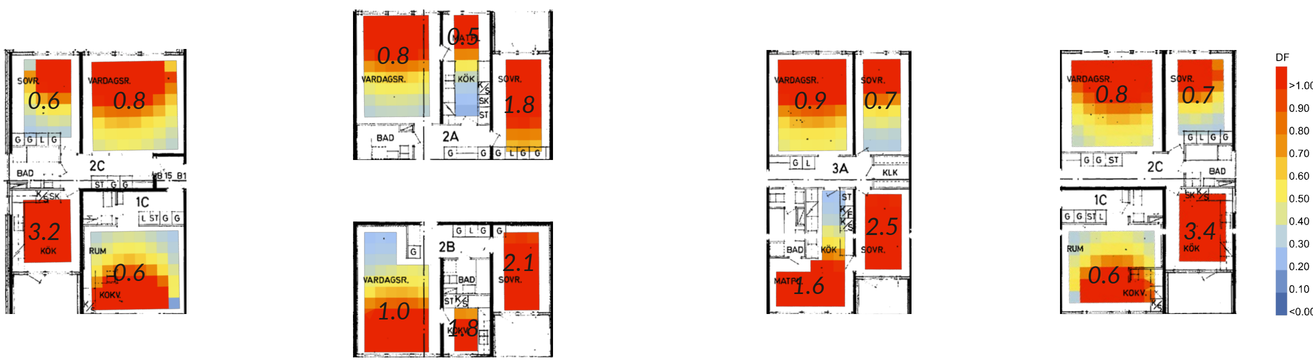

Fig 63. Compliance measured against BBR's DF > 1% target. The DF_{median} is written out for each apartment.

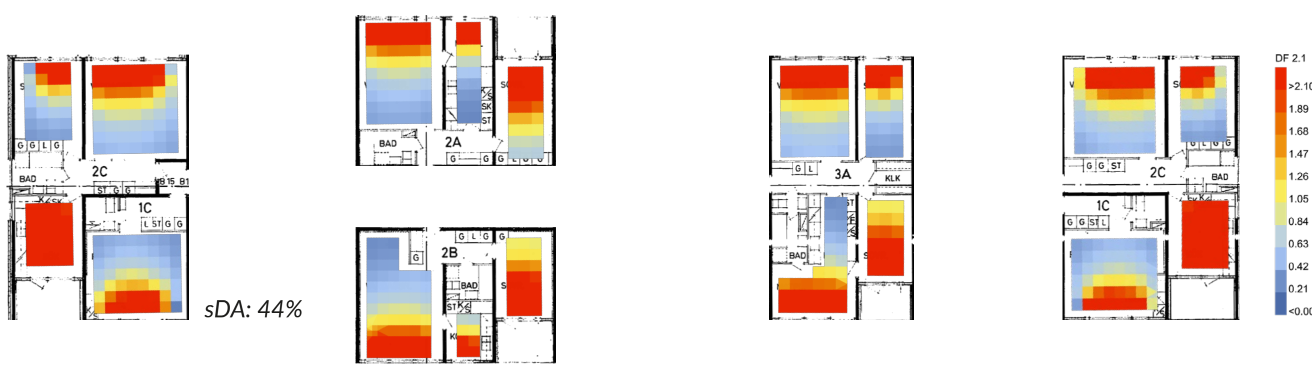

Fig 64. Compliance measured against SS-EN's suggestion of 2.1% DF being sufficient light in the context of Gothenburg. sDA is the average for all apartments combined.

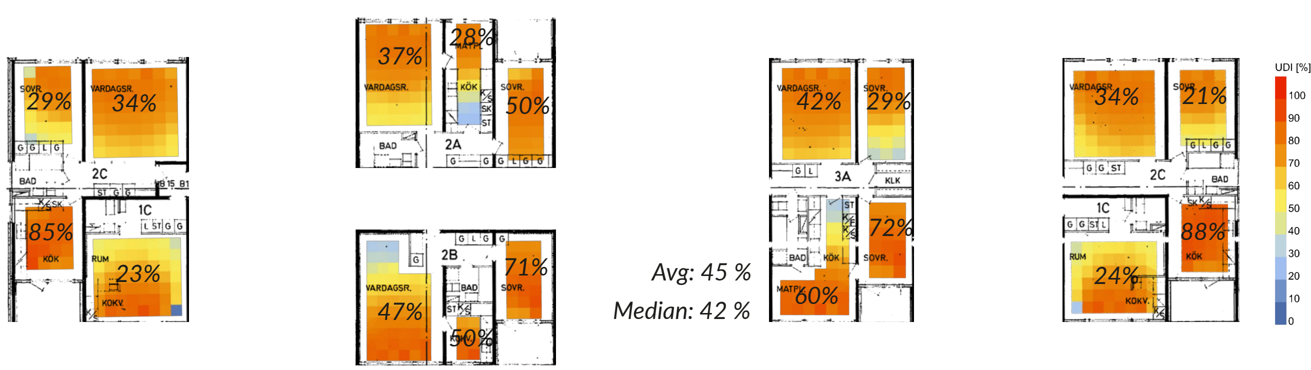

Fig 65. UDI levels in the apartments. Each apartment's compliance towards LEED's 2 point criteria is displayed.

View Performance

Current

The current quality of view is limited. To begin with, the window dimensions fall short of the SS-EN recommended minimum of 1.00 × 1.25 m, with the existing windows reaching only 1.05 m in height. Despite this, the site itself offers favorable conditions for achieving good view quality: the building sits on elevated ground, and nearby structures are set back more than 20 meters.

However, current performance remains modest. The average Sky View from the occupied area is 30%, and the average General View is 57%. These figures indicate that while partial views are available, the extent and openness of the visual connection to the exterior are limited. Given the site's potential, these values suggest that the current design underutilizes the available context, and that strategic adjustments to window dimensions could enhance visual access and compliance with view-related standards.

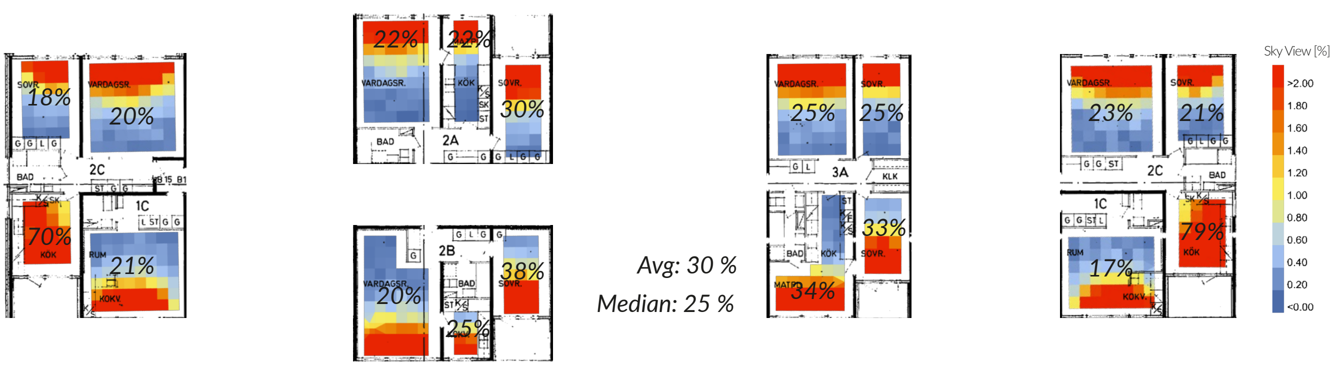

Fig 66. Area of apartments that has sufficient view of the sky.

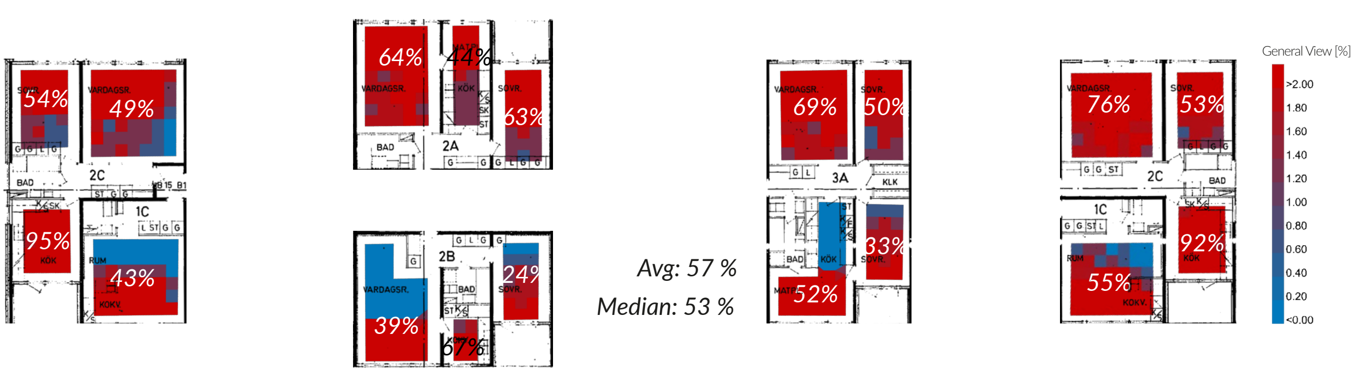

Fig 67. Area in the apartments that has an unobstructed view of the outside.

Standard Practice

Even with relatively modest changes to the window design in this scenario, the quality of view noticeably declines. The average Sky View drops to 27%, with an even steeper decline in the median value, indicating that a greater number of rooms are experiencing reduced access to qualitative view. A similar trend is seen in the General View metric, which falls to an average of 43%, with the median decreasing by 7 % units.

This decline suggests that the new window configuration not only reduces the openness of individual views but also leads to greater inconsistency in visual access across the building. The results highlight that even minor alterations to window dimensions can have an impact on perceived connection to the exterior. Especially in a context where site conditions otherwise offer strong potential for good view quality.

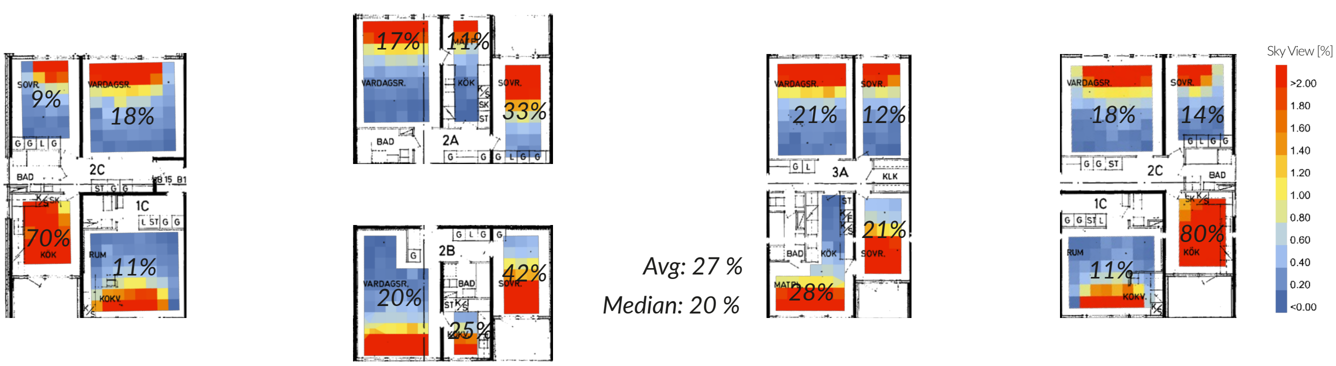

Fig 68. Area of apartments that has sufficient view of the sky.

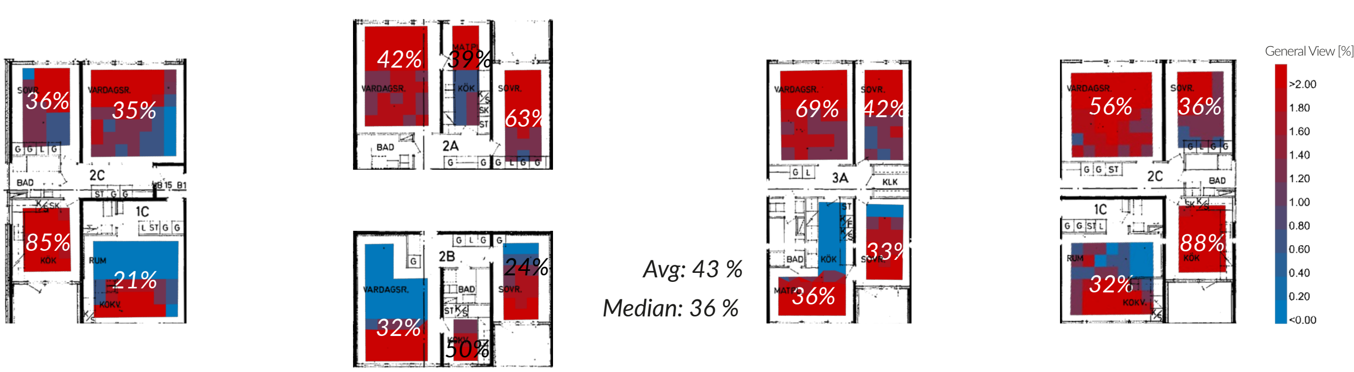

Fig 69. Area in the apartments that has an unobstructed view of the outside.

6.2.2 Iterative Process of Siriusgatan

Evaluation I

The first test in the transforming approach focuses on daylight conditions in the building, and investigates the relationship between window size, placement, and surface reflectance.

Based on findings from previous research, vertically increasing window size is generally more effective than horizontal expansion in improving daylight access. In this specific case, it is also a more structurally feasible option. The facade's structural elements make it easier and less risky to extend the window opening upward rather than outward, as mentioned by Camilla Gyllestrand. Additionally, vertical adjustments better align with the proportions of the existing facade. For this reason, the first parameter input tests how much the top of the window opening should be raised. The range is set between 5–30 cm, since anything above 30 cm would both be structurally difficult to handle as well as risk conflicting with the ceiling height.

The second parameter is the window's placement within the wall. This input is meant to test how the depth of the window affects both daylight distribution and the risk of overlighting, causing potential glare or overheating. The range is set between 0–40 cm.

The reflectance values are set at 0.4-0.7 for the interior side, simulating values for common, light interior finishes such as light wood, plaster or light-colored paint, with these being preferred in our interior spaces (Vogiatzi, 2018). The exterior range is set between 0.2–0.5, since shiny or highly reflective materials are rarely used in facade finishes.

The resulting outputs that the parameters are measured against are UDI compliance and overlit space.In total, 270 different iterations were tested in this batch.

The evaluation results indicate that increasing window size is the most influential parameter, consistently associated with higher UDI compliance. Window depth, on the other hand, acts as a moderating factor for overlighting risk. A deeper window placement slightly reduces UDI values but significantly minimizes the amount of overlit space (Fig. 70). While placing the window closer to the facade surface yields higher UDI but also elevates the risk of exceeding comfortable lighting levels (Fig. 71).

Reflectance seems to work best when it is balanced. Combining a higher exterior reflectance with a lower interior one, or selecting moderate values for both, helps optimize daylight without tipping into glare or overheating issues (Fig. 70 & 71). When attempting to compensate for smaller window sizes through increased reflectance, the results are more difficult to balance. These scenarios often either achieve acceptable UDI levels at the cost of high overlighting, or reduce overlighting at the expense of daylight sufficiency, demonstrating a narrower margin for effective design (Fig. 72).

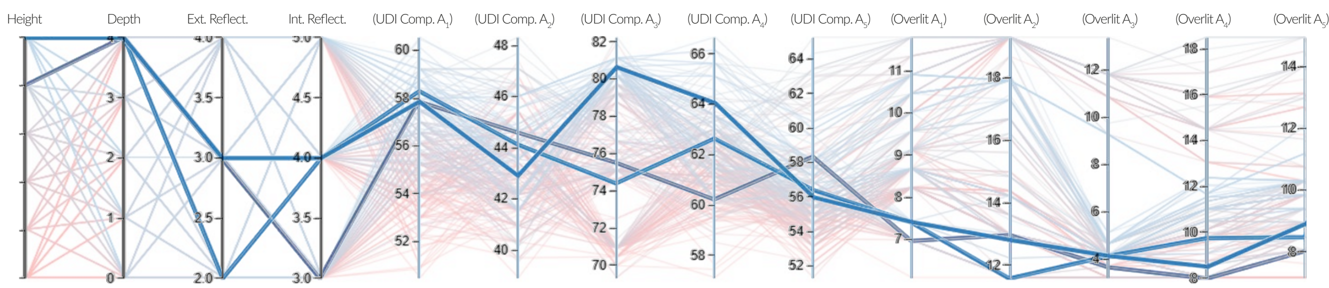

Fig. 70. Big window, further into the facade.

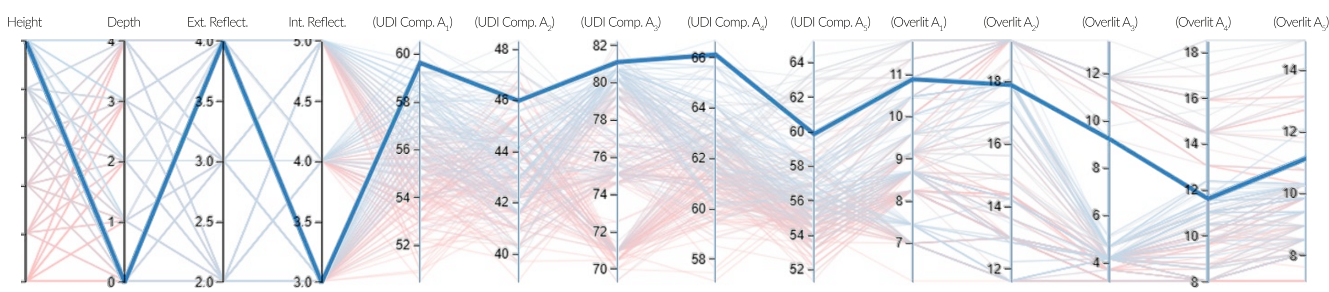

Fig. 71. Big window, close to the facade.

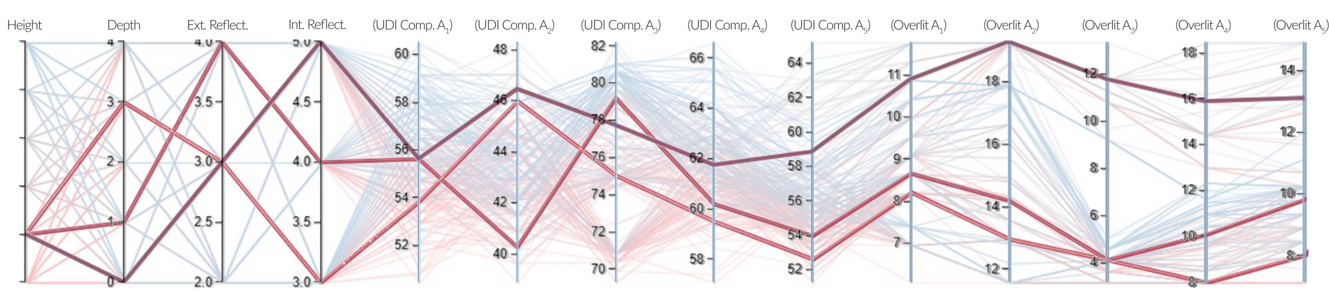

Fig. 72. Smaller window with higher reflectance.

Evaluation II

This test examines how window dimensions and placement depth affect view quality—specifically visibility of the sky and ground layers from inside the apartments. The goal is to streamline future assessments by identifying which parameters most influence perceived view as well as find the correlation between the metrics.

Window height was varied from 0 to 30 cm above the existing level, and depth from 0 to 25 cm, resulting in 36 total iterations.

As expected, taller windows improved the view. The results also confirmed that placing the window closer to the facade enhances both sky and ground visibility (Fig. 73). Notably, view curves for sky and ground followed nearly identical patterns, suggesting that future evaluations can rely on just one of these metrics as a reliable proxy for overall view quality.

Evaluation III

The third test further builds upon the parametric combination of window height, depth, and material reflectance to evaluate the relationship between overlighting and quality of view. While the previous simulations have already established that taller windows significantly improve both UDI compliance and the perceived quality of view, they also revealed that shallower window depths help enhance view-out, but simultaneously increase the risk of overlighting. Balanced reflectance values, particularly in interior finishes, have shown potential to mitigate excessive illuminance to some extent.

The objective of this test is to explore how these parameters can be adjusted to maximize view quality while minimizing overlighting. In total, 144 iterations were tested.

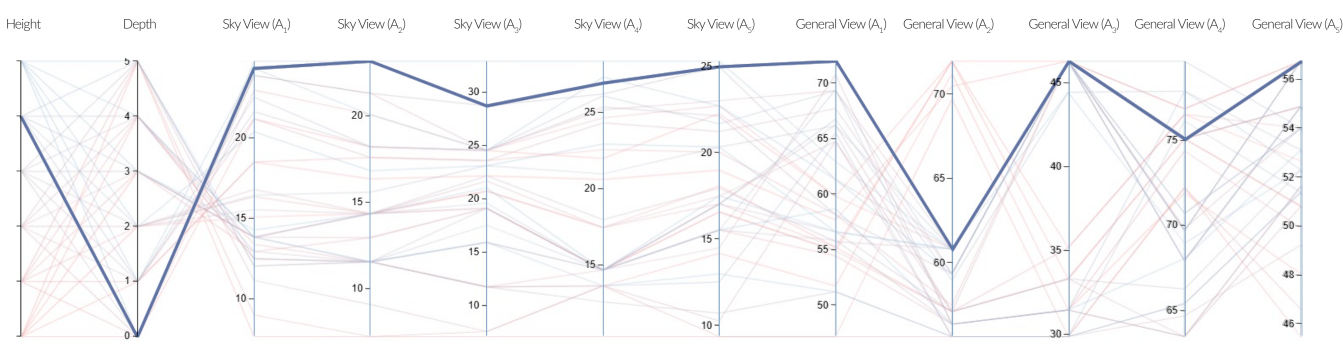

Fig. 73. Big windows close to the facade achieves best values in both sky and general view.

A clear pattern emerges across the tested parameter combinations. Moderate window heights, particularly in the range of 20 cm above current height, consistently deliver high-quality view results (Fig. 74). Increasing the window height beyond this threshold do not improve the view significantly, whereas it is increasing the risk of visual and thermal discomfort due to overexposure.

Window placement depth in the wall is identified as the second most influential parameter. As the window is placed closer to the facade surface, the potential for overlighting increases significantly. Interestingly, material reflectance, while somewhat effective at balancing daylight penetration in prior tests, proves insufficient in counteracting the effects of a shallow window placement in this case.

Evaluation IV

The next stage of the iterative process evaluates the potential of external shading as a strategy to moderate daylight penetration and reduce the risk of overlighting.

Building on insights from earlier tests—where larger window heights improved both daylight availability and view quality, but required deeper placements to mitigate overexposure—this simulation explores whether external shading can serve as a complementary or alternative method for achieving a balanced lighting environment.

To refine the scope, the window height was limited to a range of 15–30 cm, based on earlier high-performing configurations. The window depth was fixed at 10 cm to isolate the effects of exterior shading alone, as deeper placements would interfere in the results.

The shading strategy involved two variables. The projection depth of the shading element, tested at 0.0 m, 0.5 m, and 1.0 m, and the element's thickness, tested at 20, 30 and 40 cm, to assess whether the structural mass affects the shading performance. This resulted in 36 total combinations.

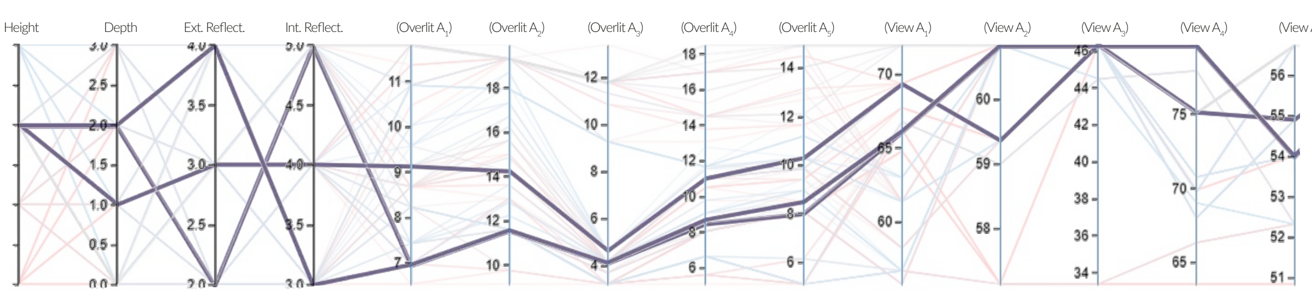

Fig. 74. Avoiding too big windows reduces the risk of overlit spaces while still achieving good view-out.

The results revealed a compelling pattern. While the initial hypothesis assumed that external shading could assist in creating a more balanced performance, the outcome demonstrated that certain configurations could achieve both high UDI compliance and low overlighting. Specifically, the setup with the maximum window height, combined with the deepest shading projection and greatest thickness, delivered the strongest performance, reaching peak UDI values in 4 out of 5 apartments while maintaining below-average overlight levels across all cases, including one with minimal exposure (Fig.75).

Isolating the analysis of the 20 cm-high window, previously identified as the optimal size, also confirmed that a pairing with the maximum shading setup would provide strong results. This configuration slightly outperformed the 30 cm variant in terms of reducing overlighting, but did not reach the same levels of UDI compliance, even though the results were great (Fig.75).

Evaluation V

The last researching step in the iterative testing process examines the impact of increased transparency on the exterior elements of the building, around the balconies. While the site visit have already indicated that these spaces feel dark and enclosed, this batch aims to quantify how changes to balcony transparency would affect the interior climate conditions of the adjacent rooms.

The primary objective is to ensure that improving the spatial quality of the balconies does not compromise the interior climate and comfort of the apartments, since the daylight evaluations showed good conditions for the interior spaces in its current state. In the evaluation, transparency is explored through two variables: balcony windows and railings.

The window parameter involves introducing a small opening between the balcony and, in most cases, the kitchen. While its contribution to daylight may be modest, the intent is to create better spatial and social connection between interior and exterior, especially since the balconies are currently only accessible via the bedrooms.

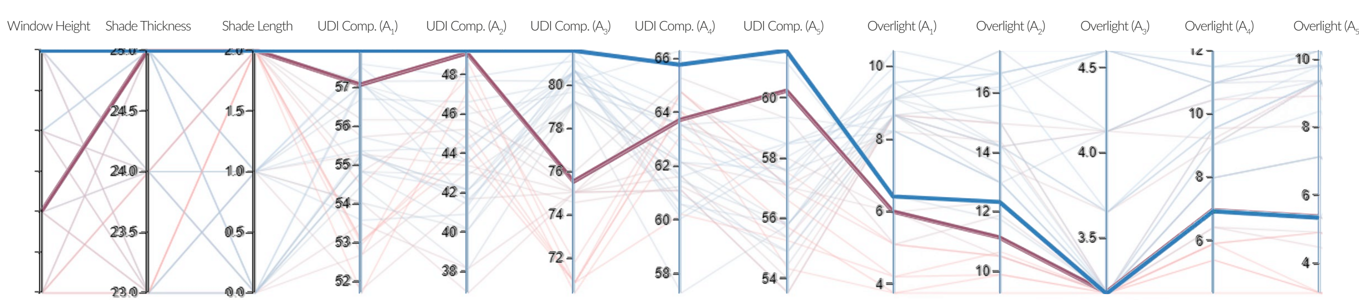

Fig. 75. Maximum amount of exterior shade creates the best results.

Although there are structural constraints, particularly due to the optimized nature of the building envelope, research and interviews suggest that the balcony zone presents the most viable opportunity for this type of architectural intervention. To still maintain realism, the proposed window dimensions are limited, with a height range of 20–60 cm and a width range of 60–120 cm.

The railing parameter is more straightforward. The current opaque sheet metal railings limit daylight penetration and visual openness. This evaluation tests alternative transparency levels through glazed options: 0% transparency (existing conditions), 40% (frosted glass), and 80% (clear glass).

In total, this created 36 different combinations.

Results indicate that high UDI levels and minimal overexposure are achievable across all transparency levels depending on how the window is configured (Fig. 76). However, since the primary aim is to create a lighter, more inviting balcony space, focus is placed on iterations using higher-transmittance railings.

Within this subset, several combinations of balcony window dimensions are shown to both mitigate overlighting and enhance daylight conditions in adjacent interiors (Fig. 77). Nonetheless, these gains are relatively minor, and the window itself does not significantly contribute to achieving the overall goal. Given the likely structural and financial constraints associated with inserting new openings into the envelope, the balcony window is therefore excluded from the final design proposal.

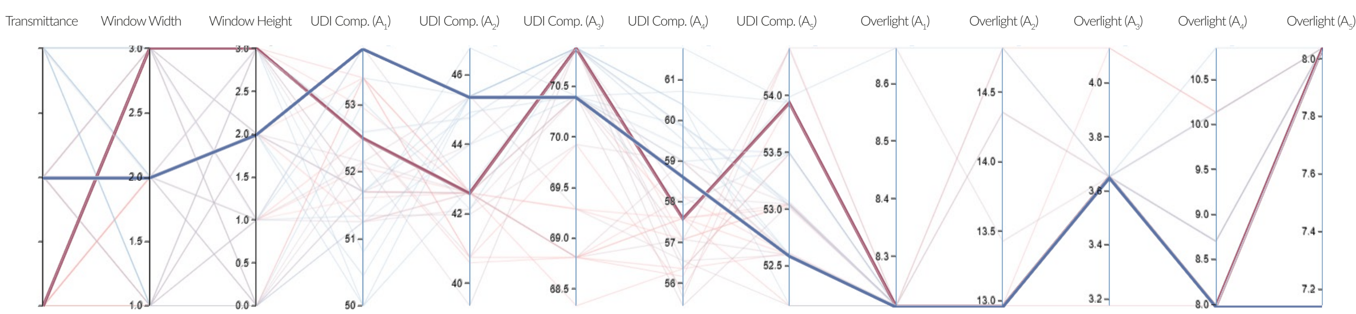

Fig. 76. Low transmittance railing.

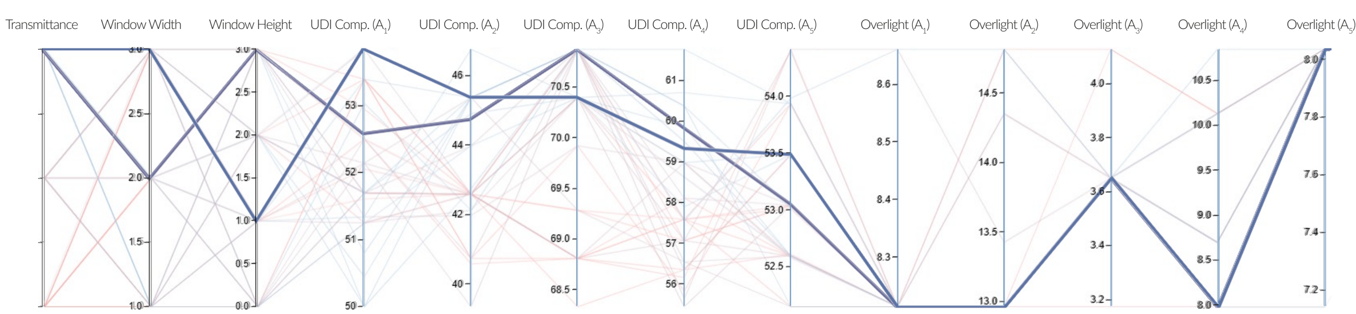

Fig. 77. High transmittance railing with different window combination.

Conclusive Evaluation

The final conclusive test aims to identify the most suitable design solution for the transformation strategy—one that balances strong daylight performance with architectural quality. To that end, the following parameters are prioritized for their proven impact.

Window height has consistently emerged as a highly influential factor. In this test, it is constrained to a contextually appropriate range of 20–30 cm to align with the facade composition. The window's depth, not previously tested alongside exterior shading, is now tested at 5, 10 and 15 cm, to further understand their combined effect.

Exterior shading has shown substantial influence on daylight control but can compromise both view quality and facade expression. To better assess its thresholds, shading depth is tested across four increments ranging from 0.25 to 1.0 m. The aim is to determine whether significant daylight gains can be achieved with a smaller architectural compromise.

As window depth becomes a variable again, exterior reflectance is reintroduced to evaluate how the material treatment of the external niche affects performance. Finally, railing transmittance is tested at 40%, 60%, and 80%—providing a spectrum between frosted and clear glass to explore the potential of semi-transparent options. The conclusive test included 324 total iterations.

As expected, shade length is the most impactful variable, with the longest shading (1.0 m) producing most of the highest-performing iterations (Fig. 78). However, because of its strong effect on visual and architectural qualities, the final selection places greater weight on aesthetic considerations. By isolating shorter shade lengths of 0.25–0.5m and shallower window depths of 5–10 cm, the test identifies the best-performing, architecturally feasible solutions. Two iterations stand out with a strong average UDI and low overexposure values (Fig. 79). Both use a 10 cm window depth, 0.5 m shade, and 80% railing transmittance. They differ slightly in window height and niche reflectance values, with the larger window iteration preferred due to its improved view-out performance.

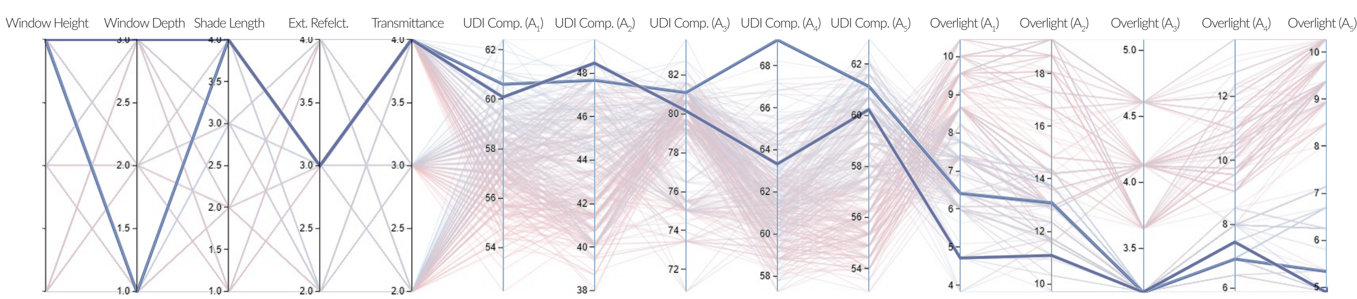

Fig. 78. Longer shade elements provides a high and balanced result.

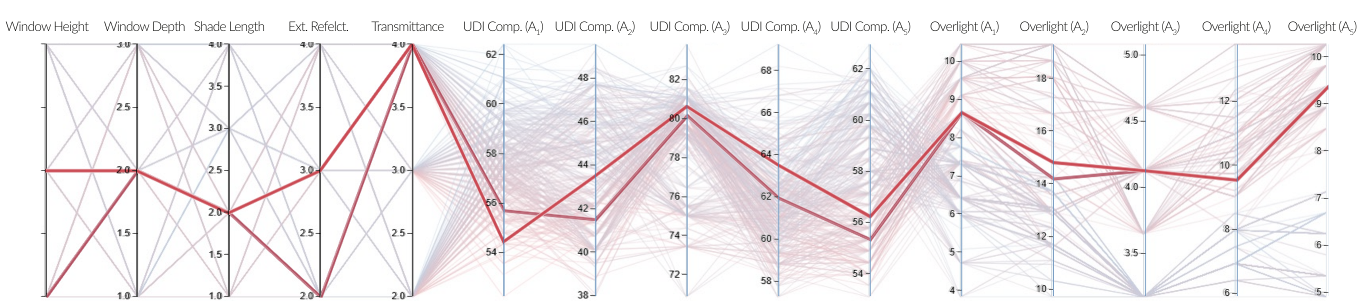

Fig. 79. More aesthetic and view-freindly combinations.

7. DESIGN PROPOSAL - CASE STUDIES

7.1 Preservation of Kv. Tuppfjätet

Following 484 iterations in the parametric testing process, a final design strategy for the new wall composition has been established. The objective has been to combine strong daylight performance with architectural sensitivity and material clarity, while staying within the constraints of the existing building.

The window is positioned close to the facade, with a shallow reveal depth of 5 cm. This setup achieves high values in terms of daylight penetration and view quality, while also aligning with the proportions and facade logic of the original building and its surrounding context.

The interior reveal is angled at 35 degrees, which has proven to be an effective geometry for increasing both the amount and distribution of daylight into the room. This angle directs incoming light further across the ceiling and walls, softening contrast ratios and enhancing perceived brightness in areas further from the window. It also enhances the interior space by broadening the view of the outside and introducing a subtle sense of openness in otherwise compact rooms.

A reflectance value of 0.5 is selected for the interior niche surfaces. This level performs well in terms of both daylight reflection and visual comfort, and it corresponds closely with light wood finishes such as bright pine or white oak (Gustafs Scandinavia, 2021). These materials not only support light diffusion, but also introduce a tactile and warm character to the interior environment. While the exterior reveal is less impactful due to the minimal depth, maintaining a balanced reflectance level around 0.4 helps ensure consistent light across the window frame. This can be achieved through a matte surface in light grey or soft white (Decrolux, 2018).

To reintroduce detailing that reflects the original character of the windows, one vertical divider is added along with a single horizontal muntin, positioned 50 cm from the top. This provides subtle articulation without significantly reducing the quality of view or daylight intake.

Fig. 80. 3D Detail of current exterior wall.

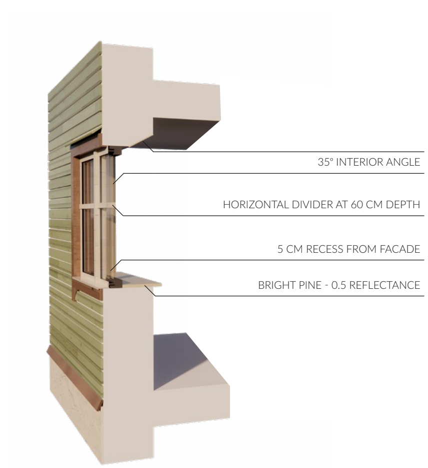

Fig. 81. 3D Detail of proposed new wall.

Measurements for Proposed Design

Wall thickness: 0.48 m, U: 0.17 W/m²-K
Interior Niche: 35°, 0.43 m deep, 0.5 reflectance
Exterior Niche: 0°, 0.05 m deep, 0.4 reflectance
Window size (Width/Height): W_1: 1.55m x 1.2m, W_2: 0.8m x 1.2m, U: 0.9 W/m²-K
Sill Height: 1m
Muntin/Divider size (Width/Depth): Vertical: 50mm x 50mm, Horizontal: 30mm x 50mm

The proposed design maintains the original glazed area of the window, but replaces the pane with a slightly better-insulated alternative. According to Elitfönster, their standard window has a U-value of 1.0, while high-performance models can reach as low as 0.7. For this thesis, a U-value of 0.85 is used, representing a realistic middle ground between typical and best-case performance. The wall construction remains identical to the standard renovation approach to ensure that the proposed design strategy is compatible with the typical building methods and insulation thicknesses.

Energy Performance of Proposed Design

The optimized proposal for Kv. Tuppfjätet retains the same wall construction as the standard renovation approach but incorporates a slightly improved window with a U-value of 0.85. This configuration achieves an EUI of 122 kWh/m²— identical to the performance of the standard model, despite maintaining the original window size.

The ability to preserve the existing architectural proportions while keeping the energy use unchanged suggests that key design features can be retained or reintroduced without compromising performance. This outcome supports the idea that aesthetic and architectural considerations, when addressed strategically, can be integrated into renovation solutions without negatively impacting energy efficiency. It reinforces the claim that energy performance and architectural quality are not inherently conflicting, especially when design strategies are considered early in the process.

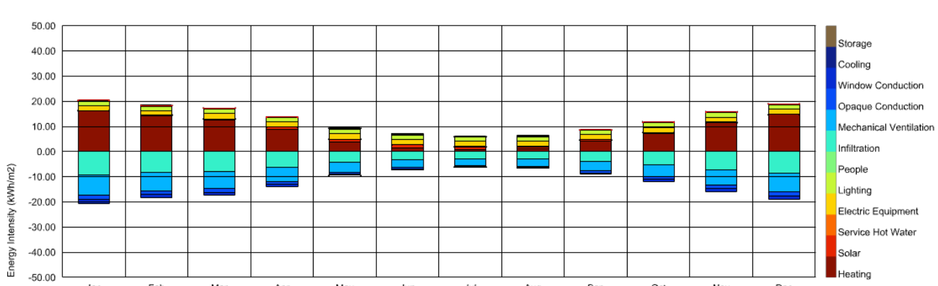

Fig 82. *Average energy consumption per every month of the year, per use.*

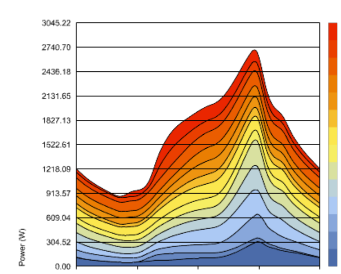

Fig 83. Cooling load profile on the hottest summer day.

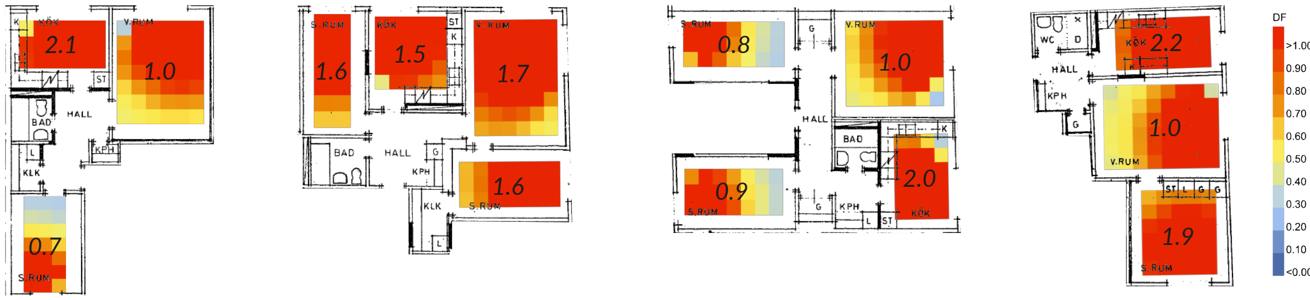

Fig 84. Compliance measured against BBR's standard of DF > 1%. The DF_{median} is written out for each apartment.

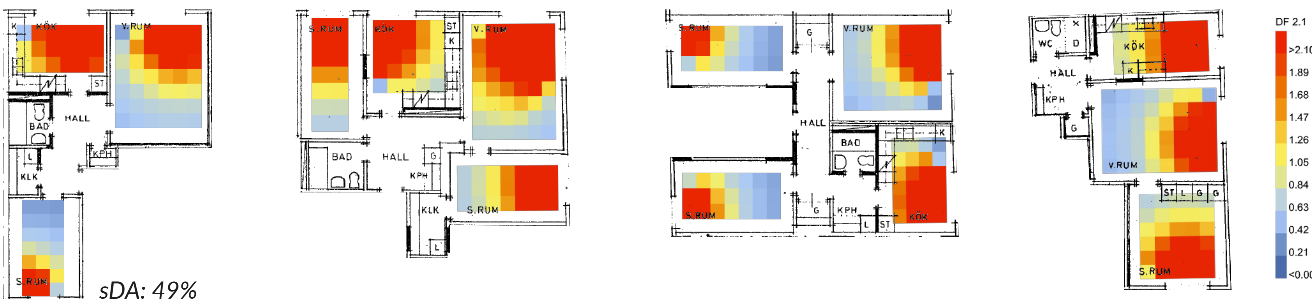

Fig 85. Compliance measured against SS-EN's suggestion of 2.1% DF being sufficient light in the context of Gothenburg. sDA is the average for all apartments combined.

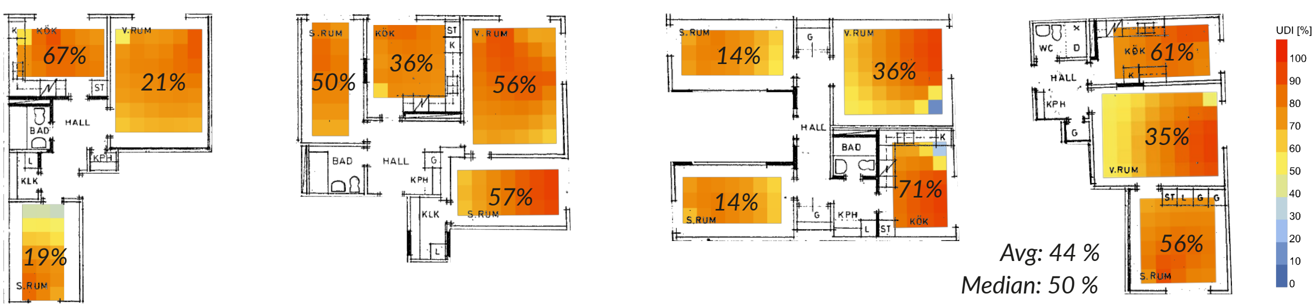

Fig 86. UDI levels in the apartments. Each apartment's compliance towards LEED's 2 point criteria is displayed.

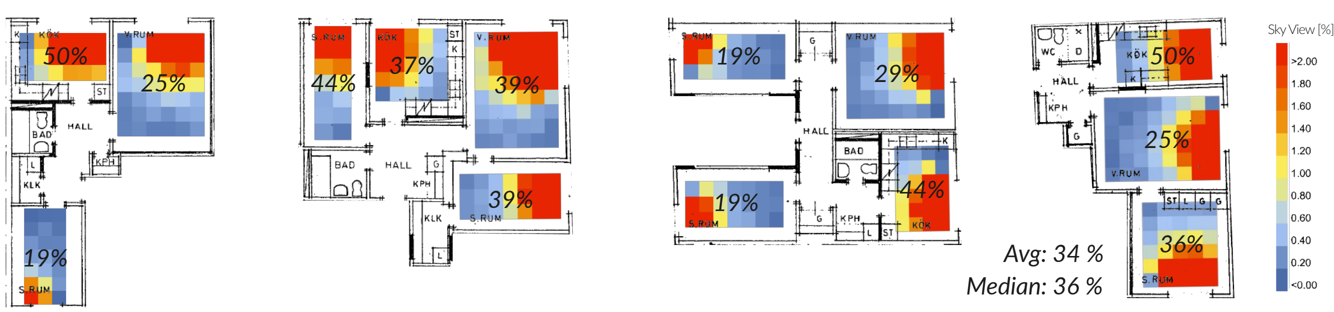

Fig 87. Area of apartments that has sufficient view of the sky.

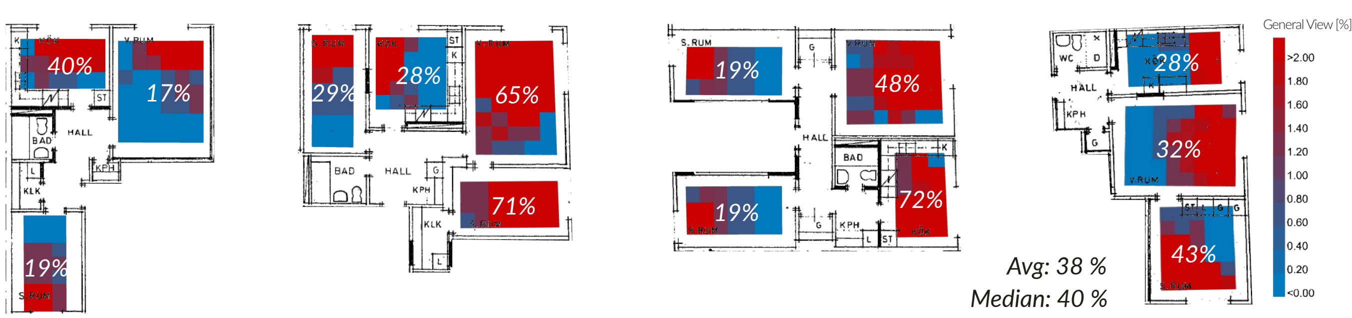

Fig 88. Area in the apartments that has an unobstructed view of the outside.

The preservation strategy aims to enhance interior qualities through small, well-considered interventions that allow the building's exterior to remain largely intact or be reinterpreted in a way that respects its original character. The results indicate that this is not only feasible, but effective—even with minimal adjustments.

The proposed design outperforms both the standard renovation approach and the building's current condition. In terms of BBR compliance, all apartments now comply with the BBR regulation with an average DFmedian above 1.0, with the only individual exceptions being the three narrow courtyard-facing bedrooms, which fall just below the threshold.

Dynamic daylight performance shows a similarly positive trend. What would have been an average UDI result of 29% in the standard scenario has increased to 44%, with a median compliance of 50% and an sDA of 49%. These values place the project far above the threshold for the LEED one-point level for sDA measurement and a lot closer to the two-point level in terms of UDI compliance, representing a significant improvement in climate-based daylight performance.

View-out quality, while still constrained by the urban context, has also improved. The median General View has increased from 29% to 40%—a relative gain of 38%—demonstrating that even minor spatial and geometric adjustments can contribute to a stronger visual connection with the exterior.

These improvements go hand in hand with the reintroduction of qualitative and cultural aspects. The proposed interior niche, with its angled geometry, increased depth, and light wooden finish, enhances both light distribution and the tactile experience of the space. Paired with the reinstated window muntin detailing, the design supports a softer, more diffuse daylight entry, while allowing the exterior facade to return to an expression more in line with its original architectural identity.

Fig. 89. Previous facade.

Fig. 90. Suggested facade.

7.2 Transformation of Siriusgatan

After 846 iterations in the parametric testing process, the final transformation strategy has been defined. The objective has been to elevate the existing facade expression while simultaneously improving daylight conditions and view-out quality for the apartments.

The new window is 25 cm taller than the original, enhancing interior qualities such as light spread and view angle. More importantly, it aligns with the vertical lines of the facade, establishing a clearer and more cohesive architectural rhythm. The window is placed moderately close to the facade, at a depth of 10 cm. This position strikes a balance between maximizing daylight without risking overlight, even with the introduction of glazed railings. This allows the railings to be fully transparent, allowing maximum light penetration into the balcony spaces.

To further minimize the risk of overlighting, a subtle external shading element is introduced, extending 50 cm horizontally from the facade. In addition to providing functional solar control, this element helps articulate the currently flat facade, offering a subtle but effective change to the building's exterior character.

The most suitable reflectance values to support this configuration are balanced but slightly muted: 0.3 on the exterior and 0.4 on the interior. A fitting material for the interior reveal is oak (Gustafs Scandinavia, 2021) while the exterior niche can use brick, or more fitting in this case, a concrete finish (Decrolux, 2018). These materials will help reduce glare while maintaining a bright and comfortable atmosphere within the apartments.

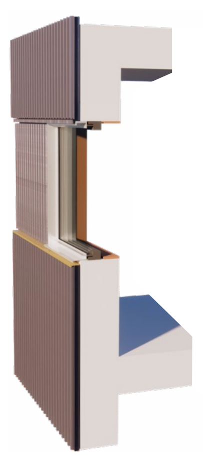

Fig. 91. 3D Detail of the current exterior wall.

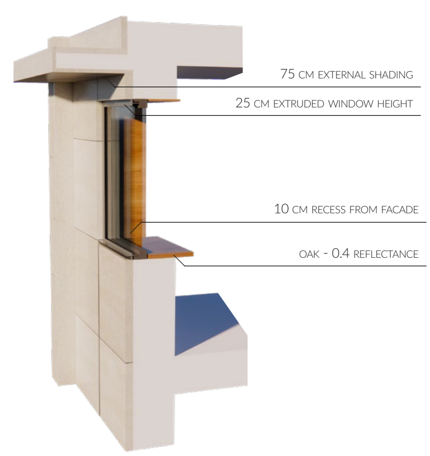

Fig. 92. 3D Detail of the suggested exterior wall.

Measurements for Proposed Design

Wall thickness: 0.48m, U: 0.14 W/m²-K
Interior Niche: 0º, 0.38 m deep, 0.35 reflectance
Exterior Niche: 0º, 0.1 m deep, 0.2 reflectance
Window size (Width/Height): W_1: 1.1 m x 1.3 m, W_2: 0.7m x 1.3 m, U: 0.85 W/m²-K
Sill Height: 0.9m
Railing transmittance: 80%

The proposed design increases the window height by 25 cm and replaces the pane with a slightly better-insulated alternative. As in the preservation study, a U-value of 0.85 is used to represent a realistic balance between standard and high-performance glazing. The balcony railing is modeled with 80% transmittance, simulating a typical transparent glazed solution. The wall construction remains unchanged from the standard renovation approach to ensure compatibility with conventional building methods and insulation requirements.

Energy Performance of Proposed Design

The optimized proposal for Siriusgatan, which retains the same wall construction as the standard renovation approach but incorporates a slightly improved window with a U-value of 0.85, achieves an EUI of 127 kWh/m². This performance is nearly identical to the standard model, despite the architectural enhancements made to the window design.

The minimal increase in energy consumption suggests that it is possible to preserve or even enhance key architectural features without significantly compromising overall energy performance. This result supports the idea that modest technical upgrades, when strategically applied, can offset the energy impacts of more architecturally driven decisions. It reinforces the thesis' central claim that energy efficiency and architectural quality do not have to be in conflict, particularly when design strategies are integrated from the outset.

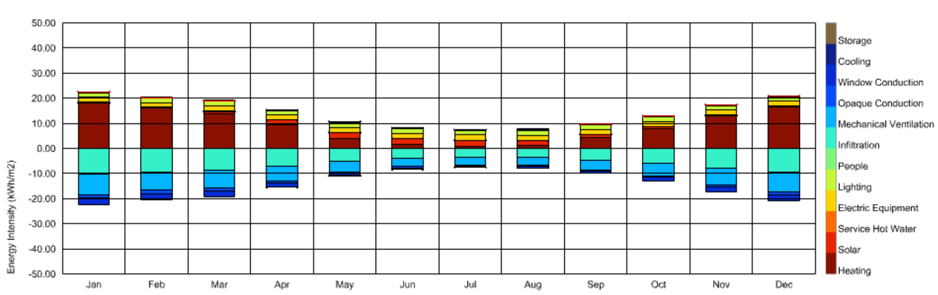

Fig 93. *Average energy consumption per every month of the year, per use.*

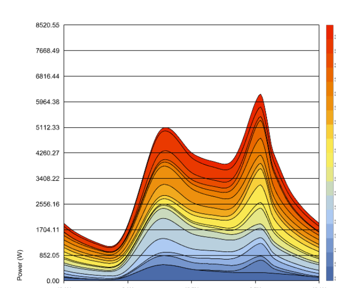

Fig 94. Cooling load profile on the hottest summer day.

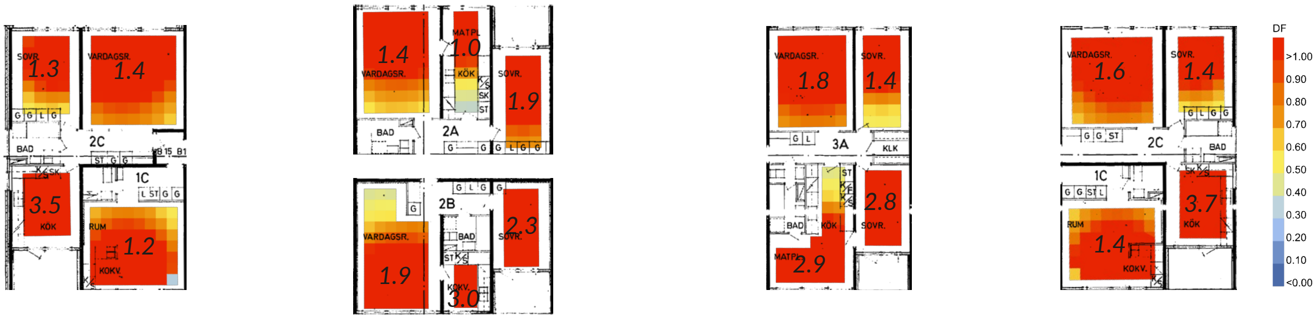

Fig 95. Compliance measured against BBR's standard of DF > 1%. The DF_{median} is written out for each apartment.

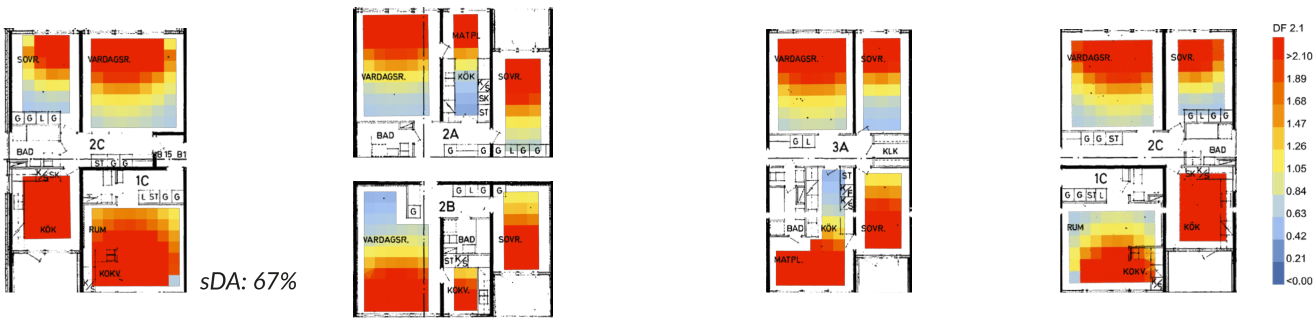

Fig 96. Compliance measured against SS-EN's suggestion of 2.1% DF being sufficient light in the context of Gothenburg. sDA is the average for all apartments combined.

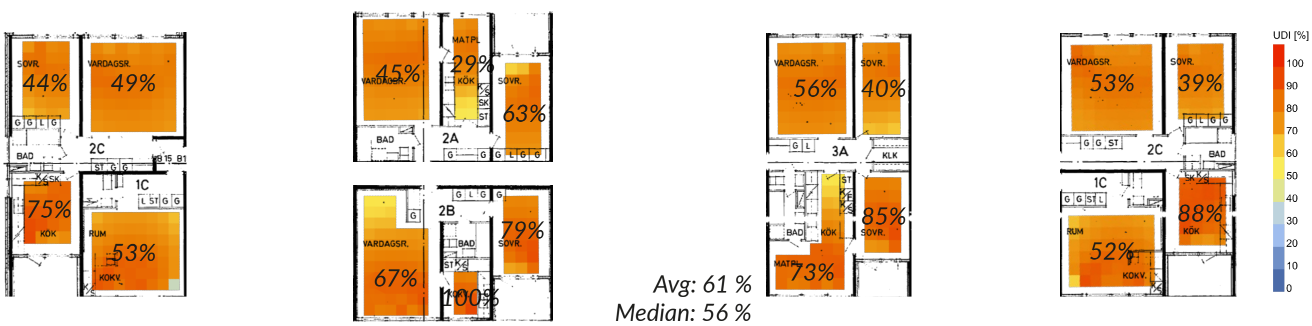

Fig 97. UDI levels in the apartments. Each apartment's compliance towards LEED's 2 point criteria is displayed.

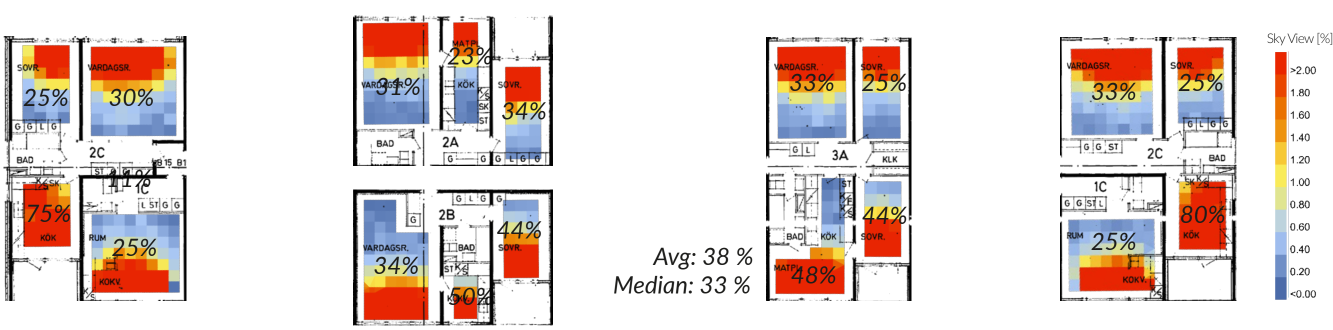

Fig 98. Area of apartments that has sufficient view of the sky.

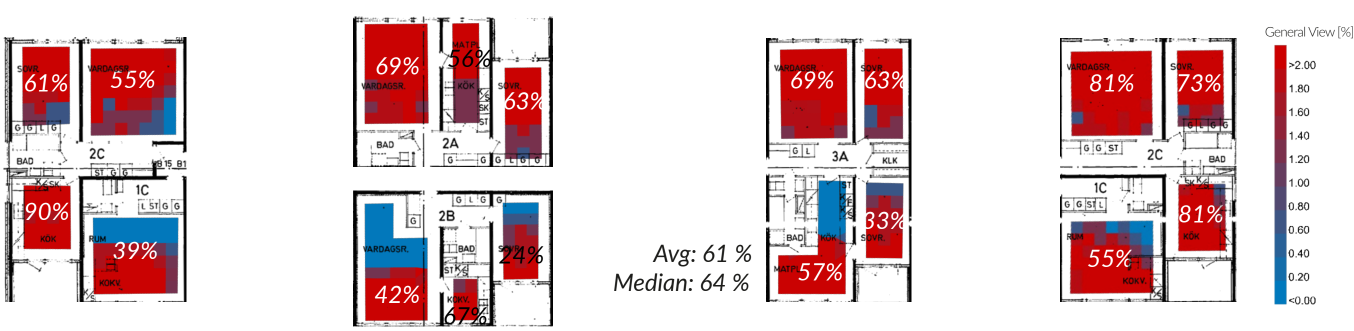

Fig 99. Area in the apartments that has an unobstructed view of the outside, displayed in percent.

The transformation strategy aimed to significantly enhance the facade expression while using those changes to generate clear improvements in interior daylight and view quality. While the baseline conditions at Siriusgatan were not as poor as in the preservation case, there was still considerable room for improvement. Something the proposed design successfully demonstrates.

Although all apartments initially complied with the upcoming BBR daylight regulations, the transformation strategy also brings them into full compliance with the current standard, with all individual rooms now exceeding the DF > 1.0 threshold. The median daylight factor across the apartments also increased from 1.2 to 1.5, confirming a consistent improvement in static daylight conditions.

View-out quality also improved notably, despite the addition of external shading elements. This highlights the benefit of increasing the window height. The average Sky View rose from 30% to 38%, and while the average General View increased more modestly, the median improved from 53% to 63%—indicating a more consistent and equitable visual connection to the outside across all rooms.

A major focus of the iterative process was to balance these improved daylight and view conditions, with the risk of overlighting. Especially since several of the proposed design measures involved increasing the glazing area and positioning the window closer to the facade. The results show that this balance was achieved. The sDA increased from 60% to 67%, while the UDI median—which accounts for both insufficient and excessive light—rose from 48% to 56%, indicating healthier daylight conditions overall.

When isolating the overlight values, apartments 1, 3, and 4 actually saw a decrease compared to their current state. Apartments 2 and 5 experienced only minimal increases, with overlit areas rising modestly from 8% to 9% and 12% to 13%, respectively. These results confirm that the strategy not only improves daylight and view quality but does so while keeping glare and overexposure well within acceptable limits.

Fig. 100. Previous facade.

Fig. 101. Suggested facade.

8. DISCUSSION

This thesis has placed a strong focus on daylight as a guiding parameter in renovation design. While this was a deliberate choice due to its architectural relevance, it also reflects certain practical limitations. Parametric daylight simulations were more accessible and easier to integrate into an iterative workflow, while dynamic energy modeling posed greater challenges in terms of time, technical complexity, and software limitations.

Energy performance was still evaluated in the study, just not incorporated into the parametric iteration process itself. Including it alongside daylight and overlighting metrics could have resulted in an even more balanced and optimized outcome. This is something to explore further if time had allowed, particularly to better understand trade-offs between spatial quality and energy efficiency.

Overheating risk was assessed using metrics such as peak cooling load, hours above 27 °C, and overlit space. While these provide a general indication of thermal discomfort, they do not fully reflect actual cooling demand or future performance under climate change scenarios. Many studies on overheating rely on projected weather data, such as TRY 2050, which was not available to me for this project. As a result, design responses to overheating were primarily informed by literature rather than tested directly through future-based simulations.

This limitation led to a partial mismatch between the simulation results and the risk scenarios described in research. Here, the hours above 27 °C and the cooling demand actually decreased in models with higher insulation—contrary to findings in the literature, that suggest increased overheating risk in well-insulated buildings without adequate ventilation or shading. For this reason, overlit space became the most consistently discussed and evaluated indicator throughout the design process, as it was the only available metric that directly related to both visual comfort and energy implications.

Another area not explored in this thesis is the impact of different window types. While glazing properties such as g-value and visible light transmittance could have influenced both daylight and thermal performance, they were not varied in the iterative process. This was a conscious decision, as such parameters do not alter the architectural design in a spatial or formal sense. Since the aim was to evaluate performance-linked design strategies, fixed glazing properties were used to isolate the impact of geometry and placement, rather than product specification. However, testing alternative window systems — such as low-g coatings or dynamic glazing — would be one of the most simple yet impactful strategies to include, since it has close to no impact on the aesthetics of the facade.

Maybe the main part excluded in this evaluation, is the qualitative and subjective side of the daylight analyses. Improving the performance digitally is one thing, but having it backed up by real life experience would definitely enhance the results, and the arguments for them. This was excluded due to the time needed to send out, collect and conclude this type of analysis. Instead, the thesis relied on previous research to inform the design measures.

Altogether, these are all areas that could strengthen future studies. Despite these limitations, the thesis demonstrates how performance-informed daylight strategies can meaningfully guide renovation design — and sets a foundation for broader, multi-criteria workflows going forward.

9. CONCLUSION

9.1 Evaluation of Strategies

The preservation and transformation strategies developed in this thesis serve not only as practical renovation proposals, but as two distinct ways of approaching the broader question of how to improve existing buildings without compromising architectural integrity. Through the design process and evaluation, both strategies revealed the importance of aligning technical performance with spatial and cultural considerations, even though they arrived at this balance through different means.

The preservation strategy is rooted in architectural restraint, working with the existing building rather than altering it. Instead of pursuing visible change it focuses on small-scale, interior modifications, such as the niche geometry and surface material, to improve daylight conditions and spatial quality. One of its key takeaways is that meaningful gains in comfort, perception, and regulatory performance can be achieved through subtle, well-calibrated interventions that respect the existing structure.

While the strategy operates within clear limitations, with fixed window sizes, orientations, and facade constraints, these boundaries become a productive part of the design process rather than obstacles. The reduced scope of intervention encourages greater precision, forcing the design to respond to what already exists. In this way, the strategy demonstrates that performance improvements are not necessarily tied to large-scale change. They can emerge from an understanding of the building's current characteristics, and thoughtful adaptation of its components. The preservation approach ultimately shows that spatial and environmental quality can be enhanced through refinement, not replacement.

In contrast, the transformation strategy embraces architectural change as a tool for performance. It demonstrates how larger interventions, when handled with precision, can improve both quantitative performance and qualitative experience, while still operating within the constructional constraints. What defines this strategy is not just the willingness to modify the facade, but the way it integrates spatial improvement, visual identity, and environmental logic into a combined system. The enlarged glazing, added shading elements, and adjusted rhythms in the facade expression work together to support both energy and daylight goals as well as improve the building's aesthetics.

Of course, this approach also carries more complexity. The transformation strategy demands more resources, more design negotiation, and potentially more friction with community expectations. It needs a confident design stance. One that not only measures outcomes but also justifies change through architectural reasoning. This is one part where qualitative analyses could have improved the strategy.

Ultimately, the comparison between the strategies is not about declaring one *better* than the other, but about understanding which strategy suits which context. The preservation strategy offers a path for sensitive upgrades in buildings with architectural value and limited design flexibility. The transformation strategy opens a path for more ambitious interventions, where performance deficits and, or, design potential call for bolder moves.

What ties them together is the recognition that renovation is not just a technical exercise, but a design challenge and an opportunity to improve. In both strategies, architecture becomes the medium through which energy, comfort, and character are negotiated—not added as an afterthought, but built into the very logic of the solution.

9.2 Applicability Beyond Case Studies

While the design strategies in this thesis are based on two specific buildings, the underlying principles and methods offer broader relevance for the aging Swedish housing stock.

Many of the older buildings share key characteristics: outdated energy performance, deep floor plans, and regulatory or historical constraints that limit intervention. In such contexts, the preservation strategy provides a valuable model. The use of niche considerations, adjusted materials and finishes, and passive design logic can be replicated in other buildings where window size or facade changes are not permitted or desirable. The approach is especially applicable in preservation areas or typologies with heritage value, where design freedom is restricted but performance upgrades are required.

The transformation strategy, while more context-specific, is still adaptable. Particularly for buildings where facade renewal is already under consideration or where envelope performance is critically low. The use of parametric iteration to find optimal window sizing, shading depth, or reflectance combinations can guide upgrades regardless of its context. This approach is suitable for early renovation planning stages, where different levels of intervention can be evaluated before the design directions are fixed.

However, the generalization must still consider urban and climatic context. In dense urban environments, view-out strategies become more complex. The positive results from the design strategies at Siriusgatan, where spacing between buildings and the high altitude allowed visual openness, proved to be efficient in its context. Whereas Kv. Tuppfjätet could not achieve as high standards, but still managed to improve, with another set of strategies. Similarly, daylight performance is highly dependent on orientation and site shading, which must be factored into future applications.

Another critical limitation lies in climate data. The energy and overheating evaluations in this thesis were based on standard weather files. To apply these strategies more broadly and robustly, TRY climate data or future weather scenarios should be included to understand performance under likely 2050 conditions. This is particularly relevant for overheating risk, which may be underestimated in the current analysis.

Despite contextual variations and limitations, the workflow itself is highly transferable. The process of using parametric modeling to evaluate daylight, view, and energy metrics in parallel can be applied across a wide range of buildings. It offers a framework for informed decision-making that aligns architectural intent with performance requirements from the earliest stages.

Ultimately, the preservation and transformation strategies proposed in this thesis are not fixed templates but strategic mindsets. They offer two ends of a spectrum. Ranging from minimal impact to bold intervention, along which most renovation projects risk failing without correct considerations. Their applicability lies in their flexibility and their capacity to guide nuanced, context-sensitive, and performance-oriented renovation decisions. Thereby, the thesis demonstrates how energy renovations are an opportunity, rather than an obstacle, for future architecture.

However, it is also important to note that the adaptability and generality of these design strategies extend beyond renovation alone.

At their core, the strategies represent a way to integrate performance analysis into the design process, allowing architects to make more informed decisions and develop stronger, more grounded arguments for their design choices.

While this thesis focuses on renovation, and emphasizes daylight and view-out performance as key metrics, these can easily be adjusted depending on the context, the project end goal or the expertise of the architect. The development of interactive analysis tools is highly transferable and can be applied in a variety of ways to deepen the understanding of a building's function, form, and performance.

As energy renovation becomes one of the most pressing architectural challenges of the coming years, this thesis argues that architects should not be brought in after performance goals are defined, they should be part of setting them. Because the tools needed in order to meet both spatial and environmental goals already exist. The challenge lies in applying them with intention and a design ambition.

10. REFERENCE LIST

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LIST OF FIGURES


DAYLIGHT: DF, UDI, SDA
VIEW: SKY & GENERAL VIEW
ENERGY: ENERGY USE INTENSITY
OVERHEATING: OVERLIT SPACE, HOURS OVER 27°C
OPTIMIZING DAYLIGHT AND AESTHETICS IN ENERGY RENOVATIONS
DYNAMIC DAYLIGHT PERFORMANCE

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