Degree Project in Architectural Lighting Design
Second Cycle 15.0 hp

Optimizing Daylight Utilization in Nordic Homes
Enhancing Energy Efficiency, Well-being, and User Satisfaction through Design

KATJA TEINILÄ
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2023

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School of Architecture and the Built Environment - Lighting Design
Degree of Master of Science - Architectural Lighting Design
Course: AF270X
ABSTRACT

This thesis examines daylight utilization in Nordic home environments without artificial lighting. One of the aims is to save energy and create healthy living spaces that fully harness daylight benefits. The research question focuses on how to effectively use daylight as the sole illumination source for functional, comfortable, and aesthetically pleasing homes.

Existing guidelines overlook the importance of daylight in homes and fail to consider human preferences, resulting in a research gap. To address this, this thesis analyses three buildings, presents design alternatives for orientation, openings, and materials, and conducts daylight calculations for proposed design. The key findings emphasize that a home without artificial light can be easily achieved during the summer months through strategic room placement, incorporation of skylight windows, and utilization of various window types. Material selection is crucial in creating a comfortable atmosphere while maximizing daylight transmission for optimal lighting. These findings highlight the importance of considering unique daylight conditions in Nordic countries and aligning designs with individual preferences. The study contributes by emphasizing the need for optimal daylight solutions that enhance energy efficiency, well-being, and user satisfaction in home environments.

ACKNOWLEDGMENTS

I would like to express my gratitude to all those who have supported and contributed to the completion of this thesis. First and foremost, I would like to thank my supervisor, Federico Favero, for his guidance, expertise, and support throughout the entire research process. His valuable insights, constructive feedback, and encouragement have been instrumental in shaping the direction and quality of this work. I would also like to extend my appreciation to my tutor, Foteini Kyriakidou, for her invaluable input, critical review, and helpful recommendations. Her expertise and scholarly contributions have significantly enriched this research and enhanced its overall quality.

Furthermore, I would like to acknowledge the support and encouragement I have received from my colleagues, friends, and family. Their stimulating discussions, feedback, and belief in my abilities have been invaluable sources of motivation and inspiration.

I am truly thankful to everyone mentioned above and to all those who have played a part in making this thesis a reality.
Daylight shapes architecture, highlights features of buildings and creates dynamic patterns with shadows. It also divides spaces and creates different atmospheres. The use of daylight in architecture has also been connected to health benefits, such as improving mood, productivity and well-being (Rosenthal, 2012 & Boyce, et al., 2003).

Is it possible to design a home that doesn’t have any artificial light and what design solutions are most comfortable, functional and aesthetic in a home environment? This thesis aims to determine if it is possible to design a house in a Nordic country that relies solely on daylight, while still providing the necessary levels of comfort, functionality, and aesthetics. The goal is to find design solutions that can reduce or replace the artificial light in the home environment. The subject is studied using existing literature and research, an examination is conducted of three Nordic residential buildings, and in creation of a building design.

The design is crafted for the Buildner organizations competition, “The Home of Shadows,” where participants must design a residence for an imaginary couple, that doesn’t have any artificial light.

The research question that is focused on in this thesis is following: How can we utilize daylight as the only source of illumination to create a home environment that is functional, comfortable and aesthetic?

In Finland, the lighting of a 120 m² detached house consumes an average of 1150 kWh per year. This is about 14% of the house’s electricity consumption, making it the second largest consumer of electrical appliances in the home (Fortum, 2019). United Nations Sustainable Development Goal (SDG) 7 is to ensure access to affordable, reliable, sustainable, and modern energy for all and to take urgent action to combat climate change.

1.1 Sustainable Development Goal

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1.2 Daylight in the Nordic Countries

The daylight conditions in the Nordic countries are special in a few ways. For example, there is a huge contrast between daylight conditions in the winter and summer time. Winter is dark and gloomy and the amount of daylight is limited. For example in Helsinki (60.2°N, 24.9°E) during winter solstice the sun rises at 9.30 am and sets at 3 pm (see Figure 1). Polor night happens in the northernmost parts of Finland, Sweden and Norway. In these areas the sun doesn’t rise above the horizon for weeks. For example in Utsjoki (69.9°N, 27.0°E) the sun doesn’t rise at all from the end of November till the middle of January (see Figure 1). In contrast during summer months Nordic countries have long hours of daylight and in the northernmost parts of these countries the sun is shining up to 24 hours a day. The phenomenon is called the polar day.

Civil twilight, when the sun is between 0 and 6 degrees below the horizon, can last in summer months for several hours. The summer civil twilight casts a soft, warm glow over the sky and scenery painting them in a dreamy, pastel-colored light that is often seen as aesthetically pleasing. Nautical twilight, occurring when the sun is 6 to 12 degrees below the horizon during sunrise or sunset, takes place during summer as well, and it provides a dimly lit sky. Astronomical twilight is the darkest of the twilight phases and occurs when the sun is between 12 and 18 degrees below the horizon (see Figure 2). For example in Helsinki, there is no astronomical twilight from mid-May until the beginning of August.

The low angle of the sun, which creates long shadows and the golden light, appears especially during the autumn and winter. The nordic climate and the weather connected to it affects the lighting conditions. In Finland, about 19% of the annual daylight is direct sunlight, while the rest originates from an overcast sky (Ilmatieteenlaitos, 2023).

1.3 Definition of Home

The word “home” is usually considered as being a place where someone lives. At the same time when a home is a physical space it is also an emotional and a mental space. Home is a whole that consists of emotional, physical, social and symbolic elements (Protoomo, 2020). Easthope (2010) concluded in their study that homes are places that are nodal points within networks of social relations that hold significance for individuals or groups beyond physical locality. Rootedness and sense of place are two relationships people can have with places. The definition of a “home” can vary depending on cultural, personal, and social perspectives. What is a home for nordic people?

Protoomo (2020) made a study about the ideals of living in Finland. Topics that came up in the
research were emotional and mental bond, rooting, peace, silence, sauna, hypermodernism, functionality, minimalism and closeness to nature. Rooting and the importance of the home as a place of peace emerged from the research. It can often take a long time for a new apartment or living area to start feeling like a home. Many participants in the study described that they were only rooting in the place of their childhood. Making the new apartment feel like a home requires a person’s belongings, the presence of family or simply spending longer periods of time in the apartment. Having a peaceful home environment was connected to closeness of nature and privacy. Some people pointed out that nature has to be untouched. According to the Finnish Department of Health and Welfare (2022) in Finland, people of working age spend about 90% of their time indoors, small children and the elderly even more. The worldwide COVID-19 pandemic expanded the concept of home into a workplace as well. According to Pentikäinen’s (2021) study, multi-location work is here to stay after the pandemic, meaning that homes will function as workplaces in the future. As urbanization is a rising trend in the Nordic countries people seek elements mentioned above also from their second homes. Ståmo et al. (2020) presents that about half of the people in the Nordic countries can access a second house through ownership, family, or acquaintances. Second homes are often only used during summer time, as they might not have as effective insulation or proper electricity as primary homes.

1.4 Daylight at Home

How daylight affects people’s lives or how they think of daylight at home is still little researched. Hauge (2015) made a study in Denmark, where he investigated people’s experience of the world through daylight. They stated that daylight is a sense that people have, one that is bio-social-cultural like all other senses and more than just another sporadic experience of an occurrence. According to the study people felt that daylight was more practical light than artificial light. Daylight was felt to be a more pleasant light for activities, such as cooking and working. Corrodi et al., (2008) present that rooms shouldn’t be illuminated but rather focus on illuminating workplaces. The notion of bright and airy living spaces has become synonymous with modernity and the spirit of the times, more than any other concept. Corrodi & Spechenhause (2008) state, that light-flooded rooms are not as necessary as commonly believed and that our preference for light-flooded rooms may be due to habit, societal influences, and the equation of brightness with better that has been ingrained in us for decades. They highlight that eliminating all darkness and blurriness can stifle the imagination.

In their book Corrodi & Spechenhause (2008) bring up the importance of change in the lighting that revitalizes us. They suggest that instead of uniform brightness, it is important to prioritize variability of light. The movement of the sun through the day, creating shifting shadows and contrasts of light and dark, allows the passage of time to be experienced within a room and can evoke a range of emotions from morning to evening. Elements that are usually counted as negative aspects in daylighting may be comfortable in a home environment. Hauge et al. (2008) study found that many participants enjoyed sitting in a spot of sun and pointing their heads to the sun. This is contrary to the general daylight design idea of glare prevention and thermal comfort (IES, 2020).
This thesis consists of three parts. The first part is the existing building analysis. Three residential buildings that are designed by well-known Nordic Architects are looked into. The analysis focuses on qualities of daylight inside the buildings. Buildings are studied by their orientation, openings and materials. During the studies, factors comfort, functionality, and aesthetics have been considered, in terms of daylight and in relation to standards and human preferences. For this reason parameters used for this analysis are functionality, comfortability and aesthetics.

The second part is the qualitative analysis of the design proposal for the competition. Because of the lack of daylight during winter, the building is designed as a summer house that is mainly used from late spring to the start of autumn. Design solutions are developed by considering the lighting conditions from May 1st to September 1st, as well as analyzing the existing buildings for functionality, comfort, and aesthetics using the same parameters. Revit, a software tool, is utilized to study the effects of building orientation, openings, and materials under different daylight scenarios.

The third method is daylight calculations. Daylight calculations including illuminance from working plane height (800 mm) and daylight factor. The calculations are based solely on the hours of sunlight, while in Nordic countries, the twilight hours can also provide interior illumination. Programmes used for the calculation is Climate Studio. Calculations are performed to compare them with qualitative results of comfort, functionality, and aesthetics and if they meet the existing daylight standards.

Figure 3 is a visual representation of the different parts of this thesis including the previously explained analysis process.
3.1 The Building Analysis

To support the design work, three residential buildings designed by renowned architects from the Nordic countries have been selected for analysis. These buildings, including Alvar Aalto’s Villa Mairea in Noormarkku, Finland (1939), Sverre Fehn’s Villa Norrköping in Norrköping, Sweden (1964), and Jørn Utzon’s Kingo Houses in Helsingør, Denmark (1953), showcase innovative considerations of Nordic daylight conditions (see Figure 4). The analysis focuses on various aspects, such as the integration of daylight within the building’s mass, room placement, openings, and material choices. Functionality, comfort, and aesthetics serve as key parameters for this analysis.

3.1.1 Orientation

By analyzing the building mass, a shadow analysis was conducted to show the shadows cast by the buildings during sunrise, noon, and sunset in both winter and summer solstice (see Figure 5). The variation in sunrise and sunset times is due to the different geographical locations of the buildings.

Villa Mairea and Kingo House both have L-shaped masses, but Villa Mairea’s staggered mass creates diversity in indoor spaces. The sheltered courtyard of Villa Mairea faces northwest and is shaded by the building for most of the day except for summer evenings, whereas the courtyard of Kingo House faces southeast and is shaded in the evenings.

The mass of Villa Norrköping forms a cross pattern, which creates sheltered spaces in the interior and an aesthetically pleasing interplay of light and reflection at different times of the day. Various corners of the building have sunny and shady spots at different times of the day.

All buildings are designed to utilize natural light and establish a harmonious relationship between the interior spaces and the natural surroundings. The placement of rooms follows a similar principle in each of the buildings (see Figure 6). The main living areas are positioned to the south and west, while the bedrooms and private spaces face north and east. This orientation allows for morning and afternoon daylight in the bedrooms and in the evening the rooms are dark. This can help regulate the sleep-wake cycle.

See Table 1 for the summary of findings.

Table 1

Table 1 Functional, comfortable, and aesthetic elements of the orientation of Villa Mairea, Villa Norrköping, and Kingo House

<table>
<thead>
<tr>
<th>Feature</th>
<th>Villa Mairea</th>
<th>Villa Norrköping</th>
<th>Kingo House</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Living Areas</td>
<td>Ample Daylight All Day (All Three Buildings)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bedrooms</td>
<td>Located North/East, Cooler/Darker at Night</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cross-Shaped Mass</td>
<td>Creates Shaded Conditions for Visual Interest (Villa Norrköping)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 4

Location of Villa Mairea, Villa Norrköping & Kingo House
From [Map Europe], by Esri, 2023, World Imagery. (https://www.arcgis.com/home/item.html?id=1d6f22799f846e46b96a706866ec2a9f)
Figure 5
Shadow analysis of Villa Mairea, Villa Norrköping & Kingo House in summer and winter solstices. The selected times are sunrise, noon and sunset during summer solstice and winter solstice. Own work

Figure 6
Rooms’ orientation analysis of Villa Mairea, Villa Norrköping & Kingo House. Own work

1. Villa Mairea 1st floor
2. Villa Mairea 2nd floor
3. Villa Norrköping
4. Kingo Houses

- Main living areas
- Bedrooms & private areas
- Kitchen
- Service rooms
3.1.2 Openings

All three buildings follow a similar principle in window sizes, with large windows in the living areas and smaller ones in bedrooms and other private spaces. Views are arranged in such a manner that the sensation of outdoors is transferred indoors. However, each building also has distinctive solutions.

Alvar Aalto used different shapes of windows in Villa Mairea, some of which are organic in shape, which reflects his design philosophy of the natural world. The living room in Villa Mairea allows daylight to filter through the surrounding nature, creating variability and movement of light (see Figure 7). Bay windows have been used in the rooms on the second floor to maximize the amount of light from the east and south at different times of the day (see Figure 8).

Villa Mairea is also known for its recognizable elements, such as the openings of the library and the balustrade of the stairs (see Figure 9). The library has wooden grilles covering openings above the bookshelves to filter light and create a dynamic pattern of light and shadow on the walls and ceiling. Vertical wooden poles alongside the stairs mimic trees.

In Villa Norrköping, every window has a clear mission, and the four corner windows are a recognizable element. The northern bedrooms have no windows, so daylight comes through reflections from the corner windows facing north and east. The corner windows also work as shelves due to their unique structure (see Figure 10). The higher part of the building has upper windows to enable functional lighting in the kitchen, by reflecting uniform lighting from the ceiling (see Figure 11). Ferre used skylights to highlight tasks, such as placing one above a desk (see Figure 12).

In Kingo House, the louvers maximize privacy in front of windows facing the public, and the big openings mainly face the courtyard for privacy purposes (see Figure 13).

See Table 2 for the summary of findings.
Figure 10
Corner window with shelf structure
From Villa Norrköping [Photography], by Teigen Fotoatelier, 1964,
Dextra Photo. (http://digitaltmuseum.no/011012603445/villa-norrkoping). CC BY-SA 4.0

Figure 11
Upper ribbon windows in kitchen
From Villa Norrköping [Photography], by Teigen Fotoatelier, 1964,
Dextra Photo. (http://digitaltmuseum.no/011012603445/villa-norrkoping). CC BY-SA 4.0

Figure 12
Skylight highlighting tasks
From Villa Norrköping [Photography], by Teigen Fotoatelier, 1964,
Dextra Photo. (http://digitaltmuseum.no/011012603445/villa-norrkoping). CC BY-SA 4.0

Figure 13
Louvres in front of windows facing the public areas.
From The Kingo Houses [Photography], by Andersen F.B., n.d.,
3.1.3 Materials

The interiors of the buildings are characterized by the use of natural materials and colors that create a warm and inviting atmosphere. The different textures of the materials bring personality to the interiors, for example the use of brick creates a play of light and shadow, removing the too uniform feeling of the spaces.

The main material in both Villa Mairea and Villa Norrköping is wood, which adds a sense of warmth and connection with nature. In Villa Mairea, Aalto has worked with the reflectiveness of the materials to create an inviting atmosphere in the living areas. The glossy tile floor next to the staircase creates almost glary reflections and the wooden floor in the living room creates soft reflections that invite people to enter the space. The light color of surfaces work as a reflector that creates general lighting indoors, filling the place with daylight.

The warm-toned terrazzo tile floor in Kingo House acts as a soft reflector for daylight and brings softness to the interior, while the white plaster walls and ceilings create a bright and airy atmosphere.

Table 2

<table>
<thead>
<tr>
<th>Functional, comfortable and aesthetic elements of the openings of Villa Mairea, Villa Norrköping and Kingo House</th>
<th>Own work</th>
</tr>
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<tbody>
<tr>
<td>WINDOW SIZE VARIES BY ROOM PURPOSE (ALL THREE BUILDINGS)</td>
<td></td>
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<tr>
<td>USE OF BAY WINDOWS FOR MAXIMUM LIGHT (VILLA MAIREA)</td>
<td></td>
</tr>
<tr>
<td>UPPER BEEHN WINDOWS PROVIDE UNIFORM KITCHEN LIGHTING (VILLA NORRKÖPING)</td>
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</tr>
<tr>
<td>SKYLIGHTS MAXIMIZE HIGH QUALITY DAYLIGHT (VILLA NORRKÖPING)</td>
<td></td>
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<tr>
<td>LOUVERS OFFER PRIVACY FOR PUBLIC-FACING WINDOWS (KINGO HOUSE)</td>
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<tr>
<td>LIVING AREA WINDOWS WITH VIEWS OF THE GARDEN OR NATURE (ALL THREE BUILDINGS)</td>
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<tr>
<td>LIVING ROOM WITH DAYLIGHT FILTERING THROUGH SURROUNDING NATURE (VILLA MAIREA)</td>
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<tr>
<td>ORGANIC-SHAPED WINDOWS THAT REFLECT THE NATURAL WORLD DESIGN PHILOSOPHY (VILLA MAIREA)</td>
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<td>WOODEN GRILLES AND POLES TO FILTER LIGHT, CREATING A DYNAMIC PATTERN OF LIGHT AND SHADOW (VILLA MAIREA)</td>
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<td>NATURAL MATERIALS AND WARM COLORS CREATE A WELCOMING ATMOSPHERE (ALL THREE BUILDINGS)</td>
<td></td>
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<tr>
<td>MATT SURFACES PROVIDE SOFT REFLECTIONS (VILLA MAIREA &amp; KINGO HOUSE)</td>
<td></td>
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<tr>
<td>DIFFERENT TEXTURES BRING PERSONALITY TO INTERIORS IN ALL THREE BUILDINGS</td>
<td></td>
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<tr>
<td>BRICK CREATES CONTRAST AND REMOVES UNIFORMITY IN ALL THREE BUILDINGS</td>
<td></td>
</tr>
<tr>
<td>REFLECTION OF LIGHT USED FOR CREATING MOODS (ALL THREE BUILDINGS)</td>
<td></td>
</tr>
<tr>
<td>WHITE SURFACES KEEP SPACES BRIGHT ON CLOUDY DAYS OR WHEN SKYLIGHTS ARE THE ONLY LIGHT SOURCE (VILLA NORRKÖPING &amp; KINGO HOUSE)</td>
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Figure 14

Kingo House living room.

3.2 The Design Proposal

The concept of this design is to seamlessly integrate the building into its natural surroundings and optimize the use of daylight for space illumination, without using any artificial light. The design focuses on achieving suitable lighting conditions for all the different spaces within the building, based on their respective functions. See Figure 16 of the concept illustration. This approach results in a unique design solution for each space through the strategic placement and selection of the building’s mass, rooms, openings and materials.

The external cladding system is utilized to bring together the various elements of the building and promote a sense of unity, while also facilitating a harmonious integration of the structure with its natural surroundings. The design features a 107 m² building, which includes a living room, a kitchen, a dining area, a bedroom, a home office, a toilet, a bathroom and a sauna (see Appendix A-D).

The design solutions are based on the analysis of the existing buildings and the same parameters of functionality, comfortability and aesthetics are used as in the existing building analysis. The building is designed for an imaginary couple and the selected location for the design work is a seaside plot (3.16 ha) in the island called Pakinainen (60.4°N, 21.7°E) of the west coast of Finland in Naantali (see Figure 17). The island has significant height variations and is known for its rocky terrain, pine trees, coastal vegetation, and sandy beaches. The property is bounded by the coast, and in the plot’s center the ground rises abruptly to a height of up to 25 meters (see Figure 18). At the same time as the plot’s elevation changes enable for vast views of the surrounding archipelago landscape, and they significantly affect the plot’s daylight conditions.

3.2.1 Orientation

The building’s location is carefully chosen to maximize the access to daylight, allowing for optimal utilization of the beneficial low-angle morning and evening sun, as well as the advantageous midday sun that facilitates daily tasks. This is especially important during periods of limited daylight caused by cloudy skies throughout most of the year. Since the building serves as a secondary residence, primarily used from late spring to early autumn, the design takes into consideration the lighting conditions during these seasons.

The initial stage involves assessing the daylight conditions of the plot. The variations in terrain height create considerable shadows in the lower areas when the sun is at a low angle, which causes a significant decrease in the amount of light. After a shadow analysis, it was determined that a small portion on the northeast border of the plot receives sunlight until eight o’clock in the evening during the summer solstice. See Appendix E-G for the plot’s daylight conditions at different times. Taking inspiration from the Villa Mairea and the Kingo House, the building’s mass is L-shaped.
This configuration allows for the creation of a sheltered courtyard and rooms orientated towards different directions. However, unlike its predecessors, this building’s courtyard faces southwest to maximize sunlight exposure and provide wind protection. By widening the L-shaped structure from 90° to 135°, improved views and reduced shadows between the wings were achieved (see Figure 19). Additionally, the wider angle allows for morning sun exposure on the upper wing without casting shadows on the courtyard’s south side in the evening. The roof pitch is directed towards the south and west, and the inclusion of roof windows ensures greater amount of daylight penetration, resulting in brighter indoor conditions throughout the entire day.

The room arrangement follows the principles observed in the analyzed buildings (see Figure 20). The goal was to divide the space into functionally related wings, ensuring appropriate lighting for each wing’s purpose. One wing includes the primary living areas, while the other wing contains the private spaces. The main living areas are oriented towards all cardinal directions, allowing ample daylight and offering views of the captivating twilight sky. The importance of proximity to nature was emphasized in Protoomo’s (2020) research, necessitating a direct connection between these areas and the outside to effectively incorporate nature and the seaside atmosphere into the living spaces. Corrodi’s & Spechenthaus’ (2008) book emphasized the significance of prioritizing light variability. Inspired by Villa Mairea, the living rooms are designed to create a similar ambiance with changing shadows cast by sunlight interacting with the surrounding environment throughout the day. The entire northwest wing was dedicated to living spaces to ensure panoramic views of the sea, forest, and various compass points.

The private areas, including the bedroom and home office, are located in the other wing, facing east to receive morning light that supports the circadian rhythm.

See Table 4 for the summary of findings.
3.2.2 Openings

The design of the living areas featured windows from floor-to-ceiling, strategically positioned to face the northeast and southwest, offering views of nature and the sea. The design caters to people’s desire for sunlight exposure, allowing direct sunlight to flood in during morning, noon, and evening, which is in line with findings of Hauge et al. (2008) (see Figure 21).

The living room features a skylight at its northwestern end, most of the time, diffusing light onto the brick wall. This wall is designed with small openings that produce an ever-changing interplay of light and shadow as the daylight shifts. In addition, the small openings serve to provide general lighting for the space (see Figure 22).

Hauge et al.’s (2008) observation that daylight is perceived as a pleasant working light, the kitchen lighting in this design was focused on maximizing the benefits of natural light for optimal work conditions. Inspiration was taken from Villa Norrköping’s use of ribbon windows, which reflect light from the ceiling and frame/shelve structure of the windows. In this design, windows extend from the height of the kitchen counter to the ceiling, with a middle frame that doubles as a storage shelf. Since the functionality of working spaces are highly dependent on illumination (Corrodi & Spechenhause’s, 2008), the windows are placed above the kitchen counters to provide sufficient light for cooking activities (see Figure 24).

On the other hand Corrodi et al. (2008) state that...
the absence of darkness and contrast can hinder imagination. To address this, deliberate measures were taken to introduce darkness and contrast in the corridor of the southeast wing and the bedroom. The corridor incorporates a low ribbon window at floor level, offering subtle and delicate floor lighting. Adjacent to the windows, a sheltered promenade features timber elements positioned at various intervals, creating slender shadows reminiscent of the lighting found in a coniferous woodland, similar to the staircase and library of Villa Mairea (see Figure 25). The darker hallway provides a contrast to the brighter entrance and living areas. The brighter spaces attract passers-by, guiding them toward those areas, while the darker hallway ensures sufficient lighting for navigation.

The objective of the home office is to ensure ample and even lighting, facilitating the provision of diverse working areas for various functions. The office window is constructed with a shelf-like structure and the window extends from the working plane to the ceiling, much like the kitchen window. A circular skylight situated at the center of the office augments natural daylight as the windows face east only. Adjacent to the table area is a bay window, offering the occupant an opportunity to bask in natural light and feel almost like being surrounded by nature (see Figure 26).

The bedroom features a similar bay window to the office. The north east side of the window is covered with slatted timber cladding on the exterior, providing privacy similar to Utzon’s Kingo house (see Figure 27) and it also allows filtered sunlight to enter the room from the early morning hours, creating a forest-like effect similar to that found in the library and staircase of Villa Mairea. The bed room features a skylight that is frosted and tinted with amber shade (see Figure 27). As a result, the overall ambiance in the room remains subdued, yet there is enough indirect light to navigate the space.
The bathroom and toilet feature a rectangular skylight window, which is positioned to provide lighting for specific tasks within the space. For instance, the bathroom window is placed directly above the shower, creating an experience that closely emulates an outdoor shower by allowing the user to bathe under natural sunlight and the clear sky (see Figure 28). The glass of the skylights are coated with patterned glass, producing a shimmer and moving light.

Sauna is a calming area where the light is supposed to be minimal for the creation of a private and calm space. The sauna’s high ribbon window offers a sea view, while a canopy structure outside regulates natural light. The result is balance of light and darkness creating a calming atmosphere (see Figure 29).

Table 3

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<thead>
<tr>
<th>Functional, comfortabe</th>
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| Table 5 Functional, | about | about |}
| aesthetic elements of | the | the |}
| the openings of the | design | design |}
| work | own work | own work |}

Figure 29

Section I.1 2000
12 pm, summer solstice, the sauna receives solely scattered light.

Own work

Figure 30

The bathroom and toilet feature a rectangular skylight window, which is positioned to provide lighting for specific tasks within the space. For instance, the bathroom window is placed directly above the shower, creating an experience that closely emulates an outdoor shower by allowing the user to bathe under natural sunlight and the clear sky (see Figure 28). The glass of the skylights are coated with patterned glass, producing a shimmer and moving light.

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Figure 29

Section I.1 2000
12 pm, summer solstice, the sauna receives solely scattered light.

Own work

Figure 30

The bathroom and toilet feature a rectangular skylight window, which is positioned to provide lighting for specific tasks within the space. For instance, the bathroom window is placed directly above the shower, creating an experience that closely emulates an outdoor shower by allowing the user to bathe under natural sunlight and the clear sky (see Figure 28). The glass of the skylights are coated with patterned glass, producing a shimmer and moving light.

Sauna is a calming area where the light is supposed to be minimal for the creation of a private and calm space. The sauna’s high ribbon window offers a sea view, while a canopy structure outside regulates natural light. The result is balance of light and darkness creating a calming atmosphere (see Figure 29).

Table 3

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Figure 30

The building’s interior is composed of brick walls, wooden floors, and a white-painted ceiling with a matte finish (see Appendix K-N). The primary building material is brick, which can absorb the sun’s heat during the day and release it inside the building at night, reducing heating and cooling costs. According to the concept to ensure that the building blends into the forest setting and provides various sun shading options, the exterior is covered with slatted timber cladding (see Figure 30 and Appendix B).

The design takes inspiration from Villa NorgäRWang’s light-colored floors, the white walls and ceilings of the Kingo House, which act as effective reflectors. A matte paint was used on the ceiling to achieve a similar effect to this. This serves as a reflector, diffusing a pleasant and evenly distributed ambient light throughout the rooms without causing glare.

The interior of the building features brick walls throughout, similar to the analyzed buildings. The texture of the brick creates an interplay of light and shadow, which helps to break up the uniform light reflecting from the white ceiling.

To prevent glare and harsh reflections caused by direct sunlight hitting the floor at low angles, careful attention was given to choosing a floor material. Wood was selected for its ability to minimize these issues. As daylight streams into the indoor spaces, the floor reflects the light, creating a captivating bubble of light, reminiscent of the living room in Villa Mairea. This inviting effect invites users to enter the space.

In the dining area, the home office, and the bedroom, the design takes inspiration from Villa NorgäRWang’s light-colored floors, the white walls and ceilings of the Kingo House, which act as effective reflectors. A matte paint was used on the ceiling to achieve a similar effect to this. This serves as a reflector, diffusing a pleasant and evenly distributed ambient light throughout the rooms without causing glare.

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room, skylights are covered with paints of different colors, which reflect daylight inside the building with varying hues. The skylight in the dining area is covered with warm-toned paint, reflecting a warm and inviting daylight above the dining table (see Appendix K), creating a atmospheric and luminaire like lighting for dining and other tasks on the table. The office skylight is covered with white paint, creating a neutral working light in the room (see Appendix L). The skylight in the bedroom is covered with shiny warm-toned paint, creating a soothing and calming atmosphere (see Appendix M).

To enhance the dark and calming atmosphere of the sauna, while still allowing a view of the sea from the window, the wooden interior structures of the sauna are tinted with a matte black shade. This color absorbs daylight, preventing any distracting reflections and maintaining a tranquil ambiance.

See Table 6 for the summary of findings.

<table>
<thead>
<tr>
<th>Functional, comfort- and aesthetic element of the materials of the design work</th>
<th>Own work</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Brick walls provide resistance to harsh weather conditions.</td>
<td>- Brick walls create an interplay of light and shadows.</td>
</tr>
<tr>
<td>- Brick’s thermal insulation reduces heating and cooling costs.</td>
<td>- Slatted timber cladding on the exterior resembles high-rise Vene wooden fra-</td>
</tr>
<tr>
<td>- Different colors of paint inside skylights create suitable lighting for different spaces.</td>
<td>- Selected materials prevent glare issues.</td>
</tr>
<tr>
<td>- White paint on the ceiling works as a reflector to create ambient lighting.</td>
<td>- Matte black tint on the wooden interior of structures keeps the sauna ambiance dark.</td>
</tr>
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</table>

3.3 Daylight Measurements

The final version of the design was then used to take daylight measurements to determine the illuminance and daylight factor (DF). During the summer solstice, illuminance was measured at three different times: 9 am, 12 pm, and 8 pm. The highest levels of illuminance were found in the bay windows, office area, and living room. In contrast, the lowest lux levels were recorded in the sauna, bedroom, and hallway (see Appendix H).

The whole building has an average DF of 12%. The office, kitchen, dining areas, living room, bathroom, and toilet reach the DF of 5%. Meanwhile, the DF in the two bedrooms, hallway, and sauna is less than 2% (See Appendix H). Rooms that have an average DF of 2% or higher can be classified as daylit, while rooms with a DF of 5% or higher are unlikely to require electric lighting during daylight hours.

See Appendix I for the daylight calculation results of four selected dates.
During a four-month observation period in the... and changing seasons also play a crucial role in how daylight impacts the space. Other factors, such as the color and texture of materials, window placement, surrounding nature and changing seasons also play a crucial role in how daylight impacts the space. During a four-month observation period in the office space as an example, the lux levels peaked at 1200 lx at 8 pm in early July but declined to 0 lx by September 1st. The question arises as to whether additional standards should be established to further integrate daylight into home design or if daylight planning is too subjective to be quantified and regulated.

The Finnish Government launched an electricity-saving campaign in the fall of 2022, in response to the rising energy prices and the impact of Russia's actions in Ukraine on energy availability in Europe (Astetos Alemanas, 2023). In addition to addressing the energy crisis, prioritizing climate change mitigation and its consequences, conserving energy plays a crucial role in achieving the UN Sustainable Development Goal 7. Calculations from the design have revealed that building orientation and the size and shape of openings can result in significantly different illuminated environments. Even if a room faces north and receives no direct sunlight through the window, rooms with skylights can still achieve high illuminance values and increase the daylight factor. The thesis found that the three architects employed similar design principles to create functional, comfortable, and aesthetic buildings. The analysis led to the incorporation of various elements into the design work, including the building's orien- tation, openings, and materials. Finally, daylight calculations were carried out on the completed plans to confirm how the different design solutions affect the illuminance levels and daylight factor.

In Finland, the residential daylight design requirement mandates a minimum window size of 10% of the floor area and at least eight meters of unbuilt space in front of the primary window. In addition to addressing the energy crisis, prioritizing climate change mitigation and its consequences, conserving energy plays a crucial role in achieving the UN Sustainable Development Goal 7. Calculations from the design have revealed that building orientation and the size and shape of openings can result in significantly different illuminated environments. Even if a room faces north and receives no direct sunlight through the window, rooms with skylights can still achieve high illuminance values and increase the daylight fac- tor. With an average daylight factor of 12%, the building's illumination levels exceed the threshold for strong daylighting, effectively reducing the re- quirement on electric lighting during the daytime. This high daylight factor of the building aligns directly with the energy-saving objectives of its design.

The design solutions have considered the UN Sustainable Development Goal 3 “Good health and wellbeing” in several aspects. The circadian rhythm has been taken into account when design- ing the bedrooms, as it is clear that the impact of morning light exposure has been shown to positively impact alertness and mood (Choi et al., 2019 & Figueroa et al., 2017), while red light wave- lengths stimulate melatonin production (Lee & Kim, 2017 & Zhao et al., 2012). In the finished design, the occupant can wake up to the morning sun through slatted wooden cladding and fall as- sleep to the soft glow of orange toned light from the skylight.

Daylight's dynamic variation in intensity, color, and direction has been proven to have a positive effect on mood (Christoffersen, J., 2011). By positioning the living areas in a separate wing with the bedroom, as it is clear that the impact of morning light exposure has been shown to positively impact alertness and mood (Choi et al., 2019 & Figueiroa et al., 2017), while red light wave- lengths stimulate melatonin production (Lee & Kim, 2017 & Zhao et al., 2012). In the finished design, the occupant can wake up to the morning sun through slatted wooden cladding and fall asleep to the soft glow of orange toned light from the skylight. Daylight's dynamic variation in intensity, color, and direction has been proven to have a positive effect on mood (Christoffersen, J., 2011). By positioning the living areas in a separate wing with the bedroom, high daylight factor of the building aligns directly with the energy-saving objectives of its design.

Additionally, incorporating adjustable blinds can address these issues based on occupants' preferences. Addi- tionally, the surrounding forest in the design location surrounding forest in the design location...
filters the light, resulting in lower lux levels than initially calculated. Based on a four-month comparison of lighting conditions, it was observed that the building becomes dark around 8 PM in early September. While the daylight calculations do not account for civil twilight or moon and starlight, all three aspects - comfort, functionality, and aesthetics - suffer once the sun has set. Designing a functional year-round building in northern latitudes without relying on artificial lighting presents a real challenge. It is likely necessary to incorporate artificial lighting in a year-round building, but ecological and sustainable concepts can be followed by opting for green electricity, such as solar energy. Future studies should consider gathering qualitative opinions on design solutions to assess their comfort, functionality, and aesthetics. It would be valuable to explore potential differences in opinions among individuals from various countries, backgrounds, and cultures, as Nordic daylight conditions are distinct, even compared to other European countries and those closer to the equator. Through the analysis of three existing buildings and the development of design solutions that incorporate considerations about the site selection, room arrangement, massing, openings, and materials, it is feasible to create optimal lighting conditions during the summer months that can effectively replace artificial lighting in residential spaces. It became evident that customized solutions tailored to space utilization support parameters of functionality, comfort, and aesthetics. These solutions not only enhance energy efficiency but also foster health, well-being, and user satisfaction in home environments. Andersen F. B. (n.d.). The Kingo Houses [Photography]. Utzon Photos. http://www.utzonphotos.com/guide-to-utzon/projects/kingohusene-helsingor/

Muro R. & Kyriakidou F. (n.d.). Important times [Illustration].


Sleep Health, 3(3), 204-215.


IES. (2020). Recommended practice: Lighting for interior and exterior residential environments. [PDF]


Muro R. & Kyriakidou F. (n.d.). Important times [Illustration].


1. ENTRANCE/HALLWAY
2. HOME OFFICE
3. BEDROOM
4. TOILET
5. KITCHEN
6. DINING AREA
7. LIVING ROOM
8. BATHROOM
9. SAUNA
Table shows the plots daylight conditions during different times on the selected time frame 1st of May until 1st of September. The 9 am and 12 pm light conditions stay fairly similar during selected dates. Only in 1st of September the shadows are longer. The situation at 8 pm differs more due to the height differences of the plot, which where behind the sun sets. In 1st of May, 1st of August and 1st of September, Building and it’s surroundings are completely in shadow. This causes that no direct sunlight access inside the buildings in the evenings. The only light source during this time is the skylight.

As winter approaches, the noon sun shines at a lower angle. The presence of a short canopy enables direct sunlight to reach the edge of the living room, providing an opportunity for users to sit in direct sunlight. This direct sunlight reflects from the floor, illuminating other areas of the interior.
The skylight captures both morning and evening light, enhancing the lighting conditions inside the space. The evening light, which filters through the forest, creates a unique atmosphere. However, due to variations in plot elevation, only direct sunlight reaches the building on the 1st of July and 1st of June.
The illuminance levels during different times from May 1st to September 1st are depicted in the table. The living area and home office are the brightest areas, even reaching illuminance values of up to 500 lx at 8 pm.

At 12 pm, the toilet and bathroom reach illuminance levels of up to 2000 lx, but remain relatively xdim at 8 pm. The sauna maintains a dim atmosphere throughout the day.

In the bedroom, lux values stay below 500 lux in the bed area. However, the bay window in the bedroom is bright, reaching up to 3000 lux at 9 am and 12 pm.

By September 1st at 8 pm, the illuminance values drop close to 0 in almost every area of the building.
APPENDIX K: VISUALIZATION, VIEW OF THE DINING AREA AND LIVING ROOM

APPENDIX L: VISUALIZATION, VIEW OF HOME OFFICE