The role of snow on quality of daylight in Finnish urban apartments

Maryam Heibati
Master's Thesis

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2023

Tampere University
Faculty of Built Environment
Department of Architecture

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Abstract

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Urban apartment buildings are popular urban housing options in many cities (Pelsmakers, Saarimaa & Vaattovaara, M K 2021). Probably because they are an efficient response to the market's high demands, also because they are the only affordable option for most citizens. However, the great majority of these apartments are small "tunnel-like" units, lacking proper daylight for the different needs of the residents (Pelsmakers, Saarimaa & Vaattovaara, M K 2021).

The effect of natural light on the spatial quality of the apartments, as well as the health and well-being of the residents have been widely studied. However, in a country like Finland, with long winters, there is a lack of research on the factors enhancing daylight quality, especially the effect of snow-covered surfaces on the quality of daylight in urban apartments. Therefore, this thesis is focused on understanding the role of snow-covered surfaces on the quality of daylight in Finnish urban apartments.

To gain a better insight into the role of snow on quality of daylight a mixed method of field measurements and daylight simulations are used, analysing three case studies. A mixed-method analysis was chosen, first to achieve a thorough vision of the role of snow-covered surfaces on DF, and second to gain a better understanding of different methods and their sensitivity towards snow-covered surfaces. The daylight measurement for three case studies was conducted in different outdoor conditions. For instance, when the outdoor surrounding environment was covered with snow; when together with the ground, the surrounding trees and vegetation were covered by snow, and when there were old grey snow-covered surfaces, throughout the cloudy or semi-cloudy sky. However, a limitation of field measurements is that due to lack of time, there is no field measurement when there is no snow on the ground. In addition, to gain a better insight into the role of various snow-covered surfaces on the quality of daylight, daylight simulations in four different scenarios were run.

Based on the results snow-covered surfaces can increase the quality of daylight in urban apartments, however, the significance of its influence is affected by other factors such as the distance between snow-covered surfaces and the openings. The simulation models also demonstrate a similar outcome, yet their reaction towards the presence of snow and the change in the number of snow-covered areas were less significant in comparison to data collected on-site.

This study suggests that during the dark month of the year, by careful design to collect more snow on different surfaces, bringing them closer to the openings and increasing the time they cover the surfaces, the snow can help to achieve better-daylit apartments in Finland. However, now that we are designing for a warmer future, with probably fewer snowy days, it is our duty as an architect to not just identify the influential factors, but also to develop design strategies that could enhance the quality of our living environment at all times of the year.

Tiivistelmä

Valkoinen peitto
Lumen rooli päivänvalon laadussa suomalaisissa kaupunkiasunnoissa

Diplomityö
Maryam Heibati
2023

Tampereen yliopisto
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Kuvat: Maryam Heibati ellei toisin mainittu

183 sivua

Kaupunkikerrostalot ovat suosittuja kaupunkiasumisen vaihtoehtoja monissa kaupungeissa (Pelsmakers, Saarimaa & Vaattovaara, M K 2021). Luultavasti siksi, että ne ovat tehokas vastaus markkinoiden korkeisiin vaatimuksiin, myös siksi, että ne ovat ainoa edullinen vaihtoehto useimmille kansalaisille. Suurin osa näistä asunnoista on kuitenkin pieniä "tunnelimaisia" asuntoja, joista puuttuu kunnollinen päivänvalo asukkaiden erilaisiin tarpeisiin (Pelsmakers, Saarimaa & Vaattovaara, M K 2021).

Luonnonvalon vaikutusta asuntojen tilalaatuun sekä asukkaiden terveyteen ja hyvinvointiin on tutkittu laajasti. Suomen kaltaisessa maassa, jossa talvet ovat pitkiä, ei kuitenkaan ole tutkittu päivänvalon laatua parantavia tekijöitä, erityisesti lumen peittämien pintojen vaikutusta kaupunkiasuntojen päivänvalon laatuun. Siksi tämä opinnäytetyö keskittyy ymmärtämään lumisten pintojen roolia päivänvalon laadussa suomalaisissa kaupunkiasunnoissa.

Jotta saadaan parempi käsitys lumen roolista päivänvalon laadussa, käytetään kenttämittausten ja päivänvalosimulaatioiden yhdistelmämenetelmää, jossa analysoidaan kolme tapaustutkimusta. Sekamenetelmäanalyysi valittiin ensinnäkin perusteellisen näkemyksen saamiseksi lumen peittämien pintojen roolista DF:ssä ja toiseksi saadakseen parempi käsitys eri menetelmistä ja niiden herkkyydestä lumen peittämiä pintoja kohtaan. Kolmen tapaustutkimuksen päivänvalon mittaus suoritettiin erilaisissa ulko-olosuhteissa. Esimerkiksi kun ulkona ympäröivä ympäristö oli lumen peitossa; kun ympäröivät puut ja kasvillisuus olivat yhdessä maan kanssa lumen peitossa ja kun oli vanhoja harmaita lumen peittämiä pintoja koko pilvisellä tai puolipilvisellä taivaalla. Kenttämittausten rajoituksena on kuitenkin se, että ajanpuutteen vuoksi kenttämittausta ei tehdä, kun lunta ei ole maassa. Lisäksi, jotta saataisiin parempi käsitys eri lumen peittämien pintojen roolista päivänvalon laadussa, ajettiin päivänvalosimulaatioita neljässä eri skenaariossa.

Tulosten perusteella lumiset pinnat voivat lisätä päivänvalon laatua kaupunkiasunnoissa, mutta sen vaikutuksen merkitykseen vaikuttavat muut tekijät, kuten lumisten pintojen ja aukkojen välinen etäisyys. Simulaatiomallit osoittavat myös samanlaisen lopputuloksen, mutta niiden reaktio lumen esiintymiseen ja lumen peittämien alueiden määrän muutokseen oli vähemmän merkittävä verrattuna paikan päällä kerättyyn tietoon.

Tämä tutkimus viittaa siihen, että vuoden pimeänä kuukautena, huolellisella suunnittelulla keräämään lisää lunta eri pinnoille, tuomalla ne lähemmäksi aukkoja ja lisäämällä pintojen peittämisaikaa, lumi voi auttaa saavuttamaan paremmin päivänvalaistuja asuntoja Suomessa. Mutta nyt, kun suunnittelemme lämpimämpää tulevaisuutta, luultavasti vähemmän lumisia päiviä, meidän velvollisuutemme arkkitehtina on paitsi tunnistaa vaikuttavia tekijöitä, myös kehittää suunnittelustrategioita, jotka voisivat parantaa elinympäristömme laatua ylipäänsä vuodenajat.

Introduction,

Anybody living in Finland, or generally countries further away from the equator, has experienced a similar feeling of a suddenly brightened -up environment after a fresh snow. This thesis investigates the effect of snow on the daylight quality of Finnish Urban Apartments.

This is a research-based master's thesis that studies the factors influencing the daylight quality of Finnish urban apartments. The objective of the thesis is to investigate the impact of snow-covered surfaces on the daylight quality of residential units in Finland which includes an introduction to the importance of daylight on health and well-being, the factors influencing the quality of daylight in residential units, and daylighting rules of thumb. In order to investigate the impact of snow on daylight quality, 3 case studies were chosen to measure DF in different weather conditions and to undertake daylight modeling. The last step suggests some recommendations on possible solutions that architects could apply to enhance the quality of daylight in the Finnish context, considering its climatic and geographic characteristics.

The positive influence of natural light on the health and well-being of humans has been discussed thoroughly for a long time. As long as the 19th century, when Florence Nightingale (1820– 1910) mentioned that there are "five essential points in securing the health of houses: 1 Pure air. 2 Pure water. 3 Efficient drainage. 4 Cleanliness. 5 Light. Without these, no house can be healthy" (Nightingale, 1974).

Therefore, any home should be designed to have well-lit interior spaces; because the elimination of access to natural light not only can increase Seasonally affective disorder (SAD) or sick building syndrome, but it can change the circadian cycle of residents as well (Baker & Steemers, 2019). Also, the connecting value of daylight by creating a link between interior spaces and outdoor environments, via its temporal changes, can be a powerful tool for creating delightful and adaptable spaces (Baker & Steemers, 2019). Consequently, applying design solutions that enhance daylight quality in residential units is an important issue for architects to consider.

The impact of snow on health and well-being has also been investigated in terms of well-being: e.g., the level of negative mood indicators decreases after exposure to the snow-covered forest (Bielinis E, et al., 2019). Snow-covered surfaces as well as access to good daylight can influence the psychological health and well-being of people, hence the following questions arise:

1.) What is the impact of snow on the quality of daylight?

2.) How can snow-covered surfaces influence the quality of daylight in urban apartments?

Nevertheless, it should be considered how climate change can lead to the loss of snow, resulting in greater physical and mental health risks (Burenby, et al., 2021). In Finland, the rise of air temperature and changes in solar radiation will affect the environment, leading to warmer and darker winters, and less frequent snow-cover periods (Burenby, et al., 2021). This is another reminder of our role as an architect in tackling the climate crisis.

Research method

The main material of the thesis can be categorized into three sections, the first section is a literature review on daylight; why is it important? How can it affect our life? What are the roles of architects and their tools to design well-lit apartments? The second part of the thesis is developed based on a mixed-method analysis. Investigating the application of daylighting rules of thumb in each apartment, data collected through field measurements under different snow conditions, and daylight simulations run under different outdoor statuses. The final section is focused on suggesting some new design strategies to enhance the quality of daylight in urban apartments.

Sample selection

The main material of the daylight measurements consists of 3 selected urban apartment buildings, built between 2000-2021, in the Uusimaa region of southern Finland. The 3 samples were mainly chosen based on their accessibility to collect data. However, each of them adds a factor to research, in terms of their distance from outdoor ground level, the location of their windows, if they have openings on a single façade or multiple facades, the orientation of the buildings, their surrounding environment, if there are trees and other types of vegetation near the apartment blocks, all influencing factors for daylight availability inside and outside the apartments. This sampling strategy was intended to capture the potential impact of various snow-covered surfaces (ground, facades, roofs, vegetation including tree branches) on daylight factor.

Methods

The first step of the study was getting approval from the owners of the apartment to conduct daylight measurements and map the indoor and outdoor conditions by taking photographs (using a Consent form, Information sheet, and Privacy notice). After this stage, all 3 case studies were measured to draw a floor plan and base model of the spaces. The rooms were divided into 1-meter grids (some cases smaller than 1 m due to the obstacle created by the furniture) in which their intersections represent the points where daylight measurement would be taken. As all samples were occupied by residents, and there was no possibility to remove the furniture; only mirror surfaces were covered to reach better accuracy in measurement.

During each measurement session, daylight was measured with a Lux meter. The process demands two people taking simultaneous measurements, one standing outside, measuring outdoor daylight illuminance (standing in a fixed location which is not overshadowed by buildings or trees, holding the lux meter in a stable location and height). The other person standing inside moves between the points to measure indoor daylight illuminance. In order to ensure accuracy in data collection, each measurement was conducted at the same point and height.

The collected data was carefully mapped, and for each measurement, the daylight factor was calculated on each point, creating the initial data for DF maps. During each measurement, the outdoor condition, the depth of snow-covered surfaces, the sky condition, and the general outdoor and indoor conditions were also mapped and photographed. To analyse the influence of snow on daylight, the measurements were conducted on days with fresh snow-covered surfaces on the ground, on surrounding trees and roof surfaces, during the time that the sky was cloudy or semi-cloudy, and on a mild snowy or rainy day. Data were also collected when there was old snow on the ground (grey and melted on main pathways). Another desirable scenario was to collect data when there was not any snow covering the ground and surrounding vegetation, however, due to the continuing snow season and the low temperature, this was not achieved in the time scale of writing the thesis.

Moreover, the same three apartments were also modeled with the DIALux evo 11.0. To gain a better insight, several daylighting scenarios were defined; the difference between each scenario was based on the presence or absence of snow on the ground and surrounding vegetation. A total of four scenarios were developed, the first scenario was when there was not any snow covering the outdoor surfaces, the second scenario was when there was old grey snow with an albedo of 0.4 covering some part of the yards. The third scenario was developed based on the presence of fresh snow with an albedo of 0.85 just on the ground and small parts of the roofs. In the fourth scenario, all the ground surfaces, rooftops, and trees were covered with snow (albedo: 0.85).

Several simulations were run during February and March, on different days and hours. As the dates were chosen based on the dates that daylight measurements were collected, the simulations created the opportunity to compare results and findings between measured case studies and models. The reflectivity of outdoor surfaces was changed to adjust the snow albedo, as well as the albedo of similar materials covering the ground and the surrounding buildings. However, the outdoor daylight level, the spatial distribution of daylight, and the reflection levels remained at the software default level.

Additionally, to make a comparison between average daylight availability in different units, and to analyse the impact of snow on daylight quality of each case study, simulations were run on the same day and time in different scenarios.

Part One

Daylight

This chapter would focus on the importance of daylight

in housing design

1.1 Introduction:

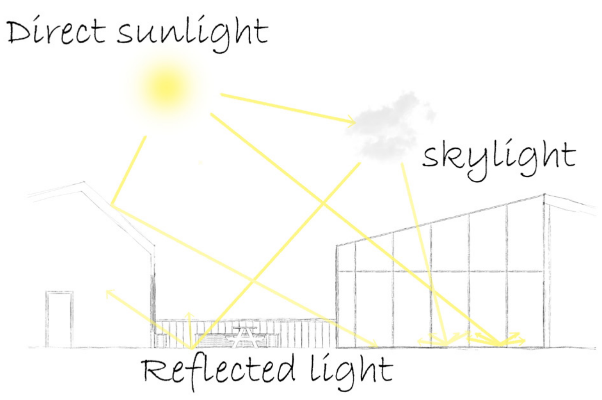
Living under the shadow of climate crisis obliges us to consider the climate emergency design approaches in order to develop a sustainable design. "The fact that we are operating in a changing climate can no longer be ignored" (Pelsmakers, 2015). The architecture of our time should be focused on applying different design principles for climate change challenges. Based on "Designing for the Climate Emergency: A Guide for Architecture Students" there are 10 themes to develop holistic sustainable architecture and Passive resilience design is one of those ten themes, which is based on using freely available sources, harnessing good daylight, optimising building fabric efficiency, designing solar shading, as well as pure ventilation and cooling in summer which minimise the buildings' demand for external energy sources (Pelsmakers, 2022). Good daylit design is one of the passive resilience design solutions that are the topic of this chapter.

When reading about the history of passive design, it is clear that, when developing passive design strategies, decisions should not lead to negative consequences on other aspects of the buildings. For instance, in the 1970s, during the energy crisis, many countries started to address this issue by reducing window size and air-tightening units (Baker & Steemers, 2019). The result of this response in the building was a significant reduction in the quality of natural light, fresh air, and visual connection between indoor and outdoor environments. At the same time, psychological conditions, such as Seasonally Affective Disorder (SAD) and Sick Building Syndrome appeared among residents (Baker & Steemers, 2019). Therefore, to provide users with proper light, clean air, and diverse views, while designing energy-efficient buildings, it is important for architects to consider these factors simultaneously from the early stages of design.

But what is daylight? And what is the difference between sunlight and daylight? The intense parallel rays of light received directly from the sun are known as sunlight (Heschong, 2021). Sunlight is the cause of sharp shadows; glare and it is a light source which covers the full spectrum of light. It also brings radiant heat which based on the climate and season could create a delightful indoor environment or threaten users' thermal comfort (Heschong, 2021). In comparison to direct sunlight, daylight is softer solar radiation received from the diffuse sky (Baker & Steemers, 2019), if daylight cast shadows, its shadows are softer, as UV and IR are barely scattered through the atmosphere, daylight is mostly known as pure light (Heschong, 2021).

The study of daylight increased when its role in saving energy become clear (Baker, Steemers, 2014), but daylight is much more than energy efficiency; a well-lit apartment is a thorough response to the diverse needs of the residents, as further unfolded below.

Figure 1.1.1 The components of natural light:



Note: Descriptive phrase that serves as title and description in daylight from VELUX Group is adapted April. 2023, https://www.velux.com/what-we-do/research-and-knowledge/deic-basic-book/daylight/daylighting.

Adapted by Maryam Heibati.

1.2 Daylight, health and wellbeing:

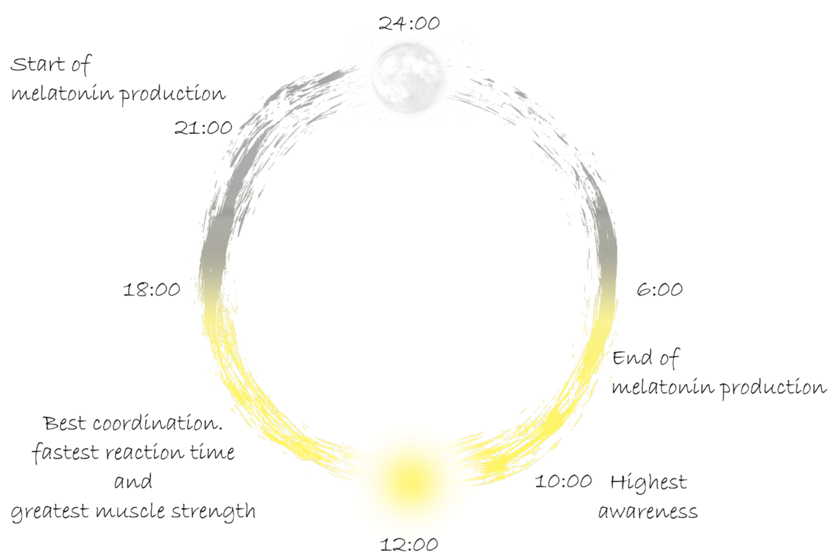
In cooler climates, like Finland, every year, by the start of winter the importance of natural light can be felt vividly by individuals. Either by the changes in the circadian cycle, the fatigue resulting from the reduction in the level of vitamin D, or changes in emotional and behavioral rhythm (Baker & Steemers, 2019). Over these past two years, as a newcomer not only I have experienced these changes individually, but also, I have noticed that in the early days of November in Finland, conversations mostly start by mentioning how November is the darkest month of the year. People spend their days hoping for the start of the snow season to brighten their surrounding environment.

The consequences of gradual climate change in Finland may affect the health and well-being of the people. By the end of this century, it is expected that Finland will experience warmer and longer summers, the winter will become warmer, and the snow cover period would become shorter (Burenby, 2021). The same research mentions that it is expected that based on the increasingly cloudy days, winter solar radiation will decline, leading to even darker winters (Burenby, 2021). Both of these predicted changes could influence people by increasing mortality rate (directly or indirectly, meaning by direct physical effect or increasing depression leading to a rise in suicide variance), sleeping issues, Seasonal Affective Disorder (SAD), eco-anxiety, as well as changing patterns and level of outdoor activities (Burenby, 2021). For instance, in winter 2023 pictures of dry winter ski sites were going viral with short captions reminding us that climate change is happening and is already influencing our lifestyle.

1.2.1 Circadian rhythm and Circadian house

One of the many roles that daylight plays in our life is influencing the secretion of different hormones regulating our metabolism and circadian rhythm (UK Green Building Council, 2016). Our everyday life is developed based on the diurnal and seasonal light and dark cycle (See figure 1.2.1.1). However, in modern times, with more humans living in urban environments with poor daylit apartments where residences are mostly exposed to electrical light, different aspects of our physical and mental conditions have been disrupted, such as our Circadian rhythm (Baker & Steemers, 2019). The disruption in circadian rhythm can lead to several physical and physiological disorders; such as premature death, cancer, metabolic syndrome, immune dysregulation, reproductive problems, mood disorders, and learning problems (Baker & Steemers, 2019). Therefore, the timing of exposure to light, the amount and type of light (natural or artificial) and its colour should be considered carefully in designing healthy homes.

Figure 1.2.1.1 Infographic of a conventional circadian rhythm:



Note: Descriptive phrase that serves as title and description is from elenabsl / Shutterstock.com.

Adapted: Maryam Heibati

In 2013, in Denmark VELUX, introduced the concept of a Circadian House as a concept for a healthy home that supports the diverse biological needs of the residents, centered around the circadian cycle (Hawkes, Dean, et al, 2015). VELUX has introduced three main concepts for a Circadian house:

1.) Living in balance with nature,

2.) Adaptability in terms of being responsive towards daily and seasonal changes and ever-changing users' needs,

3.) Sensibility, meaning that it protects the residents from harmful substances (harmful substances in the air or covering materials) while offering control over the parameters that can be felt (Hawkes, Dean, et al, 2015). For instance, adjusting the indoor illuminance or air temperature and air quality based on the needs of the users (The Circadian House Is a Vision for Human-centric Building Design, 2013).

The orientation of a building is the first and the most important step in developing a Circadian design, accompanied by a floor plan which is responsive towards the orientation. Meaning that it can bring natural light into living spaces based on when and how much light is required in each room. When designing a Circadian house, the cross-section of the building should also illustrate how much and how deep light could penetrate living spaces, during the day and in different seasons. The details of the design, for instance, the size or the location of the windows and openings, or the materials and their colour, whether they are reflective or bright, do they cause a room to feel brighter or if they create a calm environment, are all part of Circadian design. Last but not least, each design should have room for future adaptability and adjustability to meet the users' needs (Hawkes, Dean, et al, 2015).

The favorable orientation for a building in Finland is influenced by different factors, such as avoiding overheating during summer, protecting the building from cold winter winds (RT 103217, 2020), and bringing daylight into living areas, while avoiding glare (RT 07-10912, 2008), heat loss, or heat gain. But what is the ideal orientation to design a circadian house in Finland?

In Finland, the southern facades bring winter light deep into the plan to create a better-daylit environment during dark seasons, yet in summer they require a buffer, such as a balcony, to stay functional and create comfortable space for the residents all around the year (RT 103217, 2020). Orientation towards the south in single detached houses or apartments with multiple window directions can create a pleasant indoor environment over the year, because opening in multiple directions would allow the building to have adjustable spaces, however, designing a circadian house when having a single facade facing the south is more challenging, as it lacks the required adaptability to avoid overheating during summer (RT 07-11300, 2018). While light through the northern façade could eliminate the threats such as glare and overheating (RT 103217, 2020).

Therefore, when designing a circadian house in Finland, it is crucial to consider the time and duration of daylight availability in each direction. For instance, it is generally recommended that the bedrooms should face the east, to receive early morning light to start the circadian cycle (Baker & Steemers, 2019). However, in Finland during summer because of the low angle of the sun, an eastern-oriented bedroom in Helsinki will receive daylight from as early as 4 a.m. (RT 07-11300, 2018), disrupting the circadian cycle and influencing the residents' health and well-being. Therefore, to build a Finnish circadian house, instead of the east-facing bedroom, this room could face northeast, creating a pleasant sleeping environment as it is less affected by seasonal changes.

Moreover, it is better for the kitchen to be located in the southeast both because it allows for penetration of softer morning sun into the indoor environment, and because it is one of the first rooms that most people use when starting their days (Baker & Steemers, 2019). While the living room and dining area oriented towards the southwest will receive warm evening light which prepares occupants for a good night's sleep and completes the diurnal light and dark cycle (See figure 1.2.1.2).

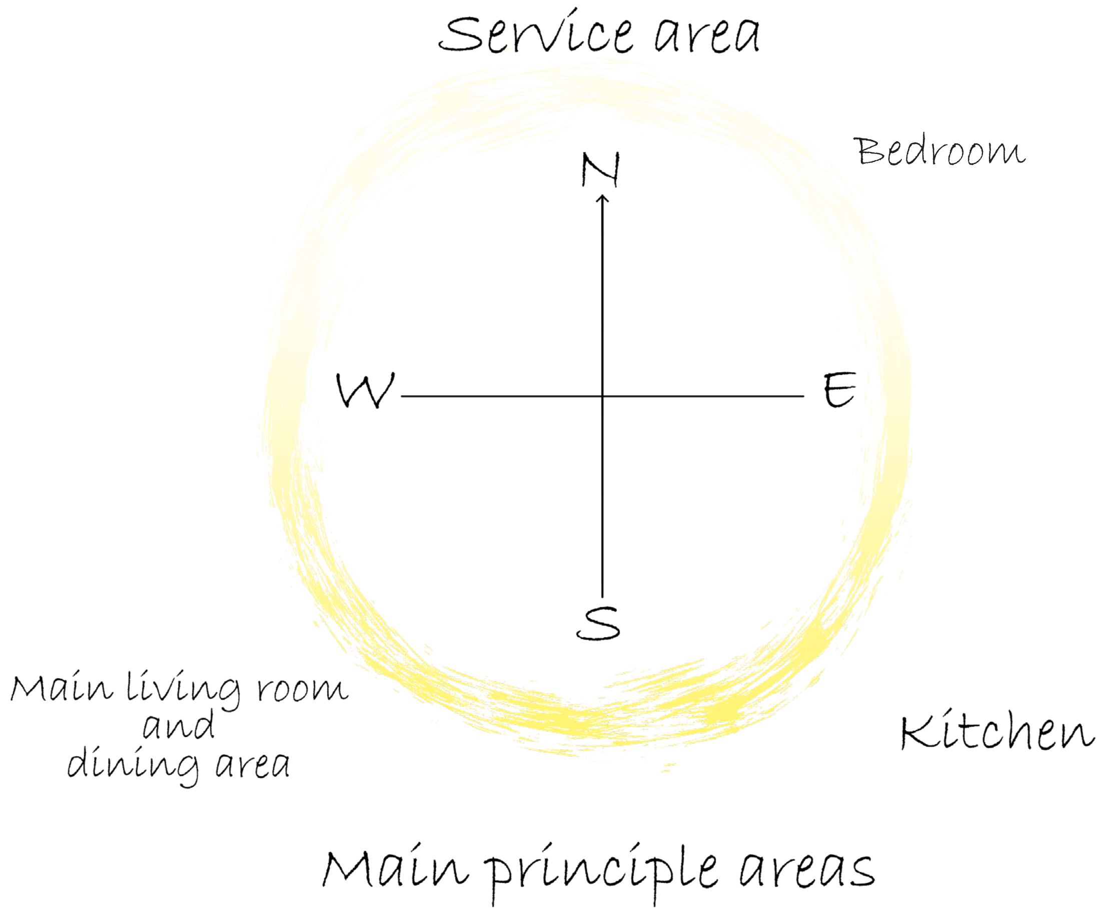


Figure 1.2.1.2 Recommended rooms' orientation in a high northern latitude

The low angle of the sun causing sharp rays of sun in the eastern and western facades, reduce the disability of positing rooms in these directions, therefore the southeast to southwest facades which receive gentler natural light are best directions to position principle rooms (RT 07-11300, 2018).

1.3 Daylight and delight:

Nowadays, the discussion over the effect of daylight is not just about its role in understanding space and vision, it is more about the variability and efficiency of natural light and the connection that it creates to the outdoor environment. For instance, one of the factors that can be seen in a circadian house is the relation between outdoor and indoor environments via delightful and easily accessible outdoor and semi-outdoor areas, and the visual connection between the outdoor environment and the main living spaces (Hawkes, Dean, et al, 2015).

Daylight is a free clean source that can be considered as an energy-efficient lighting strategy, however, in recent years there is more discussion on its potential in creating diverse and dynamic spaces (See figure 1.3.1 and figure 1.3.2), rather than its energy efficiency (Baker & Steemers, 2019). Of course, these aspects become more significant in Finland, as there is a huge difference in daylight availability over the year; based on data from WorldData.info, daylight availability in Finland could differ between 19 hours around Midsummer to as low as 6 hours in December.

However, with increasing reliance on artificial light, architects sometimes tend to neglect access to natural light, either to achieve economic efficiency or to avoid unwanted results (such as glare) caused by the unpredictability of natural light (an issue mostly influencing non-domestic spaces) (Baker & Steemers, 2019). In Finland, one may neglect good daylight because it is mostly dark in winter. Yet, the opposite is true, with few daylight hours, it is even more important to maximise the daylight quality in living spaces. This is discussed in a study by Katerina Parpairi, suggesting that people tend to prefer daylight to artificial light, even if it has poor illuminance and intensity. The same research also mentions that as long as the poor lighting condition is caused by natural factors people tend to accept the lighting condition, even when it could lead to eyestrain and temporary discomfort (Baker & Steemers, 2019).

Figure 1.3.1 Playroom, receiving daylight from circular skylight and small glass opening , villa Mairea by alvar Aalto.
Photo by Rauno Träskelin

Figure 1.3.2 Library, villa Mairea by alvar Aalto, upper glass openings, create a dramatic and variable combination of light and shadow,
Photo by Lindman Photography.

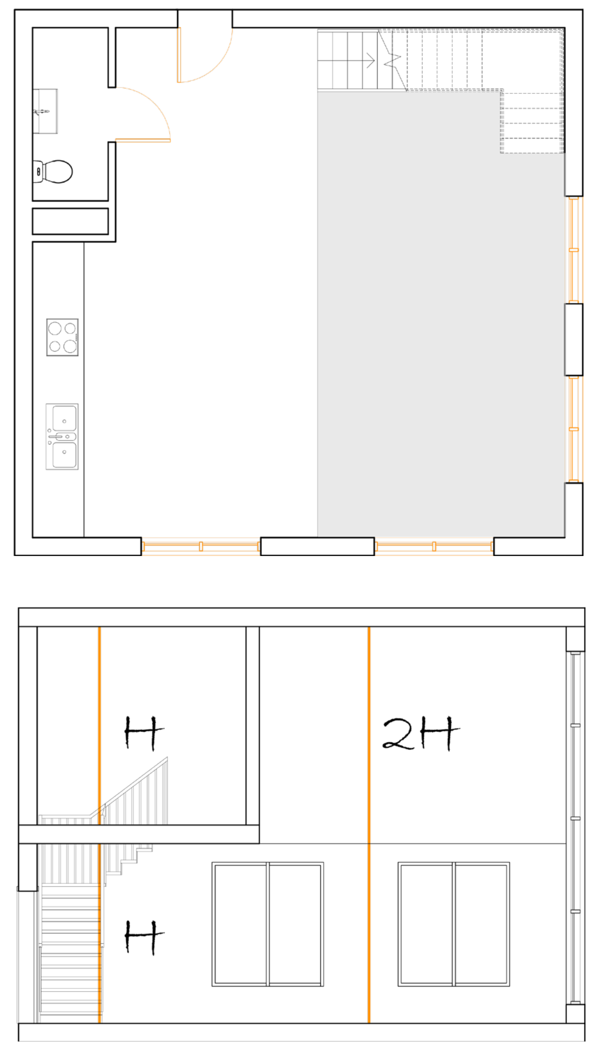
1.4 Daylight, adaptability and adjustability:

When a house becomes a home, it is no longer a shelter for the user against natural forces. A home is a place where people live and experience a dynamic life. Their home could be a space to work or study in, a meeting point, a place where they can thrive based on their ever-changing needs (Health and wellbeing in homes, 2016). Therefore, the ability of the house to adapt itself to users' needs is considered an important factor in housing design (Pelsmakers, S, Saarimaa, S & Vaattovaara, 2021).

Adaptable and responsive design is particularly important when considering demographic changes, climate change, changes in lifestyle, and new available technologies; a design should offer users the opportunity to make choices and control their living environment (Baker & Steemers, 2019). The availability of good daylight or the lack of it could influence the spatial adjustability of space (Saarimaa & Pelsmakers, 2020). Therefore, when designing user-friendly houses, it is important to consider daylight availability and factors influencing its quality. For instance, by flexible layout, users will have the freedom to achieve short-term adaptability via foldable partitions or long-term adaptability with non-structural partition walls, and by providing each unit with multiple and evenly distributed windows (See figure 1.4.1), it can be assured that when adapting or transforming the space to achieve a certain goal new spaces would still have access to natural light (Pelsmakers,2022). This indicates the importance of careful window location in spaces.

Figure 1.4.1 Possibilities created by open plan and open section:

Even distribution of openings, suitable room size, separation of different spaces, different arrangement and adjustability of spaces, accessibility, higher ceiling level.



Note: Descriptive phrase that serves as title and description is from "Designing for the Climate Emergency: A Guide for Architecture Students", Pelsmakers, Sofie et al, 2022.

Adapted: Maryam Heibati

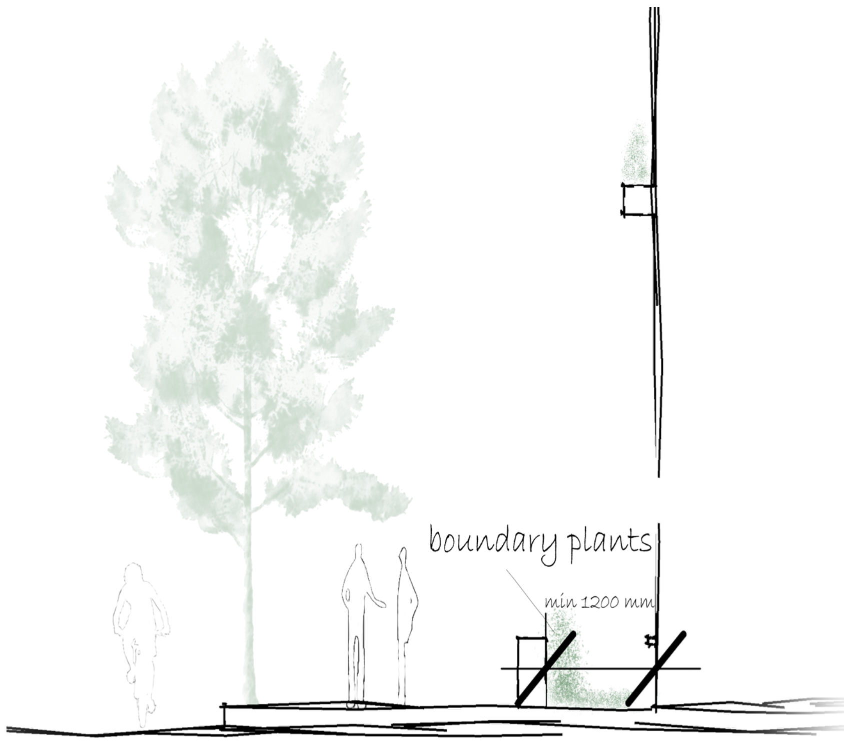
1.5 Daylight and privacy:

When designing for resilient living environments, several factors including proper daylighting, furnishability and better overlapping of essential circulations area, and variable interior routes offering residences to regulate their level of privacy should be considered (Lehtinen & Pelsmakers et al, n.d.). Based on a survey conducted by Lehtinen et al. (2022), access to proper daylight was one of the most-mentioned desirable factors to support own's well-being. In the same survey, participants mentioned different privacy levels, as well as visual and physical connections between indoor and outdoor environments, as desirable.

People have the need to control the level of their privacy, creating spatial connections between rooms, having boundaries between interior and outdoor environments, to define different adjustable levels of privacy, which is an important factor of housing design (Schmid & Säumel 2021). One of the ways to achieve adjustable levels of privacy is through having control over visual and physical connections (Lehtinen & Pelsmakers et al, n.d.). For example, the ability to open and close the door and windows, or the possibility to open or limit visual connections between indoor and outdoor environments through different shading devices.

Therefore, when designing for maximum daylighting it is important to retain users' privacy while not reducing or blocking access to natural light. To achieve privacy, designs should be developed to create a hierarchy between inside and outdoor spaces (Pelsmakers, 2015). In first-floor urban apartments, the edge of the units should have a minimum of 1.2 m private strips, such as low walls or semi-private gardens (See figure 1.5.1) (Pelsmakers, 2015). It is also important to avoid floor-to-ceiling windows, especially on the first floor, and generally where it invades residents' privacy and security (Pelsmakers, 2015). The easiest way to achieve privacy in apartments is the use of curtains, however, there are risks that the curtains stay closed most of the time, leading to a reduction in the amount of daylight in the indoor environment. Hence, it is important for architects to think of boundary plants, window boxes, and window orientation and division when designing for better daylighting and privacy (Pelsmakers, 2015).

Figure 1.5.1 Private strip in urban apartments:

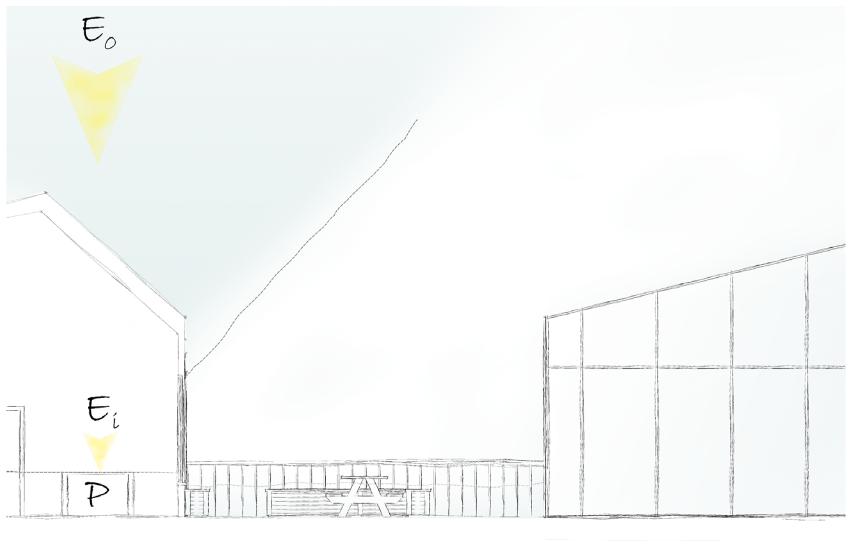


1.6 Introduction to daylight factor

The light from the diffused sky, cloudy or clear, is known as daylight (Baker & Steemers, 2019). In the Finnish RT-1032317 card daylight is introduced as a desirable form of light, as it increases the brightness of both indoor and outdoor environments without causing overheating. When describing the available daylight in northern Europe, it is common to use the proportion of available daylight inside to the externally available daylight at the same time, known as the Daylight factor (DF) (Pelsmakers, 2015).

Figure 1.6.1 The definition of DF

$$DF\ \% = \frac{\text{internal illuminance } (E\ i)}{\text{illuminance from the unobstructed sky } (E\ o)}$$



Note: Descriptive phrase that serves as title and description is from *"Healthy Homes : Designing with Light and Air for Sustainability and Wellbeing"*, Baker & Steemers, 2019.

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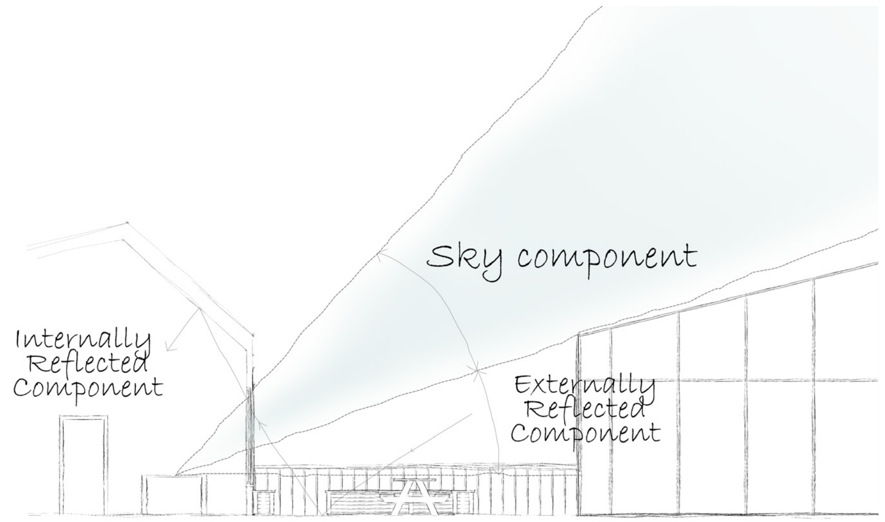
The daylight factor (DF) has three elements including the Sky Component (SC), the Externally Reflected Component (ERC), and the Internally Reflected Component (IRC) (See Figure 1.6.2). The architect can influence these factors by defining the geometry of a building, the transmission of the glazing, and the reflectance of the surfaces (Baker & Steemers, 2019). The position, shape, and size of the windows, as well as external obstructions influencing the view of the sky, can affect the quality of the Sky Component. On the other hand, the presence of the Externally Reflected Component is influenced by the available outdoor view through windows, as well as the geometry and reflectance of surrounding obstructions (Baker & Steemers, 2019). While the Internally Reflected Component is available everywhere; it is affected by the average reflectance of surfaces in each room, the reflectance of external surfaces, and the distribution of reflectance in an interior space (internal objects or furniture) (Baker & Steemers, 2019).

Figure 1.6.2 The three components of the Daylight Factor.



Note: Descriptive phrase that serves as title and description is from *"Healthy Homes : Designing with Light and Air for Sustainability and Wellbeing"*, Baker & Steemers, 2019.

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The minimum acceptable DF in a habitable space is between 1.5% and 2%. Although to reduce the need for artificial lighting during the overcast sky and to achieve proper daylighting standards the DF of 5% is recommended (Pelsmakers, 2015). However, when discussing the minimum or average required DF, the values are always recommended for users with normal vision, yet these minimums do not provide adequate light for a wide range of users, for example, elderly users or users with poor vision. Our design should be inclusive (Pelsmakers, et al., 2022). One way to develop an inclusive design could be defining the minimums based on the required minimum factors for vulnerable people not just the general population.

Table 1.6.1 The table shows the average and minimum average daylight factors for different room functions. The average DF should never get lower than minimum (Pelsmakers, et al., 2022). Also, ensure the proper light for every users a design should aim for bringing more daylight into the design.

	Bedroom	Living room	Kitchen
Average DF	2%	5%	5%
Min. average DF	1%	2%	2%

Having proper daylight, just close to the windows, is not the aim of good daylighting. Good daylight in housing should be provided evenly and as controlled as possible (RT 07-10912, 2008), deep into the rooms (Pelsmakers, et al., 2022), which through proper window positioning (Pelsmakers, et al., 2022) can increase the adaptability and flexibility of the units. There are several key recommendations for achieving well-daylit urban apartments known as “daylighting rules of thumb”. In the following paragraphs the global standard daylighting rules of thumb, which could be applied to a wider range of climate zones and different types (Reinhart, C. F, 2010) would be introduced.

1.7 Daylighting rules of thumbs

To achieve good daylight in interior spaces there are simple guidelines that architects could follow from the early stages of design. Applying these simple rules known as daylighting rules of thumb, not only can create better daylit interior spaces without extra cost but also would reduce the building’s reliance on artificial lighting during daylight hours.

1.7.1 Shallow plan:

In residential construction, too deep floor plans and rooms and windowless kitchens should be avoided (RT 103217, 2020), shallow plans would enhance the available daylight in living spaces (Brophy & Lewis, 2011). But what is a shallow plan? In fully glazed façades, when the floor plan’s depth is up to two times the ceiling height, natural daylight, and ventilation can be achieved in that area. Meaning that based on a 3m floor-to-ceiling height, in fully glazed faced with single-sided window, in order to have adequate daylight the depth of the plan should not be greater than 6 m. Although, if there is more than one wall allowing daylight penetration the depth could increase up to 12 m (Pelsmakers, 2015).

In addition, based on an old rule, the depth of a well-lit room should not be greater than 2-2.5 times the distance between the upper edge of the opening and the floor (RT 07-10912, 2008). It should be noted that when having a single façade, it becomes more important for a room to have a shallow plan to achieve balanced daylight distribution in the room (Pelsmakers, Saarimaa & Vaattovaara, M K 2021).

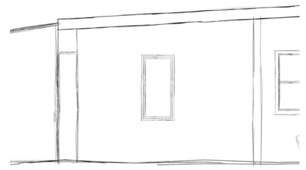
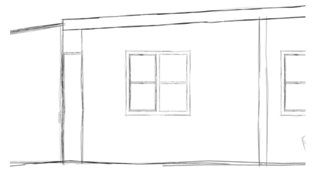
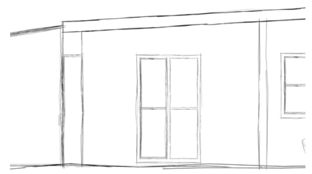
1.7.2 Window area to floor area in apartments:

The ideal total window area should be around 20% of the floor area(Pelsmakers, 2015), and not smaller than 10% (RT 07-10912, 2008). However, to avoid overheating, when facing south the window area should not be greater than 40% and 32% on other orientations (Pelsmakers, 2015). When having rooms with only one single-sided window, the window length should be 35% of the wall length to avoid overheating (Pelsmakers, 2015).

1.7.3 Window area to wall area in apartments:

When the window area is less than 10% of the wall area (with an average of less than one percent daylight factor) the room feels little connected to the outside and is poorly daylit, therefore it is required to use artificial light all the time (Pelsmakers, et al., 2022). With 40 to 60 % window area to wall area, the average daylight factor would be around 5 to 10 percent, the room would have a good connection to outdoor light and weather conditions (Pelsmakers, et al., 2022). With a very well-daylit area, the need for artificial light during daylight hours is reduced and the users of the space would have a generally positive experience in that room (Pelsmakers, et al., 2022).

Average DF and general impression of the room based on window area as a percentage of the wall area:

Average DF	General impression	window area / wall area
<1%	Poor daylight quality Very little connection to the outside Always need artificial light	 <10%
1-2%	very little influenced by natural light Usually needs artificial light for certain tasks	 10-20%
2-5%	Good daylight quality Good connection to the outside Very little need for artificial light, just for specific tasks	 20-40%
5-10%	High daylight quality Better connection with the outside Barely need artificial light during daylight hours Delightful environment for residents	 40-60%

Note: Descriptive phrase that serves as title and description is from "Designing for the Climate Emergency: A Guide for Architecture Students", Pelsmakers, et al., 2022.

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1.7.4 Window Placement:

Placing the window on the upper part of the wall would increase the daylight penetration into space, as it decreases the amount of light near the windows while increasing the access to the sky view (Baker & Steemers, 2019); consequently, distributing the daylight evenly into a space (RT07-10912, 200). Not just the higher window placement can increase daylight quality, but also, it ensures adequate daylight penetration. It is recommended to use higher windows in housing, as the light will penetrate about 2 times the window height into the room (Pelsmakers, et al., 2022).

Having control over the amount of received daylight can create a positive opportunity for the residents to adapt the space based on their needs (Baker & Steemers, 2019). Therefore, windows could be designed in a way to provide a variety of opportunities for the users, such as dividing a larger room into smaller daylit areas, equal light penetration from multiple directions (Pelsmakers, et al., 2022), accessible direct and diffuse light, adaptable amounts of light through shutters, louvers, and blinds.

1.7.5 Window glazing specification:

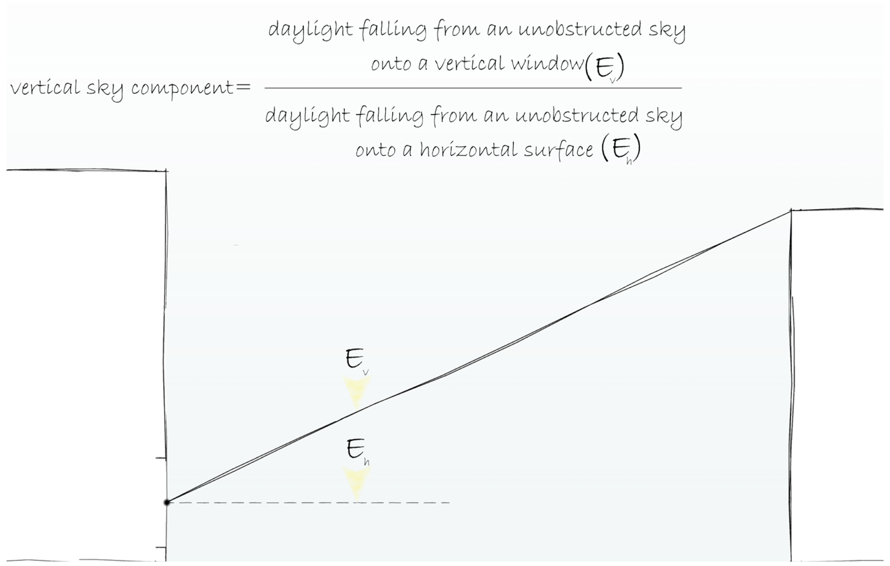
When choosing a glazing type there is always a decision to be made between enhancing light penetration and reducing heat transmission (Steemers & Baker, 2014). Based on Finnish regulations, triple glazing is a common window specification; as the middle glass, creates an obstacle between indoor and outdoor glass (RT 38-10941,2008), there is not a significant gap between surface temperature and indoor air temperature, hence, triple glazing can create internal comfort during cold winter days (Pelsmakers, 2015).

However, it can influence daylight quality as it reduced daylight and solar transmission (Pelsmakers, 2015). For instance, a single-glazed window has daylight and solar transmission of 88% and 83% respectively. While a triple-glazed window reduces these amounts to about 72% and 54 % respectively (RT 38-10941,2008). It should be noted that even using different glazing types such as tinted glazing can reduce daylight and solar transmission. For example, a usual double-glazed window has solar and daylight transmission of 65-76% and 77-80% respectively, while these numbers fall to as low as 29% and 29% respectively in tinted double-glazed windows (Pelsmakers, 2015).

1.7.6 Maximize view of the sky:

The percentage of daylight falling from an unobstructed sky onto a vertical window, in comparison to the amount of daylight falling onto a horizontal surface under the same sky, at the same time (See figure 1.7.6.1), is known as the vertical sky component (Pelsmakers, 2015). It is usually measured at 2 m from the ground; Ideally, it should be around 40%, a target which is hard to achieve in urban areas, especially on lower levels (Pelsmakers, 2015). However, by orienting the window to the sky, increasing the floor-to-ceiling height, increasing the height of the window, and reflecting daylight by surrounding obstructions good daylighting can be achieved (Pelsmakers, 2015).

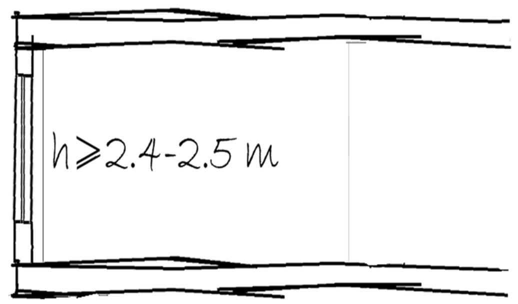
Figure 1.7.6.1 The definition of vertical sky component



1.7.7 High ceiling:

In Finland, the minimum ceiling height in residential units is about 2.4-2.5 m and more (RT 103260, 2020). The higher the ceiling height, the more it allows daylight penetration by allowing for placing taller windows. This is more influential on lower floors (Pelsmakers, 2015). Nevertheless, it should be remembered that increasing ceiling height, by increasing the building volume, would increase the construction costs as well as the required energy for heating space. It is recommended that always high ceilings should be combined with well-insulated structural elements (Pelsmakers, 2015).

Figure 1.7.7.1 The minimum ceiling height in residential units in Finland



1.7.8 Internal and external reflectance of daylight:

DF is influenced by internal and external surface reflectance. Each material reflects the daylight in a different way, which influences the qualities of internally or externally available daylight (RT-103169, 2019). In general, light color surfaces either on the ground or vertical surfaces will increase the reflectance of light, resulting in a higher level of daylight availability; this will lead to lower contrast between bright window frames or glazing surfaces and interior spaces leading to a balanced and more delightful living space(Brophy & Lewis, 2011).

In Finland, the sun reflectors, skylights and glazed courtyards, light façade materials, and based on the result later introduced in part two, probably bright surface of snow will collect the low-shining rays of the sun during autumn, winter, and spring and further reflect light into the interior spaces (RT 103217, 2020).

Reflectance is described by the material's albedo, which means the ratio of the radiation reflected from the surface to the incoming radiation. The higher the albedo a material has, the more radiation it reflects (RT-103169, 2019). For instance, based on the same research, fresh snow (Tuore lumi) has an albedo of 0.85 which is more reflective than white acrylic paint (0.80) - see Table 1.7.8.1. While the albedo of old snow (vanha lumi) is about 0.4 which is as low as light sand or wet concrete (see Table 1.7.8.1). Although, there is not any clarification on the definition of old snow based on the albedo it is assumed that old snow could be the type of snow which stays on the ground for a longer period, and as a result, it is covered with dust and gravel with a grayish color. Because of the significant difference between fresh and old snow, this is one of the conditions that is investigated in this thesis to understand the impact on the quality of daylight.

Table1.7.8.1 The albedo of some external surfaces

Material	Albedo n.	Material	Albedo n.	Material	Albedo n.
Fresh asphalt	0.04 - 0.05	Dark, damp earth	0,08	Mixed forest	0,15 - 0,20
old asphalt	0.10 - 0.12	Dark, dry earth	0,14	Short grass	0,16
Swamp	0,10 - 0,14	Coniferous tree	0,05 - 0,15	Long grass	0,26
Gravel pavement	0,72	Al and chrome	0,50 - 0,75	White acrylic paint	0,80
Fresh snow	0,85	Old snow	0.4	Portland cement	0,70 - 0,80
Light sand	0.45	Old concrete	0,20 - 0,30	Wet concrete	0,40 - 0,55

Table1.7.8.2 The albedo of some internal finishes

Material	Albedo n.	Material	Albedo n.	Material	Albedo n.
White paint (glossy)	0.85	Carpet - cream	0.4	Yellow brick	0.3
Wood finishes- light color	0.4	Carpet - dark	0.1	Black paint (glossy)	0.05

Knowing the fact that the reflectance of the different surfaces could influence the quality of available daylight and the numbers in Table1.7.8.1, raised the thesis question "How might snow-covered surfaces influence the quality of daylight in Finnish housing? ", which is the subject of the next chapter.

Note: Descriptive phrase that serves as title and description in Table 2.2.8.1 is from RT103169, 2019.
Note: Descriptive phrase that serves as title and description in Table 2.2.8.2 is from "The environmental design pocketbook" , Pelsmakers, Sofie, 2015.

Adapted: Maryam Heibati

PART TWO

Analysis and findings

This chapter would focus on daylight measurement and simulations for three case study

2.1 Introduction:

Living in an era under the shadow of climate change asks us to set adaptation to climate change as our priority (Pelsmakers, et al., 2022); for a simple reason, it is necessary for our survival! Consequently, designing in climate emergency demands" a cultural shift and a new ethical position" (Pelsmakers, et al., 2022). When designing for a climate emergency, the design process should start by exploring the context and gaining information about climate, flora and fauna, and any other factors influencing the design. Climatic design is an essential part of contextual design, as it not only addresses the potential challenges of designing in a specific climate and the opportunities that local climatic conditions bring to the design but also because of the probable challenges that climate change would bring to the performance of existing buildings (Pelsmakers, et al., 2022).

Because of my previous studies which were heavily focused on vernacular architecture and its potential in developing modern contextual design, subconsciously, when starting a new design project, I looked for contextual passive design strategies. At the beginning of my studies in Finland, I was so confused, trying to understand the context and existing passive design strategies specific to Finland. I asked, searched, and discussed but it seemed the only answer to my question was the standard global strategies which I knew they need adaptation to be efficient enough in Finland.

Therefore, knowing that every building should follow the RT regulations, I started reading RT cards to gain a better understanding of contextual Finnish regulations. However, the more I read about daylight, the more I felt that even architects tend to look at it as a secondary priority. The RT 07-10912, was mainly focused on how to control the daylight in interior spaces and avoid its negative effects (overheating or glare), rather than enhancing its quality in interior spaces. The detailed focus on controlling daylight was surprising considering the fact that based on the Finnish Meteorological Institute, there are more overcast days in Finland than the clear sky, meaning over 80% of the cloud-covered sky around the year[28].

While reading about daylight, there was a table in RT-103169, mentioning the albedo of different external surfaces; with a row of fresh snow albedo, about 0.85 (see previous section). Based on this fact it can be assumed that snow-covered surfaces can enhance the quality of daylight, however, while searching for possible references, it was clear that there is a huge gap in architectural research on the effect of snow-covered surfaces on the quality of daylight. Although, there are various articles about the influence of snow on the health and well-being of humans.

For instance, research conducted in Iceland, claims that in winter, average daylight availability considering the latitude of Iceland, is much more than expected I.e., 60% or less than clear sky conditions, concluding that the decline in daylight availability cannot be the only reason for low winter depression in Iceland, there are other undiscovered factors (Axelsson, Jóhann, et al., 2004). Based on this paper environmental factors such as the cloudy sky or snow cover can influence daylight availability. Although the same research suggests that snow-covered surfaces do not illustrate a significant rise in average daylight (Axelsson, Jóhann, et al., 2004).

But is this still true? Now that due the climate change we have milder and darker winters, average daylight availability and the role of snow-

Therefore, based on these observations, this chapter will investigate the possible effects of snow-covered surfaces on the quality of daylight; firstly, to understand if snow-covered surfaces can impact the DF in urban apartments or not. Initial data was gathered by Lux meters to identify the spatial distribution of DF in a room, as it is one of the easy methods for communicating and validating daylight availability in a design (Pelsmakers, et al., 2022), however, for supporting the measured data, digital models were developed, as well.

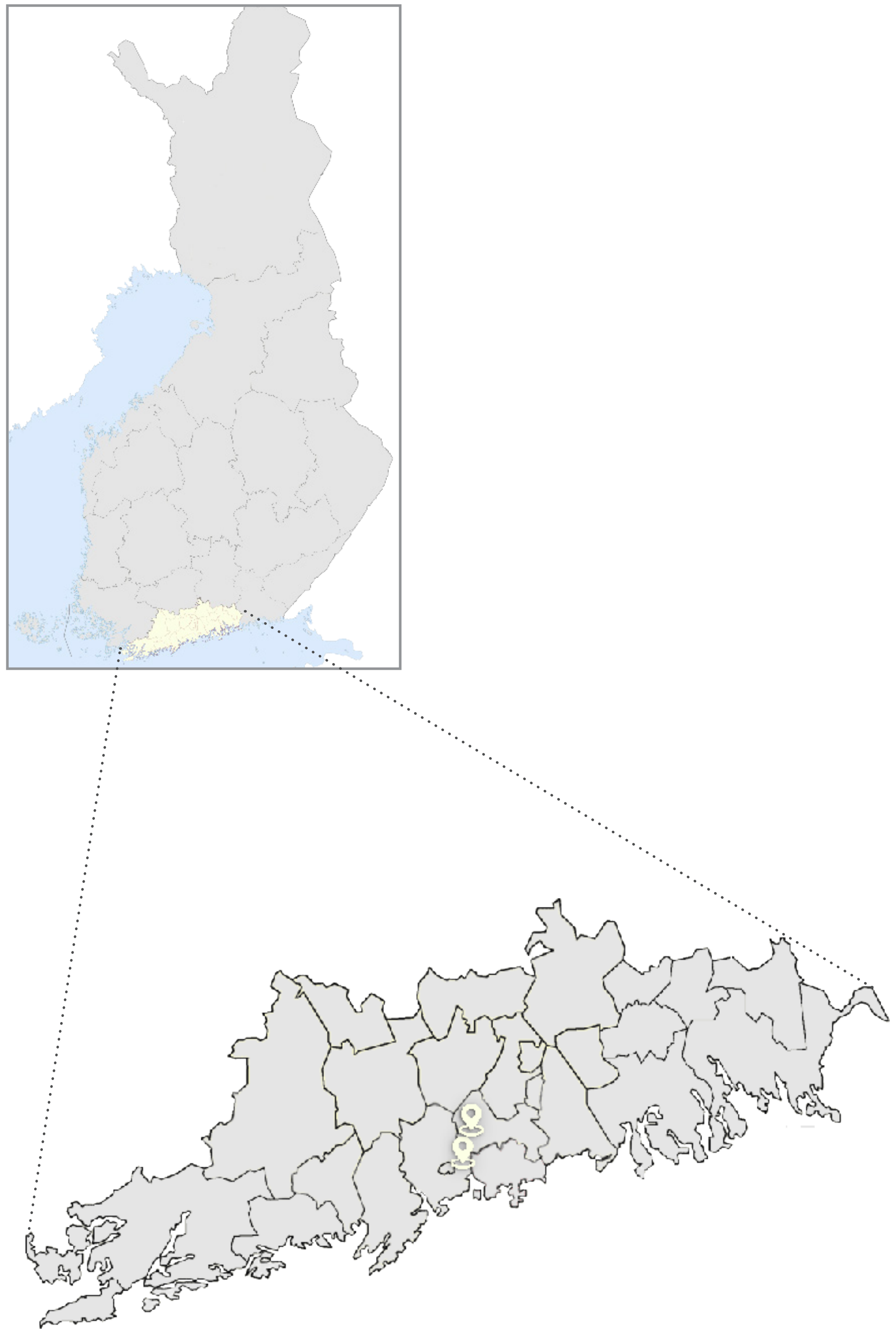
2.2. Samples characteristics

Before starting the data analysis, each sample was analyzed based on the previously mentioned daylighting rules of thumbs, to investigate if the depth of the floor plan allows for proper penetration of daylight, meaning that the depth of the room should be no greater than 2-2.5 times the height of the top edge of the window opening from the floor, when the windows are only on one wall (RT 07-10912, 2008).

Window placement, the height of windows, and the proportion of the window openings to the room area were also investigated to analyze if these basic rules of thumb applied to create a better-day-lit living environment or not.

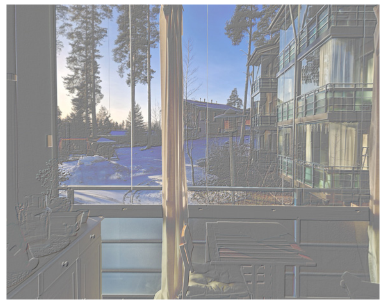
Before presenting the analysis, the following paragraphs provide a short introduction to the general characteristics of each case study.

Figure 2.2.1 The location of selected samples



2.2.1 Case Study N.1

The first case study is located on the second floor (about 3 m above the ground); a three-room apartment facing northwest, with multiple facades facing northwest and west. The view from this apartment is towards the street and a green courtyard occupied by tall evergreen trees, as well as deciduous trees and bushes (see the site plan on the next page). The apartment has quite an open view, absorbing afternoon and evening light. Daylight measurements for this apartment were conducted in the main living area and study room both facing northwest, and the bedroom and home office area facing west.



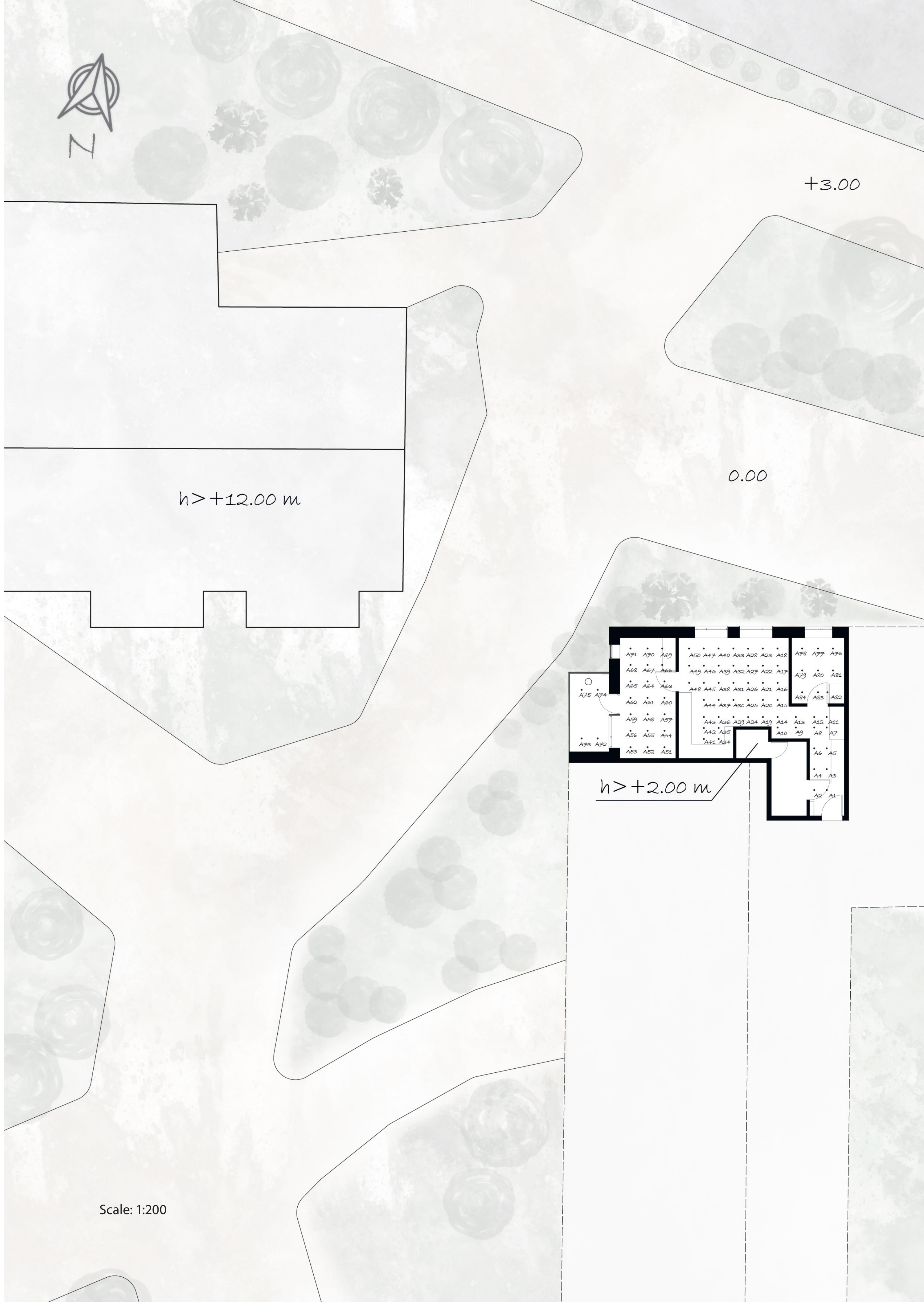
Western view

Study room, facing northwest

Living room, facing northwest

Bedroom, facing west

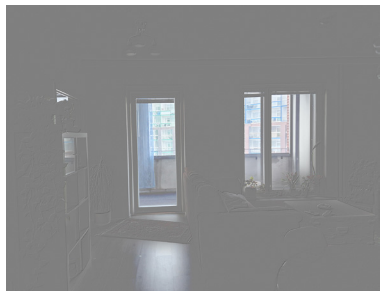
Note: The quality of images was lowered to hide the personal objects, and direct the focus toward the main openings influencing daylight availability.



2.2.2 Case Study N.2

The second case study is a two-room apartment on the third floor, facing south, with a single-side window and a huge glass-covered balcony. The view from this apartment is towards an empty courtyard. This is a very different case study because of its distance from ground level (more than 7 m), and this is the only case study with single-sided windows.

View to the courtyard



Living room

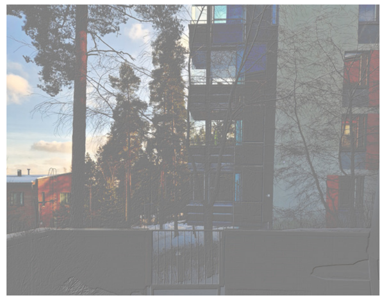
Main living area

Bedroom

Note: The quality of images was lowered to hide the personal objects, and direct the focus toward the main openings influencing daylight availability.

2.2.3 Case Study N.3

The second case study is located on the first floor (ground level), a three-room apartment facing southeast, with multiple window directions facing southeast and east. The view from this apartment is towards another apartment block but the distance between the apartments is occupied by tall evergreen trees, blocking the view and daylight. Daylight measurement for this apartment was conducted only in the main living area and the home office room, excluding the bedroom from the study.



Southern view

Home office

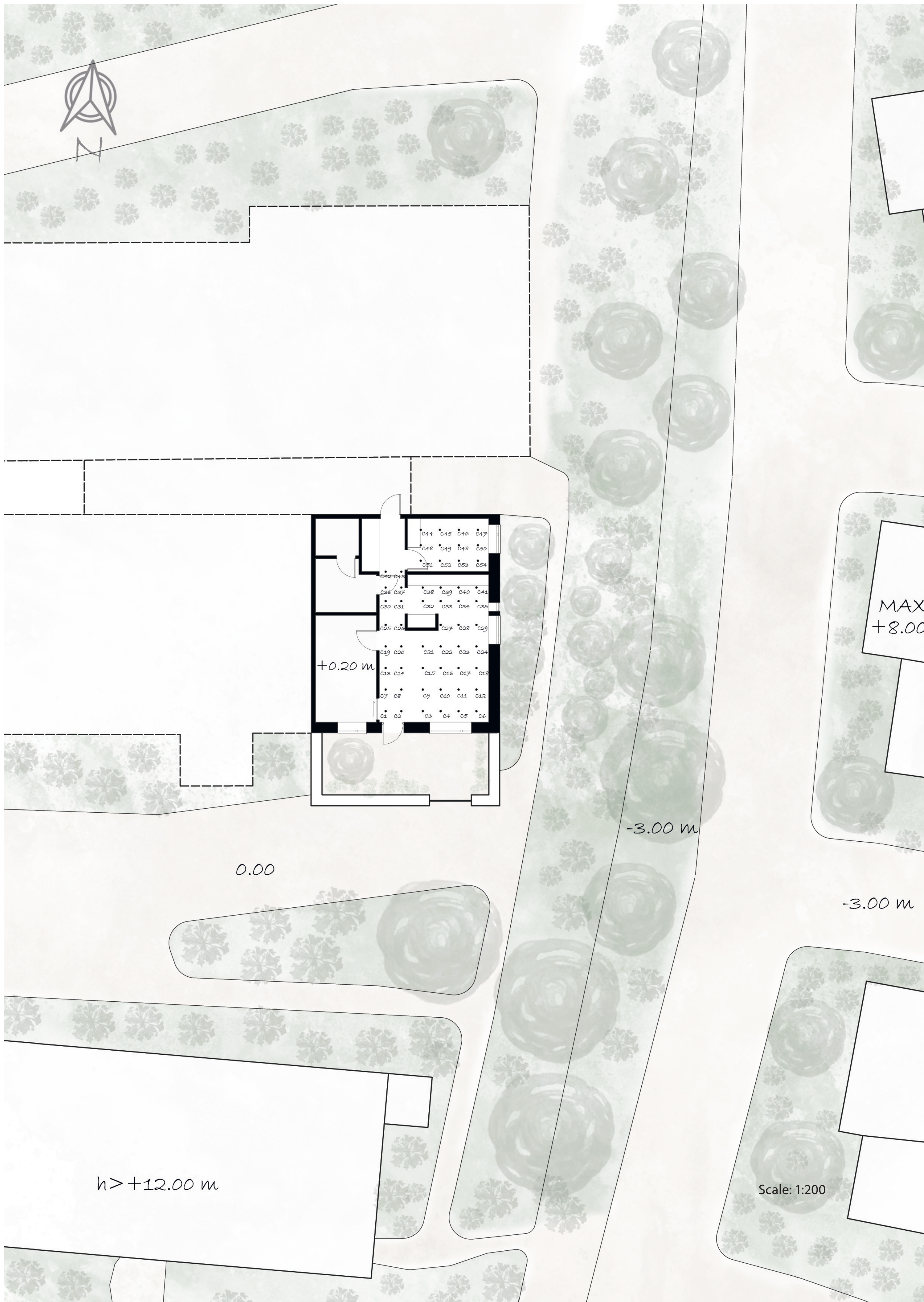
Living room

Living room

Living room

Kitchen area

Note: The quality of images was lowered to hide the personal objects, and direct the focus toward the main openings influencing daylight availability.



2.3 Findings and analysis

2.3.1 Case study N.1:

According to daylight rules of thumb indicators one of the recommendations for having a better-daylit apartment is having windows in multiple directions (Pelsmakers, et al., 2022). According to this statement, although this sample has openings on two facades, each room receives light only from a single direction (see figure 2.3.1.1).

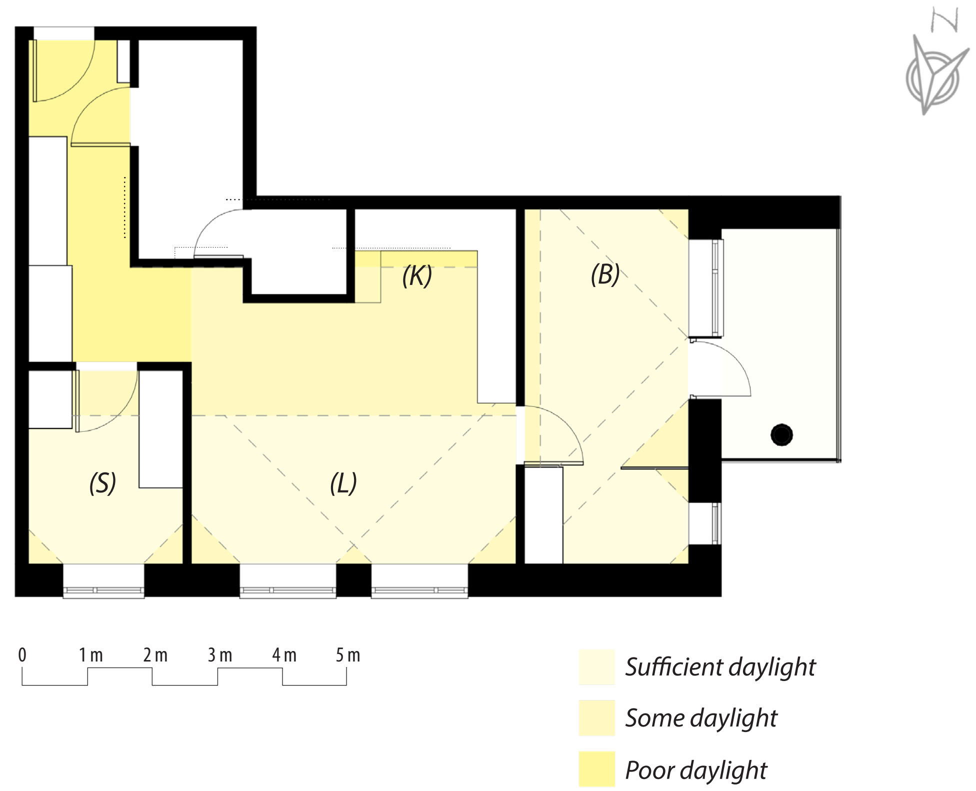


Figure 2.3.1.1 Daylight penetration based on daylighting rules of thumb According to daylighting rules of thumb for a window without shading elements, the room receives good daylight up to 2.3 m deep into the space (DF> 2%), between 2.3-4.6 (0<DF<2%) the room receives some daylight, and space is poorly daylit (DF near 0%) when the space is deeper than 4.6 m (Lehtinen, et al., 2022).

A shallow plan is another factor for well-lit apartment, the main living area (L) has a ratio of 1.72 which is below the recommended proportion, creating a reasonably daylit space. The kitchen area (K) receives light from the same openings, yet it has a slightly higher proportion (2.34), resulting in a darker kitchen area (see figure 2.3.1.2). Additionally, the same ratio in bedroom (B), when considering the width of the balcony (see figure 2.3.1.3), is about 2.08, slightly higher (only 0.8) than the maximum recommended ratio of 2 for a well-lit space. Yet, the same ratio in the study room (S) is 1.27 (see figure 2.3.1.4) which is below the maximum of 2, resulting in a better-daylit environment.

According to Table 2.3.1.1, the checklist for daylighting rules of thumb, the study room receives the best daylight in this case study. Although the room only receives light from a single north-facing window, the shallow plan, the ideal window area to the floor and wall area (see table 2.3.1.1), creates an opportunity for a good daylight penetration into the room.

Figure 2.3.1.2 Depth of the main living area

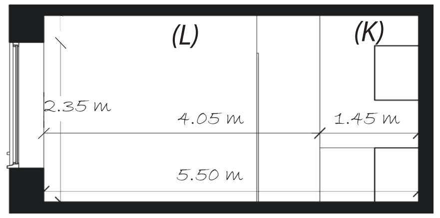


Figure 2.3.1.3 Depth of the Bedroom

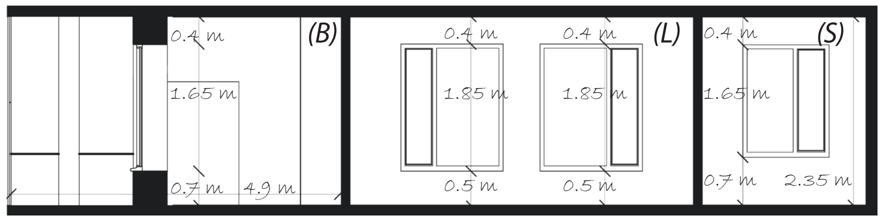
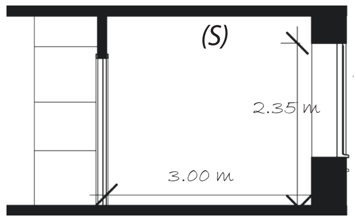


Figure 2.3.1.4 Depth of the main Study room



On the other hand, the bedroom with a window area to wall area of 38% rarely needs artificial light during daylight hours. However, the high ratio of window to floor area (41%) might threaten the comfort of the residents by overheating during daylight hours (to avoid over-heating the window area to floor area shoud not be greater than 32% (Pelsmakers, 2015)). The checklist shows that this apartment meets some daylighting standards and provides relatively acceptable access to daylight.

The following pages are dedicated to the analysis of field measurements and daylight simulation to gain a better understanding of the role of snow on DF.

Table 2.3.1.1 Checklist for daylighting rules of thumb

Rules of thumb checklist	Main living area (L)	Kitchen area (K)	Bedroom (B)	Study room (S)
Window on multiple facade	No	No	No	No
Shallow plan				
$\frac{\text{Deapth of the room}}{\text{Distanace between upper edge of the opening and the floor}} < 2$	1.72	2.34	2.08	1.27
$10\% < \frac{\text{Window area}}{\text{Floor area}} < 40\%$ Ideally around 20%	≈ 22 %		≈ 41%	≈ 28 %
$10\% < \frac{\text{Window area}}{\text{Wall area}} < 60\%$	≈ 39%		≈ 38%	31.5%

Note: Window glazing specification, and reflectance factors of the internal and external surfaces' material, are not included in the checklist as the author don't have access to actual data. In addition, as all three case studies are typical urban apartments, following standard ceiling height (above 2.4-2.5), this factor is not included in the checklist.

General evaluation of daylight measurements

The DF is calculated under an overcast sky (Steemers & Baker, 2014), therefore the measurement conducted on the 16th of March under the clear sky (Figure 2.3.1.6 and 2.3.1.18) was excluded from the analysis, and the 23rd of February with the highest snow-covered areas and average DF of 2.84% was chosen as the base for analysis.

The desirable average DF in main living areas ranges from a minimum of 2% to 5% (Pelsmakers, et al., 2022). The average DF in the study room (S) varies from 2.88% under a fully overcast sky to 1.98% (see figure 2.3.1.7 and 2.3.1.8). This room usually has an average DF above 2%, creating a well-daylit space (as expected based on the DRT checklist).

The average DF in the study room (S) on the 23rd of February, 27th of February, and 3rd of March highlight that when the snow-covered surfaces decrease or when they get darker the average DF also decreases. The average DF decreased from 2.84% on the 23rd of Feb to 2.11% on the 27th of Feb with slightly greyish pathways and slightly less snow on plants and outdoor surfaces (see figure 2.3.1.9 and 2.3.1.10). Additionally, on the 3rd of March, when the snow started to fade away when it got older and darker, the average DF in the study room dropped to 1.98%.

Although, the 20th of Mar has the lowest snow-covered area the average DF in the study room is slightly higher (0.12%) than the 3rd. A glance at the DF maps shows all points have a lower value on March 20th in comparison to March 3rd (see figure 2.3.1.17 and 2.3.1.15) except the middle point right next to the window resulting in a higher average DF. This could have been caused by an error in data collection.

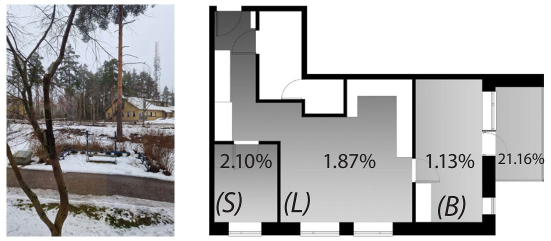


Figure 2.3.1.5 Average DF on 20th of Mar, 9:00 a.m.

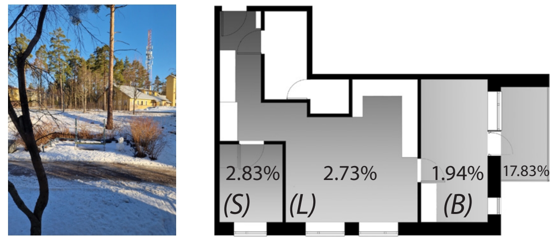


Figure 2.3.1.6 Average DF 16th of Mar, 8:30 a.m.

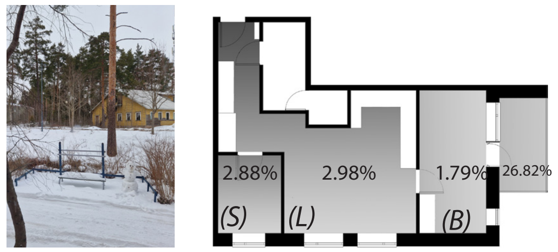


Figure 2.3.1.7 Average DF on 13th of Mar, 5:30 p.m.

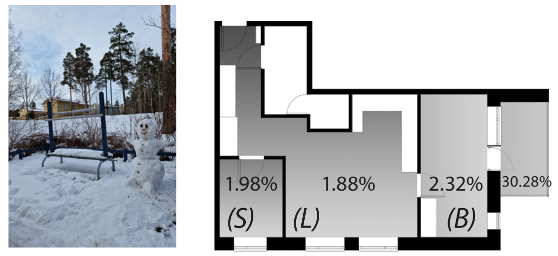


Figure 2.3.1.8 Average DF on 3rd of Mar, 2:30 p.m.

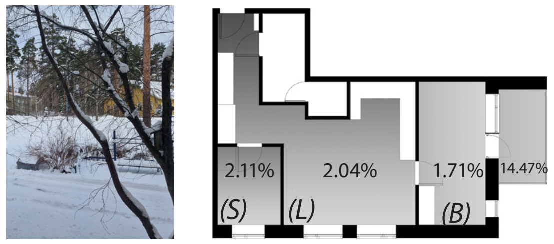


Figure 2.3.1.9 Average DF on 27th of Feb, 12:30 p.m.

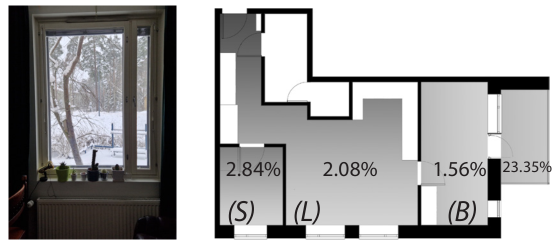


Figure 2.3.1.10 Average DF on 23th of Feb, 10:30

The highest value for average DF (2.88%) was mapped on the 13th of March under a fully overcast sky with old white snow covering the outdoor surfaces except for plants. This value is slightly higher (0.04%) than the average DF during a snowy day with a fresh and thick layer of snow covering surrounding surfaces as well as plants. A deeper analysis of the collocated data illustrates that out of 9 points, 4 of them have a higher DF in comparison to the 23rd of February (see figure 2.3.1.11 and 2.3.1.12) resulting in a higher average DF in this room.

This analysis suggests that the outcomes could have been influenced by human error or the irregular reflectance from indoor surfaces resulting in higher values at certain points. The same pattern can be seen in the average DF of the main living area (L); with the highest value of 2.98% (Figure 2.3.1.7) on the 13th of March. A comparison between this day and the 23rd of Feb indicates that 52% of the points have a higher DF on March 13th resulting in considerably higher DF (about 0.9%) than February 23rd (see figure 2.3.1.7 and 2.3.1.10).

A comparison between data collected between the 23rd of Feb and the 3rd of March as well as the 20th of March highlights that when the snow-covered surfaces get smaller and darker the average DF in the main living area (L) declines from 2.08% on the 23rd of Feb to 1.87% on 20th of March (see figure 2.3.1.10 and 2.3.1.5). The outcomes of the field measurements illustrate that the main living area is the second best-daylit room, as most of the time the average DF in this room was around a minimum of 2%.

The average DF in the bedroom differs from 2.32% to a minimum of 1.13%. The results illustrate that this room has the lowest DF among other

Figure 2.3.1.11 13th of Mar, 5:30 p.m.
Cloudy day with old white snow on ground.

Figure 2.3.1.12 23th of Feb, 10:30
Mild snowy day with fresh snow on trees and ground

rooms with only one day with an average DF above 2%. However, as the bedroom can have a lower DF between 1-2% (Pelsmakers, et al, 2022), the values still meet the minimum standards for a bedroom.

The highest DF for the bedroom and balcony is 2.32% and 30.28%, respectively (Figure 2.3.1.8 and 2.3.1.15). These data were collected under a semi-cloudy sky with old snow covering the ground. Nevertheless, the semi-cloudy sky has probably led to errors in measurements. As both the bedroom and balcony are oriented towards the west, and it was near the sunset that data was collected. Due to the semi-overcast sky, it is possible that the results had been influenced by direct sunlight (see figure 2.3.1.13).

Figure 2.3.1.13 General Sky view from bedroom on 3rd of March at 15:00

As previously discussed, the 23rd of February is a day with the highest snow coverage, however, when comparing the average DF, the 27th of February (Figure 2.3.1.14) with less snow covering the trees, the bedroom, and the balcony have a higher average DF (about 1.71%, 0.15% more than February 23rd). The average DF in this room is even higher (1.79%) on the 13th of March, with less snow covering the ground and no snow on bushes and trees (see figure 2.3.1.7).

Figure 2.3.1.14 27th of Feb, 12:30
Cloudy day with old white snow on some trees and ground.

Figure 2.3.1.15 3rd of Mar, 2:30 p.m.
Cloudy day with old white snow on ground, melted on the main roads.

By this time there were several snowy days in the Uusimaa region and municipalities had started cleaning the roads piling up snow in courtyards. The figure 2.3.1.16 shows that with a distance of (15-20 m) from the bedroom façade the pile of snow got higher, I assume this could be a reason for the average DF in the bedroom and the balcony. As the trees facing this façade are mature and taller than the level of the openings and there is more than 20 m distance between the trees and the openings, we cannot see the influence of collected snow on their branches on DF in this façade.

Figure 2.3.1.16 The size of the snow pile on 23rd and 27th of Feb and 13th of March, from left to right.

The daylight measurements on March 20th, with the lowest snow coverage, show the lowest average DF in the bedroom (B) and balcony 1.13% and 21.16% respectively (see figure 2.3.1.5 and 2.3.1.17), highlighting that reflectance from snow-covered surfaces increases the average DF in this sample.

Figure 2.3.1.17 20th of Mar, 9:00 a.m.
Foggy day with old melted grey snow on ground, melted on the main roads.

Figure 2.3.1.18 16th of Mar, 8:30 a.m.
Clear sky with old snow on ground, melted on the main roads.

General evaluation of daylight simulations

The evaluation of simulation maps of this case study depicts – as expected and measured- a minor rise in daylight availability when the number of snow-covered surfaces increases. Despite having about a 3 m height difference from the ground level, and a longer distance between the openings and surrounding mature evergreen trees, the bedroom, and balcony, facing towards the open courtyard with dense trees, show more sensitivity towards the presence of snow.

The simulations do not illustrate any changes between clear surfaces and small snow-covered surfaces with the same texture as the fresh snow with a reflectance factor of 40% (see figure 2.3.1.21 and 2.3.1.22). Only when the whole ground is covered with snow (reflectance factor of 85%), the bedroom and the balcony demonstrate a minor increase in average DF; from 0.850% to 0.851% in the bedroom and 14.361% to 14.369% in the balcony (see figure 2.3.1.20).

Moreover, when the trees and the roofs are covered with the same snow (reflectance factor of 85%), all rooms except the main living area (L) show a rise in average DF comparing the clear outdoor spaces and snow-covered outdoor environment (see figure 2.3.1.19 and 2.3.1.22). The average DF in this room decreased from 1.453% to 1.430%, an unpredictable change as nothing except the roof material and materials covering the trees changed. This could be caused by the limitation in modeling the gaps between tree branches and applying the right texture on deciduous trees, making it more difficult to investigate the role of snow-covered trees and other plants on average DF.

The analysis of this case study demonstrate that this sample with multiple openings on different facades receives some daylight during daylight hours. Nevertheless, when the snow covers the outdoor surfaces, the average DF increases; the vicinity of the trees to the openings, and the distance between the ground and openings are some of the factors influencing the role of snow on DF in this sample.

Average DF based on simulation *Daylight simulation* *DF %*

Figure 2.3.1.19 Fresh snow on the ground and trees

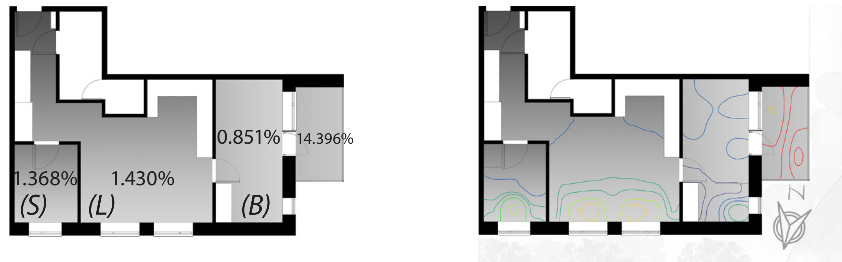


Figure 2.3.1.20 Fresh snow on the ground

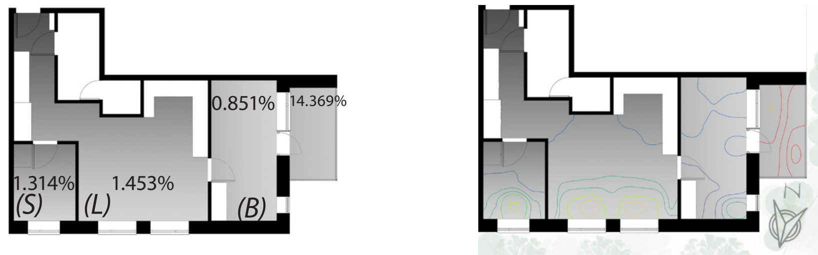


Figure 2.3.1.21 Some old snow on the ground

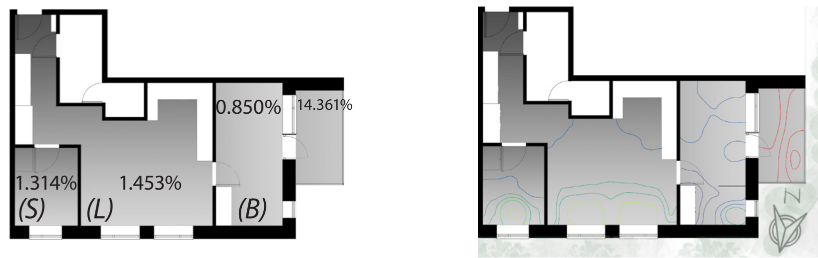


Figure 2.3.1.22 Clear ground_ no snow on the ground

- 8<x
- 7<x<8
- 6<x<7
- 5<x<6
- 4<x<5
- 3<x<4
- 2<x<3
- 1<x<2
- 1<x

2.3.2 Case study N.2:

According to the daylighting rules of thumb checklist, all living spaces have a deep plan, the ratio of the depth of the plan to the height of the upper edge of the opening is above 2 in all rooms (see table 2.3.2.1), and the kitchen area with the ratio of 3.52 is the worst daylit space in this case study.

Furthermore, both window area to floor area and the ratio of window area to wall area, create an opportunity for good daylight penetration (see table 2.3.2.1). However, it has been known that a glazed balcony can reduce daylight in the living spaces behind the balcony (Ribeiro, et al., 2020). Based on this fact, sample N.2 with a single southern façade and a glazed balcony covering all its openings, receives lower daylight throughout the day.

Table 2.3.2.1 Checklist for daylighting rules of thumb

Daylighting rules of thumb checklist	Main living area (L)	Kitchen area (K)	Bedroom (B)
Window on multiple facade	No	No	No
Shallow plan			
$\frac{Deapth\ of\ the\ room}{Distanace\ between\ upper\ edge\ of\ the\ opening\ and\ the\ floor} < 2$	≈ 2.74	≈ 3.52	2.81
$10\% < \frac{Window\ area}{Floor\ area} < 40\%$ Ideally around 20%	≈ 20 %		≈ 28%
$10\% < \frac{Window\ area}{Wall\ area} < 60\%$	≈ 40%		≈ 40%

Figure 2.3.2.1 Daylight penetration based on daylighting rules of thumb

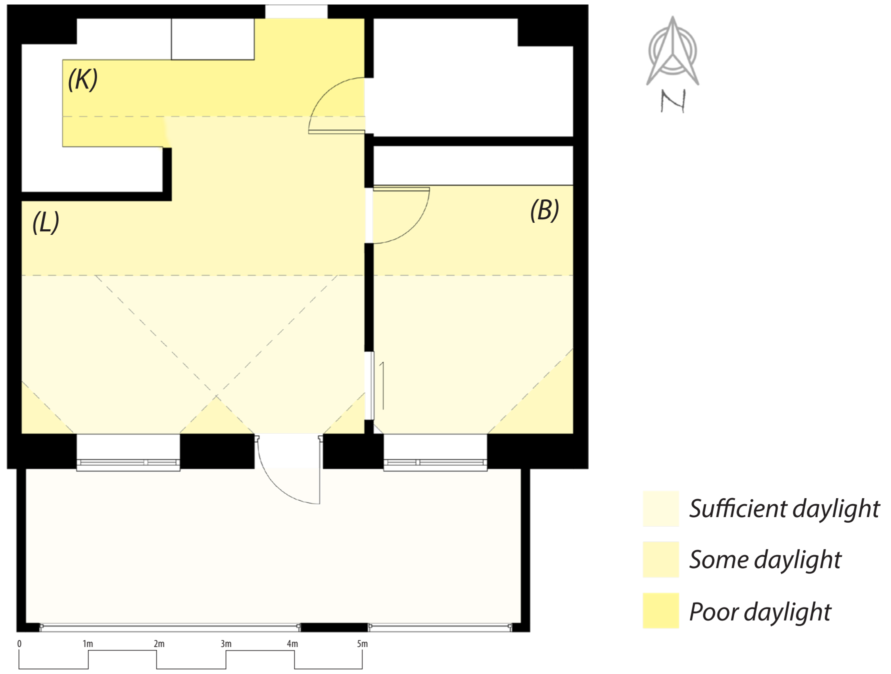


Figure 2.3.2.2 Depth of the main living area

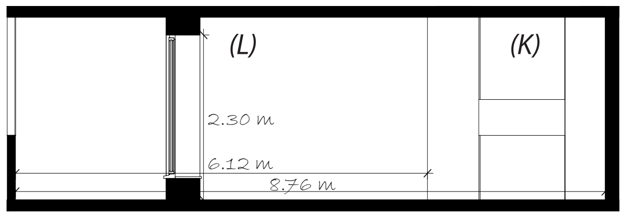
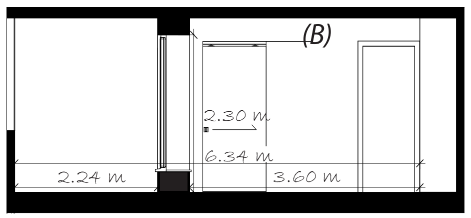


Figure 2.3.2.3 Depth of the bedroom



General evaluation of daylight measurements

Daylight was measured in 9 days, during February and March 2023 under different outdoor conditions. Two of these measurements were conducted under a semi-overcast sky, the 7th of March and the 11th of February (Figure 2.3.2.6 and 2.3.2.12). The average DF in the main living area, on these two days (old white snow covering the ground) are close to each other 1.27% on March 7th and 1.25% on February 11th, while the bedroom and the balcony have a higher value on the 7th of March 2.33% and 30.94%, respectively. The outcomes may have been influenced by the direct ray of the evening sun. These two days are excluded from the analysis, as the semi-overcast sky decreases the reliability of the data (See Figure 2.3.1.23 and 2.3.1.24, page 73, for a deeper investigation of the DF map). Additionally, the 19th of February with the highest snow coverage is chosen as a base for the study.

Figure 2.3.2.4 Average DF on 24th of Mar 4:00 p.m.

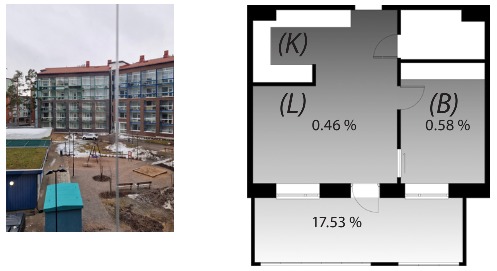


Figure 2.3.2.5 Average DF on 15th of Mar, 8:00 a.m.

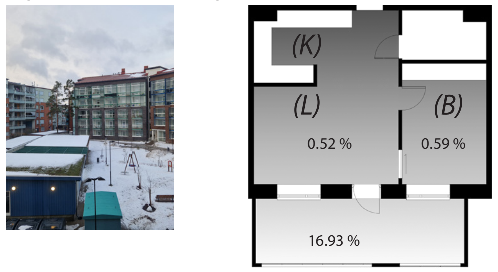


Figure 2.3.2.6 Average DF on 7th of Mar, 4:00 p.m.

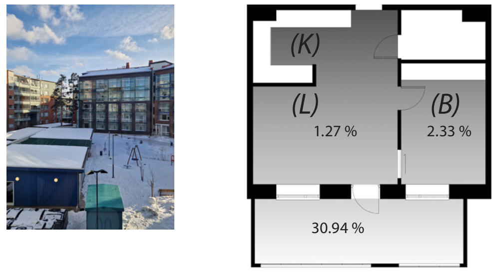


Figure 2.3.2.7 Average DF on 28th of Feb, 4:00 p.m.

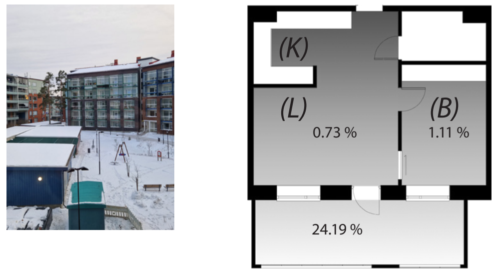


Figure 2.3.2.8 Average DF on 25th of Feb,1:00 p.m.

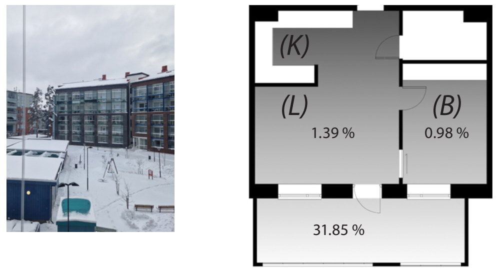


Figure 2.3.2.9 Average DF on 19th of Feb, 10:00 a.m.

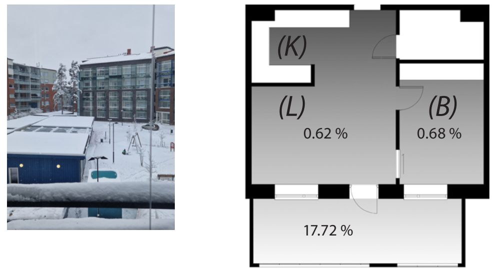


Figure 2.3.2.10 Average DF on 18th of Feb, 10 a.m.

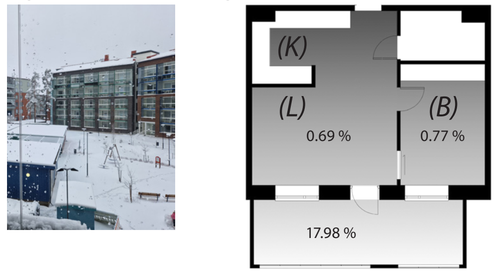


Figure 2.3.2.11 Average DF on 12th of Feb, 10:00 a.m.

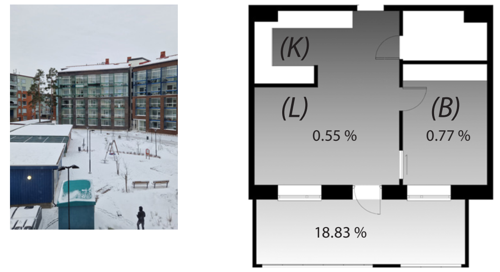
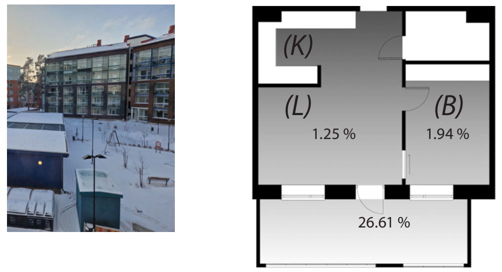


Figure 2.3.2.12 Average DF on 11th of Feb, 10:00 a.m.



As expected, the glazed balcony with single glazing has the highest average DF, ranging from 31.85% on the 25th of February to 16.93% on the 15th of March (figure 2.3.2.13). The high average DF in the balcony could be caused by the building's orientation towards the south, the open courtyard, the reflection from the surrounding glazed surfaces, and the glazing type (Lumon, EN12150-1), allowing more daylight to penetrate the space while reducing the light penetration into main living area and bedroom.

On February 19th, the average DF in the balcony is 17.72 % (figure 2.3.2.9), comparing this outcome with the average DF on the day with the lowest snow coverage (24th of Mar) does not illustrate a noticeable difference, the average DF is only 0.19% lower on March 24th (figure 2.3.2.4). Furthermore, the 12th (Figure 2.3.1.14), 18th, 25th, and 28th of Feb with smaller snow-covered surfaces have a higher average DF in comparison to the 19th of Feb (18.83%, 17.98%, 31.85%, and 24.19% respectively), suggesting that these results might have been influenced by other factors, such as

Figure 2.3.1.13 15th of Mar, 8:30 a.m.
Cloudy day, old dirty snow on the ground.

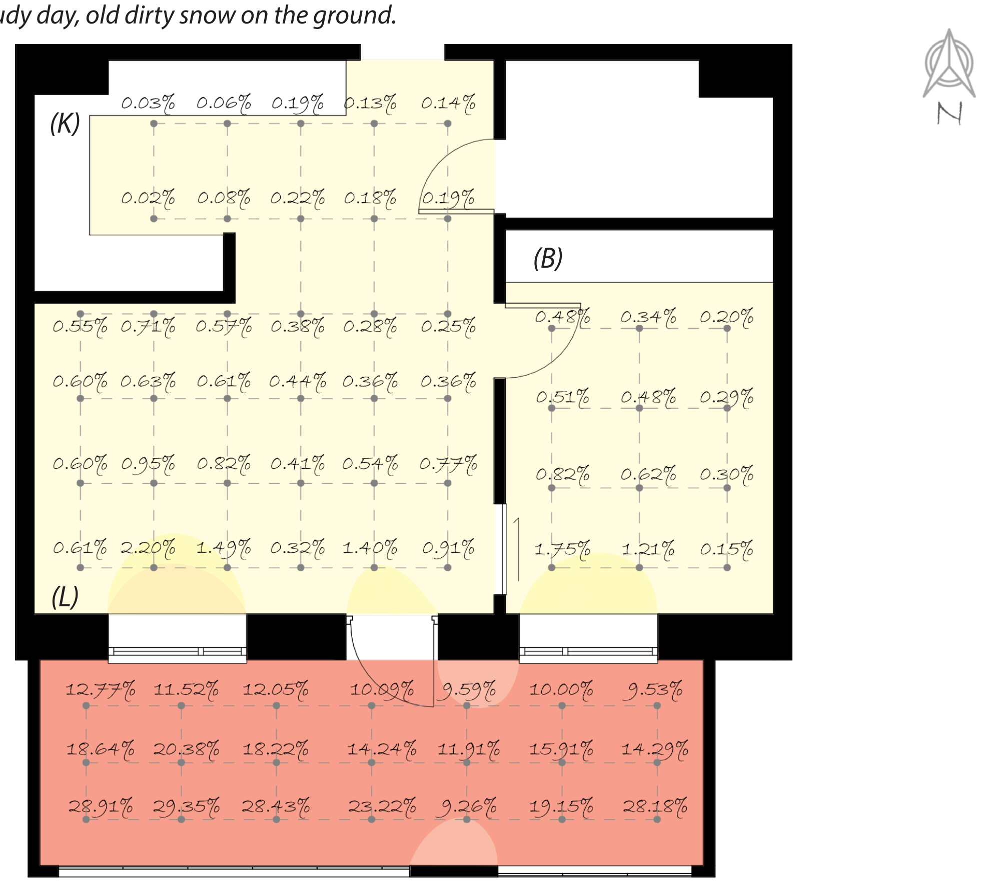
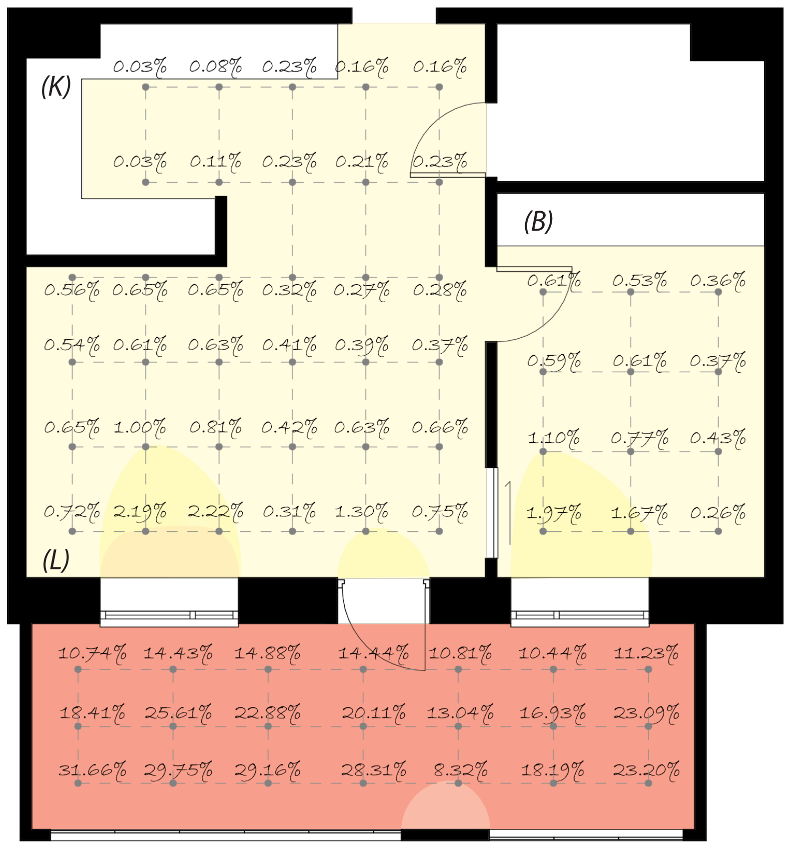
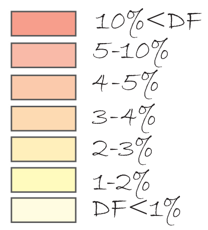


Figure 2.3.1.14 12th of Feb, 10:00 a.m.
Cloudy day, fresh snow on ground and the trees.





The bedroom (B) is the best-daylit space in this case study with average DF ranging from 1.11% on the 28th of Feb (figure 2.3.2.7) to 0.58% on the 24th of March (figure 2.3.2.4 and 2.3.2.16). The minimum acceptable DF for a bedroom is 1% (Pelsmakers, et al., 2022), nevertheless the average DF in the bedroom is mostly below 1% increasing the need for artificial light even during daylight hours.The highest average DF (1.11%) belongs to February 28th (Figure 2.3.1.17), under the overcast sky, with some snow on the roofs, old snow covering the ground, and a pile of snow near the buildings and different parts of the courtyard (figure 2.3.2.15).

Figure 2.3.2.15 The difference in snow coverage on the 28th and 25th of Feb.

Figure 2.3.2.16 24th of Mar 4:00 p.m.
Cloudy day, less old dirty snow on the ground.

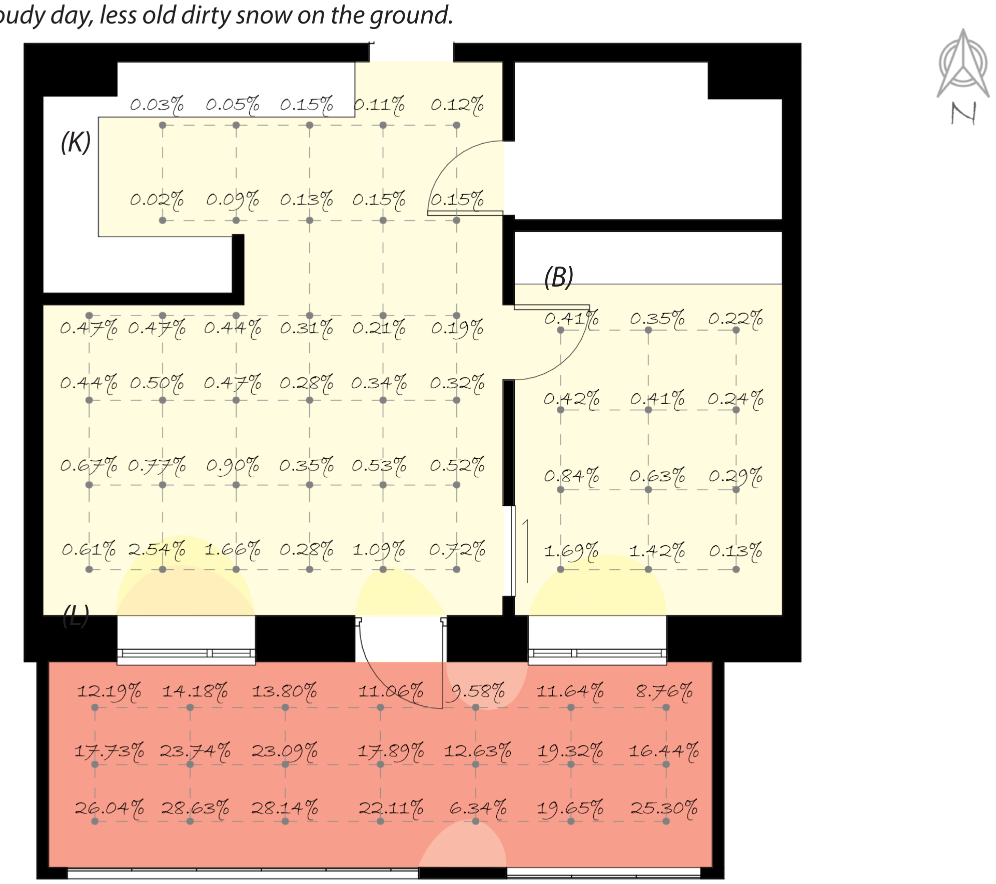
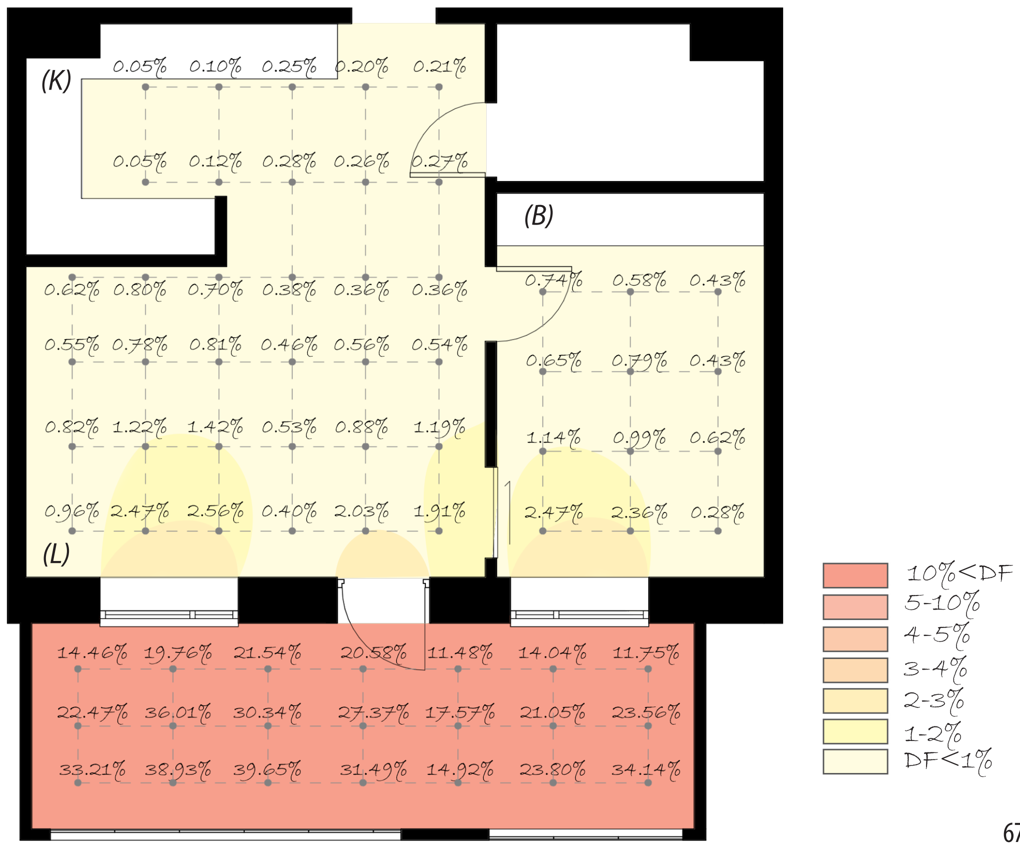


Figure 2.3.1.17 28th of Feb, 4:00 p.m.
Cloudy day, old white snow on the ground, nothing on trees.

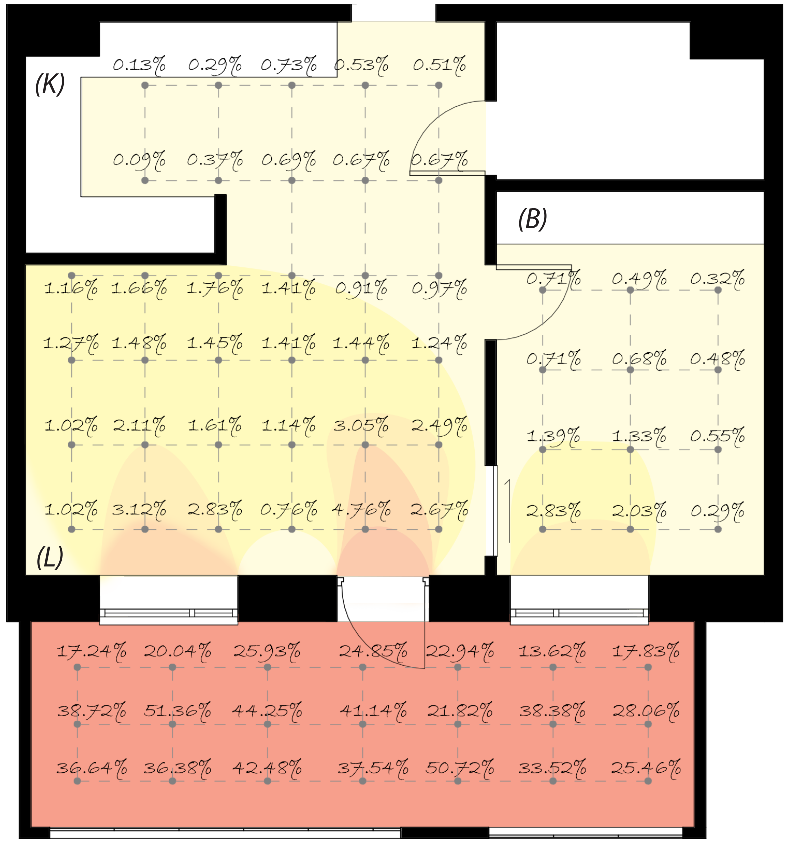


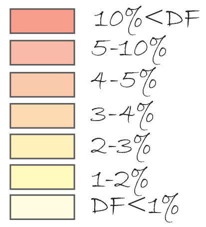
The second highest value (0.98%) was mapped on the 25th of February (Figure 2.3.2.19), under a fully overcast sky, with snow on trees and ground. On this day the snow coverage is higher than Feb 28th, while the average DF is lower (about 0.13%). By investigating the outdoor condition, pictures highlight that on the 28th of Feb, some of the glass surfaces in surrounding blocks act as a mirror and this condition might influence the reliability outcome (figure 2.3.2.18).

Figure 2.3.2.18 The outdoor condition on 28th of Feb .

Although the snow coverage on trees was less on the 28th and 25th of February, the average DF in the bedroom was higher in comparison to the 19th of February (1.11%, 0.98%, and .68% respectively. Suggesting that the bigger and closer the snow-covered surface is to the building it has more influence on the DF. The lowest average DF (0.58%) was recorded on the 24th of March with the smallest snow coverage (figure 2.3.2.16). Based on the analysis, as the snow-covered areas melt the average DF decreases.

Figure 2.3.2.19 25th of Feb,1:00 p.m.
Cloudy day, white snow on the ground, snow on the trees.





The main living area (L) including the living room and the kitchen, as predicted by the DRT checklist, has the lowest average DF ranging from 1.39% to 0.46%, making it unlikely to do the daily tasks without artificial light. The highest data was collected on the 25th of February, under a fully overcast sky. Due to piles of snow covered with new snow, it is reasonable that the average DF is 0.77% higher than the 19th of February (figure 2.3.1.19 and 2.3.1.20).

A comparison between the average DF on 18th and 19th of February demonstrate a higher DF, in all rooms (figure 2.3.1.20 and 2.3.1.21), on 18th of February with less snow covering the outdoor surfaces and trees, the only noticeable factor was that on 18th daylight was measured during a snowy sky, raising an assumption that DF could be even higher when it is snowing. The lowest DF in main living area (0.46%) was also mapped on 24th of March with lowest snow coverage (figure 2.3.2.4 and 2.3.2.16).

Figure 2.3.1.20 19th of Feb, 10:00 a.m.
Snowy day, white snow on the ground, snow on the trees.

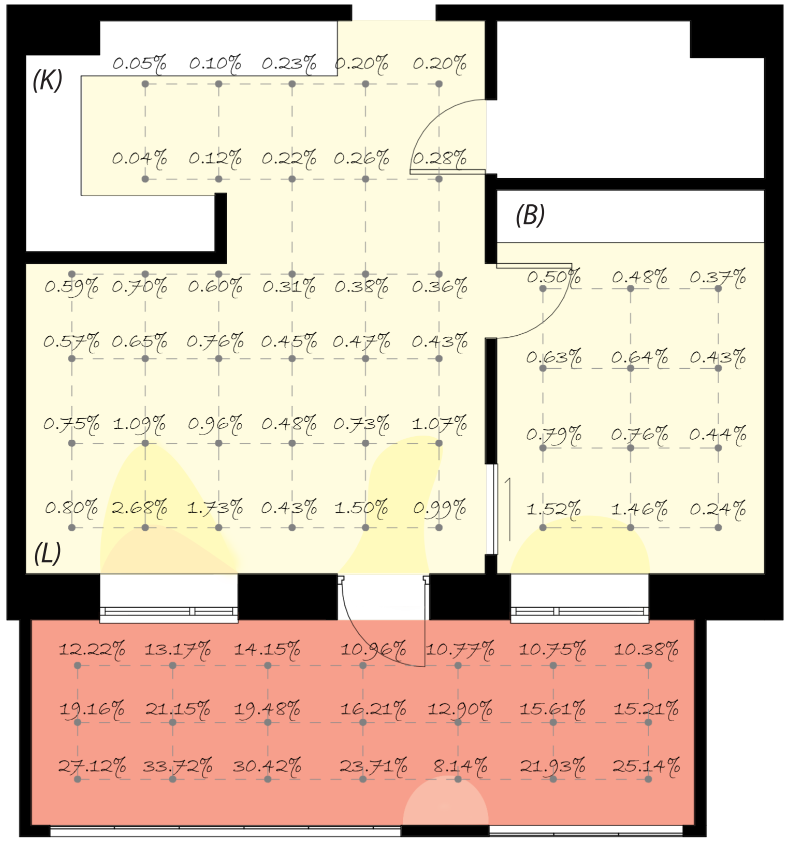


Figure 2.3.2.21 18th of Feb, 10:00 a.m.
Snowy day, white snow on the ground, snow on the trees.

This apartment is on the third floor (about 7 m or more above the ground level), facing an open courtyard with young trees (height < 2 m) and the only two mature evergreen trees are at a great distance (figure 2.3.1.22) with the main openings decreasing their influence on DF. Nevertheless, the snow collected on the green roof of the storage area and the sloped roof of the surrounding buildings, the piles of snow created by cleaning the roads increase the reflectance resulting in higher DF.

Figure 2.3.2.22 The position of trees in the site

Figure 2.3.2.23 7th of Mar, 4:00 p.m.
Semi-cloudy day, old white snow on the ground, nothing on trees.

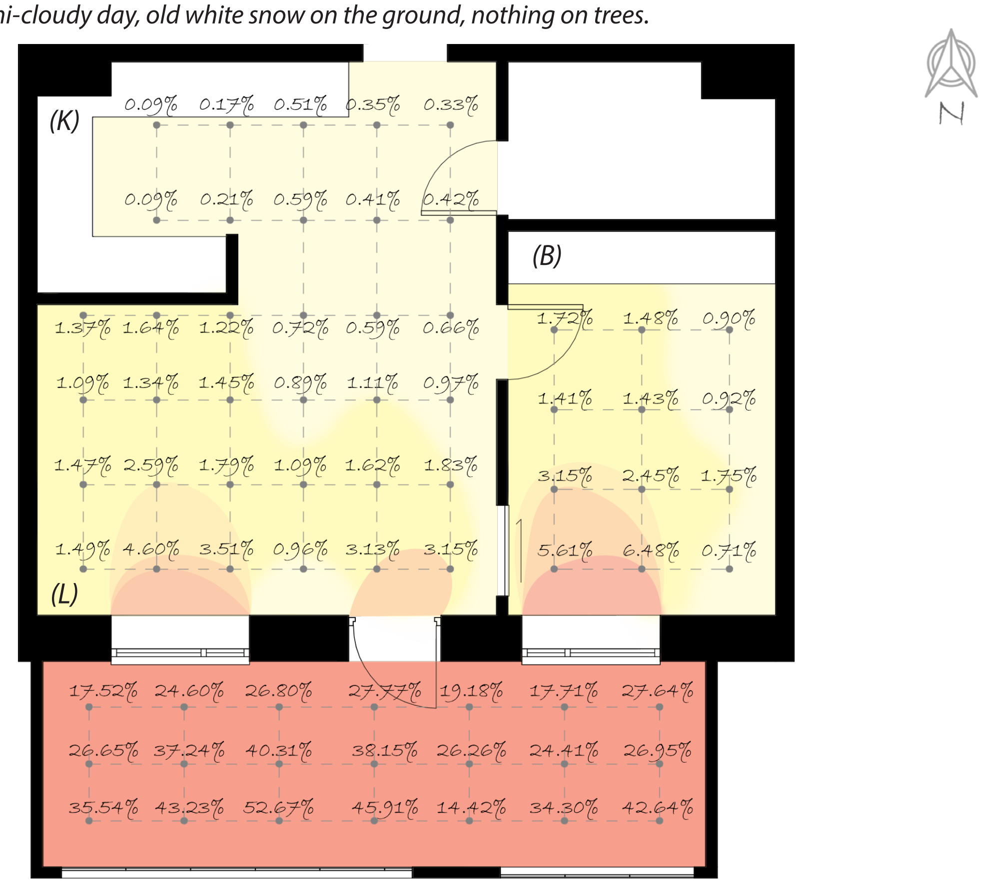
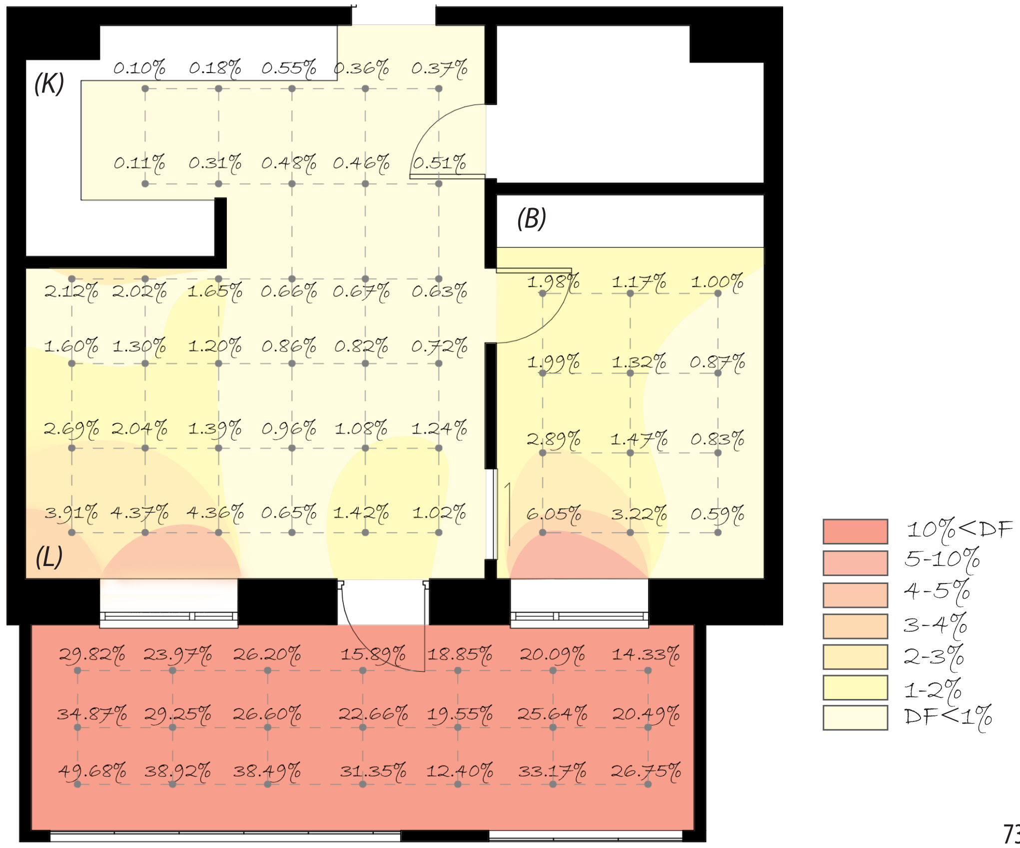


Figure 2.3.1.24 11th of February, 10:00 a.m.
Cloudy day, fresh snow on ground and the trees.



General evaluation of daylight simulations

The evaluation of simulation results, in this case, does not demonstrate a clear pattern between the number of snow-covered surfaces and the average DF. In all simulations run on different days and hours, with exact same indoor and outdoor materials, with only difference in the increasing number of snow-covered areas, the simulation results show a small fall in average DF in all rooms (Table 2.3.2.2). As it is illustrated in the figure 2.3.1.27 and 2.3.1.28, by changing the grass material with a reflectance factor of 15% to old snow with a reflectance factor of 40% the average daylight factor decreased from 0.312% on clear ground condition to 0.310% with some old snow on the ground.

Nevertheless, when all outdoor surfaces (grounds and rooftops) are covered with fresh snow with a reflectance factor of 80% the average DF decreases in all rooms (Figure 2.3.1.26 and 2.3.1.27). Additionally, when trees are covered with fresh snow the average DF in all rooms rises back to the average DF in days without snow see table.

Table 2.3.2.2 Average DF in different scenarios

Average DF on	Clear ground	Some old snow on ground	Snow on ground and some roofs	Snow on grounds, roofs and trees
Main living area	0.312%	0.310%	0.295%	0.312%
Bedroom	0.471%	0.471%	0.444%	0.471%
Balcony	8.962%	8.962%	8.835%	8.962%

Average DF based on simulation — *Daylight simulation* — *DF %*

- 8<x
- 7<x<8
- 6<x<7
- 5<x<6
- 4<x<5
- 3<x<4
- 2<x<3
- 1<x<2
- 1<x

Figure 2.3.1.25 Fresh snow on the ground and trees

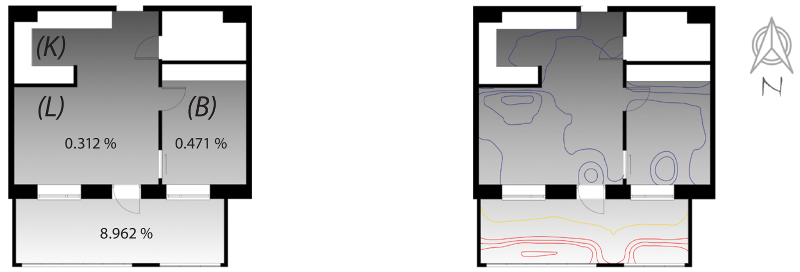


Figure 2.3.1.26 Fresh snow on the ground

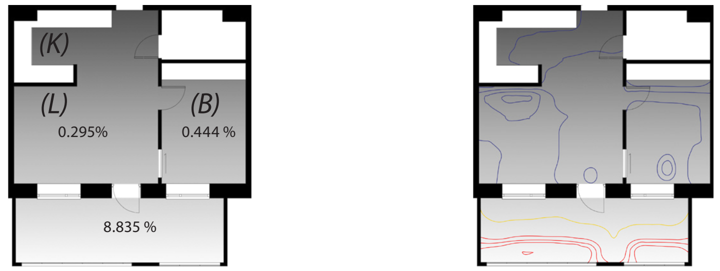


Figure 2.3.1.27 Some old snow on the ground

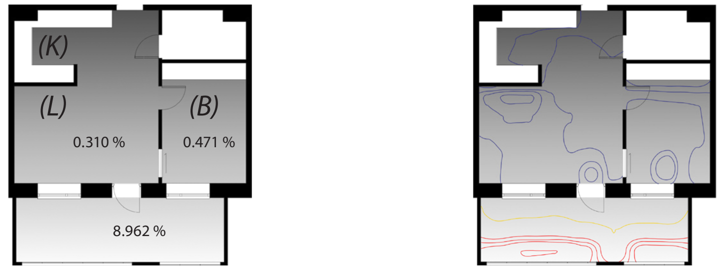
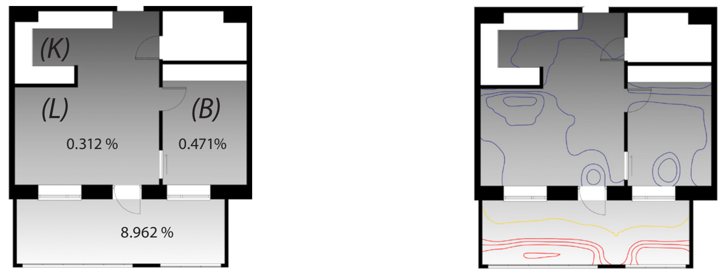


Figure 2.3.1.28 Clear ground_ no snow on the ground

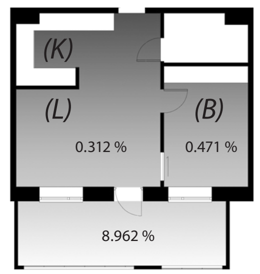


According to the simulation results, the average DF is significantly low (0.321% in the main living area and 0.471% in the bedroom). Although to reach better accuracy in simulations, the whole block was modeled, and the location of the buildings, their size, and height are as same as the actual buildings, the details of the façades are not included in the models. Moreover, the material applied to each surface is similar to real material, however, the actual reflectance factor of surfaces is not identified, therefore, materials were assigned based on assumption). These differences between the model and the real condition cloud be one of the reasons for unreliable simulation results.

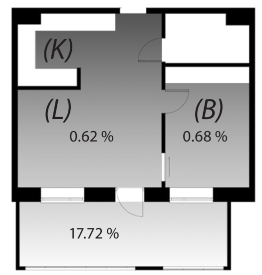
Comparing the outcomes from the simulation, run on the same day and time as the daylight was measured illustrates a significant gap between the results. The average DF from daylight measurement is remarkably higher than simulation results, almost 2 times. For instance, based on the field measurement the average DF on the 19th of Feb in the main living area, bedroom, and balcony are as followed 0.62%, 0.68%, and 17.72% (Figure 2.3.2.29). While under the same outdoor condition (Fresh snow on trees and other outdoor surfaces) simulation results show the average DF of 0.312%, 0.471%, and 8.9662% for the main living area, bedroom, and balcony (Figure 2.3.1.29). However, the results of the field measurements on days with melting snow, become closer to simulation results (Figure 2.3.2.30), suggesting that the software does not have the necessary sensitivity towards the presence of snow.

According to the three method (DRT, field measurements and simulations), this sample has the lowest average DF. In addition, due to its distance from ground level, it is less influenced by the presence of snow, and factors such as reflectance from surrounding glazed balconey influence the DF more than snow-covered surfaces.

Figure 2.3.1.29 Comparison between average DF in simulation results (fresh snow on the ground and trees) and field measurement on19th Feb.

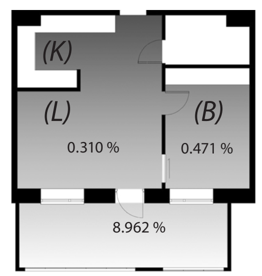


Average DF in simulation results

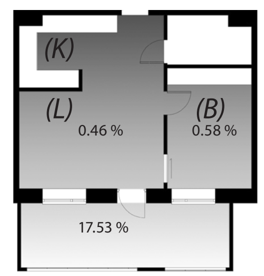


Average DF in field measurement

Figure 2.3.1.30 Comparison between average DF in simulation results (Some old snow on the ground) and field measurement on 24th of Mar



Average DF in simulation results



Average DF in field measurement

2.3.3 Case study N.3:

This case study is the only case study without a glazed balcony covering its opening, resulting in a better-daylit penetration. In addition, case study N.3 is the only sample with a room receiving light from multiple directions. Although the main living area is slightly deep (2.79 more than the max ratio of 2), the room receives adequate daylight due to the light penetration from multiple façades. The southern façade with a window area to wall area of 40% feels connected to the outdoor environment. The eastern façade in the main living area has a poor visual connection to the outside (Figure 2.3.3.2) due to its low (17%) window-to-wall area.

The office room with its shallow plan (1.52< max of 2), ideal window to floor area (25%), as well as window to floor area of 35% is the best-daylit room.

Table 2.3.3.1 Checklist for daylighting rules of thumb

Daylighting rules of thumb checklist	Main living area (L)	Office room (O)
Window on multiple facade	Yes	No
Shallow plan $\frac{\text{Deapth of the room}}{\text{Distanace between upper edge of the opening and the floor}} < 2$	≈ 2.79	≈ 1.52
$10\% < \frac{\text{Window area}}{\text{Floor area}} < 40\%$ Ideally around 20%	≈ 25 %	≈ 25%
$10\% < \frac{\text{Window area}}{\text{Wall area}} < 60\%$	≈ 17% Eastern wall ≈ 40% southern wall	≈ 35%

Figure 2.3.3.1 Daylight penetration based on daylighting rules of thumb

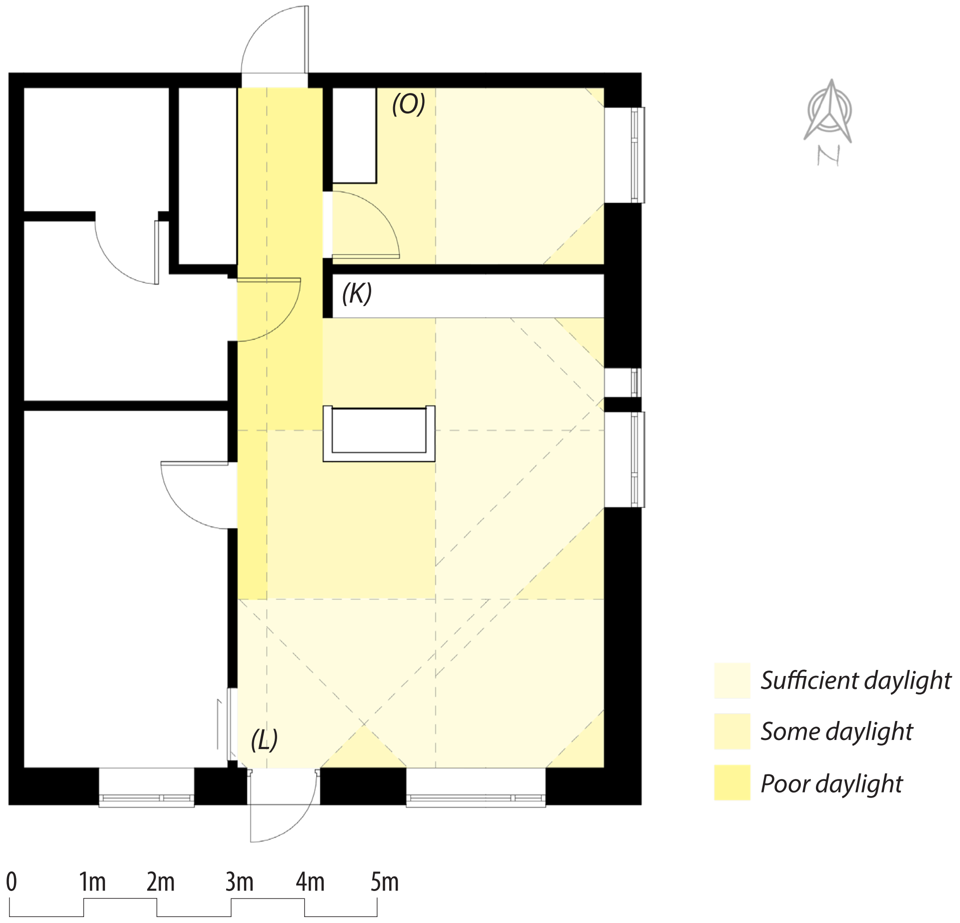


Figure 2.3.3.2 Depth of the main living area

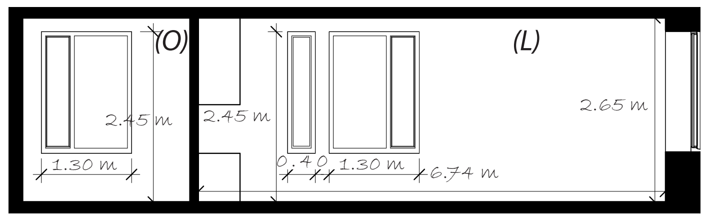
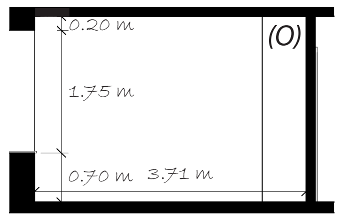


Figure 2.3.3.3 Depth of the office



General evaluation of daylight measurements

The daylight was measured on 10 days starting from the 11th of February until the 24th of March, under different conditions ranging from fully snow-covered surfaces to melting snow under the overcast or clear sky. In order to achieve a better insight into the role of snow on daylight, the data collected on the 11th of Feb (Figure 2.3.3.13) and the 7th of Mar (Figure 2.3.3.6) are excluded from the analysis, as the semi-overcast sky with direct sunlight, might have influenced the accuracy of the results (See Figure 2.3.3.19 & Figure 2.3.3.22, pages 85 &87 for a deeper investigation of the DF map.. Additionally, the owner of this sample changed the furniture and function of the Office room (O) after the 11th of February which influenced the average DF significantly, increasing from 1.77% on the 11th of February to 4.89% on the 12th of February (Figure 2.3.3.13 and 2.3.3.12). The 19th of February with the highest snow coverage is chosen as a base for the analysis.

As predicted by the DRT checklist, the measurements also depict that the office room (O) is the best-daylit room in this sample with average DF ranging from 5.97% to 3.42%. The highest average DF (5.97%) was recorded on the 19th of February with fresh snow covering the ground and the trees (Figure 2.3.3.9).

Figure 2.3.3.4 Average DF on 24th of Mar 4:30 p.m.

Figure 2.3.3.5 Average DF on 15th of Mar, 8:15 a.m.

Figure 2.3.3.6 Average DF on 7th of Mar, 3:45 p.m.

Figure 2.3.3.7 Average DF on 28th of Feb, 3:45 p.m.

Figure 2.3.3.8 Average DF on 25th of Feb,2:00 p.m.

Figure 2.3.3.9 Average DF on 19th of Feb, 10:00 a.m.

Figure 2.3.3.10 Average DF on 18th of Feb, 10:00 a.m.

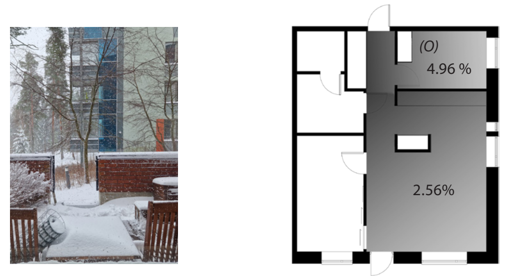


Figure 2.3.3.11 Average DF on 13th of Feb, 12:00 p.m.

Figure 2.3.3.12 Average DF on 12th of February, 12:00 p.m.

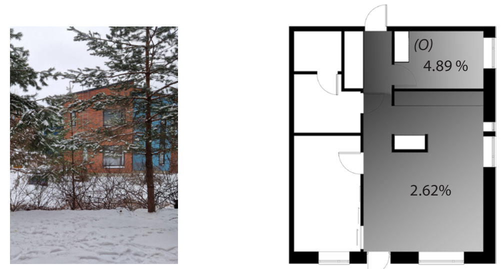


Figure 2.3.3.13 Average DF on 11th of February, 10:00 p.m.

This room illustrates a clear pattern regarding the presence of snow and DF. Take the 12th and 13th of February as an example (DF map on page 91, Figure 2.3.3.29 & Figure 2.3.3.30), the snow covers the ground and nearby evergreen trees resulting in an average DF of 4.89%, and the average DF decreased to 4.65% when the snow started melting on February 13th (Figure 2.3.3.11 and 2.3.3.12).

12th Feb

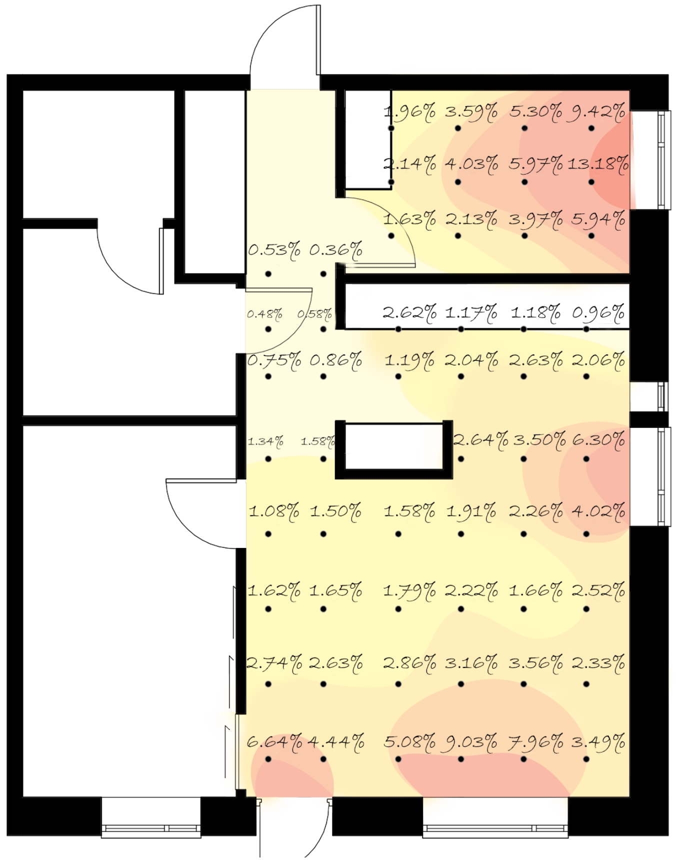
13th Feb

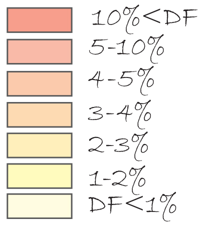
Figure 2.3.3.14 The snow condition on 12th and 13th of February

Yet, the average DF increased to 4.96% on the 18th of February (Figure 2.3.3.10) when the fresh snow covers the ground and the trees. A comparison between the 18th of February and the 25th of February (Figure 2.3.3.8) with average DF of 5.49% highlights that when there is more snow on trees the room has a higher average DF (Figure 2.3.3.15 and 2.3.3.16).

Figure 2.3.3.15 25th of Feb,2:00 p.m.
Cloudy day, white snow on the ground, snow on the trees.

Figure 2.3.3.16 18th of Feb, 10:00 a.m.
Snowy day, white snow on the ground, snow on the trees.



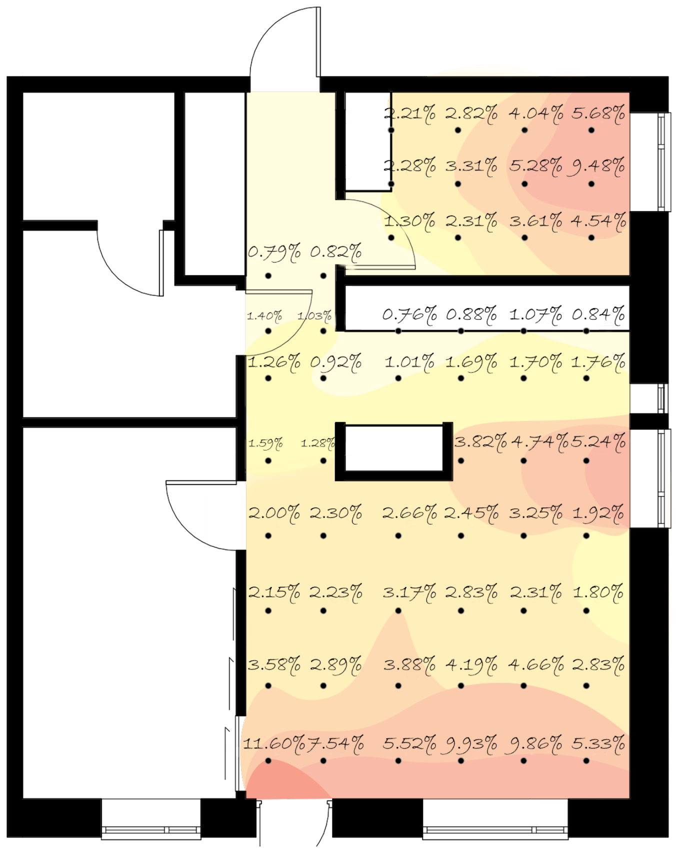


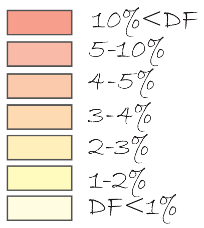
The average DF in the office room decreased when the snow started to fade away, the 24th of March with the lowest snow coverage (Figure 2.3.3.4) has the lowest DF (3.42%). The only irregular result was mapped on the 15th of March (Figure 2.3.3.18 and 2.3.3.5), further analysis of the pictures shows that, although the daylight was measured under an overcast sky the morning sun is visible, and it is possible that the sunlight was measured in some points.

Figure 2.3.3.17 The sky condition on 15th of March.

Figure 2.3.3.18 15th of Mar, 8:15 a.m.
Cloudy day, old dirty snow on the ground.

Figure 2.3.3.19 7th of Mar, 3:45 p.m.
Semi-cloudy day, old white snow on the ground, nothing on trees.





According to the field measurements, the average DF in the main living area (L) with openings on multiple façades and a solid wall dividing its space and blocking the light penetration on the deepest part of the plan (Figure 2.3.3.1), rages from 3.41% to 1.98%. As expected, the lowest value (1.98%) belongs to the 24th of March with the lowest snow coverage (Figure 2.3.3.21)

Figure 2.3.3.20 The snow coverage on 24th of March.

Figure 2.3.3.21 24th of Mar 4:30 p.m.
Cloudy day, less old dirty snow on the ground.

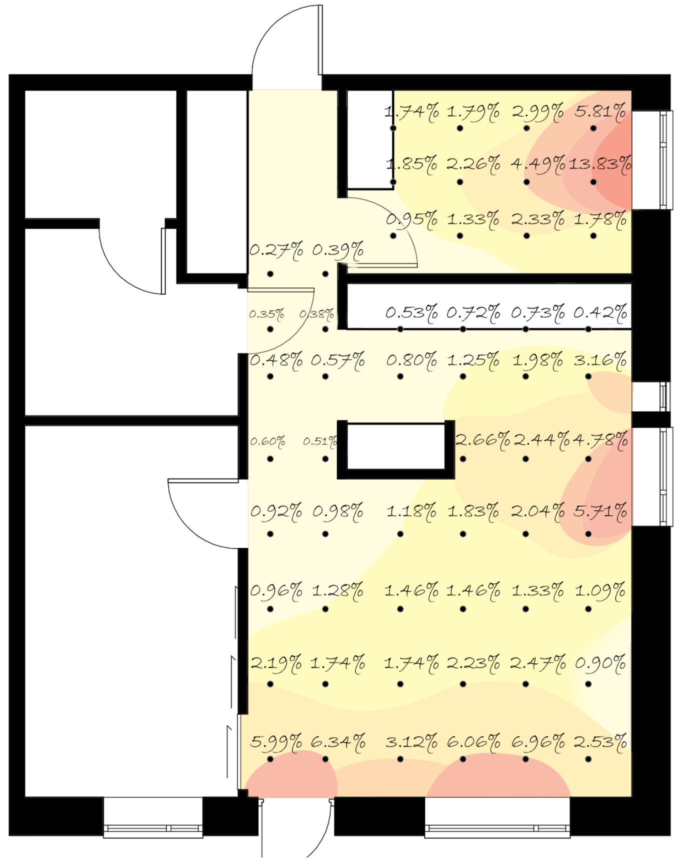
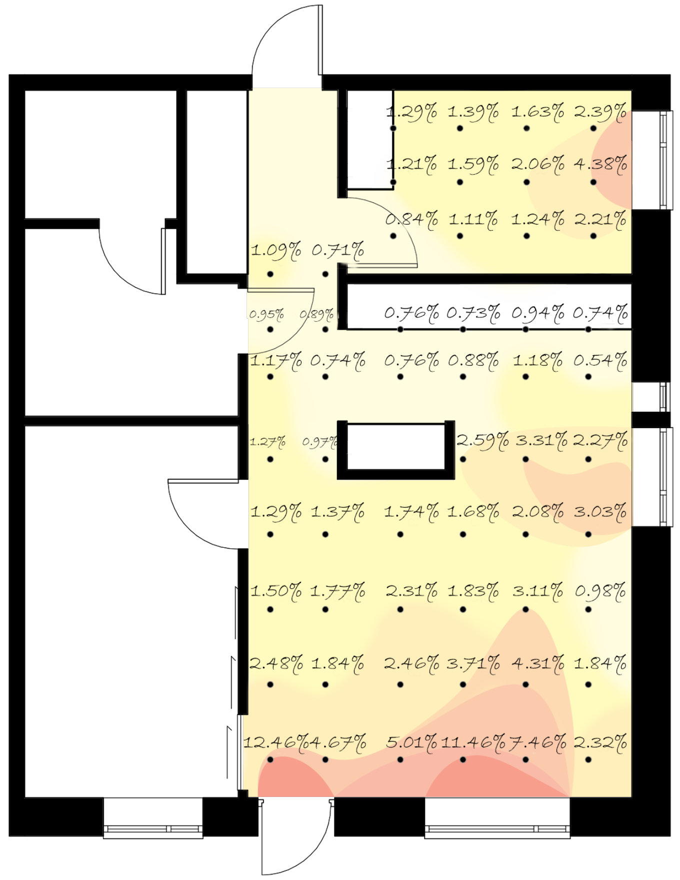
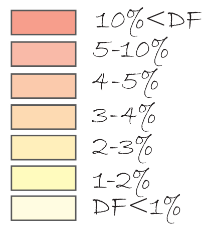


Figure 2.3.3.22 11th of February, 10:00 a.m.
Cloudy day, fresh snow on ground and the trees.





The highest average DF was recorded on the 25th of February with less snow on trees in comparison to the 19th of February (Figure 2.3.3.23), the only difference was that the patio in front of the southern opening was covered with snow on the 25th, while the snow was removed from this surface on 19th, the average DF on February 19th(Figure 2.3.3.26), in main living area, was 3.09%, 0.32% less than 25th of February (Figure 2.3.3.24). This suggests that when the snow-covered surfaces are closer to the openings, they can have a greater influence on average DF.

25th Feb   19th Feb

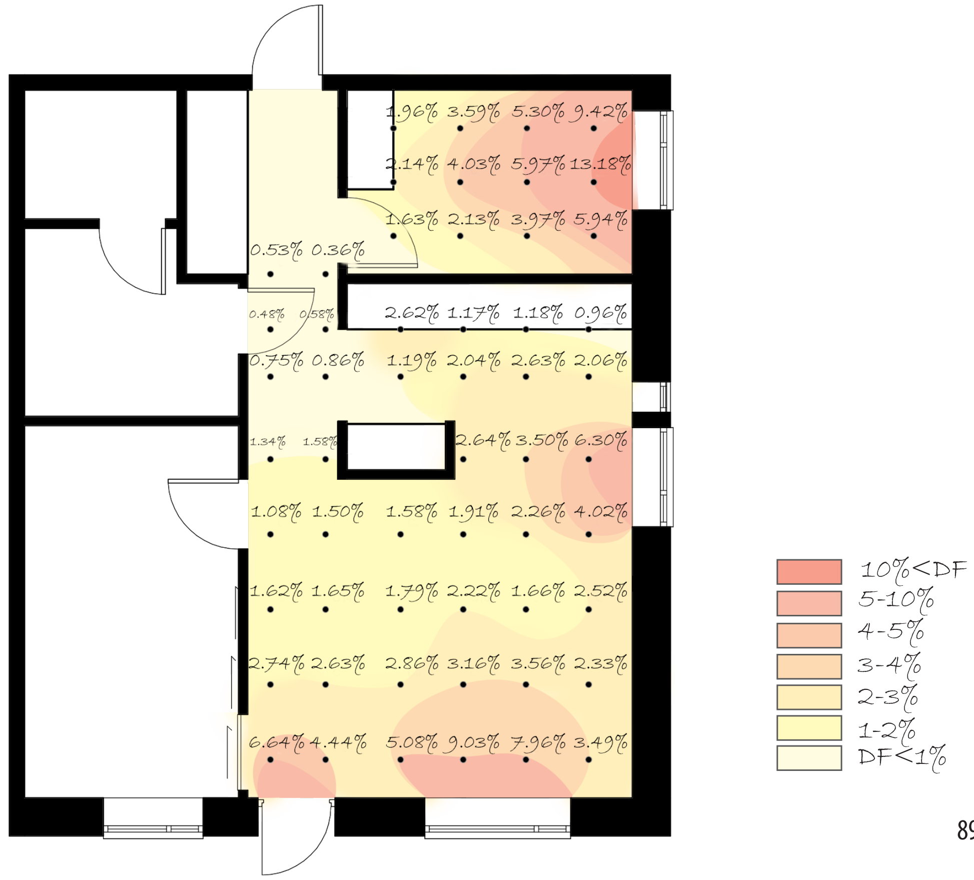
Figure 2.3.3.23 The comparison between snow coverage on trees

25th Feb   19th Feb

Figure 2.3.3.24 The comparison between snow coverage on patio

Figure 2.3.3.25 28th of Feb, 3:45 p.m.
Cloudy day, old white snow on the ground, nothing on trees.

Figure 2.3.3.26 19th of Feb, 10:00 a.m.
Snowy day, white snow on the ground, snow on the trees.



Based on the measurements, the average DF in the main living area is similar on the 13th and 18th of February (2.57% and 2.56% respectively), despite the significant difference in snow coverage (Figure 2.3.3.27). The accuracy of the results might have been affected by the error in data collection, either error caused by humans or unstable sky conditions, figure 2.3.3.28 shows that the southern window might have received direct sunlight on the 13th of February.

13th Feb *18th Feb*

Figure 2.3.3.27 The comparison between snow coverage on 13th Feb and 18th Feb

Figure 2.3.3.28 The sky condition on 13th Feb.

Figure 2.3.3.29 12th of Feb, 12:00 a.m.
Cloudy day, fresh snow on ground and the trees.

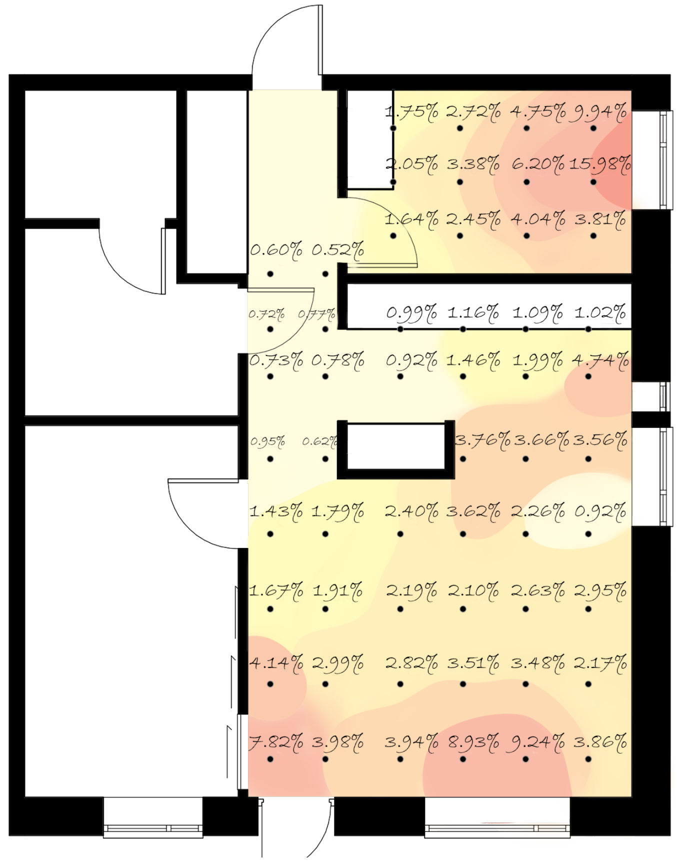
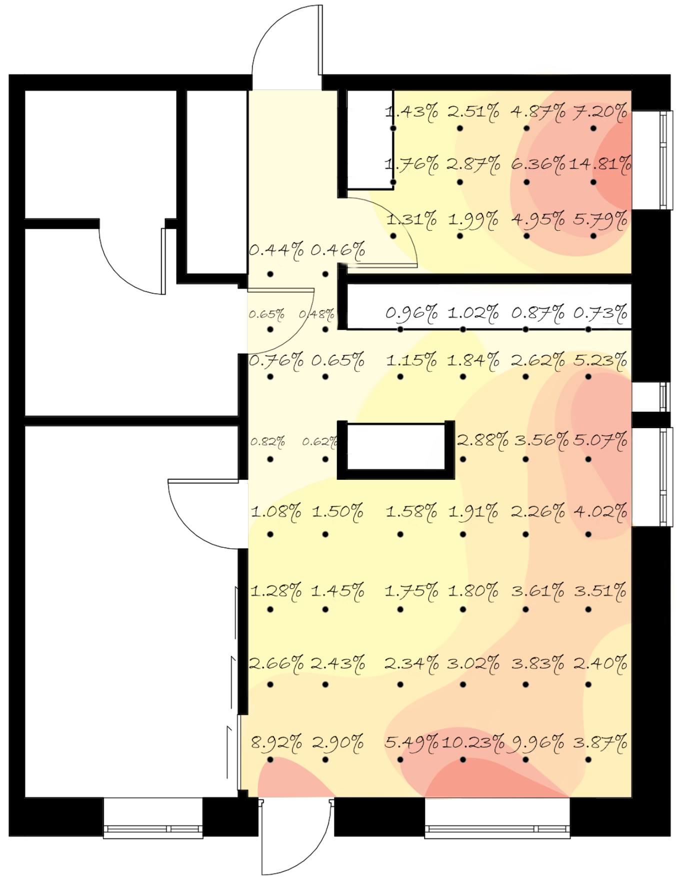
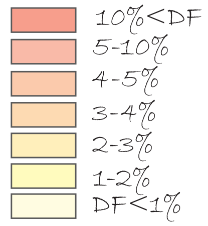


Figure 2.3.3.30 13th of Feb, 12:00 p.m.
Cloudy day, melting snow on the ground, nothing on trees.





General evaluation of daylight simulations

The evaluation of the simulation's outcomes illustrates a minor rise in average DF in the main living area (L) and the office room (O) when the number of snow-covered surfaces increases (Figure 2.3.3.32 and 2.3.3.34). For instance, in the main living area average DF range from 0.685% when there is no snow to 0.686% with snow covering all outdoor surfaces.

Moreover, the average DF in the bedroom and office room decreases (from 0.153% to 0.099% in the bedroom and from 0.864% to 0.863% in the office room) when the outdoor environment is covered with some old snow (reflectance factor 40%). When the outdoor environment is covered with fresh snow (reflectance factor 80%) the average DF in the office increase to 0.863%, yet no matter how the amount and the albedo of snow increase the average DF in the bedroom remains unchanged. One explanation could be that the old evergreen tree is so close to the window, which acts as a barrier to daylight, while the other trees surrounding the house are much younger and smaller than this tree and there is about a 2 m distance between them and the openings.

Although to gain a better insight into the role of snow in daylight quality, the location of the surrounding buildings, their highest and the general form was modeled accurately, the difference in details of the façade, the actual reflectance factor of the material, and the real distance between surrounding trees and the openings might have influenced the results. As the simulations do not illustrate a noticeable pattern between different scenarios.

Average DF based on simulation *Daylight simulation* *DF %*

Figure 2.3.3.31 Fresh snow on the ground and trees

DF %:
- 8<x
- 7<x<8
- 6<x<7
- 5<x<6
- 4<x<5
- 3<x<4
- 2<x<3
- 1<x<2
- 1<x

Figure 2.3.3.32 Fresh snow on the ground

Figure 2.3.3.33 Some old snow on the ground

Figure 2.3.3.34 Clear ground_ no snow on the ground

A general comparison between outcomes from daylight measurements and the simulation under the same outdoor condition indicates that the models are less affected by the presence of snow, as they do not demonstrate the same changes between the results when the amount and the quality of snow change. Moreover, the average DF based on the simulation is far less than the measured data, take the scenario with fresh snow covering the ground and trees as an example, the average DF in this scenario is below 1% in all rooms (Figure 2.3.3.31) while the average DF on 19th of February with a similar outdoor condition is 5.97% in the office room and 3.09% in the main living area.

This is much lower than the acceptable range, it could be assumed that the results from simulations are not reliable enough, as the software is not sensitive to different outdoor conditions and the reflectance factor of the covering material. Additionally, as there is a difference between the actual outdoor environment and the model, there is a noticeable difference between outcomes.

The general evaluation of daylight availability based on three methods illustrates that this case study has a high average DF, and due to its low distance from ground level is more affected by snow-covered surfaces, as a small snow-covered surface such as a patio can increase its average DF. Although the field measurements and DRT indicates that this sample has a high DF and is more influenced by the presence of snow, the simulation results do not demonstrate a reliable outcome.

2.3.4 Summary and comparison:

The purpose of this research was to understand the role of snow on daylight availability in Finnish housing, by analyzing the difference in DF under different outdoor conditions ranging from fully snow-covered surfaces and clear surfaces. However, during this period there was no opportunity to collect data with clear outdoor surfaces, therefore the highest snow coverage is chosen as the base for understanding the role of snow in daylight.

Table 2.3.4.1 Checklist for daylighting rules of thumb

Daylighting rules of thumb checklist	***N.1***	***N.2***	***N.3***
Orientation	North, Northwest	South	South, East
Window on multiple facade	Yes	No	Yes
Shallow plan	Bedroom, and study room <2 Not the main living area (2.34)	No	Bedroom, and Office room<2 Not the main living area (2.79)
Glazed balcony	Yes	Yes	No

According to the DRT checklist and field measurements, sample N.3 with multiple openings on different façades is the best-daylit unit with an average DF between 2-5% in the main living area and office room. The orientation towards the south, multiple façades with openings on allowing for more daylight penetration, the ideal window to floor area (25% in both rooms), and the shallow plan are some of the factors influencing the average DF. This is the case study in which its field measurements show a clearer pattern between the increasing number of snow-covered surfaces and average DF, as a simple rise in the amount of snow covering a patio increased its DF from 3.09% to 3.41%.

According to the same indicators (DRT checklist and field measurements), case study N.2 with an average DF below 2% is the worst daylit unit. Despite its orientation towards the south, the ideal window to floor area (about 20%), a single façade with a deep glazed balcony (about 2.24 m wide) covering all its openings, reduce the daylight in this case study. The average DF was below the minimum acceptable range of 2%.

Due to its noticeable distance from the ground (height > 7m) surrounding buildings and vegetation, as well as its low DF, this case is less sensitive towards the snow, when the number of snow-covered surfaces increased, the average DF did not raise in some measurements. For example, although the snow coverage on the 19th of Feb is much higher than 25th of February (Figure 2.3.4.1), the average DF on the 19th of Feb is lower (0.62%) in the living area almost half of the average DF on 25th (1.39%), this difference in average DF is big enough to be noticeable. (Figure 2.3.2.17 and 2.3.2.20)

Figure 2.3.4.1 The outdoor condition on 19th and 25th of Feb .

19th Feb *25th Feb*

These results suggest that the effect of the snow-covered surface is noticeable when they are closer to the openings. As Sample N1, with multiple façades with about a 3 m height difference with ground level shows a noticeable rise in its average DF, when there is snow covering the ground, this difference even becomes more noticeable when the snow-covered surfaces such as a pile of snow get closer to opening levels.

The evaluation of outcomes based on simulation does not demonstrate clear results. Take case N.3 as an example, the DRT checklist as well as daylight measurements highlights that this case study receives the best daylight while simulation results show a noticeably lower average DF for this case (Figure 2.3.3.31). Additionally, a noticeable gap between the average DF based on simulation results and field measurements decrease the reliability of the results, raising the question if the results have been influenced by the simulations' limitation or human error, or both.

Although a possible error in field measurement is undeniable, the evolution of the daylight measurements and excluding unreliable data decrease the role of human error in the difference between simulation outcomes and daylight measurements. Additionally, this difference is such notable that it cannot be only the result of human error.

The software's limitation in terms of importing objects and applying the right texture on trees makes it more difficult to investigate the role of snow on trees and other plants on average DF. In the models the evergreen trees were modeled as a solid mass, which is a far different form than reality, with all those gaps between their branches and different levels of snow on trees, it seems the low results of the simulations were partly influenced by this factor.

Moreover, when changing the reflectance factor of snow to create a difference between old and fresh snow, the software shows an irregular pattern in calculating the DF, in some cases decreasing the average DF (Figure 2.3.3.33 and 2.3.3.34). A simple model was developed to understand if the software is sensitive enough to different reflectance factors, 3 scenarios were defined including a ground covered with grass (reflectance factor 15%), old snow (reflectance factor 40%), and fresh snow (reflectance factor 80%). The results demonstrate that the average DF remains unchanged in different scenarios with a minor rise (just about 0.001%) in a single room (See figure 2.3.4.2 and 2.3.4.3). Suggesting that due to Dialux evo 11.0 limitations in considering different reflectance factors in calculations, the simulations are not sensitive enough to understand the role of snow-covered surfaces on average DF.

After the evaluation of daylight in the selected samples, it can be assumed that when snow covers the outdoor surface average DF increases in living areas. Nevertheless, the role of snow-covered surfaces on DF depends on the distance between snow-covered surfaces and openings, meaning that the influence of snow-covered surfaces is more noticeable when they are closer to the openings.

Daylight simulation with Dialux evo 11.0

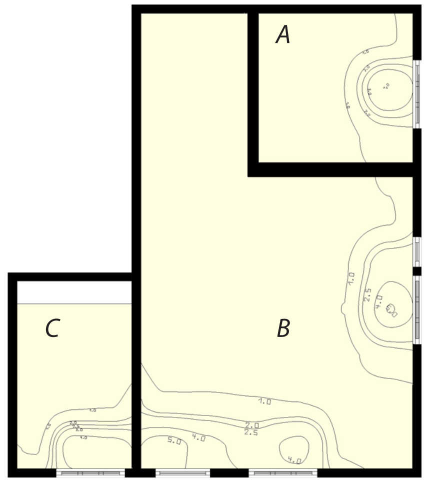


Figure 2.3.4.2
Average DF
Outdoor surface material:
Grass (albedo: 0.15)

A: 0.988%
B: 1.073%
C: 1.274%

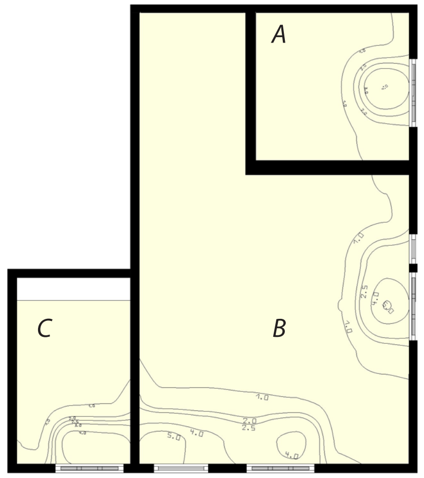


Figure 2.3.4.3
Average DF
Outdoor surface material:
Old snow (albedo: 0.40)

A: 0.988%
B: 1.074%
C: 1.274%

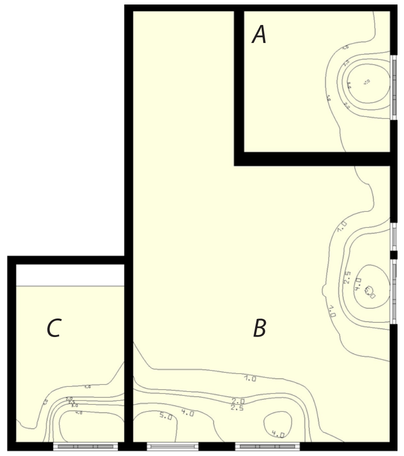


Figure 2.3.4.4
Average DF
Outdoor surface material:
Fresh snow (albedo: 0.80)

A: 0.988%
B: 1.074%
C: 1.274%

Part Three

Recommendations

Suggestion on enhancing the quality of daylight in Finnish urban apartments.

3.1 Why alternative contextual rules of thumb?

Sustainable architecture is developed based on context (Newman & Pelsmakers, 2021), our buildings are not isolated cubes that can function in the same way in different contexts, their location and climatic features have a significant effect on their efficiency. As buildings respond to their surrounding environment in various ways, our design guidelines cannot be global, therefore, when developing contextual design, it is important that design regulations are responsive towards the local environment, landscape, and local natural systems (Pelsmakers, et al, 2022).

Climatic features are one of the key factors of contextual design, by considering the challenges and the opportunities that a climate brings to the design, our buildings could function in more efficient ways. Climatic features of a certain location are defined by its latitude and altitude, the distribution of land, sea, and wind, as well as the distance from the sun. This distance from the sun is the main factor influencing the characteristic of a climate, the seasonal changes of a location, and its climatic zones (Pelsmakers, et al, 2022).

Knowing that daylight availability is also affected by climatic features, it is important that our design guidelines for a better daylit environment be responsive towards the contextual and climatic characteristics of the site. Nature-based solutions are both affordable and release significantly fewer greenhouse emissions (Newman & Pelsmakers, 2021), therefore developing climate-positive design language is not just economically beneficial but also an ethical solution in the time of climate emergency.

3.2 Finnish context and snow

As discussed earlier, the climate and weather are affected by sun radiation which depends on the latitude and the tilted angle of the earth's axis compared to the sun (RT 103169, 2019). The location of Finland in high northern latitude has a significant impact on daylight availability over the year, an important factor which should be considered when developing a place-based design. Also, it should be noted that the distance between the most northern point in Finland (Nuorgam at 70-degree latitude) and the southernmost point (Hanko at 59-degree latitude) create a difference in daylight availability (Vikberg, Hanna, 2014) which could be a starting point to think of developing local design guidelines for each zone.

Based on the Köppen climate classification, while the northernmost part of the country belongs to the tundra (ET) climate zone with an average temperature of 0 °C and 10 °C during the warm season, Finland mainly has continental subarctic climate; with warm, cloudy and rainy summers, as well as cold snowy or rainy winters (RT 103169, 2019). Meaning that even during daylight hours, both in winter as well as summer, the outdoor illuminance would be lower than expected resulting in lower indoor illuminance. In this situation, if a design is aimed at reaching the minimum acceptable DF, with increasingly cloudy days the users will suffer from a lack of sufficient daylight in their homes.

There are several sources predicting the effect of climate change on Finland, however, possible changes in ocean currents that influence the climate make it harder to predict what would be the exact changes (RT 103169, 2019). Table 3.2.1 lists some of the predictions for the future Finnish climate.

Table 3.2.1 Predictions on the future Finnish climate.

Summer air temperatures are expected to increase	In Finland it is expected that air temperature start rising faster than global average, with more significant effect in norther Finland (Burenby, et al., 2021).
Greater heatwaves	The length and the frequency of the heatwaves would increase, threatening human health and well-being and biodiversity (Burenby, et al., 2021).
Precipitation is expected to increase during winter	It is more likely for winters to have higher perception both in volume and frequency, however because of the rising temperature, it is less likely to experience snowy days (Statistics Finland).
Less solar radiation during winter	While the probable changes in solar radiation during summer are not certain, winter solar radiation is expected to decrease mainly because of increased cloudiness (Burenby, et al., 2021).
Climate change will raise the sea level in the Gulf of Finland	By the end of the 21st century, the sea level might rise on the Finnish coast by around ninety centimeters. But Finland will also increase in height due to glacial uplift, limiting territorial loss. (The Finnish Meteorological Institute, 2013)
Snow cover will decline, staring from south	Shorter and discontinues snow season (Statistics Finland).
Less ground frosts	In general, the number of ground frost days and its depth will decrease in snow free areas, such as roads or yards, influenced by changes in snow cover (Statistics Finland).
Ice cover	Shorter ice cover period and less strong ice (Statistics Finland).

3.3 Recommendations

In 2019, it was predicted as the climate gets warmer, winters are going to become milder, cloudier, and rainier with less snow cover season (RT 103169, 2019). Just after 4 years, in March 2023, The Finnish Environment Institute reported, February 2023 was milder than usual in all parts of Finland, additionally, the precipitation generally was normal or slightly less than normal; on average, there was less snow in the western part of the country.

Just imagine this continues to the point that snowy days become a rare phenomenon, first in southern Finland and then the whole country. It means to have better daylight on short winter days, architects should aim for achieving higher average DF in main living areas, by developing climatic design (Pelsmakers, et al, 2022), increasing the effect of reflectance from outdoor environments, and the design for adjustability and adaptability (Pelsmakers, Saarimaa & Vaattovaara, M K 2021).

The following pages are some of my recommendations for achieving better DF in Finnish urban apartments.

3.3.1 Urban breaks:

The outcomes of case study N.2 illustrated that even in high-rise apartments, the snow collected on rooftops of the surrounding buildings would enhance the daylight quality in higher-level apartments. Therefore, designing apartment blocks with urban breaks (the difference in roof level by one- or two-story height difference (Pelsmakers, 2015)) not only would increase the winter solar gain inside apartments as well as the neighborhood but also would collect and reflect snow from different levels.

Finland experiences more days with overcast skies than clear skies throughout the year; in addition, the light from the overcast sky has the heights illuminance from overhead (zenith area), as a result, opening the roof would bring more daylight into the apartments in comparison to vertical wall openings (Baker &Steemers, 2002). Therefore, the other advantage of urban breaks would be creating an opportunity to bring light inside the apartment from above. However, having a skylight in a Finnish climate could raise specific threats in terms of maintenance, insulation, or desirability of the light.

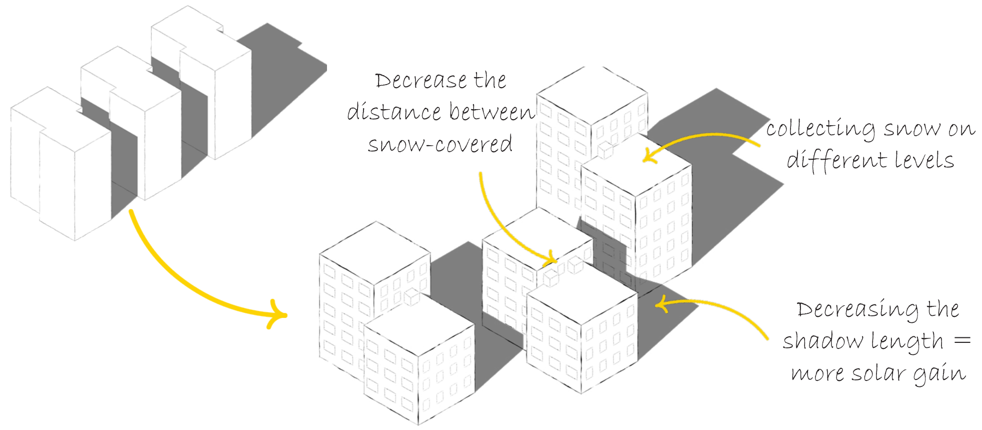


Figure 3.3.1.1 Advantages of having urban breaks:
- Allow more solar gain (Pelsmakers, 2015), by decreasing the length of the shadow on streets and other buildings.
- Allow for installing skylights, roof terraces, or ceiling lanterns in units.
- Increasing the reflectance and outdoor illuminance by collecting snow on different levels

3.3.2 Well-thought positing of trees to collect snow:

The advantages of having more landscape with rich vegetation rather than streetscapes in cities are well- established (Lance, 2012). Urban planting adds numerous values to cities, such as oxygen production, carbon absorption, lower energy consumption, acting as a buffer for wind, noise and rays of sun and balancing the temperature in different seasons, either by creating shades in summer or losing leaves in winter (Lance, 2012). Trees and other plants through their temporal changes over the year, create visual attraction influencing health and well-being of the people, they also act as strong support for balancing biodiversity in urban areas (Pelsmakers, et al 2022). On the other hand, results of the daylight measurements show that trees also act as snow collectors allowing more daylight reflectance in winter.

Therefore, planting trees will bring various opportunities to create a delightful and efficient living environment. Despite their numerous advantages, as well as enhance the quality of light by collecting the snow and reflecting the light in multiple directions, their location on the site and their density, the type of the tree (if its evergreen or deciduous), and their height and size when they reach maturity should be thought carefully, to preserve the desirable view and daylight in urban apartments (Pelsmakers, et al 2022).

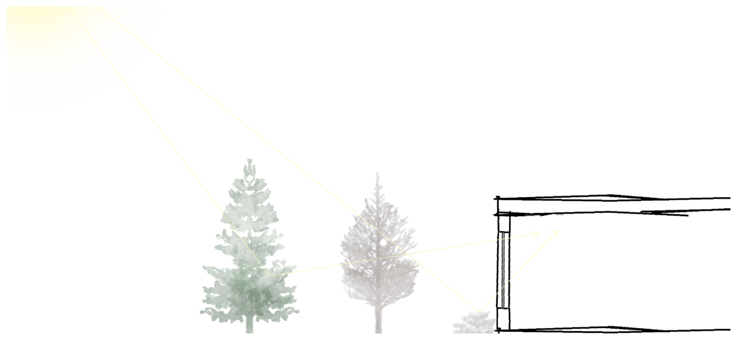


Figure 3.3.2.1 One solution could be:
_ planting dense bushes near the window to collect snow, without blocking the view.
_ At a near distance from the window rows of deciduous trees, both to allow more daylight penetration and collect snow in winter
At some greater distance from the openings, dense evergreen trees for maximizing the snow collection

3.3.3 A façade to collect snow

In Finland sometimes due to the power of the wind the snow starts covering the vertical façades (Figure 3.3.3.1). This was the starting point of thinking of a façade that is designed to collect snow. Bringing this opportunity into a design to have different reflectance factor based on the seasonal changes. In winter as we need a brighter outdoor environment to reflect limited daylight the snow collected on façade could take this responsibility. While in summer the darker color of the façade could decrease the reflectance and avoid unbalanced daylight distribution.

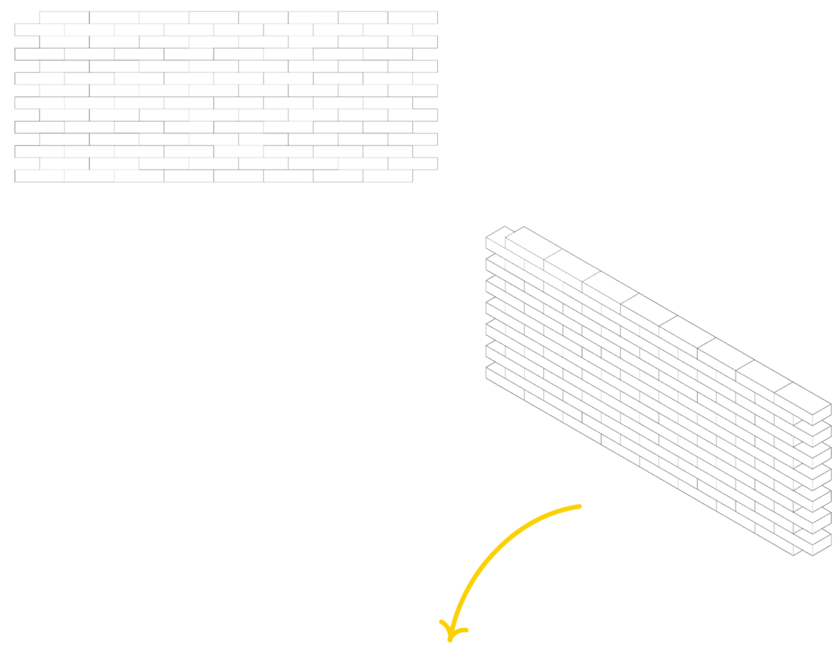
Figure 3.3.3.1 Snow attached to the façade, January 2022, Uusimaa

In mainland Finland the use of brick as building material started in the late 13th century (Ratilainen, Tanja, 2020). Brick because of its great mass is a suitable material to store heat, on the other hand it took a longer time for clay brick to emit the stored heat, therefore these characteristics makes it one of the suitable building materials in Finland (Hegger, Manfred, et al, 2006).

Many of the recently built residential buildings in Finland have brick cladding, so why not create an opportunity for snow to stay longer on the façade?

When applying the brick cladding, by creating small offsets snow can stay longer on the façade. Therefore, through changing the reflectance factor of the façade, this design can influence the DF inside the apartments. It is important for this design to have careful insulation and material characteristics to avoid cracks and damage to the walls.

Figure 3.3.3.2 Typical brick façade with no difference in tiles' depths



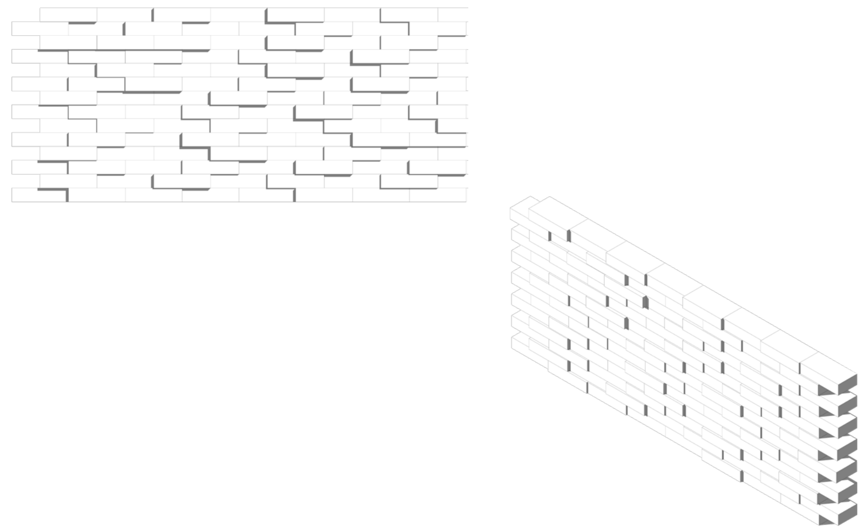


Figure 3.3.3.3 Snow collector façade with differences in tiles' depths, creating a horizontal surface for snow to remain on the façade

3.3.4 Glazed balconies:

In Finland, it is common, in order to control the thermal comfort of the interior space, to have a glazed balcony in front of the windows, however, this will decrease the daylight availability of rooms behind the balcony. Still, when having single southern façade, we could think of alternative solutions for controlling heat gain while preserving the quality of daylight in interior space. For example, either by decreasing the depth of the balcony or the room behind the glazed balcony we could achieve a better daylight factor in interior spaces. It should be noted that the suggestion to decrease the depth of the balcony does not mean constructing small unfunctional spaces, it focuses on balancing the depth of the space and the daylight penetration.

The other solution could be using brighter material for the balcony structure to increase the reflectance factor of the surfaces to bring light deeper into the room. The window positioning, its size and the glazing type both in balcony and the room behind could also influence the daylight availability in living areas (RT 07-11300, 2018).

The other way to address this issue could be by creating breaks in the floor plan or façade, in order to have both glazed balconies and uncovered windows. For instance, covering the bedroom window with glazed balcony, while acting as a vertical shading element for other windows. Because a bedroom can have less daylight factor between 1-2% (Pelsmakers, et al, 2022) and requires greater thermal comfort (Pelsmakers, 2015), to create a better environment for a better night's sleep, in comparison to living space.

Figure 3.3.5.1
Average DF in each room,
Existing condition

Balcony: 8.962%
Main living area: 0.312%
Bedroom: 0.471%

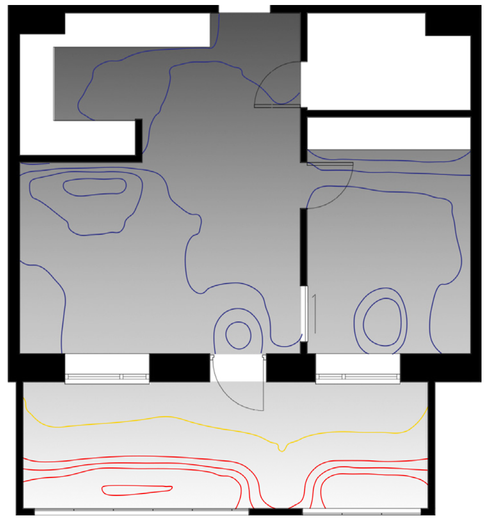
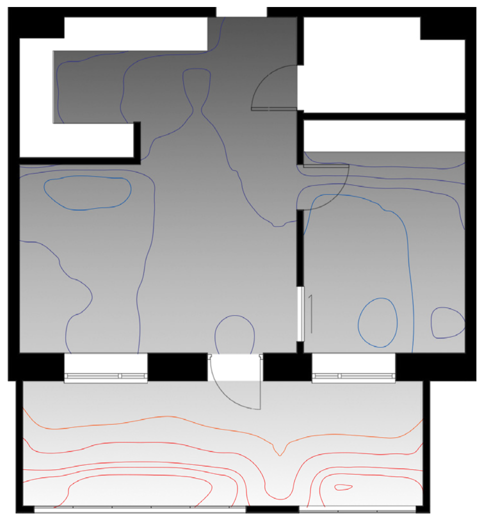


Figure 3.3.5.2
Average DF in each room,
Bigger glazed openings

Balcony: 8.600%
Main living area: 0.492%
Bedroom: 0.475%

Figure 3.3.5.2
Average DF in each room,
Bright material in balcony

Balcony: 11.233%
Main living area: 0.521%
Bedroom: 0.779%



3.3.5 Adjustable and adaptable homes during seasonal changes:

As it is difficult to be certain about the influence of climate change in over long period, and the results could be influenced if we start changing our attitudes, when designing for future homes it is better for us to add adjustable and adaptable spaces where residents can alter the rooms based on their needs (Pelsmakers, Saarimaa & Vaattovaara , M K 2021).

As discussed previously, when there is huge difference between daylight hours throughout the year, it becomes more challenging to use the same room with the same level of efficiency over the year. Therefore, it becomes more important for apartments to have enough space to alter the position of furniture, or the function of a room based on the temporal changes, the equal division between the size of the rooms, positing opening in multiple façades, choosing the depth of the plan based on the function and the light penetration patterns throughout the year would allow better opportunities for adaptation of homes.

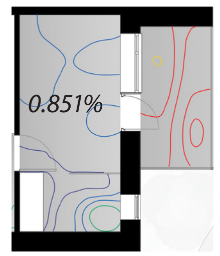
3.3.6 Size, numbers and the orientation of windows

All existing daylighting rules of thumbs advise us to increase the window to floor or wall area, making sure that each room receives light from multiple directions, and windows are positioned in a way that they create balanced daylit areas. But following which of these rules would have affected the daylight quality the most?

Simulation results for this case study illustrate that with the same window size, when a room receives light from different direction the daylight quality would increase average DF to 1.114 % while having bigger windows only on one façade would increase the average DF to 1.346 % Therefore, in this certain case study, if there is choice to be made between having smaller windows in multiple directions or bigger windows on the same façade, bigger windows increase the average DF more.

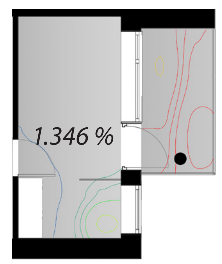
Figure 3.3.6.1 The difference in average DF when changing the location, size, or both of the glass openings.

Existing condition

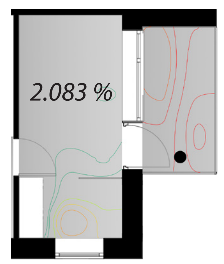


Change in location

Change in size



Change in both location and size



Conclusion,

Climate change urges us to define novel thorough and impeccable standards in sustainable design (Pelsmakers, Sofie, et al, 2022). Enhancing the quality of natural light over artificial light brings new values to the design, as it is a free efficient source of energy, it can increase the energy efficiency of the design, un-predictable dynamic patterns of natural light, and the connection it creates the outdoor environment would affect health and well-being of the residents (Baker & Steemers, 2019). In Finland the variable hours of natural light throughout the years, direct the focus on developing the design strategies to control the direct sunlight penetration (RT 07-10912, 2008), while the factors enhancing the quality of daylight remains neglected.

This research-based thesis focused on the role of snow-covered surfaces on daylight availability in Finnish urban apartments. The study focuses on three urban apartments built between 2000 and 2021 in the Uusimaa region of Finland. Daylight was measured in each apartment to gain a better understanding of average daylight availability in each unit during February and March 2023. In order to understand the role of snow on the quality of daylight, daylight was measured under different outdoor conditions, especially when the amount of snow was variable on outdoor surfaces. In addition, to gain a better insight into the role of snow on daylight quality, four scenarios were developed for each apartment in DIALux evo 11.0, varying from when all the outdoor surfaces were covered with snow to the snow-free surfaces. To reach better accuracy in results the vegetation and surrounding building were also included in models, nevertheless, the software's limitation in calculating snow-covered surfaces, and the lack of suitable objects for different types of trees (evergreen, bushes, and deciduous trees) made it difficult to investigate the role of snow-covered surface on DF with this tool.

According to daylight measurement in these three case studies, the first main outcome is that the snow-covered surfaces can enhance the average daylight availability of living spaces, meaning that the presence of snow increases the average daylight availability in apartments. Based on the outcomes, when the snow is collected on different levels, such as tall tree branches or rooftops, it can even influence the daylight quality in urban apartments that are at higher elevations, although the results are influenced by the distance between snow-covered surfaces and the indoor environment.

The general comparison between the three chosen samples demonstrates that as the snow-covered surfaces get closer to the house the changes in DF by the presence of snow become clearer. The study of these samples also demonstrates how glazed balconies when covering the main windows, reduce the daylight quality in living areas. Two of the three case studies have glazed balconies, however, one of these two cases, has a deeper balcony covering all the windows in the apartment, reducing the average DF in main living spaces to 0.83% and 1.08% while the balcony itself has an average DF of 22.50%.

The second main outcome of this study illustrates the difference between simulation results and data collected on site; suggesting that probably the DIALux evo 11.0 lacks the required sensitivity to demonstrate the impact of snow-covered surfaces on average DF. Although the outcome of the simulations illustrates a slight difference in average DF under different conditions, it is more challenging to identify a clear pattern between increasing snow-covered surfaces and average DF in all case studies. The impact of snow on daylight availability is less significant

Thirdly, this study also demonstrates how different the conclusions and results would have been if the investigation relied on simulation, suggesting that to gain a thorough understanding of the factors influencing the design we should not solely rely on software. The software is here to help us to gain a better understanding of our designs and their characteristics, however, there would be always a difference between the simulations results and reality. We do not create architecture in a virtual world, we build it in our cities for real.

The analysis in this thesis focuses on the role of snow-covered surfaces on the quality of daylight and the opportunities that can bring for architects in a country like Finland with long dark snow seasons. This study suggests architects think of design strategies that can increase the collection of snow on different levels. Not only to enhance the quality of daylight in urban apartments but also to create a dynamic and delightful city where urban breaks and different outdoor elements increase the quality of life, health, and well-being of the residents. Key recommendations for design include:

1. Urban breaks:
2. Well-thought position of trees to collect snow
3. Façade design idea
4. Glazed balconies
5. Adjustable and adaptable homes during seasonal changes
6. Size, numbers, and the orientation of windows

Nevertheless, as a student spending some months investigating the role of snow on the quality of daylight, I feel still there is need for a further investigation, to gain a better understanding of all factors influencing the role of snow on the quality of daylight. Moreover, this thesis reminds me that, now that climate change will shorten the snow season in Finland (YLE news, 11.8.2021), the quality of daylight in urban apartments will suffer from a lack of snow. investigation, to gain a better understanding of all factors influencing the role of snow on quality of daylight. Also, now that climate change will shorten the snow season in Finland (YLE news, 11.8.2021), how the quality of daylight in urban apartments will suffer from lack of snow?

Closing words

First, I would like to thank dear Sofie Pelsmakers for her deep knowledge, inspiring talks, motivation, and support not throughout my studies at Tampere University.

Secondly, I would like to thank dear Raul Castano De la Rosa for his knowledge, help, and support.

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Appendix

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A10 A9 A8 A7
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A4 A3
A2 A1
A78 A77 A76
A79 A80 A81
A84 A83 A82

Table.1 *Average DF for each point*

Point	20th Mar	16th Mar	13th Mar	3rd Mar	27th Feb	23rd Feb	Average
A1	0.06%	0.17%	0.11%	0.07%	0.15%	0.12%	0.11%
A2	0.06%	0.20%	0.12%	0.08%	0.14%	0.16%	0.12%
A3	0.10%	0.24%	0.15%	0.12%	0.26%	0.21%	0.18%
A4	0.08%	0.24%	0.13%	0.11%	0.24%	0.17%	0.16%
A5	0.17%	0.36%	0.25%	0.19%	0.32%	0.36%	0.27%
A6	0.14%	0.29%	0.16%	0.13%	0.33%	0.18%	0.20%
A7	0.25%	0.63%	0.50%	0.30%	0.38%	0.47%	0.42%
A8	0.28%	0.65%	0.50%	0.41%	0.47%	0.57%	0.48%
A9	0.32%	0.86%	0.60%	0.44%	0.55%	0.58%	0.55%
A10	0.46%	1.01%	0.71%	0.53%	0.60%	0.63%	0.65%
A11	0.28%	0.74%	0.59%	0.39%	0.54%	0.59%	0.52%
A12	0.21%	0.85%	0.62%	0.42%	0.55%	0.60%	0.54%
A13	0.25%	0.78%	0.71%	0.42%	0.54%	0.51%	0.53%
A14	0.46%	1.37%	1.17%	0.58%	0.70%	0.71%	0.83%
A15	0.54%	1.25%	1.22%	0.60%	0.94%	1.49%	1%
A16	1.34%	2.47%	2.37%	1.45%	2.09%	2.03%	1.95%
A17	1.56%	2.60%	2.12%	1.90%	2.20%	2.78%	2.19%
A18	0.64%	1.20%	1.21%	1.32%	1.59%	2.55%	1.41%
A19	0.62%	1.95%	1.37%	1%	1.10	0.95%	1.16%
A20	0.82%	2.17%	2.37%	1.01%	1.21	1.55%	2.37%
A21	1.75%	2.70%	3.56%	1.74%	2.12%	2.38%	2.37%
A22	4.26%	5.49%	7.08%	3.40%	4.44%	3.20%	4.64%
A23	10.17%	10.14%	11.76%	7.68%	5.77%	7.05%	8.76%
A24	0.71%	1.93%	1.29%	1.13%	1.38%	0.90%	1.22%
A25	0.94%	2.08%	2.25%	1.24%	1.56%	1.47%	1.59%
A26	2.13%	3.11%	3.52%	2.55%	2.52%	2.49%	2.72%
A27	3.70%	4.57%	8.14%	3.07%	4.93%	3.48%	4.64%
A28	10.22%	9.52%	16.86%	9.22%	8.33%	7.38%	10.25%
A29	0.72%	2.03%	1.58%	1.09%	1.30%	0.90%	7.62%
A30	0.97%	2.26%	2.59%	2.25%	1.51%	1.80%	1.89%
A31	1.98%	4.01%	4.19%	2.04%	3.03%	2.61%	2.97%
A32	4.53%	5.39%	5.35%	3.98%	4.70%	3.50%	4.57%
A33	3.32%	5.24%	4.43%	3.44%	3.81%	5.14%	4.23%
A34	0.39%	0.98%	0.76%	0.48%	0.77%	0.65%	0.67%
A35	0.62%	0.86%	0.94%	0.59%	0.92%	0.95%	0.81%
A36	0.70%	1.84%	0.83%	0.97%	1.26%	1.21%	1.13%
A37	1.06%	2.53%	2.19%	1.15%	1.97%	1.27%	1.69%
A38	2.35%	5.31%	4.12%	2.66%	3.36%	2.79%	3.43%
A39	5.34%	8.88%	7.80%	4.62%	5.06%	4.94%	6.10%
A40	11.44%	11.72%	16.46%	10.47%	8.67%	11.62%	11.73%
A41	0.37%	0.87%	0.85%	0.56%	0.79%	0.73%	0.69%
A42	0.41%	0.75%	0.99%	0.61%	0.92%	0.75%	0.73%
A43	0.62%	1.78%	0.65%	1.29%	1.09%	0.92%	1.05%
A44	0.98%	2.39%	1.97%	1.29%	1.84%	1.15%	1.60%
A45	1.79%	2.95%	2.74%	2.04%	2.31%	2.31%	2.35%
A46	2.95%	4.37%	4.50%	2.70%	2.19%	2.85%	3.26%
A47	6.89%	7.22%	8.00%	5.96%	6.19%	7.52%	6.96%
A48	1.35%	2.27%	2.41%	1.79%	1.86%	1.67%	1.89%
A49	1.55%	2.52%	2.60%	2.07%	2.08%	1.93%	2.12%
A50	0.80%	1.08%	1.63%	1.33%	0.76%	1.37%	1.16%
A51	0.58%	1.20%	1.27%	1.30%	1.11%	1.11%	1.09%
A52	0.65%	1.43%	1.41%	1.54%	1.71%	1.4%	0.91%
A53	0.32%	1.12%	1.15%	0.66%	0.83%	1.14%	0.87%
A54	0.85%	2.15%	1.46%	2.29%	1.39%	1.38%	1.58%
A55	1.12%	2.42%	2.33%	2.84%	1.82%	1.44%	1.99%
A56	2.28%	3.29%	2.98%	3.44%	3.19%	1.54%	2.78%
A57	0.83%	1.88%	2.20%	2.59%	1.60%	1.22%	1.72%
A58	1.09%	2.90%	2.23%	2.66%	2.07%	1.83%	2.13%
A59	2.30%	3.39%	2.74%	4.07%	3.38%	3.47%	3.22%
A60	0.80%	2.24%	1.50%	1.98%	1.46%	1.45%	1.57%
A61	0.91%	2.53%	1.88%	2.92%	2.65%	1.62%	2.08%
A62	2.94%	3.53%	1.89%	4.10%	3.22%	3.21%	3.14%
A63	0.77%	1.19%	1.06%	1.69%	1.30%	1.11%	1.18%
A64	0.51%	0.96%	1.16%	2.30%	0.87%	0.80%	1.1%
A65	0.26%	0.49%	0.63%	0.60%	0.66%	0.65%	0.54%
A66	0.51%	0.81%	0.84%	0.99%	0.88%	0.79%	0.80%
A67	0.76%	0.97%	0.90%	1.01%	1.03%	0.92%	0.93%
A68	0.45%	1.20%	0.72%	1.16%	1.21%	0.77%	0.91%
A69	0.94%	2.14%	1.48%	3.27%	2.15%	1.60%	1.93%
A70	1.70%	2.10%	1.85%	2.88%	2.97%	2.02%	2.25%
A71	3.20%	2.99%	6.10%	4.47%	3.81%	3.43%	4%
A72	6.73%	10.14%	10.74%	15.10%	10.38%	7.95%	10.17%
A73	26.86%	20.60%	33.30%	39.62%	3.38%	21.09%	24.14%
A74	22.02%	19.09%	29.57%	35.91%	20.74%	24.31%	24.60%
A75	27.04%	21.51%	33.68%	30.49%	23.41%	40.06%	29.36%
A76	0.64%	1.50%	1.90%	0.84%	1.21%	1.78%	1.31%
A77	12.21%	9.64%	12.98%	8.78%	7.66%	10.49%	10.29%
A78	0.42%	1.18%	0.79%	0.64%	0.84%	1.60%	0.91%
A79	1.11%	2.46%	2.17%	2.07%	2.42%	2.66%	2.14%
A80	1.73%	2.89%	2.64%	1.95%	2.24%	3.54%	2.49%
A81	1.01%	2.57%	1.67%	1.26%	1.51%	1.58%	1.6%
A82	0.65%	1.71%	0.95%	0.71%	1.06%	1.48%	1.09%
A83	0.69%	1.56%	1.84%	0.85%	1.08%	1.27%	1.21%
A84	0.52%	1.98%	1.00%	0.80%	0.97%	1.17%	1.07%

Table2. *20th of March, 9:00 a.m.*

Foggy day with old melted grey snow on ground, melted on the main roads.

Point	Inside (in lux)	Outside (in lux)	DF
A1	4.5	6490	0.06%
A2	4.2	6370	0.06%
A3	7.1	6520	0.10%
A4	5.5	6340	0.08%
A5	11.2	6580	0.17%
A6	9.3	6330	0.14%
A7	16.8	6600	0.25%
A8	17.9	6250	0.28%
A9	20	6190	0.32%
A10	28.5	6150	0.46%
A11	19	6620	0.28%
A12	14.5	6650	0.21%
A13	17.2	6670	0.25%
A14	30.9	6610	0.46%
A15	35.1	6390	0.54%
A16	86.7	6460	1.34%
A17	94.3	6040	1.56%
A18	41.2	6420	0.64%
A19	40.4	6510	0.62%
A20	52.8	6370	0.82%
A21	113.4	6470	1.75%
A22	257	6030	4.26%
A23	642	6310	10.17%
A24	46.5	6500	0.71%
A25	60.2	6370	0.94%
A26	137.8	6440	2.13%
A27	224	6050	3.70%
A28	633	6190	10.22%
A29	47.2	6530	0.72%
A30	62.4	6380	0.97%
A31	125	6300	1.98%
A32	277	6110	4.53%
A33	201	6050	3.32%
A34	23.9	6000	0.39%
A35	37.5	6010	0.62%
A36	46	6520	0.70%
A37	67.5	6360	1.06%
A38	145.5	6190	2.35%
A39	329	6150	5.34%
A40	680	5940	11.44%
A41	22.5	6020	0.37%
A42	25.3	6070	0.41%
A43	40.6	6490	0.62%
A44	62.7	6360	0.98%
A45	110.2	6130	1.79%
A46	184	6230	2.95%
A47	391	5670	6.89%
A48	82.2	6070	1.35%
A49	99.2	6380	1.55%
A50	45.3	5650	0.80%
A51	36.9	6350	0.58%
A52	41.7	6360	0.65%
A53	20.8	6430	0.32%
A54	53.9	6290	0.85%
A55	72.2	6410	1.12%
A56	148.5	6490	2.28%
A57	51.6	6210	0.83%
A58	70.5	6420	1.09%
A59	150.3	6520	2.30%
A60	49.2	6150	0.80%
A61	58.9	6460	0.91%
A62	193.3	6570	2.94%
A63	48	6200	0.77%
A64	50.2	6480	0.51%
A65	17.2	6440	0.26%
A66	32	6210	0.51%
A67	50.2	6590	0.76%
A68	29.5	6450	0.45%
A69	58.6	6230	0.94%
A70	110.7	6510	1.70%
A71	208	6500	3.20%
A72	417	6190	6.73%
A73	1690	6290	26.86%
A74	1368	6210	22.02%
A75	1682	6220	27.04%
A76	40.6	6300	0.64%
A77	760	6220	12.21%
A78	26.1	6150	0.42%
A79	70.8	6370	1.11%
A80	110.5	6380	1.73%
A81	64.5	6370	1.01%
A82	42.2	6440	0.65%
A83	45	6450	0.69%
A84	33.7	6400	0.52%

Table3. *16th of March, 8:30 a.m.*

Clear sky with old snow on ground, melted on the main roads.

Point	Inside (in lux)	Outside (in lux)	DF
A1	6.5	3630	0.17%
A2	7.5	3620	0.20%
A3	8.7	3600	0.24%
A4	9	3650	0.24%
A5	22.5	3580	0.36%
A6	11	3720	0.29%
A7	22.5	3550	0.63%
A8	25.2	3830	0.65%
A9	34.9	4040	0.86%
A10	41.1	4050	1.01%
A11	26.2	3530	0.74%
A12	30.3	3530	0.85%
A13	27.7	3540	0.78%
A14	49.2	3590	1.37%
A15	42.9	3420	1.25%
A16	85.3	3450	2.47%
A17	90.3	3460	2.60%
A18	40.2	3340	1.20%
A19	70.9	3630	1.95%
A20	73.5	3380	2.17%
A21	93.3	3450	2.70%
A22	190	3460	5.49%
A23	340	3350	10.14%
A24	69.2	3570	1.93%
A25	71.2	3420	2.08%
A26	108.3	3480	3.11%
A27	157.5	3440	4.57%
A28	318	3340	9.52%
A29	72.3	3560	2.03%
A30	77.1	3400	2.26%
A31	138.8	3460	4.01%
A32	185.2	3430	5.39%
A33	174.2	3320	5.24%
A34	42.2	4300	0.98%
A35	36.8	4230	0.86%
A36	64.4	3500	1.84%
A37	87.8	3470	2.53%
A38	183.4	3450	5.31%
A39	303	3410	8.88%
A40	388	3310	11.72%
A41	41.3	4740	0.87%
A42	31.3	4160	0.75%
A43	61.2	3420	1.78%
A44	81.5	3410	2.39%
A45	101.5	3440	2.95%
A46	148.2	3390	4.37%
A47	240	3320	7.22%
A48	79.4	3490	2.27%
A49	85.2	3370	2.52%
A50	36.1	3320	1.08%
A51	50.5	4200	1.20%
A52	54.2	3790	1.43%
A53	39.1	3470	1.12%
A54	87.1	4040	2.15%
A55	91.2	3760	2.42%
A56	117.9	3580	3.29%
A57	77.3	4100	1.88%
A58	113.7	3920	2.90%
A59	121.8	3590	3.39%
A60	90.2	4020	2.24%
A61	100.5	3970	2.53%
A62	133.4	3770	3.53%
A63	47.2	3960	1.19%
A64	37.7	3900	0.96%
A65	18.3	3680	0.49%
A66	31.5	3860	0.81%
A67	38.8	3960	0.97%
A68	44.5	3690	1.20%
A69	83.2	3870	2.14%
A70	82.4	3920	2.10%
A71	111.9	3740	2.99%
A72	422	4160	10.14%
A73	888	4310	20.60%
A74	802	4200	19.09%
A75	936	4350	21.51%
A76	54.3	3620	1.50%
A77	350	3630	9.64%
A78	42.5	3600	1.18%
A79	88.2	3580	2.46%
A80	103.5	3580	2.89%
A81	91.6	3560	2.57%
A82	64.3	3750	1.71%
A83	57.2	3660	1.56%
A84	68.2	3440	1.98%

Table4. *13th of March, 5:30 p.m.*

Cloudy day with old white snow on ground.

Point	Inside (in lux)	Outside (in lux)	DF
A1	1.1	979	0.11%
A2	1.2	932	0.12%
A3	1.5	984	0.15%
A4	1.3	954	0.13%
A5	2.5	997	0.25%
A6	1.6	966	0.16%
A7	5	994	0.50%
A8	4.9	970	0.50%
A9	5.7	945	0.60%
A10	6.7	935	0.71%
A11	6	1008	0.59%
A12	6.4	1019	0.62%
A13	7.3	1025	0.71%
A14	12.1	1032	1.17%
A15	13.3	1090	1.22%
A16	28.2	1187	2.37%
A17	26.8	1264	2.12%
A18	16.6	1371	1.21%
A19	14.3	1041	1.37%
A20	26.3	1107	2.37%
A21	42.7	1197	3.56%
A22	90.5	1277	7.08%
A23	150.2	1390	11.76%
A24	13.5	1044	1.29%
A25	25.1	1115	2.25%
A26	42.5	1207	3.52%
A27	104.4	1282	8.14%
A28	236	1397	16.86%
A29	16.9	1068	1.58%
A30	29.2	1125	2.59%
A31	51.1	1219	4.19%
A32	70.2	1310	5.35%
A33	62.8	1416	4.43%
A34	7	920	0.76%
A35	8.8	927	0.94%
A36	16.5	1970	0.83%
A37	25	1140	2.19%
A38	50.6	1227	4.12%
A39	103.2	1323	7.80%
A40	235	1427	16.46%
A41	7.6	891	0.85%
A42	9	901	0.99%
A43	13	1977	0.65%
A44	22.8	1152	1.97%
A45	34	1237	2.74%
A46	60.2	1337	4.50%
A47	115.2	1440	8.00%
A48	30.1	1247	2.41%
A49	35.1	1348	2.60%
A50	23.6	1447	1.63%
A51	6.1	480	1.27%
A52	7.9	558	1.41%
A53	7.7	664	1.15%
A54	7	477	1.46%
A55	13	556	2.33%
A56	18.8	630	2.98%
A57	10.8	490	2.20%
A58	12.3	550	2.23%
A59	16.7	609	2.74%
A60	7.4	493	1.50%
A61	10.2	540	1.88%
A62	11.3	595	1.89%
A63	5.3	499	1.06%
A64	6.2	530	1.16%
A65	3.7	583	0.63%
A66	4.2	498	0.84%
A67	4.7	522	0.90%
A68	4.2	580	0.72%
A69	7.5	505	1.48%
A70	9.5	513	1.85%
A71	35.2	577	6.10%
A72	48.8	454	10.74%
A73	156.2	469	33.30%
A74	132.2	447	29.57%
A75	155.3	461	33.68%
A76	15	789	1.90%
A77	105.2	810	12.98%
A78	6.4	802	0.79%
A79	16.9	777	2.17%
A80	20.2	764	2.64%
A81	12.7	757	1.67%
A82	6.7	700	0.95%
A83	13.6	736	1.84%
A84	7.4	740	1.00%

Table5. *3rd of March, 2:30 p.m.*

Cloudy day with old white snow on ground, melted on the main roads.

Point	Inside (in lux)	Outside (in lux)	DF
A1	6.6	8620	0.07%
A2	7.7	8580	0.08%
A3	10.7	8300	0.12%
A4	9.3	8330	0.11%
A5	16.2	8310	0.19%
A6	11.7	8390	0.13%
A7	26.2	8470	0.30%
A8	35.2	8480	0.41%
A9	37.3	8430	0.44%
A10	44.2	8260	0.53%
A11	33	8390	0.39%
A12	36.2	8520	0.42%
A13	39.1	8440	0.42%
A14	48.9	8320	0.58%
A15	52.4	8680	0.60%
A16	121.8	8380	1.45%
A17	159.2	8340	1.90%
A18	110.8	8350	1.32%
A19	84.2	8350	1%
A20	87.6	8640	1.01%
A21	146.5	8390	1.74%
A22	284	8340	3.40%
A23	637	8290	7.68%
A24	95.2	8420	1.13%
A25	107.2	8630	1.24%
A26	215	8400	2.55%
A27	255	8290	3.07%
A28	788	8540	9.22%
A29	91.6	8370	1.09%
A30	195.2	8650	2.25%
A31	172.5	8420	2.04%
A32	332	8330	3.98%
A33	297	8630	3.44%
A34	42.1	8640	0.48%
A35	51.1	8580	0.59%
A36	81.5	8360	0.97%
A37	100.2	8640	1.15%
A38	225	8430	2.66%
A39	383	8290	4.62%
A40	900	8590	10.47%
A41	48.2	8600	0.56%
A42	52.6	8500	0.61%
A43	73.2	8530	1.29%
A44	112.3	8650	1.29%
A45	172.4	8410	2.04%
A46	225	8330	2.70%
A47	518	8690	5.96%
A48	150.2	8360	1.79%
A49	174	8370	2.07%
A50	116.4	8700	1.33%
A51	93.2	7160	1.30%
A52	112.2	7280	1.54%
A53	48.5	7320	0.66%
A54	163.1	7110	2.29%
A55	210	7390	2.84%
A56	253	7340	3.44%
A57	186.5	7180	2.59%
A58	192.4	7220	2.66%
A59	302	7410	4.07%
A60	142.3	7170	1.98%
A61	210	7180	2.92%
A62	297	7240	4.10%
A63	125.8	7430	1.69%
A64	165.3	7160	2.30%
A65	43.5	7190	0.60%
A66	71.4	7170	0.99%
A67	73.2	7210	1.01%
A68	84.2	7220	1.16%
A69	233	7110	3.27%
A70	206	7130	2.88%
A71	322	7190	4.47%
A72	1077	7130	15.10%
A73	2770	6990	39.62%
A74	2740	7630	35.91%
A75	2220	7280	30.49%
A76	70.1	8250	0.84%
A77	720	8200	8.78%
A78	54.1	8330	0.64%
A79	172.5	8310	2.07%
A80	162.5	8320	1.95%
A81	102.4	8120	1.26%
A82	57.3	7970	0.71%
A83	68.2	7950	0.85%
A84	65.2	8070	0.80%

Table6. *27 of February, 12:30 p.m.*

Cloudy day with old white snow on some trees and ground

Point	Inside (in lux)	Outside (in lux)	DF
A1	19.2	12020	0.15%
A2	18.2	12480	0.14%
A3	34.8	13010	0.26%
A4	30.2	12250	0.24%
A5	43	13080	0.32%
A6	47.3	13980	0.33%
A7	60.2	15550	0.38%
A8	72.5	15140	0.47%
A9	79.9	14440	0.55%
A10	92.6	15400	0.60%
A11	82.5	15270	0.54%
A12	82.5	14860	0.55%
A13	79.2	14550	0.54%
A14	100.1	14110	0.70%
A15	132.9	14070	0.94%
A16	281	13440	2.09%
A17	288	13050	2.20%
A18	210	13200	1.59%
A19	152.2	13820	1.10
A20	162.3	13400	1.21
A21	285	13390	2.12%
A22	588	13230	4.44%
A23	768	13300	5.77%
A24	192.3	13860	1.38%
A25	220	14080	1.56%
A26	332	13150	2.52%
A27	657	13300	4.93%
A28	1100	13200	8.33%
A29	182.5	13950	1.30%
A30	211	13920	1.51%
A31	398	13100	3.03%
A32	625	13280	4.70%
A33	500.2	13100	3.81%
A34	90	11570	0.77%
A35	106.6	11480	0.92%
A36	178	14090	1.26%
A37	285	14440	1.97%
A38	443	13160	3.36%
A39	671	13250	5.06%
A40	1175	13550	8.67%
A41	93.3	11760	0.79%
A42	104.2	11550	0.92%
A43	142.5	13050	1.09%
A44	265	14390	1.84%
A45	302	13070	2.31%
A46	288	13150	2.19%
A47	852	13750	6.19%
A48	242	13000	1.86%
A49	277	13300	2.08%
A50	105	13670	0.76%
A51	162.8	14640	1.11%
A52	264	15430	1.71%
A53	118.9	14220	0.83%
A54	205	14730	1.39%
A55	281	15360	1.82%
A56	468	14670	3.19%
A57	237	14770	1.60%
A58	315	15150	2.07%
A59	505	14940	3.38%
A60	220	14990	1.46%
A61	388	14590	2.65%
A62	497	15430	3.22%
A63	198.2	15160	1.30%
A64	123.5	14120	0.87%
A65	110.1	16530	0.66%
A66	138.2	15630	0.88%
A67	145.2	14080	1.03%
A68	198.2	16260	1.21%
A69	330	15340	2.15%
A70	421	14140	2.97%
A71	612	16030	3.81%
A72	1550	14920	10.38%
A73	512	15130	3.38%
A74	3110	14990	20.74%
A75	3505	14970	23.41%
A76	148.3	12220	1.21%
A77	880	11480	7.66%
A78	94.3	11180	0.84%
A79	349	14420	2.42%
A80	330	14720	2.24%
A81	222	14660	1.51%
A82	162.3	15280	1.06%
A83	162.5	15040	1.08%
A84	141	14530	0.97%

Table7. *23 of February, 10:30 a.m.*

Mild snowy day with fresh snow on trees and ground

Point	Inside (in lux)	Outside (in lux)	DF
A1	3	2430	0.12%
A2	4	2430	0.16%
A3	6.1	2870	0.21%
A4	5	2860	0.17%
A5	10.2	2820	0.36%
A6	5.2	2820	0.18%
A7	12.9	2700	0.47%
A8	16	2780	0.57%
A9	16.1	2750	0.58%
A10	17	2680	0.63%
A11	14	2350	0.59%
A12	14.2	2350	0.60%
A13	12.1	2370	0.51%
A14	17	2370	0.71%
A15	35.2	2350	1.49%
A16	48.5	2380	2.03%
A17	61.2	2200	2.78%
A18	52.4	2050	2.55%
A19	23	2420	0.95%
A20	38.1	2450	1.55%
A21	58	2430	2.38%
A22	69.2	2160	3.20%
A23	142.5	2020	7.05%
A24	22.5	2480	0.90%
A25	37.2	2520	1.47%
A26	62.1	2490	2.49%
A27	73.8	2120	3.48%
A28	148.5	2010	7.38%
A29	22.6	2500	0.90%
A30	45.7	2530	1.80%
A31	66.2	2530	2.61%
A32	73.2	2090	3.50%
A33	103.5	2010	5.14%
A34	17.2	2630	0.65%
A35	23.2	2440	0.95%
A36	30.1	2470	1.21%
A37	32.1	2520	1.27%
A38	68.5	2450	2.79%
A39	102.8	2080	4.94%
A40	243	2090	11.62%
A41	18.9	2580	0.73%
A42	18.5	2440	0.75%
A43	22.5	2420	0.92%
A44	28.3	2460	1.15%
A45	55.3	2390	2.31%
A46	58.2	2040	2.85%
A47	154.2	2050	7.52%
A48	39.1	2330	1.67%
A49	38.8	2010	1.93%
A50	28.7	2080	1.37%
A51	32.1	2890	1.11%
A52	39.2	2800	1.4%
A53	30.3	2650	1.14%
A54	40.1	2890	1.38%
A55	40.8	2820	1.44%
A56	42.1	2720	1.54%
A57	35.2	2880	1.22%
A58	52.5	2860	1.83%
A59	94.5	2720	3.47%
A60	42	2880	1.45%
A61	46.5	2860	1.62%
A62	88.5	2750	3.21%
A63	32.2	2890	1.11%
A64	23.3	2890	0.80%
A65	18.1	2760	0.65%
A66	23.3	2930	0.79%
A67	26.7	2890	0.92%
A68	21.4	2770	0.77%
A69	47.7	2970	1.60%
A70	58.2	2870	2.02%
A71	97.1	2830	3.43%
A72	241	3030	7.95%
A73	827	3920	21.09%
A74	744	3060	24.31%
A75	1210	3020	40.06%
A76	50.1	2800	1.78%
A77	295	2810	10.49%
A78	45.5	2830	1.60%
A79	75	2810	2.66%
A80	99.2	2800	3.54%
A81	44.5	2800	1.58%
A82	43.3	2910	1.48%
A83	36.4	2860	1.27%
A84	33.2	2850	1.17%

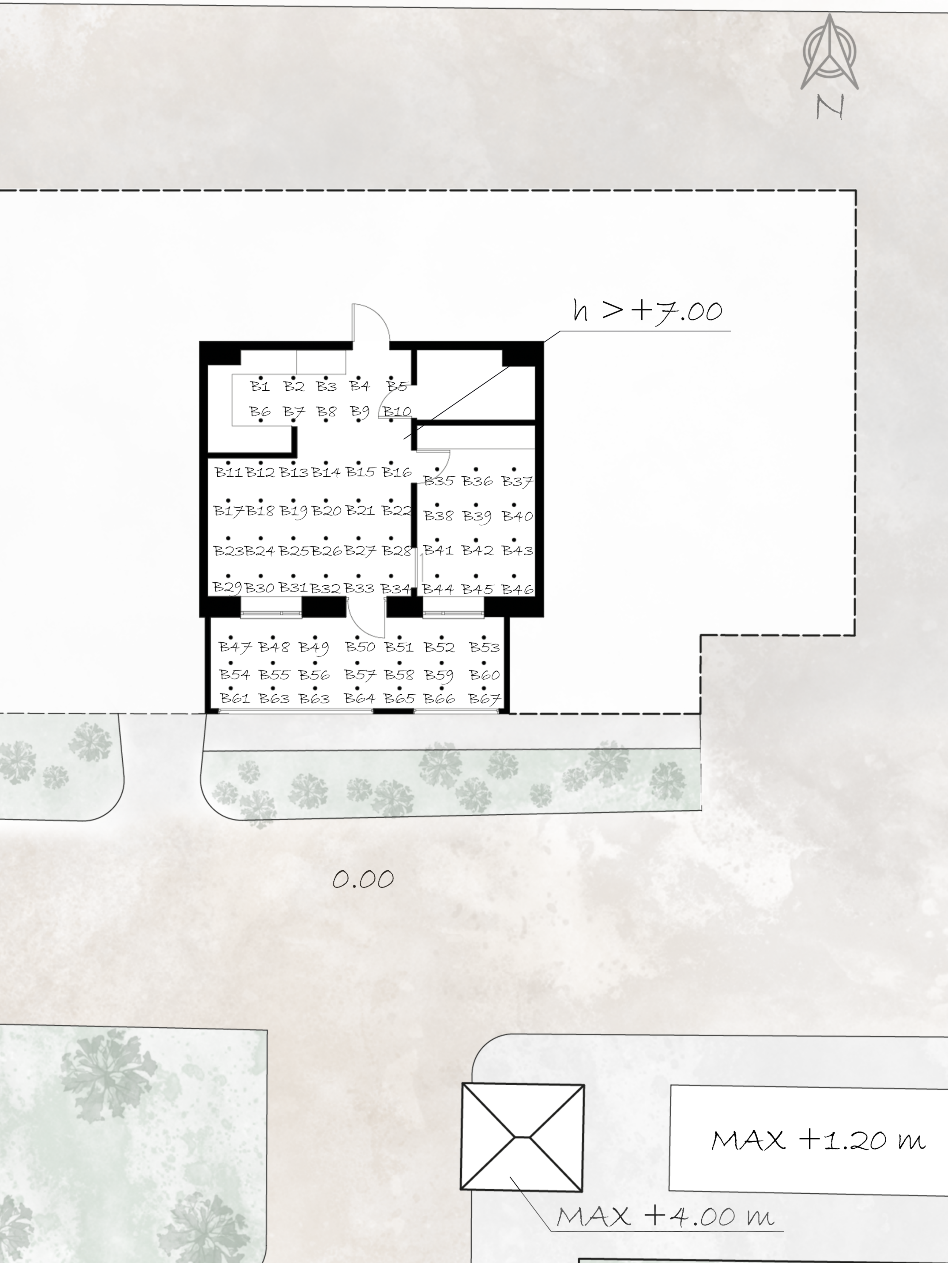

Table8. *Average DF for each point*

Point	24th Mar	15th Mar	7th Mar	28th Feb	25th Feb	19th Feb	18th Feb	12th Feb	11th Feb	Average
B1	0.03%	0.03%	0.09%	0.05%	0.13%	0.05	0.10%	0.03%	0.10%	0.06%
B2	0.05%	0.06%	0.17%	0.10%	0.29%	0.10	0.27%	0.08%	0.18%	0.14%
B3	0.15%	0.19%	0.51%	0.25%	0.73%	0.23%	0.18%	0.23%	0.55%	0.33%
B4	0.11%	0.13%	0.35%	0.20%	0.53%	0.20%	0.21%	0.16%	0.36%	0.25%
B5	0.12%	0.14%	0.33%	0.21%	0.51%	0.20%	0.16%	0.16%	0.37%	0.24%
B6	0.02%	0.02%	0.09%	0.05%	0.09%	0.04%	0.13%	0.03%	0.11%	0.06%
B7	0.09%	0.08%	0.21%	0.12%	0.37%	0.12%	0.15%	0.11%	0.31%	0.17%
B8	0.13%	0.22%	0.59%	0.28%	0.69%	0.22%	0.14%	0.23%	0.48%	0.33%
B9	0.15%	0.18%	0.41%	0.26%	0.67%	0.26%	0.30%	0.21%	0.46%	0.32%
B10	0.15%	0.19%	0.42%	0.27%	0.67%	0.28%	0.30%	0.23%	0.51%	0.33%
B11	0.47%	0.55%	1.37%	0.62%	1.16%	0.59%	0.61%	0.56%	2.12%	0.89%
B12	0.47%	0.71%	1.64%	0.80%	1.66%	0.70%	0.78%	0.65%	2.02%	1.04%
B13	0.44%	0.57%	1.22%	0.70%	1.76%	0.60%	0.61%	0.65%	1.65%	0.91%
B14	0.31%	0.38%	0.72%	0.38%	1.41%	0.31%	0.26%	0.32%	0.66%	0.52%
B15	0.21%	0.28%	0.59%	0.36%	0.91%	0.38%	0.37%	0.27%	0.67%	0.44%
B16	0.19%	0.25%	0.66%	0.36%	0.97%	0.36%	0.31%	0.28%	0.63%	0.44%
B17	0.44%	0.60%	1.09%	0.55%	1.27%	0.57%	0.63%	0.54%	1.60%	0.81%
B18	0.50%	0.63%	1.34%	0.78%	1.48%	0.65%	0.68%	0.61%	1.30%	0.88%
B19	0.47%	0.61%	1.45%	0.81%	1.45%	0.76%	0.78%	0.63%	1.20%	0.90%
B20	0.28%	0.44%	0.89%	0.46%	1.41%	0.45%	0.42%	0.41%	0.86%	0.62%
B21	0.34%	0.36%	1.11%	0.56%	1.44%	0.47%	0.52%	0.39%	0.82%	0.66%
B22	0.32%	0.36%	0.97%	0.54%	1.24%	0.43%	0.44%	0.37%	0.72%	0.59%
B23	0.67%	0.60%	1.47%	0.82%	1.02%	0.75%	0.91%	0.65%	2.69%	1.06%
B24	0.77%	0.95%	2.59%	1.22%	2.11%	1.09%	1.10%	1.00%	2.04%	1.43%
B25	0.90%	0.82%	1.79%	1.42%	1.61%	0.96%	1.06%	0.81%	1.39%	1.19%
B26	0.35%	0.41%	1.09%	0.53%	1.14%	0.48%	0.39%	0.42%	0.96%	0.64%
B27	0.53%	0.54%	1.62%	0.88%	3.05%	0.73%	0.93%	0.63%	1.08%	1.11%
B28	0.52%	0.77%	1.83%	1.19%	2.49%	1.07%	0.94%	0.66%	1.24%	1.19%
B29	0.61%	0.61%	1.49%	0.96%	1.02%	0.80%	0.87%	0.72%	3.91%	1.22%
B30	2.54%	2.20%	4.60%	2.47%	3.12%	2.68%	2.69%	2.19%	4.37%	2.98%
B31	1.66%	1.49%	3.51%	2.56%	2.83%	1.73%	1.97%	2.22%	4.36%	2.48%
B32	0.28%	0.32%	0.96%	0.40%	0.76%	0.43%	0.41%	0.31%	0.65%	0.50%
B33	1.09%	1.40%	3.13%	2.03%	4.76%	1.50%	1.73%	1.30%	1.42%	2.04%
B34	0.72%	0.91%	3.15%	1.91%	2.67%	0.99%	0.88%	0.75%	1.02%	1.44%
B35	0.41%	0.48%	1.72%	0.74%	0.71%	0.50%	0.69%	0.61%	1.98%	0.87%
B36	0.35%	0.34%	1.48%	0.58%	0.49%	0.48%	0.51%	0.53%	1.17%	0.65%
B37	0.22%	0.20%	0.90%	0.43%	0.32%	0.37%	0.38%	0.36%	1.00%	0.46%
B38	0.42%	0.51%	1.41%	0.65%	0.71%	0.63%	0.51%	0.59%	1.99%	0.82%
B39	0.41%	0.48%	1.43%	0.79%	0.68%	0.64%	0.63%	0.61%	1.32%	0.77%
B40	0.24%	0.29%	0.92%	0.43%	0.48%	0.43%	0.34%	0.37%	0.87%	0.48%

B41	0.84%	0.82%	3.15%	1.14%	1.39%	0.79%	0.98%	1.10%	2.89%	1.45%
B42	0.63%	0.62%	2.45%	0.99%	1.33%	0.76%	0.94%	0.77%	1.47%	1.10%
B43	0.29%	0.30%	1.75%	0.62%	0.55%	0.44%	0.42%	0.43%	0.83%	0.62%
B44	1.69%	1.75%	5.61%	2.47%	2.83%	1.52%	1.74%	1.97%	6.05%	2.84%
B45	1.42%	1.21%	6.48%	2.36%	2.03%	1.46%	1.92%	1.67%	3.22%	2.41%
B46	0.13%	0.15%	0.71%	0.28%	0.29%	0.24%	0.25%	0.26%	0.59%	0.32%
B47	12.19%	12.77%	17.52%	14.46%	17.24%	12.22%	14.15%	10.74%	29.82%	15.67%
B48	14.18%	11.52%	24.60%	19.76%	20.04%	13.17%	14.62%	14.43%	23.97%	17.36%
B49	13.80%	12.05%	26.80%	21.54%	25.93%	14.15%	15.19%	14.88%	26.20%	18.93%
B50	11.06%	10.09%	27.77%	20.58%	24.85%	10.96%	13.03%	14.44%	15.89%	16.51%
B51	9.58%	9.59%	19.18%	11.48%	22.94%	10.77%	11.65%	10.81%	18.85%	13.87%
B52	11.64%	10.00%	17.71%	14.04%	13.62%	10.75%	13.14%	10.44%	20.09%	13.49%
B53	8.76%	9.53%	27.64%	11.75%	17.83%	10.38%	11.22%	11.23%	14.33%	13.63%
B54	17.73%	18.64%	26.65%	22.47%	38.72%	19.16%	23.14%	18.41%	34.87%	24.42%
B55	23.74%	20.38%	37.24%	36.01%	51.36%	21.15%	22.40%	25.61%	29.25%	29.68%
B56	23.09%	18.22%	40.31%	30.34%	44.25%	19.48%	20.57%	22.88%	26.60%	27.30%
B57	17.89%	14.24%	38.15%	27.37%	41.14%	16.21%	16.54%	20.11%	22.66%	23.81%
B58	12.63%	11.91%	26.26%	17.57%	21.82%	12.9%	13.89%	13.04%	19.55%	16.61%
B59	19.32%	15.91%	24.41%	21.05%	38.38%	15.61%	16.05%	16.93%	25.64%	21.47%
B60	16.44%	14.29%	26.95%	23.56%	28.06%	15.21%	16.26%	23.09%	20.49%	20.48%
B61	26.04%	28.91%	35.54%	33.21%	36.64%	27.12%	24.37%	31.66%	49.68%	32.57%
B62	28.63%	29.35%	43.23%	38.93%	36.38%	33.72%	27.73%	29.75%	38.92%	34.07%
B63	28.14%	28.43%	52.67%	39.65%	42.48%	30.42%	21.49%	29.16%	38.49%	34.58%
B64	22.11%	23.22%	45.91%	31.49%	37.54%	23.71%	20.75%	28.31%	31.35%	29.37%
B65	6.34%	9.26%	14.42%	14.92%	50.72%	8.14%	12.22%	8.32%	12.4%	15.19%
B66	19.65%	19.15%	34.30%	23.80%	33.52%	21.93%	23.02%	18.19%	33.17%	25.19%
B67	25.30%	28.18%	42.64%	34.14%	25.46%s	25.14%	26.34%	23.20%	26.75%	25.74%

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Table9. *24th of March 4:00 p.m.,*

Cloudy day, less old dirty snow on the ground, no snow on the trees.

Point	***Inside (in lux)***	***Outside (in lux)***	***DF***
B1	1.1	3610	0.03%
B2	2.2	3720	0.05%
B3	5.9	3790	0.15%
B4	4.5	3800	0.11%
B5	5	3880	0.12%
B6	0.8	3560	0.02%
B7	3.2	3470	0.09%
B8	4.7	3440	0.13%
B9	5.2	3370	0.15%
B10	5.2	3360	0.15%
B11	15.5	3280	0.47%
B12	15.7	3330	0.47%
B13	15.2	3390	0.44%
B14	10.7	3410	0.31%
B15	7.3	3410	0.21%
B16	6.5	3390	0.19%
B17	14.7	3290	0.44%
B18	16.9	3320	0.50%
B19	16.2	3400	0.47%
B20	10	3560	0.28%
B21	11.9	3450	0.34%
B22	11.7	3560	0.32%
B23	23	3390	0.67%
B24	26.1	3370	0.77%
B25	30.3	3340	0.90%
B26	11.9	3390	0.35%
B27	19.3	3600	0.53%
B28	19	3600	0.52%
B29	20.7	3390	0.61%
B30	87.4	3430	2.54%
B31	59.3	3570	1.66%
B32	10.5	3660	0.28%
B33	38	3460	1.09%
B34	26	3570	0.72%
B35	16.3	3970	0.41%
B36	14.3	4060	0.35%
B37	9.3	4100	0.22%
B38	17.2	4050	0.42%
B39	15.9	3870	0.41%

B40	9.3	3850	0.24%
B41	33.4	3940	0.84%
B42	24.6	3890	0.63%
B43	11.5	3880	0.29%
B44	75.3	4440	1.69%
B45	58.9	4130	1.42%
B46	5.6	4020	0.13%
B47	605	4960	12.19%
B48	702	4950	14.18%
B49	715	5180	13.80%
B50	583	5270	11.06%
B51	507	5290	9.58%
B52	622	5340	11.64%
B53	426	4860	8.76%
B54	855	4820	17.73%
B55	1166	4910	23.74%
B56	1185	5130	23.09%
B57	952	5320	17.89%
B58	657	5200	12.63%
B59	1032	5340	19.32%
B60	837	5090	16.44%
B61	1250	4800	26.04%
B62	1446	5050	28.63%
B63	1441	5120	28.14%
B64	1181	5340	22.11%
B65	337	5310	6.34%
B66	1040	5290	19.65%
B67	1341	5300	25.30%

Table10. *15th of March, 8:00 a.m.*

cloudy day, old dirty snow on the ground, no snow on the trees.

Point	***Inside (in lux)***	***Outside (in lux)***	***DF***
B1	0.5	1349	0.03%
B2	0.9	1345	0.06%
B3	2.5	1304	0.19%
B4	1.8	1295	0.13%
B5	1.8	1276	0.14%
B6	0.4	1372	0.02%
B7	1.1	1336	0.08%
B8	2.9	1315	0.22%
B9	2.3	1262	0.18%
B10	2.5	1273	0.19%
B11	8.8	1595	0.55%
B12	10.5	1465	0.71%
B13	8.4	1457	0.57%
B14	5.5	1446	0.38%
B15	3.6	1263	0.28%
B16	3.2	1255	0.25%
B17	9	1487	0.60%
B18	9.9	1561	0.63%
B19	9.3	1509	0.61%
B20	7.3	1641	0.44%
B21	4.5	1240	0.36%
B22	4.6	1250	0.36%
B23	10.5	1744	0.60%
B24	16.6	1735	0.95%
B25	14.3	1726	0.82%
B26	7	1690	0.41%
B27	6.7	1237	0.54%
B28	9.6	1236	0.77%
B29	10.8	1762	0.61%
B30	37.5	1704	2.20%
B31	25.2	1705	1.49%
B32	5.5	1695	0.32%
B33	17.1	1221	1.40%
B34	11.2	1222	0.91%
B35	7.4	1522	0.48%
B36	5.1	1460	0.34%
B37	2.9	1435	0.20%
B38	8	1543	0.51%
B39	7.2	1477	0.48%

B40	4.2	1409	0.29%
B41	13.1	1580	0.82%
B42	10	1604	0.62%
B43	500	1621	0.30%
B44	29.2	1667	1.75%
B45	20.1	1659	1.21%
B46	2.5	1634	0.15%
B47	155.5	1217	12.77%
B48	136	1180	11.52%
B49	141.3	1172	12.05%
B50	111	1100	10.09%
B51	102.9	1072	9.59%
B52	106.4	1064	10.00%
B53	105.2	1103	9.53%
B54	226	1212	18.64%
B55	243	1192	20.38%
B56	212	1163	18.22%
B57	158.4	1112	14.24%
B58	127.9	1073	11.91%
B59	171.4	1077	15.91%
B60	158.7	1110	14.29%
B61	349	1207	28.91%
B62	352	1199	29.35%
B63	327	1150	28.43%
B64	262	1128	23.22%
B65	99.3	1072	9.26%
B66	205	1070	19.15%
B67	321	1139	28.18%

Table11. *7th of March, 16:00*

semi-cloudy day, old white snow on the ground, no snow on the trees.

Point	***Inside (in lux)***	***Outside (in lux)***	***DF***
B1	3.9	4160	0.09%
B2	7.5	4220	0.17%
B3	22.9	4430	0.51%
B4	15.3	4340	0.35%
B5	14.3	4320	0.33%
B6	3.7	4030	0.09%
B7	9.3	4400	0.21%
B8	26.2	4420	0.59%
B9	18.5	4490	0.41%
B10	18.2	4280	0.42%
B11	53.2	3860	1.37%
B12	64.3	3900	1.64%
B13	50.4	4130	1.22%
B14	30.9	4260	0.72%
B15	25	4220	0.59%
B16	27.7	4180	0.66%
B17	41.3	3770	1.09%
B18	51.5	3840	1.34%
B19	59.7	4100	1.45%
B20	36.9	4140	0.89%
B21	42.7	3830	1.11%
B22	39.7	4090	0.97%
B23	53.4	3610	1.47%
B24	88.5	3410	2.59%
B25	60.2	3350	1.79%
B26	36.9	3360	1.09%
B27	62	3810	1.62%
B28	68.4	3720	1.83%
B29	49.2	3300	1.49%
B30	150.7	3270	4.60%
B31	115.2	3280	3.51%
B32	32.3	3330	0.96%
B33	121.2	3870	3.13%
B34	117.2	3720	3.15%
B35	66.4	3860	1.72%
B36	58.1	3900	1.48%
B37	34.4	3810	0.90%
B38	53.7	3800	1.41%
B39	56.5	3930	1.43%
B40	34.5	3720	0.92%

B41	99.8	3160	3.15%
B42	87.6	3570	2.45%
B43	64.3	3670	1.75%
B44	198.2	3530	5.61%
B45	232	3580	6.48%
B46	26.2	3660	0.71%b
B47	589	3360	17.52%
B48	785	3190	24.60%
B49	914	3410	26.80%
B50	997	3590	27.77%
B51	687	3580	19.18%
B52	604	3410	17.71%
B53	937	3390	27.64%
B54	909	3410	26.65%
B55	1285	3450	37.24%
B56	1387	3440	40.31%
B57	1343	3520	38.15%
B58	935	3560	26.26%
B59	840	3440	24.41%
B60	930	3450	26.95%
B61	1244	3500	35.54%
B62	1522	3520	43.23%
B63	1833	3480	52.67%
B64	1598	3480	45.91%
B65	505	3500	14.42%
B66	1180	3440	34.30%
B67	1467	3440	42.64%

Table12. *28TH of February, 4:00 p.m.*

Cloudy day, old white snow on the ground, no snow on the trees.

Point	***Inside (in lux)***	***Outside (in lux)***	***DF***
B1	2.2	4010	0.05%
B2	4.1	4040	0.10%
B3	10.3	3990	0.25%
B4	8	3980	0.20%
B5	8.4	3960	0.21%
B6	2.1	4000	0.05%
B7	5.1	4040	0.12%
B8	11.4	4060	0.28%
B9	10.8	4070	0.26%
B10	11.1	4090	0.27%
B11	25.1	4020	0.62%
B12	32.5	4030	0.80%
B13	28.5	4040	0.70%
B14	15.7	4120	0.38%
B15	15.2	4180	0.36%
B16	15.2	4130	0.36%
B17	23	4110	0.55%
B18	32.4	4110	0.78%
B19	33.7	4140	0.81%
B20	19.5	4170	0.46%
B21	23.7	4160	0.56%
B22	22.8	4150	0.54%
B23	33.4	4040	0.82%
B24	49.5	4050	1.22%
B25	57.7	4040	1.42%
B26	22.6	4190	0.53%
B27	37.3	4200	0.88%
B28	50.5	4210	1.19%
B29	38.5	3990	0.96%
B30	99	4000	2.47%
B31	102.7	4010	2.56%
B32	16.9	4180	0.40%
B33	85.2	4190	2.03%
B34	79	4120	1.91%
B35	29.9	4000	0.74%
B36	23.6	4010	0.58%
B37	17.5	3980	0.43%
B38	26.1	4010	0.65%
B39	31.1	3930	0.79%
B40	18.3	4160	0.43%
B41	45.5	3990	1.14%

B42	36.9	4000	0.99%
B43	24.9	3960	0.62%
B44	97.4	3940	2.47%
B45	93.2	3940	2.36%
B46	11	3910	0.28%
B47	603	4170	14.46%
B48	844	4270	19.76%
B49	1019	4730	21.54%
B50	875	4250	20.58%
B51	510	4440	11.48%
B52	625	4450	14.04%
B53	528	4490	11.75%
B54	955	4250	22.47%
B55	1545	4290	36.01%
B56	1320	4350	30.34%
B57	1210	4420	27.37%
B58	784	4460	17.57%
B59	901	4280	21.05%
B60	1072	4550	23.56%
B61	1415	4260	33.21%
B62	1678	4310	38.93%
B63	1737	4380	39.65%
B64	1392	4420	31.49%
B65	670	4490	14.92%
B66	1064	4470	23.80%
B67	1540	4510	34.14%

Table13. *25TH of February,1:00 p.m.*

Cloudy day, white snow on the ground, snow on the trees.

Point	***Inside (in lux)***	***Outside (in lux)***	***DF***
B1	19.1	14430	0.13%
B2	43.8	14670	0.29%
B3	107.2	14600	0.73%
B4	77.4	14530	0.53%
B5	74	14240	0.51%
B6	14.4	14530	0.09%
B7	55.8	14700	0.37%
B8	99.7	14390	0.69%
B9	99.1	14700	0.67%
B10	97.4	14480	0.67%
B11	163	13950	1.16%
B12	234	14090	1.66%
B13	252	14250	1.76%
B14	202	14250	1.41%
B15	132.1	14380	0.91%
B16	140	14390	0.97%
B17	175.4	13780	1.27%
B18	198	13350	1.48%
B19	195.8	13430	1.45%
B20	185	13100	1.41%
B21	187	12980	1.44%
B22	158.9	12790	1.24%
B23	132.1	12840	1.02%
B24	270	12790	2.11%
B25	205	12700	1.61%
B26	143.9	12570	1.14%
B27	384	12550	3.05%
B28	312	12490	2.49%
B29	115.3	11240	1.02%
B30	352	11260	3.12%
B31	329	11620	2.83%
B32	92.1	12010	0.76%
B33	573	12030	4.76%
B34	323	12090	2.67%
B35	81.5	11450	0.71%
B36	57.1	11540	0.49%
B37	37.3	11460	0.32%
B38	81	11350	0.71%
B39	76.5	11200	0.68%
B40	55.2	11320	0.48%

B41	155	11110	1.39%
B42	146.2	10920	1.33%
B43	61.3	11100	0.55%
B44	315	11130	2.83%
B45	228	11230	2.03%
B46	33.3	11190	0.29%
B47	2550	14790	17.24%
B48	2960	14770	20.04%
B49	3810	14690	25.93%
B50	3540	14240	24.85%
B51	3460	15080	22.94%
B52	2070	15190	13.62%
B53	2650	14860	17.83%
B54	5750	14850	38.72%
B55	7720	15030	51.36%
B56	6630	14980	44.25%
B57	6230	15140	41.14%
B58	3280	15030	21.82%
B59	5860	15280	38.38%
B60	4140	14750	28.06%
B61	5500	15010	36.64%
B62	5440	14950	36.38%
B63	6470	15230	42.48%
B64	5670	15100	37.54%
B65	7720	15220	50.72%
B66	5380	16050	33.52%
B67	3730	14650	25.46%s

Table14. *19TH of February, 10:00 a.m.*

Snowy day, white snow on the ground, snow on the trees.

Point	***Inside (in lux)***	***Outside (in lux)***	***DF***
B1	4.8	9560	0.05
B2	10	9220	0.10
B3	17.7	7570	0.23%
B4	15.1	7400	0.20%
B5	15.2	7420	0.20%
B6	4.3	9300	0.04%
B7	11	9070	0.12%
B8	17.2	7510	0.22%
B9	19.6	7460	0.26%
B10	21.2	7370	0.28%
B11	45.5	7670	0.59%
B12	54.1	7650	0.70%
B13	46.6	7710	0.60%
B14	23.9	7490	0.31%
B15	28.2	7310	0.38%
B16	26.8	7290	0.36%
B17	44.3	7650	0.57%
B18	50.2	7650	0.65%
B19	58.4	7650	0.76%
B20	34.2	7450	0.45%
B21	34.5	7190	0.47%
B22	31.5	7210	0.43%
B23	58.3	7690	0.75%
B24	83	7570	1.09%
B25	74.2	7670	0.96%
B26	36.3	7490	0.48%
B27	54.1	7360	0.73%
B28	78.5	7320	1.07%
B29	62	7670	0.80%
B30	208	7750	2.68%
B31	131.3	7550	1.73%
B32	31.9	7410	0.43%
B33	111	7390	1.50%
B34	73.3	7390	0.99%
B35	37.2	7400	0.50%
B36	35	7180	0.48%
B37	27.3	7360	0.37%
B38	44.8	7060	0.63%
B39	46.4	7220	0.64%
B40	31.7	7340	0.43%

B41	56.5	7090	0.79%
B42	56.2	7370	0.76%
B43	32.7	7330	0.44%
B44	109.2	7180	1.52%
B45	105.9	7200	1.46%
B46	17.7	7140	0.24%
B47	879	7190	12.22%
B48	909	6900	13.17%
B49	985	6960	14.15%
B50	762	6950	10.96%
B51	750	6960	10.77%
B52	744	6920	10.75%
B53	705	6790	10.38%
B54	1380	7200	19.16%
B55	1481	7000	21.15%
B56	1358	6970	19.48%
B57	1127	6950	16.21%
B58	903	7000	12.9%
B59	1057	6770	15.61%
B60	1027	6750	15.21%
B61	1945	7170	27.12%
B62	2320	6880	33.72%
B63	2130	7000	30.42%
B64	1648	6950	23.71%
B65	570	7000	8.14%
B66	1498	6830	21.93%
B67	1685	6700	25.14%

Table15. *18TH of February, 10 a.m.*

Snowy day, white snow on the ground, snow on the trees.

Point	***Inside (in lux)***	***Outside (in lux)***	***DF***
B1	6.1	5890	0.10%
B2	15.5	5720	0.27%
B3	11.5	6090	0.18%
B4	11.7	5490	0.21%
B5	9.4	5540	0.16%
B6	7.6	5680	0.13%
B7	9.1	5770	0.15%
B8	8.7	6170	0.14%
B9	16.4	5450	0.30%
B10	17	5650	0.30%
B11	37.3	6080	0.61%
B12	46.4	5940	0.78%
B13	36.2	5860	0.61%
B14	16.2	6130	0.26%
B15	20.5	5460	0.37%
B16	17.7	5630	0.31%
B17	39	6120	0.63%
B18	40.5	5920	0.68%
B19	45.5	5830	0.78%
B20	25.7	6050	0.42%
B21	29.3	5540	0.52%
B22	25.3	5630	0.44%
B23	57.1	6210	0.91%
B24	69.2	6270	1.10%
B25	65.5	6170	1.06%
B26	23.3	5830	0.39%
B27	53.3	5690	0.93
B28	52.4	5540	0.94%
B29	53.2	6100	0.87%
B30	158.2	5880	2.69%
B31	114.2	5780	1.97%
B32	24.1	5760	0.41%
B33	101.9	5870	1.73%
B34	48.4	5440	0.88%
B35	37.7	5420	0.69%
B36	28.9	5590	0.51%
B37	21.7	5660	0.38%
B38	29.4	5750	0.51%
B39	36.2	5740	0.63%
B40	19.9	5730	0.34%
B41	56.3	5690	0.98%

B42	53.9	5690	0.94%
B43	24.1	5640	0.42%
B44	96.2	5520	1.74%
B45	106	5520	1.92%
B46	14	5540	0.25%
B47	794	5610	14.15%
B48	822	5620	14.62%
B49	845	5560	15.19%
B50	718	5510	13.03%
B51	620	5320	11.65%
B52	598	4550	13.14%
B53	513	4570	11.22%
B54	1303	5630	23.14%
B55	1257	5610	22.40%
B56	1140	5540	20.57%
B57	918	5550	16.54%
B58	720	5180	13.89%
B59	740	4610	16.05%
B60	727	4470	16.26%
B61	1370	5620	24.37%
B62	1545	5570	27.73%
B63	1195	5560	21.49%
B64	1154	5560	20.75%
B65	604	4940	12.22%
B66	1027	4460	23.02%
B67	1238	4700	26.34%

Table16. *12TH of February, 10:00 a.m.*

Cloudy day, fresh snow on ground and the trees

Point	***Inside (in lux)***	***Outside (in lux)***	***DF***
B1	1.4	3640	0.03%
B2	2.8	3490	0.08%
B3	8.2	3490	0.23%
B4	5.9	3530	0.16%
B5	5.6	3490	0.16%
B6	1.2	3630	0.03%
B7	4.1	3650	0.11%
B8	8.7	3670	0.23%
B9	7.8	3700	0.21%
B10	8.8	3730	0.23%
B11	23	4090	0.56%
B12	25.7	3900	0.65%
B13	25.3	3870	0.65%
B14	12.6	3840	0.32%
B15	10.6	3800	0.27%
B16	10.7	3760	0.28%
B17	22.2	4060	0.54%
B18	24.4	3960	0.61%
B19	25.5	3990	0.63%
B20	16.7	4040	0.41%
B21	15.8	4040	0.39%
B22	15.2	4070	0.37%
B23	26.6	4050	0.65%
B24	41.2	4100	1.00%
B25	33.4	4110	0.81%
B26	17.5	4070	0.42%
B27	25.9	4080	0.63%
B28	26.7	4040	0.66%
B29	29.4	4030	0.72%
B30	67.3	3070	2.19%
B31	68.1	3060	2.22%
B32	12.3	3880	0.31%
B33	50.2	3860	1.30%
B34	28.7	3810	0.75%
B35	22.6	3690	0.61%
B36	19.4	3660	0.53%
B37	13.3	3630	0.36%
B38	20.7	3500	0.59%
B39	21.7	3530	0.61%
B40	13.5	3610	0.37%
B41	38.5	3470	1.10%

B42	26.7	3460	0.77%
B43	15.1	3510	0.43%
B44	68.2	3450	1.97%
B45	58.4	3480	1.67%
B46	9	3450	0.26%
B47	403	3750	10.74%
B48	475	3290	14.43%
B49	512	3440	14.88%
B50	497	3440	14.44%
B51	385	3560	10.81%
B52	375	3590	10.44%
B53	418	3720	11.23%
B54	582	3160	18.41%
B55	835	3260	25.61%
B56	778	3400	22.88%
B57	704	3500	20.11%
B58	463	3550	13.04%
B59	613	3620	16.93%
B60	850	3680	23.09%
B61	950	3000	31.66%
B62	979	3290	29.75%
B63	983	3370	29.16%
B64	991	3500	28.31%
B65	293	3520	8.32%
B66	664	3650	18.19%
B67	854	3680	23.20%

Table17. *11TH of February, 10:00 a.m.*

Cloudy day, fresh snow on ground and the trees.

Point	***Inside (in lux)***	***Outside (in lux)***	***DF***
B1	5.1	4870	0.10%
B2	9.3	4910	0.18%
B3	26.2	4710	0.55%
B4	17	4700	0.36%
B5	17.7	4720	0.37%
B6	5.7	4850	0.11%
B7	15.2	4780	0.31%
B8	23.2	4770	0.48%
B9	22.1	4780	0.46%
B10	24.5	4770	0.51%
B11	107.2	5040	2.12%
B12	101.1	5000	2.02%
B13	82.5	4970	1.65%
B14	32.7	4920	0.66%
B15	33.2	4820	0.67%
B16	30.2	4750	0.63%
B17	81.9	5100	1.60%
B18	67	5130	1.30%
B19	61.7	5100	1.20%
B20	44.3	5120	0.86%
B21	42.1	5110	0.82%
B22	37.3	5130	0.72%
B23	133.9	4970	2.69%
B24	102.5	5020	2.04%
B25	70.1	5010	1.39%
B26	48.5	5040	0.96%
B27	54.6	5030	1.08%
B28	63.7	5110	1.24%
B29	192.4	4920	3.91%
B30	214	4890	4.37%
B31	215	4920	4.36%
B32	32.6	4950	0.65%
B33	66.5	4680	1.42%
B34	48.1	4690	1.02%
B35	89.9	4530	1.98%
B36	54.2	4620	1.17%
B37	46.7	4640	1.00%
B38	90.1	4520	1.99%
B39	60.6	4560	1.32%
B40	40.3	4610	0.87%
B41	125.1	4320	2.89%

B42	62.5	4240	1.47%
B43	34.2	4080	0.83%
B44	233	3850	6.05%
B45	124.3	3860	3.22%
B46	23.2	3900	0.59%
B47	1375	4610	29.82%
B48	1127	4700	23.97%
B49	1174	4480	26.20%
B50	701	4410	15.89%
B51	809	4290	18.85%
B52	840	4180	20.09%
B53	592	4130	14.33%
B54	1632	4680	34.87%
B55	1302	4450	29.25%
B56	1192	4480	26.60%
B57	995	4390	22.66%
B58	835	4270	19.55%
B59	1072	4180	25.64%
B60	834	4070	20.49%
B61	2340	4710	49.68%
B62	1767	4540	38.92%
B63	1709	4440	38.49%
B64	1367	4360	31.35%
B65	527	4250	12.4%
B66	1400	4220	33.17%
B67	1070	4000	26.75%

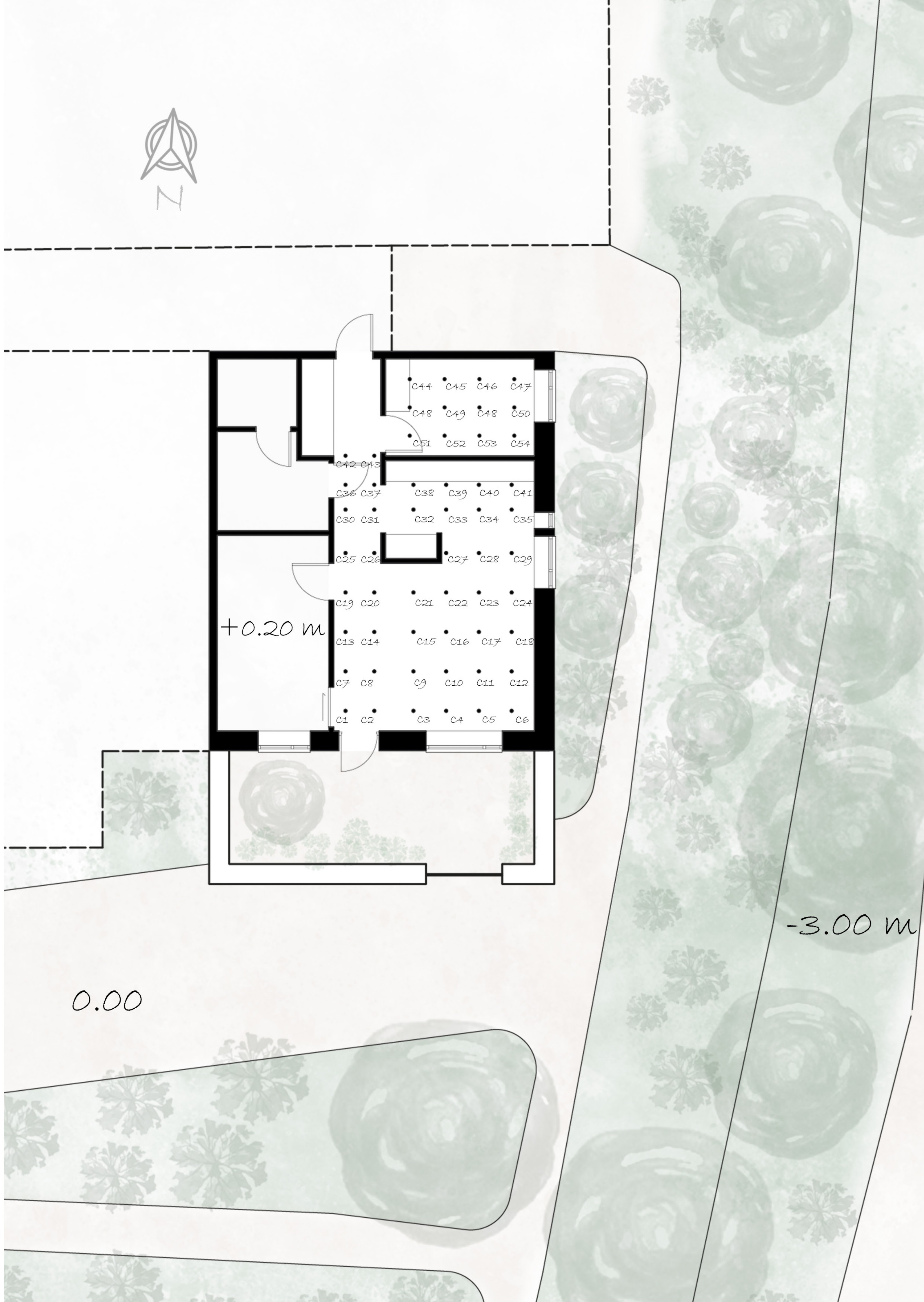

Table18. *Average DF for each point*

Point	24th Mar	15th Mar	7th Mar	28th Feb	25th Feb	19th Feb	18th Feb	13th Feb	12th Feb	11th Feb	Average
C1	5.99%	7.84%	11.60%	9.26%	11.12%	6.77%	6.64%	8.92%	7.82%	12.46%	8.84%
C2	6.34%	5.79%	7.54%	5.68%	6.37%	3.98%	4.44%	2.90%	3.98%	4.67%	5.16%
C3	3.12%	5.47%	5.52%	3.64%	5.78%	5.93%	5.08%	5.49%	3.94%	5.01%	4.89%
C4	6.06%	6.24%	9.93%	8.35%	10.45%	9.05%	9.03%	10.23%	8.93%	11.64%	8.99%
C5	6.96%	6.58%	9.86%	8.66%	9.30%	9.55%	7.96%	9.96%	9.24%	7.46%	8.55%
C6	2.53%	3.30%	5.33%	4.90%	4.32%	4.53%	3.49%	3.87%	3.86%	2.32%	3.84%
C7	2.19%	2.66%	3.58%	2.20%	5.76%	2.26%	2.74%	2.66%	4.14%	2.48%	3.06%
C8	1.74%	1.76%	2.89%	2.37%	3.64%	2.84%	2.63%	2.43%	2.99%	1.84%	2.51%
C9	1.74%	2.96%	3.88%	2.82%	4.76%	3.56%	2.86%	2.34%	2.82%	2.46%	2.99%
C10	2.23%	3.03%	4.19%	4.33%	5.59%	3.96%	3.16%	3.02%	3.51%	3.71%	3.67%
C11	2.47%	3.21%	4.66%	3.88%	4.27%	4.32%	3.56%	3.83%	3.48%	4.31%	3.79%
C12	0.90%	1.70%	2.83%	2.19%	3.09%	2.45%	2.33%	2.40%	2.17%	1.84%	2.19%
C13	0.96%	1.20%	2.15%	1.48%	2.34%	1.88%	1.62%	1.28%	1.67%	1.50%	1.60%
C14	1.28%	1.36%	2.23%	1.82%	2.91%	2.13%	1.65%	1.45%	1.91%	1.77%	1.85%
C15	1.46%	1.64%	3.17%	2.17%	3.22%	2.59%	1.79%	1.75%	2.19%	2.31%	2.22%
C16	1.46%	1.81%	2.83%	2.37%	3.39%	2.91%	2.22%	1.80%	2.10%	1.83%	2.27%
C17	1.33%	2.15%	2.31%	2.50%	2.94%	3.14%	1.66%	3.61%	2.63%	3.11%	2.53%
C18	1.09%	1.39%	1.80%	1.96%	2.70%	2.30%	2.52%	3.51%	2.95%	0.98%	2.11%
C19	0.92%	0.96%	2.00%	1.40%	1.82%	1.80%	1.08%	1.08%	1.43%	1.29%	1.37%
C20	0.98%	1.21%	2.30%	1.50%	1.91%	1.84%	1.50%	1.50%	1.79%	1.37%	1.56%
C21	1.18%	1.48%	2.66%	2.02%	2.04%	2.53%	1.58%	1.58%	2.40%	1.74%	1.92%
C22	1.83%	2.03%	2.45%	2.85%	3.40%	3.16%	1.91%	1.91%	3.62%	1.68%	2.48%
C23	2.04%	3.64%	3.25%	4.04%	4.54%	4.35%	2.26%	2.26%	2.26%	2.08%	2.48%
C24	5.71%	6.55%	1.92%	7.01%	8.61%	7.68%	4.02%	4.02%	0.92%	3.03%	4.94%
C25	0.60%	0.72%	1.59%	1.03%	1.32%	1.23%	1.34%	0.82%	0.95%	1.27%	1.08%
C26	0.51%	0.61%	1.28%	0.66%	0.92%	1%	1.58%	0.62%	0.62%	0.97%	0.87%
C27	2.66%	3.96%	3.82%	3.58%	2.27%	4.15%	2.64%	2.88%	3.76%	2.59%	3.23%
C28	2.44%	3.74%	4.74%	3.52%	2.79%	3.18%	3.50%	3.56%	3.66%	3.31%	3.44%
C29	4.78%	9.45%	5.24%	4.38%	4.74%	5.47%	6.30%	5.07%	3.56%	2.27%	5.12%
C30	0.48%	0.59%	1.26%	0.79%	1.16%	1.11%	0.75%	0.76%	0.73%	1.17%	0.88%
C31	0.57%	0.65%	0.92%	0.74%	0.84%	1.13%	0.86%	0.65%	0.78%	0.74%	0.78%
C32	0.80%	0.99%	1.01%	1.20%	1.59%	1.42%	1.19%	1.15%	0.92%	0.76%	1.10%
C33	1.25%	2.22%	1.69%	1.92%	2.45%	2.06%	2.04%	1.84%	1.46%	0.88%	1.78%
C34	1.98%	3.08%	1.70%	3.15%	3.82%	3.02%	2.63%	2.62%	1.99%	1.18%	5.23%
C35	3.16%	5.90%	1.76%	1.36%	1.55%	5.25%	2.06%	5.23%	4.74%	0.54%	3.15%
C36	0.35%	1.11%	1.40%	0.81%	1.20%	1.02%	0.48%	0.65%	0.72%	0.95%	0.86%
C37	0.38%	1.04%	1.03%	0.68%	1.19%	1.11%	0.58%	0.48%	0.77%	0.89%	0.81%
C38	0.53%	0.90%	0.76%	0.95%	1.33%	1.11%	2.62%	0.96%	0.99%	0.76%	1.09%
C39	0.72%	1.24%	0.88%	1.26%	1.57%	1.39%	1.17%	1.02%	1.16%	0.73%	1.11%
C40	0.73%	1.44%	1.07%	1.12%	1.30%	1.38%	1.18%	0.87%	1.09%	0.94%	1.11%
C41	0.42%	1.14%	0.84%	0.92%	1.15%	1.18%	0.96%	0.73%	1.02%	0.74%	1.16%
C42	0.27%	0.55%	0.79%	0.52%	0.71%	0.70%	0.53%	0.44%	0.60%	1.09%	1.03%
C43	0.39%	0.67%	0.82%	0.55%	0.78%	0.77%	0.36%	0.46%	0.52%	0.71%	0.60%
C44	1.74%	2.90%	2.21%	1.83%	2.19%	2.50%	1.96%	1.43%	1.75%	1.29%	3.30%
C45	1.79%	4.13%	2.82%	2.58%	2.89%	3.19%	3.59%	2.51%	2.72%	1.39%	2.76%
C46	2.99%	4.12%	4.04%	3.09%	5.41%	5.61%	5.30%	4.87%	4.75%	1.63%	4.18%
C47	5.81%	9.66%	5.68%	7.60%	9.59%	9.86%	9.42%	7.20%	9.94%	2.39%	7.71%
C48	1.85%	3.25%	2.28%	2.03%	2.54%	2.83%	2.14%	1.76%	2.05%	1.21%	2.19%
C49	2.26%	4.39%	3.31%	2.67%	3.33%	3.59%	4.03%	2.87%	3.38%	1.59%	3.14%
C50	4.49%	9.76%	5.28%	5.73%	7.81%	7.35%	5.97%	6.36%	6.20%	2.06%	6.06%
C51	13.83%	16.36%	9.48%	12.97%	17.13%	17.26%	13.18%	14.81%	15.98%	4.38%	13.53%
C52	0.95%	1.32%	1.30%	1.34%	1.77%	1.87%	1.63%	1.31%	1.64%	0.84%	1.39%
C53	1.33%	2.31%	2.31%	1.95%	2.59%	2.73%	2.13%	1.99%	2.45%	1.11%	1.85%
C54	2.33%	4.51%	3.61%	2.92%	4.45%	5.27%	3.97%	4.95%	4.04%	1.24%	3.72%
C55	1.78%	1.09%	4.54%	7%	6.19%	9.68%	5.94%	5.79%	3.81%	2.21%	4.80%

Table19. *24TH of March, 4:30 p.m.*

Mild rainy day, less old snow on the ground, no snow on the trees.

Point	Inside (in lux)	Outside (in lux)	DF
C1	193	3220	5.99%
C2	208	3280	6.34%
C3	82	2620	3.12%
C4	152.3	2510	6.06%
C5	202	2900	6.96%
C6	74.3	2930	2.53%
C7	70.3	3200	2.19%
C8	55.7	3190	1.74%
C9	45.6	2620	1.74%
C10	58.7	2630	2.23%
C11	68.3	2760	2.47%
C12	26.2	2880	0.90%
C13	31	3220	0.96%
C14	41.3	3210	1.28%
C15	38.2	2610	1.46%
C16	38.2	2600	1.46%
C17	35.3	2640	1.33%
C18	30.7	2800	1.09%
C19	29	3130	0.92%
C20	31.2	3160	0.98%
C21	30.9	2600	1.18%
C22	48.2	2620	1.83%
C23	51	2500	2.04%
C24	160.5	2810	5.71%
C25	18.7	3100	0.60%
C26	16.2	3150	0.51%
C27	69.3	2600	2.66%
C28	65	2660	2.44%
C29	127.4	2660	4.78%
C30	16.4	3200	0.48%
C31	18.5	3230	0.57%
C32	21.4	2660	0.80%
C33	33.2	2650	1.25%
C34	49.7	2510	1.98%
C35	84.8	2680	3.16%
C36	10	2840	0.35%
C37	10.9	2850	0.38%
C38	14.3	2650	0.53%
C39	18.2	2500	0.72%
C40	19	2600	0.73%
C41	11.3	2640	0.42%
C42	7.7	2810	0.27%
C43	11	2810	0.39%
C44	3.4	2690	0.12%
C45	3.5	2740	0.12%
C46	3	2510	0.11%
C47	2.1	2580	0.08%
C48	45.2	2590	1.74%
C49	48.7	2720	1.79%
C50	86	2870	2.99%
C51	162.7	2800	5.81%
C52	45	2430	1.85%
C53	58.4	2580	2.26%
C5	130.7	2910	4.49%
C51	375	2710	13.83%
C52	23.4	2440	0.95%
C53	38.7	2900	1.33%
C54	68.2	2920	2.33%
C55	46.3	2600	1.78%

Table20. *15th of March, 8:15 a.m.*

Cloudy day, old snow on the ground, no snow on the trees.

Point	Inside (in lux)	Outside (in lux)	DF
C1	128.5	1639	7.84%
C2	95.1	1640	5.79%
C3	90.3	1650	5.47%
C4	106.2	1701	6.24%
C5	115.9	1761	6.58%
C6	59.9	1811	3.30%
C7	54.1	2030	2.66%
C8	38.4	2180	1.76%
C9	62.3	2100	2.96%
C10	59.8	1972	3.03%
C11	61.2	1901	3.21%
C12	31.8	1841	1.70%
C13	28.1	2330	1.20%
C14	33	2410	1.36%
C15	39.9	2420	1.64%
C16	45.5	2510	1.81%
C17	54	2510	2.15%
C18	35.5	2540	1.39%
C19	25	2600	0.96%
C20	31.1	2560	1.21%
C21	38.2	2570	1.48%
C22	51.9	2550	2.03%
C23	92.6	2540	3.64%
C24	167.9	2560	6.55%
C25	18.4	2540	0.72%
C26	15.7	2550	0.61%
C27	88.9	2240	3.96%
C28	78.7	2100	3.74%
C29	210	2220	9.45%
C30	14.9	2500	0.59%
C31	16.3	2490	0.65%
C32	24.2	2440	0.99%
C33	51.2	2300	2.22%
C34	62.3	2020	3.08%
C35	107.7	1824	5.90%
C36	19.3	1736	1.11%
C37	18.5	1776	1.04%
C38	21.8	2400	0.90%
C39	29.1	2330	1.24%
C40	28.5	1970	1.44%
C41	22.1	1930	1.14%
C42	9.7	1746	0.55%
C43	11.7	1730	0.67%
C44	51.9	1786	2.90%
C45	74	1790	4.13%
C46	82	1990	4.12%
C47	205	2120	9.66%
C48	66.5	1769	3.25%
C49	80.6	1835	4.39%
C50	187	1915	9.76%
C51	360	2200	16.36%
C52	23.2	1748	1.32%
C53	53.6	1867	2.31%
C54	84.4	1869	4.51%
C55	24.8	2260	1.09%

Table21. *7TH of March, 3:45 p.m.*

Semi-cloudy day, old white snow on the ground, no snow on the trees.

Point	Inside (in lux)	Outside (in lux)	DF
C1	297	2560	11.60%
C2	197	2610	7.54%
C3	158.5	2870	5.52%
C4	286	2880	9.93%
C5	282	2860	9.86%
C6	151.4	2840	5.33%
C7	87.5	2440	3.58%
C8	72.6	2510	2.89%
C9	102.5	2640	3.88%
C10	128.7	3070	4.19%
C11	127.4	2730	4.66%
C12	76.5	2700	2.83%
C13	51.6	2400	2.15%
C14	54.7	2450	2.23%
C15	87.5	2760	3.17%
C16	88.1	3110	2.83%
C17	61.3	2650	2.31%
C18	47	2610	1.80%
C19	46.9	2340	2.00%
C20	55.5	2410	2.30%
C21	81.9	3070	2.66%
C22	78.4	3200	2.45%
C23	85.4	2600	3.25%
C24	50.1	2600	1.92%
C25	39.9	2500	1.59%
C26	31.3	2430	1.28%
C27	128.6	3360	3.82%
C28	131.3	2770	4.74%
C29	139.5	2660	5.24%
C30	30.7	2430	1.26%
C31	23	2500	0.92%
C32	35.5	3510	1.01%
C33	58.2	3430	1.69%
C34	49	2870	1.70%
C35	50.9	2880	1.76%
C36	34.3	2440	1.40%
C37	25.2	2430	1.03%
C38	27.4	3560	0.76%
C39	31.2	3510	0.88%
C40	30.9	2870	1.07%
C41	24.6	2910	0.84%
C42	19.5	2450	0.79%
C43	20	2420	0.82%
C44	68.5	3090	2.21%
C45	83.3	2950	2.82%
C46	115.4	2850	4.04%
C47	165.5	2910	5.68%
C48	66.5	2910	2.28%
C49	98.4	2970	3.31%
C50	153.9	2910	5.28%
C51	274	2890	9.48%
C52	37.7	2880	1.30%
C53	69.5	3000	2.31%
C54	107.3	2970	3.61%
C55	129	2840	4.54%

Table22. *28[TH] of February, 3:45 p.m.*

Cloudy day, old white snow on the ground, no snow on the trees.

Point	Inside (in lux)	Outside (in lux)	DF
C1	159.3	1720	9.26%
C2	100.5	1767	5.68%
C3	63.7	1748	3.64%
C4	146.2	1750	8.35%
C5	151.8	1751	8.66%
C6	86.3	1761	4.90%
C7	37.7	1713	2.20%
C8	40.6	1711	2.37%
C9	48.11	1702	2.82%
C10	73.9	1706	4.33%
C11	67.1	1729	3.88%
C12	38.2	1740	2.19%
C13	25.5	1716	1.48%
C14	31.4	1718	1.82%
C15	37	1705	2.17%
C16	40.1	1690	2.37%
C17	42.6	1698	2.50%
C18	32.5	1657	1.96%
C19	23.7	1681	1.40%
C20	24.8	1651	1.50%
C21	33.5	1655	2.02%
C22	48.5	1696	2.85%
C23	68.2	1687	4.04%
C24	118.5	1690	7.01%
C25	17.1	1652	1.03%
C26	11	1655	0.66%
C27	58.2	1625	3.58%
C28	57.2	1625	3.52%
C29	70.8	1615	4.38%
C30	12.9	1629	0.79%
C31	12	1620	0.74%
C32	19.5	1614	1.20%
C33	31.3	1630	1.92%
C34	50.4	1597	3.15%
C35	22	1607	1.36%
C36	13.4	1645	0.81%
C37	11.1	1628	0.68%
C38	15.5	1623	0.95%
C39	20.5	1619	1.26%
C40	18.1	1611	1.12%
C41	14.8	1595	0.92%
C42	8.2	1570	0.52%
C43	8.7	1580	0.55%
C44	28.5	1552	1.83%
C45	39.7	1535	2.58%
C46	46.3	1495	3.09%
C47	111.9	1472	7.60%
C48	31.2	1532	2.03%
C49	40.9	1527	2.67%
C50	86.6	1510	5.73%
C51	190	1464	12.97%
C52	21.2	1571	1.34%
C53	29.3	1501	1.95%
C54	43.6	1492	2.92%
C55	102.2	1459	7%

Table23. *25TH of February, 2:00 p.m..*

Cloudy day, white snow on the ground, snow on the trees.

Point	Inside (in lux)	Outside (in lux)	DF
C1	555	4990	11.12%
C2	340	5330	6.37%
C3	297	5130	5.78%
C4	529	5060	10.45%
C5	457	4910	9.30%
C6	205	4740	4.32%
C7	225	3900	5.76%
C8	148.2	4070	3.64%
C9	197	4130	4.76%
C10	240	4290	5.59%
C11	190	4440	4.27%
C12	141	4550	3.09%
C13	88.3	3760	2.34%
C14	105.4	3620	2.91%
C15	111.1	3440	3.22%
C16	114.3	3370	3.39%
C17	101.9	3460	2.94%
C18	93.4	3450	2.70%
C19	83.5	4580	1.82%
C20	85.4	4450	1.91%
C21	86	4200	2.04%
C22	134.5	3950	3.40%
C23	171.2	3770	4.54%
C24	305	3540	8.61%
C25	61.7	4670	1.32%
C26	43.1	4660	0.92%
C27	108.3	4770	2.27%
C28	131.2	4700	2.79%
C29	205	4320	4.74%
C30	42.8	3660	1.16%
C31	30	3560	0.84%
C32	55.8	3490	1.59%
C33	85.3	3470	2.45%
C34	144.2	3770	3.82%
C35	63.3	4080	1.55%
C36	42.2	3510	1.20%
C37	42.5	3570	1.19%
C38	47	3520	1.33%
C39	55.5	3520	1.57%
C40	47.2	3630	1.30%
C41	42.5	3680	1.15%
C42	26.6	3730	0.71%
C43	29.9	3830	0.78%
C44	88.2	4020	2.19%
C45	115.5	3990	2.89%
C46	195	3600	5.41%
C47	333	3470	9.59%
C48	103.3	4060	2.54%
C49	133.7	4010	3.33%
C50	283	3620	7.81%
C51	574	3350	17.13%
C52	71.6	4030	1.77%
C53	101.6	3920	2.59%
C54	169.8	3810	4.45%
C55	210	3390	6.19%

Table24. *19TH of February, 10:00 a.m.*

Snowy day, white snow on the ground, snow on the trees.

Point	Inside (in lux)	Outside (in lux)	DF
C1	282	4160	6.77%
C2	166	4170	3.98%
C3	247	4160	5.93%
C4	383	4230	9.05%
C5	405	4240	9.55%
C6	193	4260	4.53%
C7	97.2	4300	2.26%
C8	120.5	4240	2.84%
C9	152.6	4280	3.56%
C10	172.8	4360	3.96%
C11	189.3	4380	4.32%
C12	106.5	4340	2.45%
C13	82.5	4370	1.88%
C14	94	4410	2.13%
C15	112.5	4340	2.59%
C16	126	4320	2.91%
C17	137.9	4380	3.14%
C18	101.5	4400	2.30%
C19	78.5	4350	1.80%
C20	80.5	4360	1.84%
C21	110.7	4370	2.53%
C22	138.5	4380	3.16%
C23	192	4410	4.35%
C24	335	4360	7.68%
C25	52.4	4250	1.23%
C26	42.7	4270	1%
C27	178.9	4310	4.15%
C28	136.5	4290	3.18%
C29	235	4290	5.47%
C30	48.8	4370	1.11%
C31	49.9	4390	1.13%
C32	62.9	4400	1.42%
C33	87.4	4230	2.06%
C34	131.7	4360	3.02%
C35	229	4360	5.25%
C36	45	4380	1.02%
C37	48.7	4380	1.11%
C38	49.6	4440	1.11%
C39	60.6	4350	1.39%
C40	61.5	4430	1.38%
C41	52.3	4400	1.18%
C42	31.4	4480	0.70%
C43	33.7	4330	0.77%
C44	114.2	4550	2.50%
C45	142	4450	3.19%
C46	245	4360	5.61%
C47	440	4460	9.86%
C48	132.2	4660	2.83%
C49	165	4590	3.59%
C50	317	4310	7.35%
C51	751	4350	17.26%
C52	84.3	4500	1.87%
C53	123.8	4520	2.73%
C54	233	4420	5.27%
C55	426	4400	9.68%

Table25. *18TH of February, 10:00 a.m.*

Snowy day, white snow on the ground, snow on the trees.

Point	Inside (in lux)	Outside (in lux)	DF
C1	240	3610	6.64%
C2	170.7	3840	4.44%
C3	181.5	3570	5.08%
C4	309	3420	9.03%
C5	270	3390	7.96%
C6	118.2	3380	3.49%
C7	108.7	3960	2.74%
C8	100.6	3820	2.63%
C9	109.2	3810	2.86%
C10	117.2	3700	3.16%
C11	129.2	3620	3.56%
C12	80.2	3430	2.33%
C13	64.5	3970	1.62%
C14	68.2	4120	1.65%
C15	74.4	4140	1.79%
C16	90.4	4070	2.22%
C17	67.3	4050	1.66%
C18	105.2	4170	2.52%
C19	34.5	3190	1.08%
C20	47.8	3180	1.50%
C21	50.3	3170	1.58%
C22	60	3140	1.91%
C23	72.4	3190	2.26%
C24	127.1	3160	4.02%
C25	57.3	4250	1.34%
C26	66.9	4220	1.58%
C27	115.9	4380	2.64%
C28	150.9	4300	3.50%
C29	266	4220	6.30%
C30	31.9	4240	0.75%
C31	36.4	4190	0.86%
C32	52.1	4360	1.19%
C33	92.1	4510	2.04%
C34	123.7	4690	2.63%
C35	94.2	4570	2.06%
C36	20.7	4300	0.48%
C37	24.9	4290	0.58%
C38	111.7	4260	2.62%
C39	53.7	4560	1.17%
C40	55.3	4670	1.18%
C41	43	4460	0.96%
C42	23.1	4280	0.53%
C43	15.7	4260	0.36%
C44	97.5	4950	1.96%
C45	175.3	4880	3.59%
C46	255	4810	5.30%
C47	413	4380	9.42%
C48	111.1	5190	2.14%
C49	195.7	4850	4.03%
C50	280	4690	5.97%
C51	579	4390	13.18%
C52	86.3	5280	1.63%
C53	101.7	4770	2.13%
C54	181.8	4570	3.97%
C55	264	4440	5.94%

Table26. *13TH of February, 12:00 p.m.*

Cloudy day, Two-day old melting snow.

Point	Inside (in lux)	Outside (in lux)	DF
C1	274	3070	8.92%
C2	85.4	2940	2.90%
C3	166.5	3030	5.49%
C4	309	3020	10.23%
C5	295	2960	9.96%
C6	115.2	2970	3.87%
C7	86.2	3230	2.66%
C8	78.4	3220	2.43%
C9	78	3330	2.34%
C10	97.5	3220	3.02%
C11	119.7	3120	3.83%
C12	74.2	3080	2.40%
C13	41.5	3220	1.28%
C14	48.3	3310	1.45%
C15	56.4	3210	1.75%
C16	58.2	3220	1.80%
C17	113	3130	3.61%
C18	112.7	3210	3.51%
C19	34.5	3190	1.08%
C20	47.8	3180	1.50%
C21	50.3	3170	1.58%
C22	60	3140	1.91%
C23	72.4	3190	2.26%
C24	127.1	3160	4.02%
C25	26	3140	0.82%
C26	19.8	3150	0.62%
C27	95.6	3310	2.88%
C28	119	3340	3.56%
C29	168.5	3320	5.07%
C30	23.6	3080	0.76%
C31	20.3	3090	0.65%
C32	35.6	3080	1.15%
C33	57.3	3110	1.84%
C34	83.5	3180	2.62%
C35	169.7	3240	5.23%
C36	20.5	3140	0.65%
C37	15.3	3160	0.48%
C38	29.8	3080	0.96%
C39	31.7	3100	1.02%
C40	27.8	3170	0.87%
C41	23.5	3200	0.73%
C42	13.7	3100	0.44%
C43	13.8	3000	0.46%
C44	46.7	3250	1.43%
C45	81.5	3240	2.51%
C46	148.2	3040	4.87%
C47	240	3330	7.20%
C48	58.3	3300	1.76%
C49	92.7	3220	2.87%
C50	207	3250	6.36%
C51	474	3200	14.81%
C52	44.5	3380	1.31%
C53	65.4	3280	1.99%
C54	158.4	3200	4.95%
C55	186	3210	5.79%

Table27. *12TH of February, 12:00 p.m.*

Cloudy day, one day old snow on ground and the trees.

Point	Inside (in lux)	Outside (in lux)	DF
C1	197.9	2530	7.82%
C2	100.5	2520	3.98%
C3	99.3	2520	3.94%
C4	226	2530	8.93%
C5	233	2520	9.24%
C6	100.4	2600	3.86%
C7	109.1	2630	4.14%
C8	78.5	2620	2.99%
C9	73.2	2590	2.82%
C10	93.4	2660	3.51%
C11	92.4	2650	3.48%
C12	57.3	2630	2.17%
C13	45.3	2700	1.67%
C14	52.4	2740	1.91%
C15	59.4	2710	2.19%
C16	58.4	2770	2.10%
C17	74.3	2820	2.63%
C18	80.1	2710	2.95%
C19	39.1	2730	1.43%
C20	51.3	2860	1.79%
C21	63.3	2630	2.40%
C22	96.3	2660	3.62%
C23	60.7	2680	2.26%
C24	25.1	2710	0.92%
C25	25.3	2650	0.95%
C26	17.3	2790	0.62%
C27	119.3	3170	3.76%
C28	116.7	3180	3.66%
C29	114.2	3200	3.56%
C30	20.7	2800	0.73%
C31	21.7	2750	0.78%
C32	28	3020	0.92%
C33	44.7	3050	1.46%
C34	61.5	3080	1.99%
C35	152.7	3220	4.74%
C36	20.5	2820	0.72%
C37	22	2840	0.77%
C38	29.7	3000	0.99%
C39	36.7	3160	1.16%
C40	35.1	3210	1.09%
C41	33.5	3260	1.02%
C42	18.2	3010	0.60%
C43	15.5	2960	0.52%
C44	56.9	3250	1.75%
C45	89.5	3280	2.72%
C46	159.9	3360	4.75%
C47	337	3390	9.94%
C48	67.3	3280	2.05%
C49	109.9	3250	3.38%
C50	213	3430	6.20%
C51	553	3460	15.98%
C52	53.9	3270	1.64%
C53	80.9	3290	2.45%
C54	137.2	3390	4.04%
C55	128.2	3360	3.81%

Table28. *11*[TH] *of February, 10 a.m.*

Cloudy day, fresh snow on ground and the trees.

Point	Inside (in lux)	Outside (in lux)	DF
C1	379	3040	12.46%
C2	149.7	3200	4.67%
C3	173.4	3460	5.01%
C4	482	4140	11.64%
C5	363	4860	7.46%
C6	126.7	5440	2.32%
C7	160.9	6470	2.48%
C8	127.5	6910	1.84%
C9	180.3	7310	2.46%
C10	232	6240	3.71%
C11	235	5440	4.31%
C12	99.2	5380	1.84%
C13	103.3	6850	1.50%
C14	122.5	6910	1.77%
C15	161.8	7000	2.31%
C16	173	9410	1.83%
C17	324	10390	3.11%
C18	83.6	8510	0.98%
C19	105.2	8120	1.29%
C20	123.2	8950	1.37%
C21	140.5	8040	1.74%
C22	152.8	9080	1.68%
C23	195	9340	2.08%
C24	249	8200	3.03%
C25	104.7	8240	1.27%
C26	81.5	8340	0.97%
C27	219.3	8460	2.59%
C28	312	9400	3.31%
C29	225	9910	2.27%
C30	98.7	8410	1.17%
C31	77.3	10400	0.74%
C32	62.2	8180	0.76%
C33	74.8	8490	0.88%
C34	93.7	7890	1.18%
C35	51.2	9320	0.54%
C36	91.6	9560	0.95%
C37	66.7	7490	0.89%
C38	65.4	8540	0.76%
C39	61.1	8260	0.73%
C40	70.7	7450	0.94%
C41	49.9	6740	0.74%
C42	80.3	7360	1.09%
C43	56.6	7940	0.71%
C44	113.4	8730	1.29%
C45	122.3	8740	1.39%
C46	162.9	9940	1.63%
C47	225	9380	2.39%
C48	113.5	9310	1.21%
C49	145.9	9120	1.59%
C50	198	9600	2.06%
C51	362	8250	4.38%
C52	77.7	9250	0.84%
C53	107.3	9650	1.11%
C54	118.4	9540	1.24%
C55	222	10010	2.21%