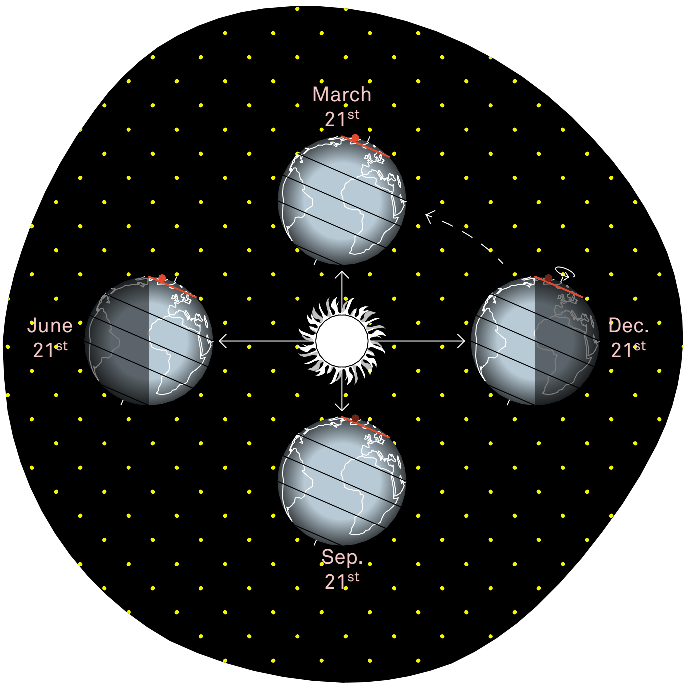
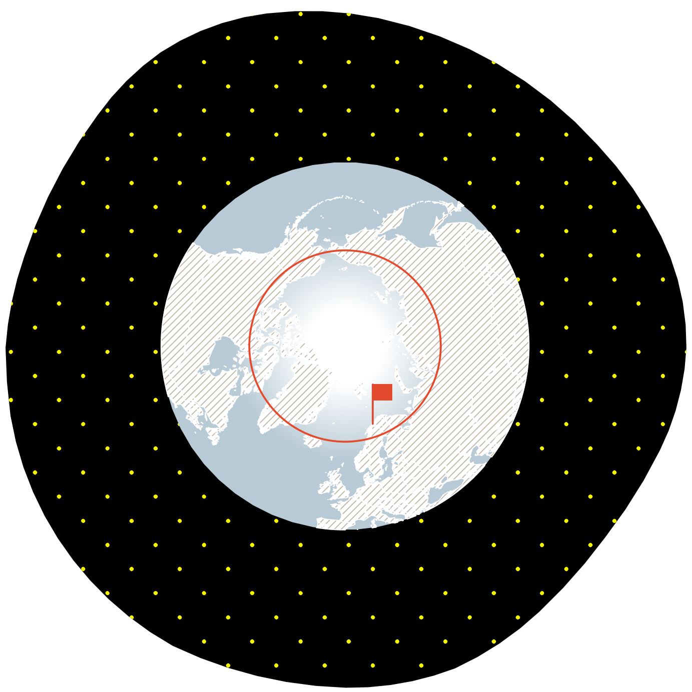


The Building for the Yearly Cycle:

A Bioclimatic and Biophilic Approach exemplified on the Circumpolar North

developed by
Elisabeth Maria Horodynski

To my parents and my brothers:
fixed stars of my galaxy.



Diplomarbeit

The Building for the Yearly Cycle:

A Bioclimatic and Biophilic Approach exemplified on the Circumpolar North

ausgeführt zum Zwecke der Erlangung des akademischen Grades
einer Diplom-Ingenieurin
unter der Leitung

von
a.o. Prof. Dipl.-Ing. Dr. Alireza Fadai
E 259.2 Institut für Architekturwissenschaften |
Abteilung für Tragwerksplanung und Ingenieurholzbau

eingereicht an der Technischen Universität Wien
Fakultät für Architektur und Raumplanung

von
Elisabeth Maria Horodynski
01326824

Wien, am

Datum | Unterschrift

Kurzfassung

Im Sinn der Erde mit ihrer stark zyklisch geformten natürlichen Welt, stellt diese Arbeit die vorherrschende Vernachlässigung von Kreisläufen in der gebauten Welt in Frage und versucht, für diese versteckten Potenziale zu sensibilisieren. Am Beispiel des Jahreskreises zeigt der Ansatz, wie das meiste aus jeder Jahreszeit herausgeholt werden kann.
Auf der Suche nach dem „Haus im Jahreskreis" verwendet die Arbeit die Methodik einer Entwurfsstudie in der zirkumpolaren Norden - genauer gesagt in Nordnorwegen - aufgrund der dort vorherrschenden reichhaltigen Lichtkontraste und Zyklen.
Unter bioklimatischer und biophiler Anleitung wird die effiziente Herstellung sowie der effiziente Betrieb von Gebäuden untersucht. Es werden Möglichkeiten aufgezeigt, ressourcenschonender durch die Jahresperioden der Dunkelheit, des Übergangs und der Helligkeit zu kommen. Es werden architektonische Ausdrucksformen erforscht, die die Bewohner:innen des Gebäudes das ganze Jahr über mit der Natur verbinden, sodass sie mehr Teil als Opfer der jahreszeitlichen Änderungen und Bedingungen sind.
Umgesetzt in den drei architektonischen Schichten, dem „Innersten" (dem nutzungsflexiblen Raum), der „bewohnten Hülle" (dem weitergedachte Kastenfenster) und der „Verflechtung" (dem Glashaus am Dach), bringt die Entwurfsstudie neue Ideen für Architektur in der Natur und Natur in der Architektur hervor, die Schönheit und Vielfalt des Temporären zeigend.

abstract

In the realm of planet Earth with its vast cyclical shaped natural world, this thesis challenges the prevailing ignorance of cycles in the built world and seeks to foster an awareness of these hidden potentials. Concentrating on the seasonal cycle, the approach shows how to make the most of what each season has to offer.
Searching for "The Building for the Yearly Cycle," this thesis draws on the methodology of a design study located in the Circumpolar North – precisely Arctic Norway – due to its rich light contrasts and cycles.
With bioclimatic and biophilic guidance, it investigates and demonstrates the efficient construction and operation of buildings to conserve resources in the yearly periods of darkness, transition and brightness. It examines architectural expressions that reconnect the building's occupants with nature throughout the year, enabling them to be part rather than victim of the seasonal forces and harshness of the environment.
Materialized into the three architectural layers, "the innermost" (the multi-purpose space), "the inhabited envelope" (the double window rethought), and "the interweaving" (the greenhouse on the roof), the design study imposes new ideas about architecture in nature and nature in architecture, benefitting from and showing the beauty and variety within the temporary.

preface

“What is the extinction of a condor to a child who has never known a wren?”[1], Kellert et al. ask in *Biophilic Design: The Theory, Science, and Practice of Bringing Buildings to Life*.
From summer to winter of 2019, I was an Erasmus+ student at the Norwegian University of Science and Technology in Trondheim, Norway. There, I experienced friluftsliv (literally free-air-life and the spirit of the nation) through its seasons: I went on hiking trips almost every weekend, staying overnight in a tent or a cabin.
Mountains change you and your perspective. The more time I spent outdoors, the more I appreciated the intrinsic beauty of nature and the rhythms around us.

“Where is the ritual in the microwave ready meal?”[2], I read somewhere else.
To go on a hiking trip means to go back to a simple and often troublesome life. Most of the cabins in Norway are not luxurious at all – no electricity, no plumbing. But to go on a hiking trip also means to go back to a life full of experience and ritual. A dish cooked on a campfire with water from the river nearby and ingredients carried in the backpack all day long gets a new value. Echoing the Norwegian mountaineer and environmental philosopher Arne Næss, it was “a life of simplicity of means and richness of ends”[3]: just a sunset can make a moment magic.

This thesis does not aim to be a plea for sheer simplicity, neglecting precious inventions and information of the last decades and centuries – because let’s be honest, after a hiking trip, nothing beats a long, hot shower, freshly washed clothes, and a scroll through social media.
However, our appreciated and valued progress has a price: climate change and the loss of biodiversity – and we have to be aware that there are no building panaceas against the planetary climate crisis.[4]
But then, what might be a sign of strength? How can we, in the building sector, orient ourselves?

First of all, we do have to start to green the building sector: not only to benefit from natural resources and wisdom but also to foster harmony and smart simplicity. In addition, as we pay rent for our home, we have to start paying rent for our life on Earth as Kristine McDivitt Tompkins talks about in her TED Talk *Let’s make the world wild again*.[5]
Furthermore, we need more curiosity, kindness and courage in the building sector. It always takes effort to climb a trackless mountain – but on the top a grand vista is waiting – most of the time.

Elisabeth Maria Horodynski
March 2021

1 Kellert et al., 2008: 216
2 Tyrrell, 2017: 153
3 Næss et al., 2008: 56
4 cf. Mahdavi, 2021: Lecture
5 Kristine McDivitt Tompkins, 2020: 02:01

index

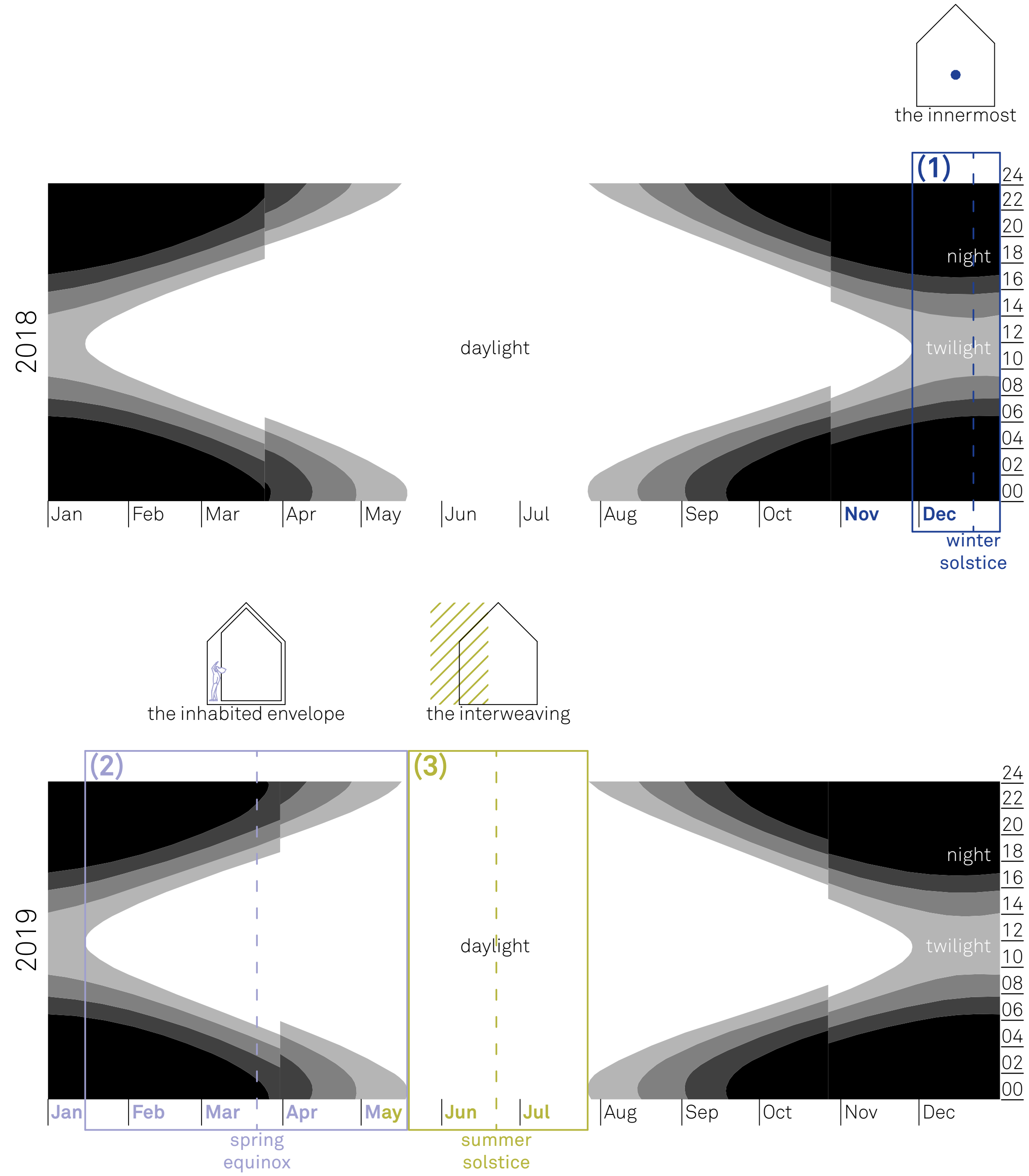


fig. 0.03: The three different phases of darkness, transition, and brightness, plus the three architectural layers as a reaction to the prevailing circumstances.

thesis navigation

The thesis portrays the three different phases of darkness, transition and brightness, marked by the winter/ summer solstices and the spring/ fall equinoxes. (fig. 0.03)
Metaphorically, the matrix for change is darkness; *the end of a year* (end of November - end of December with the winter solstice on December 21st) (1) is set as the starting chapter of the thesis. The day the sun is back heralds a new beginning; therefore, the chapter of transition is entitled *the beginning of a new year* (mid-January - mid-May with the spring equinox on March 21st) (2), although this period of time does not start with January 1st. The year culminates with the time of brightness when everything seems to be possible; the chapter *the middle of a year* (mid-May - end of July with the summer solstice on June 21st) (3) portrays this special time. These three chapters discuss seasonal challenges and potentials.

Within the realm of the three chapters *the end/ the beginning/ the middle of a year*, the thesis introduces three architectural layers, *the innermost*, *the inhabited envelope*, and *the interweaving, as a possible answer to the seasonal prevailing circumstances.* (fig. 0.03) The objective of the chapter *results and evaluations* is to visualize and evaluate their interplay.

Although the proposed design in this thesis is a small-scale dwelling as it is located in Arctic Norway, a sparsely populated area, the discussed concept is equally applicable to buildings with other functions and scales. This is made possible since the design study presented here is explicitly devised from general *The Building for the Yearly Cycle* design paradigms.

introduction

fig. 0.04: Earthrise. Apollo mission 1968. A picture by Bill Anders.

0.1 the building for the yearly cycle

0.1.1 aims

The earth as a small orbiting sphere in an ever expanding universe. We experience this kind of intense awe, forgetting our Anthropocentrism for a blink, when we switch perspective and see our planet floating in space. (fig. 0.04)
Nevertheless, nowadays we tend to forget this astronomical interconnectedness that shapes our diurnal, moon and seasonal cycle.
"In urban life you don't even know what time of year it is because you go from one box to another, wake up, open a box of cereal, go into your metal box, [and] spend all day in your glass and steel box looking at a box [...]."[6], an interviewee in the book *Losing Eden: Why Our Minds Need the Wild* puts it well.

With modern technologies, even a glass façade building in a sand desert can be climate controlled but creating a second world inside comes at a high price: energy consumption.
"Electrical energy is needed to break the rhythms of day and night. Breaking the seasonal rhythm to create green grass in winter and ice in summer requires much energy. Breaking straight roads through the fractal landscape requires energy."[7]
"[T]o work with, not against, the forces of nature,"[8] should be the aim of professionals in the building sector. Saving energy starts with the first line of a design – and with an understanding of the rhythms around us.

6 Jones, 2020: 160-161
7 Gelter, 2000: 84
8 cf. Olgyay, 2015: 10

However, since the middle of the 20th century architects mainly rely on mechanical and electrical equipment instead of starting with basic climate principles.[9]
So, why don't we go outdoors as architects and investigate? What do we encounter? Why does it look the way it looks? What are the benefits? How can we bring it into the built world? Just think of a deciduous tree. It gives shelter during summer and allows light to pass through during winter.[10] Why doesn't a building also represent an adapting or –"new, living, healthy entity"[11] of a place?

When we look at the built world with fresh eyes using nature as our lens, we recognize the ways mankind strives to replicate the tools of nature but does so poorly. For example, a tree evolved an intrinsic method for shading from the heat of the sun, nevertheless window shades are considered a luxury.
Renderings and press photos of buildings still only present a snapshot in time, showing mainly a blue sky and green grass. But what happens during the seasons between the blue sky and green grass?
In phenological terms, a tree undergoes the proliferation, the leaf unfolding, the blossom, the maturity and the leaf senescence.[12] (fig. 0.05) Year for year, evolvement and retreat alternates. The whole natural world, including humanity, is shaped by the diurnal and seasonal rhythm – so why aren't our shelters?

This thesis questions the prevailing neglect and ignorance of the seasonal cycle in buildings and seeks to foster an awareness of the potentials of this kind of sensitivity.
It investigates the efficient construction and operation of buildings to conserve resources in different seasons and examines architectural expressions that reconnect the building's occu-

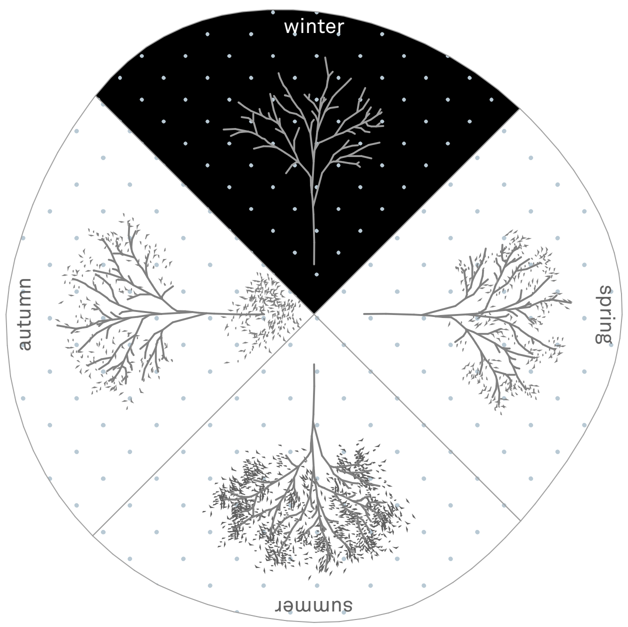


fig. 0.05: The phenology wheel of a tree.

9 cf. Peters and Peters, 2018: 45
10 cf. Lechner, 2015: 11
11 Brophy and Lewis, 2011: 35
12 cf. Hedderich, 2020 10 04: personal interview

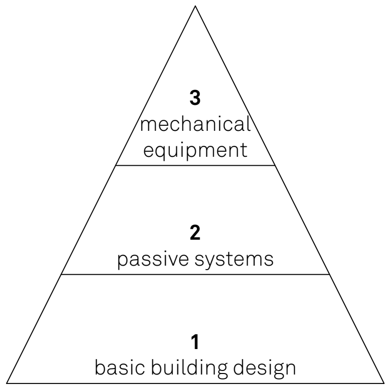


fig. 0.06: The three-tier system.

fig. 0.07: Biophilia. Our intrinsic desire to connect with other forms of life. A picture by Christina Hedderich.

pants with nature throughout the year.
This is the study of one building created to thrive in each cycle of the year, making the most of what each season has to offer.

0.1.2 definitions

The first pillar of *The Building for the Yearly Cycle*, the investigations on constructing and operating efficiently, are guided by a three-tier, pyramid-shaped approach of bioclimatic architecture.
Therefor, the first and bottom tier represents the basic building design, as a suitable orientation and surface-to-volume ratio.[13] The second tier exploits the natural energies and passive techniques, like the greenhouse effect and natural ventilation.[14] That means, only at the top of the pyramid – a tiny fraction – the mechanical and electrical equipment has to be drawn on.[15] (fig. 0.06)
Generally speaking, in this thesis, resource efficiency is understood as building with more care – to nature, to other living beings, and to resources.

The second pillar of *The Building for the Yearly Cycle* – the architectural expressions that aim to reconnect the building occupants with nature throughout the year – are guided by the idea of biophilic architecture. Biophilia is our intrinsic desire to connect with other forms of life.[16]
Nowadays, more than ever, we are separated from nature and all the wonderfully buzzing life within it. Spending 95% of a day inside is not uncommon.[17] Having a home is crucial – but a more biophilic architecture may be the missing link. (fig. 0.07)
For one part, biophilic architecture fosters health

13 cf. Lechner, 2015: 8-9
14 cf. Lechner, 2015: 8-9
15 cf. Lechner, 2015: 8-9
16 cf. Wilson, 1984: 85
17 cf. Kellert et al., 2008: 214

and well-being. For the other part, a biophilic architecture can plant the seed for a love to nature and a stronger will to protect it.[18]

For example, the tree in front of the hospital window in the ubiquitously cited study still mitigates air pollutants, still converts CO_2 to O_2, still is a noise-insulator, a shade-provider and an urban-heat-island-effect-defender[19] – regardless of whether seeing the tree helps the patient to recover or not.[20]

The thesis speaks to the dualism of a low-environmental impact architecture and a biophilic design that has potential to lead to a holistic change.

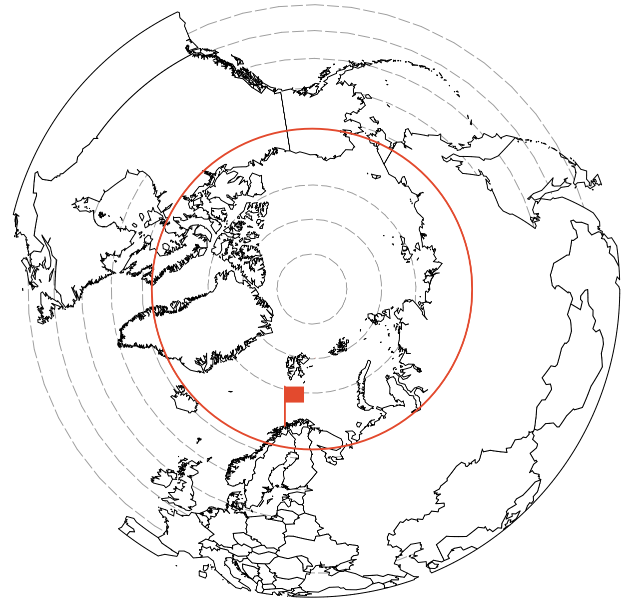
0.1.3 the circumpolar north

To evolve the concept of *The Building for the Yearly Cycle*, the thesis draws on the methodology of a design study located in the Circumpolar North, the area above the Arctic Circle. (fig. 0.08)

The Arctic Circle at around 66,50° is the northernmost of the five main circles of latitude. It marks the southernmost point where the sun is visible for at least 24 continuous hours during summertime (on June 21st or summer solstice) and invisible for at least 24 continuous hours during wintertime (on December 21st or winter solstice).[21] This phenomenon is the consequence of the earth's axis not being in a normal angle to the orbital plane but in a tilt of 23,50°.[22] (fig. 0.09)

Because of this tilt, there are different altitude angles at which the sun's radiation strikes the earth throughout the year, being 47° degrees lower at

18 cf. Kellert et al., 2008: 326
19 cf. Kellert et al., 2008: 115
20 cf. Ulrich, 1984: 420-421
21 cf. "Arctic Circle," 2020: www
22 cf. Lechner, 2015: 140



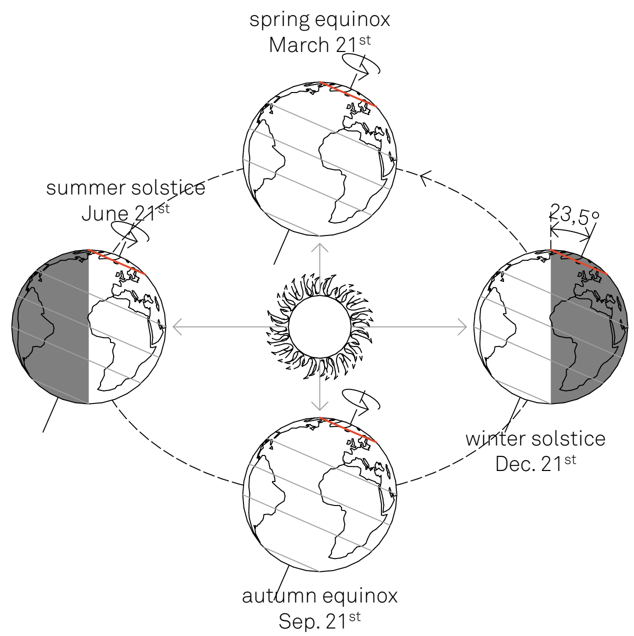


fig. 0.08-0.09: The circumpolar north; The reason for the seasons.

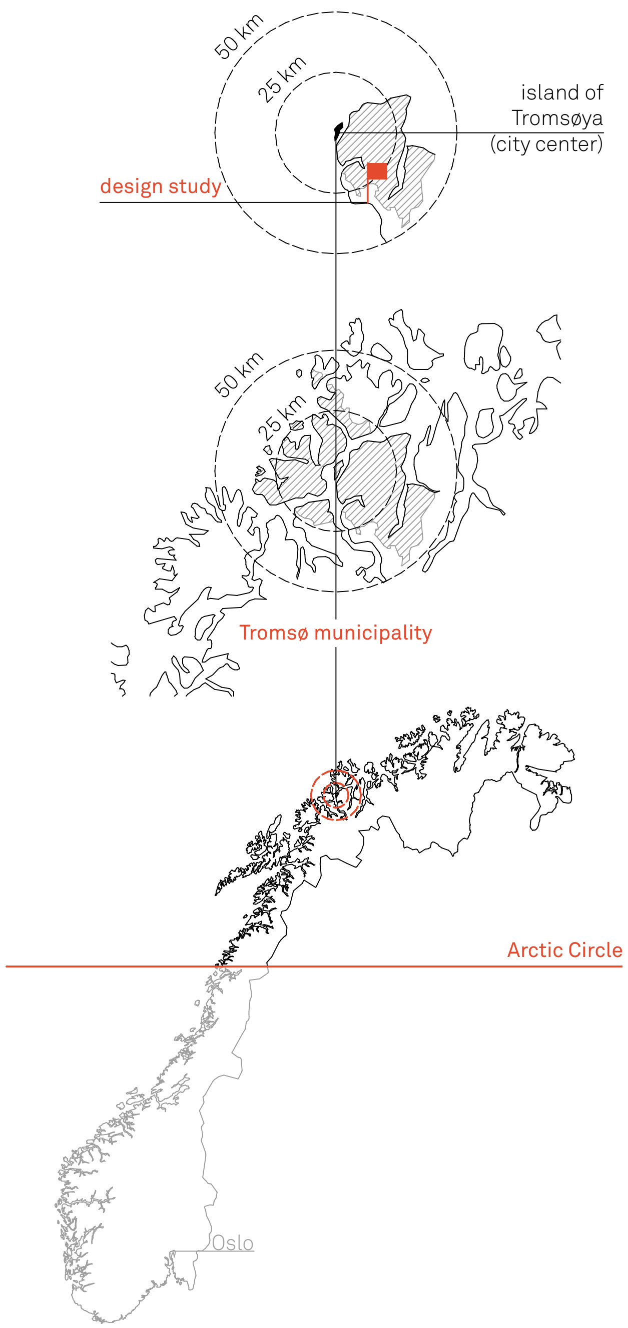


fig. 0.10: Localization of the design study.

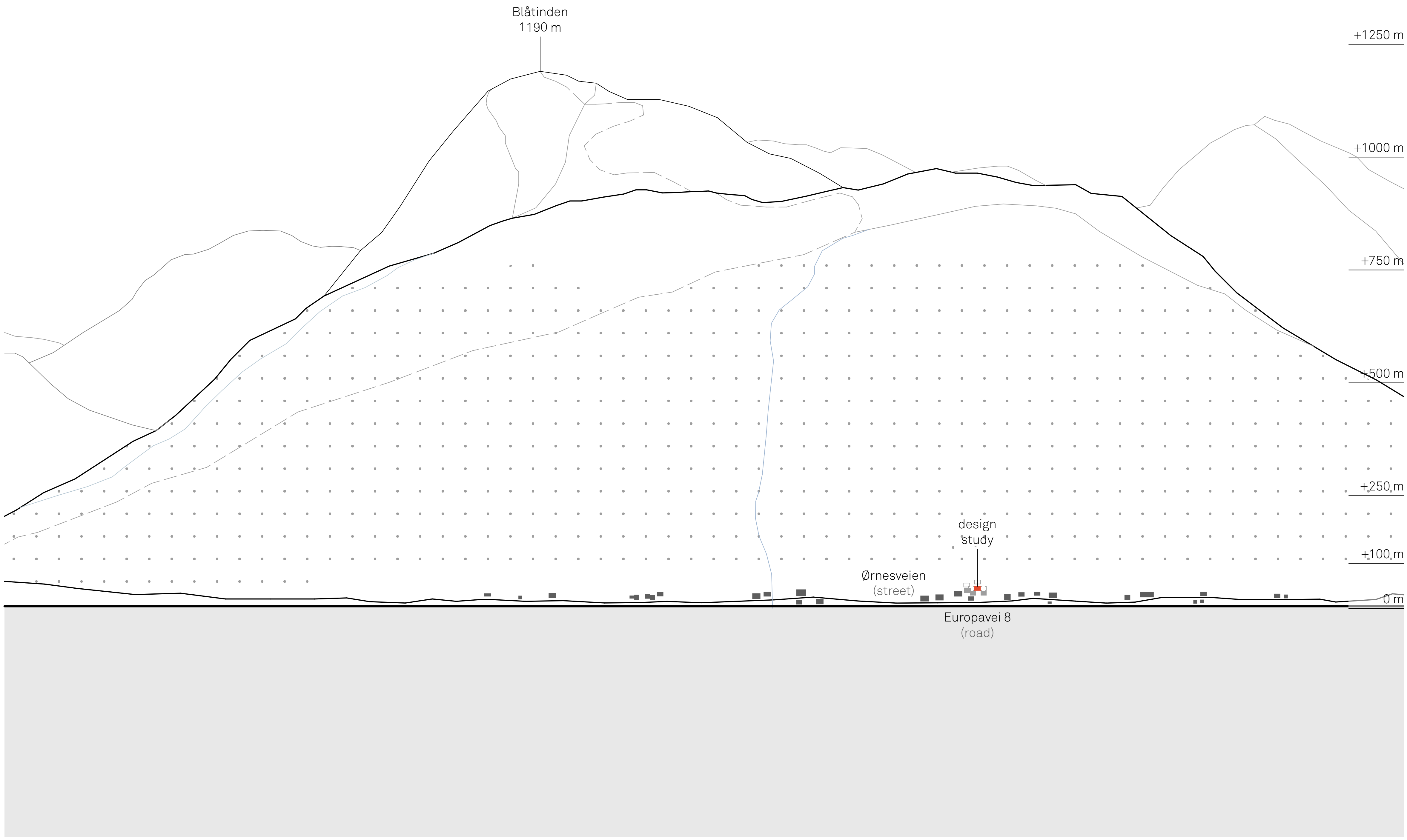
winter than at summer noontime. This is the cause of the seasonal cycle on earth.[23]
Due to the tilt, not the Polar, but the Polar Circle axis stands orthogonally to the sun's radiation. The earth circling around the sun, above the Arctic Circle, the sun stays under the horizon on at least one day during wintertime and vice versa during summertime.

In this way, the Circumpolar Region is a place tremendously rich in cycles and contrasts – there are times of darkness, times of brightness, and times of transition inbetween. It is a place of incredible beauty and an important place to protect, asking for responsible sourced and resource-efficient solutions. But it is also a place where the lack of sunshine during wintertime makes carbon-neutral buildings highly challenging or even impossible. Therefore, the circumpolar region is the perfect place for *The Building for the Yearly Cycle*, taking advantage of the shifting circumstances.

0.1.4 site plans

The design study is located in Arctic Norway within the Circumpolar North. It is located near Tromsø, the biggest city of the Arctic and the reference data are from there (69,50°N, 19,00°E). (fig. 0.10)
Most of all, a north-south orientation is crucial. Sea levels are rising, therefore care should be taken to chose a site higher up the slope than previously built structures. Moreover, as elucidated in the following chapters, a slope in the back mitigates wind effects and heightens insolation.
The village of Laksvatn near Tromsø municipality represents these conditions. Therefore, this following site was selected to experiment on *The Building for the Yearly Cycle*-strategies:

23 cf. Lechner, 2015: 140; 164



| 100 m| 200| 500|

fig. 0.11: Site plan. Elevation. 1: 10 000

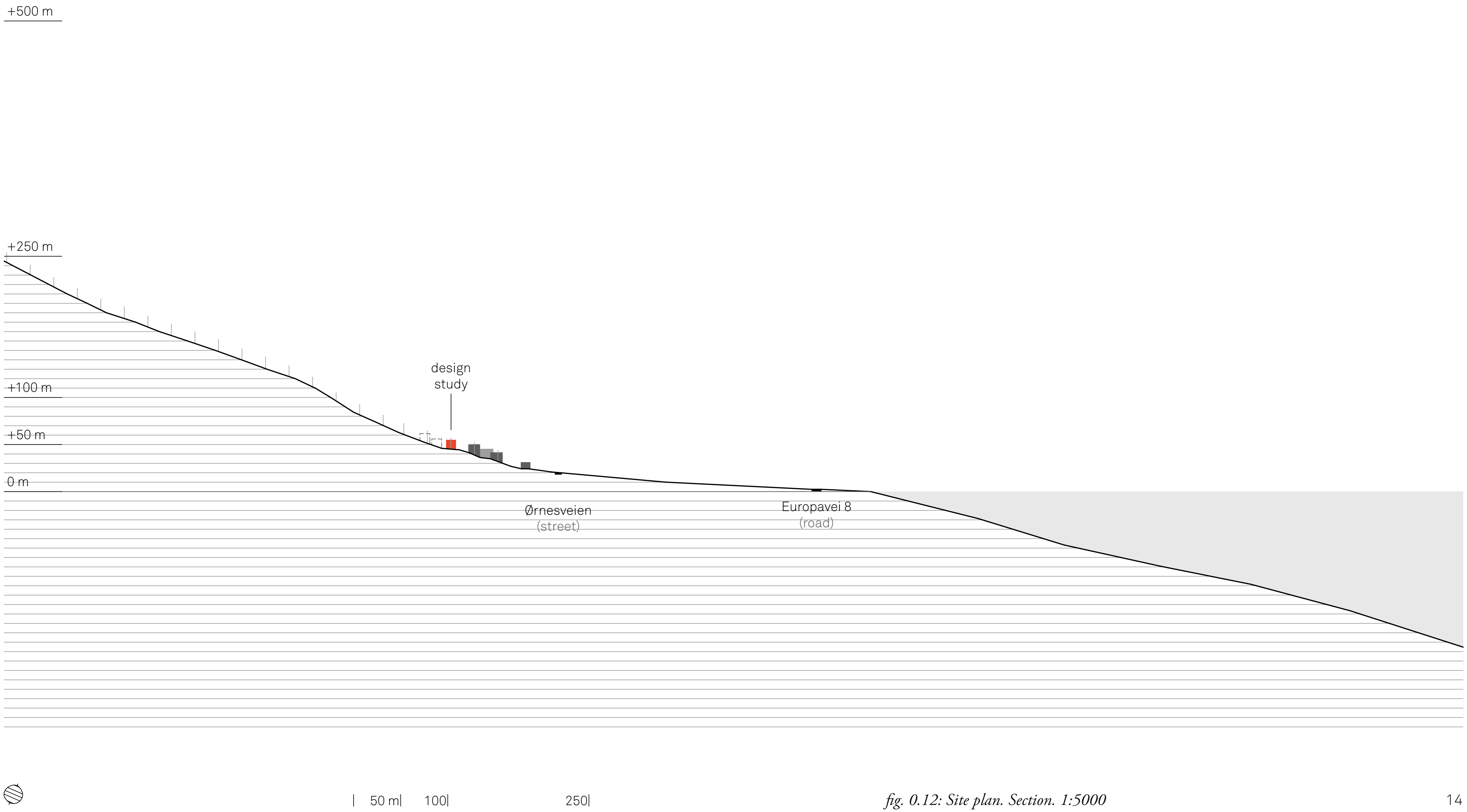


fig. 0.12: Site plan. Section. 1:5000

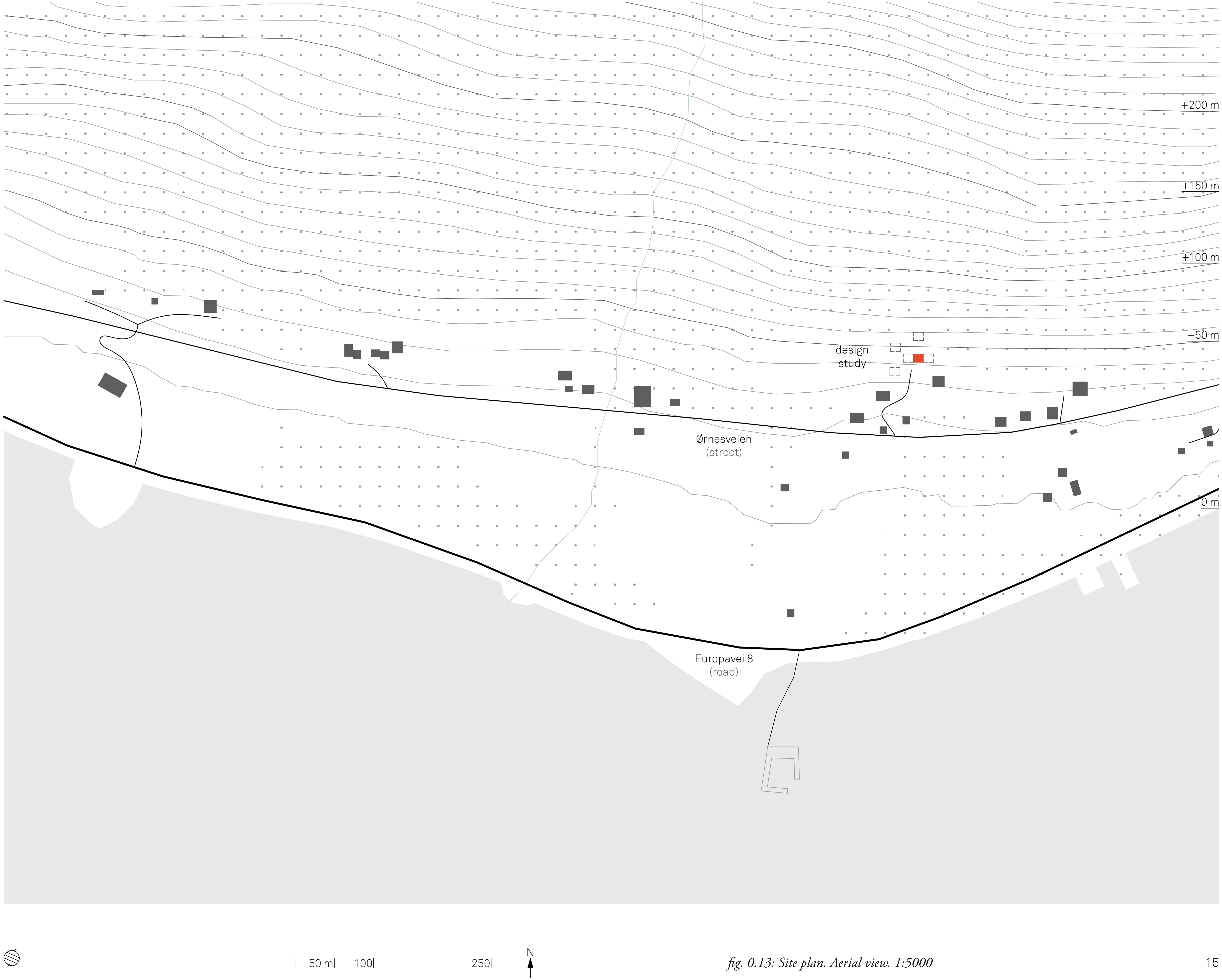


fig. 0.13: Site plan. Aerial view. 1:5000

2018

Jan | Feb | Mar | Apr

May | Jun | Jul | Aug

Sep | Oct | **end of Nov** | **31st Dec**

end of Nov: 1st day of the sun being invisible for 24 continuous hours

31st Dec: New Year's Eve

1
the end of a year

1.1 characteristics of time period

Metaphorically, the matrix for change is darkness; *the end of a year* (end of November - end of December with the winter solstice on December 21st) is set as the starting chapter of the thesis.

It is the time period between the first day of the sun being invisible for 24 continuous hours and New Year's Eve.

1.1.1 photo essay 'play of brilliants'

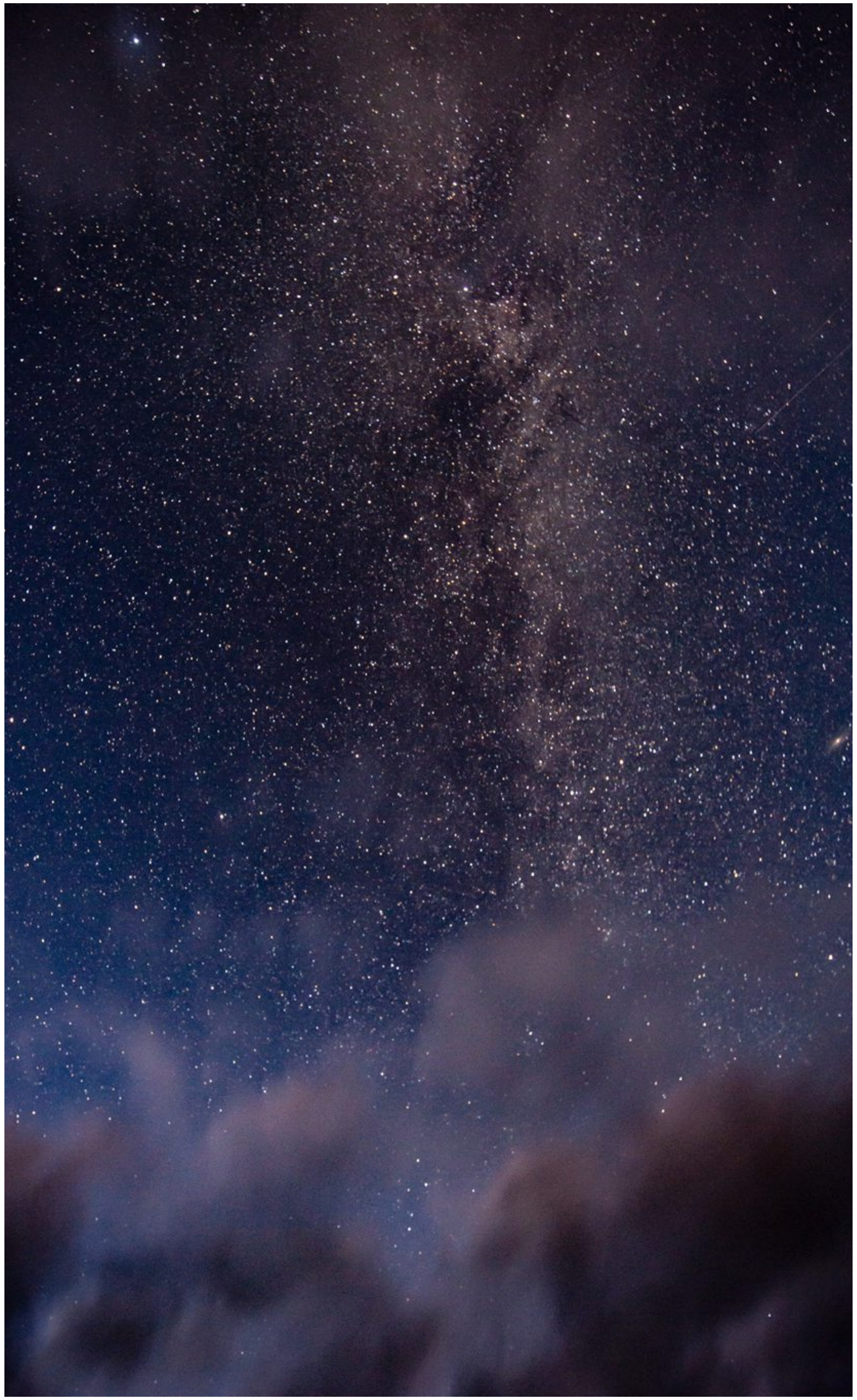
During the polar nights, when day and night (with the exception of some blue hours around midday) are covered in complete darkness, challenges are inevitable. But it is also during these darkest hours, when we see stars, light, and colors best. As the titles of the three photo essays are borrowed from the three layers of lighting design by Richard Kelly, this one is crowned with "play of brilliants."[24] (fig. 1.01-1.07)

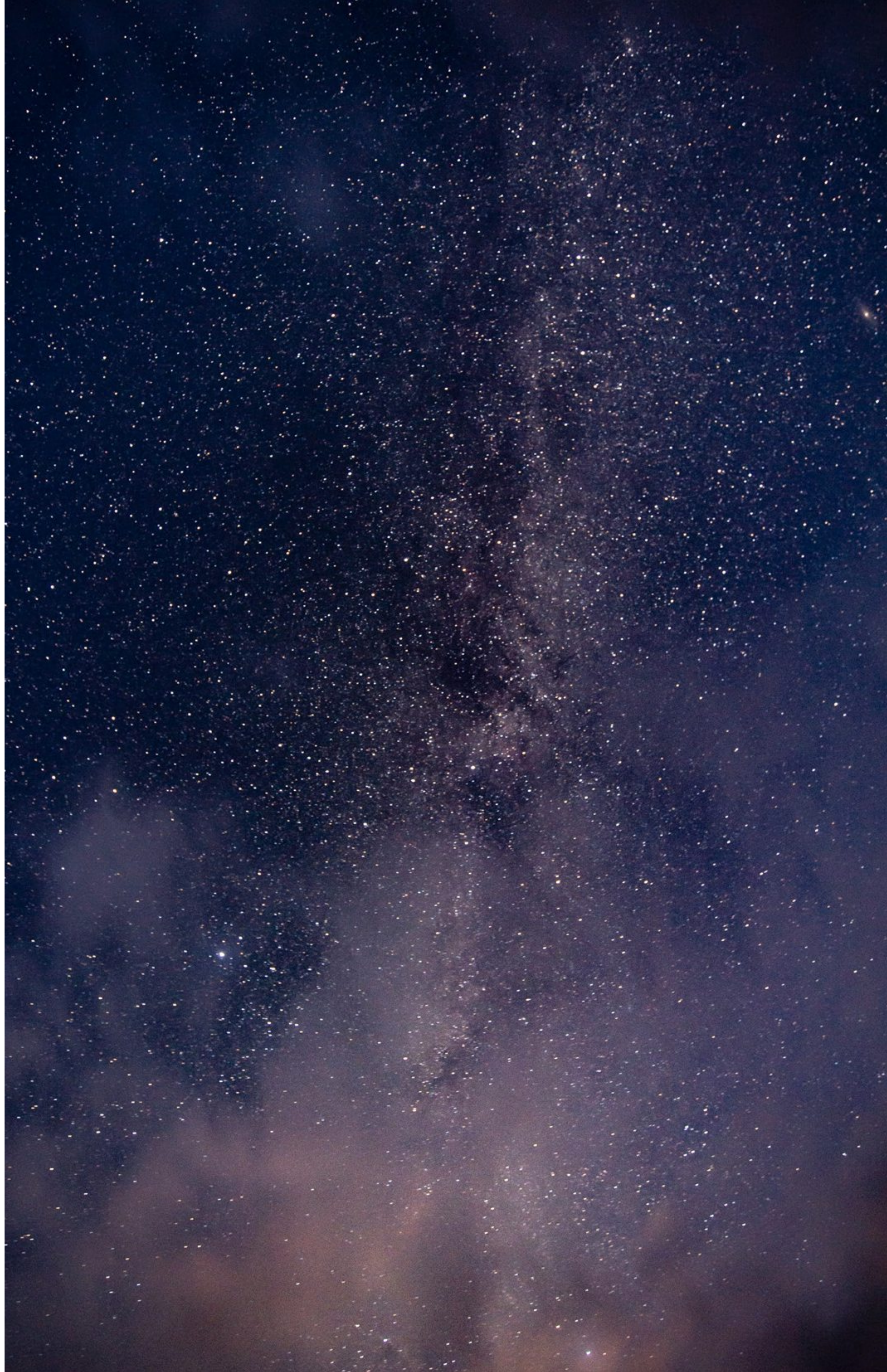
field study
16 - 20/12/2019

(Because of bad weather conditions, photos are also from friends: fig. 1.01: Christina Hedderich, fig. 1.02-1.03: Sigmund Ole Granaas, fig. 1.05: Antonia Mangold)

fig. 1.01
(fig 1.02-1.07 on the following pages)

24 cf. "Richard Kelly," 2020: www





1.1.2 climate conditions

Reference data are from Tromsø (69,50°N, 19,00°E) between end of November and December 31st, 2018, representing the time of darkness. As Tromsø is located 69,50° north, on the equinox the altitude angle at solar noon – the sun being at its highest position but not necessarily at 12:00 – is 20,50° (90,00°-69,50°).

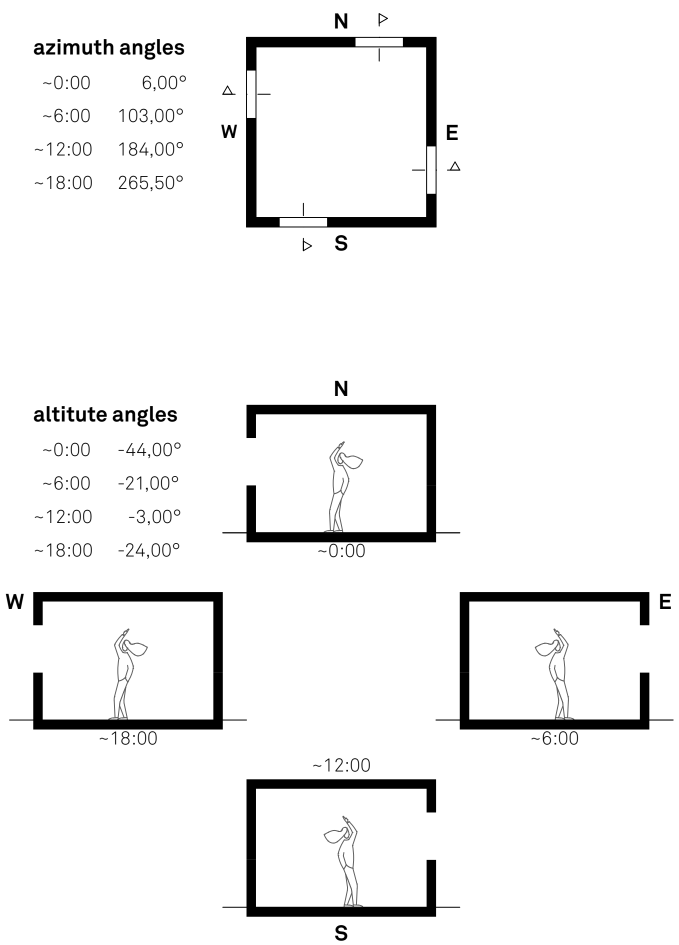


fig. 1.08: Azimuth and altitude angles on winter solstice (December 21st).

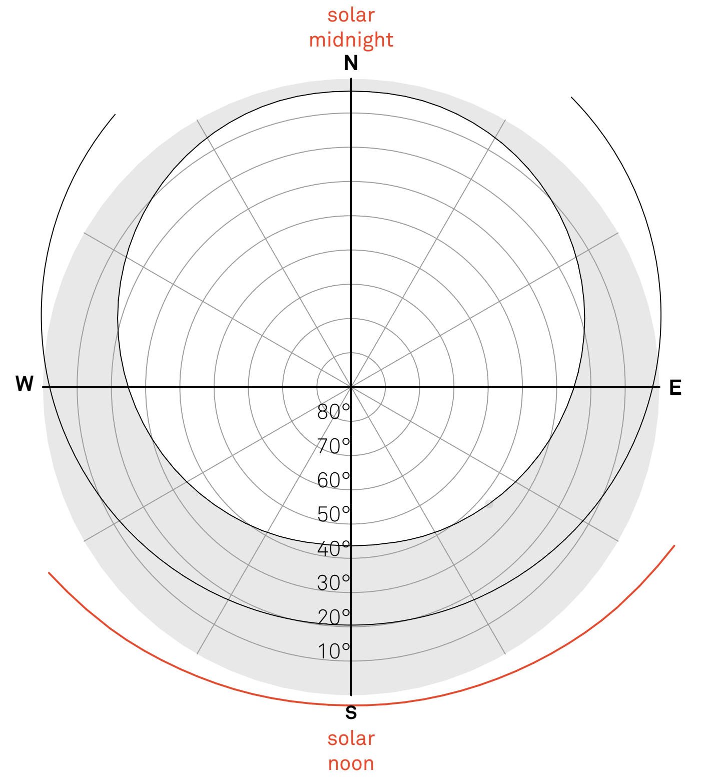


fig. 1.09: Sun path on winter solstice.

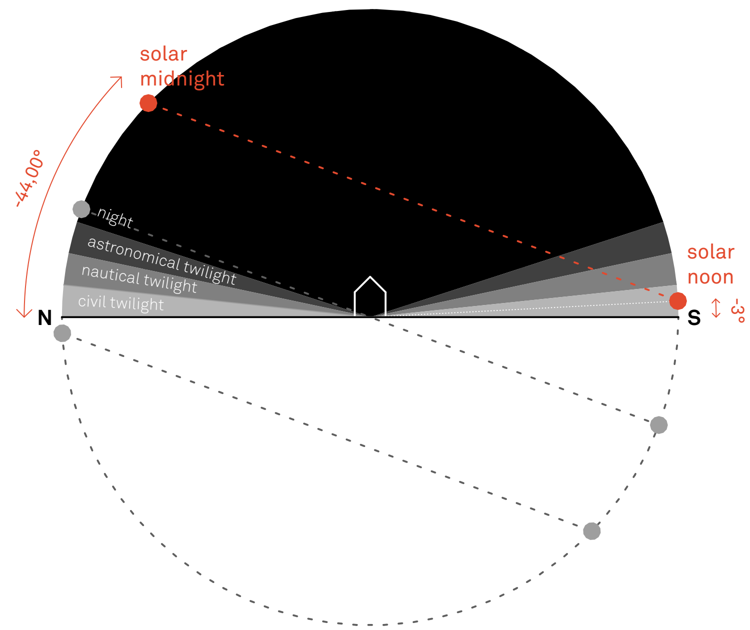


fig. 1.10: Section of sun path. On winter solstice, the altitude angle at solar noon is the equinox angle minus the Earth's tilt: 20,50°-23,50°=-3,00°

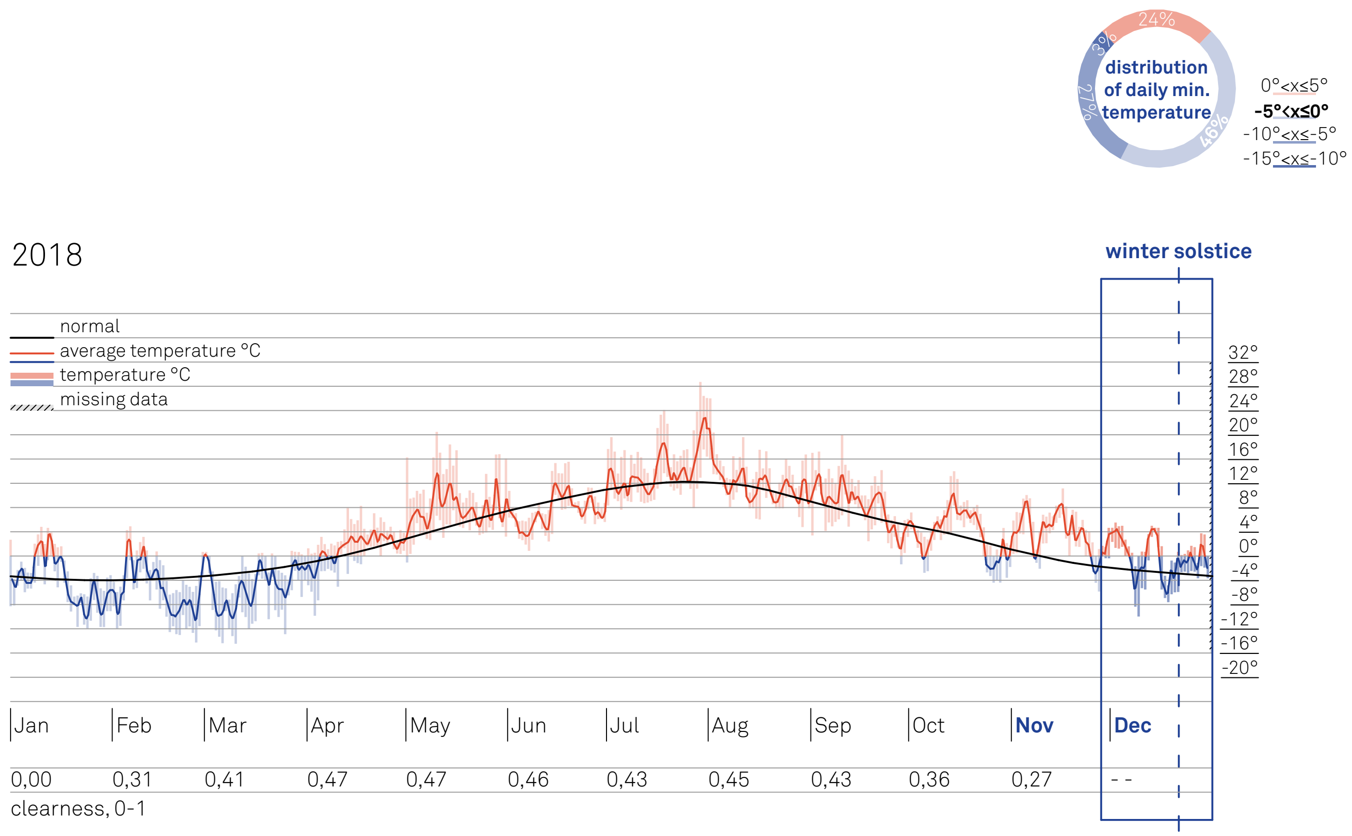


fig. 1.11: Temperature and clearness graph.

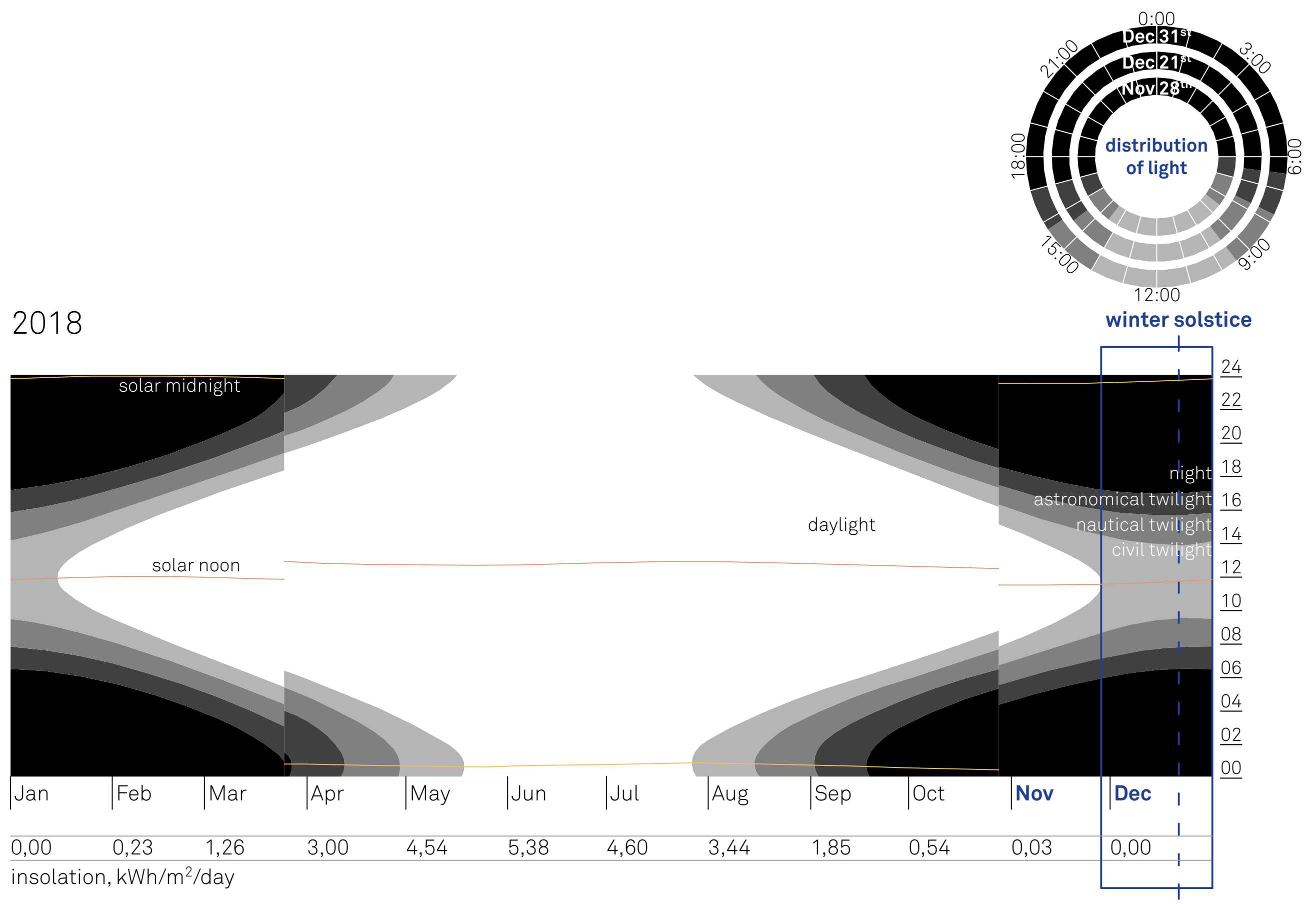


fig. 1.12: Light and insolation graph.

missing data: Dec. 31st

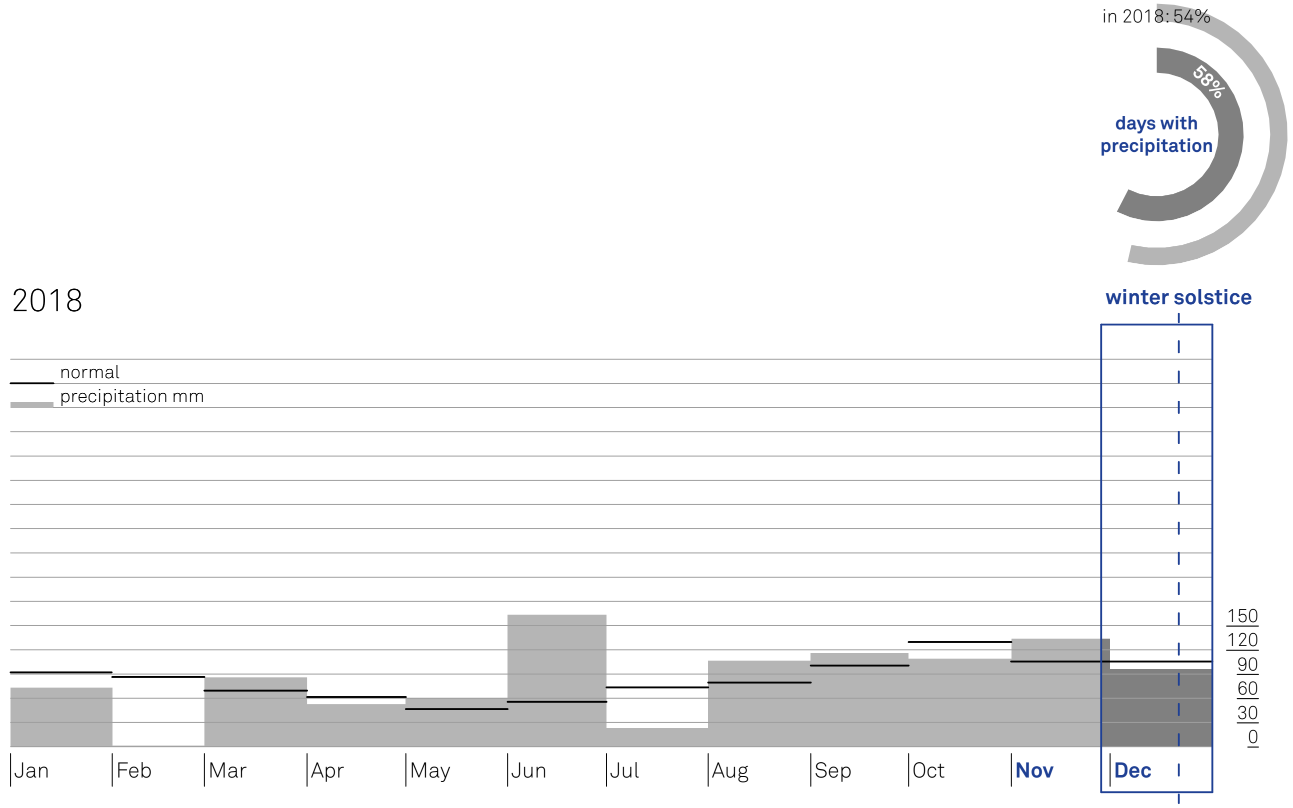
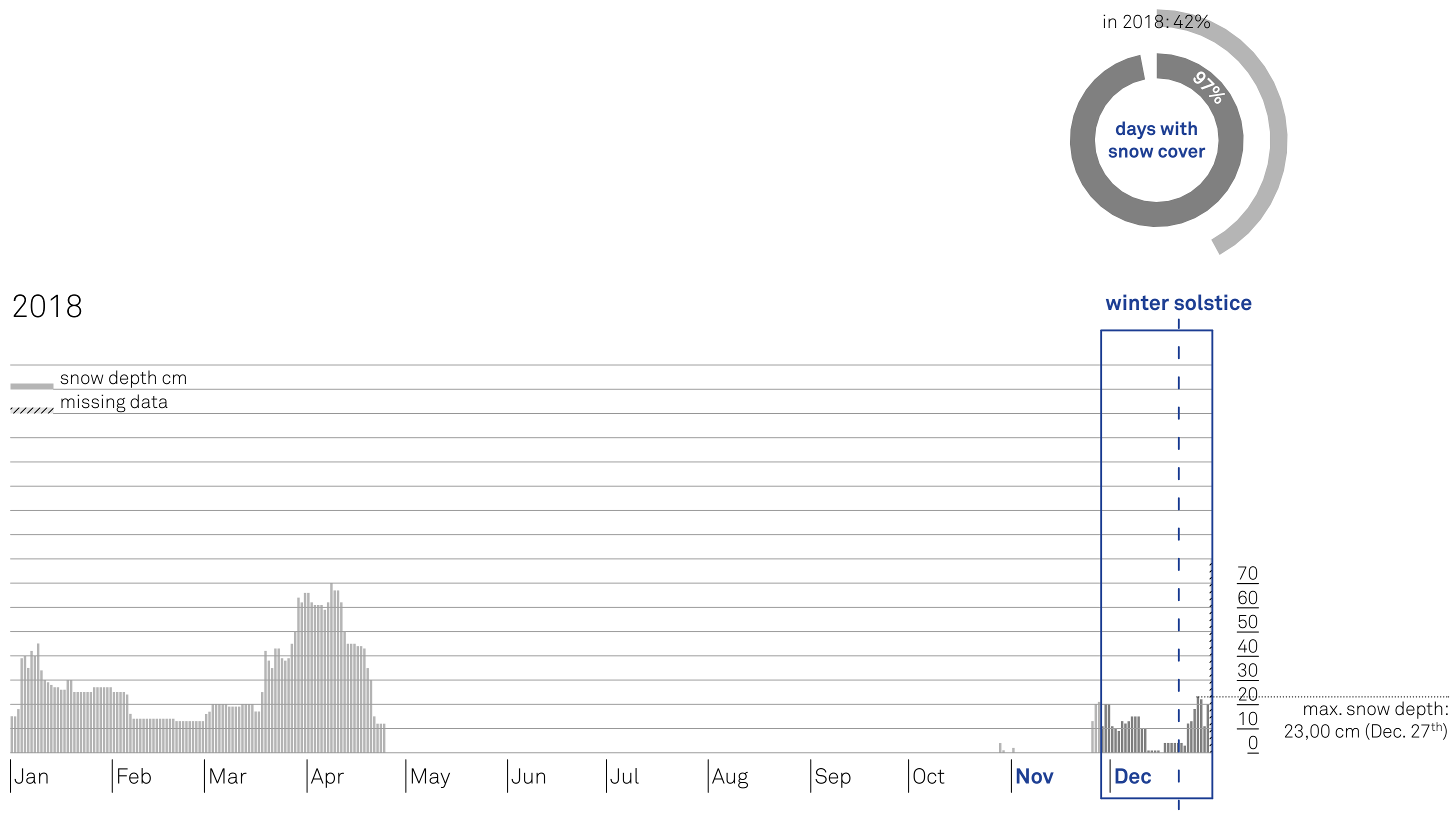


fig. 1.13: Precipitation graph.



missing data: Dec. 31st

fig. 1.14: Snow depth graph.

Arising design priorities:
1st: preserving the heat

1.2 strategies for thermal resource efficiency

1.2.1 the compact building

Looking at plant leaves from around the world, it is noticeable that the leaf shape of native plants correlates with the prevailing climate.[25]
In friendly environments like the temperate and the hot-humid zones, plants open up. Leaves have an increased surface and a reduced section. On the contrary, in hostile territories like the cool and hot-arid zones, plants close up. Leaves have a reduced surface and an increased section[26] – and so should our buildings. (fig. 1.15)

In Arctic Norway, a cubical and simple shape is desirable. According to Victor Olgyay in *Design with Climate: Bioclimatic Approach to Architectural Regionalism*, in cool zones the optimal building has a proportion of 1:1.1-1.3 and is arranged on an east-west axis.[27]
For the roof structure, a sloping roof is beneficial as it fosters snow removal by wind, preventing the roof from an exceeded snow load. Moreover, a simple roof formation reduces moisture penetration.[28]
In this regard, in Arctic Norway, one should stick to simple volumes richly decorated rather than vice versa.[29] In ornamenting in an artisanal way, a building can have "a 'face' that invites you in and welcomes you home"[30] – a beautiful thought.

The hemispherical shape of the Inuit igloo, as the

25 cf. Olgyay, 2015: 84-85
26 cf. Olgyay, 2015: 84-85
27 cf. Olgyay, 2015: 155
28 cf. Olgyay, 2015: 156
29 cf. Lechner, 2015: 490
30 Susanka, 2008: 199

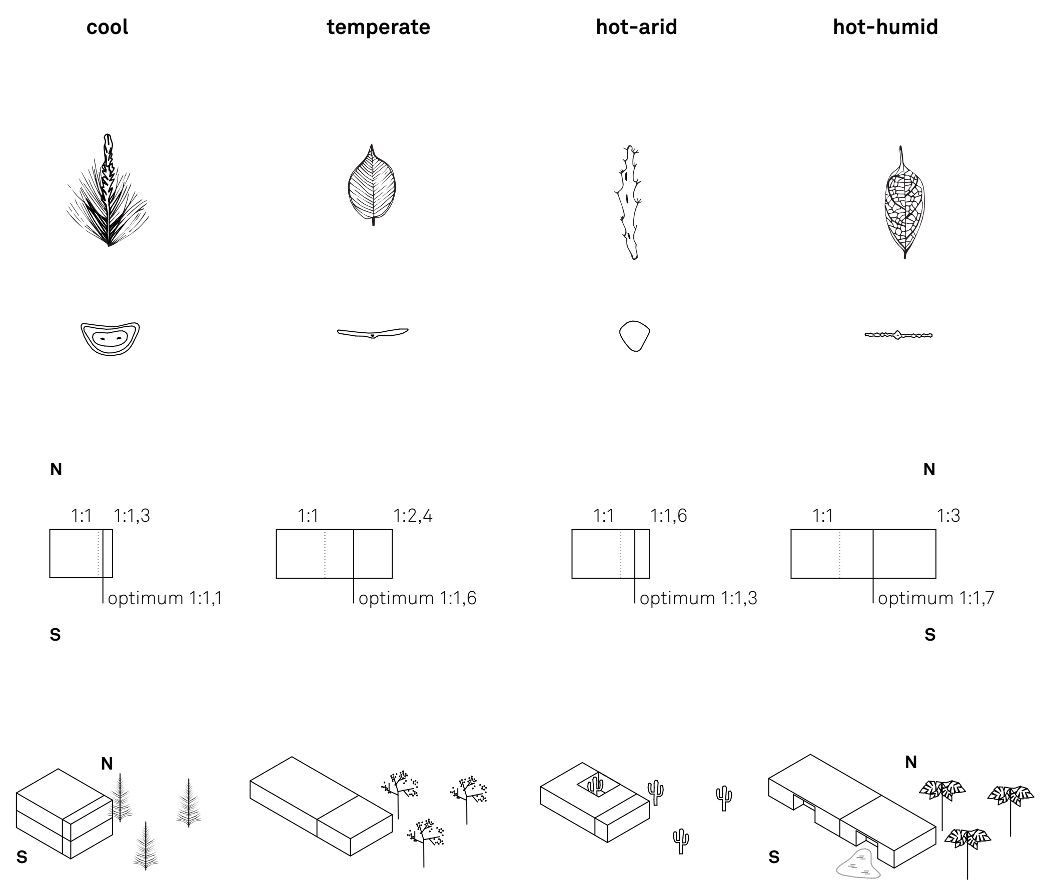


fig. 1.15: Indigenous plant leaves and bioclimatic building forms around the world.

fig. 1.16: 'The New Monte Rosa Hut'. A picture by Tonatiuh Ambrosetti (edited).

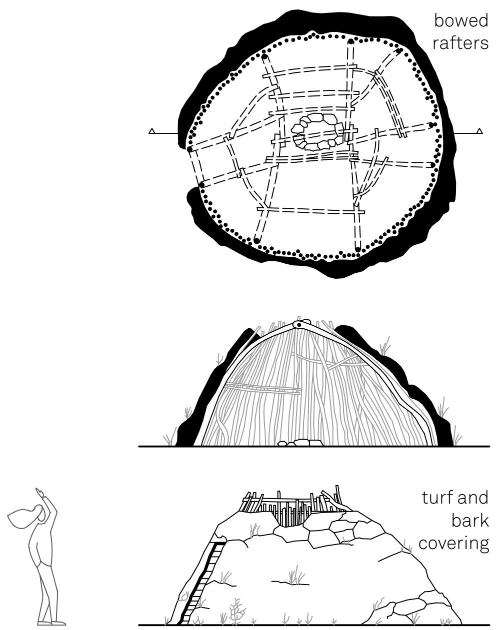


fig. 1.17: A Sámi gamme of post-medieval date.

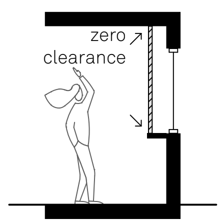


fig. 1.18: Thermal drapes as movable insulations.

incarnation of the compact building, is ubiquitous. However, the Sámi gamme – the home of the indigenous people of Northern Scandinavia – also has a perfect surface area to volume ratio and thus offers excellent shelter from the prevailing harsh climate conditions. (fig. 1.17)
The New Monte Rosa Hut, a research project by the ETH Zürich at nearly 3000 m altitude, represents another example for an ambitious surface area to volume ratio experiment in a challenging environment. The mountain lodge has its origin in the compactness and structure of an orange. (fig. 1.16)

Airtight and compact windows are crucial, otherwise they turn into sheer black surfaces where heat and light escape. Here, movable insulations are a solution. Although outdoor shutters are common in traditional architecture of cool climates, they are scarcely effective because of the joint gap between the shutter and the wall.[31] Hence, indoor thermal drapes with airtight seals and a vapor barrier (to prevent condensation on the window) are preferable and can additionally add an aesthetic value.[32] (fig. 1.18)

"More is more," says the prevailing credo when it comes to insulating buildings. Insulation not only keeps the house warm during cold times, but also protects the inhabitants longer in case of a power emergency[33], transforming a building into a true shelter for the inhabitants.
For the design project, the passive house standard is set as a minimum concerning insulation measurements.

31 cf. Lechner, 2015: 512
32 cf. Lechner, 2015: 512-513
33 cf. Lechner, 2015: 493

1.2.2 renewable active sources

In comparison to nonrenewable energy sources like fossil fuels and nuclear power, renewable ones are not accelerating global warming. Solar, wind, biomass, hydroelectric, and geothermal are renewable energy sources.[34] For a building, the final decision of the most appropriate renewable active source plus the medium and method of distribution is particularly site driven and therefore will not be finalized for the design project.

In Northern Norway, buildings are often equipped with a hearth in addition to the central heating system. Although wood stoves, if not properly constructed, tend to be polluting and low-efficient, they contribute to more comfortable conditions in spaces of high occupancy. As some rooms have higher heating demands than others – just think of the place where one enjoys a glass of wine in contrast to the ancillary rooms – this is especially beneficial.

1.3 strategies for luminous resource efficiency

1.3.1 artificial lighting

In Arctic Norway, an artificial lighting system, that nourishes the range of situations inside a dwelling, is especially crucial during the polar nights.
“Light is intrinsically connected to mood. A sunny day seems to express a cheerful mood, while a cloudy one might make us feel more introspective.”[35] It is mainly the color of light that sets the atmosphere. [36] Warm light sources are in the range of red, orange, and yellow colors, while cool light sources are blue and green based.[37] For example, candles give a very warm light and are artificial yet natural.

34 cf. Lechner, 2015: 34; 38

Also, during the months of darkness, artificial lighting plays a crucial role in sustaining the circadian rhythm. Our body clock needs to receive constant signals for alertness or sleepiness, which normally the 24-hour solar day triggers.[38]
Warm light promotes the release of melatonin, enveloping us in a sleepy mood, while cool light supresses it, making us feel alert.[39] Therefore, sleeping in a very dark room in tandem with a high light exposition after getting up is advantageous.[40]

The Seasonal Affective Disorder (SAD), whose symptoms are, among others, lowered performance and depression, may be a severe consequence of the lack of daylight.[41]
Bright light therapy, where patients are exposed to extreme high light levels in addition to spending enough time outside and being active, come snow or wind, can mitigate the symptoms.[42]
In this way, in Arctic Norway, bright lighting is pivotal for buildings.

However, a lit interior with a dark exterior results in reflexions on glass surfaces, resulting in a visual barrier. To create a visual connection between the inside and the outside, the outside has to be equally

35 Susanka, 2008: 66
36 cf. Mills, 2018: 69
37 cf. Mills, 2018: 59
38 cf. Boubekri, 2008: 53-54
39 cf. Mills, 2018: 70
40 cf. Lechner, 2015: 395
41 cf. Boubekri, 2008: 56
42 cf. Boubekri, 2008: 59

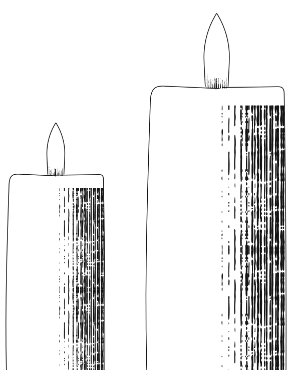


fig. 1.19: The door handle as a gateway to a new world. Salgenreute Chapel by Bernardo Bader, western Austria. A picture by Adolf Bereuter (edited).

lit or brighter.[43]
To spin a thread vice versa – between the outside and the inside – many windows of the houses in northern Norway are decorated with beautiful lamps which are lighting the pedestrians' way while walking in the darkness.

1.4 strategies for spatial expression

1.4.1 the haven

During the polar nights, when the outside world is dark and hostile, a total retreat to the built world takes place. Therefore, in high latitudes, the entrance door of a building must open up to another nurturing world (fig. 1.19) – or a world that is not the complete contrary from our Environment of Evolutionary Adaption, but rich with information, natural elements and sensual stimuli. Our brain needs vast and varying stimuli that address all our five senses and foster our curiosity to evolve and stay healthy.[44] In this way, buildings become havens.

Yet, "[as] square footage is all that is required, [buildings] are being built without the level of detail so important to humanizing life,"[45] Sarah Susanka, states in her book *The not so big house: A Blueprint for the Way We Really Live.*
In truth, a common way of constructing new residential buildings is with load-bearing walls out of concrete, insulations out of foam and dividing walls out of drywall, all unified with white plaster, incorporating the sheer void.

43 cf. Mills, 2018: 81
44 cf. Grinde and Patil, 2009: 2334
45 Susanka, 2008: 14

“[T]here is no doubt that our technological culture has ordered and separated the senses even more distinctly,”[46] the architect Juhani Pallasmaa puts it well. In the built world, seeing and hearing are prevailing, while touching, smelling, and tasting are suppressed.[47]

What creates the complex feeling of comfort?, the architects Sergison and Bates ask in their essay compilation on architecture titled *Aufsätze 3* (original English version: *Papers 3*) and cite the elements of comfort by the arts and crafts architect Baillie Scott – tranquillity, restfulness, warmness and light – as an answer.[48]
However, to see the light, it must always be accompanied by darkness, or differently articulated, spaces of prospect must be counterweighted by spaces of refuge, as it is the refuge where “we procreate, sleep, meditate, and recover from illness and injury [...].”[49]

A powerful design strategy for heightening comfort – or prospect-refuge-mediation – are differentiated ceiling heights within a room. (fig. 1.20)
By doing so, nuanced spaces appear, which have their own character, yet are part of the whole room.[50]
Moreover, differentiated ceiling heights foster the activity taking place within a space. Therefore, high ceilings for public spaces like the living area and low ceilings for more intimate spaces like the sleeping area are beneficial. Just as in the natural world, there are places of security and places of spaciousness.

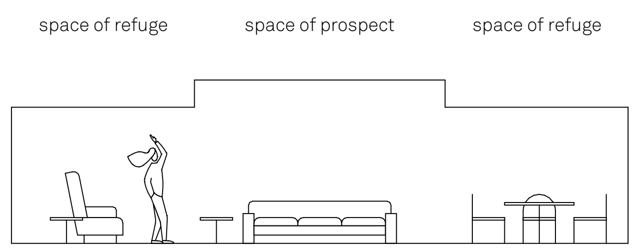


fig. 1.20: Individually defined spaces within a room.

46 Pallasmaa, 2012: 18
47 cf. Pallasmaa, 2012: 18
48 cf. Sergison Bates architects, 2016: 57; 60 (translated by the author)
49 Kellert et al., 2008: 267
50 cf. Susanka, 2008: 65

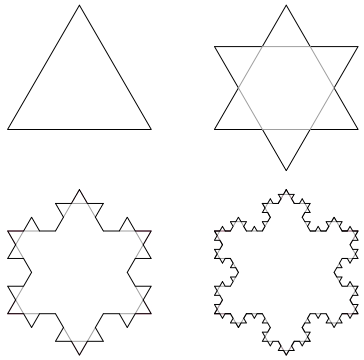


fig. 1.21: Fractals.

fig. 1.22: The hearth of the Villa Busk by Sverre Fehn, southern Norway. A picture by Roger Tyrrell.

1.4.2 natural shapes and keepsakes

Many of the phenomena of nature have a fractal shape – self-repeating but varying in scale. (fig. 1.21) Snowflakes, salt flats, seashells, lightning, broccoli, ferns, pineapples, clouds, trees, leaves, and so much more can be enumerated as examples of it.[51] Also the eye's venous systems and the branching patterns of retinal are of fractal shape.[52]
This special form of shape, so simple and rich at once, is ubiquitous in the natural world, yet alarmingly scarce in the built one.
Strategies for a more fractal habitation are ornamentations – in their deepest expression a distillation of geometrical connective rules[53] – and natural keepsakes like fire, plants, animals and water.

fire. Fire is the place to gather and cook. The flames of a fire are constantly altering, yet remaining the same, provoking relaxation. A fire fosters comfort and safety.[54]
The light of a fire in the forest is like the primal room, and in Norway with its harsh climate, the hearth often still represents an essential element in a building.[55] In the Villa Busk by the Norwegian architect Sverre Fehn, for example, the hearth sits in the corner and is framed by two big windows, merging the inside with the outside. While looking at the flames, one simultaneously sees the sea, the trees, and the sky.[56] (fig. 1.22)

plants. Plants strongly shaped our Environment of Evolutionary Adaption. Therefore, they are highly

51 cf. Jones, 2020: 87
52 cf. Mainster, 1990: Abstract
53 cf. Kellert et al., 2008: 64
54 cf. Kellert and Wilson, 1993: Chapter 5
55 cf. Tyrrell, 2017: 140
56 cf. Tyrrell, 2017: 159-160

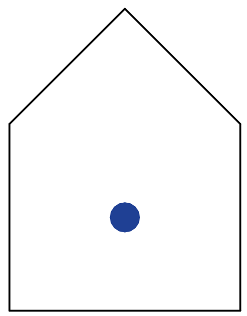
relevant to the quality of modern indoor rooms.
As a review in the International Journal of Environmental Research and Public Health summarizes from various studies, benefits of indoor plants are, for example, an improved microclimate, improved acoustics, and fragrance.[57] Furthermore, various health benefits like a reduction in fatigue, cough, and dry throat are reported.[58]
For Arctic Norway, one compelling strategy for enhancing buildings with numerous plants – also during the months of complete darkness – are indoor living walls due to their closed and self-sustaining system.

animals. Bringing animals into the built world can be difficult and often unwanted.
Hence, animals are mainly found in representational form through ornamentation, decoration, art, and are often stylized.[59]
But when they are present, they are often a source of pleasure and interest, like the aquarium at the dentist's office. It might make the greatly feared visit a little bit more enjoyable.

water. Nowadays, water is just running out of the tap when the faucet handle is turned, revealing little of its nuances of volume, texture, timbre, and rhythm.[60]
Conversely, in the bathroom of a hotel in Japan, Kengo Kuma seems to celebrate the flow and the presence of water, blazing its trail over the wooden cuboid into the ground like a trickle in the mountains. (fig. 1.23)
To give water its permanent visibility in the built world, glass vases or bowls with flowers can be considered. Moreover, with these interventions, plants are also brought into the building.

57 cf. Grinde and Patil, 2009: 2335
58 cf. Kellert et al., 2008: 128
59 cf. Kellert et al., 2008: 7
60 cf. Kellert et al., 2008: 46

fig. 1.23: The sink as a wooden cuboid by Kengo Kuma, Japan. A picture by Daichi Ano (edited).



introducing the

1st architectural layer:

the innermost

the end of the year **is the time of retreat. Many plants have defoliated and many animals hibernate. Like everything comes to rest, so may we.**
the end of the year **is the time where deep relationships are crucial and cultivating life in community is precious. It is the time of being close to other people and helping each other through the challenges of darkness. Equally, it is the time of feeling close to the indoor spaces as they envelope us the majority of time.**
Here, the first architectural layer of the design study is introduced: ***the innermost*** **– the pearl that is safely protected by a robust shell.**

the innermost **is a multi-purpose space. It is simple and therefore economical. With its well-proportioned size it can be used variously, but still kept warm easily. It is a space big enough to gather and dance together. Furniture, like beds, are flexible, allowing space for change in a world full of changes. To make it dear, which is crucial for maintenance, the innermost offers surfaces and space for keepsakes and creativity.**
Moulding it into Sarah Susanka's words, the innermost aims to be a "total expression of comfort." (Susanka, 2008: 18)

precious little delights

… baking Christmas cookies with family and friends … blowing out a beeswax candle and smelling its scent … resting one's eyes on the leaves of the indoor lushness … feeling the warmth of a wool carpet under one's feet … decorating the windows with Christmas lights … telling stories around the fireplace …

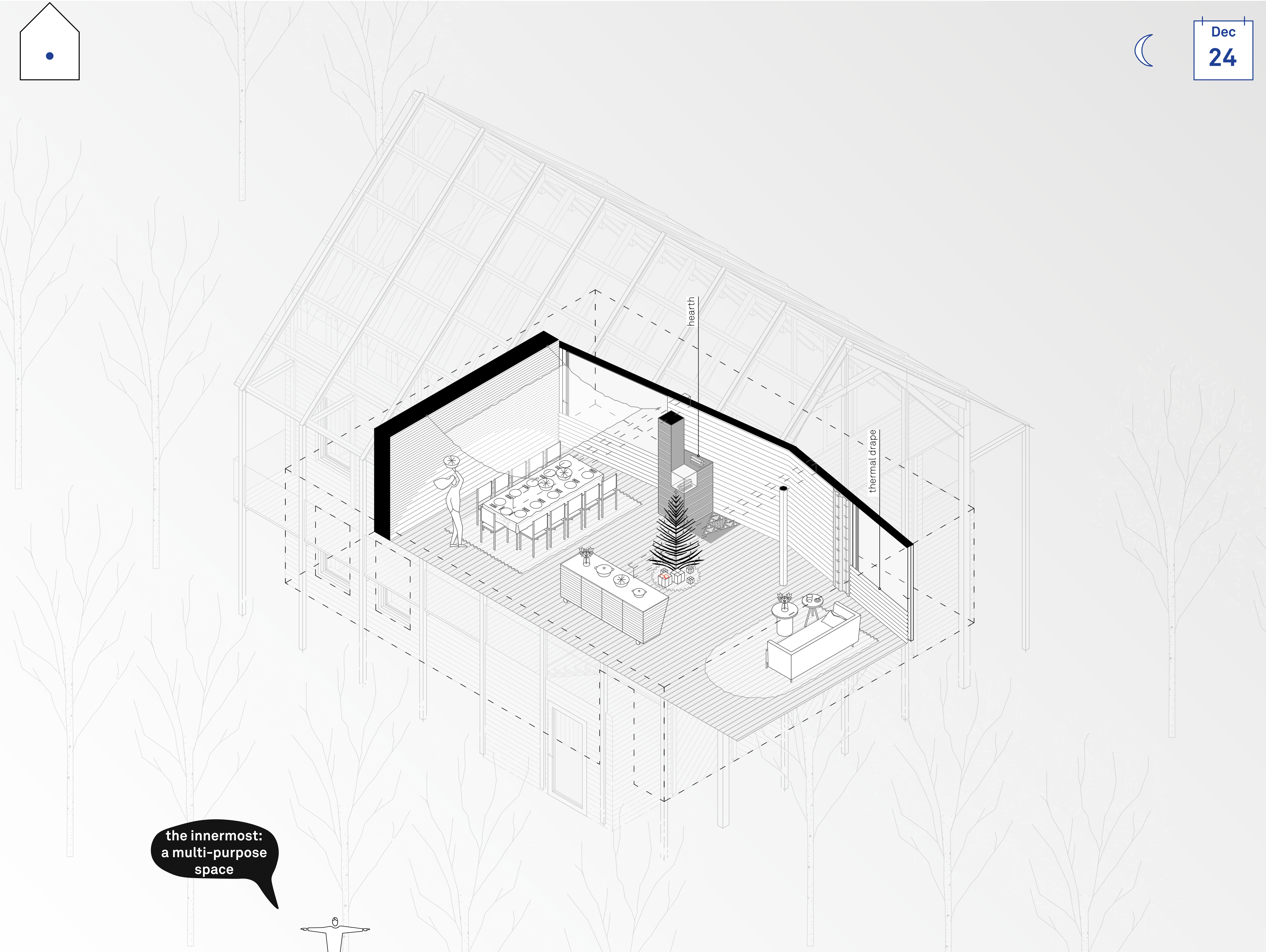


fig. 1.24: The innermost 1st level. Axonometric plan. Viewing direction: south. 1:100

fig. 1.25: The innermost 1st level. Axonometric plan. Viewing direction: north. 1:100

fig. 1.26: The innermost 2nd level. Axonometric plan. Viewing direction: south. 1:100

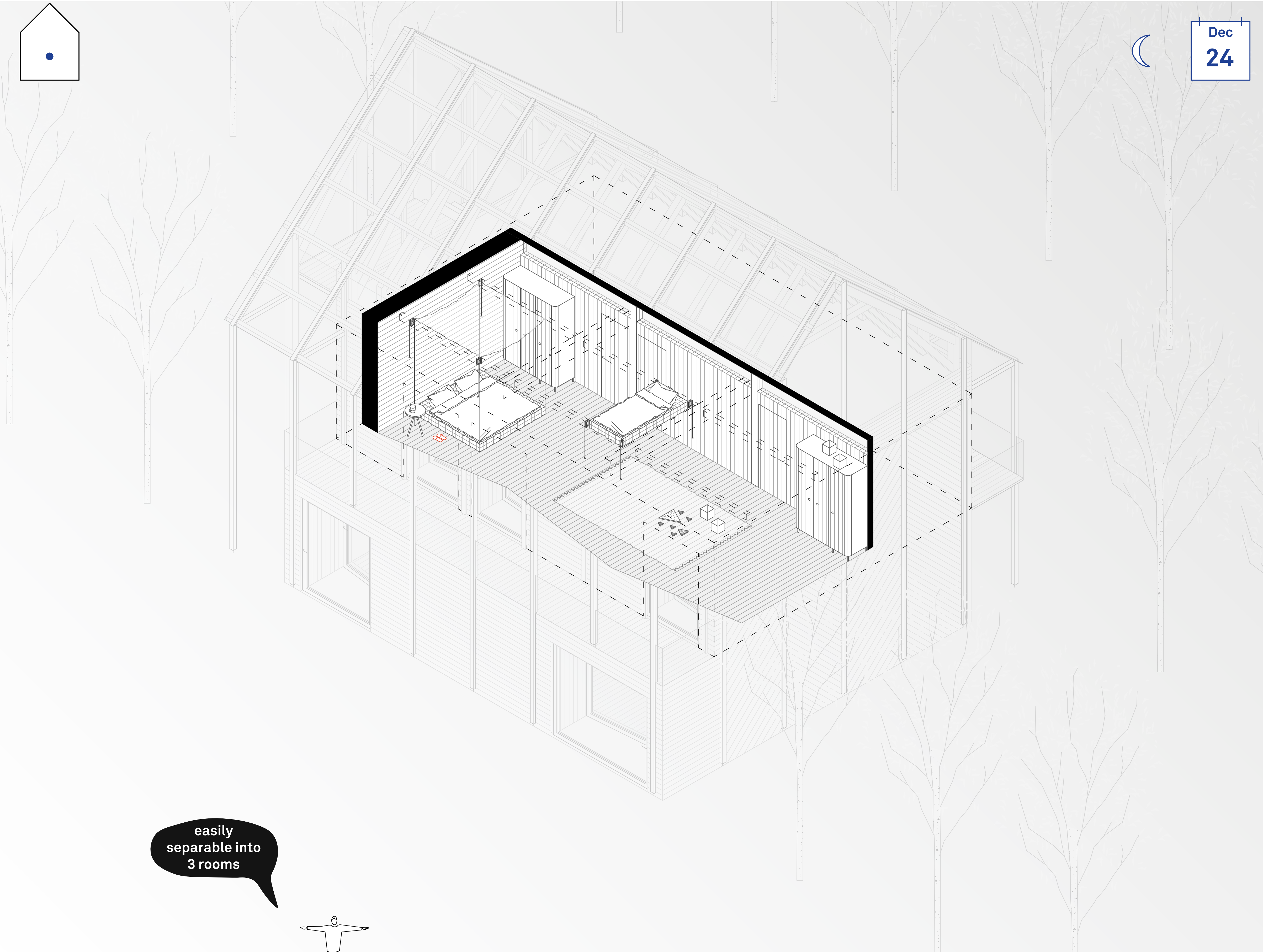


fig. 1.27: The innermost 2nd level. Axonometric plan. Viewing direction: north. 1:100

1m 2 5

2019

mid-Jan | Feb | Mar | Apr

1st day of the sun being not
invisible for 24 continuous hours

mid-May | Jun | Jul | Aug

last day of the sun being not
visible for 24 continuous hours

Sep | Oct | Nov | Dec

2
the beginning of a new year

2.1 characteristics of time period

The day the sun is back heralds a new beginning; therefore, the chapter of transition is entitled *the beginning of a new year* (mid-January - mid-May with the spring equinox on March 21st), although this period of time does not start with January 1st.

It is the time period between the first day of the sun being not invisible for 24 continuous hours and the last day of being not visible for 24 continuous hours.

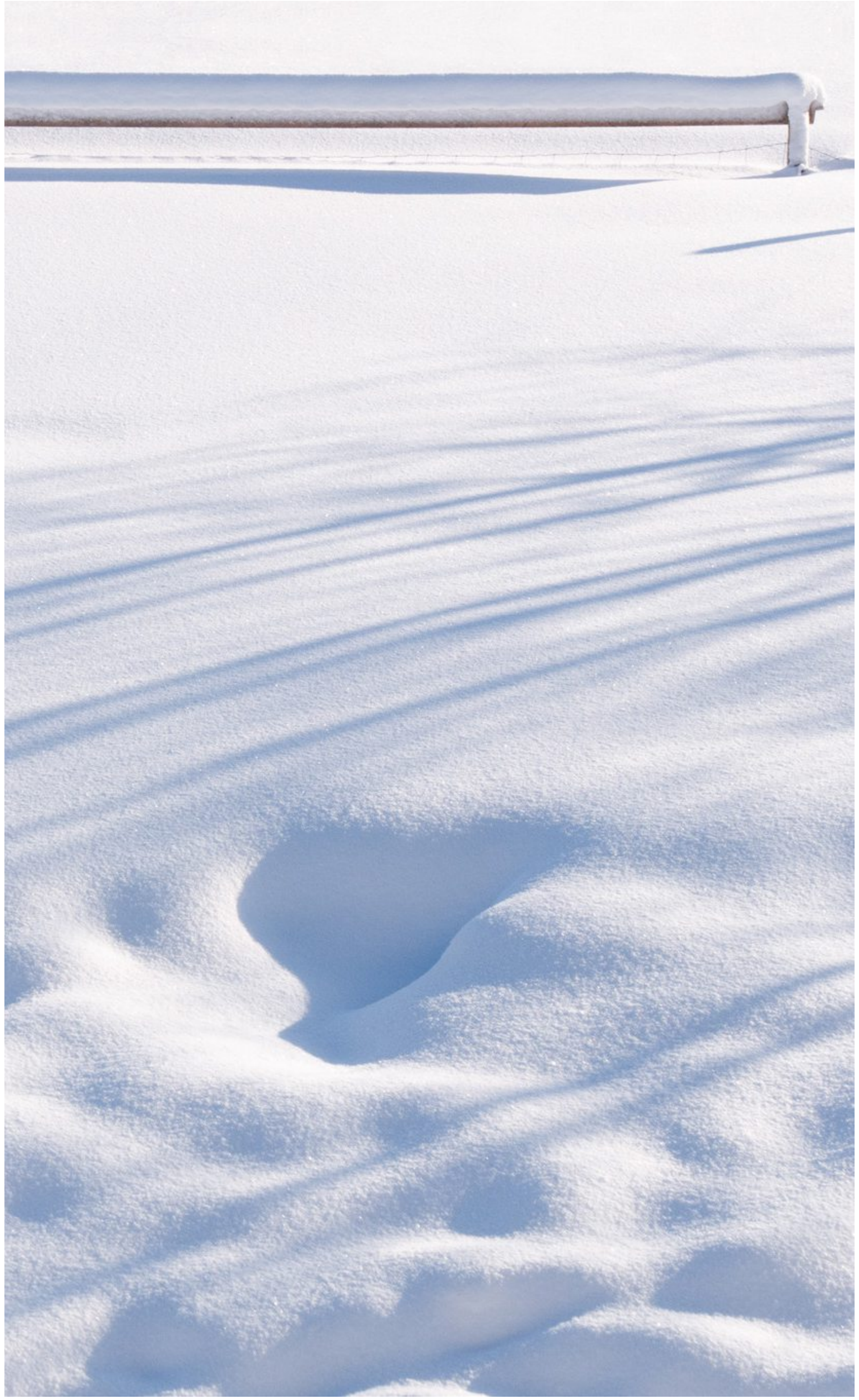
2.1.1 photo essay ‘focal glow’

After two months of darkness, there is an incredible happiness when the sun is back.
The “focal glow,”[61] another layer from the lighting concept by Richard Kelly, captures the spirit of this time of new beginnings. (fig. 2.01-2.07)

field study
19/2 - 15/3/2020

fig. 2.01
(fig 2.02-2.07 on the following pages)

61 cf. “Richard Kelly,” 2020: www



2.1.2 climate conditions

Reference data are from Tromsø (69,50°N, 19,00°E) between mid-January and mid-May, 2019, representing the time of transition. As Tromsø is located 69,50° north, on the equinox the altitude angle at solar noon – the sun being at its highest position but not necessarily at 12:00 – is 20,50° (90,00°-69,50°).

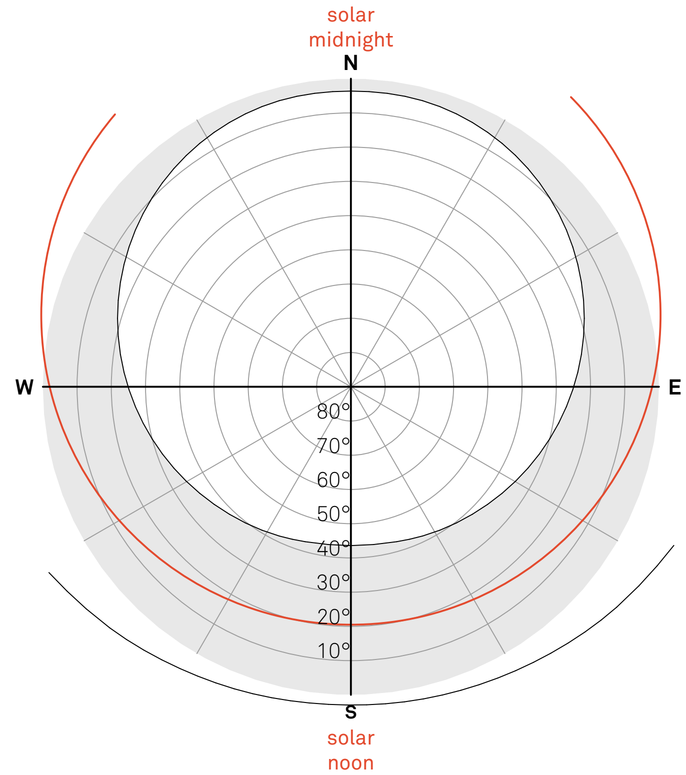


fig. 2.09: Sun path on spring equinox.

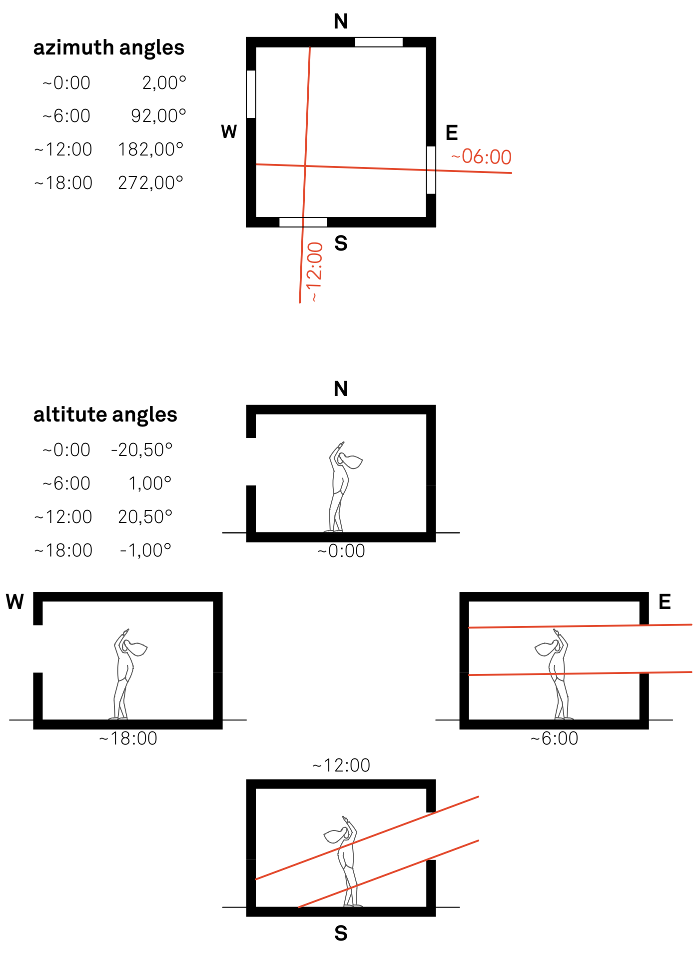


fig. 2.08: Azimuth and altitude angles on spring equinox (March 21st).

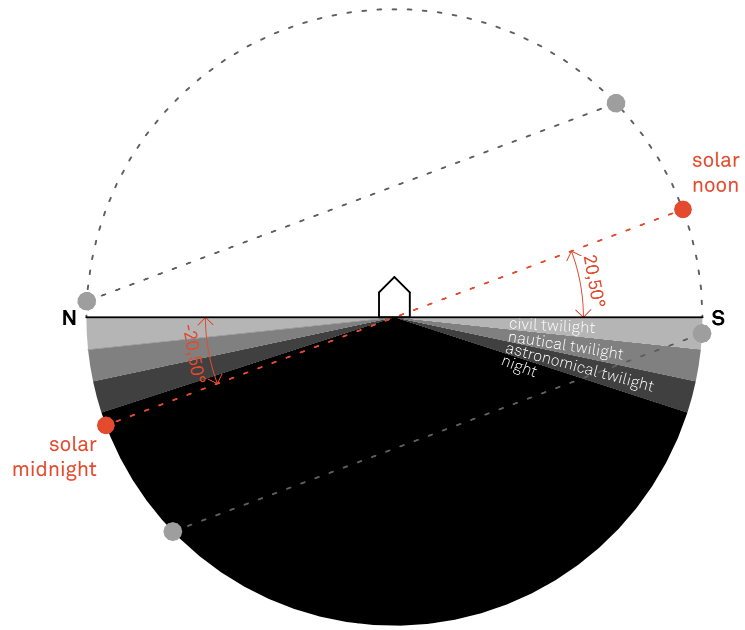


fig. 2.10: Section of sun path. On spring equinox, the altitude angle at solar noon is 90° minus the latitude: 90,00°-69,50°=20,50°

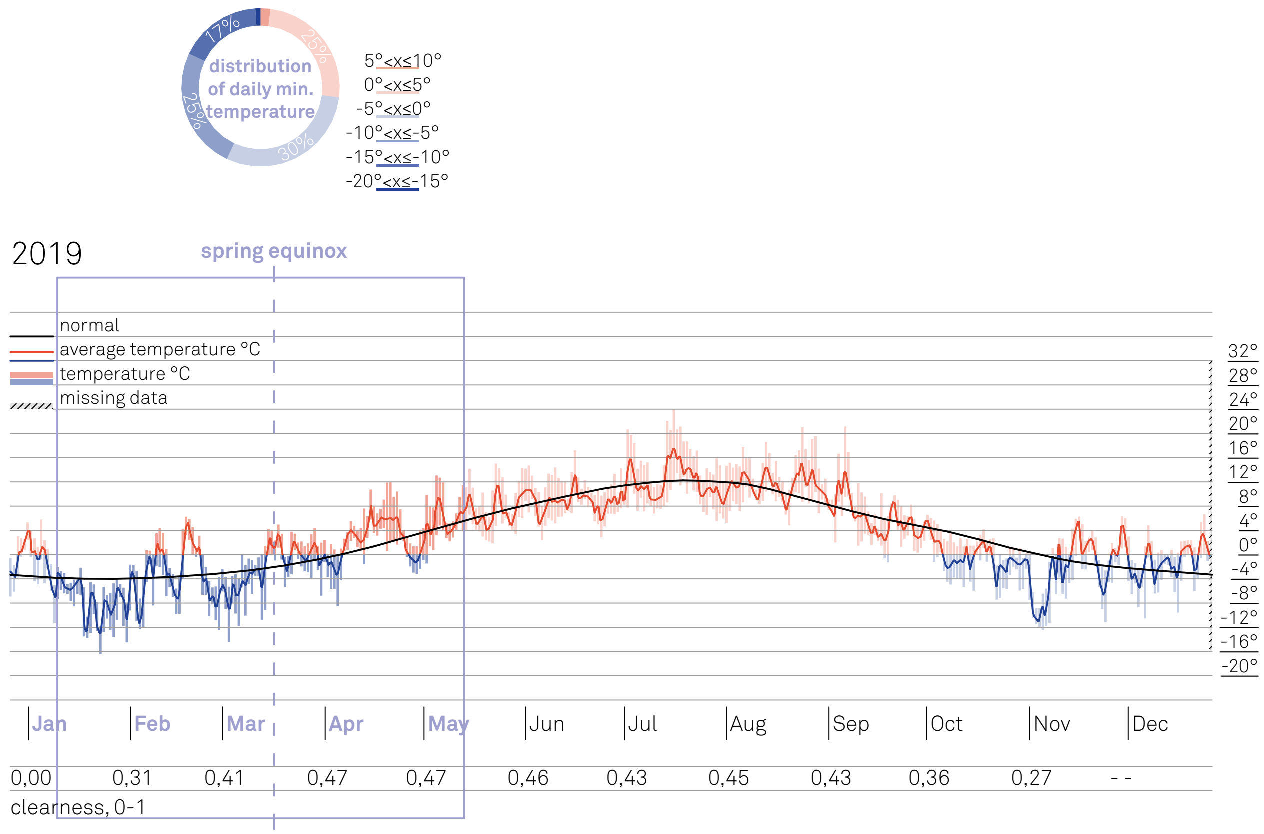


fig. 2.11: Temperature and clearness graph.

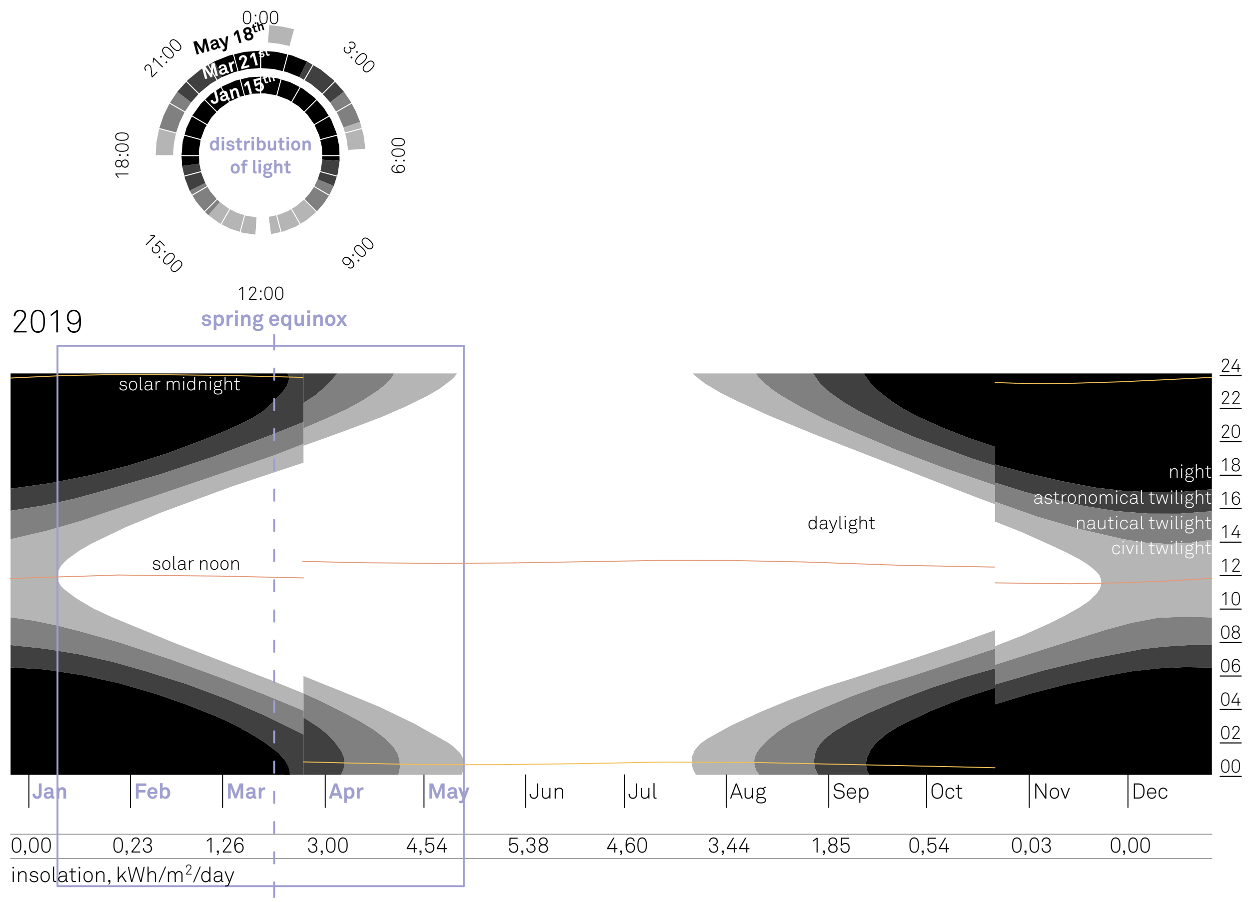


fig. 2.12: Light and insolation graph.

The day of the sun's come back can vary. (f.e. due to overcast skys)

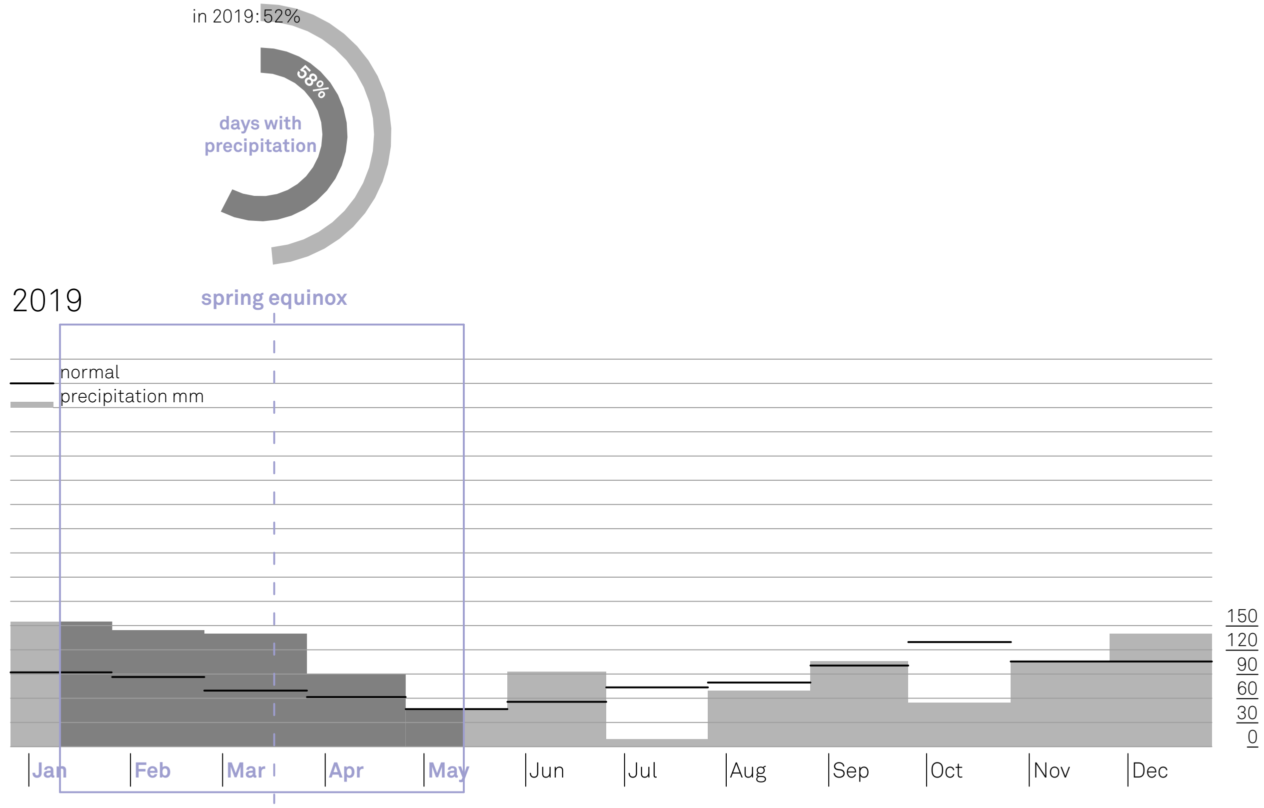


fig. 2.13: Precipitation graph.

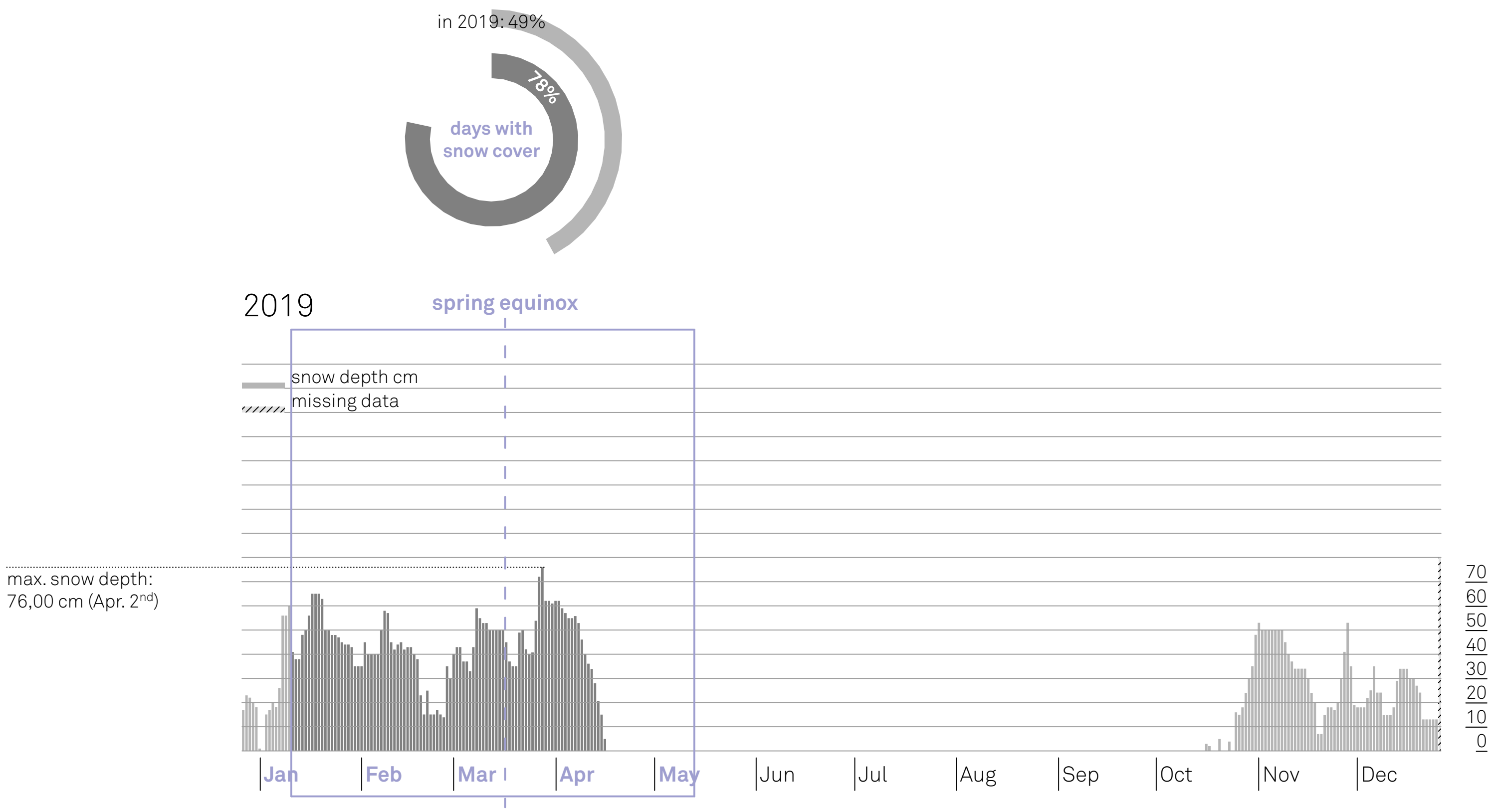


fig. 2.14: Snow depth graph.

Arising design priorities:
1st: preserving the heat

2.2 strategies for thermal resource efficiency

2.2.1 the south-facing coastal slope

Imagining Arctic Norway after the sun is back, snowy mountains and the Atlantic Ocean might appear before one's eyes.
The average mountain in Norway is 460 metres high and with the fjords and the approximately 50 000 islands the whole country's ragged total coastline measures an unimaginable 60 000 kilometres.[62 63]
However, Arctic Norway's ocean-mountain combination is not only an incredibly beautiful one, but it is also beneficial for building more resource-efficiently in high latitudes.

Building on south-facing hills is beneficial in cold climates for the following reasons:
Firstly, because of the stack effect, the warm air tends to move upwards the exposed hill at night time.[64] Secondly, a site far enough up a south-facing slope often lies in the wind shadow as prevailing winds tend to come from the north.[65] Thirdly, the south-sloping land reduces the low solar altitude angle of the circumpolar regions and with it decreases the shadow length.[66] Lastly, the solar-access boundary – or how high objects can be before obstructing the sun's radiation on other objects – gets less severe with the tilt. (fig. 2.15)

As water has a higher heat capacity and conductivity than land, its surface temperature oscillates less. Therefore, coastal areas have a more temper-

62 cf. Tyrrell, 2017: 135
63 cf. Dekkerhus et al., 1992: 4
64 cf. Brophy and Lewis, 2011: 52
65 cf. Lechner, 2015: 83
66 cf. Lechner, 2015: 328

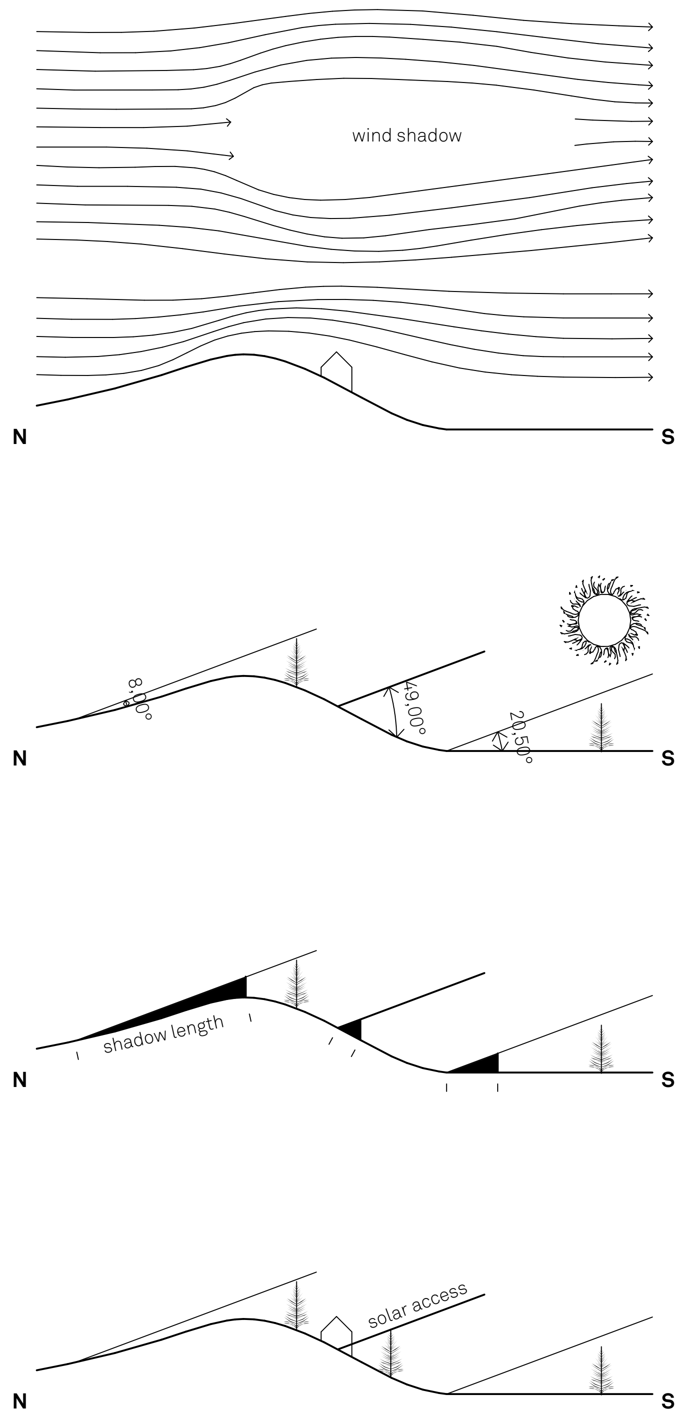


fig. 2.15: The south-facing slope and
... the wind shadow
... the increased solar altitude angle
... the decreased shadow length
... the improved solar access.

fig. 2.16: The east elevation. A picture by Tonatiuh Ambrosetti.

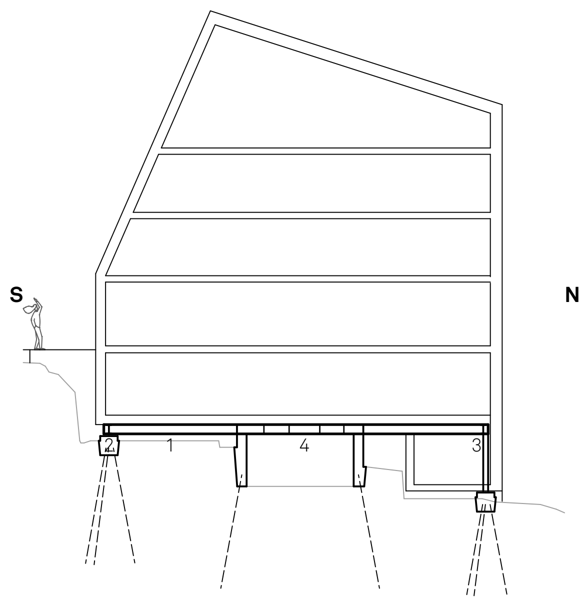


fig. 2.17: The table-like steel construction.

ate climate than continental ones.[67]
Moreover, the warm waters of the Gulf Stream mitigate northern Norway's Arctic climate and bring a more pleasant Scandinavian one: colder summers and comparably milder winters.[68] That is why northern Norway – a very coastal shaped area – has a higher population density than other polar regions. However, in Arctic Norway building on a slope also involves challenges, like the grounding, and the drainage of excess rain- or meltwater.

The New Monte Rosa Hut, the Swiss mountain lodge of chapter *1.2.1 a compact building*, can be drawn as a reference for building in sloping terrains, the difference is, this building is located on a north-facing slope.
Looking at the east elevation of *The New Monte Rosa Hut*, the mountain lodge seems to weigh heavily on the alpine rocks.[69] (fig. 2.16) Little do we know that the building is actually lifted on a table-like steel construction (fig. 2.17)– a ring carrier with 10 radial axes (1) for each of the 10 load-bearing walls – resting on the uphill point foundations (2), the downhill stilts (3) and the central concrete core (4).[70] This paradox circumstance of a building simultaneously being detached from and connected to the ground results in the following benefits:

First of all, it is an easier way to build in a rocky and sloping terrain with less demand for concrete, and more protection of the prevailing permafrost ground.[71] Moreover, it creates an aerated void underneath the mountain lodge, minimizing the heat conduction from the building to the ground, protecting the inlet air of the ventilation system from the snow and managing the water drainage.[72] Also,

67 cf. Lechner, 2015: 80-81
68 cf. Dekkerhus et al., 1992: 4
69 cf. ETH Zürich, 2010: 114-115 (translated by the author)
70 cf. ETH Zürich, 2010: 114-115 (translated by the author)
71 cf. ETH Zürich, 2010: 114-115 (translated by the author)
72 cf. ETH Zürich, 2010: 114-115 (translated by the author)

with this construction, very few rocks had to be detonated up the slope, preserving the integrity of the rock formation. A sun terrace in the south easily bridges the gap between the rock and the building.[73] Lastly, the building's occupants are still rooted to the mountains and there is no feeling of supremacy.

1.2.2 passive solar technologies

There are numerous benefits of passive solar technology, like a curled cat snoozing in a sunny place knows.
According to the book *Heating, Cooling, Lighting: Sustainable Design Methods for Architects*, "passive solar refers to a system that collects, stores, and redistributes solar energy without the use of fans, pumps, or complex controllers."[74]
The most powerful contributor to passive solar is the greenhouse effect. It can be used directly, through a Trombe wall or a sunspace. (fig. 2.18) The solar radiation can access the building through the roof, the wall or as a reflection from the ground.[75]

Dark floors and walls are beneficial for enhancing the greenhouse effect, although it is like walking a tightrope. To avoid making the overall space too dark and therefore weakening the power of natural lighting (3.3.1), dark floors and light walls/ ceilings can be a solution.
In Arctic Norway, since the appearance of high-performance windows, the old wisdom of little fenestration is an outdated one[76]. However, in latitudes that high it is especially crucial that the majority of the windows face south. (fig. 2.19) Days are short during winter and it is the south sun that has the highest altitude and therefore power.

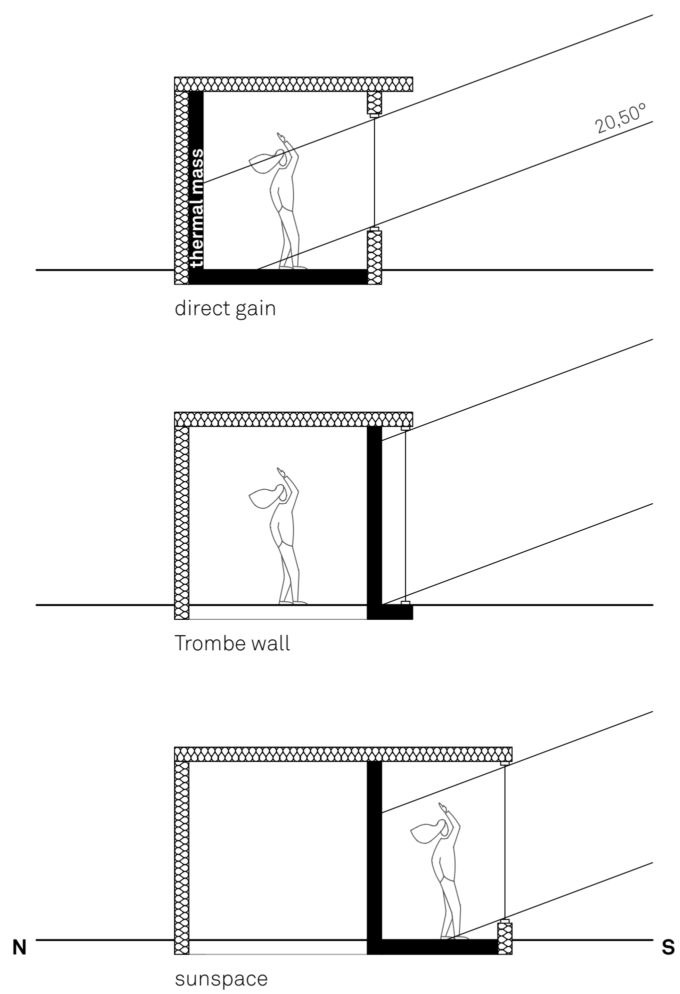


fig. 2.18: The greenhouse effect.

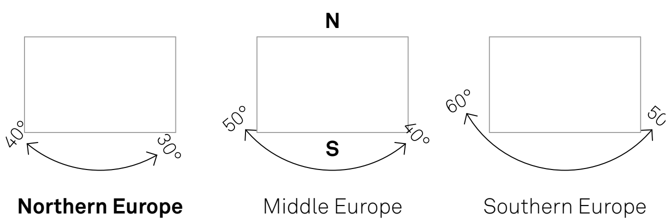


fig. 2.19: A south orientation becomes more crucial with latitude.

73 cf. ETH Zürich, 2010: 114-115 (translated by the author)
74 Lechner, 2015: 169
75 cf. Lechner, 2015: 170; 338
76 cf. Lechner, 2015: 508

type of pane	u-value W/m²K	light transmission %	solar transmission %
clear glass			
single glass (4 mm)	6,00	88,00	83,00
double glass with air (4-12-4)	3,00	80,00	76,00
double glass with low-e coating & argon	1,50	77,00	65,00
triple glass with air (4-12-4-12-4)	2,00	72,00	67,00
triple glass with low-e coating & argon	1,00	67,00	68,00
triple glass with low-e coating & krypton	0,70	67,00	69,00
vacuum pane with low-e coating (4-12-4)	0,50	77,00	65,00
reflective glass			
double medium reflective glass with low-e coating (6-12-6)	1,60	29,00	39,00
double glass, bronze & low-e coating with argon (6-12-6)	1,60	9,00	13,00

fig. 2.20: Characteristics of glazing types. Best choices for Arctic Norway are highlighted.

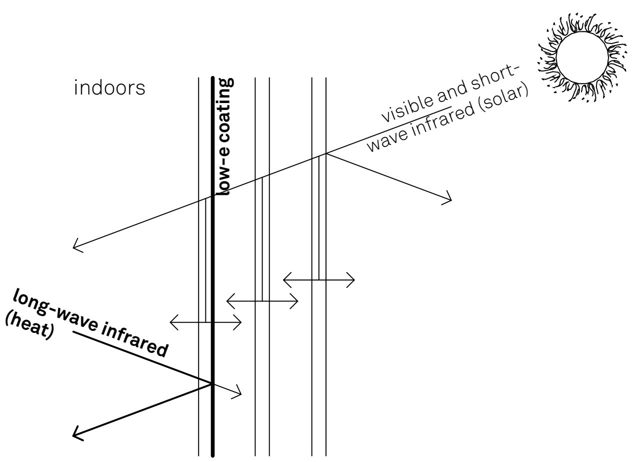


fig. 2.21: Aiming for high radiation and little re-radiation.

Solar radiation does not only heat the objects and, as a consequence, the space of a house, it also heats our bodies and make us feel comfortable despite low temperatures.[77]
This is called the radiation effect – and it is the one the curled cat in the sun is enjoying so adorably. However, the effect has its limits with an air-wall-temperature-difference of more than 4° - 5° F, or 2,2° - 2,7°C.[78]

For passive solar heating, there are special demands for the windows too. First of all, it is pivotal that the windows have a minimum solar transmittance of 60% or higher to ensure the greenhouse effect and a low-e coating on the inside of the pane(s) to suppress re-radiation.[79] [80] Thus, in northern latitudes the triple glass with low-e coating and krypton as an insulating gas, or the vacuum pane with low-e coating are considered the best choices.[81] (fig. 2.20-21)

2.3 strategies for luminous resource efficiency

2.3.1 between natural and artificial lighting

After the last polar night, in Tromsø the length of daylight increases by around 10 minutes a day, one hour a week, or 5 hours a month (*2.1.2 climate conditions*), resulting in a fast transition from artificial to natural lit indoor spaces.

77 cf. Olgyay, 2015: 21
78 cf. Olgyay, 2015: 21
79 cf. Brophy and Lewis, 2011: 66
80 cf. Lechner, 2015: 511
81 cf. Brophy and Lewis, 2011: 67

Nevertheless, daylight does not automatically reduce lighting energy consumption – therefor the electric lights have to be turned off beforehand.[82]
As "[t]he cost of maintaining a high-efficiency artificial light source is one thousandth of that which a tallow candle represented 120 years ago,"[83] there is often little awareness for energy conservation – especially in Norway where hydropower produces cheap and abundant energy.

However, every potentially saved Joule should be aimed for. Moreover, there are plenty of easy implementations to minimize lighting energy consumption in building operations.
For example, literature refers to control systems, like occupancy sensors and time-based controls.[84]
In addition, photosensors that adapt the light level automatically to the daylight level, and light sources with high luminous efficiency are worth considering.[85] [86] Lastly, smartphone/ tablet applications can easily simplify the operation of control systems.[87]

2.4 strategies for spatial expression

2.4.1 the window seat

In the beginning of the year when the sun is back, heat preservation still represents design priority number one. The building still remains a microcosm, completely shielded away from the outside natural world.

82 cf. Lechner, 2015: 601
83 Brophy and Lewis, 2011: 1
84 cf. Mills, 2018: 95
85 cf. Mills, 2018: 96
86 cf. Brophy and Lewis, 2011: 84
87 cf. Mills, 2018: 97

fig. 2.22: Daylight in the beginning of the year.

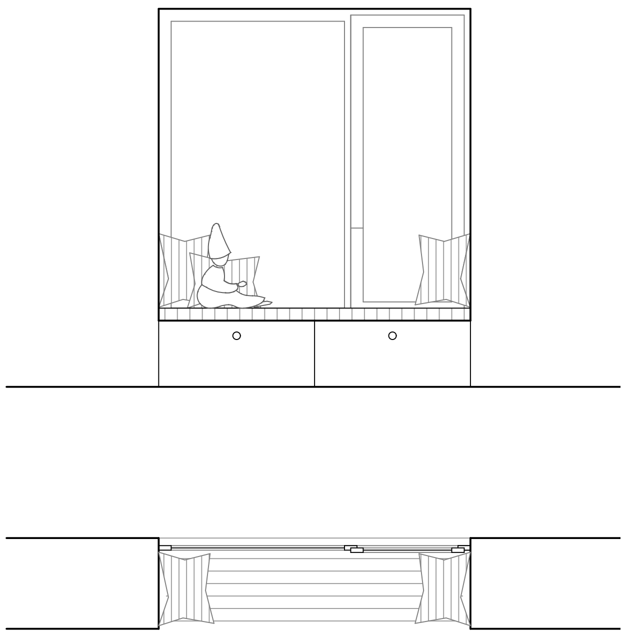


fig. 2.23: The window seat.

One strategy to connect the building occupant with the surrounding outer world is through windows that become doors.[88] A window can give access to natural views, daylight, sunlight, diurnal/ annual changes, and life.[89]
However, "a person in the room will be torn between two forces: 1. He [She] wants to sit down and be comfortable. 2. He [She] is drawn toward the light,"[90] Alexander et al. argue in *A Pattern Language*.

To solve the conflict, and for a window that becomes a door, in Arctic Norway, a window can be turned into a window seat. (fig. 2.23) This is especially precious for enjoying the sun but being still protected by the building.
The window seat is a window, enhanced from a sheer hole in the wall to a volume.[91] It has a raised floor, a lowered ceiling and is broad enough for two people to sit comfortably[92], offering "an embrace from the house"[93] – a beautiful thought.
To save money and heat, the window seat can be shaped by interior wingwalls or furniture and need not be readable from the exterior.[94]

In this way, besides its connecting function between the inside and outside world, the glazed alcove also simultaneously connects and separates the group of people inside. This is crucial as "[n]o homogeneous room, of homogeneous height, can serve a group of people well."[95]
Just imagine a family living room. The children are absorbed in doing a puzzle in the window seat, so the parents can easily set the table for the family dinner. The family can enjoy time together but are not interfering with each other.

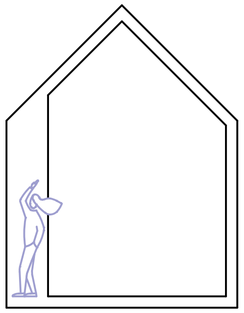
88 cf. Kellert et al., 2008: 119
89 cf. Kellert et al., 2008: 119
90 Alexander et al., 1977: 834
91 cf. Alexander et al., 1977: 836
92 cf. Susanka, 2008: 18
93 Susanka, 2008: 18
94 cf. (Susanka, 2008): 143
95 Alexander et al., 1977: 829

However, as important window seats with natural views are, they can be negatively compared to seeing an animal in a zoo, like "their dangers held at bay by the slender bars of cages."[96]
At a glazed alcove, there is still the glass – the caesura, but also the protection – inbetween.[97] To close the distance between the natural and the architectural world, and for an enhanced design sensibility, little shifts can be made:

For example, natural patterned curtains and potted plants or vases on the windowsill move the viewer and the view closer together.[98]
Moreover, for the window seat itself, natural materials, which simulate all the five senses, are preferable. Just think of a leather bench, "[o]ver time, human touch will patinate [it], giving its color and texture a natural richness."[99]
Lastly, for the glass pane – and this is more expensive to implement – framing, insulated glass blocks soften the boundary between the wall and the window.[100] (fig. 2.24)

96 Kellert et al., 2008: 254
97 cf. Kellert et al., 2008: 254
98 cf. Kellert et al., 2008: 256-257
99 Kellert et al., 2008: 355
100 cf. Susanka, 2008: 80

fig. 2.24: A window place by Sarah Susanka & James R. Larson. A picture by Christian Korab (edited).



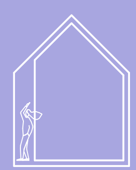
introducing the

2nd architectural layer:

the inhabited envelope

The earth is still under a thick mantle of snow but the time of darkness is over and the sun is back, greeting us with vastly colored sunrises and sunsets. In this way, *the beginning of the year* is the time of transformation. There is still retreat, but also discovery. It is the time of convergence between the natural and the built world.
Here the second architectural layer of the design study is introduced: *the inhabited envelope*.

the inhabited envelope rethinks the double window. With the means of basic bioclimatic principles, it bridges temperature differences between the inside and the ouside world, making the building energy-efficient.
Moreover, it forms indoor and outdoor niches. They transform the boundary between the built and natural environment from a block of building material to a threshold space, mediating the occupant between experience and protection, opening and closure, natural and artificial world. It is about feeling outside inside and inside outside.
In this way, the offerings range from introverted to extroverted, small to large rooms – as the spectrum of humans is. The desire was to create a place that is beautiful and fantastic to live in for the diversity of characters.
Mirroring the inhabited envelope on the south side, for a clear and simple system, there is also one in the northern side, encompassing the ancillary rooms.



precious little delights

… sitting in the window place with a large cup of hot morning coffee … lying in the window place after an active day on skis … enjoying the colorful sunset through the panorama window… putting kitchen herbs into the greenhouse …

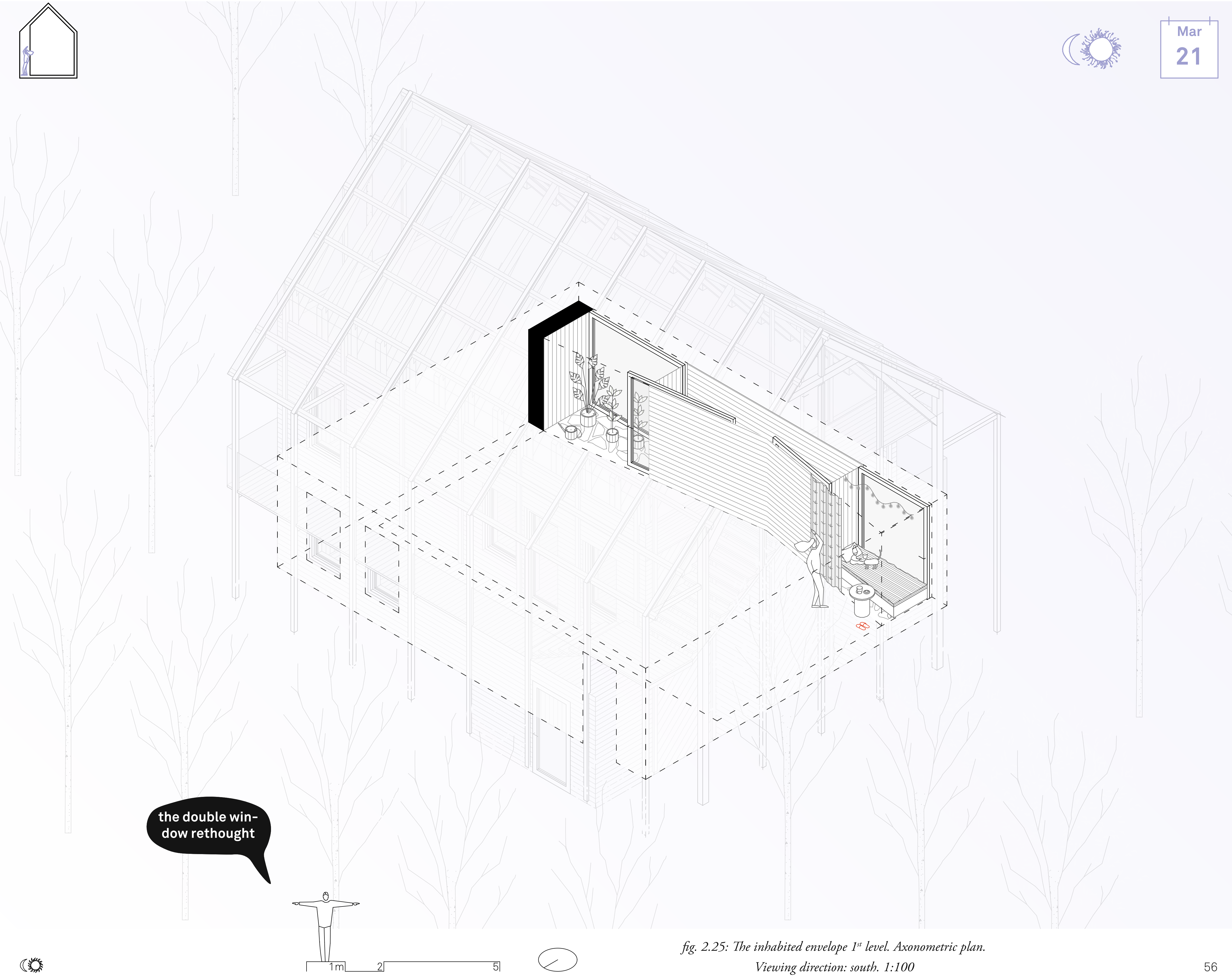
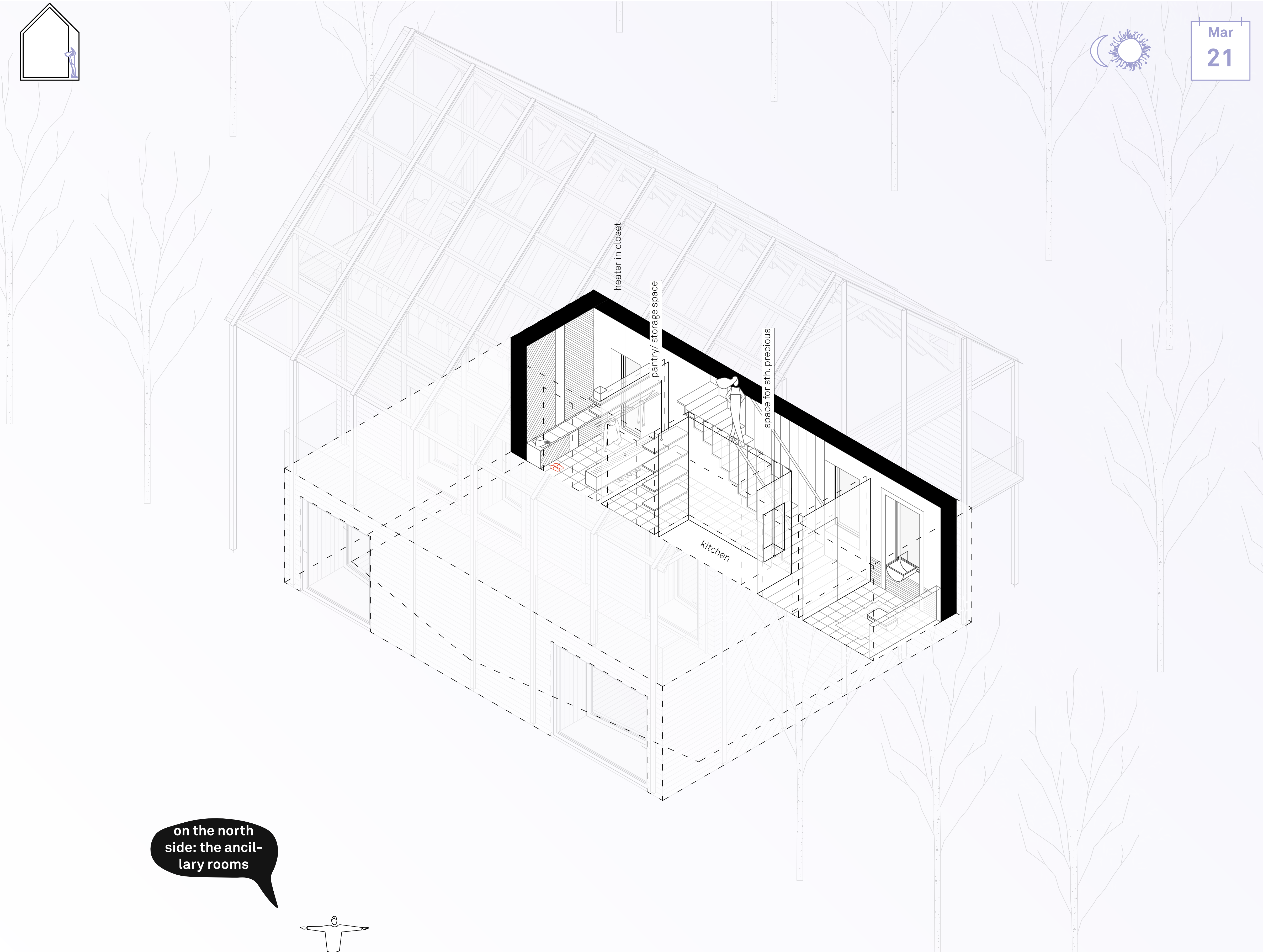


fig. 2.25: The inhabited envelope 1st level. Axonometric plan.
Viewing direction: south. 1:100

fig. 2.26: The inhabited envelope 2nd level. Axonometric plan.
Viewing direction: south. 1:100



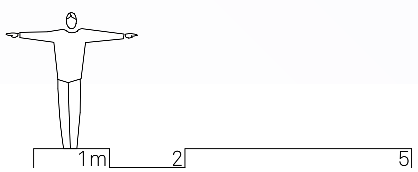
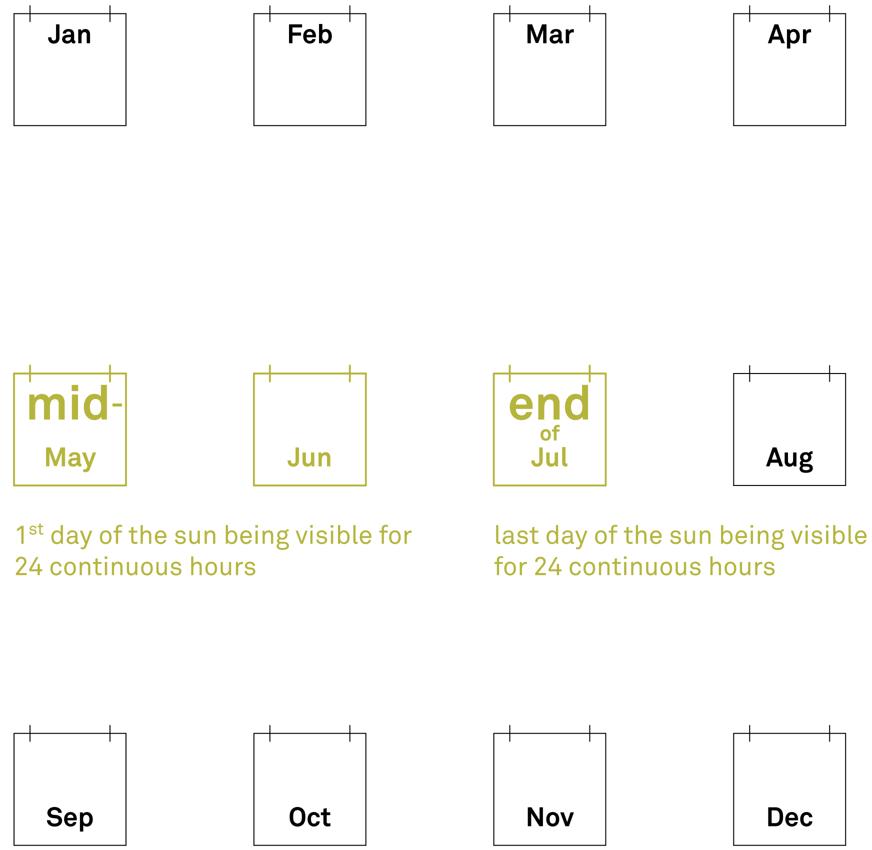


fig. 2.27: The inhabited envelope 1st level. Axonometric plan.
Viewing direction: north. 1:100

fig. 2.28: The inhabited envelope 2nd level. Axonometric plan. Viewing direction: north. 1:100



3

the middle of a year

3.1 characteristics of time period

The year culminates with the time of brightness when everything seems to be possible; the chapter *the middle of a year* (mid-May - end of July with the summer solstice on June 21st) portrays this special time.

It is the time period between the first and the last day of the sun being visible for 24 continuous hours.

3.1.1 photo essay 'ambient luminescence'

As the sun never sets, Arctic Norway is enveloped with an "ambient luminescence"[101] (the last layer of Richard Kelly's lighting strategy) – come day and night. During the polar days, everything seems to be possible. (fig. 3.01-3.07)

impressions from days of the midnight sun

(This field study had to be cancelled due to the Corona pandemic. Figures 3.01-3.07 are from the auther's father, Andreas Horodynski's trip to northern Norway in 2011.)

fig. 3.01
(fig 3.02-3.07 on the following pages)

101 cf. "Richard Kelly," 2020: www


3.1.2 climate conditions

Reference data are from Tromsø (69,50°N, 19,00°E) between mid-May and end of July, 2019, representing the time of brightness. As Tromsø is located 69,50° north, on the equinox the altitude angle at solar noon – the sun being at its highest position but not necessarily at 12:00 – is 20,50° (90,00°-69,50°).

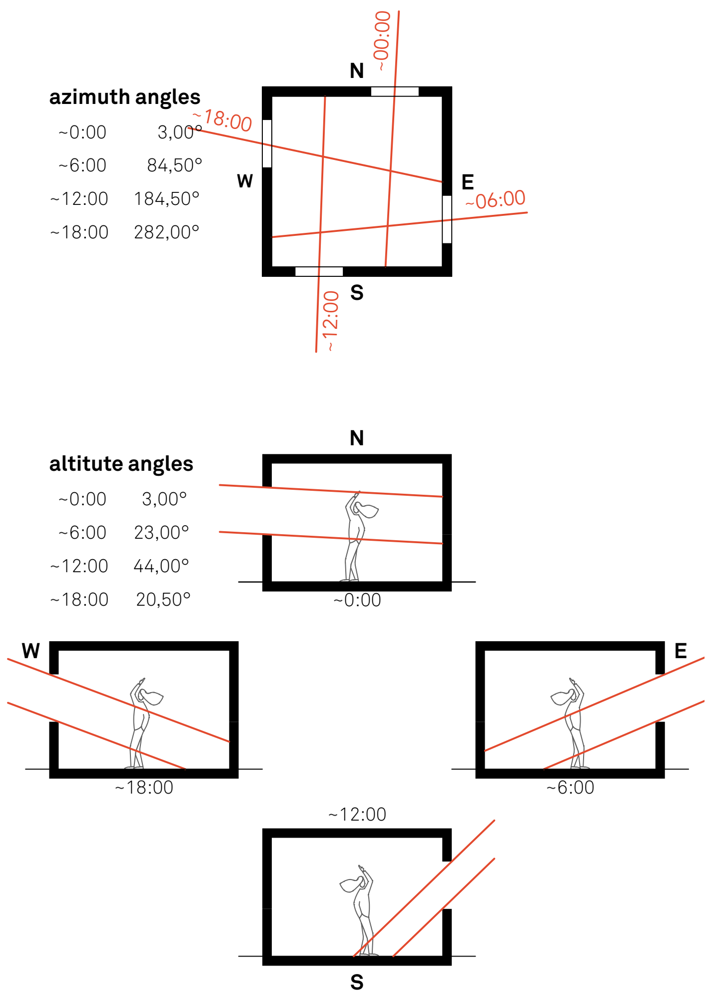


fig. 3.08: Azimuth and altitude angles on summer solstice (June 21st).

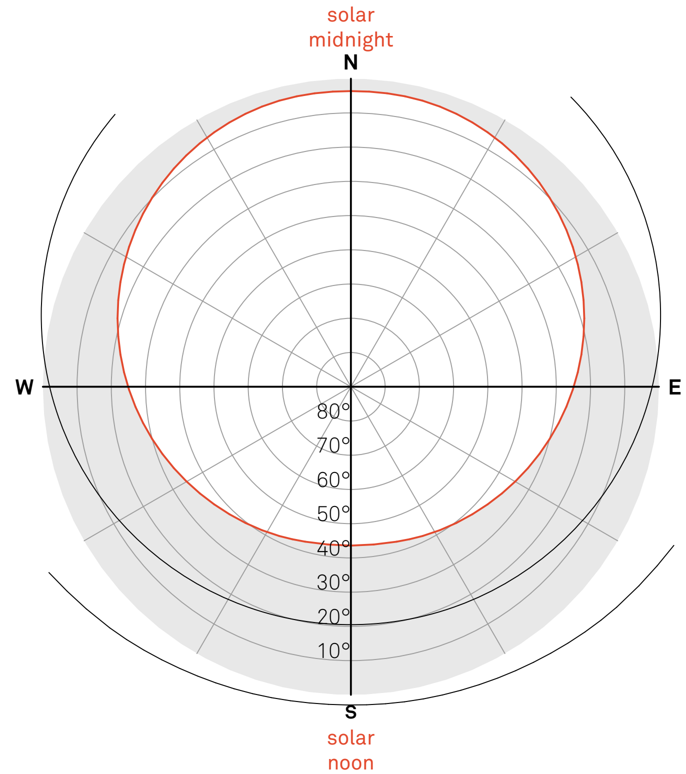


fig. 3.09: Sun path on summer solstice.

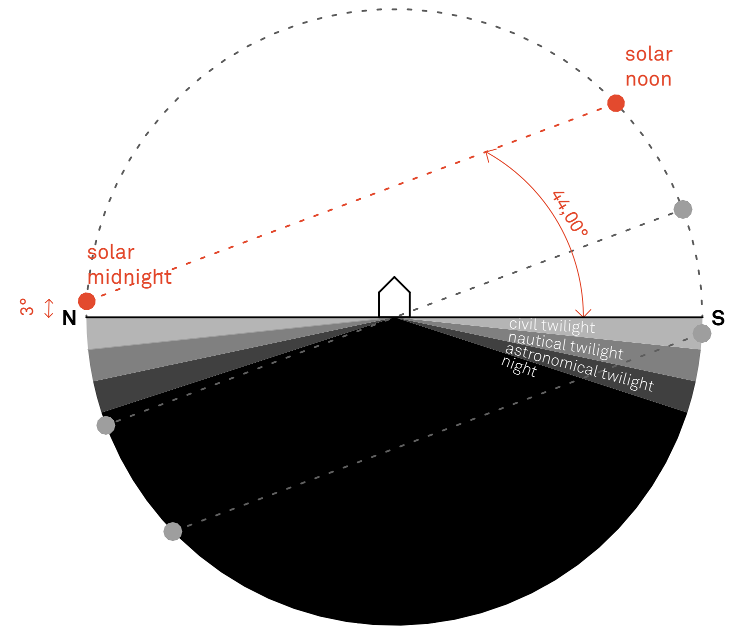


fig. 3.10: Section of sun path. On summer solstice, the altitude angle at solar noon is the equinox angle plus the Earth's tilt: 20,50°+23,50°=44,00°

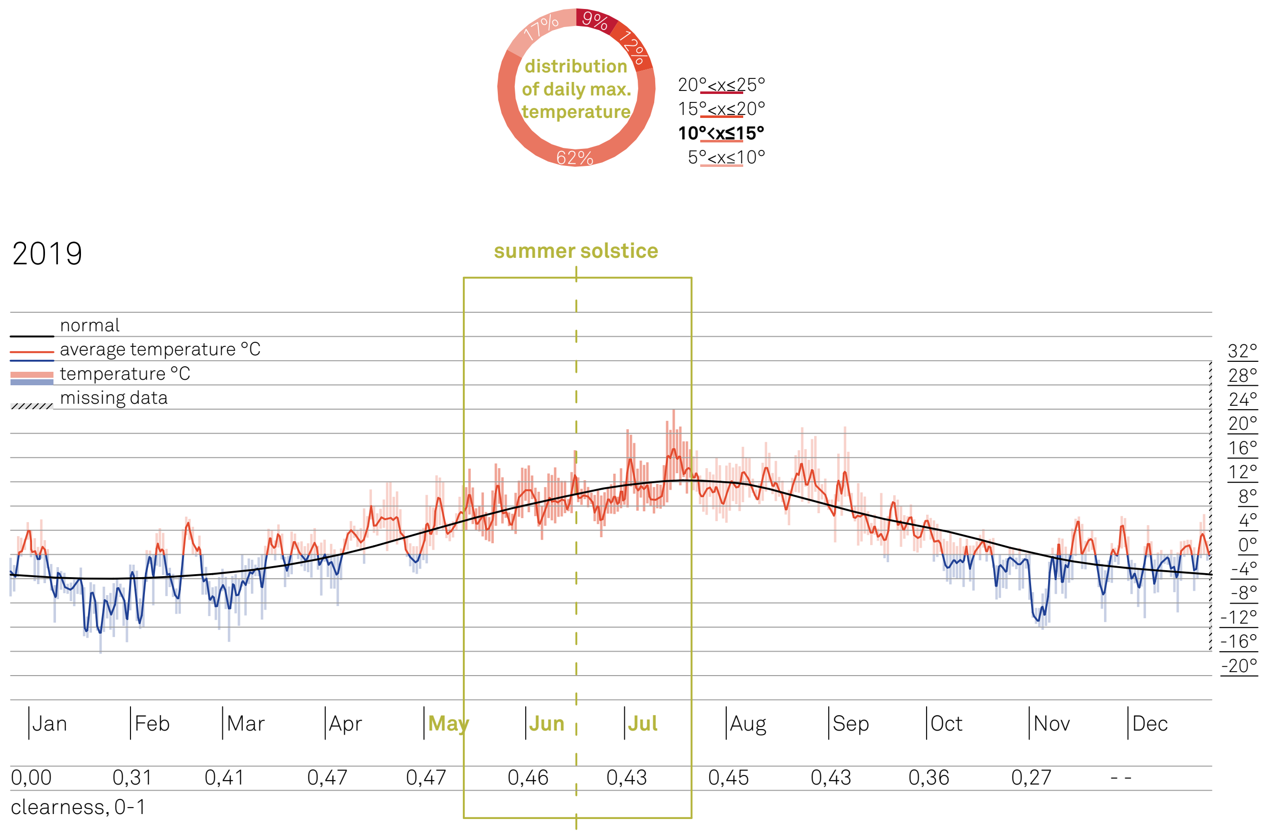


fig. 3.11: Temperature and clearness graph.

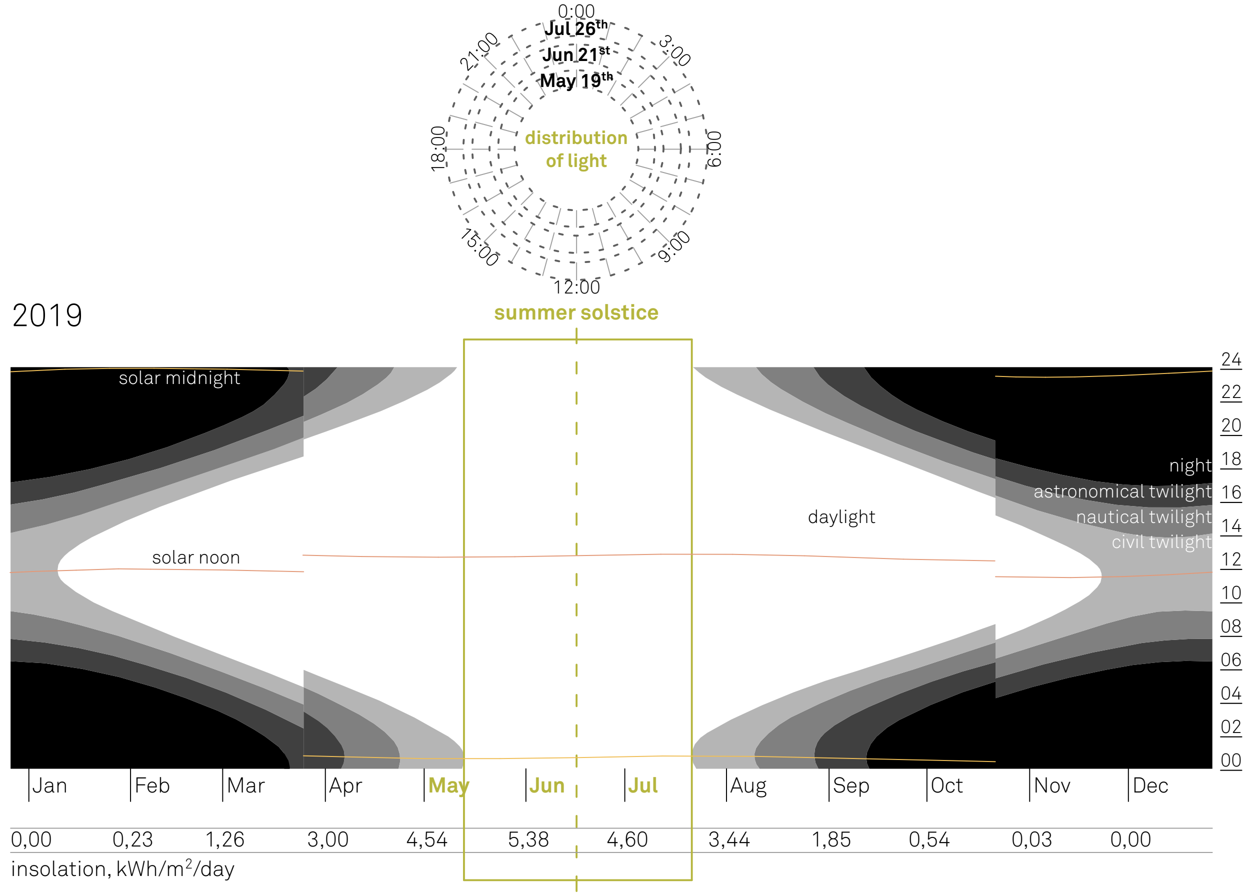


fig. 3.12: Light and insolation graph.

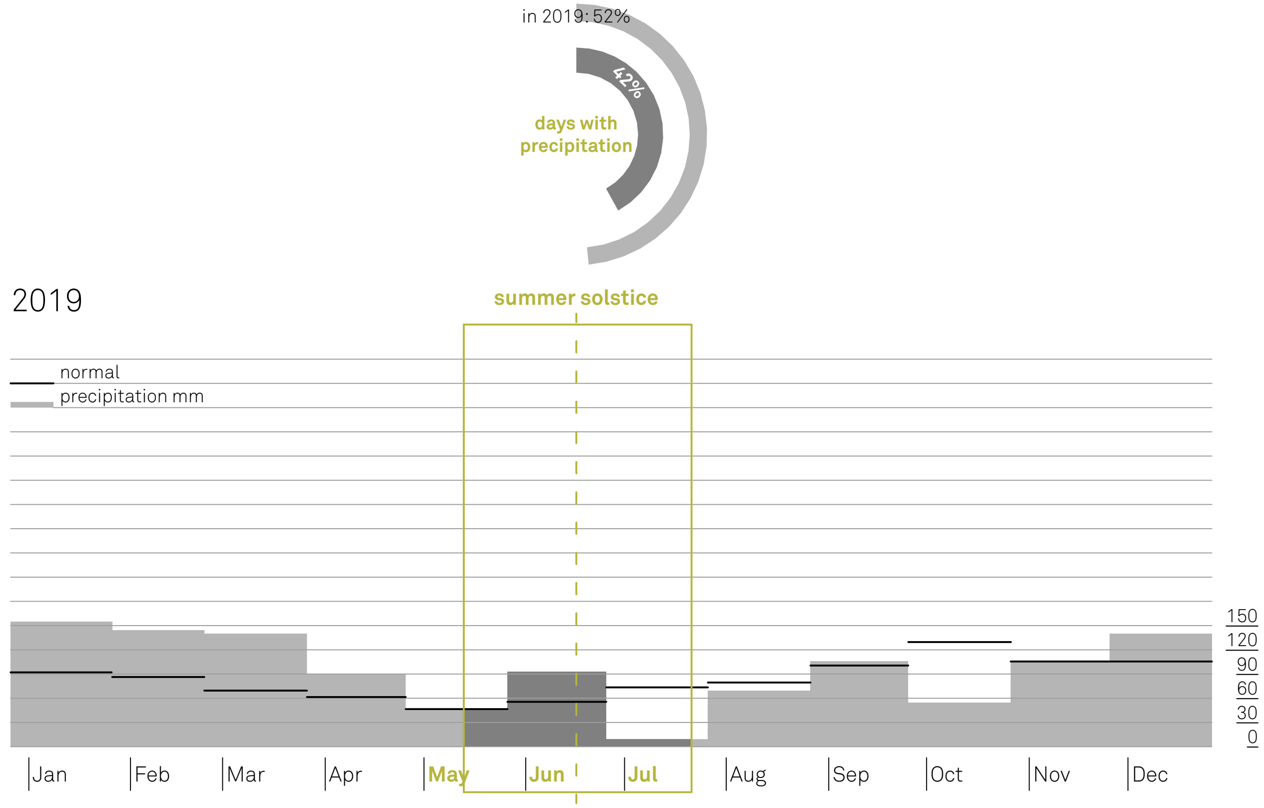


fig. 1.13: Precipitation graph.

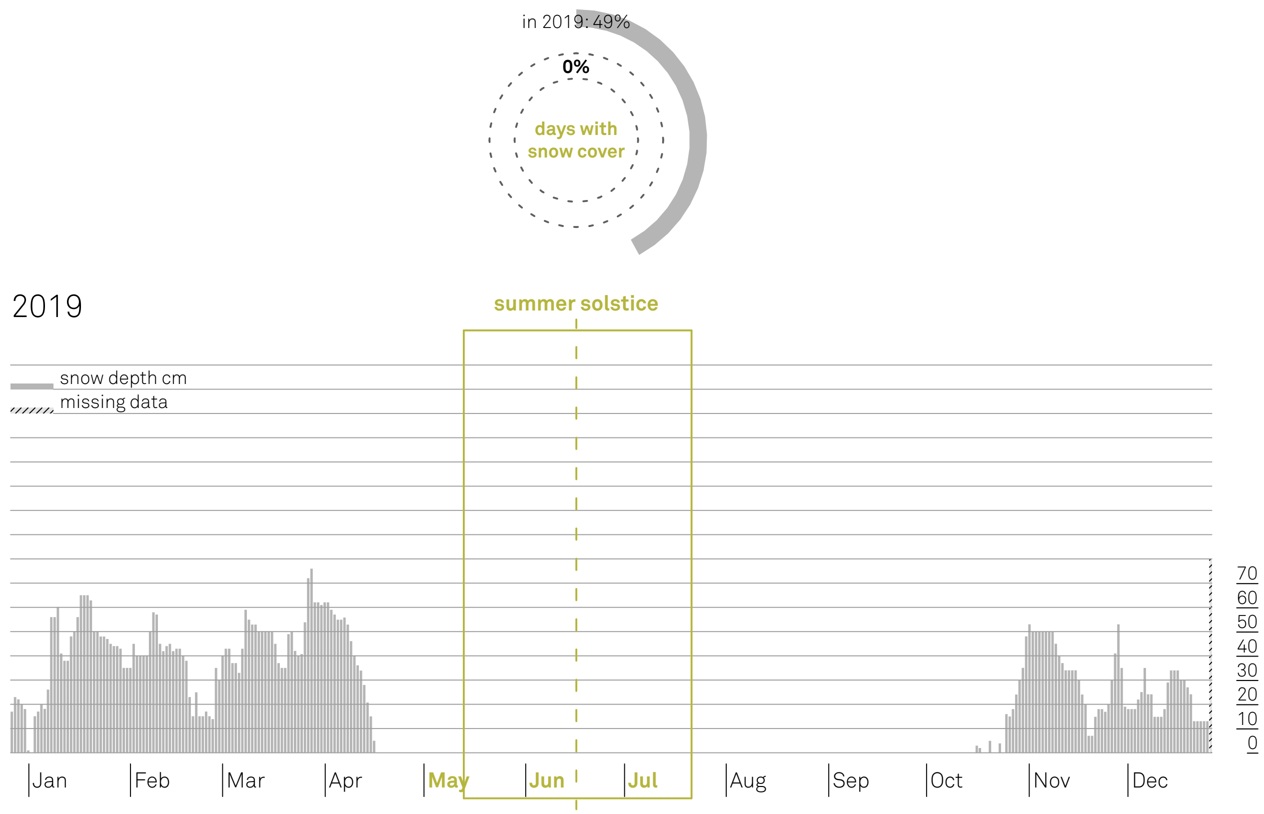


fig. 3.14: Snow depth graph.

Arising design priorities:
1st: balancing out

3.2 strategies for thermal resource efficiency

3.2.1 active solar technologies

A building's self-sufficiency can be easily increased through using the most powerful source of energy: the sun. In photovoltaic (PV) panels, solar cells, made from the common element silicon, convert light directly into electricity.[102] Although they do not look like a leaf, this bionic element works like one.[103] Solar thermal collectors (STC) transform solar irradiation through a transfer-and-storage medium into heat.[104] Supported by grid-connection and backup heating, these systems are a reliable choice – also in Arctic Norway.

Although self-sufficiency won't be possible all over the year because of the light circumstances there, active solar technologies do enrich parts of the year. For example, during the summer months, even when it is cloudy PV panels have an approximate output of around 80% on partly overcast and a 50% one on hazy/humid days.[105] Moreover, from mid-May to end of July, when the sun does not set, the PV panels can collect consistently – day and night – and therefore have double the power.
Here, the driving idea of the thesis, *The Building for the Yearly Cycle*, clicks into focus.

For STCs, the offer even ranges to vacuum solar collectors that are highly efficient with little heat loss and resistant to freezing and therefore are also suitable for Arctic Norway.[106]
Moreover, concerning solar thermal collectors, the heat-transfer-and-storage media can differ. It is either air (ASTC) or a liquid (LSTC) like water, water plus antifreeze, or a highly thermal resistant oil.[107]
There are different fields of applications for the different types:

As moving water by pumps instead of air with fans reduces the energy demand by a factor of 20[108], the LSTC system is preferable for heating and domestic water heating (best with hydronic floor heating as therefor a relatively low temperature is sufficient).[109] [110] For this, a storage device like an insulated tank is necessary.[111]
The ASTC system with air as a transfer-and-storage medium is advantageous for preheating the ventilation air (e.g. for drying clothes[112] and warming greenhouses). (*2.2.2 passive solar technologies*)
As in 2019 almost 2/3 of the days of the middle of the year had between 10 and 15°C (see climate conditions 3.1.2), these are potent strategies to reach and maintain the comfort zone inside.

To take full advantage of the potential energy and heat harvests, care should be exercised for the right setup of the panels: Besides the obvious southern orientation, 45° and 90° angles are the best choices. The 45° angle is right-angled to the summer solar altitude, the time the sun has the most power. The 90° angle – thus not a roof, but a façade application – is beneficial, as in this way the panels are constantly snow-free while simultaneously taking advantage from the snow's solar reflection and the low solar altitude angle.[113]

102 cf. Lechner, 2015: 201
103 cf. Kellert et al., 2008: 29
104 cf. Medved et al., 2019: 152; 163
105 cf. Lechner, 2015: 198
106 cf. Lechner, 2015: 218
107 cf. Medved et al., 2019: 152
108 cf. Lechner, 2015: 533
109 cf. Medved et al., 2019: 152
110 cf. Lechner, 2015: 218
111 cf. Lechner, 2015: 217
112 cf. Medved et al., 2019: 152
113 cf. Lechner, 2015: 206-207

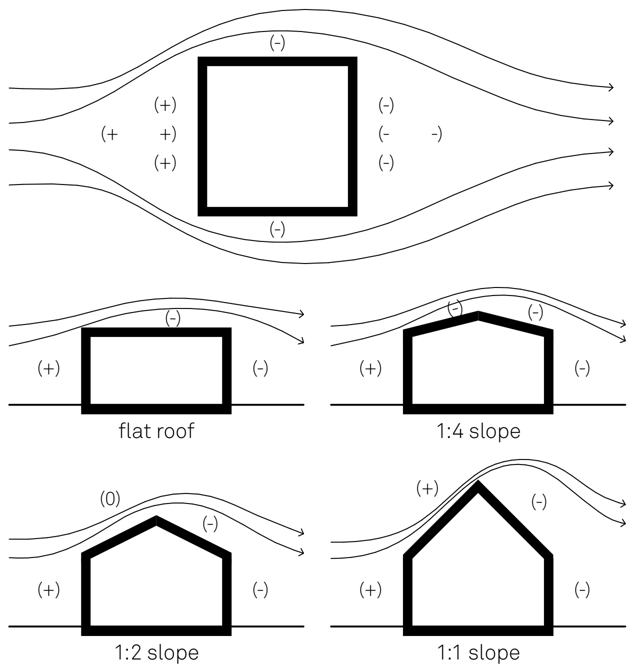


fig. 3.15: Air streams around a building.

3.2.2 natural ventilation

Permeability. “The term itself infers that there are both inward flows and outward flows possible […].”[114]

To open all windows on a sunny summer day, feeling the warmth of the sun’s rays and the breeze of the ocean air on the skin, that is a moment of beauty and joy.

Permeability – in all its facets – merges the natural with the artificial world. Although uncontrolled natural ventilation is a liability for underheated periods, controlled cross ventilation is an asset for more heated ones, balancing the indoor temperature to sheer comfort by simply opening the windows.

In an air stream, a building represents a barrier. It decelerates and accumulates the air flow at its windward side, resulting in a high-pressure area (+). Hence, on the opposite side – on the leeward side – a wind shadow with low-pressure occurs (-). On the sides in between, the redirected air stream equally produces low-pressure areas (-).[115] (fig. 3.15)

With opened, well-positioned windows, this pressure difference leads to a pleasant inside air breeze in case the building is overheating. This is especially precious for buildings designed for passive solar heat gain.

Different executions result in scaled efficiency. To benefit the most from natural ventilation, a shallow-plan building with no separate divisions that cut the air speed is beneficial.[116 117]

The inlet should be on the high-pressured side and the outlet on the low-pressured one.[118] Smaller in-

114 Tyrrell, 2017: 169
115 cf. Olgyay, 2015: 102
116 cf. Brophy and Lewis, 2011: 68
117 cf. Olgyay, 2015: 106
118 cf. Olgyay, 2015: 102

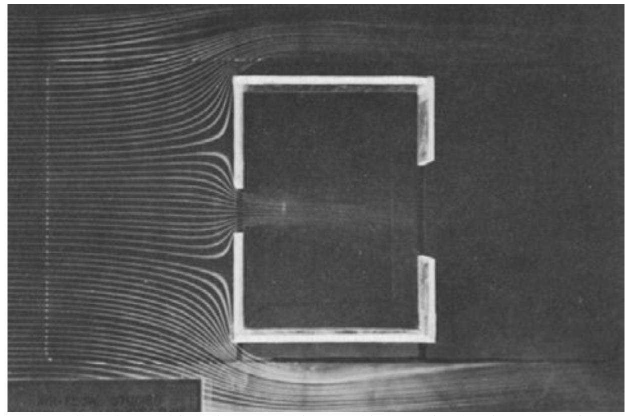
let sizes combined with bigger outlet sizes lead to a pleasant air speed, exploiting the *Venturi effect*.[119] Victor Olgyay shows in his publication *Design with Climate: Bioclimatic Approach to Architectural Regionalism* experiments for a satisfying natural ventilation: (fig. 3.16)

The tests were conducted in a two-dimensional wind tunnel, with models built of plexiglas. The streamlines are the paths of kerosene smoke entering the tunnel at the left hand side through a series of nozzles. Smooth and continuous lines indicate laminar flow. The distance between streamlines can be directly related to the air speeds. Where the lines are close, high speeds occur indicating low pressure areas; where the lines are far apart, the speed is low with high pressure regions."
Olgyay, 2015: 108

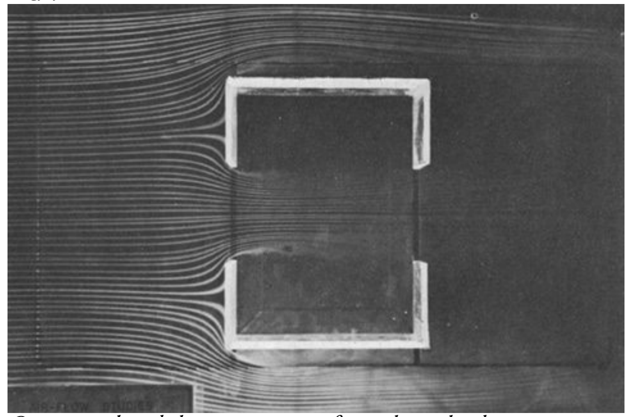
On cooler days however, energy-efficient buildings with their airtight envelopes have strong emphasis on a resource-efficient and healthy, mechanical ventilation system. In Arctic Norway, preheating the ventilation air is inevitable for most of the year.[120]
A resource-efficient strategy therefor is to use demand-controlled ventilation (DCV). In this way, the amount of fresh outdoor air is controlled by CO_2 sensors. In addition, a heat recovery ventilator reuses heat from the exhaust air without cross-contamination and in this way saves energy.[121]
While a lower air pressure in polluted areas (e.g. toilets, kitchens) prevents contaminated air from spreading, a slightly higher pressure than the atmospheric one in the rest of the building mitigates the infiltration of cold air through joint gaps.[122]

In Arctic Norway with its wet and cold climate, care should be exercised to limit moisture and in

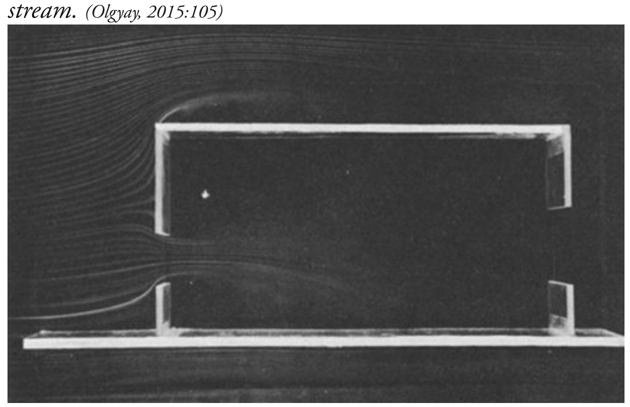
119 cf. Olgyay, 2015: 104
120 cf. Lechner, 2015: 225
121 cf. (Lechner, 2015): 568
122 cf. Lechner, 2015: 567



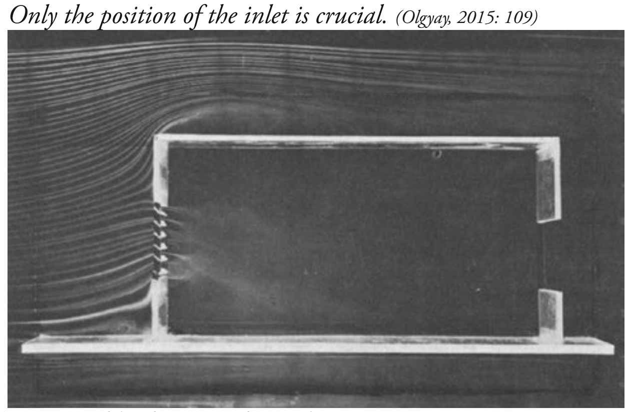
A small inlet with a large outlet results in the highest speed. *(Olgyay, 2015: 105)*



Opposite placed, large openings of equal size lead to max. air stream. *(Olgyay, 2015:105)*



Only the position of the inlet is crucial. *(Olgyay, 2015: 109)*



Venetian blinds can re-direct the air stream. *(Olgyay, 2015:111)*

fig. 3.16: Air streams inside a building. An experiment by Victor Olgyay.

this way water damage in the building's skin.
The New Monte Rosa Hut – profoundly analysed in this thesis – for example, has a mechanical ventilation and, therefore, quite a dry climate in the inside. Hence, water vapour diffusion is not excessive. Simulations show that the wooden three-layer plate in the inside has already enough vapour resistance without the additional vapour barrier.[123]

3.3 strategies for luminous resource efficiency

3.3.1 natural lighting

An unimaginable 100 60W incandescent light bulbs are needed to get the same amount of light as a 0,9x1,5m window provides[124]. Hence, smart daylighting represents a powerful form of zero-emission energy.
Natural light contains direct (from the sun), diffuse (from the sky) and reflected (from adjacent surfaces; reflections from snow are especially beneficial in the time of darkness) lighting.[125] (fig. 3.17)
On a sunny day, up to 100 000 lux, on an overcast day, up to 20 000 lux outside illumination levels are possible. Electrical lighting can only acquire fractals thereof. [126]
The ratio between the outdoor (of a cloudy day) with the inside illumination is qualified by the daylight factor (DF). For example, a DF of 5% means the inside is lit by 1000 lux (20 000 x 0,05 = 1 000). Spaces with a DF under 4 need additional task lights for difficult visual duties.[127]

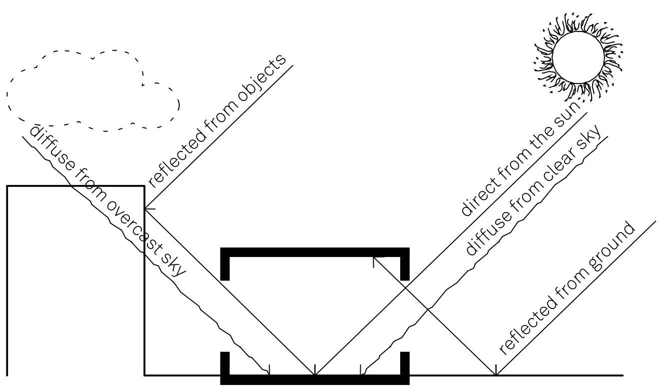


fig. 3.17: Forms of natural light.

123 cf. ETH Zürich, 2010: 171 (translated by the author)
124 cf. Lechner, 2015: 404
125 cf. Mills, 2018: 56
126 cf. Boubekri, 2008: 61
127 cf. Lechner, 2015: 409

In Arctic Norway, moderate sized collecting areas and highly efficient distribution, are crucial. Like a living being is different from different sides, so should the building be.
According to passive and active solar technologies, an emphasis on south faced windows is preferable. Combined with north faced windows – with their great constancy of light – a two-sided, even illumination is ensured.[128] (fig. 3.19)
Windows on the east and west side have increased glare issues and decreased sunlit hours and, therefore, might be minimized. With a two-sided lighting, adjacent buildings can be close or even join. (fig. 3.18)

Although with partitional walls, rooms are reduced to one-sided natural illumination, the following strategies mitigate the single-directional distribution, enveloping the whole room with natural light.
Firstly, glass partitions bring daylight farther into the building. To ensure visual privacy, they can be placed above eye level, be translucent or equipped with venetian blinds.[129]
Secondly, if windows are situated only on one side of a room, it is beneficial to place them adjacent to interior walls, as they perform as low brightness reflectors which results in a more balanced natural light distribution.[130] (fig. 3.20)

To act as a low brightness reflector, a bright finish is crucial.
Besides, a light-colored interior mitigates harsh shadows and the brightness ratio between the window and the surrounding area. Most important is the wall hosting the window, followed by the ceiling, the back wall, side walls, the floor, and small furniture.[131] In the realm of wood, light birch has the best

fig. 3.18: Huddling together.

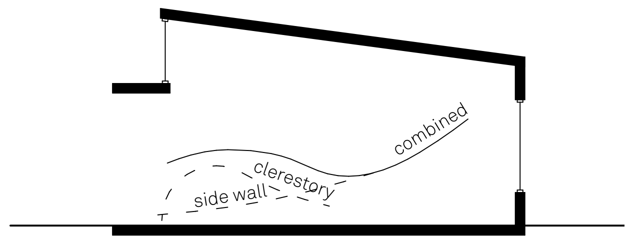


fig. 3.19: Balanced daylight distribution by opposite side windows.

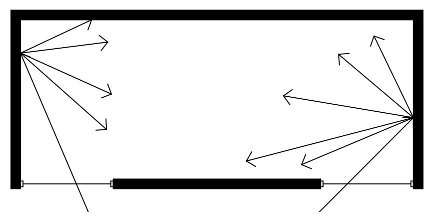


fig. 3.20: Reflections by windows adjacent to bright interior walls.

128 cf. Lechner, 2015: 413-414
129 cf. Lechner, 2015: 414-415
130 cf. Lechner, 2015: 416
131 cf. Lechner, 2015: 415

albedo – the quantification of a surface's reflectivity – with reflection rates between 35 and 50%.[132]
Additionally, the light-colored interior and the diffusion of light helps to reduce glare discomfort and disability caused by the incredibly low sun altitude angles in Northern Norway.[133]

3.4 strategies for spatial expression

3.4.1 the extension to the outdoors

Gardens. In our insatiable society, a gardener acts as the sheer opposite. Echoing the author and professor of literature, Robert Pogue Harrison in his book *Gardens. An Essay on the Human Condition*, a gardener is a cultivator and giver. A gardener plants a seed, watches it grow and appreciates it.[134]
In return, a gardener takes not only pleasure in doing so, but also receives various health benefits. The gardener is outdoors and physically active. Moreover, the contact with soil and therefore with particular bacteria in it, is reported to help with stress relief.[135] Root vegetables like carrots, potatoes, or parsnips are a reliable choice to plant in Arctic Norway. Planting in greenhouses broadens the variety of possibilites.
In the Circumpolar North, indigenous plants are, for example, small heather shrubs like berry bushes, flowerless plants like moss and lichen, coniferous trees like pines and deciduous ones like birches.[136] (fig. 3.21)

fig. 3.21: Calluna vulgaris (common heather). A picture by Christina Hedderich.

132 cf.Mills, 2018: 101
133 cf. Lechner, 2015: 384; 412
134 cf. Harrison, 2008: Chapter 3 The Human Gardener
135 cf. Jones, 2020: 25
136 cf. Hedderich, 2020 05 04: personal interview

introducing the

3rd architectural layer:

the interweaving

the middle of the year is the time of blossom. Like plants are in full florification, so may we.
When the sun never sets and temperatures are milder, we make both our domicile and its surroundings into our place.
The middle of the year is the time of weaving together the built and the natural world, raising an awareness of the relationship between the two. It is the time of blurring boundaries.
Here the third architectural layer of the design study is introduced: *the interweaving*.

the interweaving appreciates and embraces the diversity of life. It is the architectural layer that aims to acknowledge and give space to the more than human world. Kristine McDivitt Tompkins, cofounder of Tompkins Conservation, puts it well, "step up to reimagine our place in the circle of life. Not in the center, but as part of the whole." (Mc Divitt Tompkins, 2020: 14:55) In the example of the design study in Arctic Norway with its hostile environment, it is a greenhouse on the roof that offers space to plant vegetables. It transforms the attic from a space to store junk to a space to store CO_2.

precious little delights

… sitting outside under a roof listening to the sound of the rain … harvesting vegetables … sleeping outdoors at day … sleeping outdoors at night … enjoying an outdoor shower …

fig. 3.22: The interweaving. Axonometric plan. Viewing direction: south. 1:100

fig. 3.23: The interweaving. Axonometric plan. Viewing direction: north. 1:100

Within the realm of the three chapters *the end/ the beginning/ the middle of a year*, the thesis introduced three architectural layers: *the innermost, the inhabited envelope, and the interweaving*.

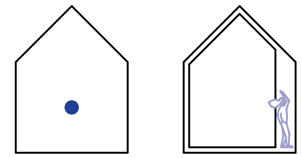
The objective of the chapter *results and evaluations* is to visualize and evaluate their interplay.

4
results and evaluations

4.1 plans

4.1.1 floor plans

To materialize the three architectural layers – *the innermost* (the multi-purpose space), *the inhabited envelope* (the double window rethought), and *the interweaving* (the greenhouse on the roof) – best, a post and beam construction was selected. This kind of construction offers flexibility within the building and is resource-efficient.



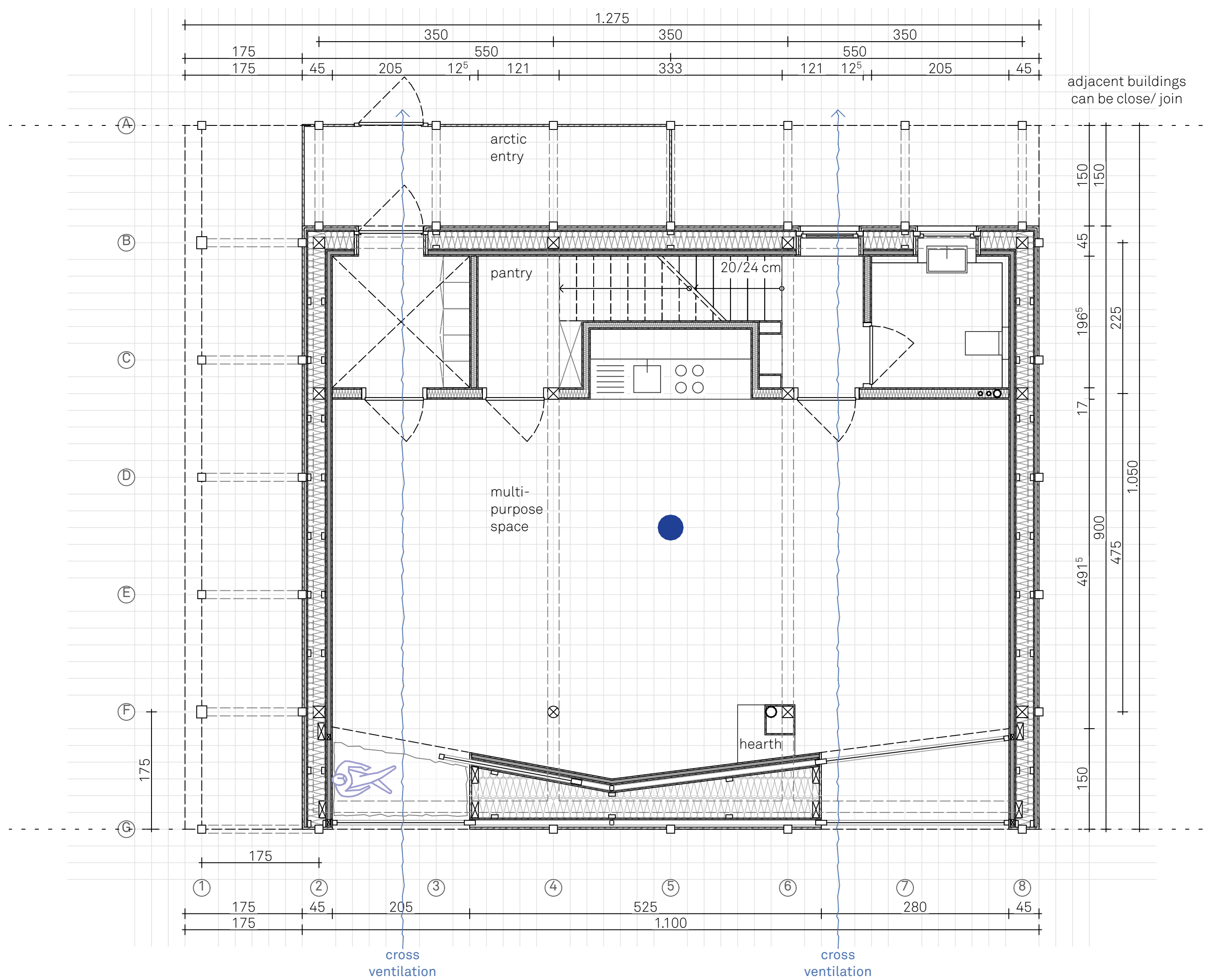
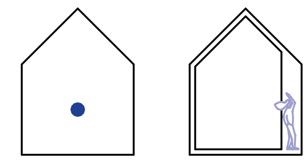
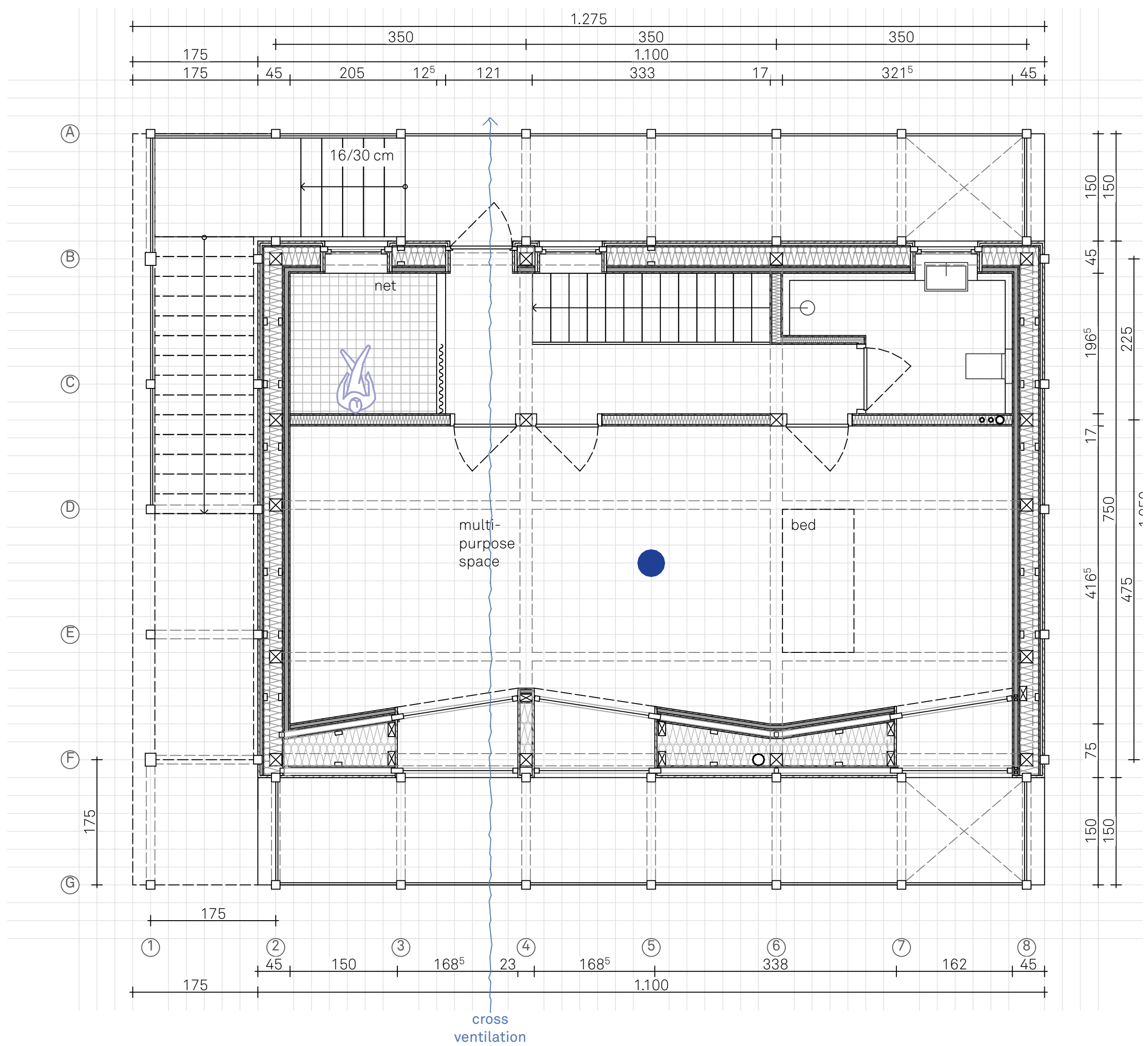


fig. 4.01: 1st level. Floor plan. 1:100

| 1 m| 2| 5| N



The construction wood is Scandinavian harvested spruce and pine. The interior is clad with light birch because of its regionality and high reflection rate. The exterior is clad with larch due to its durability. For the specific insulation measurements, the passive house standard was set as a minimum.



1m| 2| 5| N

fig. 4.02: 2nd level. Floor plan. 1:100

To ensure an unsupported greenhouse on the roof, as a timber roof truss the Liegender Stuhl was opted for.

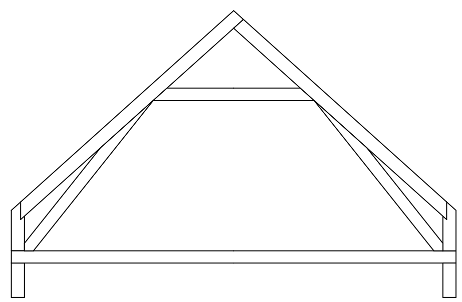


fig. 4.03: The Liegender Stuhl.

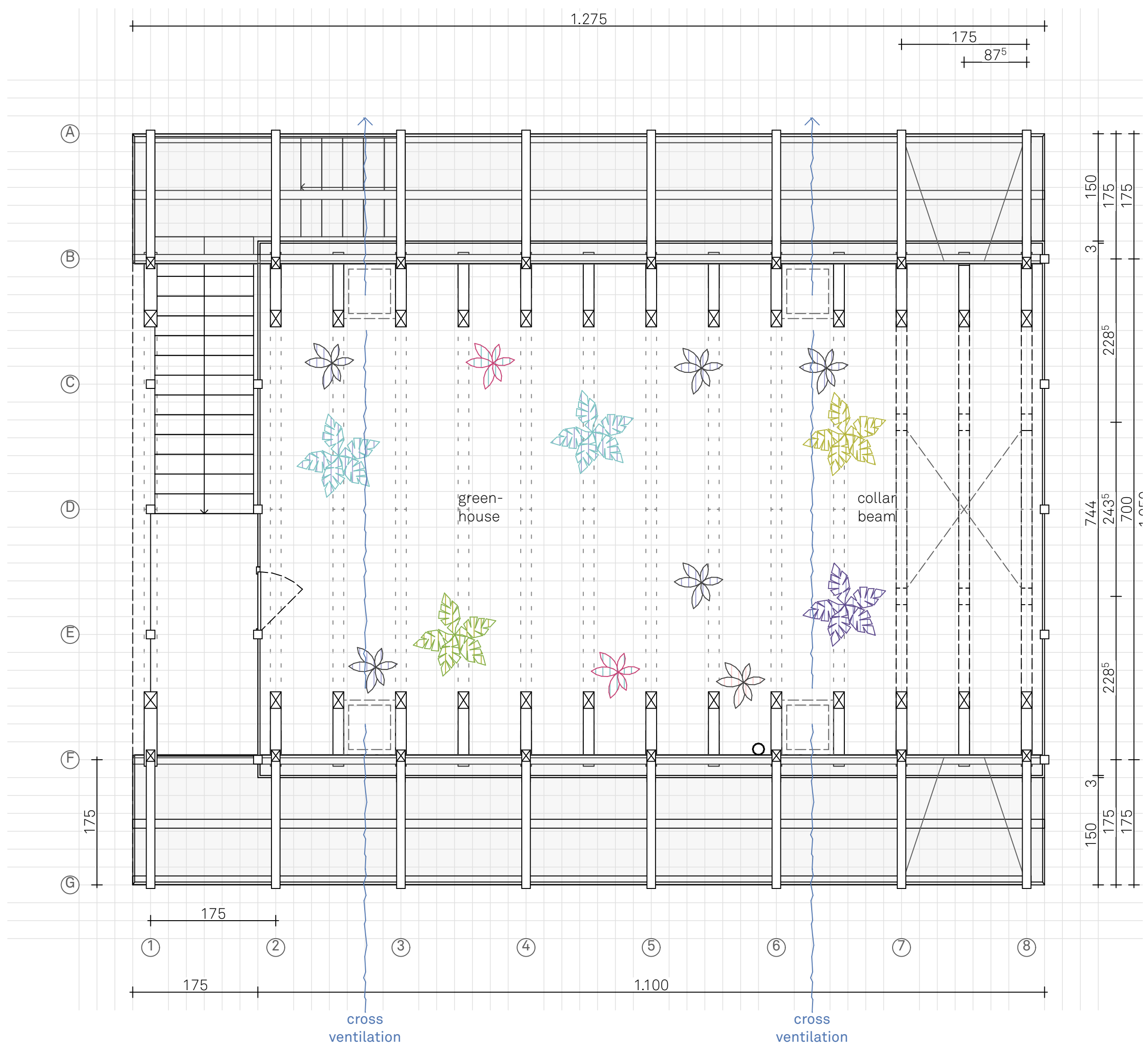


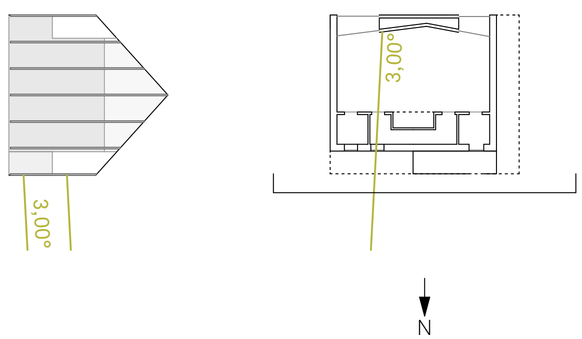
fig. 4.04: Roof level. Floor plan. 1:100

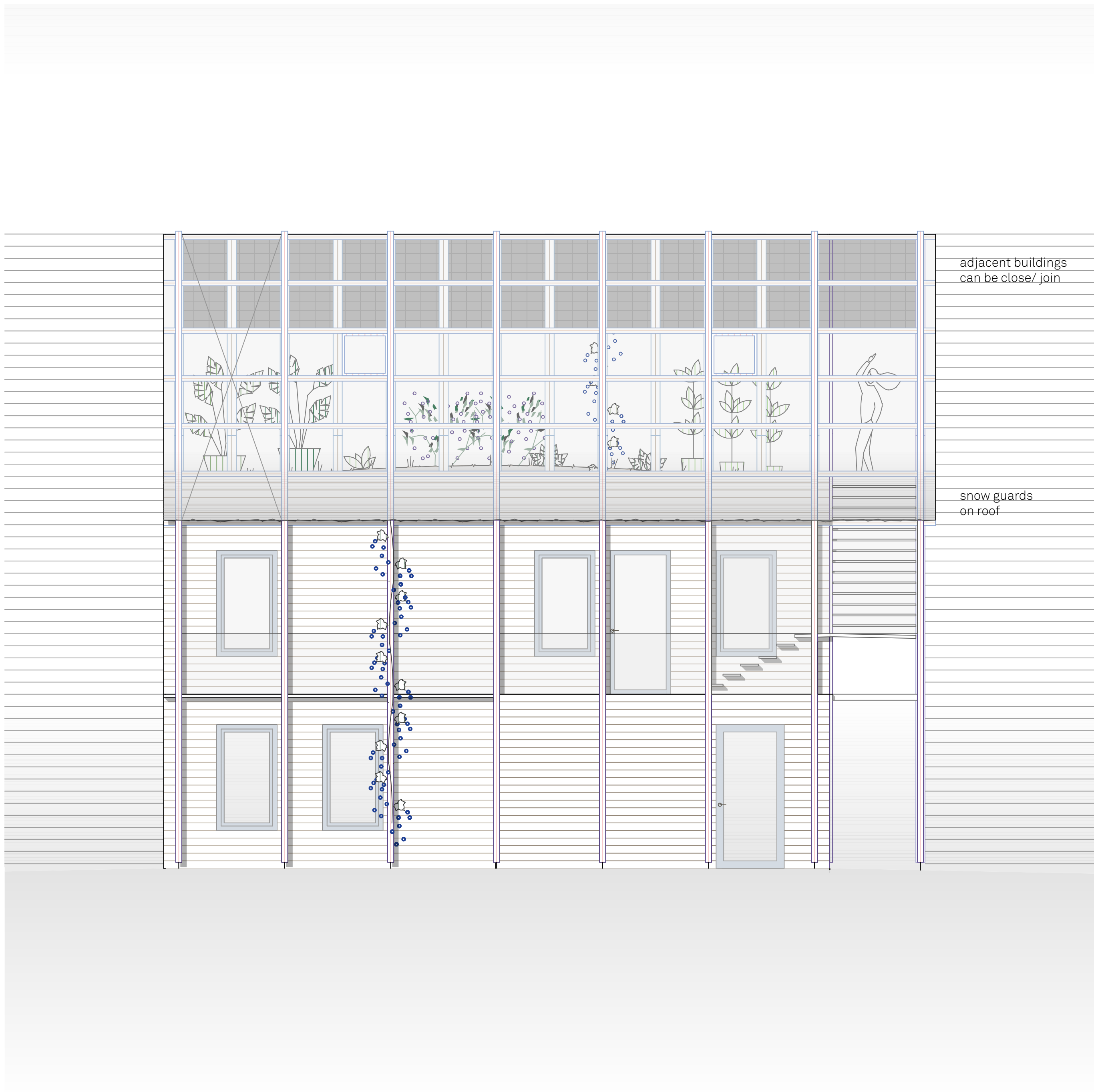
4.1.2 elevations and sections

Jun
21

The following elevations show the shadow formations on summer solstice, June 21st, or the day where the sun is at its highest point of a year.

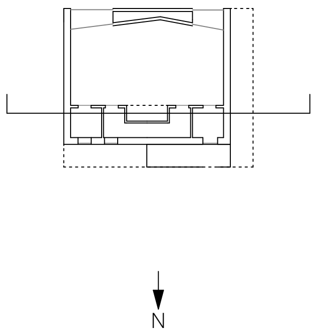
~00:00





| 1m| 2| 5|

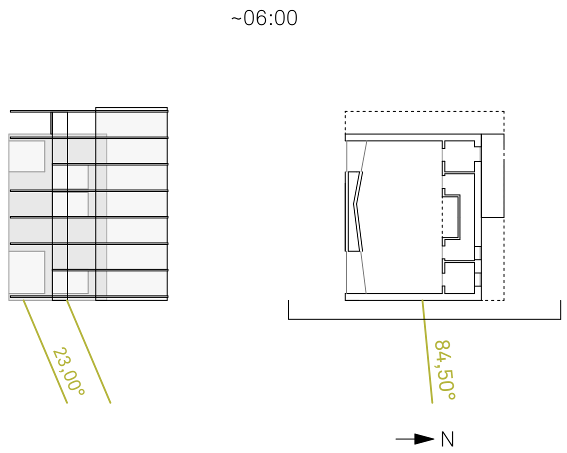
fig. 4.05: Elevation. North. 1:100

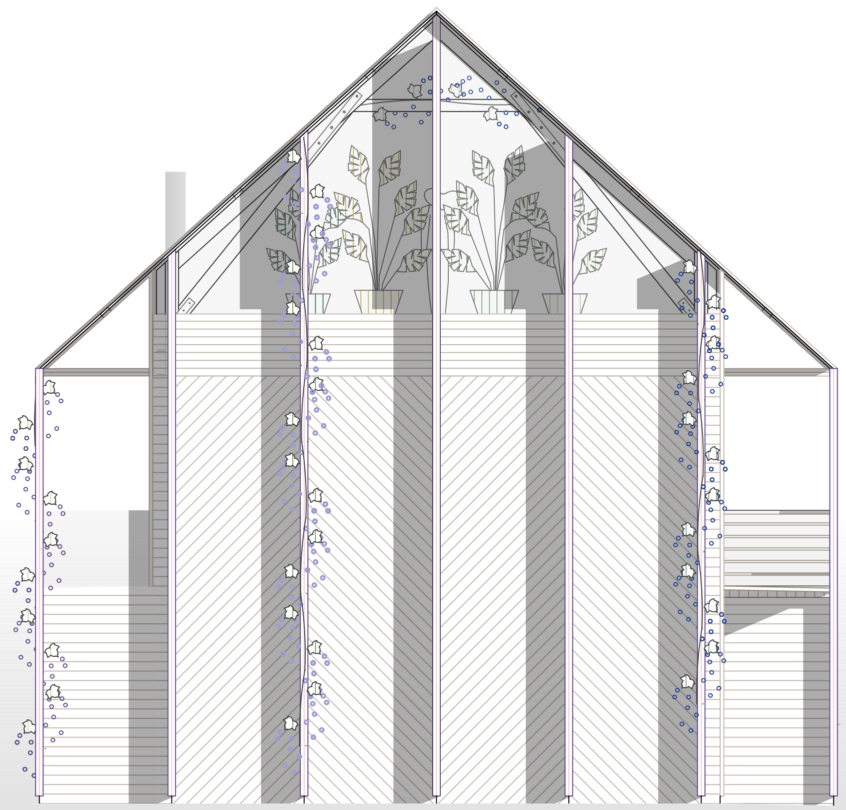


| 1m| 2| 5|

fig. 4.06: Section. 1:100

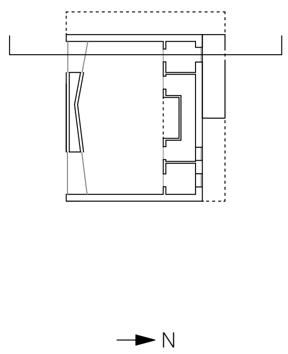
Jun
21

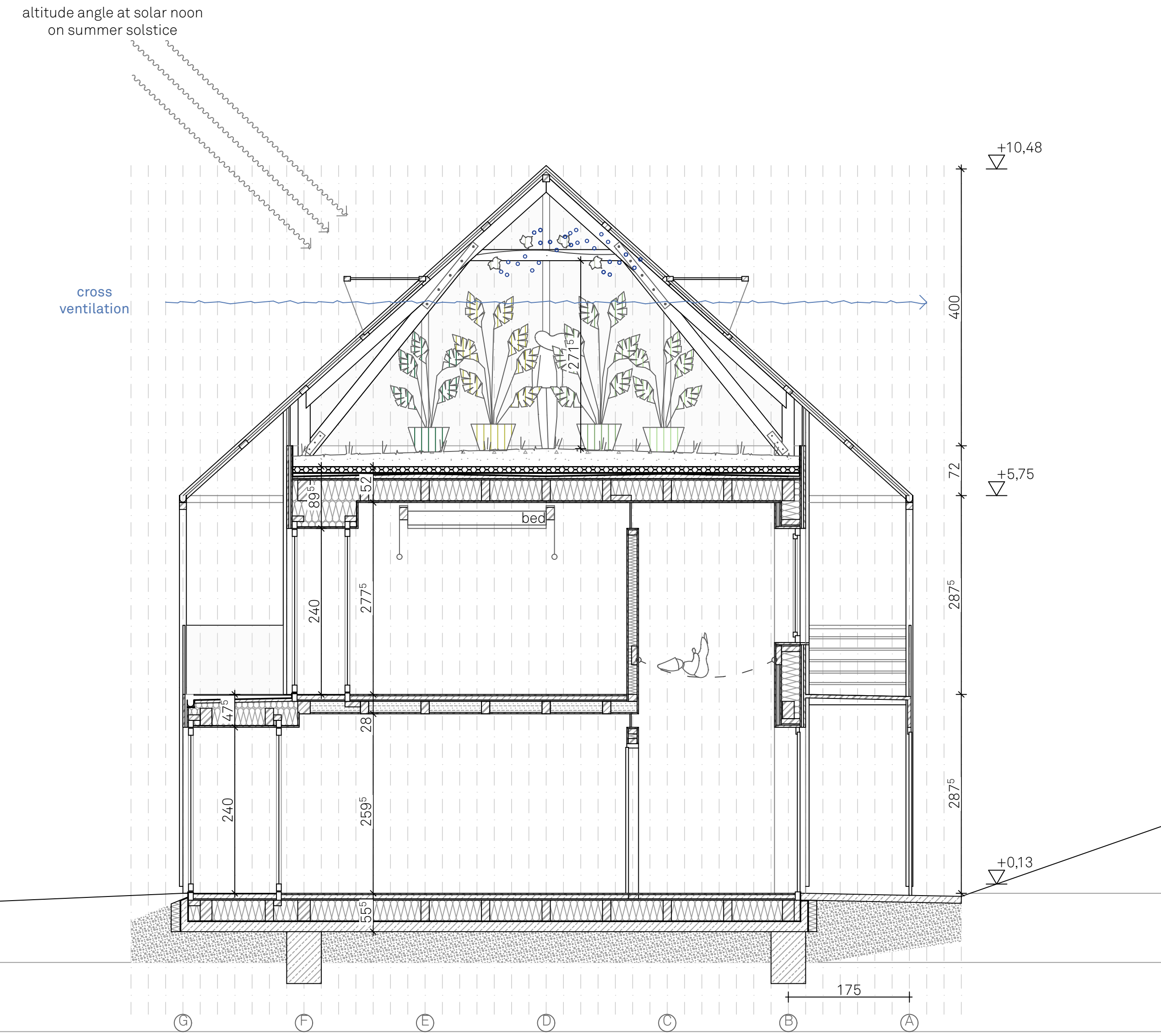




| 1m| 2| 5|

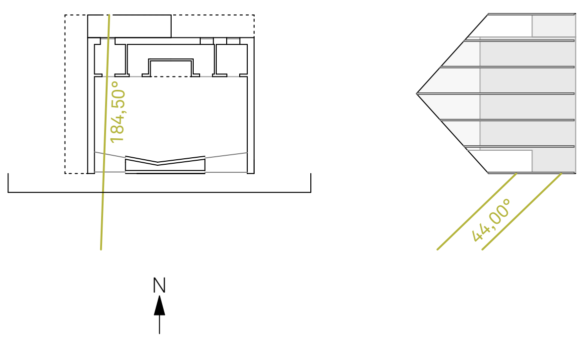
fig. 4.07: Elevation. East. 1:100

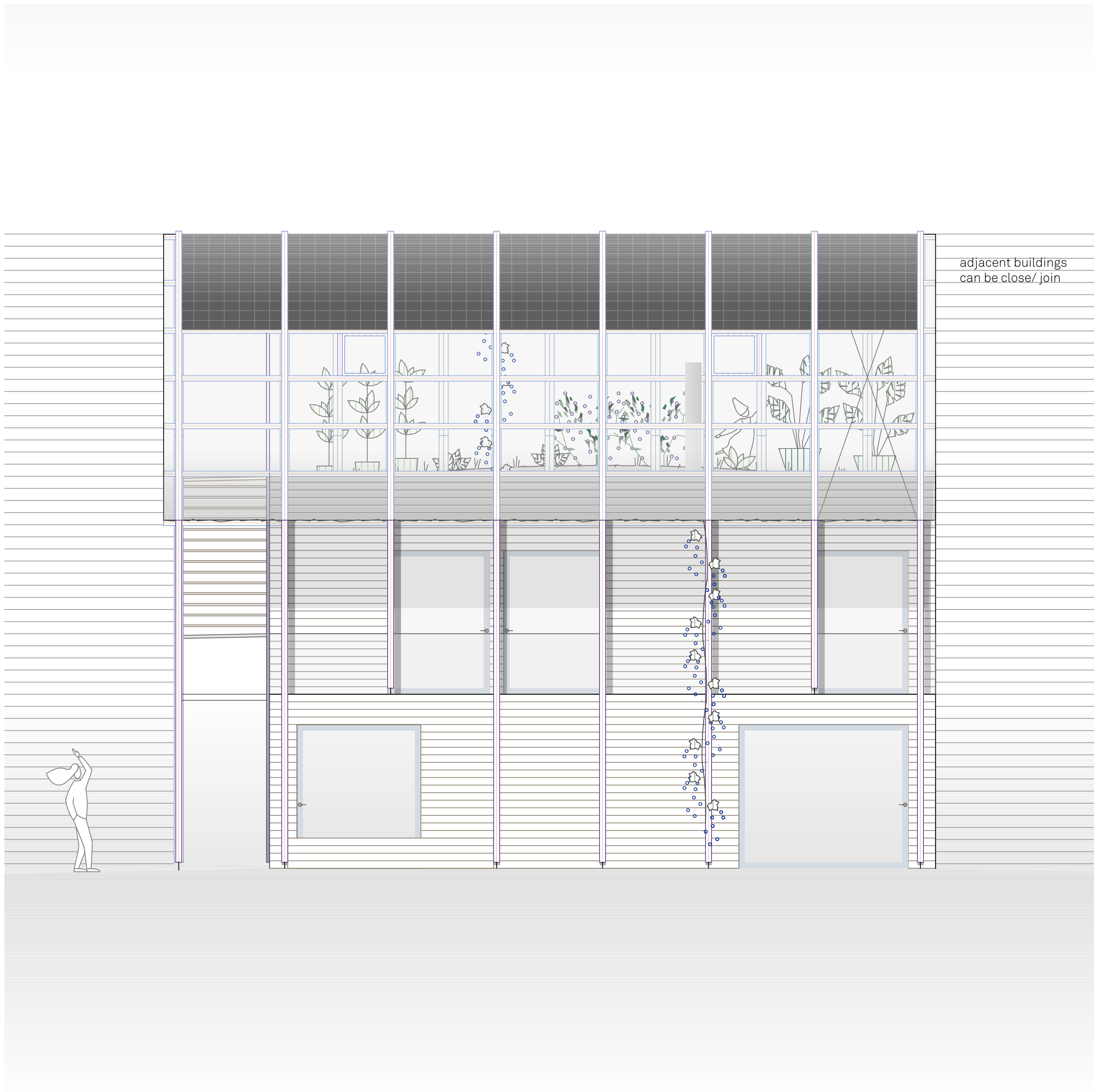




1m| 2| 5|

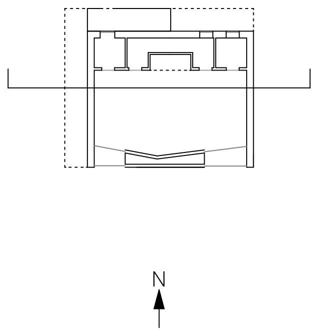
fig. 4.08: Section. 1:100





| 1m| 2| 5|

fig. 4.09: Elevation. South. 1:100



| 1m| 2| 5|

fig. 4.10: Section. 1:100

4.2 the building envelope

Because of the double shelled building envelope, intimate niches evolve, enhancing a wall from a pure building element to an inhabited threshold space. With opening or closing one or both of the two windows, these niches range from completely interior, partly interior/ exterior, or completely exterior. (fig. 4.11) In this way, the thesis rethinks and amplifies a rather traditional building element of colder climates: the double window.
Specifically, in the design study, there are five niches: one large niche suitable for a small group and 4 smaller niches big enough for an individual or a couple.

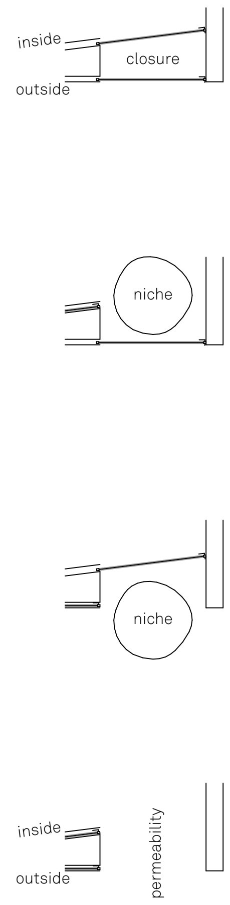


fig. 4.11: The system of the inhabited envelope.

4.2.1 the window ballet

The following *window ballet* explores the spectrum of the transforming possibilities within *the end* (the time of darkness), *the beginning* (the time of transition), and *the middle* of a year (the time of brightness). Specifically, in *the window ballet* the two windows on the ground level are exemplified. (fig. 4.12-4.14)

Rituals and experiences during *the end of a year* (the time of darkness) could include closing, but decorating, all windows and huddling together around the fireplace of *the innermost* and feeling warm, close and secure by the many surrounding layers. (fig. 4.12)
Annexing one more layer, during *the beginning of a new year* (the time of transition), one may sit on a sheep skin in *the inhabited envelope*, holding a large hot cup of morning coffee and witnessing the first sunrises of the new year – but still feeling hugged by the house. (fig. 4.13)
Reducing the building to a temporary shelter, during *the middle of a year* (the time of brightness), one might find the perfect sheltered outdoor space for a relaxing afternoon hammock nap. (fig. 4.14)
All these ritual moments are precious little delights, transforming a shelter into a true home. This is especially crucial when our world shifts.

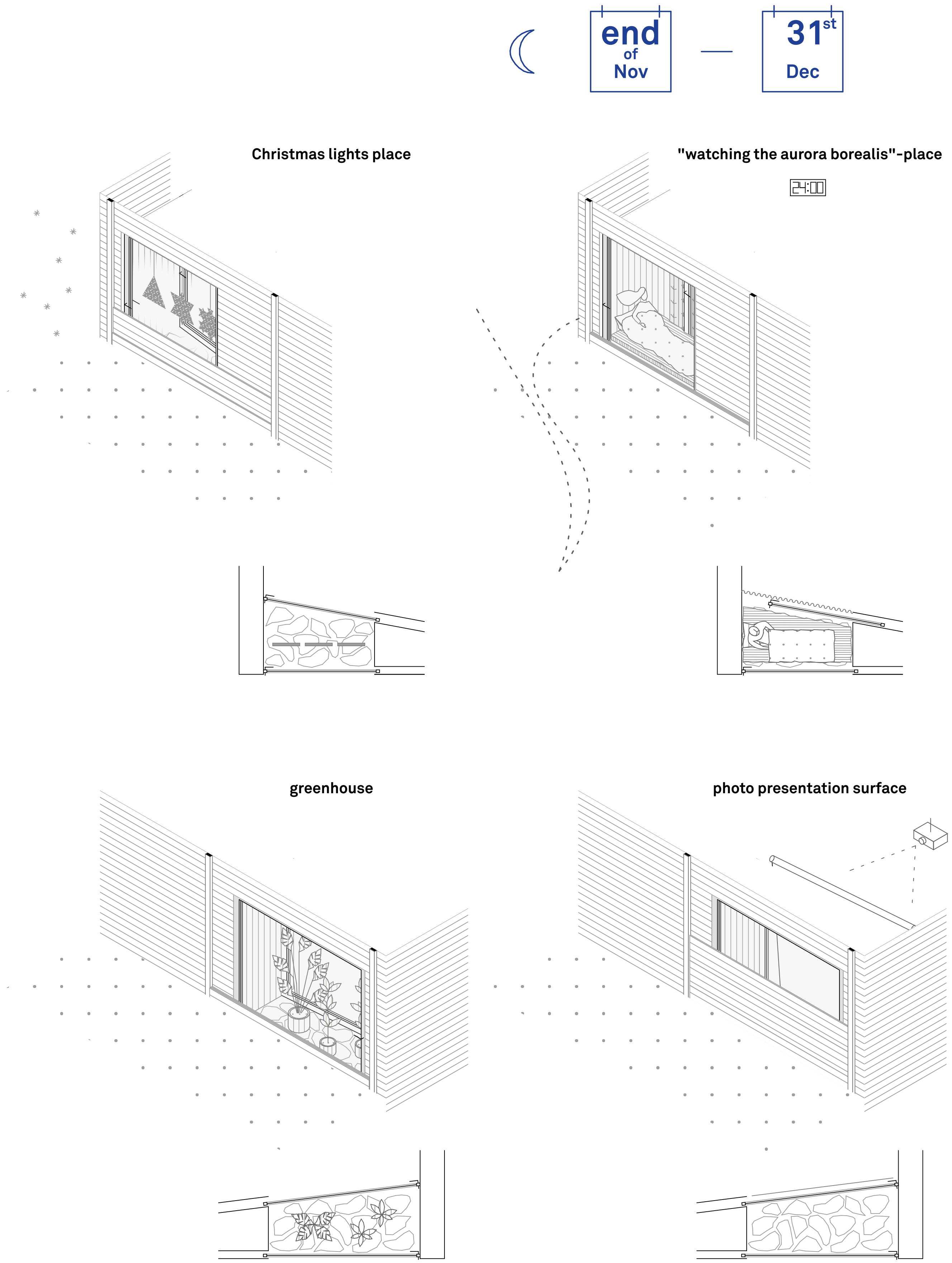
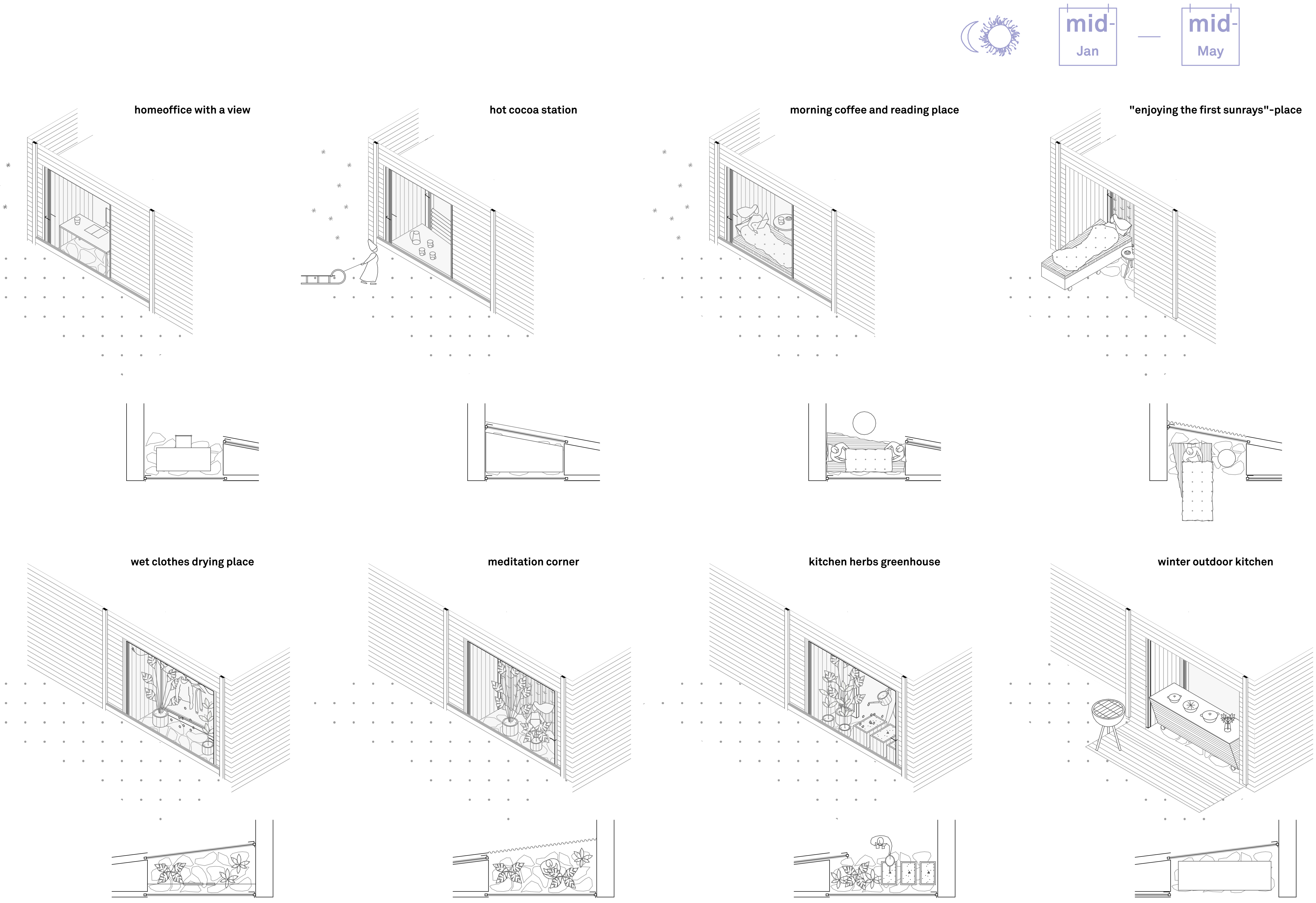


fig. 4.12: The window ballet: 1st act. Axonometric plan. Viewing direction: south. 1:100

| 1m| 2| 5| N



| 1m| 2| 5| N

fig. 4.13: The window ballet: 2nd act. Axonometric plan. Viewing direction: south. 1:100

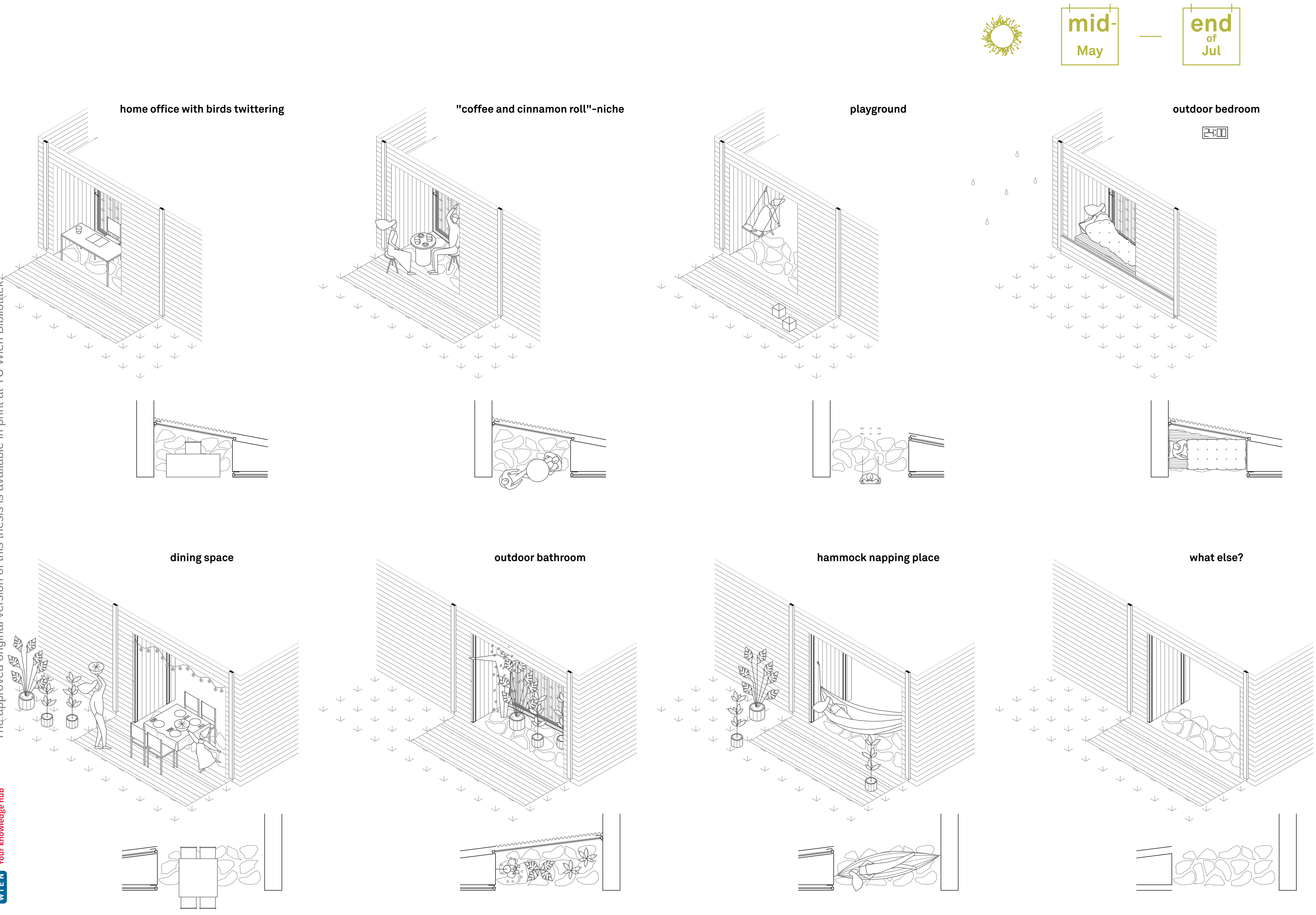
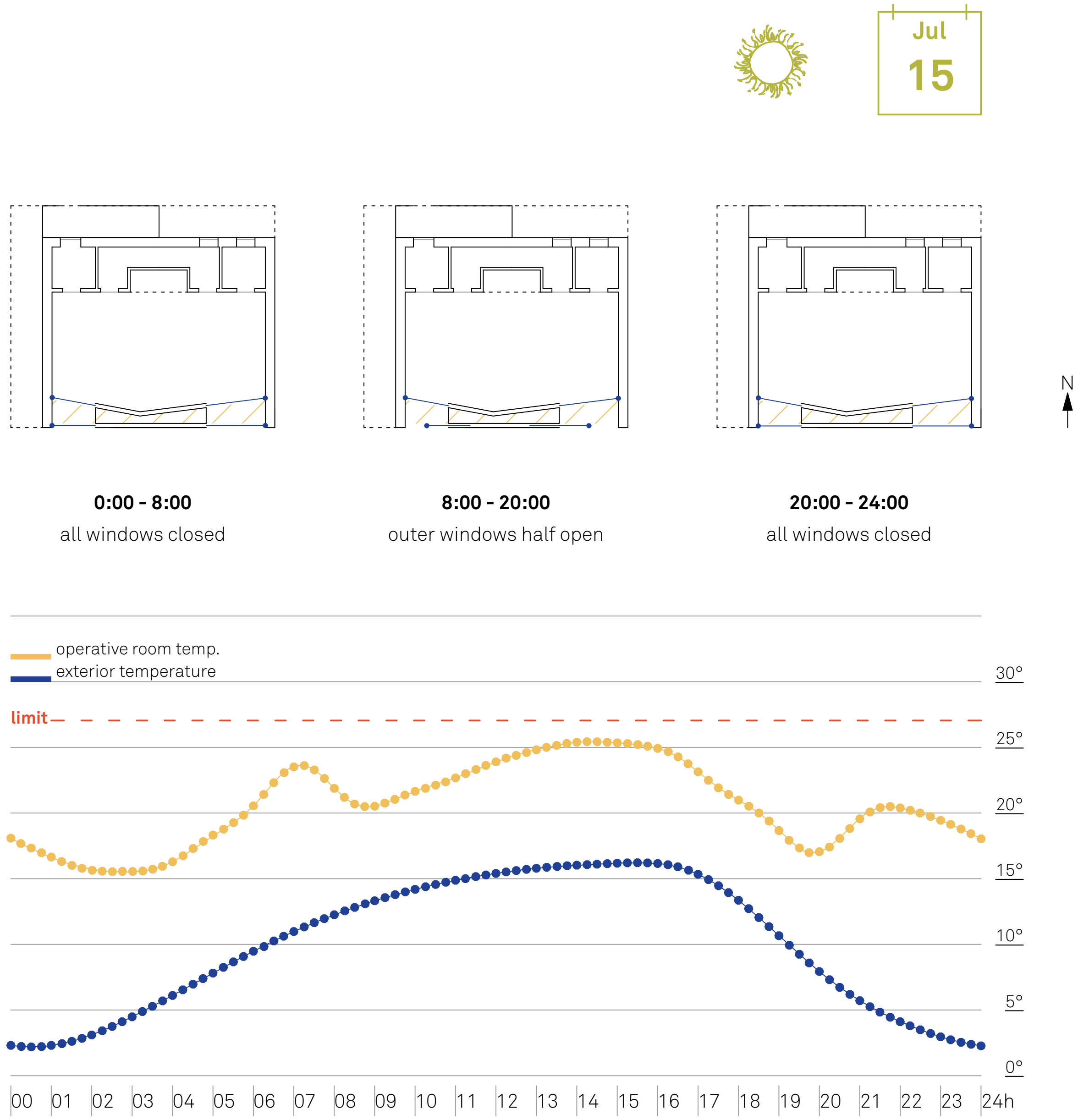


fig. 4.14: The window ballet: 3rd act. Axonometric plan. Viewing direction: south. 1:100

4.2.2 passive solar heat gains

The double window not only creates intimate niches. As the following calculations and simulations demonstrate, it also creates a microclimate that mediates passive solar heat gains between the inside and the outside.
Although the calculations and simulations represent only a rough approximation, they do have value as they guide the design from the concept on.[137] As elucidated in the chapter *0.1.2 defintions*, it is the basic building principles that make the most impact.

The simulations of passive solar heat gains are based on the example of July 15th. Within the 24 hours of the day, it shows the constant right amount of passive solar heat gains – by just opening or closing one of the two windows. Therefor, the temperature reference is 12°C; in Tromsø, this is the normal average temperature of July 15th (see *3.1.2 climate conditions: figure 3.11*). Simulations are via *thesim.at*. (fig. 4.15-4.17)
Moreover, the u-values vastly improve due to the double shell.

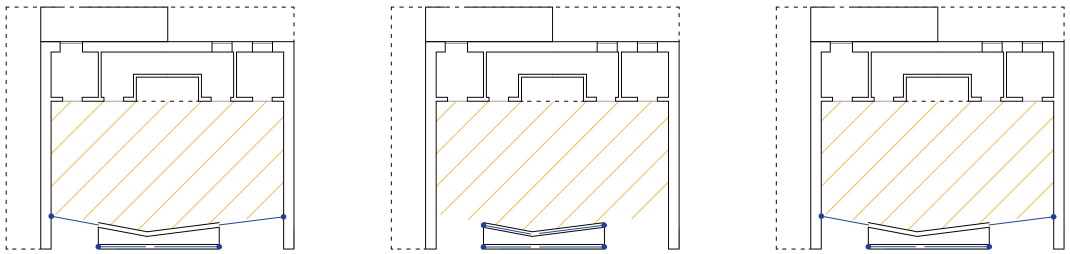


t [h]	Θ_e [°C]	Θ_{op} [°C]	t [h]	Θ_e [°C]	Θ_{op} [°C]
00:00	2,3	18,0 ✓	12:00	15,4	23,9 ✓
01:00	2,3	16,6 ✓	13:00	15,7	24,8 ✓
02:00	3,1	15,6 ✓	14:00	16,0	25,4 ✓
03:00	4,4	15,5 ✓	15:00	16,1	25,3 ✓
04:00	6,1	16,3 ✓	16:00	16,1	24,9 ✓
05:00	7,8	18,3 ✓	17:00	15,3	23,1 ✓
06:00	9,4	20,5 ✓	18:00	13,3	20,9 ✓
07:00	10,9	23,5 ✓	19:00	10,6	18,6 ✓
08:00	12,2	21,9 ✓	20:00	7,9	17,0 ✓
09:00	13,3	20,5 ✓	21:00	5,7	19,5 ✓
10:00	14,2	21,6 ✓	22:00	4,1	20,4 ✓
11:00	14,8	22,7 ✓	23:00	2,9	19,4 ✓

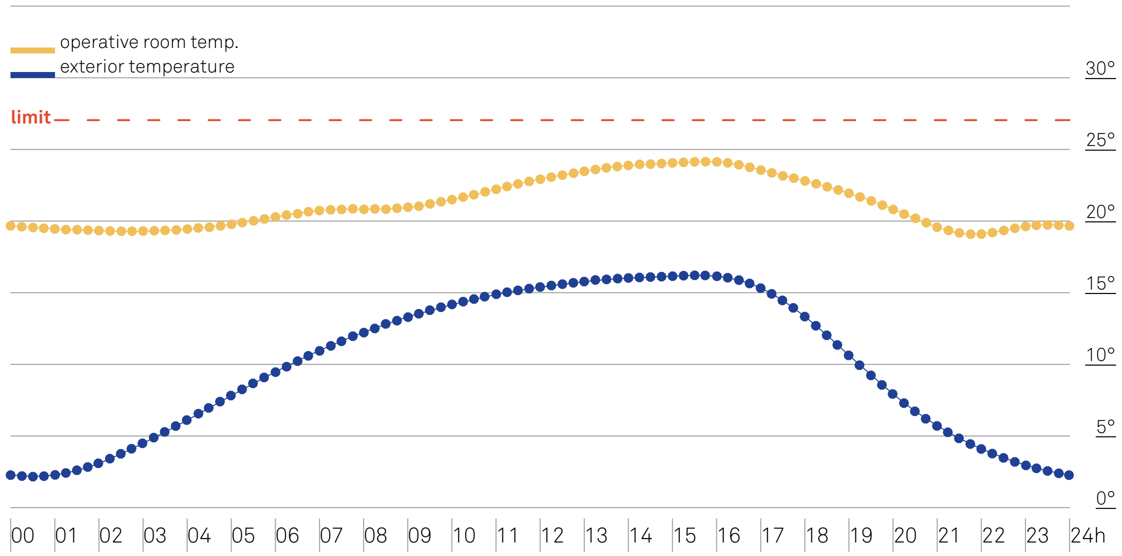
fig. 4.15: Passive solar heat gains July, 15th: Inhabited Envelope.

137 cf. Peters and Peters, 2018: 27; 41

Jul
15

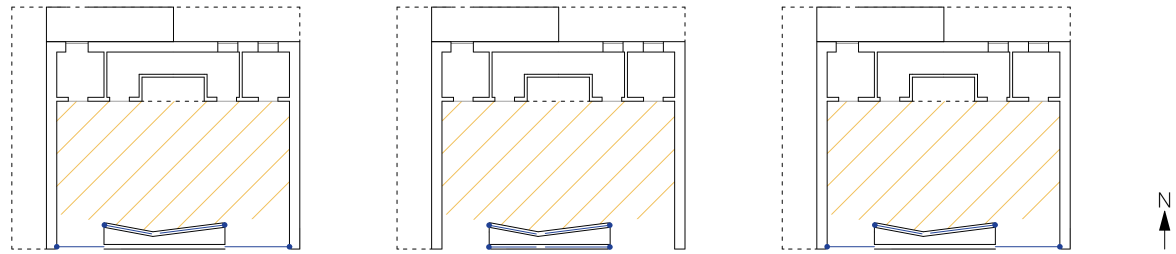


0:00 - 8:00	8:00 - 20:00	20:00 - 24:00
inner windows closed	all windows open	inner windows closed

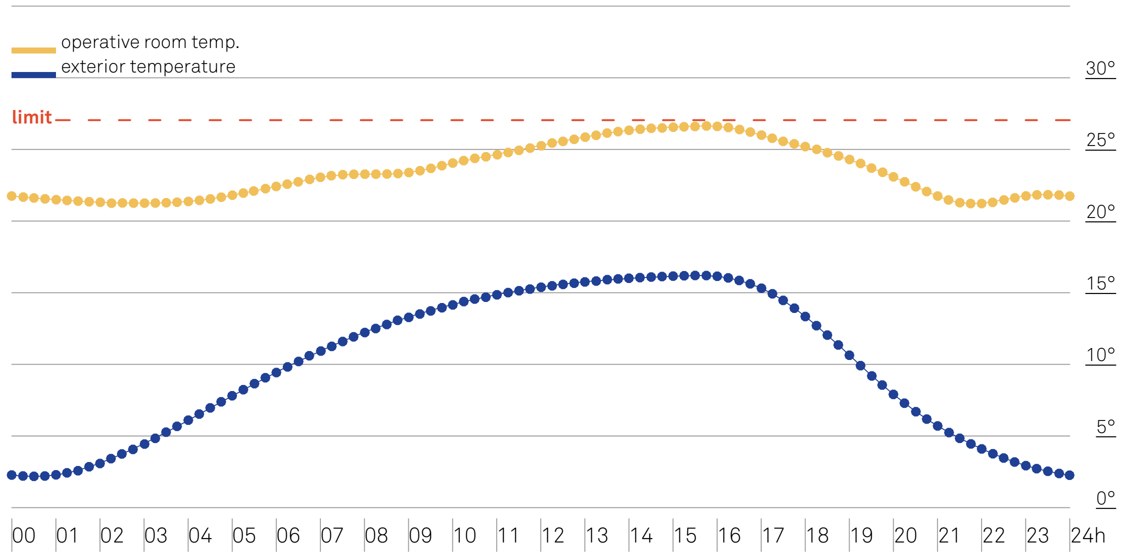


t [h]	Θ_e [°C]	Θ_{op} [°C]	t [h]	Θ_e [°C]	Θ_{op} [°C]
00:00	2,3	19,6 ✓	12:00	15,4	22,9 ✓
01:00	2,3	19,4 ✓	13:00	15,7	23,4 ✓
02:00	3,1	19,3 ✓	14:00	16,0	23,9 ✓
03:00	4,4	19,3 ✓	15:00	16,1	24,0 ✓
04:00	6,1	19,4 ✓	16:00	16,1	24,1 ✓
05:00	7,8	19,8 ✓	17:00	15,3	23,5 ✓
06:00	9,4	20,2 ✓	18:00	13,3	22,8 ✓
07:00	10,9	20,7 ✓	19:00	10,6	21,9 ✓
08:00	12,2	20,8 ✓	20:00	7,9	20,8 ✓
09:00	13,3	20,9 ✓	21:00	5,7	19,6 ✓
10:00	14,2	21,5 ✓	22:00	4,1	19,1 ✓
11:00	14,8	22,2 ✓	23:00	2,9	19,6 ✓

fig. 4.16: Passive solar heat gains July, 15th: The Innermost.



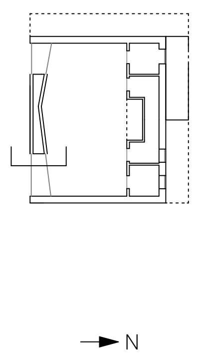
0:00 - 8:00	8:00 - 20:00	20:00 - 24:00
outer windows closed	all windows open	outer windows closed

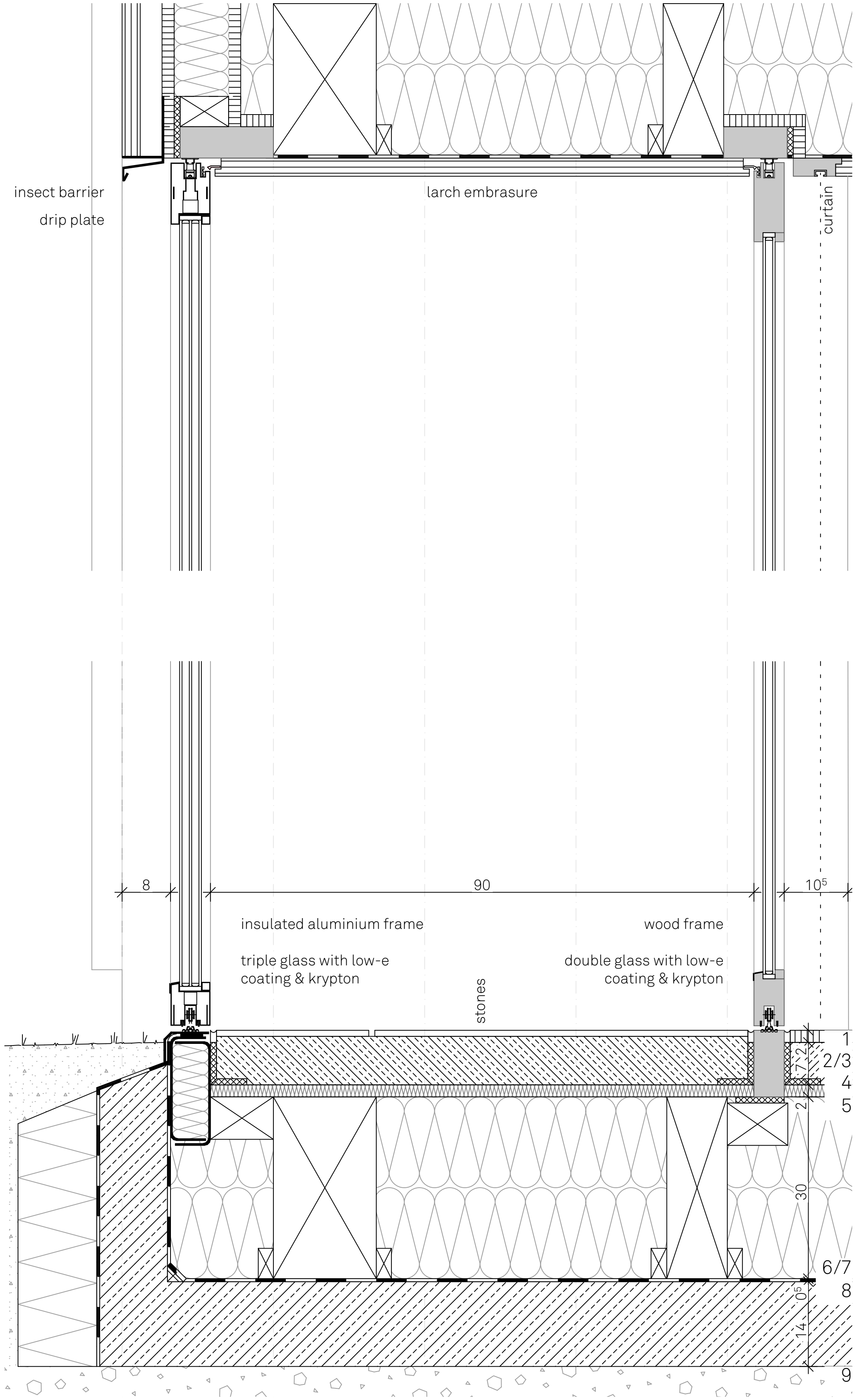


t [h]	Θ_e [°C]	Θ_{op} [°C]	t [h]	Θ_e [°C]	Θ_{op} [°C]
00:00	2,3	21,7 ✓	12:00	15,4	25,3 ✓
01:00	2,3	21,5 ✓	13:00	15,7	25,8 ✓
02:00	3,1	21,3 ✓	14:00	16,0	26,3 ✓
03:00	4,4	21,2 ✓	15:00	16,1	26,5 ✓
04:00	6,1	21,4 ✓	16:00	16,1	26,6 ✓
05:00	7,8	21,8 ✓	17:00	15,3	26,0 ✓
06:00	9,4	22,4 ✓	18:00	13,3	25,2 ✓
07:00	10,9	23,0 ✓	19:00	10,6	24,3 ✓
08:00	12,2	23,3 ✓	20:00	7,9	23,1 ✓
09:00	13,3	23,4 ✓	21:00	5,7	21,7 ✓
10:00	14,2	24,0 ✓	22:00	4,1	21,2 ✓
11:00	14,8	24,6 ✓	23:00	2,9	21,7 ✓

fig. 4.17: Passive solar heat gains July, 15th: The Innermost.

4.2.3 façade sections



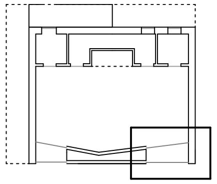


Ceiling over ground.

1	birch plank flooring	2,0 cm
2	screed with underfloor heating	7,0
3	separating layer	
4	impact sound insulation	2,0
5	wood fibre insulation	30,0
6	bituminous seal (2 layers)	0,5
7	bituminous prepainting	
8	concrete	14,0
9	gravel	

| 10 cm| 20| 50|

fig. 4.18: Façade section. Vertical. 1:10

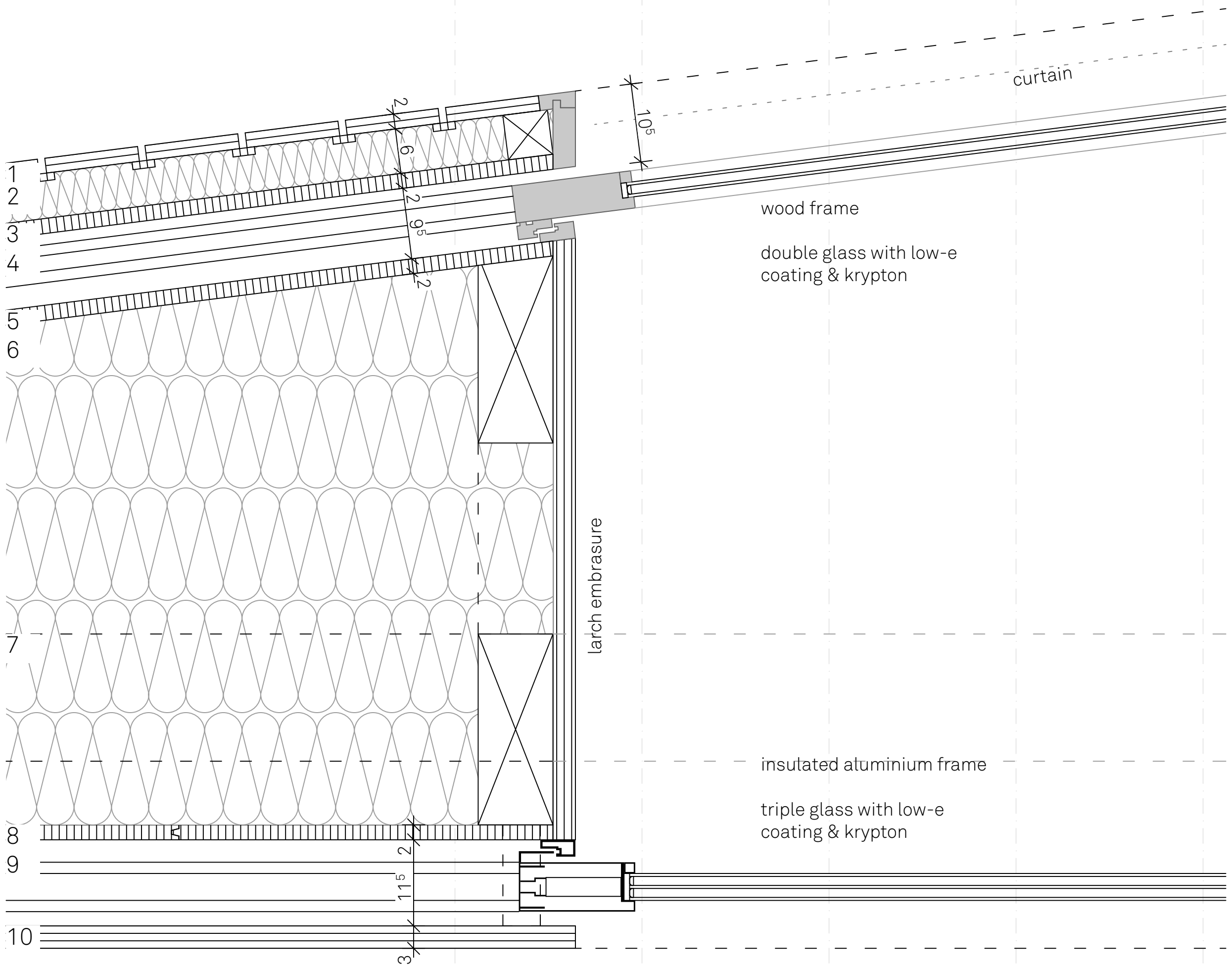


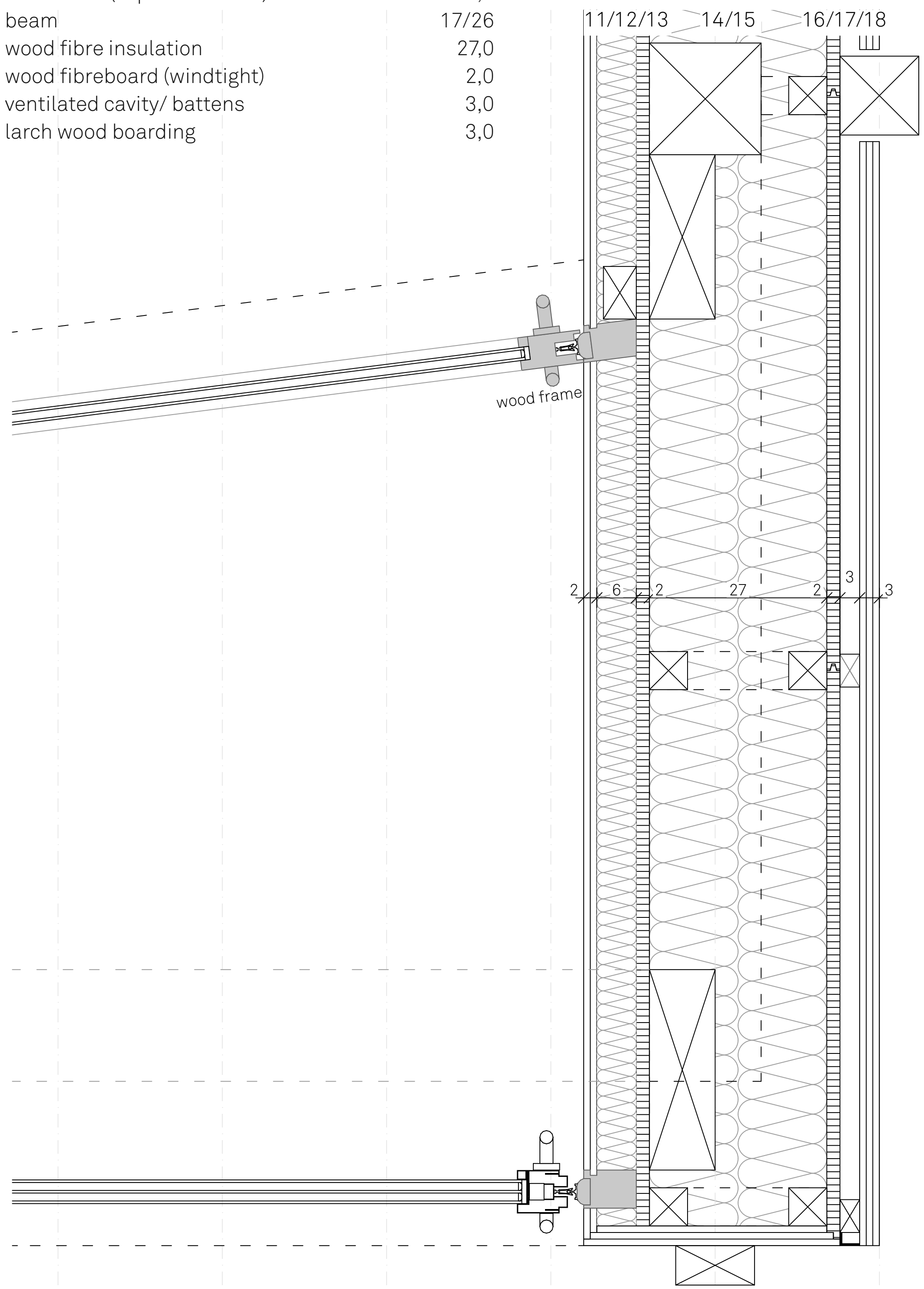
Inhabited envelope.

1	birch wood boarding	2,0 cm
2	wood fibre insulation/ battens	6,0
3	wood fibreboard	2,0
4	rail for inner sliding window	9,5
5	OSB board (vapour retarder)	2,0
6	wood fibre insulation	varying
7	beam	17/26
8	wood fibreboard (windtight)	2,0
9	rail for outer sliding window	11,5
10	larch wood boarding	3,0

Exterior wall. East.

11	birch wood boarding	2,0 cm
12	wood fibre insulation/ battens	6,0
13	OSB board (vapour retarder)	2,0
14	beam	17/26
15	wood fibre insulation	27,0
16	wood fibreboard (windtight)	2,0
17	ventilated cavity/ battens	3,0
18	larch wood boarding	3,0





| 10 cm| 20| 50| N

fig. 4.19: Façade section. 1st level. Horizontal. 1:10

5
summary

5.1 the building for the yearly cycle

5.1.1 conclusion

Passions of rain, or moods in falling snow;
Grievings in loneliness, or unsubdued
Elations when the forest blooms; gusty
Emotions on wet roads on autumn nights;
All pleasures and all pains, remembering
The bough of summer and the winter branch.
These are the measures destined for [one's] soul.
(Wallace Stevens, "Sunday Morning")

The natural world on our planet is vast and cyclically shaped – there are times of evolvement and times of retreat, times of blossom and times of senescence. As natural as cycles are, we live in a society where we are scared of the temporary, letting little space for change in a world full of changes.
On the contrary, we tirelessly attempt to remain in heydays. As change inevitably comes, we end up triggering various universal tensions.

Thoughtfully designed as a counterpoint, the approach of *The Building for the Yearly Cycle* is developed to acknowledge that just like the natural world the built world must be shaped by cycles, showing its potentials when we experience change with pride and purpose.
In this thesis, a whole class of *The Building for the Yearly Cycle*-strategies is introduced. These strategies are based on an understanding of the natural world around us: bioclimatic and biophilic strategies for a cold climate are presented within the pages 16-30 (for *the end of a year*), 38-51 (for *the beginning of a new year*), and 60-74 (for *the middle of a year*). They show how to make the most of what each season has to offer.

The key feature of the concept, the architectural layers, transform the knowledge into a building: the design study. They are called the *innermost* (a multi-purpose space) (p.32-37), *the inhabited envelope* (a double window rethought) (p.54-59), and *the interweaving* (a greenhouse on the roof) (p.75-78).

On account of the inhabited envelope, a responsive double sliding window, *The Building for the Yearly Cycle* adapts to seasonal changing light and weather conditions. It creates a microclimate that mediates passive solar heat gains between the inside and the outside. (p.93-94)
In this way, the building operates situationally and therefore efficiently, resulting in a heightened adaptability to future changing climate conditions too. When rhythms are synchronized, it takes little effort to thrive through the forces of change.
In addition to the heightened adaptivity, with the means of the double sliding window, intimate niches form. They are completely interior, partly interior/exterior or completely exterior. They are embracing or permeable. (p.90-92)

All three architectural layers show architectural expressions that reconnect the building's occupants with nature throughout the year. They show that one can live in a hostile environment (whatever it may be) and simultaneously be protected but through physical, visual, emotional, and material affiliation in constant dialogue with it. This enables one to be part, rather than victim, of the seasonal changes and circumstances of the environment. Rich with sensual and emotional experiences throughout the year, it is a typology that not only acknowledges but also shows the building's occupant

the beauty and variety of (seasonal) change.
When rhythms are synchronized it takes little effort to thrive through the forces of change.

These elaborate layers of *the innermost*, *the inhabited envelope*, and *the interweaving* are all different to the current awkward cut between the inside and the outside world due to the prevailing external thermal insulation composite system and rooms made out of white drywalls: a universe of disvalue in a world full of excitement and changes.

To conlcude, with the beauty of nature in the spotlight and a world full of dreams, the approach of *The Building for the Yearly Cycle* immodestly claims to inspire to a more cyclical thinking and to see the natural world through the lens of wonder. The Building for the Yearly Cycle is about architecture in nature and nature in architecture, benefitting from and showing the beauty and variety within the temporary.

5.1.2 outlook

As the dualism of a low-environmental impact architecture and a biophilic design might have the potential to lead to a more holistic change in the building sector, the method of *The Building for the Yearly Cycle* is particularly elegant.
Parametric design is an exciting and precise tool and might further improve the translation from research to design. Furthermore, a transdisciplinary approach holds great promise to elevate the outcome – an approach that has so far been vastly underutilized in the prevailing mono-discipline education and office culture, although such paradigm change might be crucial for a more holistic design and building process.

fig. 5.01: Golden reflections on a stone. Sunset in Trondheim, Norway, in early 2020.

Although the proposed design in this thesis is a small-scale dwelling, the discussed concept is equally applicable to buildings with other functions and scales. This is made possible since the design study presented here was explicitly devised from general *The Building for the Yearly Cycle* design paradigms.
Due to its cyclical and differentiated observation and an understanding of the rhythms around, the approach presented in this work could lead to exciting applications for almost any functions and scales in the world of architecture – *The School for the Yearly Cycle*, *The Office for the Yearly Cycle*, or *The Residential Building for the Yearly Cycle*.

fig. 5.02: Earthrise. Apollo mission 1968. A picture by Bill Anders.

5.1.3 acknowledgements

…it's like this. Sometimes, when you've a very long street ahead of you, you think how terribly long it is and feel sure you'll never get it swept. […] And then you start to hurry […] You work faster and faster, and every time you look up there seems to be just as much left to sweep as before, and you try even harder, and you panic, and in the end you're out of breath and have to stop — and still the street stretches away in front of you. That's not the way to do it. […] You must never think of the whole street at once, understand? You must only concentrate on the next step, the next breath, the next stroke of the broom, and the next, and the next. Nothing else. […] That way you enjoy your work, which is important, because then you make a good job of it. And that's how it ought to be.

Ende, 1973: Momo 35-36

It was a long journey, but also a beautiful one – takk for turen!

Special thanks to

My supervisors at the Vienna University of Technology:

- Alireza Fadai for giving me trust and freedom.

- Sandra Häuplik-Meusburger for teaching with kindness.

- Otto Mittmannsgruber for kindly overtaking the role of my examiner.

Fredrik Lund, Professor at the NTNU in Trondheim, for planting the seed of this thesis.

My study collegue Anna Prüller for our precious ongoing dialogue since day 1.

Justine Simonson, producer and writer from NYC, for her incredible work in improving my writing and all the heartwarming conversations.

Christina Hedderich, botanist in Vienna, for her vast expertise and support.

The lecturers of the series *Emerging Fields in Architecture* for their constant food of thought and reflection during the evolvement of this project (https://www.youtube.com/channel/UCO1kKw5xzCOmkU5yVQ1CrRA).

The Helling Family in Northern Norway for letting me fully experience the Arctic way of living.

My parents for their incredibly generous financial and moral support in every way and my elder brother for running errands for me in Vienna.

5.1.4 bibliography

literature

books

Alexander, C., Ishikawa, S., Silverstein, M., 1977. A Pattern Language: Towns, Buildings, Construction. Oxford University Press, New York.

Boubekri, M., 2008. Daylighting, Architecture and Health: Building Design Strategies. 1st ed, Elsevier/ Architectural Press, Oxford [a.o].

Brekke, N.G., Nordhagen, P.J., Sjkold Lexau, S., 2019. Architecture in Norway: An Architectural History from the Stone Age to the Twenty-first Century. Birkhauser, Basel.

Brophy, V., Lewis, J.O., 2011. A Green Vitruvius: Principles and Practice of Sustainable Architectural Design, 2. ed, Earthscan, London.

Dekkerhus, K., Moen, U., Rørvik, O.P., Østraat, B., 1992. Norge = Norway = Norwegen. Aune, Trondheim.

El croquis (Ed.), 2019. Bernardo Bader 2009-2019: la audacia de lo familiar | fearlessness of the familiar. El croquis editorial, Madrid.

Ende, M., 1973. Momo. 2009th ed, Puffin Books, London.

ETH Zürich (Ed.), 2010. Neue Monte-Rosa-Hütte SAC: Ein autarkes Bauwerk im hochalpinen Raum. Presented at the Ausstellung Neue Monte-Rosa-Hütte SAC, gta-Verl, Zürich.

Harrison, R.P., 2008. Gardens: An Essay on the Human Condition. e-book, University of Chicago Press, Chicago.

Jones, L., 2020. Losing Eden: Why Our Minds Need the Wild. e-book, Penguin Books, London

Kellert, S.R., Heerwagen, J., Mador, M. (Eds.), 2008. Biophilic Design: The Theory, Science, and Practice of Bringing Buildings to Life. John Wiley & Sons, Inc, Hoboken, New Jersey.

Kellert, S.R., Wilson, E.O., 1993. The Biophilia Hypothesis. e-book, Island Press, Washington D.C.

Lechner, N., 2015. Heating, Cooling, Lighting: Sustainable Design Methods for Architects. 4th ed, John Wiley & Sons, Hoboken, New Jersey.

Medved, S., Domjan, S., Arkar, C., 2019. Sustainable Technologies for Nearly Zero Energy Buildings. Springer, Chan, Switzerland.

Mills, S.M., 2018. Fundamentals of Architectural Lighting. e-book, Routledge, New York.

Næss, A., 2008. The Ecology of wisdom: Writings by Arne Naess. ed. by Drengson, A. and Devall, B. Counterpoint, Berkeley, CA.

Olgyay, V., 2015. Design with Climate: Bioclimatic Approach to Architectural Regionalism. New and expanded ed. e-book, Princeton University Press, Princeton.

Pallasmaa, J., 2012. The eyes of the skin: architecture and the senses. 3. ed. John Wiley & Sons, Chichester.

Peters, B., Peters, T., 2018. Computing the Environment: Digital Design Tools for Simulation and Visualisation of Sustainable Architecture. John Wiley & Sons, Chichester.

Sergison Bates architects, 2016. Aufsätze 3, Papers, Sergison Bates architects. Quart Verlag, Luzern.

Stevens, W., 1923. Harmonium (Poetry Collection). e-book, Ed. of 1990, Vintage Books, New York.

Susanka, S., 2008. The not so big house: A Blueprint for the Way We Really Live. Expanded ed. Taunton Press, Newtown, CT.

Tyrrell, R., 2017. Aalto, Utzon, Fehn: Three Paradigms of Phenomenological Architecture. e-book, Routledge, New York.

Wilson, E.O., 1984. Biophilia: the human bond with other species. Harvard Univ. Press, Cambridge, Mass.

journals/ papers

Gelter, H., 2000. Friluftsliv: The Scandinavian Philosophy of Outdoor Life. Canadian Journal of Environmental Education 5.

Grinde, B., Patil, G.G., 2009. Biophilia: Does Visual Contact with Nature Impact on Health and Well-Being? Int. J. Environ. Res. Public Health 6, 2332–2343. https://doi.org/10.3390/ijerph6092332
access: 2020 12 11

Gunawardena, K., Steemers, K., 2019. Living walls in indoor environments. Building and Environment 148, 478–487.
https://doi.org/10.1016/j.buildenv.2018.11.014
access: 2020 12 11

Mainster, M.A., 1990. The fractal properties of retinal vessels: Embryological and clinical implications. Eye 4, 235–241.
https://doi.org/10.1038/eye.1990.33
access: 2020 12 11

Reber, S.O. et al., 2016. Immunization with a heat-killed preparation of the environmental bacterium Mycobacterium vaccae promotes stress resilience in mice. PNAS 113, E3130–E3139.
https://doi.org/10.1073/pnas.1600324113
access: 2020 12 11

Ulrich, R., 1984. View Through a Window May Influence Recovery from Surgery. Science Vol. 224, 420–421.

online

all coordinates:

https://latitudelongitude.org
access: 2020 12 11

McDivitt Tompkins, K., 2020. Let's make the world wild again. Ted Talk
https://www.ted.com/talks/kristine_tompkins_let_s_make_the_world_wild_again/transcript#t-129348
access: 2020 12 16
Mahdavi, A., 2021. On the global planetary crisis: Are buildings the solution? Lecture
https://www.youtube.com/watch?v=BleNH80Aw4w
access: 2021 01 27

https://en.wikipedia.org/wiki/Arctic_Circle
access: 2020 12 11

https://en.wikipedia.org/wiki/Richard_Kelly_%28lighting_designer%29
access: 2020 12 11

list of figures

uncredited figures and all icons are by the author © Elisabeth Maria Horodynski access: 2020 12 30

1.12 Light and insolation graph
based on:
https://www.timeanddate.com/sun/norway/tromso
https://www.gaisma.com/en/location/tromso.html
access: 2020 12 30

1.13 Precipitation graph
based on:
https://www.yr.no/en/statistics/graph/5-90490/Norway/Troms%20og%20Finnmark/Tromsø/Tromsø%20LH?q=2019
access: 2020 12 30

1.14 Snow depth graph
based on:
https://www.yr.no/en/statistics/graph/5-90490/Norway/Troms%20og%20Finnmark/Tromsø/Tromsø%20LH?q=2019
access: 2020 12 30

1.15 Plant leaves and bioclimatic buildings
Olgyay, V., 2015. Design with Climate: Bioclimatic Approach to Architectural Regionalism. New and expanded ed. e-book, Princeton University Press, Princeton. p.85; 89

1.16 The New Monte Rosa Hut
ETH Zürich (Ed.), 2010. Neue Monte-Rosa-Hütte SAC: Ein autarkes Bauwerk im hochalpinen Raum. Presented at the Ausstellung Neue Monte-Rosa-Hütte SAC, gta-Verl, Zürich. p.98; 103
© Tonatiuh Ambrosetti
edited by the author

1.17 Sámi gamme
based on:
Brekke, N.G., Nordhagen, P.J., Sjkold Lexau, S., 2019. Architecture in Norway: An Architectural History from the Stone Age to the Twenty-first Century. Birkhauser, Basel. p.36

1.18 Thermal drapes
based on:
Lechner, N., 2015. Heating, Cooling, Lighting: Sustainable Design Methods for Architects. 4th ed, John Wiley & Sons, Hoboken, New Jersey. p.513

1.19 Salgenreute Chapel, Bernardo Bader
https://www.bernardobader.com/projekt/kapelle-salgenreute
© Adolf Bereuter
access: 2020 12 13

1.20 Individually defined spaces within a room
based on:
Susanka, S., 2008. The not so big house: A Blueprint for the Way We Really Live, Expanded ed. Taunton Press, Newtown, CT. p.65

1.21 Fractals
data from:
http://soft-matter.seas.harvard.edu/index.php/Fractal_Dimension
access: 2021 01 19

1.22 Villa Busk, Sverre Fehn
Tyrrell, R., 2017. Aalto, Utzon, Fehn: Three Paradigms of Phenomenological Architecture. e-book, Routledge, New York. p.159
© Roger Tyrrell

1.23 Hotel, Kengo Kuma
https://inspiration.detail.de/hotel-in-obanazawa-100175.html
© Daichi Ano
access: 2020 08 10
edited by the author

2 the beginning of the year

2.08-
2.14 ibid 1.08-1.14

2.15 The south-facing slope
based on:
Olgyay, V., 2015. Design with Climate: Bioclimatic Approach to Architectural Regionalism. New and expanded ed. e-book, Princeton University Press, Princeton. p.50
Lechner, N., 2015. Heating, Cooling, Lighting: Sustainable Design Methods for Architects. 4th ed, John Wiley & Sons, Hoboken, New Jersey. p.328; 330

2.16 East elevation 'New Monte Rosa Hut'
ETH Zürich (Ed.), 2010. Neue Monte-Rosa-Hütte SAC: Ein autarkes Bauwerk im hochalpinen Raum. Presented at the Ausstellung Neue Monte-Rosa-Hütte SAC, gta-Verl, Zürich. p.83
© Tonatiuh Ambrosetti

2.17 Grounding 'New Monte Rosa Hut'
based on:
ETH Zürich (Ed.), 2010. Neue Monte-Rosa-Hütte SAC: Ein autarkes Bauwerk im hochalpinen Raum. Presented at the Ausstellung Neue Monte-Rosa-Hütte SAC, gta-Verl, Zürich. p.112

2.18 The greenhouse effect
based on:
Lechner, N., 2015. Heating, Cooling, Lighting: Sustainable Design Methods for Architects. 4th ed, John Wiley & Sons, Hoboken, New Jersey. p. 170

2.19 South orientation
based on:
Brophy, V., Lewis, J.O., 2011. A Green Vitruvius: Principles and Practice of Sustainable Architectural Design, 2. ed, Earthscan, London. p.52

2.20 Characteristics of glazing types
data from:
Brophy, V., Lewis, J.O., 2011. A Green Vitruvius: Principles and Practice of Sustainable Architectural Design, 2. ed, Earthscan, London. p.67

2.21 High radiation and little re-radiation
based on:
Brophy, V., Lewis, J.O., 2011. A Green Vitruvius: Principles and Practice of Sustainable Archi-

tectural Design, 2. ed, Earthscan, London. p.66
Lechner, N., 2015. Heating, Cooling, Lighting: Sustainable Design Methods for Architects. 4th ed, John Wiley & Sons, Hoboken, New Jersey. p. 511

2.24 A true window place
Susanka, S., 2008. The not so big house: A Blueprint for the Way We Really Live, Expanded ed. Taunton Press, Newtown, CT. p. 80
© Christian Korab
edited by the author

3 the middle of the year

3.01-3.07 photo essay
© Andreas Horodynski

3.08-3.14 ibid 1.08-1.14

3.15 Air stream around a building
based on:
Lechner, N., 2015. Heating, Cooling, Lighting: Sustainable Design Methods for Architects. 4th ed, John Wiley & Sons, Hoboken, New Jersey. p. 294

3.16 Air streams inside a building
Olgyay, V., 2015. Design with Climate: Bioclimatic Approach to Architectural Regionalism. New and expanded ed. e-book, Princeton University Press, Princeton. p. 105, 109, 111

3.17 Forms of natural light
based on:
Medved, S., Domjan, S., Arkar, C., 2019. Sustainable Technologies for Nearly Zero Energy Buildings. Springer, Chan, Switzerland. p.330

3.18 Huddling together
https://www.geocaching.com/geocache/GC31NDF_havratunet
access: 2020 08 26

3.19 Balanced daylight distribution
based on:
Boubekri, M., 2008. Daylighting, Architecture and Health: Building Design Strategies. 1st ed, Elsevier/ Architectural Press, Oxford [a.o]. p. 114

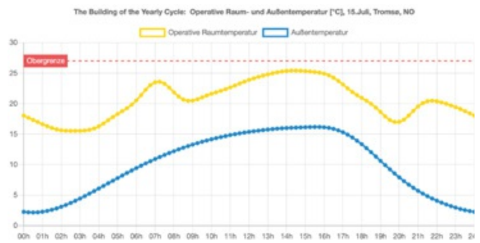
3.20 Windows adjacent to bright interior walls
based on:
Lechner, N., 2015. Heating, Cooling, Lighting: Sustainable Design Methods for Architects. 4th ed, John Wiley & Sons, Hoboken, New Jersey. p. 417

3.21 Common heather
© Christina Hedderich

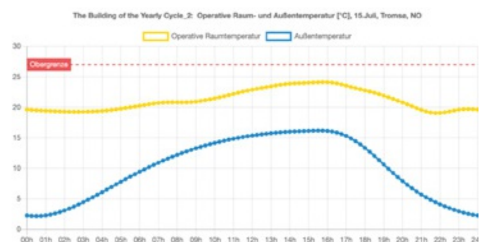
4 in the cycle of the year

4.03 The Liegender Stuhl
based on:
https://www.holzbauaustria.at/architektur/2021/01/schwedischer-holzbaupreis-vergeben.html
access: 2021 03 19

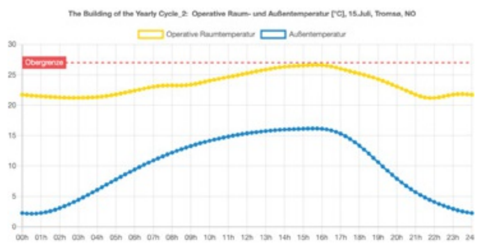
4.15-4.17 passive solar heat gains
simulated via:
thesim.at
access: 2020 02 05



t [h]	Θ_e [°C]	Θ_{op} [°C]	t [h]	Θ_e [°C]	Θ_{op} [°C]
0:00	2,3	18,0	12:00	15,4	23,9
1:00	2,3	16,6	13:00	15,7	24,8
2:00	3,1	15,6	14:00	16,0	25,4
3:00	4,4	15,5	15:00	16,1	25,3
4:00	6,1	16,3	16:00	16,1	24,9
5:00	7,8	18,3	17:00	15,3	23,1
6:00	9,4	20,5	18:00	13,3	20,9
7:00	10,9	23,5	19:00	10,6	18,6
8:00	12,2	21,9	20:00	7,9	17,0
9:00	13,3	20,5	21:00	5,7	19,5
10:00	14,2	21,6	22:00	4,1	20,4
11:00	14,8	22,7	23:00	2,9	19,4



t [h]	Θ_e [°C]	Θ_{op} [°C]	t [h]	Θ_e [°C]	Θ_{op} [°C]
0:00	2,3	19,6	12:00	15,4	22,9
1:00	2,3	19,4	13:00	15,7	23,4
2:00	3,1	19,3	14:00	16,0	23,9
3:00	4,4	19,3	15:00	16,1	24,0
4:00	6,1	19,4	16:00	16,1	24,1
5:00	7,8	19,8	17:00	15,3	23,5
6:00	9,4	20,2	18:00	13,3	22,8
7:00	10,9	20,7	19:00	10,6	21,9
8:00	12,2	20,8	20:00	7,9	20,8
9:00	13,3	20,9	21:00	5,7	19,6
10:00	14,2	21,5	22:00	4,1	19,1
11:00	14,8	22,2	23:00	2,9	19,6



t [h]	Θ_e [°C]	Θ_{op} [°C]	t [h]	Θ_e [°C]	Θ_{op} [°C]
0:00	2,3	21,7	12:00	15,4	25,3
1:00	2,3	21,6	13:00	15,7	25,8
2:00	3,1	21,3	14:00	16,0	26,3
3:00	4,4	21,2	15:00	16,1	26,5
4:00	6,1	21,4	16:00	16,1	26,6
5:00	7,8	21,8	17:00	15,3	26,0
6:00	9,4	22,4	18:00	13,3	25,2
7:00	10,9	23,0	19:00	10,6	24,3
8:00	12,2	23,3	20:00	7,9	23,1
9:00	13,3	23,4	21:00	5,7	21,7
10:00	14,2	24,0	22:00	4,1	21,2
11:00	14,8	24,6	23:00	2,9	21,7

4.18-4.19 Façade sections
based on/ after:
El croquis (Ed.), 2019. Bernardo Bader 2009-2019: la audacia de lo familiar | fearlessness of the familiar. El croquis editorial, Madrid. p.194
https://www.dataholz.eu
access: 2021 01 02

discussion

5.02 ibid 0.05

imprint

concept and design
Elisabeth Maria Horodynski
supervision
a.o. Prof. Dipl.-Ing. Dr. Alireza Fadai
fonts
Akkurat, Garamond
print and bookbinding
Kölbl Buchbinderei, A-4600 Wels

Made with care, so be kind.

In the realm of planet Earth with its vast cyclical shaped natural world, this thesis challenges the prevailing ignorance of cycles in the built world and seeks to foster an awareness of these hidden potentials. Concentrating on the seasonal cycle, the approach shows how to make the most of what each season has to offer.
Searching for “The Building for the Yearly Cycle,” this thesis draws on the methodology of a design study located in the Circumpolar North – precisely Arctic Norway – due to its rich light contrasts and cycles.
With bioclimatic and biophilic guidance, it investigates and demonstrates the efficient construction and operation of buildings to conserve resources in the yearly periods of darkness, transition and brightness. It examines architectural expressions that reconnect the building’s occupants with nature throughout the year, enabling them to be part rather than victim of the seasonal forces and harshness of the environment.
Materialized into the three architectural layers, “the innermost” (the multi-purpose space), “the inhabited envelope” (the double window rethought), and “the interweaving” (the greenhouse on the roof), the design study imposes new ideas about architecture in nature and nature in architecture, benefitting from and showing the beauty and variety within the temporary.