Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Architecture and Design
Department of Architecture and Technology

Magdalena Ryszkowska

Rewilding Oppdal

How to make cabin life more sustainable and biodiversity friendly

Master's thesis in Sustainable Architecture
Supervisor: Patricia Schneider-Marin
Co-supervisor: Dagmar Hagen
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Abstract

This master's thesis explores the Norwegian cabin culture, a tradition that has evolved into a valid threat to the country's natural habitats and environment. By examining the historical and current state of cabin development in Norway, this study aims to identify the root causes of the "cabin fever" and its detrimental effects on the environment. The thesis focuses on Oppdal, a prominent hyttekommune, and its role in showcasing good practices of cabin development. The project is linked to the CommonGround initiative, which seeks to reduce the environmental impact of second-home development. Through a site analysis, design proposal, and Life Cycle Analysis, this study proposes a regenerative approach to cabin development in Norway. The design incorporates more-than-human design features and caters for native species reintroduction. Architectural design aims to minimize environmental impact by using sustainable materials, optimizing energy efficiency, and incorporating renewable energy sources. The findings of this study highlight the need for a paradigm shift in cabin development, prioritizing environmental sustainability and regenerative design principles. This research contributes to the ongoing debate about sustainable second-home development in Norway and suggests steps to undertake in order to make the cabin culture more environmentally and biodiversity-friendly.

keywords: cabin architecture, sustainable design, regenerative design, LCA, ecosystem restoration, biodiversity, BIPV, embodied emissions

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Abbreviations

BIPV Building Integrated Photovoltaics

BRA *Bruksareal* - usable area

BTA *Bruttoareal* - gross area

CO_2eq Carbon dioxide equivalent

DFØ *Direktoratet for forvaltning og økonomistyring* - en. The Norwegian Agency for Public and Financial Management

EPD Environmental Product Declaration

EPW Energy Plus Weather Files

GHG Greenhouse Gas

GWP Global Warming Potential

LCA Life Cycle Assessment

NINA *Norsk institutt for naturforskning* - Norwegian Institute for Nature Research

NIBIO *Norsk institutt for bioøkonomi* - Norwegian Institute of Bioeconomy Research

NS *Norsk standard* - Norwegian standard

NTA Nettoareal - Net floor area

OPA Oppvarmet areal - heated usable area

TEK17 *Forskrift om tekniske krav til byggverk (Byggteknisk forskrift 2017)* - Regulations on technical requirements for construction works (The building code 2017)

ZEB Zero Emission Building

Introduction

Cabin culture in Norway has a long and rich history dating back to the 19th century. Traditionally, cabins were built as simple hunting and fishing lodges, known as *hytter*, by wealthy landowners and nobility. Over time, the concept of cabin development evolved to become a popular form of recreational retreat for Norwegians, with many families building their own cabins in the mountains and fjords. The country's vast wilderness and stunning natural beauty have made cabin development a beloved national tradition, with many families passing down their cabins from generation to generation.

Sadly, the Norwegian tradition has evolved into something similar to a cabin fever that weakens natural habitats and nature as a whole. More and more virgin areas are converted into cabin plots, more building permits are granted for bigger cabins with more square meters and better appliances. This leads to both land use change and bigger environmental impact in terms of GWP.

Oppdal is one of the biggest *hyttekommuner* that builds up its popularity on the quality of natural mountain landscape, the ski centre that comes with it and a bigger city within 2-3 hours drive distance that accounts for the flow of people. This way it can serve as an incubator of ideas and showcase good practices of cabin development.

Moreover, Oppdal and Ringebu communes are both incorporated in the CommonGround project, that links scientists from NINA and NIBIO and research workers from NTNU with architects, cabin developers and business parties (Nasjonalparken Næringshage). The goal of the project is to: *reduce cumulative detrimental effects and enable second home development (SHD) with minimum (maybe positive) impact.* And since this Master thesis is connected to the project, its goal is coherent with the CommonGround aim.

In the following chapter I am introducing the background and history of cabin development in Norway, outline the current state of it and explain some basics behind nature conservation and regenerative design.

In the site analysis part I look into the site in two scales: bigger by presenting Oppdal as a cabin destination, and smaller by identifying the natural areas around the project plot. I sum up the climate current and future characteristics and talk about the changes that have been made to the surrounding ecosystem.

Design part presents the proposal of the cabin with the implementation of native species, that are meant to be reintroduced or supported on the plot.

Design analysis includes Life Cycle Analysis (LCA) which is the analysis of the potential environmental impacts of the proposed cabin design during their lifetime. Apart from that the chapter provides insight to the energy demand and the grid and PV electricity embodied emissions.

Discussion and conclusion chapters contain the comparison and results of the analysis. They sum up the outcomes of the project and suggest the future work direction.

Background

How the cabin fever begun

"A small, unremarkable often primitively built house" is the first definition of a cabin (no. *hytte*) provided by the Great Norwegian Dictionary. And indeed, its history started this way. The archetype of the Norwegian cabins can be found in mountain huts used for grazing animals in the summer months (no. *seter*) and fisherman houses with one of its ends anchored in land, and the other supported on piles in water (no. *rorbu*). When the industrial revolution in the 19th century started, some of the cabins where abandoned. Industrialization, new possibilities that cities offered attracted people raised in the countryside. On the other hand, 19th century was also a time when romantic movements were gaining strength, favouring discovering nature and spending time outdoors. Cabins placed in very attractive locations seemed a natural choice for those seeking tranquillity and skiing or hiking opportunities. The upper-class begun to take on trips into „the unknown" and not much later they started to look for existing cabins to convert into a vacation home or build their own lodges in nature. The cabin-culture boom continued to raise and by 1900 it was a must for the Scandinavian bourgeoisie to embrace the primitiveness of living in a rural or coastal scenery. (Löfgren, 1999) After the First World War the new middle class joined the upper one in the hunt for rustic life. *Hytteliv* became more approachable with the introduction of collective agreements and the Holiday Act, which entitled workers to paid holidays.

Cabin-culture, however, has also other roots emerging from the working-class influx to overpopulated towns. In order to secure affordable accommodation, the newly arrived residents were compelled to create satellite "cabin neighbourhoods" adjacent to the larger towns. (Kaltenborn, 2005) What was the main housing at the begging of their careers, later on became an attractive holiday settlement.

The period following the Second World War until the 1960s witnessed a surge in "self-builders". In times of housing shortage, the cabins were a primitive, makeshift solution constructed with whatever material was available. An abundance of land made it easier for people to procure a site somewhere in nature rather than in the urbanised area. Only later, some of these cabins gained a status of a holiday home, initially they served as a main living accommodation. However, rustic and basic they may seem the power generator and a septic tank was often there, satisfying basic needs of everyday life. (Garvey, 2008)

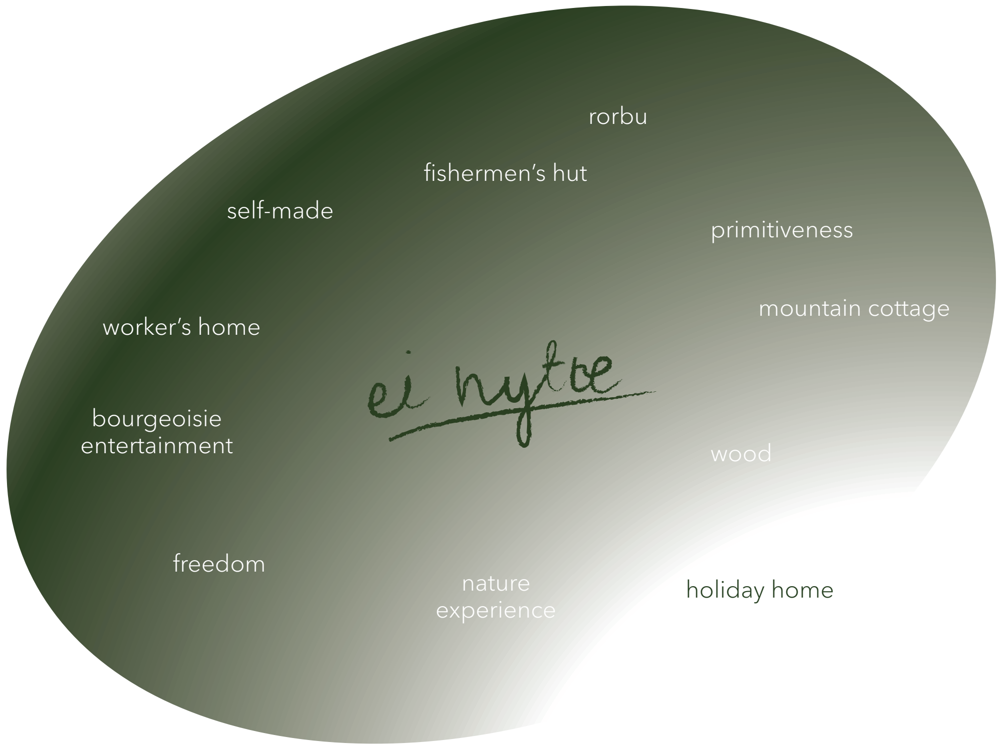


Fig. 1 From what cabins evolved into a holiday home

The picture of the cabin draws itself as a rather complicated conglomerate of a desire of nature experience, working class primitive housing, self-made home, pasture hut with barely any appliances and a posh holiday home for those who can afford it. However, there is a link between all these elements - the profound sense of freedom, both physically and from societal expectations.

Cabin stats & reality

The core idea of the cabin lifestyle stayed more less the same with some minor alterations – what had to be done with manpower, now is done by machines and the physical work has switched towards sport activities. The outer shell, however, and its materiality are the factors opening the new chapter in cabin history. As one may expect the picture of today's cabin has undergone major changes throughout the past 50-60 years.

Primarily, there has been a significant change in the size of the cabins. At the start of gathering statistical data, in 1983 the average usable area of a newly completed cabin was 62 m2, the area has been rising since then with a peak in 2009 and the average cabin size of 104 m2. The latest data for 2022 shows that the average newly built cabin square footage lays at 100 m2. One must remember that those statistics include extensions and annexes to the existing cabins, so the size of actual, new, standalone cabins might be even bigger. With the size the architectural opportunities multiply. Nowadays a cabin doesn't necessarily have to have a rectangular plan. Many of them have gone into more sophisticated shapes, with an atrium or have been dispersed into smaller units. (for e.g. hytte i Portør, arch. Bengt Espen Knutsen).

Right now (at the begging of 2024) there are exactly 450 492 cabins, summer houses and similar leisure homes. Apart from that, there are 32 442 all-year round houses or farmhouses which are used as a holiday home. This means that almost every tenth Norwegian is a cabin owner. In practice, different surveys show that between 47% and 56% of Norwegians have access to a cabin either as an owner, co-owner or through friends or family. (Rye, 2012)

The number of completed holiday homes in Norway is rising, as well as the area of them, with a clear upward trend. Starting at around 2000 newly built cabins in the 80s', we are now exceeding 7000 in 2022. Taking into account the fact that the cabins stay empty for around 300 days a year, we have to find a way to minimise their environmental impact and find a way to make them nature-positive (Hattrem, 2022).

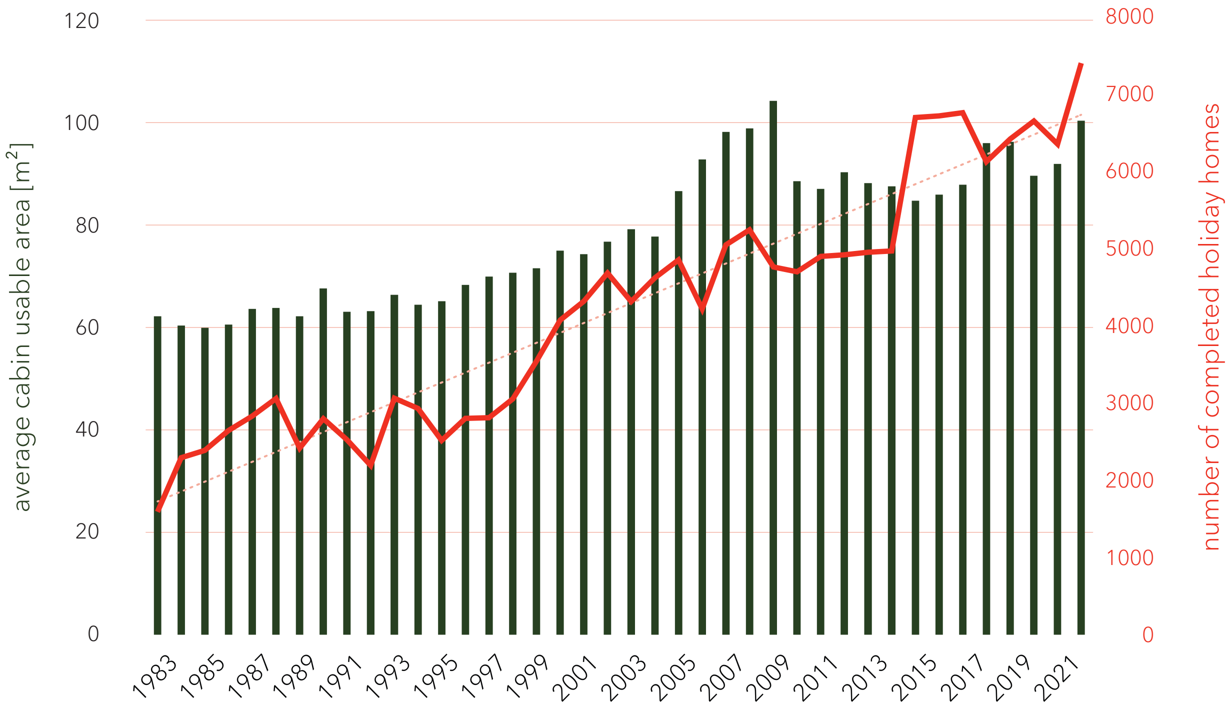


Fig. 2 Growth of the number of completed cabins and their usable area over the span of 40 years

Any profits?

But what is it about the cabins that makes such a clear passion in Norwegians for owning one? The primary reasons for owning a cabin revolve around the opportunities it presents for outdoor living, recreation, and unwinding. Additionally, it serves as a way to escape the monotony of everyday life and connect with nature. For numerous individuals, it also functions as a hub for engaging in sports activities and symbolizes an emotional connection to a particular location, often rooted in familial ties.

Many surveys show that nature has direct impact on people's well-being, evokes positive emotions, reduces stress. (Kuo, 2015) (Hartig, Mitchell, de Vries, & Frumkin, 2014) Daily life easily becomes monotonous and hectic and a cabin in nature gives cabin visitors a feeling of peace, grounding and relaxation. Consequently, cabin culture with a lot of time spent outdoors, recreation and nature observation has a positive influence on public health and can reduce risk of many lifestyle diseases such as depression, obesity, diabetes and hypertension (Kaltenborn, et al., 2005).

It will be unjust however not to mention some financial positives that owning the cabin brings into life of its owners. Purchasing a cabin with an idea of renting it can bring an extra income, but more importantly the property will very likely increase in value over time. Some say it is the safest investment on the market. Still, not every commune has a property tax, but many of them are taxing as much as they can. (Pihl, 2021) On the other hand, renting a cabin is also not very popular among Norwegians. 79,8% have never rented their cabin out. (Hytteavisen, 2022)

Nature in a losing position

Sadly, the cabin life with all the positives it brings to life has grown to an enormous extent and consequently resulted in significant drawbacks for nature. First and foremost, cabin building is responsible for major land use change. Since most of the cabins lay in the coastal or mountain areas various ecosystems are being influenced such as: wetlands, forest, mountain areas and open lowlands. In Oppdal commune, 3,63 km2 of land is allocated for cabins or leisure homes, as they are often referred to in Norwegian sources. In comparison, housing makes up only 2,10 km2 in this commune (SSB, 2024). With the transport infrastructure needed, it makes up a significant piece of altered land. With the road infrastructure comes traffic, noise, light and air pollution. And it is exactly land-use change that is responsible for putting 90% of Norwegian species in danger of extinction. (Artsdatabanken, 2024) The overall impression of the cabin culture can be described with a renowned image of a man sewing off a branch he is sitting on. All of us want to experience nature at its best, untouched state, while at the same time we are doing much to leave it impaired and fragmented with less biodiversity and more human traces.

What is biodiversity?

Biodiversity refers to the variety and variability of life on Earth, encompassing all living organisms from plants and animals to fungi and microorganisms. It includes the diversity of ecosystems, species, and genetic resources that interact and contribute to the complex web of life sustaining our planet. This diversity plays a crucial role in maintaining ecological balance, supporting ecosystem services, and providing resilience against environmental changes. In other words, preserving and enhancing biodiversity is essential for the health of the planet and all living beings inhabiting it. We rely on nature and what it provides for but most of it we take for granted. Healthy ecosystems are oxygen factories, organic matter source, home of pollinators and carbon sinks. And apart from that nature is undoubtedly a value of itself.

Biodiversity can be measured in several ways, from which the species richness is the main one and has many implementations. Quantifying the number of species is the basis of many ecological models of community structure and is valid for comparisons between sites. (Gotelli & Colwell, 2001) For example Living Planet Index is a well-established model for the big animals, plants and ecosystems, showing that we are now missing 69% of species globally compared to what was recorded in 1970, and 18,7% in Europe and Central Asia macroregion. (World Wildlife Fund (WWF), Zoological Society of London, 2022) There are also other ways of monitoring which are being introduced in Norway specifically such as: acoustic monitoring, eDNA and seabird monitoring that help to detect alien species. (Norsk institutt for naturforskning (NINA), 2024) Norway also established its own way of showing trends in loss or repair of biodiversity which is the Nature Index. It is based on numerous indicators (native species) that represent different aspects of biodiversity in different types of ecosystems (mountains, forest, sea etc.) For forest ecosystems the index measured in 2020 is 0,41 (in the scale 0-1) and 0,68 for wetlands. (Miljødirektoratet, 2024)

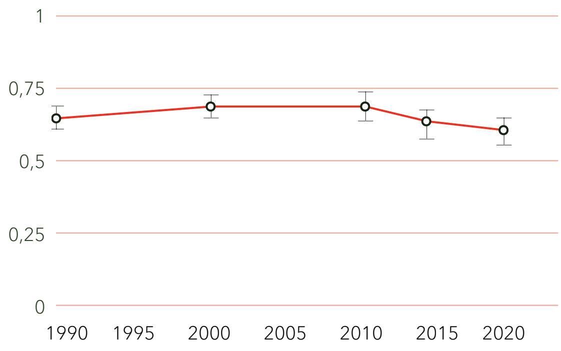


Fig. 3 Changes of Nature Index over the years in mountain ecosystems in Central Norway.

Apart from experiencing biodiversity loss the extensive build and way of using the cabins is a major energy trap. In 2023 all second homes in Norway and their owners were responsible for 1,9% total energy use of the country. (Elhub, 2024) Since they are built with more and more amenities relying on running water it is recommended not to switch off the heating completely in winter, to avoid pipe freezing and damage. The more amenities the cabin has, the greater the risk of significant damage. (Huseierne, 2022) This explains the amount of power used by cabins even though they stay empty most of the time. The conclusions are quite simple: built the cabins more rustic or make them occupied more often.

Another aspect of cabin development is the cultural landscape it creates. Cultural landscapes are an example of human-influenced nature which is in itself an important ecosystem, but also a cultural heritage. A view over a fjord with a red cottage on piles has become a selling picture for those wanting to explore Norwegian nature. Extensive built up of cabins distorts the perception of natural areas and disrupts the proportion of man-made versus natural.

Possible solutions and way ahead

Having the awareness and expertise it is possible to restore nature and bring back biodiversity to the places where it was damaged. Nature restoration, however, cannot compete with intact nature and serve as an excuse for excessive land development but it can significantly help nature to recover by preparing a room for ecological processes better start for living organisms. Practically it is done by reintroduction of animals or plants to their native ecosystems where now there may be a grey area, filling ditches on peatlands or establishing spawning habitat in regulated rivers. When it comes to cabin plots, change of land use is the main driver for biodiversity loss, so the focus should be put into that. (Semenchuk, et al., 2022)

The Norwegian Institute for Nature Research "NINA" have listed area neutrality, material and energy reduction, and limited extension of infrastructure as the basis for sustainable vacation home development (Kaltenborg, 2022).

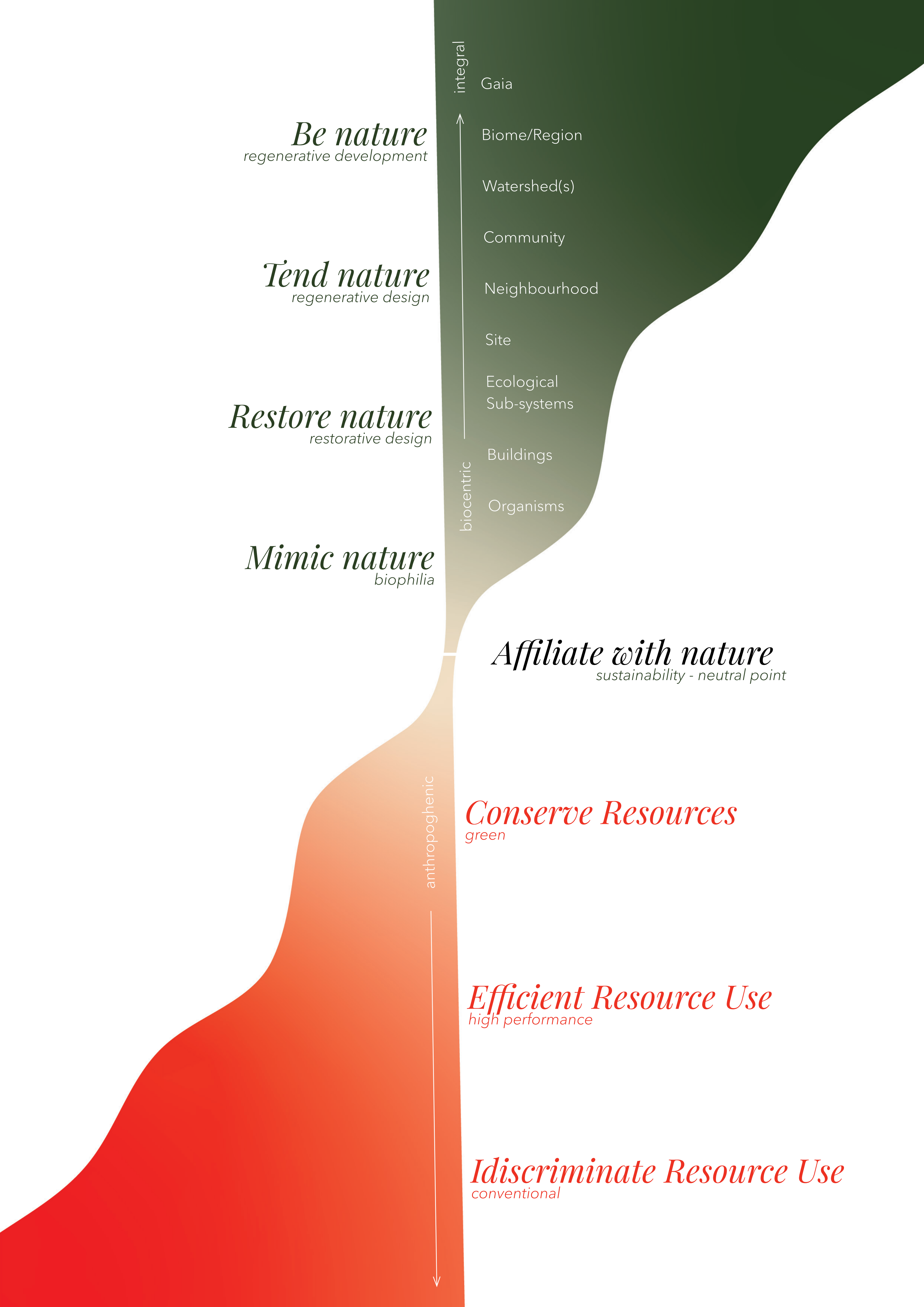
Regenerative architecture

The design I am going to develop shall adhere to the principles of regenerative and biophilic architecture. Regenerative architecture is a design approach that aims to create buildings and spaces that actively contribute to the health and well-being of the environment. This approach goes hand in hand with the so called Naturavtale (eng. The Nature Agreement) that Norway agreed to follow in December 2022. It was signed with the aim to protect 30% of nature and restore 30% of all nature that has been degraded or partially destroyed by 2030.

It is not easy to define regenerative design, but if a short and straightforward definition is needed, it could be described as a design that has a positive impact on nature. It requires holistic approach and aims to create resilient and equitable solutions that align the needs of society with the complexity of nature. The principle of regenerative design seeks to establish a beneficial cycle where the use of resources within a process, such as raw materials, water, air and energy, is counterbalanced by the generation of products or by-products, which are of the same quality and quantity. In the architecture field, the aim is to plan the design in a way, that it reproduces and recreates all of its components and the resources it consumed to be built, to perform and to function. Regenerative means something more than sustainable. (Attia, 2018)

The term regenerative withholds other ecological approaches in it:

Fig. 4 [opposite page] Regenerative approach framework. Contrast between conventional and integral design. On the basis of Regenesis group.


integral
Gaia
Biome/Region
Watershed(s)
Community
Neighbourhood
Site
Ecological Sub-systems
Buildings
Organisms
biocentric
Be nature
regenerative development
Tend nature
regenerative design
Restore nature
restorative design
Mimic nature
biophilia
Affiliate with nature
sustainability - neutral point
anthropoghenic
Conserve Resources
green
Efficient Resource Use
high performance
Idiscriminate Resource Use
conventional

Biomimetic design is a philosophy that utilises naturally developed functional patterns, natural forms and processes as a model for humans to follow. It argues that nature developed solutions and techniques are much more effective and sustainable. Cradle to cradle and biomimicry are in line with this philosophy. (Mang & Reed, 2012)

Biophilia is a term that generally acknowledges the people's desire to affiliate with other forms of life. It is less engaged in biodiversity and more anthropocentric than biomimetic design. Those that employ biophilic methodologies in their design create direct associations with natural characteristics and components; imitative associations through the utilization of nature-related imagery and resources; and evocative associations that use the characteristics and attributes of nature in design, including sensory diversity, prospect and refuge, serendipity, as well as discovered complexities. (Mang & Reed, 2012)

Restorative is an approach that underlines the re-establishing and the self-organizing or evolving capability of natural systems. This method recognises the involvement of humans in the process and thus is closely intertwined with the ecosystems. The role of human is more active than in previous two approaches, but still often limited to occasional intervention and when the well-being of an ecosystem is being restored and set in motion the role of human is finished. (Mang & Reed, 2012)

Regenerative design ties closely humans and nature and agrees that those are one. As described above, in order to create healthy ecosystems, people have to create conscious integrity with nature so that both are beneficial.

In order to achieve the goals of regenerative design different frameworks have been developed, of which one of the first was developed by Regenesis group and John Lyle. The four premises described below, function cohesively to incorporate and coordinate motivation and resources, establishing the structure through which techniques and principles from different ecological design systems can be assimilated into a sustainable practice.

Key premises of regenerative design

Place and Potential - First step is to understand, in the most multidisciplinary manner, the dynamics of a place. Place is always unique and is a function of many factors. It can be defined as a multilayered network of living systems that results from interactions within a certain geographical location and time (with its climate, mineral and other deposits, soil, vegetation, water and wildlife) and culture (with its traditions, distinctive customs, economic activities, traffic etc.) (Dias, 2015) This will give the designer a base to identify the potential for bringing more viability as a result of human presence in that place. (Mang & Reed, 2012)

Goals focus on regenerative capacity - Only after analysis of a place, defying the goals of a regenerative project is possible. The performance of the project is measured according to the contribution of its built environment to the regenerative capacity of the larger living ecosystem as well as of the ongoing co-evolution of all involved actors in built, cultural and natural environments. The goals should address three aspects of regenerative built environment: operational, organisational and aspirational capacity. The first one focuses on energy, materials and support systems that enable evolution of life in a place. The second one focuses on how to enhance the place and its core values so that it becomes something to be cherished. The third one focuses on evoking creativeness and sense of empowerment in the inhabitants who are able to make significant contributions to the place. (Mang & Reed, 2012) Within that context, regenerative goals are set and performance measured in terms of the intended contribution of the built environment to the regenerative capacity of that larger living contex.

Partnering With Place - This step bases on a new role we, as the architects, should undertake. It asks for switching from the mindset of a builder to a mindset of gardener, who expects the design to change and work with evolving systems. This step requires all of the stakeholders to be involved and all of their needs to be considered, including site and surroundings context. (Mang & Reed, 2012)

Progressive Harmonization - The final design, or even the building, should not be the ultimate goal. Regenerative approaches aim to start and support a process of continually increasing the pattern harmony between human and natural systems. The responsibility of a regenerative designer includes putting in place, during the design and development process, what is required to ensure that the ongoing regenerative capacity of the project, and the people who inhabit and manage it, is sustained through time. and require indicators and metrics that can track dynamic, holistic and evolving processes (Mang & Reed, 2012).

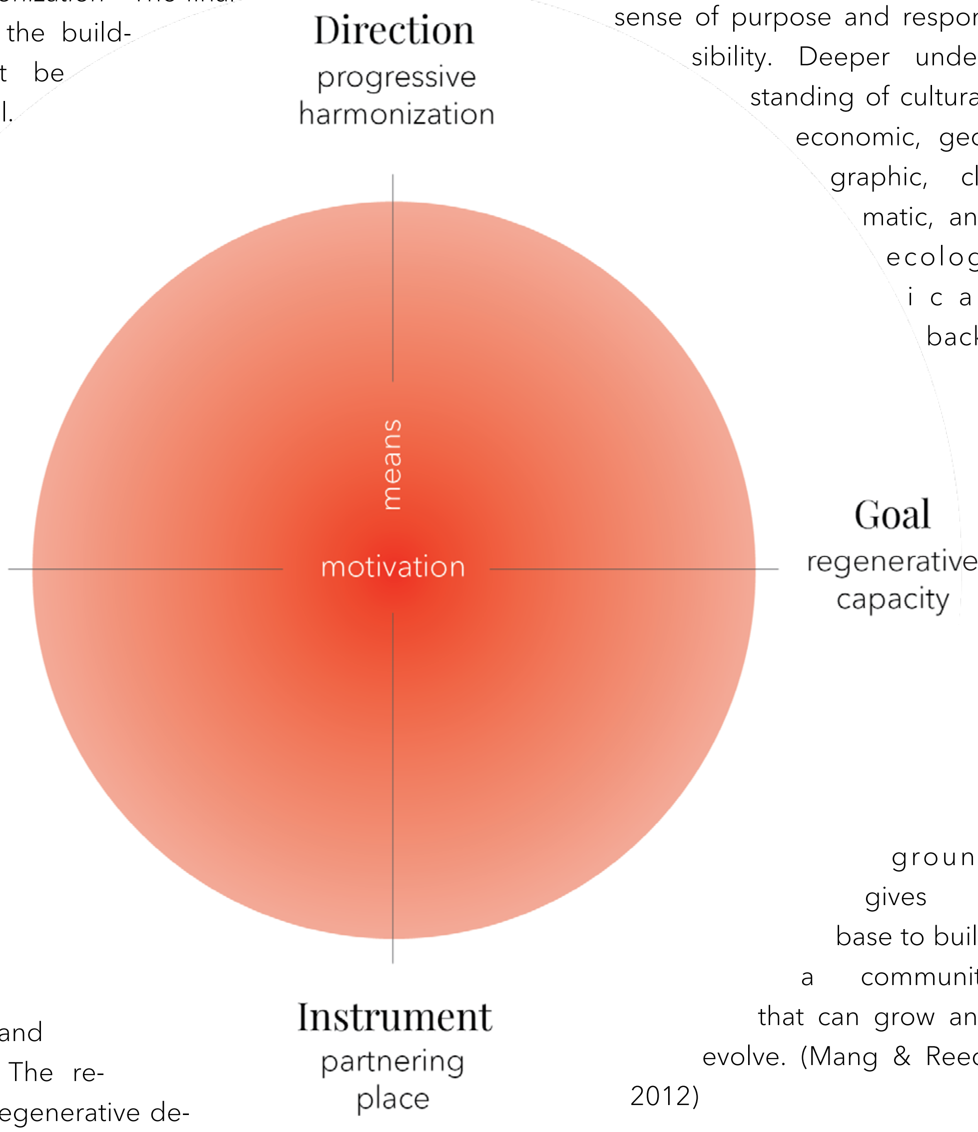


Fig. 5 [above] Key premises of regenerative design

To translate this key premises into the language of the architectural designer one can extract 3 main steps:

1. Understand the relationship to a place

It involves integral assessment of the whole system that a place belongs to. Discovering the patterns that are preset in the place, its essence and function can provide inhabitants with a sense of purpose and responsibility. Deeper understanding of cultural, economic, geographic, climatic, and ecological background gives a base to build a community that can grow and evolve. (Mang & Reed, 2012)

2. Design for harmony with a place

This step is a decision saturated one, with choices of form, materials, technologies and long term operation and maintenance. The designer should base on the insights of the previous step to develop a coherent concept that integrates human and nature needs and is beneficial to both parties (Dias, 2015).

3. Co-evolution

The life of the regenerative project doesn't end with it's construction. During the design and development process choices that have been made should ensure ongoing regenerative capacity of a project. The well-being of the people who inhabit and maintain it should be satisfied and have the same value as the biodiversity growth. (Mang & Reed, 2012)

The success of the project depends on ways we approach the task. It is important to:

+ Utilize a holistic approach to incorporate whole systems thinking into the design, planning, and decision-making processes.
+ Establish collaboration and synergy among different disciplines, project phases, team members, and local stakeholders.
+ Enhance stakeholders' comprehension and recognition of the location and its new opportunities, as well as their ability to become more effective collaborators within the evolving system of life.

Site analysis

Oppdal area and its characteristics

Oppdal is a village located in the municipality of the same name in Trøndelag county, approx. 120 km south of Trondheim. The first settlements in Oppdal date back to the 7th century and were probably linked to lucrative hunting possibilities (specifically for reindeer) in the mountain range, but over time the intersection between the trade routes to Sunndal at the coast, Dovrefjell mountains and Trondheim laid the foundation for growth. (Stokkan & Haugen, 2024) Right now, it is also laying on the E6 road that goes through whole of Norway.

In the Viking era there were about 70 farms in the area and despite several obstacles on the way (worsening climate for farming and Black Plague) agriculture was the main occupation for people living in Oppdal till the end of 19th century. Currently, breeding and milk production continue to form a considerable portion of the commune's economic foundation. Almost all of the agriculture areas are used for grazing and grass production, since Oppdal commune is Norwegian leader in sheep breeding with approximately 45 000 sheep grazing there on the summer pastures. (Stokkan & Haugen, 2024)

Oppdal's name originated from a farm established there and can be translated into "upper valley". Indeed, the village lays in the valley, at 545 m.a.s.l. and is surrounded by mountains of 1500–1900 m with the highest peak of Storskrymten at 1985 m. There are also 7 lakes and 7 rivers crossing the commune. The geographical characteristics and the biggest ski centre in Norway make Oppdal one of the biggest "hytte kommuner" with 4 254 holiday homes as of 2024. (Trøndelag fylkeskommune, 2024)

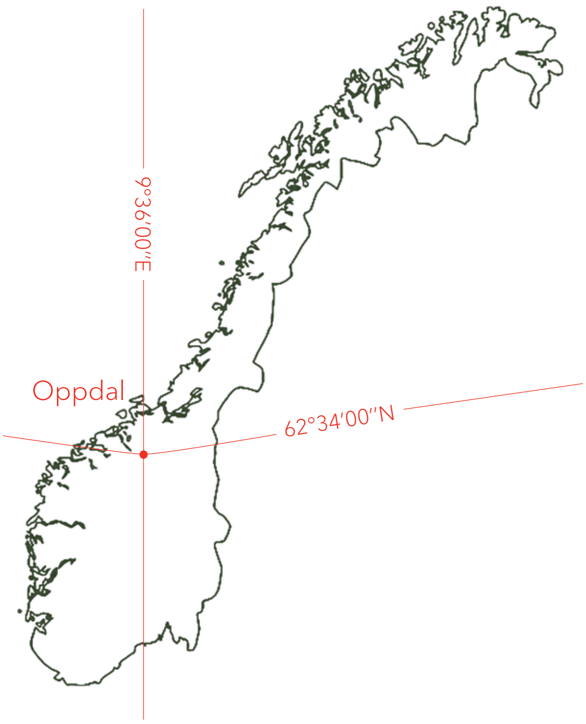


Fig. 6 Location of Oppdal in Norway

Oppdal climate

Oppdal climate is characterised by cold winters, chilly summers and generally quite a lot of precipitation days. According to Koppen-Geiger classification it is a subarctic climate (Dfc).

On the temperature diagram on the right (Fig. 8) one can see that the highest temperatures are reached in July, barely exceeding 20°C, while the lowest are usually reaching -10°C, but can sometimes drop to -27°C, as stated in the EPW file. Only during the 3 months of the year one can expect thermal comfort in Oppdal, whereas from November to April mean daily temperature stays below zero. (Weather Spark, 2024)

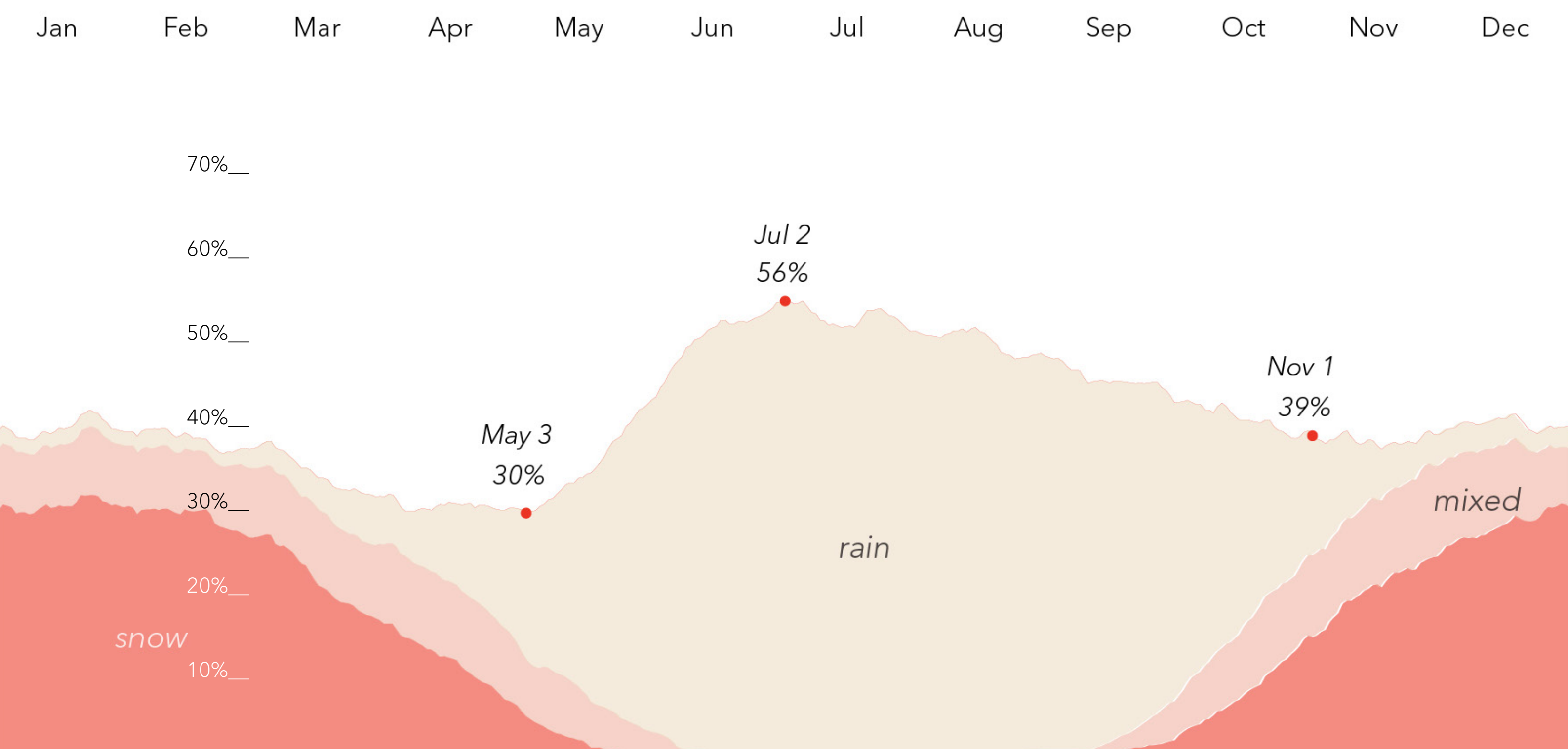
The probability of precipitation in Oppdal is fairly high throughout the whole year, with summer being the wettest season (on average 126 mm of rain in July). The snow season starts in mid-October and ends in the end of May with a sliding 31-day snowfall of at least 25 mm. January is the month with the biggest snowfall average – 607 mm. Consequently, Oppdal is mostly cloudy or overcast (over 60% of sky cover) throughout the year. Spring is the season however, when one should expect most sunshine, with up to 41% of the time with sky cover lower than 60%. (Weather Spark, 2024)

Since, the site is located 62° to the north the day and night hours vary greatly throughout the year. The shortest day is only 4 hours and 54 minutes long (December 21st), whereas the longest lasts for 20 hours and 4 minutest (June 20th). In June, it never gets fully dark in Oppdal, after sunset civil twilight can be observed until the sunrise. (Weather Spark, 2024)

Judging by the daylight hours, one can expect that the most radiation comes from the sun in the summer. Average daily total global horizontal radiation in June is 4,9 kWh/m^2 what makes it a great season for PV production. During the winter however, not only the radiation is very low but also the position of the sun over the horizon. Mountainous terrain affects the light range and there will be areas that do not get any sunlight in the period of the shortest days.

Winds in Oppdal are mostly influenced by the natural corridors shaped by mountains and valleys. The E6 road crossing the municipality also shapes the wind patterns in the nearest areas. Most of the winds come from west and south direction. Those directions are prevailing from August to May. In June wind directions are fairly even with north winds being more noticeable. The average strength of the wind reaches 5,2 m/s

Fig. 7 Daily Chance of Precipitation in Oppdal - the percentage of days in which various types of precipitation are observed, excluding trace quantities: rain alone, snow alone, and mixed



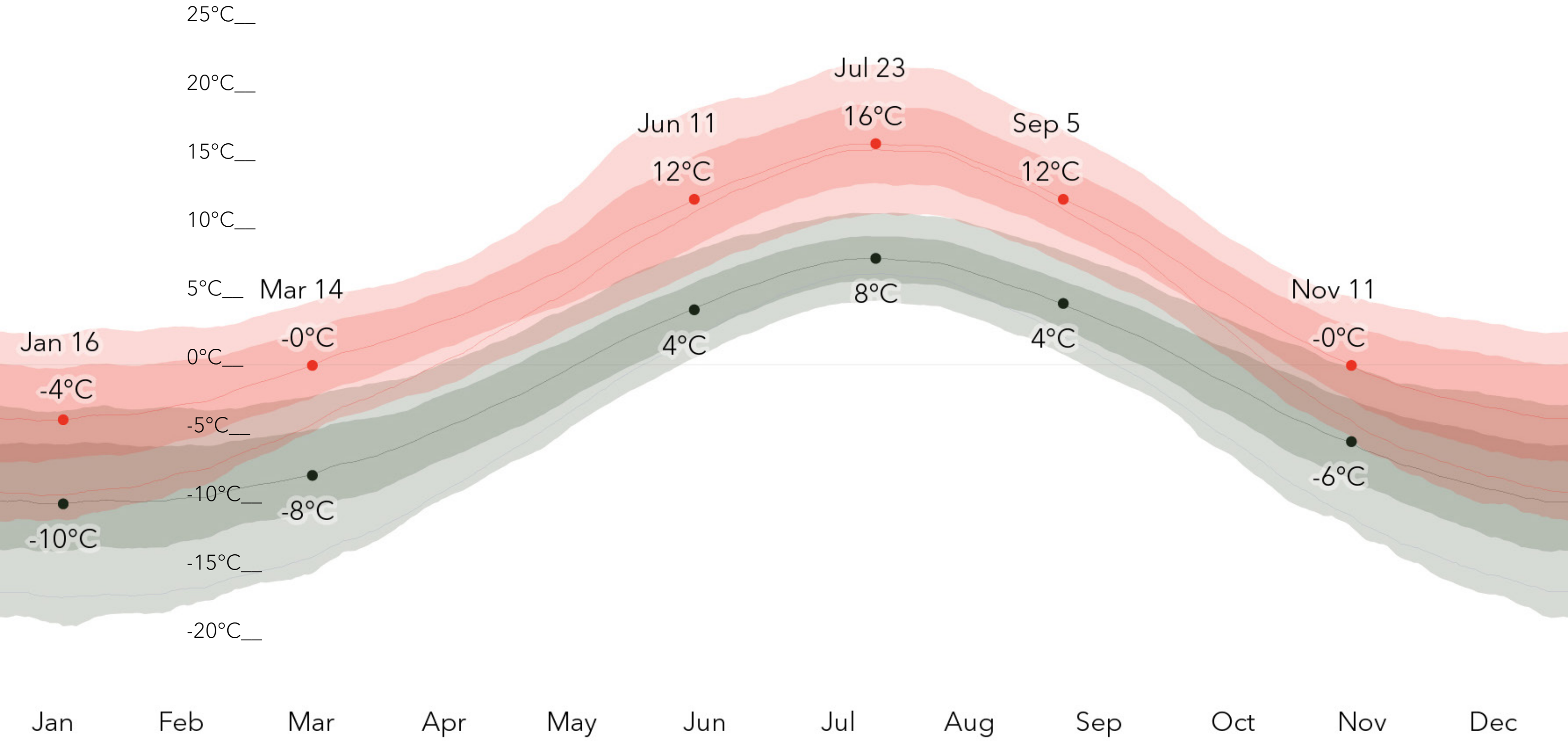


Fig. 8 The daily average high (red line) and low (blue line) temperature, with 25th to 75th and 10th to 90th percentile bands. The thin dotted lines are the corresponding average perceived temperatures.

in January and is the lowest at the beginning of August with just 2,8 m/s. Both the direction and the speed of the wind has great seasonal variations. Winters are characterised by colder, stronger winds from west and east direction reaching 14 m/s. Summers by smaller wind speed and varied wind directions. (Norsk Klima Service Senter, 2024) (Weather Spark, 2024)

All of the climate characteristics influence the way we live and design our buildings. The primary goal of a built environment is to provide shelter from unfavourable conditions, or in other words to ensure comfortable environment to live in. Since Oppdal has a harsh climate, the number of hours that are comfortable during a year without any shelter is just 43 (0,5%). Those hours are depicted on a psychrometric chart together with the strategies to widen the comfort zone. (Fig. 9) By ensuring those 5 strategies proposed in Climate Consultant, namely:

1. heating and humidification if needed,
2. passive solar gain
3. internal heat gain
4. wind protection of outdoor spaces
5. Sun shading of windows

100% of hours throughout a year can be comfortable for the occupants of the building.

Designing according to climate, however, is not only crucial for our well-being but also for the energy performance of the building. The more effort we as designers will put in the planning process the less energy will be used in operational phase of the building. All decisions according to the shape of the building, its orientation, insulation and material choice, size and placing of the windows should be taken with climate characteristics in the forefront when we talk about regenerative architecture… Those decisions influence not only human comfort but also energy demand of the building. And of course, the less energy we need to produce the more space we leave for nature. Nature, unlike any manmade products or designs, is only becoming better with time, more liveable, pleasant, green and thriving. As the project aims to be regenerative this is exactly what we are trying to achieve - self-sustaining design, which is part of the ecosystem, of its wellbeing. Learning from that, trying to implement this way of thinking in the project can bring us much (non) revolutionary ways of designing which were already "invented" years ago by nature.

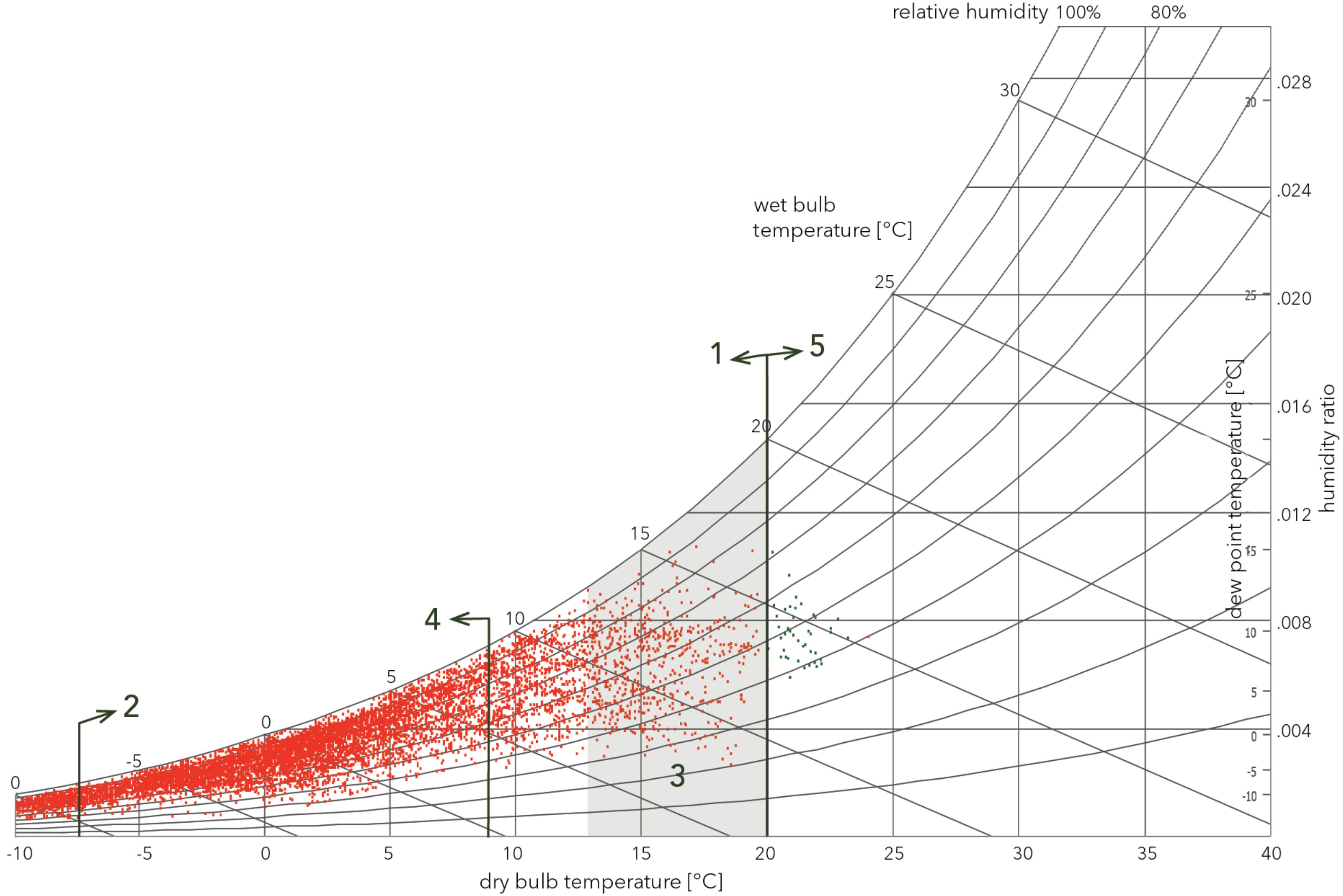


Fig. 9 Psychrometric chart. Green (red) dots represent hours of the year with (un)comfortable conditions according to California Energy Code Model

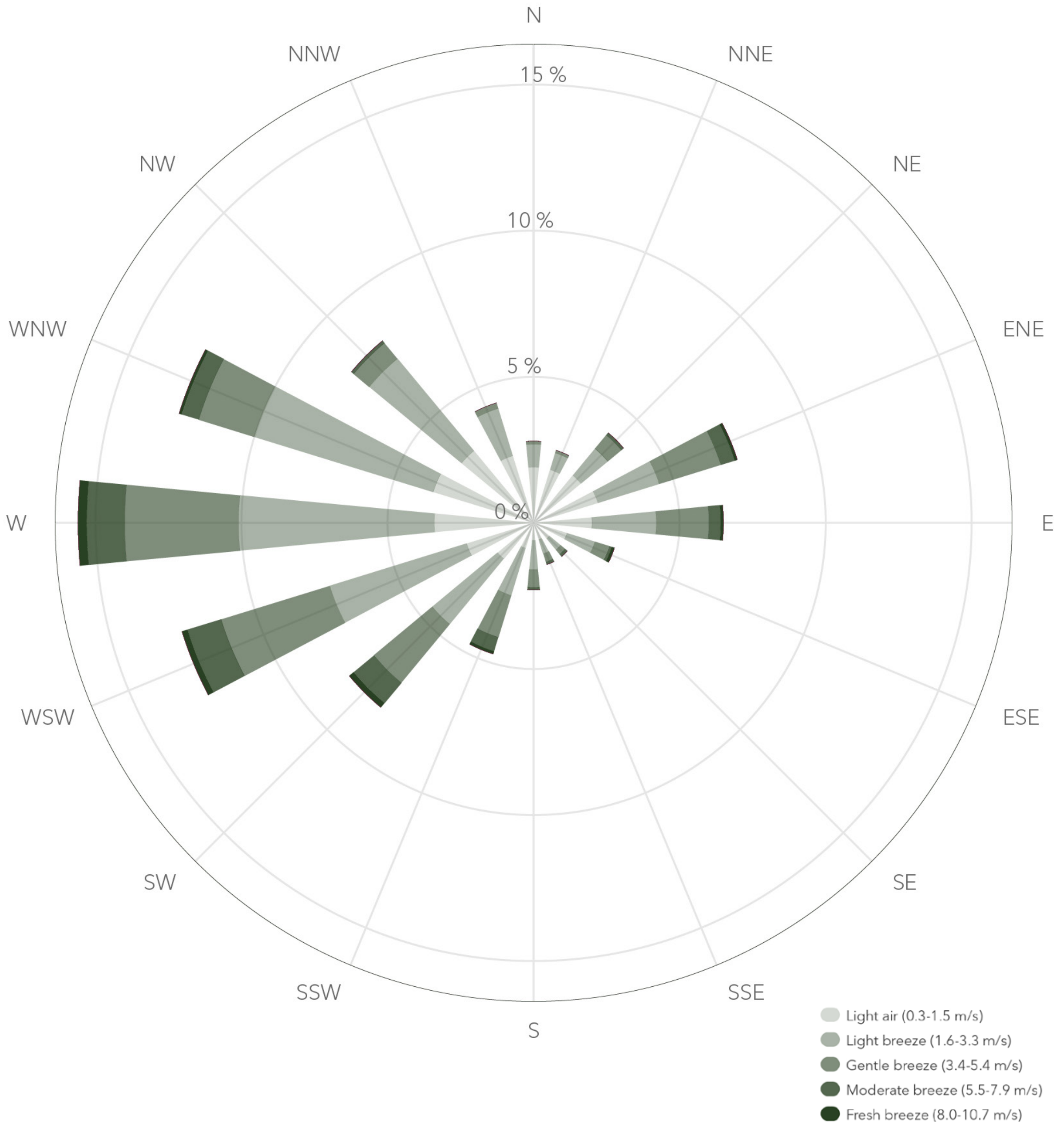


Fig. 10 Wind Rose for Oppdal - Sæter for the period of last 10 years (3/2014 - 3/2024) https://seklima.met.no/windrose/?timeresolution=last_10_years&locationid=SN63705

In 2100, however, the climate won't look the same as we can expect from the graphics based on data gained so far. Oppdal municipality will experience more extreme precipitation leading to increased flooding and a higher risk of landslides and storm floods. The temperature is projected to rise by 2.4 degrees Celsius, resulting in fewer skiing days and allowing more space for forests to grow at the expense of reindeer habitats. This shift in climate patterns will undoubtedly have significant impacts on the environment and wildlife in the region. (Støstad, Skjæraasen, & Holvik, 2020)

Oppdal natural specifics

The area has a large variety of ecosystems and vegetation types, which are changing with height in Oppdal's mountainous terrain. In the valleys NIBIO specified mostly forests: coniferous, mixed and boreal deciduous forest with wetlands and lakes in some places apart from built-up terrain. Higher up it is mostly grassland, coniferous forest, deciduous forest and cultivated land. Close to the peaks one can experience moor (no. hei), bare rock other sparsely vegetated land with permanent snow banks in certain places (NIBIO, 2024). The plot is situated on quite a steep terrain, but it doesn't imply a low variety of species. On the contrary, there are diverse types of vegetation that we can describe in the closest area.

Risheia – is the low vegetation type that often occurs on in places with stable snow cover, but relatively early melting (June). The snow cover provides good protection against wind and low temperatures and helps prevent drying out. Risheia's vegetation has much in common with the blueberry forest and can serve as a continuation of this type of vegetation across the forest boundary. The most common formations have dwarf birch, blueberry, mountain sorrel, and wood cranesbill as the dominant species cover of moss. If there is a good water supply, willows and silver willows can have high coverage (Angeloff, 2022).

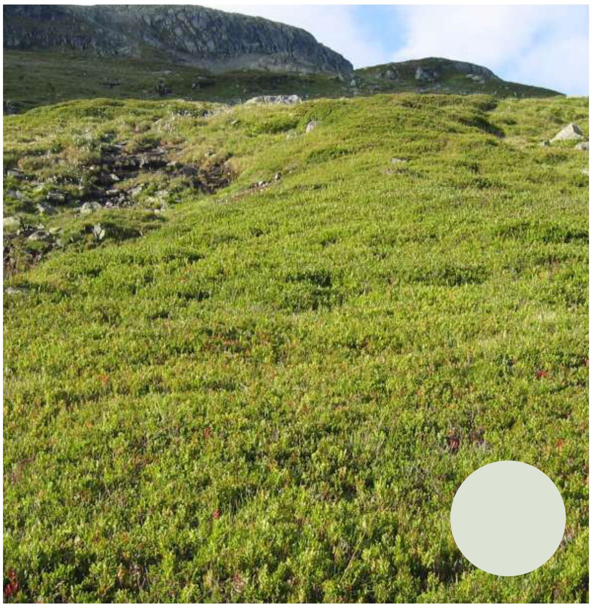


Fig. 11 Risheia landscape with blueberry

Boreal deciduous forests make up nearly 30 percent of Norway's forest area. In the area surrounding the plot birch and willow are dominating tree spieces.

Hagemarkskog - The vegetation in a garden forest – which is a direct translation of hagemarkskog is the result of strong influence from people and animals through grazing, mowing, fertilising, trampling and clearing. The type can originate from any forest community, but typically consists of meadow-type forest and richer sections of blueberry forest. The most extensive presence is usually near farms where one can see regrowth stages of previously cultivated land that still show signs of cultivation. Characteristic of the garden forest is a sparce layer of birch, alder, spruce or warm-loving deciduous species (Angeloff, Hagemarkskog, 2022).

Fig. 12 Hagemarkskog

Blåbærbjørkeskog - The most common of the birch forests is blueberry birch forest. This type occupies a middle position with regard to requirements for both water and nutrients in the soil. The type occurs in both upland and sloping terrain, with a moderate water supply. This type of vegetation is not especially rich in species, but the tree layer here is higher, denser and with more straight trunks. The most important species in the field layer will usually be blueberry and wavy hair-grass (Angeloff, Blåbærbjørkeskog, 2022).

Fig. 13 Blåbærbjørkeskog

Engbjørkeskog - Meadow birch forest is a common term for all types of birch forest on nutrient-rich land dominated by herbs, grasses and ferns. The meadow birch forest most typically occurs at the bottom of ridges, in depressions and along watercourses, but also on higher terrain forms when there are enough nutrients. Meadow birch forest is a highly productive and species-rich vegetation type. The tree layer is straight-stemmed and dominated by birch, but other species such as aspen, rowan and willow species can also have high coverage (Angeloff, Engbjørkeskog, 2022).

Fig. 14 Engbjørkeskog

Besides that, we can also identify two types of agricultural land, build-up areas and other areas (here – downhill ski-slope) which are poorer in species and dependent on human actions.

Beitevoll (Pasture) - This is grass- and herb-dominated vegetation that has arisen from long-term use for mowing and grazing. There are very different forms, from wet meadows with elements of bog species to dry meadows dominated by drought-tolerant herbs and grasses.

Fig. 15 Pasture

Dyrka mark (agricultural land) – the image of this land is relying on the crop growth. Cultivated land out of operation is also under this type with a presence of pioneer species.

Fig. 16 Cultivated land

Fig. 17 Vegetation map - Risheia, Hagemarkskog, Blåbærbjørkeskog, Engbjørkeskog, Pasture, Cultivated land, Built-up area, Other used area. Red frame shows the area classified as grazing forest, (Jordal, 2009)

The area marked around the plot was designated as grazing forest (no. beiteskog) in Naturbase by Miljødirektoratet (Jordal, 2009). The evaluation was based on the fieldwork done in August 2008 and the location was given value B (important) due to its ongoing use and numerous grazing indicators, suggesting a lengthy history of grazing. The site is adjacent to the downhill slopes at the Stølen ski centre (north-east of Oppdal centre) in the east, and fully borders cultivated land, fertilised pasture and garden land in the south and west. The site is located in the middle boreal vegetation zone and also in the transition section between oceanic and continental vegetation sections. (Miljødirektoratet, 2024)

The site is located on the slopes of Syndre Aurhøa. The vegetation is dominated by birch forest with undergrowth rich in grass and herbs (C2c - low herbaceous cover of tall perennial birch forest). There are transitions between moist, fresh and slightly dry areas with somewhat different undergrowth. Grazing forest is generally considered somewhat threatened as a vegetation type (Miljødirektoratet, 2024).

Jordal, during his fieldwork recorded 65 plant species, including auricle's vetch, brook flower, meadow bumblebee flower, mountain violet, mountain goulax, Lapland forget-me-not, mountain timothy, cold eyebright, meadow pea, hare's rye, white-leaved thistle, white and marsh ant, John's & common sedge, priest collar, red clover, sweet violet, yellow rattle, tiril's tongue which confirms the richness of this environment (Miljødirektoratet, 2024).

The site was grazed by sheep, before it was divided into plots for holiday homes. The forests in Gjevilvassdalen have been more open in the period 1850-1950, but the details of the forest history for this locality are not known (Miljødirektoratet, 2024).

It is advised to avoid or minimise physical interventions in the locality if one wishes to preserve the natural values. Grazing should be maintained at a level that is sufficient to preserve the vegetation and prevent overgrowth (Miljødirektoratet, 2024). These are the guidelines which I would implement in the design of the cabin and surrounding areas.

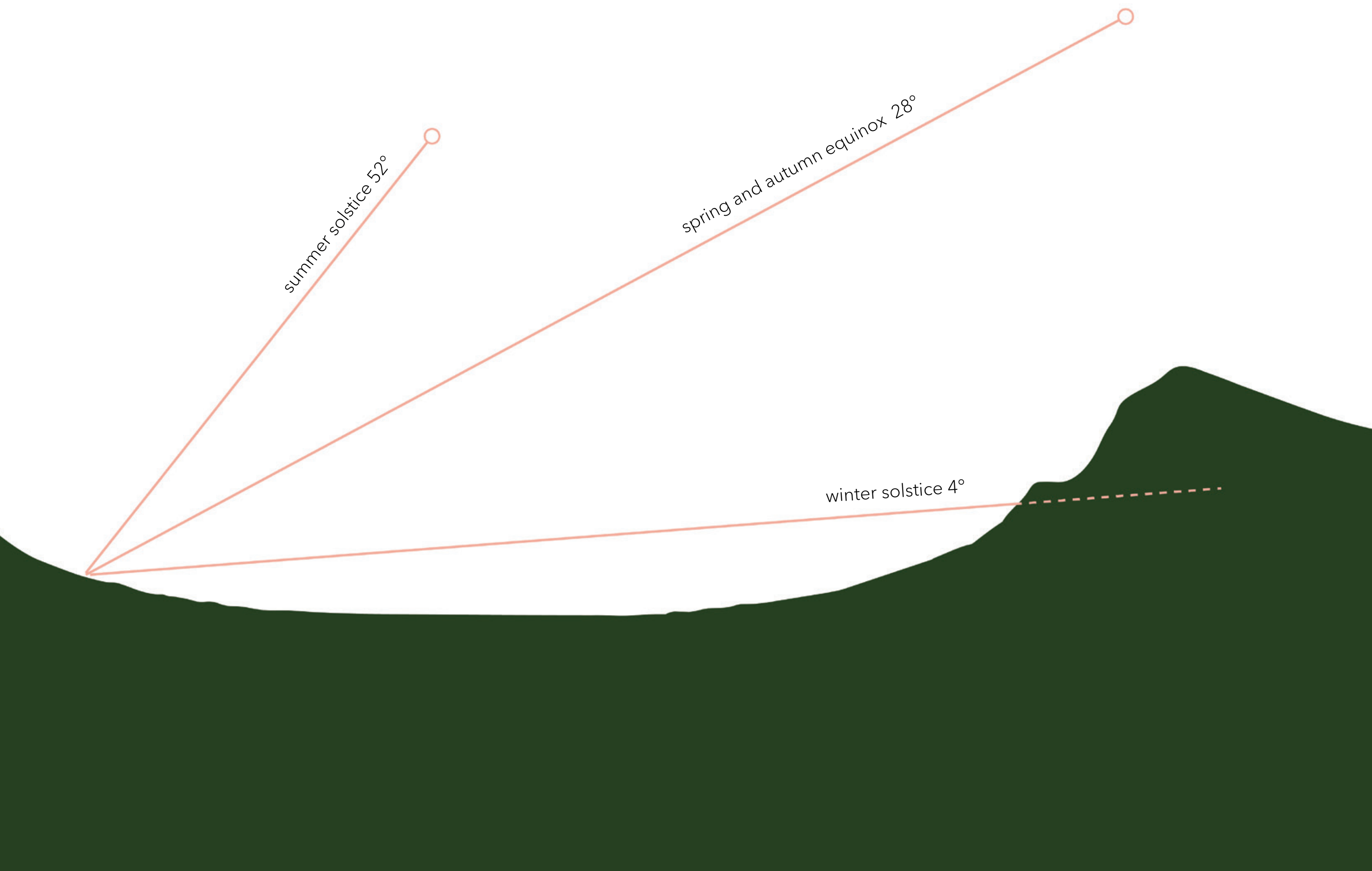
Site map

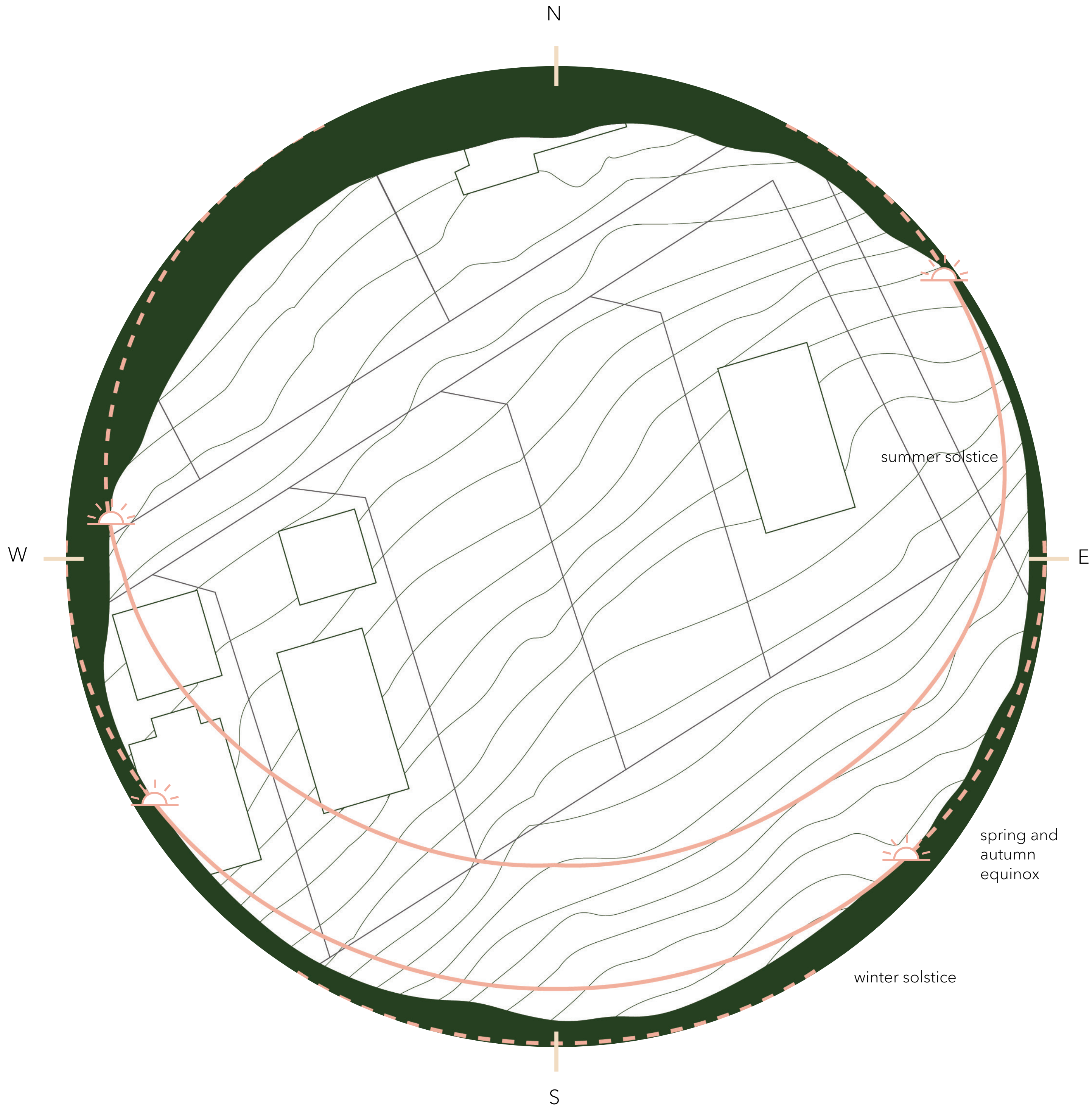
Sun path

The sun-path in Oppdal is quite unique due to its high latitude and mountainous terrain. As stated before: the shortest day is only 4 hours and 54 minutes long and the longest lasts for 20 hours and 4 minutest. This creates drastic shifts in daylight hours and influences everything from daily routines to wildlife behaviour. The height of the sun over the horizon fluctuates greatly throughout the day, casting long shadows and creating stunning lighting effects against the mountainous terrain of Oppdal. Due to the mountains however, some places (especially those on the northern slopes, or in the valley) do not get any sunlight in the winter season. Thus, two diagrams showing the sun-path for the chosen plot, on the equinoxes and solstices are presented below.

The dark green parts represent the terrain around. On the terrain section one can see that in December and early January the plot will not receive any sun rays due to the peak of Allmannberget to the south of the plot. From the horizon study, it is visible that the sunrises are taking place later and sunsets earlier that it would be calculated just from the latitude of Oppdal.

Fig. 18 (below) The highest Sun position on given days - north-south terrain section
Fig. 19 (next page) Sunpath - top view and horizon




N
W
E
S
summer solstice
spring and
autumn
equinox
winter solstice

Functions and transport analysis

On the maps presented on the previous and next page one can see the most important features location and connection-wise.

The map in a bigger scale shows the closest neighbourhood. Within the radius of half kilometre we would find mostly holiday housing, buildings related to skiing centre and a few farm buildings or one-family houses. If we exceed the range of our interest to slightly more than a kilometre (1,1km), we will find a Christian community house and a long-distance bus stop. Centre of Oppdal is 3,4 km away, where one can find shops, cafés and different kinds of entertainment in e.g. climbing wall. There is also a culture house, stadium and a museum nearby. Oppdal has 7 schools for different levels and 10 (private and communal) kindergartens. Oppdal videregående skole offers programmes with sport focus such as: alpine skiing, outdoors living, football and curling, so that it is important that there is a good infrastructure offer within this sport focus. There is a health centre and an emergency in Oppdal.

When it comes down to accommodation, there are three hotels in Oppdal and one in Stølen. Short term renting services are much more popular with numerous privately and company owned cabins or holiday apartments to rent in the area.

Regarding transport to and from Oppdal there is a train and bus station there and a trip from/to Trondheim takes about 1 h 50 min regardless of the means of transport. However, the most popular means of reaching Oppdal among visitors is now the private car. The well-maintained E6 and charging stations on the road and at the destination provides a comfortable experience for the majority of those journeying to this picturesque Norwegian destination.

Fig. 20 (next page) Site map 1:40 000

Map legend

- Oppdal built-up area
- forest
- downhill ski slopes
- roads
- train tracks
- streams, rivers
- project location

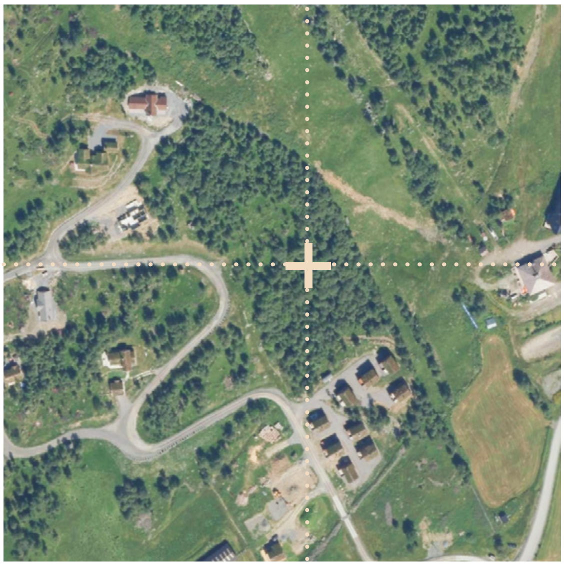
Site map 1:40 000

Site evolution

The plot is located in the cabin field area, but it wasn't always like that. On the pictures below you can see how it 'evolved' from birch grazing forest to fully built-up land, throughout just 15 years. The knowledge of how the plot looked like in the past is crucial for regenerating it and bringing back the previous, natural landscape.

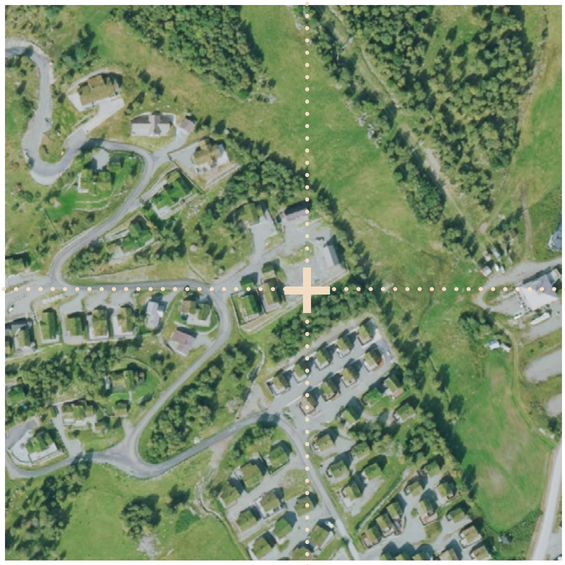
Fig. 21 Evolution of the site surroundings 2009-2024

2009



2014

2019



2024

Fig. 22 Picture from the site taken by John Bjarne Jordal in 2008 (Jordal, 2009).

Fig. 23 Picture from the site taken in March 2024. In the background ski centre building is visible. On the left, there is a group of birches that grow to the south of the design plot.

Design

Introduction

The cabin design emerges from the climate and nature analysis but also from the current Norwegian cabin building habits. The design treats all of the plot inhabitants equally and is therefore more than human design. The cabin, after completion, will require less and less intervention and maintenance since it relies mostly on passive strategies and ecosystem bonds that sustain all forms of living organisms.

The design disregards the parts of the regulation plan of the cabin field, that do not support wildlife or on-site energy production in e.g. sealing the void beetween the ground and the floor built on piles or buildings ridge orientation in relation to the terrain.

The borders of the plot do not exist in the natural world. Therefore, the dotted lines and gradient indicate that the regenerative processes evolve from the plot but are, by no means, limited to it. The animals move freely through the plot and the trees will spread within a few years.

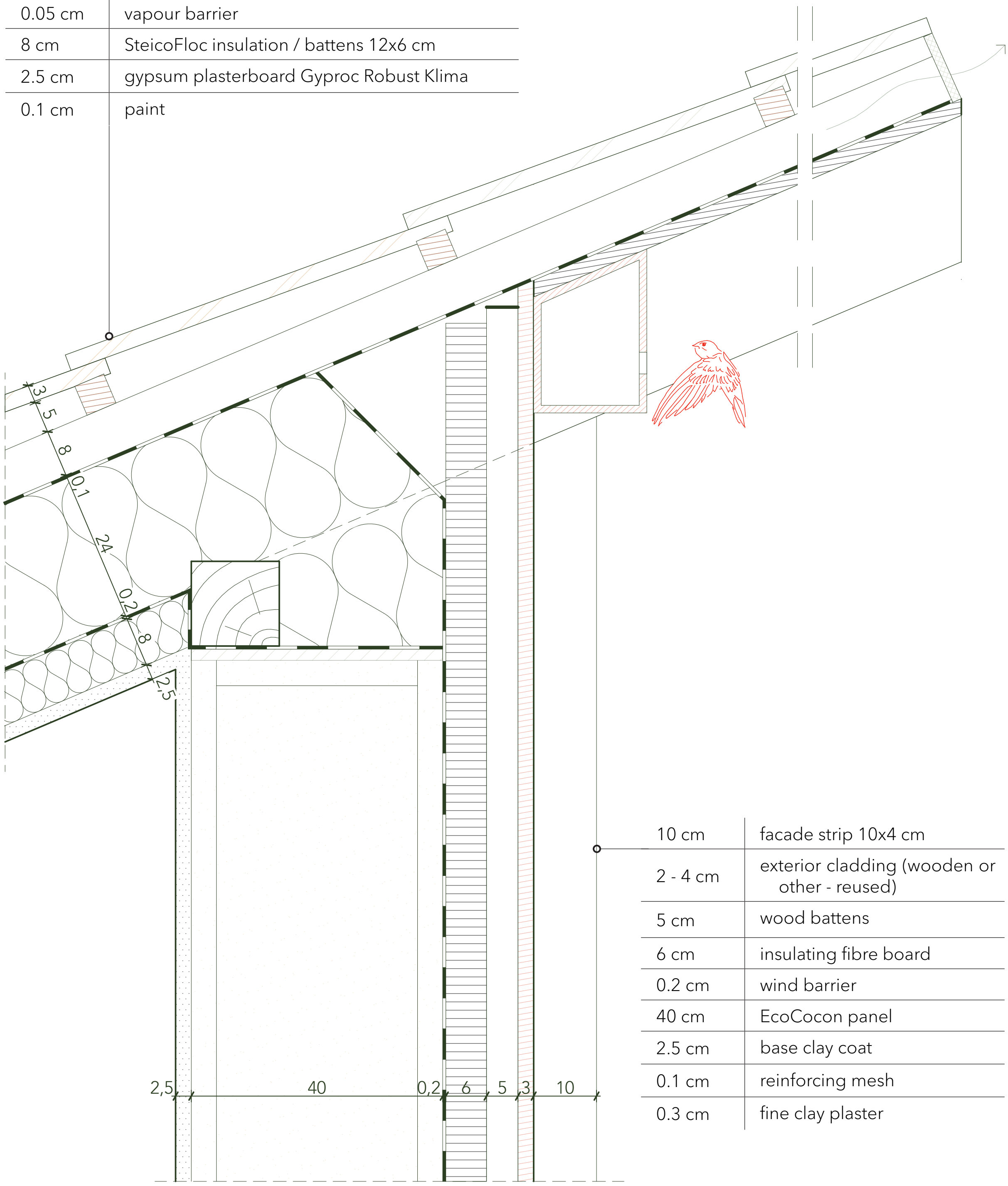
Since the project is situated on 2 plots designated for cabins, the idea was to maintain the space for 2 groups of guests, within one building while making it more flexible at the same time. Joined cabins enable a seamless transition between different number of guests, multiply the space functionality suiting different needs and activities. Apart from that, the cabin promotes sustainability by minimizing the need for multiple structures and reduction in the area of building envelope. As the cabin is supposed to be available for short term rent, the occupancy is expected to be much higher in comparison to individual holiday homes, which drastically lowers the emissions per person.

The design incorporates several reused elements such as facade cladding and windows. Norway is well upfront among other European countries when it comes to making the second-hand materials available for new projects. There are several companies or organisations, also within Trøndelag county that offer second hand materials in e.g. Sirken, BrukOm, Loopfront.

The cabin, with its flexible size is a perfect space for hosting smaller events or workshops for the community of Gorsetgrenda. This way the ideas of supporting wildlife and regenerative architecture can be showcased and explained to later be implemented in surrounding projects.

Details 1:10

3 cm	Ennogie PV rooftiles 60x120 cm
5 cm	wooden battens 5x5 cm
8 cm	secondary beams 8x2 / ventilation level
0.1 cm	weather resistant barrier
24 cm	SteicoFloc insulation / LVL beams 24x10 cm
0.05 cm	vapour barrier
8 cm	SteicoFloc insulation / battens 12x6 cm
2.5 cm	gypsum plasterboard Gyproc Robust Klima
0.1 cm	paint



10 cm	facade strip 10x4 cm
2 - 4 cm	exterior cladding (wooden or other - reused)
5 cm	wood battens
6 cm	insulating fibre board
0.2 cm	wind barrier
40 cm	EcoCocon panel
2.5 cm	base clay coat
0.1 cm	reinforcing mesh
0.3 cm	fine clay plaster

Fig. 35 Detail of the BIPV roof overhang

	vegetation
8 -13 cm	soil
5 - 0.8 cm	studed drainage sheet Floraset
0.5 cm	root protection mat
8 cm	XPS
0.5 cm	waterproofing layer
2.2 cm	wooden roof sheating
24 cm	SteicoFloc insulation 20 cm / LVL beams 24x10 cm
0.2 cm	vapour barrier
2.5 cm	gypsum plasterboard Gyproc Robust Klima
0.1 cm	Paint

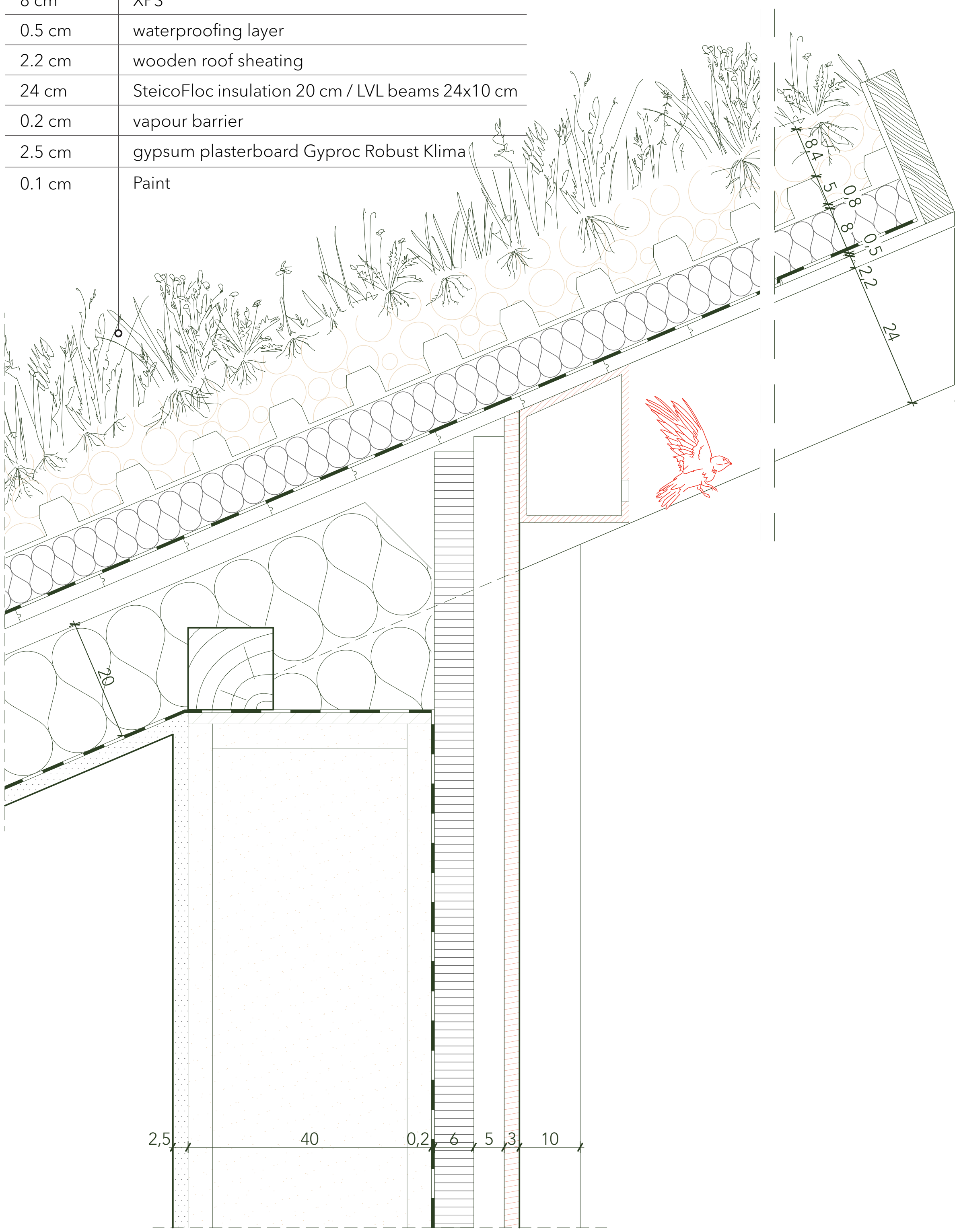


Fig. 36 Detail of the green roof overhang

Bill of materials

Materials of the cabin are chosen to have minimal impact on the environment. This means that components with the lowest GWP factor and the most local are favourites. Consequently, some of the building elements are reused.

WALLS

The structural system of the cabin is based on prefabricated straw wall system. EcoCocon modules are load bearing due to the twin stud frame. They serve as both load-bearing and insulation element.

External wall: U = 0.123 W/(m^2·K)

3 cm	exterior cladding (wooden or other - reused)
5 cm	wood battens
6 cm	insulating fibre board
0.2 cm	wind barrier
40 cm	EcoCocon panel
2.5 cm	base clay coat
0.1 cm	reinforcing mesh
0.3 cm	fine clay plaster

External storage wall:

3 cm	exterior cladding (wooden or other - reused)
5 cm	wood battens
6 cm	insulating fibre board
1.2 cm	OSB plate
20 cm	wooden studs 20x5 cm

Internal bearing wall:

2.5 cm	fine clay plaster
30 cm	EcoCocon panel
2.5 cm	fine clay plaster

Internal division wall:

1.2 cm	plywood finish
10 cm	sheep wool/wood battens
1.2 cm	plywood finish

Internal bathroom division wall:

0.5 cm	tiles
1.2 cm	impregnated plywood finish
10 cm	sheep wool/wood battens
1.2 cm	plywood finish

FOUNDATIONS

The cabin rests on the grid of timber columns connected to steel screw piles foundation (175 cm deep). This solution allows to have the least possible intervention in the landscape, leaves ground area underneath available for shade-loving plants and mushrooms and, above all, serves as a shelter for sheep. Moreover, the piles are easily removable and in case the cabin would be disassembled at some point, they can be removed from the ground and would leave almost no trace, letting the soil regenerate swiftly by itself.

SLABS

The slab above the ground is built of a timber joists. The mezzanine slab has a similar structure, with less insulation.

Floor on piles: U = 0,11 W/(m²·K)

2.5 cm	wooden flooring
0.5 cm	flooring underlay
2.5 cm	gypsum fibreboard (dry screed)
4 cm	Steico woodfibre flooring insulation
1.8 cm	OSB plate
10 cm	SteicoFloc insulation / secondary beams 10x5 cm
30 cm	SteicoFloc insulation / glulam beams 24x10 cm
0.05 cm	permeable air barrier
2.5 cm	wood battens

Floor on piles - bathroom: U = 0,11 W/(m²·K)

0.5 cm	ceramic tiles
0.5 cm	waterproof flooring underlay
4.5 cm	gypsum fibreboard (dry screed)
4 cm	Steico woodfibre flooring insulation
1.8 cm	OSB plate
10 cm	SteicoFloc insulation / secondary beams 10x5 cm
30 cm	SteicoFloc insulation / glulam beams 24x10 cm
0.05 cm	permeable air barrier
2.5 cm	wood battens

Inner mezzanine floor

2.5 cm	wooden flooring
0.5 cm	flooring underlay
2.5 cm	gypsum fibreboard (dry screed)
4 cm	Steico woodfibre flooring insulation
1.8 cm	OSB plate
6 cm	SteicoFloc insulation / secondary beams 6x3 cm
12 cm	SteicoFloc insulation / glulam beams 12x6 cm
0.05 cm	permeable air barrier
2.5 cm	wood battens

Inner floor over bathroom

2.5 cm	wooden flooring
0.5 cm	flooring underlay
2.5 cm	gypsum fibreboard (dry screed)
4 cm	Steico woodfibre flooring insulation
1.8	OSB plate
6 cm	SteicoFloc insulation / secondary beams 6x3 cm
12 cm	SteicoFloc insulation / glulam beams 12x6 cm
0.05 cm	permeable air barrier
2.5 cm	impregnated fibreboard
0.2 cm	paint

ROOFING

The roof is structured as a rafter pitched roof (22° slope) and there are 3 solutions taken into account when in comes to the roof upper layers: PV roof tiles, metal sheets and intensive green roof. The layers are described below and the environmental profitability of each of those is discussed in the Design analysis and Discussion chapters

BIPV roof U = 0.12 W/(m^2·K)

3 cm	PV rooftiles 60x120 cm
5 cm	wooden battens 5x5 cm
8 cm	secondary beams 8x2 / ventilation level
0.1 cm	waterproof barrier
24 cm	SteicoFloc insulation / LVL beams 24x10 cm
0.05 cm	vapour barrier
8 cm	SteicoFloc insulation / battens 12x6 cm
2.5 cm	gypsum plasterboard Gyproc Robust Klima
0.1 cm	paint

metal cladding roof U = 0.12 W/(m^2·K)

3 cm	metal cladding
5 cm	wooden battens 5x5 cm
8 cm	secondary beams 8x2 / ventilation level
0.1 cm	waterproof barrier
24 cm	SteicoFloc insulation / LVL beams 24x10 cm
0.05 cm	vapour barrier
8 cm	SteicoFloc insulation / battens 12x6 cm
2.5 cm	gypsum plasterboard Gyproc Robust Klima
0.1 cm	paint

Extensive green roof U= 0.14 W/(m²·K)

	vegetation
8 -13 cm	soil
5 - 0.8 cm	studed drainage sheet Floraset
0.5 cm	root protection mat
8 cm	XPS
0.5 cm	waterproofing layer
2.2 cm	waterproof plywood
24 cm	SteicoFloc insulation 20 cm / LVL beams 24x10 cm
0.2 cm	wind barrier
2.5 cm	gypsum plasterboard Gyproc Robust Klima
0.1 cm	paint

OPENINGS

Windows are meant to be sourced at the second-hand market. Any shape that fits within the elevation grid pattern of 137 x 143 cm is applicable. If available windows have poor U-values it is advised to install two of the same size on top of each other. This will limit a bit of light coming in but will ensure tighter building envelope. The balcony doors, however, are not calculated as reused. Their surface is quite big and therefore the heat-loss when using older windows might be significant. Doors both inner and outer are also reused.

STAIRS AND RAILINGS

Inner stairs have an integrated wardrobe on the side and are made out of plywood. The structure is made out of wooden beams.

External stairs leading to the main entrance and those to the terrace are also made out of wood. Impregnated wooden steps are rested LVL beams. The railings are fitting with the terrace railing and the material of the whole building.

HVAC and water management

The location of the project on the cabin field has many advantages when it comes to the utilities. The cabin has access to grid power and water. Moreover the Gorsetgrenda cabin area caters for sewage and wastewater management. Since there is no specific technical information on how is the water treatment organised, different scenarios are taken into consideration

HEATING

The cabin is primarily heated with a simple wood burning stove. Wood is a renewable resource and has a much lower GWP factor than fossil fuels. Moreover it is easy to find a second-hand stove online, it doesn't need complicated maintenance and can be used off-grid.

However, since the cabin is not a permanent place of residence, it is necessary to introduce solutions that will ensure a plus temperature during periods of absence. Otherwise, the plumbing could be damaged in winters when the temperatures drop well below zero. There are two main ways of tackling this issue:

+ Draining the water from the piping every time ones leave the cabin
+ Ensuring a secondary heating system that maintains a constant, above zero, temperature on the vacant periods

The first solution was not chosen for 3 reasons. Firstly, it wastes drinking water. Secondly, it depends too much on the users. It may happen that the occupants forget to do it. Thirdly, it wastes the potential of grey water installation.

When it comes down to the second alternative, there are many heating systems to choose from. Firstly, there are electrical radiators, that nowadays are offered with the wi-fi connection and remote control, so control over the temperature would not be a problem. Secondly, there are different types of heat pumps to choose from. The ground source heat pump was rejected (despite its higher efficiency in comparison to air source) because of the scale of landscape intervention it needs. Air source heat pumps however, could be considered for heating when the cabin has a grid connection, which is the case here. Air to air heat pump might be quicker to heat up single rooms but convection is not that pleasant way of heating. Air to water heat pump, on the other hand, gives pleasant heat through floor heating, but requires installation of significant amount of plastic (HDPE) piping and use of screed which makes the whole floor structure harder to disassemble and recycle. Apart from that, the external ventilator of the heat pump generates some noise between 40 and 60 decibels on average (Garner, 2023), that could have an effect on wildlife around.

To sum it up, the electric heaters seem to be the most reasonable solution within this project because of the simplicity of installation and possible double use. The units should be installed in the kitchen, bathroom and bedroom. Their primary task would be to maintain the stand-by, above zero, temperature in vacant times, but they could serve as an additional heat source when the cabin is occupied, especially when it comes down to heating the enclosed rooms which gain less heat from the wood stove.

VENTILATION

Good ventilation is crucial for pleasant climate in the cabin. It allows to avoid humidity problems, foggy windows and unwanted smells particularly when the periods of unoccupied cabin are longer.

All of the rooms are naturally ventilated with passive vents apart from the bathrooms. These are equipped with an exhaust fan with humidity sensor. All of the vents have filters that prevent dust and insects from coming in. Kitchen electrical stove is equipped with cooker hood with and external fan and a grease filter.

AIR CONDITIONING

No mechanical cooling systems are provided in the design of the cabin, since there are very few times during the year that the outside temperature exceeds comfort levels. [check Fig. 9] There are however several passive systems provided to maintain comfortable indoor climate in summer months such as:

+ window shutters - prevent both indoors from sunlight and outdoors from light pollution
+ operable woven fabric shades, with UV coat, installed on the rafters over the terrace
+ roof windows - let the heat that accumulates at the top of the building escape easily
+ stack effect - since there is no barrier between the living room on the ground floor and the open space/bedroom at the mezzanine the heat will go up, leaving the most used kitchen - living room area cooler

DOMESTIC HOT WATER

Water for domestic purposes is heated in a 50 litre electric boiler. The boiler is situated under the kitchen counter top, in the corner, and provides both bathroom and kitchen sink, as well as the shower and a washing machine with hot water.

WASTEWATER MANAGEMENT

The sewage is discharged to the communal wastewater treatment.

Water from the bathroom taps, shower and washing machine is collected in a storage tank after going through a set of biofilters. The tank is situated under the stairs and the water outlet is connected to the toilet flush, outside tap for gardening and an overflow pipe. This way the grey water can be recycled and utilised wherever needed.

Floor areas

The areas of the rooms and the whole building are as presented in the Table below. The total areas are important for the energy demand and LCA analysis.

	area [m^2]
living room	20.9
bedroom	9.4
bathroom	4.0
corridor	5.7
top floor	16.8
storage space (unheated)	2.3
1 unit netto area	56.7
total netto area with storage (NTA)	118.1
heated usable area (HBRA/OPA)	124.1
usable area (BRA)	128.7
gross area (BTA)	157.3

Design analysis

Life Cycle Analysis

The LCA conducted for the purpose of this thesis concentrates on material emissions. This means, the emissions coming from the production of the materials, transport from the factory gate to the construction site and to waste management, and the waste management itself (waste incineration, gains from reusability and material recycling) are all accounted for in the calculations. Power supply embodied and consumption emissions are estimated based on typical consumption data. Furthermore, embodied emissions and operation credits of photovoltaic panels are calculated.

The LCA calculations are done within FutureBuilt ZERO v3 system boundary (Futurebuilt ZERO, 2024) when it comes down to the material emissions. Generally FutureBuilt scheme assumes that, the greenhouse gas emissions are calculated for each emission source, for each year of the calculation period (the construction years and 50 years of operation), and then added up for the three main phases: construction phase (incl. construction site), operation phase, end-of-life phase.

The calculations include, among other things, potential emission reductions through carbon sequestration, material recycling, reuse of materials and export of energy. The calculation method gives greater weight to emission cuts that are made early in the building's lifetime compared to those that come late in its lifetime, but at the same time encourages the prevention of future emissions by providing emissions credits to facilitate dismantling and reuse. Apart from that, the method implements the technology development factor, which lessens the emissions over the years due to technological development, among other things in material technology, production technology, recycling rate, transport technology, and electrification together with a decarbonisation of the energy grid (Futurebuilt ZERO, 2024).

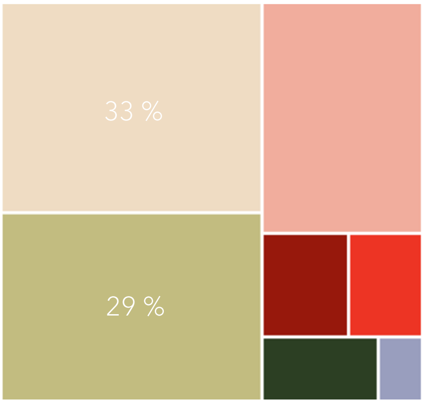
When it comes down to the building elements included in the calculations FutureBuilt scheme omits groundwork and foundation (21)* and fixed inventory (27)*. It can incorporate, however, calculations of PV panels and sun collectors embodied emissions.

The primary software used to conduct the LCA analysis was Reduzer (Reduzer, 2024). Embodied emissions calculation of BIPV panels was done separately with a use of MS Excel and data gained from EPD's.

* numbers in brackets indicate building and installation parts according to NS 3451 Bygningsdelstabell

Different roofing scenarios

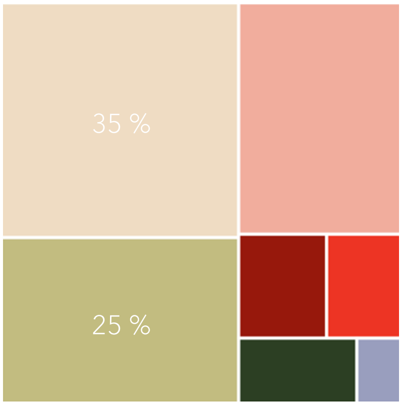
On the following graphics the total GWP from the material stock of the cabin are presented with a difference in roof cover. The first scenario implements simplest metal sheet roofing, the second - intensive green roof and the third - BIPV roof tiles. The last scenario is unique, since the roof tiles serve double function - they are an external roofing layer and also produce energy.



CABIN WITH METAL SHEET ROOFING

91.2 $kgCO_2eq/m^2$BTA

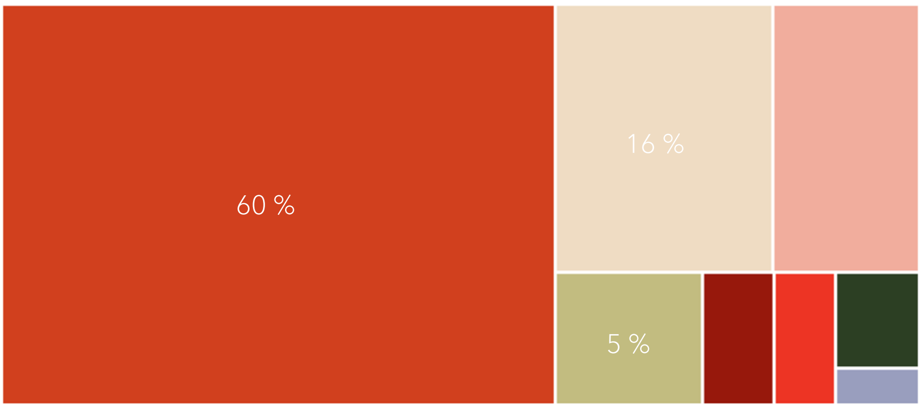
14.3 t CO_2eq total



CABIN WITH INTENSIVE GREEN ROOF

85.4 $kgCO_2eq/m^2$BTA

13.4 t CO_2eq total



CABIN WITH BIPV ROOF

187 $kgCO_2eq/m^2$

29.4 t CO_2eq total

- 22 load-bearing systems
- 24 internal walls
- 26 roof
- windows
- 23 external walls
- 25 slabs
- 28 stairs, balconies, etc.
- 49 other technical power installations

Fig. 37 Comparison of cabin total emissions depending on the roof structure. The size reflects the total amount of emissions.

Emissions by building elements - green roof scenario

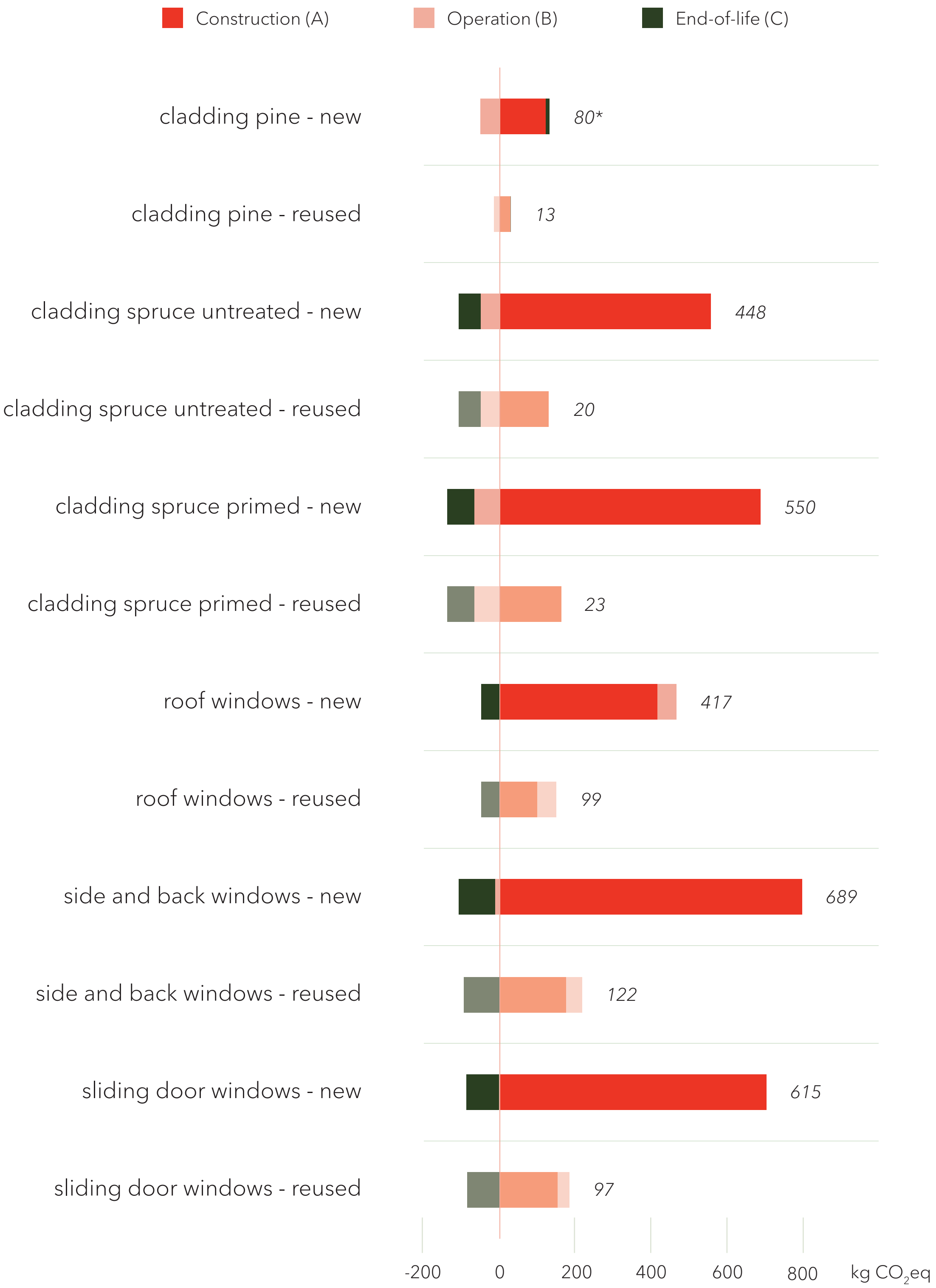
The following graph presents building elements and their emissions divided into life cycle phases. This presentation allows for in depth component analysis. Phase B1 accounts for biogenic carbon uptake.

- A1: Raw material extraction and processing, processing of secondary material input (e.g. recycling processes)
- A2: Transport to the manufacturer
- A3: Manufacturing
- A4: Transport to the building site
- A5: Installation into the building.
- B1: Use or application of the installed product
- B4: Replacement
- B5: Refurbishment
- C2: Transport to waste processing
- C3: Waste processing for reuse, recovery and/or recycling
- D: Reuse, recovery and/or recycling potentials, expressed as net impacts and benefits

Fig. 38 Green roof cabin emissions by elements

New vs reused elements lifetime GWP

In the project reused windows and facade cladding is used. Figure 38 shows what are the emissions savings gained from this decision in absolute values (kg CO_2eq). Although, the terrace sliding doors were not meant to be reused due to U-value reasons, they are also compared below.



* lifetime GWP for each element

Fig. 39 Impact of reuse in the project

Energy demand

The cabin energy demand varies greatly throughout the year - the lower the outside temperature - the higher the demand. This is generally true for the cold climates, when both temperatures and natural light levels are low in winter.

The the biggest influential factor on the cabin energy demand is probably the occupation scheme. Even the building envelope and its U-values won't influence the energy demand more than the variations in occupancy. Naturally, the more time one spends at the cabin, the more energy it requires for heating, lighting, pumps and devices etc. In order to calculate the yearly heating energy demand of the cabin the assumption regarding time spent at the cabin was made, which is that the cabin is expected to be occupied on weekends and holidays for a total of 127 days throughout the year. Heating load for this type of occupancy was calculated in Shima's master thesis and totals 31,16 kWh/m² (Sabzehban, 2023).

Energy use during construction was calculated using typical values provided in Reduzer. The "fossil free construction site" mode was chosen.

heating load	31.16 kWh/m² OPA
total heating demand	3867.7 kWh/year
construction phase electricity demand	55 kWh/ m² BTA
construction phase biodiesel demand	65 kWh/ m² BTA
total construction phase demand	18840 kWh

Grid power supply & on-site production

The cabin plot has access to power grid, however since the aim of the project is to conserve resources, regenerate the ecosystem and try to close the loops of produce and waste, the primary option is to have the energy production on-site, that is: to cover the roof with BI-PV modules. This solution could provide energy independence when combined with energy storage.

The energy provider in the area is Tensio (Rogstad, 2021) and it allows customers to transfer surplus energy back into the grid, turning them into "plus-customers". This means the excess energy can be discharged to the grid at times of higher produce and regained in winter.

The energy to emissions conversion factor in Norway is very low in comparison to other countries, due to high share of hydro-power in energy production. On the other hand, Norway is main energy partner for the EU and in 2023 it was the major supplier of oil, gas and electricity (European Commission, 2024). Thus, two energy to emissions conversion factors are taken into consideration: Norwegian factor from 2023 which is 18 g CO_2eq/kWh (Nowtricity, 2024), and the combined Europe + Norway conversion factor which is based on NS03720 standard, which is 136 g CO_2eq/kWh.

To calculate the energy output the following data is used provided by Photovoltaic Geographical Information System (EC PVGIS, 2022) and PV panel producer (Ennogie ApS, 2023):

geographical location	62.615N 9.724E
system losses	14%
PV slope	22°
PV orientation (azimuth)	198°
PV area	180.5 m²
PV product	Ennogie rooftile
nominal PV power	175 Wp
PV GWP A1-A3 per 1 Wp	0.95 kgCO_2eq
PV GWP A1-A3 per 1 m²	1.66 kgCO_2eq
electricity to emissions conversion factor for Norway	0.018 kg/kWh
electricity to emissions conversion factor EU + Norway	0.136 kg/kWh
PV capacity installed	31.58 kWp

PV energy output

The BIPV rooftiles installation produces 669.8 kWh per 1 kwp yearly, resulting in 21153.5 kWh from the full roof. The graph shows how is the energy output distributed along the year.

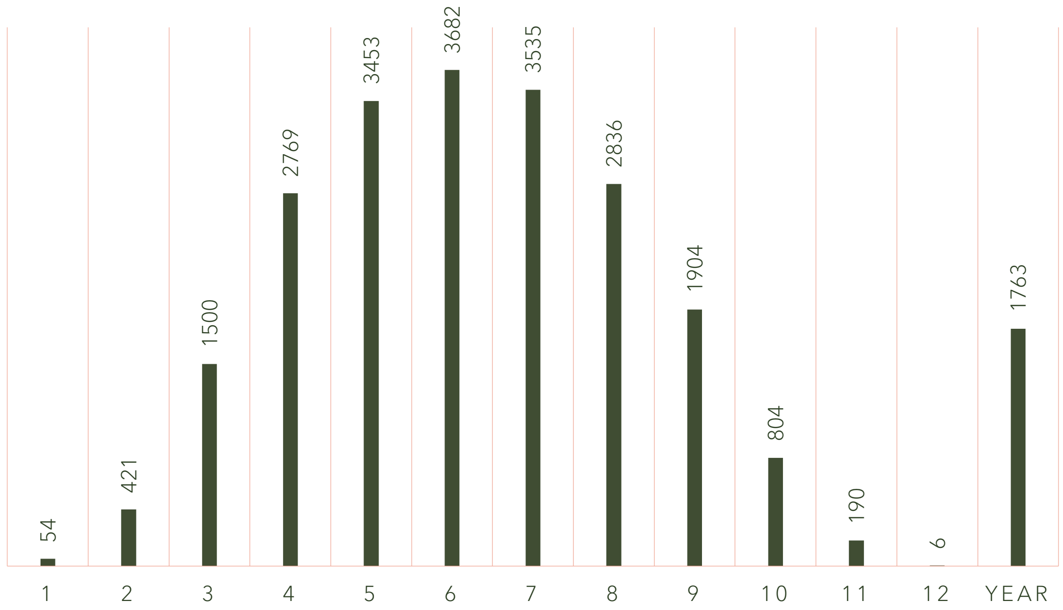


Fig. 40 PV energy output monthly averages. YEAR - yearly average PV output. [kWh]

PV system embodied emissions

The calculation of embodied emissions from the PV installation helps to determine whether and when the installation will break even in terms of CO_2 emission in comparison with the grid power supply. This allows for a more informed assessment of its environmental benefits. The calculations involve degradation of PV system (0.5% loss of capacity each year) and 3 scenarios: no replacement, 1 replacement - 25 years after installation and 2 replacements - in year 20 and 40. In the table the results for combined Europe + Norway conversion factor are presented.

	Ratio of (embodied emissions/emissions credit) of PV system after 50 years	Cumulative total lifecycle emissions of the PV system (embodied + credit) [kg CO2 eq]	Emissions per kWh of electricity [g/kWh]
No replacement	9,9 %	-1515,8	13,4
1 replacement (year 25)	12,6 %	-2299,8	17,2
2 replacements (year 20 and 40)	16,1 %	-2590,9	21,9

NORWEGIAN ENERGY TO EMISSIONS CONVERSION FACTOR

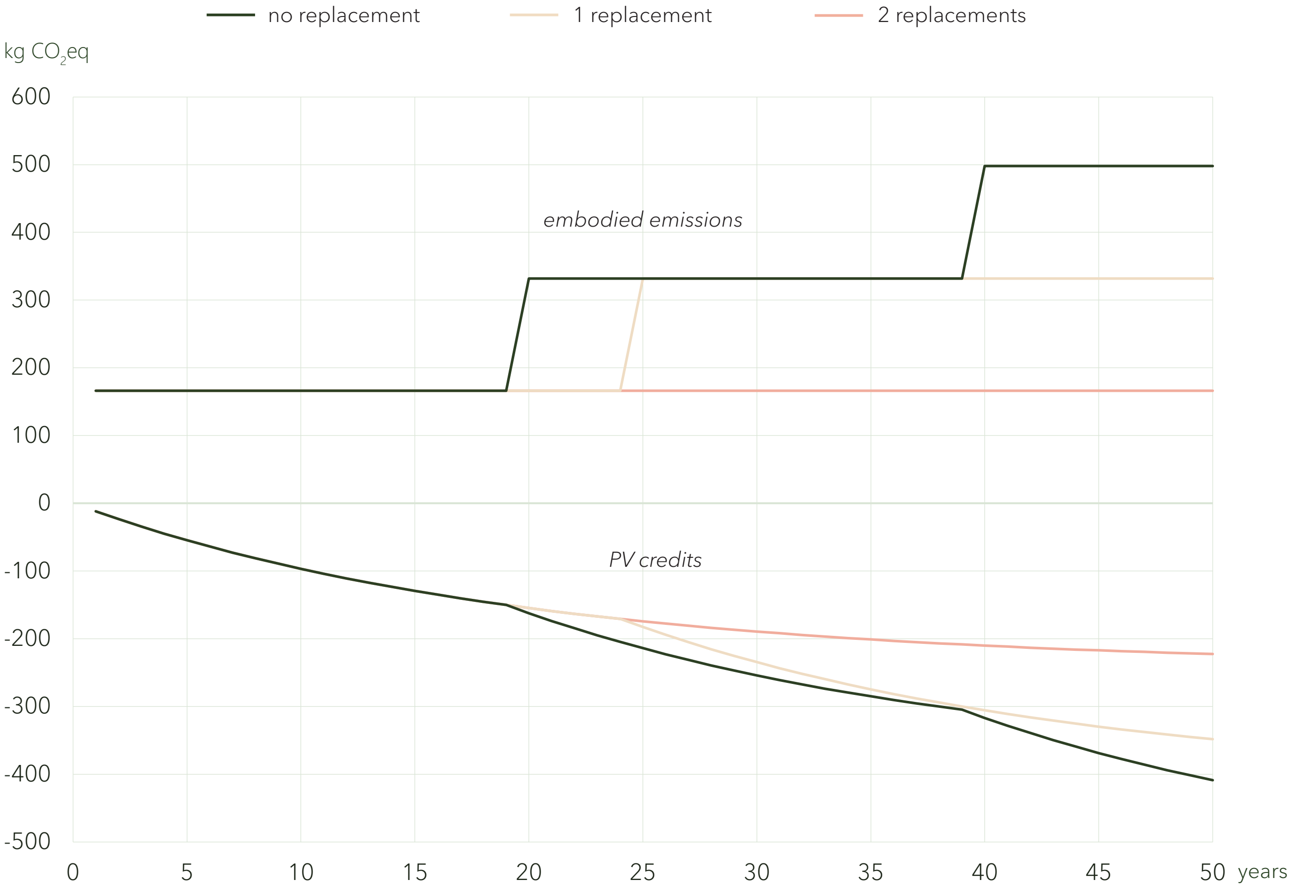


Fig. 41 Cumulative PV credit and embodied emissions - Norway

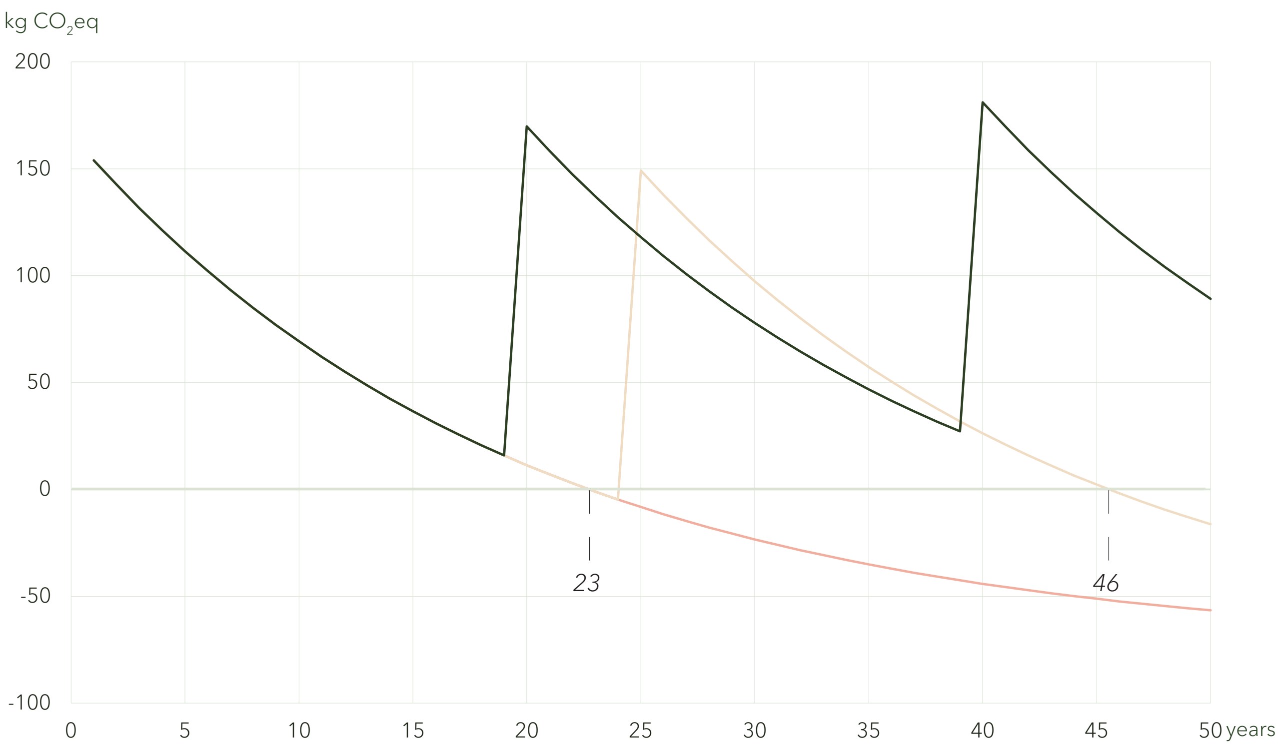


Fig. 42 Cumulative net PV emissions - Norway

COMBINED EU + NORWAY ENERGY TO EMISSIONS CONVERSION FACTOR

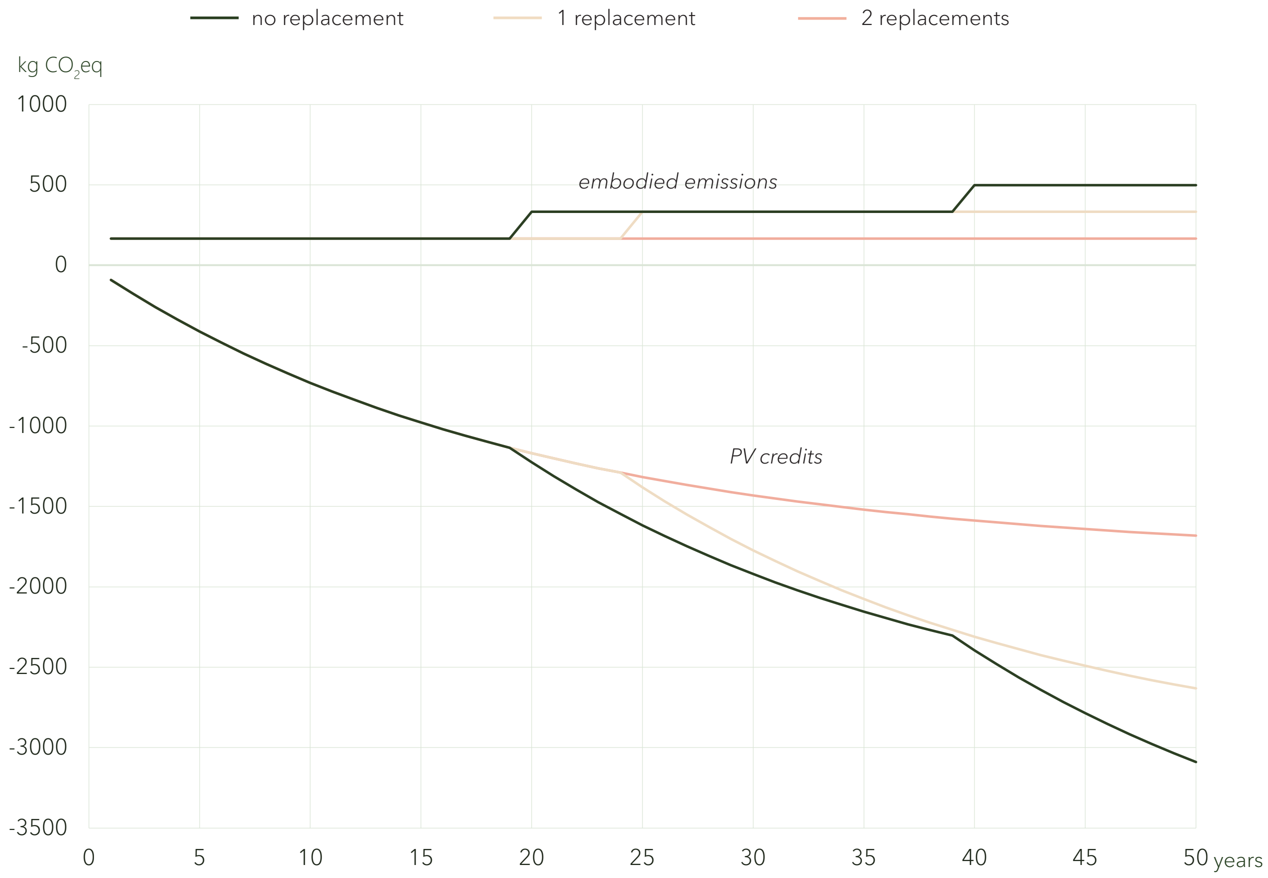


Fig. 43 Cumulative PV credit and embodied emissions - Norway + EU

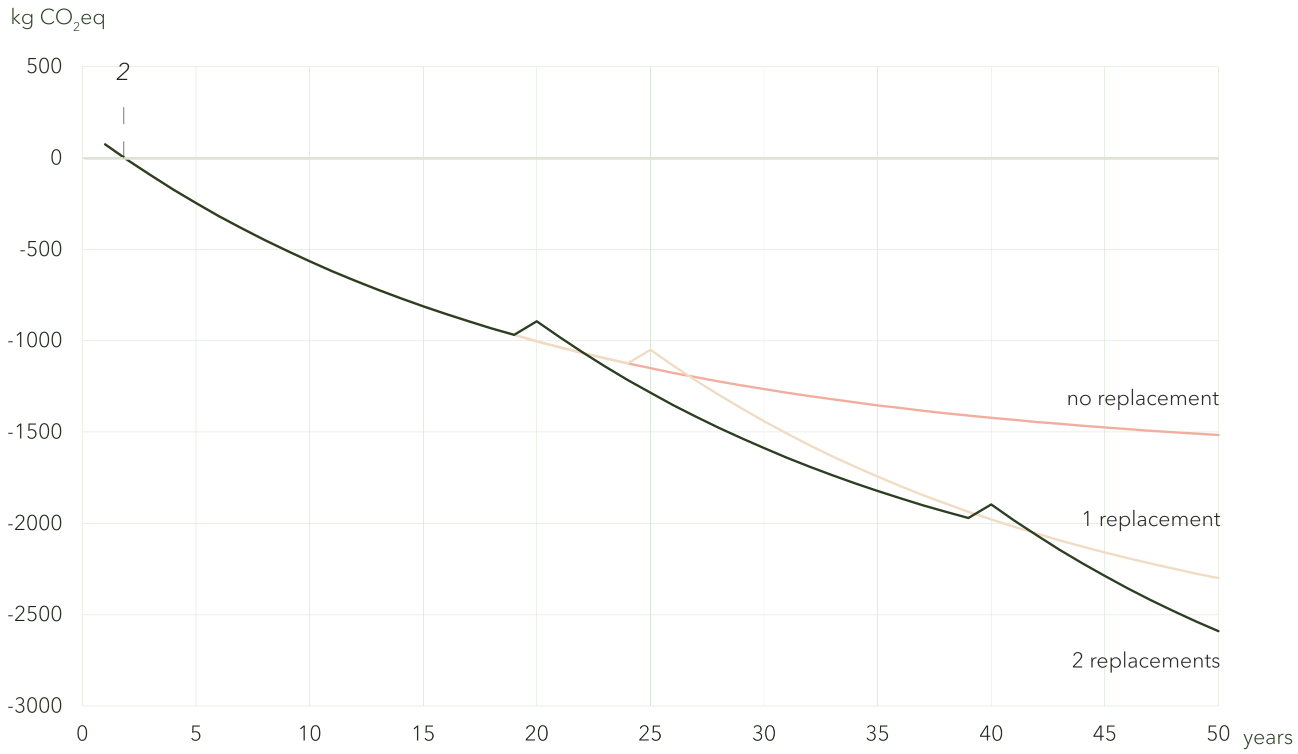


Fig. 44 Cumulative net PV emissions - Norway + EU

Offsetting CO_2 emissions by planting trees

Even though the cabin generates its own energy, it is not carbon neutral. To compensate its carbon footprint and further enhance biodiversity, tree planting is planned. In the table it is shown how many trees should be planted in the nearby area, assuming that every hectare of European forest removes 9.8 tons of CO_2 per year in the first 20 years, and 4.5 tons CO_2 per year in years 21 to 60 (Bernal, Murray, & Pearson, 2018). It is assumed that a hectare of forest equals to 1600 trees (Coed Cymru, 2017).

cabin scenario	total emissions	How many sq. meters of forest to grow for 50 years?	How many trees does it equal to?
cabin with metal roofing	14.3 t CO_2eq	432,0	69
cabin with green roof	13.4 t CO_2eq	404,8	65
cabin with BIPV	23.9 t CO_2eq	722,1	116

The area of the plot is 1200 m^2 (after substracting build-up and paved areas: 980 m^2), which means that it technically would be possible to plant these amount of trees on site. However, *beiteskog* is not that dense and has different characteristics to average european forest. The number of trees that is now sketched on the site plan (birches and willows) within the plot is 36. It is suggested there however, to plant more birches on the nearby plots in order to blur the lines and soften the borders between different vegetation types. When applying this approach it should be easily doable to offset the emissions with native trees in the nearby area.

Discussion

Regenerative approach to cabin development

Humans, their crops, and their breeding take up an increasing share of the Earth's land area. All of our actions ranging from satisfaction of physiological needs to building up the economic growth are causing land-use change because there is just so many of us.

Practices such as forest cut-outs, wetland drainage, stream channelling and re-routing, and infrastructure development are also not unknown in Norwegian environment and clearly influence its unique natural landscapes. Recently, awareness of this problem have been raised by the media, through series of articles and a TV-show published by NRK. This thesis might serve as one of those voices stating that the problem exists, while also proposing some solutions to mitigate the problem in the scope of cabin development.

Probably the first question that a person thinking about building a cabin should ask him/herself is: *Do I really need it, can't I just rent whenever willing to have an away weekend?*, then: *Can I buy it on a secondary market?* This project covers, the scenario when a cabin is being built to satisfy the needs of several groups of people that agree to share the cabin through short-term rent periods.

In the cabin design we should be particularly careful and change the conventional design approach because of the character of the housing (secondary - not necessary) and because of the usual settings that happen in pristine places. The guidelines to look for, are those of regenerative design presented on the pages 10-14.

The possible work-flow regarding new cabin development should look as follows:

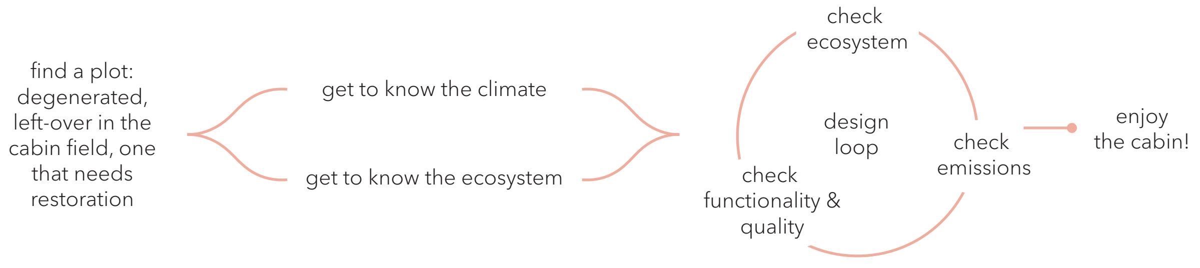


Fig. 45 Cabin design workflow

Cabin that is built within the grey-zone, that emerges from the analysis of the climate and ecosystem around (or the ecosystem that was there before the degradation) and that accounts for the needs of both humans and other living organisms on and around the site can have a positive impact on wild-life and help in natural landscape restoration. In order to achieve this, however, the current status-quo in design work-flow, especially when the cabin project is chosen from the catalogue, needs to be improved. The expertise of ecologists that can advise on local ecosystem and its native species, as well as their habits should be brought into play and utilized.

On the other hand, on the level of local authorities, certain actions could be undertaken to alter master-plans and regulation plans, in a way that they would take into account the vegetation types and ecosystems they are made for. In example: the Gorsetgrenda regulation plans (Oppdal kommune, 2009; Oppdal kommune, 2017) insist on building the cabins as close to the terrain as possible, allowing building into the terrain and forcing closure of all openings between the ground and the floor of those buildings that are built on piles. This approach promotes bigger ground intervention and basically prevents the utilization of ground-to-floor voids for biodiversity. Moreover, the plans do not permit use of photovoltaic roof tiles or any other PV solutions as the roofing must be turf, slate or wood shingles.

Generally, I believe that communes should avoid designating new cabin fields in areas that are of high ecological values. Individually built cabins, if they are distant from utilities, should be built as simple as possible without utilities connection. If the buildings are set among others, common systems should be established like car charging spots, common storages or verandas that could limit the built up area of individual cabins.

Environmental cost of the cabin dream

We are now in year 2024 and only 26 years are left to achieve the EU net-zero GHG emissions goal. To achieve the target, our emissions need to decline exponentially with at least 50% cut every decade until 2050. Apart from that, only 1.5 year ago, it was estimated that we are 7 to 8 years away from crossing the 1.5°C temperature increase above pre-industrial levels (Goering, 2022). However, this year in February, it was already official: for the past 12 months, the Earth temperature crossed the critical line of 1.5 degree increase, scientists confirmed (Osaka, 2024).

Since we are already this far, it is crucial to put exceptional effort on minimising the emissions. Figure 45 illustrates how the proposed cabin design scenarios compare to the DFØ benchmarks from last and this year regarding *småhus*. The cabin with usable area smaller than 150 m^2 doesn't even fall into this criteria, but it is the closest to refer to. Holiday homes are entitled to many exceptions when it comes to energy requirements in the TEK17.

Nevertheless, all of the cabin designs fall below the benchmarks. With the BIPV roof having making only 6,5% below the benchmark (when not accounted for energy use and production), but the green roof scenario saving 57% emissions in relation to the benchmark.

On the graph 45 one can also see that when energy is taken into account and the PV panels are not replaced, the exported energy carbon credits outline the CO_2 emitted from energy delivered.

Generally, the difference between the cabin versions lays in the production, cement carbonation and transport.

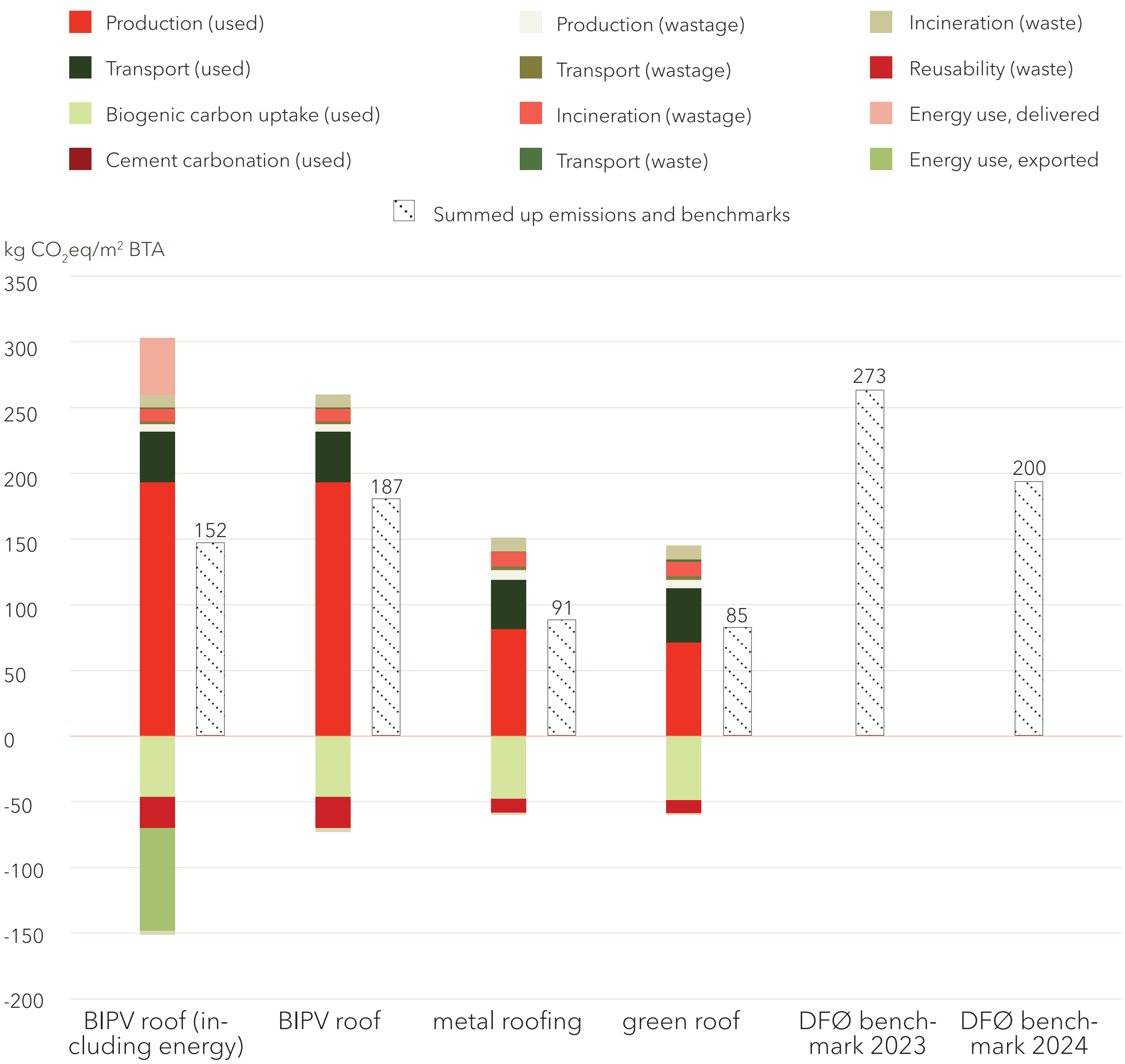


Fig. 46 Comparison of 3 different building scenarios with DFØ benchmarks, split up by emission sources

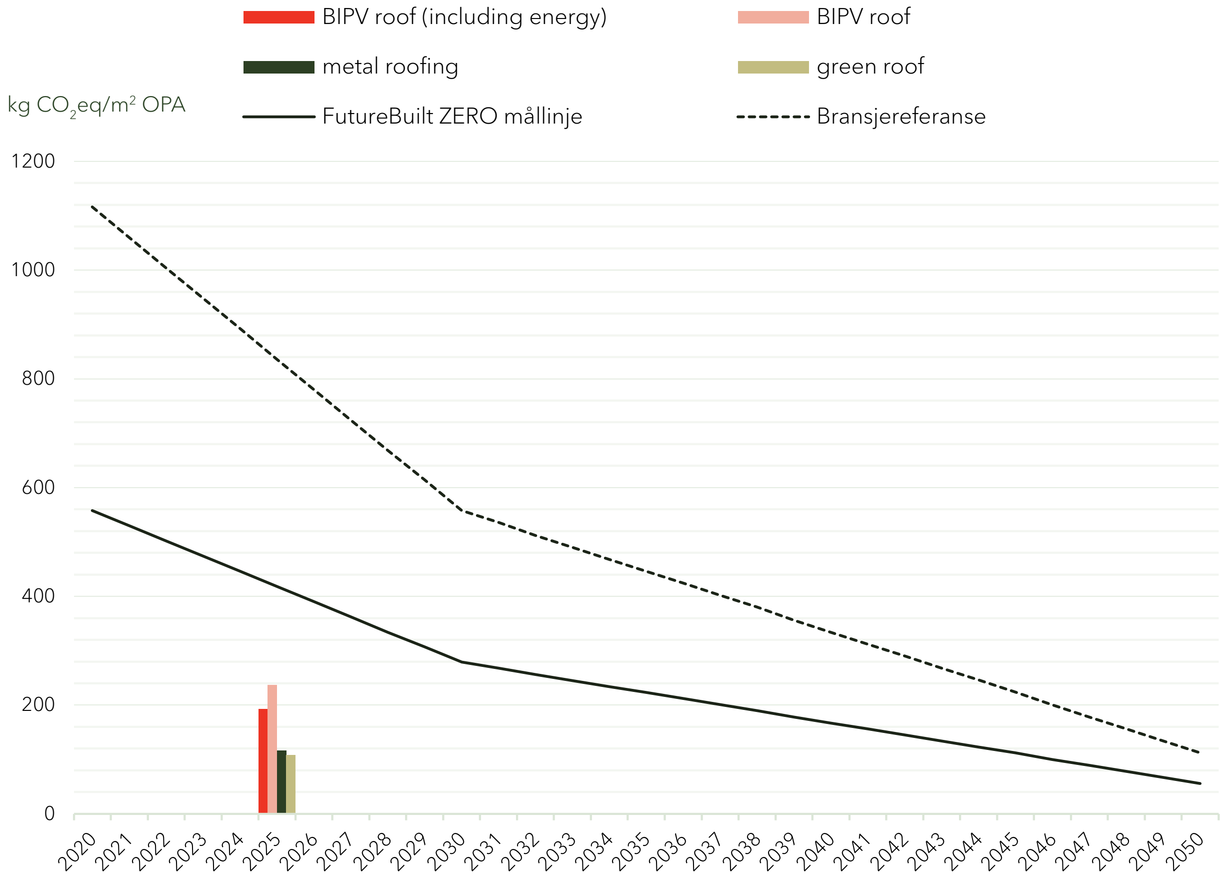


Fig. 47 Comparison of 3 cabin design scenarios with Futurebuilt benchmark and common practices in residential housing

In figure 46 the cabins are compared with the Futurebuilt benchmark which is gradually increases its requirements in order to reach the 2050 goals net-ZEB buildings.

Impact of reused materials

The example of reused wooden facade cladding and windows (fig. 38) shows how much CO_2 emissions can be saved when sourcing materials on the second-hand market. Reused materials account for only a fraction of new materials emissions (here: from 24% - roof windows, to only 4% - spruce primed and untreated cladding).

The cladding however accounts for only a tiny part of emissions of the whole building. It makes up for 8.5% of the external EcoCocon wall emissions, which means it is responsible of 2% of all material emissions of the cabin (green-roof version). Similarly, reused windows account for 6% of total material emissions of green-roof cabin. Although the numbers may not appear significant, they would increase if new material was utilized instead. Thus, it is important to remember that even changes that might not seem very radical at first glance, are worth to implement.

The impact of reused floor slabs or roof structures would be clearly more visible in the total emissions because those elements are the most emissive in the LCA. With this studies it is evident, that reusing structural parts from a building set for demolition is an environmentally profitable practice, whether done on-site or off-site.

Energy embodied emissions

The energy demand of a cabin is very hard to determine since it depends widely on the use patterns of the owners (or guests). In this thesis several assumptions have been made concerning heating loads, occupation schedules and energy use during construction phase. The estimations can show however, the outline of the energy emissions share in the total cabin project (fig. 47).

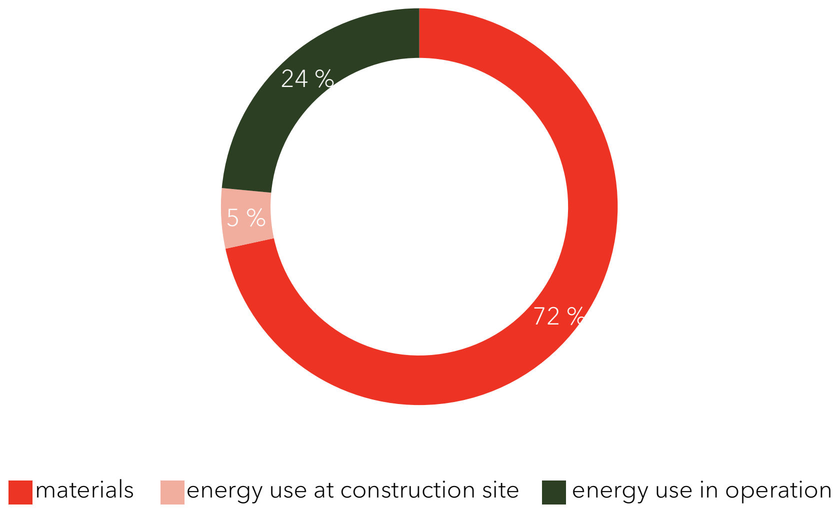


Fig. 48 Share of materials and energy use GWP for cabin with BIPV roof

The BIPV roof cabin scenario shows that the installation of PV panels is only GWP-wise justified when they are not replaced in the 50 year time span. This is however only true when set in countries like Norway, with a clean energy supply. On the other hand, we are all responsible for climate change and since Norway trades energy with EU that comes from gas (European Commission, 2024), the electricity to emissions conversion factor provided by NS3720 seems more applicable and just. In that scenario with one replacement of PV roof tiles after 25 years there are 2299,8 kg CO_2eq saved by year 50 and over 2.5 t CO_2eq saved without any replacement during this time. Only in this scenario, the BIPV installation emissions are lower than the Norwegian grid average and equal to 13.4 g/kWh.

It may seem that this much of a win is not worth an effort but the low emissions of Norway also depend on the small suppliers. Moreover if one is increasing the power demand, then the person should cater for it himself and do not rely on the "clean" grid supply. Perhaps a choice of different PV panels with lower embodied emissions could be more profitable. Additionally with this much of an electricity produce that (in a year perspective) is 5.5 times the energy demand, the cabin could serve as a small powerhouse for neighbours. It could also provide energy for car charging.

Conclusions

The project covers a part of the sustainable architecture that might be easily forgotten in the numbers and profit-oriented environment. The biodiversity factor is measurable indeed but unlike U-values or heating loads, also something very tangible in everyday (especially: cabin-) life. The simple acts of kindness towards nature presented in this thesis: like planting some native trees or leaving a pile of dead-wood for the bumblebees to inhabit does not involve much effort or cost but can make a big change and contribute to the healthier and well balanced ecosystem.

Of course it is not always this easy and not everything depends on single person decision. In fact, the cabin industry is woven into a network of various connections and dependencies. One of the first one to name are local authorities together with legislative bodies that have the tools to implement certain measures and regulations to support regenerative development. Another key players in the cabin development scene that should be highlighted are scientists and researchers, with their expertise. The connection between research and design should be strengthened. Implementation of energy efficient technologies and getting an ecologist to examine your plot is equally as important in the search for regenerative and biodiversity friendly design.

The exchange of thoughts and good connection between different stakeholders in cabin industry is crucial for its further development in regenerative direction. That is already being done in Oppdal within the CommonGround project, which connects scientists, architects, local authorities and business owners in order to develop set of best practices for a second home development. I hope, projects like that spread the knowledge, change people's approach and spark the love for biodiversity.

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Site plan

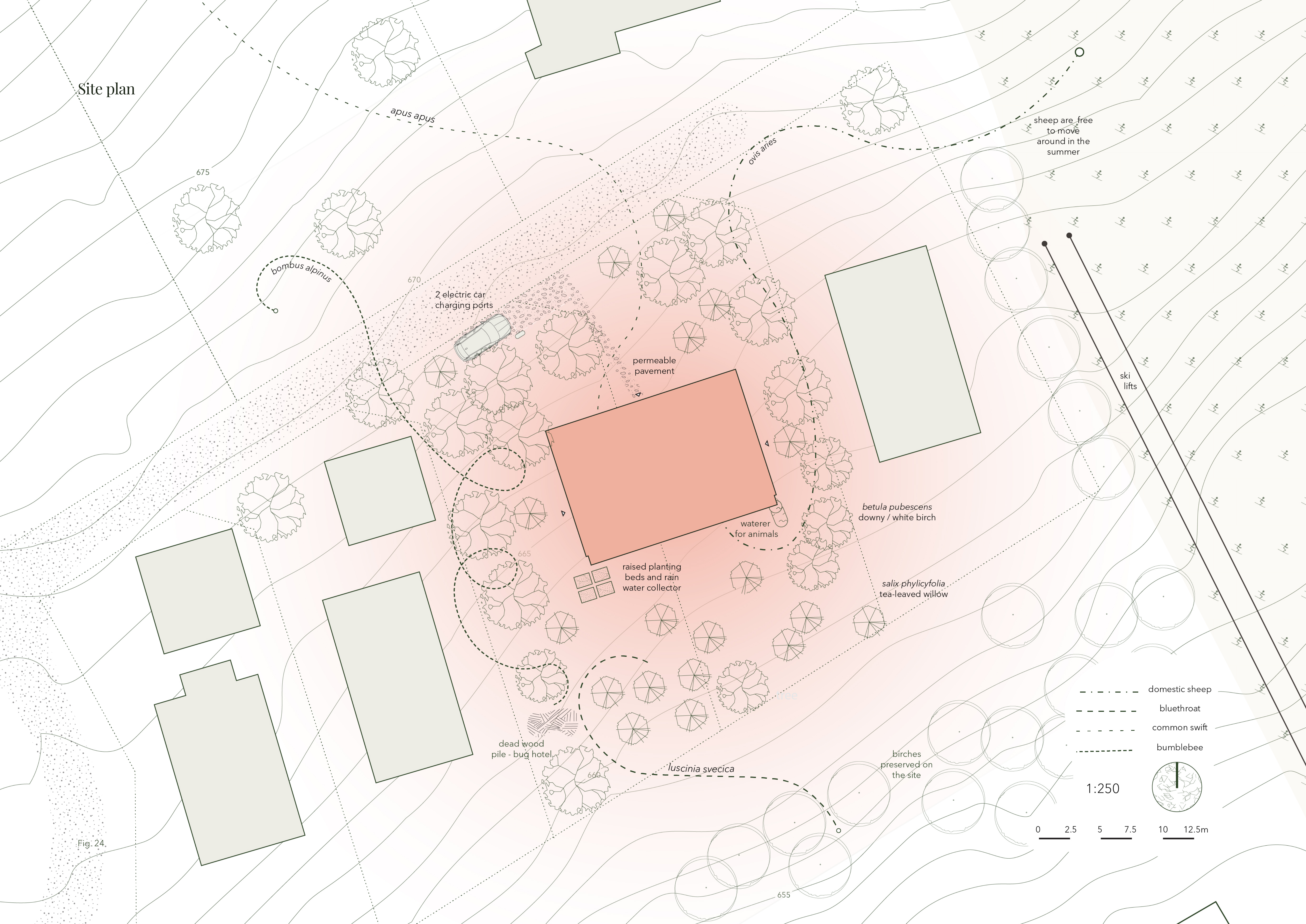

Fig. 24.

Ground floor plan

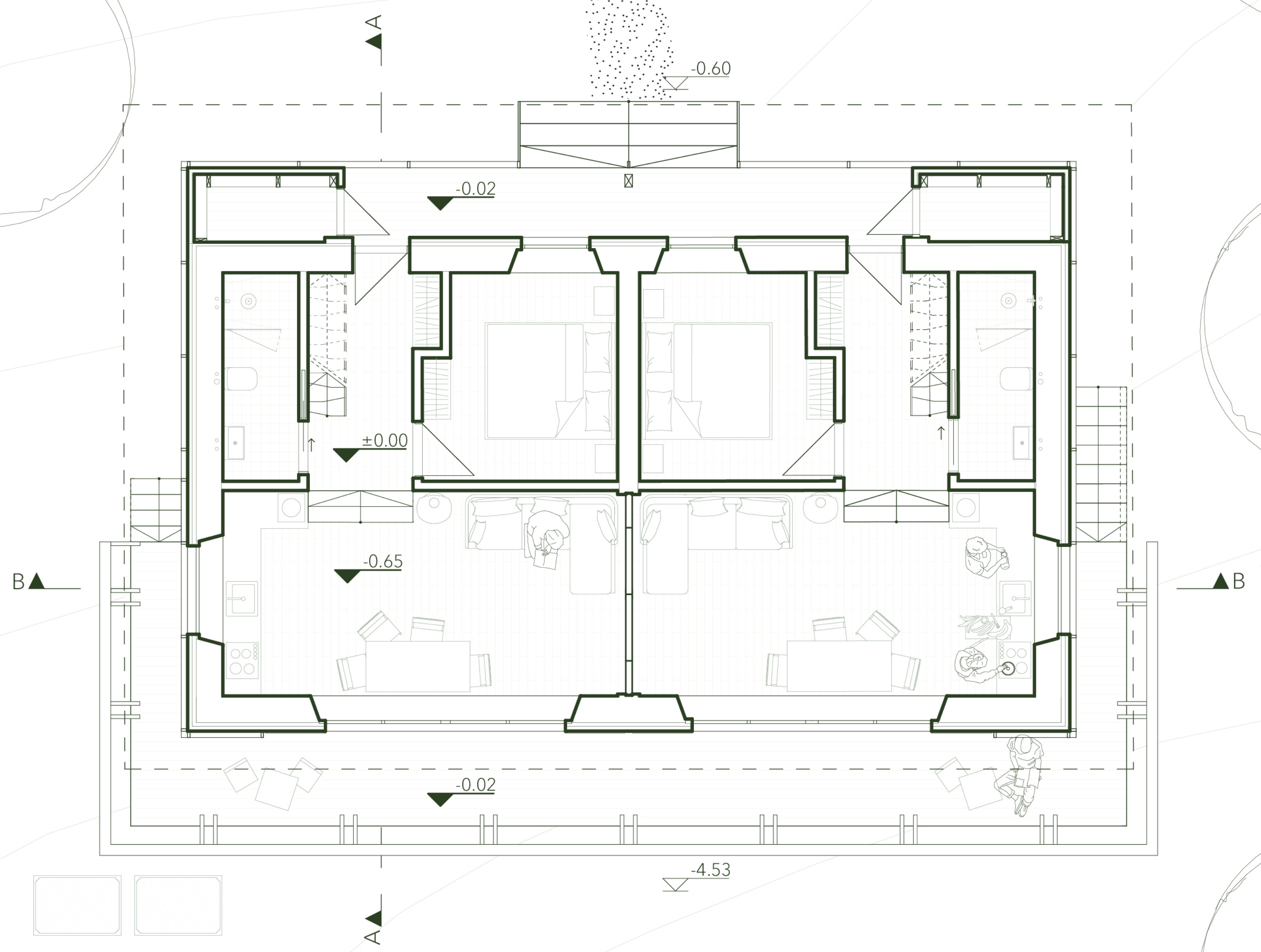

Fig. 25

1:100

Bluethroat

Luscinia svecica

The project represents more than human design and aims to be the seed of increased biodiversity in the area. Therefore, on the upcoming pages, together with the technical drawings, key species are presented, that are meant to be reintroduced. Those plants and animals are important for the ecosystem to stay balanced, healthy, and self supportive, serving both people and nature itself. Some of the highlighted species were recognized and registered on the site before it was built-up, and all of them are native to the vegetation type of *beiteskog* - grazing birch forest (Artsdatabanken, 2024).

The Bluethroat is one of the most eye-catching birds in the mountains. Its vibrant blue throat patch is a distinctive feature of the male, earning it its English and Norwegian name. Bluethroat has great song and can mimic other birds, as well as the other sounds including a ringing sheep bell. All of the above make him a great bird to look up for, as the birdwatching activities are proved to reduce stress and improve well-being. Sadly, in Norway between 2007 and 2013, approximately 6% fewer individuals were observed each year, but recently the decline seem to stagnate. The bird, like any other mountainous species, is highly influenced by the climate change but also by the loss of living habitat due to change of land use, less grazing pressure and more construction (Asmervik, 2023).

Ground floor plan - joined cabins

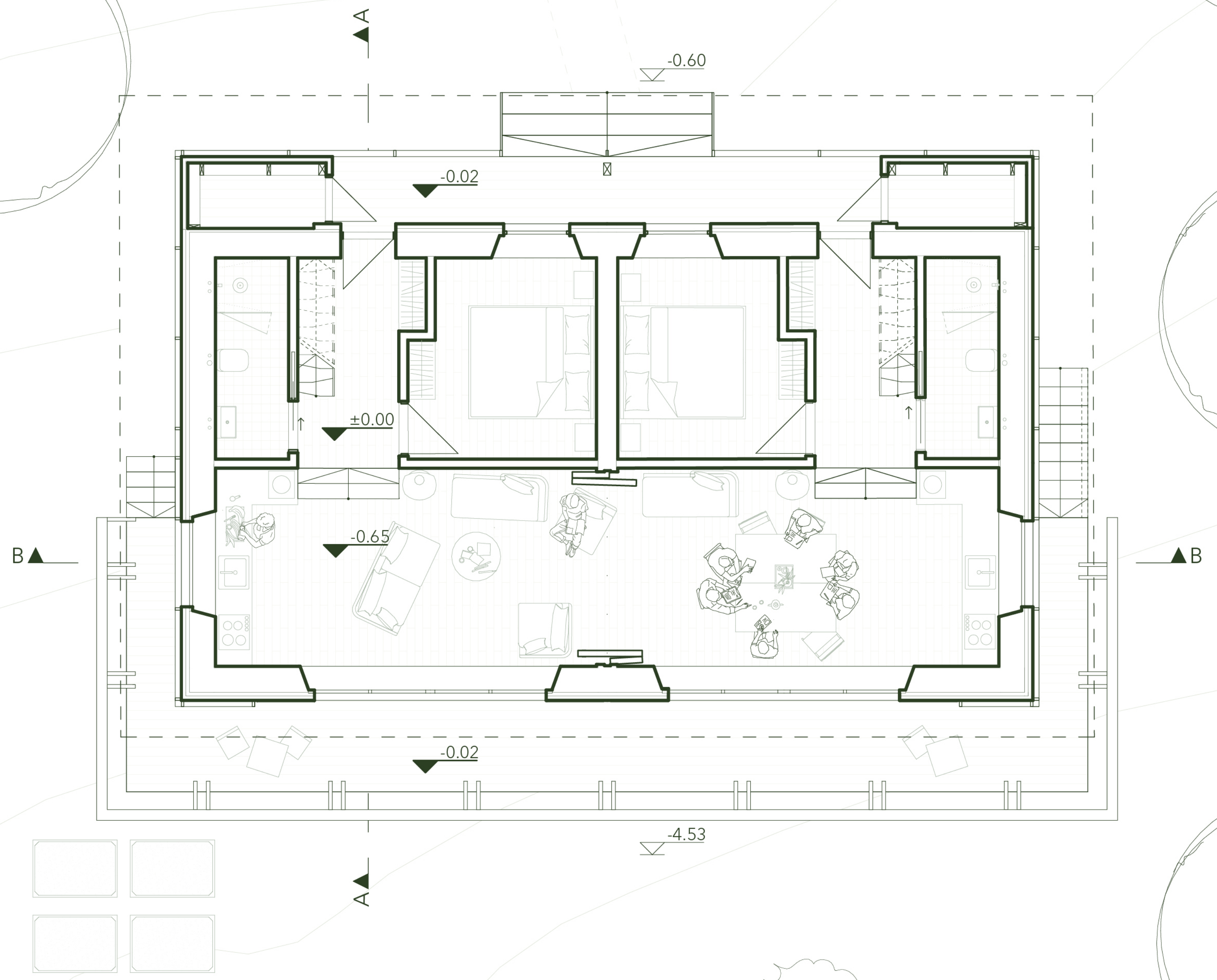

Fig. 26

1:100

Upper floor plan

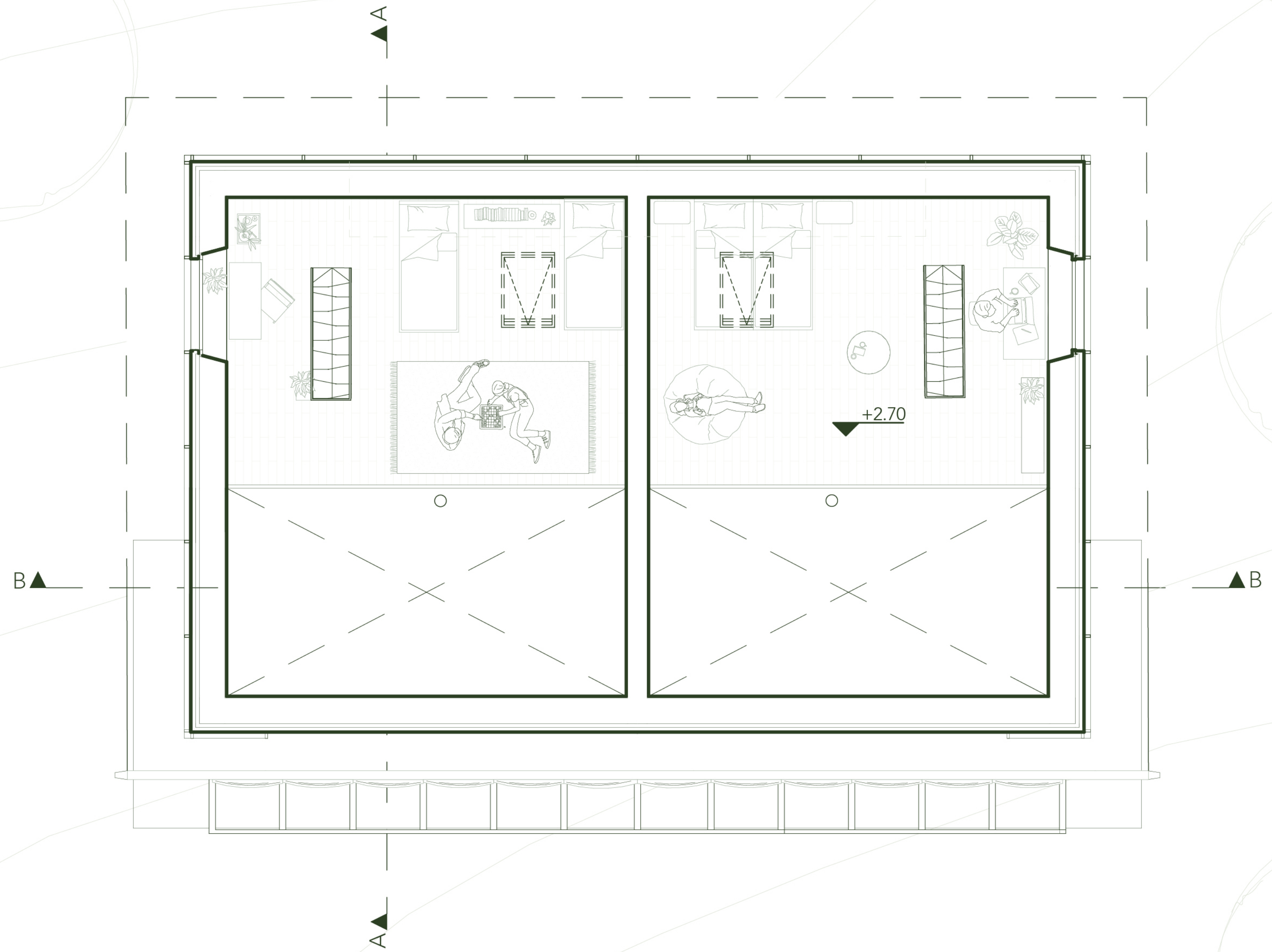

Fig. 27

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Downy birch

Betula pubescens

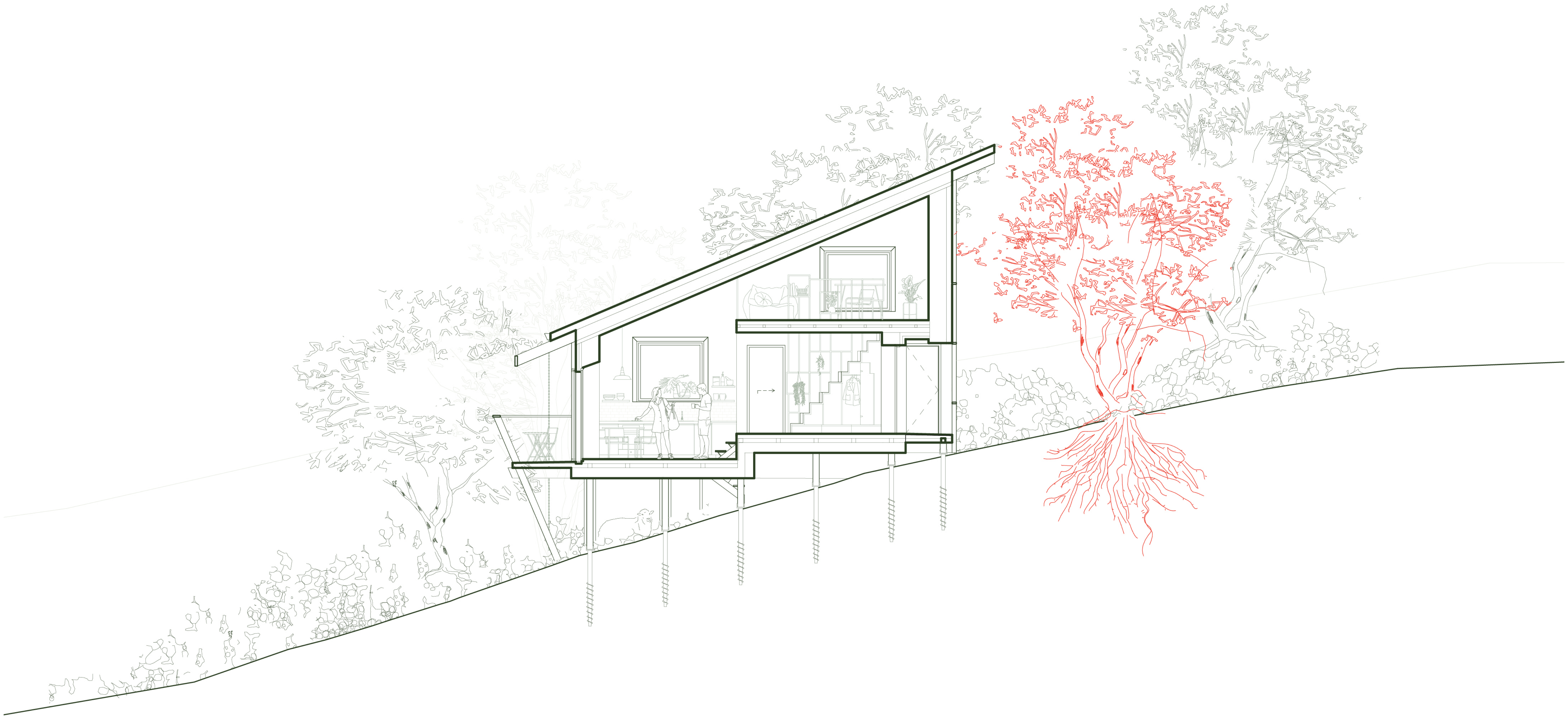

Fig. 28

Downy birch, with its subspecies mountain birch, *betula pubescens tortuosa*, is a deciduous tree, with a great intra-specific variation, native and abundant throughout northern Europe, growing farther north than any other broadleaf tree. It forms "scandinavian montane birch forests and grasslands" which are defined by the WWF as a terrestrial tundra ecoregion in Norway, Sweden, and Finland. Here it recreates the essence of the ecosystem, strengthens birds' and insects' biodiversity, prevents soil erosion and filters air and water (Eufogren, 2024). It is even capable of capturing the microplastic from the soil (Austen, MacLean, Balanzategui, & Hölker, 2022), which might come handy with the proximity of ski slope. With a canopy letting a fair amount of light through, birches create a pleasant atmosphere around the cabin for all living organisms.

Section B-B

Alpine bumblebee

Bombus alpinus

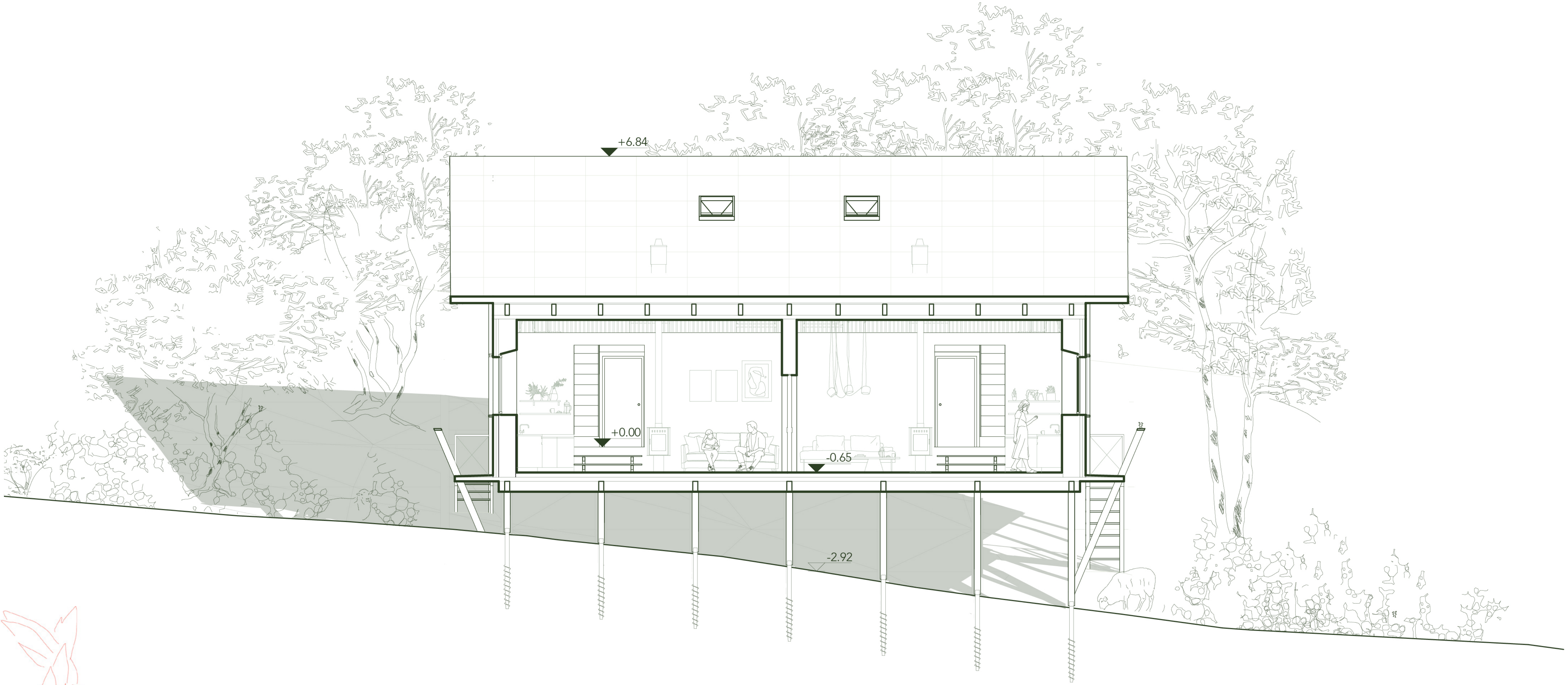

Fig. 29

Bumblebees play a crucial role in maintaining the health of ecosystems. They pollinate plants (like willow displayed on the left), that are essential for the survival of many other animals, including birds, bats, and other insects. They help to maintain the diversity of plant species in an ecosystem what makes them more resilient and better equipped to recover from disruptions. They are a link in the chain, without which the ecology as a whole can be heavily affected. They build their nests in various cavities such as: in hollow trees, abandoned bird nests, rock walls, or under a tussock of grass, but they mostly nest underground looking for a rodent hole to adapt (Xerces Society, 2024). They have a pile of dead wood laying in the corner of the plot to serve their needs.

West elevation

Tea-leaved willow

Salix phylicyfolia

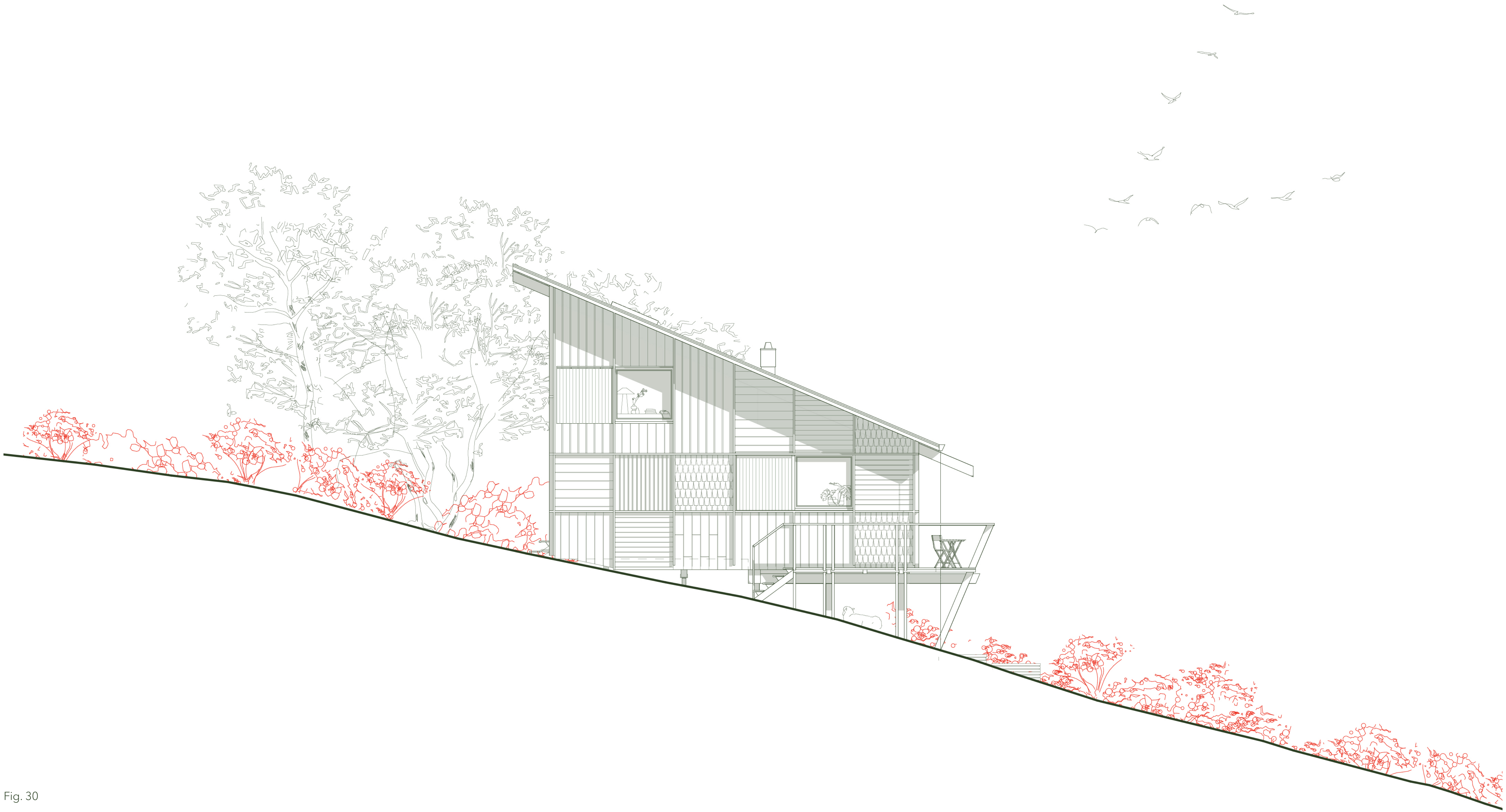

Fig. 30

Tea-leaved willow is a shrub or a small tree that is observed all around Norway apart from the most southern, coastal areas. It is native to hilly and mountainous terrains, it also grows in the lowlands along waterways. Willows do not need especially rich-nutrient soil but they prefer moist areas. *Salix phylicyfolia* usually grows up to 2 meters in Norway (Grindeland, 2023). Planting willows adds up to the regenerative nature of the project, since they are able to capture heavy metals from the soil and store them in the roots (Sandhi, Gao, Rosenlund, & Landberg, 2023). Apart from that, tea-leaved willows serve as a lower ground cover here, providing shelter for birds, in e.g. bluethroat, without view obstruction. They also prevent soil erosion, and regulate water conditions thanks to their abilities of water retention.

South elevation

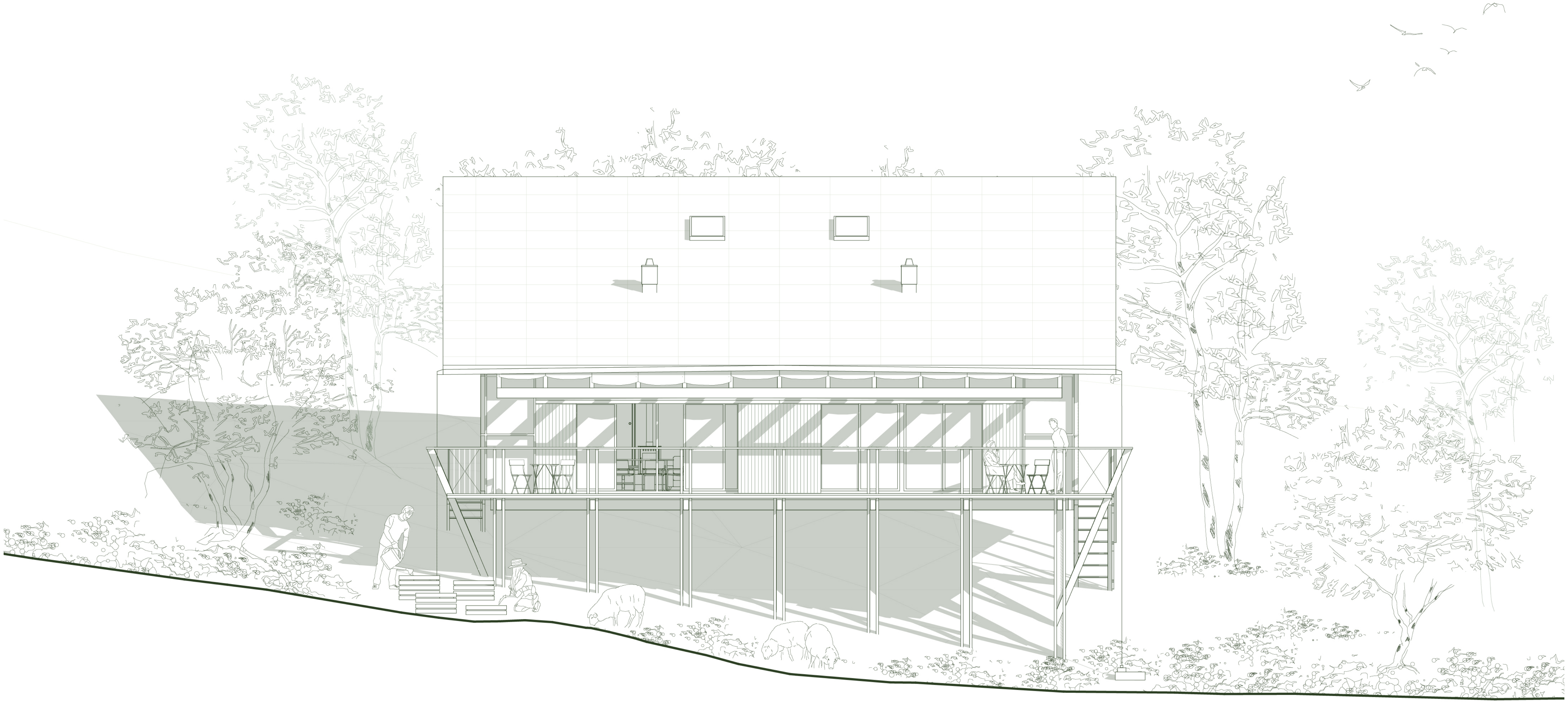

Fig. 31

On the plot there is a gardening system installed that collects water from the roof, which may be used for watering crops in the raised boxes. On the right side of the building however, there are open water containers for animals of different sizes. They are supplied with rain water as well.

The elevation of the cabin is made out of scrap wooden elevation boards that were used to build cabins in the area and might still be lying around as the cabin field is relatively new. The divisions aamde with wooden strips allow to use different types of cladding, cover the seams and achieve and interesting patchwork effect.

East elevation

Domestic sheep
Ovis aries

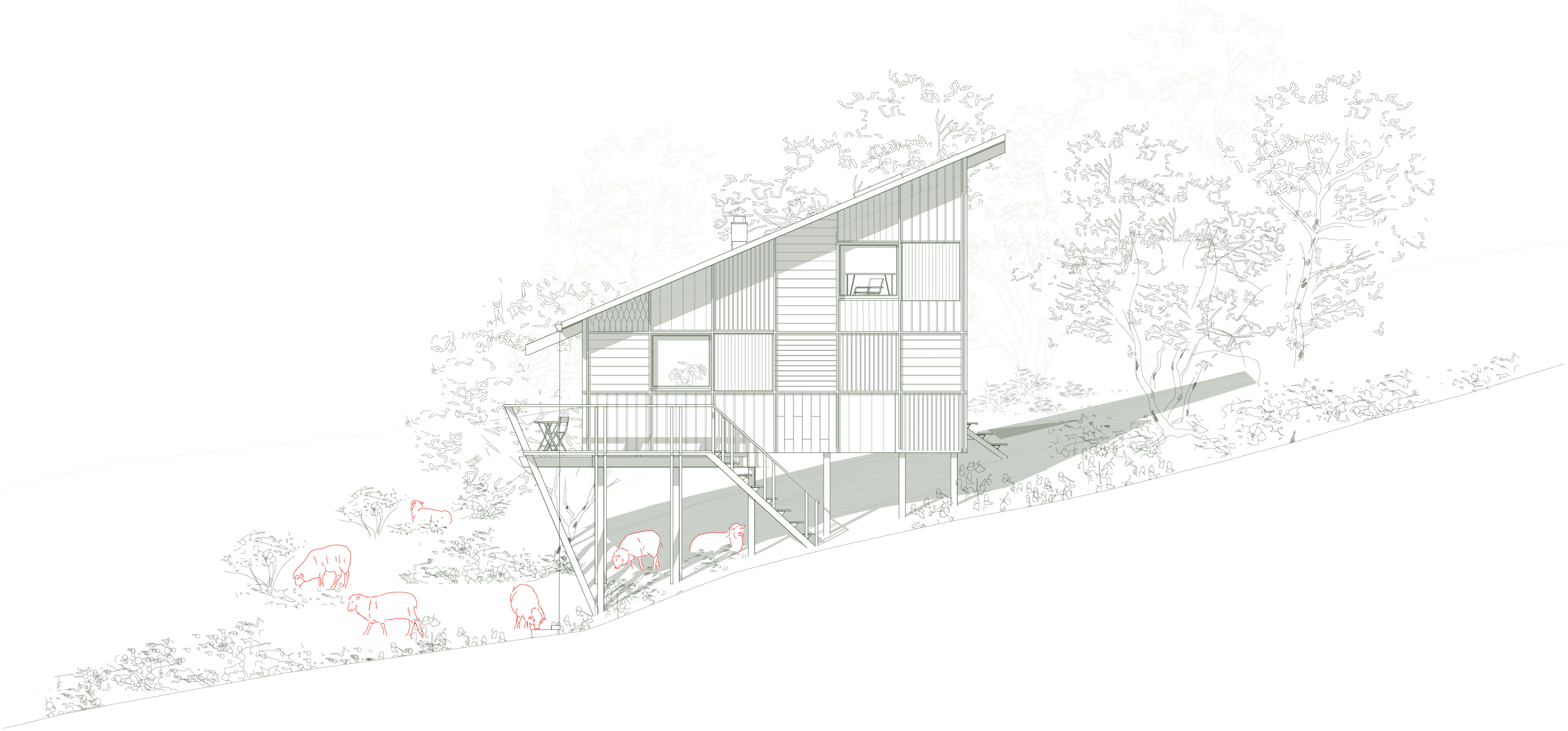

Fig. 32

Sheep are crucial for the grazing forest to retain its values. They play a key role in shaping the landscape through their grazing activities, which helps to maintain the diversity of plant species, keeps the vegetation low and prevents one species from dominating. By controlling the growth of certain plants, sheep also help to reduce the risk of wildfires and promote the growth of other species that are more resilient to fire (Canon, 2023). Additionally, sheep are creating pathways and clearings that allow other animals to move through the area. The cabin offers them a shelter in case of heavy rain or excess sun, while they are grazing at the nearby ski-slope meadow. They attract attention and are probably the most evident example of the project assumptions.

North elevation

Common swift
Apus apus

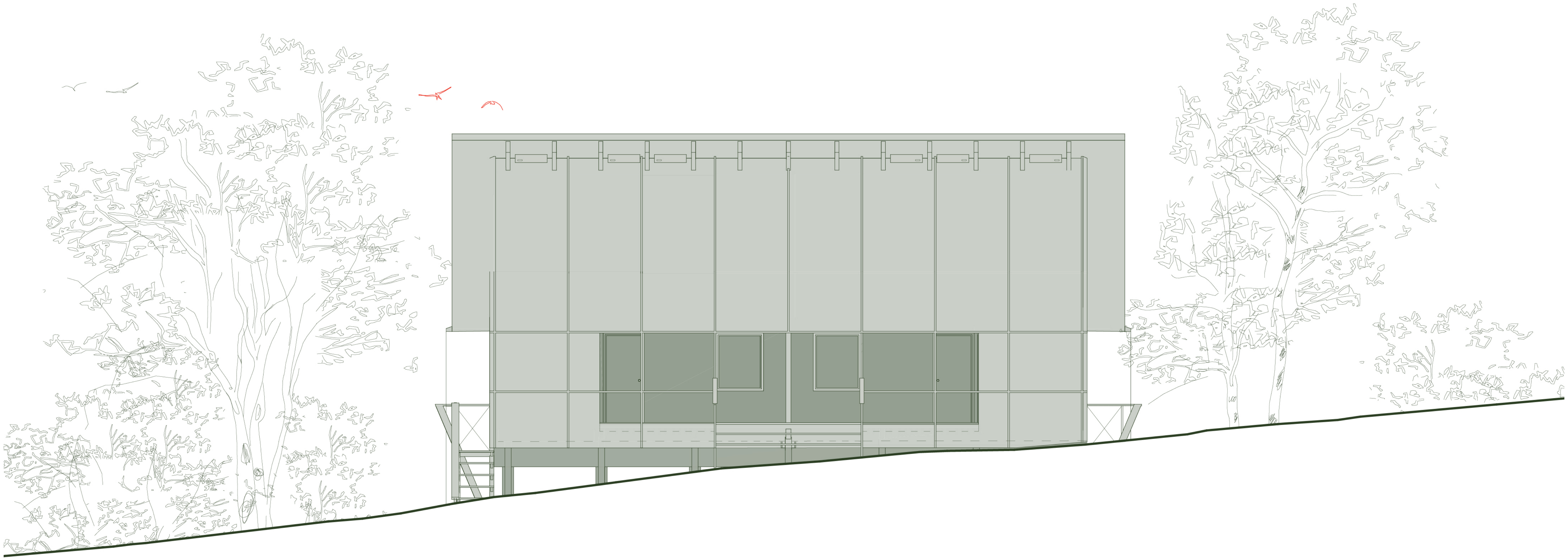

Fig. 33

The Common Swift is a migratory bird that is known for its impressive aerial agility and ability to spend up to 10 months of the year in the air, only returning to land to breed, not even to sleep. They are social birds that thrive in colonies, so their nests are always close to each other. They hunt for nuisance air-borne insects such as flies, mosquitoes and midges, leaving the area around more pleasant for people. For nesting, they require swift-specific nest boxes hung on the northern or eastern side of the building at least 5 meters above the ground (here 6.5 m). The entrance hole is very narrow (only about 3 x 6 cm) situated to the side of a hollow and deep box. On this side of the building the strips on the facade are limited and starting lower so that the fledgling birds have an easier start from the box. The population of swifts is decreasing and they are classified as close to threatened on the norwegian redlist, so it is important to make them a nice place to live (Hogstad, 2023).

Fig. 34 Perspective drawing

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