Mývatn Visitor Center

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Mývatn Visitor Center

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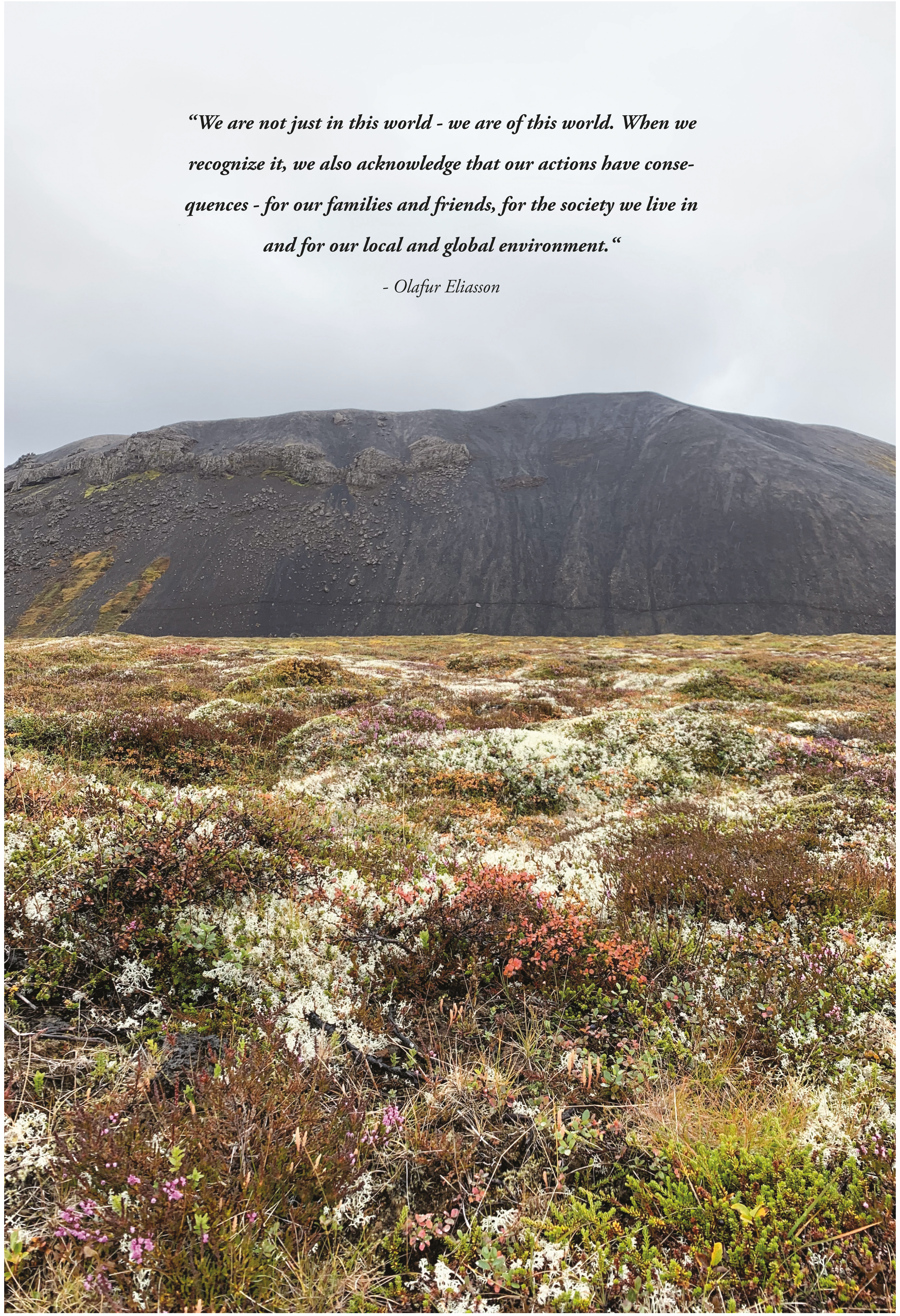
Contents

"We are not just in this world - we are of this world. When we recognize it, we also acknowledge that our actions have consequences - for our families and friends, for the society we live in and for our local and global environment."

- Olafur Eliasson



ill. 1 - fields of moss in Northern Iceland
- photo by: E. Juul

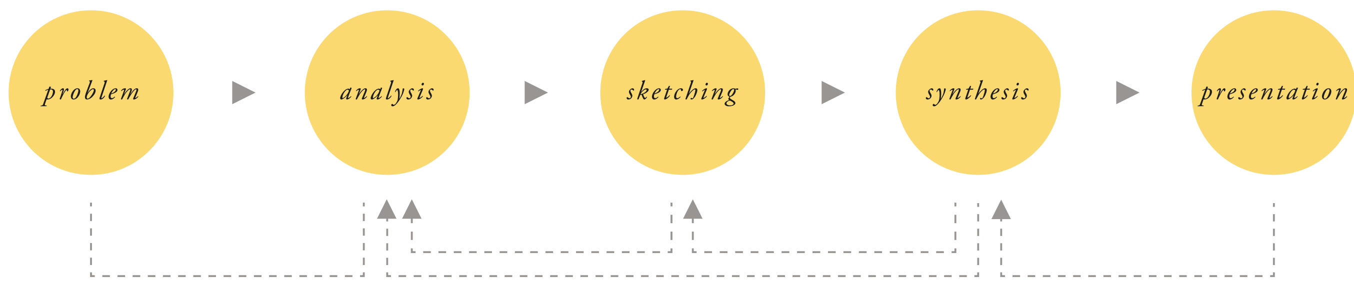
Motivation

Our motivation for this project is a common wish to design a building in a context different from an urban setting: a rural site. This wish combined with a shared interest in sustainable design sets the foundation for the project, which will concern a Visitor Center with accommodation in Iceland. Architecture should consider many aspects such as functionality, aesthetics and atmosphere, but a big part of making architecture is also about designing for the context, why different approaches are used when designing in an urban setting compared to a rural site. A close relation to Nordic design and an interest in the challenges of integrating a harmless but changing nature phenomena; the Northern light, into a design, makes Iceland a suited location for the project. The tourism in Iceland helps the country's economy but also takes its toll on, especially, the original nature. We found it interesting to face these problems in the project, and work with a high consideration on contextuality and a focus on sustainable architectural solutions with the goal of responding to these problems.

Readers guide

The thesis report is organised in ten chapters starting with a short introduction describing the applied methodology of the project as well as a description of the scope of the project. After this the studied theory is presented in mainly text and some illustrations. From the theory, the report continues to the Framework of the project, which describes some of the general conditions of building in Iceland. After this, the report goes a step closer to the actual site and the physical site conditions are presented through analyses of micro climate, a site visit and analyses of the conditions for seeing the northern lights. Following the site analyses, some case studies are presented, using proposals from the original competition. Based on all of the above, a programme for the design is presented in the following chapter.

The next chapter shows the design process based on the findings in all previous analyses. The design process consists of both the sketching and the synthesis of the project.
After the design process, the final ideas for the concept is shown through diagrams in the ideation chapter, which is followed by the final presentation of the project.
The final chapter is an epilogue containing a conclusion and a reflection.



ill. 2 - the phases of the integrated design process

Methodology

This project concerns the design of a Visitor Center with accommodation in Iceland. Being an architectural project, a holistic approach will be used to combine the different aspects from the architectural and the engineering field. This chapter will describe the approach to the project in terms of the overall process as well as an explanation of different methods used to achieve results throughout the project.

The project work will be based on the Integrated Design Process (IDP) by Mary-Ann Knudstrup (Knudstrup, M., 2005). The IDP consists of five phases, aiming to combine knowledge and methods related to the architectural and engineering approaches from an early stage. The IDP is an iterative process presented in a rough time line, meaning that one may go back and forth between the phases to improve the project when gaining new knowledge, and thereby creating an integrated and holistic design

The first phase is the problem definition, which is where the constraints of the project are explained. This phase contains a limitation of the project to clearly specify the initial approach. The problem is the foundation for what to achieve with the project and it clarifies the problematic areas that the projects should cover.

The second phase is the analysis phase. Based on the initial problem definition several subjects are analysed to fully understand the extent of the project. Different approaches are used to interpret gathered information and material. The analysis phase is concluded with a number of design criteria and a vision to create a more defined direction for the process of designing and a basis for qualified decisions.

The third phase is the sketching phase. In this phase a concept is developed, and design proposals are made based on the knowledge gained in the analysis. In this phase a lot of different ideas are tried out to meet the design criteria and answer the problem.

The fourth phase is the synthesis. In this phase the ideas are made into one main idea synthesizing the best solutions from the sketching phase. The project gets more detailed and further developed regarding the different aspects of its technical performance.

The final phase is the presentation phase. Here different approaches are used to present and explain the final concept and design both in terms of aesthetic and functional aspects, but also in terms of technical performance. The project will be presented in this report as well as in the materials brought at the exam. Different types of presentation material will be used to make the project comprehensible for the reader.

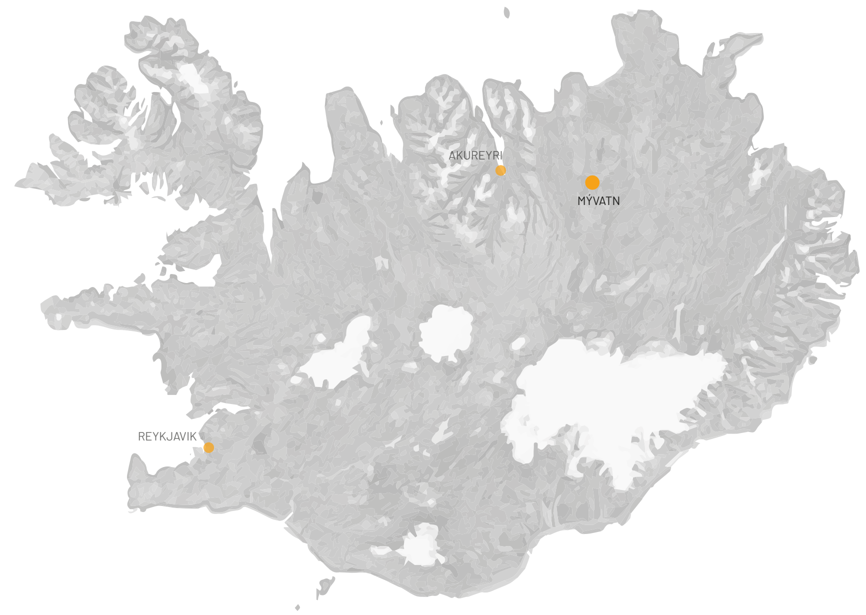
	Description	How to use	Purpose
Analysis phase			
Theme studies	Investigation of different themes relevant for the project.	Critical research is made to find sources with relevant information. Based on the sources, several topics will be described in independent analysis providing a summary of the reading for each topic.	The purpose of the method is to understand and describe the extend of the project. The method is used to explain the framework of the project, narrow the field for the project and determinate directions for the project.
Mapping	A method used to identify and understand the site in its context.	The infrastructure and the functions in the area are described using a map and research.	To understand the physical structure of the area, how to arrive to the site and which functions the area can provide in connection to the project as well as its shortcomings.
Measurable site studies	Investigation of the micro-climate including wind, sun, clouds, precipitation and temperature.	Based on quantitative data, diagrams are used to describe the weather conditions at the site.	To understand how the seasonal changes will affect the site and the vegetation, and when there will be the best weather conditions for watching the northern light.
Visit at site	A phenomenological registration done at site.	When being on the site, all physical and atmospheric experiences are noted and photographed if possible.	To achieve a visual and atmospheric perception of the nature and the landscape at the site and the nearby surroundings.
Sketching phase			
Hand sketching	Fast drawings to communicate and brainstorm different ideas.	Drawings based of thoughts and references.	A way of quickly communicate and express different ideas for design solutions.
3D modelling	Three-dimensional representation of sketches.	A 3D model made i Revit or sketchup based on initial thoughts and drawings.	To give an better overall understanding of the complexity of a design and how to fit the building to the context. Can help solve problems arising when going from 2D drawings to 3D.
Physical models	Hand-made models in paper, foam etc.	Models made in different scales based on initial thoughts and drawings.	To quickly investigate and compare different shapes, and get an understanding of the building proportions.
Synthesis phase			
Simulation software	Working with different building simulation software such as Bsim.	Using simulation software to understand how a given environmental aspect can influence the dimensioning of constructions and placement of openings etc.	To give a realistic result and understanding of how an environmental aspect can influence a design and the building's technical performance.
Presentation phase			
3D modelling	A spatial representation of the final design.	A final 3D model is used as foundation for presenting the project with renders.	To give an understanding of spatiality and volumes, and to visualize the final ideas for the reader.
Diagrams and illustrations	Visual material to present the final design.	A visual description of the project explained through different kinds of diagrams and illustrations.	To give the reader a visually understanding of the project as well as describing different principles in the building.

Problem

In recent years an increasing number of tourists have been visiting Iceland to experience the nature phenomenon: The northern lights. As a country close to the northern magnetic pole, Iceland provides some of the best locations and conditions to see the phenomenon, which combined with its otherwise impressive and unique landscape, have become one of the biggest tourist attractions in Iceland (Óladóttir, O., 2018). The tourism helps the Icelandic economy, but also takes its toll on, especially, the original nature (Iceland monitor, 2018). Therefore, the theme of this project will be to design a sustainable tourist accommodation along with a visitor center to inform and educate about the Icelandic nature.

One challenge is to design with the utmost respect for the nature, while still providing the visitors the unique experience, that they are searching for. With a focus on sustainability, the project should investigate how different environmentally sustainable approaches can be used to re-establish a, in tourism often lost, connection to the original nature to promote sustainable tourism. The tectonic principles in the project should support the environmental sustainability. The scale of the building will allow close detailing of connections and joints in the building, leading to the question; how can the construction be designed to enhance the experience and atmosphere of the building in correlation to the environmental sustainability approach?

ill. 3 - fields of moss in Northern Iceland - photo by: E. Juul



ill. 4 - map of Iceland showing placement of major cities and Mývatn

BeeBreeder's Competition

The project takes it starting point in the competition for the Iceland Northern Lights Rooms hosted by Bee Breeders in spring 2018 (BeeBreeders, 2018). The competition conditions contain an initial building program as well as a range of requirements which will be a part of the framework for the project. The competition site is a 3 hectares-large site located in the northeast region of Island. The site is nearby the lake Mývatn and close to the volcano, Hverfjall, and thermal pools.

The competition brief states that the overall purpose of the project is to create a concept for a guest house from which to view the nature phenomenon Northern Light. The building complex is to functions as a guest house, with facilities for accommodation for up to 20 staying guests as well as facilities needed for the hosts running the place.

Separated bedrooms ranging from one to four people should be provided for the guests as well as kitchens and bathrooms. From all the bedrooms there should be a view to the sky with the opportunity to capture the Northern Light. A dining area is needed for the visitors, and it should be able to host and serve all the visitors at once. Along with the dining there should be space for the hosts and up to five invited staff members, to provide room for the needed related facilities.

Housing both guests and hosts, a clear division should be made between the guest house facilities and the private accommodation for the hosts. The host facilities should provide a permanent home for the hosts and their family and include a bedroom, living room, bathroom and a small kitchen. Additionally the brief states, that a covered terrace should be included in the design as well as a barn used as shelter for 10 Icelandic horses owned by the host. The project must also include a strategy for parking and considerations should be put on the internal and external circulation spaces.

Project proposal requirements from the competition brief:

1. Adaptable and moveable types of bedrooms

2. Able to provide comfortable shelter for several days to all occupants in all weather conditions

3. Cost effective construction for remote areas

4. Resistant to heat, cold, rain, snow and wind

5. Environmentally responsible and energy efficient for providing bath amenities

6. Able to generate its own power and provide safe drinking water

7. Low maintenance in terms of effort and costs.

Theory

This chapter will elaborate on different focus areas in the project. With sustainability being the main specialization for the project, the chapter will start by introducing the essential sustainable focuses of the project. The sustainable focus will be followed by an elaboration of the themes atmosphere, the tectonic detailing and the building's relation to the landscape. The aim of the chapter is to clarify and determine superior directions for the project.

ill. 5 - ice block on beach in Iceland - photo by: E. Juul

Sustainable approach

The most common and universal definition of sustainability comes from the Brundtland Report, 1987 also called 'Our Common Future'. In the report sustainable development was specified as: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (United Nations, 1987). In 1992 sustainability was defined in the Rio-declaration on environment and development, from which we know the three pillars: environmental, social and economic sustainability (United Nations, 1992).

When looking at sustainability in relation to architecture, it is essential to consider the building in a short-term as well as a long-term perspective.

Environmental:
A building will use different resources as well as it will generate waste meaning that buildings will impact the environment through all its lifecycle and are roughly responsible for 40% of the energy consumption in Europe (European Commision, 2018). This makes reduction of the environmental impact in all phases an important theme to address when making architecture.

When considering environmental sustainability in relation to this specific project, a variety of different parameters should be met. The site itself is an essential premise for creating environmentally sustainable architecture. Working with a rural site in a remote location invites to great considerations regarding how to work with a natural context and how to preserve and respect the qualities of the site.

Materials are a central aspect of the environmentally sustainable dimension. The sustainability of a material will depend on both the technical properties of the material itself as well as the climatic conditions in a location (Bejder, A. et al, 2014, p. 38). In general, the location will have great influence on the materials, as accessibility and transportation will be parts of defining the sustainability of a material at a specific location. These aspects will play a central role when making a project on a more secluded site as transport of materials needs to be considered.

When designing an individual building with its own specific qualities and characteristics, it is important to consider the production and assembling of the building. A remote location and the natural conditions of a rural site makes it essential to consider other sustainable solutions than prefabrication, to ensure easy transportation as well as unique qualities fitted to the specific project and site.

Iceland offers great conditions for the use of renewable energy strategies, which makes the country leading in the field (Askja Energy). With its unique conditions, great considerations should be brought to the use of the renewable resources that Iceland offers, and what these specific conditions of Iceland can bring to the project. In the same way the harsh Icelandic micro-climate should pay an important role in the design, not only in terms of the material and maintenance but it will also cause great influence on the design of the building in terms of the use of different passive strategies to develop the energy consumption as well as the indoor climate conditions.

The environmentally sustainable aspects should direct the design from the very beginning to achieve a holistic and integrated design.

ill. 6 - Teshima Art Museum, Naoshima, Japan - photo by: E. Juul

Tectonic approach

As stated previously, architecture is more than just numbers – it contains a subtlety and sensibility, that through atmosphere can be felt and thereby affect the users of the architecture. To work with atmosphere, it was in the previous chapter stated, that we wish to incorporate the work of Peter Zumthor and Juhani Pallasmaa. Their findings and theories will be crucial in our work with the tectonics of the building – more specifically, in the work with detailing the building, since the detailing of joints concerns especially the materiality and the relation to the human scale, which is some of their main focuses. To investigate how details can add quality to architecture, the theories of Marco Frascari will be discussed in the following.

"The art of detailing is really the joining of materials, elements, components, and building parts in a functional and aesthetic manner. The complexity of this art of joining is such that a detail performing satisfactorily in one building may fail in another to very subtle reasons." (Frascari, M., 1984, p. 2)

In his work Tell-the-Tale-Detail from 1984, Marco Frascari states the above. In this he addresses the challenge of making elements meet and describes details as being 'much more than subordinate elements; they can be regarded as the minimal units of signification in the architectural production of meanings' (Frascari, M., 1984, p. 1). To him, detailing can make or break architecture and must be considered and carefully designed to avoid building failure – both on the ethical and the aesthetic level.

To Frascari, the detail is always a joint, and he separates joints into two types: material joints – such as the meeting between a column and a beam – and formal joints – such as a porch, that is the connection between interior and exterior. When thinking of details in this way, it is clear that all details are always the functional considerations in a building. How the building is supposed to be used must be told in the details – hence the tell-the-tale detail. Architecture is not only a profession; it is also an art, that seeks to put spaces and materials together in a meaningful way. To do this, the process of making a detail – whether it is a material or formal joint – involves first the mental construing of the joint and then the actual physical construction of the joint. As he says: "The joint, that is the fertile detail, is the place where both the construction and the construing of architecture take place" (Frascari, M., 1984, p. 11).

The mental construing comes before the actual construction and requires the architect to be able to visualize the detail before making it. The architect has a certain idealistic wish of how the detail must look to express the architectural idea that is the reasoning behind the detail. However, the mental construing requires a skilled mind and often challenges are not thought of before the actual construction of the detail, meaning that the clarity of the architectural idea can be weakened.

Working with tectonics by focusing on the detailing, will fit very well to our wish of incorporating atmosphere in the shape of materiality and the human relation to the surroundings. Since Frascari describes joints as both formal and material, the two key features of Peter Zumthor, The Material Compatibility and Tension between Interior and Exterior will be addressed through detailing of joints and connections. Pallasmaa's fundamental theory, that the sense of touch is the basis of all senses, further supports the importance of working with materiality and scale in the detailing.

Atmosphere in Architecture

"Quality of architecture … is when a building manages to move me." (Zumthor, P. 2005, p. 10).

Architecture is not all about creating the physical frames and shelter for the users, architecture can appeal to our minds and set us in certain moods or provoke feelings. In a time, when a lot of modern architecture comes down to numbers – energy, cost, time – it is important to remember to work with the more subtle and poetic faces of architecture. A term that can be used in this context, is atmosphere – the characteristic mood or feeling of a space. In the project, the term atmosphere will be used by working with creating different atmospheres to suit the various users and their use of the spaces.

The Swiss architect Peter Zumthor uses nine key features to generate atmosphere in his architectural works. These features are described in the book Atmospheres from 2005, that is a transcript of a lecture, Peter Zumthor held in 2003 (Zumthor, 2005). In the following these nine features will be described and discussed.

The Body of Architecture: To Peter Zumthor the way the building is put together compares to the human body. The physical frame of the architecture whether it be walls, columns, vaults or anything in between, correlates to the human anatomy with its skin, bones, muscles etc. He believes we can relate and interact with the building through these similarities.

Material Compatibility: This feature concerns the use of materials and how materials are compatible with each other. Zumthor emphasizes that materials react with each other to a higher or lesser degree depending on their characteristics, and that they have endless possibilities. He also states that there is a critical proximity between materials, meaning that if they are too close or too far away from each other, they cannot react to each other.

The Sound of Space: The third feature, Zumthor describes, concerns how the building or spaces treat sound. He links it to the shape of the room, the materials and the surfaces of the room among other. To him, there is unfortunately many people who are not aware of how a room enhances sound.

The Temperature of a Space: This fourth feature concerns how a space is thermally experienced. He links the characteristics of the used materials to the way we experience the space due to its ability to store cold or heat. However, he states that it is not only a physical feeling: it can also be psychological and be experienced through not only touch but also vision.

Surrounding Objects: Zumthor values how people as the users of a space gives it character and a personal touch through the things, they decide to surround themselves with and values the presence of.

Between Composure and Seduction: This sixth feature concerns the way architecture urges us to move around, not necessarily by suggesting a certain path, but also by leaving room and choice to the human to move and stroll around as they please.

Tension between Interior and Exterior: The seventh feature addresses the meeting between the outside and the inside and discusses how the user changes from the feeling of being enveloped to being outside in the open. How the architecture treats the transition between inside and outside through elements such as facades, thresholds and crossings, determines how the user feels the change from inside to outside.

Levels of intimacy: The eighth feature concerns the dimension, scale and the building

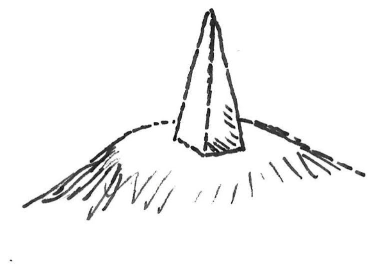
ill. 7 - Teshima Art Museum, Naoshima, Japan - photo by: E. Juul

mass as a contrast to the human body. He describes how there is a tension between different sized objects and that working with dimensions and scale, can create an experience when it is related to the human body.

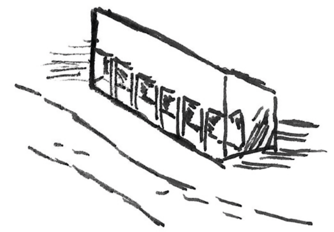
The Light on Things: The last of the nine features concerns how the light enhances architecture. Zumthor describes the two approaches to light, that he likes the most: the first being imagining the architecture completely dark, and then carefully placing lights where they are needed to showcase certain things. The other being aware of how materials reflect light around them.

Incorporating these nine features in the architectural design, will aid to design a building that urges the user to have a sensual, atmospheric experience. All the key features involve an interaction between the architecture and the human for the atmosphere to be felt by us – as in the words of Gernot Böhme: atmosphere is something felt between the object and the subject (Böhme, G., 1998). The elements, that Zumthor describes are all dependent on the relation between these two and how the human senses the elements. To further understand how the senses address architecture, the studies of Juhani Pallasmaa can be helpful. In his work The Eyes of the Skin from 1996 (Pallasmaa, J., 1996), he criticizes how many architects mainly seek to stimulate the vision as the primary sense, leaving most other senses – ear, nose, skin, tongue, skeleton and muscle - unstimulated. Instead architecture should become a multi-sensory experience by addressing all senses and the architect should design with the human body as the center of the process. Pallasmaa sees the touch as the basis of all other senses – also the vision – since the body through the other senses gets reminded of how the object feels to touch. In architecture the spatiality and our perception of distance and materiality is crucial and according to Pallasmaa, this would not be possible without the collaboration between the senses and the tactile memory. As another contrast to the sense of sight, Pallasmaa mentions the sense of hearing. The sight is directional, while sound comes from all directions and will articulate and support the spatial experience in a room.
The project will aim to incorporate aspects from all Zumthor's nine key features, however some of them will be in greater focus due to the nature of the project. The Material Compatibility will be considered important in the work with materiality related to Pallasmaa's theory on how touch is one of the basis senses and how our memory is triggered when sensing different materials. To facilitate a good experience in the Icelandic nature, the feature Tension between Interior and Exterior will also be crucial and used to enhance both the physical and mental feeling of being inside, but in connection to the outside nature. Thinking of Pallasmaa's approach to designing with the body in the center, the feature Levels of Intimacy will be applied to relate the human body to the building.

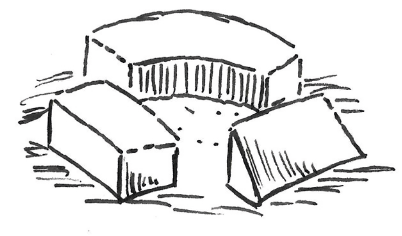
ill. 8 - merging with landscape



ill. 9 - claiming



ill. 10 - enfronting



ill. 11 - surrounding

Architecture and Landscape

To build in a remote location without an urban context, sets a great focus on the architecture in relation to the landscape. The project site along with its context is very untouched, which is a less familiar basis for us to design from. This in many ways different starting point for designing raises questions regarding how the landscape and the site can affect the design of the building.

This text has its source in the section 'Fitting the house to the land' from the book 'The Place of Houses' written by the three American architects Charles Moore, Gerald Allen and Donlyn Lyndon (Moore, C. et al., 1974). The text is interesting for us, as it proposes different ways in which a building can be designed to the landscape. How to fit a building to the landscape depends on the individual situation, and it is important that one considers both the opportunities that a site may offer as well as the problems brought by a given site. According to the three architects, the ways of fitting a building in a landscape can be summarized into four core approaches: by merging, claiming, enfronting and surrounding.

Merging: Merge can be defined as more elements combined into one. Merging a building to the land is a human made fusion between the nature and the building, to create the building as one with its surroundings. The approach is often used in a context with strong textures, such as hills or trees, which gives the opportunity for a building to naturally blend in with the site. In some cases, a merge can almost happen by itself and can be difficult to avoid without making alteration to the vegetation and terrain. Even though the merge can seem most suited for a vegetated land, it can also happen on a wide-open piece of land, where the building is merged with the background by keeping it low and horizontal in its expression.

Claiming: Being the opposite of merging, claiming can easiest be described as when a building is in a clear contrast to its surroundings. In this situation it should be clear, that the building is intended to be different and detach itself from its natural setting. Claiming is most prominent in large homogeneous rural sites undisturbed by vegetation, high terrain differences and other buildings. Colors and shape are key factors, in which one can make a clear distinction to the land around the building. A strong and prominently shape gives the building a dominating character and thereby a power to claim its own part of the context. The strength of claiming the land will depend on the individual situation. If a building is placed high, it possesses a bigger power to claim the landscape around it, as seen in the ancient Greek temples.

Enfronting: Enfronting is like defining an edge, by giving parts of a building, often one of the façades, a unique design to highlight an element on a site. Enfronting can be used to enhance a certain feature on the site and is often used to emphasize a street, a square, or a plaza. As it may seem that enfronting is mostly used in an urban context, the approach can also be used on an open rural site to enfront features such as a specific view, a nearby river or other landmarks.

Surrounding: In a surrounding building the intentions of claiming are turned inwards. Different elements of the building are used to close around and outdoor area and create a private space. The surrounding can be completely closed or partly open, creating different levels of privacy. This approach gives the opportunity to create a courtyard with a completely transformed character compared to the rest of the site. Surrounding turns away from the landscape by creating a smaller and separated outdoor area, which is why the approach is less used on the more remote open sites. Surrounding is a sought for approach in locations where it is desirable to create shielded outdoor areas due to climatic conditions.

Common for all the four possibilities is, that the chosen approach should fit to the specific site, the vegetation and the climate. As stated earlier in this text, working with a remote location is challenging by being less familiar for us. In the rural sites the building should relate to the natural texture of the terrain and trees whereas buildings in the dense urban sites should be related to a human made urban production. The more rural site offers more opportunities for different ways of fitting the building to the landscape compared to an urban context in cities and suburbs. A site can in some cases accommodate all the four ways and will sometimes do several things at once.

To investigate which way of fitting the building will be most suitable for the project site, different analysis regarding the site conditions should be considered early to narrow down and set guidelines for the possibilities for fitting the building to the specific land. However, it will also be essential to experiment with different designs based on several of the four approaches of placing the building, to fully understand the potentials of the site and how different solutions will collaborate with the other themes and criteria addressed in the project.

Framework

This chapter presents various studies and research based upon the qualities of the Icelandic context. The aim of the chapter is to understand and further describe the possible extend of the project, by investigating the unique potentials Iceland can provide to the project. The studies will investigate the tourism in Iceland, Icelandic vernacular architecture, the northern lights and a study of the accessible renewable energy sources and their potentials.

ill. 12 - Glaumbær turf houses, Iceland - photo by: P. Nguyen

Tourism in Iceland

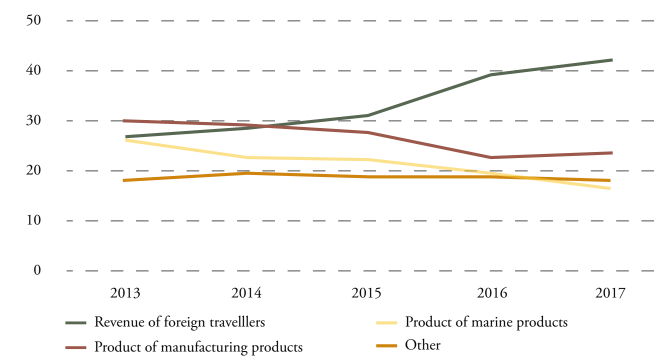
Tourism has during the latest years had an immense impact on Iceland – both positive and negative. Iceland with a population of 340.000 was in 2018 visited by no less than 2.2 million tourists – a number that has been rapidly growing since 2010 with an average increase of 24,3% each year (Óladóttir, O., 2018). As a country that was highly impacted by the economic collapse in 2008, the tourism has become one the most important economic sectors in Iceland (Guðmundsdóttir, K. H., 2016). However, the economic prosperity comes with a cost: 75% of Icelanders think that the tourism has a negative effect on the Icelandic nature (Óladóttir, O., 2018). This is a highly important topic for not only the average Icelander, but also the government that will use their presidency for the Nordic Council in 2019 to focus among other on sustainable tourism (Nordic Co-operation, 2019). Sustainable tourism focuses on the authentic respectful interaction with the local culture and nature as opposed to so-called mass-tourism that is typically driven by the urge to earn money. Though, sustainable tourism is considered the best solution, it is often economically hard for a country to go without the income from mass-tourism. (Lacanilao, P., 2017)

The increase of the number of tourists is due to many factors (Jónsson, A.). The nature phenomena and attractions that draw the tourists to the country, has existed for thousands of years, however due to raised media attention in the latest years, Iceland has gained attention from international tourists. With the eruption of the volcano Eyjafjallajökull in 2010 causing cancelled flights and a huge media attention, the country received a never seen interest from the outside world. The nature phenomenon drew an immense attention to the harsh and impressive nature of Iceland and fuelled the growth in tourism. Other elements that keep drawing attention to Iceland in a tourist's eye is Hollywood movies being shot in Icelandic locations, the economic collapse, new Icelandic music etc. combined with easier and cheaper airline access has made the number of tourists rapidly grow ever since.

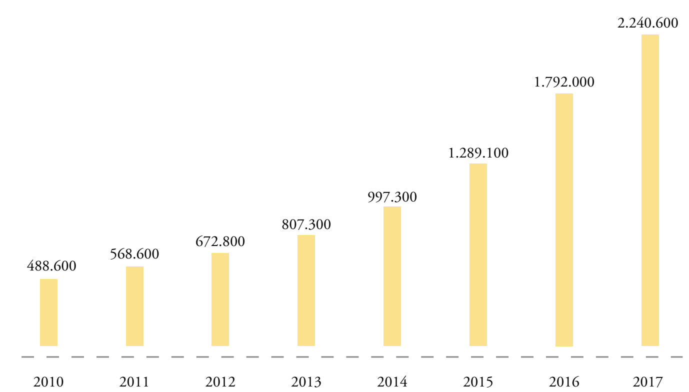
Asking the tourists themselves, topics such as the various nature features incl. the northern lights, interest in the Nordic region, and nature related recreation, are among their top reasons for visiting the country (Óladóttir, O., 2018). However, paradoxically the original Icelandic nature is under massive pressure from this tourist attention, and in many cases, experts are describing the situation as 'overtourism' with tourists being the biggest threat to the aspects that in the beginning attracted them to the island. But how to balance the financial need for tourists and the wish to preserve the unique nature? The Icelandic government is trying to implement solutions to settle the immediate problems such as a ban of bus traffic in Reykjavik and a 90-day limit for Airbnb hosts. However, these solutions are met with much criticism from government opposition and the public, who see the solutions as very short term and ineffective. (Chapman, M., 2017).

It is safe to say, that the main challenge that Iceland faces regarding the tourists, is how to protect the original and treasured nature. The solution would according to some critics be to limit the number of tourists, that are allowed to visit certain sites or Iceland in general. However, others fear that this might harm the attractiveness of Iceland to international tourists, and thereby causing fewer tourists to want to visit the country (Chapman, M., 2017). What might ideally be needed is a change of mind of both tourists and locals towards sustainable tourism: to ensure quality over quantity. For tourists to be understanding and accepting towards the measurements that need to be taken and for the locals to realize that the current income from tourists will only be possible as long as the nature is kept in respect and preserved.

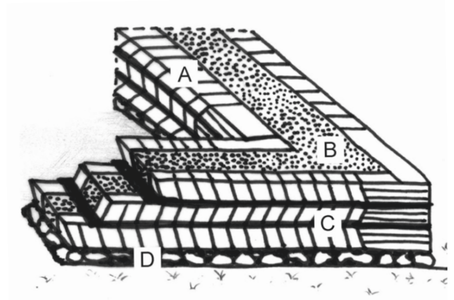
The project will therefore propose a design, that promotes sustainable tourism in a way, that is respectful to the original nature. The complex should use sustainable, biodegradable or reusable materials and promote the use of these materials and their advantages to both local building owners, tourists and the local inhabitants. The visitor center function will promote the area and its attractions while educating tourists on how to act in the area. Locals will see an example of how tourism can be done in a sustainable non-harmful way, while still providing a completely unique experience, that will attract tourists to Iceland.



ill. 13 - export of goods and services (%) 2013-2017 (Óladottir, O. - 2018)



ill. 14 - international visitors to Iceland 2010-2017 (Óladottir, O. - 2018)



ill. 15 - the construction of a turf wall. A: the outsides of the wall is constructed from turf blocks. B: the cavity between the blocks are typically filled with soil. C: In some cases, there are horizontal layers of sods, that connect the inner and outer layer of turf. D: the wall construction is built on a stone layer to protects against moisture. Source: (van Hoof, J. et al., 2007)

ill. 16 - Glaumbær turf houses, Iceland - photo by: P. Nguyen

ill. 17 - Turf house wall construction, Iceland - photo by: P. Nguyen

Vernacular Icelandic architecture

Being a country influenced and ruled by other nations several times, the architecture of Iceland has through time been affected by many architectural styles. Icelandic architecture offers among other examples of stone buildings designed and erected by Danish architects and houses in Swiss chalet style from the rule of Norway. These styles are still visible and preserved in many parts of Iceland, for example in the streets of Reykjavik where colorful corrugated iron façades show the Icelandic take on the Swiss chalet style. However, traditional vernacular Icelandic architecture has a unique approach to the harsh Icelandic climate and its challenges in the shape of turf houses. According to the UNESCO World Heritage nomination from 2011 "the turf house is an exceptional example of a vernacular architectural tradition, which has survived in Iceland," and "The form and design of the turf house is an expression of the cultural values of the society and has adapted to the social and technological changes that took place through the centuries." (UNESCO, 2011). The traditional Icelandic vernacular housing will be described in the following due to its unique approach to the Icelandic climate conditions, its morphology that merges with the landscape and its building technique shaped by scarcity of materials.

Until the 9th century, Iceland was uninhabited. Between 870-930 AD Vikings from Norway accidentally found Iceland, when exploring and decided to settle on the harsh island – this first settlement is today known as landnám (Smith, K., 1995). With the settlement there was a need of building materials and due to the scarcity of wood on the island, the answer was turf: the upper layer of the soil intervened by the roots of grass so tightly that it can be cut into mats. This vernacular technique proved to be especially suiting the Icelandic climate and provided a thermally insulating envelope for the cold environment. The concept is not unique to Iceland since the use of turf as a building material is also seen in other areas, however the users of the Icelandic dwellings are unique by being from every class of society, while they traditionally were for the lower classes in other areas (Valgardsson, E.M., 2016).

The idea for the oldest turf houses were brought from Scandinavia and was very similar to the traditional Viking longhouse. Later through time, the houses evolved to gain their own Icelandic touch shaped by the climate and the evolving culture. Turf houses typically consist of a light wooden frame (often driftwood found at shores) covered with stacked turf mats. The foundation and often the walls are constructed from Icelandic stone – either basalt or lava stone depending on the location – to prevent ground moisture. To construct the roof, there were also used turf mats, which over time would grow into each other making the roof watertight. If constructed properly, a roof made of turf can last 20-30 years before needing change. (van Hoof, J. et al., 2007). An example of a turf house, that still stands today, is the Glaumbær farm in North Iceland (see illustration 15-17).

The main goal when using turf was to shield the inhabitant from the cold Icelandic weather. By constructing walls with in some cases up to 3,5 m thick layers of turf, the indoor temperature was stabilized and the thermal comfort highly improved. However, the indoor temperature relied heavily on the number of people present in the houses, since the heat from humans in most cases were the only heat source. This also meant, that the air-change was kept low to keep the heat inside. So even though the thermal comfort might have been considered satisfactory (by that time), the quality of the indoor air must have been poor, possibly resulting in poor health among the inhabitants. (ibid.).

Turf houses were until approximately 1910 one of the most widespread housing types in Iceland housing up to 50% of the inhabitants. With the implementation of modern farming, came modern building techniques and today the existing turf houses are an important and valued cultural aspect, but are no longer used for housing. The turf houses illustrate a unique architectural approach to sustainable architecture and simultaneously express a significant architectural aesthetic by merging with the landscape. Though, their original appearance might not be directly applicable in a modern setting, they do exemplify a very sustainable approach to locally sought materials and the climatic challenges of Iceland.

Earth constructions in Iceland today:

As the general needs and function of architecture and buildings in Iceland have changed, earth is not used as load-bearing constructions anymore. Though there are several ways of making modern earth constructions, such as rammed earth and adobe bricks, the Icelandic earth is in fact not very suited for making load-bearing earth constructions due to the type of earth available in Iceland. The most common agreement among constructors, are that the wall will gain the best load-bearing properties when using a 30/70 mixture of clay and sand (Rammed Earth Works, 2010). However, the general Icelandic soil has a low amount of clay, making it hard to reach a good composure of the mixture without adding cement. The most clayey soil type available in Iceland is called histic andosol and has a clay content of around 36% (Arnalds, O. 2015), meaning that this is suitable for rammed earth construction. But as it is not present on site and the areas in which it can be found, are covered in protected and threatened Icelandic moss, it is unlikely that it can be used for construction. Instead, it is possible to make non-load bearing interior walls from rammed earth, as they will not need as load-bearing capabilities as the load-bearing walls, while still having the good hygroscopic qualities as if they had been load-bearing.

	Embodied energy (MJ/kg)	Produced CO_2 (kg CO_2/kg)	Export country
Rammed earth, unstabilized	*0,02**	*0,004***	*Iceland*
Rammed earth, stabilized (8% cement)	*0,28**	*0,018*	*Iceland*
Natural stone (basalt rock)	*0,50****	*0,035****	*Iceland*
Concrete	*0,95*	*0,04*	*Iceland*
Fired clay/bricks	*3,00*	*0,06*	*Denmark*
Wood	*8,50*	*0,13*	*Norway/Iceland*
Steel	*24,40*	*0,48*	*Iceland*

*ill. 18 - embodied energy (MJ/kg), produced CO_2 (kg CO_2/kg) and possible export country of some building materials - (Hammond, G.P. , 2008). * (Taghiloha, L., 2013). ** (Abebe, M. et al., 2018). *** (Ashby, M. F. 2013).*

The environmental impact of local building materials

When dealing with sustainability in architecture and in the general building sector, a main concern is often the choice of materials, due to their environmental impact. To address and compare the impact of different materials, two factors that can be compared are the embodied energy and the production of CO_2 when producing a material. The embodied energy is the sum of energy required to produce (in this case) 1 kg of said material, while the production of CO_2 tells the emission of CO_2 per kg produced material. When analysing the above scheme based on these factors, some materials are significantly more sustainable than others.

Rammed earth is in general the lowest impacting material, followed by natural stone, and concrete. Wood has a relatively low CO_2-emission, but the embodied energy might seem high compared to e.g. concrete. However, this is due to the much lower density of wood, making wood another sustainable choice when considering the embodied energy and CO_2 emission and the fact that wood can store CO_2 while growing. Unfortunately, locally grown wood for construction has not been very available in Iceland since the settlement. As an alternative, driftwood is widely available due to the sea currents carrying wood logs from Russia to Iceland and can be used for construction, detailing and façades.

Similar, natural basalt rock is a locally available material, that can be cut and processed at the quarry in the nearby town of Akureyri approximately 1,5 hours drive from Mývatn. Natural stone have a fairly low embodied energy and CO_2 emission, since the material is completely naturally produced and only processed by being cut into the desired slabs, tiles or blocks.

Since the embodied energy depends on production method and energy source, it needs to be considered that materials produced locally in Iceland, might have a significantly lower impact due to the country's high use of renewable energy, since renewable energy from hydro-power and geothermal activity has a much lower emissions factor than fossil fuels. Simultaneously, materials produced in Iceland will have a lower impact due to the less transport needed, and it is therefore highly preferred to use locally sourced materials for the project such as earth, concrete, stone, and driftwood. However, while some materials can be found locally, many cannot. These are for example glass, gypsum, paint, and membranes, which all must be imported from other countries. In most cases the most desirable way of transportation is by ship since the CO_2 emission from this kind of transportation is lower than other means of transportation , meaning that if possible, the materials should be imported to Iceland by ship.

	g CO_2 /tonnes /km
Air plane	*500 g*
Truck	*60 to 150 g*
Train	*30 to 100 g*
Ship	*10 to 40 g*

ill. 19 - the CO_2 emitted from different kinds of transportation of materials (Time for Change)

Aurora

ill. 20 - Aurora over Iceland - Photo credit: Guide to Iceland

Aurora Borealis, Northern Lights or Norðurljós in Icelandic, is the appearance of polar light in the northern hemisphere around the magnetic pole caused by the collision of electric charged particles from the sun and gasses in the Earth's atmosphere. The collision is visible as a dancing and undulating light spectacle in the night sky, ranging in colors from green to purple depending on the specific gas particles in the collision. However, the phenomenon aurora is much more complex and significant than a simple scientific explanation. Since the Northern Lights was first named in the Old Norse language in 1230, aurora has enchanted and mystified us humans in a way few other natural phenomena have ever done, and has in most cultures that has experienced the lights, been the subject to many legends and folklore. From being the glowing bridge leading those fallen in battle to their final resting place in Valhal in the Norse mythology to rare sightings of ancient dragons in China, the Northern Lights continue charming us to this day (Aurora Zone).

Though the scientific explanation of today might have lessened the general belief in the myths and folklore surrounding the aurora, the phenomenon is still considered worth travelling for and many tourists come to Iceland hoping to experience it. However, due to the infrequency and evanescence of the phenomenon, many leave Iceland without the experience. There are ways to determine the chances of seeing the lights, but in the end, it comes down to luck as there are no guarantee to see the lights. When planning to see the northern lights, you must consider several aspects such as solar cycles, time of year, light pollution, location, and cloud coverage.

The occurrence of the phenomenon depends on solar activity and the cycles of the sun, causing so-called solar spots to occur on the Sun. It is from these spots, that solar flares are released and send electric charged particles towards the Earth. These cycles last between 10-12 years and the solar energy fluctuates during these cycles, reaching a low in 2020 (Northern Lights Centre). While it is always possible to experience the northern lights during the cycle, some years offer better possibilities than others, and the very dedicated Aurora-hunter might plan their travels according to this. However, the typical tourist focusses on other factors.

It is crucial to consider the time of year, as the Icelandic summer nights are very short and bright, while the winter nights are long and dark, hence giving the best opportunities during winter. In general, the months from September to March are dark enough for the lights to be visible in the night sky. To further improve your changes of catching the lights, the location must be considered according to the light pollution in the area. Iceland offer some of the best dark or truly dark night skies on the Bortle scale (see page 39), and most places outside larger cities and towns offer good conditions for seeing the aurora.

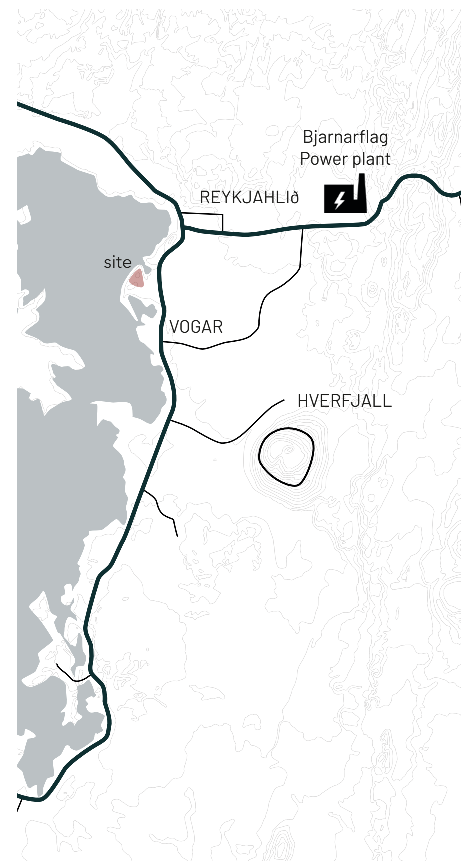
Given the above-mentioned criteria, the area around Mývatn and the site in particular offers good conditions to see the Northern Lights during the winter months. As the northern pole is the center of the Aurora, the most likely direction to observe the lights are towards North/Northwest, however due to the fluctuation in solar energy, the Aurora might at certain high-activity events be visible above or occasionally towards South of the site. The design of especially the cabins should therefore focus on the view towards North/North-West, however, they should preferably offer a view to the sky directly above, and possibly a view towards the South.

Renewable energy strategy

ill. 21 - Bjarnarflag Geothermal Power station - Photo by: E. Juul

With its unique geographical placement right on top of the Midatlantic Ridge, Iceland offers exceptional possibilities for producing renewable energy in the form of mainly geothermal power and hydro-power. As of today, almost 100% of Iceland's electricity consumption and nearly 85% of the total consumption of primary energy is covered by renewable energy (Askja Energy, a). The electricity is supplied by the so-called Landsnet, which is Iceland's electricity grid. This grid is extremely reliable and up to date, since continuous maintenance is of high priority. The Landsnet consists of both underground and overhead cables and lines, that connect appr. 70 substations run by generation companies and suppliers with the users. (Askja Energy, b). These geothermal substations consist of three kinds: power plants, heat plants and CHP plants. In power plants the geothermal energy is used to produce electricity, while heat plants use the energy to produce heat for the district heating system. A combination of these, are the CHP plants, which stands for combined heat and power plant. All power plants and CHP plants are connected to the Landsnet, while the heat plants are connected by the district heating system together with the CHP plants (Björnsson, S., 2010).

Due to this very well-developed energy grid, the benefits of connecting a building to this grid must be considered when designing the energy system for the project. Though the competition asks for a self-sufficient building, the advantages of connecting to the energy grid, weighs higher. Being connected to the grid utilizes an already existing power plant and therefore removes the need for establishing an on-site energy production. A such establishment would probably be in the shape of a geothermal system, that can have a relatively high impact on the site due to drilling far into the ground, which does not resonate well with the wish to leave as little impact as possible when the building reaches it end-of-life stage. Therefore, the building can very well be connected to the nearby Bjarnarflag plant, which is a CHP plant – a combined heat and power plant – meaning that the building complex can be connected to both the electricity grid and the district heating system from here (Orkustofnun, 2019). To connect the building complex to the grid, it will be needed to establish pipes and cables to the site, however the surrounding towns of Vogar and Reykjahlíð are presumed to be supplied by the Bjarnarflag plant and there therefore are existing lines and pipes very close to the site. The establishment of these, are expected to be done simultaneously with the connection to the sewer system in the initial building process.

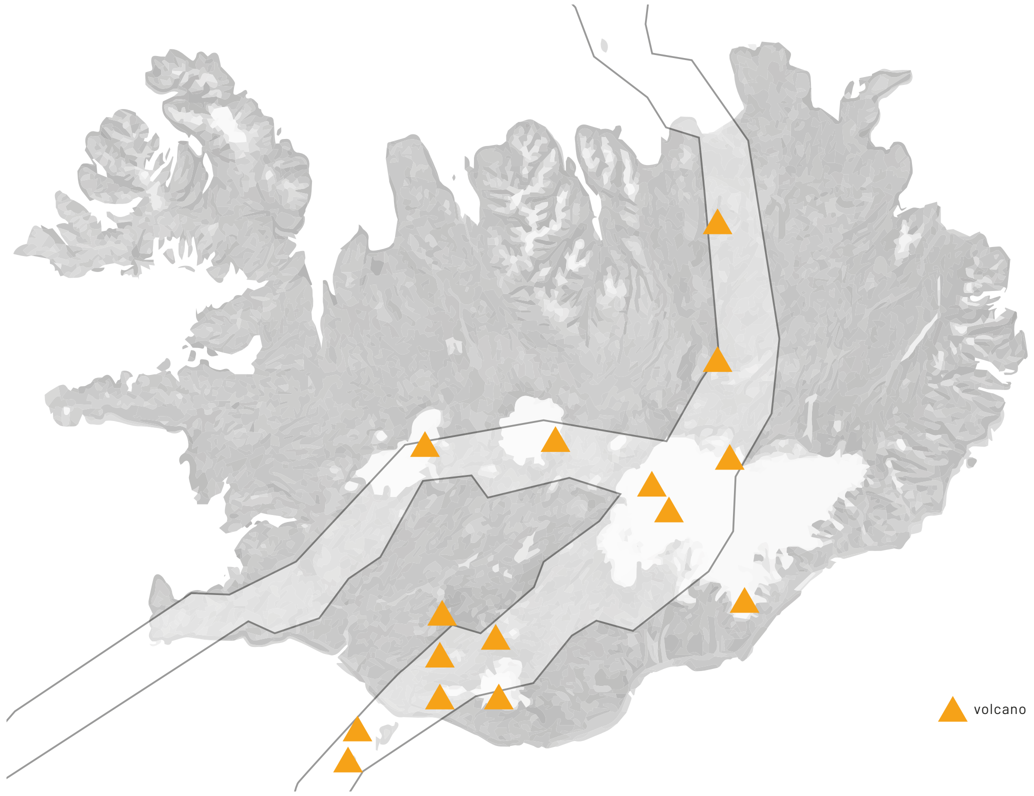


ill. 21a - map of Mývatn area with site and Bjarnarflag Powerstation

Physical context

This chapter will present the project site and its nearby context. The chapter will start by introducing the site in its context by the use of a mapping analysis. The site is afterwards further investigated in terms of its climatic conditions and considerations towards the geology, topography and vegetation. The phenomenological experience of being on the site is described. By the use of both quantitative and qualitative data, the site analysis will seek to give an understanding of both measurable characteristics of the site along with creating a more visual perception.

ill. 22 - basalt rock formations on-site, Mývatn - Photo by: E. Juul



ill. 23 - The Midatlantic Ridge across Iceland

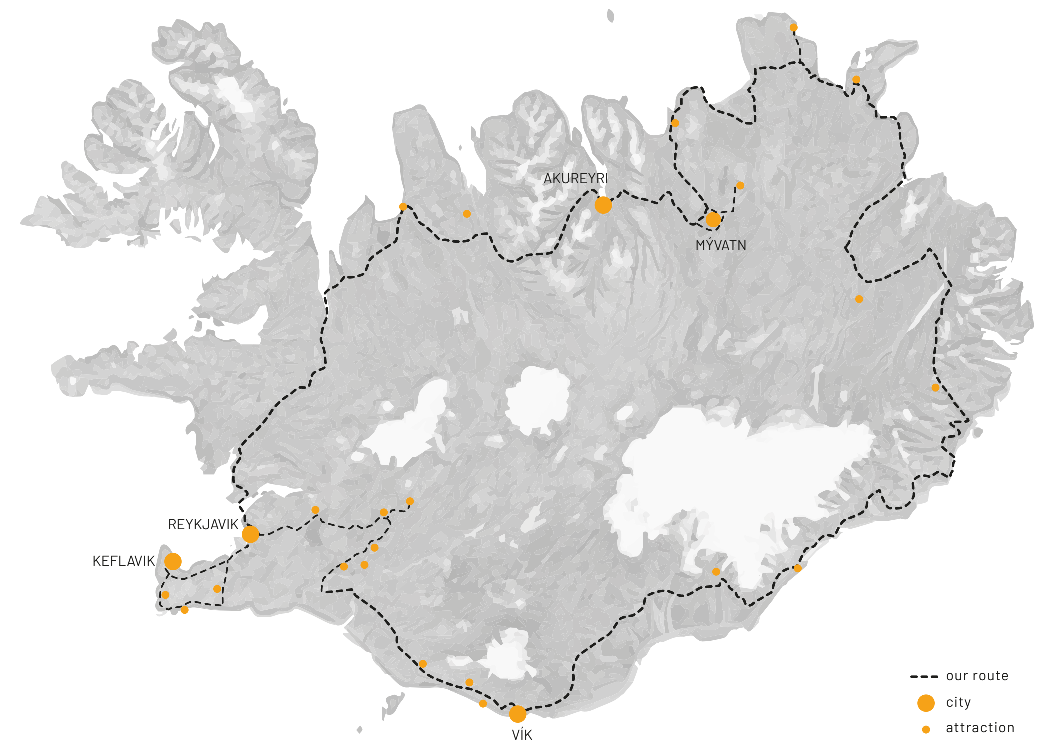
Iceland: Land of Fire and Ice

Iceland has a very unique climate being placed on the edge of the polar circle but right on top of the so called Mid-Atlantic Ridge, that is the meeting between two tectonic plates called the Eurasian plate and the North American plate (Mustain, A., 2012). Though the air temperatures might be low, the underground contains much volcanic activity that often emerges through the surface in the shape of volcanoes and hot springs. As seen on the map (ill. 23), the Lake Myvatn lies in the volcanic zone, meaning that there is a potential for volcanic activity in the area. This is seen in the presence of the Hverfjall volcano and the relatively close Krafla volcano. There are also many hot springs in the area, whereof several are used baths. The volcanic activity can also be seen when visiting the so-called pseudo craters in the area, that are caused by lava flows over wet ground.

Iceland contains glaciers with an approximate 11% of the ground being covered by glaciers. These are mostly located in the mid-lands and the southern parts of Iceland due to the lower average annual temperatures in these higher grounds than closer to the coasts. Caves are also a very common nature phenomena in Iceland, and in some places it is possible to experience ice caves, which is caves formed in the glaciers during the coldest periods. The biggest glacier of Iceland is called Vatnajökull and is around 8000 km^2 (Notendur).

There is no place with a similar clash between fire and ice and the Icelandic culture has through many aspects been affected by these climatic elements such as volcanoes erupting. These nature and climate phenomena are extremely unique to Iceland and have resulted in several natural elements near the site, that can inspire the design of the architecture – for example the volcano, volcanic rocks, pseudo craters and hot springs – to create localized architecture with a high relation between the building and the natural context. Furthermore, the rare nature phenomena of Iceland offer great opportunities and potentials for the use of renewable resources, which should be integrated into the design solutions.

ill. 23a - 'Bridge between Continents', Keflavik. The Midatlantic Ridge is visible in the Icelandic landscape - Photo by: P. Nguyen



ill. 24 - Route of study trip along the Ring Road in Iceland

Study trip to Iceland

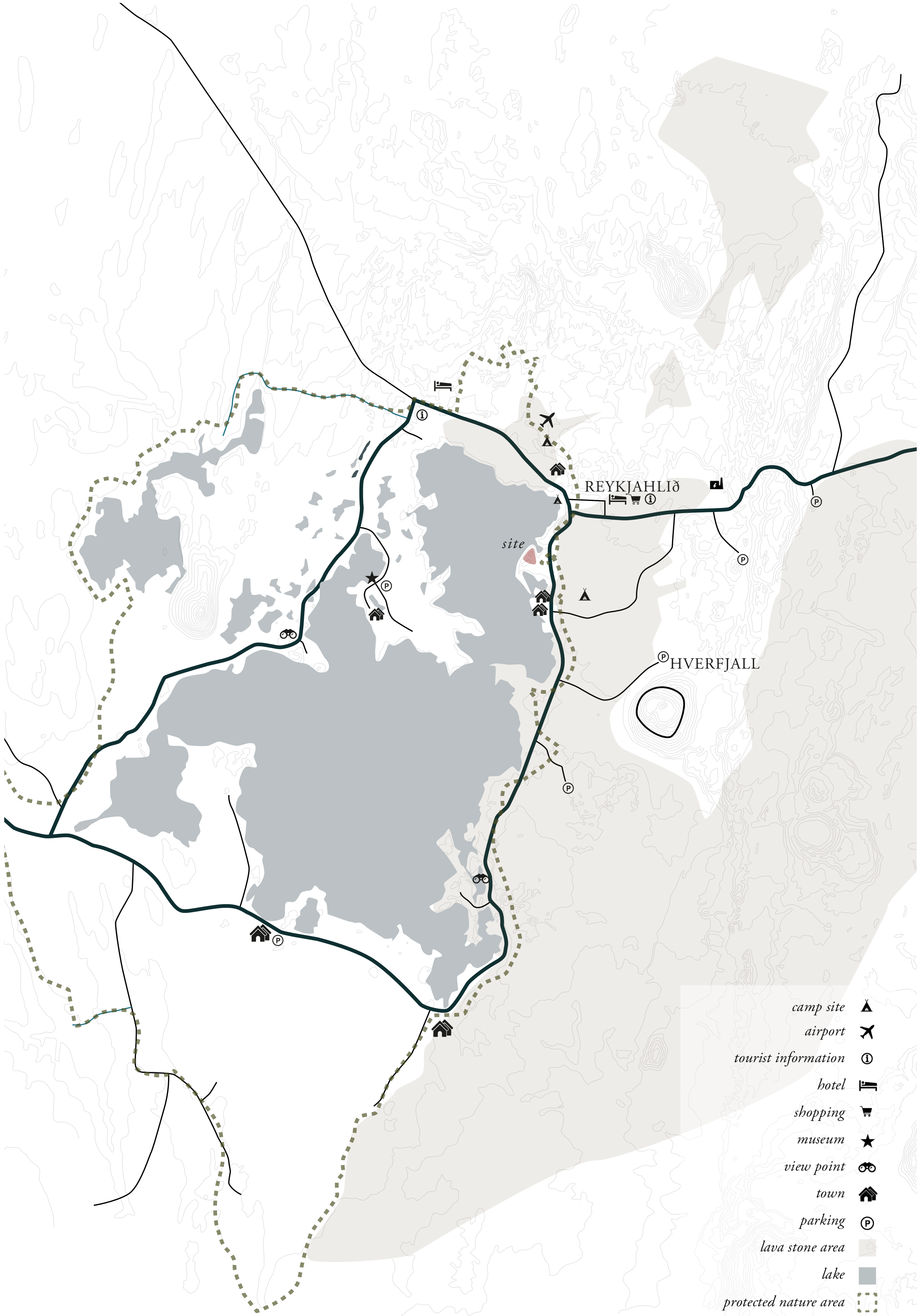
To experience the Mývatn site, the natural and cultural phenomena of Iceland, and hopefully the Northern Lights ourselves, we spent a week driving along the Ring Road of Iceland in September 2019. The following is a short description of the trip including mentions of important stops along the route.

After landing in Keflavik Airport, we rented a camper-van offering sleeping space for two inside, which gave us the possibility to drive all the way around the island and sleep at campsites. The first day were spent in the Golden Circle area, which is a popular area among tourists due to its proximity to Reykjavik. These attractions – Geysir, Gulfoss, Kerid Crater etc. - were also those visited the most by tourists, hence illustrating the typical Icelandic approach to protecting nature and dealing with many tourists. Attractions were often accompanied by small visitor/information centers, and designated paths to follow allowing the nature to remain as untouched as possible. The Golden Circle also contains the eco-village of Solheimar, that focuses on sustainable living and building, renewable energy and sustainable material choices in an Icelandic context.

Following the Ring Road along the incredible South-coast with black sand contrasting the white waves at sea, we were led towards North and entered a completely different landscape characterized by basalt soil, moss covered ground and reddish-yellow fall colors. The distance between towns increased when moving away from the coast, leaving an empty and raw landscape. We departed the Ring Road continuing along a smaller road leading us towards one Raufarhöfn: one of the most remote northern villages in Iceland. This detour led us through colorful landscapes covered in protected Icelandic moss, lichen, and heather. Stopping in Reufarhöfn we visited the Arctic Henge: an ongoing art monument by Erlingur Thoroddsen to tribute the country's Nordic roots.

Our next stop was Mývatn, where we started at the site (see Site visit, page 34). Spending a whole day in the area, we were able to visit most attractions in the area such as the geothermal area Namafjall, the pseudo-craters south of lake Mývatn, the Hverfjall volcano, and the Krafla volcano system. Driving around the area, we experienced the small villages of Reykjahlið, Vogar and Skútustaðir, as well as the two geothermal power plants, Bjarnaflag and Kröflustöð, that supply heat and electricity to the area. The two last major stops before again reaching Reykjavik, were Akureyri and Glaumbær farm. Being the largest city in North Iceland, Akureyri showed us the typical modern approach to architecture in Iceland, focusing on concrete and colored metal façades, while Glaumbær farm is considered one of the earliest places for the settlement in Iceland, and the turf houses present today are good examples of the vernacular way of building with turf.

The last two days were spent in Reykjavik, visiting Nordic architecture such as the Harpa Concerthall, the Perlan Museum and the Hallgrímskirkja. In one of the last nights, the sky was clear, and we were lucky to experience the dancing Northern Lights above us, just outside of Reykjavik.



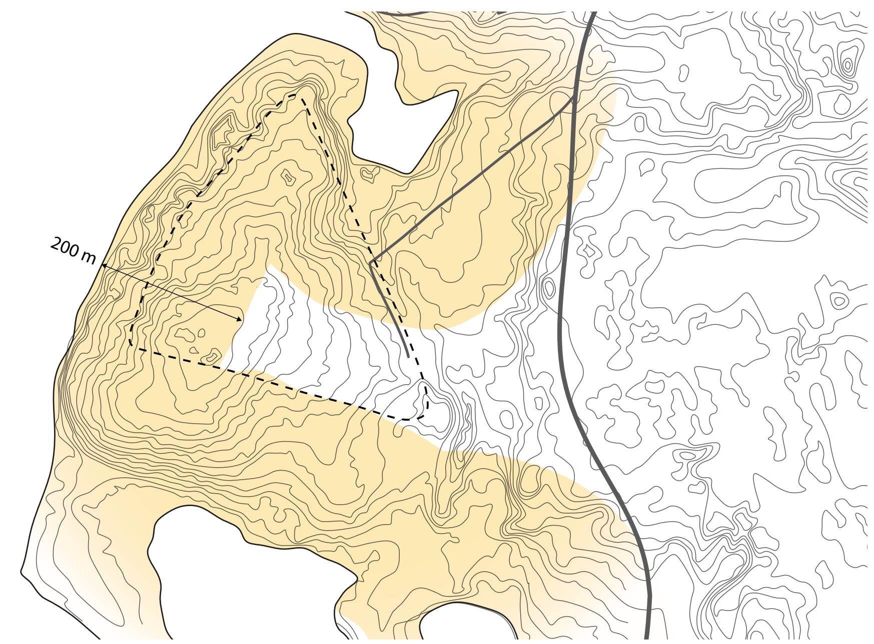
ill. 25 - Lake Mývatn - scale: 1:90.000

The Area around Lake Mývatn

The project site is located north east of the lake Mývatn between two bays. It is approximately 3 hectares and is positioned in a protected nature area which has been monitored by Mývatn Research Station since 1976, due to it being a popular nesting area for ducks. Because of this nature area, the competition material states, that no permanent construction is prohibited within 200 m of the lake.

The site is close to the small city Reykjahlíð located north of the site. The city offers hotels, shopping opportunities, a tourist information center and a visitor center which is open during the summer months. Other accommodation opportunities in the area include camping sites close to the lake. The area is connected to the remaining Iceland by the Ring Road which connects all the main cities of Iceland, and there are several opportunities for parking in the area. The area also offers different tourist attractions such as hot springs and the Hverfjall volcano, which is close to the project site. North of the lake Mývatn is a small airport, which besides having international traffic, also offers sight-seeing flights above the lake.

Being connected to the ring road and offering several nature tourist attractions to explore in the nearby area, the site offers a great potential for a project which is easy to access, compared to many other destinations in Iceland. In contrast to the existing functions in the area, the project will provide a combination of accommodation facilities along with a tourist attraction represented in the visitor center, reaching out for a wide target group. The complex should be open all year, and thereby bring activity and life to the area through all seasons.



ill. 26 - project site including the protected nature zone - scale: 1:10.000

Site visit

During the trip to Iceland in September 2019, we visited the site at Lake Mývatn to experience the place ourselves. The following is a phenomenological characterization of the walk to the site and the experience of being on the actual site. The illustration 27 and the photos 28-33 describe a serial vision (Cullen 1961).

We arrived at the site in sunny weather, parking right at the entrance to the small track road (1) leading to the grassy site. During the first couple of hundred meters walked, we found ourselves surrounded by small birch trees, yellowing in color as the autumn had begun. In-between birch trees were sharp, organic shaped basalt rock covered in soft moss and colorful lichen (3). As we walked along the tracks, the view to the right became open towards the town of Reykjahlíð (5) and we unknowingly interrupted a few sheep in their daily grazing and were met with a few upset baa´s. Continuing further, the grassy site appeared in front of us (2) and seemed to block all view to Mývatn. This were the same impression we had gotten from the competition material, studied at home. However, only a short walk up the slope revealed the view around the site in its entirety: all the way from the alien sight of the Hverfjall volcano (6) across the Vindbelgjar mountain (4) to the calmness of Reykjahlíð located in the corner of the lake with the Hliðarfjall mountain rising behind the town.

ill. 27 - map of site including views corresponding to photos below - scale: 1:15.000

ill. 34 - view towards the Hverfjall volcano and the Búrfell mountain including site limitation, main road (Mývatnsvegur), Mývatn and the towns of Vogar and Hólmar - Photo by: P. Nguyen

Arrival/road:

1

ill. 28 - wheel tracks to site

2

ill. 29 - wheel track continuing onto site

3

ill. 30 - view towards main road behind birch trees with volcanic rocks in foreground (East)

Views:

4

ill. 31 - view towards Vindbelgjar mountain (West)

5

ill. 32 - view towards Reykjahlíð with Hliðarfjall mountain behind(North-East)

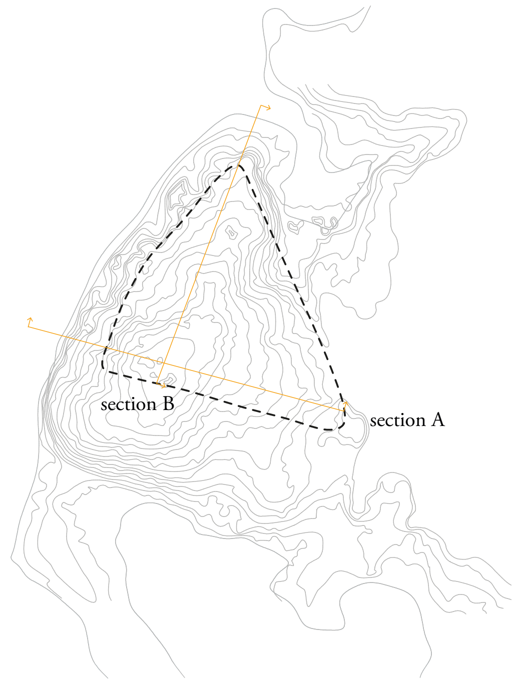
6

ill. 33 - view towards the Hverfjall volcano (South-East)

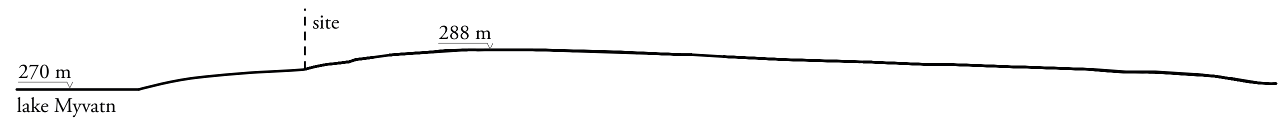
Site topography

The site and the surroundings near Lake Mývatn is characterized by being relatively flat compared to other nearby areas such as the volcano Hverfjall. The height above water of the site varies from 272 to 288 meters above water. As seen from the sections, the site has an almost steady increase in height toward the highest point on the site located in the South Western part. There is a significant height variation between the site and the surface of Lake Mývatn.

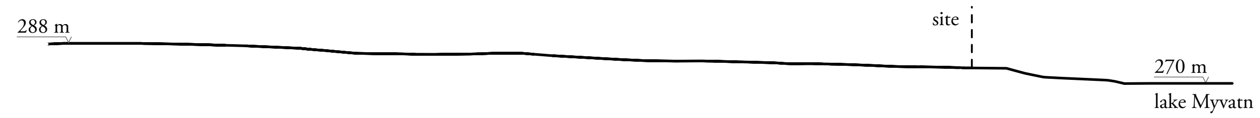
The varying topography of the site offers different approaches to the architecture, and the topography should be considered when investigating solutions for fitting the building to the landscape. The placing of the building on the site is important, as it offers different possibilities of using the topography in the design. The hill on the site, gives an opportunity for using the topography as an element in the design, for example by digging into the hill and creating a cantilevered building. In contrast, the flatter areas of the site will ask for less interference when building. When working with a terrain with different heights, it will also be important to consider the views to and from the building, when choosing where to place and how to orientate the building on the site.



ill. 35 - map of site including sections



ill. 36 - section A - scale: 1:3000



ill. 37 - section B - scale: 1:3000

ill. 38 - approaches to designing with landscape

Views from site

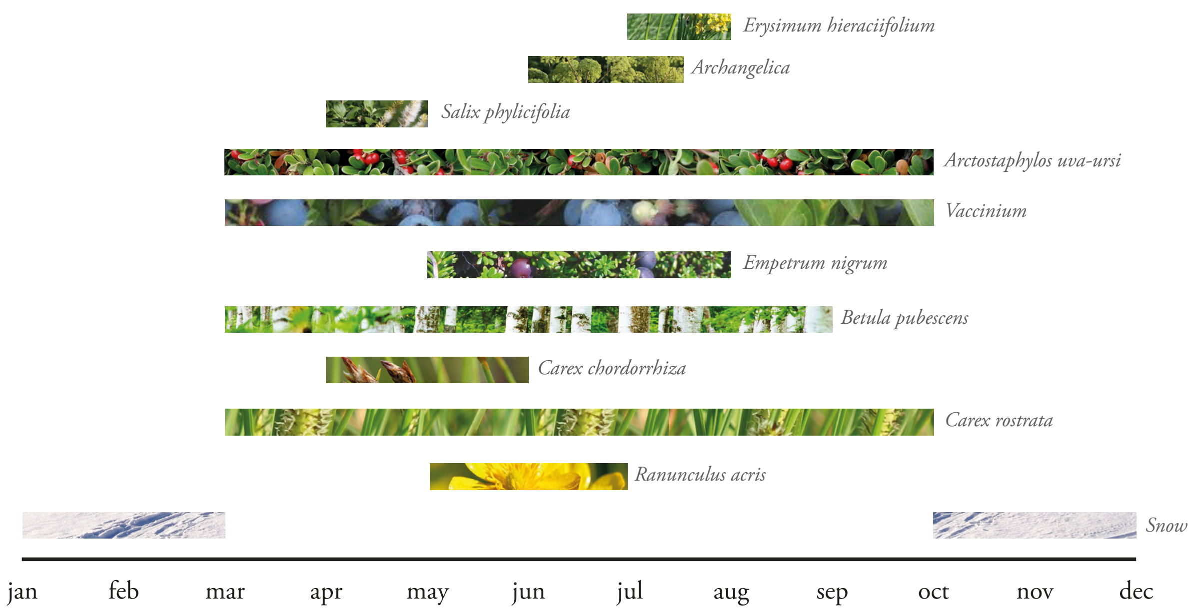
Hliðarfjall and Reykjahlið

Rock formations and birch trees shielding the Mývatnsvegur (road)

Hverfjall volcano

Small towns of Hólmar and Vogar

ill. 39 - views from the site - photo by: P. Nguyen



ill. 40 - vegetation and flowering season in the Mývatn area

Vegetation

The area around Lake Mývatn is one of the most fertile in Iceland due to the many minerals in the water from the lake. This provides good ground conditions for many types of plants and animals to live at. Regarding the vegetation, there is primarily low to medium high plants such as blueberry bushes (Vaccinum) and willow (Salix phylicyfolia).

As in the rest of Iceland, there is not many trees except for birch trees (Betula pubescens), which are most common in the northern parts of the area around the lake including the project site. In July and August, it is possible to find the plant Eysimum hieracifolium, popularly called Queen of Mývatn, which is very uncommon in the rest of Iceland (Notendur).

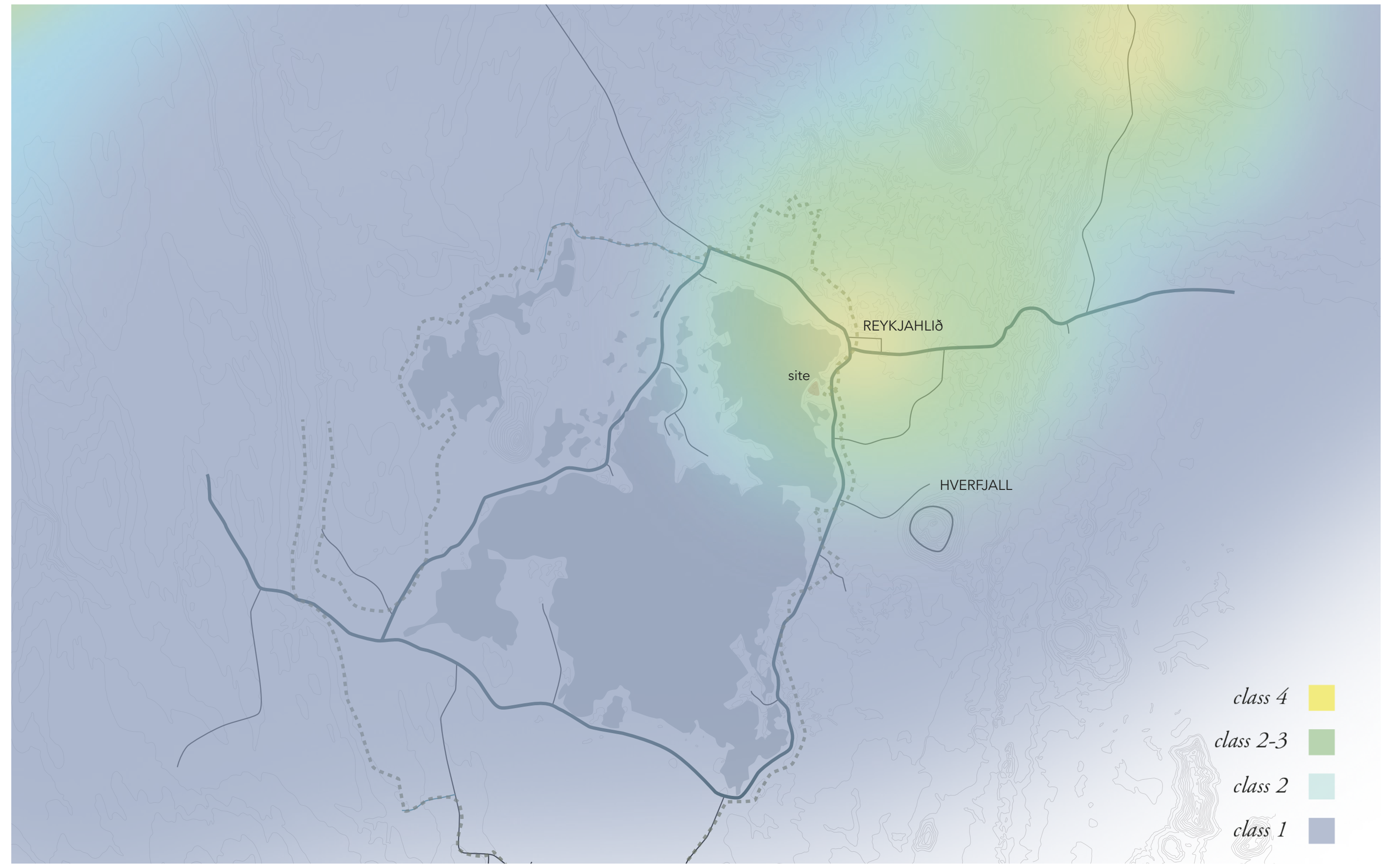
The growing season normally starts around March; however, this depends on the temperatures and when the snow melts. When exactly the landscape starts to color with plants, often varies from year to year.

The area around lake Mývatn is in general very rich on nature, where bushes and other vegetation serve as a delight for the sights as well as a survival source for animals in the area. The specific area chosen for the project is mostly composed of different grasses and other ground cover plant, making it less planted than much of the nearby area. This makes the site a suited candidate for building, compared to the rest of the area, as it will not demand the same interference with the planting.

above: ill. 41 - mushroom cluster found on site - photo: P. Nguyen

middle: ill. 42 - most of the site is covered in long grass - photo: E. Juul

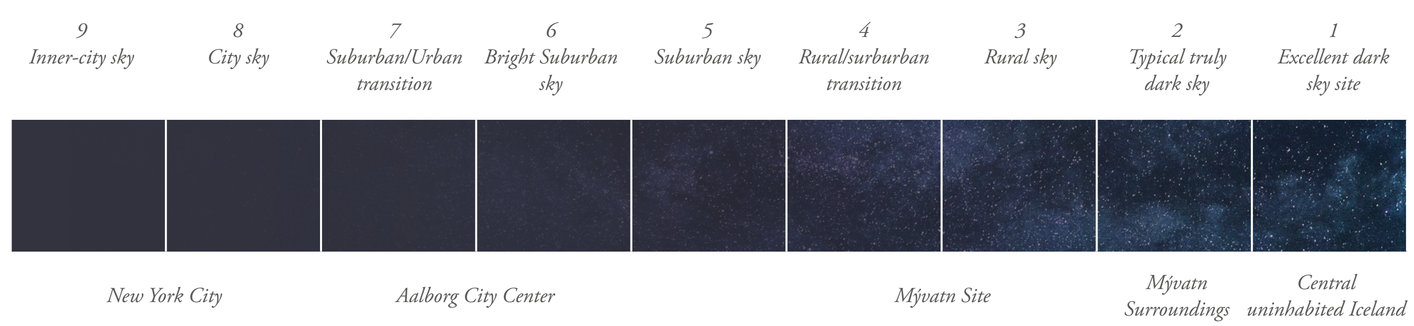
bottom: ill. 43 - birch trees shelter the site from the road - photo: P. Nguyen



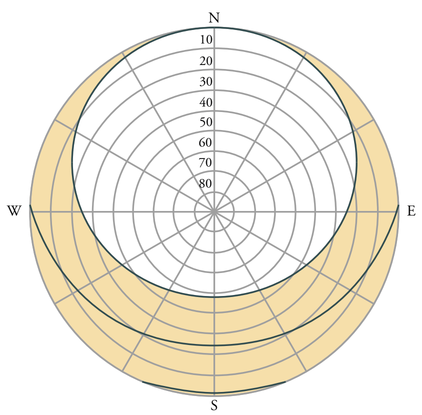
ill. 44 - amount of light pollution in the area according to the Bortle Scale - scale: 1:150.000

Light pollution in the area

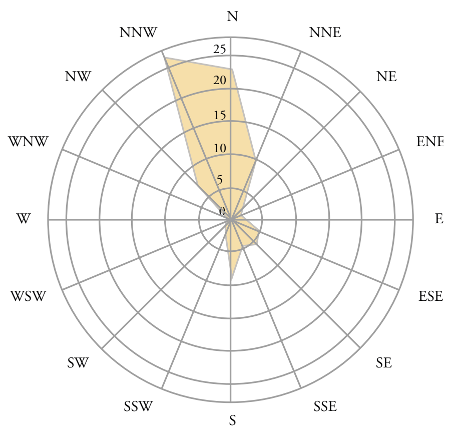
The ability to see the Aurora is very dependent on the amount of light pollution in the sky. Light pollution is caused by the excessive or inappropriate use of artificial light by industrial civilization, typically street lights, commercial lights, and lights from buildings and factories. The light illuminates the sky and causes the elements in the night sky to become duller. As a measure of light pollution, the Bortle scale can be used, which features nine levels of pollution. The map above shows the pollution in the area around the site and as seen on the scale below, most of the close surroundings experience some amount of light pollution with the site being placed at between 3 and 4 on the Bortle scale. However, the sky will still appear very dark to most tourists as they most likely are used to a much brighter sky. As seen from the map the least light polluted sky is located towards the south and the south-west of the site and it is in these directions that the night sky will be the most visible. However, this conflicts with the most likely direction of the Aurora, which is most likely to be seen towards the North/North-West, but this does not offer much concern since the area is still considered to be decently dark to provide good conditions for seeing the aurora. Though it should be taken into consideration, that the sky above Reykjahlíð and the general light from the town can affect one's night vision and if possible, direct views towards the lights in the town should be blocked.



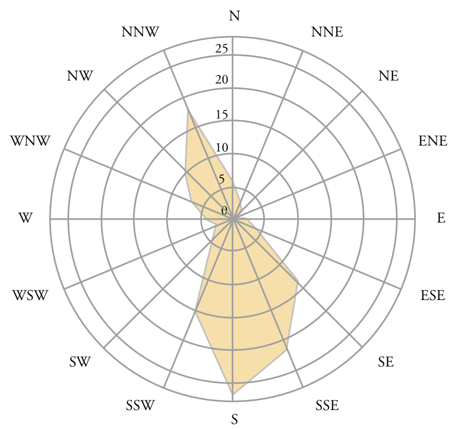
ill. 45 - the Bortle Scale with locations corresponding to the steps on the scale



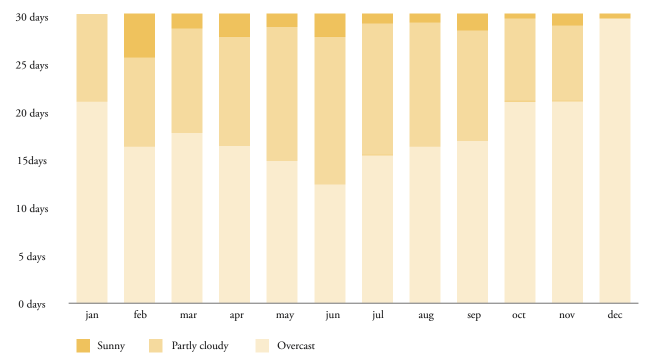
ill. 46 - sun path for Reykjahlið



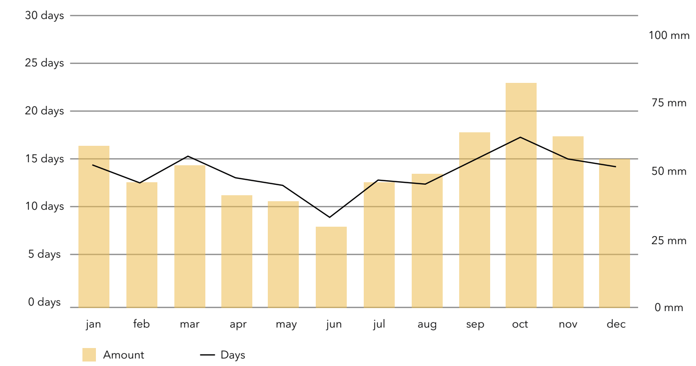
ill. 47 - wind rose, June



ill. 48 - wind rose, December



ill. 50 - amount of days pr month that are sunny, partly cloudy or overcast



ill. 51 - number of days pr month with precipitation and the amount pr month. From November to March, the precipitations occurs as snow

Climate

ill. 49 - Lake Mývatn as seen from the top of the site - photo by: E. Juul

Sun path:
The sun path is based on data from the city Akureyri located to the north west of lake Mývatn (Gaisma). It shows how the sun moves during the year, and illustrates the equinox, the summer solstice and winter solstice. It is noticeable that the day is very short during the winter, because the sun rises late and sets early. This means, that the winter month have very good conditions for watching the northern light. Opposite, the day is very long during the summer, and the phenomenon midnight sun can be experienced since the sun only sets for very few hours.

When designing in a climate, where the sun is only visible for three hours a day during winter, it will be essential to work with ways of achieving as much potential from these hours as possible. That means, that the building complex should be designed with high considerations on this aspect, which can have influence on the general orientation of the building and its outdoor areas as well as how to place different rooms inside the building.

Wind roses:
The wind roses are based on data from the Akureyri Airport located to the north west of lake Mývatn (Windfinder, 2019), meaning that they are not from the exact site which should be considered in the analysis. As seen from the two wind roses, one for summer and one for winter, the wind direction changes a lot during the year. From studies of the remaining year, it was shown that the general conditions during the winter are very similar to the one for December, where most wind comes from south, while the general conditions during summer are very similar to the one for June, where most wind comes from north.

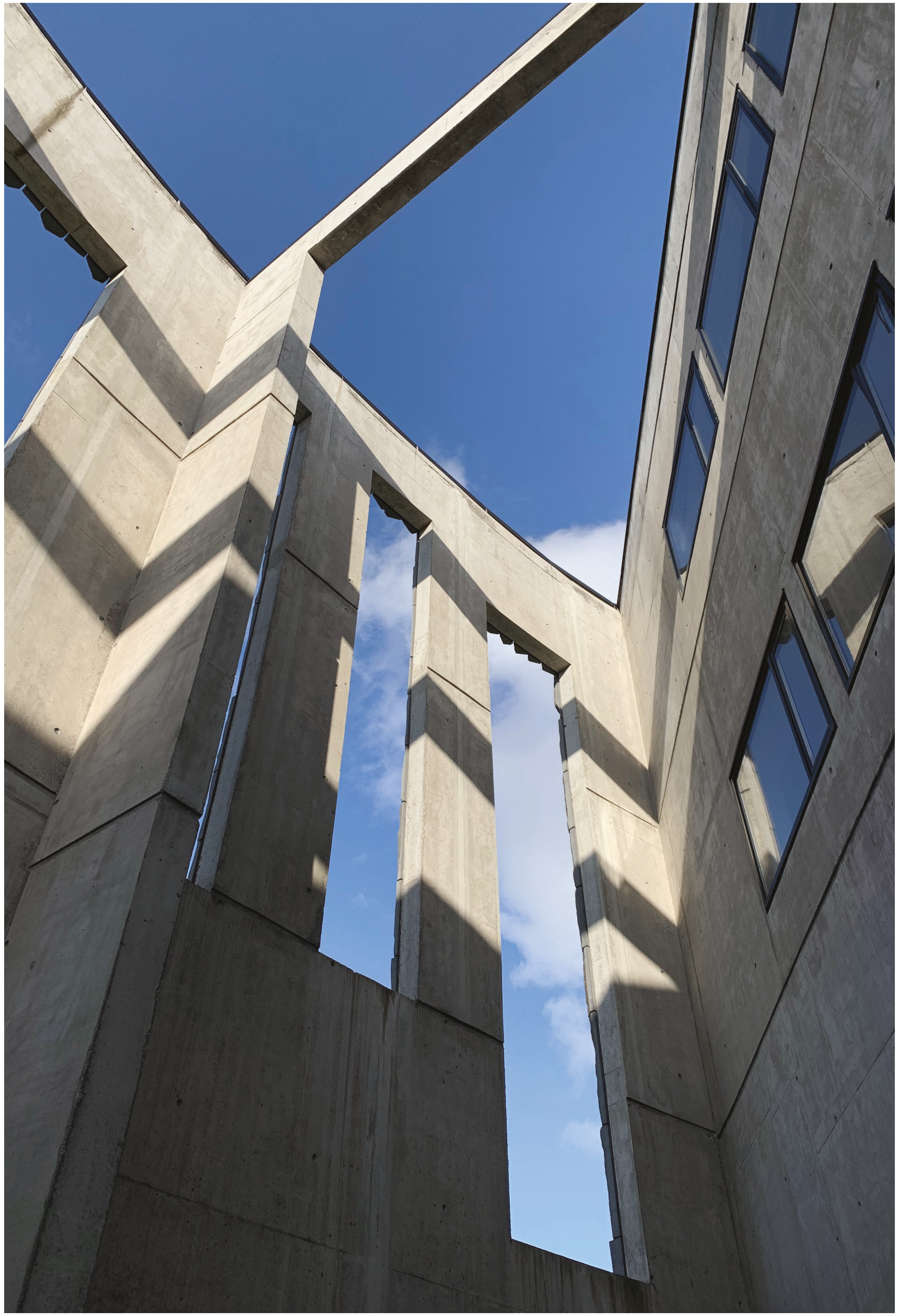
Since the building will have visitors both during summer and winter, it is important to integrate ways to shelter from wind both during winter and summer, when shaping the building and the outdoor areas. One challenge will be how to make a shield from the wind from south during winter, without compromising with the qualities of the rare winter sun, also coming from the southern direction.

Clouds:
This graph is based on data from Reykjahlid, and indicates how many sunny, overcast and partly cloudy days occurring during each month of the year (meteoblue, 2019). As seen, there is almost no sunny days during winter (December and January have none). This is also due to the very few hours with daylight each day during the winter. Most of the days during the rest of the year are overcast or partly overcast, which effects the chances to see the aurora. Since the clouds determine if the aurora is visible or not, this can have influence on the activity at the resort in periods.

In case of bad weather conditions, exhibitions and other ways of learning about the phenomena can be another way of getting close to the northern light. In situations where the sky is only partly clouded, it could be considered if the design of the building could be adaptable, to always give the best opportunities for watching the aurora.

Precipitation:
The precipitation graph is likewise based on data from Reykjahlid and shows the annual amount of precipitation along with the annual numbers of days with precipitation per month (meteoblue, 2019). The data shows that the area in general have a steady amount of precipitation all year, but most of it will fall during autumn and winter.

The data shows, that precipitation will fall all year on the site. This offer an opportunity for working with collection of rainwater to use for running the buildings as self-sufficient. This should be considered in the design, to achieve an integrated solution for gathering rainwater. The distribution of the precipitation is irregular during the year, why it should also be considered to work with storage facilities. During winter a lot of the precipitation will fall as snow due to low temperatures - this should be considered when designing, as it affects the needed load capacity of the building constructions and can cause possible complications with transport in the area. Furthermore, long periods only with snow, can also cause challenges regarding collection of rainwater, where it should be considered if a combined system with other solutions, such as exploiting the water from the lake, is needed.



Case studies

With offset from four key focus points, we chosen to analyse three entries from the BeeBreeders competition from 2018. All entries were available on the competition website, including the winning project, the two runners-ups and some honourable mentions. From all entries, three were chosen based on their general qualities and especially with the following key points in mind: Self-sufficiency, creation of atmosphere, relation to context and movability/adaptability.

To investigate the qualities of the projects, they were assessed based on their strengths and weaknesses related to the before mentioned features. Self-sufficiency is valued depending on their ability to produce own energy, independence from the grid, choice of energy source and implementation in the actual design. Creation of atmosphere is valued based on the theory of Peter Zumthor and Juhani Pallasmaa and focuses on how the materials are used, the scale of the buildings compared to the human body, and how the tension between interior and exterior is handled. Relation to context is valued depending on how the project is fitted to the surrounding landscape, the Icelandic tradition and history, and if it draws inspiration from the nature around it. The movability/adaptability of the project is discussed based on its flexibility, the users' ability to change the placement, and the overall convenience.

ill. 52 - The HOF Culture Center, Akureyri - photo by: E. Juul

IN-VISIBLE

	Strengths	Weaknesses
Relation to context	- Strong relation through traditional turf - Merge with landscape through reflective glass	- Main building becomes introvert by not utilizing the surrounding site and creating its own interior courtyard
Self-sufficiency	- Cabins are equipped with bath, toilet and kitchen - Main building uses geothermal heating - Thermal bath using hot springs from the lake	- Cabins use gas that needs to be refilled from unnamed source
Creation of atmosphere	- Transition between interior and exterior is enhanced through rough materials and use of exterior structures - 360 degree view to the Northern Lights in the cabins	
Movability/ adaptability	- Equipped with wheels	- Wheels are dependent on flat ground and can only be moved by vehicle

This project by Kamila Szatanowska and Paulina Rogalska was chosen as the winning project (Szatanowska, K. et al, 2018). The project consists of a number of moveable cabins with a central building made from turf among other materials. The cabins are constructed with wheels and are clad with reflective glass, that is transparent when looking out with no light turned on, but reflective when looking in. The central building has a strong relation to the Icelandic culture by using turf – however it is used in a combination with modern insulation to improve the performance of the wall's insulation. The use of the turf is also visible when being in the internal courtyard, which becomes a link between the interior and the exterior.

ill. 53 - Render by Kamila Szatanowska, source: BeeBreeders, 2018

The Circle

	Strengths	Weaknesses
Relation to context	- Inspiration from turf houses are used in a layout that embraces and protects against the weather conditions - Some of the permanent buildings are embedded in the ground to use soil as insulation, like turf houses	- Main building becomes introvert by not utilizing the surrounding site and creating its own interior courtyard
Self-sufficiency	- The cabins use rechargable batteries that are charged by a wind turbin on site - The permanent buildings are heated using geothermal heat - Water is collected from all roofs and stored in a central tank	
Creation of atmosphere	- A high attention to detailing and joining of construction elements, create a sensual and atmospheric building - The human scale and relation to the building is adressed through various sized rooms and building elements	
Movability/ adaptability	- Cabins are equipped with wheels - Cabins are made from functional elements, so a high flexibility in the design is reached	- Wheels are dependent on flat ground and can only be moved by vehicle

The project The Circle was made by Kinga Grzybowska, Michal Hondo, Vera Swahn and Erpinio Labrozzi (Grzybowska, K. et al, 2018). It is inspired by the traditional vernacular housing in Iceland: the turf houses, that are typically placed right next to each other. The project has a strong relation to the Icelandic culture by using this traditional principle and placing the houses in relation to each other by centering them around a hearth – another important element in the Icelandic culture. To house the people, who are going to be present in the main building, the project also focuses on the human relation to the building through varying scale in spaces and rooms and an embracing shape. The project has a clear sustainable strategy making the building completely self-sufficient by using wind power and geothermal heat. The cabins are supplied using batteries, that can be charged by the wind turbine.

ill. 54 - Render by Kinga Grzybowska, source: BeeBreeders, 2018

THULE

	Strengths	Weaknesses
Relation to context	- Inspiration from the Icelandic climate and the seven largest volcanoes gives a strong relation to the context	- Due to the strong concept of the volcanoes, the buildings are not very fitted to the actual site
Self-sufficiency	- Uses a combination of geothermal heat and photovoltaic cells as supply - Rain water is used for toilet flushes - Uses solar gain as passive strategies	- Drinking water is supplied from the grid and not produced on site - Solar panels are unreliable in winter due to very limited hours of sun
Creation of atmosphere		
Movability/ adaptability	- Bedrooms can detach from the cabins and be controlled by the user through an app	- Only bedrooms are movable and not the remaining cabin

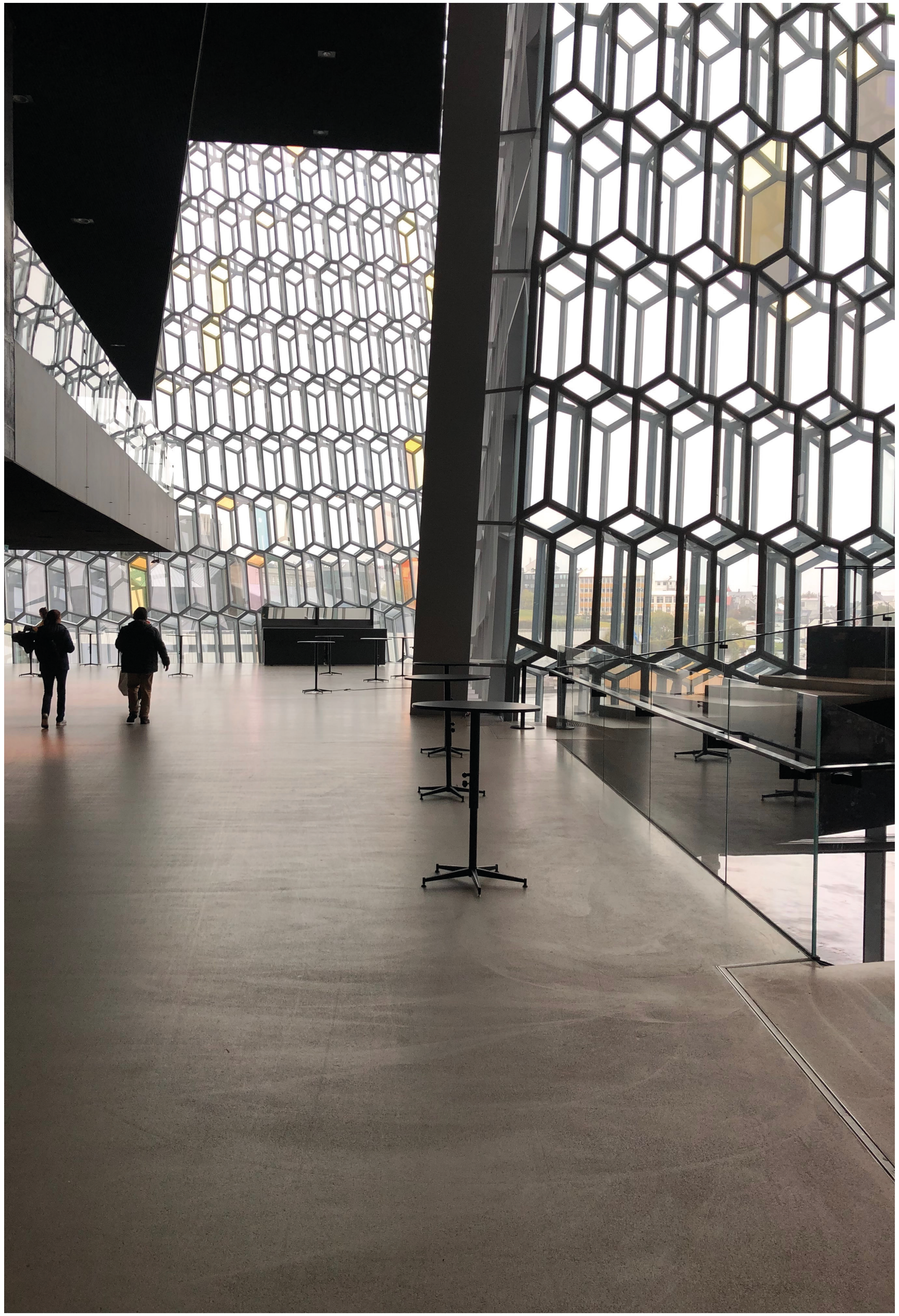
THULE is a project by Matteo Pegorin, Massimo Fontana and Franscesco Quattrone (Pegorin, M. et al, 2018). The project takes inspiration from the Icelandic climate and the seven largest volcanoes and consists of seven guest houses, a restaurant, a sauna and the host family house. The layout of the whole complex is inspired by the shape of the ridge between the tectonic plates, that are under Iceland. The guesthouses propose a unique approach to movability by having one or two bedrooms that are able to detach from the remaining house (toilet, kitchen and small living area) through an app. The bedrooms can be controlled and moved with the app and are equipped with both wheels and floatable pontoons that make the bedroom able to be on ground and water.

ill. 55 - Render by Matteo Pegorin, source: BeeBreeders, 2018

Conclusion

The studies of the competition entries help by identifying elements and aspects of the designs, that are interesting in the light of other analysis, such as relation to landscape, creation of atmosphere, detailing and movability. From the study, the importance of a strong relation to tradition, history and context is seen especially in the project The Circle, where the turf houses play a large role as inspiration. This is similar to our wish of using inspiration from traditional turf houses in a modern way, however the introversion of the project is less desired due to the wish of having a view to the surroundings. Therefore, a surrounding introvert shape is desired to be avoided. This is handled differently in the winning project IN-visible, in which the main building is constructed with traditional turf for walls but orients itself towards the outside nature as desired in our project.

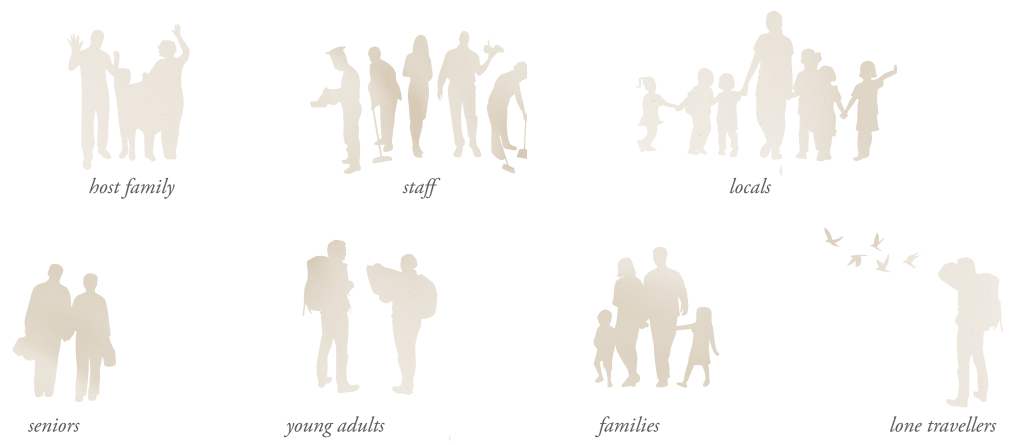
From the Thule projects cabin solution, the high level of user flexibility regarding placement on site, is inspirational. The users control where the bedrooms are placed through an app, however the cabins become rather large and static, where only the bedrooms are movable. This might be integrated by having the users decide where the cabin is placed with the help of the staff. Possibly the users can request the cabin moved after their wish and this movement around site, will facilitate a variation of experiences in nature.



Programme

The programme is an outline of studies related to different functions in the building. The chapter will begin with an elaboration on different ways of addressing a visitor center. This will be followed by a description of different user groups and their mutual interactions. Finally, a room program will further describe the intentions of the individual functions, while a design matrix explains the functions relation to one another. The aim of this chapter is to understand the importance of the individual functions and establish a point of departure for the programming of the building.

ill. 56 - Harpa, Concert and Opera House, Reykjavik - Photo by: P. Nguyen



ill. 57 - the variety of users in the visitor center

User groups

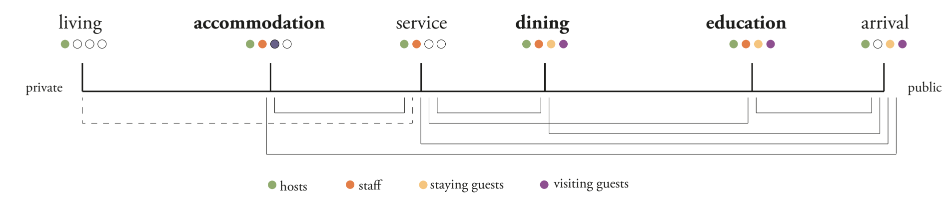
The complex will host various user groups. The two main groups of users are the people managing the complex: the host family and staff, and the guests: staying and visiting guests.

Host: The host family for the project is assumed to be locals and are defined as a family of four consisting of two parents and two children. The parents' primary tasks will be to manage the resort and be the public face of the center. They will oversee administrative assignments, managing the front desk for arrivals as well as various service tasks related to the day-to-day running of the resort. The resort is going to function as a permanent home for the hosts as well as a full-time job. Therefore, the host family will have different facilities for living which are clearly separated from the rest of the facilities, but still allow them easy access around the resort.

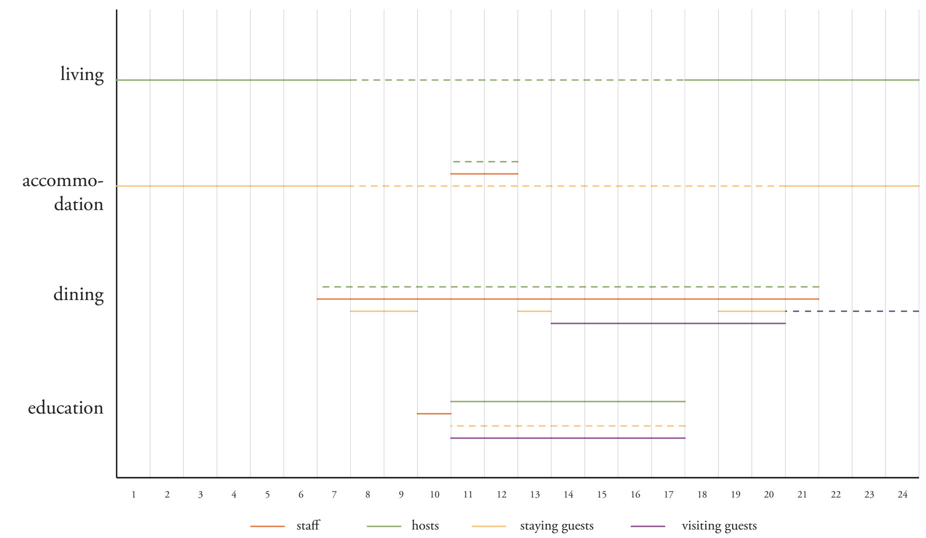
Staff: A number of staff members will be employed to assist the hosts with tasks related to the daily running of the resort. The staff members will in contrast to the host family be living elsewhere. The staff members will thereby mainly use functional spaces needed to perform different services such as cleaning, laundry and cooking.

Staying guests: The tourists staying at the resort will come searching for the Northern Lights during night and will likely stay for 1-2 nights. By choosing Mývatn as a travel destination, it is probable that they are very interested in nature and will go to experience this during the daytime, meaning they will spend most of their time at the complex during evening and night. The type of staying guest can both be foreigners and Icelanders, however it is most likely to be foreign tourists who choose to stay in guest houses (Óladóttir, O., 2018, p. 15). The composition of the staying guests will include young adults, families, couples, and seniors. In each group (except for families and couples) there will be lone travellers and people travelling in groups, though it is most likely that people travel in groups of minimum two.

Visiting guests: Due to the many accommodation spots in the area, there will naturally be a significant number of tourists who only come to the complex to visit the visitor center and/or the restaurant, without staying overnight. The visiting guests can be both Icelanders as well as tourists, since the Mývatn area is a popular vacation destination among locals (Óladóttir, O., 2018 p. 26), and the complex might be visited by large groups of tourists travelling by bus or groups of local school children on excursion.



ill. 58 - the relation between functions and their level of privacy

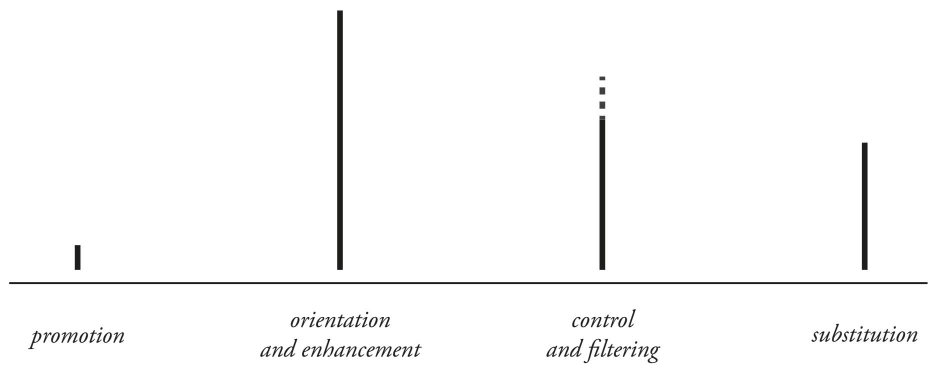


ill. 59 - the table shows when certain user groups will be present in a given function

Daily use of complex

As different user groups will be using the same facilities, it is worth investigating how these interact with each other, as the design must consider all user groups present in a given room. To understand how the different functions should be designed to create a desirable atmosphere for each user group, the level of privacy in the functions is ranging as seen above (ill. 58). Connections are drawn between the functions, which illustrates that the servant functions 'Arrival' and 'Service' will work as nodes between the additional served functions. Living does not have a direct connection to the other functions, as the function of living is a place for the host, while the rest of the functions highly depend on each other. This illustration should help set the frames regarding the design and the organisation of the building.

The served functions are the primary areas and are the functions mostly used by the users. An estimate of the daily use of the served functions shows the occupancy of the rooms, which influences the needed capacity and space for the functions as well as indoor climate considerations (ill. 59). The servant functions will only be visited briefly or by internal staff. In many cases the servant functions will be a part of the served functions, for instance the kitchen is a service function serving the restaurant, for which reasons these are not directly included in the daily usage diagram as an individual function. The illustration is an example of a typical day illustrating when the user groups will use the different spaces. As the daily use of the resort varies from day to day, the illustration also shows the more flexible periods where the users might be present, while they most likely will not or only for a short time.



ill. 60 - the enhancement of the various functions in the visitor center

Visitor centers

The Icelandic nature and its phenomena are the main reasons tourists travel to Iceland as previously stated. Nevertheless, this regional tourism is also the biggest threat towards the very same nature due to their massive number and their treatment of it. Educating tourists about the environment they are visiting, helps to raise their respect for the nature and their consideration when they are travelling and experiencing it. To actually do this, our project will comprise a visitor center functioning as a learning tool/education hub about the Icelandic nature as the setting for the Northern Lights.

The planning and design of the mentioned visitor center takes offset from the studies of Philip L. Pearce, Professor of Tourism at the James Cook University, Australia (Pearce. L., 2004). He proposes the so-called Four Plus model for the planning and functioning of a visitor center focusing on improving the experience in and effect of visiting a visitor center. This method will be used to specify the type of visitor center that is needed, and which functions should be considered in the design to promote sustainable tourism in the area.

With the Four Plus model Pearce identifies four main functions of a visitor center. They are often overlapping and differ in importance depending on the present visitor center and its purpose. The functions are:

Promotion of the area: this function involves the active promotion of an area with the goal of stimulating tourist demand and often increase the number of visitors.

Orientation to and enhancement of the area's attractions: this function focuses on improving the experience for the visitor by informing about what to do in the area and where to go. By giving tourists suggestions of what to do, it aims to shape the tourists' behaviour and thereby promote sustainable tourism by educating about the attractions.

Control and filtering of visitor flows: This function aims to control the number and flow of tourists visiting a certain area/site to lessen the pressure on the attraction. This could be in the case of a cultural heritage site or a protected nature area. This might require the visitor center to function as a gate-way that monitors and limits the number of people visiting by administrating the only access-way to the site. The control can also be done through suggestion of specific visiting hours, alternative suggestions for less visited sites and guided tours to decrease the pressure on the attraction.

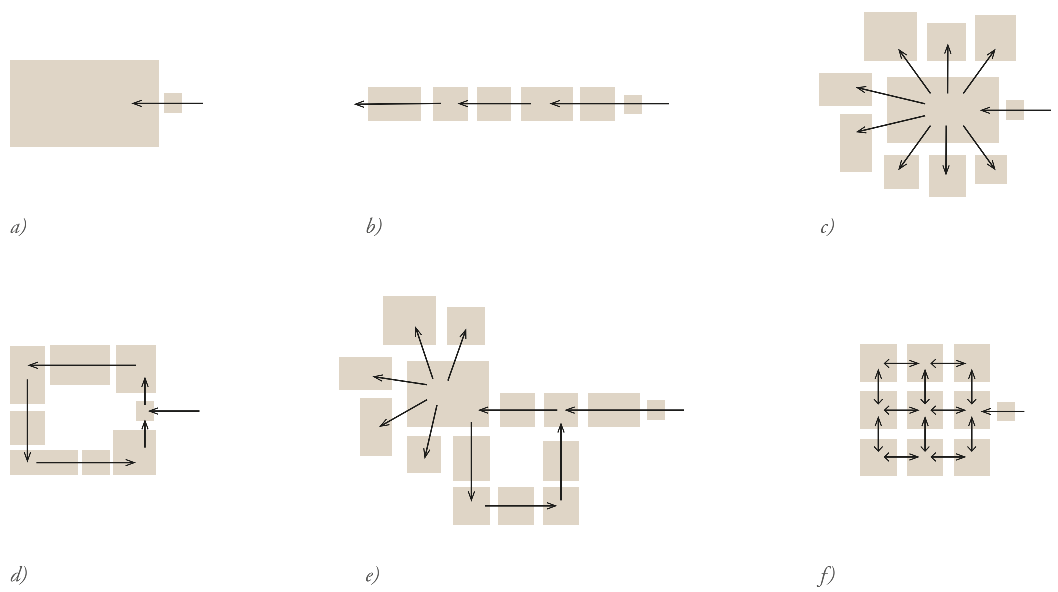
Substitution for on-site visits: this function is to be a substitute for the actual attraction by using exhibitions. It might be in an area inaccessible for the visitors (e.g. a marine area) or at least inaccessible to a high number of the visitors due to physical limitations. This can also be relevant in case the visitors lack the knowledge to understand the attraction making education and information essential.

Based on how a visitor center emphasizes the various functions, its overall character and goal can be described. Due to the nature of our site, the wish to educate, and the number of tourists, the weight of the functions will most likely be as shown in illustration 60.

Since the area around Mývatn, the northern lights and Iceland in general already is popular among tourists the wish is not to promote the area, hence the little emphasis on this function. Instead the education and information about the area to promote sustainable tourism is the main goal, which is why the orientation and enhancement together with the substitution are the most important functions. Especially the northern lights might require substitution, since you as a tourist cannot be sure to experience it and it might also require quite a bit education and explanation. Regarding the filtering function, ideally the center could help take some pressure of the nature around the lake, however since the center most likely will not be able to be a gate-way to the area, this function cannot be as emphasized as wished. Using this knowledge about the needed visitor center, can help when organizing room programs to make sure all functions are present and emphasized as needed. The actual interior design will also need to support the function of the space to give the visitor the best experience being in the center.

Regarding the function of the visitor center, it will include:
- Reception for welcoming visitors, selling tickets and memorabilia.
- Shop for tourists to buy souvenirs and/or educational gear such as guide books, posters, and maps.
- Exhibition space with educational information about the Mývatn area with focus on the flora and fauna.
- Storage and technical space for exhibition items and control of technical installations.

ill. 61 - Man-made ice cave in the Perlan Museum, Reykjavik. To give tourists the experience of entering an ice cave as they occur in glaciers, the museum has created anice cave from 350 tonnes snow - an example of substitution in musuem/visitor center architecture - photo by: E. Juul



ill. 62 - Genetic plans for museum and exhibition spaces: a) open plan, b) linear procession, c) core with satellites, d) loop, e) complex, f) labyrinth - (Adler 1999)

Planning of exhibition spaces

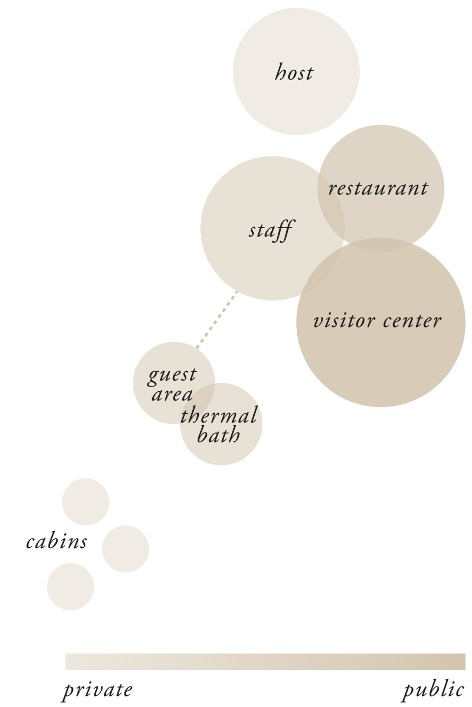
Designing the visitor center part of the project, will include suggestions for exhibition material and the architecture framing the exhibition will therefore need to fit the desired type of exhibition. Based on the findings from analysing Pearce's studies of visitor centers (previous page), the center will need to exhibit educating material about the general Mývatn area to help people find out where to go and what to see. Furthermore, the exhibition can help filtering people from being in areas, that are protected or under threat of over-tourism by providing substitutions for some of the natural sightings in the area such as fragile nature or the northern lights as they might not be appearing during a visitors stay at the complex.

Some general ways of planning an exhibition space are seen above. Choosing one that fits the center, should consider the size of the exhibition, the user groups, whether the exhibition is chronological or not, and the amount of staff that are available to take care of the exhibition.

First of all, the exhibition will most likely be between 100-300 m^2, meaning that solutions with many rooms, such as the core with satellites and the complex solutions are less suited for the exhibition space. This is also supported by knowing that there likely will only be one or two staff members keeping an eye on the exhibition, most likely only the secretary, who should have a general overview of the space. This can become challenging with the multi-room solutions as well. To accommodate the types of users, who will use the exhibition, it should be considered that there can be children visiting with their parents, and as the exhibition hopefully will seem interesting for children to partly explore on their own, parents might like to be able to have a good overview as well. Considering that the exhibition will concern natural elements around the area, there will be specific themes to each part of the exhibition, that possibly can be arranged in different rooms. As this exhibition by this is thematic and not necessarily chronological, a solution such as the labyrinth could be suited for this purpose. However, this composition of themes can also be done using the furnishing and arrangement of the room/rooms, without actually needing several rooms.

Based on the above discussion, a simple flexible solution such as the open plan or the labyrinth might be suited for the exhibition space, especially considering that the general furnishing of the space, will help adding an organisation to the exhibition. The final solution will depend on the possibilities on site and within the complex.

ill. 63 - functions inside the cabins and their level of movability and size



ill. 64 - connections between functions and their level of privacy

Organisation of functions

As the project concerns both the design of a main building/complex with visitor center, staff functions, host living and a dining area, as well as the design of the individual cabins, the organisation of both needs to be considered. As the cabins cannot be built with a permanent foundation, they will have a certain level of movability/portability to them (ill. 63). This will affect both the size and the layout of the cabin, meaning that the easier that the cabin is to move, the smaller and/or lighter it will need to be. This will set limitations for how many functions, that the cabins can include – from being only a space for sleeping and observing the northern lights to a small building with necessities for staying longer than just overnight including a bathroom and a small kitchen. As the cabins will use off-grid energy solutions to maintain only a small impact on site, the larger solution with more functions, will have a higher demand and therefore it should be investigated during the process, if the demands can be met given the conditions of the site.

For the general complex, the functions will vary in their level of privacy as some are completely public, while others are private. As seen on illustration 64, the visitor center, the restaurant and the staff area, will need to have a close connection to make it as convenient for staff as possible and to improve way-finding for guests. The host living will however not necessarily need to be as close, but as they also will be working at the complex, it is the most optimal solution to place them close to the staff area. As the host family will be living in the complex, their privacy should be respected and the placement of the function can help doing this.

Function	Space	Area, m^2	Thermal comfort	Daylight	Notes
Education	Reception	10	21-25,5	Y	Temporary and permanent exhibitions. High ceilings to fit exhibitions.
	Exhibition space	150	18-25,5	Y	
	Shop	40	18-25,5	Y	
	Storage space	30	18-26	N	
Dining	Restaurant	120	21-25,5	Y	Capacity for 30 people. Including buffet area for breakfast etc. for staying guests and bar.
	Kitchen	40	21-25,5	Y	Including freezer and refrigerator
	Toilets	10	21-25,5	N	
Accommodation	Lounge (in main complex)	40	21-25,5	Y	
	Bedrooms (2-4 people)	8	21-25,5	Y	Total of seven cabins (four 2-persons and three 4-persons). To accommodate 20 people
	Living room	12	21-25,5	Y	
	Bathroom	4	21-25,5	N	
	Technical room	2	-	N	
Living	Master bedroom	15	21-25,5	Y	
	Bedroom	12	21-25,5	Y	
	Kitchen	15	21-25,5	Y	
	Living room	30	21-25,5	Y	
	Bathroom	6	21-25,5	N	
	Utility room	6	18-26	N	
Service	Public toilets	15	21-25,5	N	2 toilets and 1 disabled toilet
	Staff room	20	21-25,5	Y	
	Staff toilet	5	21-25,5	N	
	Technical room	20	-	N	
	Laundry room	20	21-25,5	N	
	Cleaning facilities	10	21-25,5	N	
	Staff office	8	21-25,5	Y	
	Rest room	5	21-25,5	Y	Can be included in the general break room
Outdoors	Horse barn	90	-	-	Shelter for 10 Icelandic horses. Each horse requires 2x3 m
	Terrace	50	-	-	
	Thermal bath	-	-	-	Can be partly indoors. Need connection to showers. Only for staying guests. Access to a bar.
Main complex, total:		app. 730 m^2			

ill. 65 - Room programme based on competition brief and initial analyses

Room programme

To set up a starting point for the design process regarding room placement and organisation, a room programme including every room/main function of the complex, is listed as seen to the left. The room programme is a tool in the design process, meaning that some aspects might be changed slightly due to the on-going iterative process of analysis and design, hence why this room programme contains guidelines that will be used in the design process.

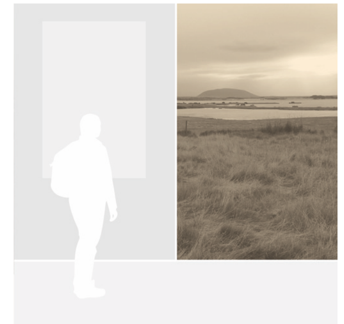
For the technical parameters, Danish regulations are used, as any Icelandic guidelines does not appear to be translated for public access. The requirement for the thermal comfort is based om the Danish Standard DS/CEN/CR 1752:2001 (Danish Standard Foundation, 2001). For simulations of the thermal performance, the Danish recommendation of maximum 100 hours above 26 degrees and maximum 25 hours above 27 degrees in office-like buildings are used for the main complex (except the host housing). For the cabins and the host living the recommendation of maximum 100 hours above 27 degrees and maximum 25 hours above 28 degrees are used as these apply to housing in Denmark (Bygningsreglementet, 2018).

strolling through the grassy site

The experience of being in the outside nature, will focus on the natural characteristics and qualities of the site, hence keeping the grassy site as untouched as possible. Paths will follow the natural topography and establish views to the dominant elements in the area.

enjoying a meal in unique settings

The restaurant will be accessible for both staying and visiting guests. It will serve locally sought and/or self-grown ingredients and dishes, giving visitors the possibility to experience Icelandic food culture. The interior of the restaurant will feature a variation of intimacy and atmosphere changing dependent of window placement, views, orientation, flow and furniture.



learning about the area while feeling close to it

For the visitor center to promote a sustainable way of being a tourist in the area, the exhibition should feature views to the surroundings and create and open and light atmosphere focusing on daylight and accessibility.

taking a break

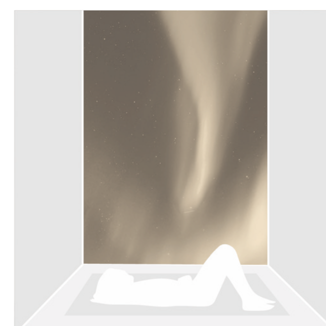
The visitor center concerns the surroundings through information and exhibition, and visitors will be able to take a break in small niches that facilitate a serene view to the surrounding nature, establishing the connection between the learned information and the natural settings.

Atmospheric experiences

As part of the programme for the complex, some desired atmospheres are illustrated here to ensure their inclusion in the design process and the final project.

The complex features many different experiences such as dining, learning, and being in a relaxed state of mind when observing the northern lights. All these various experiences should be included in the architecture and supported by the design of the spaces. These atmosphere diagrams can be seen as a tool in the design process to create variety and specific experiences throughout the complex.

ill. 66 - Diagrams describing the variety of atmospheric experiences in the design



enjoying the tranquil view to the Northern Lights

The cabins will facilitate the perfect way to experience the Northern Lights focusing on having a direct view to the sky. The viewer will be able to cancel everything else out, and solely focus on the astounding play of lights on the night sky. The atmosphere will be affected by the low-key and simple design and by having a burning stove for heating.

having a relaxed body and mind

After a long day of new experiences and thoughts, the perfect setting for focusing on one self should be the thermal bath. The features of the thermal bath will relate to all senses by changes of materials, temperatures and facilitating a view to the sky with no light pollution.

Design parameters

Physical criteria:

- Due to the function of the building as a visitor center and therefore a place for promotion and information, the building **must be exposed and visible** to the main road Mývatnsvegur and the smaller access road.

- The building should **facilitate a view to both Mývatn and Hverfjall as well as other surrounding mountains** as these are the most prominent elements visible from site.

- There must be an **interplay between building and landscape** in a way that is respectful and protective of the qualities of the site, while providing the visitors an outdoor experience as well as and indoor.

- The cabins should **facilitate the best possible view to the Northern Lights** in the way they are designed.

- There should be a clear **division between facilities for host and staff, staying guests and visiting guests**.

Technical criteria:

- Material choice should be based on sustainable solutions in an Icelandic context regarding **material transport, means of production, and resources used**.

- Indoor comfort must be achieved through reaching of **atmospheric, thermal and visual requirements** according to the room programme.

- The building must **use the resources on-site in the best way possible** and on terms with the Icelandic context regarding renewable energy sources and traditions.

Aesthetic criteria:

- A variety of atmospheres must be present in the design to provide the visitors **a clear and unique sense of space**. This should be achieved through **a deliberate use of materials, tactility, scale, and detailing.**

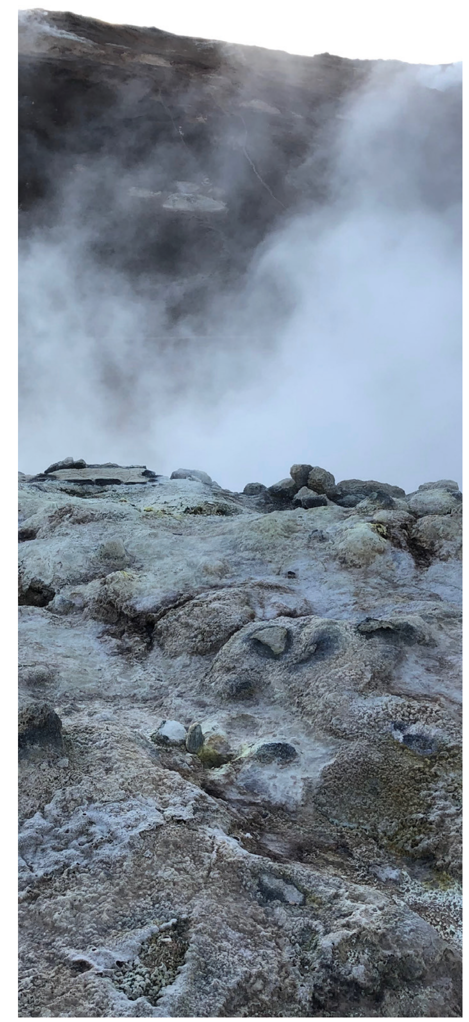
- As a center for education and promotion of the area, the building must have **an inviting gesture** allowing the public to feel welcome.

- The cabins must feature **large windows** orientated in the most optimal direction to observe the northern lights.

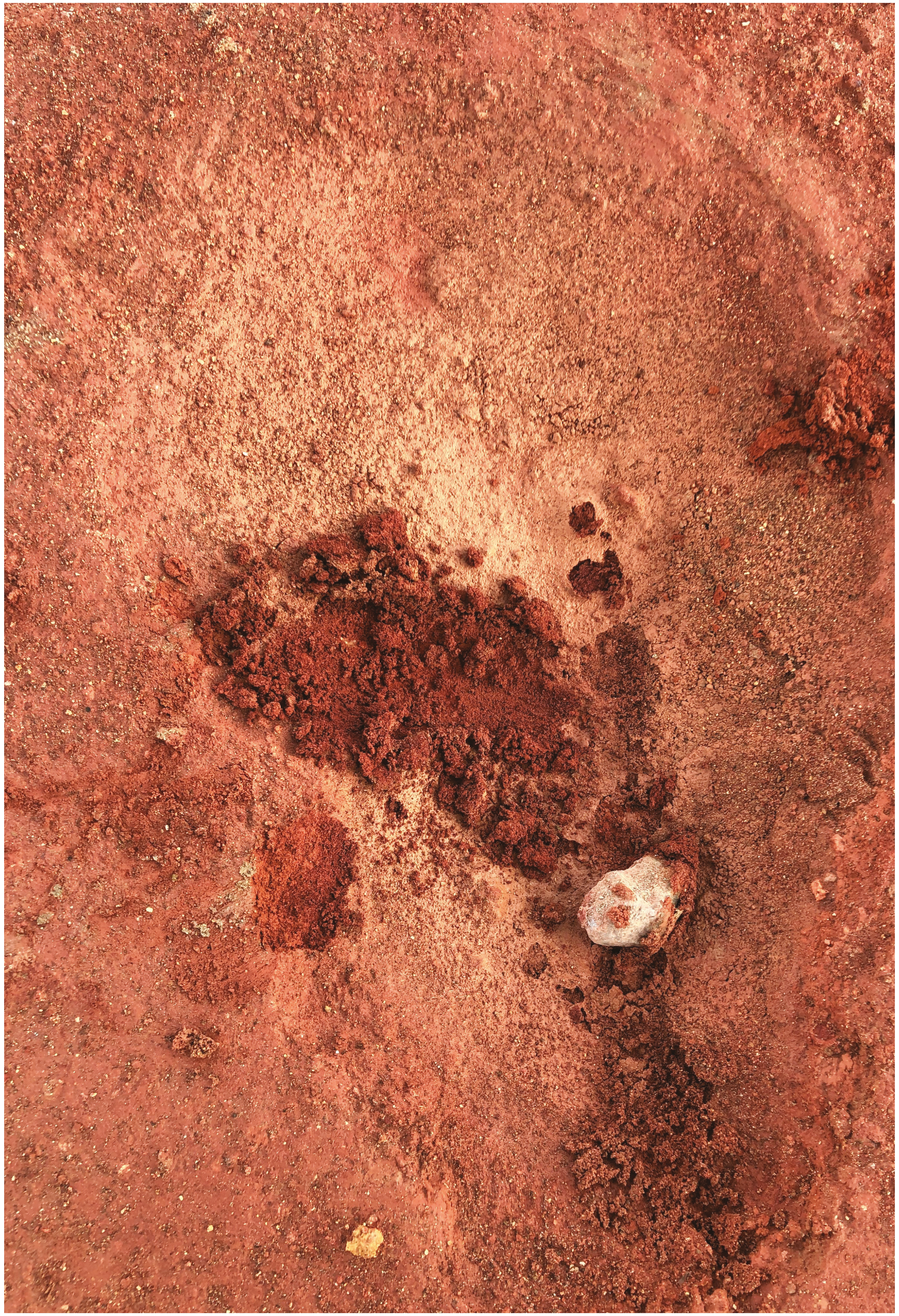
- The complex should **respect the architecture of Iceland in terms of materials, form, and scale.**

Our vision

The aim of this project is to design a Visitor Center with accommodation at a site near the Icelandic lake Mývatn for tourists to experience the Northern Lights. The experience of being in the nature and witnessing the Northern Lights, should be the central aspect of the design and must always be considered. The project will be founded in and draw inspiration from the unique and harsh nature of Iceland and the area around the lake to create an identity through a strong relation to the context. The way that the building is fitted to the land should treasure the natural potentials of the present site. Environmental sustainability must be a central part of the concept and support the aim of creating an education hub with respect and considerations towards the surrounding nature. The architecture should support the different experiences in the building by emphasizing a variety of atmospheres. These atmospheres are to reflect the various perceptions ranging from the intimate and embracing experience of being in the private zones to the educating and inviting experience when in the public zone.



ill. 67 - Icelandic sheep - photo by: E. Juul
ill. 68 - geothermal area at Námafjall Hverir, Mývatn - photo by: P. Nguyen



Design process

This chapter tells the story of how the final project came to be and includes material from several phases of the design process. The chapter discusses certain aspect of the design, how decisions were made and what eventually became crucial in the process of designing the complex.

The first parts of the process were mostly based on finding inspiration and did deliberately not take the conditions of the site into account. These were considered in afterwards workshops and design ideations, where after all ideas where processed together to create a design focusing both on the inspiration of nature and the site conditions and possibilities.

ill. 69 - red rhyolite soil, Námafjall Hverir, Mývatn, Iceland - Photo by: P. Nguyen

Icelandic natural phenomena and culture as an idea generator

The initial design process started from the incredible and unique nature phenomena in Iceland and local tradition, history and culture. These aspects were used for idea generation and concept inspiration, trying to find an aspect that could affect all parts of a design concept and to make sure that the Icelandic context would be a crucial part of the design right from the beginning. We especially investigated the three themes: glaciers, volcanoes and marimos. Marimos are a species of algae that grow in only two places in the world, Lake Mývatn being one of them. Each of the themes helped us generate initial design strategies and ideas for various aspects of the design such as the relation to context, the movability of the cabins and the materiality of the project. This initial workshop produced many design ideas, that afterwards were developed into further concepts based on one or several of the ideations. In this phase, the ideas and concepts were not site-specific to not limit the flow of ideas, however this would be considered in the next proposals based on site investigations.

northern lights

Hverfjall volcano

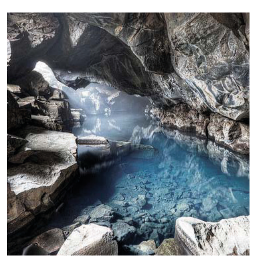
viking long house

glaciers

turf house

hot springs

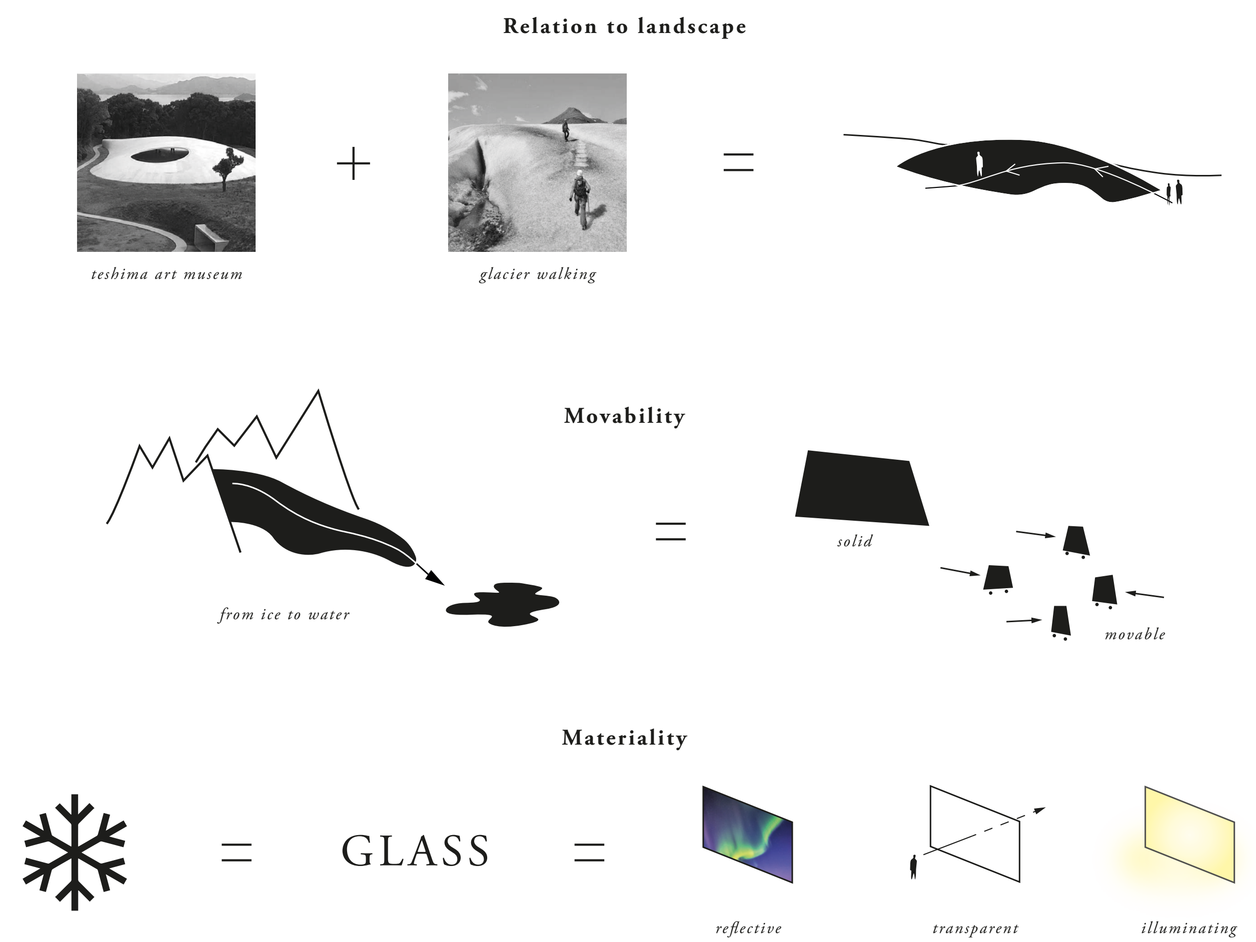
pseudocraters



grottos

marimo algaes

ill. 70 - nine natural and cultural phenomena unique to Iceland - photo by: see illustration list



ill. 71 - example of using the concept of a glacier as idea generator. See other examples in annex 1.

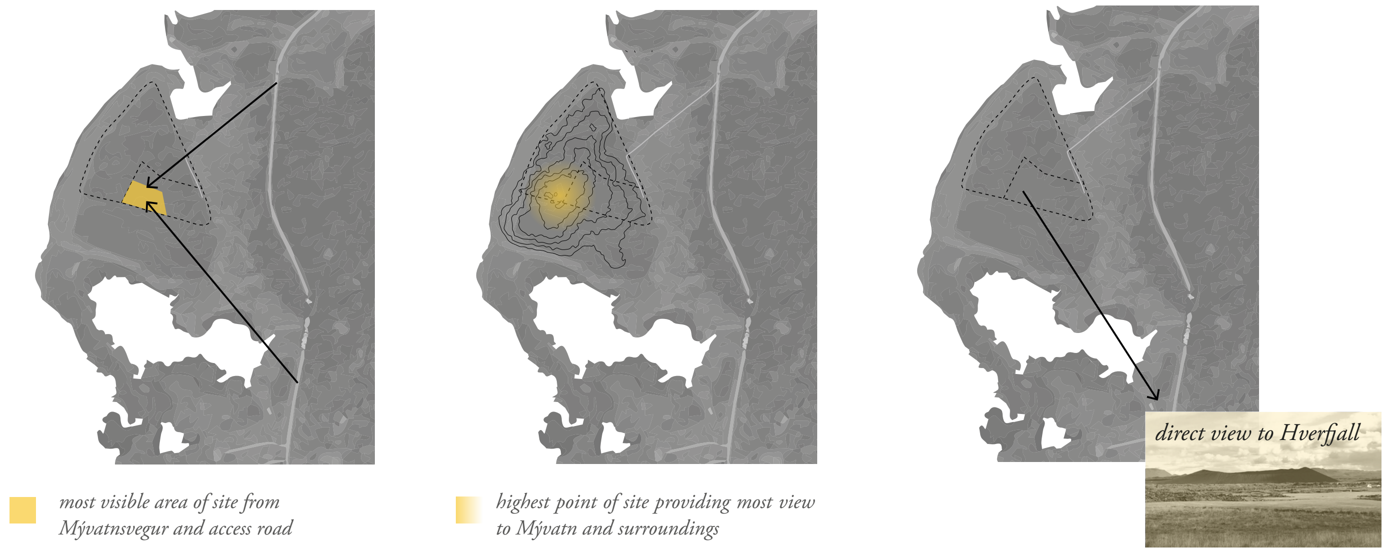
Finding inspiration in nature

As a continuation of the previous workshop, some architectural concepts for the project were sketched out. In this phase, the concepts were still only taking inspiration from the nature and phenomena, while not yet considering the actual site conditions. This was deliberately done to kick-start the design process, generating as many diverse ideas as possible, without the limitations of the site. In the search for an initial concept, we started out by focusing on one or two elements in the project, to ensure that all ideas were given a chance. Afterwards, concepts were considered in light of all elements – inspiration, site conditions, functionality, etc. - and combined or improved to become one complete idea.

Below can be seen one concept developed from the marimo idea generation and one from the volcano idea generation. In annex 2 there are similar ideas based on the basalt rocks.

ill. 72 - sketches of inspiration from nature

Inspiration from Icelandic nature/tradition → ***Conceptual ideas based on source of inspiration***

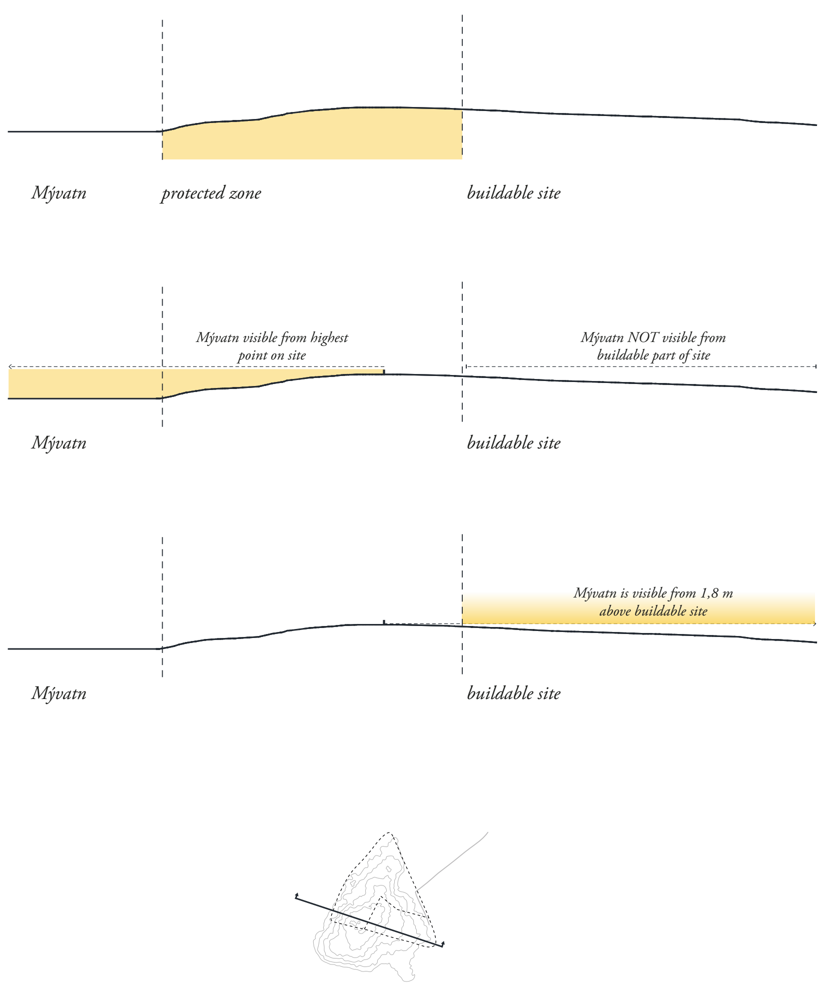


ill. 73 - investigations of site exposure, topography of site, and views from site

ill. 75 - the view towards the site from Mývatnsvegur. Driving further along the road, makes the site hidden behind birch trees - photo: E. Juul.

Identification of site properties related to views and topography

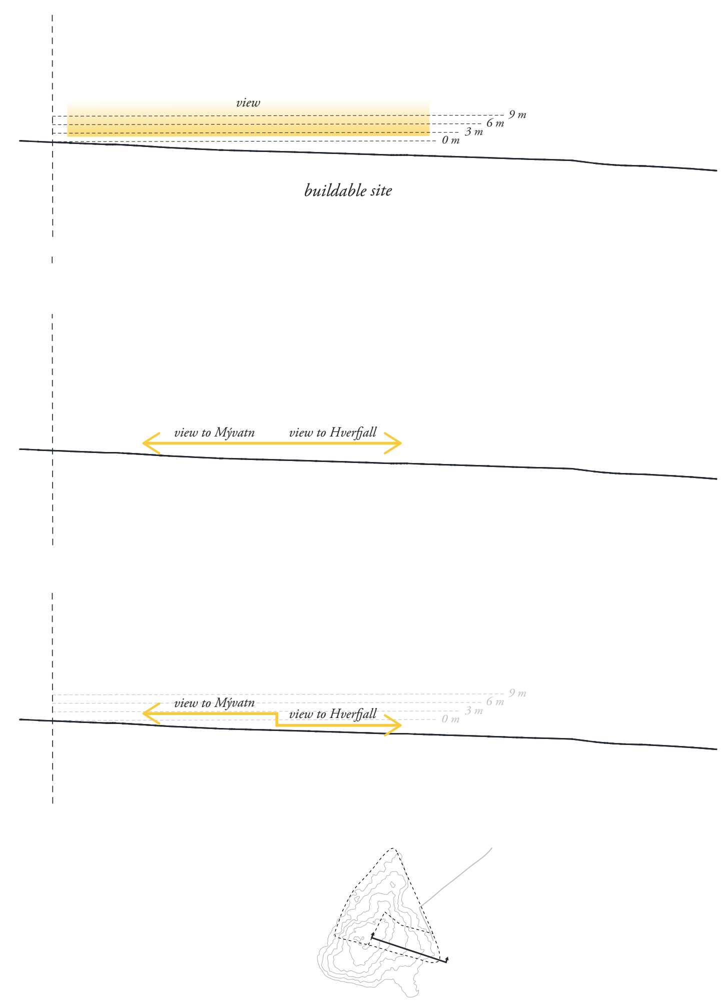
During the site visit some investigations were made regarding the visibility of the site, the topography and the views from the site. It was clear that these factors would be crucial in the placement of the building due to the limitations of the no-construction zone. The build-able part of the site offers good views towards the Hverfjall volcano. However, there is limited view to Mývatn from the build-able part except towards the South, where the lake can be seen next to the farm of Vogar. If standing at the highest point of the site, the view towards the lake improves a lot, and Mývatn is visible all round. The highest point of site is approximately 1,8 meters above the highest point of the build-able part, meaning that it is possible to obtain a view towards Mývatn.
Due to the function of the building as part visitor center, the exposure of the site from the Mývantsvegur is very important to attract tourists to promote the area. When driving along the road towards the North, the natural slope of the site makes especially the highest part of the build-able area very visible and exposed.
Based on the views that can be obtained towards Hverfjall and Mývatn, and the visibility from the main road, the most optimal placement of the building is concluded to be at the highest point in the South-Western corner of the build-able area.



ill. 74 - possibility of obtaining view towards Mývatn from the build-able site

Generel building properties based on views and topography

In the before-mentioned analyses of the site qualities, it was determined that the most optimal part of the build-able site, is in the South-Western corner. This part offers a possible view towards Mývatn along with a good view of Hverfjall. From these aspects, the general building layout in section can be investigated. To be able to see the lake, the building needs to be raised at least 1,8 meters above the site. At the other hand, the view to the volcano is in the opposite direction, giving two main orientations in the building layout. The part oriented towards Mývatn needs to be raised, while the Hverfjall-oriented part does not. These conditions were used in the later process when investigating form and building layout.



ill. 76 - possible general building section deducted from direction of views and topography

Interplay between building and landscape

The Icelandic landscape offers a one-of-a-kind experience for every tourist visiting the country. The landscape on site is grassy and curved, without any distinctive natural features. However, the site is part of the protected nature zone around the lake to preserve natural duck habitats and nesting areas. Therefore, a respectful solution in terms with nature is required. The main complex should offer visitors an outdoor experience while visiting the complex. Using case studies and features from the Icelandic nature seen during our trip to Iceland, we explored various possible ways of creating a building interacting with the landscape. A recap of some of the options can be seen as sketches on the next page. These options vary from having an interactive 5th façade to being a cluster of buildings urging people to move in between them in nature. As a general language of form, we found that the sharp and expressive features such as steep cliffs, cracks in the ground, and moss covered stone, were fitting inspiration from the Icelandic landscape.

Numbers correspond to drawings on next page

a) building curved to mimic terrain

b) building split and oriented toward the sky

c) separate building volumes spread to urge movement between functions

d) building in two levels, partly below ground

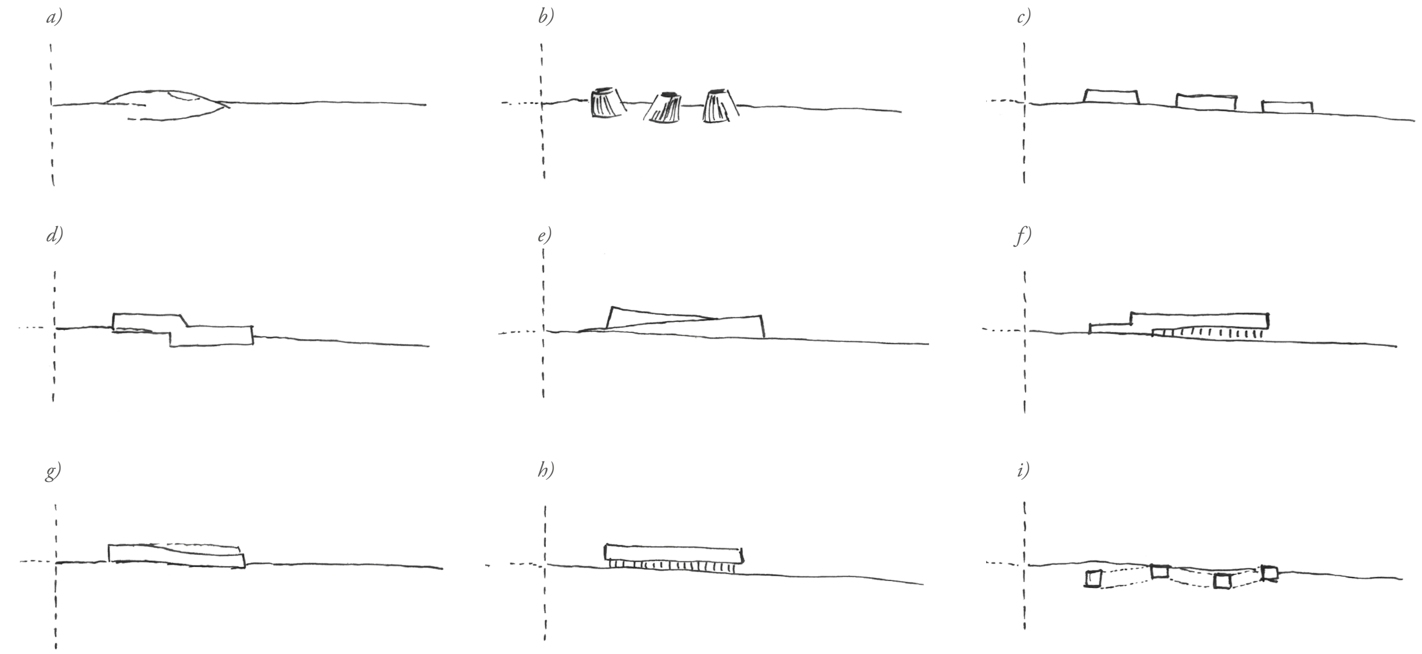
e) sloped volumes mimicking the slope of site, offering a walk-able 5th facade

f) volume partly below ground contrasting a volume raised over ground

g) circular building with varying levels

h) building volume completely raised above ground to leave ground as undisturbed as possible

i) several volumes below ground connected through the Icelandic soil



ill. 78 - various ways of creating an interplay between building and landscape on the optimal part of site

a)

b)

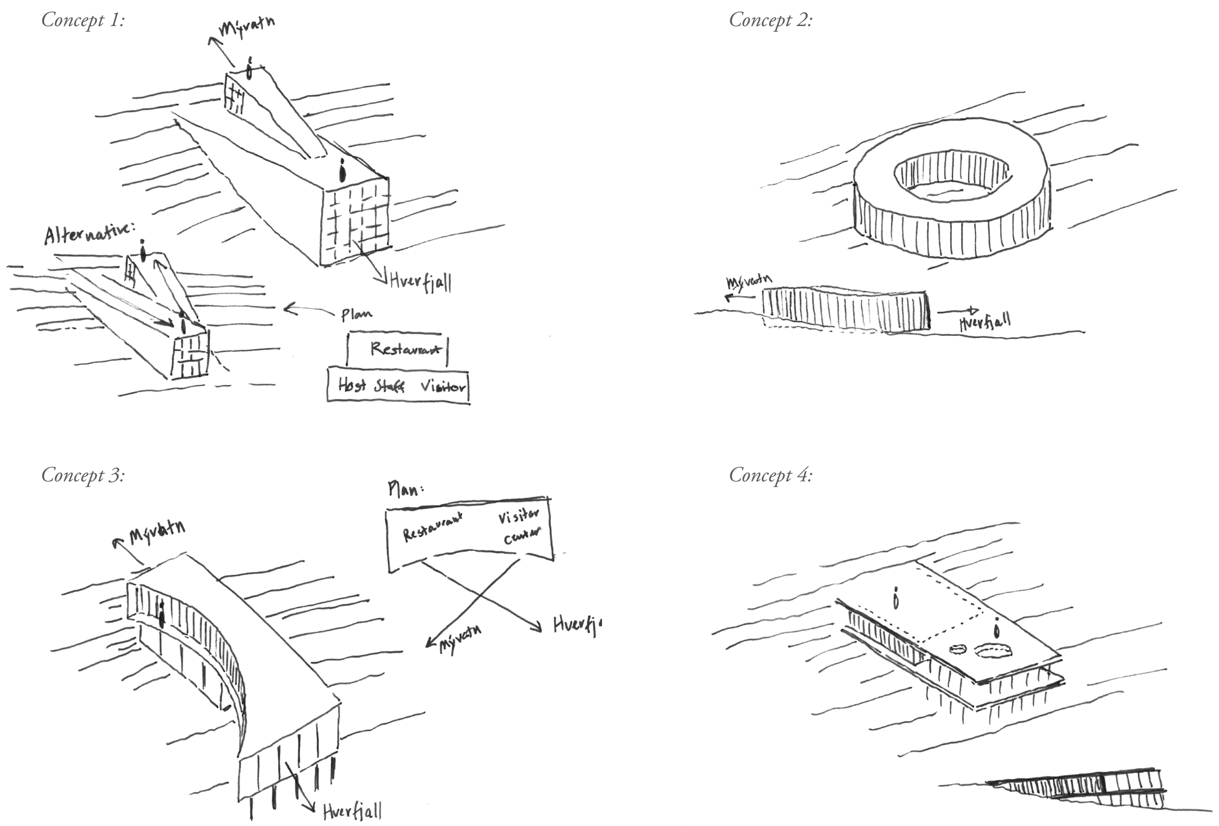
c)

d)

e)

ill. 77 - case studies for how architecture can relate to landscape - a) Wenchuan Earthquake Memorial, b) Moesgaard Musuem, c) Icefjord Center, d) Chichu Art Museum, e) Teshima Art Museum

ill. 79 - examples of the Icelandic landscape ranging from steep cliffs, cracked basalt ground, to raw canyons of Stuðlaberg



ill. 80 - the four concepts evaluated

Towards a concept

As a continuation of the previous study of how to interact with the landscape, some ideas were developed further through hands sketches, cad drawings (to investigate possible room placement and areas) and general discussion of how the concepts fulfilled the design parameters (see page 58). This was in particular the physical design parameters, as they were the most determining for the shaping of the building. Through general discussion, it seemed that the concept 1 and 3 offered solutions to many of the parameters. To quantify the talk, a simple number system was made, and each concept scores from 1 to 4 (4 being the best) in each parameter, resulting in the table seen in illustration 81. As seen the concepts 1 and 3 scored significantly higher than the two others. Through the further sketches by hand and cad drawings, the concept 1 was determined to offer the most interesting and fulfilling idea.

design parameter	1	2	3	4
Visibility/ exposure	*3*	*2*	*4*	*1*
View to Hverfjall + Mývatn	*4*	*2*	*3*	*1*
Interplay with landscape	*4*	*1*	*2*	*3*
Division between functions	*3*	*1*	*4*	*2*
	14	*6*	*13*	*7*

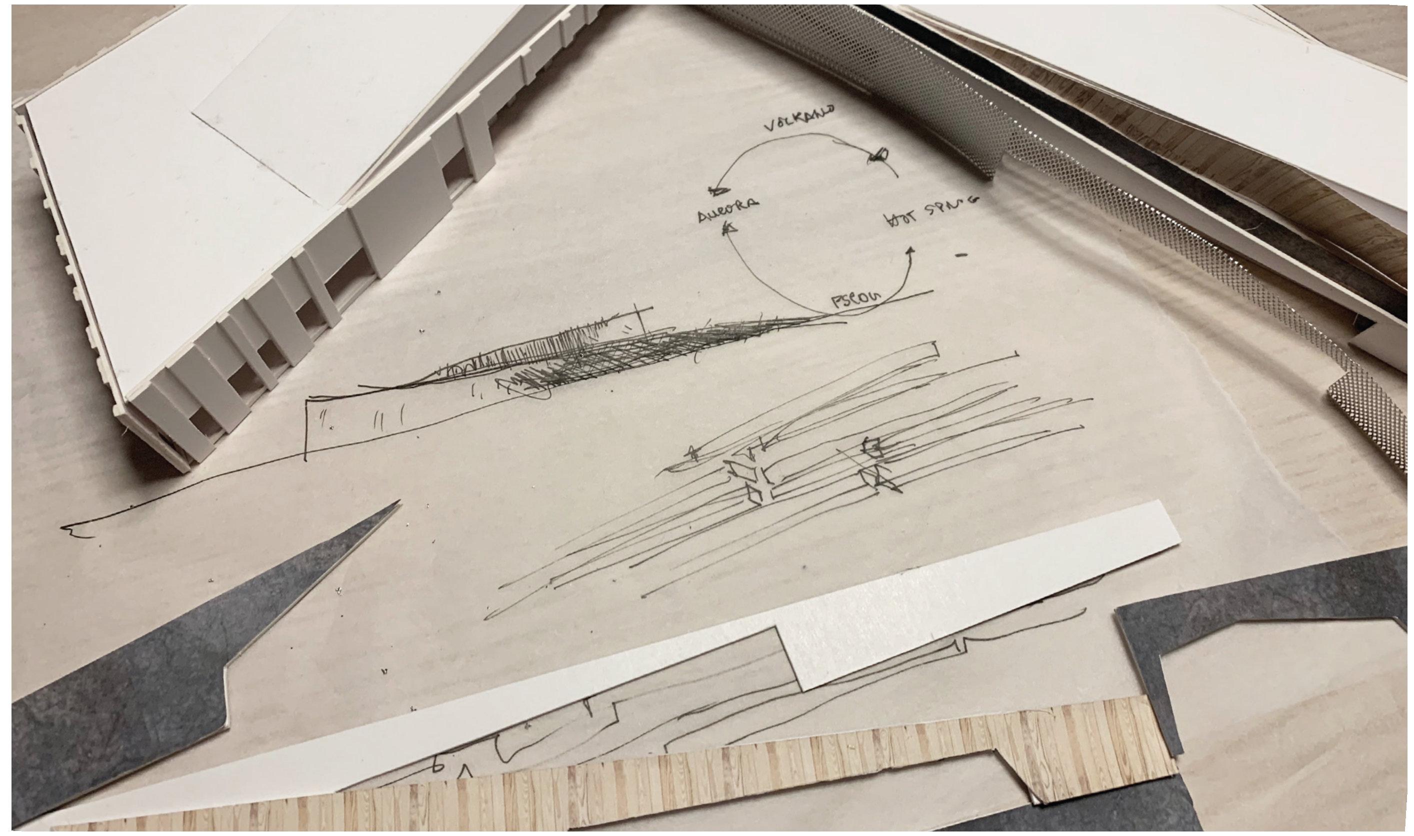
ill. 81 - the evaluation of how well the concepts fulfilled the following design parameters (from page 58):

*- Due to the function of the building as a visitor center and therefore a place for promotion and information, the building must be **exposed and visible to the main road Mývatnsvegur** and the smaller access road.*

*- The building should facilitate a **view to both Mývatn and Hverfjall** as well as other surrounding mountains as these are the most prominent elements visible from site.*

*- There must be an **interplay between building and landscape** in a way that is respectful and protective of the qualities of the site, while providing the visitors an outdoor experience as well as and indoor.*

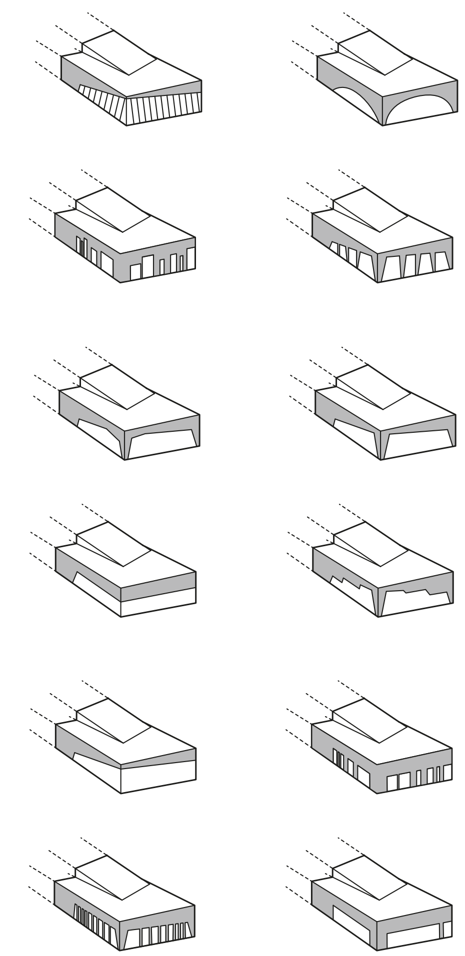
*- There should be a **clear division between facilities** for host and staff, staying guests and visiting guests.*



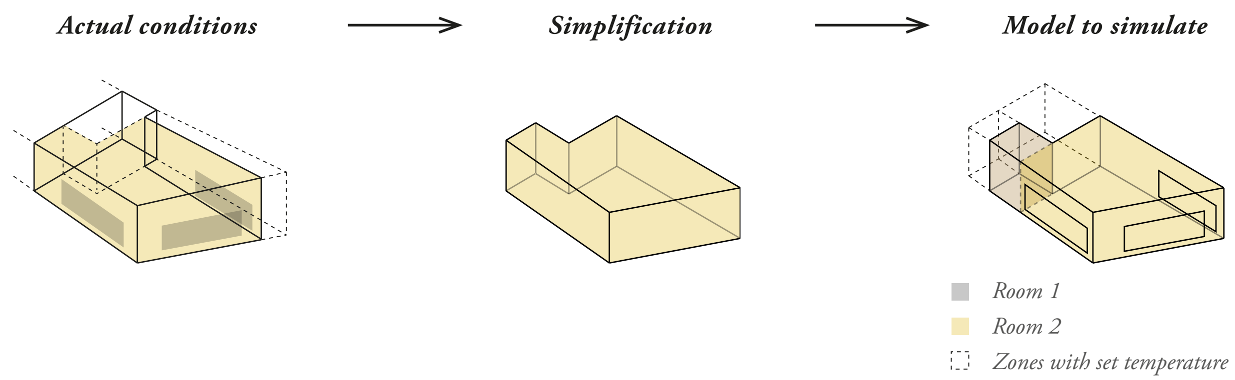
ill. 82 - some of the models and facade ideas from the physical facade workshop.

Initial facade workshop and studies

As the analyses of the site and its surroundings it was found that the façade towards Hverfjall was important both for the view towards the volcano as well as making the building visible from the main road Mývatnsvegur to attract tourists. The development of the initial façade ideas was explored through a workshop with physical models (see illustration 82) as well as a brainstorm of window layouts using Revit (ill. 83). The value of having physical models to hold and compare was clear, as the concept relatively fast was given a dynamic shape through modelling. This shape giving was to become the foundation for the further design process and the synthesis of the actual solutions. An angle that supported the desired views was found in a creative process and later synthesized into the most optimal solution for all – both architectural and technical – aspects.



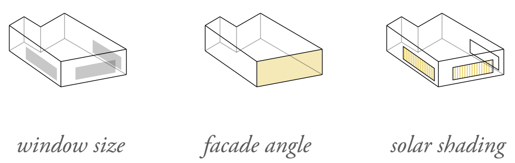
ill. 83 - some of the brainstormed ideas using Revit



The goal of the analysis is to investigate the indoor comfort (thermal and sensoric) based on three variables: window size, south/west facade angle, and solar shading. The model in Bsim is a simplified version of the actual conditions.

To simplify the model, the roof is flattened with and average room height to maintain the same room volume and surface area. The open space of the visitor center is considered as one thermal zone.

The thermal zone consists of two rooms to simulate the whole open space. The rest of the building is modelled as two rooms with a set temperature of 22°, while all other surfaces faces the outdoors except for the floor which faces the constructed Icelandic ground.
Rotation: 26 degrees



Preparation of Bsim model to assess the indoor climate in the visitor center

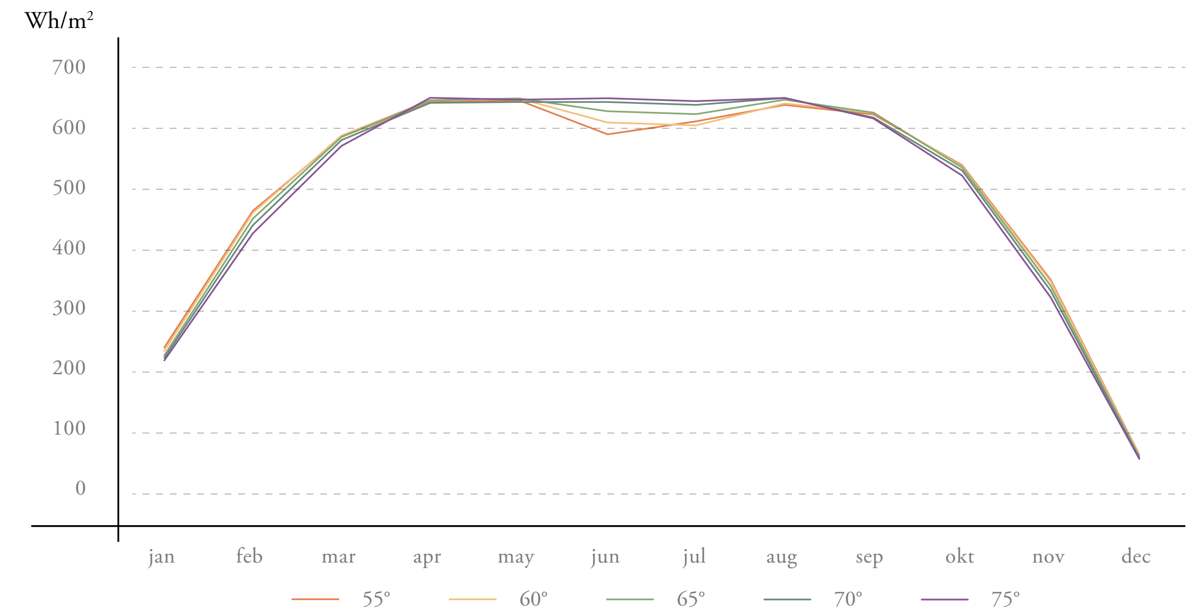
Bsim is a simulation tool that can be used for simulating indoor climate in buildings and it was used during the process to help determining what effect various changes in the design had. As the initial model was modelled, the wish was to study the window size, the façade angle and the solar shading using Bsim. Determining what the model needs to be used for, helps modelling it in the right way. As the program has some limitations to the shapes that can be simulated, a simplification was made but maintaining the same surface area and volume as these are crucial in the simulation. In the initial simulation a window area of 30 m^2 in each façade was used. This would obviously change with the design but based on some simple studies of the daylight factor in the room, this area seemed approximately sufficient (see annex 3). As for the constructions used in the model, the exterior wall, the floor and the roof were modelled as concrete constructions with a u-value of 0,08 W/m^{2}K. An initial investigation of the floor material was done comparing three types of floors: a concrete floor, a rammed earth floor and a concrete floor with a wooden flooring. The hypothesis was, that the higher specific heat capacity of the concrete and the rammed earth would perform better than the wooden flooring, causing less hours with overheating. As seen from the table ill. 85, the concrete performs the best and is therefore chosen for the further investigations. Through the investigations the parameters of the temperature and the CO_2 level, was often used to compare various options, as these can be used to describe the quality of the indoor environment.

The following analysis were not done right after each other, and numbers between two studies should not necessarily be compared. The investigations were done to assess the effect on the indoor climate of comparable design solutions, each study giving an optimal solution for the specific element investigated.

ill. 84 (above) - short description of the properties of the modelled Bsim model

floor	u-value W/m^{2}K	hours > 25°
Concrete	*0,08*	*321*
Rammed earth	*0,08*	*355*
Concrete with wooden flooring	*0,08*	*393*

ill. 85 - relation between type of floor material and overheating due to thermal mass



ill. 86 - the monthly peak solar radiation as a function of the facade angle. Values obtained from Autodeesk FormIt (see annex 4). As seen from the graphs, the angle resulting in the highest radiation during winter is also the one resulting in the lowest radiation during summer. 55 degrees.

ill. 87 - facade angles analysed in FormIt.

	hours > 25°	hours < 18°
∠55°	*258*	*146*
∠65°	*305*	*132*
∠75°	*324*	*128*

ill. 88 - table showing the overheating in the visitor center

Investigation of the relation between solar radiation and facade angle

In the initial design the angle between the North façade and the South-East façade was 63 degrees. This angle was chosen based on optimizing the view towards Hverfjall through a window placed on this facade, but the exact angle was initially an aesthetic choice based on the knowledge that the angle could be changed in the process of improving the indoor conditions in the building. In the further design, the indoor climate was improved by analysing the relation between the angle of the façade and the indoor temperature caused by solar radiation through the window on this façade. The study determined the optimal angle to achieve the highest radiation during winter to help heat up the building, while decreasing the radiation during summer when the radiation causes overheating and therefore an unpleasant indoor climate. As requirements for the indoor climate, the investigation aims to lower the number of hours with a temperature above 25 degrees as much as possible and keep the CO_2 level below 900 ppm as stated in the room program.

The study was carried out using a combination of Autodesk FormIt to determine the solar radiation (see annex 4), and Bsim to simulate the overheating based on each iteration. The scope of the investigation was limited to testing angles between 55 and 75 degrees to maintain the view towards the volcano and to keep the dynamic expression of the building emerging from the ground, hence no angles close to 90 degrees. The five iterations are: 55°, 60°, 65°, 70° and 75° as seen on the illustration above. To keep the solar radiation as the only variable, the area of windows, floor, and walls are kept as identical as possible in all simulations. The systems of the Bsim model are also identical. Especially heating and ventilation affects the temperature: heating is set to 22 degrees during the months from September to April, while the mechanical ventilation is active during the same period and is switched with only natural ventilation during the summer months of May to August. This natural ventilation is provided by cross ventilation through one open-able window on the SE façade and two on the North facade and two on the South-West facade that activates at a set temperature of 24 degrees and a CO_2 level of 700 ppm.

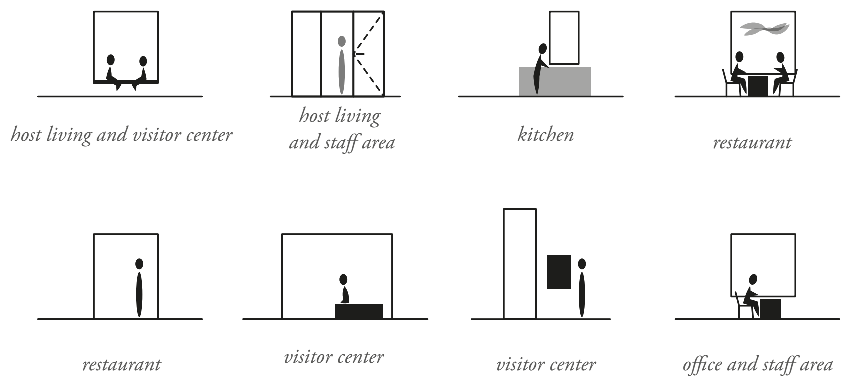
Analysing the façades in FormIt, results in the graphs seen above, ill. 86. As seen from these, the lower angles of 55° and 60° performs better during summer while simultaneously performing better during winter, most likely due to the building shading itself during the months with the highest altitude of the sun. To confirm the results, simulating the model in Bsim results in the number of hours seen in the table 88. To quantify the results, models with an angle of respectively 65° and 75° are also stated in the table. To ensure that the rotation of the façade does not cause the building to become too cold during a critical month such as May, the number of hours below 18 degrees are calculated too. As shown, this number unfortunately increases slightly, but a closer investigation determines that these hours happens early in the morning outside opening hours and is therefore not as concerning as they might have been, had they been during the opening hours. As a further control of the indoor climate to ensure the atmospheric comfort, the CO_2 levels are simulated and reach a high of 863 ppm which are acceptable as it is below 900 ppm.

As a conclusion it is determined that the most optimal angle (of the analysed) is the 55° angle, that maintains the direct view to Hverfjall while decreasing the overheating during summer and increasing solar radiation during winter. It is most likely possible that an angle below 55° could improve the conditions further, but to maintain the architectonic and atmospheric experience, the view must be preserved.

Window concept and function

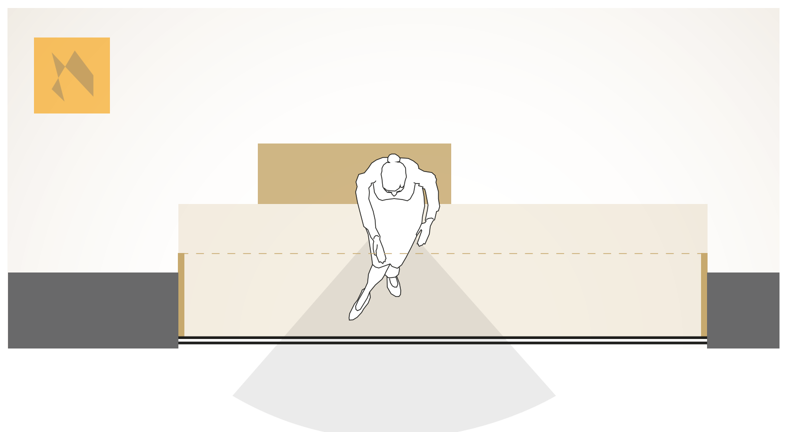
The process of designing the windows and layout of the windows, took offset from the main functions, that the windows needed to provide the interior and the user. Since the view to the surroundings is highly prioritized, the windows are of utmost importance to the user while being inside the building. However, windows also provide important daylight to light up the interior of the building as well as being essential for the atmosphere experienced in the building. The main design criteria for the window design were therefore: to supply light, create atmosphere, and provide view to the surroundings.

The first iterations of window determined what types of windows, the building needed (see illustration 89). Regarding the importance of windows for the human experience of atmosphere, Peter Zumthors nine key features should be considered in the design. The key features about light, materials, human scale, and tension between inside and outside, was used in the process of architectural detailing the windows. The window design in the visitor center includes two main concepts based on the three main functions of windows: view to surroundings, daylight, and a place for contemplation. To accommodate the function of view to the surroundings and creating a space for contemplation, the first typology of window creates a human scaled space through the sizing and proportion of the window and the use of soft and warm materials provide a calm and intimate space surrounding the user (ill. 90). The window itself is placed as far towards the façade as possible to create as defined space within the frame of the window. These aspects are used to create nook windows with seating for the user to stay and emerge themselves in the view to the landscape. As a contrast to this type of window, the more narrow window provide daylight while also making room for wall space for exhibition elements. The window is placed towards the interior of the room to urge movement along the window with no space for stopping. The materials are less soft and warm to distance the human from the actual window, giving space to observe the exhibition. The window types were examined through physical work models in the scale 1:50 to understand the spatiality of the window proportions. The models can be seen in annex 5.

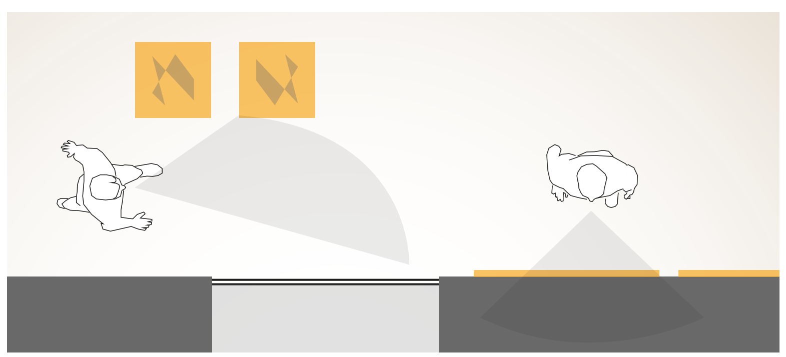


ill. 89 - initial window typologies throughout the building:

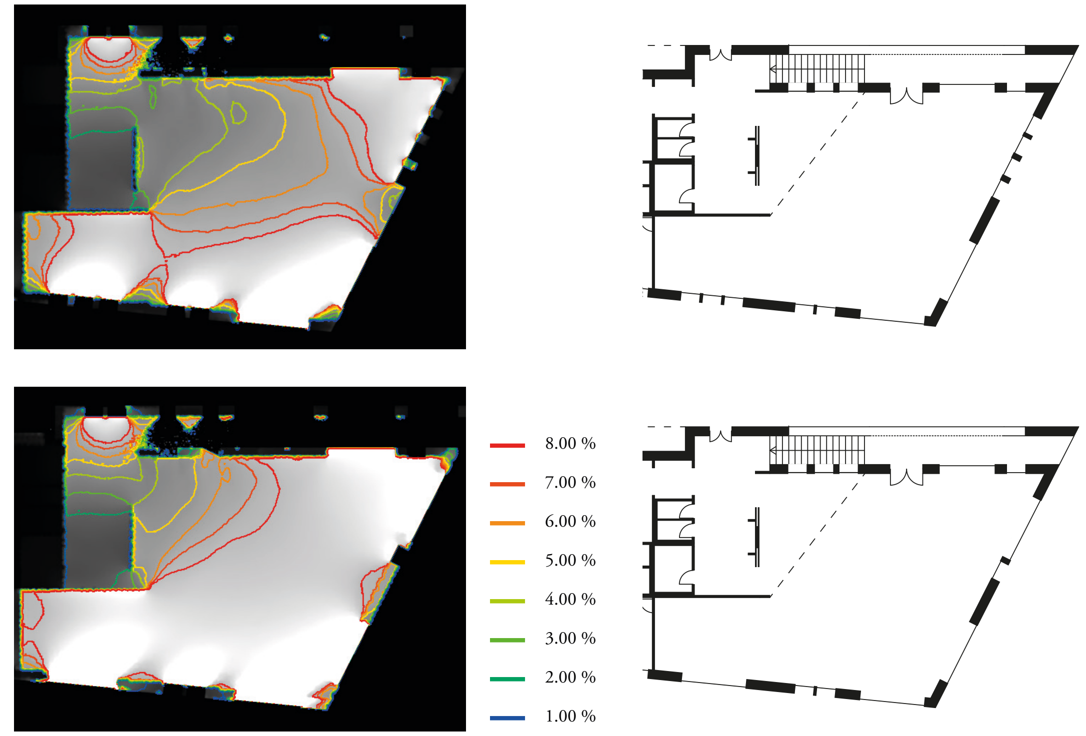
*The **nook window** provides a small, atmospheric space to stay for a little while and observe the view to the outside:*



*The **functional window** for providing light to the room, without directly urging the viewer to stay:*



ill. 90 - window typologies in plan (1:50) for visitor center: materials, depths, and width express the function of the window and urge human interaction



Iteration 1:

Window area: 77,15 m²

Nook windows: 3

Functional windows: 11

Hours <18: 170

Hours >25: 88

Hours >26: 2

Iteration 2:

Window area: 83,7 m²

Nook windows: 5

Functional windows: 7

Hours <18: 166

Hours >25:131

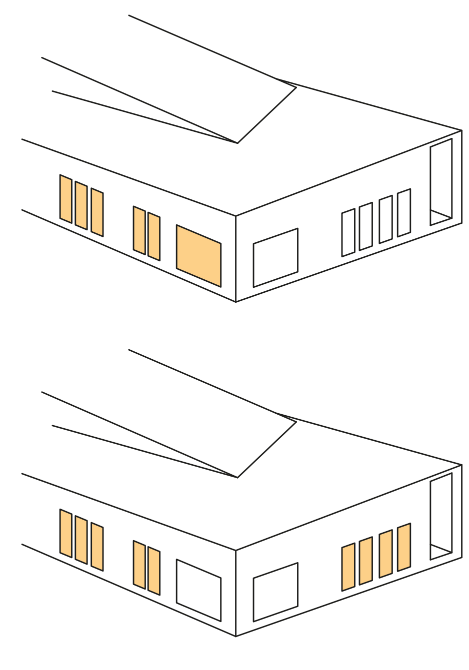
Hours >26: 2

ill. 91 - two iterations using the window typologies from the previous page and their corresponding daylight factor and hours with critical temperatures. See annex 1 for studies of daylight factor based on other window typologies and layouts.

Window placement and daylight factor in visitor center

The visitor center needs to provide the frames for learning and exhibition to promote the area of Lake Mývatn in a sustainable way. As determined in the previous window investigation, there needs to be two main typologies of windows in the visitor center. As these types were found based on atmosphere and daylight, the number of each window type and their placement needs to create sufficient daylight conditions in the interior, while supporting a comfortable indoor climate. Large window areas can be critical during summer since the solar radiation heat up the building. Two main organisations of windows are shown above with the corresponding thermal comfort of the room investigated using Bsim. The requirement for the thermal comfort were set in the initial programme and aims to lower the number of hours above 25 degrees as much as possible. As seen both solutions supply plenty of daylight with possibly even too much in the second solution. Though the window area only changes with app. 6 m², the number of hours above 25 degrees increases by 50. As the solution with one nook window on each façade both offers a functional layout with space on walls for exhibition and spaces for contemplation, as well as enough daylight, this solution is chosen for the further design.

To further lower the number of hours above 25 degrees, solar shading is added to some windows. In the Bsim simulation the solar shading consists of a continuous shading system with a shading coefficient of 0,5, corresponding to external venetian blinds, that can rotate and block up to 50% of the sunlight/radiation. Since the windows towards SSW receives more solar radiation than the other façades, the hours above 25 degrees can be significantly lowered by adding solar shading to these. However, when investigating the time of day, that the solar shading is active using Bsim, it shows that there are times, when all windows are covered blocking the view towards the lake. Instead the solar shading is placed on all narrow windows, leaving nook windows with view all day and still maintaining the number of hours above 25 degrees below 50. It should be noted that the model is simulated with natural ventilation during summer, and it was found that having two open-able windows on each of the South-West facade and the North facade, while having one on the South-East facade offers the best conditions without having a too high air change.



	h. > 25°	h. > 26°
shading on all windows towards South-West	*39*	*0*
shading on all narrow windows	*48*	*2*

ill. 92 - shading options to maintain view towards Hverfjall

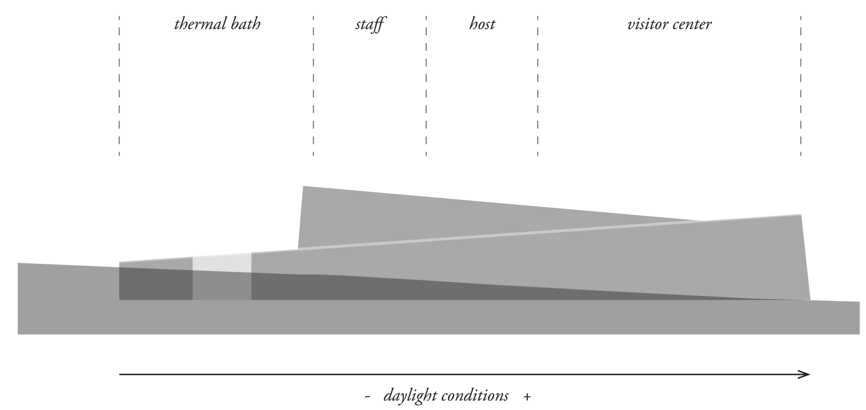
Daylight factor in the remaining building

To reach a satisfactory visual indoor climate, the daylight conditions of the building must meet the requirement of an average of 300 lux in half of the relevant floor area (or 2,0 % as daylight factor) set in the program. Furthermore, the windows must provide a view to the outside, giving the people living and working in the building a feeling of being close to the surroundings. The initial building organization of functions (staff, host, visitor center, and thermal bath) were determined based on the possible daylight conditions of the placement as seen on illustration 94. However, the functional demands of the building required a connection between staff zone and visitor center, leading the function of host living and staff zone to be switched. As the host living zone is a home for the host family, all rooms (expect for the bathroom) needs windows and daylight, while some rooms (storage, laundry, cleaning) in the staff zone can make do with less. To improve the daylight conditions and the view to the surroundings from the host living, the landscape around the building was slightly lowered, while still the building still maintained the appearance as emerging from the slope of the landscape. Furthermore, the façade towards the North-East was moved to decrease the overhang causing more light to enter the windows.

	daylight factor
Iteration 1	
- Host bedroom	*- Host bedroom*
- Staff office	*- Staff office*
- Staff room	*- Staff room*
Iteration 2	
- Host bedroom	*1,5%*
- Staff office	*1,8%*
- Staff room	*2,3%*
Iteration 3	
- Host bedroom	*2,1%*
- Staff office	*2,0%*
- Staff room	*2,3%*

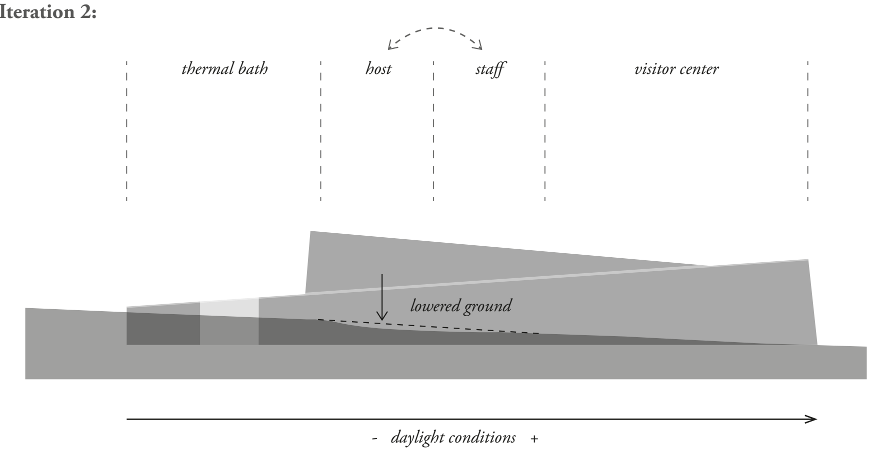
ill. 93 - daylight factors in the iterations (see annex 6)

Iteration 1:



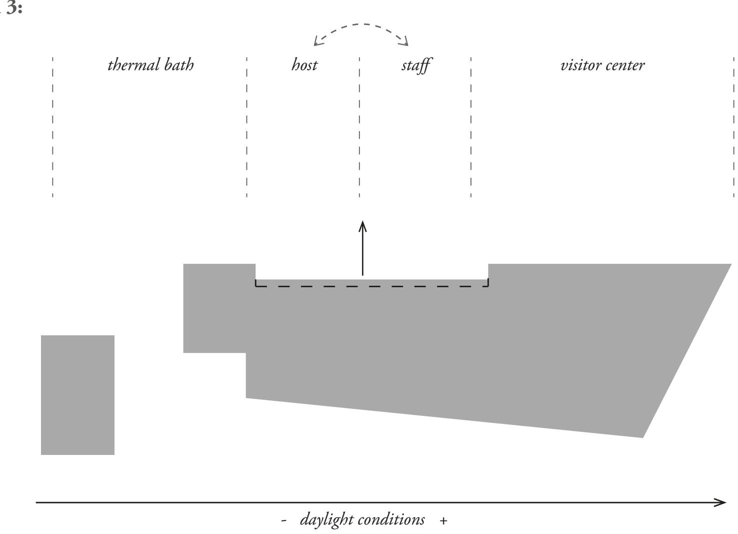
The initial placement of functions follow the daylight conditions in the building. In the part of the building emerged in the ground, are the functions that either require less daylight or can be partially outdoor.

Iteration 2:



To optimize the placement of the functions, the staff and host facilities are switched to directly connect the staff zone to the visitor center. To accommodate the switch regarding daylight, the landscape is slightly adapted to provide more light and better view.

Iteration 3:



To further improve the daylight conditions in the host living area and the staff rooms, the facade is moved so that the overhang becomes smaller, while still maintaining the feeling of privacy.

ill. 94 - three main iterations to improve the overall daylight conditions in the whole building.

“Materials react with one another and have their radiance, so that the material composition gives rise to something unique. Material is endless.”

“There’s a critical proximity between materials, depending on the type of material and its weight. You can combine different materials in a building, and there’s a certain point where you’ll find they’re too far away from each other to react, and there’s a point too where they’re too close together, and that kills them.”

- Peter Zumthor in Atmosphere, page 26-27

Determination of interior materials based on daylight, acoustics, and atmosphere

To determine the choice of materials for the interior rooms, a series of investigations were done focusing on the auditory, visual, and atmospheric experience of the user. The materials chosen for investigation were based on the analysis of the sustainability of various materials (see page 24) and the following materials have been considered: concrete, rammed earth, wood, and gypsum. For the flooring, rammed earth and concrete were possibilities based on them having a high thermal mass because of their heat capacity. As the first iteration, the thermal properties of the two materials were simulated in Bsim, and their ability to store heat can be assessed by looking at the hours above 25 degrees. As seen from the table 85 page 72, the concrete and rammed earth flooring performs significantly better than the concrete floor with wooden flooring, therefore being the two test materials for flooring.

For the study, three parameters were chosen: acoustics, daylight, and atmosphere. Acoustics are valued as the reverberation time in the room, and the suggestion of 0,6 seconds in housing from the Danish Building Regulations (BR18, 2019) are used as a knock-out criterion. In general, a low reverberation time is preferred in rooms for speech. The daylight parameter concerns the reflectance of the materials, and the program Velux Daylight Visualizer is used to asses this. The test is purely comparative, meaning that the general requirement of 300 lux in half of the room during half of the using hours (or a daylight factor of 2,1% as projection) is not necessarily met in this test, since the test only determines the materials that creates the best conditions for meeting the requirement. As the last parameter, the atmosphere of the room is assessed using the thoughts of Peter Zumthor (see page 15) and is valued based on the interplay and reaction between materials. Specifically, the variety of warm and cold materials are examined as well as their distribution in the room.

In the study the six combinations of materials shown on ill. 96 are examined. The results of daylight simulations and reverberation time calculations can be seen below each render (see annex 7 and 8). To evaluate the results each room is given as score from 1 to 6, 6 being the best score. The same is done as a measure of the atmosphere (in general rooms with few or alike materials score worse than rooms with a variety in materials and surfaces). The result can be seen in the table 97, and the iteration 3 scores the highest. Since the reverberation time is below 0,6 the iteration is chosen for the final design. The use of rammed earth creates a satisfying acoustic environment, while also being able to store heat due to a high heat capacity as stated above. However, the rammed earth also has a significantly lower reflectance (30%) than other materials. The balance of the room is achieved by using a high reflecting ceiling in wood, while maintaining the acoustic properties of the rammed earth. As a positive side effect, the rammed earth has a high humidity regulation capability, which can help eliminate temperature fluctuations.

It should be noted, that this material combination will not be applicable in all room due to functional requirements such as cleaning, hence why rooms such as kitchens and rest-rooms will need other surfaces.

Materials:
Floor: Earth   Ceiling: Birch
Interior wall: Earth   Exterior wall: Concrete
Daylight factor: 3.7 %
Reverberation time: 0,25 seconds

Materials:
Floor: Earth   Ceiling: Gypsum
Interior wall: Birch   Exterior wall: Birch
Daylight factor: 4.5%
Reverberation time: 0,37 seconds

Materials:
Floor: Concrete   Ceiling: Birch
Interior wall: Earth   Exterior wall: Concrete
Daylight factor: 4.0%
Reverberation time: 0,36 seconds

Materials:
Floor: Concrete   Ceiling: Gypsum
Interior wall: Birch   Exterior wall: Birch
Daylight factor: 4.6 %
Reverberation time: 0,80 seconds

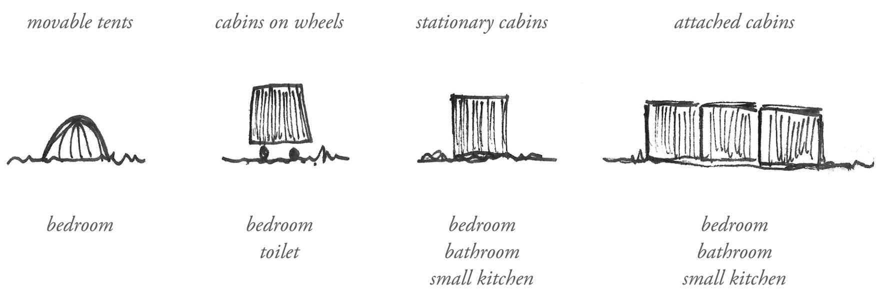
Materials:
Floor: Concrete   Ceiling: Birch
Interior wall: Birch   Exterior wall: Concrete
Daylight factor: 4.5%
Reverberation time: 0,72 seconds

Materials:
Floor: Concrete   Ceiling: Birch
Interior wall: Birch   Exterior wall: Birch
Daylight factor: 4.7%
Reverberation time: 0,66 seconds

ill. 96 - renders of each iteration of various materials in the interior design of the host living room. These are for initial studies and are used as starting points for material detailing.

	acoustics	daylight	atmosphere	score
Iteration 1	6	1	2	9
Iteration 2	4	3	4	11
Iteration 3	5	2	6	**13**
Iteration 4	1	5	5	11
Iteration 5	2	3	3	7
Iteration 6	3	6	1	10

ill. 97 - scoring system to determine which final materials will be used in the interior design in the building. NB: iteration 2 and 5 share the same daylight factor, hence scoring the same. As seen from the final score, the indifference is of no concern to the final result.

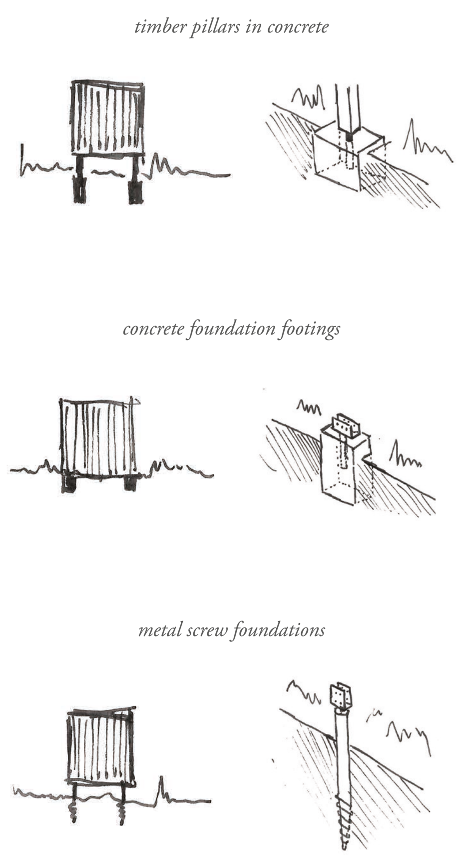


ill. 98 - possible types of cabins and their interior based on movability, size, and weight

Cabin typology

To tackle the challenge of making a non-permanent and removable cabin, the traditional concept of architecture is questioned, as much architecture today is made to last in one place as long as possible. Protecting the natural habitat of Mývatns ducks requires the cabins to be easily removable with no permanent foundation and therefore needs to be temporary to a certain extent. This can be done in several ways with ranging permanence. The lightest and least permanent solution is a tent-like structure, that the guests themselves collect at the main complex, put together at their desired spot on-site, and later pack up and bring back to the complex. This solution offers much flexibility and individuality when choosing the spot, however it also significantly limits the functions, that can be integrated in the tent. A similar solution is the cabin on wheels, that can be moved around site and still contain both bedroom and toilet. However, these cabins will need to be moved by the staff and there might be limitations to where the cabin can be safely placed. Furthermore, the site does not offer that much variety in the placement, hence having the cabins on wheels can seem like a complicated solution with little payoff regarding the experience. The constant movement of the cabins can also cause great disturbance of the duck nesting areas.

As an alternative solution to the directly removable cabins, there is the semi-permanent solutions with a light foundation with as little contact to the site as possible. This might be in the form of a pile-foundation or screw foundations. In this way a stationary cabin solution can be done, with little impact on the site. The cabins would be placed accordingly to the qualities of the site and their view to each other and can also offer the possibility of having a small kitchen since their weight is not as crucial as if they should be moved around site. As for the energy and waste management systems, stationary attached cabins can possibly share some systems, however this requires the cabins to be directly attached to not interfere with the site. Attaching the cabins to each other limits the qualities of the views from each cabin and the individuality of each cabin is compromised, hence why it is chosen to focus on creating stationary individual cabins, that can be placed around site.



ill. 99 - possible foundation types to minimize the impact on site

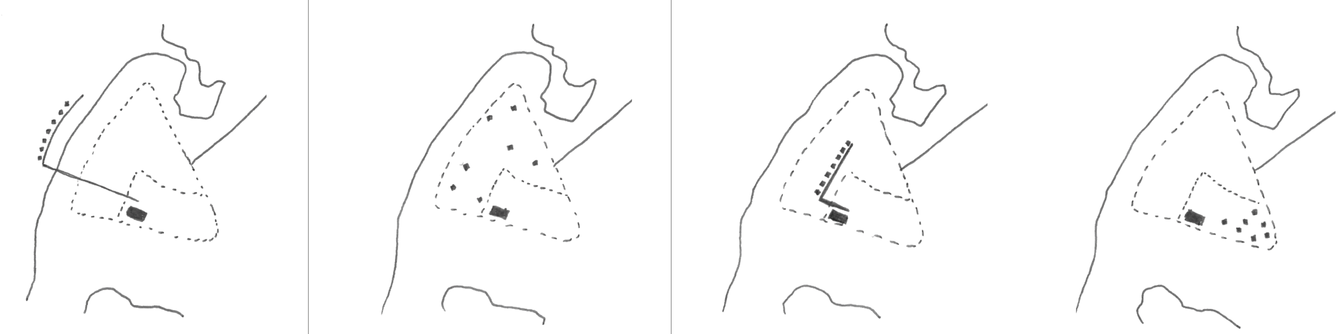
Cabin placement on site

To determine the placement of the cabins on the site, several possibilities were evaluated. The general ideas are pictured below including the specific typology of cabin that fits the placement on site. The solutions are considered regarding: view, impact on site (and interference with native duck habitats), movability, guest experience, and supply of heating, water, and electricity. The investigation shows that placing the cabins in the protected area will undoubtedly give the best experience to the visitor with a view over the lake. However, placing the cabins here, will also leave some impact on the protected site. The two ways of placing the cabins on the protected area are to either place them along a bridge raising the guests above the ground or to place them in various places around the site connected by hard pressed earth paths. Placing them around the site, will certainly offer the most variety in views and experiences, differentiating each cabin from the other, while also allowing the guests to move around on-site in a controlled way. By going with this solution, the visitors are offered the best individual location and experience of the site, but there needs to be paid attention to not disturb the natural duck habitats and nesting areas in the protected zone, while also needing a high level of self-sufficiency to avoid too much interference with the landscape.

Placement of cabins on site:

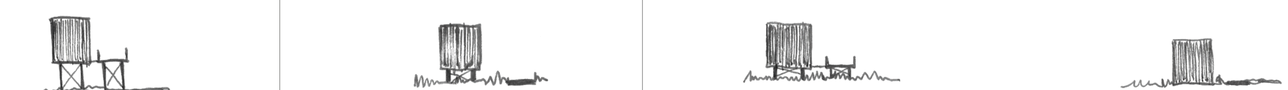
Chosen solution

Bridge over Mývatn	***Cabins spread across protected area***	***Bridge over protected area***	***Cabins on build-able site***



Relation between cabin and ground:

Cabin raised over water	*Cabins lifted on poles*	*Cabin lifted on poles*	*Cabin on ground*



Pros and cons:

Bridge over Mývatn	Cabins spread across protected area	Bridge over protected area	Cabins on build-able site
+ No disturbance of the protected area expect for path leading to bridge + No light pollution from main complex + High level of privacy due to orientation and distance of cabins + Heating, water, and electricity can be supplied through cables and pipes in bridge - Large impact on the lake - Relatively long distance from main complex to cabins can cause problems with supply and be inaccessible for some guests - Cabins are not placed on the actual site from the competition - No flexibility in placement according to guets' wishes	*+ High individuality of each cabin due to placement + Guests have the possibility of choosing which placement they want. + High level of privacy since cabins will not have direct view to each other + All cabins can be placed in a convenient distance from main complex - Cabins will need to have a high level of self-sufficiency - Will require paths spread across site to lead guests to the cabins*	*+ Relatively short walking distance from main complex + Cabins visible from access road + Less impact on protected area because of bridge for walking + High level of privacy due to orientation and distance of cabins + Oriented towards North, so no light pollution from main complex - Will still have some impact on site, though less than other solutions - No flexibility in placement according to guests' wishes - Needs material resources for bridge*	*+ Cabins can be made with a permanent foundation + Convenient distance from main complex - Views are easily obstructed due to being placed low on site - Little area to spread cabins across - Main complex affects the view towards North - Does not use the qualities of the protected zone at all - No flexibility in placement according to guests' wishes*

ill. 100 - possible placements of cabin on site and their pros and cons

Basic need	Supply	Output	Management
Heating	Fuel pellets from dried horse manure Passive solar gains	Ashes	Ashes removed and pellets refilled by staff Horse manure collected from stables, dried and processed to pellets
Electricity - Lighting - Charging phones and cameras	PV cell placed on inclined roof	-	Electricity stored in battery in cabin. Yearly demand is covered by PV cell (see annex XX)
Toilet	Human waste to composting toilet + urine to urine tank	Compost Urine	Compost tank removed by staff and stored until fully composted material can be used as fertilizer. Urine is separated and fertilizes green roof on main building
Cooking and water heating	Biogas tanks filled at on-site energy center with biogas produced from horse manure	Empty tank	Horse manure collected from stables and digested into biogas. Tank filled and refilled at energy center
Water	Lake Mývatn	Greywater	The water is pumped from the lake and purified at the energy center. Each cabin is equipped with a refillable tank and filled by staff using a small multi truck with a larger water tank Greywater is removed from the cabin in the same way

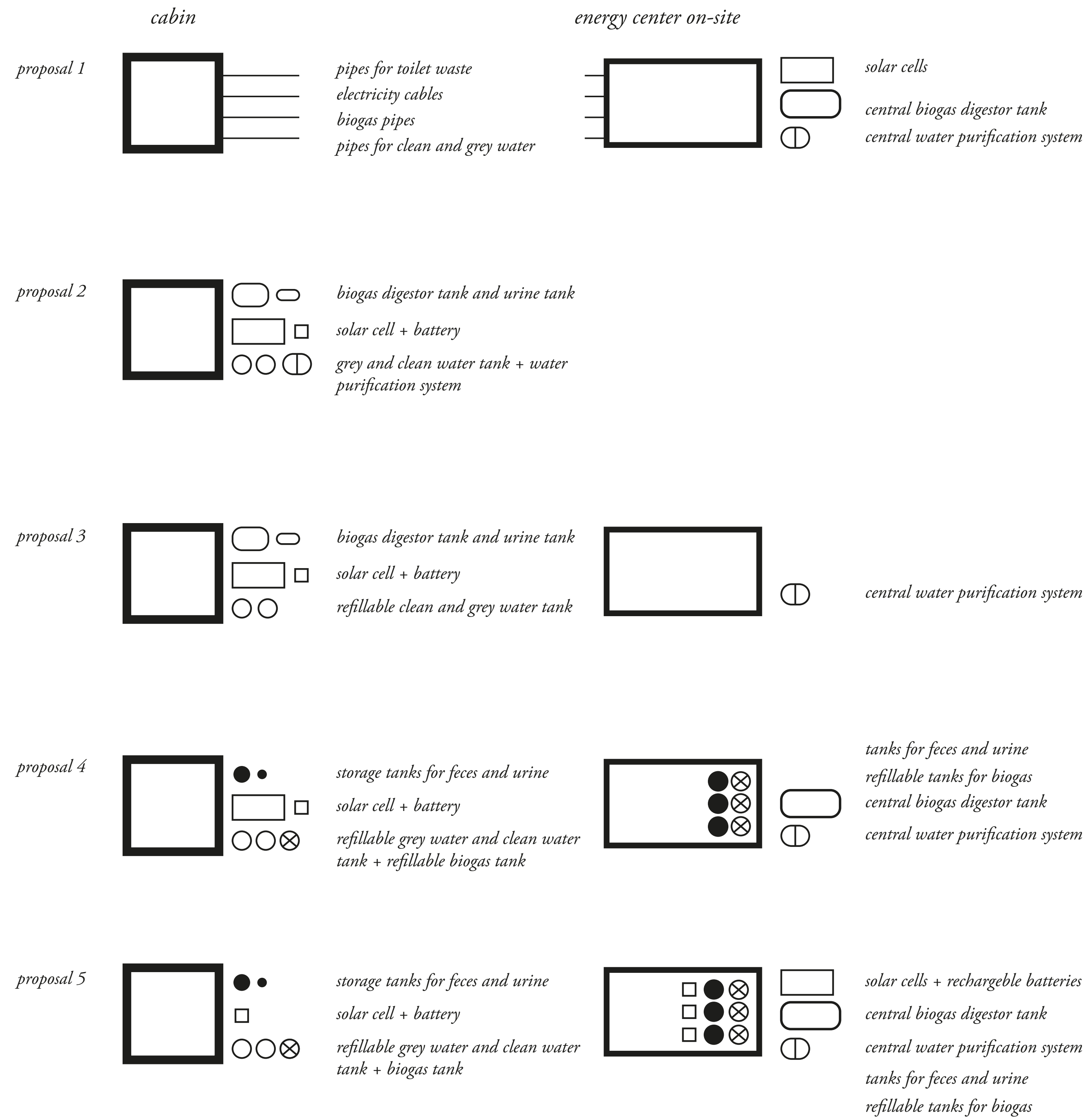
ill. 101 - how demands are supplied to the cabin based on the discussions of proposals 1-5 (ill. 102)

Self-sufficiency and off-grid solutions for cabins

The cabins will rely on several off-grid solutions as supply of electricity, water, heat and waste management to minimize the impact on the natural site. Initially, a study of various systems was made to determine how each need should be met and managed on-site. Some needs can be supplied at a central energy center in the build-able part of the site, while other can be produced directly at the cabin. The basic needs that need to be fulfilled are: heating, access to hot water, electricity, cooking, and access to a toilet. This will require systems to produce heat and electricity, gas for cooking and water heating, management of clean and grey water, and removal of human toilet waste. To understand what types of systems are needed, all heating, electricity, water and gas demands are calculated (see illustration 103, next page). The heating demand is found using Bsim while the electricity, water, and gas demands are calculated based on the consumption of 2 and 4 people corresponding to the two sizes of cabins. Since the four people cabin requires the biggest amounts, those numbers were used in the initial discussions of systems. To meet the heating demand, a pellet stove is installed in each cabin to provide the user heat and a cosy atmosphere with burning fire inside the cabin. This stove is heated using dried horse manure processed into pellets at the horse barn and transported to the cabins by staff members (see annex 9 for calculation of needed horse manure). As these pellets are produced at the horse barn, other systems for energy and waste management can possibly be placed here as well. Due to the high energy content of horse manure, calculations show, that the ten horses at the complex can supply the cabins with pellets as well as sufficient biogas for cooking and water heating (see annex 9) and further investigations are therefore based on using and producing biogas at the cabins.

In the illustration 102 is seen five proposals for how the energy and management systems can be distributed between the cabin and the energy center of the complex. Proposal 1 suggests a solution where all systems are placed at the energy center and connected to the cabin through pipes and cables. This requires all supply demands to be met at the energy center including a main biogas digester tank, main PV relay and a central water purification system. However, this causes a large impact on the site by having pipes and cables dug into the ground. As an opposite solution, proposal 2 suggests producing all needs at the cabins including a biogas digester tank, a PV relay, and a water purification system. The problem with having a local digester tank for each cabin is the Icelandic climate, where the temperatures during winter can become quite low significantly slowing the anaerobic digestion in the tank causing a very slow and low yield (mesophile digestion) (Lemvigbiogas). The tank cannot be stored completely indoor due to the fire hazard of the gas and having the tank at each cabin therefore causes several challenges. Instead a central biogas digester tank can be placed at the energy center, where it can be heated through geothermal heat like the rest of the main complex as proposal 4 and 5 suggest. Having the biogas digester tank at the energy center, requires that the gas is filled into portable tanks and then moved to the cabins during the general maintenance of the cabin. Similar solution can be made for the water supply. The general complex will be supplied with water from the lake, purified in a system at the energy center. To avoid having a purification system at each cabin, the main system can be used and a small truck with a water tank can refill and empty tanks at each cabin weekly or twice a week.

For the waste management, there are two possibilities: having the human waste be used for biogas or turned into compost. Removing it from the cabins and using it for biogas requires staff interaction and can cause sanitation problems. Alternatively,



ill. 102 - the five considered proposals for off-grid solutions

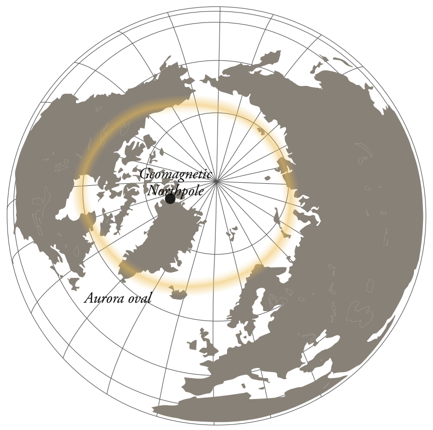
Off-grid systems

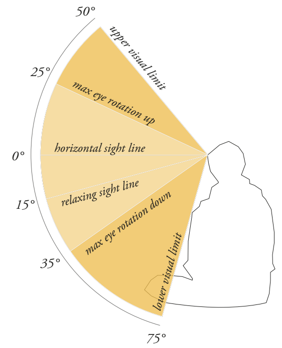
the waste can be composted using a compost toilet with a tank placed below the cabin under the toilet. As the process takes app. 6 months (Brunt, R., 2018) the tanks will have to be stored at the energy center until fully composted. The compost can be used as fertilizer for non-edible plants or returned to the ground safely which is similar for urine, that can be used as a drip irrigation system for the green roof at the main complex.

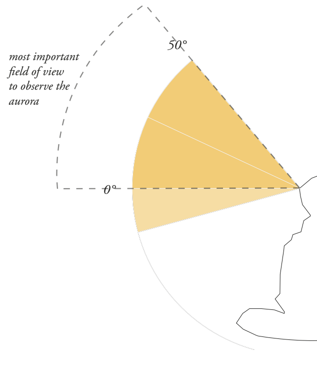
As calculations of possible yield of PV cells placed on each cabin (see annex 10) show that a relatively small relay can produce the required amount, it is preferable to have each cabin equipped with a cell and a chargeable battery to avoid having to charge batteries at the energy center and change them in each cabin. This lowers the number of needed batteries from at least 14 (7 in cabins and 7 charging) to only 7 in total.

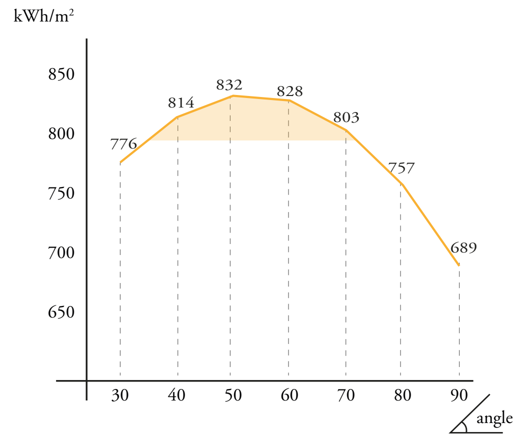
	2 people	4 people
Gas, m³	*0,35*	*0,51*
Water, l	*67*	*134*
Electricity, kWh	*659*	*739*
Heating demand, kWh	*532*	*532*

ill. 103 - dimensioning supply demands (see annex 11 and Bsim study (page 88-89)









ill. 104 - the aurora oval above the geomagnetic North pole. The oval varies in size, and can at some high-energy times be larger than above and at low-energy times be smaller. As seen the geomagnetic North pole is located towards the NNW of Iceland.

ill. 105 - the human field of vision. The windows in the cabin needs to be placed accordingly to create the best experience for the visitor.

ill. 106 - the part of the human field of view in which it is most likely to see the Northern Lights

ill. 107 - the annual solar radiation on a SSW facing angled roof depending on the inclination

ill. 108 - inclinations from 36° to 72° are most optimal towards SSW to optimize the solar radiation on the PV's

Cabin orientation and views

Orientation according to view to the Northern Lights:

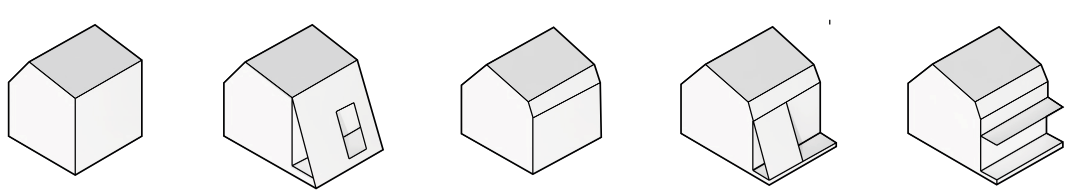
The most important function of the cabin is as required in the competition material to provide a view from the beds to the Northern Lights in the night sky. This was determining for the general orientation of the cabin and determined where windows were needed. As seen on illustration 104, the Aurora oval which is where the northern lights appears, are located towards the NNW from Iceland, meaning that the cabins need large windows in this direction for the guests to have a good view towards the most likely place of the northern lights. This can affect the indoor thermal comfort, as windows towards the north in most cases does not provide much positive radiation gain during winter, while still causing a transmission loss. However, the atmospheric experience of being able to observe the aurora from your bed must be created and large windows are therefore a necessity, and the window properties, such as g- and u-value, will have to be carefully considered.

Orientation according to human field of vision:

When being in the cabin to observe the northern lights, the placement of windows needs to follow the natural human vision to create the most comfortable settings. The human field of vision ranges from 75 degrees below a horizontal sight line to 50 degrees above. The sky would naturally be seen from 0 to 50 degrees above. The natural eye movement is however limited to between 35 degrees below and 25 degrees above, meaning that this is the most comfortable field to observe something in. The typical location of the northern lights is though in the sky, giving that the human field of view to observe the lights in, are from 0 to 50 degrees, with the field between 0 and 25 being the most comfortable where no head rotation is required. Window placement and size should allow people to stay in the bed and have this field of view unobstructed towards the night sky.

Orientation according to PV cells:

During the process of designing the cabins, it was established through an iterative process, that solar cells could be used to cover all electricity demands for the cabins (see page 82-83 and annex 11). As part of the process, the possible orientation and inclination of solar cells was determined. To investigate the possible gain, a study of radiation on inclined façades oriented towards SSE was conducted resulting in the graph in illustration 107. As seen the highest possible radiation was 832 kWh/m², but initially it was decided to allow angles between 36° and 72° in the first design iterations as these provide a radiation above 800 kWh/m² and give some architectural leeway. During later phases and studies it was continuously confirmed that the overall PV placement and inclination could supply the demand, and proper measures were made in case the demand was not met, such as changing the inclination, size or type of PV cell.



ill. 109 - various design options using an inclined roof with angles optimized for either view, radiation, or both.

type of PV	efficiency rating %	installed effect kWp	performance ratio	yearly yield kWh/year/m²	area needed to meet requirement m²
Thin film	13	0,13	0,75	80	3,37
Polycrystalline	20	0,2	0,75	123	2,19
Monocrystalline	24	0,24	0,75	147	1,83

ill. 110 - the needed area of PV cells to supply the cabin depending on type of PV and their efficiency. The cell is placed on a 45° inclined roof. Source of efficiency and performance ratio: (solarenergyforus, 2016)

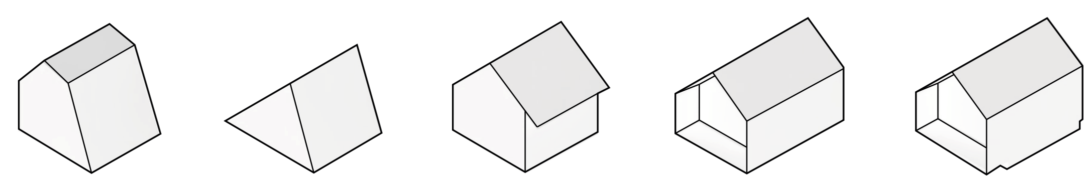
type of PV	embodied energy MJ/m²	embodied CO_2 kg/m²	total embodied energy MJ	total embodied CO_2 kg/m²	expected lifespan years
Thin film	1305	67	4402,8	226,0	14-17
Polycrystalline	4070	208	8925,4	456,1	23-27
Monocrystalline	4750	242	8680,5	442,2	25-30

ill. 111 - the total embodied energy and CO_2 depending on type of PV cells. Source: (Jha, N. K. 2016) and (solarenergyforus, 2016)

Integration of PV cells on cabin

Installing photovoltaic cells in architecture provides a way of supplying the building with all or a part of its electricity demand in a renewable way using the energy from the sun. Architecturally, PV cells can be integrated in the design, having a significant impact on how the building ends up being shaped due to optimal inclinations for radiation amounts. In Iceland, the sun angle above the horizon is relatively low especially during winter, meaning that it is important to optimize the placement of the PV cells to gain as much radiation as possible. The type of PV cell is also crucial in the choice, and choosing the right cell is an interesting discussion of embodied energy, life span and replacements.

As stated on the previous page, the angles from 36° and 72° were incorporated in some initial designs, illustration 109 shows some of the design options using either 40 or 70 degrees. To determine the size of the needed PV cell a comparison of three types of PV cells were carried out. For the comparison the radiation on a 45° inclined roof was used (820 kWh/m²) and the electricity demand as mentioned on page 83 was used. As seen in the table 110, the area of PV cells needs to be 3,37 m², 2,19 m² or 1,83 m² depending on the type of cell. Architecturally it might be preferable to choose the monocrystalline cell, as it has the highest efficiency giving the smallest cell to integrate on the building façade/roof. However, it is worth to investigate how much an environmental impact each type of cell has. Studying the embodied energy of the types, it is clear that the thin film has the lowest embodied energy with approx. half the energy as the two other investigated types (illustration 111), making it seem attractive to choose the thin film to lower the environmental impact. But, as different types of PV cells have different lifespans, the maintenance and replacement of them should definitely be considered. Dependent on the period of time that is considered, the total amount of embodied energy from PV cells during the lifespan of the cabin, varies. In annex 12 a graph of embodied energy related to replacements of PV cells can be seen. Since the cabins are semi-permanent, a period of 50 years is considered as their lifespan. From the graph, it can be seen that the thin film cells will need to be replaced three times during the 50 years, while monocrystalline will be changed once and polycrystalline will be changed twice. However, monocrystalline and thin film cells have almost the same total embodied energy after 50 years and are therefore both good choices. The final choice is determined based on the smaller area of monocrystalline cells needed and the lesser labour for maintenance during replacements. Iceland does not have any local production of solar cells, and the emission from transport also increases every time the cells need replacement. This results in a needed area of 1,83 m² of monocrystalline PV cells.



insulation	thermal conductivity *W/mk*	density *kg/m^3*	heat capacity *J/(kgK)*	embodied energy *MJ/kg*	carbon impact *kg CO^2/kg*	available locally *yes/no*
Wool	*0,038*	*23*	*1800*	*2,45****	*6*	*yes*
Straw	*0,045*	*120*	*2000**	*0,91*	*0,91*	*yes*
Glass mineral wool	*0,035*	*20*	*1030*	*26*	*26*	*no*
Rock mineral wool	*0,032-0,044*	*120*	*840***	*16,8****	*x*	*yes*
facade construction						
Wood	*0,72*	*650*	*1200*	*8,50*	*0,13*	*yes (as driftwood)*
Concrete	*1.13*	*2000*	*1000*	*0,95*	*0,04*	*yes*
Rammed earth	*1,51***	*2000*	*1260*	*0,28*	*0,004*	*yes*
Recycled aluminium	*205*	*2700*	*910*	*5*	*2,1*	*yes*
Polycarbonate	*0,19*	*1190*	*1200*	*112*	*6*	*no*

*ill. 112 - Sources: (greenspec, 2019) * (WUFI, 2011)** (Rockwool) *** (Hossain, A., 2018) **** (Minke, 2005)*

Material choice for cabins

As the overall experience and sustainability of the cabin is closely linked to the choice of material, there are several aspects to consider when making the choice. A series of investigations were carried out based on the above material properties (ill. 112). Some solutions are seen at illustration 113. First, the architectural expression should enhance the experience of being in and near the cabin when enjoying the northern lights. As previously stated, Peter Zumthor discusses the proximity of materials and their interplay with each other, while also using the proportions of the building to relate to the human body. In the choice of material, these key elements were used to ensure a variety in materials and their placement dependent on how the human would encounter the materials when entering the cabin having soft and warm appearing wood at the terrace.

Secondly, the environmental impact of the materials needs to be considered. As a measure, the embodied energy and the embodied CO_2 can be assessed based on the above properties. In general wood has a significantly lower impact than e.g. aluminium when taking the density into account. However, it should be noted, that production of materials in Iceland uses renewable energies, that undoubtedly decreases the embodied CO_2 due to a lower emission factor. Furthermore, locally produced materials have a lower CO_2 and consumed energy impact due to less needed transport, hence why a material such as polycarbonate is less sustainable than most of the other examined solutions.

Thirdly, materials affect the indoor climate, and considering this, the thermal conductivity and the heat capacity are crucial. As initial tests in Bsim showed, the cabin might experience temperatures below 18 degrees during summer nights, possibly due to a high natural ventilation air change to remove CO_2 emitted from people inside the cabin. One of the solutions for this, is to increase the thermal mass. This can be done using materials with a higher heat capacity, hence choosing straw as a natural insulation material. Similar solution could have been using concrete as construction material; however, the cabin needs to be relatively light, meaning the high density of concrete is less preferred than e.g. the one of wood. As the cabin is small and only has two floors with no significant critical load, the strength of driftwood should be sufficient for the construction.

Overall, the material choice was made considering environmental impact, indoor climate conditions, and atmospheric and aesthetic value, to reach a balance between all aspects. The final choice is a combination of a timber construction, timber and aluminium façade, insulated with straw batts to reach a satisfactory overall impression. The choice of material was naturally an ongoing iterative process using Bsim as a simulation tool (see page 88).

Materials:
Const.: wood
Facade: Driftwood
Treatment: Natural protected driftwood

+ low environmental impact due to low embodied energy and sequestration of CO_2
+ lightweight structure

- hard to obtain contrast in materials due to driftwood's consistent color
- low thermal mass

Materials:
Const.: wood
Facade: Driftwood
Treatment: Shou sugi ban

+ low embodied energy from using wood
+ highly sensoric experience due to tactility and smell of charred wood
+ light structure = high portability
+ sequestration of CO_2
+ interesting architectural expression using contrasting colors

- Shou sugi ban improves lifespan of wood, but increases the CO_2 emission
- low thermal mass

Materials:
Const.: wood
Facade: Driftwood+ recycled aluminium
Treatment: Natural protected driftwood

+ long lifespan
+ aluminium can easily be reused/melted at EOL stage
+ traditional Icelandic architectural expression
+ the embodied energy of aluminium can be lowered using renewable energy

- relatively high embodied energy compared to wood only façades
- low thermal mass

Materials:
Const.: wood
Facade: Driftwood + polycarbonate
Treatment: Shou sugi ban

+ highly sensoric experience due to tactility and smell of charred wood and translucency of polycarbonate
+ lightweight structure = high portability
+ interesting architectural expression using contrasting colors

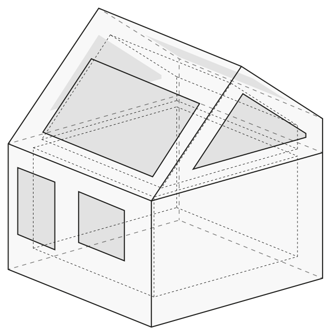
- high embodied energy compared to wood only façades
- low thermal mass
- polycarbonate facade will have a higher u-value than other constructions due to having no insulation to maintain translucency
- polycarbonate will need to be imported from outside Iceland meaning CO_2 emissions from transport

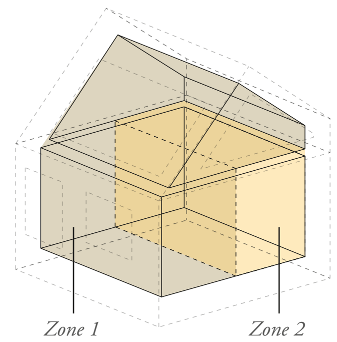
Materials:
Const.: Concrete
Facade: Concrete + driftwood
Treatment: natural protected driftwood

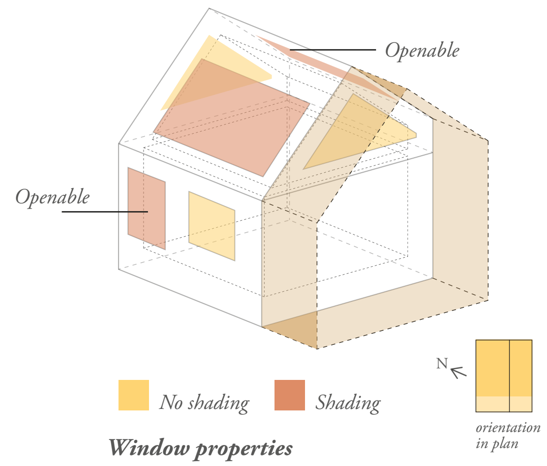
+ high thermal capacity from concrete
+ long lifespan
+ concrete need no treatment

- heavy structure = low portability
- appears less human-scaled than wood
- higher embodied energy than wood

ill. 113 - renders of the cabin with various material solutions including some of the pros and cons of each material solution







Building envelope

Construction thickness:
Ext. wall: 0,4 m
Ext. floor: 0,5 m
Roof: 0,5 m

Construction materials, in to out:
Ext. wall: wood, insulation, timber, aluminium
Ext. floor: wood, insulation, timber joists, wood panel
Roof: wood, insulation, timber joists, osb, aluminium

Thermal zones

Zone 1: open space with living room and bedroom
Zone 2: bathroom and technical room

Systems investigated:
Heating: sep-apr
Mech. ventilation: sep-apr
Venting: may-aug + apr. (daily 10-18)
PeopleLoad:
Apr-sep: daily from 22-9
Oct-mar: daily from 18-9
Equipment: 0,65 kW
Apr-sep: daily from 22-9
Oct-mar: daily from 18-9

Window properties

Solar shading:
Coefficient: 0,15 (external shutters)
Time: 9-17 (apr-sep)
On-off automatic control

Venting: may-aug: day+night
apr.: day from 10-18

Eaves and overhang for window: 1,2 m

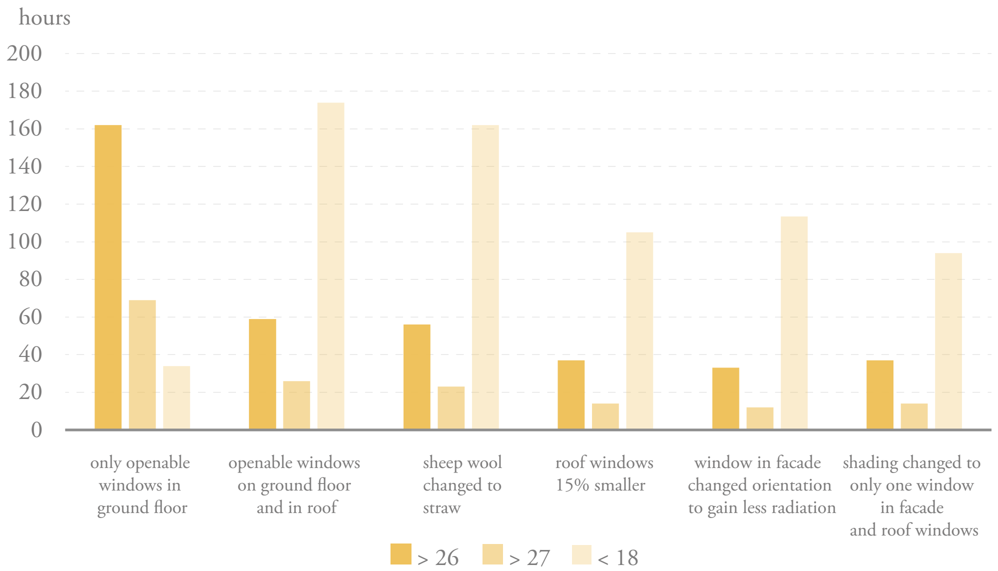
Window size:
on facade: 1,9 m² and 2 m²
roof facing NNW: 7,5 m²
roof facing SSE: 5 m²
each triangular window: 2,3 m²

Indoor climate of cabin assessed in Bsim

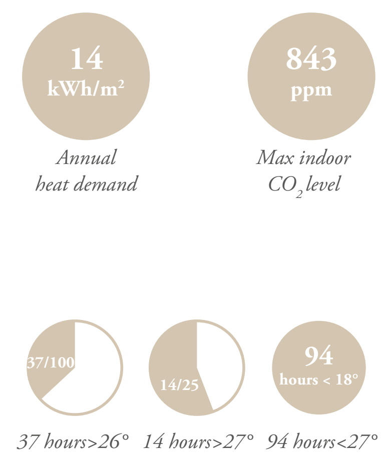
To ensure a high level of indoor climate in the cabins, Bsim was used during the process to asses and keep an eye on how the architectural and technical solutions affected the indoor conditions. As requirements for the indoor climate conditions, the Danish Building Regulations are used, as Iceland seemingly does not have as specific requirements as the Danish. The requirements for housing are: max 100 hours above 27° and max 25 hours above 28°. To ensure that the temperature does not become uncomfortably low, a criterion of max 100 hours below 18° was used in the process. As previously shown, some of the analyses that were made to design the cabin were studies of inclinations, radiation, materials and views from windows. As the project proceeded it was continuously controlled how the indoor climate responded to changes in the design. As some of the design choices directly related to fx the radiation caused a direct effect on the indoor conditions, having an overall understanding of how these aspects affected each other was crucial. Basing the design on this knowledge, resulted in a cabin design, that was suitable for optimization to meet the requirements. The final design of window placement, sizing, solar shading, ventilation and natural ventilation was done using Bsim. The final choice of insulation was also decided using Bsim. The illustration 115 shows the relation between the effect on the indoor climate of some of the design choices optimized in Bsim. As the process of optimizing the cabin was iterative and consisted of an extensive back and forth analysis of choices, changes and effects, the graph should not necessarily be seen as the chronological process of the design. It does however include results found during the process.

The final solution for the four-person cabin is described above using properties from the Bsim analysis. The solution for the windows consists of some open-able windows to provide natural ventilation. One window on the ground floor and one window in the roof are controlled by an automatic system keeping the indoor temperature as close to 22 degrees as possible and the CO_2 level below 900 ppm. The SSE facing roof window helps heat up the building during winter but can cause overheating during summer and is therefore equipped with solar shading in the form of an external shutter that rolls down automatically. Same system is placed on the other roof window as well as on one window in the façade. From the analysis it was shown, that the overheating could be brought down further had all windows been shaded, but this severely affects the daylight conditions in the cabin, and it was therefore chosen to remove the shading from the triangular windows and one window in the façade. As seen from the Velux Visualizer simulation illustration 117, the daylight conditions are adequate in this way. Furthermore, the shading is active during the day, when people are assumed to be out of the cabin.

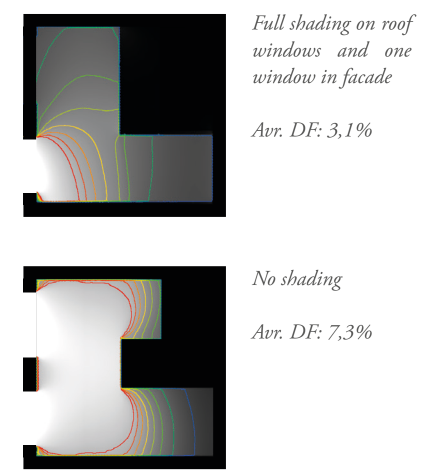
ill. 114 (above) - The modelling and final properties of the cabin found through an iterative process using Bsim



ill. 115 - graphs describing the relation between some of the design choices and the indoor thermal climate



ill. 116 - indoor climate conditions and annual heating demand reached through an extensive iterative process

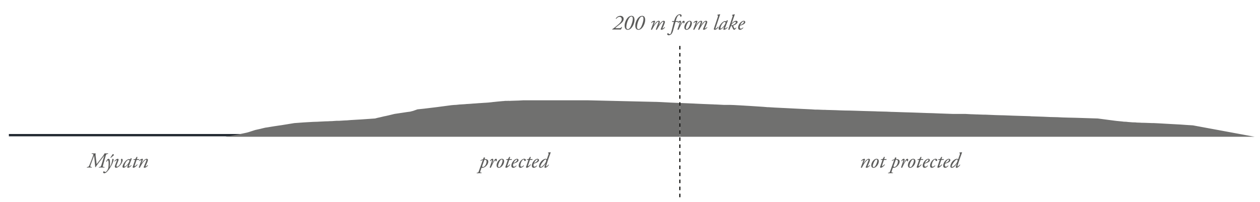


ill. 117 - daylight conditions in cabin with and without shading

Ideation

This chapter introduces the final design proposal and explains the general idea and the main features of the project.

ill. 118 - near Kvernufoss- Photo by: P. Nguyen



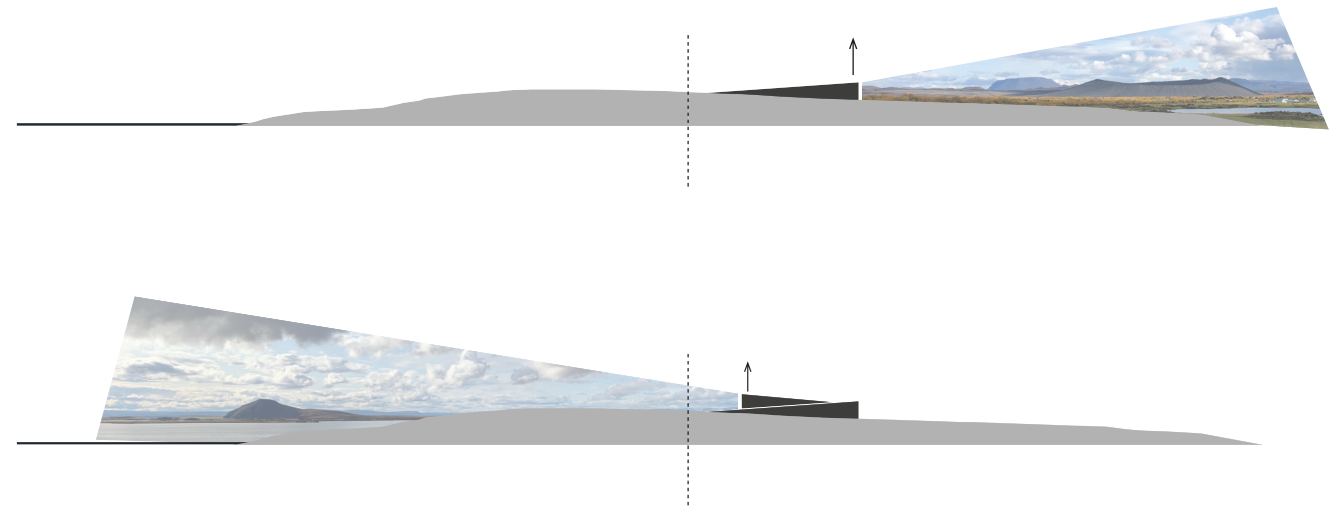
THE MÝVATN SITE

ill. 119 - the site is characterized by the protected area closest to the lake, where no permanent foundation can be built. The highest point of the site obstructs the view towards Mývatn from the area outside the protected zone.

Concept

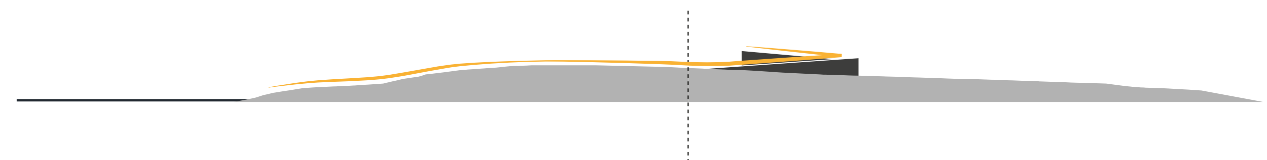
Most tourists visit Iceland to experience the unique nature but are paradoxically also the biggest threat of same nature. Many attractions are facing the new challenge of being visited by an extreme number of people, and a change need to be made to ensure that the nature will not suffer further under the impact of tourism. Mývatn is one of the most popular destinations for tourists, and this new proposal for accommodation featuring an educating visitor center, combines the overnight stay with learning about the area, that you are visiting. It promotes a sustainable way of being a tourist, giving the opportunity to learn how to be in nature, what to see, what not to disturb, and offers substitutions for the most fragile elements of the area. When being a visitor to the complex and staying overnight, one is shown how the experience of the Icelandic nature, seeing the northern lights and the promotion of sustainable tourism, is combined in a tranquil experience hosted by the main building and the cabins. One can stay and observe the playful aurora away from their busy daily lives, emptying their minds and reconnect with nature, all while being sustainably supplied by off-grid and renewable solutions in their cabins.

The main shape definition relates to the site and its possibilities and limitations, and the three main gestures in the design are describes with the illustrations above and to the right.



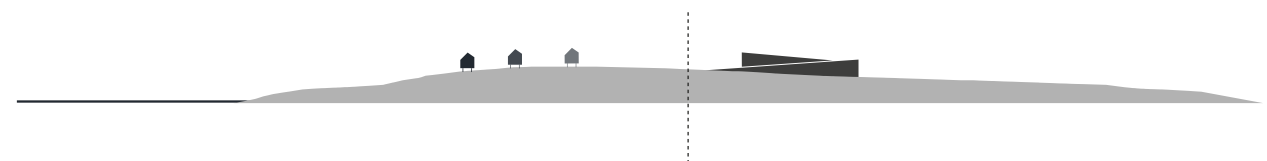
CREATING VIEWS

ill. 120 - as the site offers amazing and, for most tourists, unusual surroundings, creating a strong visual connection to the context, is the main shape giver. The shape is first raised from the ground to directly face the volcano, Hverfjall. This also creates an elevated surface from where the second level is raised to face Lake Mývatn. In this way, a two-way oriented building connects the interior with the exterior by providing direct views to the beautiful surrounding nature.



THE NATURAL SLOPE

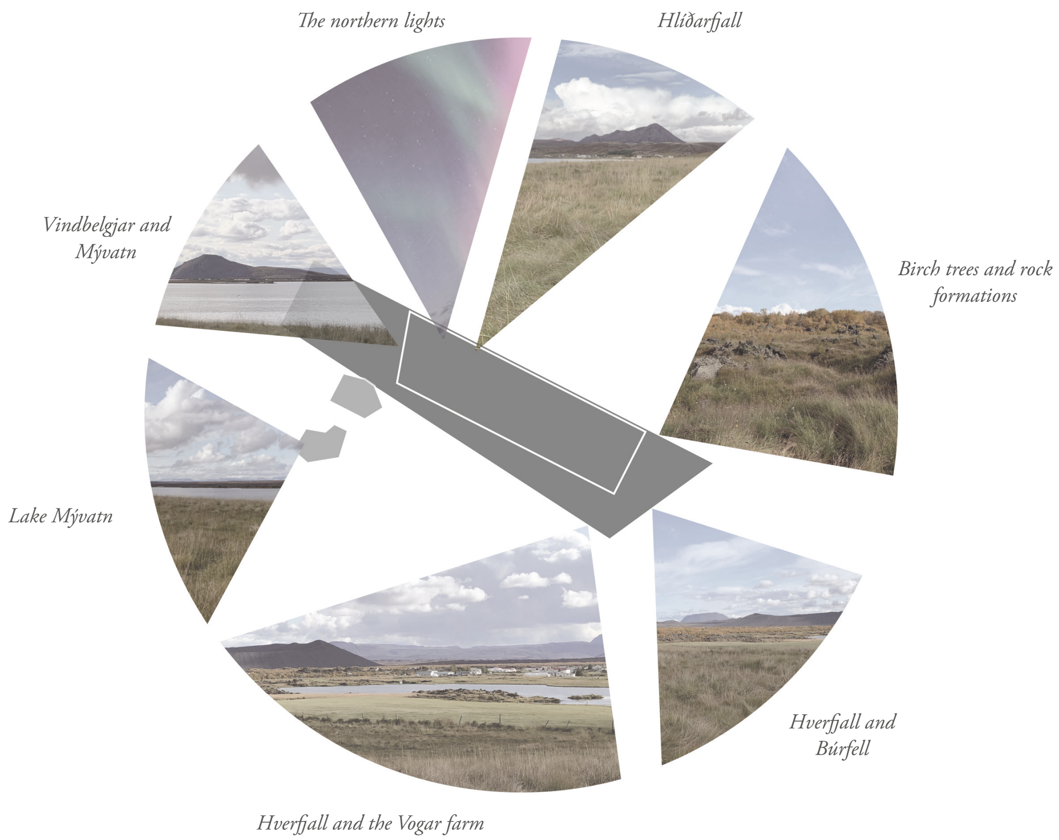
ill. 121 - by following the natural slope of the site in the shaping of the building, the fifth facade becomes a landscape for the visitor to interact with. The elevation of the ground onto the roof, provides a observation point at the top of the building from where the visitor can experience a 360° view around site. The activation of the fifth facade helps to maintain as much of the natural vegetation on the site as possible.



THE LIGHT AND THE HEAVY

ill. 122 - as the protected area around Lake Mývatn is a no-construction zone, no permanent foundation can be built for the cabins. Instead they are raised above ground contrasting the heavy character of the main building to appear more temporary and light. This gesture limits the contact with the ground and maintains as much natural nesting area for the duck population of lake Mývatn.

ill. 120-122 shape giving gestures in the design



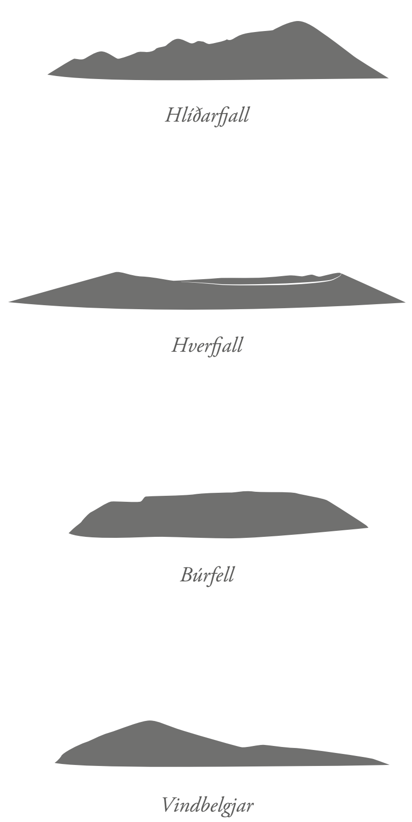
ill. 123 - views in various directions from the main building

Views from main building

Being placed at a site right next to Mývatn, the building offers views to all the main elements visible from the outside site. The site is surrounded by several mountains and it was made sure in the design, that all of these mountains would be visible from the inside of the building to ensure a direct connection between the visitor and the incredibly and for many tourists, unusual nature in the area. As the view differs substantially depending on which direction you are facing, each room and area of the building gain much of its character from the orientation. As an example, the visitor center is facing the Hverfjall volcano, which Mývatn is especially known for and it is an incredible sight to have as background for the exhibition concerning the very same thing: the Icelandic nature. Facing the opposite direction is the restaurant, which gives the visitors the opportunity to enjoy a meal with a view to the lake Mývatn itself or if lucky during evening, the northern lights in the sky.

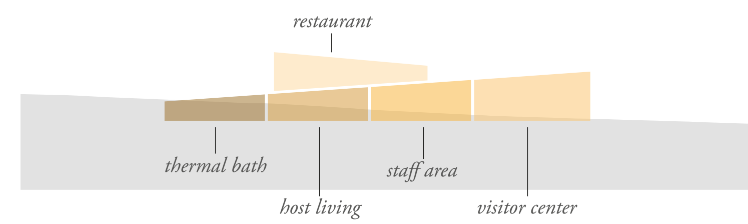
The building is surrounded by nature, and every view changes with the seasons and the weather, and will always offer a different experience depending on the time of year and day, giving the staff members and the host family a workspace with great variety.

ill. 124 - the surrounding mountains

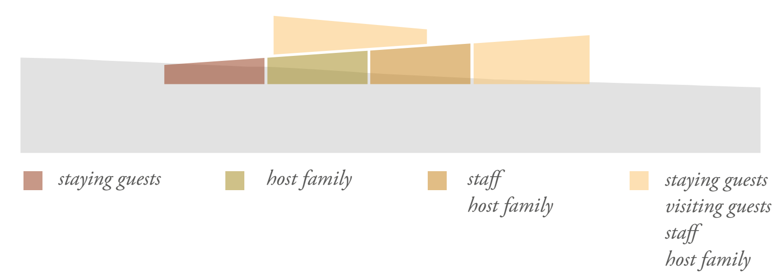


Organisation

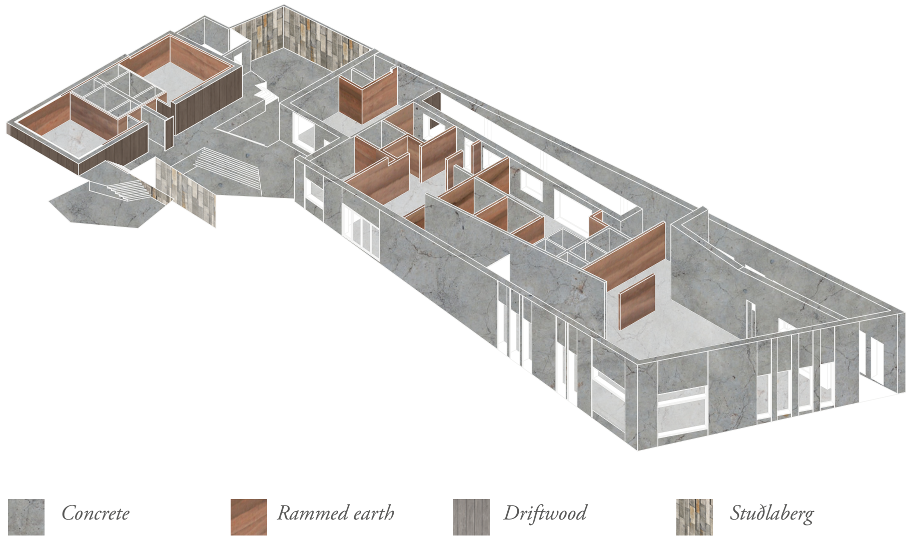
The main building accommodates several users and offers therefore varying levels of privacy. The functions corresponding to the needs of the user groups – host living, staff area, thermal bath, visitor center, and restaurant – are placed according to the required level of privacy and exposure. The visitor center is used by all user groups and is placed in the most open and visible area of the building away from the sloped landscape. Contrasting this, the thermal bath is partly covered by the roof and dug into the landscape in the opposite end of the building, creating a much more private and intimate atmosphere. In between are the host living and the staff functions (including service rooms) to directly connect the staff area with the visitor center and distance the private host living from the public visitor center. By having the restaurant placed above the other functions and facing the opposite direction of the visitor center, a different atmosphere and feeling of intimacy can be created.



ill. xx - placement of functions in main building



ill. 125 - user groups main use of building



ill. 126 - use of various materials in the building

Materials

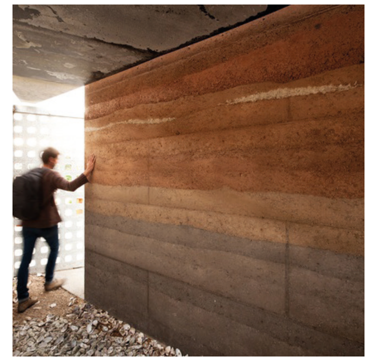
Iceland is unique regarding availability and production of building materials. From the Vikings first settled during what is known as Landnam around year 900, wood has been a very limited source, especially larger pieces, that can be used as construction material. Instead, architecture in Iceland is today characterized by using metals such as steel and aluminium as well as concrete as their main building materials, all produced using renewable energy, significantly lowering the emissions impact on nature. Following this tradition, the main load-bearing construction in the building is concrete, that frames the building and offers support for the walk-able fifth façade that unlike many other roofs, should be dimensioned with a people load in mind. The interior non-load bearing walls are made from rammed earth, referencing the vernacular Icelandic way of using earth in turf houses. Earth as a building material offers good acoustic qualities as well as a warmness and tactility adding a comfortable atmosphere in the rooms for longer stay. Earth also has good hygroscopic properties, meaning that it can absorb and store humidity within, limiting the air humidity in rooms, which can also lessen temperature fluctuations. However, earth does not reflect much light and can lead to a low daylight factor in rooms, so the combination of concrete exterior walls and rammed earth interior walls balances a comfortable acoustic, thermal and visual indoor climate.

Materials were chosen through a discussion regarding their local availability, their environmental impact considering Icelandic production methods, and their aesthetic value in the design. In illustration 127 the main materials can be seen and illustration 126 shows where they are placed in the building.

ill. 127 - the chosen materials in the main building. Photo soures: see illustration list.

Icelandic Concrete

The visual aesthetic of rough concrete is a traditional and well-known sight in Iceland. It is able to withstand the harsh climate and the unique renewable energy-based production in Iceland, lowers the environmental impact significantly.
The strong load-bearing properties of concrete makes it possible to support the walk-able roof.

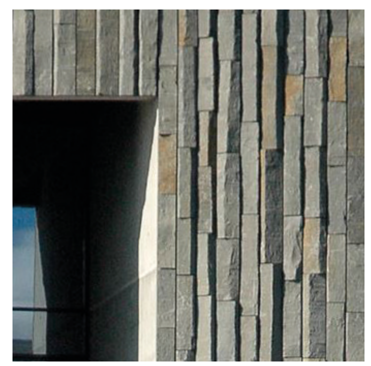


Rammed earth interior walls

Taking inspiration from the native vernacular turf-houses such as Glaumbær farm, the non load-bearing walls are made from rammed earth. Having them as non supportive, decreases the need for clay in the composition, which can be hard to obtain from Icelandic soil.
The walls give of a warm and tactile aesthetic perfect for the living and break areas.

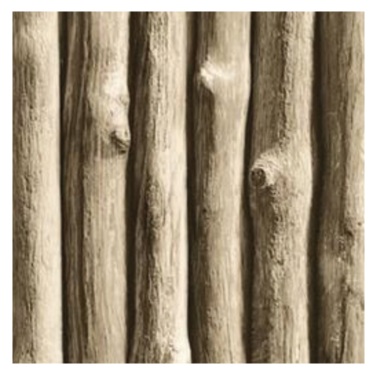
Sheep wool as insulation

Sheep wool is a bi-product from the lamb-meat production in Iceland and is known to be used for sweaters since it is available in abundance.
The material however has naturally a low thermal conductivity, is lightweight and completely biodegradable at its end of life stage.



Stuðlaberg stone as facade in bath

Studðlaberg is a natural occurring hexagonal stone found in Iceland. The material is usually cut into thin facade slabs, and the edges are considered waste. The walls facing the thermal baths are clad with these angled leftover stone elements, giving it a raw and natural look. Natural stone requires no energy for production as they are completely of nature, only energy for cutting is needed which in Iceland is done in Akureyri using renewable energy.



Driftwood facade and detailing

Wood is a scarce material in Iceland and is therefore not used very often compared to other types of construction. However, Iceland offers the possibility of using driftwood from Russian lakes, that travel through the sea to Iceland. During the journey, it becomes treated by the salt-water and requires very little treatment before use. Driftwood is used inside the building for detailing such as floors and windows, and outside for some parts of the facade.

Presentation

The following chapter presents the final design through an examination of each part of the complex - some in more detail than other due to their importance in the design and for the vision. The general material, that will be shown will among other include a masterplan, plan drawings, sections, facades, details, etc.

ill. 128 - Folaldafoss, East Iceland - Photo by: E. Juul

Masterplan

The complex is accessed from an access road leading from the main road Mývatnsvegur. Cars, bikes and buses can park at the combined parking lot nearest the main road, and visitors continue by the curved paths between the natural grass in the area towards the main entrance of the center. From here the path continues towards the cabins, and passes the combined horse barn, energy center, and green house, connected by a small path made of basalt stones. Staff members and the host family enter their quarters by continuing from the path to the main entrance by a similar stone path. Each cabin is placed facing lake Mývatn and is oriented towards the North-North-West to provide the view to the Northern Lights. All are placed with minimum view to each other to preserve the privacy of the guests.

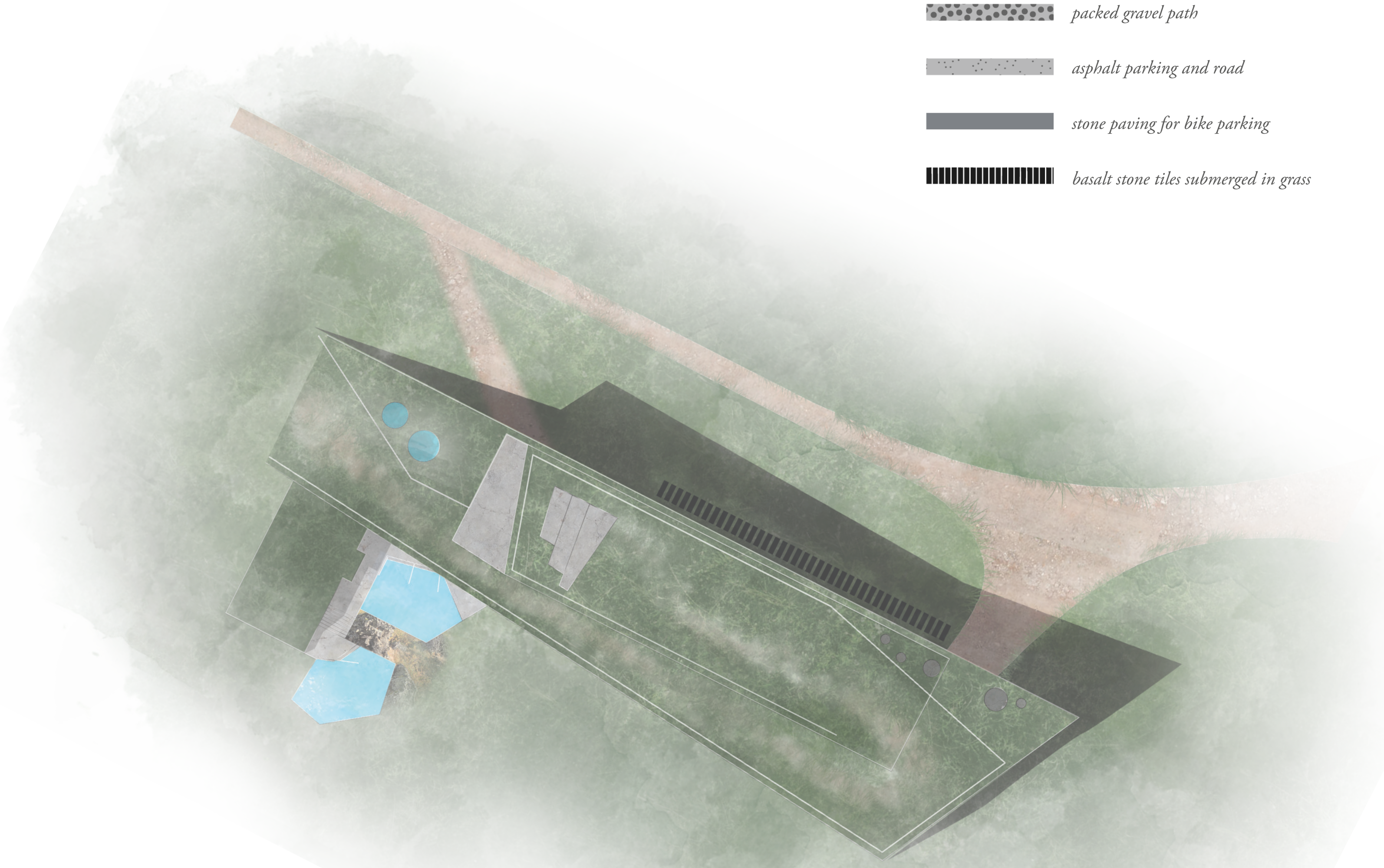
ill. 129 - masterplan 1:2000

packed gravel path

asphalt parking and road

stone paving for bike parking

basalt stone tiles submerged in grass



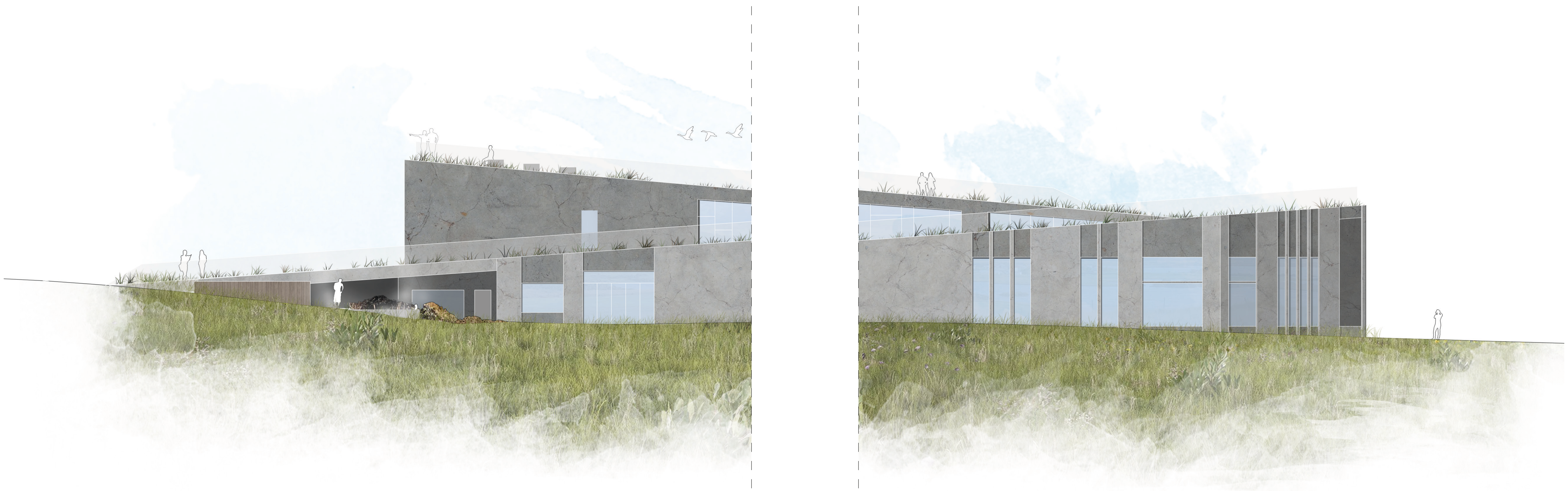
ill. 130 - landscape plan - 1:500

The fifth facade of the main complex is walk-able and has a light gravel path fading into the grass on the roof. A glass railing suggests the path for the visitor leading to the top of the building from where Lake Mývatn is seen.

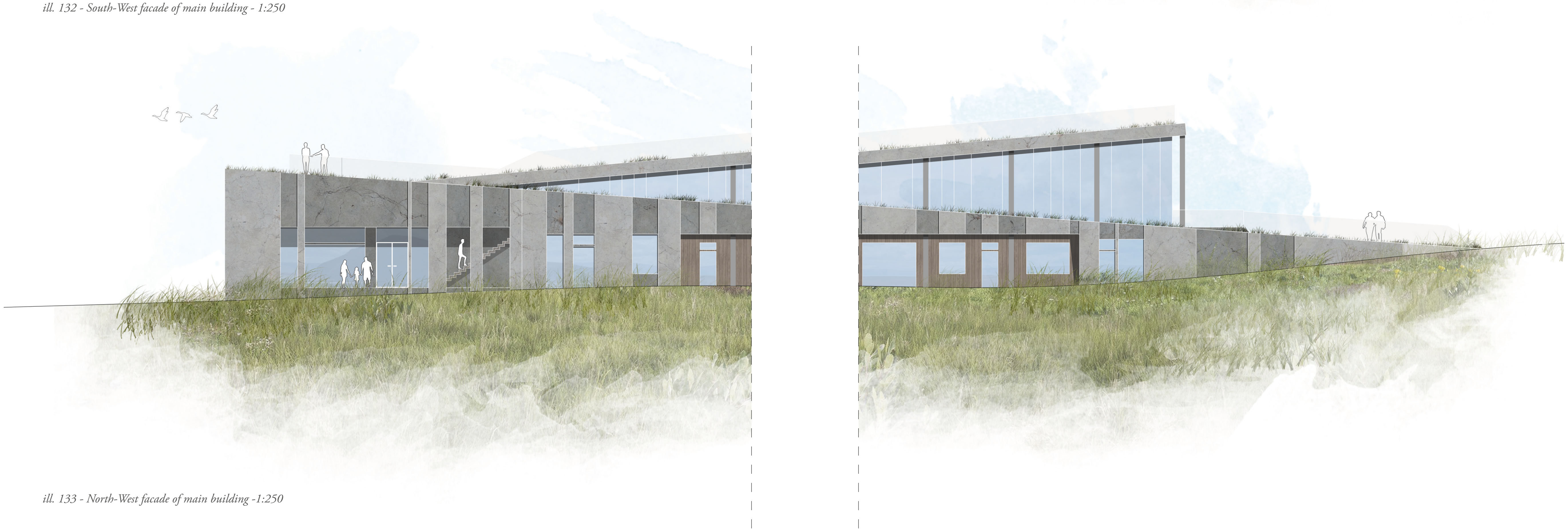
Arrival to the complex

When arriving from the parking lot, the visitor is met by the extruding building emerging from the ground. The concrete facade appears heavy and as it is coming from below the ground. The visitor immediately sees that the roof is walk-able and is drawn closer to the entrance by the stamped gravel path.

ill. 131 - render from the parking lot when arriving to the complex



ill. 132 - South-West facade of main building - 1:250



ill. 133 - North-West facade of main building -1:250

Facade elements

Glass railing frames the walk-able area of the roof

Integrated benches on the roof top to enjoy the view

Load-bearing concrete columns that support the roof construction.

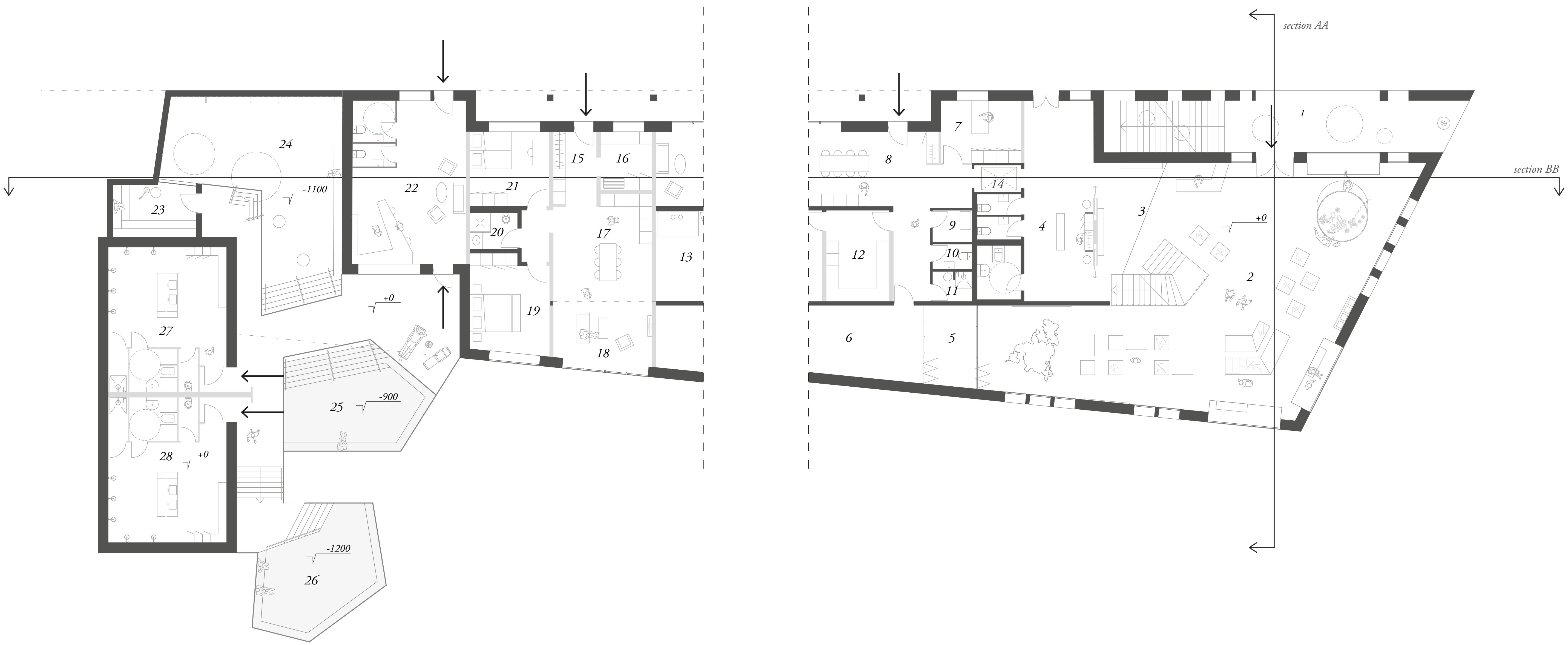
Curtain wall system, to allow a panoramic view to the Northern Lights.
The mullion grid is divided to reference the pattern of the Studlaberg stone

The concrete facade has two depths to create a dynamic rhythm in the facade, and to accentuate the feeling of the building emerging from the ground.

The host living is designed with windows with seating to strengthen the connection between the human and the nature.

The façades of the staff and host facilities are offset from the concrete facade, creating a private transition from exterior to interior. The wooden facade contrasts the hard concrete and frames the entrances.

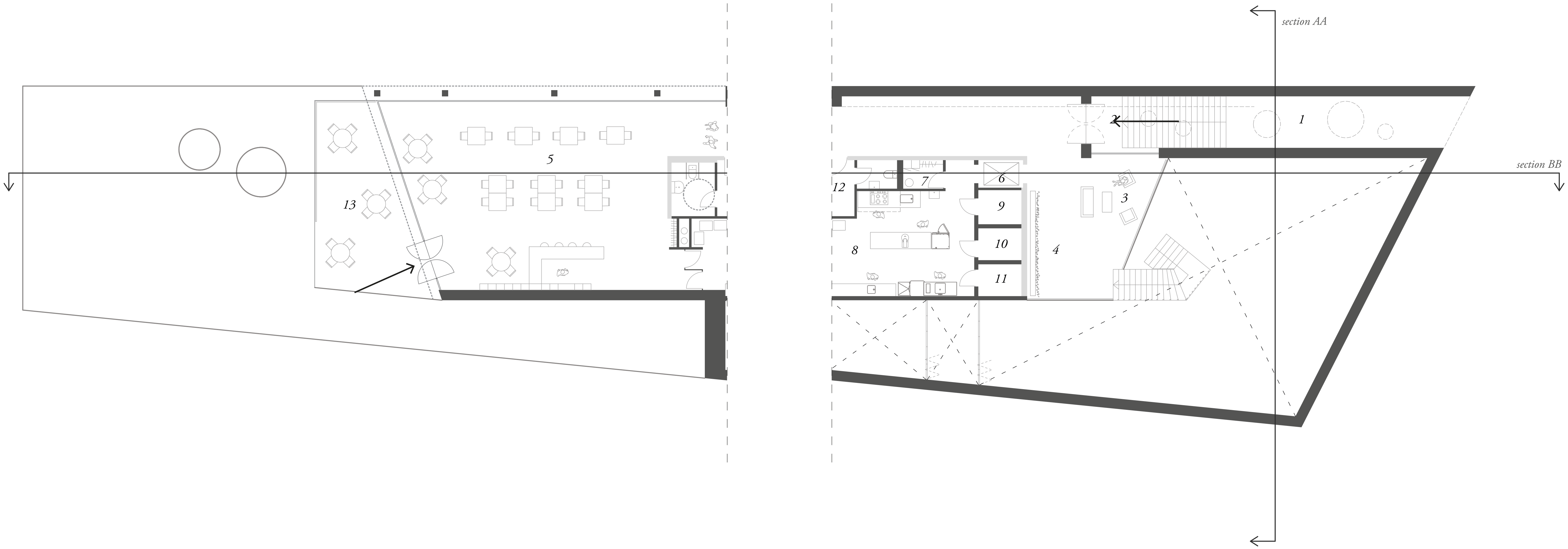
ill. 148 - main building facade detailing - 1:100



ill. 134 - plan of ground level including below thermal baths - 1:200

Room description:

1: transition from outside to inside
2: Visitor center exhibition
3: gift shop/museum shop and reception
4: wardrobe and public rest rooms
5-6: flexible storage area. The exhibition can be extended when needed
7: staff office
8: staff break room
9: printer and paper room
10: staff toilet
11: staff bathroom
12: cleaning and laundry room
13: technical room
14: elevator
15: host living entrance and wardrobe
16: utility room
17: kitchen
18: living room
19: master bedroom
20: bathroom
21: spare bedroom
22: guest lounge and bar
23: sauna
24: wellness pool
25: warmest pool
26: panoramic pool with view over the lake and the volcano
27: women's changing rooms
28: men's changing rooms



ill. 135 - plan of first level with restaurant and terrace - 1:200

Room description:

1: transition from outside to inside
2: entrance to restaurant
3: coffee/charging area
4: green wall with edible plants native to Iceland
5: restaurant with bar
6: elevator
7: changing room for kitchen staff
8: kitchen
9: pantry
10: cooler
11: freezer
12: public toilets
13: terrace

The Visitor Center

The Visitor Center has an inviting and open atmosphere, where learning is in focus. The central element in the room is the wooden and metal stair that leads to the upper floor with the restaurant and a small open space overlooking the visitor center, furnished with charis and tables for reading books about the Mývatn area or possibly charging a computer.

The Visitor Center features window niches, where the visitor can get lost in the view to the surrounding nature. A warm and human scaled space is created using the window frame and soft driftwood detailing.

The exhibition in the room allows the visitor to experience parts of the Icelandic nature such as native moss, the threatened marimo algeas and the unique Studlaberg stone.

ill. 136 - render overlooking the visitor center

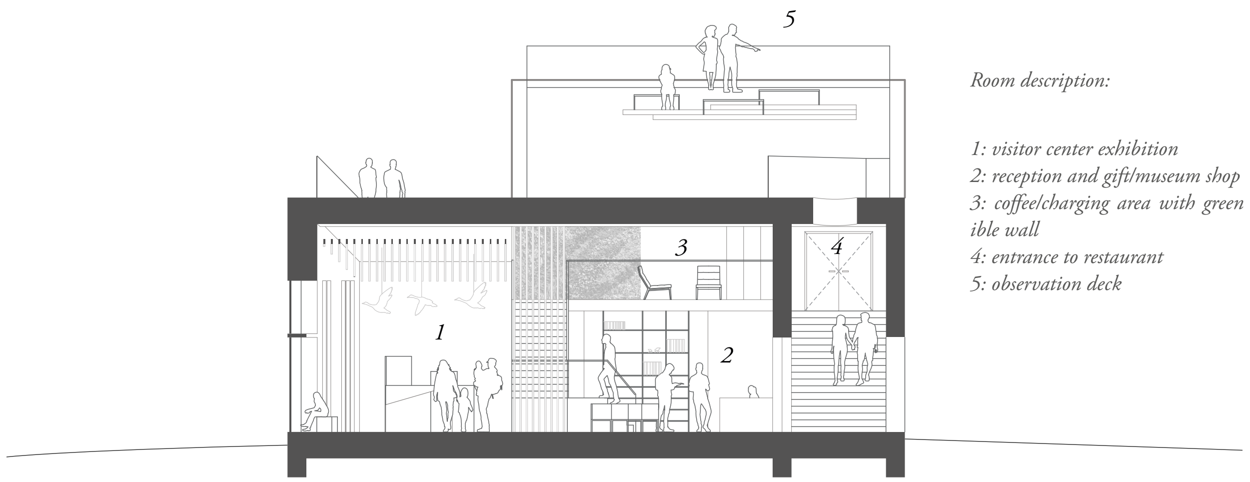
The restaurant

By being elevated to the second level and oriented towards the North-West the restaurant offers a panoramic view across lake Mývatn and if you are lucky, the Aurora will appear dancing above the lake.

The atmosphere in the restaurant is created through a variety of materials - driftwood flooring and window frames contrast the raw concrete exterior walls. The many wooden elements secure a good acoustic experience allowing many people to dine at the same time.

The ceiling is covered by a light installation mimicking the northern lights, when they are out if sight. The element substitutes the feeling of being under the Aurora if you are not lucky to be there, when it appears.

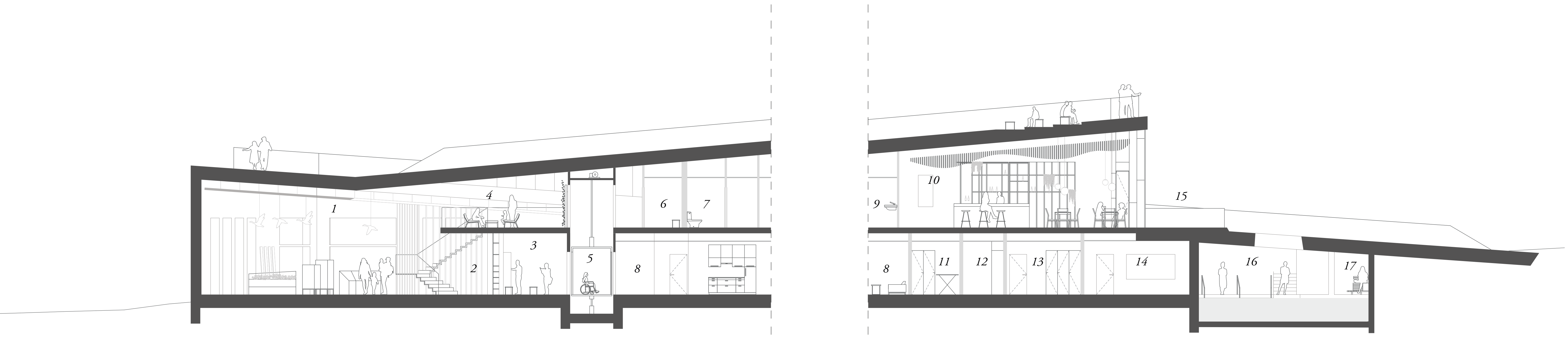
ill. 137- render showing the restaurant with the view towards Mývatn and Vindbelgjar



Room description:

1: visitor center exhibition
2: reception and gift/museum shop
3: coffee/charging area with green edible wall
4: entrance to restaurant
5: observation deck

ill. 138 - section AA - 1:200



ill. 139 - section BB - 1:200

Room description:

1: visitor center exhibition space
2: gift/museum shop
3: wardrobe
4: coffee/charging area
5: elevator shaft
6: changing room for kitchen staff
7: public toilet
8: staff break room
9: accessibility toilet

10: restaurant
11: host utility room
12: host entrance
13: spare bedroom
14: guest lounge
15: terrace for restaurant
16: thermal bath (wellness area)
17: sauna

Transition from exterior to interior

When the visitors enter the building, whether they are visiting the exhibition or the restaurant, they go through a covered exterior corridor protected from the harsh weather. The spatiality of the corridor frames the views around the complex and creates an atmosphere in-between nature and building. The round openings in the roof, creates an ever-changing play of light, that contrasts the otherwise dark linear space.

ill. 140 - render seen from the stair leading to the restaurant

The Thermal Bath

The complex features a thermal bath for the guests, who are staying in the cabins. The bath consists of three different pools, each offering a different atmosphere and experience. As seen on this illustration, one of the pools are partly covered by the roof of the main building, and has a private atmosphere to it. Above the swimming guests are two round windows, that allow the view to the sky and emits damp from the pools through to the roof, referencing the high level of geothermal activity in the Mývatn area.

The materials chosen for the thermal bath are a combination of concrete, driftwood and studlaberg stone. Choosing this stone as an element in the bath, accentuates the feeling of being inside the ground.

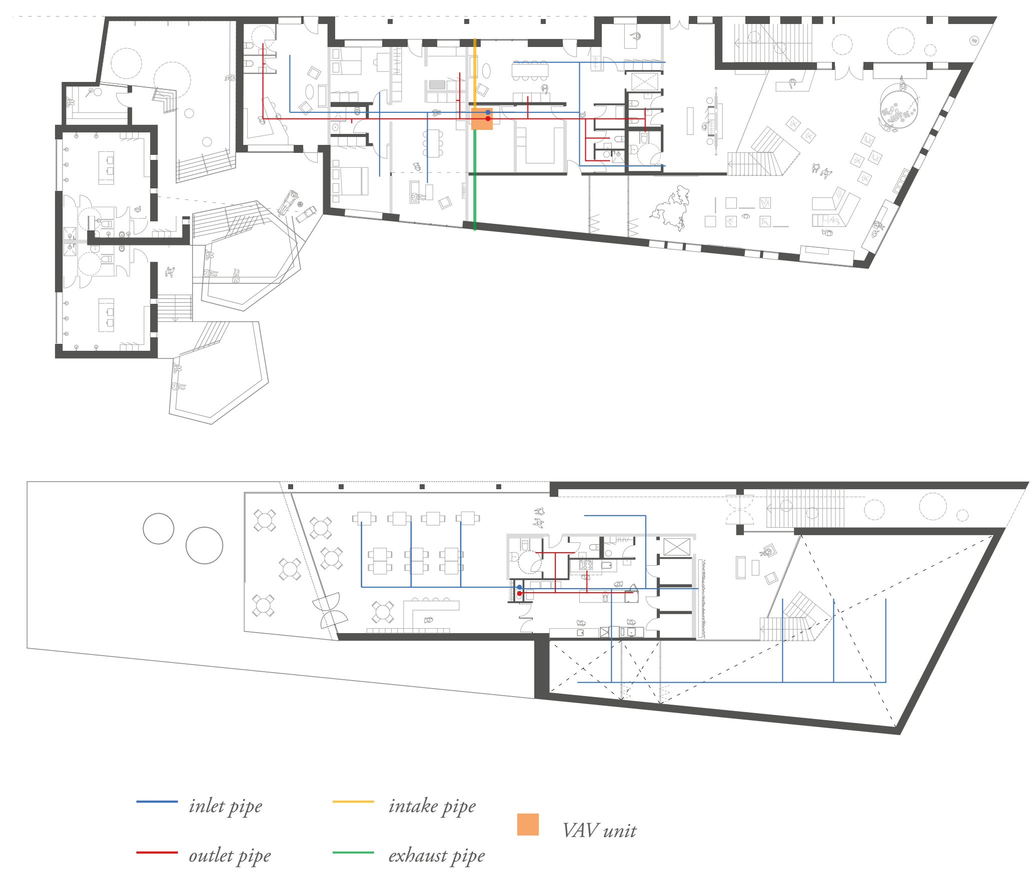
ill. 141- render from the covered pool and sauna area

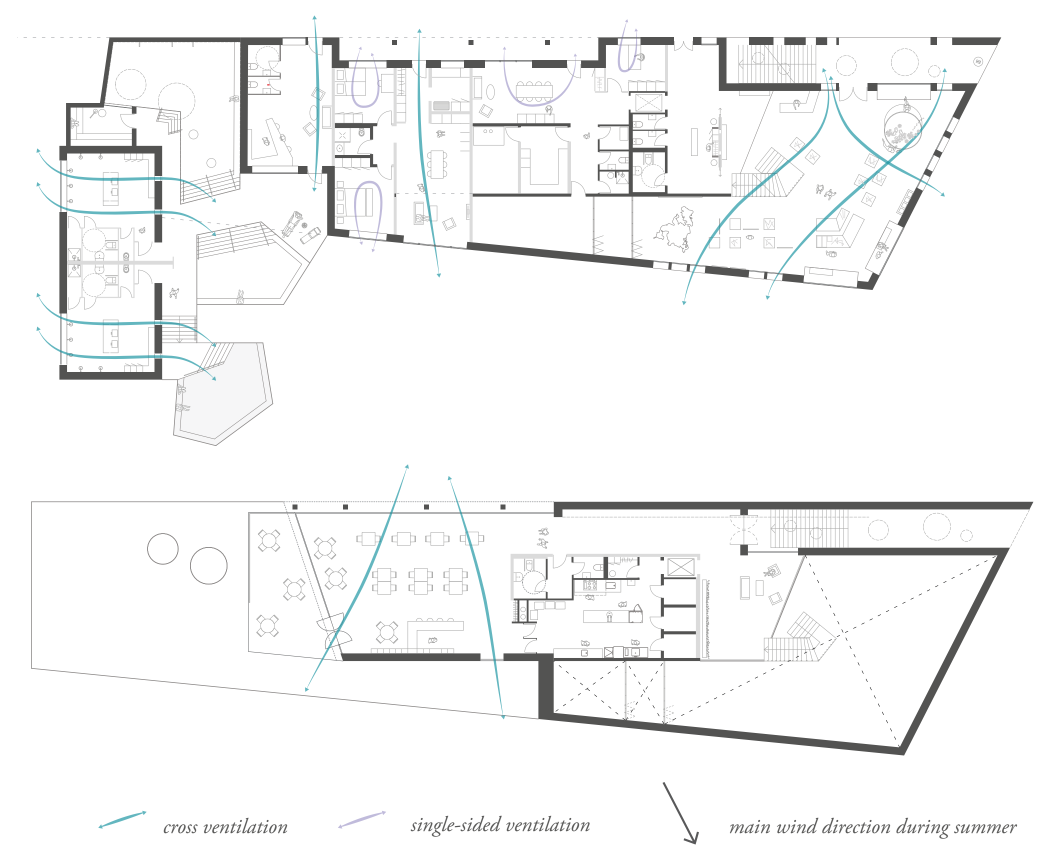
Hybrid ventilation

The building uses a hybrid ventilation strategy with a combination of mechanical and natural ventilation. As the outdoor temperatures in Iceland are quite low for a significant part of the year, the mechanical ventilation is the main source of ventilation from October to May, while the natural ventilation is used during the summer months of June to September. The mechanical ventilation is supplied by a VAV unit controlling the air flow depending on temperature and CO_2 level with a set point at 22 degrees and 800 ppm CO_2 to maintain a comfortable indoor climate for the users. Air intake and exhaust is placed on each side of the building to keep the roof free of installations and to avoid using contaminated exhaust air in the intake. All pipes are distributed from the central unit in the main technical room and are in all rooms covered by a suspended ceiling of wood, wood lamellas or a light installation (the restaurant). In smaller rooms with no suspended ceiling, the outlets are placed in the wall surface. The upper floor is supplied with air through a shaft above the technical room and is further distributed to all rooms.

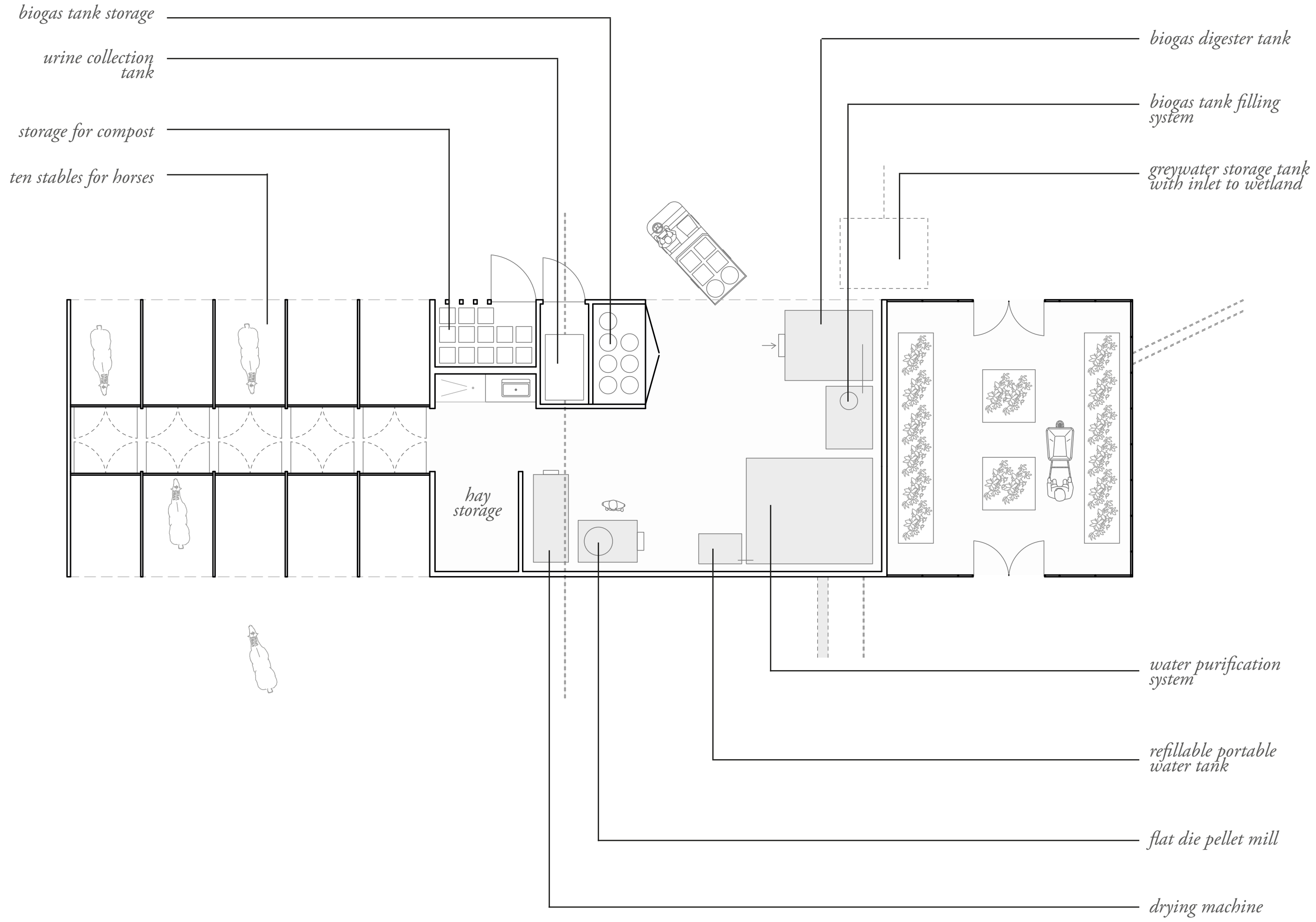
The natural ventilation is automatically controlled using sensors, that open the windows when the temperature is above 24 degrees and the CO_2 level above 700 ppm. The openable windows are placed according to the main wind direction during summer to provide the best conditions for the natural ventilation. In critical rooms with a high number of people, there are several openable windows to increase or decrease the air change. The natural ventilation in the visitor center was studied in Bsim and it was found that having the windows shown with arrows through on ill. 142 being openable, would eliminate most hours above 25 degrees in combination with solar shading. The changing rooms at the thermal bath is ventilated using natural ventilation all year around to using extra resources for an extra ventilation unit and as people are only staying here for a short time, they are considered to be more tolerant of possible temporary thermal discomfort.

Rooms are either designed for single sided natural ventilation or cross ventilation. Rooms for longer stay and/or with many people are were aimed to have cross ventilation while smaller room for less people have single sided ventilation using the rule of thumb that the depth of the room should be less than twice the height (Zhang, C, 2017).





ill. 142 - plans illustrating the principles for natural and mechanical ventilation in the main building



ill. 143 - plan of energy center, horse barn and green house - 1:200.

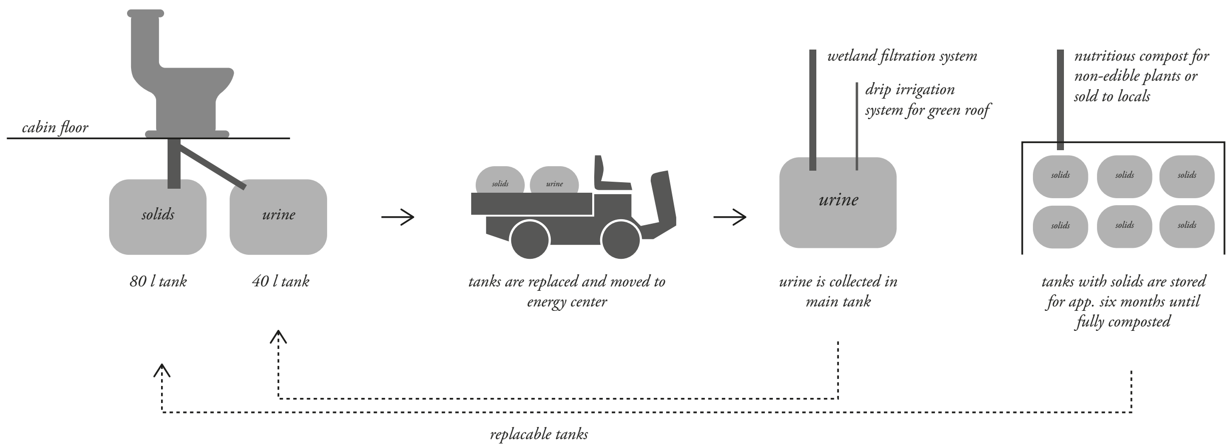
Energy center

To control the supply of energy, water and heating, as well as the management of grey water and waste, the complex includes an energy center from where most supply and waste management is controlled. The building consists of the horse barn for ten Icelandic horses as well as a green house heated by geothermal energy and fertilized with waste products. In the middle, all energy systems and machinery are located. This includes as seen on illustration 143 the systems processing horse manure into biogas and fuel pellets, the water treatment system purifying water from the lake, and storage of refillable biogas tanks for the cabins. Furthermore, there are storage for composting tank from compost toilets in the cabins and a central urine tank for storage until filtered through wetland. The wetland system (see more page 120) also takes care of the grey water stored in the tank below ground just outside the center.

As the Icelandic climate can become very cold during winter, it can challenge some of the systems such as the biogas production and the storage of waste for composting as these need a certain temperature to maintain the micro bacterial process in the tanks. Placing all systems in a central energy hub together with the horse barn and the green house offers the possibility of using excess heat from the horses and can through geothermal energy be heated in a sustainable way to a positive temperature when the winter is at its worst. As the greywater tank also risks freezing during winter, it is located below ground as the temperature of the ground is higher than the air.
The green house offers the kitchen and restaurant staff the possibility of growing their own local produce to use in the restaurant. As the compost from the toilets cannot be used for fertilizing plants for consuming, the nutritious sludge from the biogas production can be used instead as Iceland allows the use of manures and sludge from livestock as fertilizer (Stadler, C. 2013).

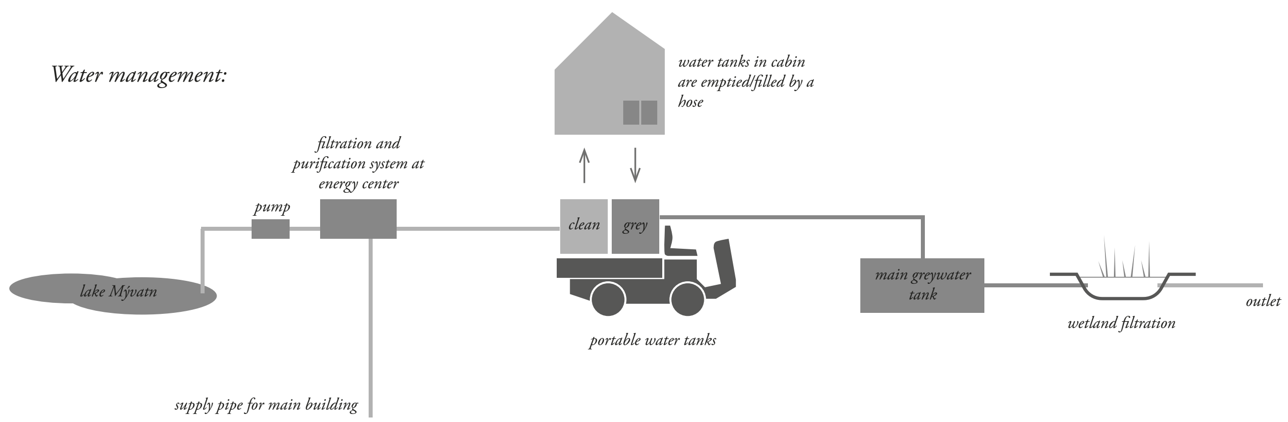
A more detailed description of some systems follows in the next chapter.

Compost toilet:



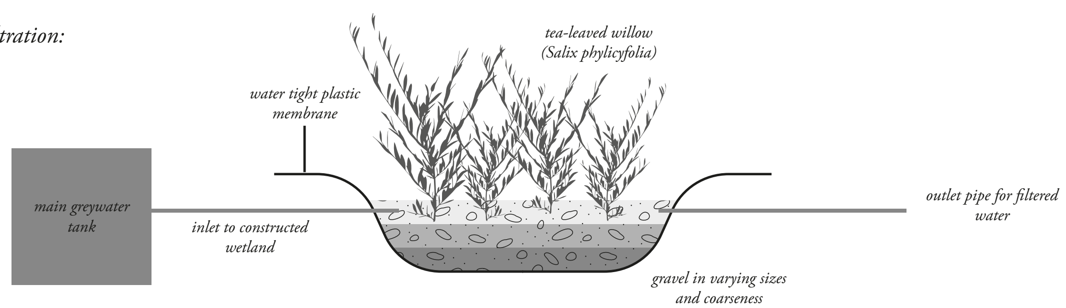
ill. 144 - principle of dry composting toilet in cabins. Tank size depends on number of people in cabin (2/4) and will need to be changed every three months (solids) and every other week (liquid). The number of needed waste tanks are 14 as there are seven cabins and they will need a composting period of 6 months. See annex XX for calculation of tank sizes.

Water management:



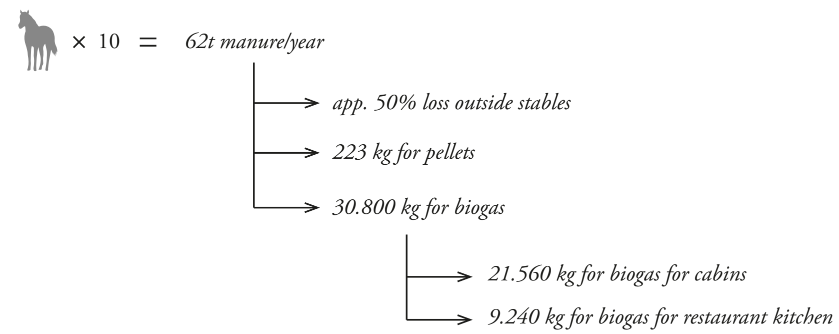
ill. 145 - principle for water management. The water is supplied by pump from Mývatn and purified at the energy center from where it is distributed to the cabins and the main complex. The cabins are equipped with two water tanks: one for clean water and one for grey water. A staff member fills and empties the tanks every 5-6 days for four-person cabins and every 10-11 days for two-persons cabins. The collected greywater is filtered through a wetland system. See annex XX for calculation f tanksizes and water demand of cabins.

Wetland filtration:



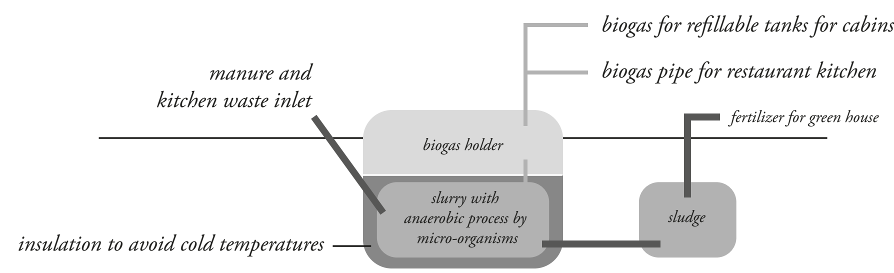
ill. 146 - principle for wetland filtration system. To filter the grey water from the main building and the cabins, a natural wetland filtration system is used. The system is equipped with tea-leaved willow plants as they are native to the Mývatn area and are fast growing providing relatively quick filtration.

Production of heat and biogas:



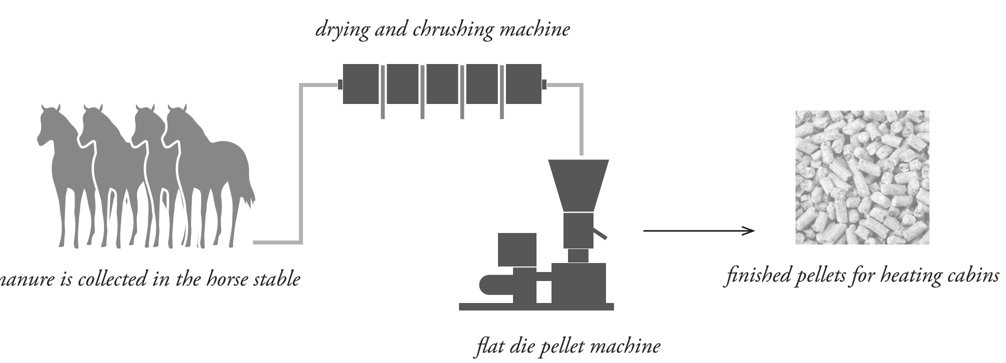
ill. 147 - amounts of horse manure needed for production of heat (as fuel pellets) and biogas for cooking and water heating. See annex XX for calculation behind the above numbers.

Biogas digester system:

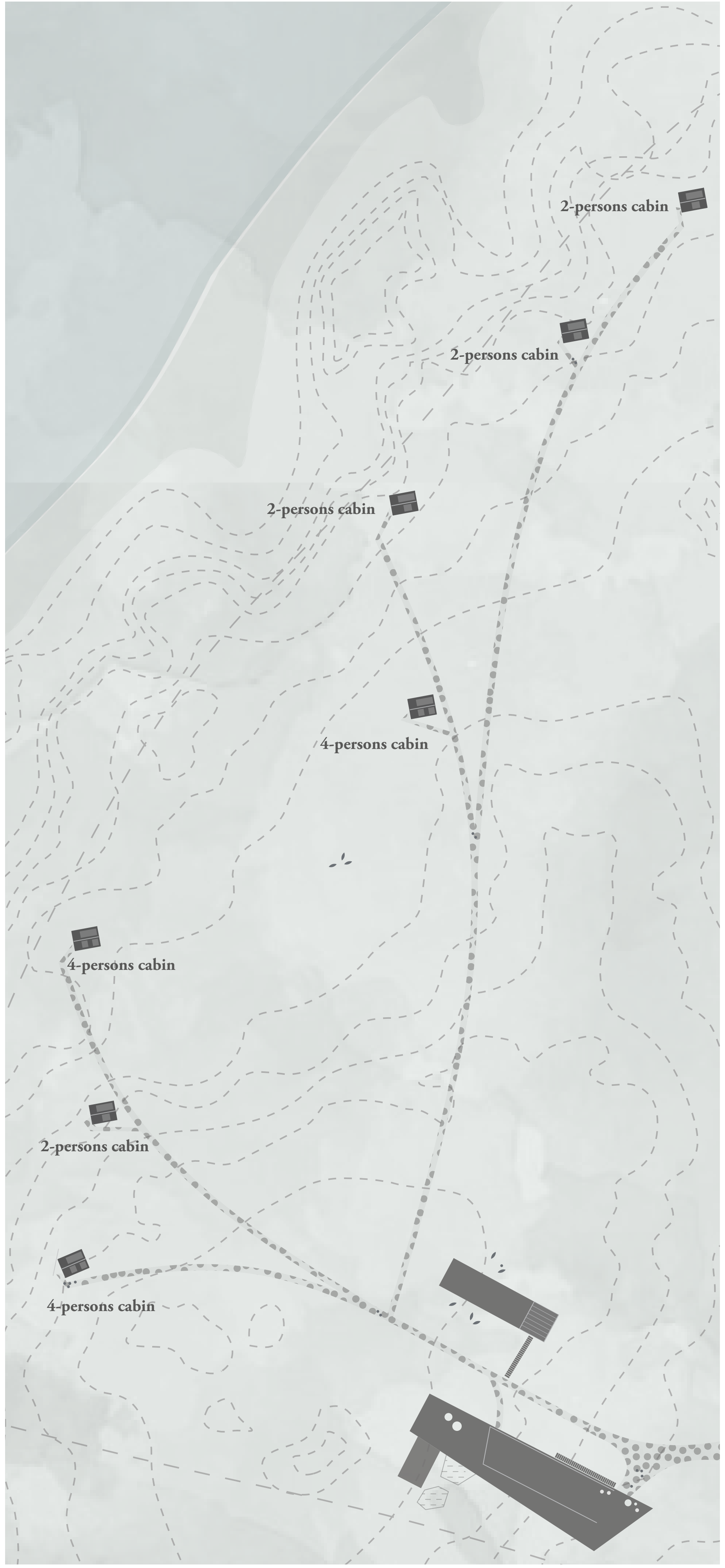


ill. 148 - principle of turning horse manure and kitchen waste into biogas. The tank should be kept at minimum 15 degrees and is therefore placed partly indoors in the energy center in a very well ventilated room. See annex XX for calculation of approximate tank size.

Production of fuel pellets from horse manure:



ill. 149 - processing of horse manure into dried fuel pellets for heating the cabins. The manure is collected at stables, dried and chrushed and then processed into pellets. As the horse manure is dried, the pellets are odor-free when fired. See annex XX for calculation of amount of needed manure.



ill. 150 - masterplan showing the placement of the two cabin sizes - 1:1500

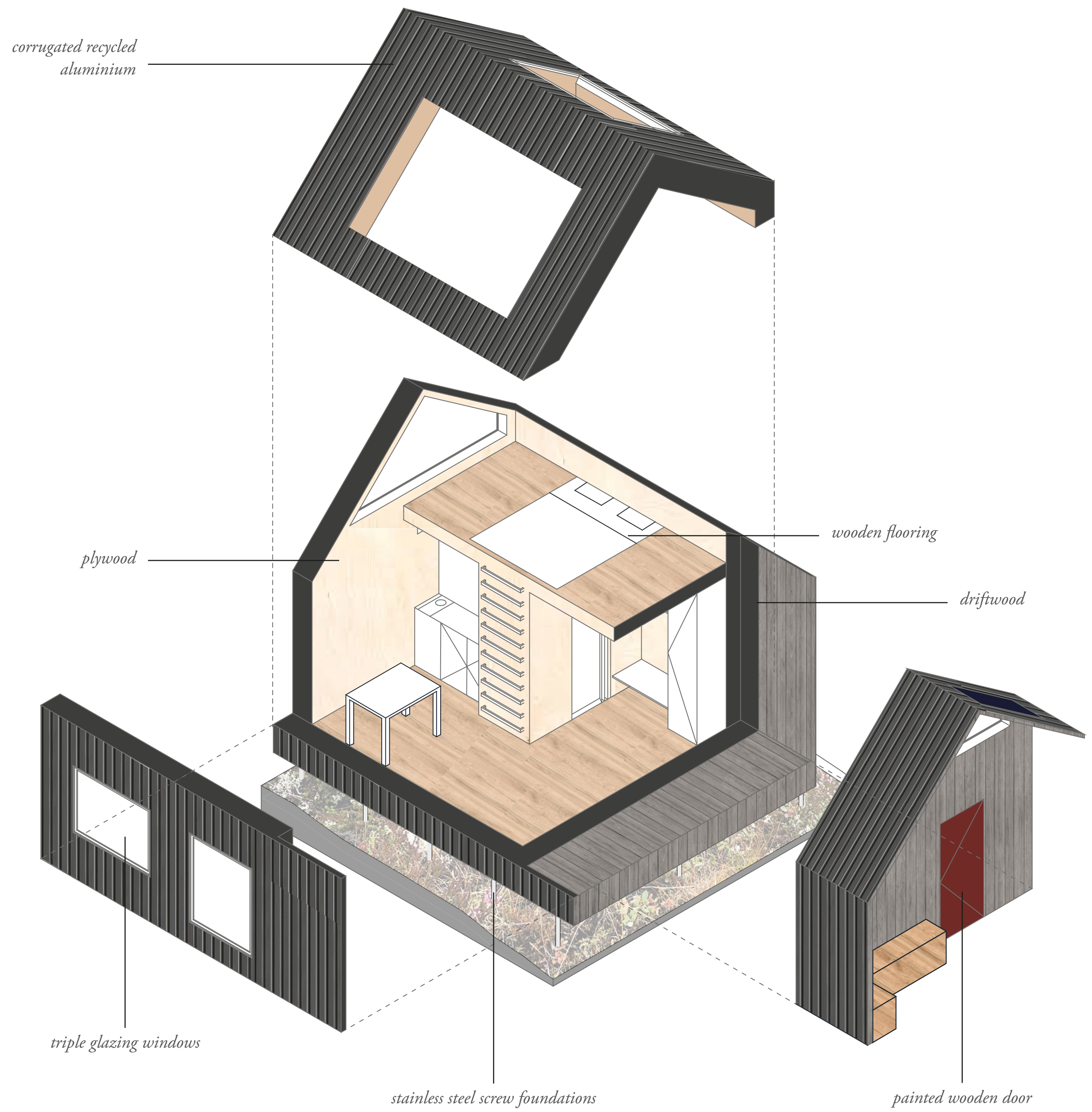
Cabins with a view to the Aurora

The rent-able cabins are spread across the protected area of the site all facing towards the North-North-West to improve the chances of seeing the Northern Lights. The cabins comes in two sizes: 2-persons and 4-persons. Their design is however almost identical except for the number of windows and beds in the bed-loft. The identical design makes it relatively easy for the complex to change the cabins, if they need to expand their number of guests.

The masterplan to the left shows the placement of the two cabin varieties. As seen the four-person cabins are in general placed closer to the main complex, making it more convenient for families with children to rent a cabin.

The isometric drawing to the right, shows the general layout, as well as the exterior and interior materials of a two-person cabin. The cabins have two levels, one being a bed-loft with beds under large North-facing windows to enjoy the northern lights directly from the bed.

The entrance of the cabin is pushed into the facade to create a small transition space with seating facing South-West to enjoy the evening sun.



ill. 151 - exploded two-person cabin illustrating interior and exterior materials

Cabin façades

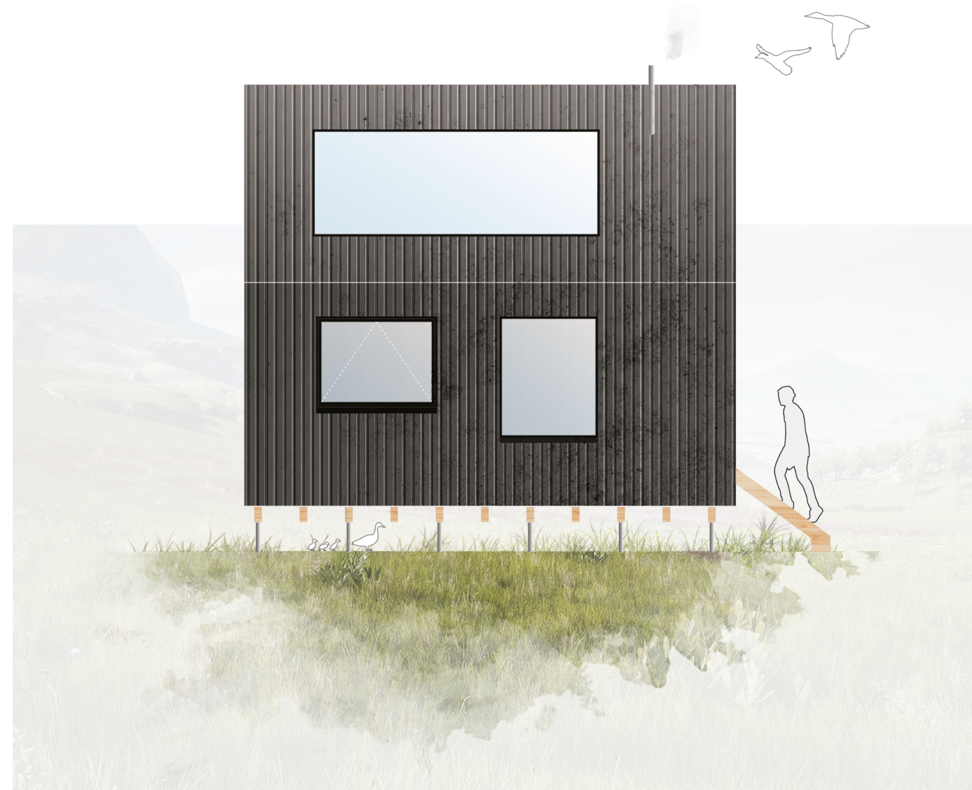
The facade materials for the cabins reflect the way the visitors will use the cabins by having driftwood at the combined entrance and terrace, while being clad with recycled Icelandic aluminium at the outer shell. The contrast of the materials expresses the transition between inside and outside while both being sustainable Icelandic solutions. The driftwood that is sourced from the Northern beaches of Iceland, has undergone a natural impregnation during their stay in the salt-water, and are further protected by being covered by overhangs, hindering some rain from reaching the façades. The corrugated aluminium clads the outer shell of the cabin and reflects one of the traditional Icelandic ways of using recycled metal. The façade appears native to modern Icelandic architecture and uses sustainable locally sourced materials to promote a sustainable way of travelling in Iceland.

As seen the four person cabin is equipped with two windows towards the South-East. This differs from the two person cabin, that only has one window, as the number of window follows the number of beds.

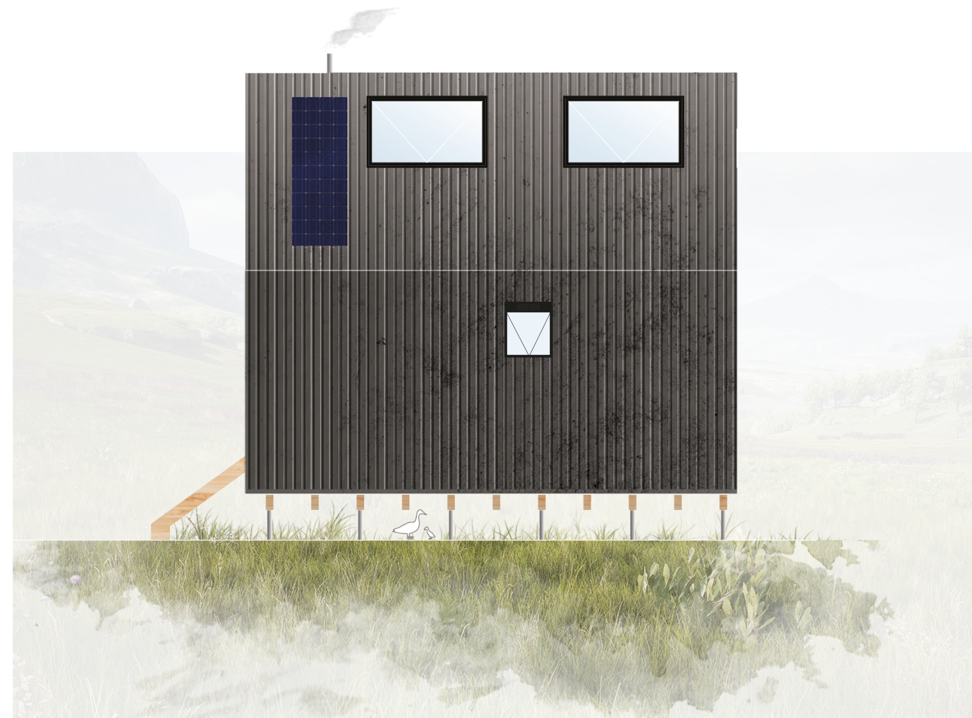
ill. 152-155 - four person cabin facades - 1:100

ill. 152 - four person cabin - South West facade - 1:100

ill. 153 - four person cabin - North East facade - 1:100



ill. 154 - four person cabin - Nort West facade - 1:100

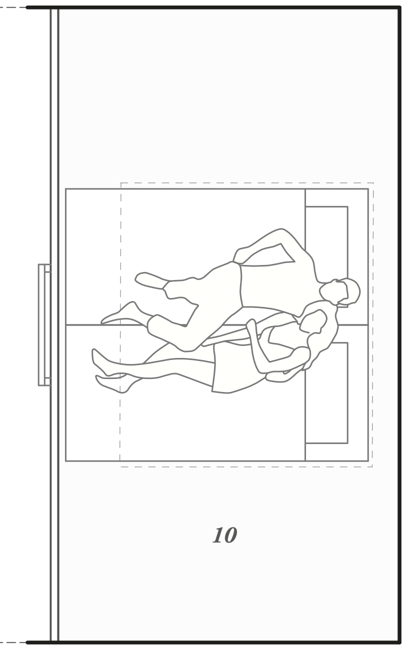


ill. 155 - four person cabin - South East facade - 1:100

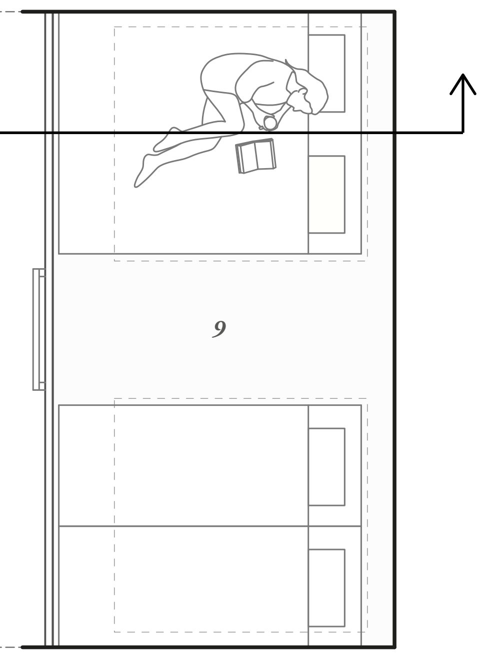
View to the Northern Lights

The cabin is equipped with large North-North-West facing windows in an inclined roof to provide the best view to the Northern Lights. The interior of the cabin is purposely kept very simple and without any distracting elements, taking away from the experience of seeing the lights dance across the night sky.

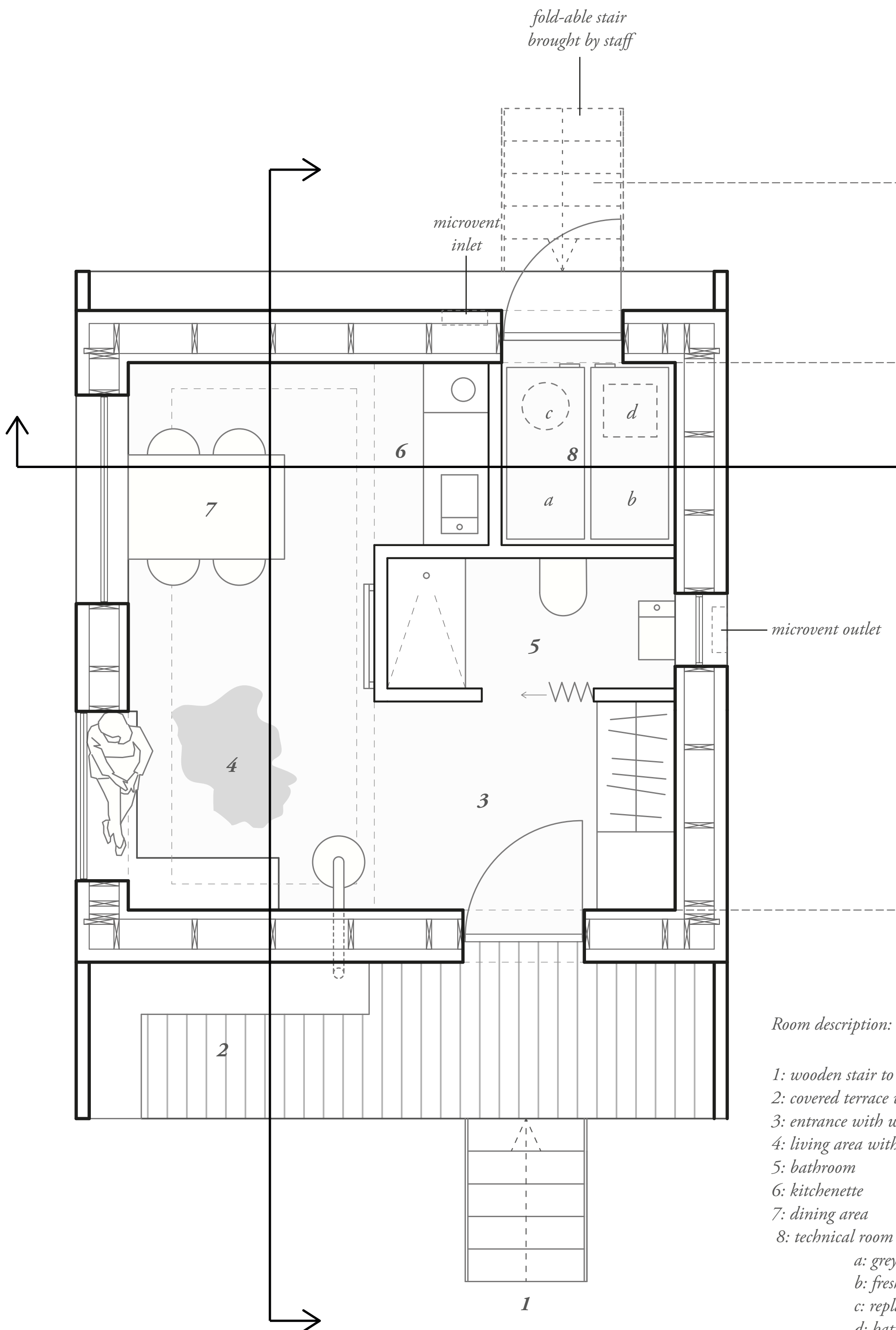
ill. 156 - the bed-loft in a two-person cabin



ill. 158 - plan of cabin: bedloft for two people - 1:50



ill. 159 - plan of cabin: bedloft for four people - 1:50

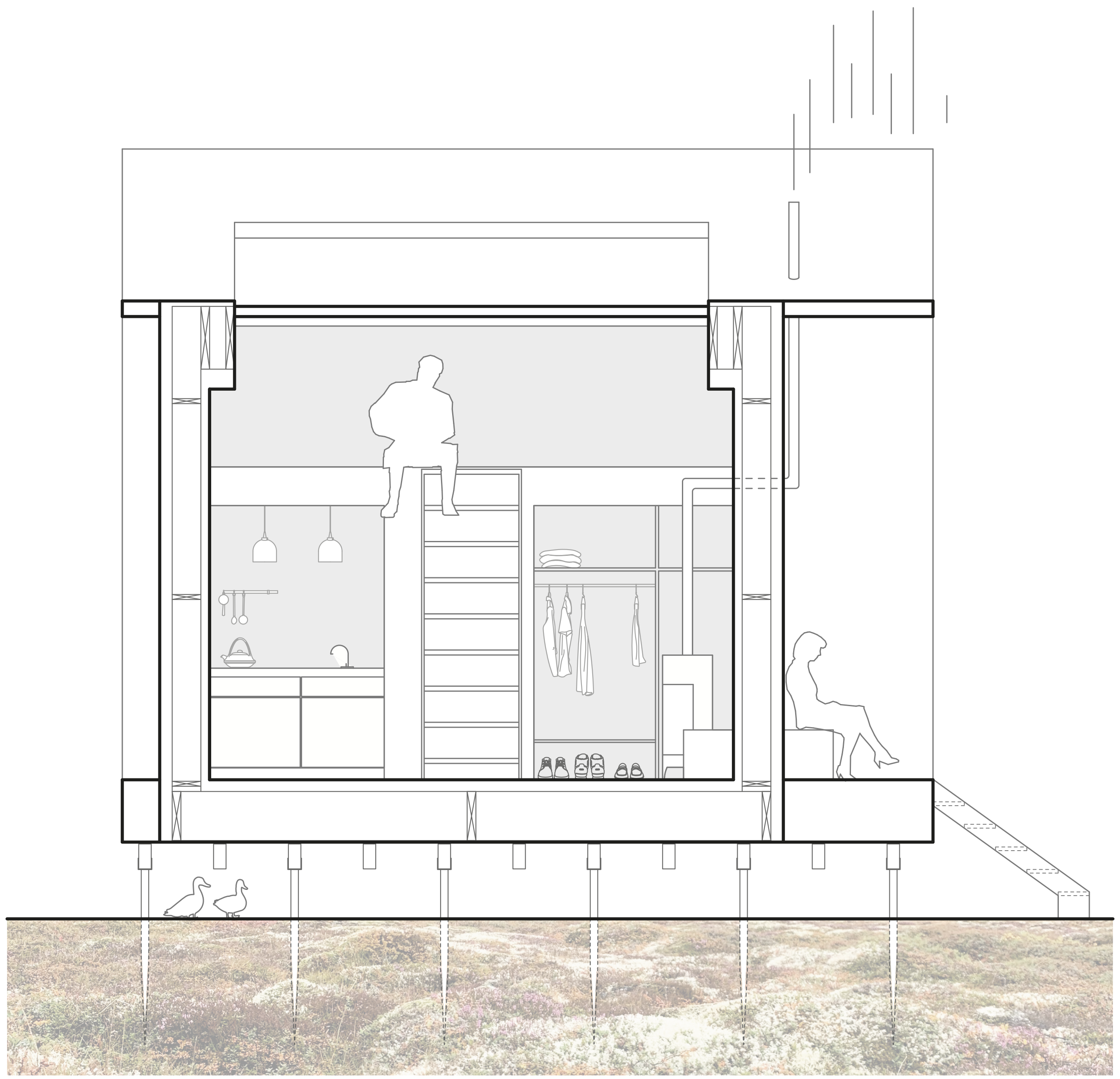


ill. 157 - plan of cabin 1:50

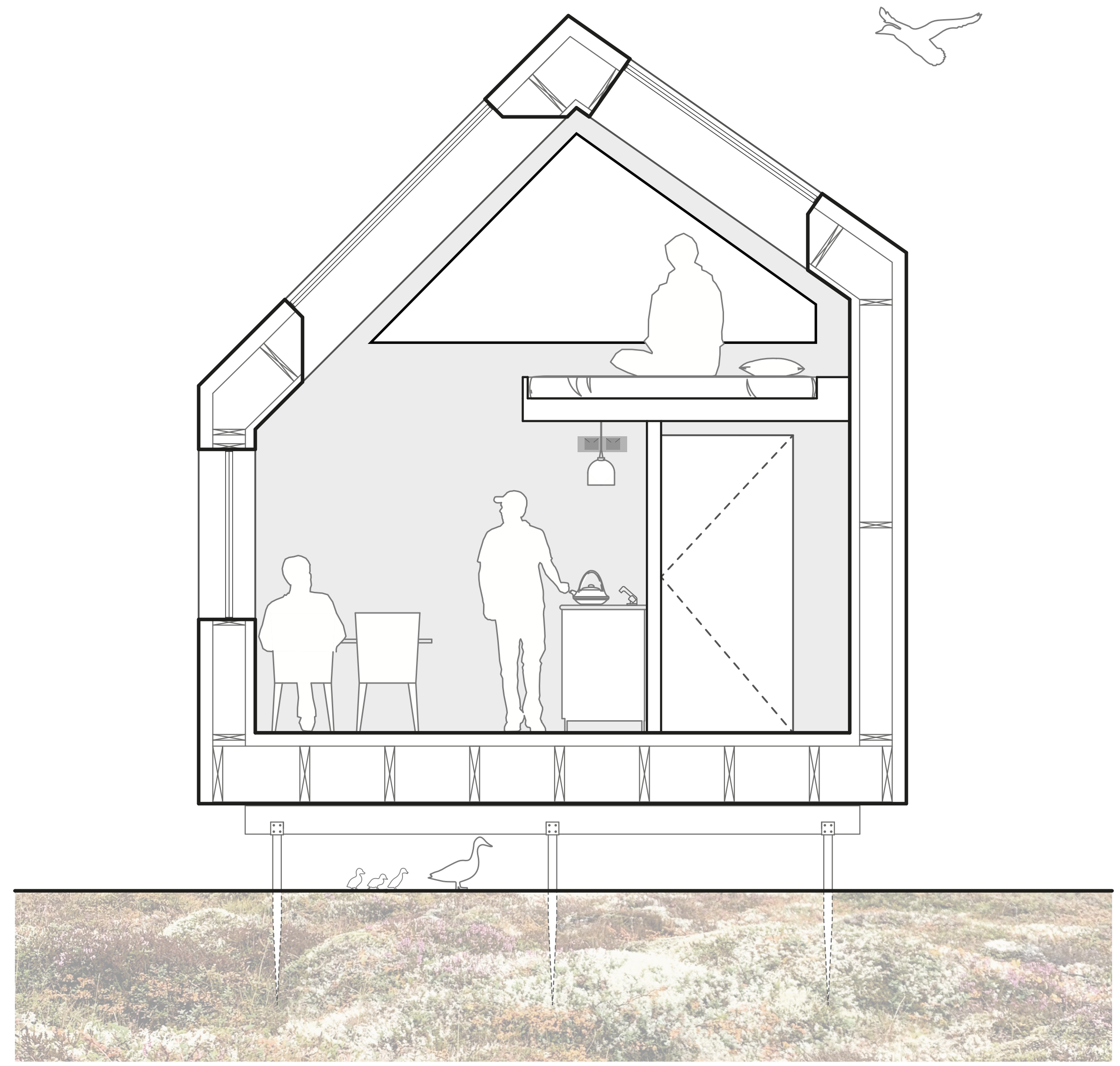
Room description:

1: wooden stair to cabin
2: covered terrace with seating
3: entrance with wardrobe
4: living area with seat in window and pellet burner
5: bathroom
6: kitchenette
7: dining area
8: technical room
- *a: grey water tank*
- *b: fresh water tank*
- *c: replaceable biogas tank*
- *d: battery for PV cell*

9: bedloft for four person cabin
10: bedloft for two person cabin



ill. 160 - section AA of cabin - 1:50



ill. 161 - section BB of cabin - 1:50

Main elements in construction of the cabins

Roof windows

Triple layered glazing to minimize transmission loss through windows.

Roof structure

The roof consists of timber I-joists making a light with easy adaptation to fit either one of two windows, if the center needs to expand their number of four persons cabins. The insulation is in-between the I-joists and consists of straw with a high heat capacity giving the insulation good thermal storage while having a low density.

Wall structure

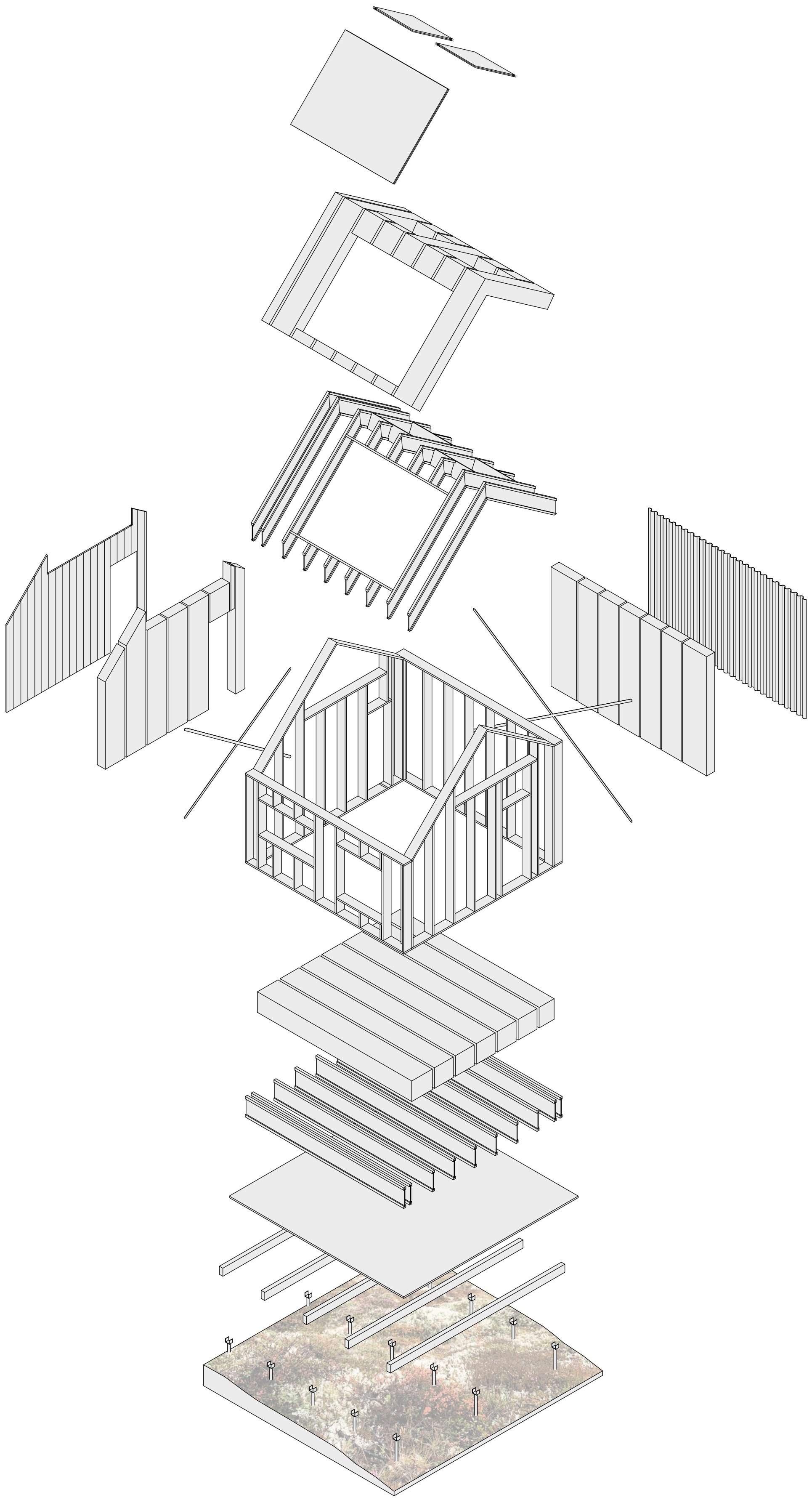
The wall structure is a balloon frame consisting of four separate wall elements. Walls are filled with the same straw material as the roof and to secure the stability of the cabin each wall is cross-braced in places with no windows. The facade material is driftwood on the gables and recycled corrugated aluminium on the remaining façades.

Floor structure

Wooden I-joist beams on top of osb board to minimize weight and amount of needed wood. Straw insulation is filled in-between the I-joist beams.

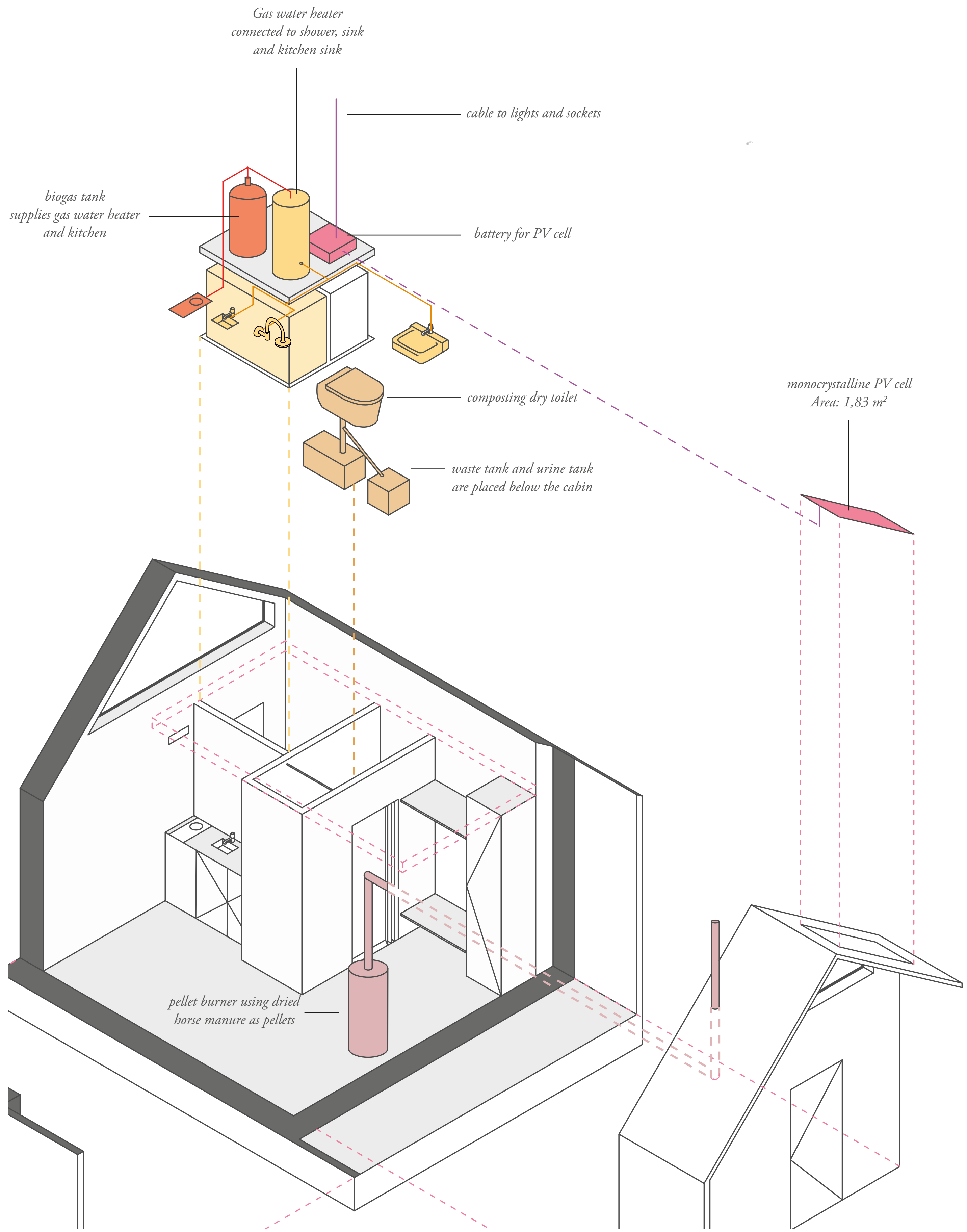
Foundation

Metal screw foundations to which timber beams can be fastened which allow the cabin to be elevated from the ground.
The screw foundations can relatively easily be loosened from the beams and moved across site if needed. The remaining cabin can be loaded on a small truck or similar and afterwards be attached to the screw foundations again.

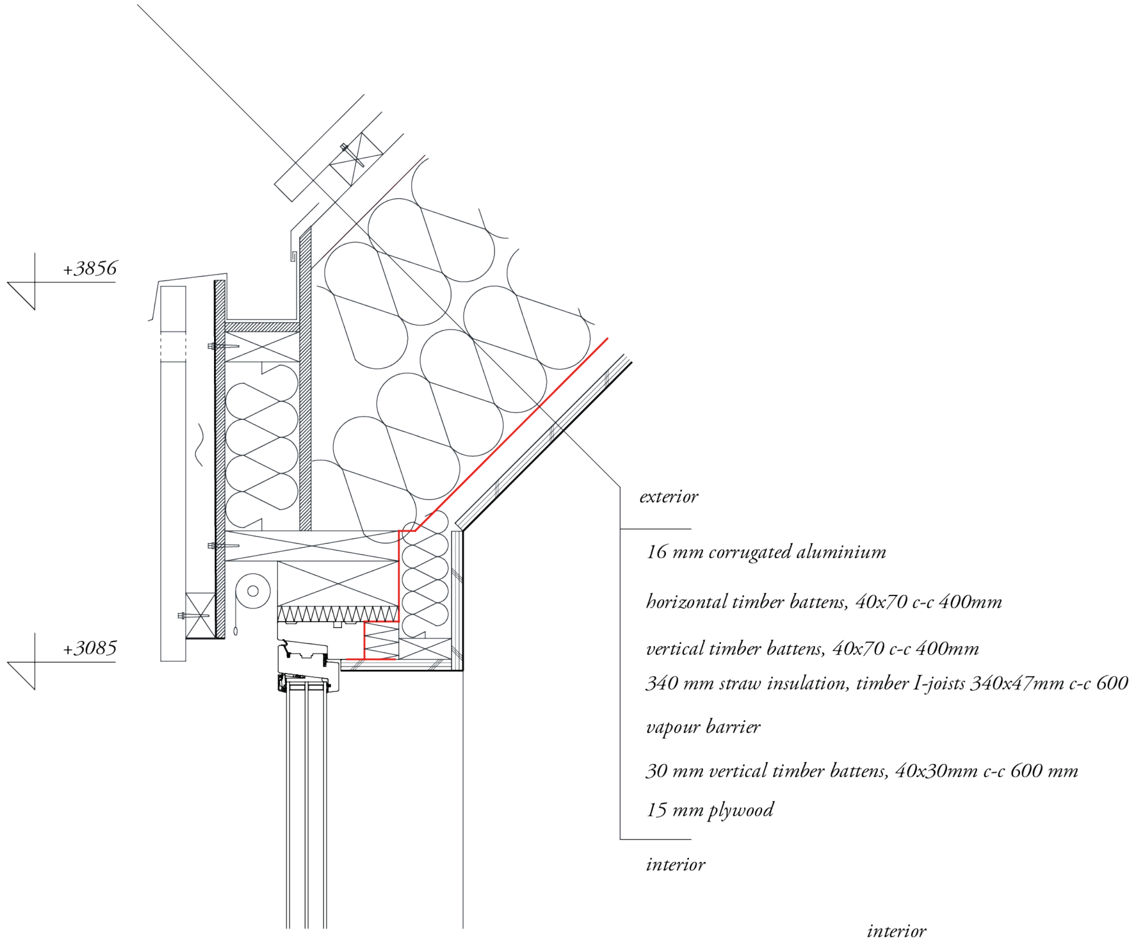


ill. 162 - exploded view of four-person cabin. Note that not all layers in the construction are shown due to clarity as well as the terrace and the overhangs. All layers can be seen in the details pp. 140-141:

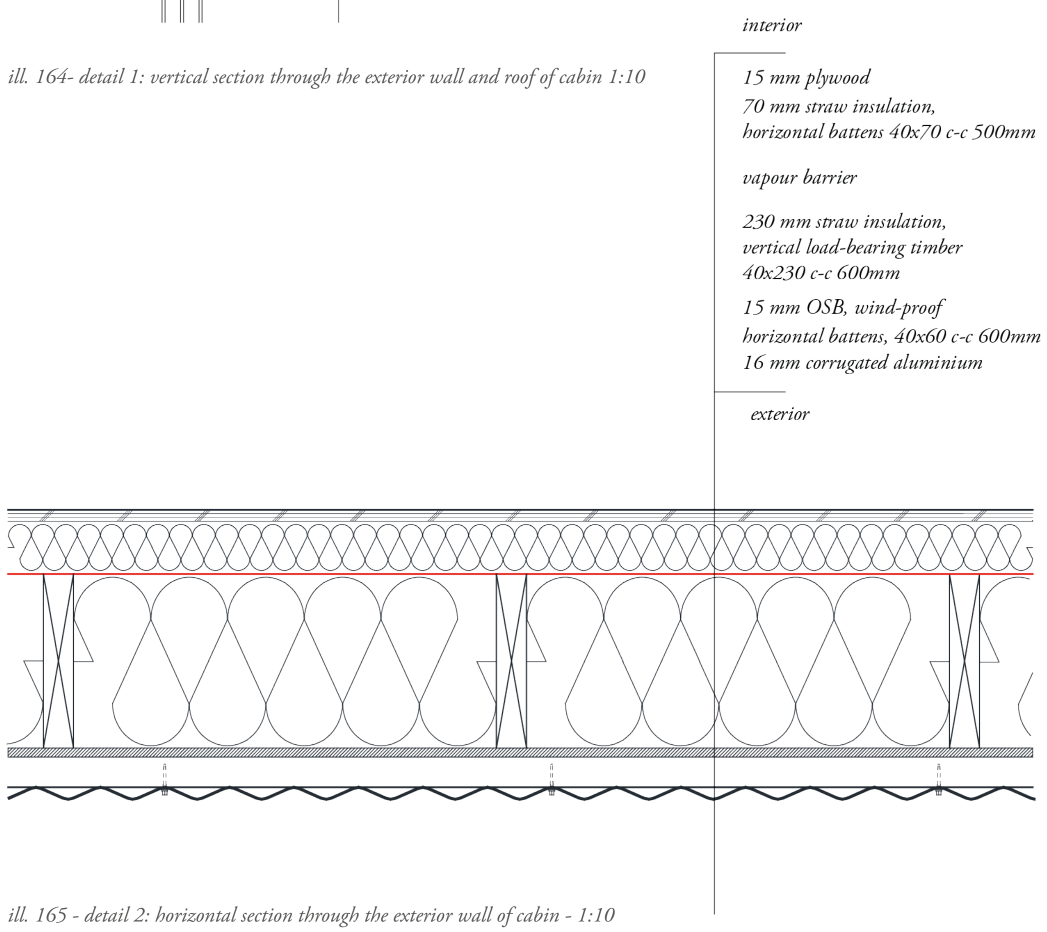
Placement of supply systems in the cabins



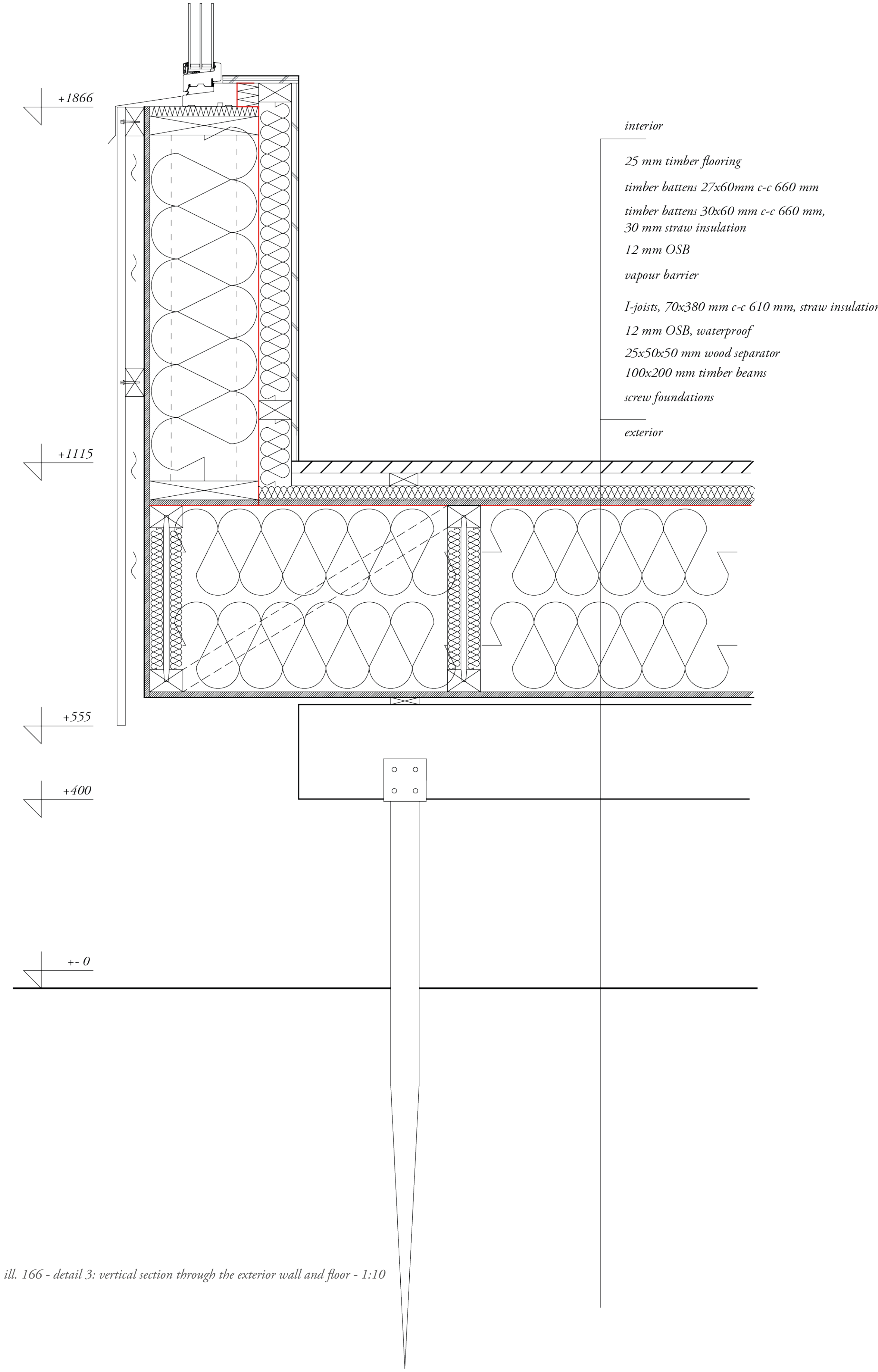
ill. 163 - exploded view showing the placement of supply systems in the cabin



ill. 164- detail 1: vertical section through the exterior wall and roof of cabin 1:10



ill. 165 - detail 2: horizontal section through the exterior wall of cabin - 1:10



ill. 166 - detail 3: vertical section through the exterior wall and floor - 1:10

Epilogue

The last chapter of the report includes a conclusion on how the design parameters were met, and a final reflection upon the whole project.

ill. 167 - Glaumbær historic farmhouses - Photo by: p. Nguyen

Conclusion

As the main goal of this project was to design a sustainable alternative to common Icelandic approaches of dealing with mass tourism, the project was from the initial analyses focused on the site and on creating a connection to the natural surroundings, giving tourists the experience they are searching for, while keeping a low impact on the site.

Through the initial problem and analysis phase, the main objectives and design parameters were set, and the following discussion concludes on how the parameters were met.

The set down physical criteria had a large impact on the general building volume and shaping. As the criteria required the main complex to be visible and exposed from the main road, the building site was chosen as the sloped hill facing Hverfjall, the volcano, as this was the place where people could see the building from both the main road and the smaller access road. This placement was determining in achieving the other parameters, as some specific design choices were made to facilitate the view to Mývatn. With the desire to give people an outdoor experience on site, the building was sloped in a way that follows the natural terrain while drawing inspiration from the raw Icelandic nature. The inclined roof gives the building a natural hierarchy in the inside spaces, which was utilized to vary the privacy and exposure of the functions, so that there is a natural separation of public and private functions. This feature was also used to make a large inviting space as the visitor center is the first area of the building, that the visitor arrives to. As for the cabins, the design was created with the natural human view towards the night sky and the Northern lights as a central shape giver. The cabins feature large skylights with direct view from the bed/beds to give the visitor the incredible experience of seeing the northern lights. The atmosphere created is tranquil and keeps the northern lights in focus, with no disturbing elements.

Concerning the technical requirements set in the program, many thoughts and investigations were made regarding sustainable material choices for both the main complex and the cabins. As one of the aesthetic criteria were to also choose materials, that respected the Icelandic architecture, there were many conflicts to solve before reaching a final material decision. Iceland has scarce natural building materials, which causes a certain aesthetic. Those materials that are used in the project, both fulfil being true to the icelandic architecture, while also being proved as sustainable regarding transport, production in Iceland and environmental impact. The material choice was also used to achieve the requirements for the indoor climate by e.g. offering thermal mass, low thermal conductivity and hygroscopic properties. To fulfil these requirements, the building was shaped to utilize as much potential of the radiation during winter, while limiting the gain during summer to avoid overheating.

The design of the cabin was faced with the challenge of being placed in the no-construction zone on the site and could therefore not have a permanent foundation. This led to the integration of several off-grid solutions to supply the cabins. A meticulous process of calculations, design, and adaptations was gone through to make sure all demands were met, and all waste was handled.

Reflection

The project of designing a proposal for a combined visitor center and accommodation complex in Iceland, could as most other architectural projects be approached in many ways and result in a corresponding number of ways, depending on the applied methods, the research done, and the personal intentions of the designers, as well as the time frame and detailing of the project.

Seeing the project in hindsight, the process of designing the complex with the most respect for the surrounding nature and the conditions of the site, proved challenging before the site visit. The Icelandic nature is unlike any other and is hard to study from home as the personal and phenomenological experience of being there is crucial to set the best foundation of the design. As a result, the design process easily became split in two: one part initially focusing on the concept of finding inspiration in general Icelandic nature as could be studied from home, while the second part consisted of an analytical approach to the actual site conditions based on the visit there. Had the site visit been done before, the process could still be split in two approaches to provoke all possible ideas, however, the general understanding of being on the site, could have helped qualifying whether ideas fit or not from the start.

As the project proved to be quite extensive including both the cabin design, the visitor center, energy systems etc. Some parts became more conceptual than initially thought and would be interesting to further improve. An example is the thermal bath, which can offer some very interesting atmospheric experiences, and had there been time, these experiences could have been further detailed and studied adding more depth to this part of the concept. The same goes for some off-grid systems such as the purification of water from the lake. As research for these systems were quite time consuming, some systems had to be prioritized to find a good solution.

As the materials became an important element in the design due to their impact on the environment, the initial wish was to test the sustainability of the materials using an LCA. However, as most materials used are locally produced, it is hard to obtain correct EPD information that takes the use of renewable energy into account. Instead an extensive research of the properties of materials was done, and materials were chosen based on those findings. However, it would have made for a good comparison between e.g. each possible wall construction.

Several studies of the indoor climate were carried out using Bsim as a tool, and satisfactory conditions meeting the requirements set, were met. However, due to the extent of the project, not all areas have been simulated, and further investigation could have been useful in the design of the façade in the restaurant area.

As a final thought, the project taught us, that there is no recipe for sustainable design and that the specific conditions always need to be considered. During the process, we often realised that some solutions that might usually be a part of a design placed in Denmark, are of less importance in Iceland. An example is the way of regarding the energy use of a building. As Iceland uses almost only renewable energy, the actual energy use of a building is not as important there as in Denmark. An element that usually plays a significant role in the design, can in other settings be much less crucial.

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Illustration list

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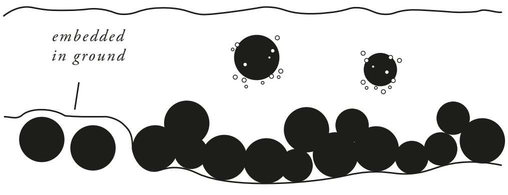
Annex 1: Using Icelandic nature as an idea generator

The idea of using some recognisable natural elements in the natural settings around Mývatn and in general Iceland as idea generators, resulted in concepts entirely based on the given element. All investigated aspects had to relate to the nature element to urge as many diverse (and possible far out) ideas as possible. As these principles can seem unrealistic as a final concept, there might be some parts that can be evolved into an untraditional solution that would otherwise have been hard to find. The below illustration is based on solely using the native marimo algae in the design, while the next page shows a similar ideation using the volcano as a generator.

Relation to landscape

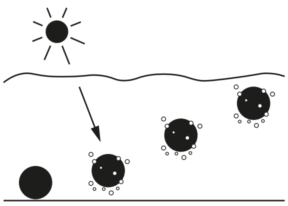


natural states of cladophora glomerata

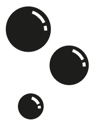
=

main building

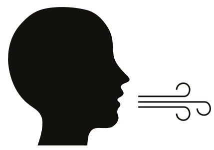
Movability



photosynthesis makes marimo float



lifted by air



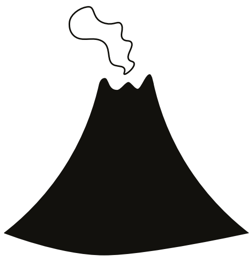
inflatable

Materiality

turf

inflatable material

Relation to landscape



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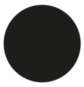
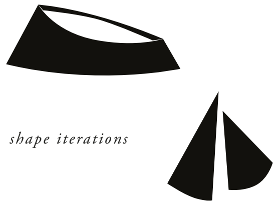


circular

+

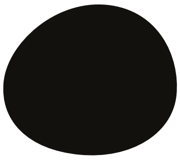
trapezoid

=



shape iterations

Movability



eruption

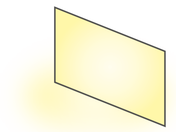
Materiality

magma

=

volcanic rock
(basalt)

+

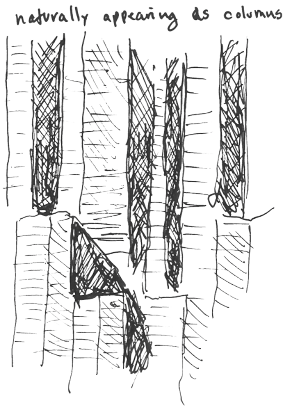


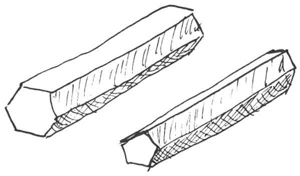
illuminating glass

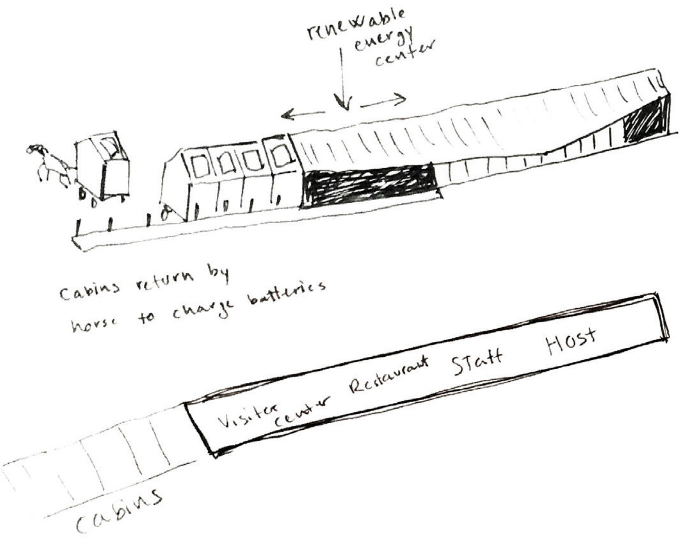
Annex 2: Conceptual ideas based on initial design workshop

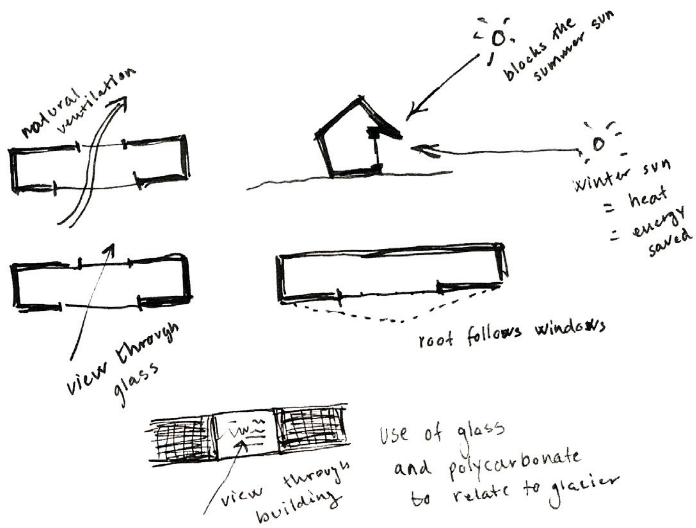
Concept: Studlaberg x Glacier

This concept is a combination of proposals regarding the studlaberg stone and the natural glaciers found in Iceland. The shape of the stone shapes the building and will be adapted based on the need for passive solar heating where the roof might change depending on the windows. However, the strict rectangular shape needs to be followed giving less flexibility and possible less atmospheric variation regarding scale and shape of spaces.



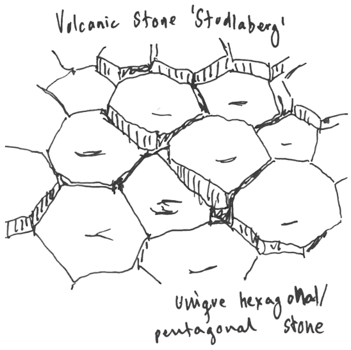


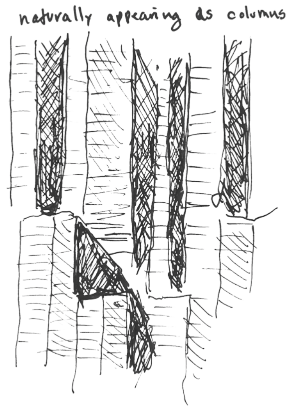


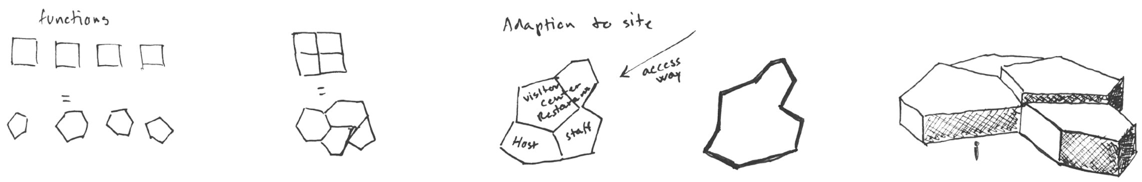


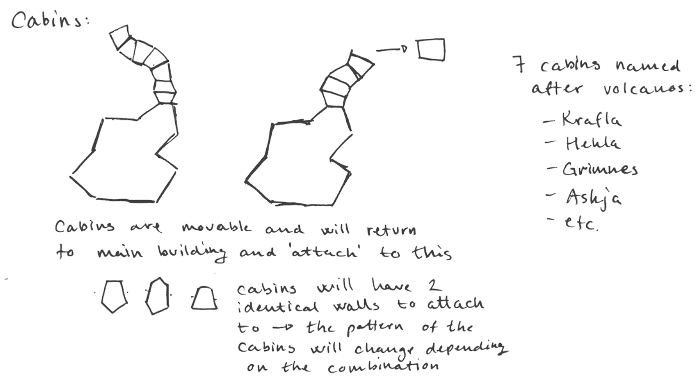
Concept: Studlaberg

This idea takes inspiration from the natural hexagonal stone called Stuldlaberg. The shape of the stone is integrated in the plan solution and the shape of the cabins, which connects to the main building to charge when not in use. However, the building shape consisting of hexagons urges a very compact building with a possible unclear shape to the viewer since they might not know about this natural stone as it is not native to the close surroundings of Mývatn.









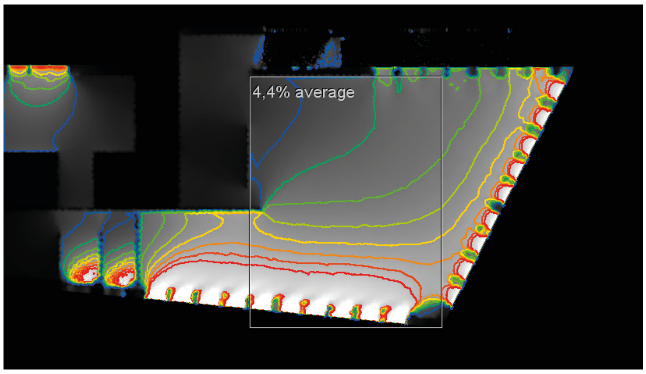
Annex 3: General studies of daylight factor related to window placement and size

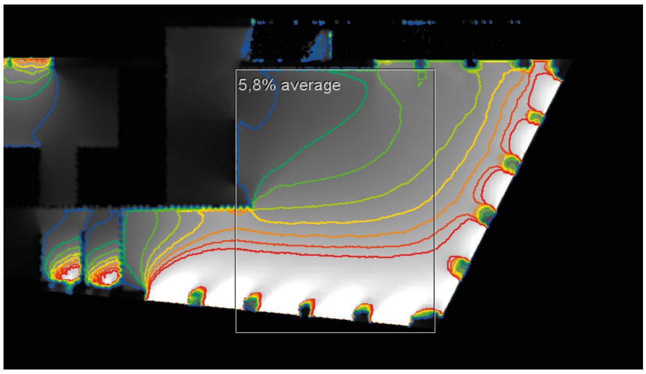
To gain an general idea of how the visitor center could be sufficiently lit with daylight, having mostly windows on the façades as the roof will be used as a walk-able facade, and therefore cannot contain skylights.

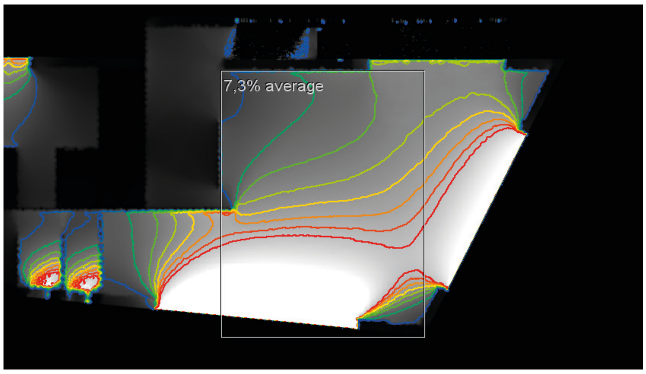
The studies were made using Velux Daylight Visualizer and models made in Revit. The models all use the same total area of window on each facade (30 m^2) distributed in various layouts. As the investigation was done to compare a variety of solutions and gain a general idea of how the daylight would be distributed, all materials and their reflectance are the same in each simulation.

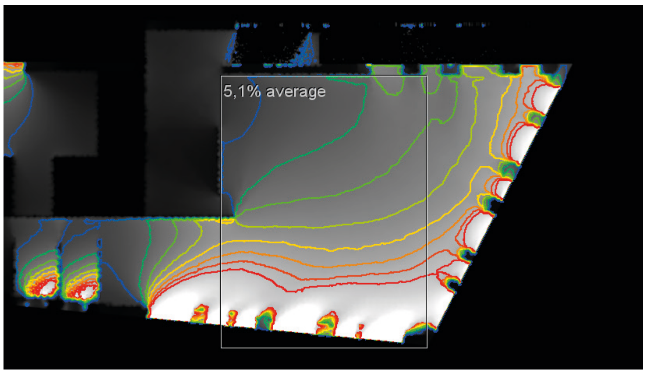
The first three illustrations all use one type of window per simulation with the first having many narrow windows, the second having almost square windows, and the third one having one large window on each facade. As seen the large windows gives a higher Daylight factor (the average of the same rectangle is compared), while the narrow windows give the lowest. This was not a surprise, since it was expected that the window frames/thin wall elements between the narrow windows, block much of the daylight. However, the large windows also cause a very high daylight factor close to the windows, which is not needed. The second option with square windows however, gives a similar distribution of the daylight (as seen from the dark green 2,0% line in the illustrations) without the high average daylight factor.

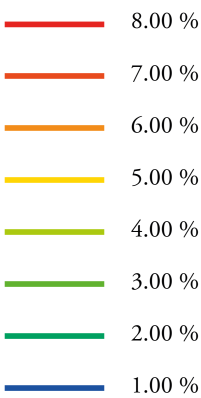
Due to this determination, some further studies were done in relation to the architectural and atmospheric experience of the windows (as discussed in the main report p. 74). Two examples of these can be seen as the last to options to the right. These helped in the final placement of windows.

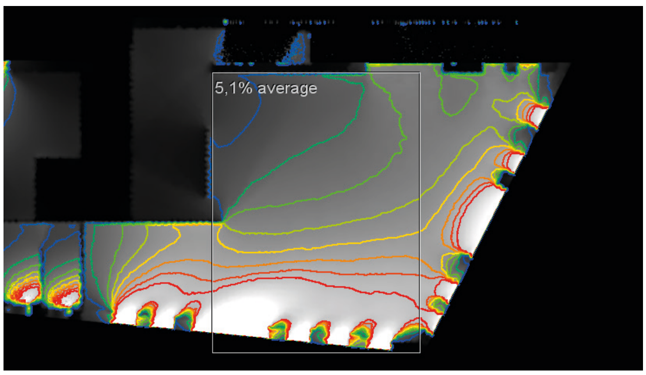












Annex 4: Study of solar radiation on facade related to facade angle in FormIt

To study the effect of changing the angle of the facade on the amount of radiation during the year, a simple model was made in Autodesk FormIt. The model consists of one volume for each of the following angles:

- 55 °
- 60 °
- 65 °
- 70 °
- 75 °

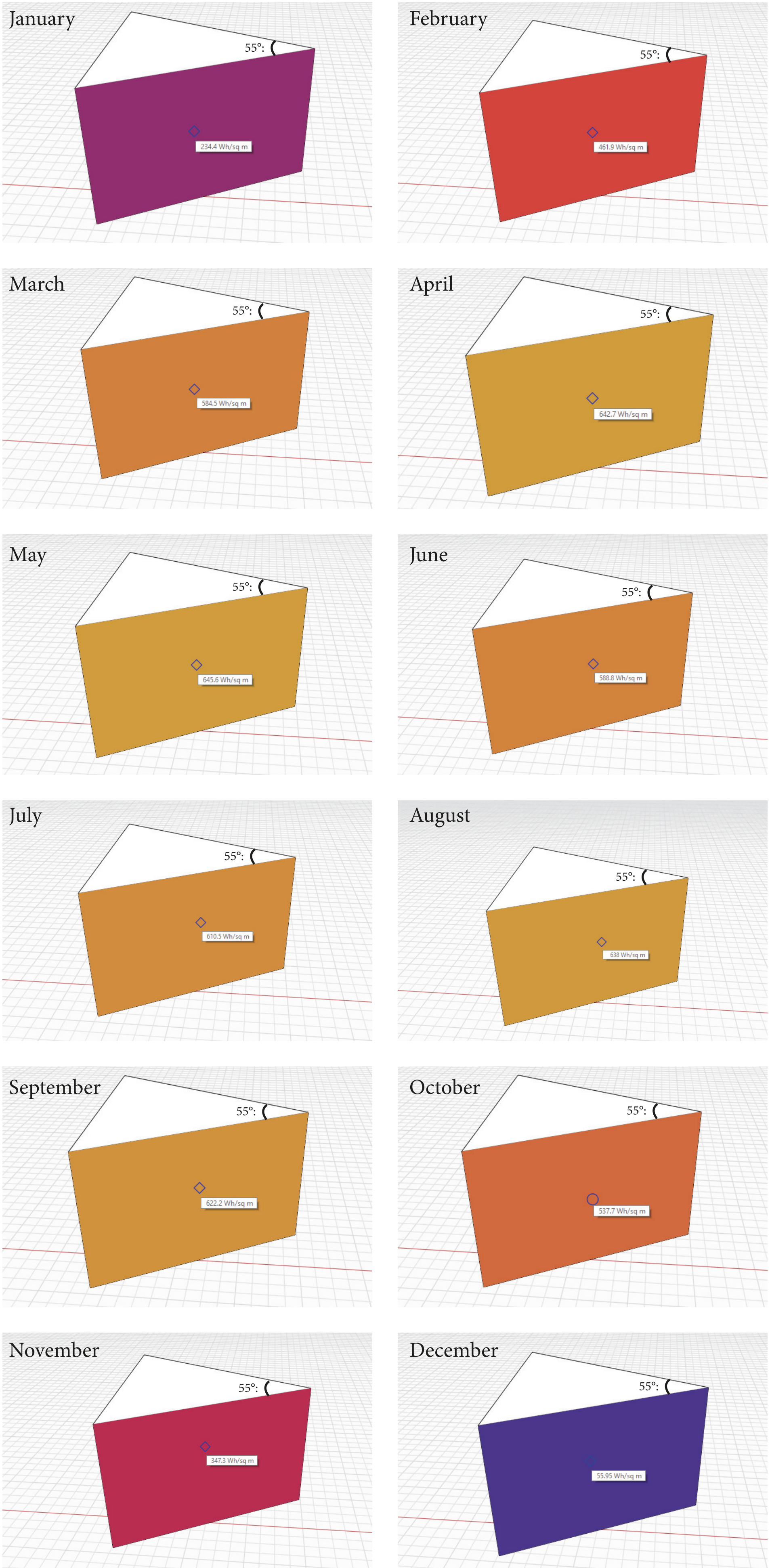
These angles were chosen in the interval 55-75 since this interval still allows for a good direct view from the interior to the Hverfjall volcano.

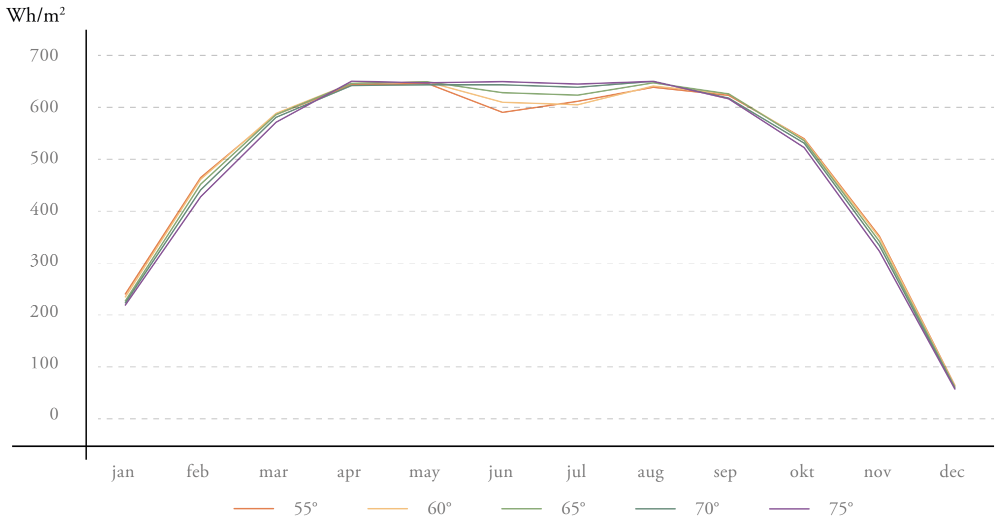
Each volume was analysed to find the peak radiation for each month to determine which angle provided the best balance between the radiation during summer and the radiation during winter, to decrease overheating during summer and help heat the building during winter. The model is located in Iceland at the site and therefore uses the sun path of that particular site. Each series of radiation values can be described with the graphs seen on the next page.

The results show that the most optimal angle (of the analysed angles) is the smallest, 55 °. This angle provides the highest radiation during winter while providing the lowest radiation during summer. It is likely that an even lower angle will cause a more optimal solution, though angles below 55 ° will obstruct the direct view and orientation towards the volcano.

The optimum of the radiation is reached because the angle of the sun during the summer, causes the building to shade itself at the smaller facade angles.

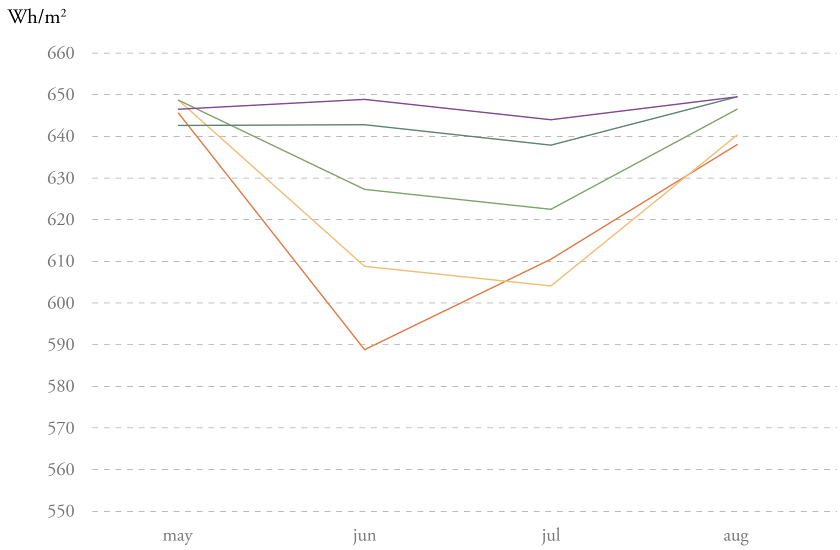
55°:





Graphs describing the relation between angle, time of year, and radiation.

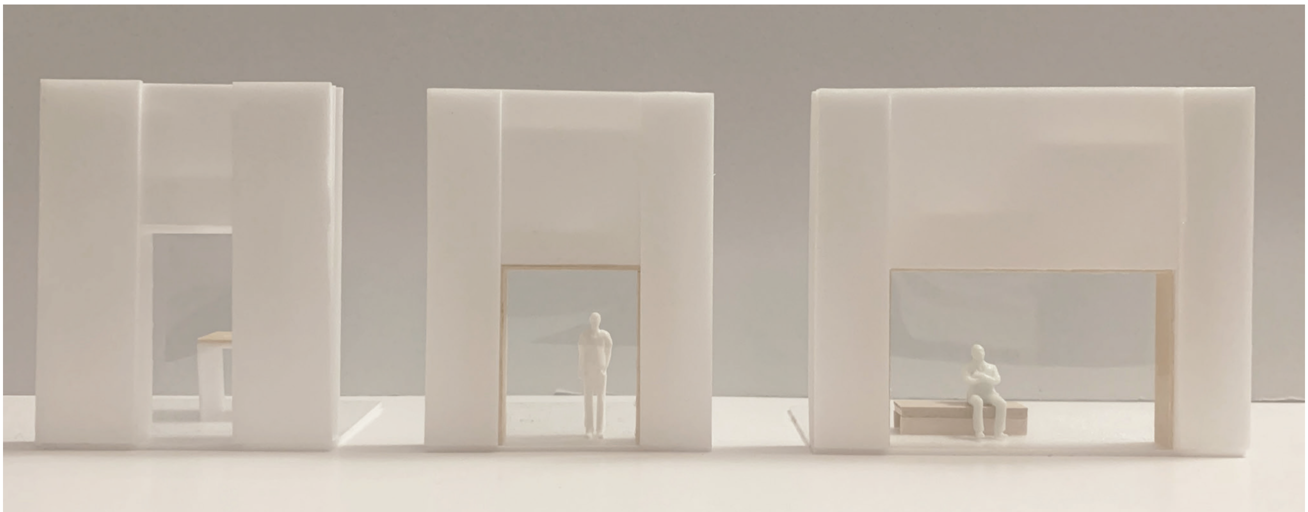
Graphs describing the relation between angle and radiation during the winter months.

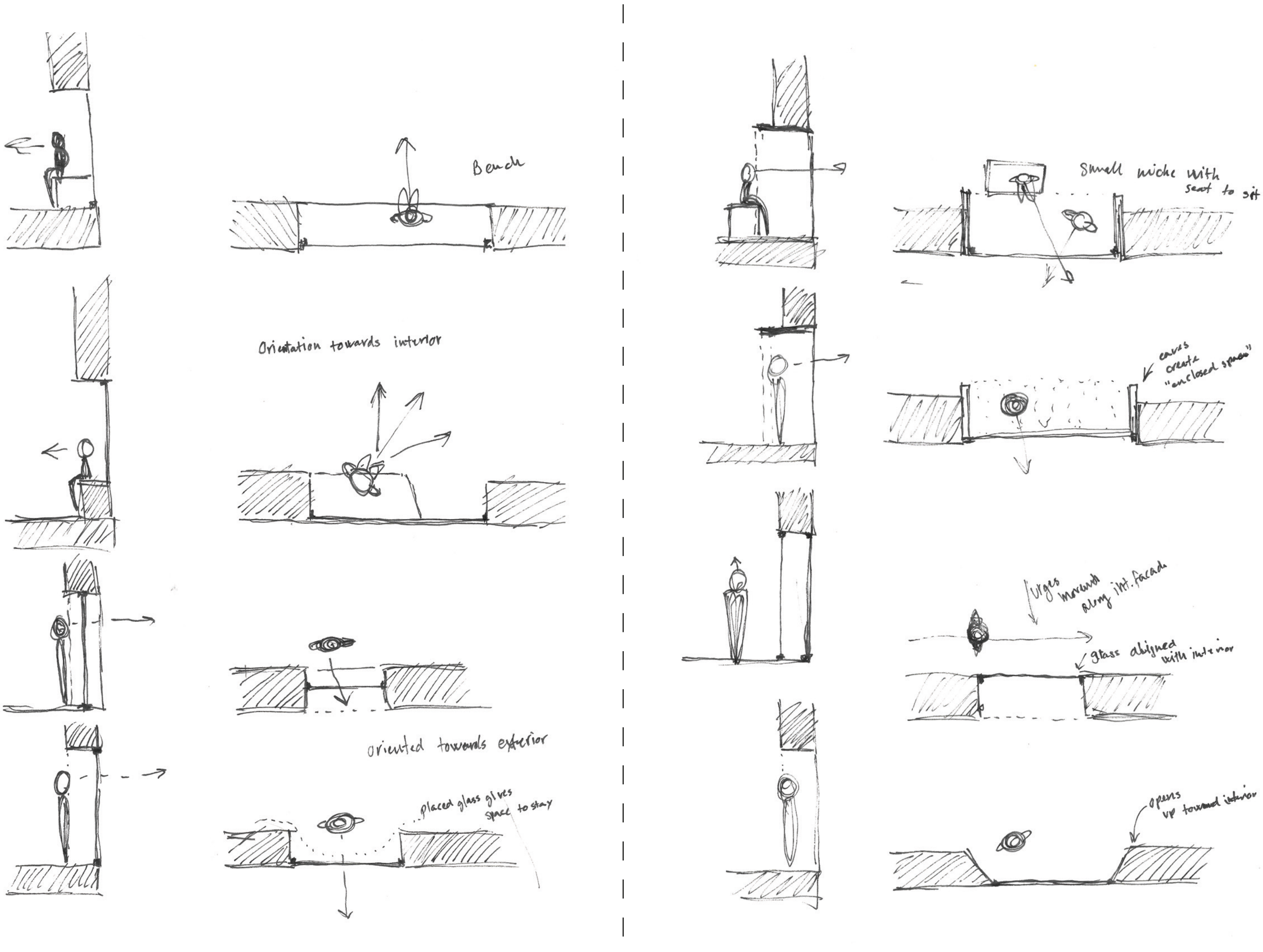


Graphs describing the relation between angle and radiation during the summer months.

Annex 5: 1:50 models and sketches of window typology in the visitor center

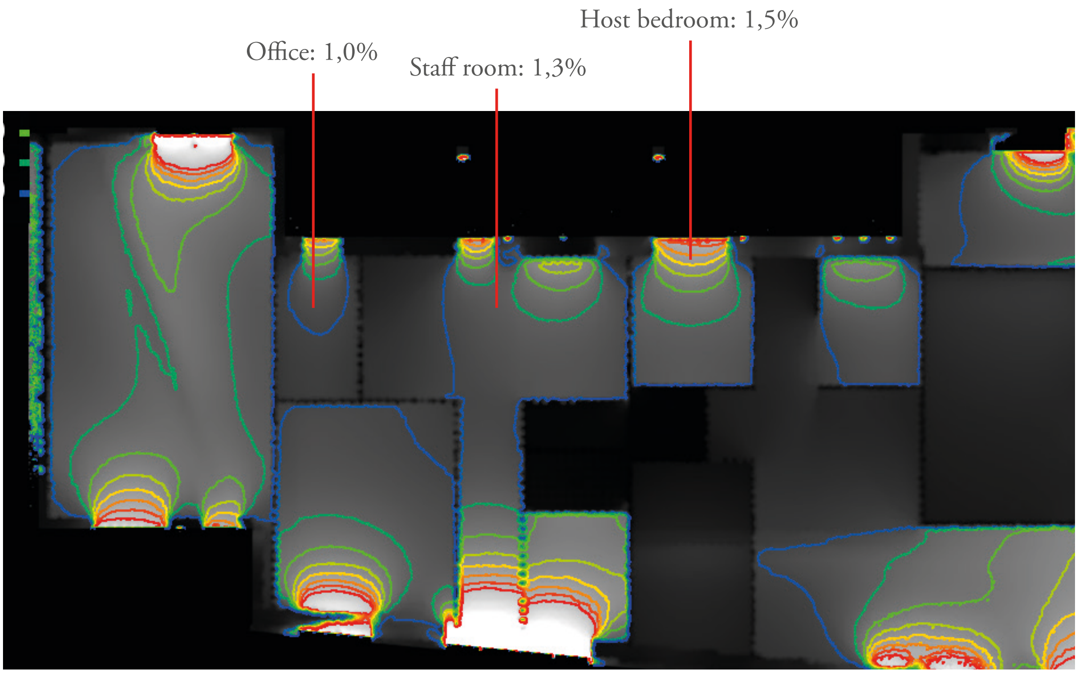
To examine the spatiality of the design of the windows in the visitor center related to the human body, some physical models were made based on a sketching process.
The models can be seen here as well as some of the most important sketches.



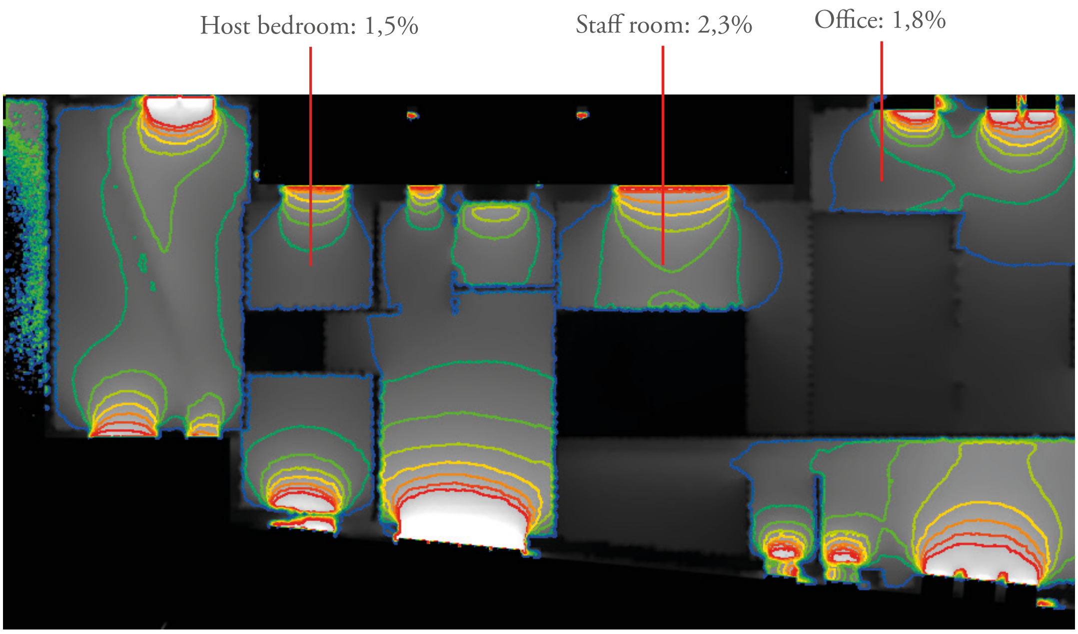


Annex 6: Daylight factor of remaining building analysed using Velux Daylight Visualizer

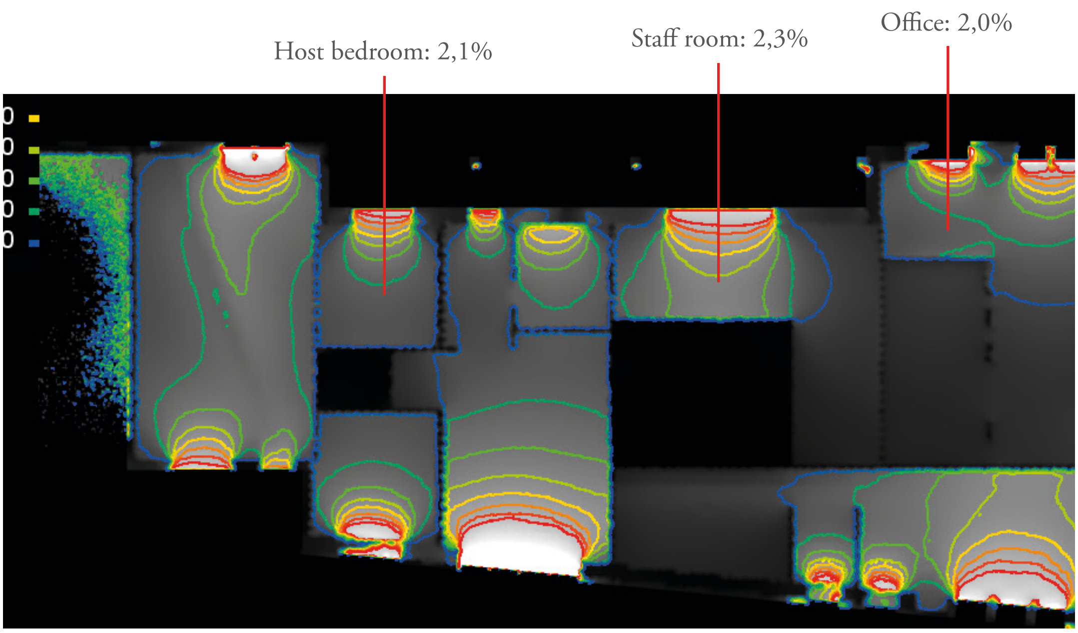
Iteration 1:



Iteration 2:



Iteration 3:

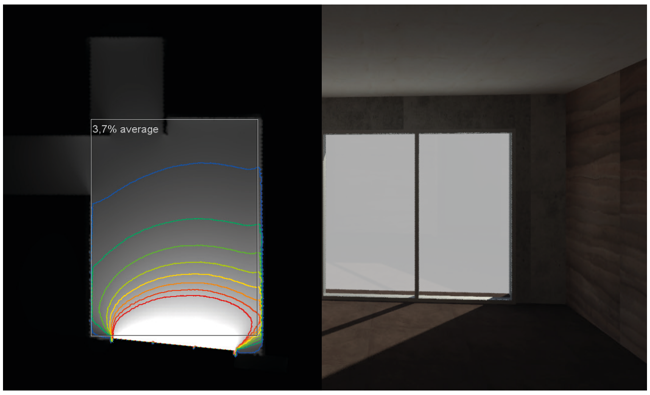


Annex 7: Determination of daylight factor in host living room

The daylight simulation was made using Velux Daylight Visualizer using an imported model made in Revit. The daylight factor mentioned in the analysis is an average of the main living room.

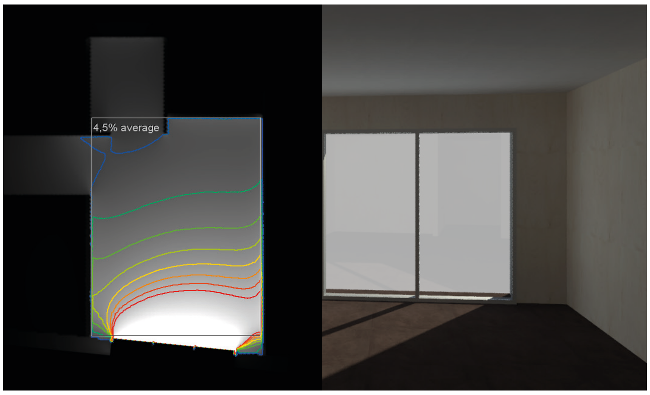
Material reflectances used:

Earth:	0,300
Birch:	0,842
Concrete:	0,400
Gypsum:	0,840



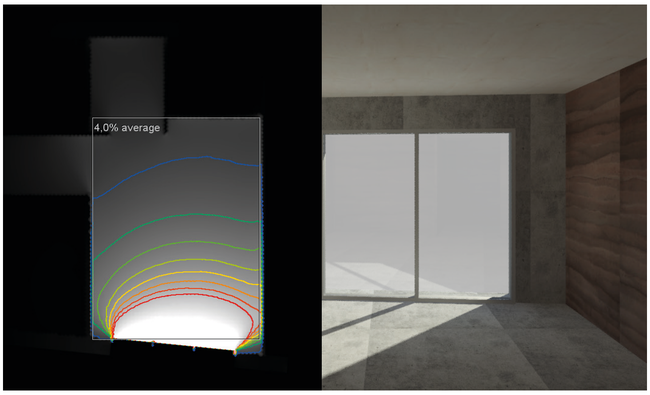
DF: 3,7%

Floor: Earth
Interior wall: Earth
Ceiling: Birch
Exterior wall: Concrete



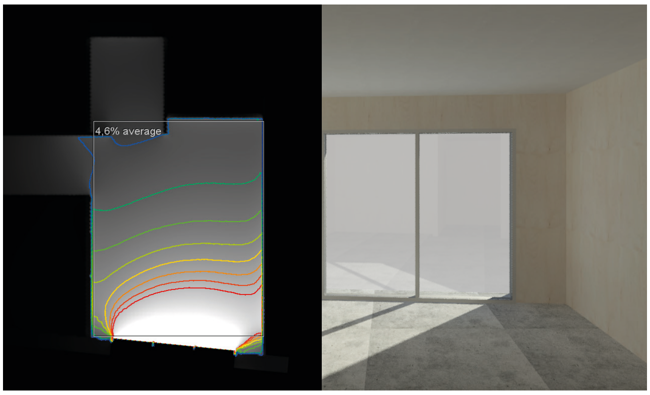
DF: 4,5%

Floor: Earth
Interior wall: Birch
Ceiling: Gypsum
Exterior wall: Birch



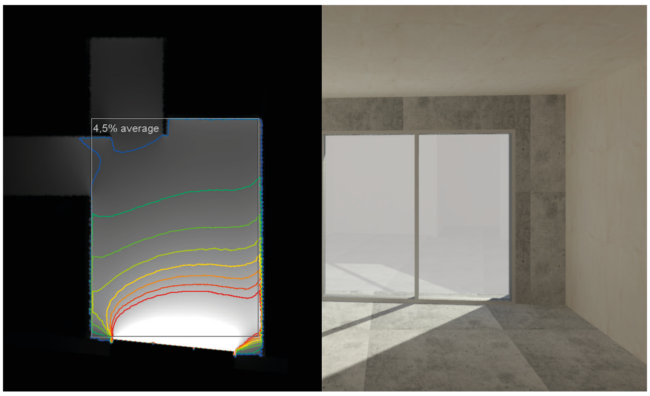
DF: 4,0%

Floor: Concrete
Interior wall: Earth
Ceiling: Birch
Exterior wall: Concrete



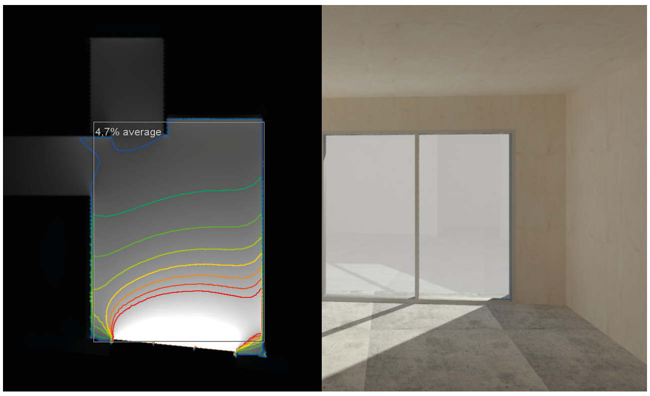
DF: 4,6%

Floor: Concrete
Interior wall: Birch
Ceiling: Gypsum
Exterior wall: Birch



DF: 4,5%

Floor: Concrete
Interior wall: Birch
Ceiling: Birch
Exterior wall: Concrete



DF: 4,7%

Floor: Concrete
Interior wall: Birch
Ceiling: Birch
Exterior wall: Birch

Annex 8: Calculation of reveberation time in host living room

The calculation is based on Sabines equation to determine the reverberation time based on absorption coefficients and area of materials.

$$T = \frac{0,16 * V}{A} = \frac{0,16 * V}{\Sigma\alpha_i * S_i + n_p * A_p + 4 * m * V}$$

T: reveberation time, s

V: room volume, m^3

A: the absorbtion area of the room, m^2

a_i: absorption coefficient

S_i: Area of surface, m^2

n_p: number of people, chairs, etc.

A_p: absorption area of one person, chair, etc., m^2

m: dimming coefficient for absorption of sound in air (only in large rooms), m^{-1}

Iteration 1:

Absorption area	Material	Area	125 Hz		250 Hz		500 Hz		1000 Hz		2000 Hz		4000 Hz	
		S	alfa	A	alfa	A	alfa	A	alfa	A	alfa	A	alfa	A
Ceiling	birch	46,00	0,30	13,80	0,25	11,50	0,20	9,20	0,17	7,82	0,15	6,90	0,10	4,60
Interior walls	earth	73,28	0,32	23,45	0,62	45,43	0,73	53,49	0,72	52,76	0,67	49,10	0,71	52,03
Floor	earth	46,00	0,32	14,72	0,62	28,52	0,73	33,58	0,72	33,12	0,67	30,82	0,71	32,66
Window	glass	8,00	0,35	2,80	0,25	2,00	0,18	1,44	0,12	0,96	0,07	0,56	0,04	0,32
Exterior walls	concrete	13,28	0,01	0,13	0,01	0,13	0,02	0,27	0,02	0,27	0,02	0,27	0,03	0,40
The total absorption area				54,90		87,59		97,98		94,93		87,64		90,01
	Number													
Chairs		6	0,15	0,90	0,19	1,14	0,22	1,32	0,39	2,34	0,38	2,28	0,30	1,80
People		2	0,03	0,05	0,04	0,07	0,04	0,08	0,05	0,09	0,05	0,10	0,05	0,10
Tables		1	0,10	0,10	0,20	0,20	0,30	0,30	0,40	0,40	0,50	0,50	0,50	0,50
				1,05		1,41		1,70		2,83		2,88		2,40
Room volume		128,8												
Reverberation time				0,4		0,2		0,2		0,2		0,2		0,2

Average 125Hz to 2000 Hz: 0,25

Iteration 2:

Absorption area	Material	Area	125 Hz		250 Hz		500 Hz		1000 Hz		2000 Hz		4000 Hz	
		S	alfa	A	alfa	A	alfa	A	alfa	A	alfa	A	alfa	A
Ceiling	gypsum	46,00	0,29	13,34	0,10	4,60	0,05	2,30	0,04	1,84	0,07	3,22	0,09	4,14
Interior walls	birch	73,28	0,30	21,98	0,25	18,32	0,20	14,66	0,17	12,46	0,15	10,99	0,10	7,33
Floor	earth	46,00	0,32	14,72	0,62	28,52	0,73	33,58	0,72	33,12	0,67	30,82	0,71	32,66
Window	glass	8,00	0,35	2,80	0,25	2,00	0,18	1,44	0,12	0,96	0,07	0,56	0,04	0,32
Exterior walls	birch	13,28	0,30	3,98	0,25	3,32	0,20	2,66	0,17	2,26	0,15	1,99	0,10	1,33
The total absorption area				56,83		56,76		54,63		50,64		47,58		45,78
	Number													
Chairs		6	0,15	0,90	0,19	1,14	0,22	1,32	0,39	2,34	0,38	2,28	0,30	1,80
People		2	0,03	0,05	0,04	0,07	0,04	0,08	0,05	0,09	0,05	0,10	0,05	0,10
Tables		1	0,10	0,10	0,20	0,20	0,30	0,30	0,40	0,40	0,50	0,50	0,50	0,50
				1,05		1,41		1,70		2,83		2,88		2,40
Room volume		128,8												
Reverberation time				0,4		0,4		0,4		0,4		0,4		0,4

Average 125Hz to 2000 Hz: 0,37

Iteration 3:

Absorption area	Material	Area	125 Hz		250 Hz		500 Hz		1000 Hz		2000 Hz		4000 Hz	
		S	alfa	A	alfa	A	alfa	A	alfa	A	alfa	A	alfa	A
Ceiling	birch	46,00	0,30	13,80	0,25	11,50	0,20	9,20	0,17	7,82	0,15	6,90	0,10	4,60
Interior walls	earth	73,28	0,32	23,45	0,62	45,43	0,73	53,49	0,72	52,76	0,67	49,10	0,71	52,03
Floor	concrete	46,00	0,01	0,46	0,01	0,46	0,02	0,92	0,02	0,92	0,02	0,92	0,03	1,38
Window	glass	8,00	0,35	2,80	0,25	2,00	0,18	1,44	0,12	0,96	0,07	0,56	0,04	0,32
Exterior walls	concrete	13,28	0,01	0,13	0,01	0,13	0,02	0,27	0,02	0,27	0,02	0,27	0,03	0,40
The total absorption area				40,64		59,53		65,32		62,73		57,74		58,73
	Number													
Chairs		6	0,15	0,90	0,19	1,14	0,22	1,32	0,39	2,34	0,38	2,28	0,30	1,80
People		2	0,03	0,05	0,04	0,07	0,04	0,08	0,05	0,09	0,05	0,10	0,05	0,10
Tables		1	0,10	0,10	0,20	0,20	0,30	0,30	0,40	0,40	0,50	0,50	0,50	0,50
				1,05		1,41		1,70		2,83		2,88		2,40
Room volume		128,8												
Reverberation time				0,5		0,3		0,3		0,3		0,3		0,3

Average 125Hz to 2000 Hz: 0,36

Iteration 4:

Absorption area	Material	Area	125 Hz		250 Hz		500 Hz		1000 Hz		2000 Hz		4000 Hz	
		S	alfa	A	alfa	A	alfa	A	alfa	A	alfa	A	alfa	A
Ceiling	Gypsum	46,00	0,29	13,34	0,10	4,60	0,05	2,30	0,04	1,84	0,07	3,22	0,09	4,14
Interior walls	birch	73,28	0,30	21,98	0,25	18,32	0,20	14,66	0,17	12,46	0,15	10,99	0,10	7,33
Floor	concrete	46,00	0,01	0,46	0,01	0,46	0,02	0,92	0,02	0,92	0,02	0,92	0,03	1,38
Window	glass	8,00	0,35	2,80	0,25	2,00	0,18	1,44	0,12	0,96	0,07	0,56	0,04	0,32
Exterior walls	birch	13,28	0,30	3,98	0,25	3,32	0,20	2,66	0,17	2,26	0,15	1,99	0,10	1,33
The total absorption area				42,57		28,70		21,97		18,44		17,68		14,50
	Number													
Chairs		6	0,15	0,90	0,19	1,14	0,22	1,32	0,39	2,34	0,38	2,28	0,30	1,80
People		2	0,03	0,05	0,04	0,07	0,04	0,08	0,05	0,09	0,05	0,10	0,05	0,10
Tables		1	0,10	0,10	0,20	0,20	0,30	0,30	0,40	0,40	0,50	0,50	0,50	0,50
				1,05		1,41		1,70		2,83		2,88		2,40
Room volume		128,8												
Reverberation time				0,5		0,7		0,9		1,0		1,0		1,2

Average 125Hz to 2000 Hz: 0,80

Iteratiion 5:

Absorption area	Material	Area	125 Hz		250 Hz		500 Hz		1000 Hz		2000 Hz		4000 Hz	
		S	alfa	A	alfa	A	alfa	A	alfa	A	alfa	A	alfa	A
Ceiling	birch	46,00	0,30	13,80	0,25	11,50	0,20	9,20	0,17	7,82	0,15	6,90	0,10	4,60
Interior walls	birch	73,28	0,30	21,98	0,25	18,32	0,20	14,66	0,17	12,46	0,15	10,99	0,10	7,33
Floor	concrete	46,00	0,01	0,46	0,01	0,46	0,02	0,92	0,02	0,92	0,02	0,92	0,03	1,38
Window	glass	8,00	0,35	2,80	0,25	2,00	0,18	1,44	0,12	0,96	0,07	0,56	0,04	0,32
Exterior walls	concrete	13,28	0,01	0,13	0,01	0,13	0,02	0,27	0,02	0,27	0,02	0,27	0,03	0,40
The total absorption area				39,18		32,41		26,48		22,42		19,64		14,03
	Number													
Chairs		6	0,15	0,90	0,19	1,14	0,22	1,32	0,39	2,34	0,38	2,28	0,30	1,80
People		2	0,03	0,05	0,04	0,07	0,04	0,08	0,05	0,09	0,05	0,10	0,05	0,10
Tables		1	0,10	0,10	0,20	0,20	0,30	0,30	0,40	0,40	0,50	0,50	0,50	0,50
				1,05		1,41		1,70		2,83		2,88		2,40
Room volume		128,8												
Reverberation time				0,5		0,6		0,7		0,8		0,9		1,3

Average 125Hz to 2000 Hz: 0,72

Iteratiion 6:

Absorption area	Material	Area	125 Hz		250 Hz		500 Hz		1000 Hz		2000 Hz		4000 Hz	
		S	alfa	A	alfa	A	alfa	A	alfa	A	alfa	A	alfa	A
Ceiling	birch	46,00	0,30	13,80	0,25	11,50	0,20	9,20	0,17	7,82	0,15	6,90	0,10	4,60
Interior walls	birch	73,28	0,30	21,98	0,25	18,32	0,20	14,66	0,17	12,46	0,15	10,99	0,10	7,33
Floor	concrete	46,00	0,01	0,46	0,01	0,46	0,02	0,92	0,02	0,92	0,02	0,92	0,03	1,38
Window	glass	8,00	0,35	2,80	0,25	2,00	0,18	1,44	0,12	0,96	0,07	0,56	0,04	0,32
Exterior walls	birch	13,28	0,30	3,98	0,25	3,32	0,20	2,66	0,17	2,26	0,15	1,99	0,10	1,33
The total absorption area				43,03		35,60		28,87		24,42		21,36		14,96
	Number													
Chairs		6	0,15	0,90	0,19	1,14	0,22	1,32	0,39	2,34	0,38	2,28	0,30	1,80
People		2	0,03	0,05	0,04	0,07	0,04	0,08	0,05	0,09	0,05	0,10	0,05	0,10
Tables		1	0,10	0,10	0,20	0,20	0,30	0,30	0,40	0,40	0,50	0,50	0,50	0,50
				1,05		1,41		1,70		2,83		2,88		2,40
Room volume		128,8												
Reverberation time				0,5		0,6		0,7		0,8		0,9		1,2

Average 125Hz to 2000 Hz: 0,66

Annex 9: Yield of biogas and dried pellets from horse manure

To determine if the cabins heating demand and gas demand (see annex 11) can be covered by using the energy in horse manure, the needed amount of manure was calculated. The host family has ten Icelandic horses that approximately produce 17 kg of manure pr day (https://lpelc.org/horse-manure-management/). The below calculations confirm that all seven cabins can be supplied with heating by pellets and biogas from the manure. After the production of pellets, there is still an abundance of manure that can be used for biogas digestion and produce more than twice the needed amount of gas for the seven cabins. The remaining m3 of gas can be used in the restaurant kitchen.

Properties of horse manure	Lower heating value	Biogas yield	TS	VS
	MJ/dried kg	L/kg VS	%	% of TS
Horse manure	18,14	337	30	84

	Pr horse pr day	Number of horses	Loss outside barn	Total daily manure	Yearly amonut
	kg/day	n	50%	kg	kg/year
Horse manure	17	10	85	85	31025

	kWh pr kg dried manure	Heating demand	Pellet burner eff.	Dried pellet need	TS	Needed fresh manure 1 cabin	Needed fresh manure all cabins	Remaining manure
	kWh/kg	kWh/year/cabin (Bsim)	%	kg/year/cabin	%	kg/year/cabin	kg/year	kg/year
Needed dried pellets	65,304	532	0,85	9,58	30	31,95	223,6	30801,4

	Gas yield	Volatile solids (VS)	Gas yield	Gas need pr 2 person cabin	Gas need pr 4 person cabin	Total gas need pr year	Remaining gas for main kitchen
	L/kg VS	kg/year	m3/year	m3/year (see annex 11)	m3/year (see annex 11)	m3/year (7 cabins)	m3/year
Biogas production	337	7761,95	2615,8	128,83	184,66	1069,31	1546,46

Sources:

Vögeli, Y. et al (2014). Anaerobic Digestion of Biowaste in Developing Countries. Eawag. [online] Availble at: https://sswm.info/sites/default/files/reference_attachments/VOEGELI%20et%20al%202014%20Anaerobic%20Digestion%20of%20Biowaste%20in%20Developing%20Countries.pdf Accessed at: 11. Nov. 2019

Annex 10: Calculation of yield of PV cells

Calculating the energy that can be produced from different PV cells was important to know the size of PV cells that is needed to integrate in the design. The electricity produced will be used to cover charging of cell phones and cameras and light inside the cabin. Furthermore the small microvent units will be supplied from the cell. The below calculation was made to find the area and the environmental impact of the PV cell depending on type. In the calculation a pv cell with an angle of 45 degrees is used resulting in a solar radiation gain of approx. 820 kWh/m2. The amount of radiation were found following the same procedure as in annex 4.

Electricity		2 people				Total need
		phones charging	camera charging	light bulbs	ventilation	kWh
number	n	2	1	2	1	
Wattage	w	5	10	9	35	
Hours	h	4	4	3	15	
Need	kWh	40	40	54	525	659

Electricity		4 people				Total need
		phones charging	camera charging	light bulbs	ventilation	kWh
number	n	4	2	2	1	
Wattage	w	5	10	9	35	
Hours	h	4	4	3	15	
Need	kWh	80	80	54	525	739

	Efficiency rating	Installed effect	Performance ratio	Radiation	Yearly yield	Area needed to meet requirement
		efficiency*area	losses	from Formit study	installed eff. * PR*radiation	
	%	kWp/m2		kWh/m2	kWh/year/m2	m2
Thin film	13	0,13	0,75	820	79,95	3,37
Polycrystalline	20	0,2	0,75	820	123	2,19
Monocrystalline	24	0,24	0,75	820	147,6	1,83

	Embodied energy	Embodied CO2	Total embodied energy	Total embodied CO2
	MJ/m2	kg/m2	MJ	kg
Thin film	1305	67	4402,8	226,0
Polycrystalline	4070	208	8925,4	456,1
Monocrystalline	4750	242	8680,5	442,2

SSW facade	
	Year cumulative
	kWh/m2
30	776
40	814
50	832
60	828
70	803
80	757
90	689

Source for efficiency and performance ratio: Solar Energy for Us (2016) *Solar Panel Efficiency and Lifespan*. [online] SolarEnergyForUs. Available at: https://solarenergyforus.com/solar-panel-efficiency-lifespan/ [Accessed at: 28. Oct 2019]

Source of amount of embodied energy pr type of cell: Jha, N. K. (2016). *Green Design and Manufacturing for Sustainability.* Taylor & Francis Group, LLC. [eBook], page: 38. Available at:https://books.google.dk/books?id=BPUYCwAAQBAJ&pg=PA38&lpg=PA38&dq=embodied+energy+monocrystalline+4750+mj/m2&source=bl&ots=rv8A5X_z5c&sig=ACfU3U0AGnwD_xeAzyIxOI4w5S3UyHZqcg&hl=da&sa=X&ved=2ahUKEwjMgOT55r7lAhUa7KYKHd5nADgQ6AEwCXoECAkQAQ#v=onepage&q=embodied%20energy%20monocrystalline%204750%20mj%2Fm2&f=false [Accessed 28. Oct 2019.]

Annex 11: Calculation of input demands for gas, electricity and water + calculation of tank sizes

Gas		2 people	4 people	
Cooking hours	h	0,5	0,5	
Gas	m3/hours	0,4	0,4	
Total gas need	m3/hours	0,2	0,2	
Water heat capacity	kJ/kg/K	4,19	4,19	
Degrees to heat up	K	17	17	
Energy for heating water	MJ	4,8	9,5	
Energy of biogas	MJ/m3	31,2	31,2	source: Lemviggas.dk
Gas for water heating	m3	0,15	0,31	
Total gas need	m3/day	0,35	0,51	

Water		2 people	4 people
Showers	l/minute	7	7
Minutes	n	6	12
Water for shower	l	42	84
Handwash	l/minute	6	6
Minutes	n	4	8
Water for handwash	l	24	48
Drinking water	l/person	0,5	0,5
Water for drinking	l	1	2
Total water need	l/day	67	134

Electricity		2 people				Total need
		phones charging	camera charging	light bulbs	ventilation	kWh
number	n	2	1	2	1	
Wattage	w	5	10	9	35	
Hours	h	4	4	3	15	
Need	kWh	40	40	54	525	659

Electricity		4 people				Total need
		phones charging	camera charging	light bulbs	ventilation	kWh
number	n	4	2	2	1	
Wattage	w	5	10	9	35	
Hours	h	4	4	3	15	
Need	kWh	80	80	54	525	739

Tank sizes:

Compost toilet

	Waste pr day/person	Emptied after n days	Tank size 2 person cabin	Tank size 4 person cabin	Tank size 2 person cabin	Tank size 4 person cabin
	m3/day	n	m3	m3	l	l
Solid waste	0,0002	90	0,036	0,072	36	72
Liqiud waste	0,0007	14	0,020	0,039	19,6	39,2

Water

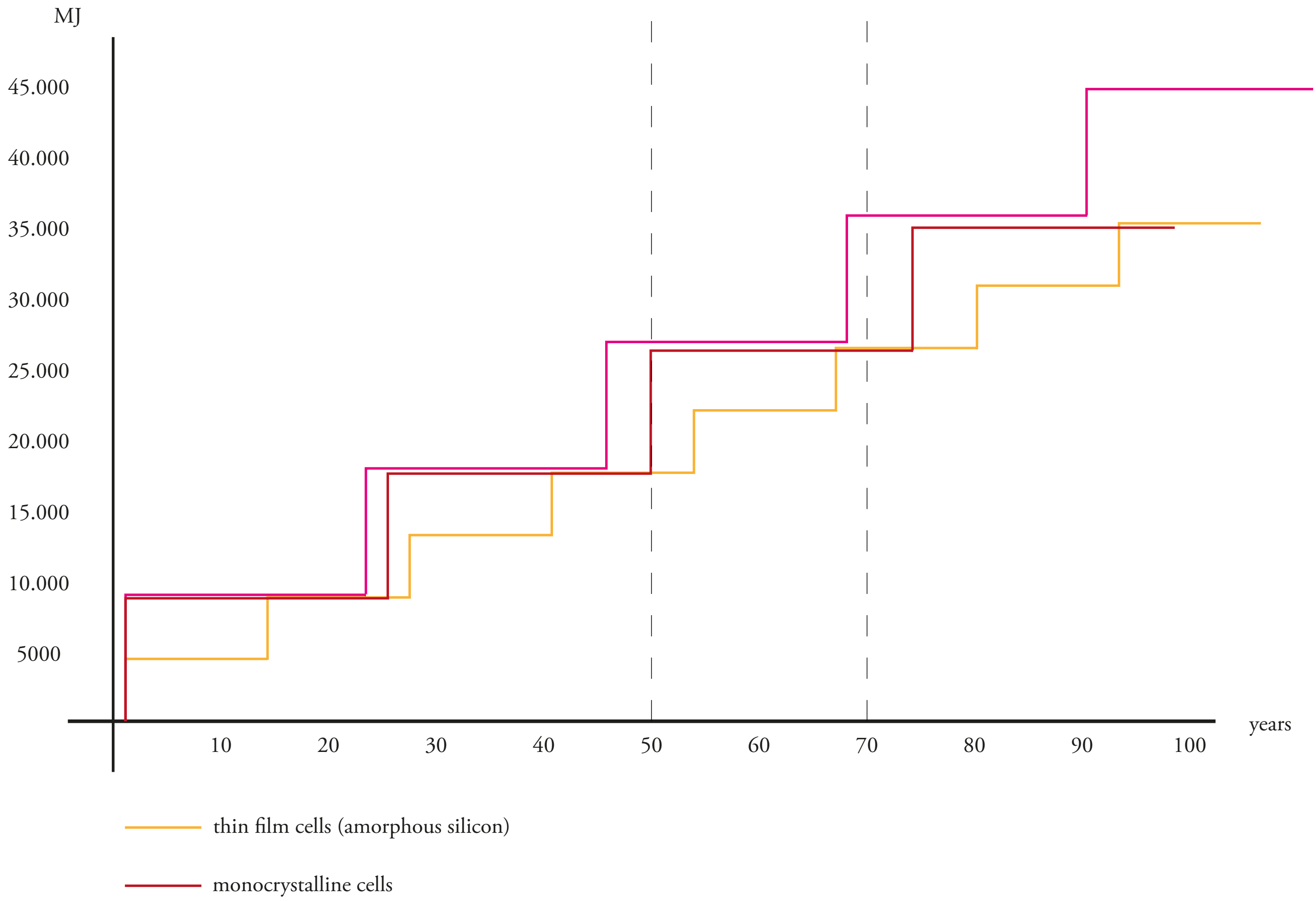
	Water need 2 person cabin	Water need 4 person cabin	Possible floor area for tank in cabin	Height of tank	Tank size	Need change after n days 2 person cabin	Need change after n days 4 person cabin
	m3/day	m3/day	m2	m	m3	n	n
Clean water	0,067	0,134	0,85	0,8	0,68	10,15	5,07
Greywater	0,067	0,134	0,85	0,8	0,68	10,15	5,07

Biogas digestor tank

	Amount pr day	TS	VS	VS	Water added	Retention time	Tank size	Tank size
	kg	%	%	kg	l	days	l	m3
Horse manure (substrate input)	170	0,3	0,84	42,84	171,36	50	8610,84	8,61

Annex 12: Expected life time of PV cells and maintenance

As the embodied energy of a building element increases every time the product is replaced, it was worth investigating which type of solar cells had the lowest environmental impact during their lifespan. The graph below shows how the embodied energy increases during time, and how often the cells need to be replaced. Considering a 50 year life span, the thin film cells and the monocrystalline cells reaches very close to the same embodied energy, however the manual labour of changing the thin film cells more often should be considered.



Source for lifespans of cells: Solar Energy for Us (2016) *Solar Panel Efficiency and Lifespan*. [online] SolarEnergyForUs. Available at: https://solarenergyforus.com/solar-panel-efficiency-lifespan/ [Accessed at: 28. Oct 2019]

Source of amount of embodied energy pr type of cell: Jha, N. K. (2016). *Green Design and Manufacturing for Sustainability.* Taylor & Francis Group, LLC. [eBook], page: 38. Available at:https://books.google.dk/books?id=BPUYCwAAQBAJ&pg=PA38&lpg=PA38&dq=embodied+energy+monocrystalline+4750+mj/m2&source=bl&ots=rv8A5X_z5c&sig=ACfU3U0AGnwD_xeAzyIxOI4w5S3UyHZqcg&hl=da&sa=X&ved=2ahUKEwjMgOT55r7lAhUa7KYKHd5nADgQ6AEwCXoECAkQAQ#v=onepage&q=embodied%20energy%20monocrystalline%204750%20mj%2Fm2&f=false [Accessed 28. Oct 2019.]