Sustainability in Iceland
- a housing project -

Ríkey Valdimarsdóttir, MA4-ARK2, February 2010

TITLE PAGE

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Synopsis

The subject of this project is to design sustainable single family housing in Eskifjörður, Iceland. The building should to have a modern architectural expression, and at the same time relate to the landscape as well as Icelandic building traditions.

SUMMARY

In this project, eight sustainable single family houses, situated in Eskifjörður in Iceland, have been designed, and the process described. Calculations in Be06 have been performed and used in the design process to optimise the building's energy consumption. The houses fulfil the Danish Low Energy Class 2. Apart from that, the BREEAM accreditation method has been used to assess the buildings environmental impact. The buildings have achieved the rating Very good.

The buildings have a modern architectural expression. The materials used are both traditional Icelandic materials, such as concrete, as well as more sustainable materials. These include driftwood sheathing and sheep wool insulation.

The project culminates in the presentation of the final proposal.

PREFACE

This project is a Master thesis made by Ríkey Valdimarsdóttir at the faculty of Architecture & Design at Aalborg University, during the fall semester of 2009.

This report conveys the process of the development of eight sustainable single family houses in the small Icelandic town of Eskifjörður, which is a part of Fjarðabyggð municipality.

A list of sources can be found at the back of the report, along with a list of illustrations. Results from the Be06 calculations as well as the initial and final calculations files can be found on the CD attached to the report. The CD also includes the BREEAM EcoHomes 2006 Guidance and the EcoHomes 2006 Pre Assessment Estimator.

I would like to give thanks to Fjarðabyggð municipality for their assistance during the project, here especially Steindór Hinrik Stefánsson.
I would also like to thank Harpa Birgisdóttir at SBi for all her help with the BREEAM scheme.

Finally, I would like to give special thanks to my friends and family, who have given me so much help and support throughout the whole process.

INTRODUCTION

Energy in Iceland is produced from geothermal heat and hydro power. This makes the carbon footprint of Icelandic energy production very low, even compared to other sustainable energy resources, such as solar power and wind energy.

This makes Iceland an exciting country to build sustainable housing in, as the problems concerning sustainable construction are different than in most other European countries.

Sustainability is a considerably new subject area in Iceland and people are becoming more and more aware of the benefits of saving for example energy and water.

Materials such as mineral wool insulation and cement have been produced in Iceland for many years. As there are limited resources in Iceland for producing construction materials, most materials have to be imported. This is therefore one of the main issues when it comes to sustainability in Iceland.

As no models exist in Iceland for calculating or measuring the environmental impact of buildings, Icelanders have been looking into several accreditation systems, among other BREEAM.

In BREEAM, buildings are assessed through a row of criteria and given a rating based on their performance. The buildings then get a certificate confirming their rating.

TABLE OF CONTENTS

Analysis

MOTIVATION

Iceland has some of the most sustainable energy resources in the world, and is a leading country when it comes to this subject.
For this reason, it is interesting to take a look at how sustainable architecture can be developed in a country, where energy and heating considerations are minor issues.

Almost everywhere in Iceland, electricity and central heating in houses comes from sustainable sources. This means that when talking about sustainability in Iceland, other issues should be taken into consideration as well. This could for example include the energy use for production and transportation of materials.

In this project, a small area with a few single family homes, in the town of Eskifjörður, will be developed.

The objective is to make buildings with a modern architectural expression, with emphasis on clear form, open spaces and flexibility.
Furthermore, it is important that the architecture relates to its surroundings, and carries some reference towards Icelandic building traditions.

Calculations on building performance will be carried out during the design process, in order to optimise the designs.

METHOD

Tools and methods

It is the aim of the project that the houses shall pass the criteria of the BRE Environmental Assessment Method (BREEAM) and qualify for a BREEAM certification. The BREEAM system will be described in the project and during the design process, the design ideas will be held up against its criteria. Finally the buildings will be assessed through the BREEAM scoring system.

As BREEAM is developed in the UK, the method is primarily designed for use in the UK. It can, however, be adapted for use in other countries. As this has not yet been completed in Iceland, it will be necessary in this project to be critical when it comes to some criteria. These will have to be adjusted to fit better to Icelandic regulations and conditions, should BREEAM be taken into use in Iceland.

As well as using BREEAM to assess the environmental performance of the buildings, an energy calculation will be carried out on the final design suggestion. This calculation will be done using the energy calculation program Be06, which calculates the annual energy use per m2 of the buildings.

As there currently exist no standards on energy consumption in Iceland, the Danish standards will be used in the project. The goal is to at least comply with the criteria of the Danish Low Energy Class 2, which will soon be the standard in Denmark.

Daylight factor calculations will be carried out on the main living areas of the house, using Dial-Europe, to ensure good daylight quality.

Ill. 1: Geothermal activity.

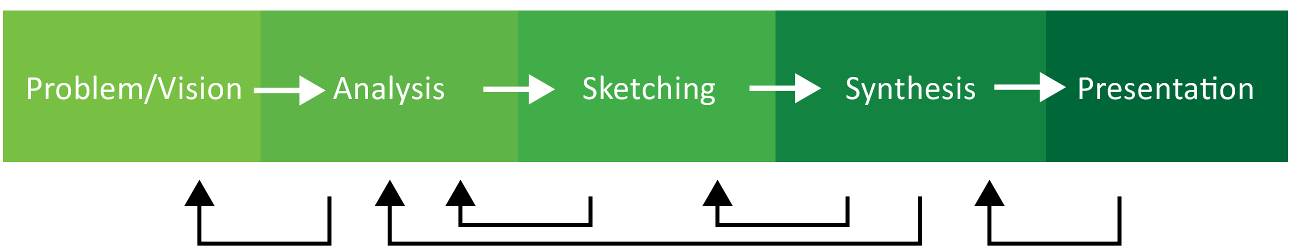
The Integrated Design Process

The purpose of the integrated design process is to make sure that during the design process, considerations about technical issues, such as indoor climate, construction, etc. are made. These elements have great impact on the design, and implementing them at an early stage will result in a more effective and less expensive process and a better building.
The integrated design process is divided into several overlapping phases (Ill. 2). As the diagram shows, it is possible to go back and forth between these different phases, for as the project progresses it may be necessary to go back and make adjustments to previous work.

Firstly, a problem or an idea for the project needs to be formulated. This describes the purpose or the vision for the project.
The first phase is the analysis phase. In this phase, research and registration should be made of the site, climate conditions, district plans, history, surrounding architecture, and other things relevant to the project. This should produce the material and knowledge necessary to move on with the project, to the next phase.

In the sketching phase, design ideas are tested and the process of finding a solution is begun. It is important to think about the influences that building form, construction principles, the building envelope, placement, etc., have when working on the design of the building. During this phase, calculations should be made simultaneously with the sketching in order to test the designs and thus be able to make educated choices towards the most optimal building. The iterative process in this phase insures that the architectural as well as technical aspects of the project are considered equally.
The synthesis phase is where all the different elements in the project come together to create a building which lives up to the goals set in the beginning of the project, both technically and architecturally. In this phase, the building is optimised and final calculations are carried out.

Finally, the project is presented in a report containing documentation of the process and calculations, as well as images and drawings of the building. In addition, the project is presented on a poster and in physical models. (Knudstrup 2005)



Ill. 2: Overlapping phases in the integrated design process.

The table below shows the tools and methods that are to be used in the different phases of the project.

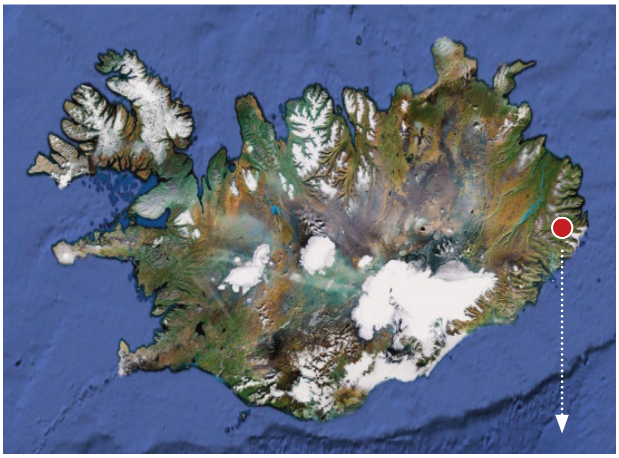
Analysis phase	Research methods Literature studies Internet search Mapping	
Sketching phase	Sketching Sketching on manifold Sketching in SketchUp Sketching in AutoCad Building models	Calculations Calculations in Varme spreadsheet Calculations in Be06
Synthesis phase	Sketching 3D model in SketchUp Plans etc. in AutoCad Models	Technical assessment Calculations of energy use via Be06 Assessment of building performance and sustainability using BREEAM
Presentation	Report - 3D visualisations - Drawings and sketches Poster Models	

Ill. 3: Phases of the integrated design process

PLACEMENT

The project area lies on a hillside in the outermost part of the town, at around 25-35 metres above sea level. The buildings will therefore not directly be influenced by the expected rise of sea level in the future.

In 2005, I did a project for Fjarðabyggð municipality, where I worked on making this part of the town denser as well as making suggestions for new residential streets in the area. I have chosen to work further with one of these suggestions in this project. There are presently no buildings nor a road on the chosen site and currently Fjarðabyggð has no plans to build in the area.



Ill. 4: Eskifjörður's placement in Iceland.

Because the area lies within town limits, it can be directly connected to the existing infrastructure, which will minimise the use of materials for pipes, drains etc..
This is in accordance with Fjarðabyggð's municipal plan, where it says that all new apartments should be within the existing town limits, and that the town should be made denser (Fjarðabyggð, 2009: 53).

As the town is built up against a mountain range, it is inevitable that the building plots will slope. This will, however, give the opportunity for each house to have a good view over the fjord. This also means that the sun will be able to reach the houses on each side of the street.

Two types of houses will be designed in the project, one type for each side of the road.

The project area's location in the town is good when considering the afternoon sun, as the mountains deeper in the fjord will cast a shadow on the town in the late afternoon. This shadow will reach the outermost part of town later than the innermost part, and therefore the day will seem longer.

Ill. 5: The project site's placement in Eskifjörður.

VISION

It is the vision in this project to create sustainable houses, which in some way combine modern architecture with Icelandic building traditions.

Rather than obscuring the identity of the landscape, the buildings should as far as possible be placed respectfully into the existing landscape, creating a contrast to it.

Clear form, **Open spaces** and **Flexibility** are key words.

Ill. 7: Casa Rural, buildings placed into the landscape.

Ill. 6: The project site´s placement on the hillside.

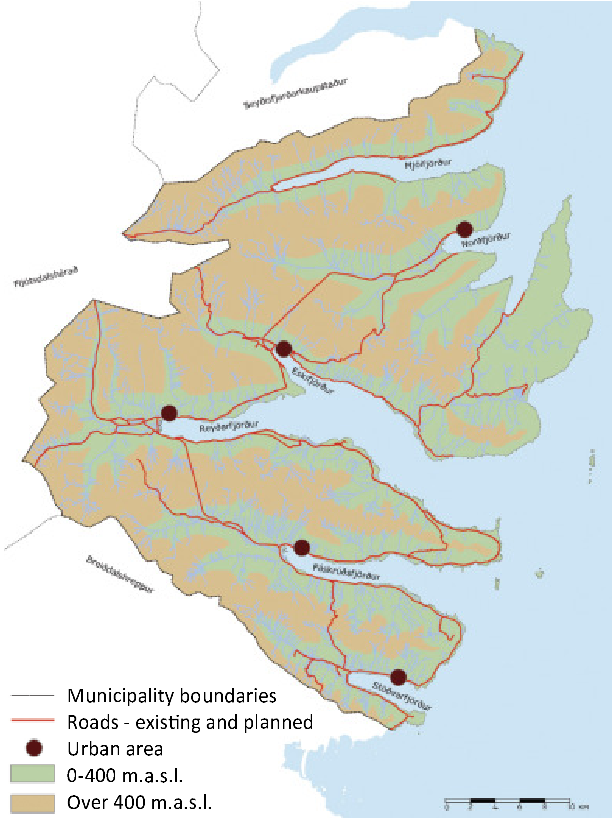
ESKIFJÖRÐUR

Eskifjörður

Eskifjörður is a small town of about 1050 inhabitants on the East coast of Iceland. It was one of the first towns in Iceland to become an authorized trade post in 1786, and was very important as such for a while (Travelnet, 2009).

In 1998, the three neighbouring towns, Eskifjörður, Reyðarfjörður and Neskaupsstaður, joined to form Fjarðarbyggð municipality. In 2006 three more towns joined Fjarðabyggð, which then had over 5500 inhabitants (see ill. 8) (Fjarðabyggð, 2010a).

Like all towns on the east coast of Iceland, Eskifjörður is placed on the north side of the fjord (see ill. 9). This has been done in order to get sunshine on the towns, as they would otherwise be in constant shadow from the mountains (Fjarðabyggð, 2009: 15).
The mountain across the town of Eskifjörður is called Hólmatindur. It is 985 m high and is the pride of the people of Eskifjörður (see ill. 10) (Fjarðabyggð, 2010b).



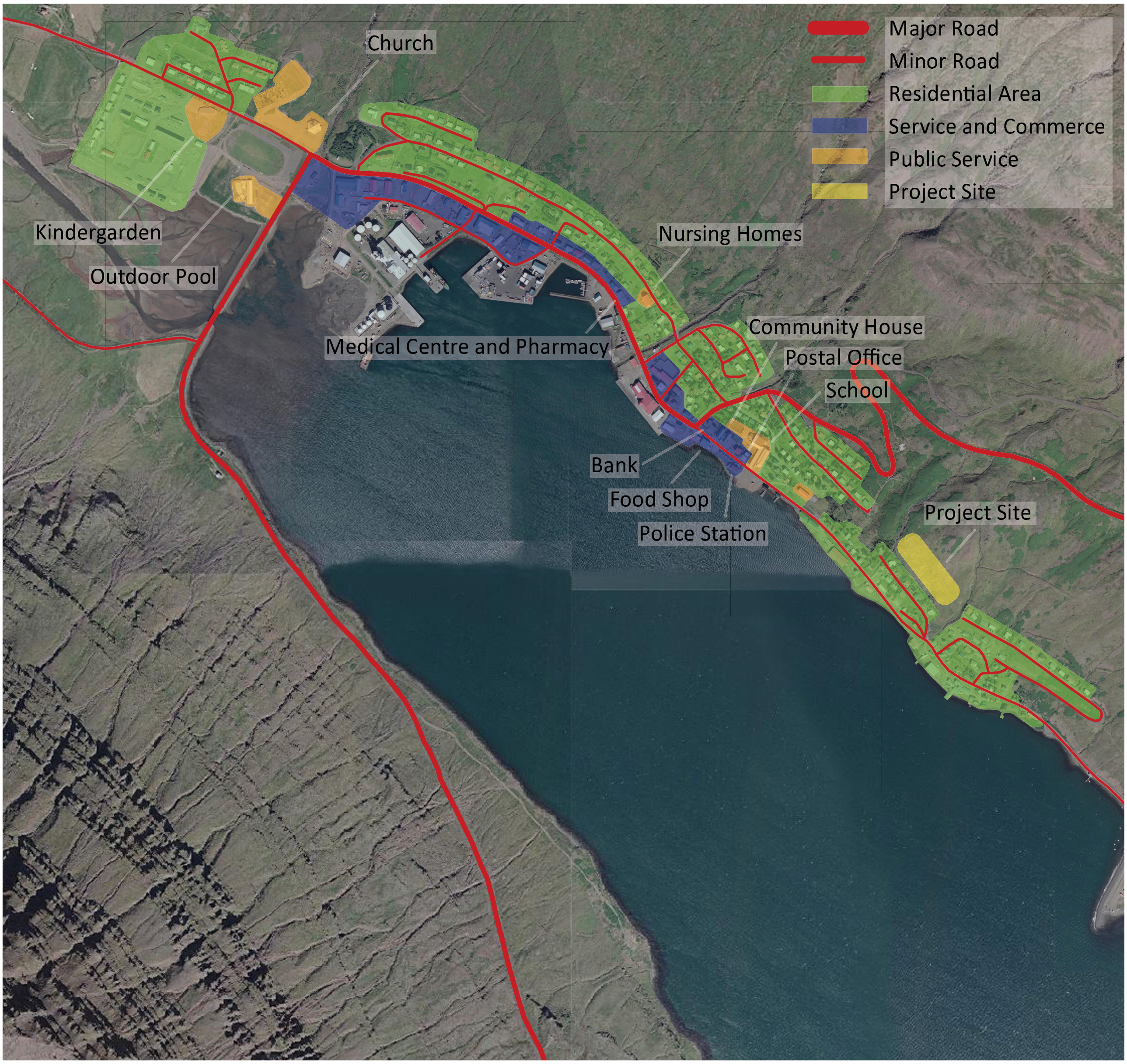
Ill. 8: Overview of Fjarðabyggð.

Ill. 9: Eskifjörður is placed on the north side of the fjord.

Ill. 10: Hólmatindur, the pride of Eskifjörður.

Context analysis

The context analysis shows the town's road infrastructure as well as some of the main local amenities. It also divides the town into zones, according to their main function.



Ill. 11: Main infrastructure and zones of Eskifjörður.

Fishing industry and Alcoa Fjarðarál

Fishing has long been the town's main industry. Eskifjörður is the hometown of one of Iceland's largest fishing industry companies, Eskja hf. (Fjarðabyggð, 2010b).
As the fishing industry has experienced a downturn recent years, many have started working in the Alcoa Fjarðarál aluminium plant in Reyðarfjörður fjord, which is one of the biggest industrial companies in Iceland.

Over many years, people had been moving away from the east coast to Reykjavík, as there had been a lack of jobs.
The idea of building an aluminium plant in Reyðarfjörður first came up in 1978. Finally, after over two decades of discussions of whether or not to establish heavy industry on the east coast, plans for building the plant were initiated. Constructions started in 2004 and the Alcoa Fjarðarál aluminium plant was officially opened in 2007.

When construction on the aluminium plant started, people started to move back to the east fjords. Many new jobs were created, which were both directly and indirectly connected to the aluminium plant.
Now, people could finally afford to restore or sell their houses, and new houses were built for the first time in over a decade.

In connection to the aluminium plant, a large harbour was built by the coast, where the alumina is shipped to the plant. This harbour is now the second largest harbour in Iceland, servicing most of the eastern part of the country (Jónsdóttir & Johnson, 2007).

Ill. 12: The church, built in 1999.

Ill. 13: Randúlfssjóhús, 1890.

Ill. 14: Randúlfssjóhús, 1890.

Architecture

The central and the outermost parts of Eskifjörður are the town's oldest parts. They contain some of the town's oldest buildings, including the old fisherman houses by the shore, some of which have been turned into museums. Most of these houses were built in the late 19th and the early 20th centuries (Veðurstofa Íslands, 2001) and are worth preserving. They possess an aesthetical quality different from the towns other buildings.

In the mid 20th century, especially the 1960's and 70's, Eskifjörður expanded and took the form it has today (Veðurstofa Íslands, 2001). Many of the town's houses are therefore built in a late functionalistic style. They have plane facades, big windows and large rooms (see ill. 15).

Recently, in connection with the economic upturn in the area, new houses have been built. Many of these houses are imported prefabricated houses, from Denmark, Norway, Canada and other countries.

The most common housing type in Fjarðabyggð is the single family house. In Eskifjörður, single family houses make out approximately 85% of all apartments. There are four large apartment buildings (with over 6 apartments) and a few small apartment buildings or row houses (with 3-5 apartments) (Fjarðabyggð, 2009: 53).
Landscape, industrial structure, economy, culture, values and societal attitudes in the community at each time are all factors which have contributed to the choice of housing type over time (ibid., p. 56).


Ill. 15: Single family house, built in 1962.


Ill. 16: Friðrikshús, 1917.


Ill. 17: Fisherman houses built between 1890 and 1947.

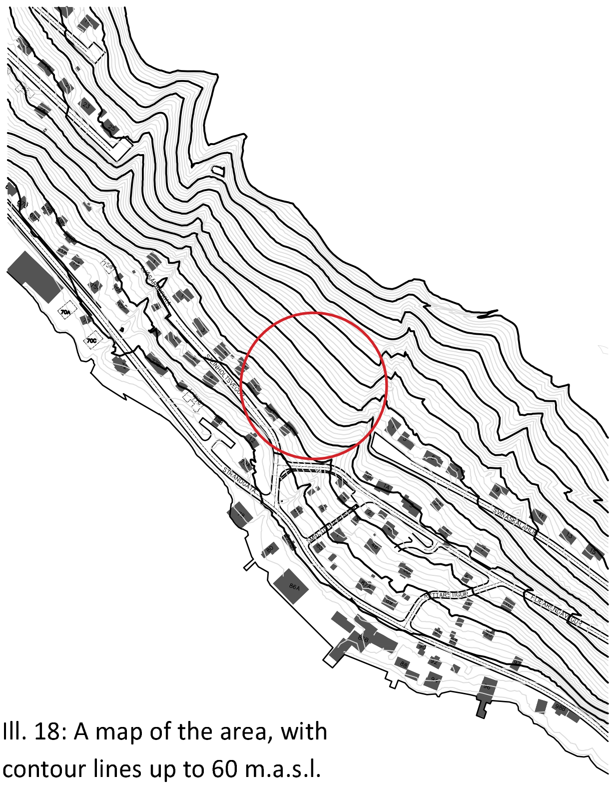
Topography

Iceland is a mountainous country devoid of trees, and with sparse vegetation.

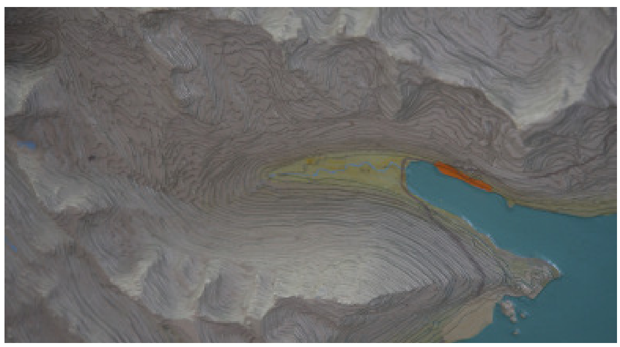
The main characteristics of Fjarðarbyggð municipality, are its relatively deep fjords, valleys, coves and mountain areas. As with the rest of the country the valleys, fjords and mountains were formed by the glaciers that covered the country during the last ice-ages. As these glaciers rolled on over the country they formed its ruff exterior, and as they subsequently melted away with rising temperatures they left it with its awe inspiring landscape.

In Fjarðarbyggð, all inhabited fjords lie from east to west, and here habitation has mainly formed on the northern side of these fjords as this is where there are the best chances for sunlight (Fjarðabyggð, 2009: 15).

The Fjarðarbyggð area's bedrock is among the oldest geological formations in Iceland, which are partly made up of basalt, originating from volcanic or effusive eruptions, and partly of volcanic origin from central volcanoes, here consisting of basalt, andesite and rhyolite (ibid.). The municipality´s bedrock is relatively solid with minimal runoff of groundwater, i.e. as this mainly takes place in more loose strata, such as sand, river spits and scree (ibid.).



Ill. 18: A map of the area, with contour lines up to 60 m.a.s.l.

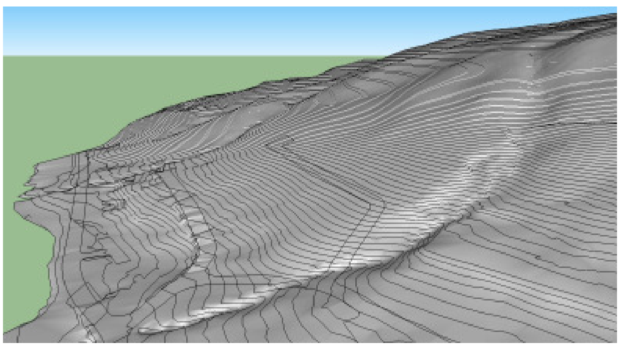


Ill. 19: The topography of Eskifjörður.

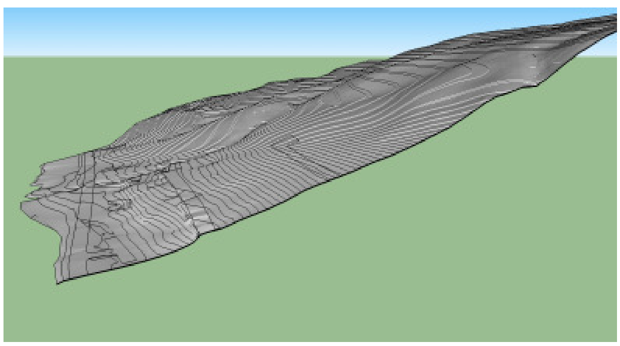
With regards to the soil in the area, this is mostly sparse soil. However most valleys and the small lowland areas in the innermost parts of the fjords are covered in vegetation – although this grows more sparse higher up in the mountains (ibid.). This vegetation consists mainly of various low-growing trees and heathers, such as blueberry heather, moss, willows and low-growing downy birch.

The topography of Eskifjörður is greatly characterized by the surrounding mountain range, and here especially the town's landmark mountain Hólmatindur, which rises 985 meter from sea level. The town itself however is built into the opposing hillside, where houses have traditionally been built into the sloping hillside of the northern mountain range. This mountain range consists of three mountains, Harðskafi, Ófeigsfjall and Svartafjall/Svínaskálahlíð (Arnalds et al, 2000). Whilst Hólmatindur is quite steep, the other mountains surrounding the town rise more gradually and are therefore less steep.

The mountain side is marked by a series of small rivers and brooks, that flow through the settlement and into the fjord (ibid.).



Ill. 20: The topography of Eskifjörður.



Ill. 21: The topography of Eskifjörður.

ICELANDIC CLIMATE

Contrary to common belief the country of Iceland has a relatively temperate climate. That is, especially seen in light of its northerly location – where the country lies just south of the Arctic circle. This is due to the influence the Gulf Stream has on the climate, as mild southerly ocean currents flow along the southern and western coasts of Iceland warming up the island and creating a relatively mild climate (Veðurstofa Íslands, 2009; Einarsson, 1984).

This means that with regards to the whole of Iceland the average daily maximum temperature ranges from 6 to 16°C during the summer and from -10 to 0°C during winter, whilst the daily minimum temperature ranges from 0 to 8°C in summer and -20 and -2°C in winter (Björnsson et al, 2007: 55).

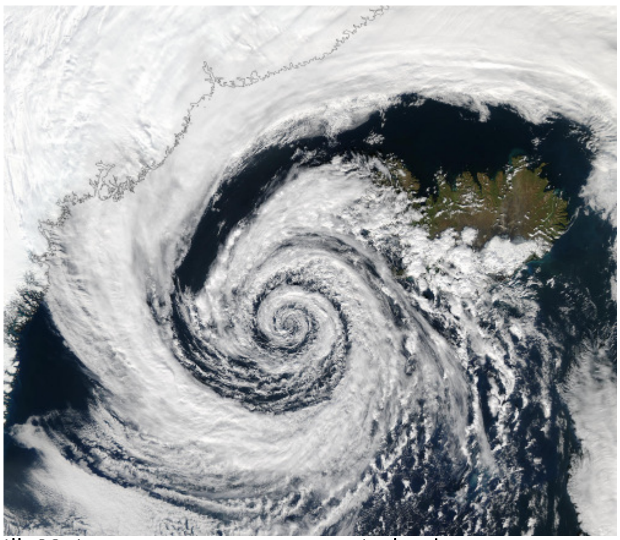
However, as this brings together mild air from the Atlantic and cold air from the Arctic this results in a relatively dynamic weather system (ibid.). That is, a system characterized by frequently changing weather, rain torrents (mostly concentrated in the south and west) and relative storminess (ibid.). This means that average wind velocities are generally high, especially in coastal areas and during winter, where typical winter values of mean monthly wind velocity are 6-7 m/s and 4-6 m/s in summer (Einarsson, 1984: 688).

Main weather types

Icelandic weather can be described as consisting of eight different main weather types, i.e. southeastern, southwestern/western, southern with warm air mass, warm air mass originating in Europe, eastern, northeastern, northern, and a high over Iceland (ibid., p. 676pp).

Generally speaking, this creates relatively different weather condition in the different parts of the country, however this also creates certain persistent weather trends in certain parts of the country (ibid.). For instance, where this creates popularly known weather conditions such as the persistent 'eastern fjord fog' in the east; heavy snow in winter, and relative warmth in summer, in the north and east; and greater precipitation and wind in the south.

With regards to the north and northeastern corner of the country, where Fjarðabyggð municipality is situated, this part of Iceland experiences the least precipitation, roughly



Ill. 22: Low pressure system over Iceland.

400-600 mm as opposed to 1000-1600 mm in the costal areas of southwestern and western Iceland (ibid., p. 684). However, during winter the north and northeast experience most of their precipitation as snow, which also means that these parts of the country are also covered in snow to a greater degree than other parts of the country, i.e. 50-70 % snow cover as opposed to 15-38% in the south and west of Iceland (ibid., p. 686).

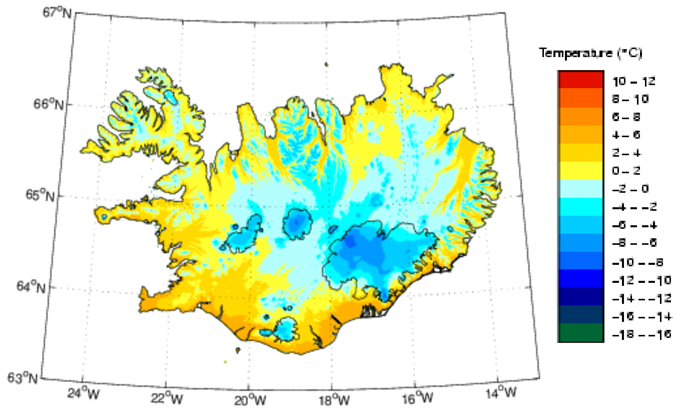
As aforementioned, the Icelandic climate is relatively temperate given its northerly situation, where the country experiences cool summers and mild winters.

Generally the month of July is the warmest in Iceland except for the north and east coasts where August is slightly warmer, and February tends to the coldest month in Iceland, except for the southwestern part of the country where January is colder (ibid., p. 681).

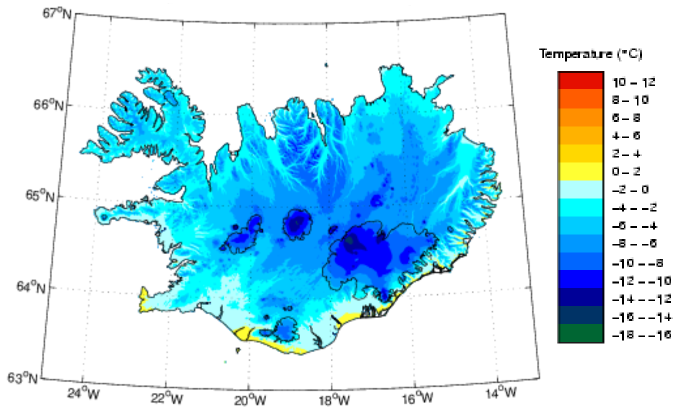
Therefore the annual average temperature in Iceland rarely rises above 4-6°C except for in the south and southwest parts of the country (ill. 23).

During winter, which as mentioned before is generally mild, the temperatures in the coastal lowlands are around 0°C and -10°C in the high-lands (Ingólfsson, 2009).

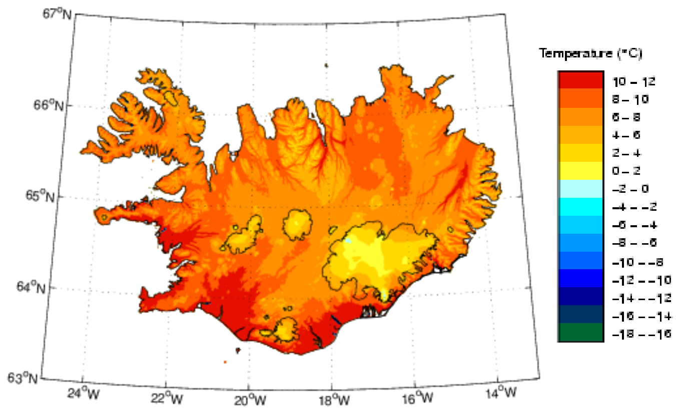
During the summer, the average temperature of July, the warmest month in Iceland, exceeds 10°C in the lowlands of southern and western Iceland but stays below that in other parts of the country (ibid.).



Ill. 23 Mean annual temperature (1961 - 1990).



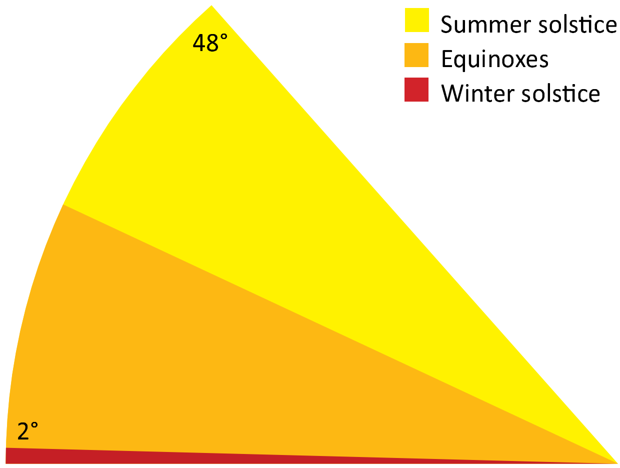
Ill. 24 Mean January temperature (1961 - 1990).



Ill. 25 Mean July temperature (1961 - 1990).

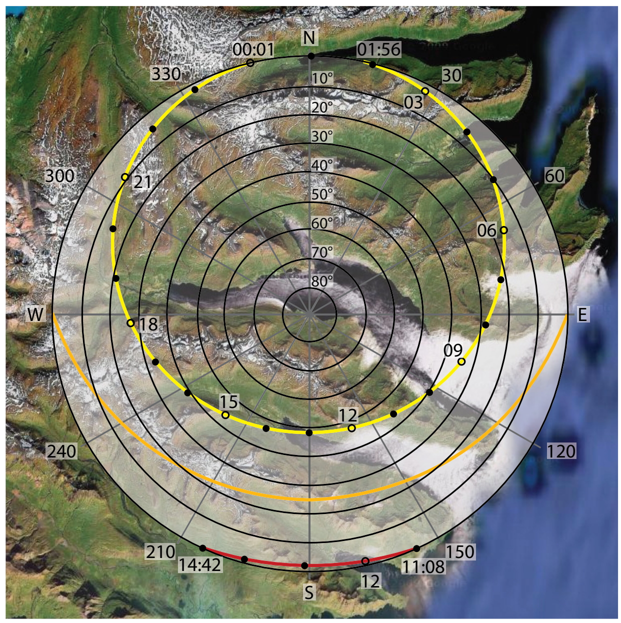
Fjarðabyggð

The proximity to the Arctic circle means that during summer it is bright the whole day and the sun sets for only a few hours.
Winter days, however, are dark and the sun only rises a few hours a day (see ill. 28).
In Eskifjörður, the sun doesn't rise from behind the mountains for about two months during winter, approximately from the middle of November to the middle of January.
The sun also disappears behind Hólmatindur for a part of the day in the spring and fall, as it doesn't rise high enough in the sky to rise above the mountain.



Ill. 26: Solar altitude angles in Iceland.

Ill. 27: Position of the weather stations.

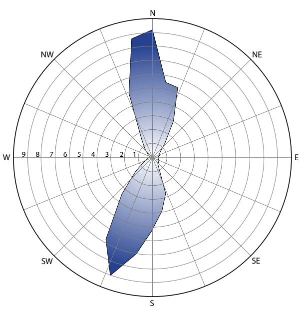


Ill. 28: Sun path diagram.

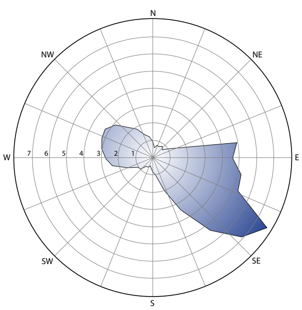
Two weather stations, which are placed in Fjarðabyggð, have been used to measure precipitation and wind conditions. The results can be seen in ill. 29-32.
The weather stations are placed at Dalatangi and Kollaleyra (see ill. 27).
The position of the Dalatangi weather station makes it susceptible to different wind conditions that the one in Kollaleyra. As the Kollaleyra weather station is placed deep in Reyðarfjörður fjord, results from this station are considered more alike weather conditions in Eskifjörður.

As can be seen on ill. 29-32 the wind in the fjords comes mainly from SE in summer and W in winter.

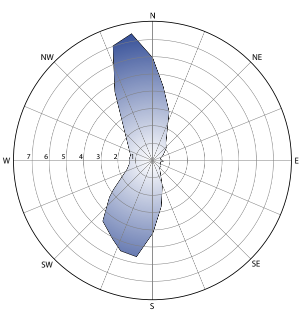
Ill. 34 shows the mean precipitation in this area and it can be seen that precipitation is the highest in autumn and lowest during spring and early summer.



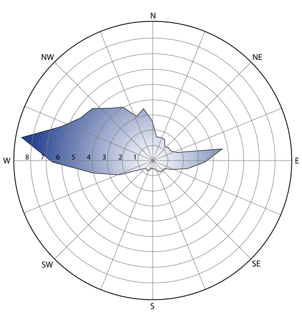
Ill. 29: Dalatangi summer 1995-2006 average.



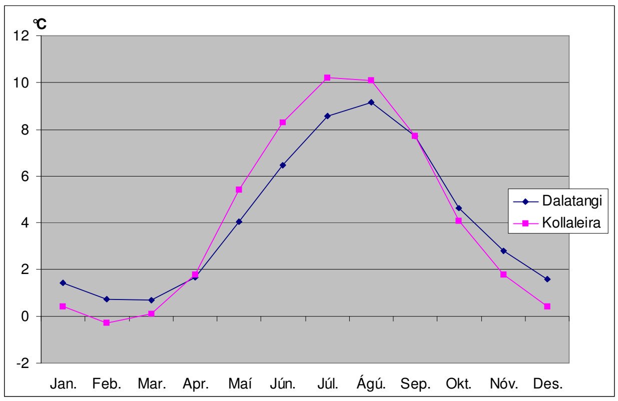
Ill. 30: Kollaleyra summer 2001-2006 average.



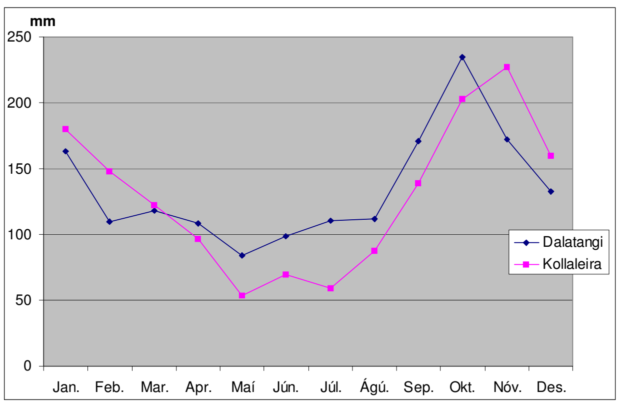
Ill. 31: Dalatangi winter 1995-2006 average.



Ill. 32: Kollaleyra winter 2001-2006 average.



Ill. 33: Mean temperatures at Dalatangi and Kollaleyra 1990-2006.



Ill. 34: Mean precipitation at Dalatangi and Kollaleyra 1990-2006.

ICELANDIC CULTURE

Throughout history, Icelanders have had to live with the island's harsh environment and the constantly changing weather. This has undoubtedly influenced the character of the Icelandic people, who have learned to adapt quickly to new circumstances and make quick decisions (Parnell & O'Carroll, 2007: 31).

Iceland lies only a few kilometres from the Arctic Circle, which means that in the summertime, the sun only sets for a few hours and the night is as bright as day. This also means that the winter days are dark, which results in many Icelanders being prone to midwinter depression.

Because of Iceland's isolation, the people are very self-reliant and independent. They are also very proud of their heritage and language, and are not keen on adopting foreign words. Instead they come up with new words, which conform to the Icelandic language. The Icelandic language has changed remarkably little over the centuries, and Icelanders are still able to read the old sagas, written 800 years ago. The literacy rate in Iceland is a full 100 % and Icelandic people love reading and writing books and making music, and are generally very artistic. In fact, the number of books published in Iceland is the greatest in the world, per capita (ibid., p. 38).

Family names are rarely used in Iceland. In stead, children are given their fathers, or sometimes mothers, first name as a surname, with the suffixes -dóttir or -son for girls and boys respectively. A boy named Jón, with a father named Einar, would therefore be called Jón Einarsson, and his sister would be Einarsdóttir.
People therefore don't address each other with surnames, but use first names instead. This also applies to the president (ibid., p. 31).

Facts about Iceland

Population: 317.593 (Dec. 1st 2009)
Foreign citizens: 21.921 - 6,9%
Capital: Reykjavík (pop. 200.852 incl. capital region)
Size: 103.000 km^2 - ca. 80% uninhabitable
Language: Icelandic

(Hagstofa Íslands, 2010)
(Udenrigsministeriet 2009)

The general mentality in Iceland is, that things have a way of sorting themselves out, no matter how bad they get, or as they say: "Þetta reddast".

Icelandic people are very superstitious and believe in the supernatural. Ghosts, trolls, elves, fairies, gnomes and hidden people are the subjects of many stories, in which many people still believe in. Even the 13 Icelandic Santaclauses are the sons of trolls and live in the mountains (ibid., p. 32).

Icelanders are very enthusiastic when it comes to new things and are quick to adopt new technologies. This interest in the new and unknown can also be seen in the number of people who go abroad, be it for work, education or just a vacation. Although so many Icelanders feel the need to emigrate, most of them return home, as the bond between country and people is very hard to break (ibid., p. 31-32).

Icelanders work hard and live long. Although the average working week in Iceland has recently been growing shorter, Icelandic people work 40 hours a week on average (full time and part time employment), which is more than in most other countries. Traditionally, Icelanders start working over the summer at the age of 11-12 years old (Statistics Iceland, 2009a).

The mean life expectancy in Iceland is also one of the highest in the world. In 2008 it was 83.0 years for women and 79.6 years for men, which is the highest life expectancy for men in the world (Statistics Iceland, 2009b).

Along with the hard work come high living standards. After WW2, where Iceland's geographical placement attracted the British Army and later the US Army, the countries economy started to blossom (Parnell & O'Carroll, 2007: 29). Icelanders are not afraid to borrow money to finance their lifestyle. Young people often take out loans to buy a house or an apartment, or a car, and spend the rest of their life paying off said loans (ibid., p. 32-33).

But still, Icelanders enjoy life. They love spending their time travelling, playing sports, partying or relaxing in one the country's many swimming pools.

Ill. 35: Relaxing in a swimming pool.

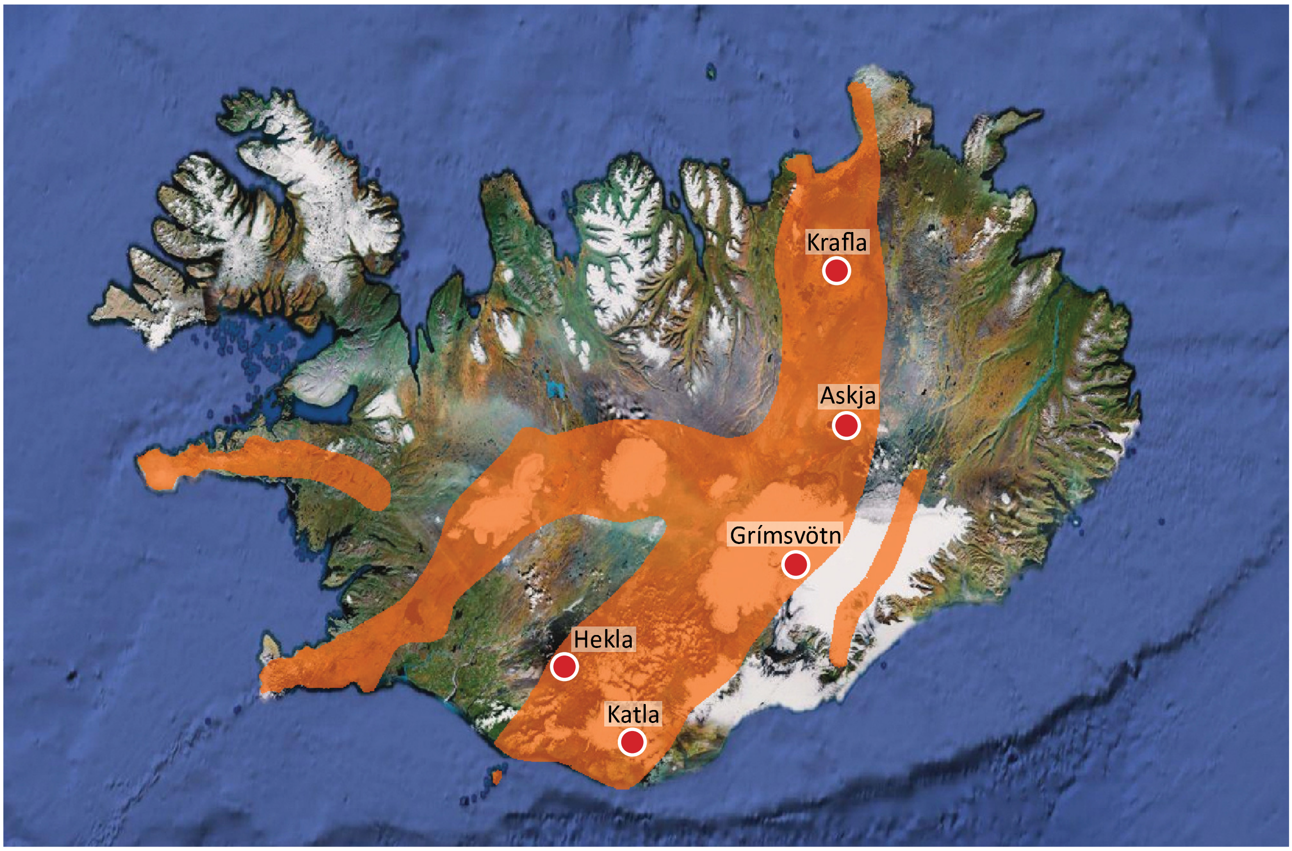
ENERGY RESOURCES IN ICELAND

Geologically, Iceland is a young country. It lies on the Mid-Antlantic Ridge, between the North American and the Eurasian tectonic plates. This means that earthquakes and volcanic eruptions are frequent, the most recent volcanic eruptions were in Hekla in 2000 and Grímsvötn in 2004 (ill. 36) (Veðurstofa Íslands, 2010a).

Around 80% of Iceland is uninhabitable, due to high mountains, deserts, icecaps, lava fields, extreme weather conditions and large rivers (Udenrigsministeriet, 2009; Parnell & O'Carroll, 2007).

There are 22 active volcanoes in Iceland and over a thousand geothermal areas and hot springs. (Parnell & O'Carroll, 2007: 44)

82% of all energy used in Iceland comes from sustainable resources. Other energy comes from imported oil and coal, mainly to power cars, aeroplanes and ships.
The renewable energy is produced in hydropower stations, which produce 20% of the energy, and in geothermal stations, which produce 62%.
Geothermal resources produce around 90% of Iceland's total heating needs (Geysir Green Energy, 2010a).



Ill. 36: The volcanic zones in Iceland and some of the most known volcanoes.

Hydropower

Hydropower stations produce electricity by harnessing the energy from glacial rivers. The natural water cycle is eternal, so the energy source cannot be depleted, and the process is completely emission-free and sustainable.
A hydropower plant uses the energy from the falling water in waterfalls to create electricity. The water runs through a turbine, which propels a magnetised wheel in the generator. As the wheel turns, electricity is generated and led through copper coils. High-voltage cables then conduct the current into the electricity grid (Landsvirkjun, 2005).

In Iceland, the need for electricity is much heavier in winter than in summer. However, the flow of the glacial rivers peaks in the summer, when the glaciers melt, making it hard to produce electricity in the winter. The rivers are therefore dammed, creating reservoirs where water is collected during summer. The water is stored there, so electricity can also be produced in the winter (ibid.).

Hydropower is mainly used to power large scale industry in Iceland.

Geothermal energy

As the tectonic plates move, the earth's crust is heated. This heat is used to generate electricity and hot water.
1-4 km deep holes are drilled into the ground, where the water reaches over 300°C. This lets out steam, which is lead through a separator, to separate water from the steam. The steam is then lead through a turbine, which produces electricity. It can sometimes be lead through the turbine more than once.
The hot water is used to heat up cold freshwater, which is brought through pipes to distributional stations and used for space heating. The water from the drill hole is then re-injected into the ground, to minimize harmful emissions (Geysir Green Energy, 2010b).

Half of the geothermal energy produced in Iceland in 2007 was used for space heating. A small part of it was used to heat greenhouses and swimming pools, for snow melting systems, aquaculture and industry, and a third was used for electricity generation (Orkustofnun, 2008).

Geothermal energy is a renewable energy resource. The geothermal fields renew themselves over a relatively short period of time, but can be expected to need to be rested after several decades of use (Landsvirkjun, 2005).

Iceland emits the least CO_2 in the whole western world, because of its sustainable electricity production, even though the electricity consumption per capita is the highest in the world. This is because of the large amount of energy going to large industries, like aluminium production (Landsvirkjun, 2005).

Hydropower and geothermal energy are largely underutilized resources in Iceland.
In 2003 it was estimated that only about 17% of the potential energy was being produced (Iceland Trade Directory, 2010).

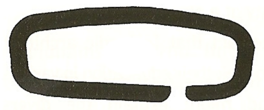
ICELANDIC BUILDING TRADITIONS

From settlement to the 19th century – Turf houses

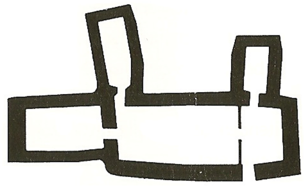
Since the settlement of Iceland in the year 870, its architecture has been strongly influenced from abroad, especially the Scandinavian countries. However, it has been necessary to adapt the building traditions to the islands harsh climate, which has made them unique.
The settlers built turf houses, from turf, wood and stone, using a building technique they had brought with them from Norway, where most of them came from. The houses were oblong, slightly convex longhouses, usually about 30 by 6 meters. There was only one room, but with different floor levels, differentiating between sleeping and working spaces. In the middle of the room there was a central hearth (ill. 37).

Later, in the 10th century, separate rooms started to appear in the back of the longhouse. In the 11th century more rooms were added, in separate annexes at the back and the end of the longhouse (ill.38).
In the 14th and 15th century, a kitchen and steam room were added, as well as a passage through the middle of the house, giving access to each room.

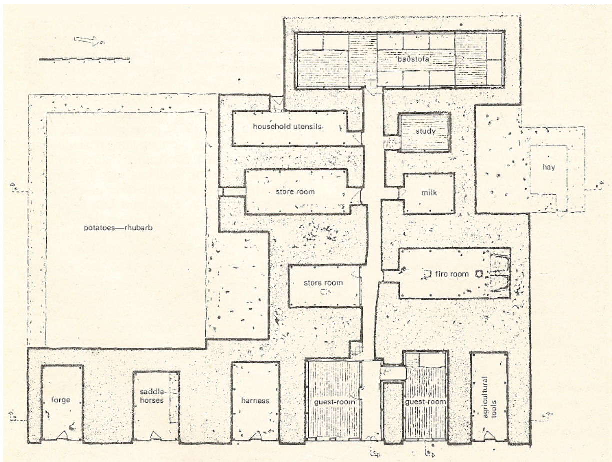
In the 18th century, the house plans had started to develop differently in separate parts of the country, although they didn't differ very much in appearance on the outside. By the 19th century most turf houses had been altered in a way to create an end wall, making the house appear as if several houses were built together, side by side. This type of turf houses is called burstabær (ill 40) (Abrecht, 2000; Morgunblaðið, 1987).



Ill. 37: Ísleifsstaðir, longhouse.



Ill. 38: Stöng, 1104.



Ill. 39: Glaumbær í Skagafirði, built ca. 1750 - 1879, inhabited until 1947.

Ill. 40: Burstabær.

From the 17th to the early 20th century – Stone constructions and timber buildings

At the end of the 14th century, Iceland came under the aegis of Denmark. Around the middle of the 18th century, some of Denmark's foremost architects of the time started designing stone buildings, the oldest one being built in Viðey in 1753 (Abrecht, 2000).
These buildings proved to be quite expensive, so after a short period of time, the Danish government decided to stop building stone houses in Iceland (ibid.).
In the late 19th century however, the construction of stone houses flourished. This revival of stone constructions in Iceland lasted until the start of the 20th century (ibid.).

In the early 17th century, merchants started to build wooden trading- and warehouses for use over the summertime. These houses were made from imported, ready-sawn timber from Scandinavia (ibid.).
Timber-frame buildings were also constructed at that time. They had infill of brick or brushwood and were clad with vertical weatherboards. The houses were tarred on the outside (ibid.).

Icelandic carpenters later developed these buildings, giving them higher rooms and bigger windows, cladding them with gray painted vertical slats or wooden shingles (ibid.).

In the mid 19th century, carpenters, who came home after studying abroad, brought with them new architectural influences, especially of classical architecture. This lead to an Icelandic classical timber architecture (ibid.).

In the late 19th century, Norwegian whalers and herring merchants, who came to the east and west coast of Iceland, brought with them prefabricated houses from Norway. These neo-Romantic, chalet style houses had great influences on Icelandic architecture, and soon Icelandic variants appeared (ibid.).

As timber was an expensive material and trade with Britain had been opened, houses soon ceased to be clad with timber and were clad with corrugated iron instead.

In the 20th century, Icelanders started to develop their own building methods, bringing timber house construction to a new level. However, after a big fire in central Reykjavík in 1915, a new building code enforced an almost total ban on timber buildings in urban areas (ibid.).

Mid 19th to the late 20th century – Concrete buildings

In the mid 19th century, in collaboration with Danish architects, an attempt was made to make stone buildings in Iceland. The buildings were constructed with rough-hewn Icelandic stone and glued together with cement-based mortar, which was being used in Iceland for the first time (Abrecht, 2000).

Some of the bigger houses, such as the Hegningarhúsið jail (ill. 41) and the Parliament House in Reykjavík (ill.42) had great influence, both for the craftsmen's knowledge and on architecture in general. Many buildings were made in their image.

In lack of a proper building material, a mason in Akranes used gravel and cement, which he cast into bricks, to build from. A few years later the first concrete building rose in Iceland. Concrete soon became common as a building material. In the early 20th century many concrete buildings rose in Reykjavík. They resembled the traditional timber and stone buildings in appearance and plan, but by the 1920's, concrete buildings had developed their own character and they even differed between different parts of the country (ibid.).

Some of the strongest influences on architecture in Iceland at that time came from Scandinavian classicism, but architects would also seek inspiration from the old turf houses and Icelandic nature. The National Theatre (1928-50) (ill. 44) and Hallgrímskirkja church (1937-86) (ill. 43), with their columnar-basalt forms, are good examples of this.

In the 1930's, architects were influenced by functionalism, as a new generation of architects came back home after studying abroad. Soon this new style was adapted to Icelandic weather conditions and building traditions (ibid.). The rendering on the exterior walls was mixed with ground local stone in order to make the surface of the buildings more durable. This became a strong characteristic of Icelandic functionalism (ill.45) (ibid.).

After the Second World War, new architects returned home from studies, bringing with them new influences, which produced more open buildings, with big glass walls, pure colours and strict geometrical forms, resembling

Ill. 41: The Hegningarhúsið jail.

Ill. 42: The Parliament House in Reykjavík.

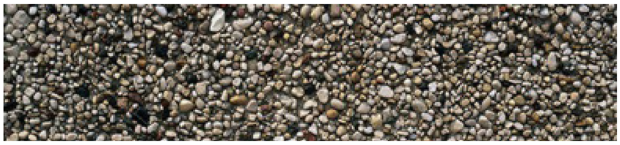
Ill. 43: The Hallgrímskirkja church.

the abstract paintings of the 1950's. Later, the open floor plans and flexible spaces became even more common.

Up until the 1970's, architecture had been strongly influenced from Denmark, as many architects studied there, but as architects started to go to other parts of the world to get their education, other trends found their way over as well (ibid.).

In the late 20th century many architects started to look beyond these influences, and adapt their ideas to local conditions and the identity of the location. They started looking again at the turf houses, corrugated iron cladding, concrete technology and the natural building materials at hand (ibid.).

Ill. 44: The National Theatre.



Ill. 45: Exterior wall stone rendering.

Ill. 46: New interpretation of classic icelandic building materials.

MATERIAL RESOURCES

Concrete

The most common building material in Iceland is concrete. This however is not the most sustainable material that can be found. The production of cement is very energy demanding and the materials used in concrete do not come from sustainable resources. However as energy in Iceland is primarily clean energy this counteracts the traditional emission factors and decreases their negative environmental effect to a certain degree.

In Iceland concrete has been manufactured for over half a century, here firstly in a government run concrete factory from 1958 to 1993, which then was privatized, and in 2003 the factory was bought by its current owners. Traditionally concrete is based on limestone and clay, but as Iceland is a volcanic country the Icelandic concrete is manufactured mainly with basalt (Sementsverksmiðjan, 2010). As sufficient amounts of limestone and clay are not available in the country other materials are used, i.e. mainly shell sand, from the bottom of Faxaflói bay, and rhyolite, extracted from a nearby mine in Hvalfjörður (ibid.).

Up until 1970 Sementsverksmiðjan was the sole provider of concrete in Iceland, but as Iceland became an EFTA member in 1970 there began a process of gradual opening up of the Icelandic market to concrete import (ibid.).

Even with increased market freedom Sementsverksmiðjan kept a 55-75% market share for the greater part of the 20th century, however the factory has come under great pressure from Aalborg Portland, which has been one of the main importers of concrete to Iceland. Aalborg Portland has come under considerable criticism, due to accusations made against the company for trying to sell concrete far below normal market price levels to increase its overall market share and drive the local Sementsverksmiðjan out of the market. These accusations have been forcefully denied by Aalborg Portland, where it has been pointed out that Sementsverksmiðjan itself has offered prices well below normal market prices (AMX, 2009).

However, with regards to the environmental factors connected to the manufacture of concrete it is clear that locally produced concrete is considerably less of an environmental burden, given that this eliminates the carbon emissions connected with foreign manufactures use of less clean

Ill. 47: Concrete.

energy and the considerable carbon emissions related to transport. Furthermore, due to the relatively extensive local use of concrete for construction over the years this has resulted in the development of a considerable local knowledge base with regards to concrete. There have even been made considerable strides in recent years, with regards to research into and future production of stronger and more environmentally friendly concrete in Iceland, which has attracted international attention (Viðskiptablaðið, 2009).

Recently, the international concrete industry has been looking into how concrete can be made more sustainable. The production of sustainable concrete entails different factors, such as the use of vegetable form oil for machines to reduce carbon emissions; the use of accumulated rainwater and recycled waste-water in production to minimize water usage; the reuse of crushed concrete in the production of new concrete; and the use of local materials in production to minimize transport – and thereby carbon emissions. Site waste management is also a factor in making the use of concrete more environmentally friendly, with the collection, sorting and re-utilization of different waste materials, such as wood, metal, cardboard, waste oil, chemicals, etc. (Betonindustriens Fællesråd, 2006).

Production of wood in Iceland

The Icelandic 'forests' have traditionally been seen as fodder for many jokes regarding the Icelandic flaura, i.e. if you ever find yourself lost in an Icelandic forest – just stand up.

However in recent years there has been some development towards increasing the domestic production of wood and related products in Iceland. As is, the import of wood and paper/cardboard amounted to 126.000 tons in 2008, whereas the domestic production amounts to around 790 tons – or roughly 0,6 pct. of the total import in tons (Ottesen & Eysteinsson, 2009).

With total forest area in Iceland growing gradually in size, there has been increasing debate around the usage of domestic sources of wood and timber – here also in relation to their interior and exterior use in buildings. Until now Icelandic wood has found varied use, such as where pruned wood is used for building traditional racks for drying fish, as wood chips for gardens – and more recently as fuel for industrial production, as firewood, for smoking various foodstuffs, and for traditional handicraft; older larch logs are used as fenceposts, sheltering fences, porches, exterior sheathing, panelling, parquet floors and furniture; Sitka spruce (Picea sitchensis) has found moderate use, mainly as outdoor tables, benches and shelters; wood shavings have been used in food production, i.e. as bedding for various livestock; and finally where various forms of spruce trees are grown for use as Christmas trees (Skógrækt Ríkisins, 2008).

The sale of Icelandic wood in whole logs and sawed wooden boards (dimensional lumber) in 2008 amounts to roughly 145 m3 in logs and 18 m3 in wooden boards (Skógrækt Ríkisins, 2008: 56f).

Driftwood

Driftwood is among the most environmentally friendly solutions for sheathing material in buildings there are, i.e. firstly because driftwood is in reality a discarded material, which otherwise might not be used, and secondly because driftwood, due to long-term exposure to saltwater, is saturated with salt which guards against rot and does therefore not require wood protection (Sesseljuhús, 2006: 6).

Driftwood has generally been seen as a considerable perquisite for those farmers lucky enough to own land adjacent to beaches where driftwood drifts ashore. Icelandic driftwood has its main origins in the rivers of Siberia, where they are carried down these rivers and out to sea. From there northeastern ocean currents carry the driftwood towards the drift or pack ice around the North Pole. After some time the timber then is released from the ice and is carried towards land with the East Greenland Stream where it lands mainly on the northern coasts of Iceland – after having spent up to 5 years floating in the sea (ibid.). The driftwood that finds its way to the Icelandic coasts consists mainly of pine, larch and lesser amounts of spruce and poplar trees (ibid.).

Ill. 48: Driftwood.

Insulation

The main production of insulation in Iceland is of the so-called 'Steinull' or mineral wool on the northern coast of Iceland. There the Icelandic company Steinullarverksmiðjan has manufactured insulation since 1985 and is capable of producing over 8.000 tons of insulation per year (Steinullarverksmiðjan, 2010).

As the manufacture is carried out using clean energy, i.e. electricity generated by hydroelectric power plants, and local raw materials, i.e. local basalt sand and crushed seashells – which are renewable resources, this minimizes the overall environmental pollution of the insulation, which is traditionally based on coal energy and extracting rock from mountain areas (ibid.).

There are other environmentally friendly types of insulation that are available in Iceland, i.e. paper insulation and wool insulation. Paper insulation consists mainly of cellulose, that is the fibres of trees and plants, where recycled materials, such as surplus newspapers, books and phone books are shredded and mixed with Borax, which is a natural mineral (Sesseljuhús, 2006: 4). This shredded paper is then pressed together into cubes for storage or transport, and then blown into the insulation compartments of the houses with blowers. Little energy is used in the production of paper insulation (ibid.).

Wool insulation consists of Icelandic sheep's wool, where there is mainly used surplus wool that is ill-suited for use in traditional woolen products, such as sweaters, hats, etc. (Sesseljuhús, 2006: 4). The wool is washed first in sodium bicarbonate, and later in environmentally friendly soap (ibid.). Thereafter the wool is boiled in high-pressure pots in a mixture of water and Borax (ibid.). This not only protects the wool from rot, insects and other vermin but also increases its fire resistance (ibid.).

The resulting insulation material offers similar insulation to dry mineral wool, however even when wet the wool offers better insulation than traditional insulation. This is due to the properties of sheep's wool, which can absorb humidity up to 1/3 of its own weight without losing its insulation properties. The insulation holds on to the humidity and emits it again when the air is dry. This helps create a good indoor climate in the building (ibid.).

Wool insulation requires no protective wear when being installed and is 100% natural. It also uses far less energy in production than most other insulation materials. Wool also eliminates many dangerous air born chemicals such as keratin, formaldehyde and ozone, which can be found in many modern construction materials. It is therefore very good for the indoor climate (ibid.).

Aluminium

Aluminium production started in Iceland in 1969 with the opening of the country's first aluminium smelter. Favourable energy prices and a relatively well educated workforce have made aluminium production an attractive business opportunity to foreign manufacturers and investors.

Currently there are three companies manufacturing aluminium in Iceland, Alcan in Hafnarfjörður, Alcoa in Reyðarfjörður and Norðurál in Hvalfjörður, and there are plans for building an extra smelter in the north of Iceland.

Icelandic aluminium production is primarily focused on manufacturing the raw material, with no substantial further production of aluminium products. However due to the rising production of raw aluminium in Iceland this creates an ideal opportunity for further development and manufacturing of aluminium products. This could for example benefit the construction industry, as the use of aluminium products for external sheeting and roofs is relatively common in Icelandic houses.

CLIMATE CHANGES & SUSTAINABILITY

Global warming

All living organisms on planet earth are facing serious consequences caused by the increasing amount of greenhouse gasses in the atmosphere and it is threatening the face of the earth as it is.

The global warming is considered caused mainly by human activities through the extensive usage of fossil fuels in the world, which has increased massively since the industrial revolution (Raupach M.R. et al, 2009; Jensen D. & Steffen K., 2009). Fossil fuel usage increases the amount of CO2 equivalents in the atmosphere and it is impossible for the natural greenhouse gasses to stay in balance. The natural greenhouse gasses are necessary for the planet to maintain life as we know now, and therefore big imbalances are harmful (DMI, 2008).

The main consequences predicted are; rising temperature that will cause unnaturally fast melting of the Poles and glaciers and large areas that will dry out, extreme weather conditions with catastrophic consequences, and sea level rise that will swamp huge areas. Apart from these there will be massive socio-economic imbalances in the world (UNFCCC, 2007).

Several initiatives have been made both globally, regionally and locally that could prevent or decrease the worst case scenario. The biggest global agreement is the Kyoto protocol, signed by 37 industrial countries. In the protocol the countries obligate themselves to decrease their greenhouse gas emissions by a certain percent before year 2012 (UNFCCC, 1998). To prevent the worst case scenario it is necessary to decrease the greenhouse gas emissions. One of the most important initiatives made by each country would be reducing the usage of fossil fuels and transfer to a more clean and green development.

As mentioned before, energy in Iceland is produced from renewable hydro and geothermal resources. Therefore energy production is not a big polluter for Iceland. However, the transportation sector, waste management as well as the heavy industries in Iceland are the countries biggest polluters.

Sustainability

In 1987 the report “Our common future” was published as a result of the UN World Commission on Environment and Development. The report is also known as the “Brundtland report” in recognition of the former Norwegian prime minister Dr. Gro Harlem Brundtland, who was the chairman of the commission. The purpose of the report was to highlight the common need for involved countries to contribute and develop a common policy for sustainable development in the world (UN, 1987).

“*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs*” (UN, 1987)

As stated in the quotation from the United Nations report there should be equality in the quality of life between generations. To increase sustainability there are three aspects which need to be considered; economic, environmental and social aspects, and it is important to create a balance between them.

Building sustainable

There are three main incentives to sustainable construction, i.e. environmental, economic and health related incentives (FSR, 2009: 4).

An environmental incentive due to the fact that the construction industry, which in Europe alone is responsible for around 40 pct. of the total use of energy and raw materials, has a considerable negative environmental effect (ibid.). This could be counteracted with a more sustainable approach, such as by reducing the build up of hazardous waste materials and construction waste by using more easily recyclable and reusable building materials.

Sustainable construction has an economic incentive in that it projects a more favourable image of the actors involved in construction to society (ibid.). Also, increased usage of life cycle cost analysis has shown that by taking sustainable factors into account during planning, design and construction this can have a beneficial effect on the operational expenses of a building.

Sustainable construction also has a health related incentive, in that increased awareness and emphasis on using less of hazardous and poisonous chemicals in construction has a beneficial effect on the working environment in buildings (ibid.). That is, as certain chemicals and materials can have a harmful effect on the personal health of workers, a reduction in these factors creates better conditions for workers and therefore can increase performance.

Sustainable building is based on the ideology of sustainable development, which tries to meet present-day demands without impairing future generations' opportunities to meet their own demands (FSR, 2009: 2f).

Therefore in sustainable building and construction, the aim is to maximize usefulness and minimize negative environmental impact (ibid.). This means that in designing sustainable buildings factors relating to energy, materials, location and health are taken into account. This is done by firstly defining an environmental policy for the building in question, where decisions are made regarding the relevant factors and whether the building will be subjected to an accreditation process (ibid.).

Sustainability factors also influence the construction process, as it can be emphasised that contractors use methods that have minimal negative environmental impact (ibid.). Future operational costs are also taken into account in sustainable construction, as is its eventual demolition. This is done by assessing the building's life cycle, which seeks to evaluate where in the process the most negative environmental impacts occur and how these can be taken into account in the design process and minimized (FSR, 2009: 3).

As mentioned before, sustainable construction takes into account factors related to energy, materials, location and health. In designing buildings, its energy demands are firstly assessed and maximum energy values for the building are determined.

Whereas in neighbouring countries there have been taken significant steps to minimize the energy- and water-demands as well as to increase the usage of renewable sources of energy, this has limited applicability in Iceland due to the prevailing use of clean and renewable energy (FSR, 2009: 8). However in recent years there has been increasing focus on preserving energy and water, as well as using these natural resources with greater care and consideration.

Factors relating to the materials used in sustainable construction are also of great importance, as both the types and location of these materials has considerable effect on the environmental impact of the building.

Iceland has a relatively limited supply of local material resources that are made from renewable sources, which creates certain challenges in the acquisition of sustainable materials.

The building material that is used most frequently in Icelandic construction is concrete, which is traditionally seen as a less environmentally friendly building material due to the amount of carbon emission its manufacturing produces – which creates additional demands for sustainable construction in Iceland (FSR, 2009: 6). In recent years attempts have been made in Icelandic construction to incorporate and use materials from renewable sources and from local sources, so as to minimize the environmental impact of the construction.

Factors relating to the actual location of the construction have an impact on the sustainability of the building in question. Here in the selection of a suitable location for construction different factors are taken into account, such as with regard to transportation, i.e. public transportation, pedestrian and bicycle traffic, etc.; local weather conditions; ecological diversity; etc. (FSR, 2009: 5).

Finally factors relating to the health and well-being of those who will work, live or visit the building are taken into account in sustainable construction (FSR, 2009: 9). This entails taking into consideration factors such as the maximum utilization of daylight, the use of natural air-conditioning, minimize the use of hazardous or harmful materials, etc. (ibid.).

Vistvæn byggð

Sustainable construction and architecture has become an area of considerable focus in Iceland over the last few years. In various countries so called Green Building Councils have been established as a relevant forum for professionals and public officials to promote, discuss and develop sustainability. In Iceland plans for the establishment of a similar forum are well under way and this forum, Vistvæn byggð – Vettvangur um sjálfbæra þróun í mannvirkjagerð, has its official formation meeting on the 23rd of February 2010. Here representatives for governmental institutions, municipalities and businesses have been invited to join and participate in shaping the future of sustainable and environmentally related construction in Iceland. This forum is seen as a venue for encouraging continued reform in the spirit of sustainable development in construction and planning, and thereby ensuring that the nation can live in ecological communities and enjoy healthy living conditions for the foreseeable future (Vistvæn byggð, 2010).

In Iceland much of the focus of the debate relating to sustainable construction and design has involved three different accreditations systems, namely LEED, Swan Label and BREEAM (FSR, 2009: 10).

LEED
Leadership in Energy and Environmental Design, or LEED, is a system of accreditation developed by the U.S. Green Building Council, and is based on the same main principles as the BREEAM system.

Swan Label
The Swan label for small residential houses sets certain requirements for the building process, materials and energy consumption (Nordic Ecolabelling, 2009: 5). This is done by setting criteria based on indoor environment requirements, i.e. criteria for constituent materials, good ventilation, the construction phase, material and quality controls to prohibit built-in damp damage, and based on external environment covering, i.e. the prohibition of environmentally hazardous substances, energy efficiency in running the house, the environmentally suitable disposal of construction waste, a service and maintenance plan for the house (ibid.).

The Swan Label has found relatively widespread use in the Scandinavian countries, although there have been taken certain strides, e.g. in Denmark, to research other accreditation systems as the Swan Label doesn't incorporate requirements for other types of housing than residential housing (Byggeriets Evaluerings Center, 2010). A new area consisting of detached houses, that all meet the Swan Label requirements, has been completed in Herfølge, in Køge municipality in Denmark (Det Grønne Hus, 2007). This is a clear example of the applicability of the Swan Label to the sustainable design and construction of residential housing.

BREEAM
The Building Research Establishment Environmental Assessment Method, or BREEAM, is an accreditation system for constructions that was established in the UK in 1990 (FSR, 2009: 10). Three public buildings were registered for a BREEAM certification in Iceland in 2008-2009. They are a Visitors Centre in Snæfellsjökull National Park, a Visitors Centre in Vatnajökull National Park and a Centre for Icelandic Studies at the University of Iceland.

BREEAM has been chosen as the environmental assessment method to be used in this project. BREEAM has up until now not been used outside the UK for residential buildings. This creates an ideal opportunity to attempt to apply the BREEAM method when building a residential home outside of the UK. BRE Global states that the method can easily be adapted in other countries and this is therefore a good way to test the method's universal applicability in sustainable construction.

BREEAM

What is BREEAM?

BREEAM, or the BRE Environmental Assessment Method, is one of the leading environmental assessment methods for buildings. It is a method for measuring and describing a building's environmental performance.

BREEAM is developed by BRE, the Building Research Establishment, in England. The method can be adapted to local regulations and conditions and used around the world.

The method is primarily aimed at developers and designers to allow them to prove the environmental credentials of their buildings to planners and clients. It is also a tool for designers and others to help them minimize the environmental impact of their building and to improve its performance.

Independent assessors, who have been trained and licenced by BRE Global, carry out the assessment of buildings. At the end of the assessment, they issue a certificate to the client, confirming the BREEAM rating.

The method uses a scoring system, which is based on a wide range of environmental and sustainability issues. These issues concern among other energy use, transport, materials and indoor climate.

The method is applicable for a number of building types, such as offices, education, healthcare, industrial and residential and a special scheme has been developed for each type. BREEAM Bespoke is used for buildings which fall outside the other categories.

Credits are awarded for performance above what the Building Regulations state. The credits gained in each category are multiplied by an environmental weighting factor, according to the importance of that environmental issue. Then, a single score is given to the building. The scores translate into ratings, which range from Pass to Good, Very Good, Excellent and Outstanding (BRE Gloabl, 2009a).
The earlier in the design process BREEAM is implemented, the higher the chance of getting a good rating becomes (Building Research Establishment, 2006b).

BREEAM in Iceland

According to BREEAM, the method can easily be adapted to use in other countries than the UK. This is then called BREEAM International. A BREEAM Europe scheme has been developed for use in European countries.

In the two visitors centres and the Centre for Icelandic Studies the BREEAM Europe scheme has been used for the assessment. This scheme does not allow for any adaptation to country specific conditions, so the buildings were or will be assessed by the scheme as it is. However, where there have been any legislation in the criteria, the Icelandic legislation have been used. (Birgisdóttir, Harpa. *Private conversation*, 4. February 2010)

Conversations between BRE Global and Iceland have already been started, to discuss how the method could be adapted to Icelandic conditions. This process, however, is very expensive, and it is not yet certain whether BREEAM will be used in Iceland or not.

Adapting the system to Icelandic regulations and conditions is a big process. Firstly, the national environmental issues have to be reviewed, to make sure no issues are missing or should be removed or altered. Also, benchmarks need to be adjusted and credit weightings reviewed, to make sure they fit the local conditions. Climate, construction materials, culture, building regulations and geography are only a few of the things which have to be considered as they influence the criteria and their weighting (Aubree, 2009).

The Icelanders have been pointing out that many criteria will have to be adapted, as not all will lead to better and more sustainable buildings as they are now. The point of the system is after all to produce more sustainable buildings with less environmental impact.
Activities such as rain water collection and introducing other low or zero carbon technologies in Iceland will not necessarily have a positive effect on the environment (Birgisdóttir, Harpa. *Private conversation*, 4. February 2010).

Buildings which fall outside the BREEAM Europe scheme are assessed through the BREEAM International Bespoke scheme. This applies to residential buildings.
However, the assessment criteria is created on a building to building basis, from a pool of BREEAM criteria. A specific scheme is therefore created for each building, by a licenced assessor, so no standard scheme is accessible (BRE Global, 2009b).
Therefore, a standard scheme used for residential buildings in the UK will be used in this project.

The BREEAM:Ecohomes Pre Assessment Estimator has been chosen. The Pre Assessment Estimator is a guidance tool for designers and others to evaluate the likely rating to be obtained through a formal assessment, which must be carried out by a licenced assessor (Building Research Establishment, 2006a). Even though the scheme will be used as is, it is necessary to be critical when it comes to certain issues. The most critical issues with BREEAM in Iceland are those concerning Energy, Transport, Water and Materials (Birgisdóttir, 2009).

Environmental issues

The categories in which the method divides the environmental issues, and their weighting are as follows:

Energy - 19%
Transport - 8%
Pollution - 10%
Materials - 12,5%
Water - 6%
Land Use and Ecology - 10%
Health and Wellbeing - 15%
Management - 12%
(Aubree, 2009)

Each category contains several criteria, such as the Dwelling Emission Rate (Ene 1) or the Environmental Impact of Materials (Mat 1). The criteria and their aims are listed in appendix B. The criteria are approachable in different ways. Some can be implemented in the design of the plan solution, others in the construction and others have to be calculated. Appendix B also shows a listing of how each criteria is approached in the project.

CASE STUDY

Sesseljuhús

Sesseljuhús is situated in Sólheimar, Grímsnesi, in the south of Iceland. Sólheimar is a community for mentally challenged people, founded in 1930 by Sesselja Hreindís Sigmundsdóttir.

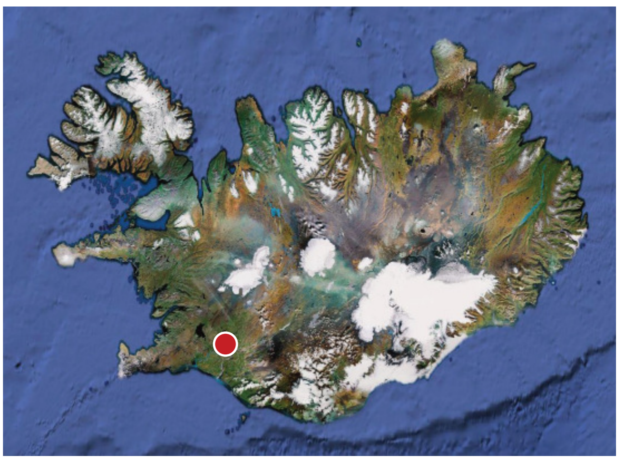
Sólheimar is a self-sufficient, sustainable community, with about 100 inhabitants. There is a big emphasis on the preservation of the environment and biodynamic cultivation. They also have their own geothermal station, which supplies the whole community with hot water. Sólheimar is the first internationally acknowledged eco-village in Iceland (Sólheimar, 2010).

Sesselja was a pioneer when it came to the care of the mentally challenged as well as sustainability and organic cultivation in Iceland (ibid.).

Sesseljuhús was built in honour of Sesselja, and was opened on July 5th 2002, on what would have been her 100th birthday. It is the first sustainable house ever built in Iceland. Sesseljuhús is a multifaceted centre, which was built mainly as an educational centre about sustainability and sustainable buildings. It contains a conference hall, with 100 seats, and meeting rooms, which are all open for the public to use. There is an exhibition held every summer, focusing on sustainable buildings, sustainability, energy and the environment.

When the building was constructed, environmental considerations played a big part in the selection of materials. The origin of the materials, the production and recycling properties were all considered carefully.

The house is constructed mainly of wood. The load carrying structure is made mostly of timber and laminated wood. The inner walls are clad with wood panels, which are treated with organic paint, containing only natural solvents. The facades are clad with driftwood



Ill. 49: Placement of Sesseljuhús in Iceland.

panels, which are made from driftwood collected from the coastline at Strandir. As has been mentioned before, driftwood is a very sustainable material as it requires no further protection against rot and is a discarded material.

Icelandic produced wool insulation is used in almost the whole building. Wool from about 2400 sheep, or 3870 kg of wool was used. Paper insulation was used in a part of the building's roof.

All floor materials are made from natural or recycled materials. Wooden floors made from Icelandic larch, planted in 1936, is the first floor material made from Icelandic wood.

The building has a turf roof, which is insulated with Icelandic mineral wool. The green roof and the natural colours of the facade make the building blend in with the surroundings.

Apart from using geothermal energy and hydro power, Sesseljuhús uses solar panels and an electricity generator which uses hot and cold water to produce electricity. There are also plans to put up a windmill in the future.

Sesseljuhús is certainly an inspiring and educative project. The materials used are a good alternative to the more commonly used materials today. All materials are sustainable, natural or recycled and all are eco-labelled (Sesseljuhús, 2006).

Ill. 50: Sesseljuhús.

Process

DESIGN CRITERIA

Futurologists suggest that the “Living together apart” form of living will become more common in the future. This means that houses will contain big multifunctional rooms where the whole family is gathered, but where each family member is doing their own thing.
Still, people will also want their own rooms, where they can engage in their own interests and individualism. Even the parents will want their own room, if only in the form of a combined office/guest room. There should be at least 2 or 3 children’s bedrooms.

The pantry will also have its comeback. This gives the opportunity for good storage space, without using up all the space in the kitchen for cupboards.

Above all, the functionality of the home will be in focus. This could for example mean that the laundry facilities are close to the bedrooms, for not having to carry the laundry all over the house (Bolius, 2010).

The main living space in the home is the kitchen and the living room. It will therefore be here that flexibility and open space will be important. These spaces are considered inseparable, and a good view and good daylight conditions are very important in these two rooms. They will therefore be placed on the 2nd floor of the houses, towards south.

Rooms with less need for daylight, such as bathrooms, pantry and the entrance, should be placed on the north side.

In the BREEAM scheme, some credits are given if certain facilities are present in the building. These facilities include a home office, recycling facilities and a private outdoor space as well as a bicycle storage and access to either an internal of external drying space.

A room programme for the two buildings was put together based on the aforementioned as well as the criteria from BREEAM.

Originally, a very ambitious room programme was set up. A special laundry room and a TV room were included. However, as the design process advanced, it was discovered that these rooms took up a lot of space, which could be better used in for example the bedrooms. So the laundry facilities were combined to the main bathroom and the TV and living rooms were combined into one space.
Small adjustments have been made to the room programme as the project has progressed and the final room programme can be seen in ill. 51 on the opposite page.

Room	Minimum m^2	North building	South building	Orientation
Living room	20 m^2	2nd floor	2nd floor	S
Dining area	8 m^2	2nd floor	2nd floor	S
Kitchen	10 m^2	2nd floor	2nd floor	S or E
Pantry	4 m^2	2nd floor	2nd floor	N
Master bedroom	10 m^2	1st floor	1st floor	S or E
Bedroom	8 m^2	1st floor	1st floor	S or E
Bedroom	8 m^2	1st floor	1st floor	S or E
Office/guest room	8 m^2	2nd floor	1st floor	S
Bathroom	6 m^2	1st floor	1st floor	N
Toilet	3 m^2	-	2nd floor	N
Entrance	4 m^2	1st floor	2nd floor	N
Storage	6 m^2	1st floor	2nd floor	-
Recycling area	4 m^2	1st & 2nd floor	2nd floor	-
Garage	25 m^2	1st floor	2nd floor	-
Terrace	30 m^2	2nd floor	2nd floor	SW

Ill. 51: Room programme.

DESIGN PROCESS

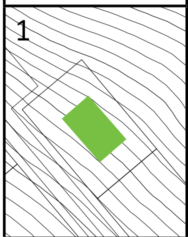
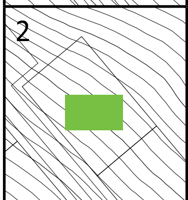
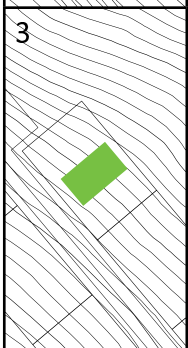
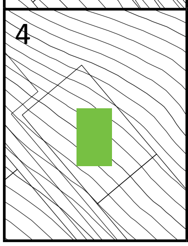
This chapter introduces the design process. The process is divided into smaller chapters, starting with the overall design of the area, narrowing in on the building and its details.

Orientation

Traditionally, the houses in the towns in the fjords are built parallel to the mountainside, as seen in proposal 1 below.

A small initial research has been made, in order to find out the pros and cons about this orientation, as well as three others.

Aside from the four criteria listed in the table below, the buildings' position toward each other was studied, with particular consideration to the view between the houses and sun conditions.

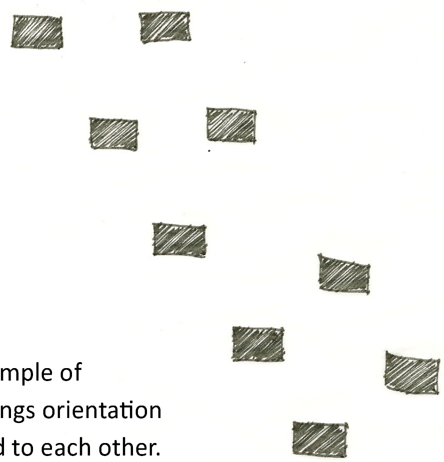
Orientation	Sun	Wind	View	Terrain
1 	Sun on short side (SE) in the morning and noon. Sun on long side (SW) in the afternoon and evening.	Summer: Lee on NW side and some lee on SW side. Winter: Lee on NE side & some lee on SE side.	View towards Hólmatindur and both into and out of the fjord. View from three sides (SE, SW, NW).	House lies parallel to the mountain side. Some of the NE side is buried into the mountain.
2 	Long side towards S. Sun on short side (W) in the afternoon and evening.	Summer: Some lee on W side. Winter: Lee on E side, some lee on S side.	View towards Hólmatindur and out of the fjord. View from two sides (S, W)	NE corner of house is buried into the mountain.
3 	Sun on long side (SE) in the morning. Sun on short side (SW) and long side (NW) in the afternoon and evening.	Summer: Lee on NW side. Winter: Lee on SE side.	View primarily from long sides, into and out of the fjord, respectively. View from three sides (SE, SW, NW).	House lies with short side towards the mountain side. The houses will be buried deep into the mountain and/or will need support on the SW end.
4 	Sun on long side (E) in the morning. Sun on short side (S) at noon. Sun on long side (W) in the evening.	Summer: Lee on W side. Winter: Lee on E side.	View towards Hólmatindur and into the fjord primarily. View from two sides (S, W)	NE corner of house is buried into the mountain.

Ill. 52: Orientation of the buildings.

Options three and four are quickly eliminated, as they don't have any particular qualities when it comes to sun conditions and meeting with the terrain.

Option two has the sun shining on the long facade facing south at noon, which blocks the sun from shining directly into the house in the summer, and allows the winter sun to shine through the windows when it comes up and before it sets, in the fall and spring.

Option one is chosen as there is view from three sides, over the whole fjord. The orientation, with a long side towards SW allows the sun to shine through the windows in the afternoon. In winter, when the sun has started to disappear behind the mountains most of the day, it will still be able to shine through the windows of the SW side in the afternoon, giving some heat.
The houses lie along the mountainside, which will give less problems when it comes to access and placing windows on the lower floors.



Ill. 53: Example of the buildings orientation compared to each other.

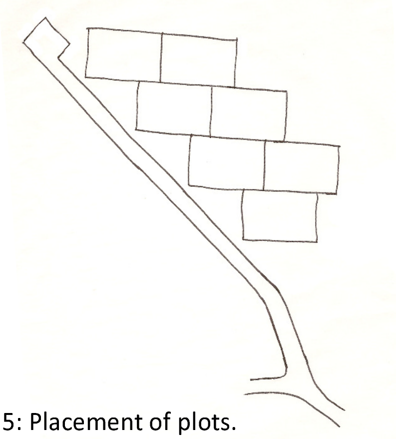
Terrain

Since the project site isn't on a planned area, with a road leading to it, the terrain had to be worked on.

First, the road to the site had to be planned. Fjarðabyggð has already made plans to connect Steinholtsvegur to Hlíðarendavegur with a small road.
A road to the project site was connected to this small road at the top, where it meets Hlíðarendavegur. It then goes up the hill and lies parallel to Steinholtsvegur. At the end of the road is a space for turning the car.

Ill. 54: The road to the site.

After the road had been planned, the position of the building plots had do be planned.
A few suggestions were made, one of which had the plots placed two and two together above the road.



Ill. 55: Placement of plots.

This positioning of the plots did not allow for direct access to the buildings, and parking lots would have to be placed on the other side of the road. It would also be difficult to place the buildings on the plots so that there would be good sun conditions and view from all the houses.

In all the other sketches, the plots lay parallel to the road, as they traditionally do. The form and size of the plots were the same, 20 by 30 m, only the number and precise position varied.

In the start there were ten plots, five south of the road and five north of the road. It could quickly be seen that the space north of the road wasn't enough for five plots, so one was removed. Space for a public playground was placed in between the plots.

Ill. 56: Placement of plots.

In order to try to get a more cohesive layout and connection between the plots, one plot was removed from south of the road. The playground area was expanded towards south, in between the plots (ill. 57).

Ill. 57: Placement of plots.

Another suggestion placed the playground area at the end of the street, below the turning space (ill. 58).

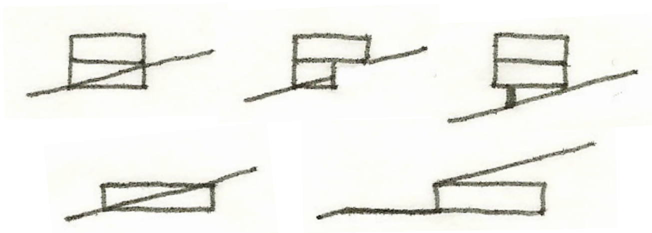
Ill. 58: Placement of plots.

When choosing between these three options, the cohesion of the layout and placement of the playground were the most important issues of concern.

The last suggestion was chosen, as this layout didn't split up the site, creating two zones, as the other two suggestions did. It also created the safest circumstances concerning the playground, as children wouldn't need to cross the road in order to get to it.

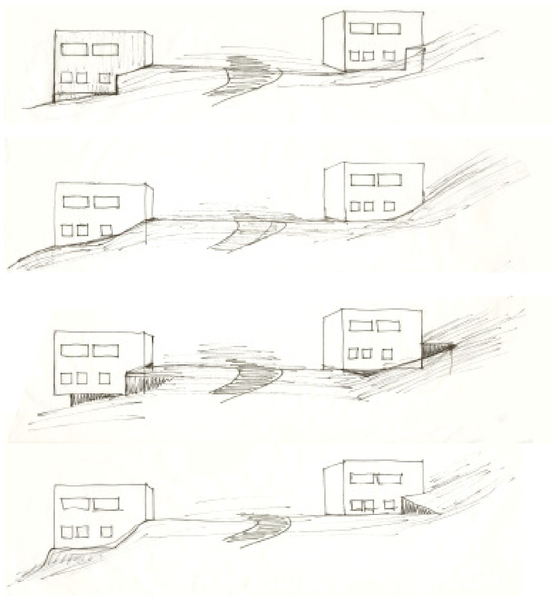
Now the site layout had been chosen, the manipulation of the terrain could begin.
Some sketches and a play dough model were made to investigate the meeting between the buildings and the terrain.

Some initial sketches were made to illustrate the different possibilities on how the houses could be placed on the terrain.
It was chosen to let the buildings sit on the terrain, with only a part of the house buried inside it.



Ill. 59: Placement in terrain.

The terrain had to be manipulated in a way which would get as much light into the lower floors as possible.
At this point in the design process, the design of the buildings was close to finished. A few suggestions on the meeting of buildings and terrain were sketched.



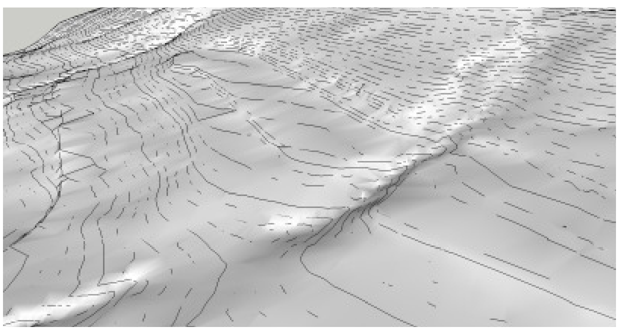
Ill. 60: Meeting between buildings and terrain.

Experiments with play dough gave a clearer picture of how the site would look like with a clear cut edge and a soft edge, respectively.

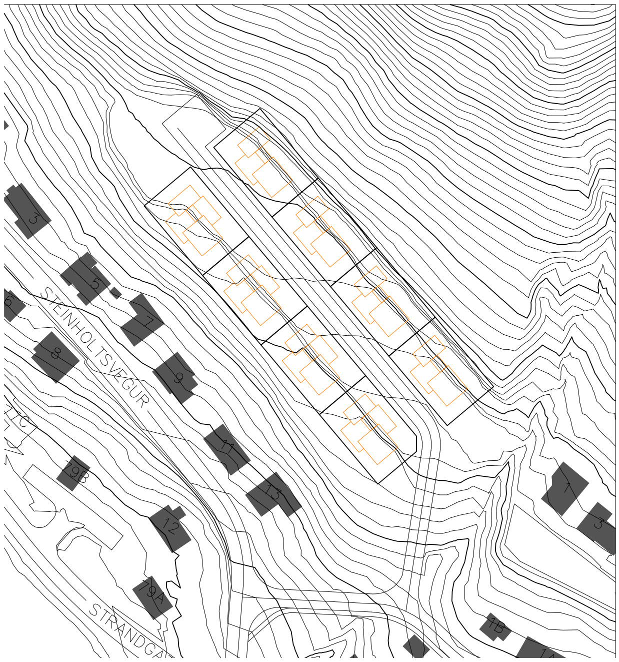
Ill. 61: Terrain with soft edges.

Ill. 62: Terrain with clear cut edges.

It was chosen to let the terrain look as natural as possible. The contour lines were moved in AutoCad according to this. The final result can be seen in ill. 63 and 64.



Ill. 63: The final terrain.

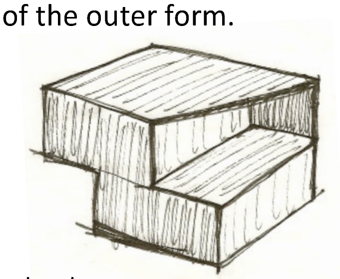


Ill. 64: The final terrain.

Buildings

The sketching process began with a form study and free sketching, as well as the making of a room program, where functions and rooms were placed in zones according to other similar functions and the cardinal directions.

In the start both plans and the outer form of the buildings were sketched, to try to come up with a clear overall form for the house. Ill. 65 below shows an example of one of the early sketches of the outer form.

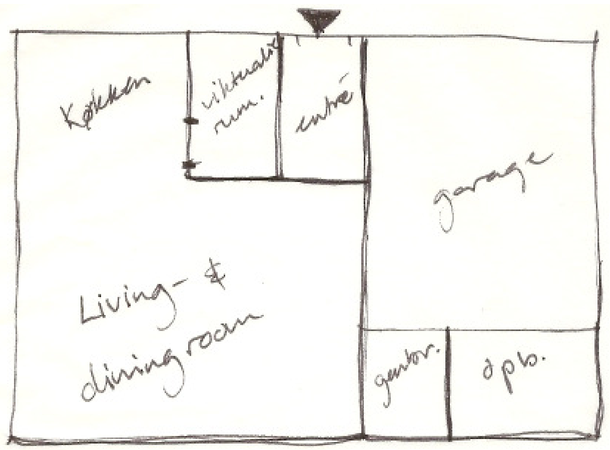


Ill. 65: Early sketch.

South building

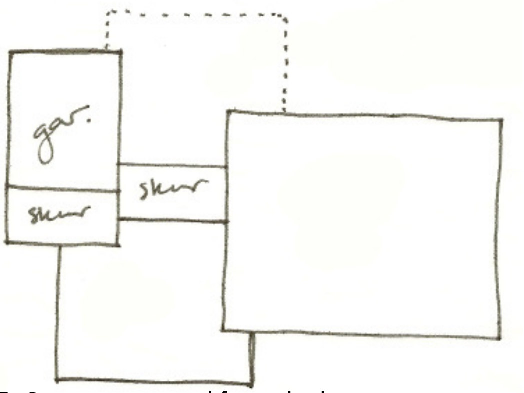
The idea with the south building was that the upper floor would be a public floor and the lower floor would be a private floor, with the master bathroom and bedrooms.

In the initial sketches, the garage was attached to the house. This often gave problems with the view from the living room and kitchen, as the garage blocked all or most of one side of the building.



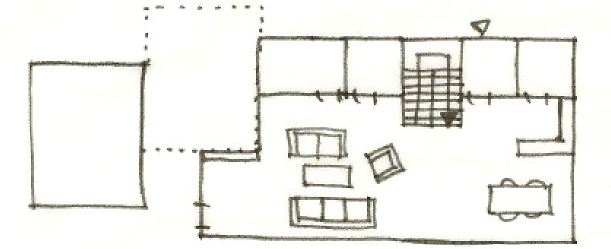
Ill. 66: Garage attached to the house.

The garage was separated from the house and a carport and outdoor storage were created between the two.



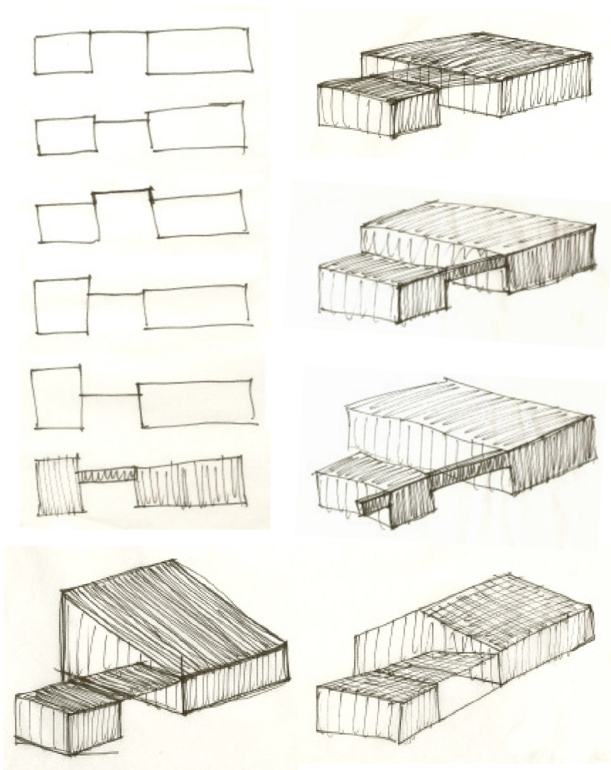
Ill. 67: Garage separated from the house.

The idea of the carport cutting out a corner of the house was investigated, but this produced some problematic zones in the living room, as well as increasing the surface area of the building.



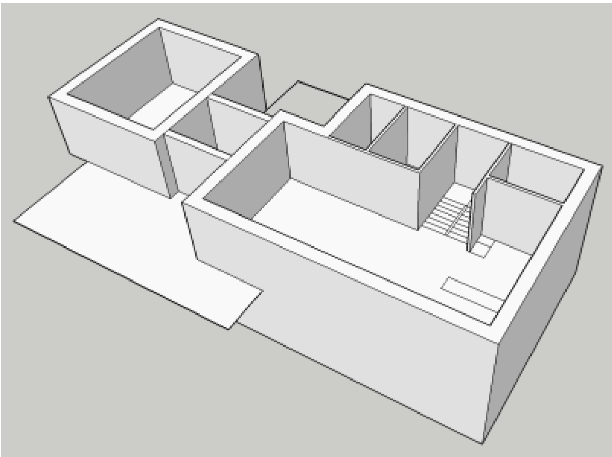
Ill. 68: Carport cutting out a corner of the building.

Alongside the plan sketches, ideas of the buildings' outer form were tested through sketching. Some examples are shown in ill. 69.

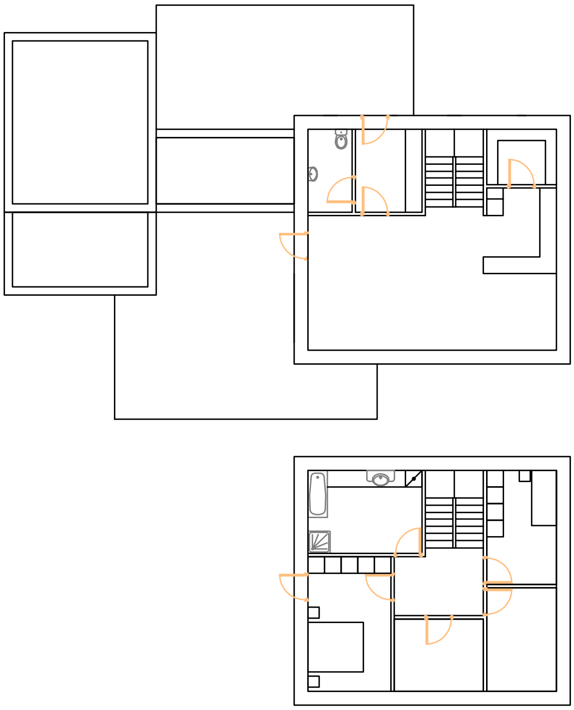


Ill. 69: Sketches of the outer form of the building.

The plans were developed further in AutoCad, as this was more precise than sketching and more sketches of the building were drawn in SketchUp. Ill. 71 shows the final plan of both floors of the south building.



Ill. 70: SketchUp model of the south building.



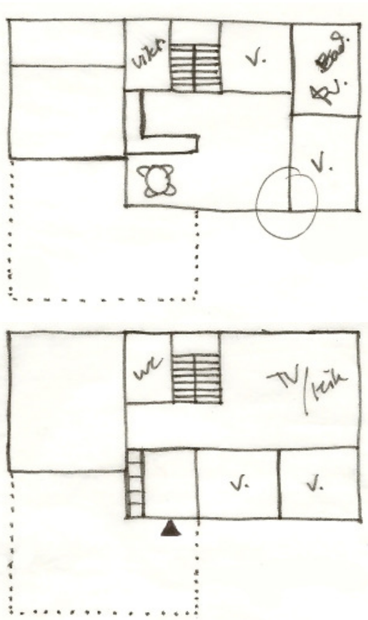
Ill. 71: Final plan of both floors of the south building.

North building

The sketching process for the buildings north of the road was a little bit more extensive. The original idea was that the lower floor would, apart from containing the entrance to the building, function as a children's floor, and the upper floor would be the adult floor, with the kitchen, living room and the master bedroom.

The sketches started similar to the south building, with the garage detached from the house. The same principle with the carport cutting out a part of the building was also tested with this building type.

The fact that some of the bedrooms were on the 2nd floor created some problems with the living room. It was both too small and the bedrooms often shaded for the view. The 1st floor, however often had too much space, that could not be properly utilised.

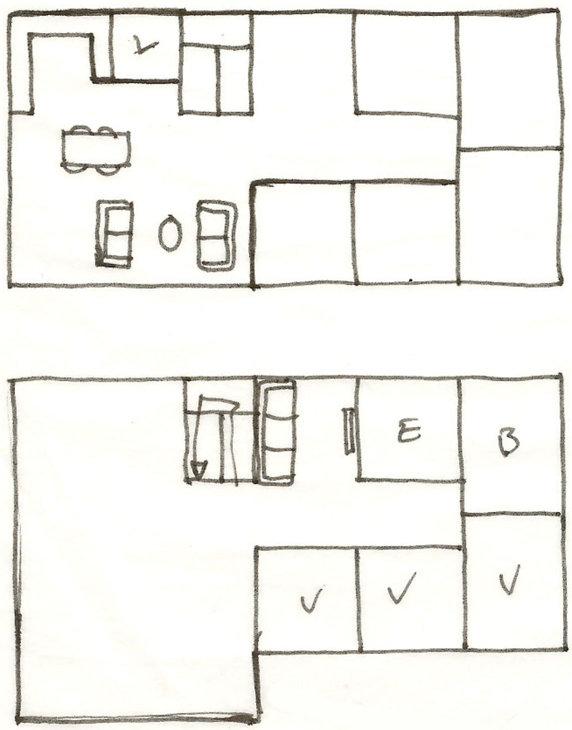


Ill. 72: Above: 2nd floor, below: 1st floor.

A common denominator for many of the sketches was also that the entrance took up a lot of space on the SW facade from the rooms, which had more need for daylight.

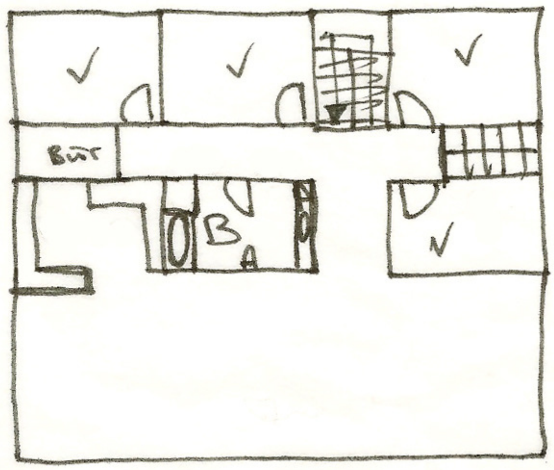
The idea of a children's floor and an adult floor was abandoned and all rooms were moved upstairs, leaving only the garage, storage and entrance down stairs.

This meant however that the upper floor became far too large and the problem with the rooms shading for the view in the living room came up again. The rule had become that the form of the house followed its functions, rather than the functions fitting into a well proportioned building.



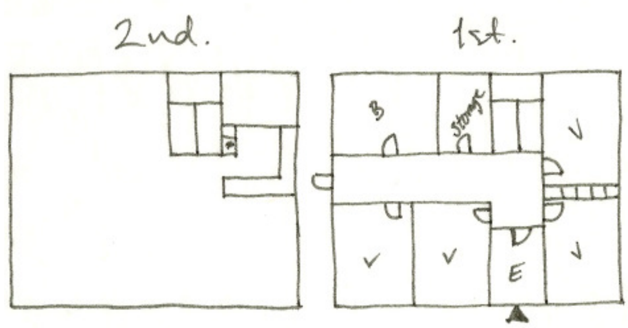
Ill. 73: Two examples of upper floors.

Another approach was taken, placing all rooms at the NE side of the building, leaving the SW side free for the kitchen and living room. This worked much better and gave good possibilities for light and view from the living room. The buildings outer form became more compact and rectangular.



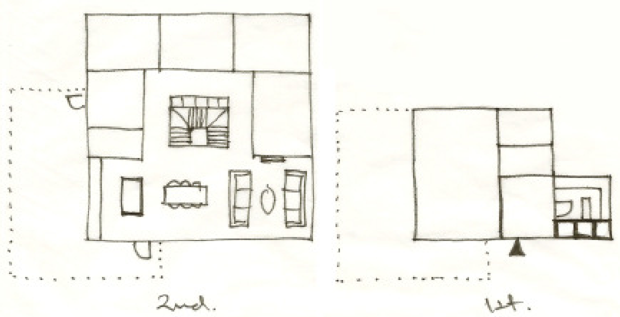
Ill. 74: All rooms placed at the north side of the building.

At the same time, moving all rooms downstairs was tested, using the same principle as with the south building, with a public and private floor. When doing this, the 2nd floor became far to big, so this was quickly abandoned again.



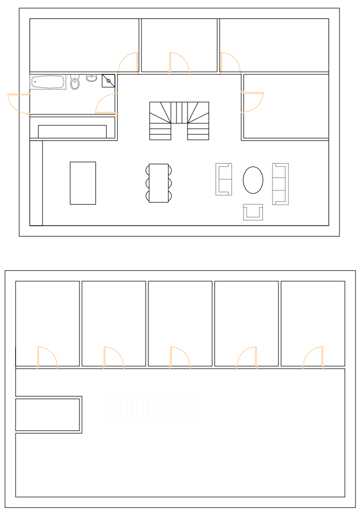
Ill. 75: All rooms placed downstairs.

More sketches were made where all rooms were in the NE side of the building. This resulted in a building of ca. 12 by 12 m, with the staircase in the middle. This gave the possibility of a smaller 1st floor than if the staircase had been by the facade, as well as keeping the facade free for the bedrooms.



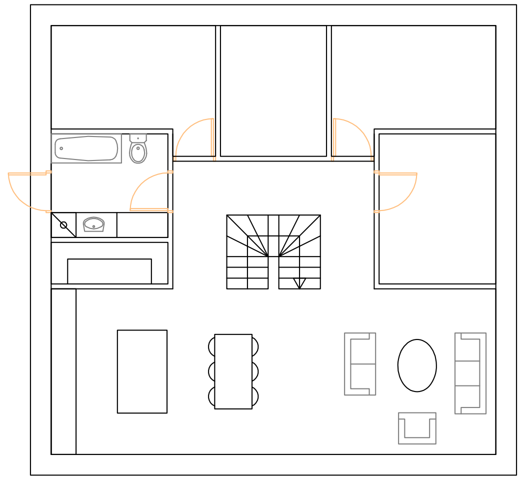
Ill. 76: Staircase in the middle of the building.

The upper floor in this suggestion is very big and deep. Sketches were drawn in AutoCad where an attempt was made to make the house narrower. This often resulted in rooms which were oddly shaped or too small or very large 2nd floors.

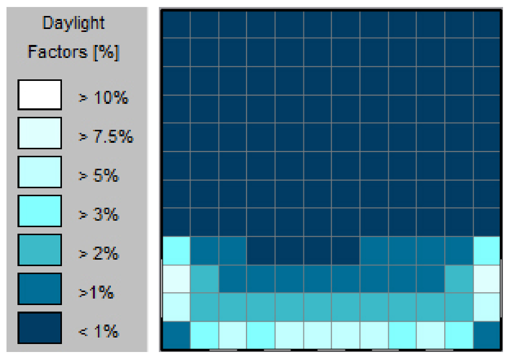


Ill. 77: Attempt to make the house narrower.

Light studies were performed in Dial-Europe on one of the design proposals to see if there was enough light by the stairs and hallway.



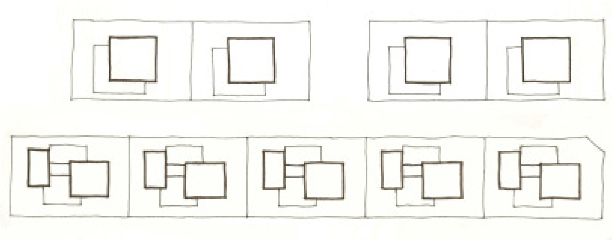
Ill. 77: Plan for daylight factor calculations.



Ill. 78: Daylight Factor results from Dial-Europe.

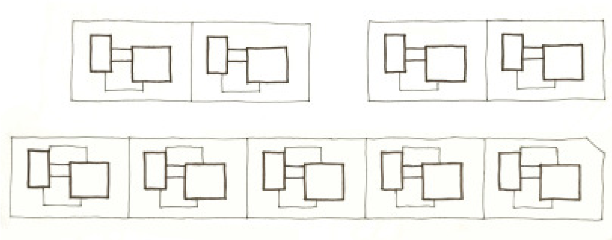
It was clear that there would not be an adequate amount of daylight in the middle of the building. A skylight above the stairs was tested but this did not give the expected results, apart from not being a desired solution to the problem.

A quick examination of the context was made to see how the overall image of the street would be with the two different building types north and south of the road.
A sketch with the outlines of the buildings placed on the plots was drawn. This gave a good picture of how the building types "communicated" with each other across the street.



Ill. 79: Two different building types.

It was noted that the form of the north building, as one big element, didn't correlate very well with the south building.
To see if it would work better if the north building were split up in smaller elements, the outlines of the south building were copied across the street.

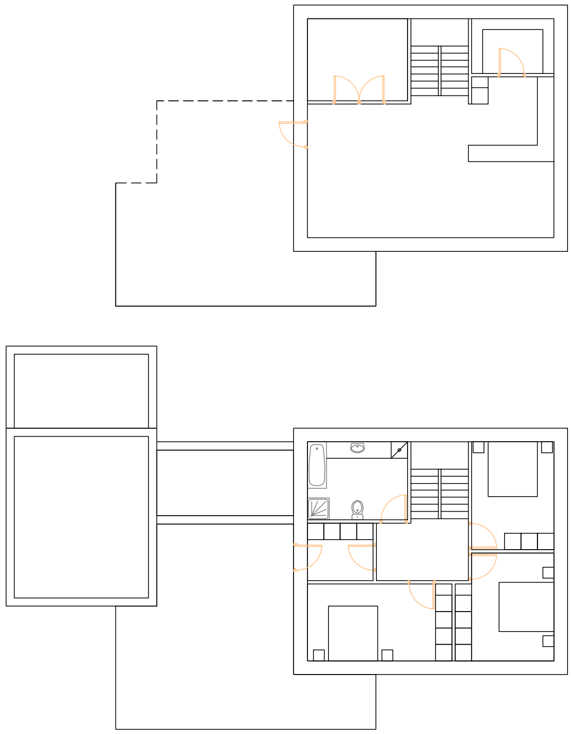


Ill. 80: Coherent architectural expression.

This gave a much better cohesion between the buildings. Given the daylight problems with the design suggestion of the north building, it was set aside and another design approach tested.

The outer shape of the south building was kept and different plan solutions inside were tried out.

The result was a plan very similar to that of the original building, with only a few adjustments.



Ill. 81: Final plan. Above: 2nd floor, below: 1st floor.

The entrance was moved to the 1st floor and placed on the NW side. This kept the SW side free to give space for the bedrooms.
Upstairs, the kitchen and living room were almost identical to those in the south building.
The biggest difference between the two buildings was that the extra room was on the 2nd floor in the north building. This meant an extra flexible room in addition to the living room.

Roof shapes

Different types of roofs were investigated, to find out what expression they would give to the houses and how they would fit into the context.

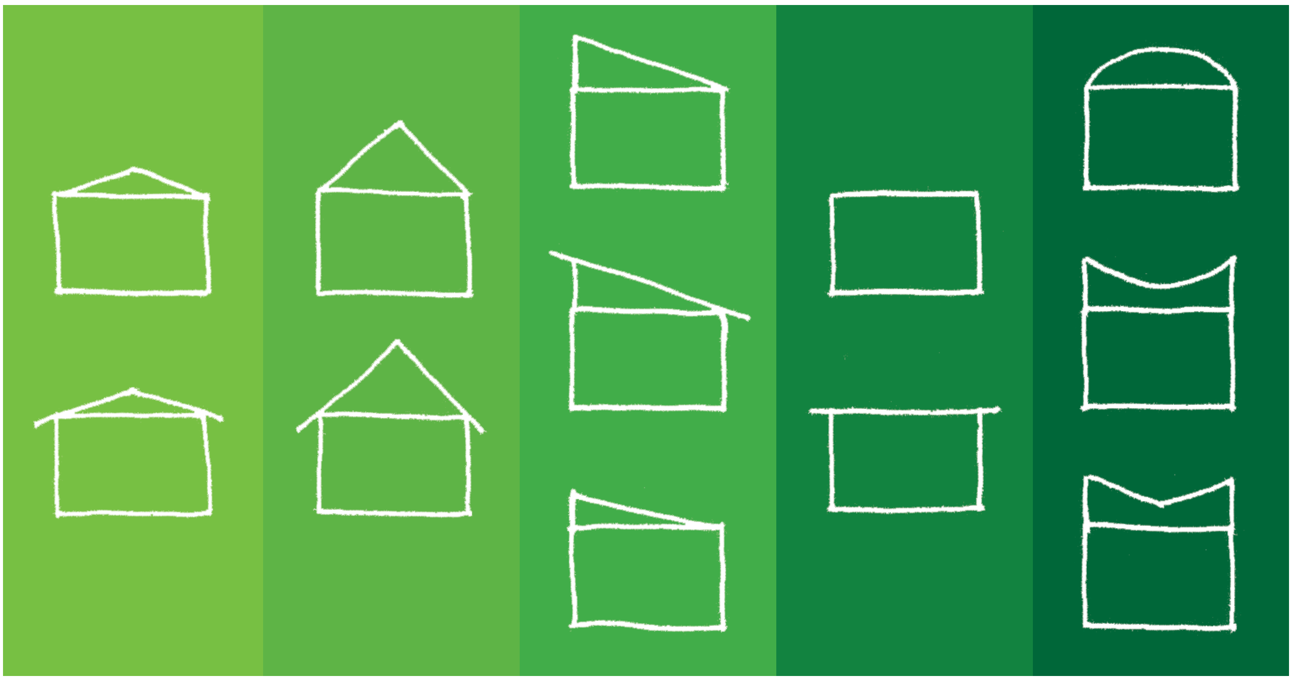
The saddle roofs and the single sloped roofs are traditional Icelandic roof types and the most common roof types in Eskifjörður.
Flat roofs are not as common, but have a very modern expression.

The last three roof types are not very common and were quickly eliminated, as they do not fit in with the context and were not the desired architectural expression.

Whether the roofs should have an overhang or not, depends on the final design and was tested further at a later point in the process.

The low saddle roof, the single sloped roof and the flat roof were tested on a 3D model in SketchUp (see ill. 83-88).

The saddle roof and the single sloped roof refer better to the surrounding architecture. The house looks like a traditional Icelandic home with the saddle roof, and the house with the single sloped roof refers to the 1960's and 70's houses which surround the site.
The flat roof gives the buildings a more modern expression. The flat roof looks better without an overhang, whereas the saddle roof looks better with an overhang.



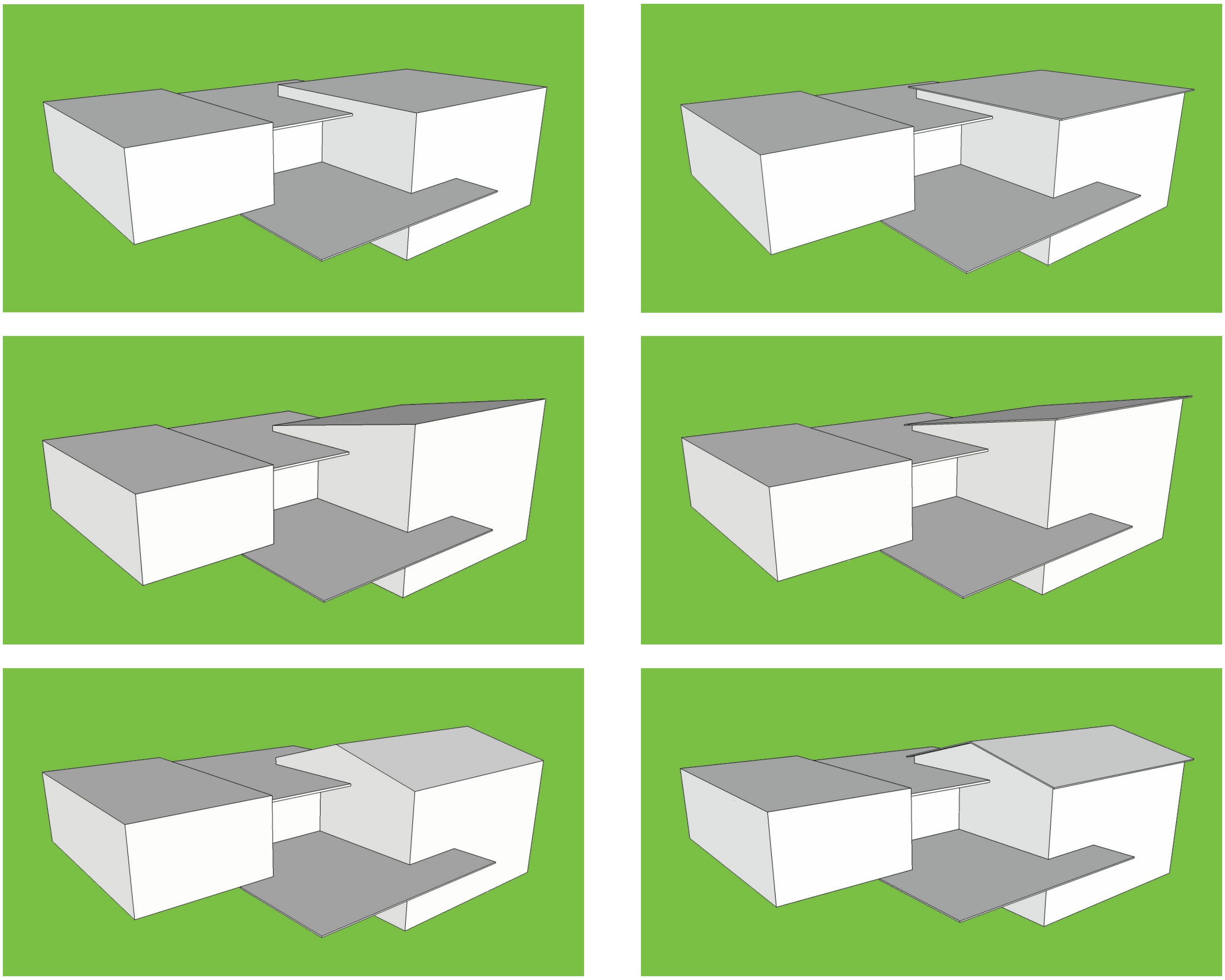
Ill. 82: Different roof types.

The flat roof without an overhang is chosen as this roof type gives the strongest contrast to the organic contours of the landscape and its modern architectural expression is preferred above the others.

Garages

The garages are 9,5 by 5,5 m with a 13 m2 storage room at the end. The wideness of the garages gives space for the recycling bins, which are a part of the BREEAM criteria.

The small building which connects the garage to the house can be used as a tool shed or for extra storage.



Ill. 83-88: Different roof types.

Windows

The windows in a house serve a few purposes. They let daylight and heat into the building and give view out of the building as well as having an aesthetical value.

The buildings were modelled up in SketchUp and a few suggestions to windows were made. Four of them were chosen out and modelled up in Dial-Europe for a daylight factor analysis. The results from Dial-Europe would be taken into consideration when choosing the final windows.

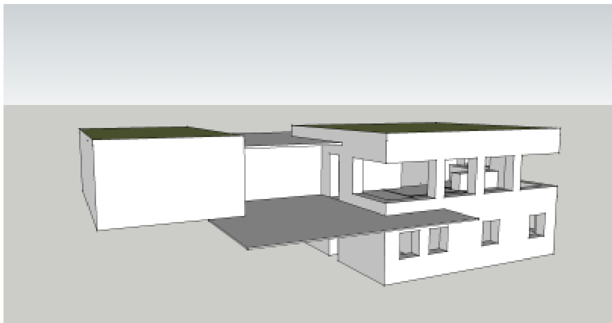
Illustrations 89-91 show the three suggestions that were not chosen. Illustrations 92-95 show the suggestions that were chosen and the results from Dial-Europe.

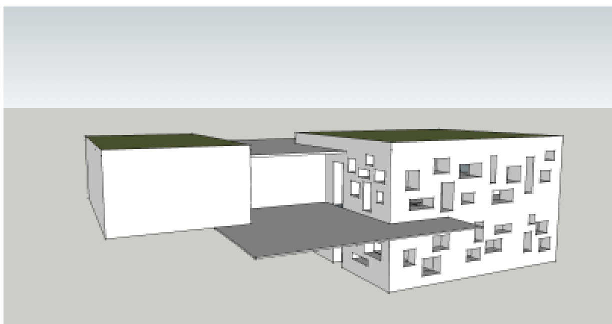
Calculations were only performed for the 2nd floor, as the size and form of the windows in the kitchen and living room were the most important. Here it was not only important to have good daylight but also good view.

In the first daylight factor calculation, the mean daylight factor (MDF) was 3,7% and the max. daylight factor (DF) was at 13%.
In the second calculation, the MDF was 2,9% and DF was at 9,7%.
In the third calculation, the MDF was 4% and DF 14% and in the last calculation, the MDF was 4,9 and the DF was 17%.

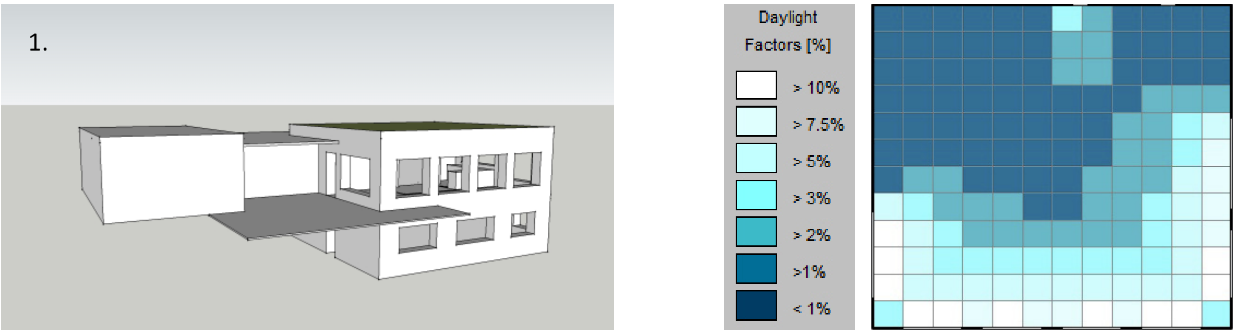
It has to be taken into consideration when looking at the mean daylight factor that the whole floor is taken into the calculation, as there are no inner walls in the model.

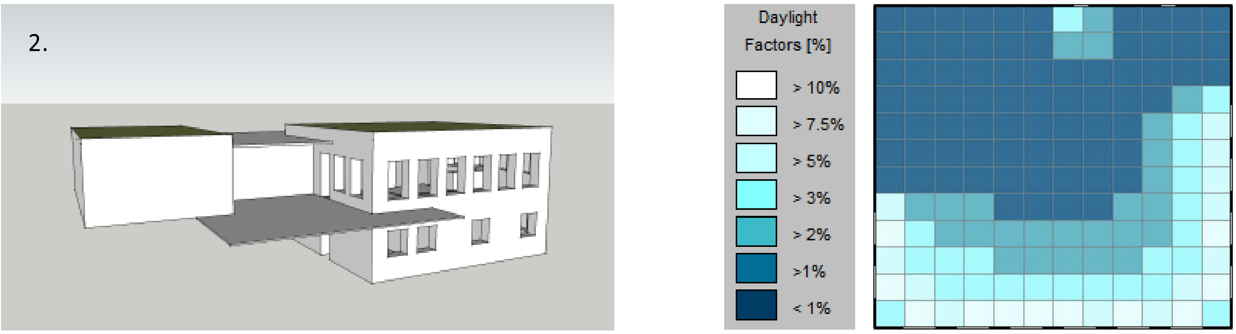
The third design suggestion was chosen as this gave one of the best results. The choice was based both on aesthetics and daylight quality. Even though the fourth suggestion gave better results, the size of the windows would mean more heat loss for the building and perhaps too much daylight. Options one and two were rejected partly for aesthetic reasons, as well as possibility of view and the daylight calculations.

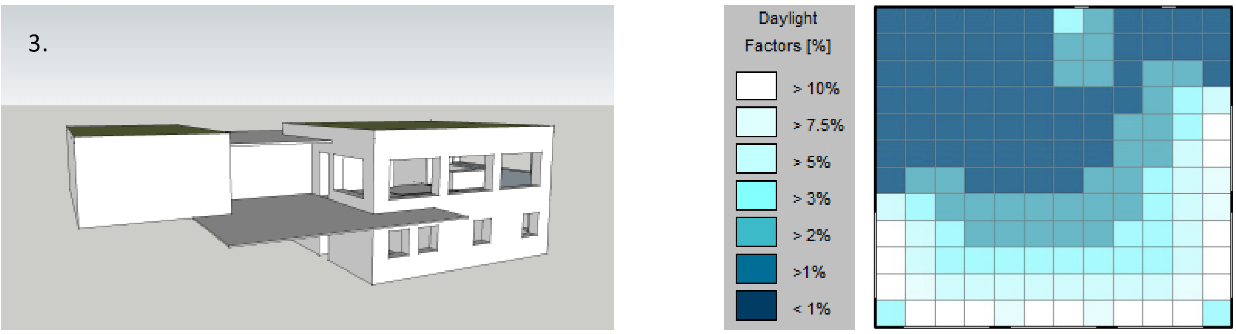


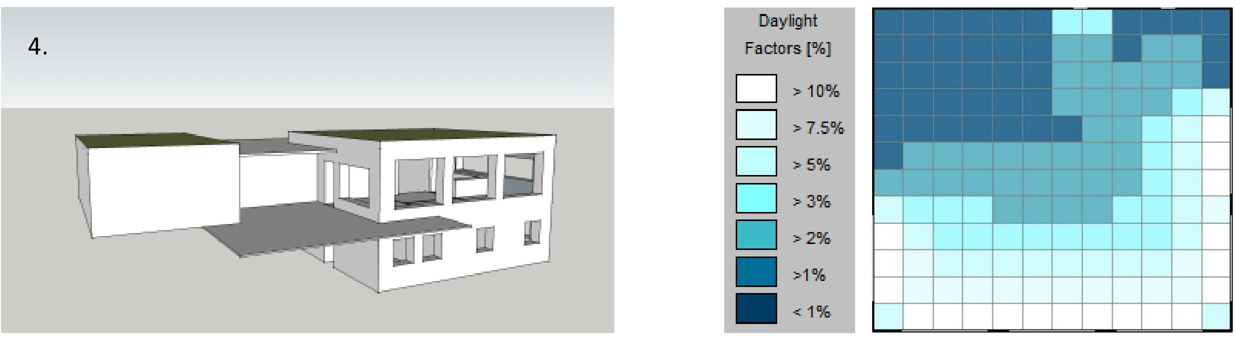


Ill. 89-91: Proposals not chosen for daylight studies.









Ill. 92-95: Proposals chosen for daylight studies and their corresponding results.

MATERIALS

In this chapter, the materials chosen and the construction of the different elements of the buildings will be described.
The choice of materials was based on aesthetics, constructional qualities and the environmental impact of the materials.

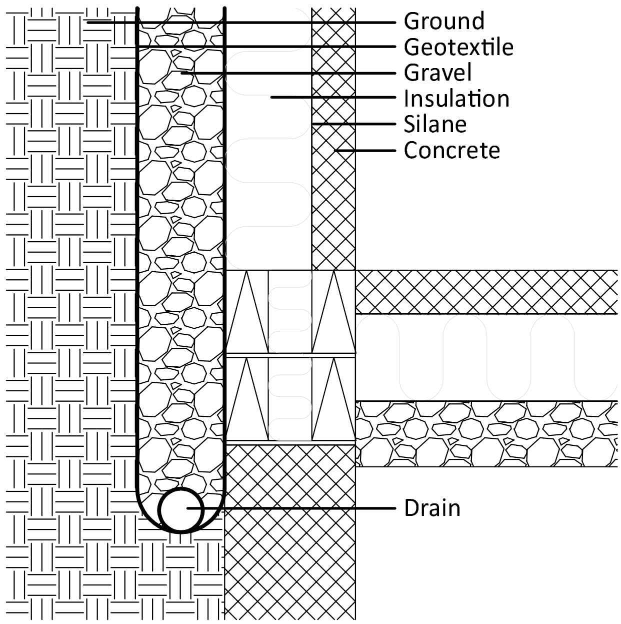
Because of the sloping terrain, a pure timber construction was not possible. The timber would not be able to withstand the pressure from the terrain or the moisture in the ground.

The lower floors are constructed of in-situ cast concrete. Concrete is the most common building material in Iceland and can easily withstand the forces coming from the ground. Environmentally friendly concrete is used in the project.

The formwork is laid horizontally and the structure of the wood can be seen on the facade. This makes the lower half of the building appear heavy and well grounded in the landscape.

Ill. 96: Concrete cast in formwork.

A drainage system surrounds the buildings, so the surface water can be led away from the construction. The construction of the wall which is buried in the landscape can be seen in ill. 97. Silane is put on the concrete on the outside to prevent water from penetrating it, causing damage.
Apart from the drains, a ditch is dug in the hill above the site, and the surface water is lead to the stream that runs east of the site. The same has been done in the hill above the buildings on the other side of the stream.



Ill. 97: Drainage system surrounding the building.

The upper floors are timber constructions, clad with wood facing, made out of driftwood.
The facing is laid vertical on the facade. This creates a contrast to the horizontal lines of the building, which are created by the flat roof, the horizontal windows and the horizontal structure on the 1st floor facade.
Laying the wood panels vertically will lead rainwater more quickly off the facade.

The buildings are insulated with wool insulation. The wool insulation is more environmentally friendly than mineral wool and helps keep a well balanced indoor climate in the buildings.

The garages of the two types of buildings are not constructed in the same material, as they are not connected to the same floor of the respective buildings. This is for both architectural and technical reasons.
The garage by the north building is constructed of concrete as it is on the 1st floor level and is therefore partly buried into the terrain. The south garage is a timber construction as it is connected to the 2nd floor of the building.
Both garages are insulated and heated to a temperature above the freezing point. This is primarily because of the storage room, which is meant for items that can not withstand freezing temperatures.

The storage shed between the buildings is a timber construction clad with corrugated aluminium, although the north side of the shed by the north building is made of concrete, as it lies up against the terrain.
The corrugated aluminium refers to an old building tradition in Iceland, where timber houses were clad with corrugated iron. The decision for choosing a different material for the storage shed is based on the wish to illustrate that this is an element of the building which serves a different function than the others. The reason for choosing aluminium is due to the proximity of the aluminium plant.

The roof is a timber structure similar to the outer walls. The possibility of having a green roof was a part of the decision of having a flat roof on the buildings. The vegetation on the roofs is the similar to the nature surrounding the buildings, which is mainly moss, heather, like Empetrum nigrum, Calluna vulgaris and Vaccinium uliginosum and small plants and flowers like Thymus praecox, Alchemilla alpina and Galium normanii (Torf.is, 2010).

Ill. 98: Vegetation on the green roof.

The terraces are constructed of wood boards and supported by slender steal columns.
The overhang on the south building is also a timber construction, with felt roofing and clad with wood panels on the underside. The overhang is also supported by steel columns.

CALCULATIONS

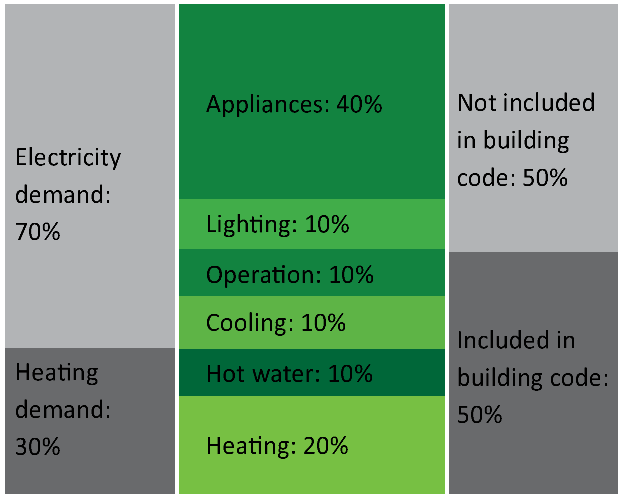
Energy calculations are carried out in the programme Be06. Since the two buildings are very similar, calculations will only be carried out for the south building. As mentioned in the 'Motivation' chapter, the goal is to comply with the Danish Low Energy Class 2 criteria. The climate data used in the calculations is from Reykjavík.

Be06 is an energy calculation programme, developed by SBi (Statens Byggeforsknings-institut) to document whether the energy demands of the Building Regulations are met (Aggerholm & Grau, 2007).

The programme makes a stationary calculation of the energy consumption for each month, based on mean values for the respective month. It is therefore a relatively simple calculation of the energy consumption, which is based on the assumption that the temperature and sun hours are the same each day of the respective month.

Sunshine through the windows gives solar heat gain. This means that less energy is needed to heat the building, but could also create overheating during summer. Solar shading is taken into account in the calculations as well as internal heat gain.

Heat loss can happen through ventilation, as cold air comes into the building and warm air is let out. Heat loss also happens through the building envelope.



Ill. 99: Division of a buildings primary energy consumption.

Heat accumulation in the building elements is not taken into account in the calculations. Many factors contribute to the buildings heat gain and loss and the more detailed the model is, the more accurate the result.

Not all of the buildings energy consumption is calculated into the final value. The energy consumption is calculated from the buildings heating demand and the energy needed to cool the building down in the case of overheating. Other energy consumption is from the operation of the building. It is the total value of these three elements which should lie within the demands of the energy frame.

The energy needed for artificial lighting, appliances and other equipment is not used in the final value, as this is not part of the energy frame (see ill. 99). It is however possible to see how much electricity these functions use if they have been put into the model (ibid.).

In the initial calculations, the design proposal previously mentioned was set up in Be06. The results showed that the house's energy consumption would be about 73,6 kWh/m2 per year and there would be no overheating in the summertime, despite the large windows towards south.

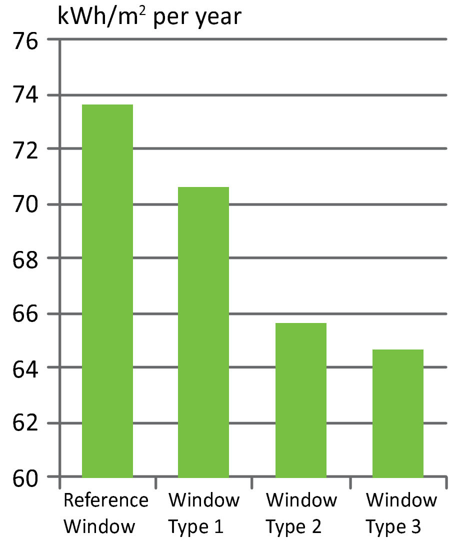
The energy consumption is rather high, and does not pass the Danish Low Energy Class 2 criteria, which is a yearly consumption of 58,9 kWh/m2.

In order to bring the energy consumption down, a few measures can be taken.
The most effective is to decrease the U-value of the building components. The lower the U-value of the building components, the less heat will pass through the building envelope. This can be achieved in different ways. Three different strategies were tested to find out which would be the most effective:

- Window types
- Window sizes
- Outer wall insulation

Window types

Firstly, better windows with a lower U-value were tested. In the initial calculations the windows had a U-value of 1,5 and a g-value of 0,63. The g-value is the solar heat gain coefficient of the glass and refers to the amount of solar energy transmitted through the window. The lower the value, the less solar gain.
The windows should therefore have a lower U-value and possibly a higher g-value, since there was no overheating in the



Ill. 100: Heat loss with different window types.

initial calculations. A higher g-value would therefore have a positive effect on the energy consumption.

The following window types were tested:

		U-value	G-value
1.	Double energy glazing	1,4	0,66
2.	Double energy glazing	1,1	0,60
3.	Triple energy glazing	0,9	0,48

The results show that the triple energy glazing is the most effective, as it has the lowest U-value (ill 100). However, the low g-value means less solar gain through the windows.

Commonly, the Visible Transmittance (VT) of triple glazed windows is a little bit lower than that of double glazed windows. VT is an indicator of how much light is transmitted through the glass. The reason for this is that the light has to pass through three layers of glass in stead of two (US Department of Energy, 2008).

Therefore, the double energy glazed window, with a U-value of 1,1 is chosen. This gives the best results, without any distortion of light quality.

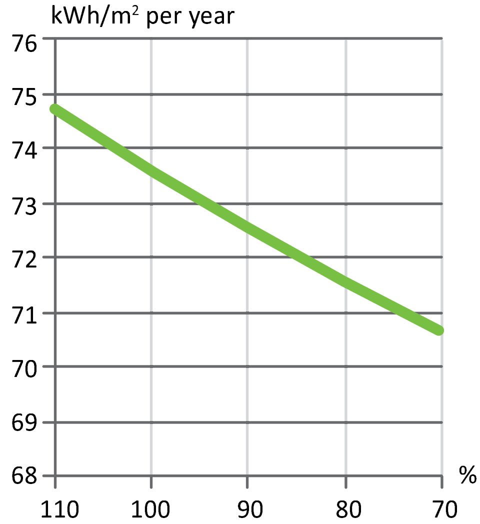
Window sizes

The percentage of windows compared to the total area of the facade was decreased. The windows have a substantially higher U-value than the walls of the building. Therefore, the effect of changing the size of the windows was tested. However, making the windows smaller also means less solar heat gain through the south oriented windows. Therefore, slightly bigger windows were also tested to see what effect that would have on the building's energy consumption.

In the design proposal used for the initial calculation, the window to facade ratio was about 15%. Window areas of 70%, 80%, 90% and 110% compared to this ratio were tested. Focus was on the NW, SW and SE facing windows, as they would have the most effect on the results.

The size of the windows not only affects the energy consumption, but also the view out of the building and the amount of daylight coming into the building. This will also has to be taken into consideration in the final design.

As can be seen on the graph in ill. 101, the decrease in energy use is almost linear as the windows decrease in size.
The results show only a slight change in the energy consumption, with only a 4% decrease with 30% smaller windows. It is therefore



Ill. 101: Heat loss with different window sizes.

decided not to change the size of the windows, as this would also have consequences for the view and daylight.

Outer wall insulation

The U-value of the exterior walls was increased. In the initial calculations, the U-value of the 1st floor walls is 0,15 with 250 mm insulation, and 0,14 for the 2nd floor walls, with a total of 305 mm insulation.

By increasing the insulation in the walls, the U-value is lowered and less heat passes through them. This also means that the walls will become thicker, leaving less space inside the buildings. This will have to be taken into consideration when deciding the amount of insulation in the walls.

The effect of putting 10%, 20%, 30% 40% and 50% more insulation in the walls was tested.

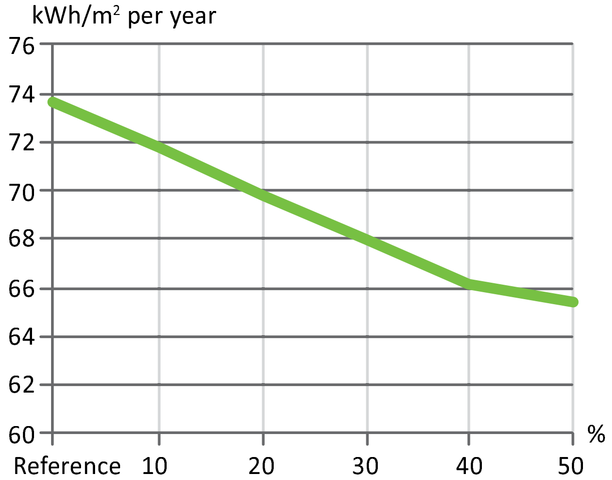
As can be seen on the graph in ill. 102, the results show that increasing the insulation has the most effect up to 40%. After that, the effect gradually becomes smaller, so the gain is not worth the cost of material.

As said, increasing the insulation in the outer walls will make them thicker. In the initial calculation, the 1st floor walls are 430 mm thick and the 2nd floor walls are 370 mm thick. With a 20% increase in insulation in the 1st floor walls they would become 480 mm thick. A 40% increase in the insulation of the 2nd floor walls would mean a total thickness of 492mm.

Therefore a 20% increase in the 1st floor walls and a 40% increase in the 2nd floor walls is chosen, to obtain maximum results without the walls exceeding a thickness of 500 mm.

Another calculation is now performed, with the aforementioned adjustments. The results are an energy consumption of 59,2 kWh/m2 year. This is very close to the low energy class 2 criteria of 58,9 kWh/m2 year.

In order to comply with/keep within the Low Energy Class 2 criteria, extra insulation of 3 cm is added to the 2nd floor outer walls and only 1 cm in the 1st floor walls. The total thickness of the insulation in the 2nd floor wall is then 460 mm and the total wall thickness is 530 mm. In the 1st floor walls the insulation thickness is now 310 mm and the total wall thickness is 490 mm.
This gives the result of 57,3 kWh/m2 year, so the building keeps within the Low Energy Class 2 criteria.



Ill. 102: Heat loss with different wall thicknesses.

In the design proposal used in the calculations, the windows are placed at front by the facade. This was done in order to create optimal conditions for solar heat gain, to see if there would be a risk of overheating due to the large windows. By moving the windows 10 cm inwards, the energy consumption increases up to 58,9 kWh/m2 year, or by 2,8%. Still, the buildings energy consumption complies with the Low Energy Class 2 criteria.
The increase in the energy consumption is caused by a shade that is cast on the window, when moving the windows back into the facade. This means that less solar heat passes through the window.

The energy consumption can be brought down further by choosing windows with a lower U-value. The values of the windows used in the calculations are only typical values for these types of windows and windows with a lower U-value can be found.

For example, the window producer Guardian has documented double glazed windows with a U-value of 0,48 and a g-value of 0,77. This would mean an energy consumption of 42,5 kWh/m2 year, which is close to the Low Energy Class 1 criteria of 41,1 kWh/m2 year (Guardian Industries, 2008).

The level of detail in the calculations must be taken into consideration when looking at the results. There are many aspects that have not been taget stilling til/considered, which would influence the final results.

Since moving the windows back doesn't influence the energy consumption by more than just under 3% and still keeps within the Low Energy Class 2 criteria, the choice of whether or not to move the windows should be based on aesthetics and the desired architectural expression of the buildings. It was decided to move the windows back as this would create more depth in the facades.

Key results from the Be06 calculations can be seen in appendix C.

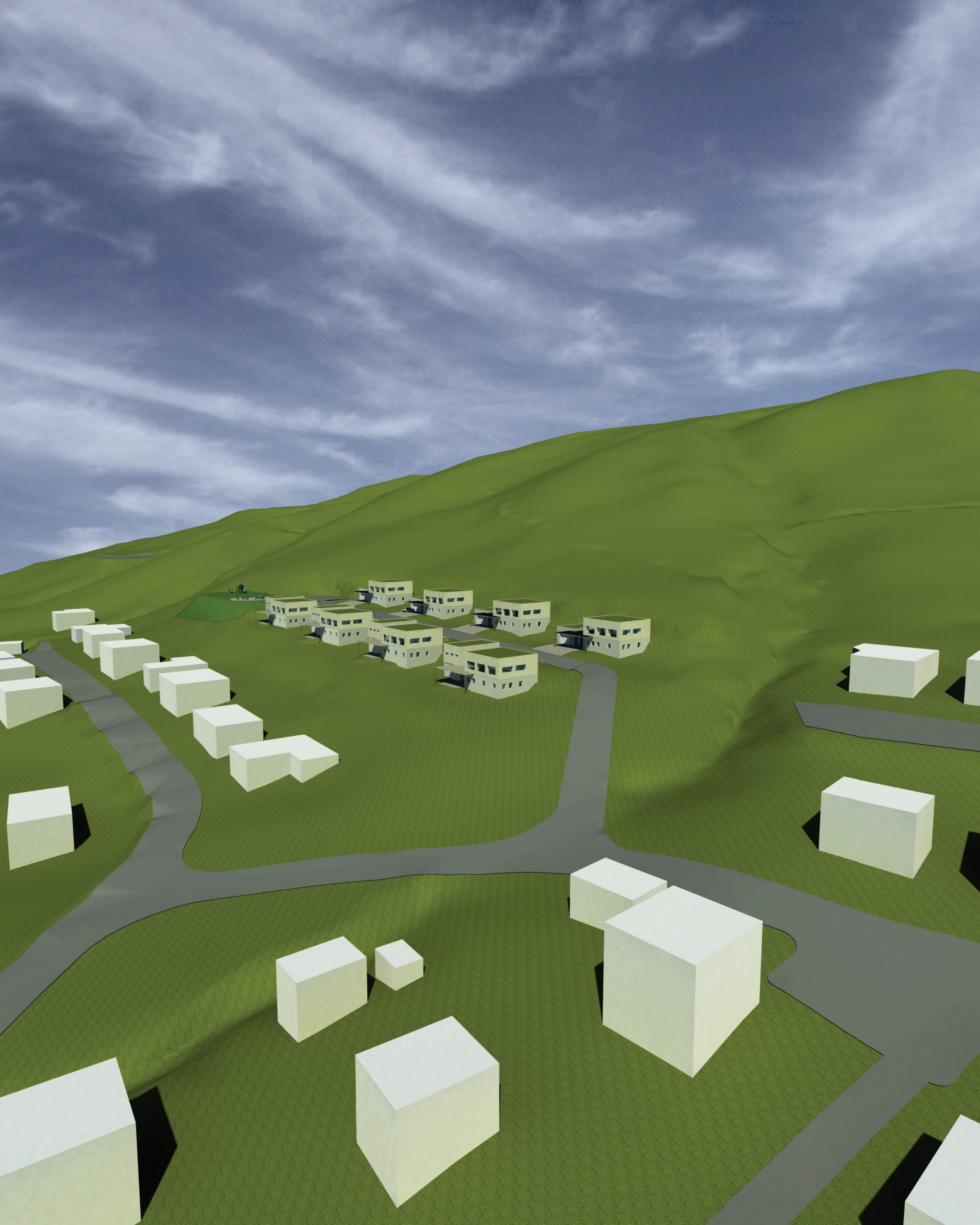
Presentation

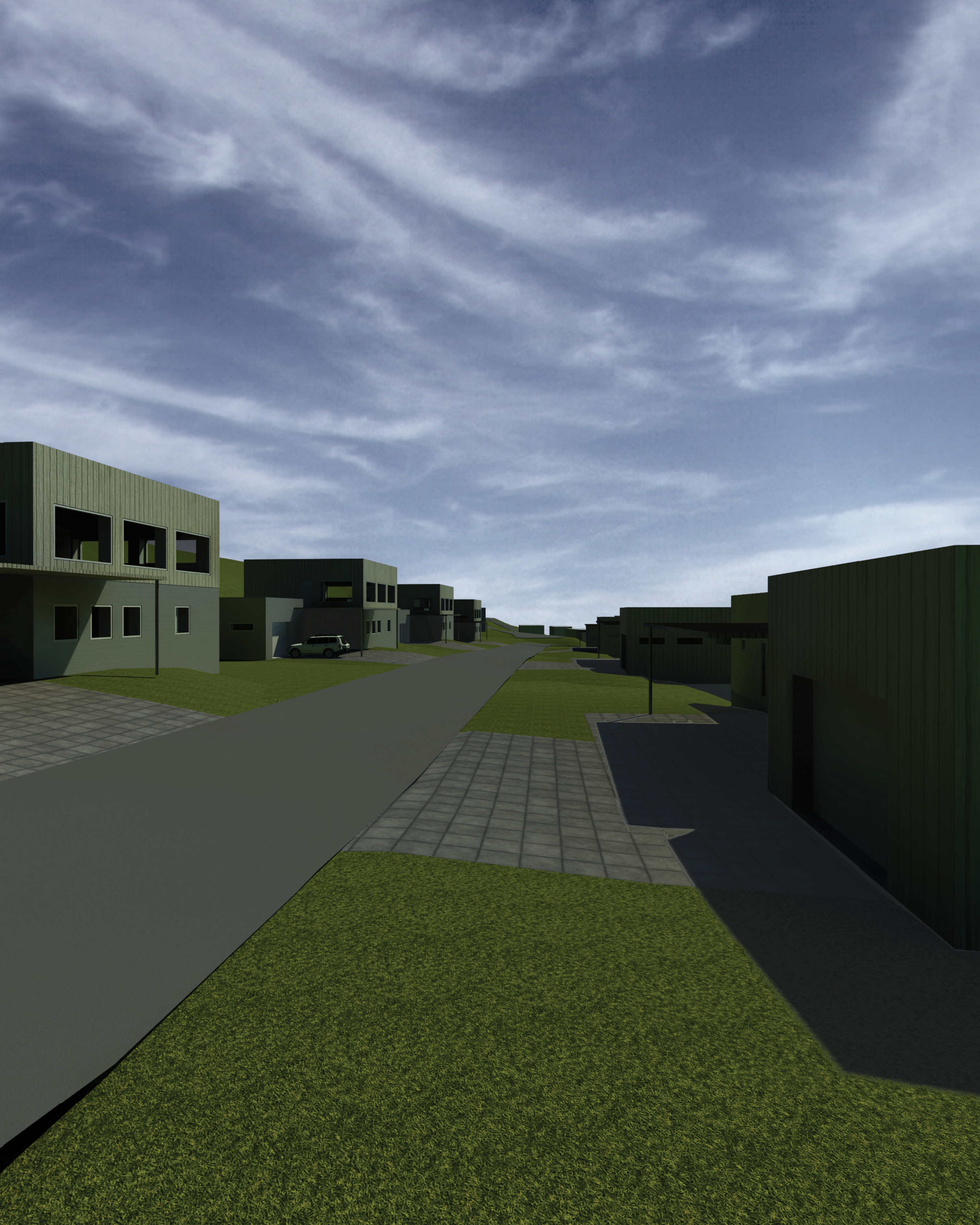
FINAL DESIGN PROPOSAL

In this chapter the buildings will be presented. A site plan in 1:1000 can be seen on the opposite page. On the subsequent pages, renderings of the buildings are shown, as well as plan drawings, facades and sections in the scale 1:100.

Firstly, illustrations of the north buildings are shown, then the south building and finally two renderings from inside the houses.

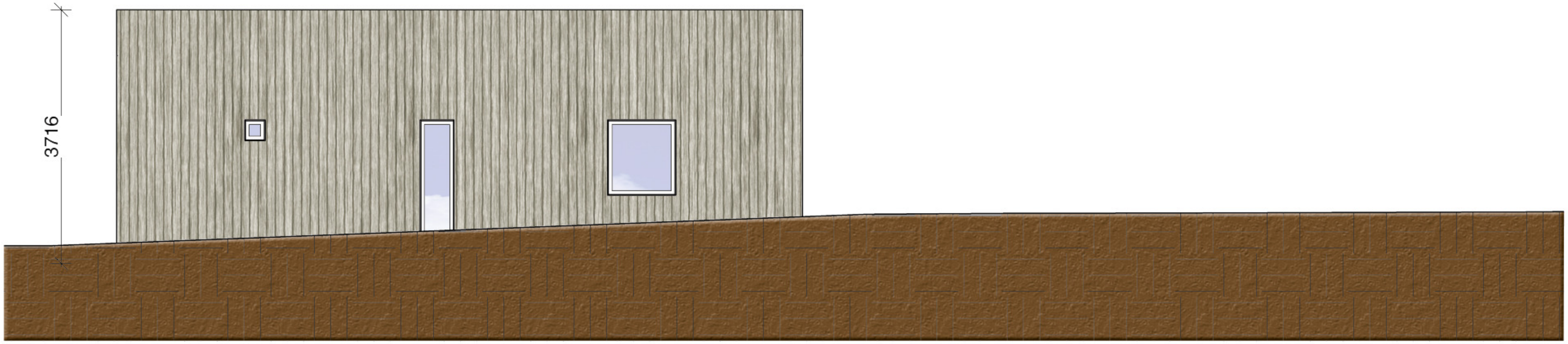
Details of outer wall constructions and the roof can be seen in appendix A.



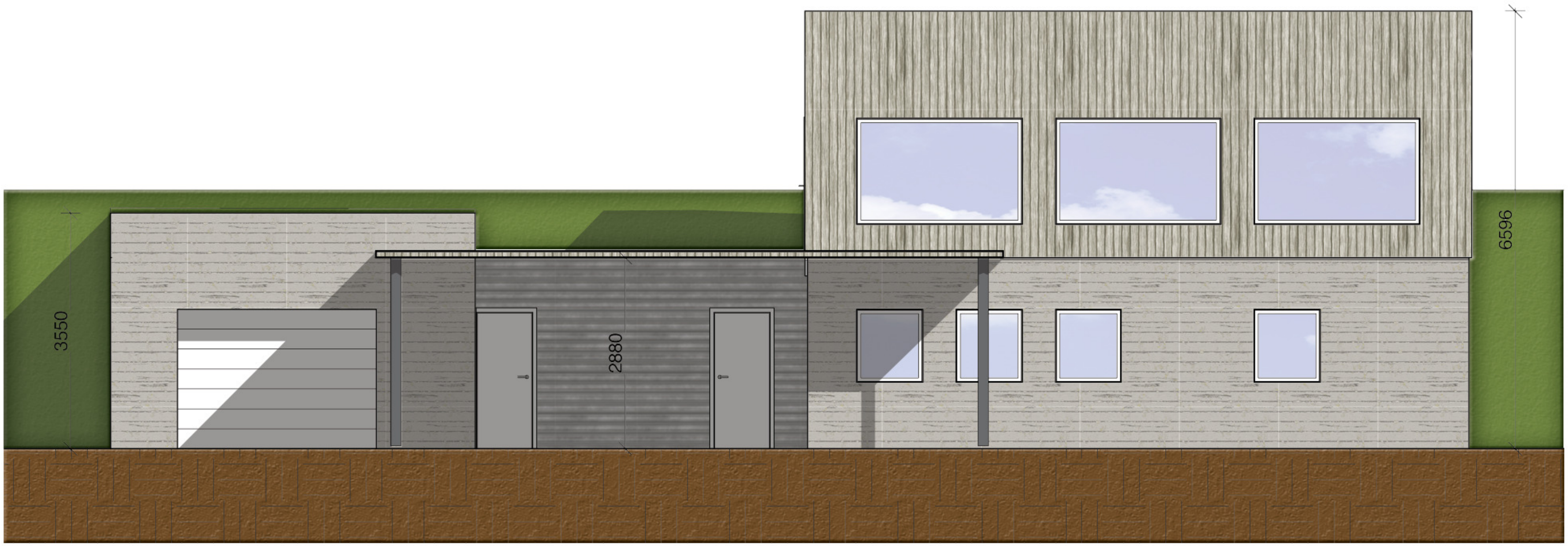


Ill. 108: North building, 2nd floor plan, 1:100

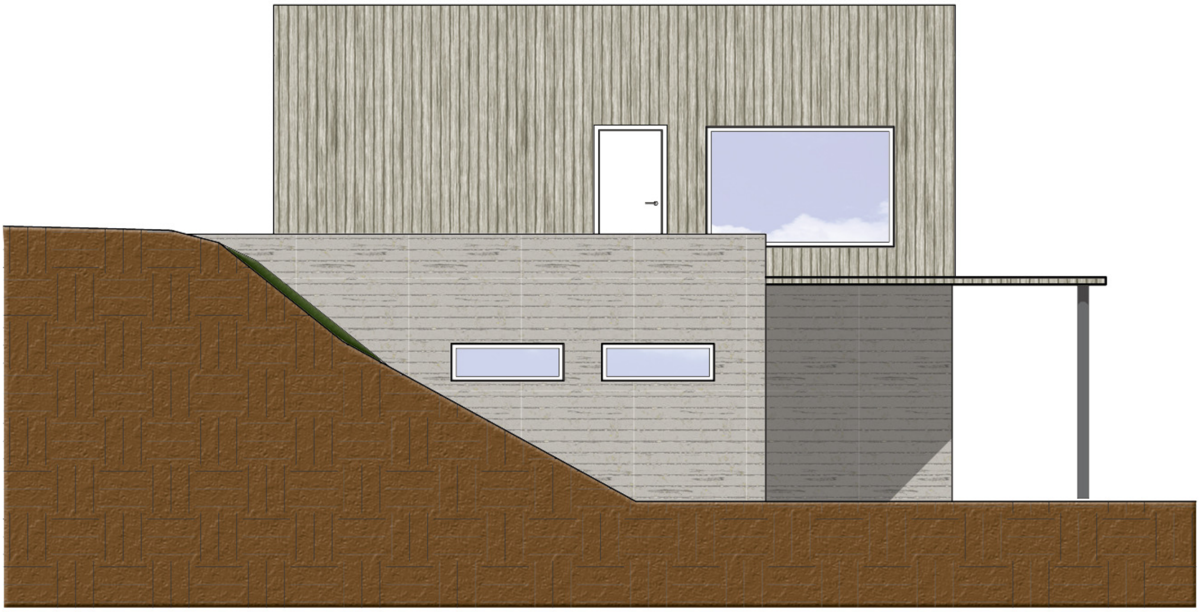
Ill. 109: North building, 1st floor plan, 1:100



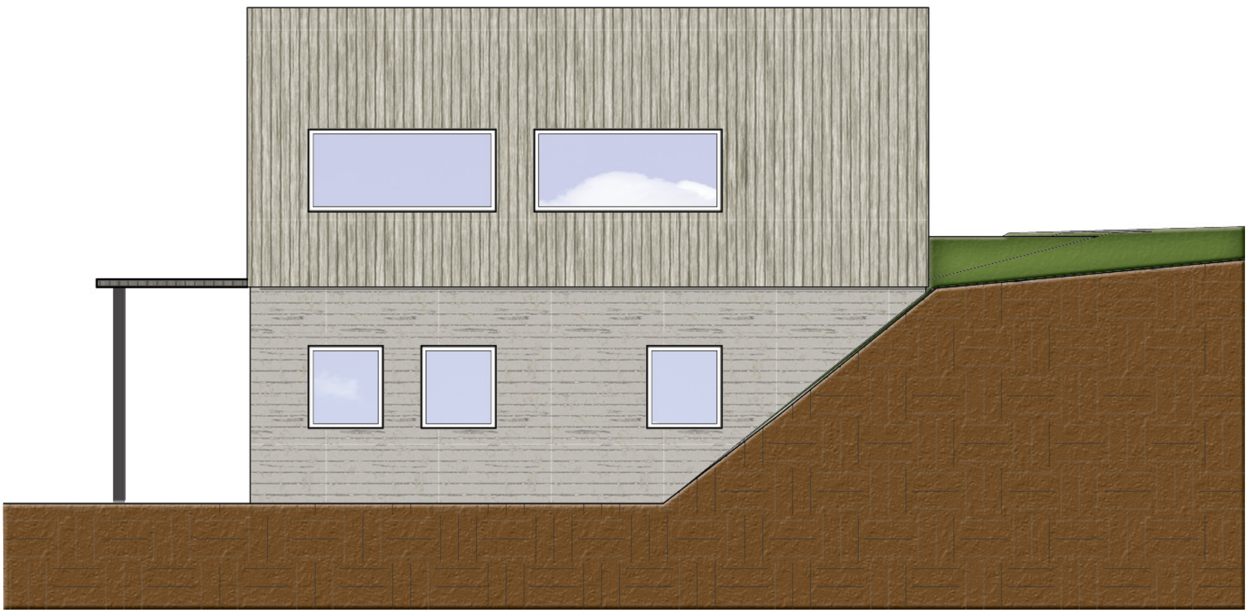
Ill. 110: North building, north facade, 1:100



Ill. 111: North building, south facade, 1:100

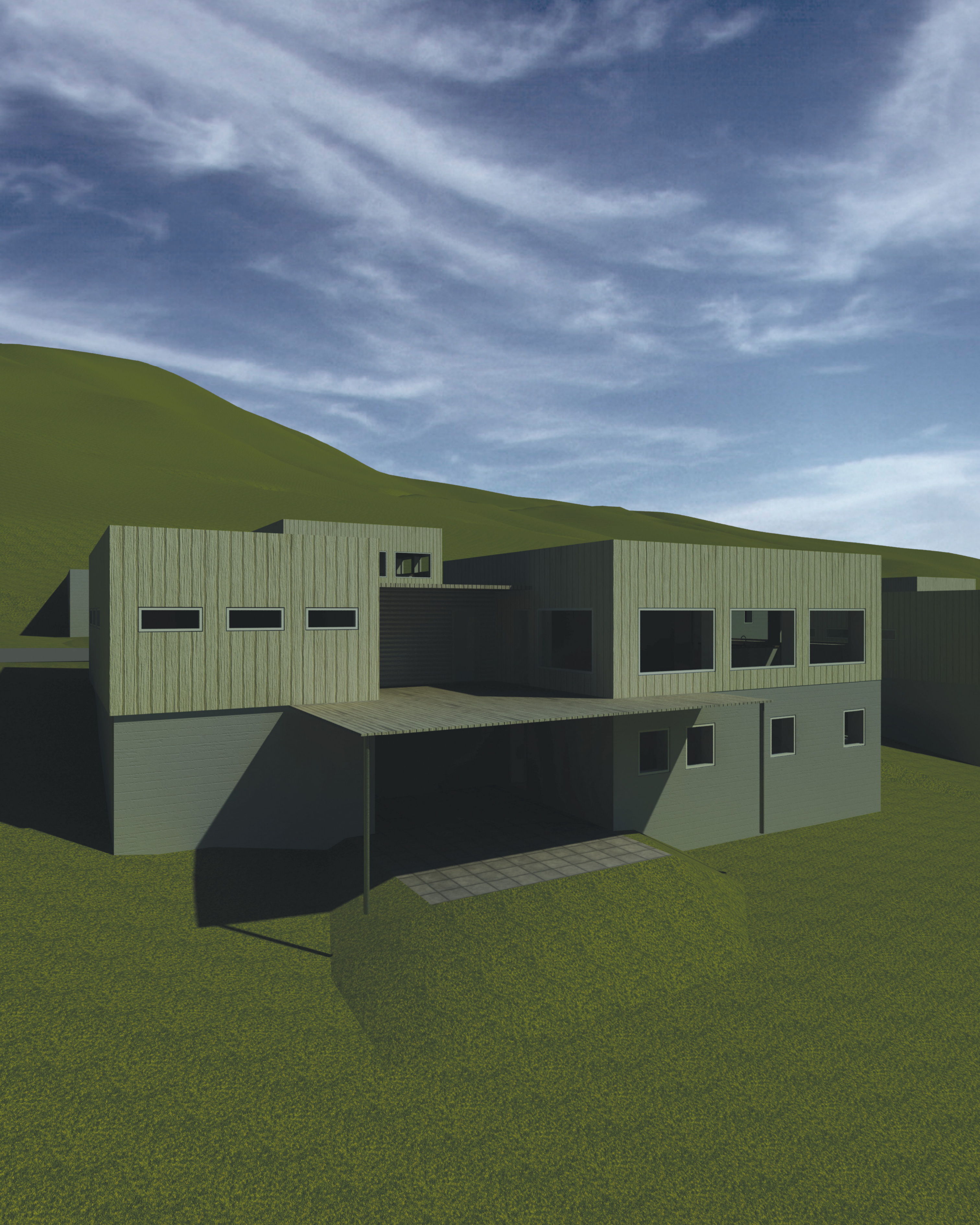


Ill. 112: North building, west facade, 1:100

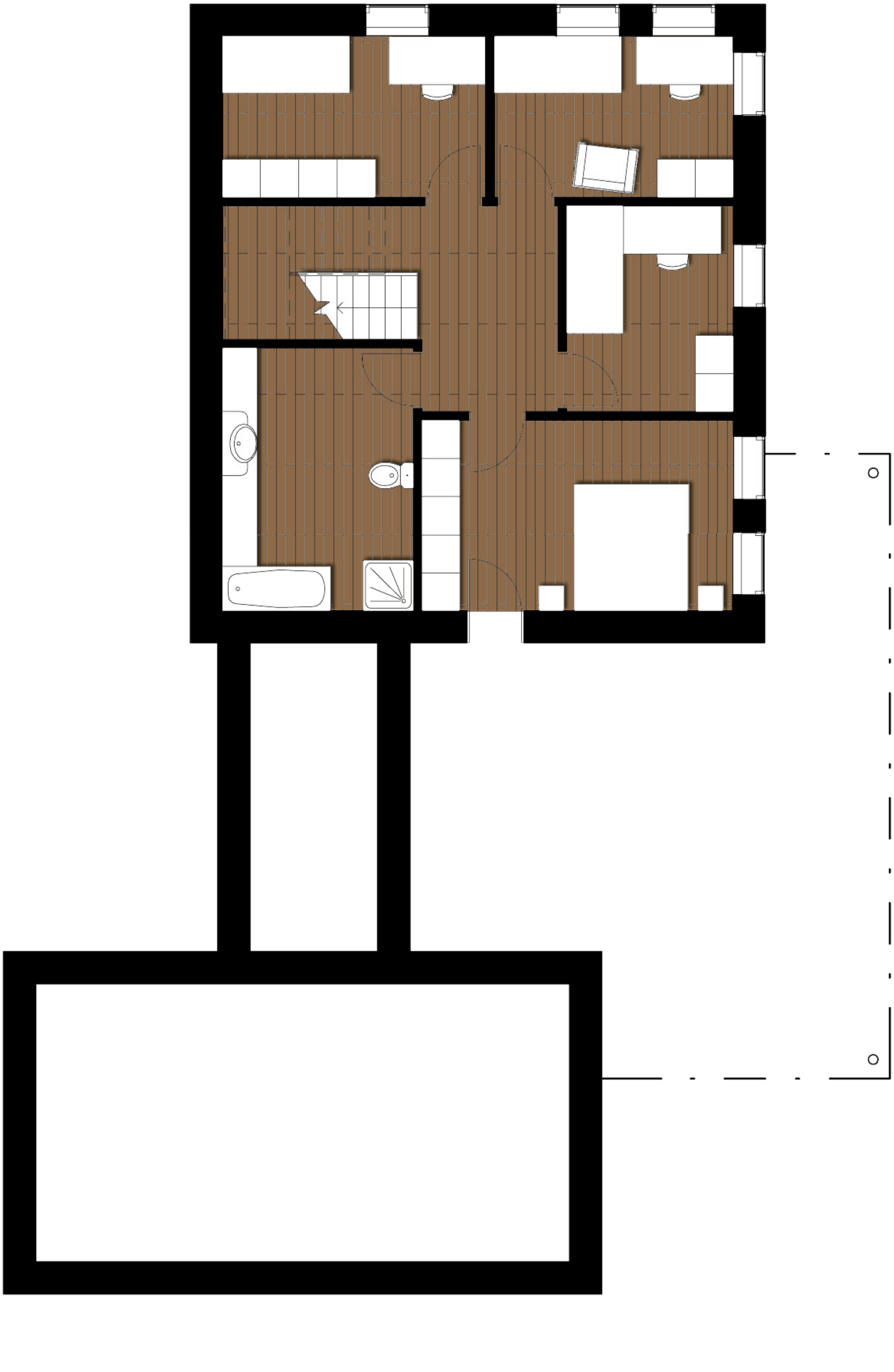


Ill. 113: North building, east facade, 1:100

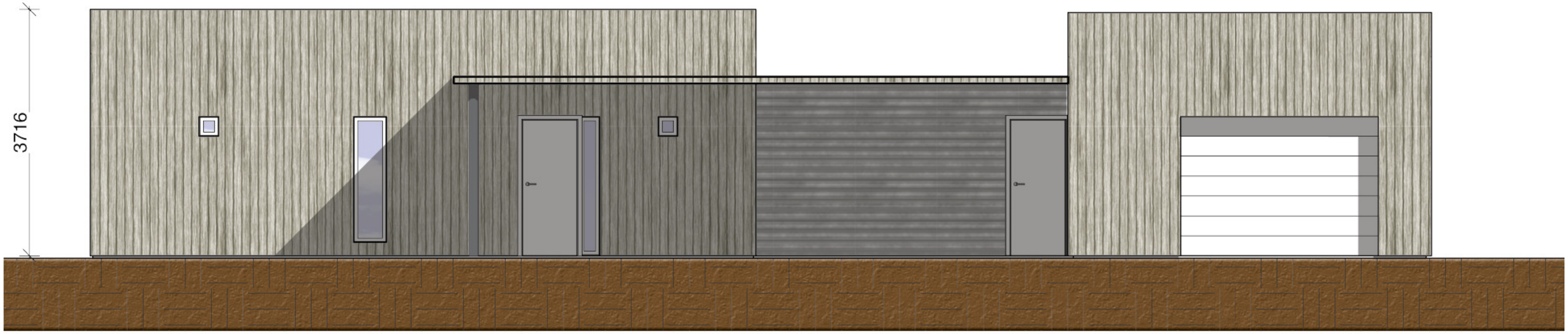
Ill. 114: North building, section, 1:100



Ill. 117: South building, 2nd floor plan, 1:100

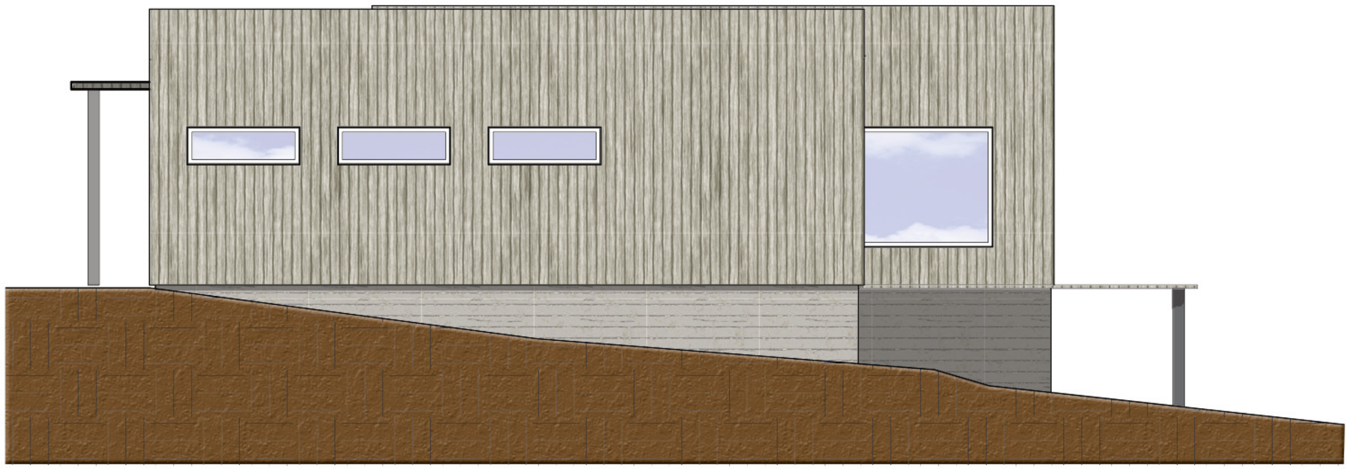


Ill. 118: South building, 1st floor plan, 1:100

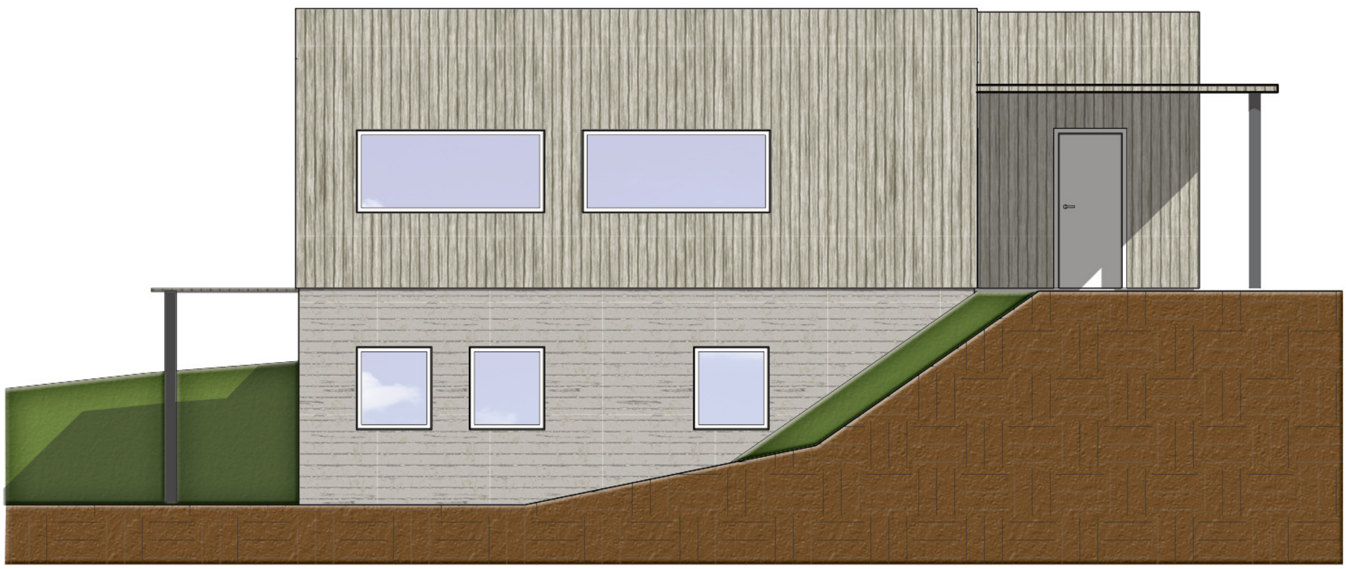


Ill. 119: South building, north facade, 1:100

Ill. 120: South building, south facade, 1:100

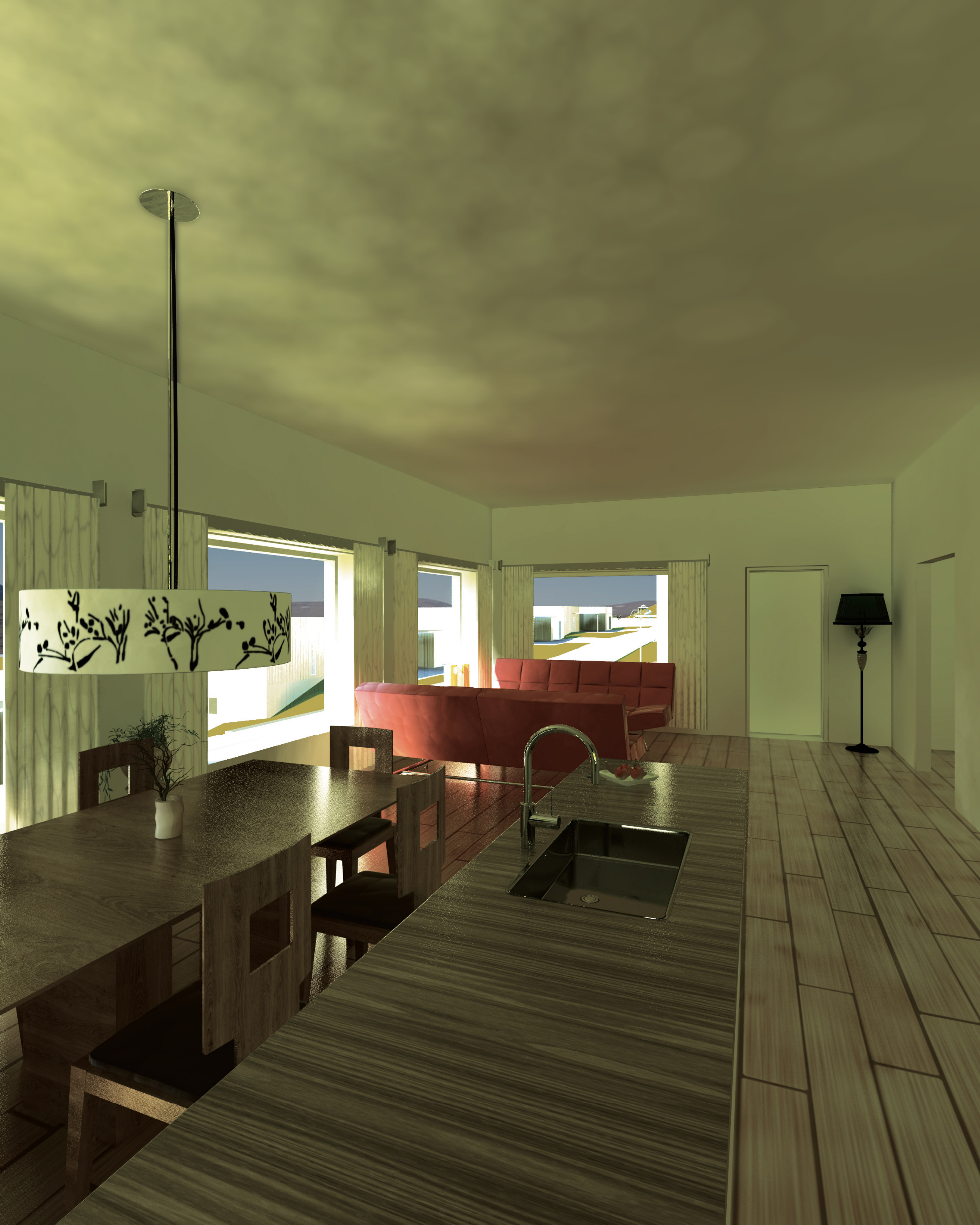


Ill. 121: South building, west facade, 1:100



Ill. 122: South building, east facade, 1:100

Ill. 123: South building, section, 1:100



BREEAM - ASSESSMENT

As mentioned before, adjusting BREEAM to Icelandic regulations and condition is an extensive process.
Criteria regarding issues such as CO2 emissions, public transport in rural areas, flood risk, Icelandic production of materials, water and low or zero carbon energies need to be carefully considered in order to be adjusted to Icelandic conditions. Additionally, various programmes and procedures need to be established in Iceland in order to be able to get credits for criteria concerning these. They include the Considerate Constructor Scheme and a building site crime observation and prevention programme.

The Ene 1 criteria concerning CO2 emissions is one of the most critical issues, as conditions for energy production in Iceland are rather rare and special. As the Icelandic energy grid consists only of low carbon energy the focus in this criteria should rather be on lowering the energy use in Iceland than CO2 emissions. Even though there is plenty of potential for energy production in Iceland, the energy should not be wasted. Therefore, a national energy calculation model needs to be developed.
It has been pointed out that normal practice in Iceland is almost sufficient to get maximum credits for the Ene 1 criteria as it is now (Birgisdóttir, 2009).

Recycling of water in Iceland is one of the criteria which has also been discussed. Iceland is rich of pure water and as recycling of water requires a lot of equipment it is uncertain wether this would result in more sustainability or not. Hot water is also used differently in Iceland, for example for snow melting systems. This means less need for snow clearing and therefore less use of fossil fuels.

When assessing materials in BREEAM a so called Green Guide is used, which contains information on various environmental impact of materials. This results in a grade for each material. Materials produced in Iceland, such as cement and mineral wool emit far less CO2 when produced due to the energy used in their production. These materials should therefore get a higher grade than they traditionally do when produced elsewhere in the world. BREEAM have suggested that a Bespoke Green Guide should be made for such materials.
The reuse of materials is not very common in Iceland. This is certainly something that should be improved (ibid.).

The result of the BREEAM Ecohomes 2006 pre assessment was 67,87 points, or the rating Very good. Very good is given for scores above 58%. To achieve the rating Excellent, a score of 70% needs to be achieved. The building is therefore only 2,13 points from being rated as Excellent.
Had the scheme been adjusted to Icelandic conditions and programmes similar to for example the Considerate Constructors been established in Iceland the result had been different. Wether it would have been better or worse is hard to say, as many points have been given as a result of the difference between the UK and Iceland, and many points have been unobtainable for the same reason.
A detailed description of the assessment can be seen in appendix B.

ARCHITECTURAL DISCUSSION

The architecture of the buildings is somewhat different from other buildings in Eskifjörður. The flat roof and choice of materials especially, are what makes them so distinctive.

The emphasis of the horizontal and vertical lines of the buildings give them a modern architectural expression. The simple forms and lack of ornament refer to the principles of modern architecture. The clear geometrical forms of the buildings and the open and flexible spaces are also in full accordance to the architectural style. The only thing which can be said to be in contrast to these principles is that the buildings' functions have not been allowed to fully control the form of the house, but have had to adapt to the outer form of the building. This has to do with the benefits of a compact shape when it comes to reduction of the buildings energy consumption. However, the buildings functions have been in focus as it has been important in this project that the house is functional in relation to its use.

The general outer form of the buildings is, as mentioned, different from what can be seen in Eskifjörður. However, the many houses that were built in the 1960's and 70's have similar characteristics, namely big facades free of ornament and large windows.

The horizontal lines that are created by the roof are underlined by the wide shape of the windows as well as the terraces and overhangs on the buildings. These elements and the strict geometrical form of the buildings are a contrast to the nature that surrounds them.

It is this stringent geometry versus the soft lines of the nature which makes the project interesting.

The form of the terrain controls the position of the buildings compared to each other, as they are placed into the landscape rather than the buildings having control over their environment, although some manipulation of the terrain was inevitable. This complies with the vision of the project of letting the landscape be in control rather than the other way around. The buildings are forced into the terrain but can not control it.

The vision stated in the start of the report says that the buildings should combine modern architecture and Icelandic building traditions.

As mentioned above, the form of the buildings refers to modern architecture. The materials used refer to Icelandic traditions and the environment. The concrete is the most used building material in Iceland, and the corrugated aluminium sheathing both refers to the extensive aluminium production in the country and the corrugated iron sheathing used in the late 19th and early 20th century. The use of timber as facing was also very common in the 19th century and is again becoming more and more popular.

Despite the contrasting geometrical forms of the buildings to nature, the neutral and earthy colours and the green roof soften their expression and make them connect to their surroundings.

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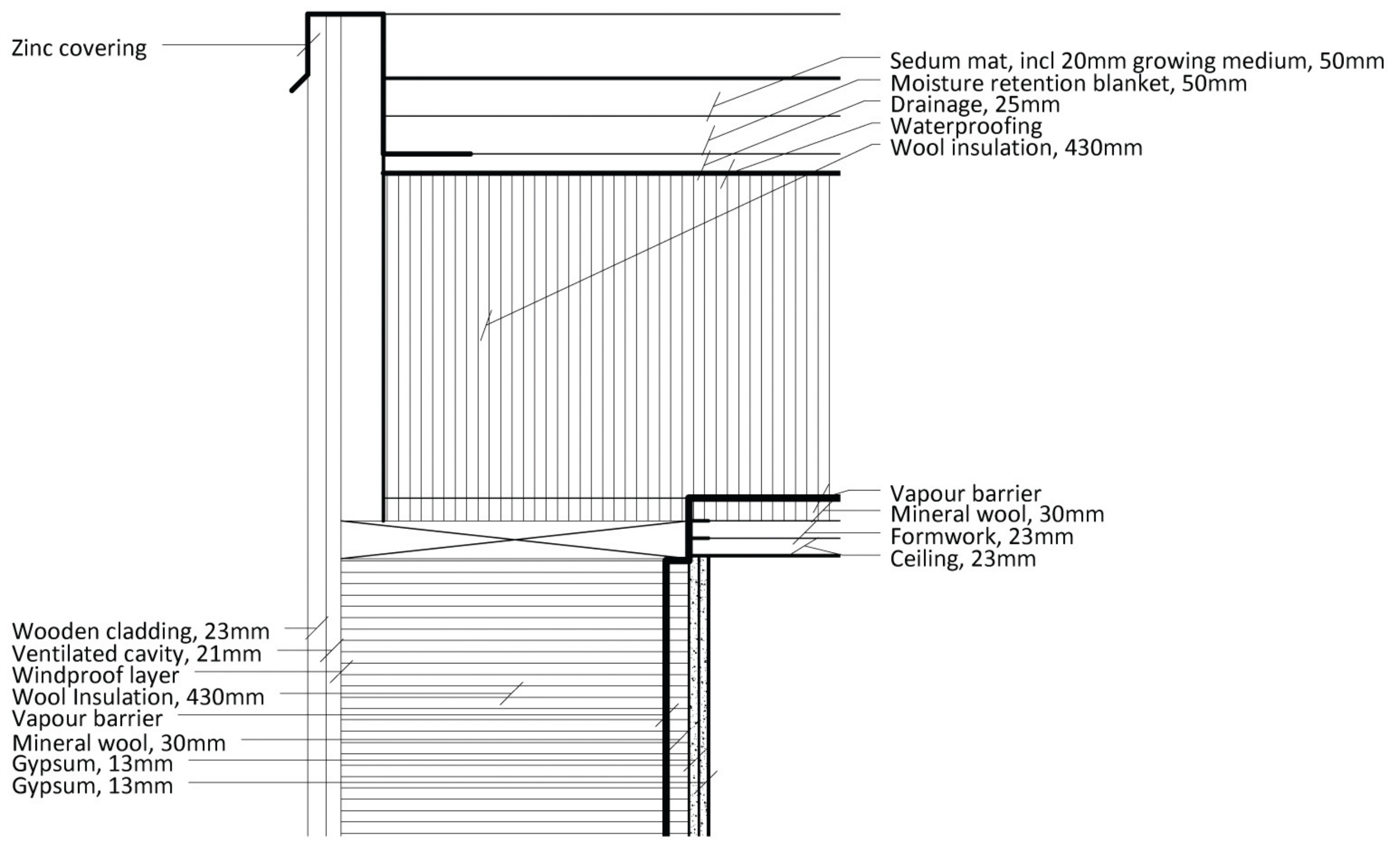
LIST OF ILLUSTRATIONS

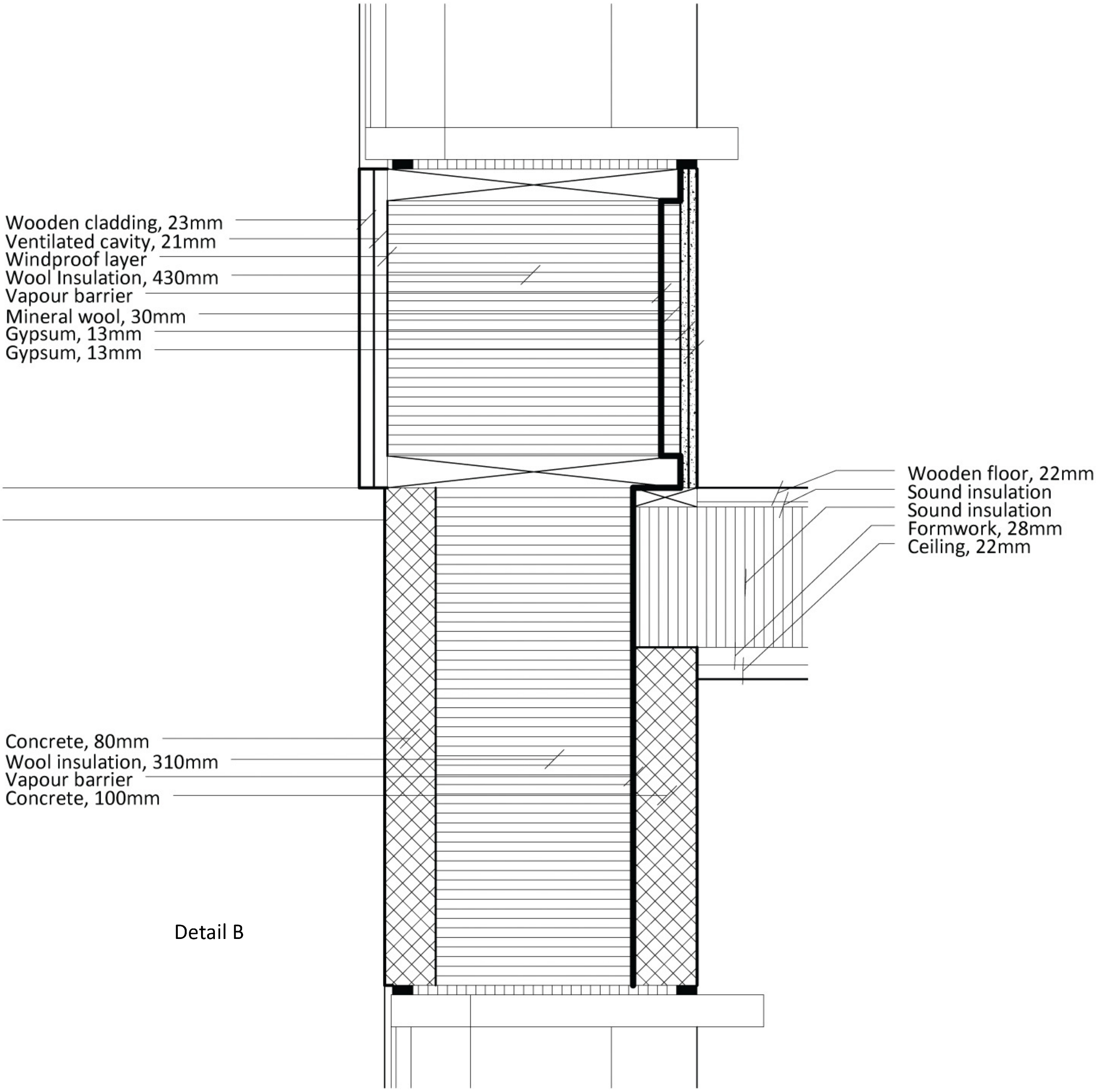
Appendices

APPENDIX A - DETAILS

This appendix contains constructural details for the joints between the two wall types and between the timber wall and the roof.



Detail A


Wooden cladding, 23mm
Ventilated cavity, 21mm
Windproof layer
Wool Insulation, 430mm
Vapour barrier
Mineral wool, 30mm
Gypsum, 13mm
Gypsum, 13mm
Wooden floor, 22mm
Sound insulation
Sound insulation
Formwork, 28mm
Ceiling, 22mm
Concrete, 80mm
Wool insulation, 310mm
Vapour barrier
Concrete, 100mm
Detail B

APPENDIX B - BREEAM

This table lists the criteria of the BREEAM method, and their aims.

	Criteria	Aim
Energy		
Ene 1	Dwelling Emission Rate	To minimise emissions of carbon dioxide (CO2) to the atmosphere arising from the operation of a home and its services.
Ene 2	Building Envelope performance	To future proof the efficiency of dwellings over their whole life, and to encourage refurbished dwellings to improve their insulation standards through good fabric performance.
Ene 3	Drying space	To minimise the amount of energy used to dry clothes.
Ene 4	Eco Labelled white goods	To encourage the provision or purchase of energy efficient white goods, thus reducing the CO2 emissions from the dwelling.
Ene 5	Internal Lighting	To encourage the provision of energy efficient internal lighting, thus reducing the CO2 emissions from the dwelling.
Ene 6	External Lighting	The purpose of this credit is to encourage the provision of energy efficient external lighting.
Transport		
Tra 1	Public Transport	To encourage developers to provide a choice of transport modes for residents, with the aim of reducing the level of car use.
Tra 2	Cycle storage	To encourage the wider use of bicycles as transport, and thus reduce the need for short car journeys, by providing adequate and secure cycle storage facilities.
Tra 3	Local Amenities	To encourage developers to plan new housing developments that are close to, or include, local shops and amenities. This will help to reduce the reliance of local residents on their cars.
Tra 4	Home office	To reduce the need to commute to work by providing residents with the necessary space and services to be able to work from home.

Pollution		
Pol 1	Insulation ODP and GWP	To reduce the potential global warming from substances used in the manufacture or composition of insulating materials.
Pol 2	NOx emissions	To reduce the nitrous oxides (NOx) emitted into the atmosphere.
Pol 3	Reduction of surface runoff	To reduce and delay water run-off from the hard surfaces of a housing development to public sewers and watercourses, thus reducing the risk of localised flooding, pollution and other environmental damage.
Pol 4	Renewable and Low Emission Energy Source	To reduce atmospheric pollution by encouraging locally generated renewable and low emission energy to supply a significant proportion of the development's energy demand.
Pol 5	Flood Risk Mitigation	To encourage developments in areas with low risk of flooding or if developments are to be situated in areas with a medium risk of flooding, that appropriate measures are taken to reduce the impact in an eventual case of flooding.
Materials		
Mat 1	Environmental Impact of Materials	To encourage the use of materials that have less impact on the environment, taking account of the full life-cycle.
Mat 2	Responsible sourcing of Materials: Basic Building Elements	To recognise and encourage the specification of responsibly sourced materials for key building elements.
Mat 3	Responsible sourcing of Materials: Finishing Elements	To recognise and encourage the specification of responsibly sourced materials for secondary building and finishing elements.
Mat 4	Recycling Facilities	To encourage developers to provide homeowners with the opportunity and facilities to recycle household waste.

Water		
Wat 1	Internel Potable Water Use	To reduce consumption of potable water in the home.
Wat 2	External Potable Water Use	To encourage the recycling of rainwater, and reduce the amount of water taken from the mains, for use in landscape/ garden watering.
Land use and Ecology		
Eco 1	Ecological value of site	To encourage development on land that already has a limited value to wildlife and discourage the development of ecologically valuable sites.
Eco 2	Ecological enhancement	To enhance the ecological value of a site.
Eco 3	Protection of ecological features	To protect existing ecological features from substantial damage during the clearing of the site and the completion of construction works.
Eco 4	Change of ecological value of site	The aim of this credit is to reward steps taken to minimise reductions in ecological value and to encourage an improvement.
Eco 5	Building footprint	To promote the most efficient use of a building's footprint by ensuring that land and material use is optimised across the development.
Health and Well Being		
Hea 1	Daylighting	To improve the quality of life in homes through good day-lighting, and to reduce the need for energy to light a home.
Hea 2	Sound Insulation	To ensure the provision of sound insulation and reduce the likelihood of noise complaints.
Hea 3	Private space	To improve the occupiers' quality of life by providing an out-door space for their use, which is at least partially private.

Management		
Man 1	Home User Guide	To recognise and encourage the provision of guidance to enable home owners/occupiers to understand and operate their home efficiently, in line with current good practice and in the manner envisaged by the developer, and to make best use of local facilities.
Man 2	Considerate Constructors	To recognise and encourage construction sites managed in an environmentally and socially considerate and accountable manner.
Man 3	Construction Site Impacts	To recognise and encourage construction sites managed in an environmentally sound manner in terms of resource use, energy consumption, waste management and pollution.
Man 4	Security	To encourage the design of developments where people feel safe and secure; where crime and disorder, or the fear of crime, does not undermine quality of life or community cohesion.

This table shows a listing of how each criteria is approached in the project.

Criteria	Design	Calculations	Assumed	Not applicable	Proven/Fact
Energy					
Ene 1		X			
Ene 2		X			
Ene 3	X				
Ene 4			X		
Ene 5			X		
Ene 6			X		
Transport					
Tra 1				X	
Tra 2	X				
Tra 3				X	
Tra 4	X				
Pollution					
Pol 1	X				
Pol 2		X			
Pol 3	X				
Pol 4					X
Pol 5					X
Materials					
Mat 1	X				
Mat 2	X				
Mat 3	X				
Mat 4	X				

Criteria	Design	Calculations	Assumed	Not applicable	Proven/Fact
Water					
Wat 1		X			
Wat 2	X				
Land use and Ecology					
Eco 1					X
Eco 2	X				
Eco 3			X		
Eco 4	X				
Eco 5		X			
Health and Well Being					
Hea 1	X	X			
Hea 2		X			
Hea 3	X				
Management					
Man 1			X		
Man 2				X	
Man 3			X		
Man 4				X	

This table shows the credits given for each criteria and the argumentation for the credits. The Ecohomes 2006 Guidance is used as support when going through the scheme. (Building Research Establishment, 2006b)

Criteria	Credits	Argumentation
Energy		
Ene 1	11	The result from the Be06 calculation gave an energy consumption of 58,9 kWh/m2 year. As this does not include the electricity use of appliances and lighting, the energy consumption for these elements needs to be added to the total energy consumption. It can be seen in the results in Be06 that other electricity consumption is 30,7 kWh/m2 year. The total energy consumption is therefore 89,6 kWh/m2 year. Landsvirkjun is Iceland's biggest electricity producer and distributor. They publish a rapport annually where they have calculated the CO2-equivalent emission from their electricity production. When it comes to electricity production in Iceland, 75% comes from hydro plants and 25% from geothermal stations. Geothermal stations primarily produce heat rather than electricity. No calculations have been done on the CO2 emissions from heat production in Iceland. Even though most of the calculated 58,9 kWh/m2 year comes from heating, these values will be used in the CO2 calculations in this credit. Electricity production from geothermal stations emits much more CO2 than hydro stations. CO2-equivalent emission from geothermal plants is 95,987 tons CO2/GWh produced electricity. For hydro stations the emissions are only 0,832 tons/GWh. Since the buildings energy consumption accounts for both electricity and heating, CO2 emissions from both hydro power and geothermal stations will be used, to try to create a worst case scenario from the values at hand (Birgisdóttir & Ólafsdóttir, 2009). The total CO2 emissions are 96,82 tons CO2/GWh which equals 0,097 kg/kWh. When multiplied with the buildings energy consumption, the buildings CO2 emissions are calculated to being 8,67 kg CO2/m2 year. This is below 10 kg/m2 year which gives 11 points.

Ene 2	1,83	Guidance point 1 refers to the SAP 2005 worksheet, box 38. Using the worksheet (can be found on http://projects.bre.co.uk/SAP2005/pdf/SAP2005.pdf) the HLP is calculated to being ca. 0,45 W/m2K. The level of detail in the project does not allow for a ventilation heat loss calculation. The thermal bridge is found in the Be06 calculation.
Ene 3	0,92	Credits can be appointed if there is access to an external drying space where posts, footings and fittings to hold a minimum of 6m line for three (or more) bed units.
Ene 4	1,83	It is assumed that there are eco labelled white goods in all apartments.
Ene 5	1,83	It is assumed that 75% of fixed internal light fittings are dedicated energy efficient fittings.
Ene 6	1,83	It is assumed that all external lighting is as described.
Transport		
Tra 1	0	There is no hourly public transport available. An hourly public transport system would increase the environmental impact. This criteria would have to be scaled down for rural areas in Iceland (Birgisdóttir, 2009).
Tra 2	2	All dwellings have a roofed space for bicycles and a bicycle stand.
Tra 3	2	In a town with only a little over 1000 inhabitants, there is no need for more than one postal facility, one pharmacy etc. Since the town is about 3 km long, not all of the towns dwellings can be within 1 km of these amenities. One credit is given as 6 amenities lie within 1 km of the house furthest away. Another credit is given for safe pedestrian routes to the local amenities.
Tra 4	1	All dwellings have an extra room where a home office can be set up.
Pollution		
Pol 1	0,91	In guidance point 3 it is stated that wool insulation has a GWP of less than 5 and zero ODP. In the Green Guide for materials, it can be seen that polystyrene insulation has the same values as sheep's wool, and can therefore be considered to be OK.
Pol 2	2,73	See the Ecohomes 2006 Guidance, guidance note 16. Zero Emission Energy source/s: Three credits can be awarded where all heat and hot water is supplied by a local zero emission renewable energy source. For these energy sources there are no resulting emissions including NOx.

Pol 3	0	No rainwater holding facilities or sustainable drainage techniques are used in the project. The green roof is not enough to obtain credits in this criteria. The extensive calculations needed to obtain these credits will not be performed in this project and the credits are therefore not sougth.
Pol 4	2,73	Since heat and electricity in Iceland come from renewable and low emission energy sources, it is considered unnecessary to carry out a feasibility study. Maximum points are given.
Pol 5	1,82	As the buildings are situated 25-35 m above sea level, they are not in a flood risk zone. It has however been pointed out, that the criteria should probably be extended to include the risk of snow avalanches, mud flows and earthquakes, should BREEAM be adapted to Icelandic conditions (Birgisdóttir, 2009).
Materials		
Mat 1	5,4	Credits appointed for roof, internal walls, floors, windows and boundary protection.
Mat 2	0	Credits are not sought in this criteria.
Mat 3	0	Credits are not sought in this criteria.
Mat 4	2,71	Internal storage bins are placed in the pantry. External bins are placed in the garage.
Water		
Wat 1	3,33	The appliances which are assumed used are: 6/4 dual flush WC, taps with flow regulators, water saving shower head (flow rate 9-12 l/min), standard size bathtub, best practice washing machine and dish washer.
Wat 2	0	No rain water collection system is installed.
Land use and Ecology		
Eco 1	0	The site is not of low ecological value, as heather is a big part of the vegetation in the area.
Eco 2	0	No ecological features will be designed-in for positive enhancement of the site ecology.
Eco 3	1,33	It is assumed that any existing ecological features on the site are protected.

Eco 4	2,67	It is not possible in this project to calculate the change of ecological value of site. It is however assumed that the change would be minimal, and therefore 2,67 points are given.
Eco 5	0	The Floor area: Footprint ratio does not comply with the criteria demands.
Health and Well Being		
Hea 1	5,25	The daylight factor in all mentioned rooms has been calculated: $DF= \frac{M\ W\ \Theta\ T}{A\ (1-R^2)} = \frac{1*(21,5*0,7)*90*0.6}{182,18\ (1-0,5^2)} = 5,9\ \%$ There is view of the sky from all rooms mentioned.
Hea 2	7	All credits are achieved by default as all buildings on the site are detached homes. The criteria only concerns direct transfer of neighbour noise (guidance point 9).
Hea 3	1,75	All dwellings have a semi private terrace.
Management		
Man 1	3	It is assumed that a Home User Guide will be provided in all dwellings.
Man 2	0	Credits are awarded if the contractor commits to applying with the Considerate Constructor Scheme. The scheme was developed to improve the image of construction in the UK and focuses on better working conditions on the site, as well as considerations for the public and the environment (Considerate Constructors, 2010). An alternative scheme can also be used, which should comply with the criteria in the checklist A2 mentioned in the Ecohomes 2006 Guide. The checklist can only be accessed by licenced Ecohomes assossors. No equivalent scheme exists in Iceland. It has been pointed out that the demands in the checklist to such a scheme do not completely comply to Icelandic traditions and should be adapted, if BREEAM is to be taken into use in Iceland (Birgisdóttir, 2009). It is therefore assumed that contractors would perhaps not be willing to follow an alternative scheme. These credits will not be sought.

Man 3	3	It is assumed that the construction site impacts are monitored. This is not normal practice in Iceland, however, this has been done among others in the Visitors Centre in Skriðuklaustur National Park (Birgisdóttir, Harpa. Personal conversation, 04/02/2010).
Man 4	o	This criteria deals with crime observation and prevention on the building site. As no equivalent programme exists in Iceland, these credits will not be sought. Credits can also be given if windows and external doors comply with certain security standards. Windows and doors have not been chosen with the compliance to such standards in mind. These credits will therefore not be sought either.
Total credits	67,87	Very good

APPENDIX C - BE06

The table lists the key results of the BE06 calculations.

Be06 Key results: South Building	
Transmission loss, W/m^2	
Building envelope excl. windows and doors	4,0
Energy frame, kWh/m^2 per year	
Low-energy building class 1	41,1
Low-energy building class 2	58,9
Total energy frame	82,2
Total energy frame, kWh/m^2 per year	
Energy frame in BR, no addition	82,2
Supplement for heigh air change because of BR demand for venting	0,0
Addition for special terms	0,0
Total energy requirement, kWh/m^2 per year	
Energy requirement	58,9
Contribution to energy requirement, kWh/m^2 per year	
Heating	58,2
El. for service of buildings, *2,5	0,2
Excess temperature in rooms	0,0
Net requirement, kWh/m^2 per year	
Room heating	43,7
Domestic hot water	14,6
Cooling	0,0

Selected el. requirements, kWh/m² per year	
Lighting	0,0
Heating of rooms	0,0
Heating of domestic hot water	0,0
Heat pump	0,0
Ventilators	0,0
Pumps	0,0
Cooling	0,0
Heat loss from installations, kWh/m² per year	
Room heating	0,0
Domestic hot water	0,0
Output from special sources, kWh/m² per year	
Solar heat	0,0
Heat pump	0,0
Solar cells	0,0
Total el. requirement, kWh/m² per year	
El. requirement	30,9

APPENDIX D - U-VALUES

This appendix describes the basic process of calculating U-values for given constructions. The calculations for a timber wall and a concrete wall in the project are shown as examples.

In order to determine the transmission loss for a construction, it is necessary to know the heat transmission coefficient, which is also called the U-value. The U-value is the reciprocal of the R-value, which describes the thermal resistance of a construction.

The R-value can be calculated by multiplying the thickness (s) of an element in the construction with the heat transfer coefficient (λ). The U-value is then the reciprocal value of the sum of all R-values in the construction.

Timber wall	s	λ	R	U
	m	W/mK	m^2K/W	W/m^2K
External transition			0,04	
Ventilated cladding	0,040		0,30	
Wood	0,430	0,140		
Wool insulation	0,430	0,039	9,07	
Extra mineral wool	0,030	0,039	0,77	
Gypsum boards	0,026	0,250	0,10	
Internal transition			0,13	
ΣR			10,53	
U-Value				0,09

Concrete wall	s	λ	R	U
	m	W/mK	m^2K/W	W/m^2K
External transition			0,04	
Concrete	0,080	1,420	0,06	
Wool insulation	0,310	0,039	7,95	
Concrete	0,100	1,420	0,07	
Internal transition			0,13	
ΣR			8,12	
U-Value				0,12