Places built with and for joy...

An environmentally friendly pavilion
that can be assembled into larger units.
For good-fellowship, play music and performance.

Henriette Ekström

Master´s thesis at Chalmers Architecture
Design for Sustainable Development
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CHALMERS
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ABSTRACT

In this master thesis I have gradually tried out a design which can function as one or be assembled into larger units. It has become a pavilion to meet altering demand for space with almost endless ways to form a large building.

The design has been made by comparing furnished, different shaped, equal sized buildings. Then I have constructed and chosen materials for a building in which you will feel well. When doing so, I have tried to apply a real precautionary principle. Hence, some information about chemicals, present in building materials, have been gathered.

During the time I have been working with this thesis I have come upon difficulties and obstructions concerning ecological building. Hence, steps to take that would support ecological building and the choice of environmentally friendly materials, have been suggested.

Compared to equal sized square rooms, the pavilion feels more spacious, including and kinder. It is also more interesting to move around in.
The form of the pavilion corresponds very well with the diagonal of the golden section rectangular form. There are also points of contact with the round form.
The form is space saving in that sense that the pavilion has more living space per building area compared to rectangular buildings.
The pavilion does not need any gutters. The roof directs the water to two drainpipes, one on each side of the building.
The possible compositions have become more numerous than first were thought. From a small pavilion, 16,4 m^2 building area, it can be developed into a music or community centre or a detached house.
It is also possible to assemble the pavilions so it becomes a conservatory or a sheltered open garden with fruit-trees and berry bushes in the centre of the building.

keywords:
sustainable, ecological building, hemp, module, mortgage free building, hållbart, ekologiskt hus, hampa, växthus, uterum

ABSTRACT

I detta examensarbete har jag successivt laborerat fram en modell som kan fungera för sig eller kopplas ihop till större enheter. Det har blivit en paviljong som kan möta skiftande behov för utrymme med nästan oändliga sätt att utforma en stor byggnad.

Utformningen av paviljongen har gjorts genom att jämföra möblerade, olikt formade, lika stora byggnader.
Sedan har jag konstruerat och valt material för ett hus i vilket man mår bra. Under den processen har jag försökt tillämpa en riktig försiktighetsprincip. Därför har en del information tagits med angående kemikalier som finns i byggmaterial.

Under arbetets gång har jag stött på svårigheter och hinder när det gäller ekologiskt byggande. Därför har förslag på åtgärder som skulle kunna gynna ekologiskt byggande och valet av miljövänliga material tagits med.

Jämfört med lika stora rektangulära rum känns paviljongen rymligare, mer inkluderande och vänligare. Den är också intressantare att röra sig i.
Paviljongens form överensstämmer mycket väl med diagonalen i gyllene snittets rektangel. Det finns även beröringspunkter med den runda formen.

Formen sparar utrymme på så sätt att paviljongen har mer boyta per byggnadsyta jämfört med rektangulära byggnader. Paviljongen behöver heller inte hängrännor. Taket leder vattnet till två stuprör, ett på vardera sidan av huset.

Det har blivit många fler möjliga sammansättningar än det först var tänkt.
Från en liten paviljong med 16,4 m^2 byggnadsarea, kan den utvecklas till ett musik- eller gemensamhetshus eller till en fristående villa. Man kan också koppla ihop paviljonger så att det blir en vinterträdgård eller en skyddad öppen trädgård med fruktträd och bärbuskar i mitten av byggnaden.

Table of contents

1 Introduction

After being in Hammarkullen due to a project at Chalmers, I got the idea of a small building, circa 15 m^2, where it would be possible to practice music without disturbing others.
At first I thought the building could be a so called “friggebod”. A small building, maximum building area 15 m^2, with maximum 3 m to the ridge of the roof. Possible to build without building permit on private properties with single-family houses in Sweden. However, building permit is always required when building on properties with block of flats.

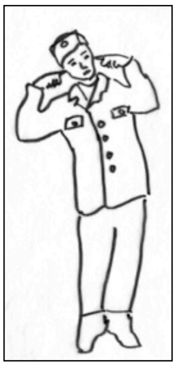
In this case, the rules for the “friggebod” have not been possible to follow and therefore, this pavilion will always need building permit.

Hammarkullen is a suburb in the north-east of Gothenburg. At the end of may each year since 1974 (apart from a two year interruption at the end of the 1970s) there is a festival. Each year it has grown and has become a multicultural popular festival. This shows their keen interest in music and dance.

In many suburbs, as in Hammarkullen, people live very close together in multistorey buildings. Compared to living in a detached house, there are two disadvantages living in an apartment:

- In an apartment you do not have your own garden. For some, this is an advantage.
- The sound is often much more easily transmitted between the apartments.

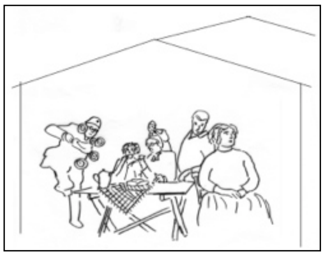
When you can hear your neighbour, your neighbour can hear you. This results in people feeling supervised. To not disturb your neighbour, you feel you have to be silent and then you can become irritated at those who are not. And if you are practicing music, knowing that others can hear you, that takes some of the joy away.



In a detached house it´s harder to disturb the neighbors but you can still disturb other family members. They can easily be disturbed when you want to practice music.
If you then can go to the pavilion all is good and well . Either the one who wants to practice or the other/others.

If you live in a block of flats and have a pavilion where you can be at times, you can get the advantages with both an apartment and a detached house.

Musicians and actors, they may need a stage in order to perform before an audience. Therefore, I wanted the pavilion to function as such too. A small stage where you can perform. An easily accessible stage that is free of cost to book.



Music can bring people together and help participate in integrating newly arrived people in Sweden. Music tends to make it easier for people to meet regardless of language.

Is it possible to create a building out of joy? I believe so. Creative joy, joy to be able to create something.

Building a house can be joyful when we know and feel that the building will be good and safe and we also will feel better when building it. The expectation that the building will be a joy to those who will use it, contributes to the joy. If we then can and are allowed to be creative that too can spice up our existence.

When we look at the design of plants they are showered with rounded shapes. I haven´t found any quite square shapes. When I searched my memory I came to think of goutweed. It feels

like it has a straight side which makes it easy to separate it from other plants but when I looked closer I saw that it was constructed of two semicircle shapes.
In nature the best construction gives the best outcome. That´s probably the reason why the square shape is missing or at least very rare. Stems and trunks are round because that is the most economical shape in order to withstand the forces of nature.
Since we are parts of nature, we are used to those varied and rounded forms.
Hence, I have tried to create a building which can give satisfaction and joy through its shape. A shape we humans more easily can feel at home in, something less square.

1.1 Background

Places where we can meet and be together in a natural, casual way are scarce. Therefore, people can feel alone although living in dense populated areas.

Music can link us together and heighten the quality of our life when there are spaces where we can meet and play music together. And spaces where it is easy to practice in between. Music influences us. Even on a physical level. In a study by Tervaniemi et al (2006) and others they found that small variations in pitch and duration influenced structures in thalamus among others (Lindqvist Gatti, 2010)

When designing spaces for music, acoustics has to be considered.
Other aspects that can influence the design are closely linked to health issues.

The design of rooms is important for mans health.
"The psychiatric clinic in Esbjerg, Denmark, has more than halved their coercive measures against their patients after they got rooms that were more light and open." (my transl.) (Palmira Koukkari Mbenga, 2016)

The sunlight, among other things, controls when we wake up and when we go to sleep. Several studies has shown that pupils who aren´t exposed to enough daylight at school achieve worse.
A working place which is farther away than circa 2 m away from a window gets too little daylight according to Torbjörn Laike who research in environmental psychology at Lund´s University of Technology. (Hult, 2011)

The green surroundings around apartment buildings are often in a larger scale than private gardens. They most often don´t have any fruit trees or berry bushes. So, when living in an apartment there can be a want for a more private garden. A peaceful, more enclosed place with fruits and berries.

"One of the few things the science has proof of is that when we come in green environments, the level of stress diminishes."
Stefan Lundin, architect (my transl.) (Lundin, S. 2016)

Consequently, I want to design a pavilion for music, that is light and open. A pavilion that also can create space for a more private garden in suburbs.
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1.1.2 Environmental influence

Since there are large amounts of materials in buildings, it is important that these materials is healthy and environmentally friendly.

In Boverkets building rules, 6:1 you can read:
"Buildings and their installations shall be made in such a way that the quality of air and the conditions of light, humidity, temperature and hygienics will be satisfactory during the life of the building and thereby avoiding inconvenience for mans health." (my transl.) (BBR, 2015)
In the next paragraph 6:11 it says:
"Materials and products for construction used in a building shall not in itself or by its treatment, effect the indoor environment or the buildings local environment in a negative way when the functional demands in these rules are met." (my transl.) (BBR, 2015)

Further more:
In the regulation (EG) nr 1907/2006 of the european parliament and of the council of 18 December 2006 concerning the Registration, Evaluation, Authorization and restriction of Chemicals (REACH) it says in General issues, Chapter 1, Article 1:3:

“This regulation is based on the principle that it is for manufacturers, importers and downstream users to ensure that they manufacture, place on the market or use such substances that do not adversely affect human health or the environment. Its provisions are underpinned by the precautionary principle.” (REACH, 2006)

“Companies or individual workers who use chemicals are called downstream users in REACH and CLP.” (Echa, 2016)

In 2015 the Swedish Government assigned “the Swedish Chemicals Agency to investigate the need to draw up national regulations concerning hazardous chemicals in construction products and in particular consider reducing children’s exposure to such substances.” (KEMI, 2015)
In Sweden there is only one regulation with national thresholds for emissions of harmful chemicals from construction products, namely formaldehyde emissions from wood-based panels.
This rule is not sufficient to protect children according to the Swedish Chemicals Agency. (KEMI, 2015)
Therefore, one can sadly say that the precautionary principle is somewhat toothless.

Existing regulations and regulations under development in Germany, France and Belgium only cover products used in the construction of flooring, wall and ceiling sections. Documentations of emissions of both volatile organic compounds (VOC) and semi-volatile organic compounds (SVOC) will be required for these products in order for them to be marketed and used, according to the EU’s Construction Products Regulation. (KEMI, 2015)

The EU’s Chemicals Regulation – Reach have already established some regulations concerning chemicals in certain construction products. They usually concern restrictions on concentrations of harmful chemicals in construction products. (KEMI, 2015)

“A typical indoor environment can contain over 6,000 organic compounds, of which around 500 can be attributed to construction products. Some of these compounds are carcinogenic or allergenic. Emissions of harmful substances from construction products have been reported in the scientific literature and have also been confirmed by studies conducted mainly in Germany, France and Belgium.” (KEMI, 2015)

Large amounts of materials are used in building. Consequently, when the materials contain chemicals it will be proportionately large amounts of chemicals.
Fibreboards can be used as an example. Wooden fibreboards are mainly glued together with different kinds of formaldehyde glue and are traditionally classified into three groups:

- Plywood/laminae wood
- Fibreboard
- Particle board

(Kemikalieinspektionen, 2014)

If there are 4 mm fibreboards in the floor, walls and ceiling in a 100 m^2 building, the building will contain 18 - 24 kg phenol-formaldehyde glue.

“As a substance, formaldehyde is classified as acute poisonous, corrosive and allergenic and carcinogenic. Formaldehyde is strongly irritating on eyes and respiratory passages. Inhaling can cause coughing, hoarseness, headache, dizziness, pressure on the chest and in more severe cases cramp in the larynx and damage in the lungs. Inhaling for a long time can cause irritation of the respiratory passage, nasal congestion and asthmatic difficulty in breathing.”(my translation) (Kemikalieinspektionen, 2014)

Phenol is strongly corrosive and toxic. “ To the human 15 g is deadly, but intake of as little as 1 g. phenol has caused death.” (my translation) (NE, 2016) The phenol is bound to the formaldehyde in a non reversible bond (Kemikalieinspektionen, 2014) but I havn´t found any information about what the fibreboards emit if it starts to burn.

When a building is on fire, poisonous chemicals are emitted and most fire deaths today in USA are caused by smoke inhalation, not burns. “The synthetic materials commonplace in today´s homes produce especially dangerous substances.” Besides possible lethal particles and vapors, the smoke contain toxic gases. Carbon monoxide is the most common. (NFPA, 2016)
Carbon monoxide is a very poisonous, combustible gas without colour, odour or taste. It is poisonous because it binds circa 250 times stronger than oxygen to the haemoglobin of the red blood cells. In that way the transportation of oxygen to the tissues of the body is blocked and as a result there is a lack of oxygen in the cells.

Carbon monoxide is also disturbing the breathing of the cells.
Lower concentration of carbon monoxide causes dizziness, headache, nausea etc. Higher concentration of carbon monoxide causes loss of consciousness, cramps, failings of breathing and circulation. (my transl.)(NE, 2017)
Another toxic gas is hydrogen cyanide from burned plastics, such as PVC (polyvinyl chloride) pipes. (NFPA, 2016)
Hydrogen cyanide is a highly volatile and extremely poisonous liquid with a scent of bitter almond . It interferes with cellular respiration. The toxic effect is very rapid and with enough amount it leads to death very quickly. Thats why this substance is used to carry out executions in USA. (my transl.)(NE, 2017)
Phosgene is formed when vinyl materials are burned. At low levels it can cause itchy eyes and a sore throat. At high levels: Pulmonary edema and death. (NFPA, 2016) During the First World War phosgene was a dreaded war gas. It causes an insidious poisoning. The symptoms appear only after some hours. Inhalation causes damage to the epithelia and capillaries in the pulmonary alveoli. (my transl.)(NE, 2017)

It is not only the dwellings of humans that have chemicals inside.
Nowadays there are bee hives built in polyurethane, a very light and well insulating material. It is composed of among other things isocyanate. Some isocyanates can cause cancer, Some are also classified as environmentally harmful since they are poisonous to waterliving organisms. (my transl.)(KEMI, 2017)
Another thing it is composed of is phosgene, see the passage above. Phosgene is still used to create numerous products including plastics, pharmaceutical agents, polyurethanes, dyes and pesticides. (Toxipedia.org, 2014) If the bees will be affected and in that case how, I believe no one knows.

Good, environmentally friendly materials are often more expensive and due to that and a lack of knowledge, they can be replaced by cheaper and inferior materials.
One example is the fibreboard Masonite with thicknesses between 3,2 to 12 mm. Compared to other types of fibreboards, Masonite could stand humidity better and was also stronger. Due to a different manufacturing method, Masonite had longer fibre and added glue was not needed. Masonite contained 16-18 **g**/m^3 formaldehyde compared to 15-20 **kg**/m^3 for other kinds of fibreboards. The now remaining type of fibreboard can thus contain *1000 times* more formaldehyde than Masonite did.

The above glue is, in addition to poisonous, a kind of plastic and as such it obstructs the humidity´s transportation through the fibreboard which makes it harder to dry up if it gets damp. Thus, the glue promotes mould.
The mould as an effect of glue can be made visible by letting glue-laminated wood stand outside, exposed to the weather. Then you clearly can see where it is glued together because it is there the mould first show itself.
To keep the content of chemicals low in the indoor air (from chemicals emitted from building materials but also from furnitures, clothes, electronics and other things) the ventilation must be larger than it would have to be if these chemicals had not been present.

In our society we strive to save time but as Bodil Jönsson, professor of physics, wrote in her book about time. If you calculate how much it costs to drive the car to work and how much you have to earn to get that amount of money, it can be profitable both regarding time, money and health to take the bicycle to work. (Jönsson, 1999)
In other words, we have to consider all aspects when we compare.

It takes equal time to build with Masonite as with other fibreboards but other aspects also take time and cost money.
For example:
- cleaning discharge of chemicals to the air and water.
- the need for increased ventilation due to chemicals in the air.
- increased costs for humans worse health due to exposure to harmful chemicals or their degraded substances.

So, if we consider all aspects regarding the fibreboards and include all costs, then it perhaps would be more profitable both regarding time, money and health to use Masonite instead of fibreboards with poisonous glue.

There are many building products that consist of a mixture of substances. A disadvantage of mixed materials is that, if we want to separate them, if at all possible, it takes much more time and energy and it costs much more money compared to mix them together.

An example is wood impregnation.
In the beginning of the 20th century, Kreosot and Cuprinol were used to impregnate wood. These wood impregnations were also used inside buildings since it was not yet known that they were carcinogenic and that they also had

other effects on the health, like disturbed eye vision.
Since it is impossible to separate the wood impregnation from the wood the impregnated wood inside a building has to be removed and taken to the recycling depot and put in the bin for impregnated wood. Since it contains poisonous chemicals we are not allowed to burn it up ourselves.

Another example is insulation made of hemp. It is easier and faster to insulate with boards rather than with loose hemp. So in order to save time when building, the hemp is mixed with polyester to form boards. The polyester is a plastic material and as such it stops humidity and therefore, the hemp board is probably more disposed to mould compared with loose hemp. Thus, perhaps more renovation costs. Further more, when the building is demolished or the insulation have to be changed for some reason, we can´t use the hemp treated with polyester in the garden or burn it ourselves. We have to take it to the recycling depot with the following expenditure for the transportation and can not derive any advantage from it in the garden. Hence, it is possible that this will be less profitable in the long run compared with insulation with loose hemp.

“A difficulty wanting to choose cheap, simple solutions is of course that they often do not exist on the market since the smart, functioning, cheap products are less profitable to sell”
(my transl.)(Wallner, 2004)

When we want environmentally friendly materials we often have to know what we are looking for and find the hardware store, farmers or ecological dealers who sell it. But even ecological products can contain chemicals.

Sadly the market is flooded with cheap materials which contain different, more or less harmful and hazardous chemicals.
New chemical materials emerge on the market as the “old” chemical materials “becomes” harmful with the latest research.
Then there are manufacturers who claim that their products are environmentally friendly although they perhaps are not so good for the nature.
One such product is a sound absorbent made of window moss, Cladonia Stellaris, a reindeer moss. This moss together with other reindeer moss are of economical importance as reindeer food. Moss grows very slowly. If the moss would be picked in larger amounts, then the reindeers would get less food, especially in the winter, and due to its slow growth, the reindeer moss perhaps be in risk for extinction.
(Wikipedia, 2016)
Instead soft materials can be put on the walls. For example textile fabrics or rugs.

To be able to motivate a restrictive attitude toward chemicals in the building process and other processes, the economical consequences must be made much more evident.

Toxic chemicals in building materials can lead to:

- Increased heating costs due to the need for increased ventilation to decrease the levels of chemicals in the indoor air
- Costs for ensuring safety for the construction workers and the public when building and demolishing a building
- Costs for taking care of the building materials after the building has been demolished, i.e. combustion or storage
- Costs for the cleaning of water and air from the chemicals
- Costs for the research regarding the harmful consequences caused by different substances
- Costs for restoring the environment after mining
- Increasing costs for health-care, new sicknesses and symptoms
- Costs for new medicals, treating those new symptoms
- Additional costs caused by side-effects from the new medicals
- Additional costs for the cleaning of water and air from medicals
- etc.

Those costs could be laid on the corresponding products as an added environmental cost, designed to make the product pay for the costs it cause, like the taxes on fuel.
A way to reflect the vision of the society and thereby also influence the demand.

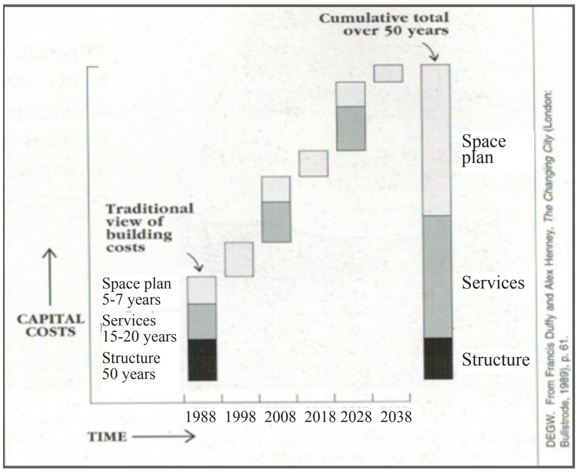
Another way to protect the environment would be to prevent chemicals and other products and services to be used at all until its consequences have been fully researched and proven to be safe or at least better than existing materials. Sadly the consequences often can´t be discovered since we haven´t yet acquired the ability to find them. If we could, that really would be a real precautionary principle.

In this master thesis I will try to follow the real precautionary principle as well as I can.

1.1.3 Building costs

Building is very expensive but the building also costs much after it is built.
Economically you often expect a building to stand in 50 years. However, most buildings stand of course much longer. They stand until it is considered economically indefensible to pay for more re-equipment and renovation.
The running expenses can in a period of 40 years run up to twice as much as the original cost of the investment. (Hagentoft, 2002)

Costs for renovation and rebuilding is big costs during the buildings lifespan. It can be illustrated with Duffy´s bar chart:



DEGW. From Francis Duffy and Alex Henney, The Changing City (London: Bullstrode, 1989), p.61
(Brand, 1997)

The chart applies first and foremost to commercial buildings. The costs can be changing of rooms, painting, paper-hanging, wire for electricity, ventilation, tubing, elevators, furnitures, counters, lamps, kitchen fixtures etc. The first column represents what is traditionally included in a building´s costs. The following five columns in the chart show that you usually change planning at intervals of 5-7 years and maintenance of the building at intervals of 15 - 20 years. The column furthest to the right shows the total costs throughout the 50 years.
The construction cost is a very small part of the total costs. Therefore, the biggest savings can be achieved if the costs for planning and maintenance can be reduced.

Different surfaces take different time to wear out. Laminated flooring has a very hard surface but it is very thin. Pergo floor gives 25-33 years guarantee on their laminated floors laid in dwellings. 33 years can seem to be a long time but time past quickly. When the thin surface is worn out or something sharp and heavy is dropped so it makes a hole, it isn´t very easy to repair. If you don´t have some pieces of the floor saved, it can be very hard to find a match. Hence, the whole floor has to be changed if you do not want it to show.

On a massive wooden floor, such problems do not occur and therefore, such a floor becomes cheaper in the long run. If you drop something, there will not be much impact.
A massive wooden floor can last much longer and is also possible to grind several times.
If you do not grind it, it can last almost forever. But if you drop something that has a strong colour, like beetroot juice, there can become staines and it can come down into the openings between the boards and be difficult to remove without grinding it away. However, staines usually fade with time and if we instead look at the staines as the floor getting patina and charm, then it does not matter. The function of the floor has not changed. And the more times the floor is scrubbed with soap, the less it is said to absorb.

The laminated floor has nevertheless a big advantage. It is more easily cleaned (when the surface isn´t damaged) so the costs for cleaning agents will be lower. But yet, all included, the massive wooden floor will still be cheaper.

Building practices change over time. Now the view that buildings must be very tight is changing.
Buildings still have to be tight against wind and water. But water vapor must be able to diffuse through. Otherwise possible water vapor in the construction phase can be confined inside the construction. (Mataki, 2016)

The production of energy is both polluting and draw on the earth´s reserves.
In Sweden 2014, the three biggest consumer of energy are industry 39 %, transportation 23 % and the households, who consume 22,3 % of the total consumption of energy. (Energimyndigheten, 2014)
Circa 20 % of the households energy consumption is used to warm water. (Göteborg energi, 2016)
65% of the households energy consumption goes to heating and ventilation. (Hagentoft, 2002)

Thus, the building should be well insulated in order to minimize the heating costs.
However, the heating costs still become bigger and bigger the more warmth vi want and the more chemicals we need to ventilate away.

A benefit from lower temperature in the bedroom is a better sleep.

Other benefits are:
- lower heating costs
- less discharge from electrical and thermal power stations
- higher relative humidity in the air, which can be good in the winter when it usually is very dry inside.

1.2 Aims

My objectives are:

- To learn more about the spatial consequences of different forms.
- To help create healthy spaces outside apartment buildings and detached houses where we can meet, play music and have fun together.
- To spread knowledge about chemicals in buildings and the need for applying a real precautionary principle.
- To create a building which has a minimum of costs for future planning and maintenance.

1.3 Objectives

To design a small building that:

- facilitates playing music
- can be used as a stage
- can be mounted together to become larger buildings
- does not contain any potential harmful chemicals to man and/or nature and thereby in principle is able to dismantle, reuse, compost and then grow vegetables in. Materials not decomposable should be able to reuse, preferably in the same shape or to be burnt in a stove to get heat.
- is possible to dismantle
- is possible to build by the people who are going to use the building.
  The advantages of that is:
  - it can reduce the costs
  - it can promote togetherness
  - it can promote self-esteem
  - it can give increased understanding and respect for the building and thereby
  - the building is better taken care of

1.4 Method and Process

Make programs, based on research, as a start of the design process.

Choose the outlines of the building based on acoustic preferences in order to facilitate playing music.

Explore how the building can be assembled to similar buildings to create larger buildings.

Develop the shape of the building by comparing different forms of furnished, equal sized buildings and assembled forms of these buildings.

Compare the building with furnished, equal sized rectangular buildings.

Compare the building with the forms of nature.

In addition to the development of the shape also explore and suggest construction and choice of material. Thereby using a real precautionary principle.

Visualize the result by giving examples of the building and assembled forms of the building.

1.5 Requirements

1.5.1 Functional program

- Building area ~ 15 m^2.
- Two walls shall be able to open in order for the building to become a stage.
- Acoustic feedback and standing waves shall be counteracted.
- The ceiling shall be open to the ridge.
- The building shall be able to mount together with similar buildings, i.e. expansion shall be prepared.
- A consequence of different possibilities to assemble the building with similar ones is that it must be possible to enter the building from all directions.

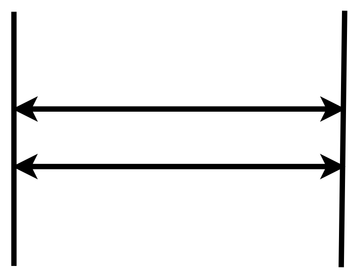
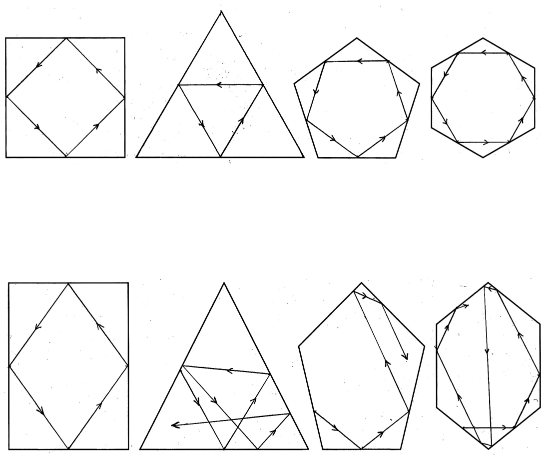
1.5.2 Environmental program

- The floor shall be durable.
- Walls shall be reflecting.
- The materials shall be good for mans health and free from chemicals as far as possible.
- The materials shall be decomposable as far as possible.
- Silent ventilation.
- Sun as a source for heating in combination with electrical heating and possibly a stove.
- Material shall be chosen in such a way that steam can´t be confined in the construction but is able to diffuse through.
- Since it´s possible the building isn´t heated throughout the year it´s important that possible moist is able to diffuse through, both inwards and outwards.
- Since the construction shall be possible to dismantle, all connections shall be made with screws. The very best would be to do the connections with dowels but then the construction must be made consistently.

2 Designing

2.1 Acoustic requirements

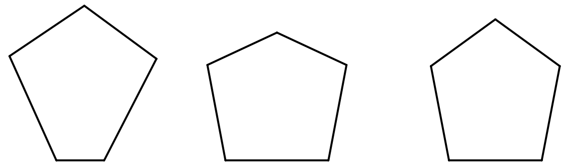
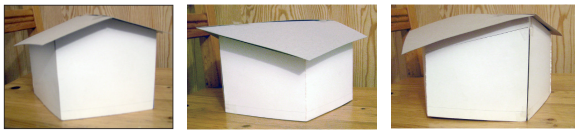
A room for music practice and performance needs to have certain demands fulfilled concerning sound.

Standing waves can occur when the sound is able to bounce back and fourth between parallel surfaces. The standing waves will either amplify or put out the sound. Hence, a very large variation in amplitude, depending on where you are in the room, is created. The sound can be very loud in one place of the room and very faint in another. To avoid this, one can for example have the walls placed inclined towards each other or have objects which alters the direction of the reflected sound, placed in the room.	Standing waves 
Acoustic feedback, were the sound travels in the same path around, around, is another phenomenon to avoid. One example is when you have a mike with a connected speaker. Then, the sound can rapidly be amplified into a roar. Equilateral forms promote acoustic feedback. The more sides the better acoustic feedback, i.e. the more surfaces were the sound can bounce around. Accordingly, the circle is the optimal form for acoustic feedback. Unequal-sided forms obstruct acoustic feedback with the exception for the rectangle.	Acoustic feedback 

To avoid both standing waves and acoustic feedback, an unequal form with no parallel sides has to be chosen. The unequal-sided triangle has narrow and sharp shapes and the six-sided forms has parallel surfaces. Hence, an unequal five-sided form is chosen. In that form there can be no standing waves, nor any acoustic feedback. A five-sided shape of the building will furthermore get a spatial more soft shape compared with a square room.

2.2 Beginning the design

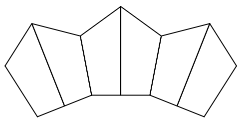
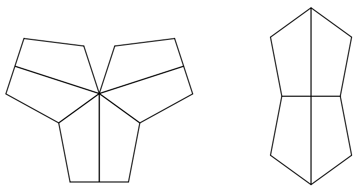
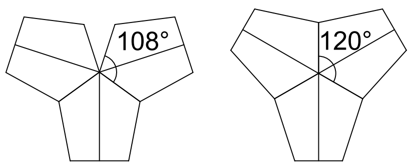
How should the unequal five-sided form look like?

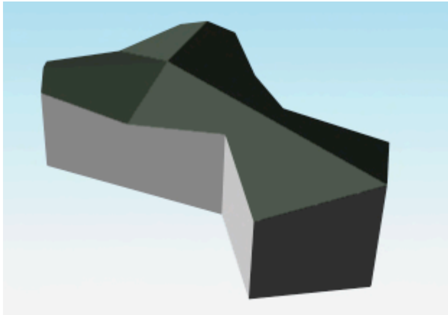
Should the shape be long, narrow, wide or pointed?	
An early model of the building with two “doors” up to the ridge. The disadvantages with this version are that the doors become very large, are unwieldy to move and catch a great deal of wind when they are open. In addition to that, the eaves get in the way when the doors open.	 

Since the building has to be able to be assembled with similar buildings in order to create larger units, the shape has to be in compliance with that.

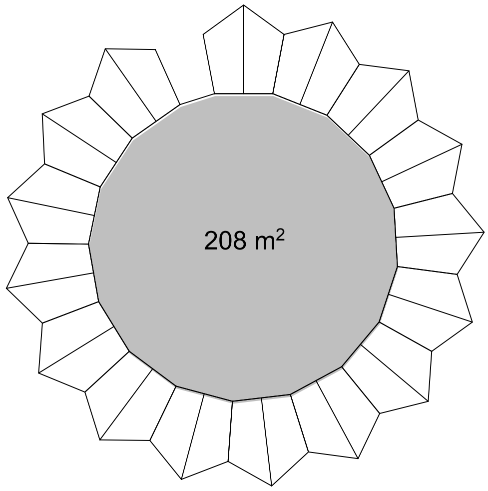
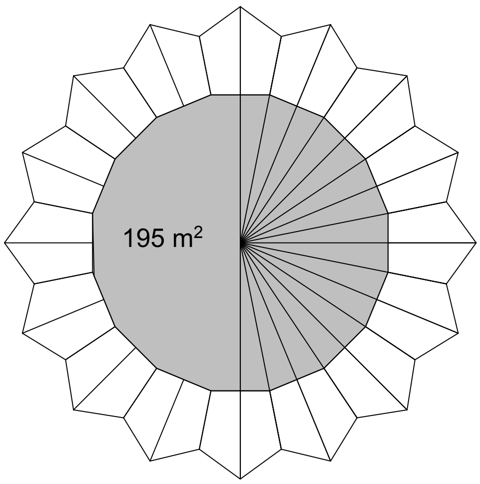
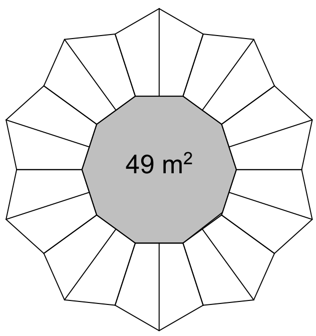
2.3 Different ways to assemble

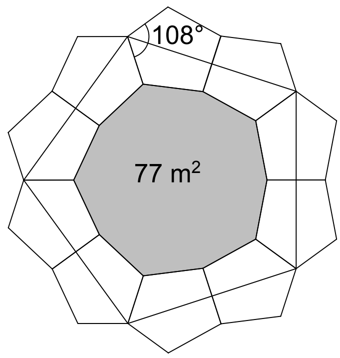
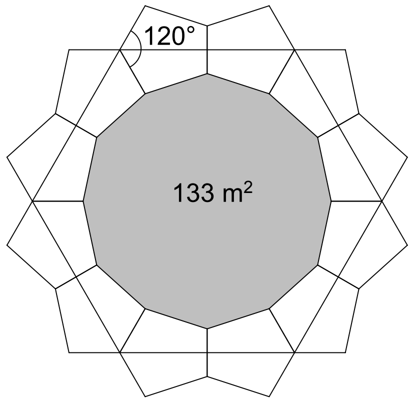
A building with saddle roof can be assembled together with the corresponding side of the other building. These first trials to connect the buildings is made without eaves.
The buildings is 15 m^2, scale 1:400

Sideways:	
Opposing: In the left assemblage there is a gap between the buildings.	
The Three-leaf clover: To be able to assemble the buildings without a gap, the angle must be 120°.	

A visualization of the Three-leaf clover together with one more building, without eaves.	

The buildings can also be assembled to shape circles.
It creates a joined, sheltered space within the walls of the surrounding buildings which either can be a joined garden or, if you build a roof, a big room or a glazed-in yard.

Sideways: The opening can be shut with a gate.	
To avoid a gap in the circle, the number of buildings and their shape must be in agreement with one another.	
The more narrowing shape of the building, the fewer number of buildings and smaller space in the middle.	

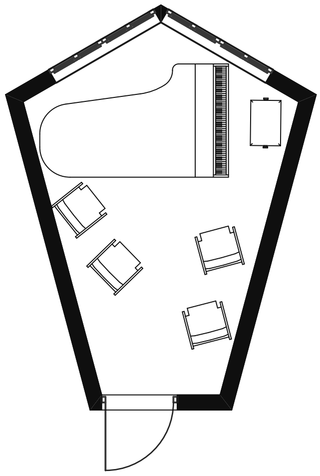
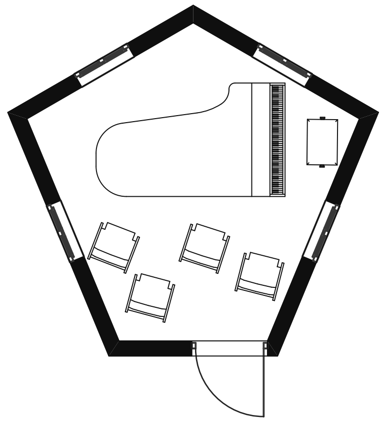
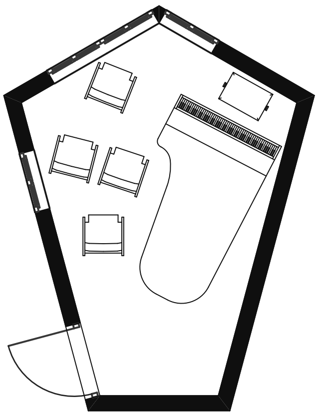
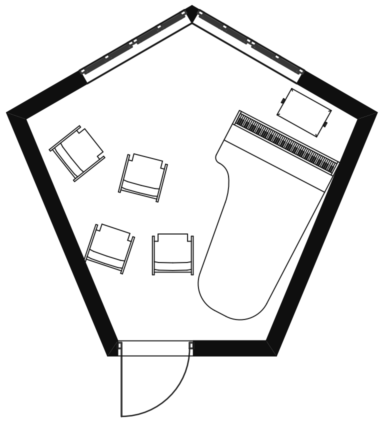
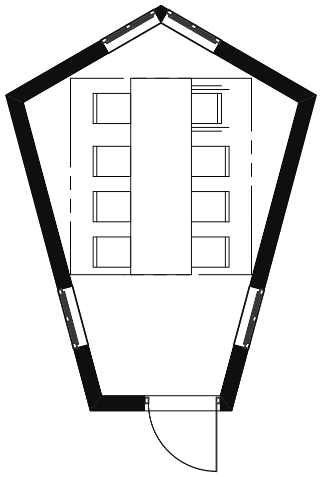
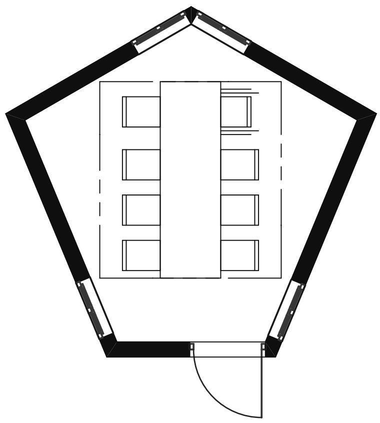
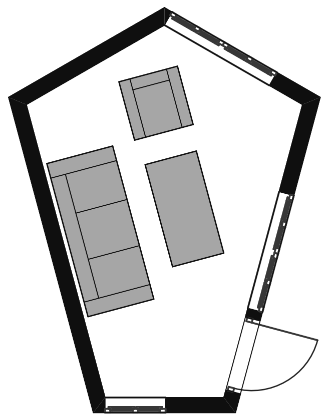
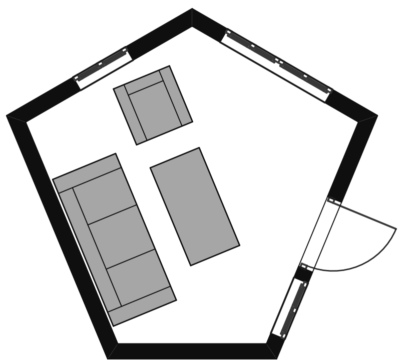
<table>
<tr>
<td>Opposing connections:
With the angle 108° there will be 10 buildings in the circle.</td>
<td>
</td>
</tr>
<tr>
<td>With the angle 120° there will be 12 buildings in the circle.</td>
<td>
</td>
</tr>
</table>

I choose to shape the building out of a number of buildings which can be mounted together in a circle and thereby create a space in the middle. To be able to have a sheltered garden in the centre or a glazed atrium with plants. Spaces which can give relaxation and natural daylight. Pleasant, light places which are needed in our cold nordic climate.

2.4 A first trial of furnishing

In order to find the best form of the building I want to discover the usable space by furnishing different equal sized shapes of the building. First, I will try to furnish one narrow and one wide. The narrow one comes from 12 buildings in a circle and the wider comes from 8 buildings in a circle. The building area is 15 m^2. The furnishing is made with large pieces of furniture: A grand piano, a dining table with 8 chairs and a group of sofa and armchair.

Since the building is both meant to be standing alone and to be assembled with similar ones to create larger buildings, the thickness of the walls is set to 200 mm as a mean value. Small buildings have usually thinner walls whereas larger buildings demand thicker walls to meet the demands of heat insulation.

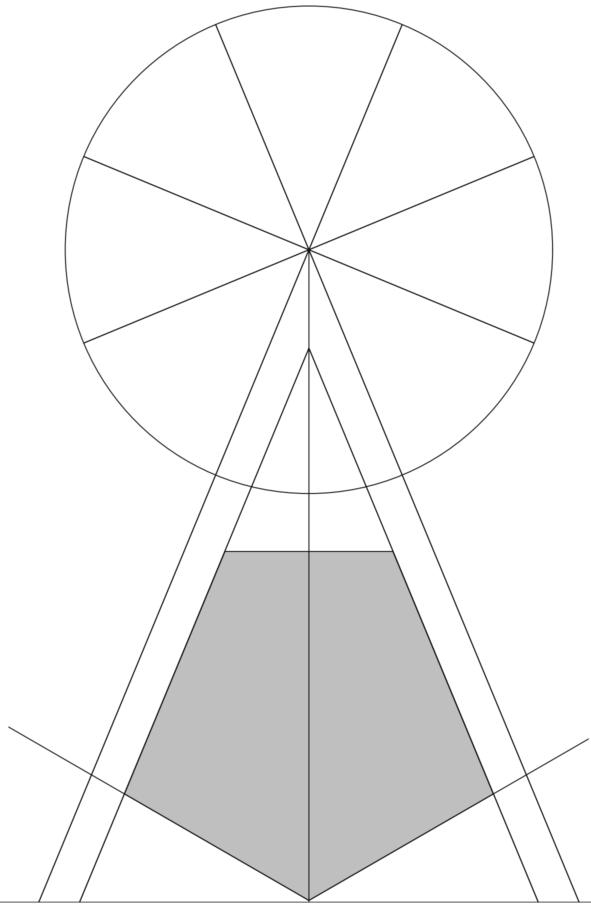
	12 buildings in a circle	8 buildings in a circle
Scale 1:100 The wide shape to the right feels more spacious and it is easier to move around the grand piano than in the narrow one to the left .		
There is an empty, unusable space at the entrance in the narrow shape to the left. The wide shape to the right feels more spacious and the space can be of better use.		
There is more space around the seats in the wide shape.		
There is larger space in front of the coffee table in the wide shape.		

2.5 Exploring shapes of the building

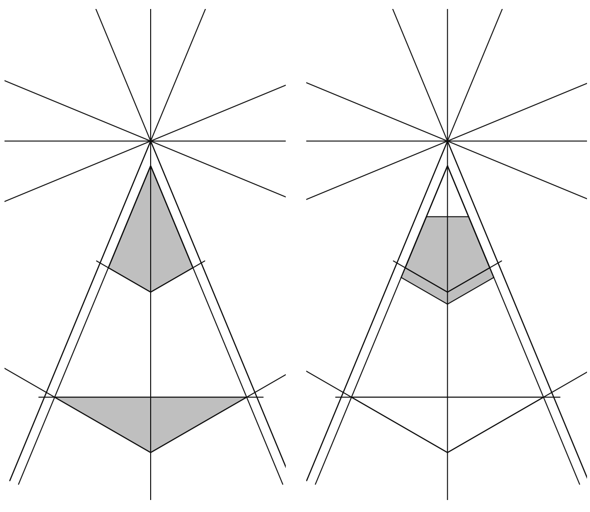
The buildings are designed with 15 m^2 building area and 0.5 m eaves.
The shape of the building and the size of the space within the walls of the surrounding buildings in a circle, have directed the number of buildings in the circle and by that the shape of the building.
A roof can more easily be built over the common space in the circle if you choose an even number of buildings.
The wide building from 8 building in a circle was better than the narrow building.
Here how the design is made.

The building designed with 8 buildings in a circle, from now on called Building 8.
A circle is split in 8 pieces.
The building is then placed in one piece and moved until I feel pleased with the shape.
It´s important that no side isn´t too short.
A line in the middle of the piece show the place of the ridge.
The outer lines of the eaves correspond with the sides of the piece.
The sides of the building is parallel with them.

Scale 1:100

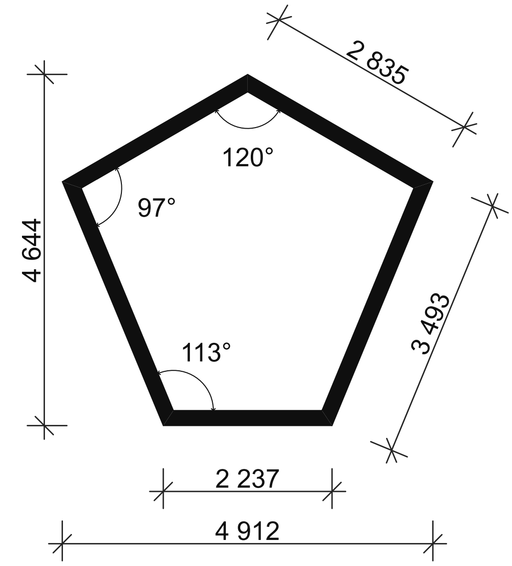


The left picture shows the two extreme forms that the building can get when the distance to the centre is either increased or decreased.
The right picture shows Building 8 in relation to the extreme forms.
Scale 1:400

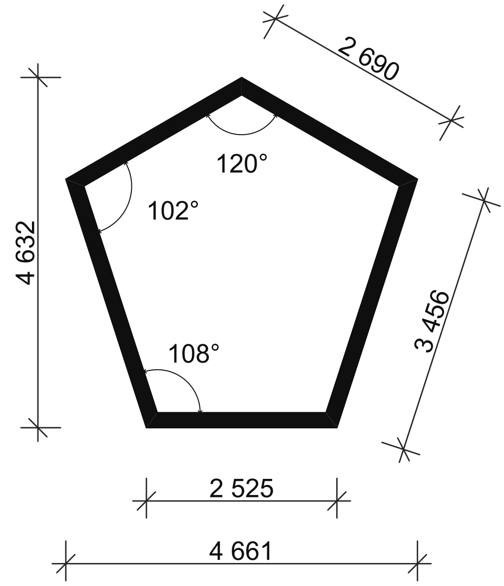


After more testing with different number of buildings in the circle vis-à-vis the shape, a building with 10 buildings in a circle is designed in the same way, from now on called Building 10.
A comparison between Building 8 and Building10:

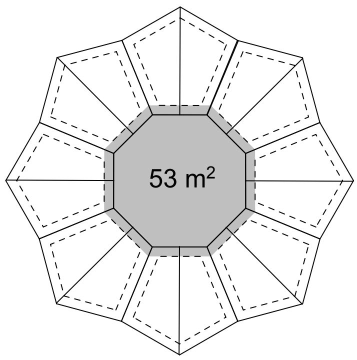
Dimensions and angles. Scale 1:100
Building 8:



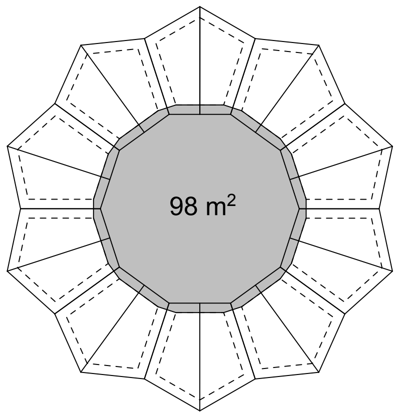
Building 10:



The buildings assembled sideways in a circle. Scale 1:400. Building 8:

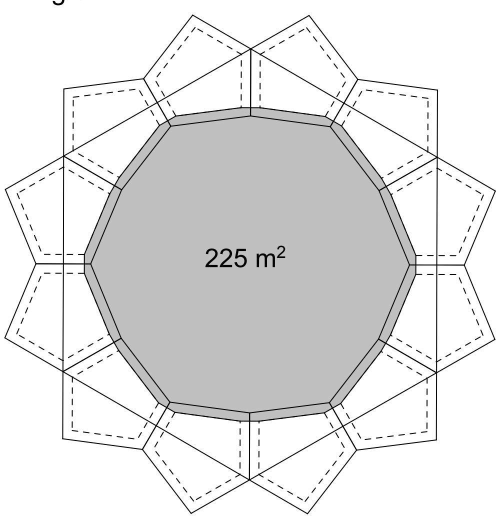


Building 10:

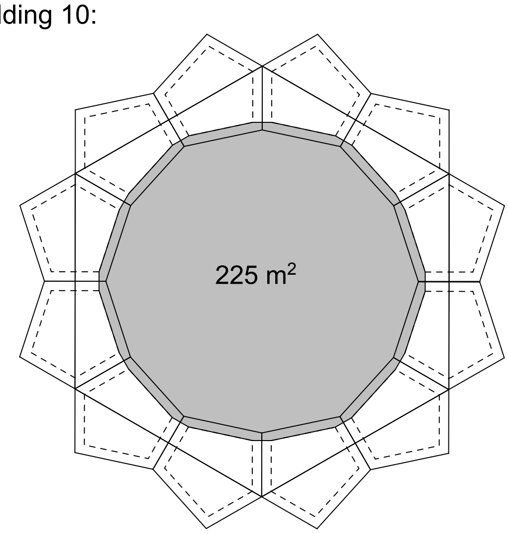


Opposing assembling give 12 buildings. The buildings have almost the same length and the angles at the connection points are the same. Hence, both areas are 225 m^2. Scale 1:400

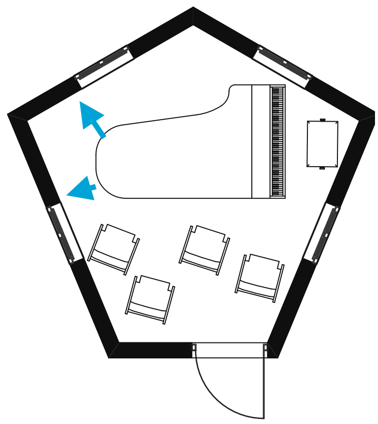
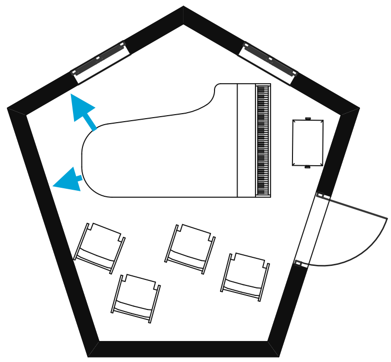
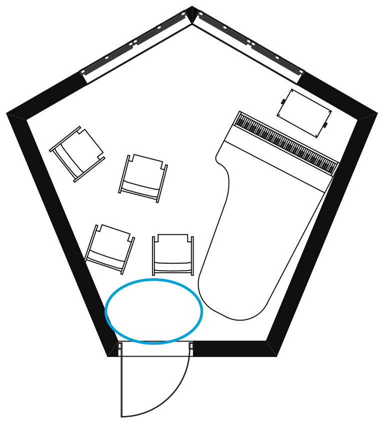
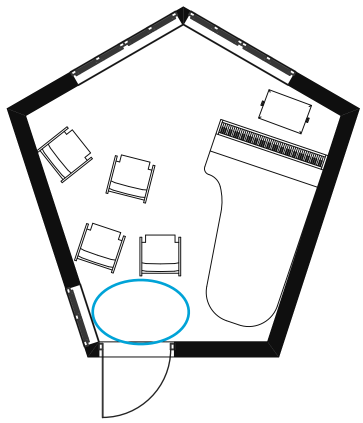
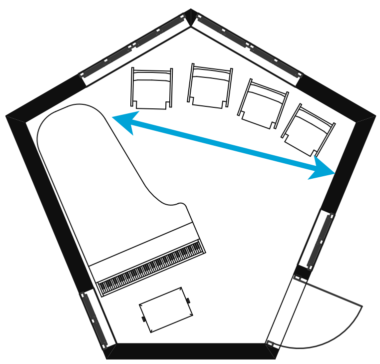
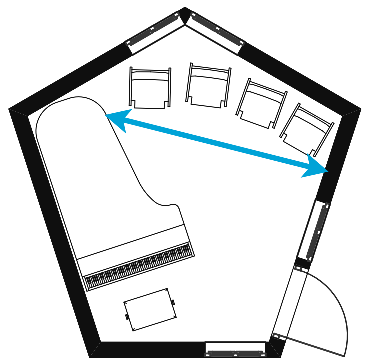
Building 8:

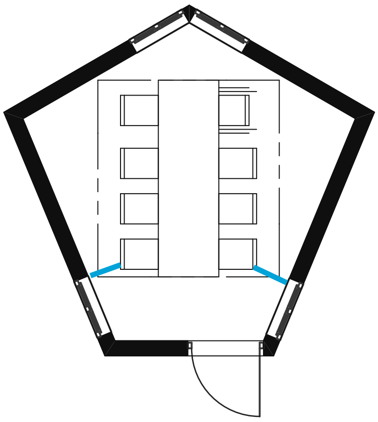
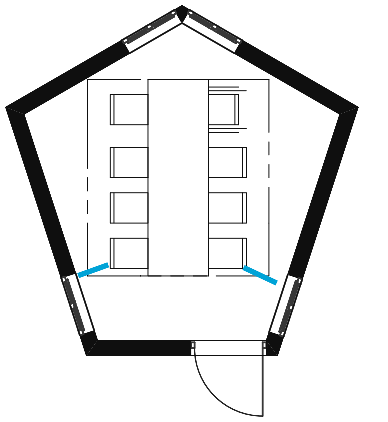
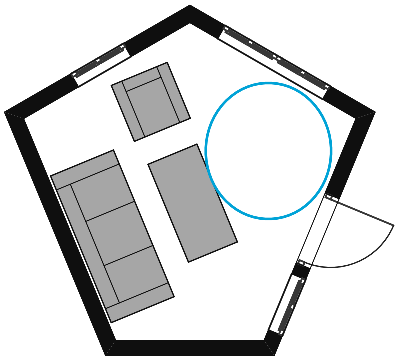
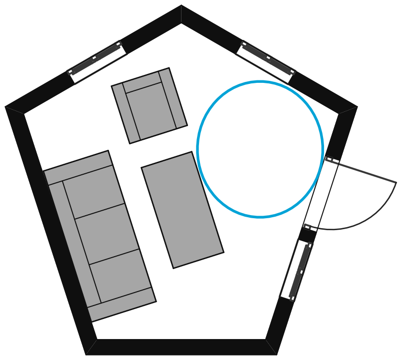


Building 10:

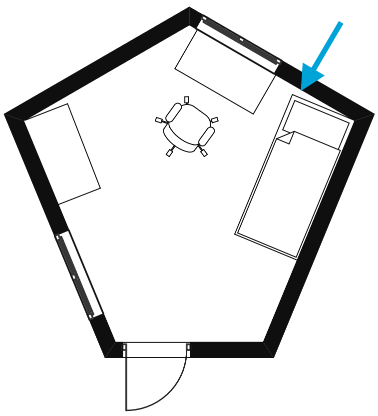
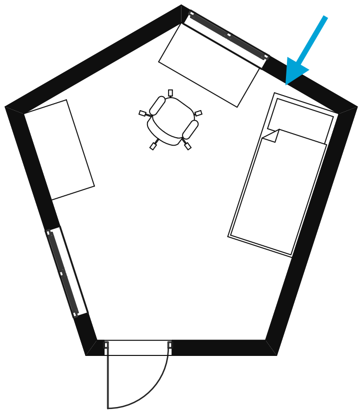


A comparison between Building 8 and Building 10 with furnitures as before. Equal sized blue shapes are placed to make it easier to see the small differences between the two buildings.
Scale 1:100

	Building 8	Building 10
In Building 10 the sitting persons will have better space but it is easier to move around the grand piano in Building 8.		
There is more space at the entrance in Building 10		
When the grand piano is placed like this, Building 8 feels larger.		

	Building 8	Building 10
In Building 8 the space behind the seats is somewhat bigger but it is slightly easier to go around the table in Building 10		
Here the open spaces are equivalent.		

What if the building is used as an extra bedroom/sleeping accommodation?

It will be a gap at the head of the bed which results in a slightly uncomfortable sideway position when sitting against the wall. The gap is smaller in Building 8 since the angle at the bed is closer to 90° compared to Building 10,		

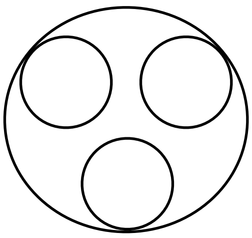
Building 10 is spatial the best. The gap at the bed is larger than in Building 8, but a larger gap is more easily cleaned.

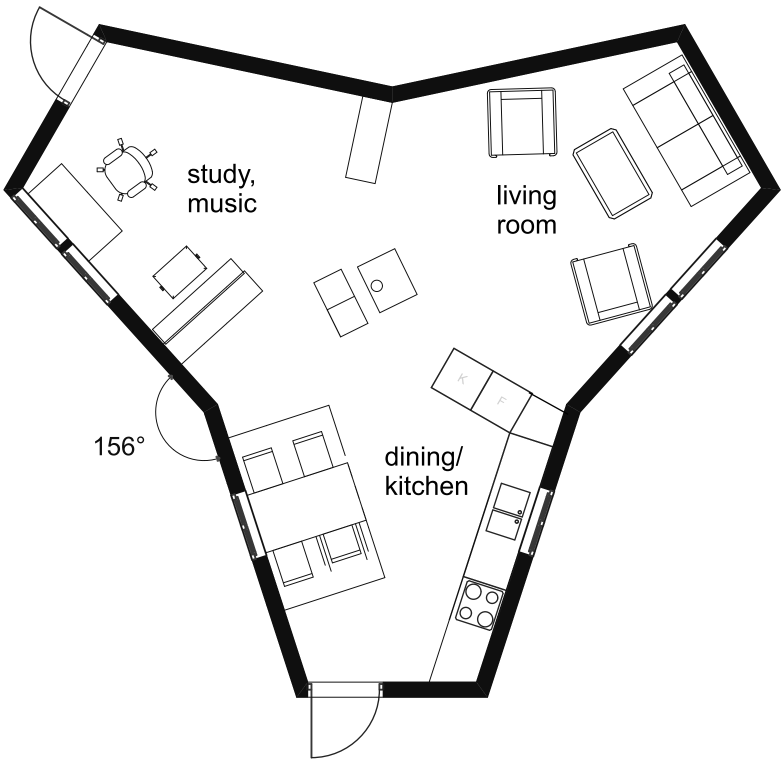
2.5.1 The Three-leaf clover

Assembling three buildings. Since the construction admits the opening of two walls, the assembling becomes one room, one building. The three buildings have been assembled with 0,5 m eaves on all the buildings which gives 1 m between them.
Scale 1:100

The Three-leaf clover;
Building 10
Scale 1:100

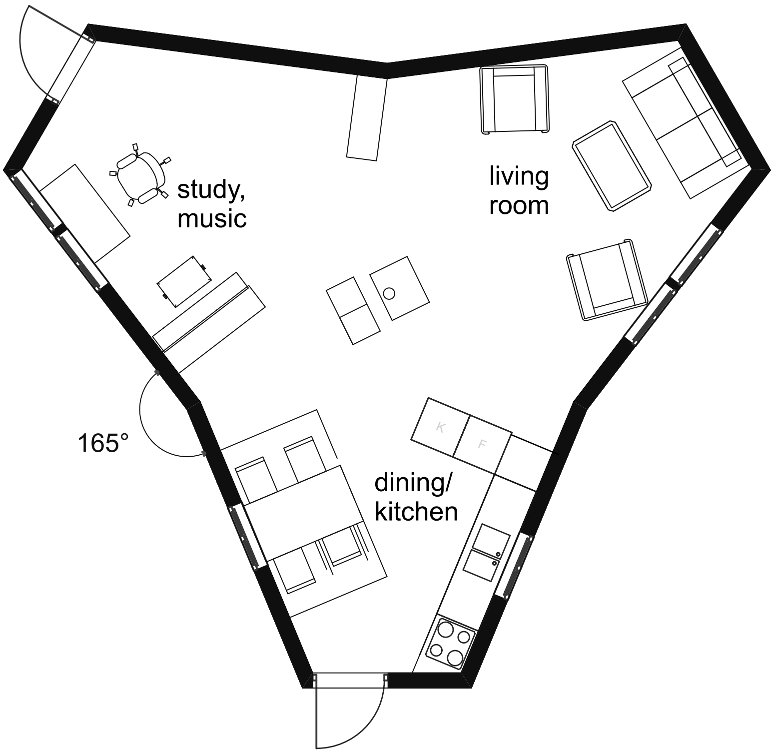
The three rooms are still rooms but at the same time parts of a larger room.





The Three-leaf clover;
Building 8
Scale 1:100

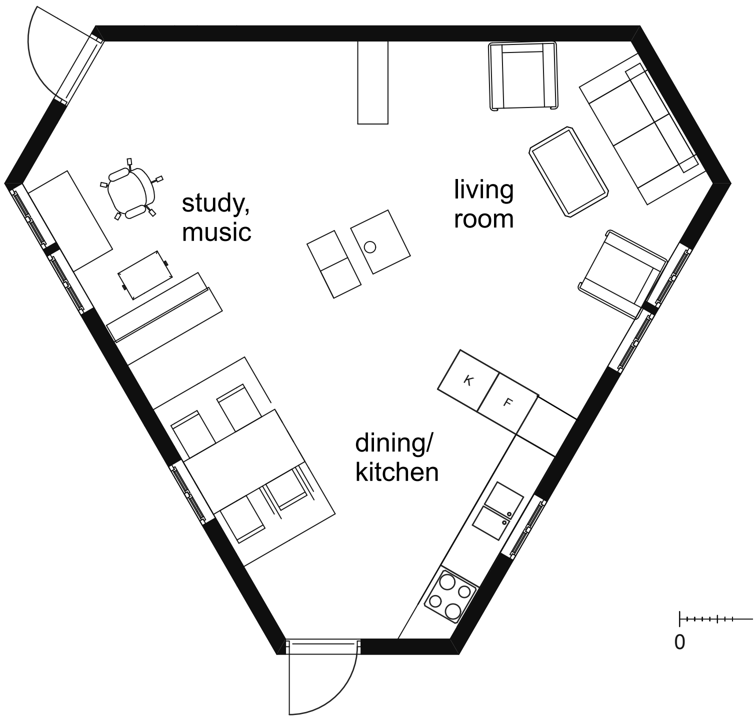
The angle between the walls is wider and the rooms open up more to each other compared to the Three-leaf clover; Building 10, which has more focus towards the centre.



What happens if the sides become straight?

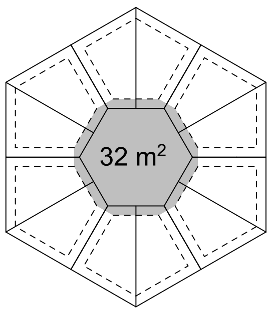
The Three-leaf clover;
Building 6
Scale 1:100

It has become one room.
Only the saddle roof tells
about the division.

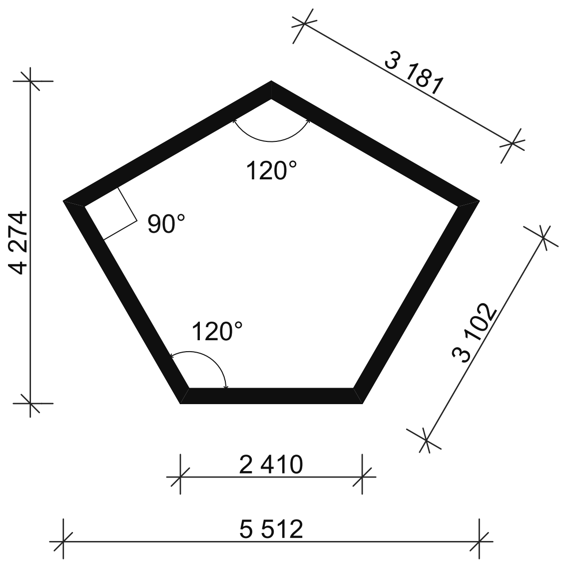


There are 6 buildings in the circle
and therefore, the building is called
Building 6.

Scale 1:400

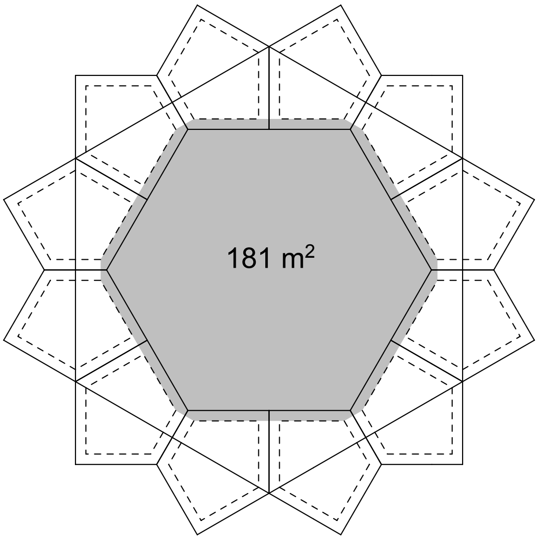


Dimensions and angles, scale 1:100:

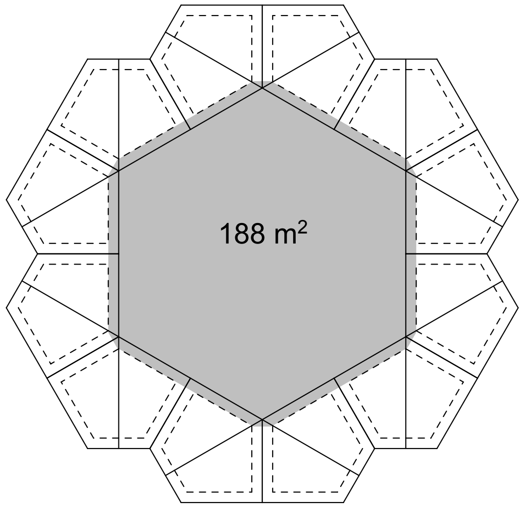


2.5.2 Different ways to assemble Building 6

Building 6 assembled opposing in a circle: The opening walls are turned outwards which facilitates performances before larger audiences.
Scale 1:400

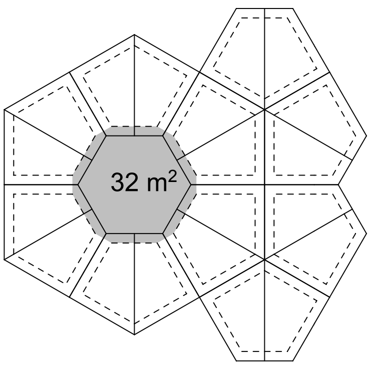


A new way of assembling which is possible with Building 6. The buildings are assembled both opposing and sideways. The opening walls are facing the common place.
Scale 1:400

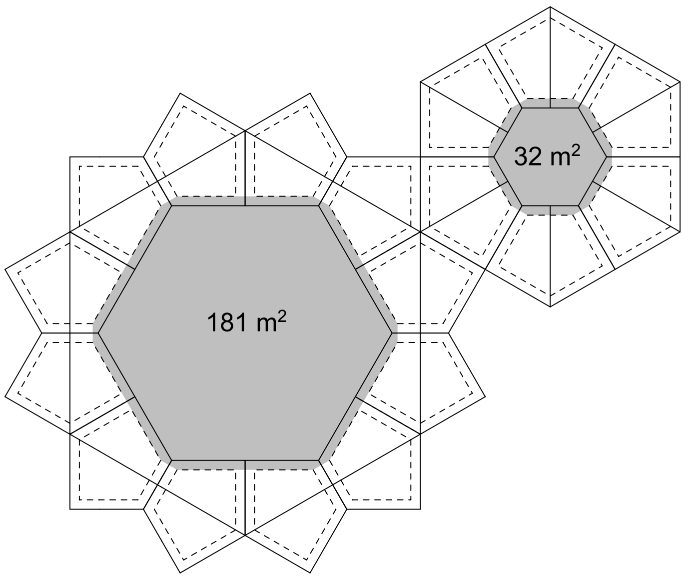


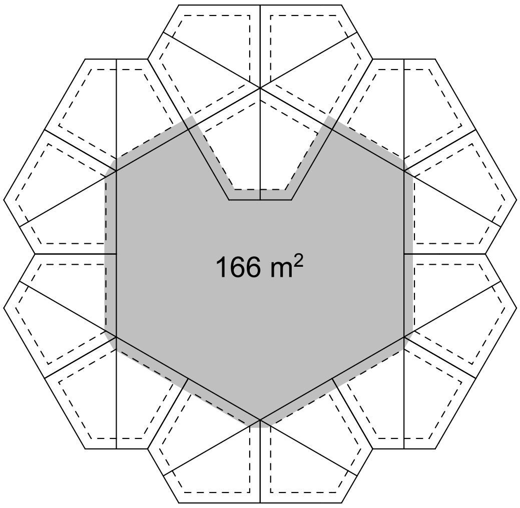
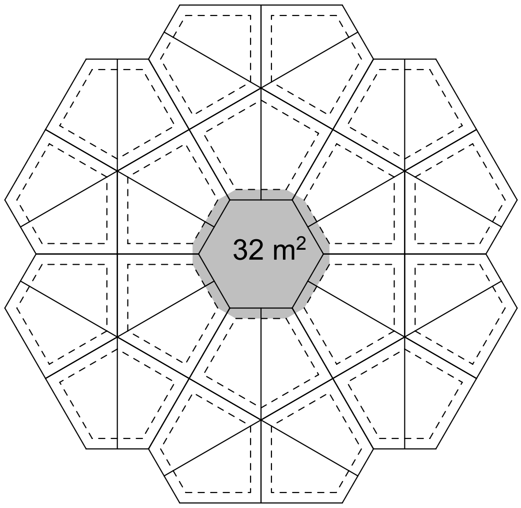
Examples of combined compositions with Building 6. Scale 1:400

Building 6 assembled sideways in a circle and two Three-leaf clovers.

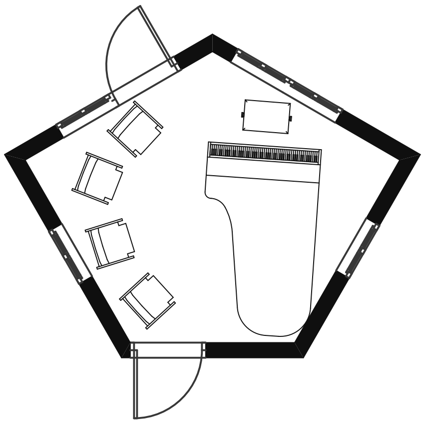
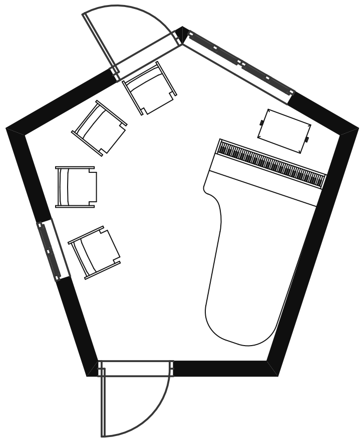
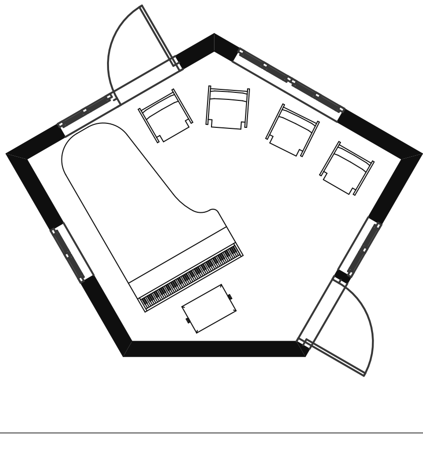
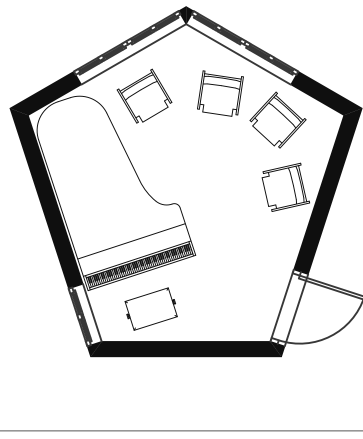


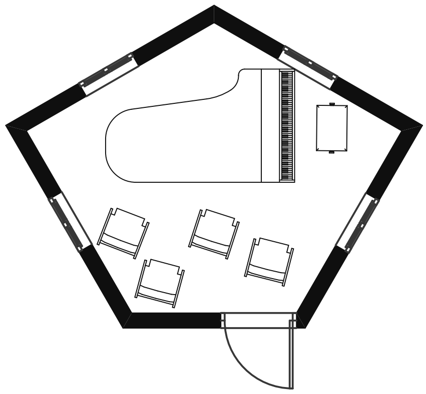
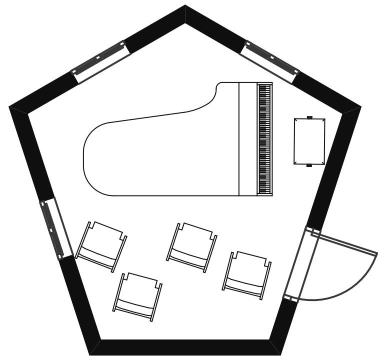
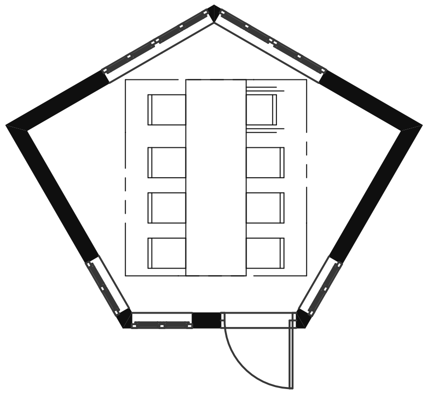
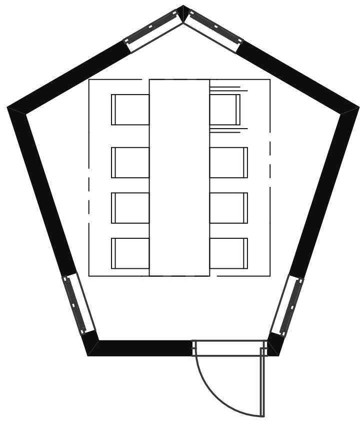
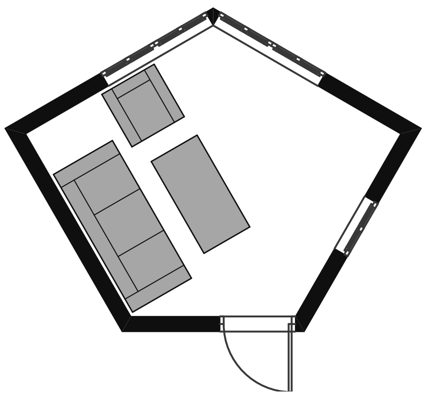
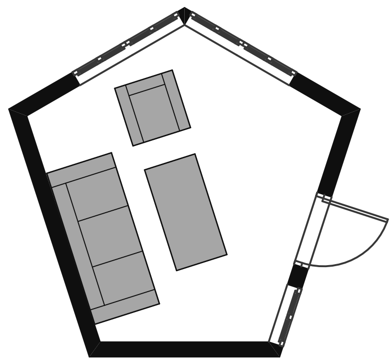
Two circles, connected sideways and opposing and thereby also forming the Three-leaf clover between themselves. With this combined assembling you can have a room with a glazed roof of 32 m^2 and a 181 m^2 garden.



In this kind of circle the Three-leaf clover can only be created towards the middle. 	The Three-leaf clovers in a circle for many activities. 

Is Building 6 better than Building 10?
A comparison with furnitures as before.
Scale 1:100

	Building 6	Building 10
There are about as good place for the seated persons in Building 6 as in Building 10 but in Building 6 there are space on both sides of the grand piano. Building 6, therefore, feels more spacious.		
Building 6 is wider and gives the seated persons more space.		

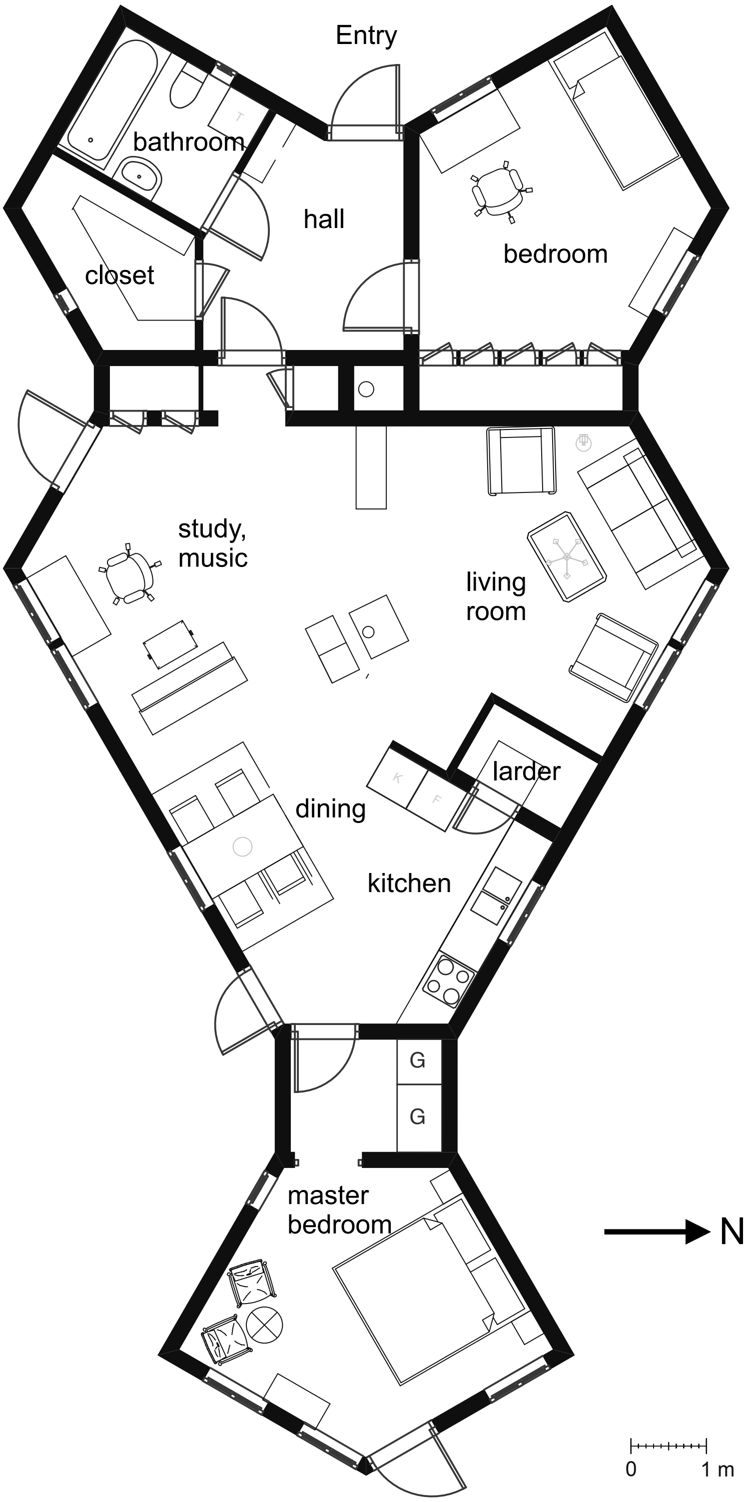
	Building 6	Building 10
In Building 6 the seated persons have more space. The pianist has more space behind him/ her.		
Building 6 feels more spacious with more space behind the seated persons.		
There is more space in front of the coffee table in Building 6.		

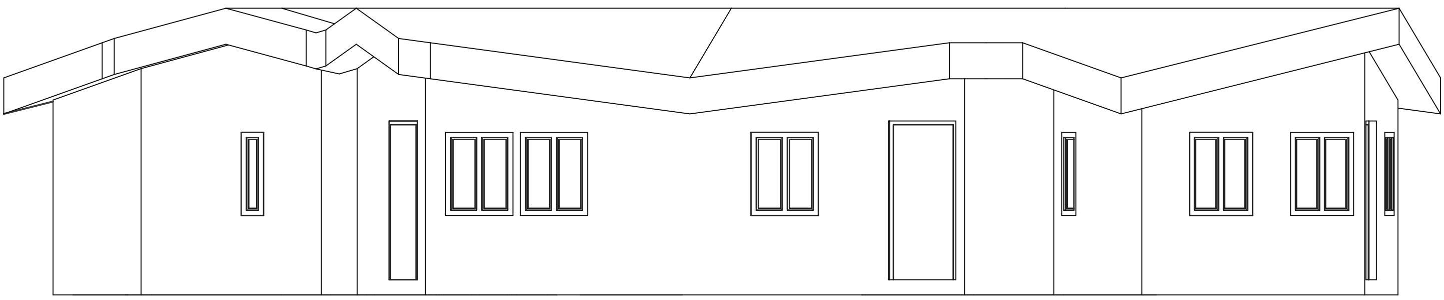
2.5.3 The detached house

This is an attempt to create a detached house with Building 6. The house is designed with the entry facing west.
If the house is mirrored the entry will face east and the master bedroom face west. It can also be placed in other directions.
The house is circa 100 m². The big living-room; The Three-leaf clover, is 49,4 m². This house is designed with 200 mm walls. With thicker walls, the area of the living-room and the hall can be bigger, due to the assembly of the buildings.
In this attempt the distances between the buildings were varied. Next to the master bedroom there is more room for wardrobes.
The doors open up to the garden for fun, outdoor eating, airing of bedclothes etc.
Scale 1:100

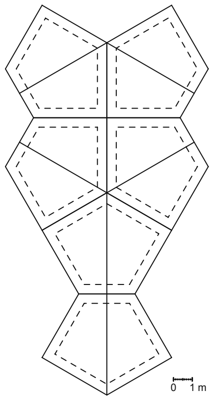
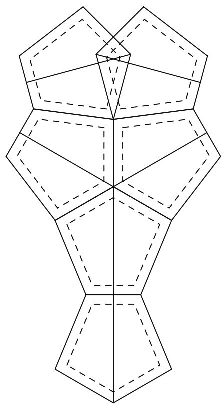
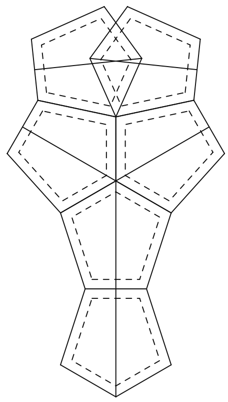
An interior picture from the Three-leaf clover with different window settings and no larder.

Below, an image of the facade to get a perception of the pavilions, assembled to a detached house.





Façade south east

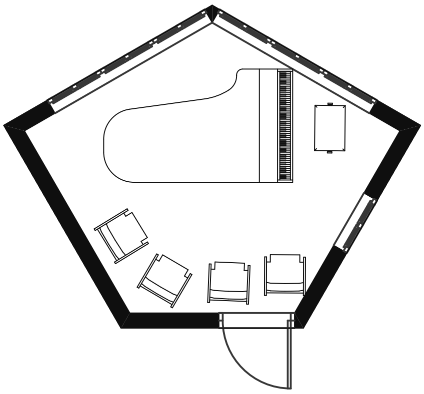
<table>
<tr><td>When the detached house is created with the same composition but with 1 m between the buildings (0,5 + 0,5 m eaves) the shape becomes like this. Scale 1:400.</td><td colspan="2">Buílding 6
</td></tr>
<tr><td>The same assemblings using Buílding 8 respective Buílding 10.
The buildings “collide” with each other!
Hence, these buildings can´t be connected in this way.</td><td>Buílding 8
</td><td>Buílding 10
</td></tr>
</table>

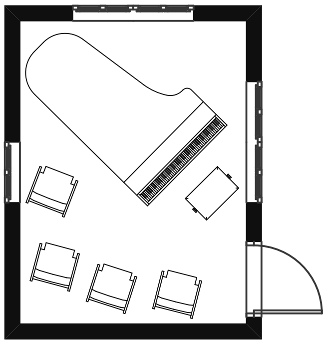
It is important to be able to assemble two Three-leaf clovers together sideways. The composition is needed when you for example want to have a room and bathroom at the entrance to a detached house.
Since the roofs slant inwards, a drainpipe is needed inside the house. But if the drainpipe is made of glass, an extra dimension is added with visual running water every time it rains.

The result of the comparison is that Building 6 is the most useable module.
Building 6 is also easier to furnish with conventional pieces of furniture when there is one 90° angle.
Therefore, Building 6 is chosen.

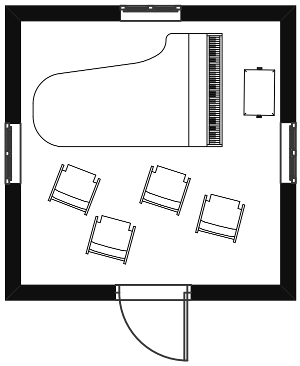
2.6 A comparison with square shapes

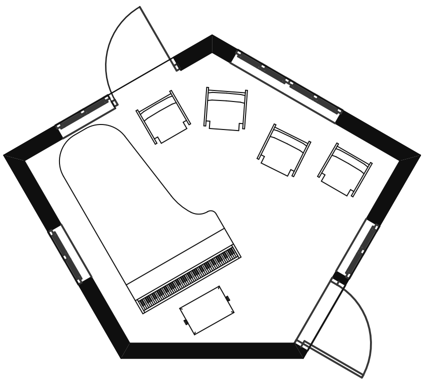
Now, when the shape of the building is chosen, I want to compare Building 6 with two equal sized, square buildings. One rectangular and one almost quadratic.
The same furnishing as before. Scale 1:100

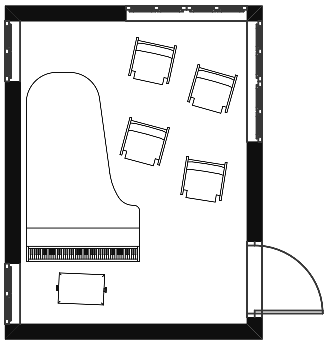




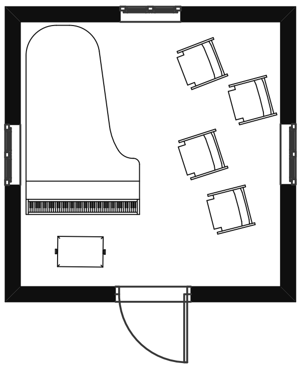
In Building 6 it is easier to move around the grand piano and the seated persons have more space than in the square buildings. The five-sided room is much more spacious. Perhaps the seated persons in the rectangular room would have more space if the grand piano stood close to the wall.

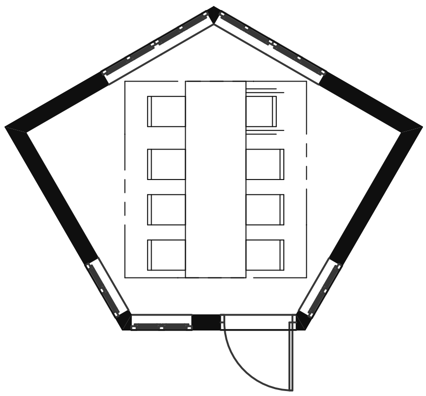


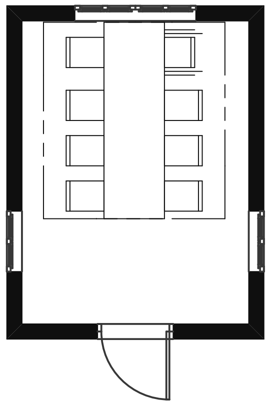




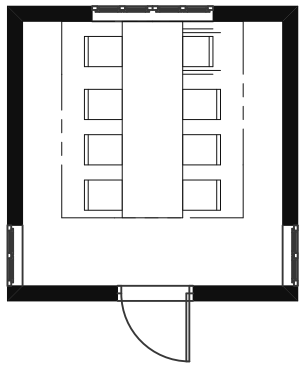
The five-sided room is still much more spacious.



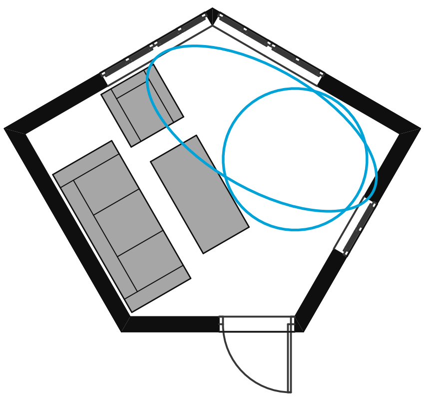


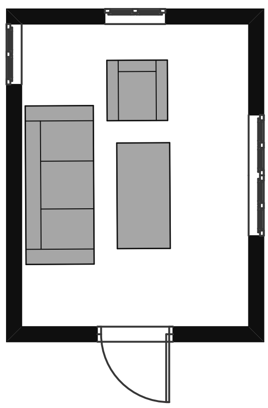


In the five-sided room there is more space behind most of the seated persons and those who look past the person seated opposite themselves can look farther away compared with those seated in the square rooms. This results in that the five-sided room feels bigger, more spacious. You also can stand together in more places in the five-sided room.

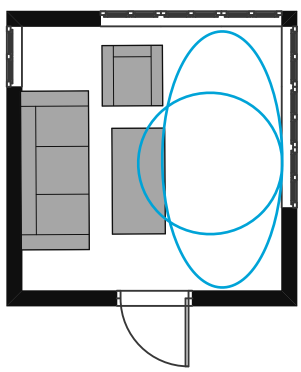


Furnishing with a group of sofa and armchair:

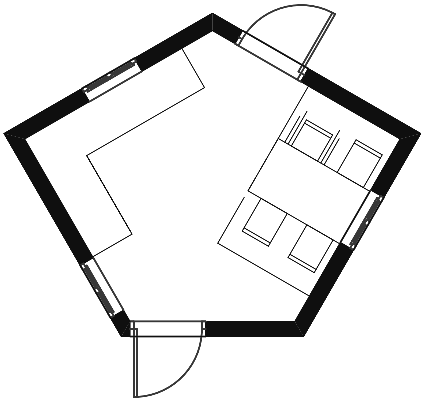
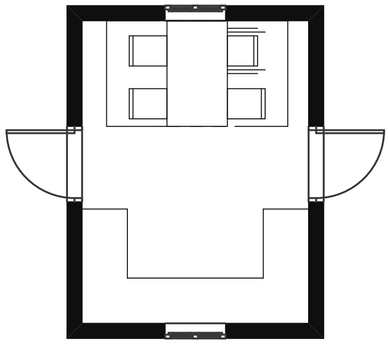
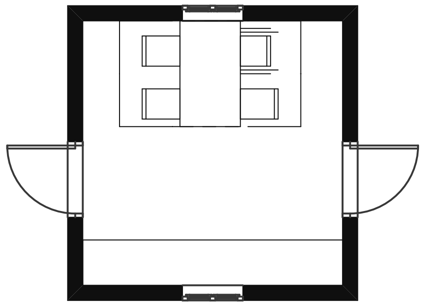
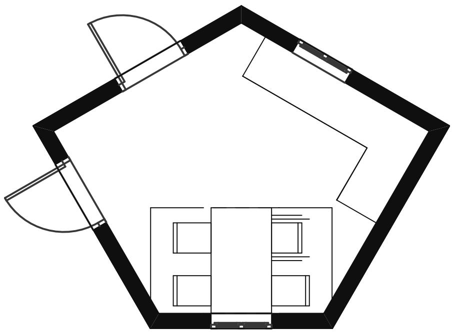
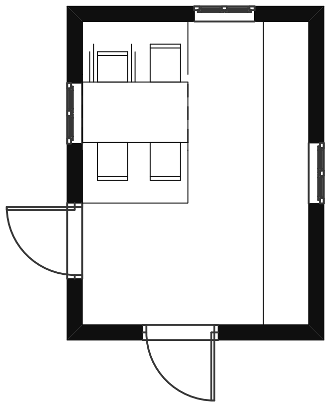
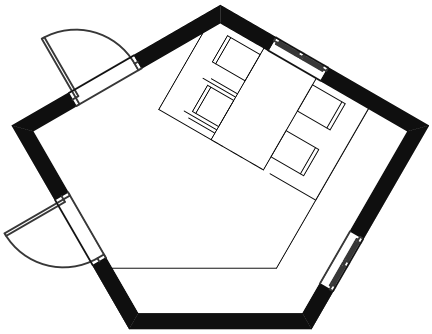
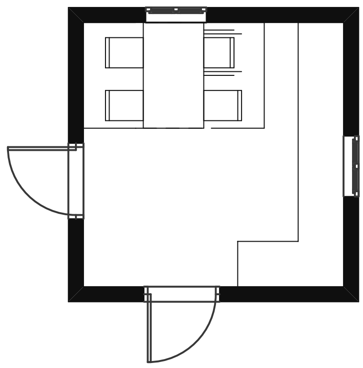




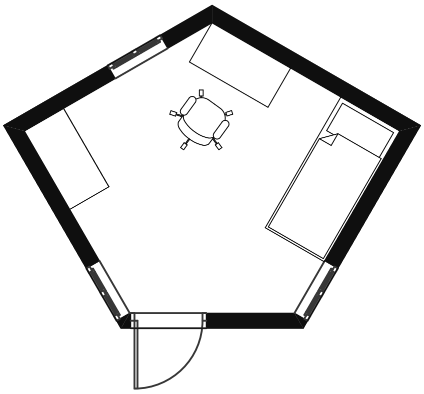
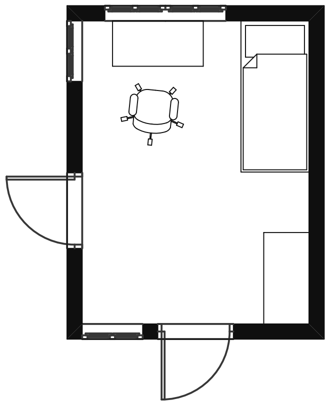
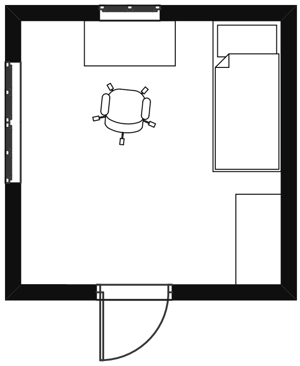
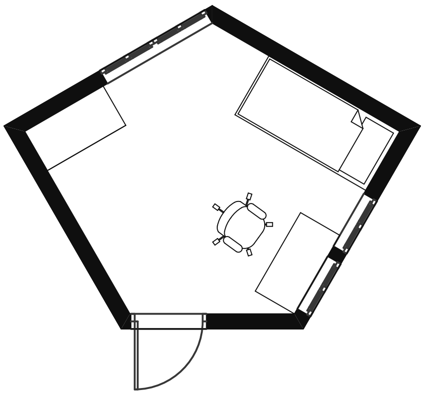
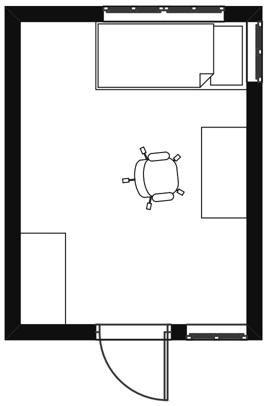
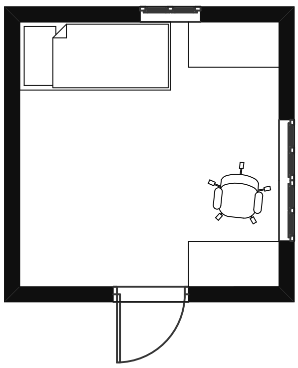
The open space in the five-sided room is more held together compared with the square rooms and therefore, is experienced as larger.



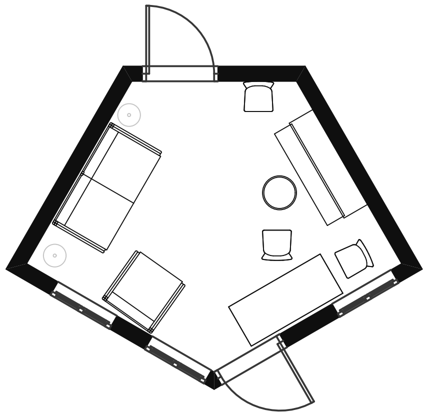
The kitchen:

	
With openings opposite one another the open space is more held together in the five-sided room. It´s also more varying. In the square rooms the space is scattered between the space behind the seated and the space in front of the cupboards.	
	
	
In all the five-sided kitchens there are more varying open spaces than in the square kitchens.	

Furnishing the bedroom:

	
It is more interesting to move around in the five-sided form. In the square forms the spaces beside the pieces of furniture feel more closed.	
	
The open space feels larger and less confined in the five-sided room.	

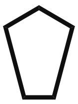
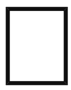
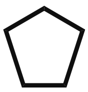
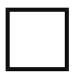
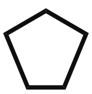
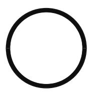
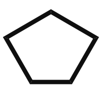
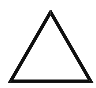
Another way to furnish the five-sided room with a piano, sofa, armchair and a desk.



The furnished plans have been attempts to show how the shape of the room influences the experience of the room. In the five-sided rooms there are indeed triangular openings when cupboards stands against the 120° wall but they can be more easily cleaned or else you can put something there, for example a standing lamp.
All together it feels like the five-sided room is more including and kinder. It also feels more spacious, varying and not so confined as the square forms.

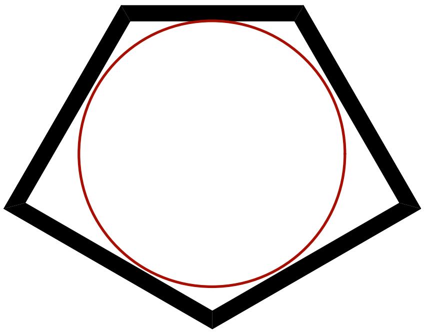
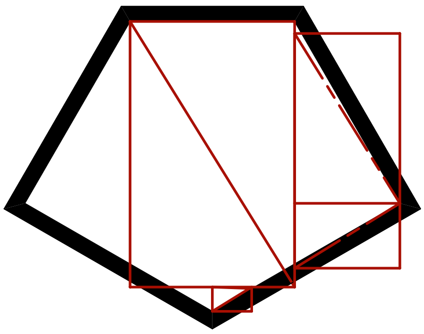
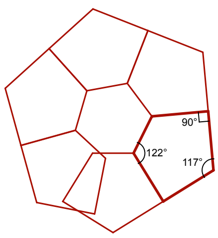
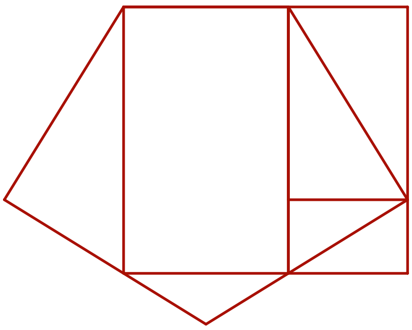
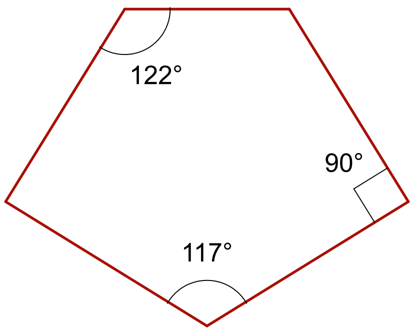
A comparison between the areas of the rooms in the different forms of buildings I have examined. For the sake of the comparison the circle and the equilateral triangle have been added.

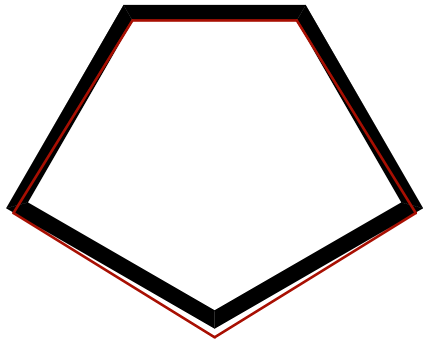
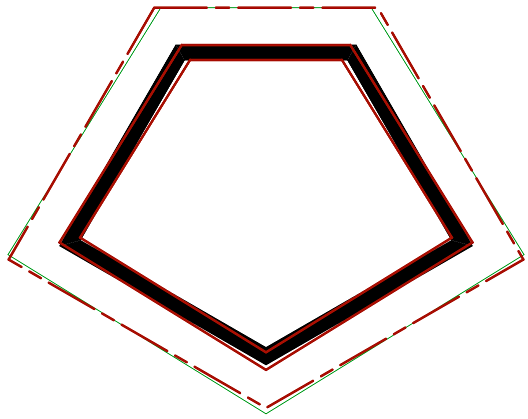
To be able to make a correct comparison of the different forms, the building areas have been adjusted to 15,000 m^2. The thickness of the walls have been set to 200 mm. The figures have no scale and therefore, they are not visually comparable.

		Living space m^2	The difference in living space compared with Building 6 dm^2			Living space m^2	The difference in living space compared with Building 6 dm^2
Building 12		12,09	−7	The rectangular		12,04	−12
Building 10		12,17	+1,4	The quadratic		12,06	−9,4
Building 8		12,18	+2	Circle		12,38	+22,4
Building 6		12,16	0	Equilateral triangle		11,68	−48

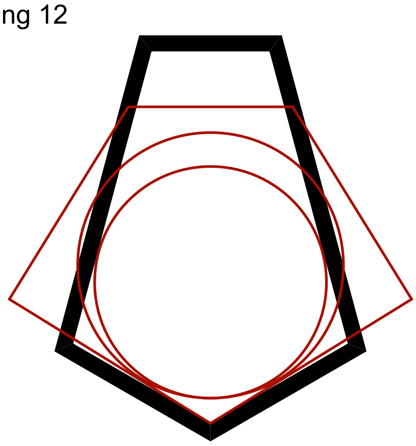
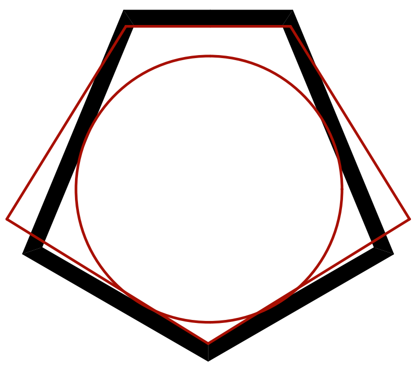
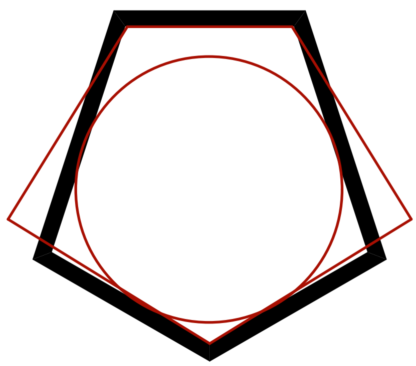
2.7 A comparison with forms of nature

Now that the form of the plan, Building 6, is decided it´s interesting to see how it correspond with more natural forms.
Scale 1:100

Since the circle is the optimal form for wall saving and also much present in nature, here Building 6 with a circle.	
The golden section is said to be present in many of nature´s forms, including man. Therefore, I have tried to see what happens when I draw rectangles with the golden section inside the building. The biggest rectangle´s upper side has the same length as the wall. It´s interesting to see that the diagonals has almost the same inclinations as the walls of the building. Now I have become intrigued.	
Here, how a five-sided room looks when it´s shaped with the help of golden section rectangles. The biggest rectangle has the same size as the biggest rectangle above. The angles don´t quite correspond with Building 6, except for the 90° angle. Therefore, they can not form a circle without overlapping. Scale 1:400. 	 

Here the golden section form over Building 6.	
Here the golden section form corrected so its area is almost the same as Building 6 and again over Building 6 but now also with the roof. The forms are very much alike.	

Now, how would the earlier forms look like with the same circle and the same golden section form?

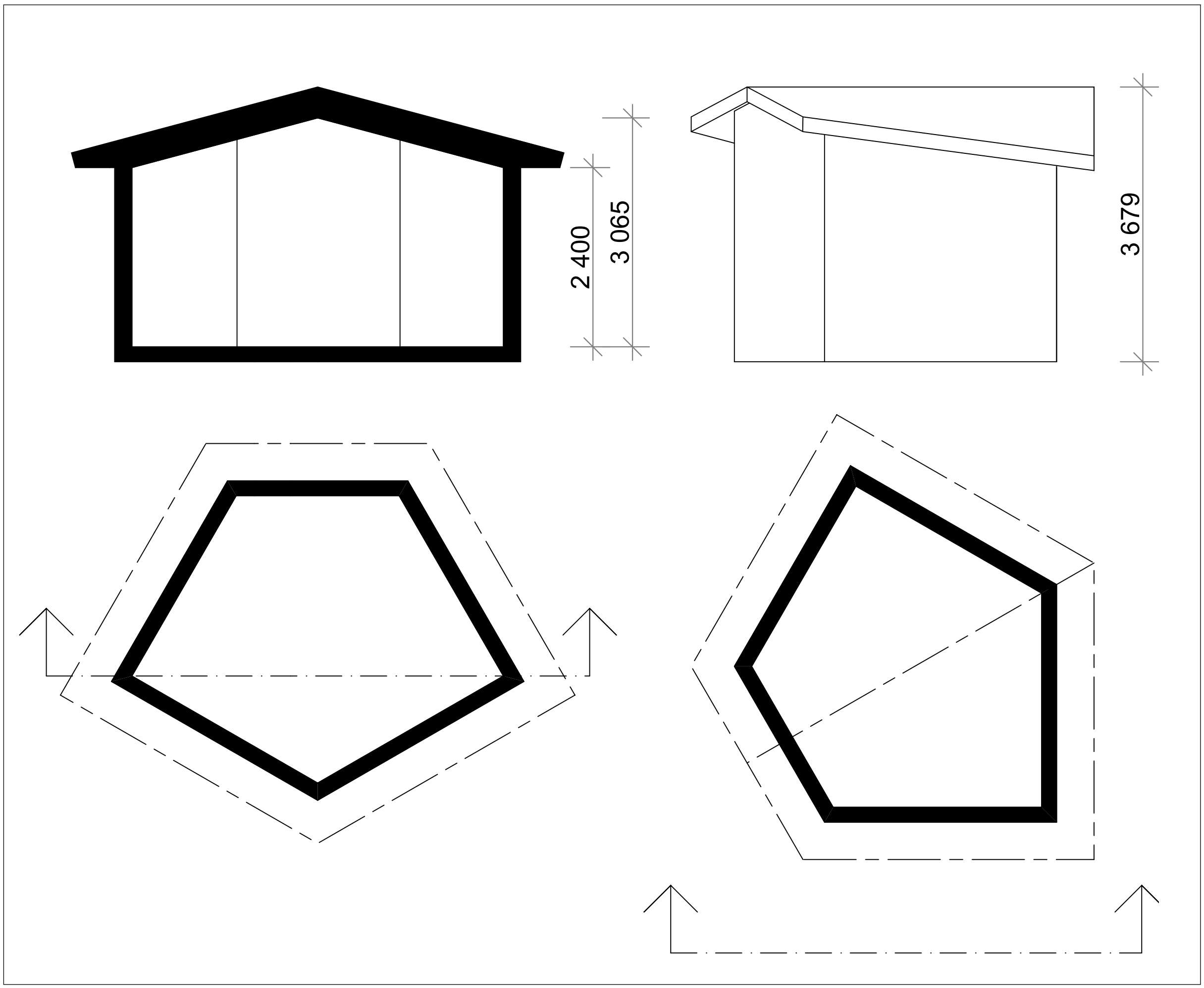
To the right, one of the first forms, 12 buildings in a circle. The bigger circle is the same as in building 6. The smaller one is inserted to see the difference clearer. There is much space above the circles and over the golden section form. In Building 8 and 10 below, the circles are the same as in building 6 but there is more space over the circles and less space around the other sides. The golden section form does not correspond so well with any of these buildings. Three sides don´t correspond at all in Building 12 nor do two sides in Building 8 and 10.	Building 12 
Building 8 	Building 10 

After this comparison, I have come to the conclusion that Building 6 is very similar to natural forms and, from this perspective, is the right choice of the Buildings.

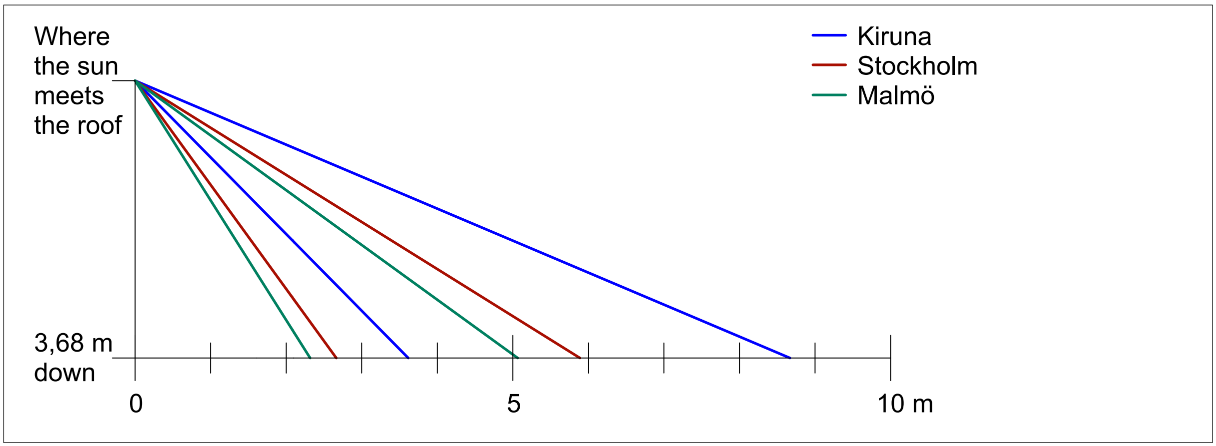
2.8 The shape of the roof

In public rooms the ceiling height must be at least 2,7 m. However, in rooms intended for maximum 16 persons the ceiling height can be 2,4 m. These rules are set to protect people´s health. (BBR 2015). Since the building is meant to be able to connect with other similar buildings to become larger buildings, the ceiling height in the room has to be at least 2,7 m. This is a good thing, considering a singer for example uses more air than someone reading a book.
When the ceiling is open to the ridge, the volume of air will be larger than with a flat ceiling.
In order for Building 6, with 15° slope of the roof, to have an equal volume of air as a similar building with a flat 2,7 m high ceiling, the minimum ceiling height will have to be 2,314 m.
To make it easier to furnish, the lowest ceiling height is instead set to 2,4 m.

Roof 15°: Here Building 6 with 15° slope of the roof and the lowest ceiling height set to 2,4 m.
The highest ceiling height is then 3,065 m.
Scale 1:100.

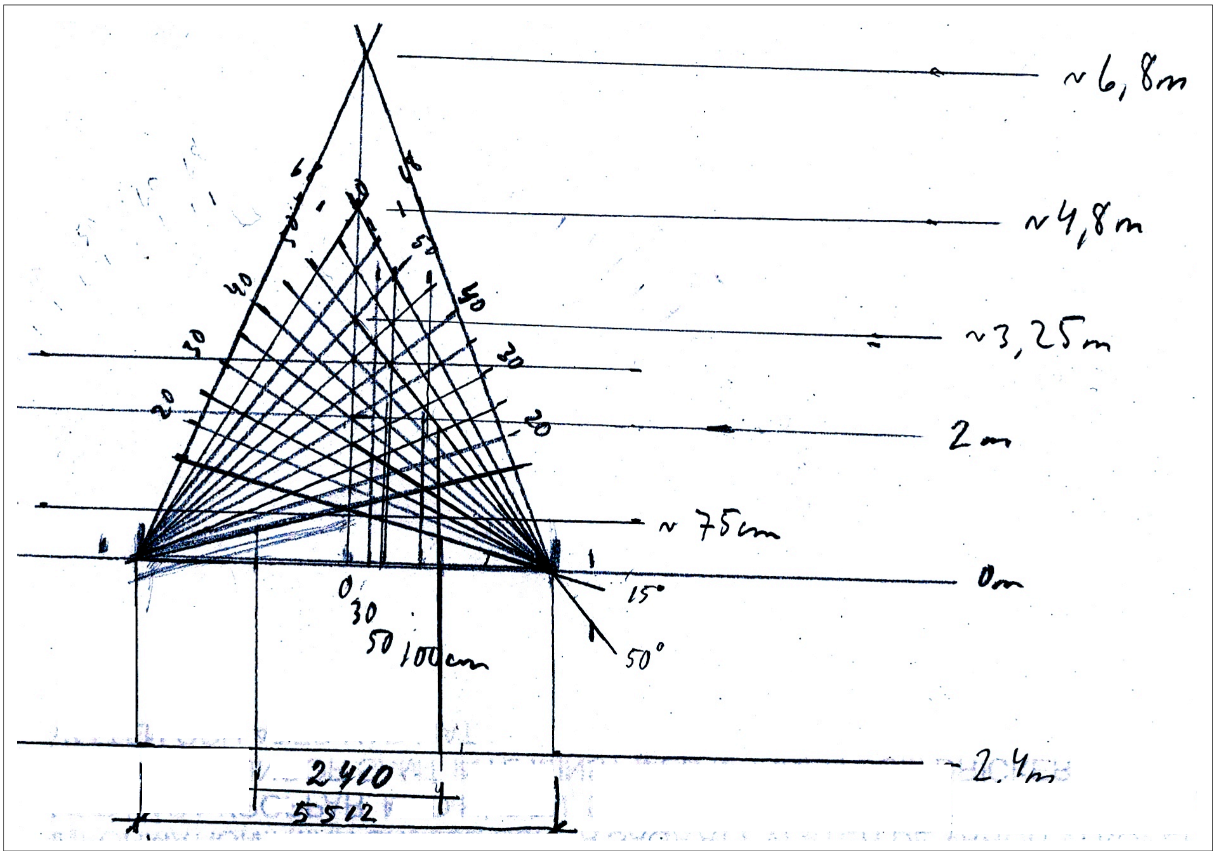


How long shadow does the highest point of the the building cast?
This graph shows the length of the casted shadow in three different places.
The three shortest shadows are casted when the sun stand at its highest position in the summer, circa 180 days in to the year.
The three longest casted shadows appear circa 90 days before, = circa 90 days after, when the sun stand at its highest position in the summer.

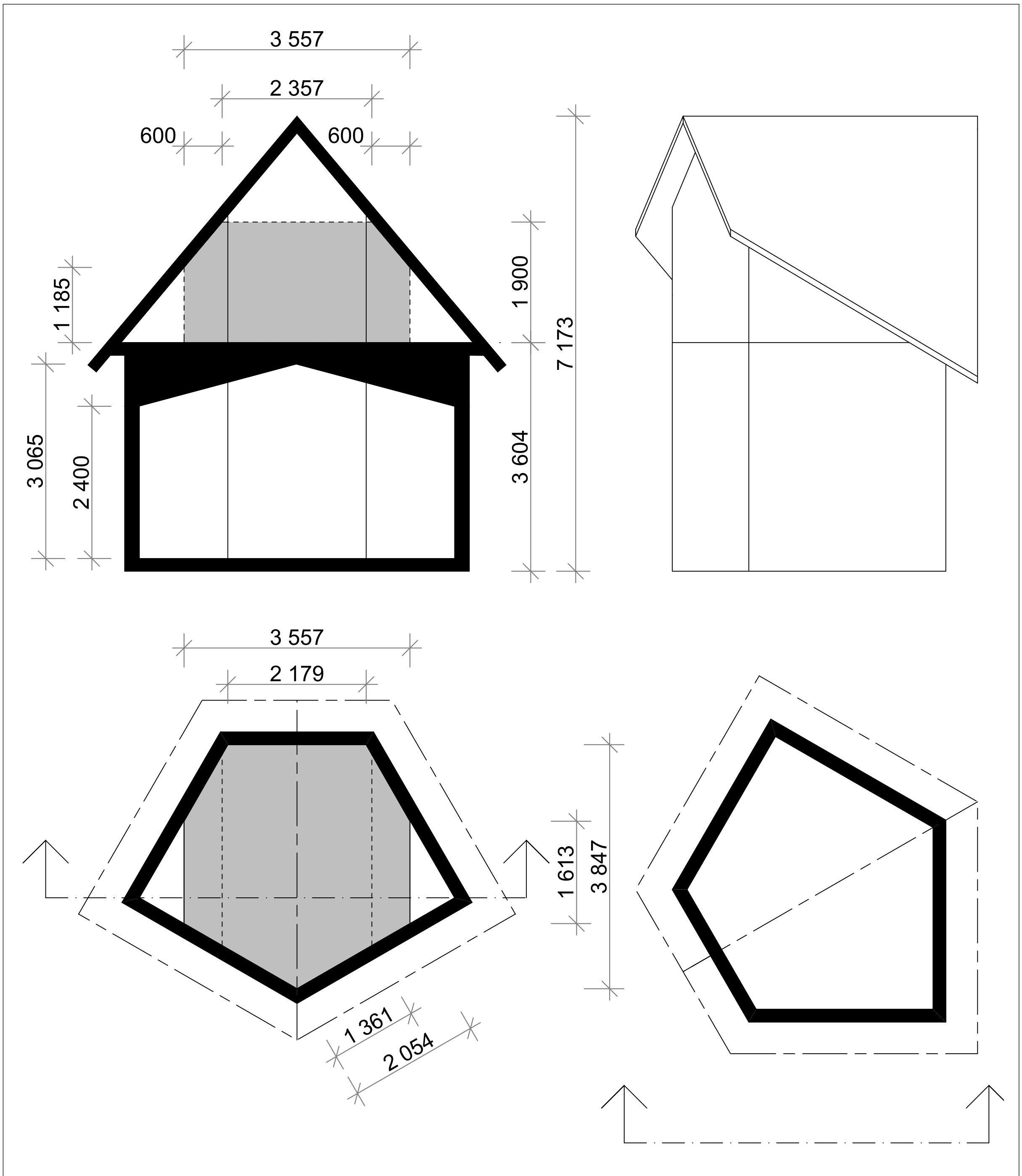


If you want to have boards on the roof, the steeper slope of the roof the better.
Regardless which roofing, if there is a leakage it often will take some time before the leakage is discovered and by then the damage may be large.
Most of us probably would like to have a winter garden. Why not then kill two birds with one stone and put it on top of the building and thereby save one roof.

Different slopes of the building, scale 1:100:



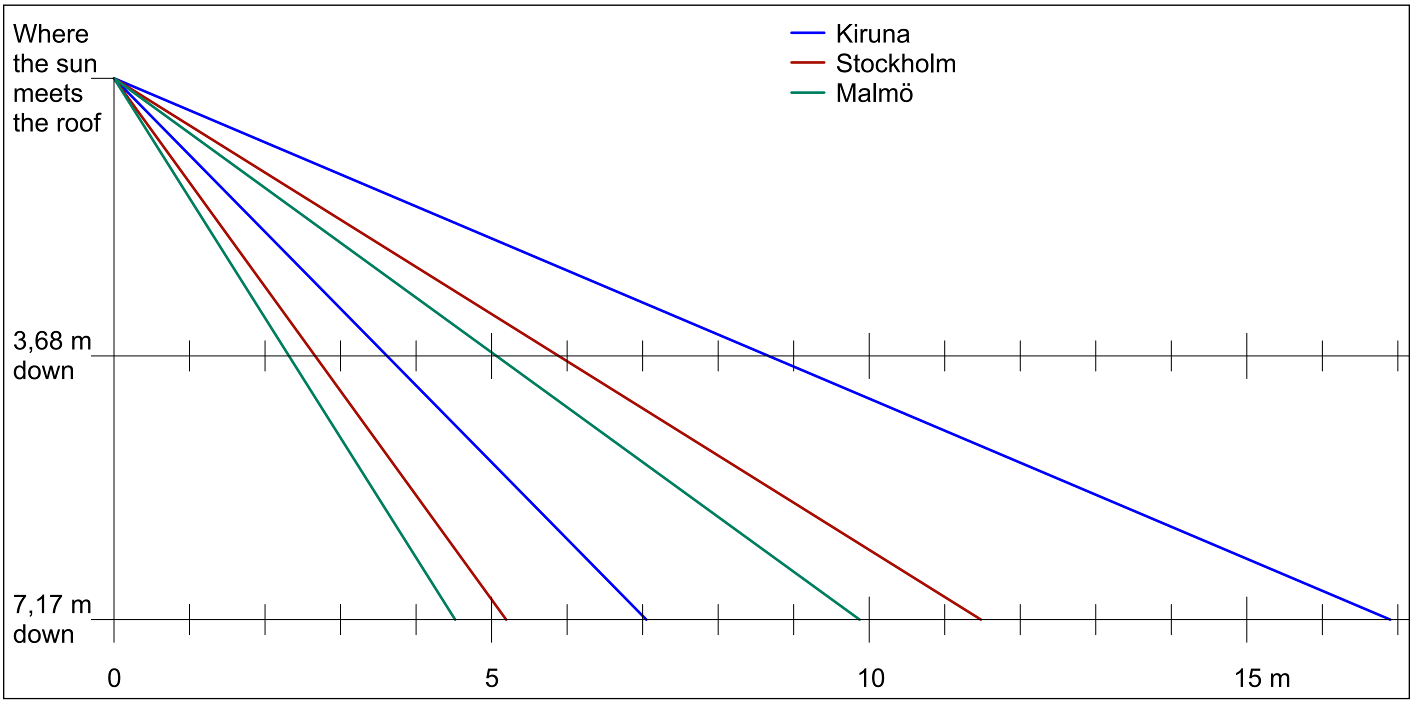
Roof 50° H: Here the building with 50° slope of the roof. It gives a good ceiling height for standing The shaded parts show the living space, BOA as it would be if the roof was insulated.



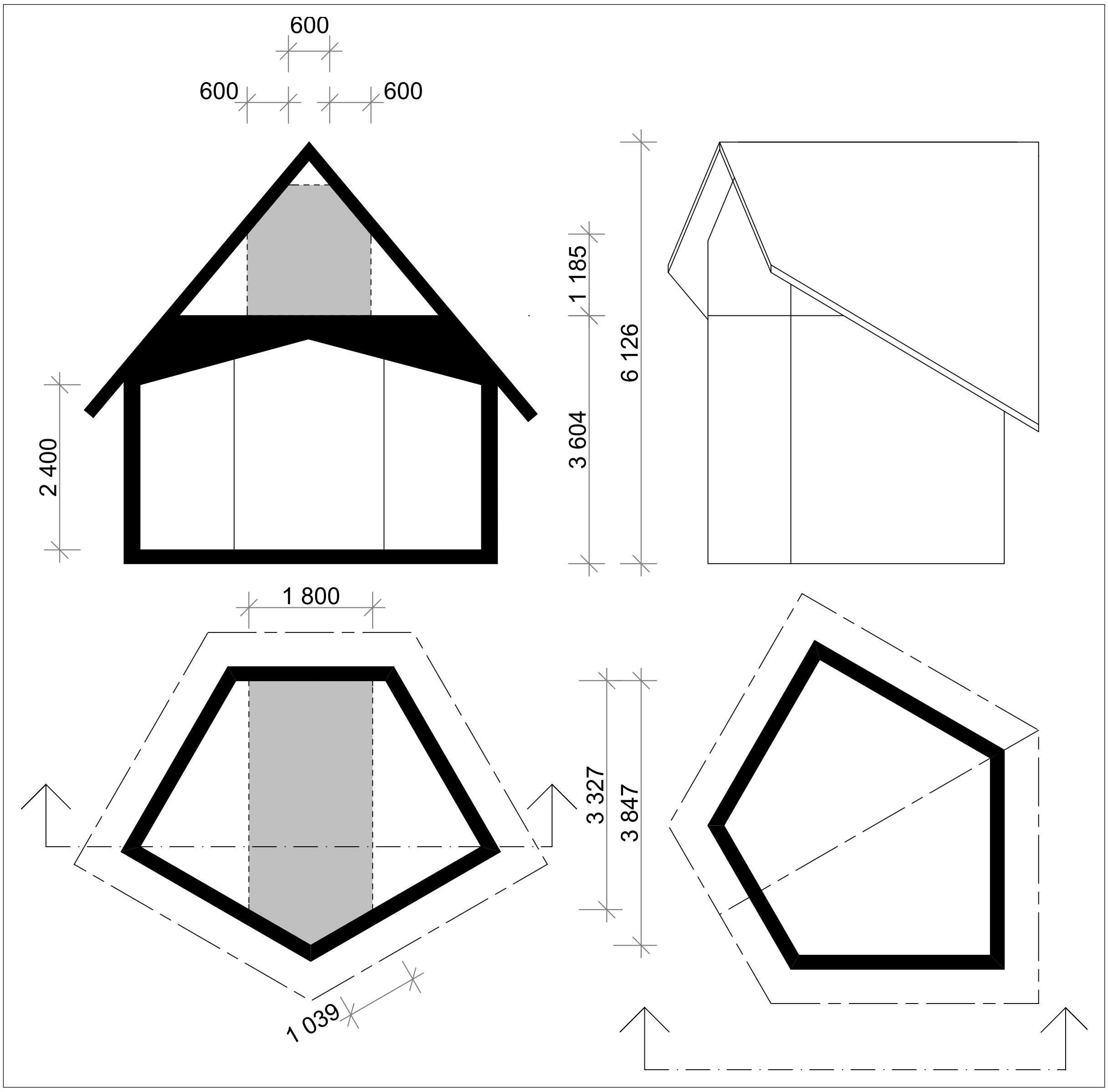
The living space and the ceiling height for standing is good but the height of the building is now 7,17 m. Hence, Roof 50° H will cast a much longer shadow than Roof 15°.
However, the shadow is not as compact as it would be if the roof was insulated. The glazed roof will transmit much of the suns radiation.

The floor in the winter garden will be approximately at the same height as the ridge of Roof 15°. Thus, the compact shadow will only become a little bit larger, compared with Roof 15°.

How long is the casted translucent shadow 7,17 m down? 3,68 m down is showed for comparison.

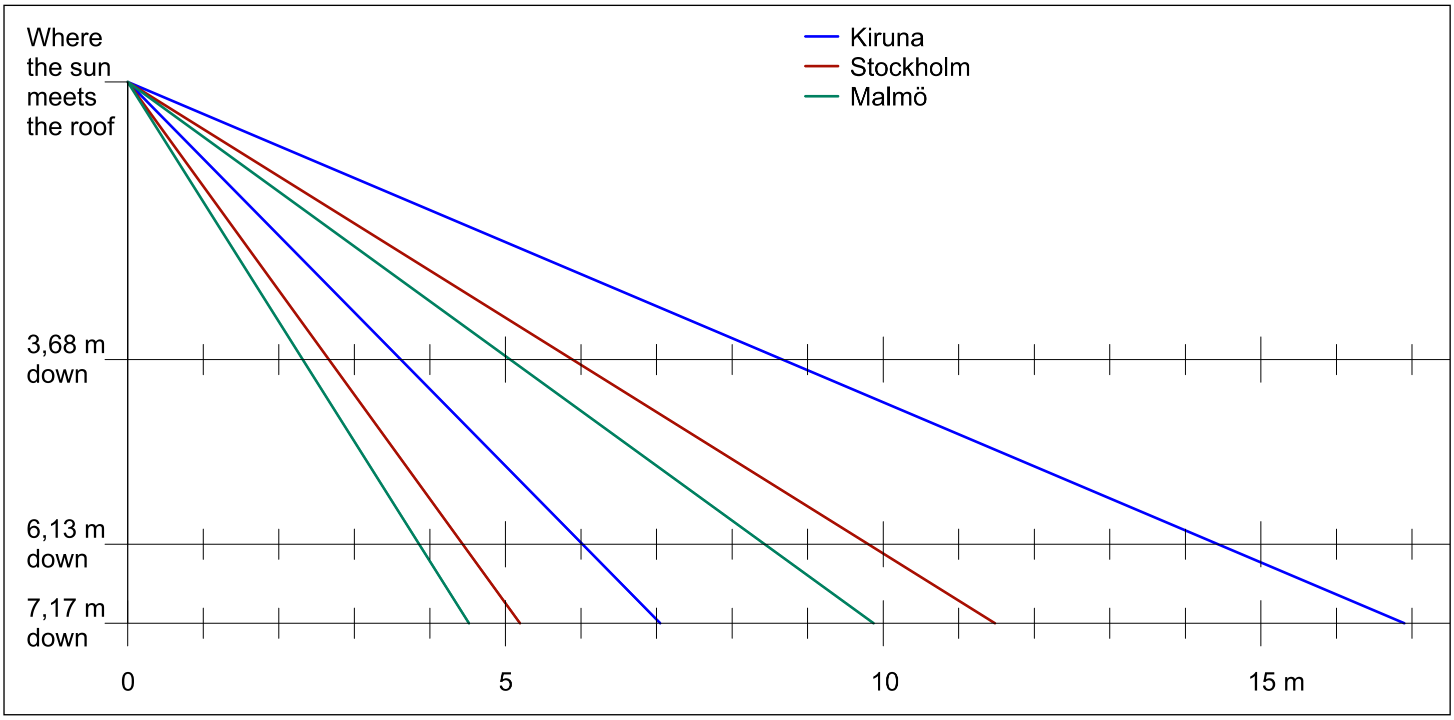


Roof 50° L: Here Roof 50°, lowered to a minimum for the living space, BOA:

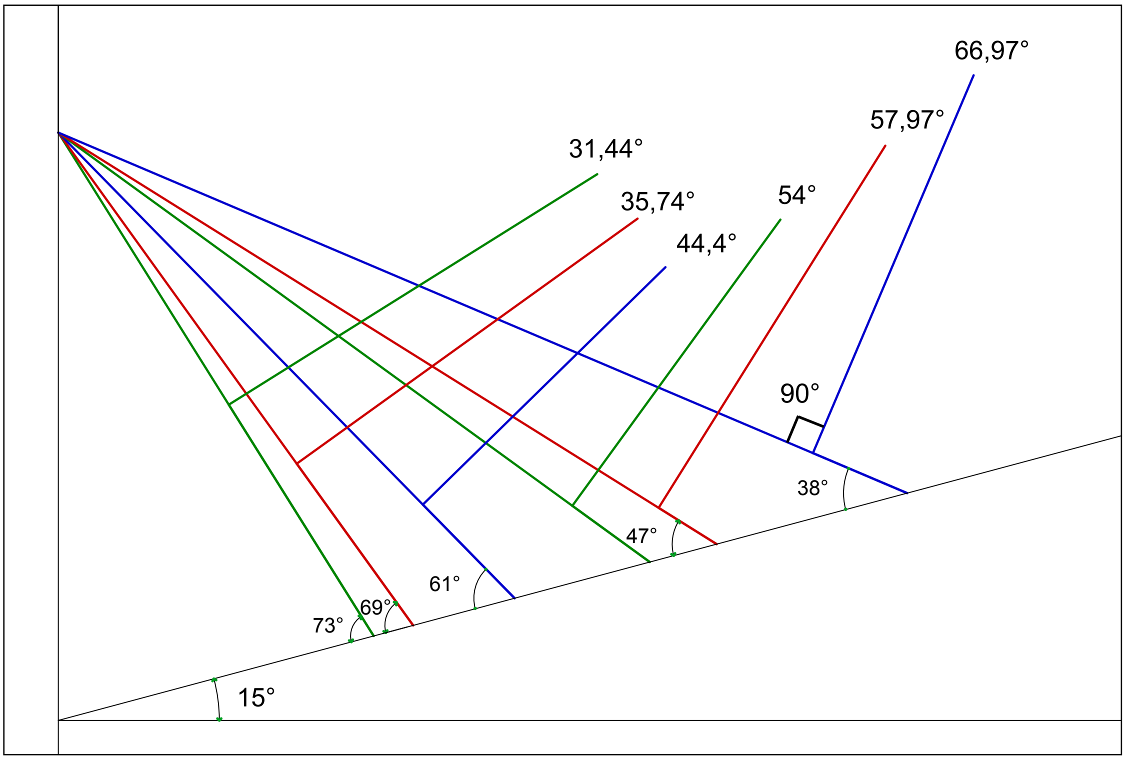


The roof has been lowered with 1 m but the width of the living space has been diminished by 1,76 m. From 3,557 m to 1,80 m.

How long is the casted shadow 6,13 m down?
A possibility to compare all three roof´s casted shadows.

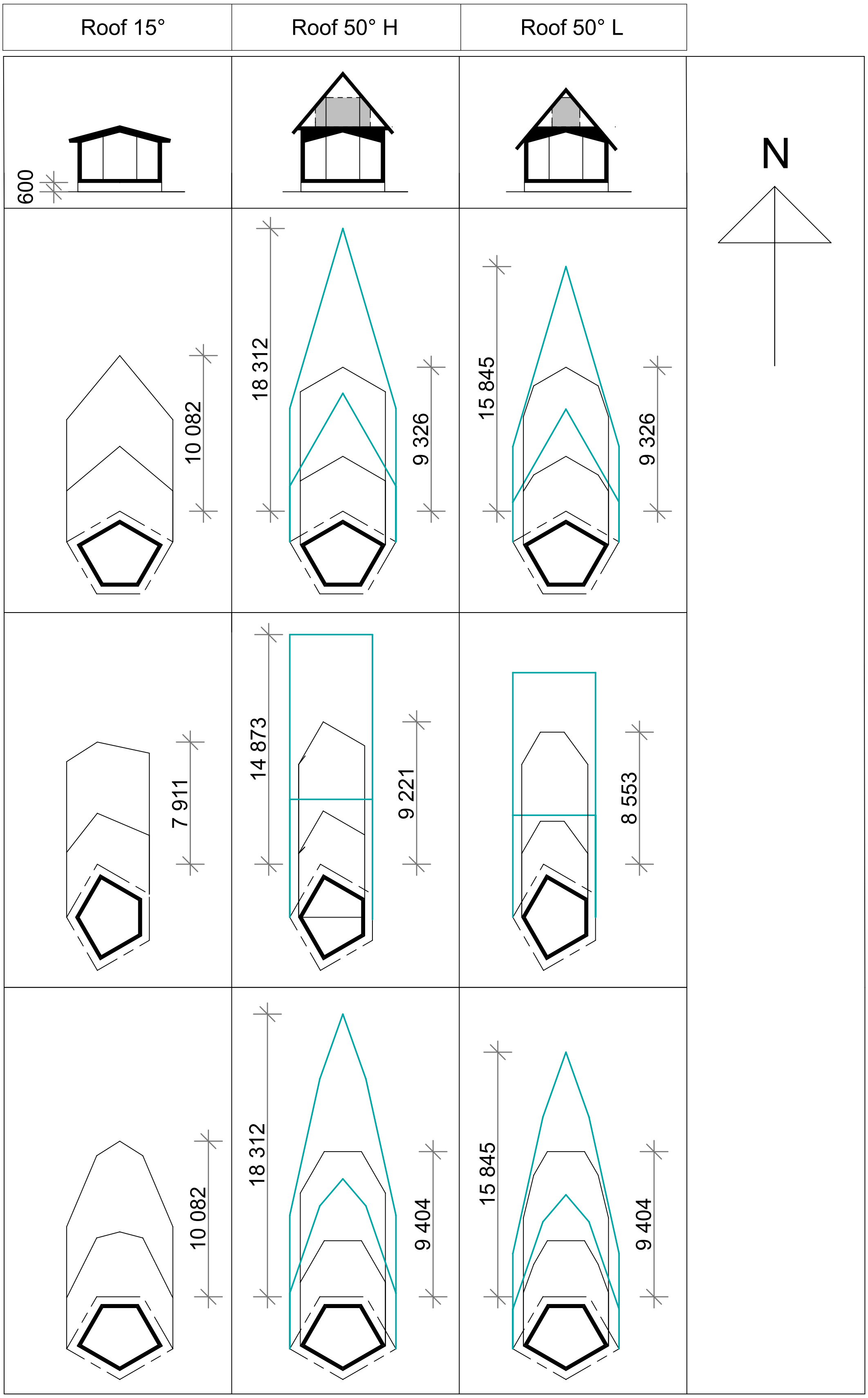


This picture shows the sun´s angles of approach facing Roof 15° and how steep the roof would have to be if the angle of approach was to be 90°. The same times and locations as before.

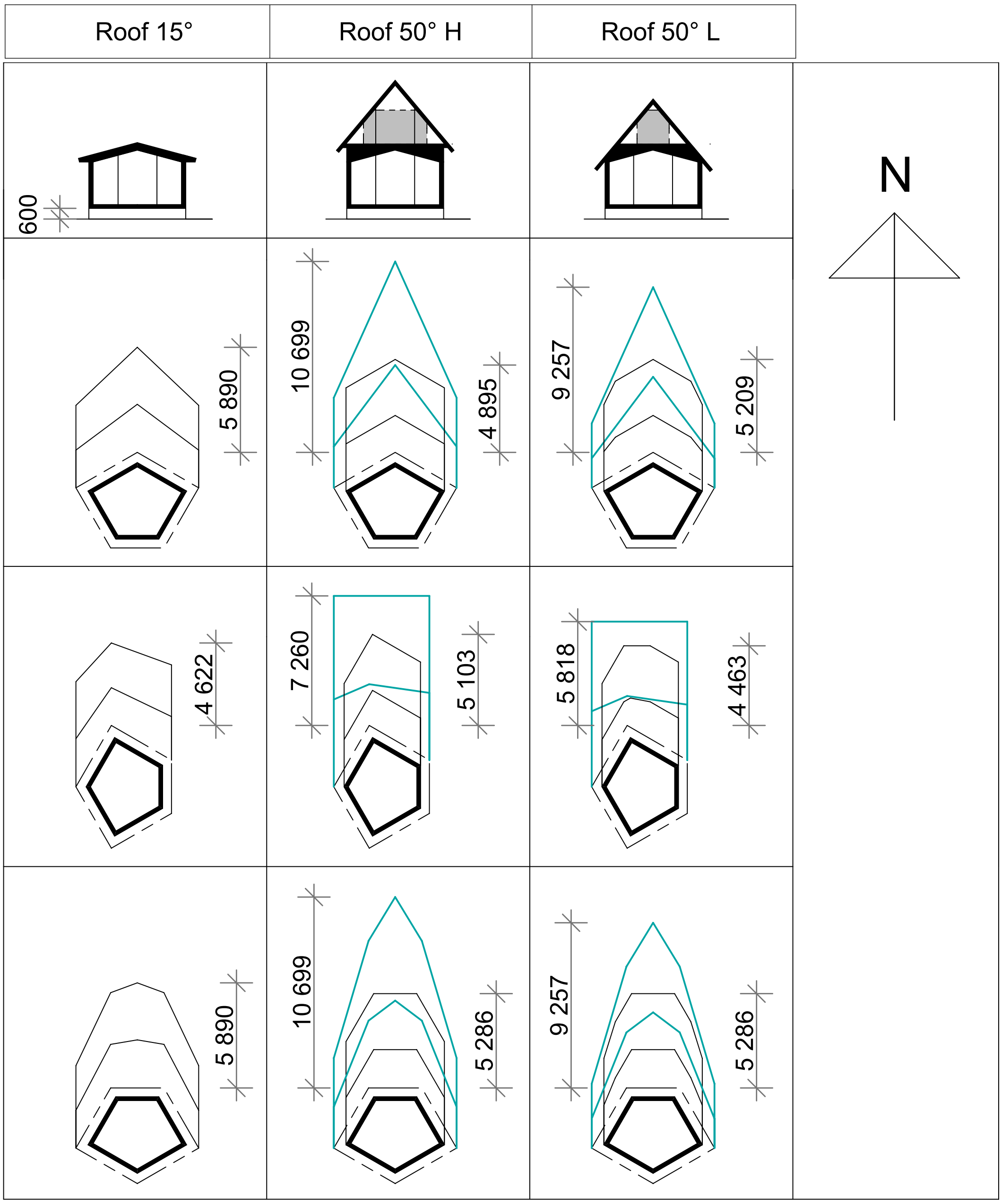


Roof 50° is the best choice if collecting warmth is the main issue and the snow can easily slide off the steep roof.

To get a better view of the casted shadows, here a comparison between the shadows in Kiruna. The blue lines are the translucent shadows. The lines show, as in the graphs before, the lengths of the shadows when the sun is at the highest in the summer, circa 180 days in to the year, and circa 90 days before = circa 90 days after. The foundations of the buildings are here 0,6 m high.



The compact shadows are almost of equal size no matter which building but the translucent shadows are not. They reflect the buildings real heights. Here the shadows in Malmö. Scale 1:400



Depending on the point of compass, Roof 50° H cast bigger or smaller compact shadows compared to the other two. Roof 50° H has bigger translucent shadows than Roof 50° L but the advantages of a much bigger living space under Roof 50° H, outweigh the longer shadows. If the translucent shadows after Roof 50° H can be accepted then it can be considered as the best of the two. The differences between the translucent shadows are bigger in Kiruna.

When comparing Roof 50° H with Roof 15°, other aspects have to be considered.

When buildings with Roof 50° H are assembled opposing it is possible to walk between the buildings, but if they are assembled sideways you can´t, unless you alter the construction. You also have to have stairs to be able to get up.

Roof 50° H is better at collecting the warmth from the sun. However, the walls will collect most warmth in the winter when the eaves do not shade the façade and the leaves have come down.

If money is an issue, the big glass area can be better to have on the ground. It is easier to access and to grow vegetables. One of the purposes is to make it possible to play music without disturbing others and if there is someone above, the soundproofing must be very good. It is different if someone pass the building and hear something or if this someone is sitting above, hearing everything. Considering that Roof 15° does not have to be altered when assembled and is cheaper, Roof 15° is chosen.

3 Construction

3.1 Insulation

Boards of mineral wool contain, beside glass or stone, among other things phenol glue, which is to be avoided.

Cellulose insulation is made of:
90 % recycled daily papers and
10 % fire inhibitants
“During the process the fibres are impregnated with an additive, free from boron, which gives the required fire inhibiting properties and increased durability.” (my transl.) (Byggvarudeklaration iCell - Lösull, Älvdalen 2014-10-08)

It is not said which substances are being used. It also states that it does not emit any emissions, which seems unlikely since daily papers contain printer´s ink and even old papers smell and then there is the fire inhibitants. Some emissions have to be emitted. There are more manufacturer but all have fire inhibitants.

Boards of flax or hemp also contain other substances, such as polyester and fire inhibitants.
An advantage with flax and hemp insulation, compared with boards of mineral wool, is that they weigh more and therefore, can keep the warmth a little longer.

Loose hemp is possible to buy and have no additives. I haven´t found any loose flax yet to buy, but hopefully it exists or will come. For now, loose hemp will be used. It has a natural resistance against mould and fire, why extra additives should be unnecessary.

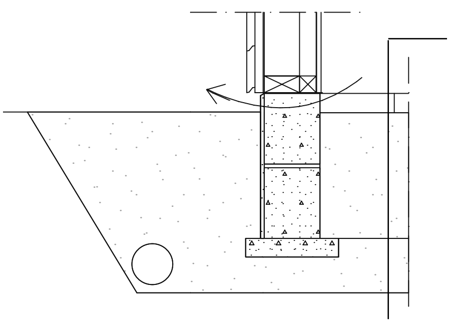
The choice of insulation can also influence the migration of moisture depending how good it is to absorb moist. For example unretted and frostretted hemp and unretted flax absorbs water very well but frostretted flax absorbs water very slowly.
(Bengt Svennerstedt, 2003)

3.2 Foundation

3.2.1 Foundation on the ground

A foundation on the ground is not ecologically defendable. First it acquires excavating and/or bursting, then drain-pipes have to be laid in order to divert the water away from the ground. Stones must be crushed and washed, cement be casted and then a foundation wall built. This kind of construction is not easy to move.
Since I want to do as little damage to the ground as possible and want the pavilion to be easy to move, foundation on the ground is not a good choice.

One example of a foundation on the ground.
When the wall of leca isn´t insulated on the outside there will be a thermal bridge through the wall.
Scale 1:100.



50 bricks
340 leca or perlit
150 washed macadam

3.2.2 Foundation on plinths

When using plinths, the distance between the building and the ground is depending on the kind of ground underneath the building. However, a distance of at least 0,5 m is considered needed in order to avoid damage, caused by humidity, to the construction.

The fastening of the plinths is depending on the nature of the ground, but much less excavating is needed compared with a foundation directly on the ground.
The depth of the foundation can be reduced if the ground is insulated. Since the aim in this thesis is to find ecological solutions, the ground then has to be insulated in an ecological way. Nature itself insulate the ground with leaves, but it will require a thick layer and it will have to be refilled, since it decompose over time and diminish.
If the building stands alone and is constructed on homogeneous ground and have a stiff construction, perhaps it won´t be so bad if the building is lifted up a little in the winter, unless it leans too much. If that is acceptable, then leaves can be used.
Otherwise Foam glass perhaps can work.
Perhaps it won´t matter so much if it smells a little since it´s outdoors.
Either way, in order to drain off the rainwater, the ground around the building needs to be sloping down and away from the building.

Since the building is intended to be able to be used as a stage, it´s an advantage that the stage is placed higher than the ground.
The room is also more shut off from peoples view when the windows are higher up.

If plumbing is to be installed, some more excavation is needed. However, the excavation can be minimized if lavatory, bath and kitchen are placed close to each other.
The choice of materials concerning plumbing and electrical wiring has to be chosen out of least poisonous material, considering the poisonous effects at burns. Not done here.

An advantage with foundation on plinths is that the installations will be easier accessible. If there is water damage you can fix it from underneath.

To avoid possible littering, laths can be put around the ground of the building.

A disadvantage is that the building will cast longer shadows.

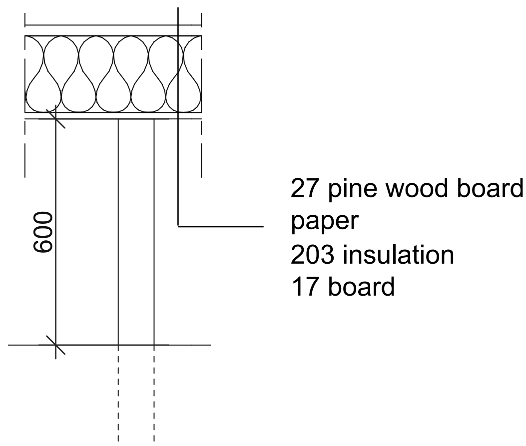
If the building is placed on a ground with varying heights, perhaps those differences can be utilized to minimize the differences in heights at the entrance and at the opening to the garden. Otherwise a ramp is needed for disabled people. If the ground outside this building is flat and horizontal, a ramp of 10,2 m plus a resting plan is required.
A ramp can also be needed to facilitate the access to the common garden when assembling the buildings. Here, alternatives to a ramp can be:
- to install a small elevator
- to heighten the ground. Then the buildings will cast shorter shadows in the garden and the plants get a deeper layer of soil.

To be on the safe side, I choose to put the building on plinths, 0,6 m above the ground, also considering the possibility of the building being used as a stage,.

A suggestion for the construction on plinths.
Scale 1:20

The same type of insulation as in walls and roof, i.e.:
Insulation with loose hemp

Instead of sticking the papers together with tape, which ages and comes off, they are glued together with good old-fashioned wallpaper glue, made out of potato flour and water, with no additives.



3.3 Construction of the walls

Masonite could have been a material of my choice, but since it, as have been said earlier, sadly has been driven out of business by the other cheaper wooden fibreboards with added toxic glue, it can´t be. Moore about that in “Environmental influence”, page 4.
Instead wooden panels are chosen.

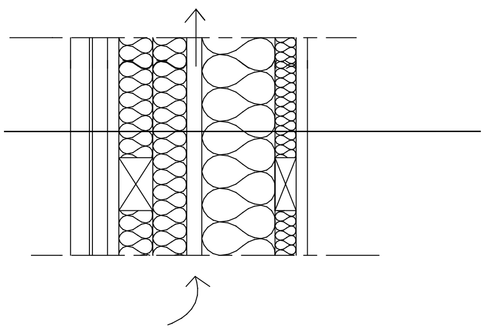
If you have glass in front of the outer panel of the building you get both a sun panel and a waterproof surface. Then the wooden panel should last for ever.
It is a known phenomenon that evaporating water consumes energy and that water leads warmth better than most other materials we have in our walls. This is why rainwater cools down the building´s façade.
When water comes in contact with wood, it can also cause trouble with rot and mould.
The maintenance of painted façades is very expensive. If the façade is covered with glass the maintenance costs are reduced, on condition the glass isn´t vandalized and broken. The heating costs should also be reduced since a warmer climate is created behind the glass.

Therefore, I choose to have glass in front of a wooden panel. The glass shall be able to open like windows to facilitate cleaning.
The air to the ventilation shall be able to pass through the air slit behind the glass in order to become warmer before entering the room.

In order to stop moist to enter the wall from inside, a plastic foil can be used. Sadly it contains softening agents and other chemicals. Some of which we know is harmful and some of which we don´t know enough about how they influence nature and ourselves in the long run.

“An alternative way is to allow a certain amount of condensation in the construction, on materials which isn´t harmed by this. The condensate shall then directly be drained away or temporarily be stored and later, with the help of ventilation, be dried out.” (my transl.) (Hagentoft, 2002)

Perhaps a construction like this could be a possible alternative to a plastic foil on the inside of the wall. Scale 1:10



25x45 vertical planed board
4 glass pane
20x45 vertical lath
20 slit of air
15x95 vertical panelling
45x70 horizontal lath
45 insulation
45x45 vertical lath
45 insulation
loosely woven hemp or flax
20x45 vertical lath
20 slit of ventilation
loosely woven hemp or flax
45x95 stud
95 insulation
Paper
28x70 horizontal lath
28 insulation
15x95 vertical wooden panelling

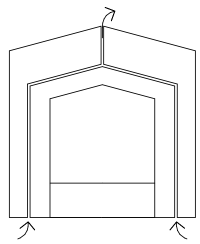
Instead of using a plastic foil to stop the vapour to enter the wall, a slit of ventilation is placed inside the wall in order to be able to ventilate away possible moist that has entered the wall.

The slit of air continues in the roof and has an outflow at the ridge. The inflow of the air can be regulated by dampers. The inflow openings to the slits of ventilation should be as small as possible, to keep the warmth.

The size of the openings is mostly depending on the humidity in the wall, the humidity outdoors, the difference in temperature between indoor and outdoor and the wind velocity. Compare with a 2-glazed hinged casement window, U-value 2,8, which has an opening towards the outdoor air between the panes to prevent condensation there. Yet the insulation is much better than for a 1-glazed window, U-value 5,8.

Here a schematic, compressed picture of the slit of ventilation and its location in walls and roof.

The size of the openings as shown in the picture is too large since the openings shall be as small as possible.



The slit of air also results in better sound-proofing, although it perhaps should be 30 mm instead. The bigger the ventilation slit the less risk for resonances. (Hamrin, 1994)

When buildings are assembled some walls become interior walls. If the extra sound-proofing of the outer wall is not needed, the outer part of the wall can be dismantled and reused on the corresponding wall on the added building.

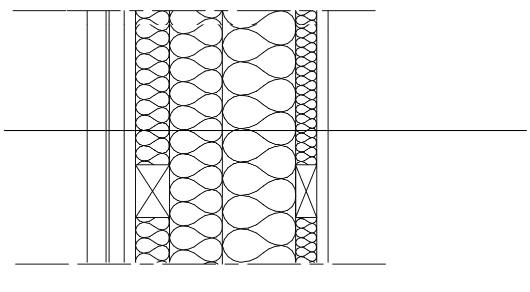
The construction with the slit of air has been examined by senior lecturer in technology of building, Ingemar Segerholm at Chalmers university of technology.
His opinion is that the construction is interesting as a concept but has risks. You have to make sure it works if you are to construct it in reality.

“ To dare building such a construction I would recommend accurate calculations (simulations) for the complex of problems concerning humidity.” (my transl.) (Segerholm, 2016).

He is also of the opinion that if you don´t make such calculations (simulations) you should put a plastic foil in the wall to be reasonably sure of avoiding problems with humidity, and then the slit of air isn´t needed and can be removed.
Therefore, I make an alternative construction.

According to Hans Allbäck at Allbäck products of linseed oil, boiled linseed oil painted on the wall works as a plastic foil. (Allbäck, 2015) Therefore, I rather choose paper painted with boiled linseed oil instead of a plastic foil.

Then the construction can look like this instead. Scale 1:10.

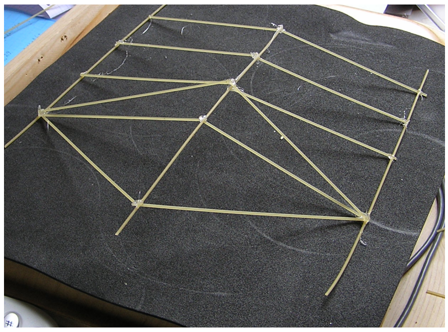


25x45 vertical planed board
4 glass pane
20x45 vertical lath
20 slit of air
15x95 vertical panelling
45x70 horizontal lath
45 insulation
45x70 vertical lath
70 insulation
45x95 stud
95 insulation
Paper painted with boiled linseed oil
28x70 horizontal lath
28 insulation
15x95 vertical wooden panelling

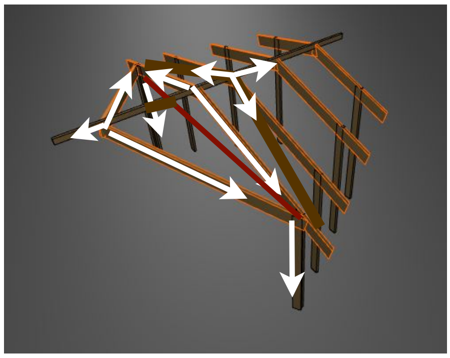
3.4 Construction of the roof

The slope of the saddle roof has been set to 15°, see p.38.

An early test with spaghetti:
The braces were needed in order to restrain the construction from being pushed forward.



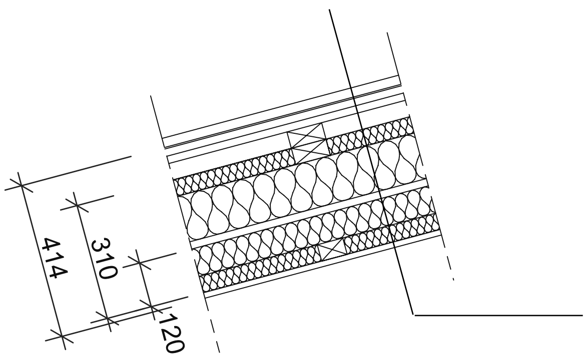
The roof is made with roof truss frames.
All junctions are made moment rigid.
For extra security a beam, here showed with a red line, can be inserted between the front studs. Since the lowest height to the ceiling is 2,4 m it won´t´be in the way.
The white arrows illustrate how the weight of the protruding roof is transported down to the ground.



If a wood burner is installed, a roof hatch needs to be installed for easy access to the chimney.
Roofing with boards of siberian pine, heat treated wood or tiles were some of my first thoughts but as the building has developed I have come to the conclusion that glass panes probably would be a better choice.

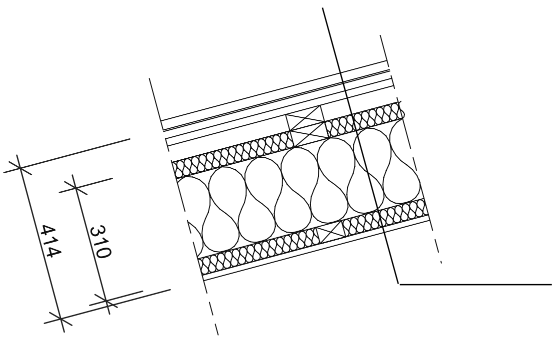
When the sun shines on the roof facing the sun it will swiftly be made warmer.
In this first construction, with a slit of ventilation, the slit continues in the roof and thereby probably can ventilate away possible moisture, before it reaches the glass on the roof.

A suggestion for the construction of the roof with a slit of ventilation. Scale 1:20



40 profiled boards
4 glass
20x45 laths
20 slit of air
wind paper
20 match-boards
45x95 joist lying down
45x95 joist lying down
45 insulation
45x220 roof truss
125 insulation
woven hemp or flax
20 slit of ventilation
woven hemp or flax
75 insulation
paper
45x70 joist lying down
45 insulation
15x95 wooden panelling

In this second construction the moisture is stopped before entering the construction from the inside. Instead of the construction with the slit of ventilation, a plastic foil or a paper, impregnated with linseed oil, can be placed on the inside of the roof. Then the construction of the roof can look like this. Scale 1:20.

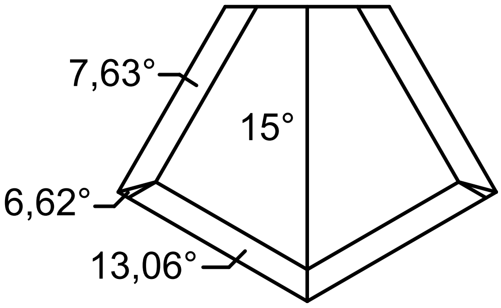
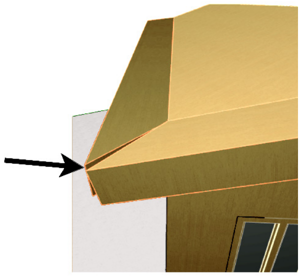
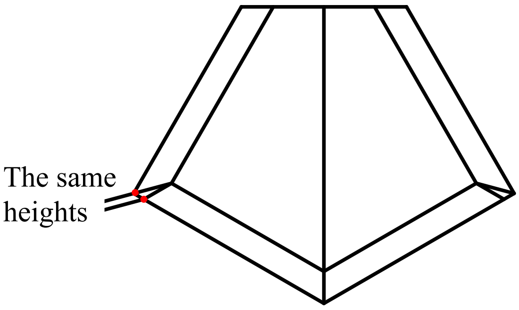


40 profiled boards
4 glass
20x45 laths
20 slit of air
wind paper
20 match-boards
45x95 joist lying down
45x95 joist lying down
45 insulation
45x220 roof truss
220 insulation
paper, painted with boiled linseed oil
45x70 joist lying down
45 insulation
15x95 wooden panelling

When the boards get wet, the annual rings will want to be straighten out. Therefore, the boards holding the glass shall have the heart of the tree turned upwards.
If the boards are turned wrongly,there is a risk of the boards loosing contact with the glass. Sealing between boards and glass is made with tared bands of flax.
All wooden surfaces facing wind and weather and glass are impregnated with raw linseed oil, which should be freed of mucilage, according to Allbäck linseed oil products. (Allbäck linoljeprodukter, 2015).

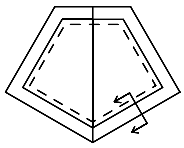
If the roofing with match-boards under the glass is made as if it were the only roofing, the wind paper can be removed. It is placed there to protect the underlaying materials and to direct the water to the drainpipes if water leak in or if a plane of glass is being broken.

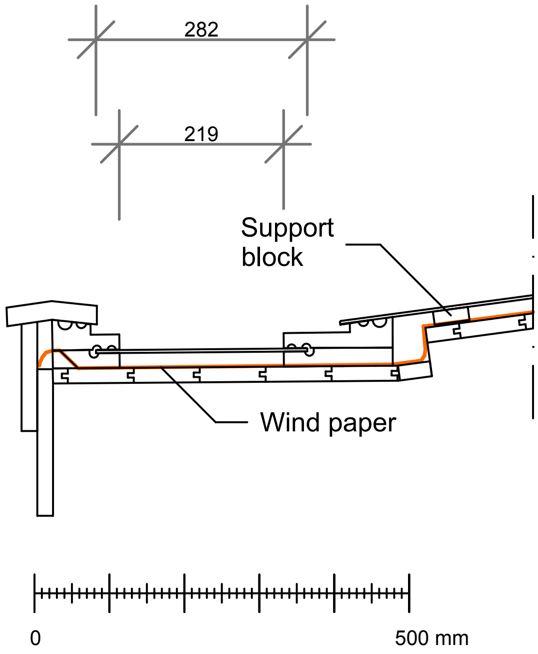
3.4.1 Draining the roof

The five-sided building in combination with a saddle roof cause the “gutters” to slope automatically.	
Different slopes of the roof.	
An image of the meeting of the “gutters”. They have different slopes and therefore, they don´t meet on the same level	
When they end at the same height you get this picture. It will be an inclination outwards with 67 mm = 6,6°. Hence, a slope towards a drainpipe.	

The meeting between slopes of the roof.

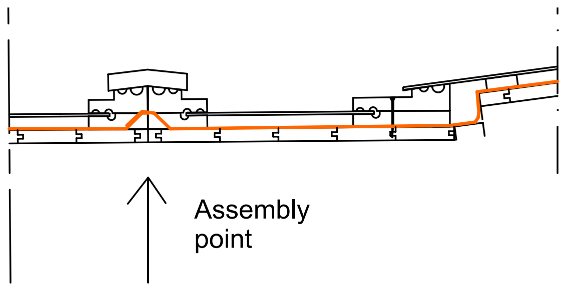
The block is there to support the glass in the event of changing the glass in the “gutter”.
The board that holds the glass to the right is broader so you can remove the glass without first needing to remove the glass above.





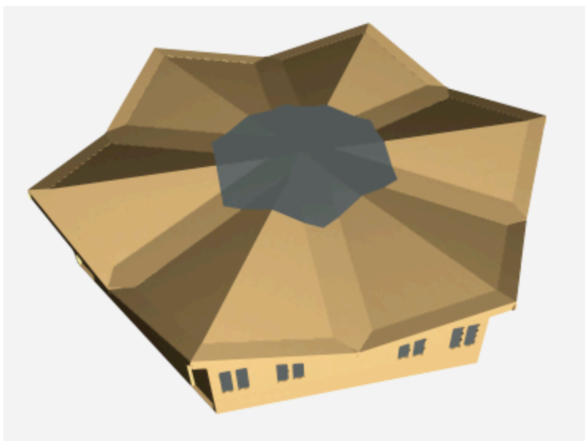
3.4.2 How to assemble the pavilions

To be able to assemble the buildings, the bargeboards are removed.



This way to divert the water makes gutters unnecessary since the water is directed to two points, one on each side of the building.

Here a roof image of assembled buildings in a circle to show “the gutters”.
The atrium in the middle being glazed.



3.5 Windows

Windows transmit much thermal energy. If it gets to warm indoors, normally it can be helped by temporary airing the room.
If the building has large windows facing south, shielding from the sun can be necessary.
Large eaves shield the sun in the summer, when it is needed the most.

g-values for different types of windows and sun-shields are shown to the right.
Source: Pilkington and the building as a system (my transl.) (Elmroth, 2009)

g-values = sun energy transmittance

The most effective sun-shields are outside sun-blinds but also venetian blinds are helpful. They approximately halve the thermal radiation.

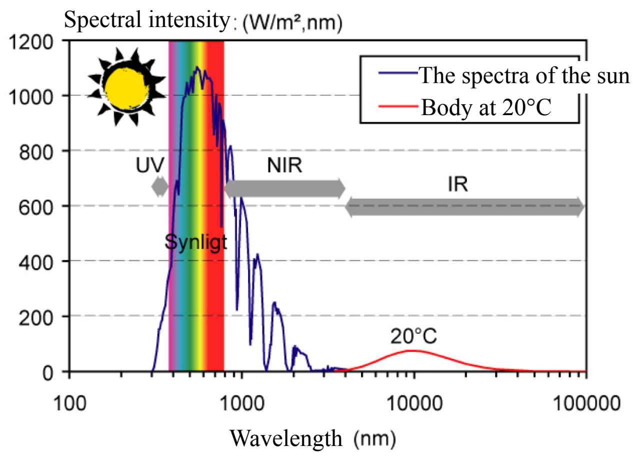
	g-value %
unshielded 2-glazed window	0,7-0,8
2 glass panes and 1 low emission layer	0,6-0,7
unshielded 3-glazed window	0,6-0,7
3 glass panes and 1 low emission layer	0,55-0,6
venetian blinds between the outer glass panes in a 3-glazed window	0,3
Window with sun-shielded glass pane	0,15-0,3
Sun-blind	0,2

3.5.1 Shutters

In the seventies and eighties, a prototype for shutters was developed by Folke Hagman, with the support of the board for technical development (STU) and the governments board for building research (Byggforskningsrådet).
He came to the conclusion that, with his shutter in function, a window with K-value (nowadays U-value) 2,4 W/m^2K could reach K-value 0,7 W/m^2K.
A window with K-value 2,0 could reach 0,5 W/m^2K. Also acoustic improvements were achieved.
(my transl.)(Bülow-Hübe and Lundgren, 2011)

When we are outdoors in the sun we are met with a whole spectrum of light.

The spectral dispersion of the sun radiation at the surface of the earth (when the radiation has passed the atmosphere) and the dispersion of the radiation originating from a body at room temperature

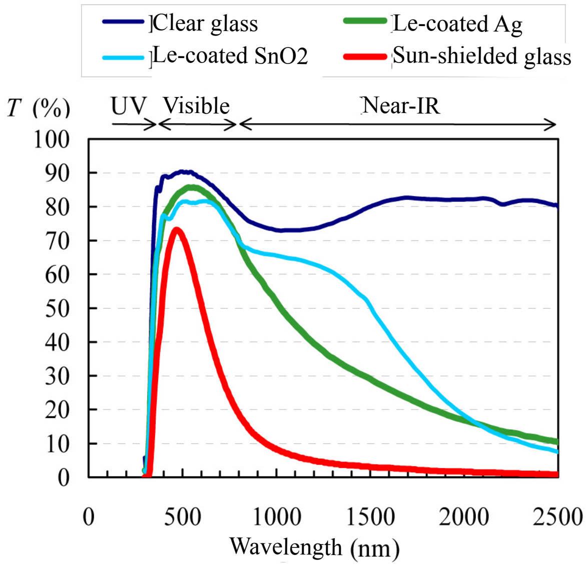


(Bülow-Hübe and Lundgren, 2011) (my transl.)

Depending on the kind of glass inserted in the windows, different wave lengths are transmitted.

The properties of transmission for clear glass, two types of le-glass and one modern sunshield glass.

Most of all wave lengths are transmitted through Clear glass while almost all of the higher wave lengths are filtered away by the glass with layer.

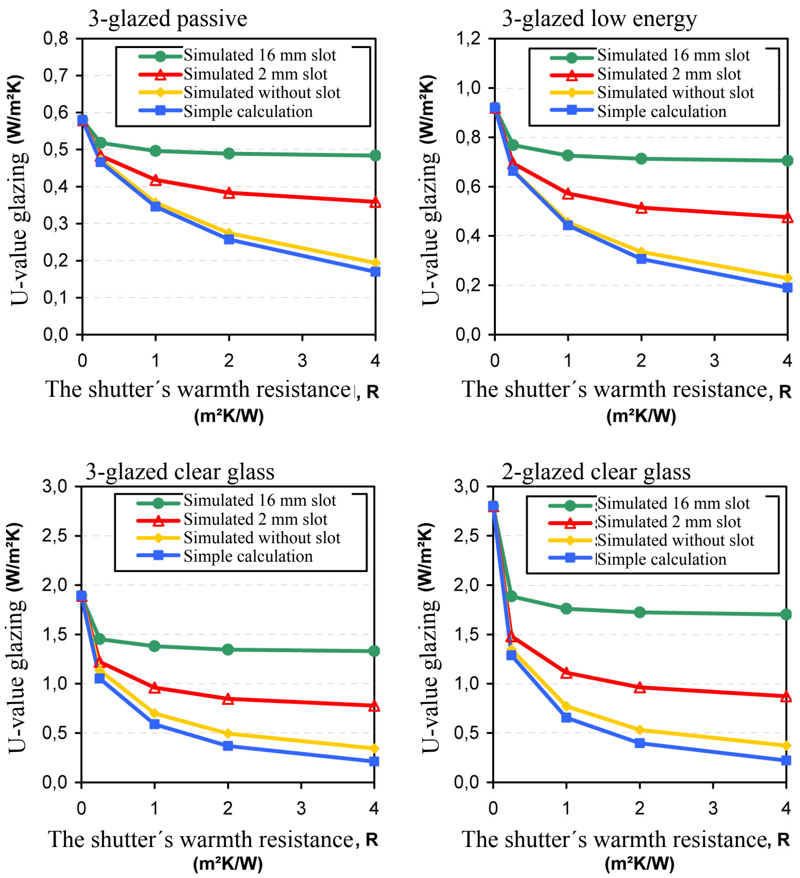


(Bülow-Hübe and Lundgren, 2011) (my transl.)

Charts showing how shutters influence net U-values.

Calculated net U-values for glazing systems (glazing + shutter) with shutters of different capacity of insulation and air tightness, together with different types of glass panes. Simulated values are produced in ParaSol.

The calculations for “net U-values” was made 1-16 january, a dark and cold period.

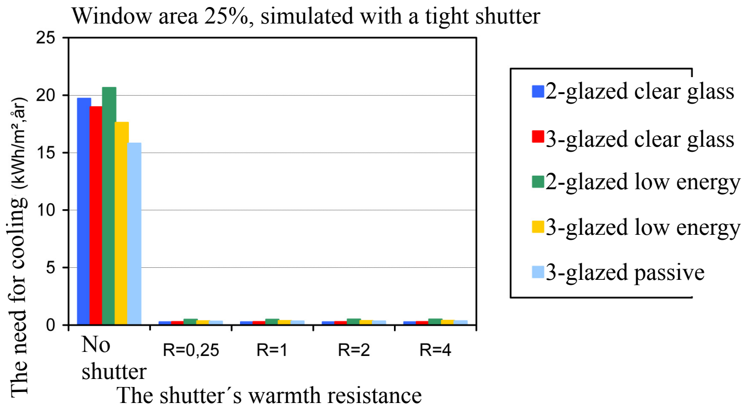


(Bülow-Hübe and Lundgren, 2011) (my transl.)

From this you can gather that layered windows with U-values circa 0,58 - 1,2 can come down to U-values between circa 0,17 - 0,20 W/m²K. Windows with clear glass with U-value circa 1,8 - 2,8 also can come down to circa 0,2 W/m²K with the best insulated shutter.

“Already with a moderately insulated shutter you can get an enormous improvement of energy for windows with high U-values, if you succeed in getting the shutter tight.” (my transl.) (Bülow-Hübe and Lundgren, 2011)

The yearly need for cooling in a room facing south, with different types of windows and different insulated shutters.



(Bülow-Hübe and Lundgren, 2011) (my transl.)

Some values from Pilkington.

LT = light transmittance, g = sun energy transmittance, Rw = Sound reduction

Pilkington Optifloat™ Clear Single glass

	Typ	U-value with air W/m²K	U-value with argon W/m²K	Surface temp. -10/+20 °C	LT %	g %	Rw dB	Weight kg/m²
3 mm	1	5,8		−1,8	91	0,88	28	7,5
4 mm	1	5,8		−1,8	90	0,87	29	10
5 mm	1	5,8		−1,8	89	0,84	30	12,5
Pilkington **Optifloat**™ Clear Hinged casement windows								
4+40+4	1+1	2,8		9,5	82	0,78	36	20
4+30+4-12Ar-4	1+2	1,8	1,7	13,6	75	0,71	37	30

Declared U-values are calculated center values according to SS-EN 673.
When the practical U-value of a window is calculated you have to consider the insulation in the edge zone, frame and the bow, and also consider the size of the window and correct for shortcomings at the installation. Practice also implies that gas filled panes is calculated to be filled with only 90% gas.

There are advantages with single clear glass:

- High transmission of the light
- Transmission of most of all wave lengths
- Much added steam indoors can be seen on the glass and tells about the need for ventilation.

Sadly it has a bad U-value, circa 5,8 W/m^{2}K.

Modern, well insulated windows can have U-values between circa 0,58 - 1,2 W/m^{2}K.
As shown above, 2-hinged casement windows with clear glass, with U-values circa 2,8 W/m^{2}K, can come down to circa 0,2 W/m^{2}K with the best insulated shutters.

Depending on the time the shutters are closed during day and night, the average U-value will vary. Also the outside average temperature during the time the shutters are closed and the outside average temperature during the time they are open, will influence the U-value. It is often much colder in the night and hence, the shutters are most often more valuable at night.

What will the U-value of the 2-hinged casement window with clear glass and shutters be?
In the following table the shutters are closed during the night when it is generally colder.

The time the shutters are closed Hours	The time the shutters are open Hours	The difference in outside average temperature between the time the shutters are open and closed. °C	U-value W/ m^{2}K.
0	24	0	2,8
8	16	0	1,93
12	12	0	1,5
16	8	0	1,07
20	4	0	0,52
24	0	0	0,2
8	16	1	1,5
8	16	2	1,24
8	16	3	1,07
12	12	1	1,07
12	12	2	0,85
16	8	1	0,72
16	8	2	0,57

If you have the shutters open only when you are in the room, let´s say 4 hours a day and there is no difference in average temperatures, then the U-value would be 0,52 W/m^{2}K.

If you have the shutters open 8 hours a day and there is 2°C difference in average temperatures, then the U-value will be 0,57 W/m^{2}K.

Hence, a building with 2-hinged casement windows with clear glass and shutters can be better than modern well insulated windows without shutters. It all come down to the extent in which the shutters will be used and the difference between the outside average temperature during the time the shutters are closed and the time they are open.

Considering the saving of energy: The colder it is during the night, when the shutters are closed, the better effect will the shutters have and the more energy will be saved.

Due to the limited spectrum of light transmitted through the layered glasses and to avoid the chemicals in the tightening materials of the insulation panes, 2-glazed hinged casement windows with clear glass are chosen here.
The windows will have venetian blinds between the panes and shutters on the outside.
The sealing will be made with bands of flax, hemp or wool. The glasses will be fastened with sprigs and linseed oil putty.

To divert the rainwater from the façade, the window-ledges will be made of wood. Condensate will not form underneath wood, as often is the case with metal-ledges. Furthermore, wood boards are less energy consuming to manufacture than sheets of metal.

3.6 Treatment of the wood/Painting

Modern paints are filled with chemicals. How toxic they are and wether they are degradable or not and if so, what they are the degraded to, is unclear. Perhaps other even more toxic substances.
After reading security data sheets, I have come to the conclusion that even paints I thought to be good, have toxic ingredients.

If we want a colour, then the safest way probably is to make our own paint. To mix pigments with either linseed oil or with some other natural products, such as eggs, beer, water and chalk, or make distemper.
The safest pigments to use is probably earth colours which are said to be harmless. They contain only natural substances, among those the ones which give the colours. Metals for instance give colours, but how healthy it is to get those substances into the earth where you want to grow vegetables, has to my knowledge not been investigated. Limits and conclusions are constantly changing with more research.
The safest thing is to not use something that is not absolutely necessary.

Here, I choose to have the windows painted with raw linseed oil, freed of mucilage. It penetrates the wood and protects it against water.
Since colour pigments are not used, expensive and work consuming scraping and repainting will not be needed.
The woods natural patterns and colours will diversify the façade.
If more colour is wanted, the best way would be to use plants. For instance, climbing plants such as Virginia creeper, roses, blackberries, hollyhocks, and/or something else.
Then you get variation during the year, both in colour and shape. It can also shield the façade.

3.7 Ventilation

In Boverkets directions for reading concerning BBR you can read the following regarding ventilation:

“It is essential to look at the building as a system and not unnecessarily see the ventilation as a solution to other problems when planning a ventilation system. In order to reduce the need of ventilation you can for example choose low emitting materials instead.” (my transl.)
(Boverkets läsanvisningar till BBR, 2015)

In the pavilion with the living space 12,2 m^2, the lowest flow of air from the outside is 4,3 l/s. This should be possible to satisfy with a humidity and timer controlled ventilator fan.

An alternative to a humidity controlled ventilator fan is to have a so called gossip window, that is, a 1-glazed window. When it gets so humid in the room that it condense on the window it´s time to ventilate.

The air shall be able to take from the warmed air slit behind the glass. It´s important that the warm air from inside does not “fall down” and condensate in the air slit. This can be prevented by creating an underpressure inside or by letting the air only flow in one direction.
To reduce sound from the building, a sound-absorbing hatch, filled with hemp insulation secured with woven hemp or flax, is put outside the ventilators.

3.7.1 Heating and cooling

Heating is to be made with sunheated air, electric heating and possibly a stove.

Heating and cooling can be regulated with sensors of temperature and humidity, valves and steering and regulating engineering. This costs money and contains chemicals. It could be profitable to install but the best would be if the system could be made self regulating, with a little practical help from those staying. That is, some control and maintenance instructions.

Since this building is covered with glass, parallels can be drawn to greenhouses. Greenhouses are at large risk to become overheated in the summer since glass transmits much heat. A glazed surface directed towards the sun receives circa 800 W/m^2 on a clear summer´s day.
To avoid overheating you can ventilate and shadow the glass-panes.

In former days, in the early part of the summer, the glass in the greenhouses was limewashed on the outside and then in the late summer/autumn the lime was washed away.
Covering the glass with bast-mats or canvas cloth have been other methods.
Today there is shading fabric you can put inside the glass that reflects back the sunlight. It can be regulated automatically or manually. Another method is to shade with climbing plants, bushes and trees. They let the sunlight through in the winter and shade with their leaves in the summer. If you want to ventilate the heat away you can use natural draw and use the so called "stackeffect". That means that if you have a system with one cold and one warm pillar of air, the cold one will sink and the warm will rise.
If you let the warm air rise through a chimney, an underpressure will be created which can draw cool air from the outside.

"The rising force is depending of, and directly proportional to two factors: the height of the warm pillar of air (= the difference in height between the inlet and outlet of air in the building) and the difference in temperature between the air inside and outside. The warmer indoor air and the higher ceiling height, the better natural ventilation. With this follows that it is important that the greenhouse has openings placed as high and as low as possible to get the best imaginable thoroughly airing during the summer.
An old rule of thumb says that the area of the roofhatches, at full opening, should be approximately 1/5 of the floor area of the greenhouse." (my transl.) (Nordström, 1999)

Nordström writes furthermore about manually managed ventilation: "As late as in the 1980s there were excellent old-fashioned pieces of ironwork to buy, but these seam to have disappeared in favour of more advanced automatic systems.
With knowledge about the old technology you can however find useable pieces of ironwork which are produced for other applications. It is also possible to specially make easy pieces of ironwork for a reasonable cost." (my transl.) (Nordström, 1999)

In this building, there should be openings for ventilation as high and low as possible to insure the best possible ventilation in the summer. Warm days, the air should be possible to take from the shaded side of the building.
If needed or wanted, trees and bushes can be planted to shade in the summer.

4. The result

The pavilion has been designed for a diversity of purposes. To be able to connect with similar buildings in order to be able to create larger rooms for common bigger events. Also to connect with similar buildings for smaller groups or individuals. Between the buildings there can be storage, bicycles, lavatory etc. A freedom of choice out of the ordinary.

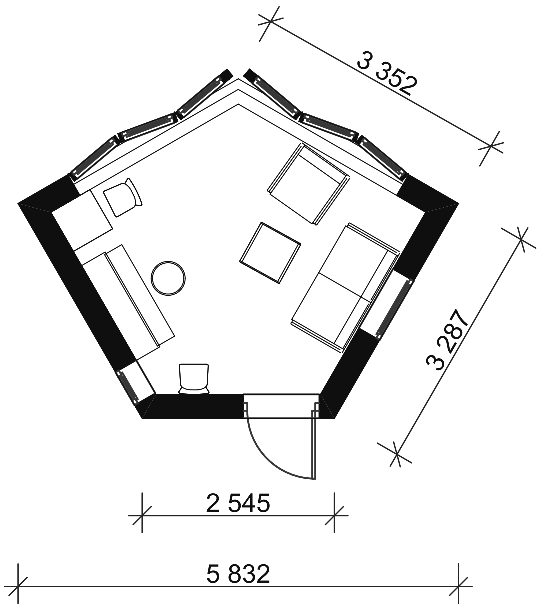
When the pavilion is made as a stage, two walls have folding doors which when closed, function as ordinary walls with one door opening outwards.

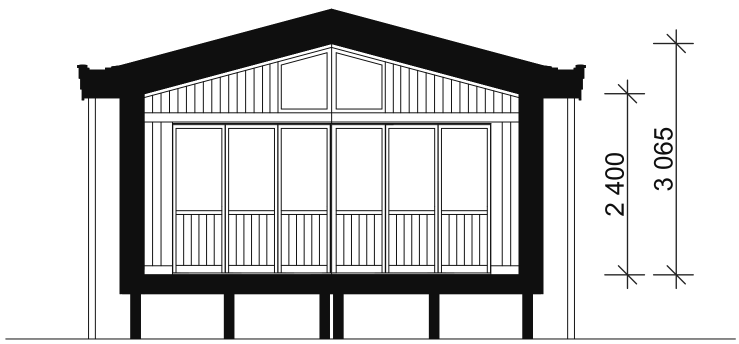
All of a sudden the use for the pavilion has expanded considerably! Why not start to build 16 m^2 - 55 m^2 and move in. As the need for more space arises you can enlarge later on.

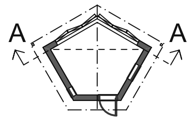
The present way of building causes people to take expensive loans and hence, they have to pay much more for the building than they would have to, if they had been able to pay in cash.
It might be better to start with a small building and enlarge as soon as money is available.

4.1 The pavilion, made for practice and performance

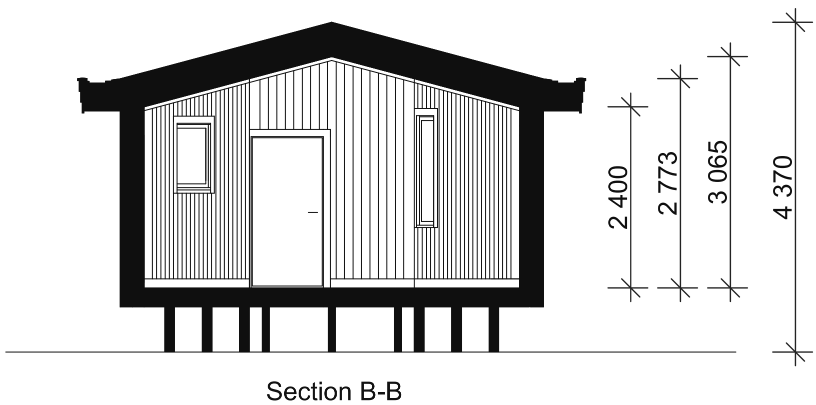
Plan and sections, scale 1:100

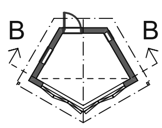






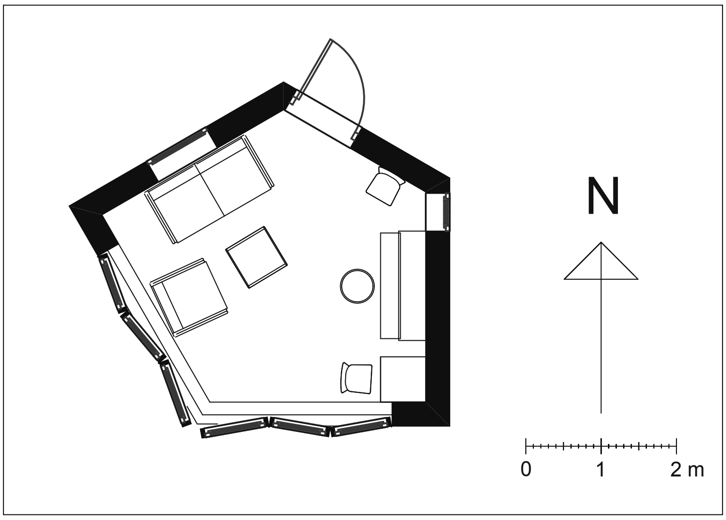
Section A-A

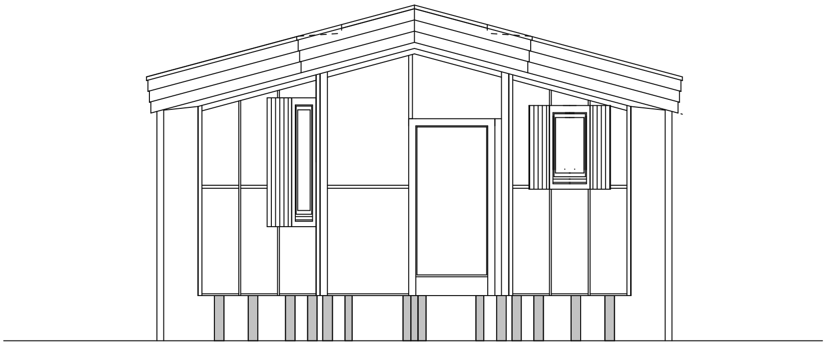




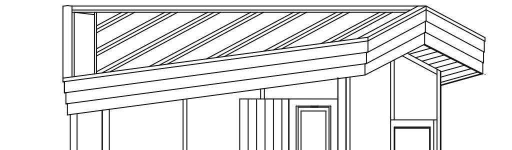
Section B-B

Plan and Façades,
scale 1:100

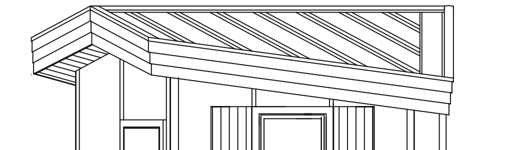




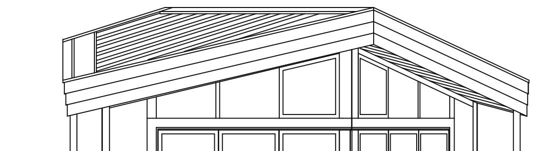
Façade north-east



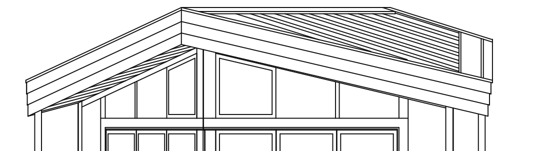
Façade east



Façade north-west



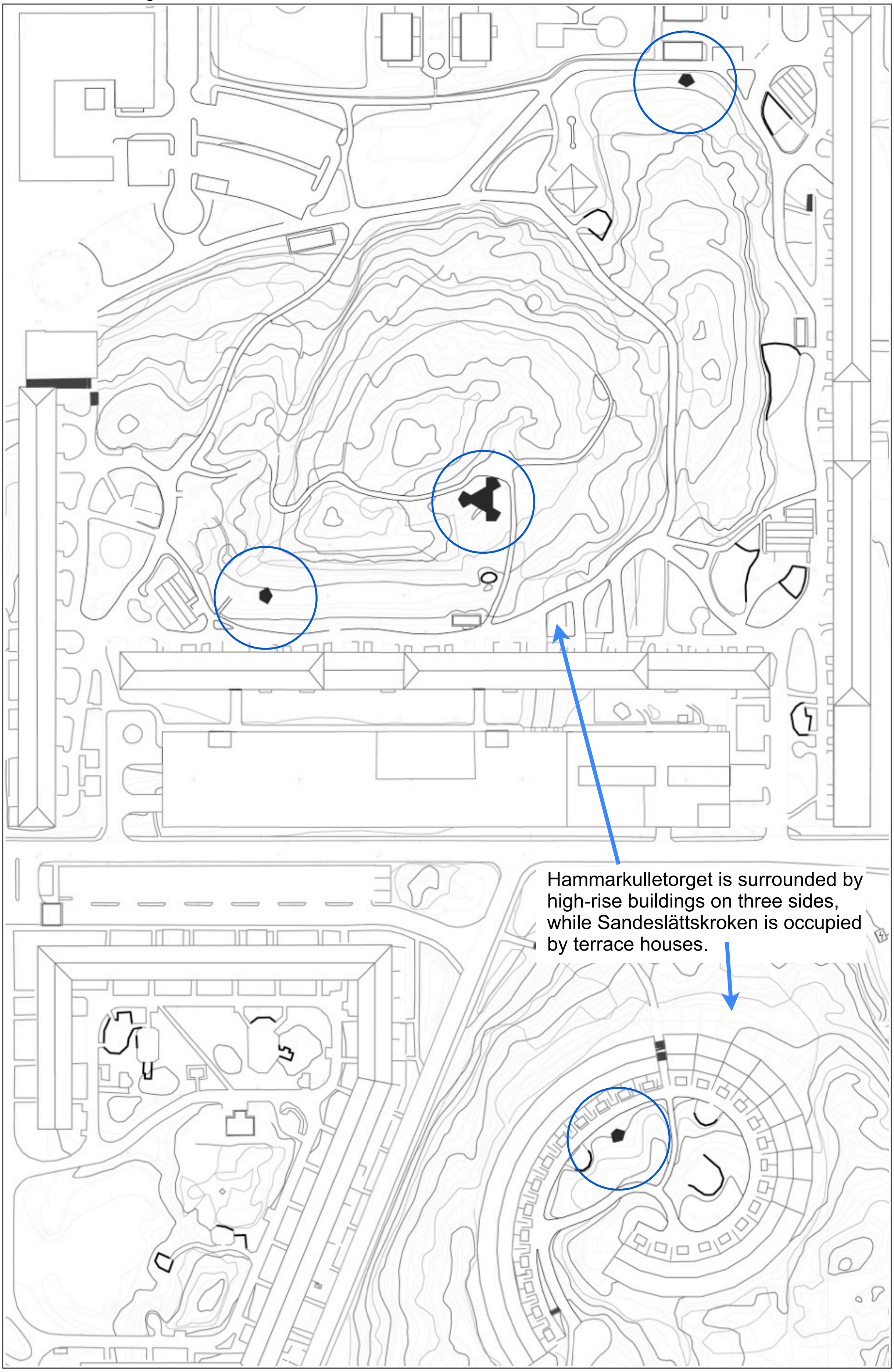
Façade south-west



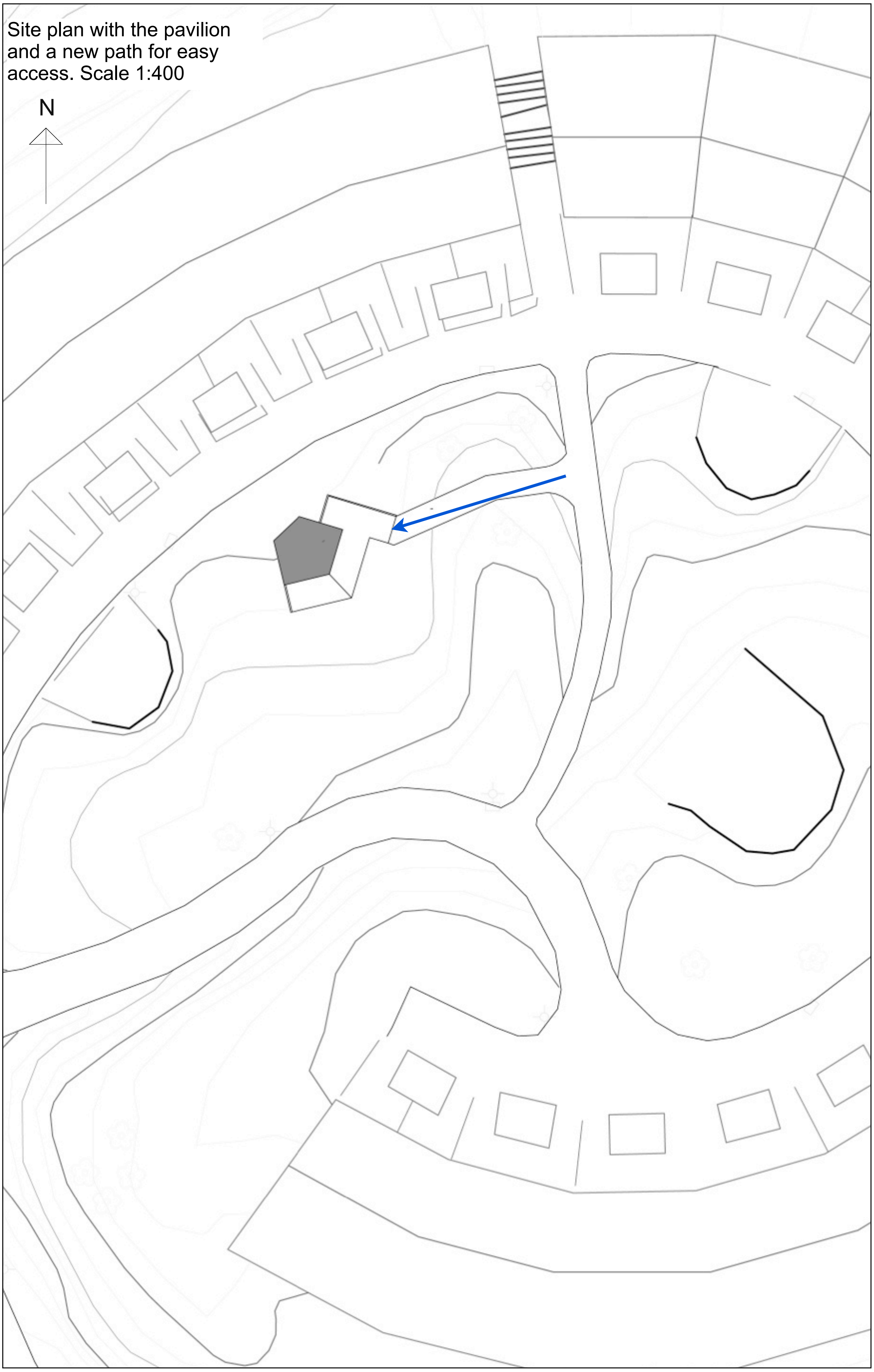
Façade south

4.2 The pavilion in Hammarkullen

Possible spots for the pavilion in Hammarkullen?
Hammarkulletorget and Sandeslättskroken. Scale 1:2000



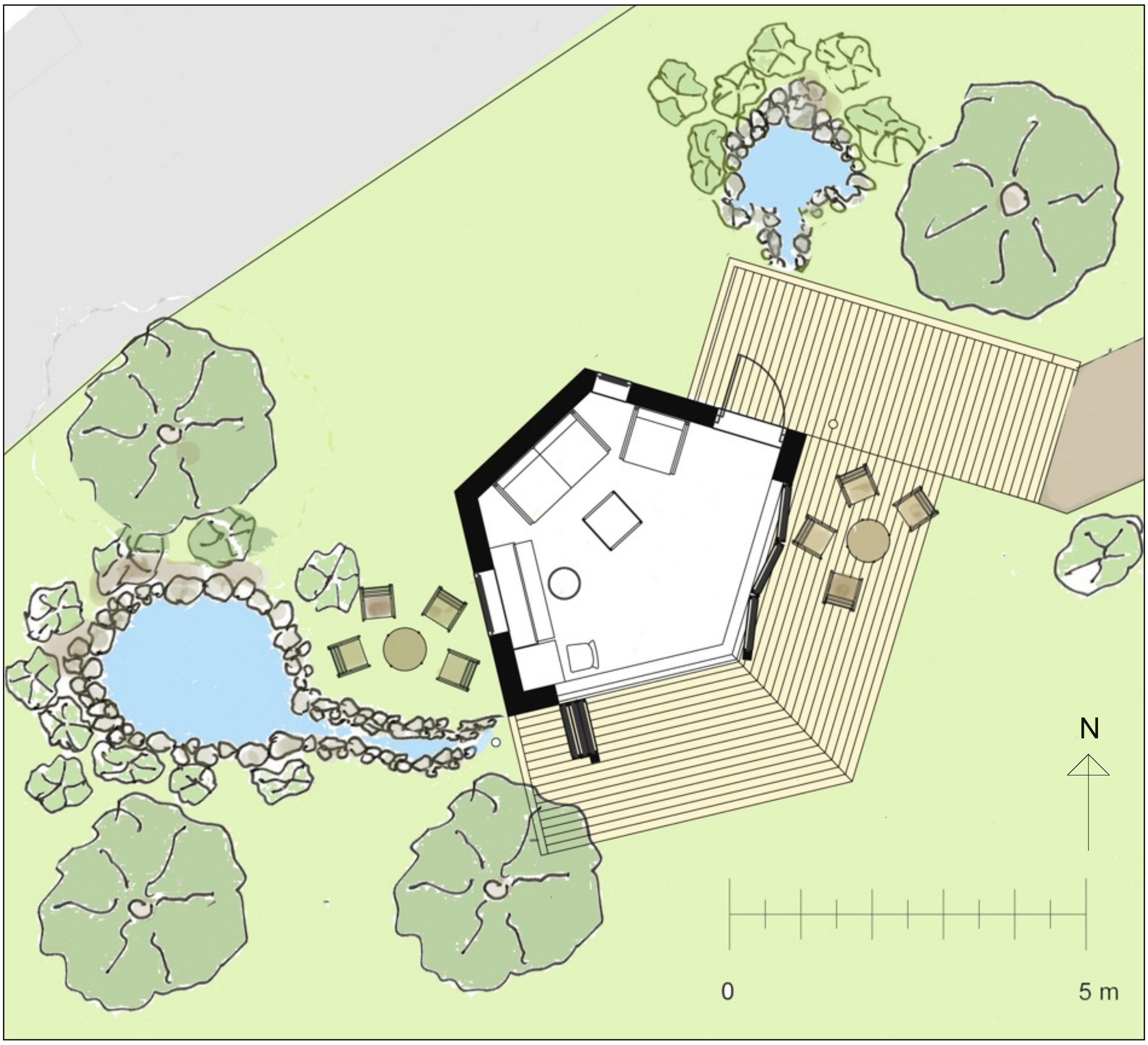
4.2.1 The pavilion in Sandeslättskroken



Layout of the pavilion in Sandeslättskroken

The building is placed on a green hillside sloping towards the street north-west of the building.

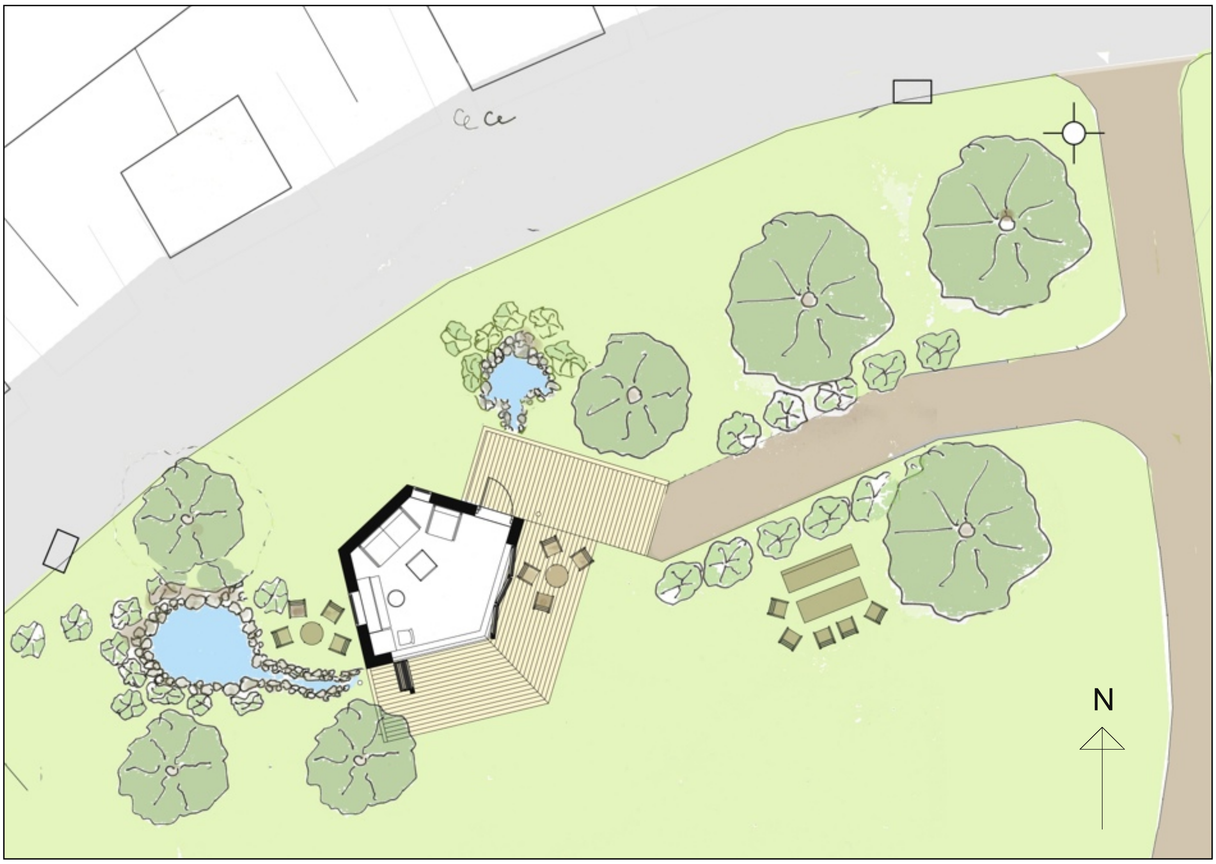
A suggestion of a layout for the pavilion with a garden.
Scale 1:100



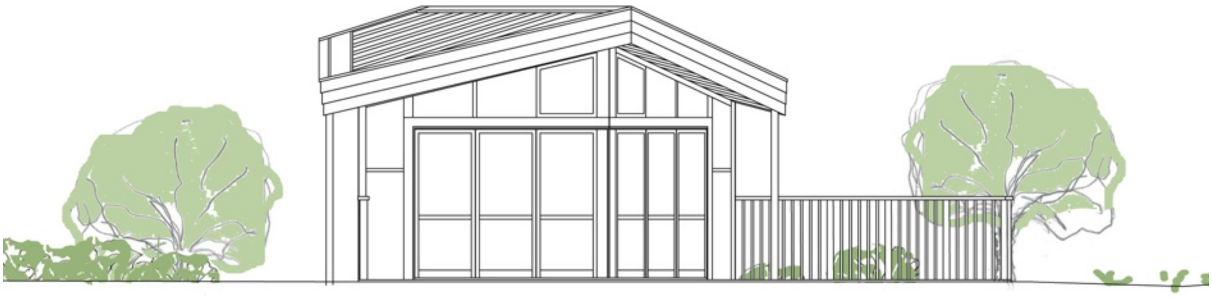
A wooden deck made of heat-treated wood or siberian pine is put before the folding doors to facilitate easy access from the lawn in front of the pavilion and from the path above. When you want to open up the building you can open one door or push all of the folding doors to the sides.

The entrance door has been moved to the side to facilitate easy entrance to the pavilion. This way no stairs are needed.
Four fruit-trees and a number of berry bushes are added. The water from the drainpipes are led to ponds.

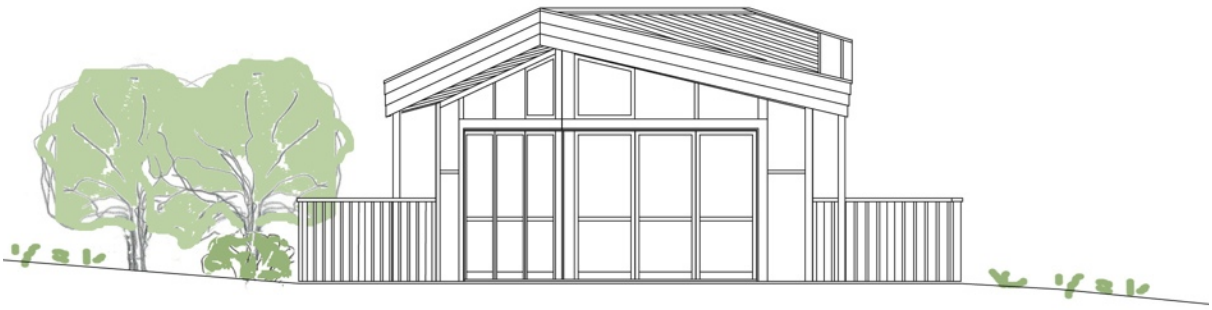
The pavilion and garden in scale 1:200. The three big trees to the right are already present.



Façades, scale 1:100

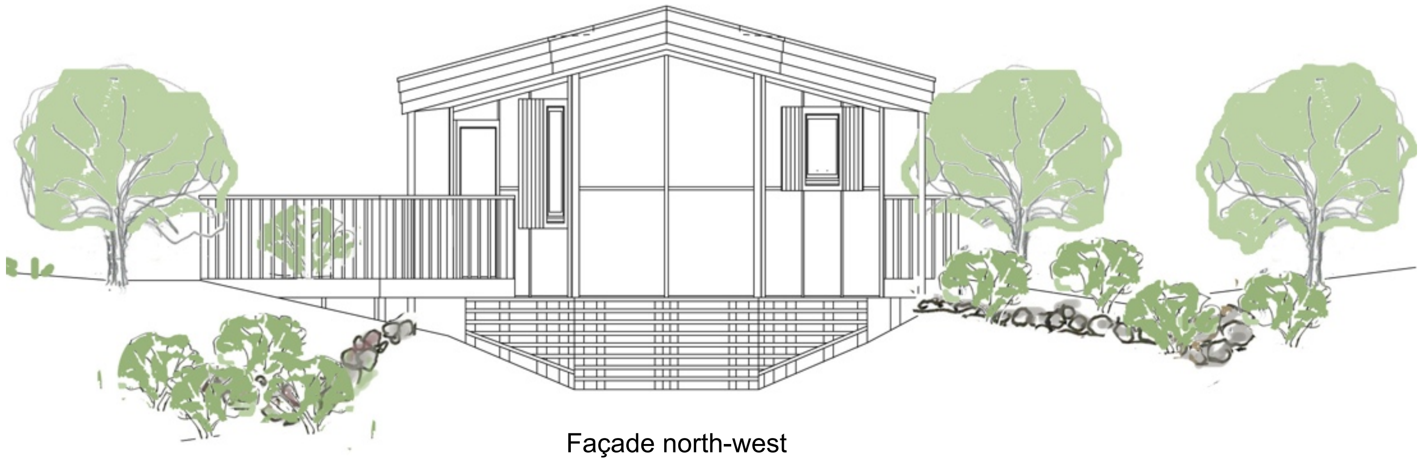


Façade south

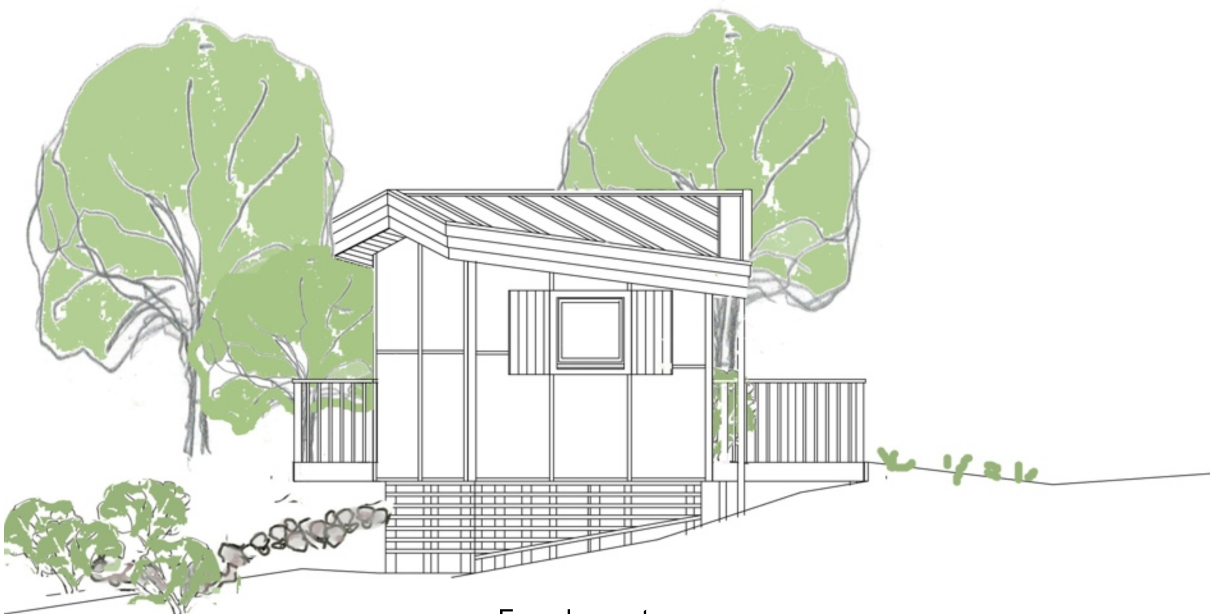


Façade east

Façade north



Façade north-west



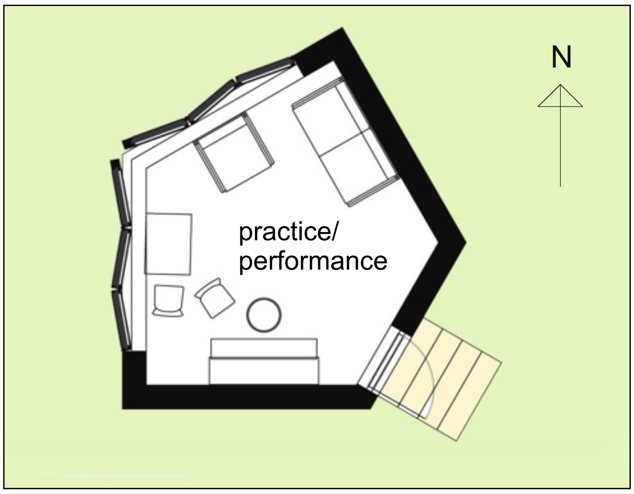
Façade west

4.3 Assembling the pavilions

4.3.1 Building with a conservatory in the centre

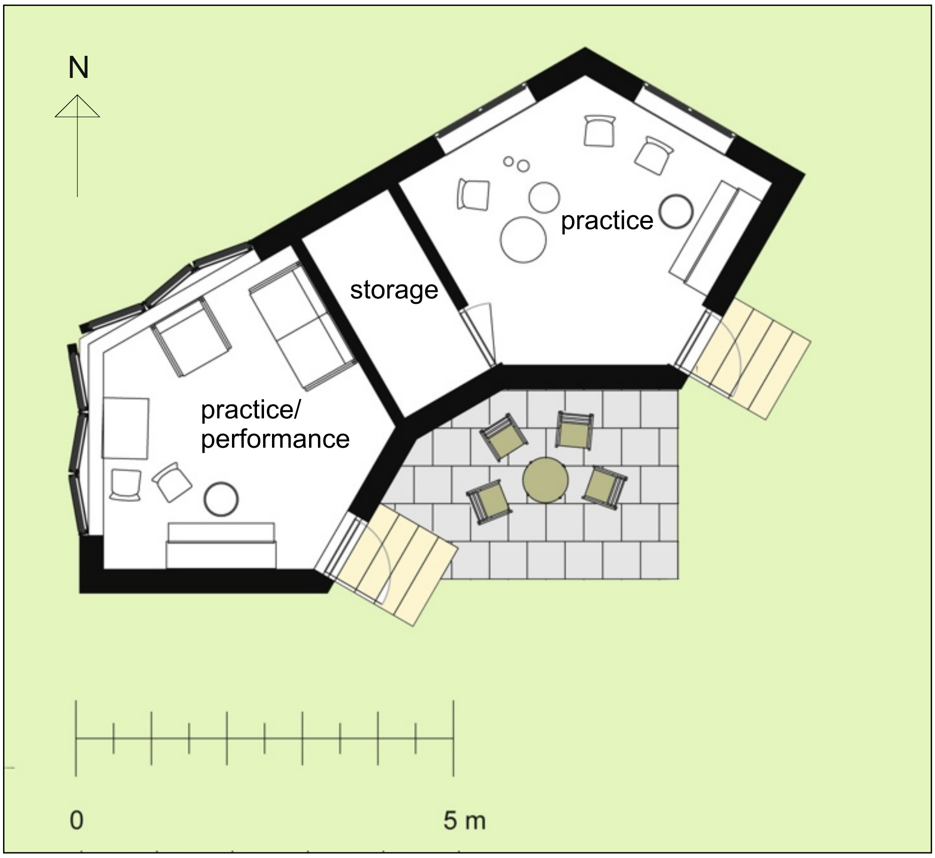
Here a suggestion of how to connect the pavilions and furnish them for playing music among other things. You can open one door or push all the folding doors to the sides.

Start with one pavilion, a practice and performance room. Scale 1:100



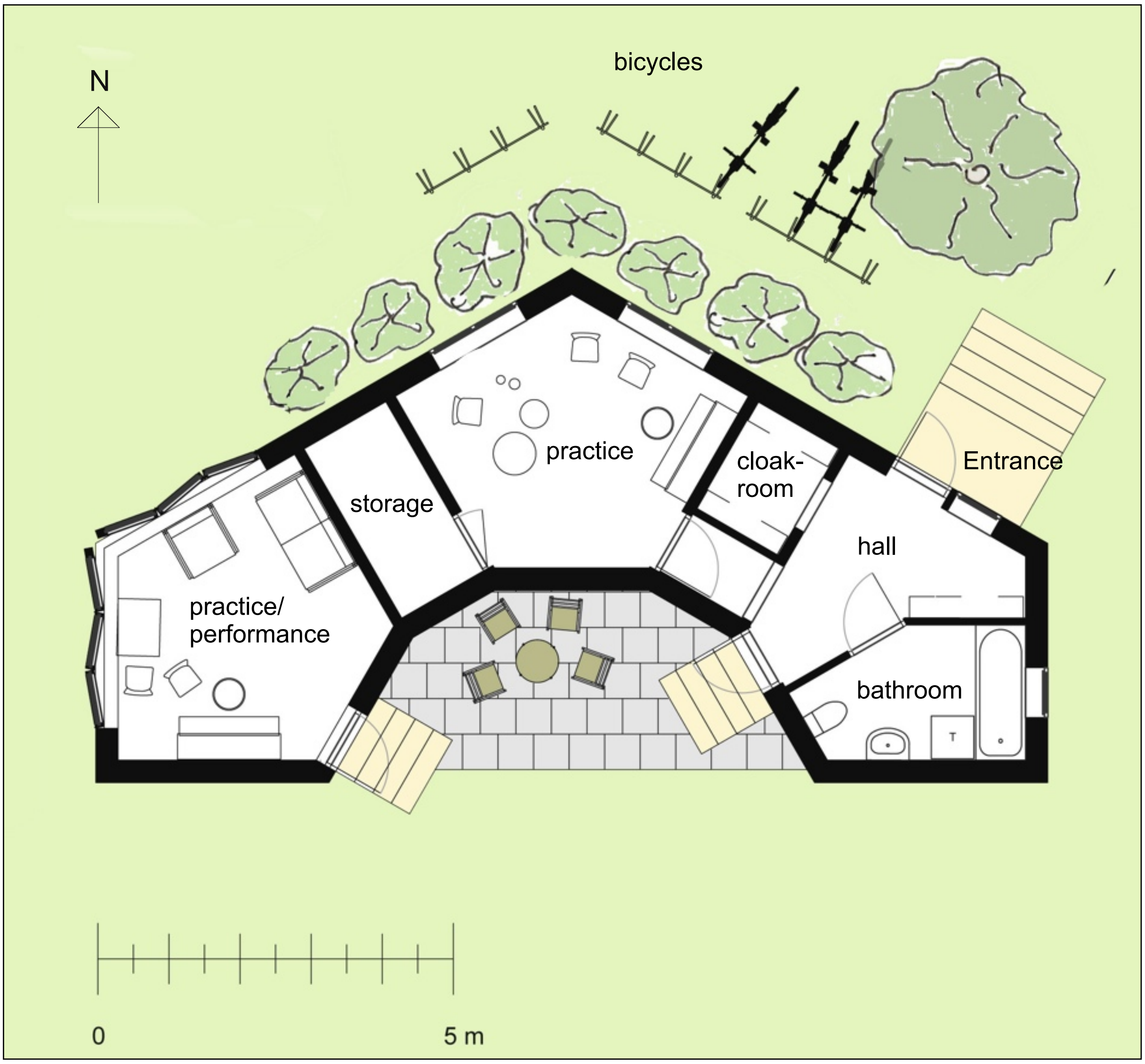
Connect another pavilion and add a patio.

Strip the outer sides of the now interior walls to enlarge the storage. Use the materials in the new walls. If you don´t want to have folding doors in every pavilion, you don´t have to.
Since those walls are not structural, doors and windows can be placed wherever you want.



Add yet another one.

Extend the patio, move one stair and add a bigger entrance stair.
Plant some berry bushes and a fruit tree.
Place bicycle stands
Make a cloakroom in the added space between the pavilions.
When installing plumbing for the bathroom, prepare for the wc and kitchen in the next pavilion.



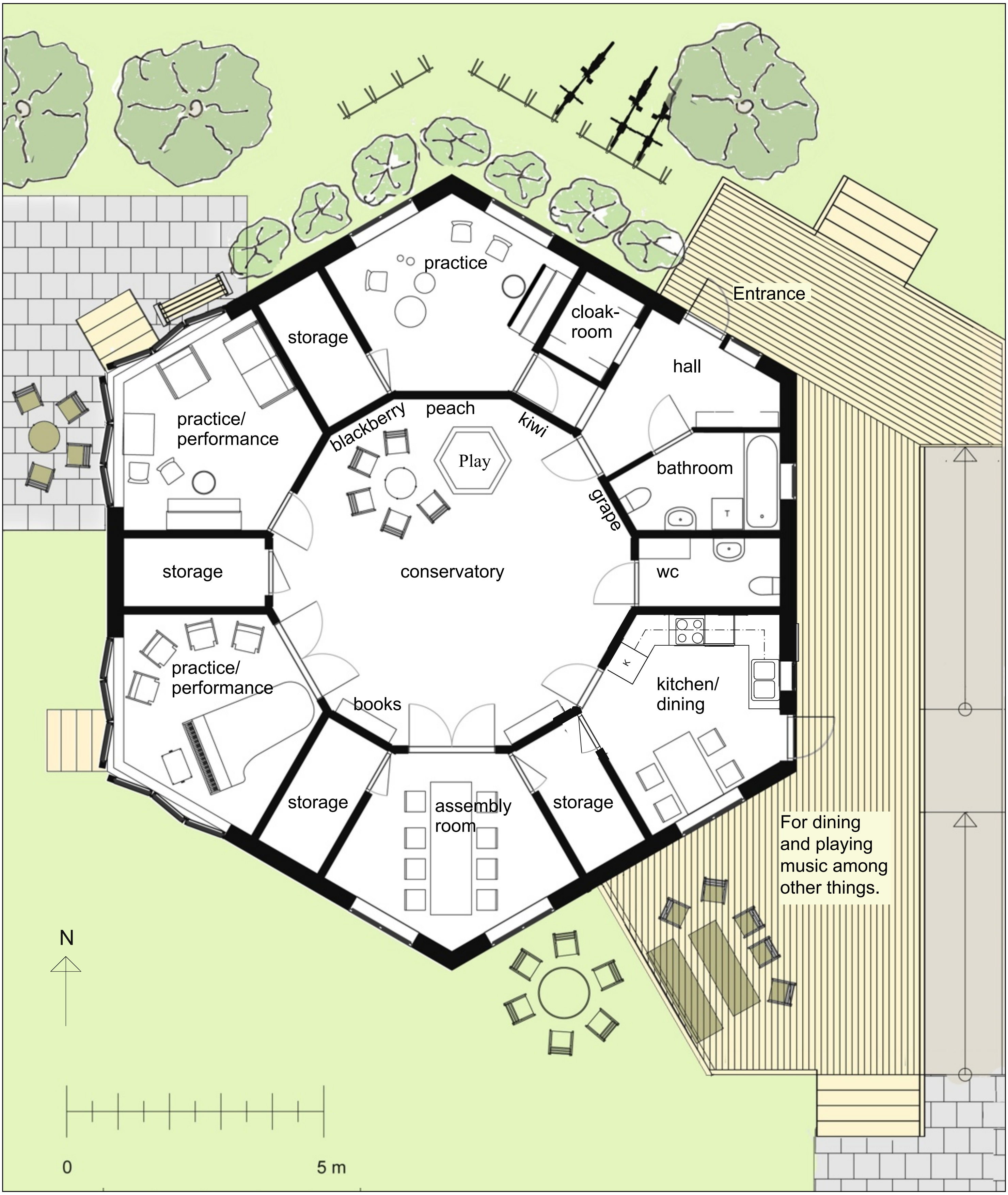
If the bath tub is made as a shower cabin with toughened glass, no chemicals to make the walls waterproof are needed.The bath tub can be converted to a shower.

Now add three more pavilions to create a circle.

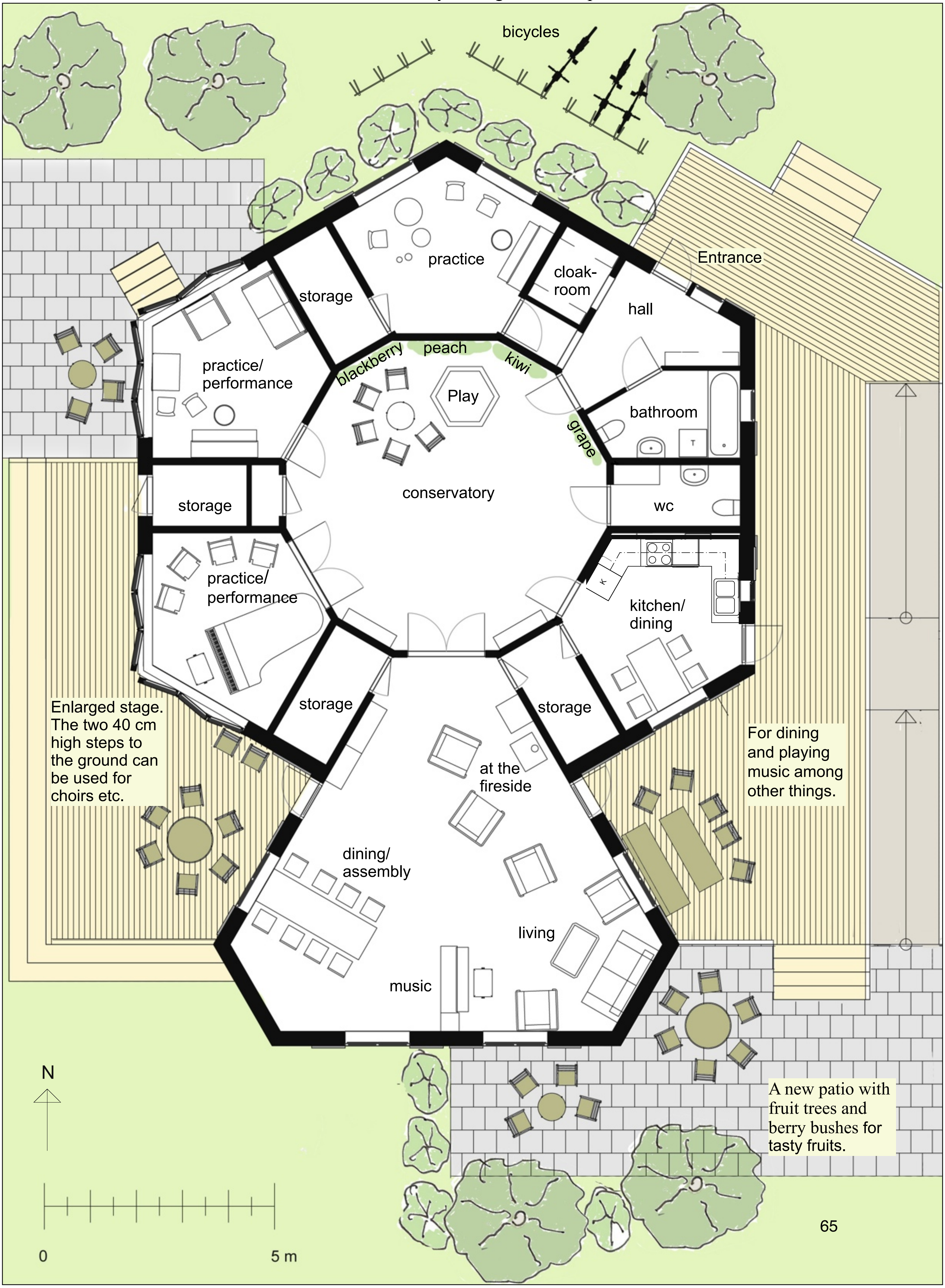
Move the tiles to a patio outside the practice/performance room, to make the outdoor space there more durable and clean. Make the size for the new patio suitable for small audiences and gatherings. Build a glazed roof over the atrium and create a light airy room of 37,6 m^2. A room for play, reading, practicing music and social gatherings. Build a ramp to enable disabled persons to enter the building and a wooden deck for social gatherings and outdoor eating. Move the three stairs to new positions. Plant two more fruit trees outside. Plant trained fruit trees and berries in the conservatory.

Blackberries

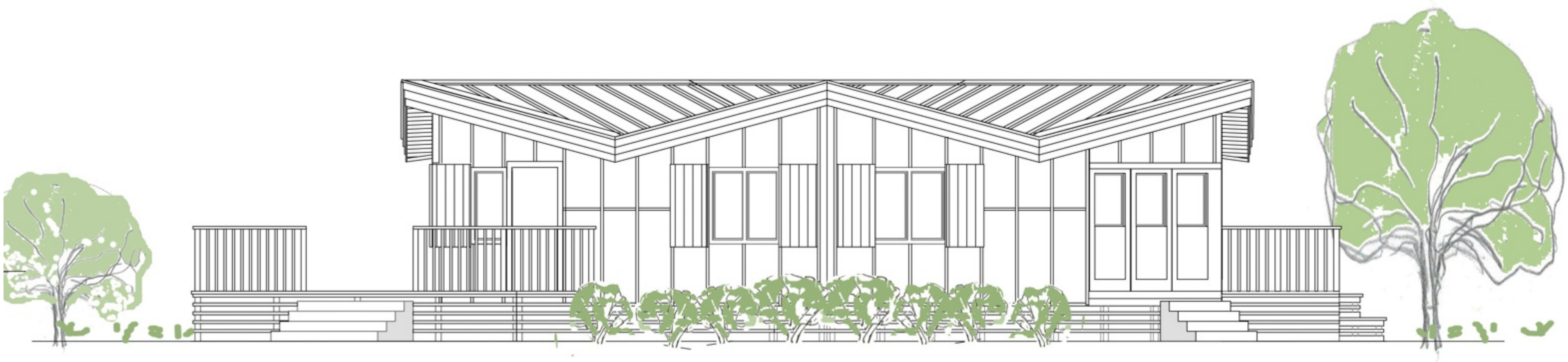
(Plantagen, 2017)



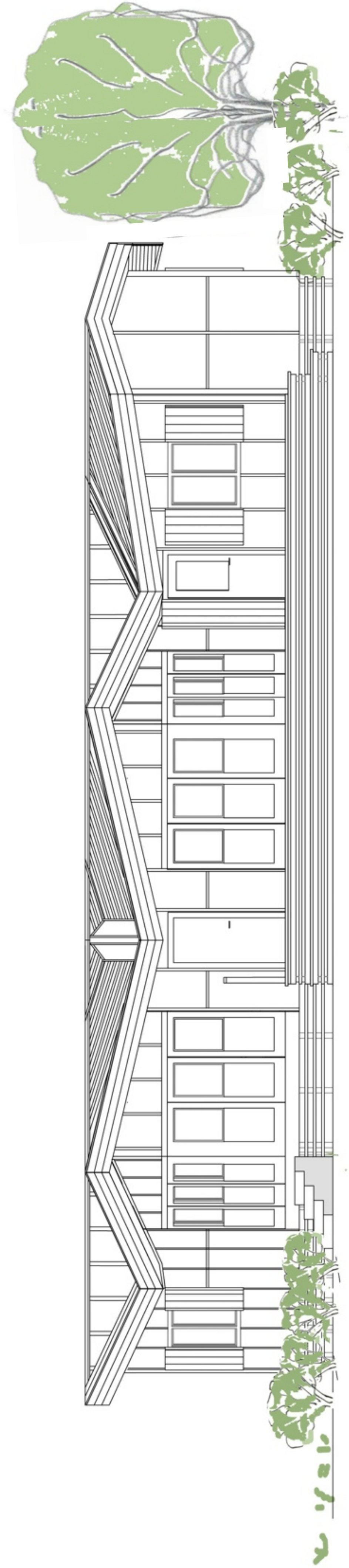
Create a Three-leaf clover by adding two more pavilions.



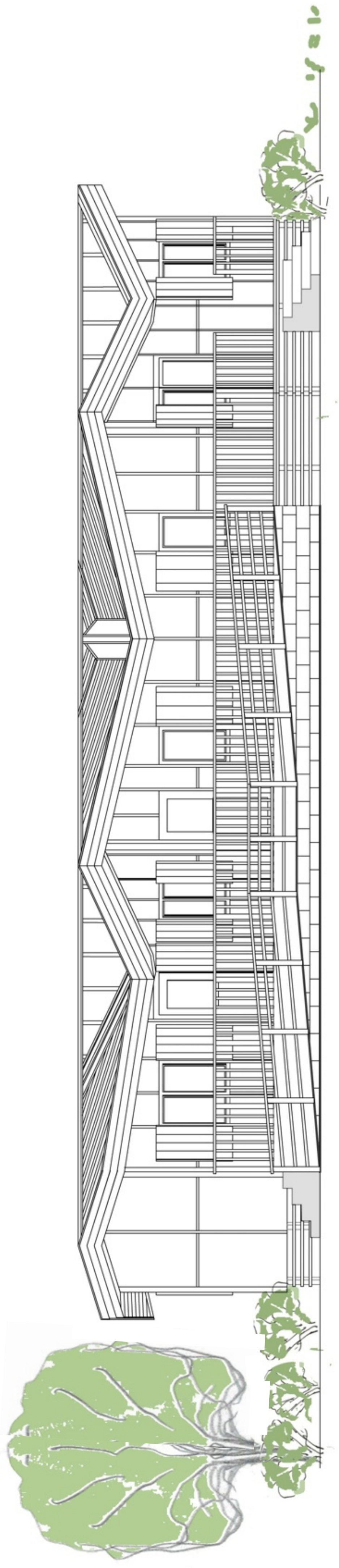
Façade south



Façade north

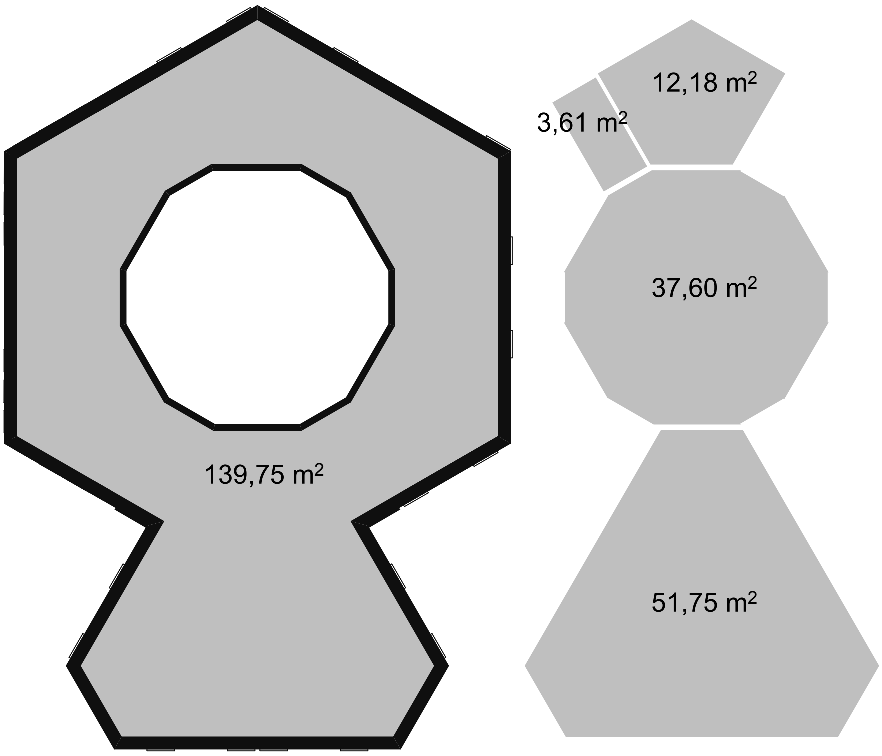


Façade west



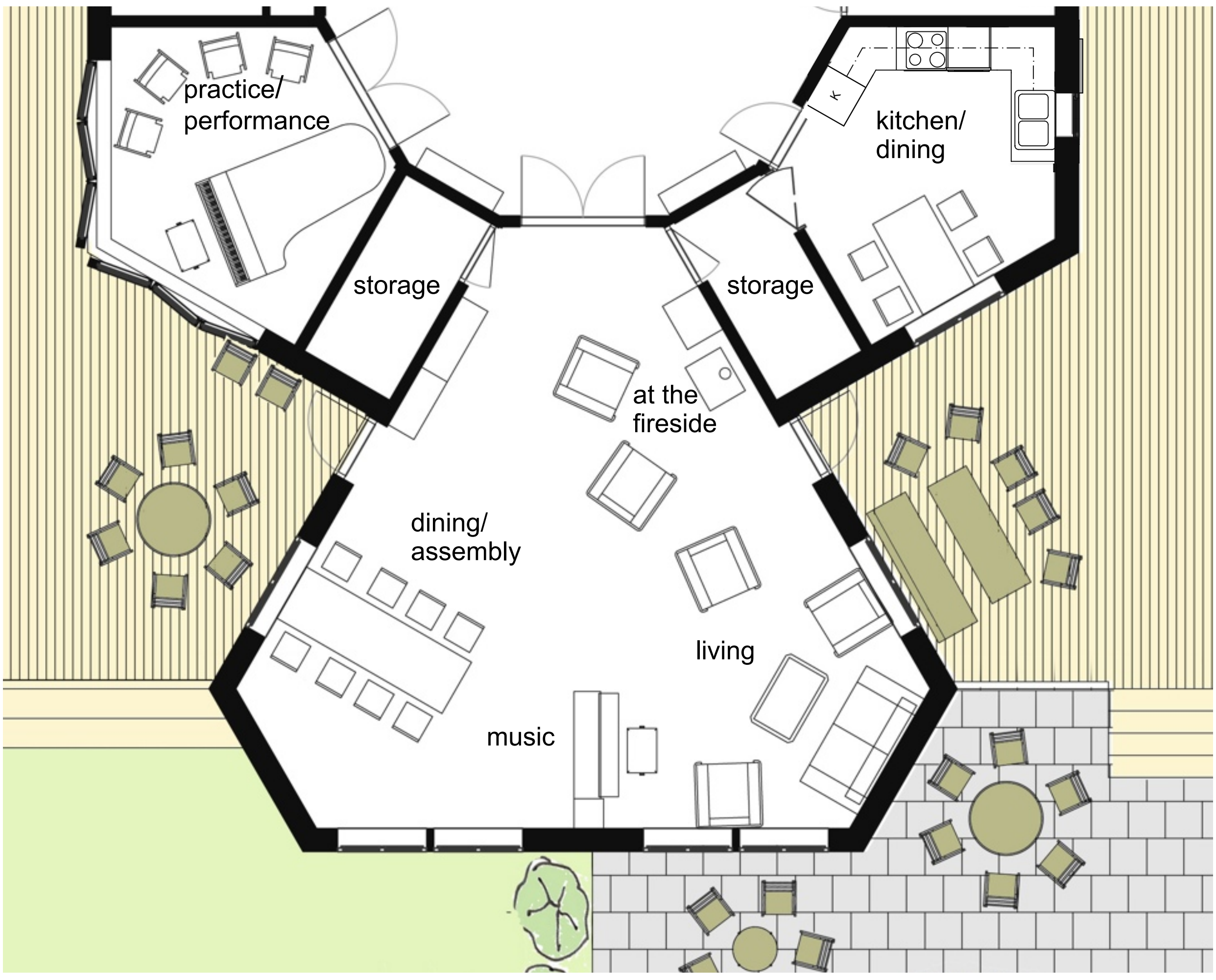
Façade east

Areas:



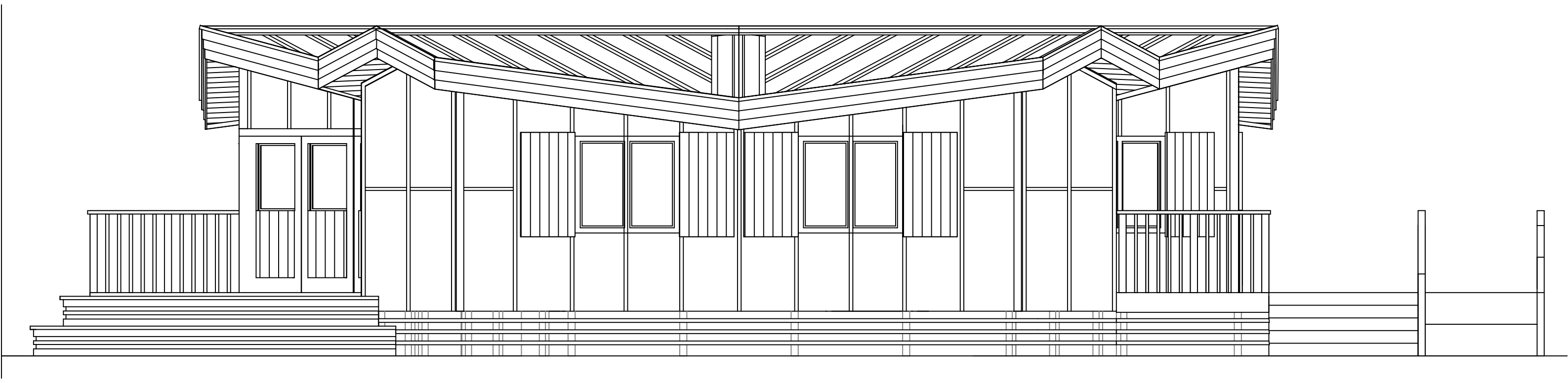
The placing of the shutters.

When the shutters are placed beside the windows, they occupy otherwise possible window space.
With sliding shutters, placed under the windows, the walls can have more windows.
Here The tree leaf clover with four windows in the south, instead of two.

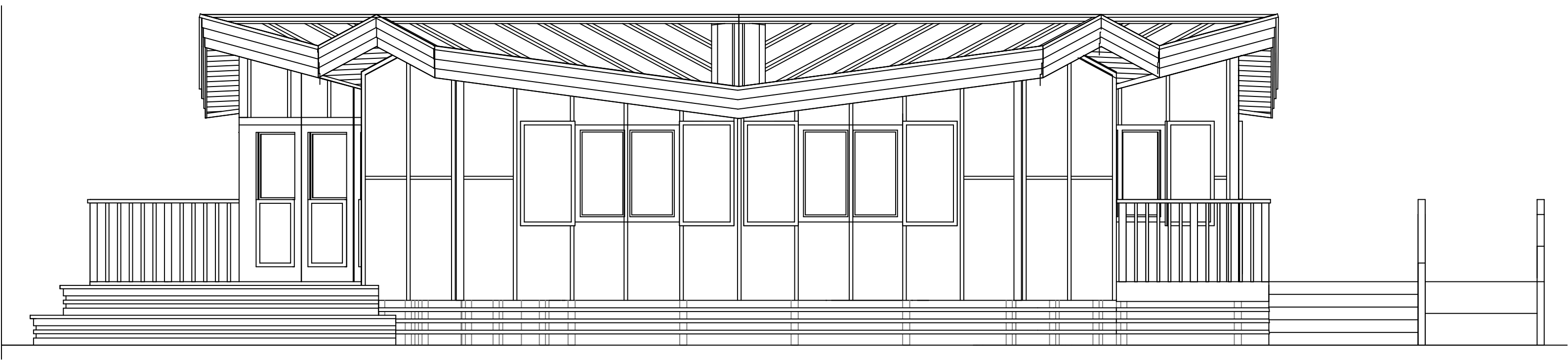


The shutters can be placed beside or under the windows.

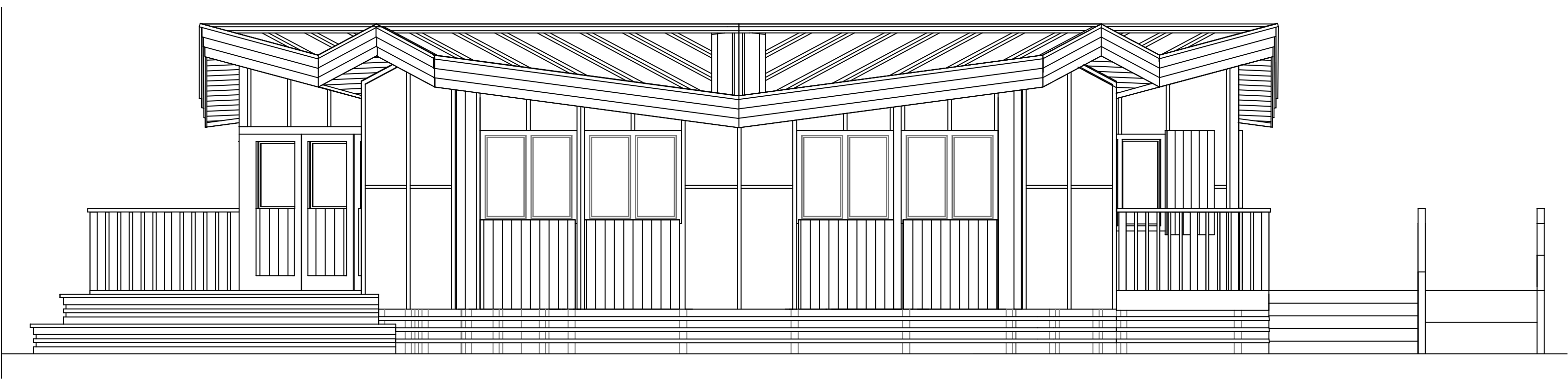
When the shutters are placed beside the windows they occupy otherwise possible window space.
Here the façade with different shutters. First wooden shutters beside the windows.



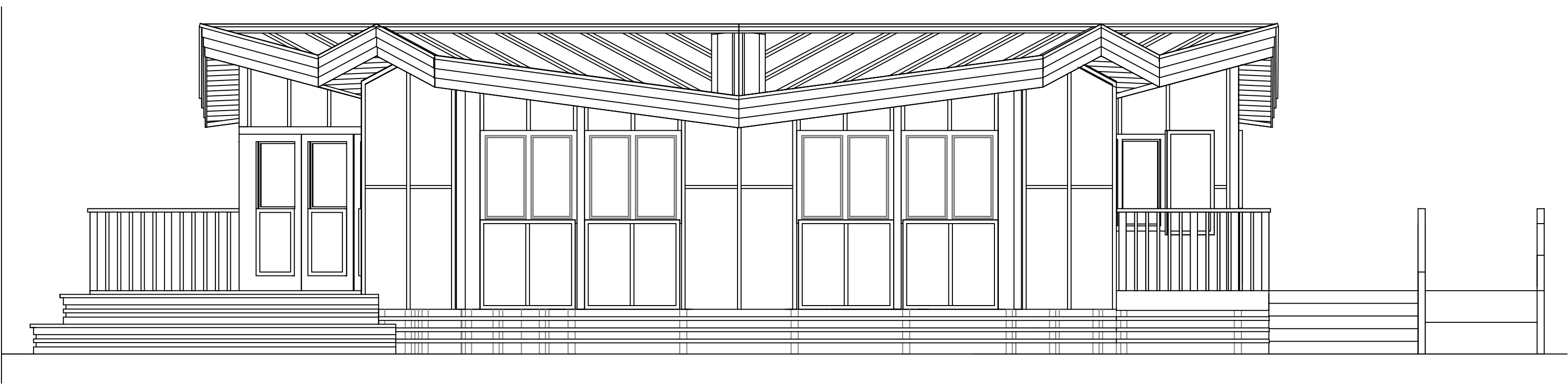
Here glazed sliding shutters beside the windows.



If the shutters are placed under the windows, then the shutters won´t be in the way for more windows.
Instead of two windows there can be space for four.



Glazed sliding shutters, placed under the windows.



4.3.2 Building with a garden in the centre

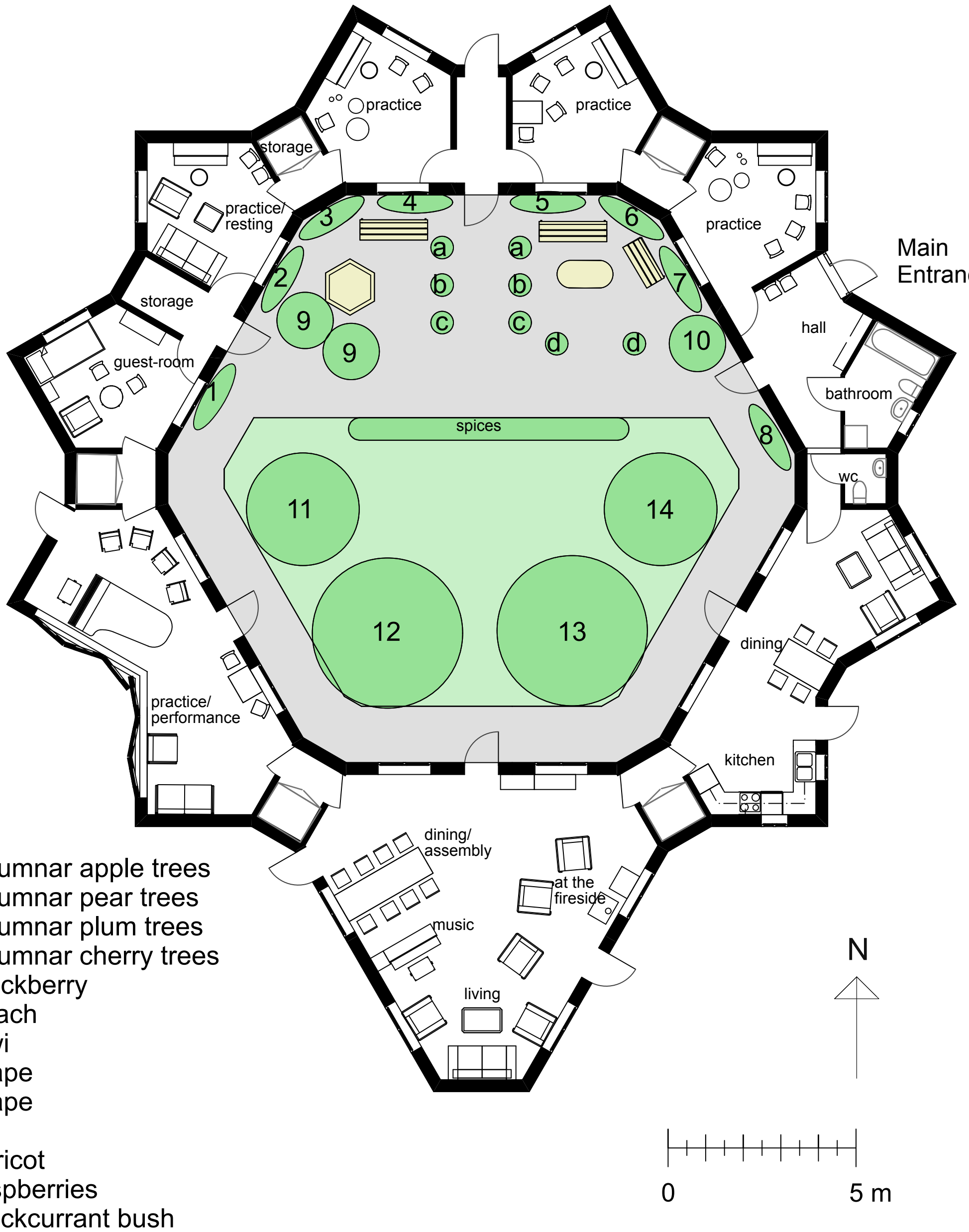
Since it is important to have a garden, here a suggestion of how to connect the pavilions in a bigger circle with a sheltered garden in the middle. The pavilions are assembled opposing and with a Three-leaf clover. The garden can be planted with combination fruit trees with several different varieties, which pollinate each other, on the same tree. Columnar fruit trees and dwarf fruit trees take little space and therefore, are suited for small gardens. The specific sorts of fruit trees and berry bushes will be chosen based on the location.
Here a suggestion of how to design the garden, scale 1:200:

Peach Riga (G)

Apricot Hargrand (G)

Columnar apple tree Flamenco (G)

Columnar apple tree Bolero (G)



Plum tree Allmänt Gulplommon (P)

Plum tree Victoria (G)

a. columnar apple trees
b. columnar pear trees
c. columnar plum trees
d. columnar cherry trees
1. blackberry
2. peach
3. kiwi
4. grape
5. grape
6. fig
7. apricot
8. raspberries
9. blackcurrant bush
10. redcurrant bush
11. combination cherry trees
12. combination plum trees
13. combination pear trees
14. combination apple trees

Pear tree Äkta Gränna rödpäron (G)

Grape Labruskavin “Sukribe” (P)

Blackberries (P)

Figs Desert King (G)

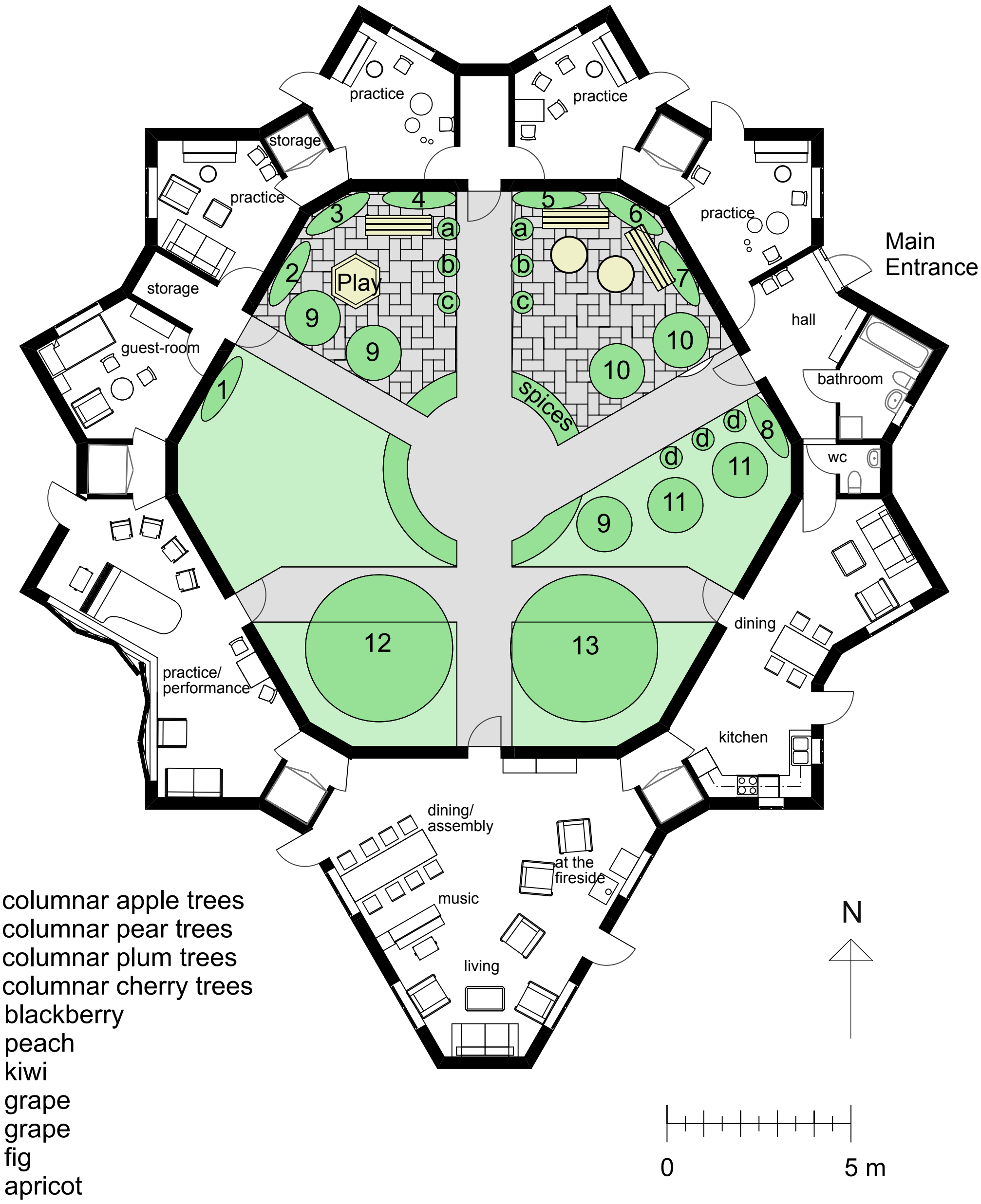
Grape Zilga (G)

Blackcurrant(P)

Plum Reine Claude d´Oullins´ (P)

(Pictures from (P) Plantagen, 2017; (G) Gränna växter, 2017)

Here another garden design with the paths dividing the garden into several parts. Instead of one extra entrance to the practice rooms in the north, three practice rooms have their own entrances, easy to access.

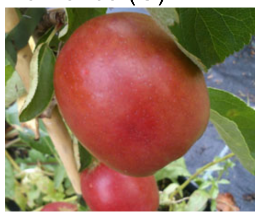


a. columnar apple trees
b. columnar pear trees
c. columnar plum trees
d. columnar cherry trees
1. blackberry
2. peach
3. kiwi
4. grape
5. grape
6. fig
7. apricot
8. raspberries
9. blackcurrant bush
10. redcurrant bush
11. gooseberry bush
12. combination plum trees
13. combination apple trees

Peach Riga (G)

Apricot Hargrand (G)

Columnar apple tree Flamenco (G)



Columnar apple tree Bolero (G)

Plum tree Allmänt Gulplommon (P)

Plum tree Victoria (G)

Pear tree Äkta Gränna rödpäron (G)

Grape Labruskavin “Sukribe” (P)

Blackberries (P)

Figs Desert King (G)

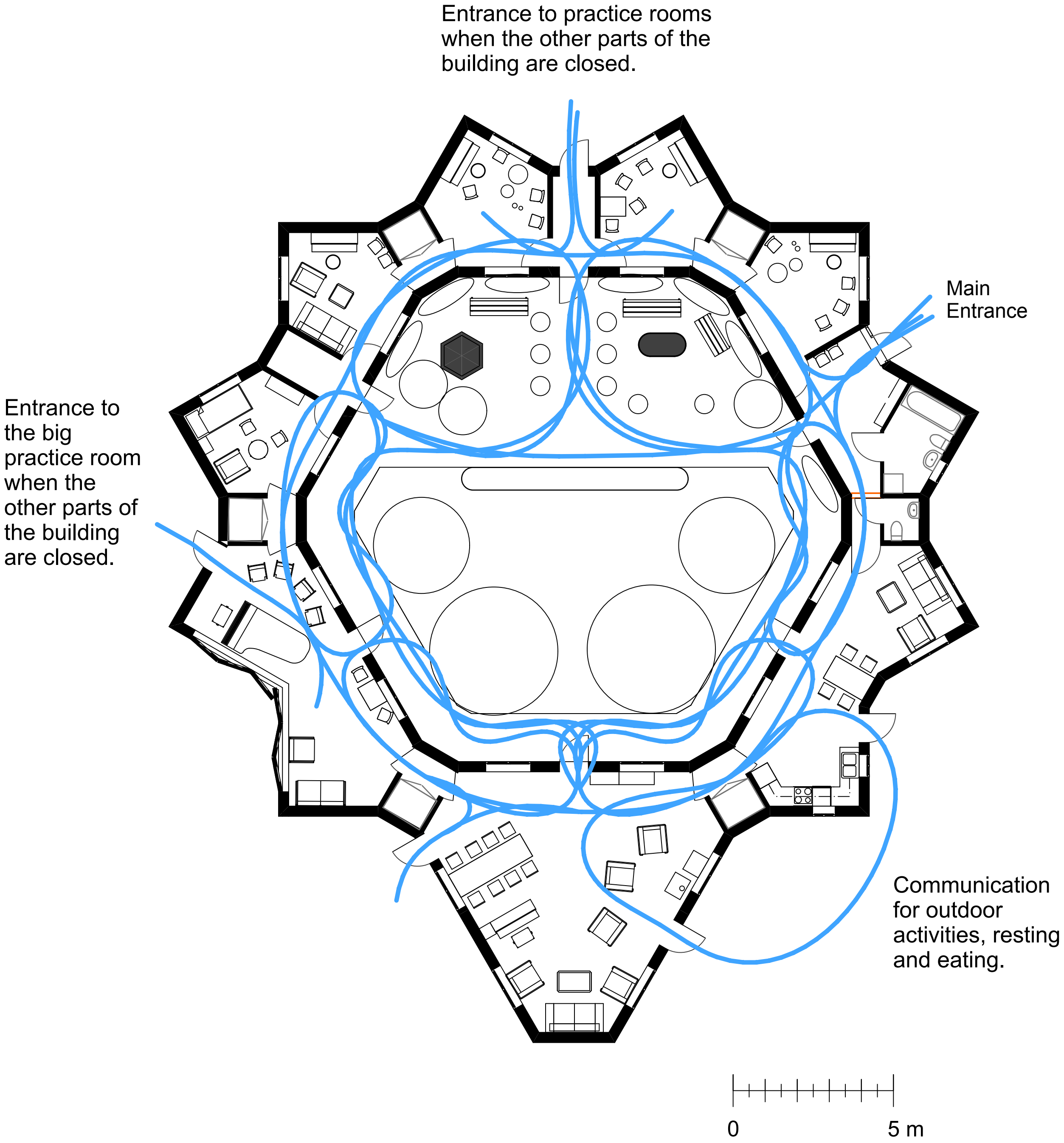
Grape Zilga (G)

Blackcurrant(P)

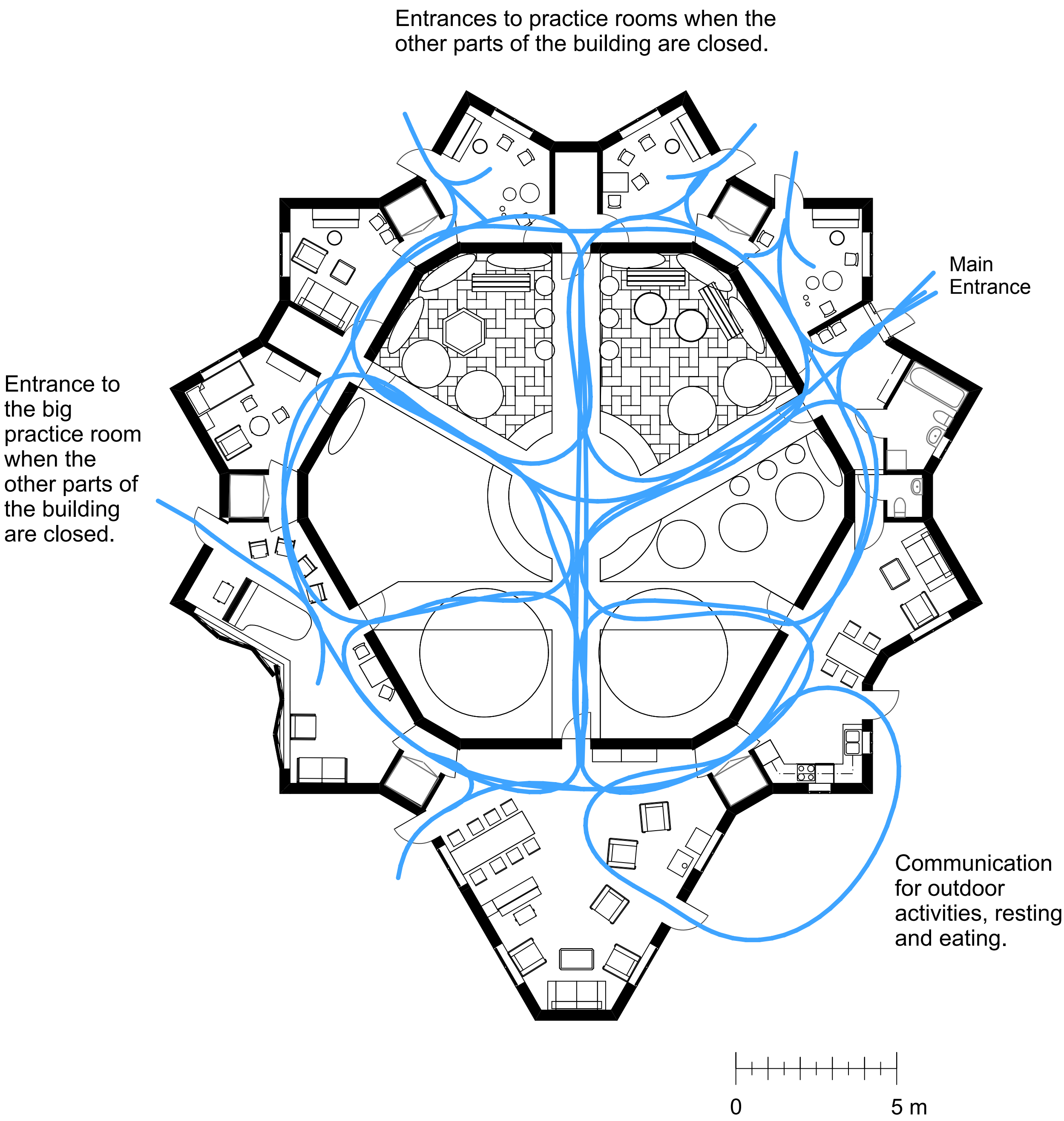
Plum Reine Claude d´Oullins´ (P)

(Pictures from (P) Plantagen, 2017; (G) Gränna växter, 2017)

The different ways to move around.

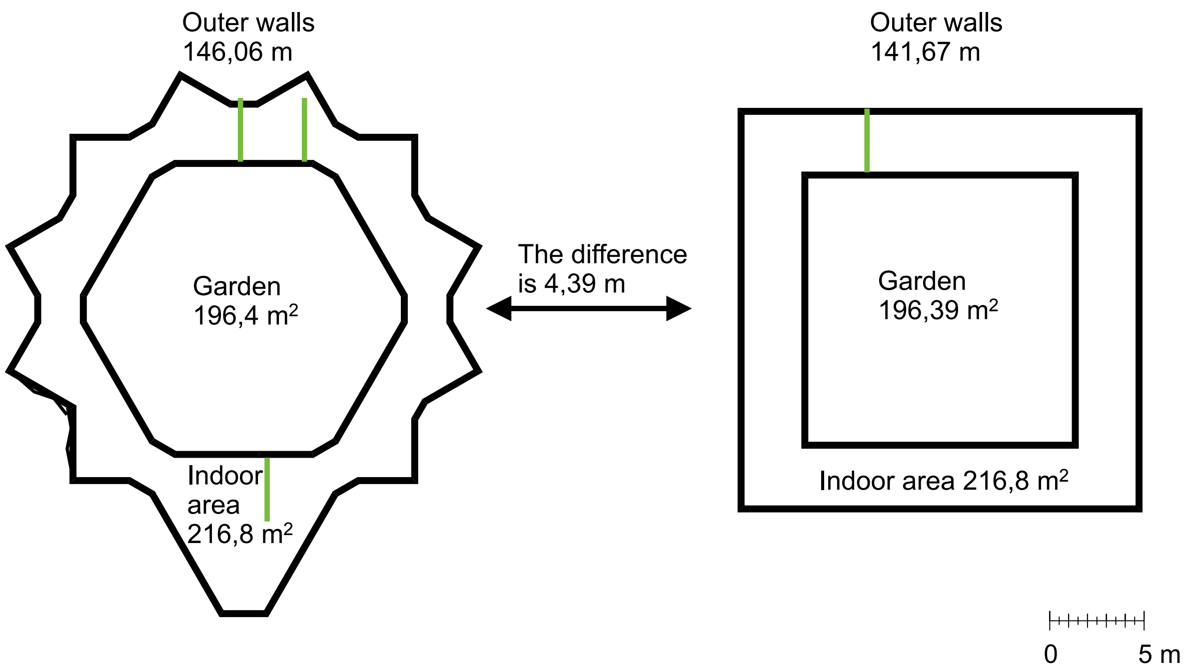


The different ways to move around.



A comparison with a rectangular building.

If the buildings are located at the same location, have equal sized walls, floor and ceiling and the same construction, the need for heating should be the same.
A comparison with an equal sized square building around an equal sized square garden. Here the two buildings have equal sized floor and ceiling, but what about the walls?
The green lines have equal lengths to make it easier to see the difference in width between the buildings.



The pavilion building has 4,39 m longer outer walls than the quadratic form.
However, the space between the outer walls in the quadratic form is constant.
To make a real comparison, the quadratic building would have to be partitioned into furnished rooms. If more space is needed to make the spatial feeling and usefulness equivalent with the rooms in the pavilion building then the outer walls will be longer.
With more m^2 added to the square building, the floor and roof will be that amount m^2 bigger, also the outer walls will be longer and and the need for heating will increase.
Of course the opposite is also valid. If it is possible to have the same functions in a smaller space with the same spatial feeling the need for heating in the square building will be further diminished. However, according to the comparisons done earlier in this thesis (p. 25-29), that is not likely. According to those comparisons, the equal sized square and rectangular rooms do not feel as spacious as the pavilion does.

5. Reflections/Discussions

As this work has progressed, the small pavilion has become more and more useful and variable. The two removable walls have made it possible to connect three rooms to create a large one. It is also possible to place doors and windows wherever you want on these two walls. The possible compositions have become more numerous than first were thought. From a small building it can be developed into a music or community centre or a detached house. The builder can decide how they are assembled. With this follows that you don´t have to decide at once how it shall be, but can decide as time goes on, with planning permit of course. Needs and desires tend to change over time as we all know.

The building area has become 16,4 m^2, slightly bigger than the original 15 m^2, because the wall has become thicker than the original 200 mm and I chose to increase the building area instead of decreasing the living area since the building always will need building permit anyway.
Since the building area has been increased, the assembled building areas have become larger. Also the space in the centre, the atriums.

I chose a one-story building. However, if a winter garden on top of the roof is wanted, perhaps a two-story house would be better. Then there would be much more space and it would be possible to walk between the buildings without altering the construction.
The choice of 15° slope of the roof has disadvantages. The snow could stay instead of sliding off the roof. In regard to that, a steeper slope of the roof would be better. The advantage with 15° slope is that it is safer to work on.

The single pavilion has less surrounding walls than a square building. However, when the pavilions are assembled, for example with a garden in the middle, the new building can have more surrounding walls than a square one would have. But since the space is very efficient, a square building would probably have to be larger in order to feel as spacious.

The rules concerning the “friggebod” have been inapplicable to this building due to ecological considerations, foremost about the foundation but also due to the slope of the roof in combination with the required ceiling height.

One question is if the materials are possible to compost.
Besides the glass, which can be reused or recycled there is the matter of screws. They should not be put in the compost. They are often not reusable but can be recycled. However, the best would be, as said before, to use dowels.

How sealing the bands of flax are and how long they will last are other questions. There should not be any problems in windows and doors but on the roof, where the bands are often wet, there can be a problem.
Here a picture of sealing jointing made of flax from byggfabriken.com.

There is no information about how the flax has been retted and therefore, there is no clue to how fast water is absorbed. How fast water is absorbed and how long time it takes before it is dry again must be tested.
Furthermore, I haven´t found any tar band of flax, so that is another thing to investigate. Would it perhaps be better not to have bands of flax on the roof and instead just let the water run in the canals on its way from the roof?
The connections to glass panes have to be more studied. When it rains or snows and the wind blows, the water/snow can flow unusual ways and it´s important to test what can happen in bad weather conditions.

To show the possibility of using draining pipes made of for example wood, instead of metal or pvc, the draining pipes have been drawn straight down from the roof, instead of close to the wall.

One of the aims was to form a building more similar to the forms of nature. After the design process I compared the chosen form to forms in nature. The form is very close to the circle, one of natures most frequent forms, and it appears that the building also correspond very well with the diagonal of the golden section rectangular form. It is almost as if I had compared and done it in advance, but I haven´t.
In nature the most effective form is aimed for and Building 6 became as it is because I strived to achieve an efficient space.

6. Conclusions

A big part of the presentation of this thesis has been an exploration to examine and compare forms.

The five-sided building has in my opinion, a more human friendly shape and have many more advantages than disadvantages compared with square buildings.

Advantages with the five-sided form:

- Less surrounding wall area compared with square forms. Hence, bigger living space per building area
- A more spacious feeling
- More easily cleaned in the corners
- Gutters are not needed. The rainwater is directed to two drainpipes, one on each side of the building.
- The space feels more commodious, as when the pavilion is furnished with a dining table with 8 chairs. There is more space behind most of the seated persons, resulting in a longer line of sight for most of them. You can also stand together in more places in the five-sided room.
- It is more interesting to move around in a five-sided form.

Disadvantages with the five-sided form:

- More bevelled cuttings

When the pavilions are assembled together in a circle, a glazed roof can be build over the atrium to create a winter garden.
In the big atrium, there can be a garden with fruit trees and berry bushes.
The combinations showed here are just examples. The ways to form a big building are endless.

It has been my intention to make it possible for you to build this pavilion yourself. The more work you do yourself, the cheaper it will be. The cost for the materials is higher than for "ordinary" materials with chemicals, but if it´s built with your own work it will be cheaper. With lower maintenance and renovation costs it will be so even more.

Drainage and water supply and the electrical installation contain hazardous chemicals which can be very dangerous at burns. It is important to choose the least harmful ones. If these systems are needed, then the building will contain these chemicals. Apart from that, I believe that I, with this pavilion, have shown that it is possible to build without chemicals, especially if using dowels instead of screws. Using dowels means more building hours but less mining-hours.

It has been a challenge to avoid chemicals but the shutters made a big difference in this aspect.

There is no longer any need for having windows with layers that filtrate away almost all of the higher wave lengths. The use of shutters makes it possible to have 2-glazed hinged casement windows with clear glass which give very good light inside.

2-hinged casement windows with clear glass and shutters can be better than modern well insulated windows without shutters. It all come down to the extent in which the shutters will be used, in combination with the difference between the outside average temperature during the time the shutters are closed and the outside average temperature during the time they are open.

If you have the shutters open 8 hours a day and there is 2°C difference in average temperatures, then the U-value for the 2-glazed hinged casement window with shutters will be 0,57 W/m^2K. (More examples in the table, page 50)

The cost for heating this building has to be evaluated. But for this building, as for every other, the cost for heating is much depending on the temperature needed inside. The temperature we want to have inside is depending of our feeling of comfort. That feeling is on the other hand depending on what we are accustomed to and on how much clothes we are wearing.

To have the 15 m^2 "friggebod" as a starting point was good, but unfortunately the demands and aims for the building did not correspond with the rules for the "friggebod".
A quiet wish is that we would have different building rules for ecological buildings since the

walls most often have to be thicker and the roof have to have a steeper slope.Some new rules for ecological buildings could for example be:

For “friggebodar”:

- Have the maximum height to the ridge to be 4 m instead of 3 m.
- Let the builder have the opportunity to choose between maximum living space of circa 13 m2 or maximum 15 m^2 building area.

For all ecological buildings:

- Possibility to include shutters, venetian blinds and other things in the calculations for average thermal passage coefficient (**U**m) [W/m^2K].
- Permission to have a steeper slope of the roof
- Let the builder have the opportunity to choose between a maximum living space or a maximum building area.

If we want less chemicals it is essential to try and take advantage of Natures own forces as far as possible. For example from warm air that rises, cold air that descend and the influence of the wind and sun. Also to use heavy materials, that can store heat and cold, to even out the temperature between day and night.
To make use of our own work to regulate the indoor climate.
In return we can get a comfortable housing environment, free from toxic chemicals and perhaps even a better health.

During search for information regarding materials and chemicals I have come upon Society for the conservation of Nature´s guide for toxic substance injurious to the environment. “Naturskyddsföreningens Guidehandledning. Guida om miljögifterna omkring oss.” and the report “everything you (don´t) want to know about plastics.” “Allt du (inte) vill veta om plast”.
They can be searched and downloaded from the internet at www.naturskyddsforeningen.se and is strongly recommended.
The first one can be downloaded in Swedish, the second one both in English and Swedish.

Research is far behind the development of products. How dangerous the products are we usually won´t be aware of until long after the products are out on the market. We are, like all other creatures on this planet, in that sense like guinea-pigs.

As I have read more about harmful substances I have discovered that for example nano products can make their way into our bodies and into our cells, where they among other places have been found in the mitochondria and in the nucleus.

“The risks with nano technology is yet in principle not investigated and nano technology is rapidly developing and nano particles exist in a wide range of products such as cosmetic, tennis rackets, glass panes in cars etc.
Due to their size, nano particles can pass through a number of biological barriers including cell membranes and the blood-brain barrier.
The special characteristics of nano particles(for example high reactiveness) are, among other things, due to the extremely large surface compared with the volume, which imply that a large proportion of all atoms are on the surface, where they have increased opportunity to interact with everything surrounding them.” (my transl.) (Grudd, 2012)

Allergies, which for many years have been blamed on us, having it too clean at home, have now been discovered to probably have a completely different cause.
“Research has shown that there are a clear covariance between children´s allergic symptoms and the concentration of softening agents in the children´s homes.
Many products and surface materials such as PVC-maths contain softening agents, phthalates. The production in the world of such softening agents has increased dramatically since the 1950s. At the same time asthma and allergies have increased considerably during the last 3-4 decades. Higher concentration of phthalates was found in the sick children compared with the healthy ones. The higher concentration of softening agents the stronger symptoms in the children.” (my transl.)(Grudd, 2012)

It is not always clear which alternative is the best for the environment. Research and open lines for information are needed. Information has become easier accessible with the internet, but more can be done.

Here are some suggestions of possible actions that would make it easier to choose:

- Lists of contents and safety sheets on all building products, placed on the product or close by, easy to read. These lists of contents and safety sheets easily accessed on internet too on the companies home pages.
- Lists of contents and safety sheets for all products placed in one register on internet, easily accessed for all. In connection to the safety sheets, suggestions of better alternatives to use and explanations of why the better alternatives are better.
- All scientific research easily accessible, for all to read.
- all advertisements for building products and other products need to have contradicting advertisements right afterwards which show better products and/or the disadvantages of the product. Including the advertisements on TV.
- An open forum for ideas that can help Mother Earth, concerning every aspects of life. For anyone with a good idea to publish it here. With a reward for a good idea. A reward, of let us say 10.000 SEK, will lead to a swift contribution of ideas. The contributions need to be examined and if questionable, so commented. Harmful ideas stopped.

“Necessity is the mother of invention”

If we only could sell environmentally friendly products with profit, then many new, or old, inventions would come forward.

I believe the following quotation is somewhat harsh, but worth considering and reflecting upon.

We create our own environment. We get exactly that which we deserve. How can we be offended by the life we ourselves have created? Who can we blame, who shall we give the recognition but we ourselves? Who can change it, whenever we want, but we ourselves?
Richard David Bach (my transl.)(Grudd, 2012)

”Vi skapar vår egen miljö. Vi får precis vad vi förtjänar. Hur kan vi bli förnärmade
av livet vi själva skapat? Vem kan vi lägga skulden på, vem ska vi ge erkännandet
utom oss själva? Vem kan förändra det, när vi än vill, utom vi själva?”
Richard David Bach (Grudd, 2012)

We all can make a big difference by choosing environmentally friendly products and by saving energy.
The architect have an ethical responsibility to work for a better environment. Not just the visible one but also the invisible, i.e. the quality of the air and light inside the building, prescribing and arguing for good, environmentally friendly materials.

It would be very interesting if this building could be built and evaluated.

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Appendix 1

MASONITE AB		BOARD EGENSKAPER 1999			SIS STANDARD					1999-11-15
PRODUKT	Tjock-lek	Vikt	Densi-tet	Böjhåll-fasthet	Drag-hållfast-het	Elasti-citets-modul	Tvär-draghåll-fasthet	Vatten-absorpt. 24 t.	Tjockl. svällning 24 t.	Längdutv. koefficient 30-90 % R.F.
	mm	kg / m2	kg / m3	MPa	MPa	MPa	MPa	%	%	mm/m
MASONITE HÅRD	3,2	3,0	900	30-40	15-20	4200	0,8-1,2	20-30	12-16	2,0-2,2
	4,8	4,4	900	30-40	15-20	4200	0,8-1,2	15-25	12-15	2,0-2,2
	6,4	5,9	900	30-40	15-20	4200	0,8-1,2	15-20	8-12	2,0-2,2
	8,0	7,2	900	30-40	15-20	4200	0,7-1,0	12-18	8-12	2,0-2,2
MASONITE OLJEHÄRDAD	3,2	3,3	980	40-50	20-25	6000	1,5-2,0	20-25	10-14	1,9-2,1
	4,8	4,7	980	40-50	20-25	6000	1,2-1,8	15-20	10-14	1,9-2,1
	6,4	6,3	970	40-45	20-25	6000	1,2-1,8	12-18	8-10	1,8-2,0
	8,0	7,8	970	40-45	20-25	6000	1,2-1,8	10-15	8-10	1,8-2,0
MASONITE VÄGGSKIVA	6,4	4,8	750	20-30	10-15	3400	0,3-0,5	20-28	10-15	1,8-2,0
	9,2	6,5	700	>12	>6	3000	0,2-0,4	20-25	7-10	1,8-2,0
	12,0	7,8	650	>12	>6	2100	>0,10	<28	<9	1,7-1,9
MASONITE UNDERGOLV	6,0	5,7	850	25-35	16-20	>3600	0,4-0,8	18-22	10-15	1,8-2,0
	8,0	*6,8*	*850*	*25-35*	*16-20*	*>3600*	*0,4-0,8*	*18-22*	*8-12*	*1,8-2,0*
KONSTRUKT. BOARD	*6,0*	*6,1*	*>940*	*>42*	*>23*	*>4800*	*1,2-1,5*	*15-18*	*8-12*	*1,8-2,0*
	8,0	7,9	>940	>42	>23		1,2-1,5	15-18	6-10	1,8-2,0
UNDERLAGS-TAK	4,0	4,1	>940	>42	>23	>4200	1,2-1,5	18-25	8-12	2,0-2,2
MASONITE VINDSKYDD	9,2	6,8	730	22-30	8-15	3400	0,2-0,5	12-18	5-8	1,7-1,9

MASONITE AB								
PRODUKT	Tjock-lek	Hård-het	Ånggenom-gångs-motstånd	Panel-skjuv	Skjuv-modul	Formal-dehyd-halt	Formal-dehyd-emmiss.	Luftgenom-släppl. m3/m2
	mm	Brinell	Sek/mx10E3	MPA	MPA	mg/100g *)	mg/m³ ')	t. mm V.P.
MASONITE HÅRD	3,2	4-5	9-12	12-14	1600	1,80	0,03	0,004
	4,8	4-5	12-18	11-13	1600	1,80	0,03	0,004
	6,4	4-5	18-24	11-13	1600	1,80	0,03	0,002
	8,0	4-5	24-36	11-12	1600	1,80	0,03	0,002
MASONITE OLJEHÄRDAD	3,2	5-7	18-24	14-18	2400	2,00	0,01	0,002
	4,8	5-7	20-30	14-17	2400	2,00	0,01	0,002
	6,4	5-7	30-45	12-16	2400	2,00	0,01	0,002
	8,0	5-7	45-70	11-13	2400	2,00	0,01	0,002
MASONITE VÄGGSKIVA	6,4		8-10	9-12	1300	1,80	0,02	0,003
	9,2		10-14	7-9	1300	1,80	0,02	0,002
	12,0		6-8	>3	800	1,80	0,02	0,003
MASONITE UNDERGOLV	6,0	3-4	0	10-12	1400	1,80	0,02	<0,003
	8,0	*3-4*	*20-35*	*10-12*	*1400*	*1,80*	0,02	*<0,002*
KONSTRUKT. BOARD	*6,0*	*5-6*	*20-30*	*>14*	*1900*	*1,80*	0,02	*0,002*
	8,0	5-6	30-45	>14	1900	1,80	0,02	<0,001
UNDERLAGS-TAK	4,0	5-6	12-18	12-14	1700	1,80	0,02	0,004
MASONITE VINDSKYDD	9,2		6-8	>3	800	1,80	0,02	0,003

The table is divided into two parts to fit the A4.