Group nr. 1

ZE+Hytte

- Norwegian wood team

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Preface

This document is the result of a two-weeks teamwork between seven master level students at NTNU. The group was interdisciplinary with both architecture and engineering students.

The aim of this project was to find solutions for a building that should be built for a competition, Solar Decathlon, in Madrid in 2012. One of the central aims of this competition is to design and build a "plus-energy" house that produces more energy, by utilization of solar power, than it consumes.

Our starting point was the application documents for the competition that the architecture students were preparing in autumn semester 2010. In this document we will start discussing the original solution and develop this further for a better performance.

The first step was to find the user demands and targets for this. Then we focused on the steps in the Kyoto-pyramid to find solutions with lower energy demand.

Two approaches were followed in the simulations for the low energy demand - using the original building and testing the potential of using **dynamic** elements within the building envelope (movable insulation panels, shading) and developing an alternative/updated building design with a **static** lower energy demand due to decreased window area.
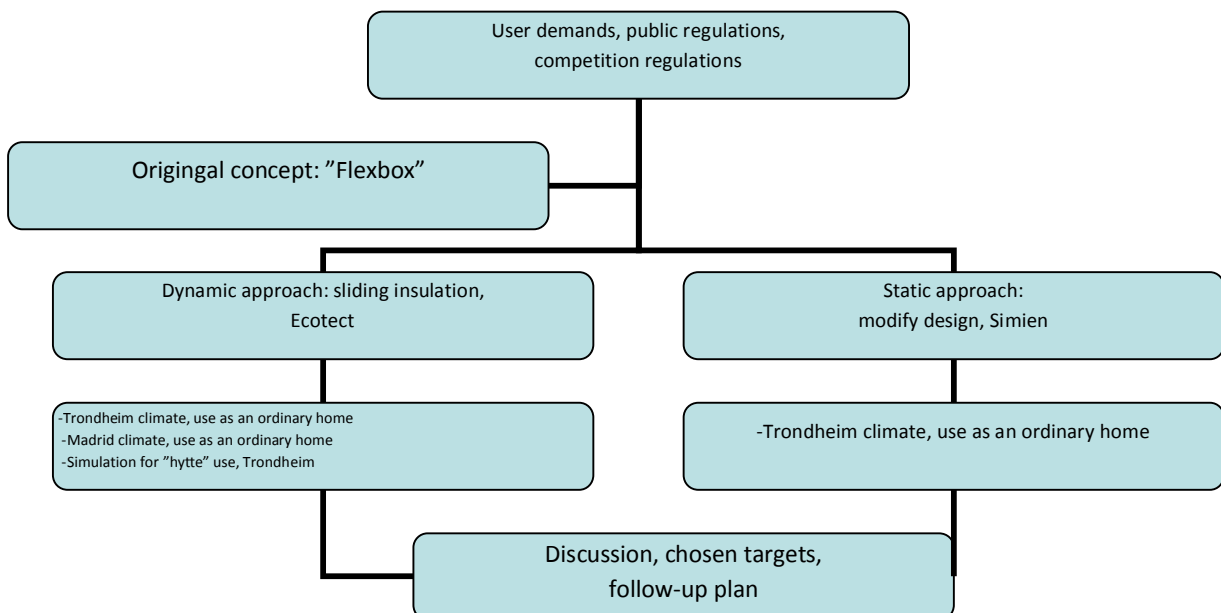
Schematic figure of the structure in this project.

To simulate the energy demand we used two different programs; SIMIEN and Ecotect. For further work we recommend to use a more sophisticated program to simulate for more accurate results.

Targets and demands

The targets for our building are partly set by the competition description (temperature, humidity, size etc). Other targets and demands are set by us trying to think as a potentially "Hytte"-buyer. In some cases we have mismatch between our targets and demands, and the values set in the passive house standard NS 3700. The task is then to try to find the best balance while keeping the users wishes and needs and still try to reach a good energy performance.

Because of the small footprint of the building (maximum 75 m^2) the targets in the passive house standard are quite difficult to achieve. The heated area of the building is only 60 m^2 while the smaller category of buildings in NS 3700 is 100 m^2. These imply that it will be difficult and maybe too expensive to build a proper passive house at this small size in the Norwegian environment.

The potential "Hytte"-buyer have these requirements for his/her "hytte":
- good sense of space*
- good indoor air quality
- plenty of daylight*
- nice view / open to nature*
- little noise from technical equipments
- possibility to rearrange the furniture (lifetime flexibility)*
- all year use (fit for use both summer and winter)
- easy handling of technical equipment*
- low energy demand, (especially when unoccupied)
- low maintenance need*
- storage for outdoor sports equipment*
- no worrying about too much snow on the roof*

Our task as engineers and architects will be to consider the points above and make measurable targets that reflect these qualitative requirements. This is summarized in the table below. Points marked with a star (*) are not possible to quantify as numbers. In the table the minimum targets are set. To achieve the passive-house norm, as we shall see later in this report, we must choose stricter numbers for U-values etc, than listed below.

Category	Requirements	Source
Requirements for indoor climate:		
indoor air quality	Class II: 0,42 l/s* m^2 = 1,5 m^3/hr* m^2 or 7l/s*person= 25,2m^3/hr*person	(NS 15251 tab B.5)
noise	Livingroom 25-40 db , Bedroom 20-35 db	(NS 15251 tab E.1)
light	500 lx	(NS 15251)
themperature	ppm/ppd class II <10% dissatisfied	(see graph in "Enøk i bygninger")
Requirements for building specifications:		
U-values (average)	Floor: <0,15 W/(m^2K) Roof: <0,13 W/(m^2K) Wall: <0,15 W/(m^2K) Window/door: <0,8 W/(m^2K)	NS 3700 tab 5.
Linear thermal transmittance (thermal bridges)	0,03 W/ m^2K	NS 3700 tab 5.
Temperature efficiency heat exchanger	>80%	NS 3700 tab 5.
SFP-factor	<1,5 kW/(m^3/s)	NS 3700 tab 5.
Leakage number av 50 Pa,n50	<0,6 h^{-1}	NS 3700 tab 5.
Heat loss, H"	A_{fl} < 100m^2: 0,6 W/(m^2K)	NS3700 tab.2

Another important issue is to make sure that the building meets the requirements set by the law. In Norway that means that the TEK 2010 and the corresponding standards (NS 3031, NS 15251 etc) have to be met.

Approaches:

The energy demand calculated with the original building concept showed that this concept was far away from achieving a plus-house energy goal. The heat loss distribution showed that the huge window area was a problem. The two approaches are:

"Dynamic": evaluate the use of sliding insulation panels that can be placed in front of the glazing to limit the heat loss during cold periods, including summer nights etc.

"Static": the next step in making the building more energy efficient was to try to reduce the window area without losing the sense of space.

Both programs used for the building performance analysis – SIMIEN and Ecotect – have limitations regarding simulation of dynamic changes in the building elements. Thus to simulate the dynamic use of shading and insulating panels within the "dynamic" approach simplified methods were used.

Because of the lack of footprint area and the reluctance to reduce the inner area the insulation in the walls have a restriction related to its thickness. A better U-value could have been achieved by using expensive vacuum insulation. The floor and roof have not got the same restrictive thickness limitation and can achieve a better U-value with thicker layers of normal insulation.

This building should perform both in Oslo-climate (all year) and in the competition week in Madrid (June). We suggest developing a building envelope that performs good all-year round in Norway and also in June-Madrid. The equipment inside the building will probably be a bit different for Madrid and Norway. For example will there in Madrid be a cooling need while in Norway there will be a heating demand in winter time.

Dynamic

First approach was using sliding system for reducing energy demand. Simulation shows total heating and cooling demand of building in original model with the same window area (65%) without insulation panels is near 84 kWh/m2

Trondheim- insulation panels:

These figures display daylight factor and light distribution of building in 4 different situations in the first of December.
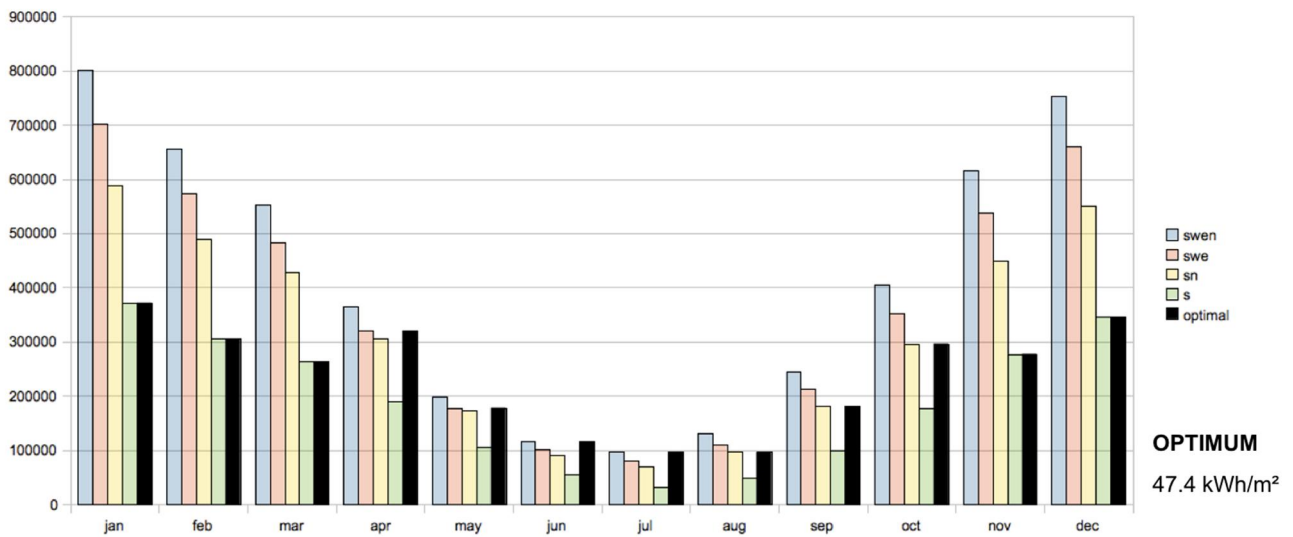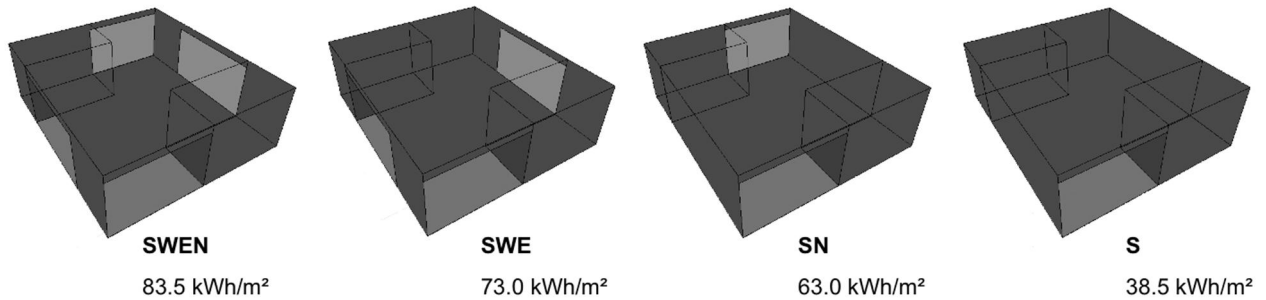
1. No insulation panels
2. Using insulation layer in north window
3. Using insulation layers in east and west windows
4. Using insulation layers in north, east and west windows

As it can be seen average DF in original model where it is not shaded and not insulated is too high.

DF: 15.23 %   DF: 11.84 %   DF: 7.02 %   DF: 3.52 %
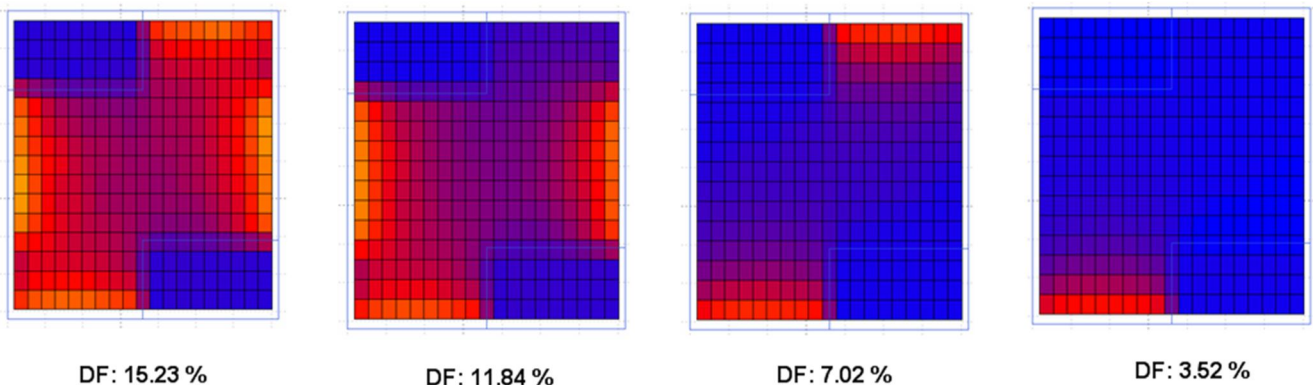
Energy demand:

These figures display the total energy demand of building in four mentioned situations. Finally, the variable schedule has been chosen- insulation layer in east, west, north windows in winter (from Nov to March) and removing them in summer (from Jun to Sep). Simulations show in the last schedule energy demand would be approximately 47.4 kwh/m2.

SWEN	SWE	SN	S
83.5 kWh/m²	73.0 kWh/m²	63.0 kWh/m²	38.5 kWh/m²

OPTIMUM

47.4 kWh/m²

Total energy demand in different situation

Madrid- shading and insulation panels:

Energy demand when it is not shaded and not insulated: 35.8 kWh/m2

For simulation the model in Madrid using shading layers in summer has taken into consideration.

Energy demand:

Analysis show with shading in summer (from 1st Jun to 15th Oct) and insulating east and west windows in winter (from Nov to Feb) annual heating and cooling demand will be 29 kwh/m2 .

In Madrid Shading and insulation layers have significant affect to the energy demand.

It can reduce the heating demand in winter and cooling demand in summer. In variable schedule by using insulation layer in in east and west window in winter and shading north, east and west windows in summer, energy demand of building can reach to 29.6 kWh/m2.

SWEN   SWE   SN
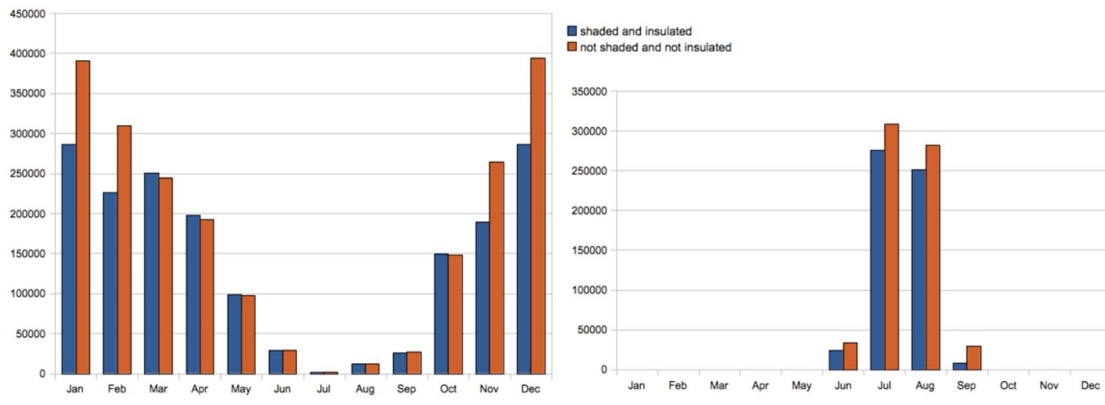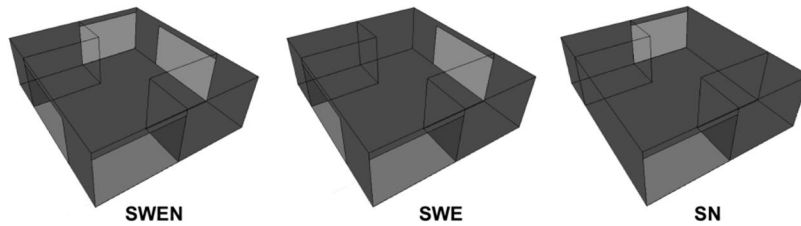
Heating demand (SWEN): 35.8 kWh/m²

Heating demand (optimal): 29.7 kWh/m²

Cooling demand (SWEN): 11.1 kWh/m²

Cooling demand (static): 9.5 kWh/m²

The "Dynamic" approach needs a further explanation:

First one translucent layer of double polycarbonate sheets insulated with aerogel, for shading and insulation. Outside that a layer of opaque insulation, that also reduces weather strain on windows when unoccupied. Both these layers need to be closed with gasket systems to reduce air leakage, and can be operated manually or automatically.

For our calculations we defined the u-value of the translucent layer as 30mm XPS, added 10% for frame, and ended up with a total for translucent covered window of 0,45 w/m2k.

The opaque layer was defined as 100mm EPS and 15mm chipboard, again adding 10% for frame, and ending up with a total U-value for window covered with both layers of 0,2 w/m2k.

When unoccupied, both layers are closed.

When occupied the translucent layer can be closed in some cold winter days and hot summer days (also shading). Both layers can be closed when it is dark. To reflect this changing insulation we made an estimate of an "average U-value": 0,45 for full time residence, and 0,3 for typical Norwegian hytte-occupation. We ran simulations with these values in Ecotect and Simien.

Energy performance improvement

The design was made within the requirements of the Solar Decathlon and within the requirements of the **TEK ' 10** and the goal was to make it as energy efficient as possible, without reducing the performance in terms of indoor climate, comfort and so forth. The specifications of the building elements were taken from the standard.

The calculations made in SIMIEN gave a heat loss number of 0,83 W/m2K, which was higher than the heat loss number in the passive house standard (0,6 W/m2K). Then suggestions were made for improving the performance, with focus on the building elements with the highest potential reduction. The suggested improvements were improved U-value for floor, roof and windows.

In the "Dynamic" approach the average over all year window U-value was assumed to be lower than the windows U-value as listed below. In the "Static" approach the window area was changed.

Original inputs:	- U-values (W/m^{2}K): - floor: 0,15 - roof: 0,13 - windows:0,8 - Window size - south 2,4m height - north 8,64 m^2 - east and west 2,4m height
Before improvement	Heat loss number: 0,83 W/m^2 K
New inputs (for both "Static" and "Dynamic"):	- U-values(W/m^{2}K) - floor:0,08 - roof:0,09 - windows: 0,7
"Static" changes:	- reduced window size - south 2m height - north 2,16 m^2 - east and west 1,6m height
"Static" new performance (heat loss number):	Result after changes: 0,57 W/m^{2}K
"Dynamic" changes:	- Sliding insulation and shading in front of windows when the building is not used or when there are large heating or cooling loads. - The average U-value (fro Windows) was calculated to be 0,45 W/m^{2}K.
"Dynamic" new performance (heat loss number):	Result after changes: 0,55 W/m^{2}K

Improvement of existing design

In the process to make the "hytte" we started to look at the governments requirements and the residents requirements, then we have followed the Kyoto pyramid to make the plans for the "Hytte". We started at the bottom and worked against the top.

Step 1: Reduce heat loss.
The target for this "hytte" is to use as little energy as possibly. In addition with solar PV-panels the goal is to produce more energy than the building consumes. In the passive house standard (NS3700) the requirements to heat loss is equal or less then 0,6 W/(m^2K). With the original concept the heat loss number was 0,83 W/(m^2K). Because of the thrifty area (only 60 m2) the passive house standard is hard to reach (the smallest house category is 100 m2).

Step 2: Reduce electricity consumption
To compare the "hytte" against the Norwegian TEK10, we needed to use some standardized values for the electricity consumption. But since this this building are going to be used as an "hytte" the standardized values would be too high to the real consumption. Also use of A++ installations, like dishwasher, TV, oven etc would reduce the energydemand.

Step 3: Utilize solar heat
To use some of the free solar energy we need a lot of windows in the building, the problem here is to satisfy the residents, both in Madrid and Norway with the same "hytte", without changes. The recommendation from the government is that the window area should only be 20 % compared to the floor area. Since the BRA are so small, only 60 m^2, the responding allowed window area is 12,1 m^2. Since the conditions for solar heat utilization is so different in Madrid and Norway there is some challenges to placing the windows. There would maybe be cooling needs in Madrid but not in Norway etc.

Step 4: Display and control energy consumption
A energy budget can show how much energy the building needs for normal use, how much energy it needs to run all the components, to keep the ventilation going or keep the building warm or cold. Since it would be reduced use of this building compared to a regular house, the temperature can be reduced when the building is empty for a couple of days, and when you are on your way to the "hytte" you can call to the automatic management system and turn the heat or other components on so there is more comfortably to finally get there after a long drive. These points are a part of a developing concept called "Smart"-house.
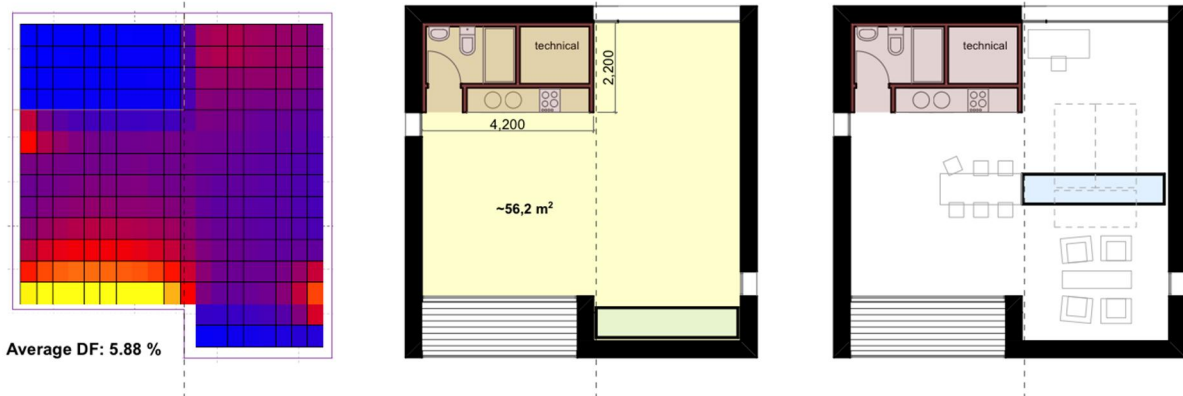
Step 5: Select energy source
From the contest description the energy source are decided, solar power. PV-panels and thermomax solar panels. But in the winter, especially in Norway, there may be need for more heating like an effective stove using bio-mass.
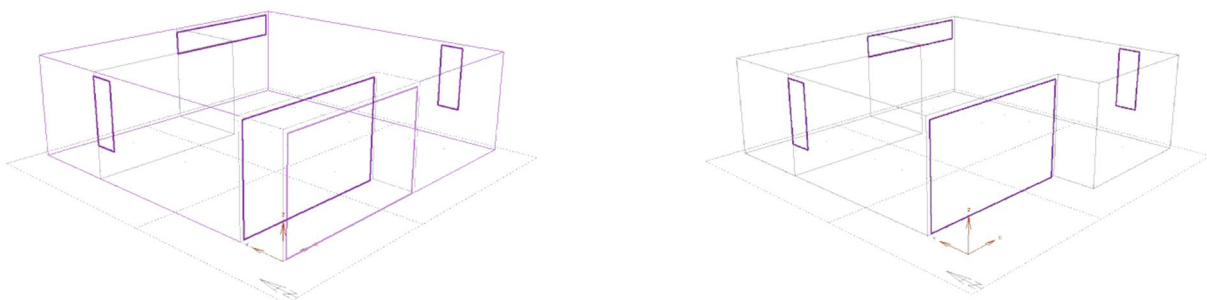
Static

FlexBox 1.1

FlexBox 1.2

Average DF: 5.88 %
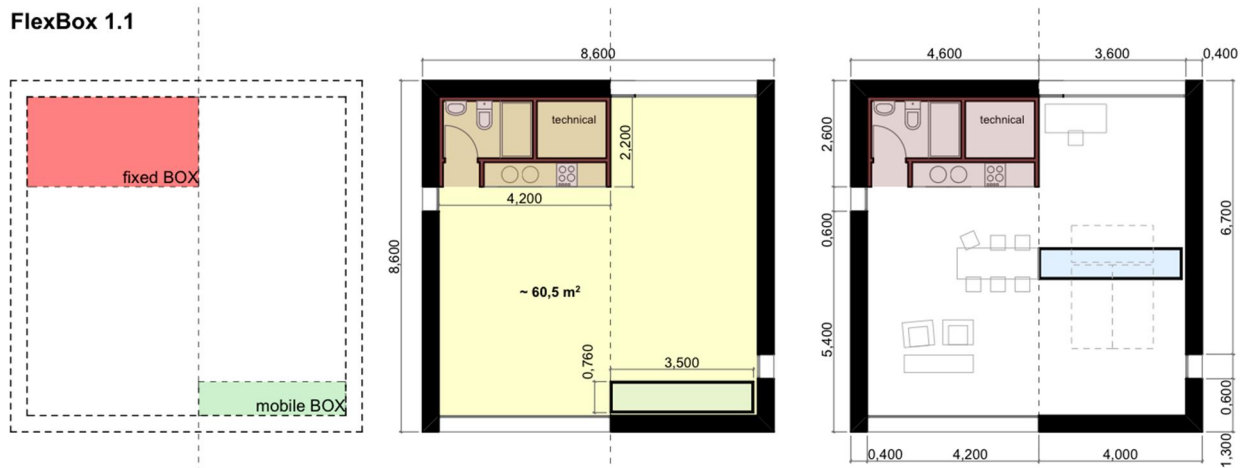
During the next step, we made a number of modifications- reducing floor and window areas, combining technical room with kitchen and bathroom, having one movable box.

The model has been simulated in two phases both for Madrid and Trondheim, first with sunspace in south faced, and second without sunspace.
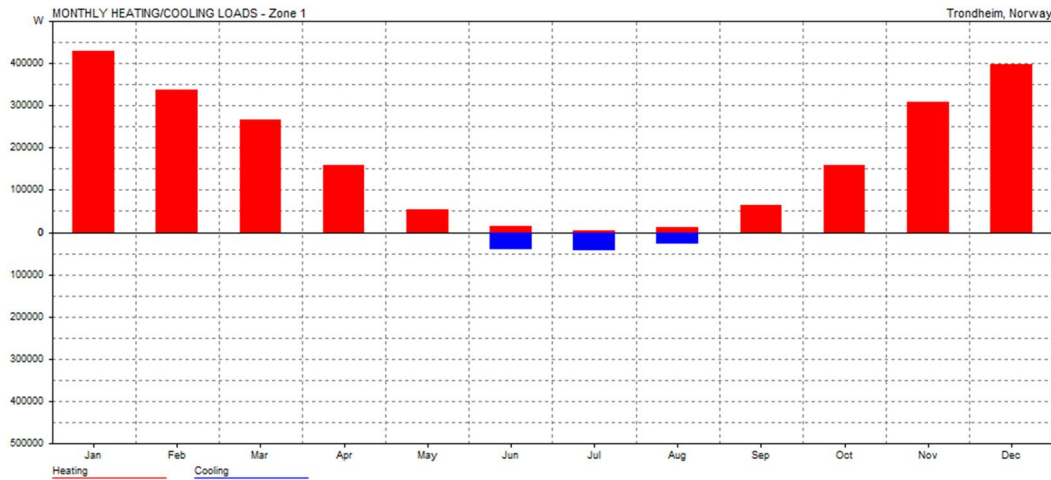
Trondheim:

with sunspace:
Heating demand: 29 kWh/m²
Cooling demand: 3.6 kWh/m²
Total: 32.6 kWh/m²

without sunspace:
Heating demand: 39 kWh/m²
Cooling demand: 1.9 kWh/m²
Total: 40.9 kWh/m²

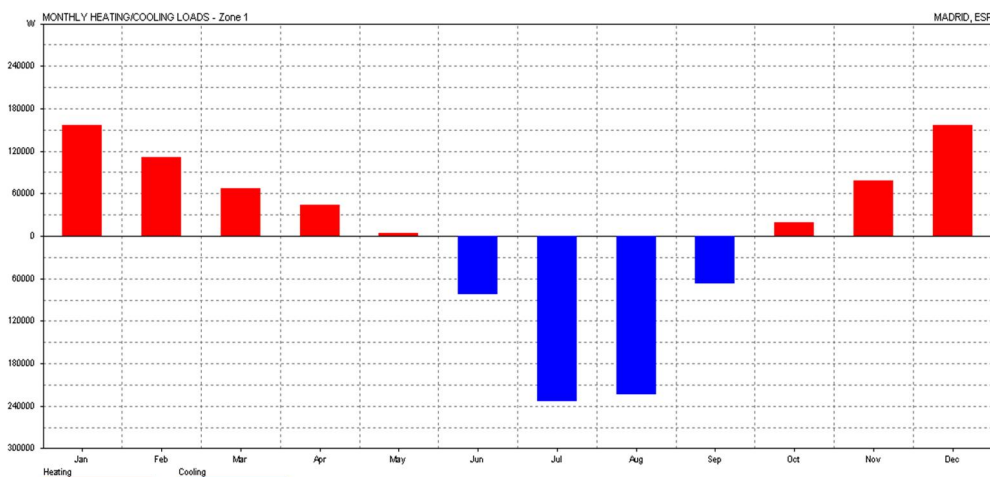Monthly Energy demand in Trondheim- (with sunspace)

Madrid:

with sunspace:
Heating demand: 8.1 kWh/m²
Cooling demand: 10.3 kWh/m²
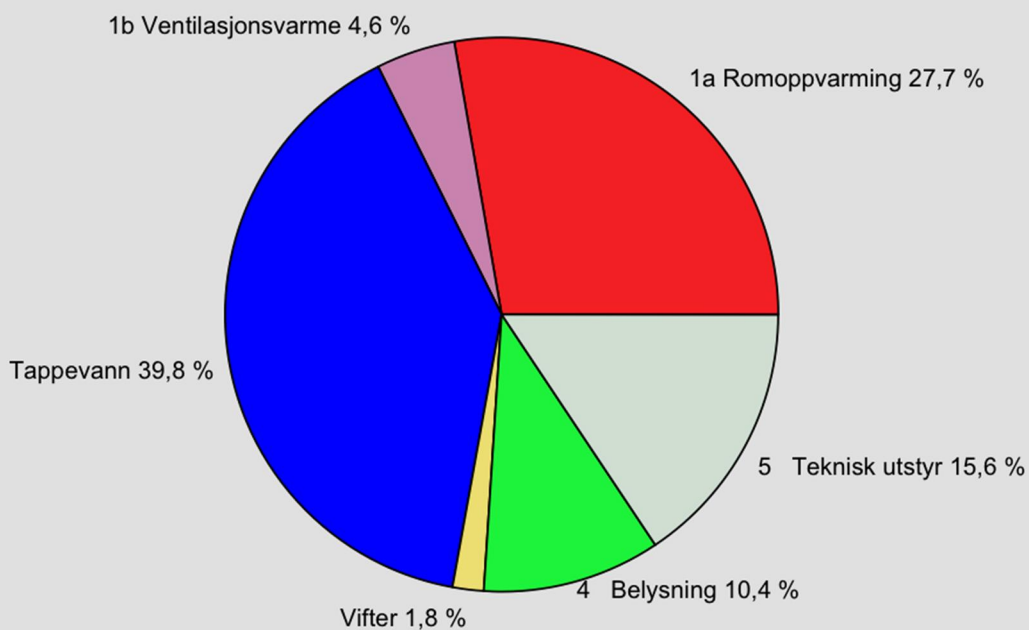Total: 18.4 kWh/m²

without sunspace:
Heating demand: 11.1 kWh/m²
Cooling demand: 10.8 kWh/m²
Total: 21.9 kWh/m²

Monthly Energy demand in Madrid- (with sunspace)

Calculation shows sunspace can be effective in both Trondheim and Madrid. In new design heating demand in Madrid is below 15 kWh/m².

Årlig energibudsjett

Pie chart:
- 1b Ventilasjonsvarme 4,6 %
- 1a Romoppvarming 27,7 %
- Tappevann 39,8 %
- 5 Teknisk utstyr 15,6 %
- 4 Belysning 10,4 %
- Vifter 1,8 %

1a Romoppvarming	1869 kWh
1b Ventilasjonsvarme (varmebatterier)	312 kWh
2 Varmtvann (tappevann)	2681 kWh
3a Vifter	122 kWh
3b Pumper	1 kWh
4 Belysning	701 kWh
5 Teknisk utstyr	1051 kWh
6a Romkjøling	0 kWh
6b Ventilasjonskjøling (kjølebatterier)	0 kWh
Totalt netto energibehov, sum 1-6	6737 kWh

Energibudsjett

Energipost	Energibehov	Spesifikt energibehov
1a Romoppvarming	1869 kWh	31,1 kWh/m²
1b Ventilasjonsvarme (varmebatterier)	312 kWh	5,2 kWh/m²
2 Varmtvann (tappevann)	2681 kWh	44,7 kWh/m²
3a Vifter	122 kWh	2,0 kWh/m²
3b Pumper	1 kWh	0,0 kWh/m²
4 Belysning	701 kWh	11,7 kWh/m²
5 Teknisk utstyr	1051 kWh	17,5 kWh/m²
6a Romkjøling	0 kWh	0,0 kWh/m²
6b Ventilasjonskjøling (kjølebatterier)	0 kWh	0,0 kWh/m²
Totalt netto energibehov, sum 1-6	6737 kWh	112,3 kWh/m²

Energy performance of the alternative design (with the reduced window area, and dynamic window insulation scheme)

Discussion

In this report we have developed the building envelope with focus on performance in Norwegian climate trough the year. We have also tried out the building performance in Madrid climate and the performance are acceptable also there. (See page 14)

The next step in this project will be to develop a HVAC system for the building. This will be quite different for a whole-year Norwegian use, part time Norwegian use and the competition use in Madrid. For a whole year Norwegian use the focus will be in develop a system that give a stable indoor environment with low annual energy use and low power need in installed equipment. There will be useful to install advanced DCV-systems, user monitoring etc to control HVAC-system.

In a "hytte" for part time Norwegian use the power need will probably be higher for the heating system to obtain the wanted indoor temperature quick. Smart and innovative systems to prevent freezing in water pipes etc should be developed.

For the competition week in Madrid the energy output will be the big issue and goal. In supplement the competition requirements will be important to reach. For instance the temperature inside should be between 23-25 degrees. For this quite small building with small thermal mass this mean a challenge in the HVAC system.

Another issue will be in the question if the "hytte" will be connected to the electricity grid or not. This difference will mean a total different choice of technical system. On a monthly basis solar energy production (PV and thermal) is sufficient to cover energy demand with a typical norwegian hytte-occupation. However this would require some storage capacity that might be expensive.

With a solar collector (or a heat pump) providing half the annual DHW demand, and a system that recovers 30% of the energy in the wastewater, the electrisity needed for this will be reduced from 2681 kWh to 938 kWh.

This will reduce the electricity demand to 4994 kWh.
The estimated annual production from PV-system on the roof is well above that, with 6390 kWh, thus making this a plus-energy house.
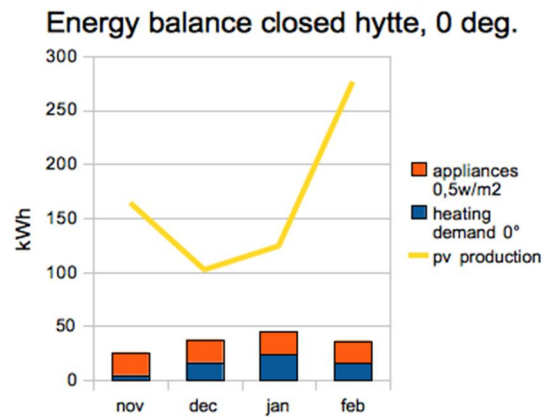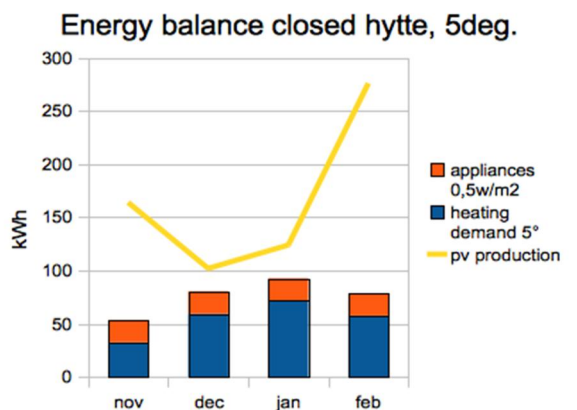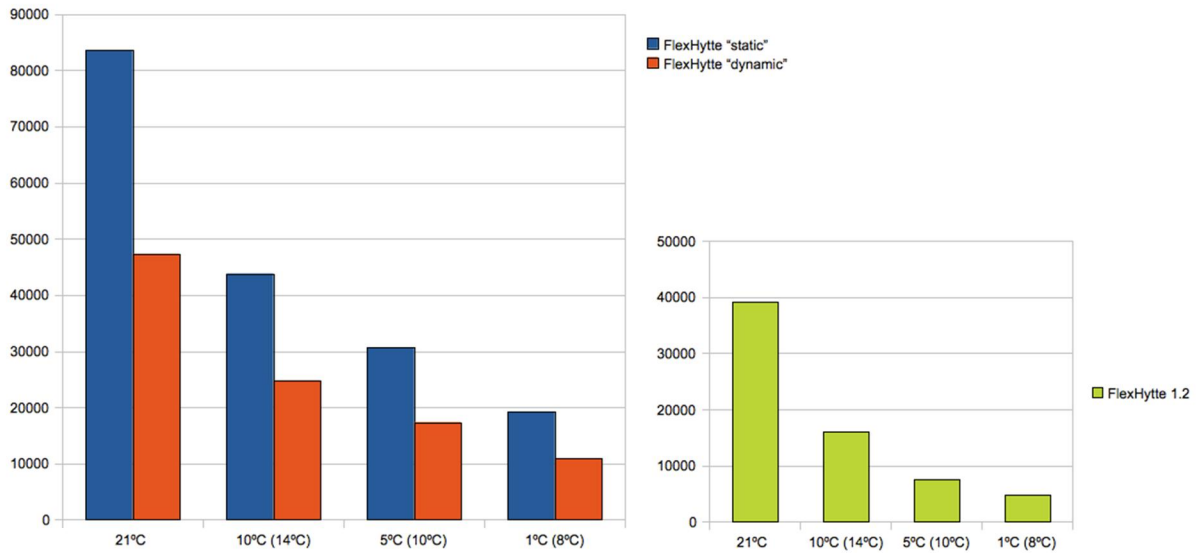
Short conclusion:

DYNAMIC

sliding insulation has a significant impact on the thermal performance of the building both in Madrid and Trondheim – has potential with more "sensitive" scheduling

STATIC

by reducing the window area and improving the U-values of the building envelope the thermal performance can be improved – "too small to be passive" for Norway, "passive" in Madrid

HYTTE

with limited occupancy it is possible to cover the energy demand of the building as an off-grid hytte with PV system providing the required heating to keep the water system from freezing – however, due to need for an energy storage, the cost of the building will be very high

Follow-up plan:

The next step in the planning process will be to find solutions that reach our targets set in this report. This include design of the ventilation system to reach the SFP-factor and the requirement to noise, choice of heating system (radiators or floor-heating), maybe a combined ventilation, hot water and heat pump system profitable, etc

Sliding Insulation
Our calculation shows that sliding insulation on glass areas reduces the annual heat loss significantly. This can be a realistic and cost-efficient way to get zero- or plus-energybalance in a cold climate. However these systems need further development on several aspects:
-problems with snow and ice
-airtightness
-robust sliding and closing system
-optimal thickness and U-value
-optimal thickness/g-value of translucent system
-automatic shutting systems
-automatic control systems

Roof structure
A hytte can be placed in areas with extreme snow-loads. The owners do not want to travel a long way just to showel snow down, so the roof needs to be very strong, especially a flat roof where nothing slides of.

PV / snow
The PV-system needs to be placed in a way so that it also can work when there is snow. This can be done by mounting the panels steep enough and high enough, or by allowing safe and easy shoveling.