Integrated Energy Design (IED)

Assignment 3

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Introduction:

All along the design process, we went through several steps: The first step consisted in calculating the energy budget of the existing building, before any transformation. Then the design started, and a preliminary energy budget of the project has been done. All along the design phasis, it was very important to go back and forth between architectural and energetical concepts and decisions. In the further development of the design, the technical systems (ventilation, domestic hot water system, lighting…) have been integrated. The passive and active energy strategies modified the energy production and the needed delivered energy. This is where the calculations of heat loss factor, energy budget, delivered energy and CO2 emissions have been updated.

The main goal of this step is to further detail the design concept. For this, we will focus on 3 main tasks. First we will update and analyze the energy budget. Then explain which data's have been put into the program, and finally we will update the quality control plan.
After this done, the next step would be the production of construction documents.

I. Updated energy budget

1. Energy consumption

While entering the project data's in the PHPP program, the total heating demand is of 21 kWh/m², which is too high for the project to become a passive house. For this reason, the U-values of the external walls, floors and roof had to be improved. In order to reach better U-values, more insulation has been added in the external walls, roof and basement slab. A detailed calculation and comparison of the U-values of the previous and updated construction elements can be found in the Appendix 1.

Construction element	**Previous U-value [W/m²K]**	**Updated U-value [W/m²K]**
Wall (1st floor)	0,101	0,090
Wall (ground floor)	0,147	0,101
Basement slab	0,116	0,073
Roof	0,101	0,075

This will make the walls becoming 10 cm thicker. They will become 55 cm thick, but as we insulate at the outside of the wall, it doesn't influence the indoor area.

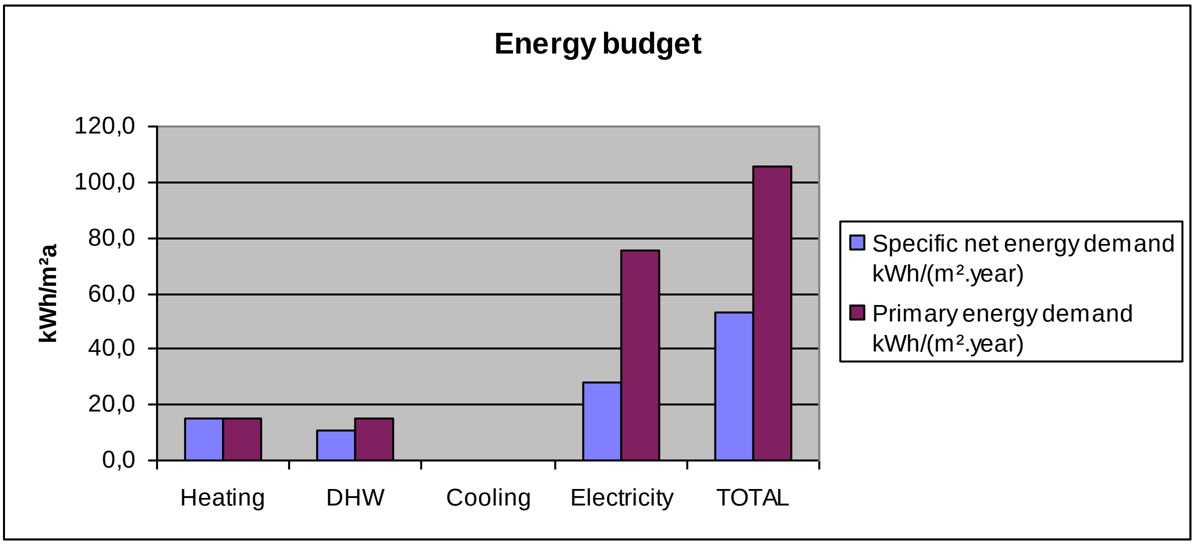
After improving the U-values, we could respect the passive house requirements:

- heating demand < 15 kWh/m²a
- total primary energy demand < 120 kWh/m²a

Treated Floor Area:	437,0	m^2				
	Applied:	**Monthly Method**		**PH certificate**		**Fulfilled?**
Specific Space Heat Demand:	**15**	**kWh/(m²a)**		**15**	**kWh/(m²a)**	**Yes**
Pressurization Test Result:	**0,6**	**h^{-1}**		0,6	h^{-1}	**Yes**
Specific Primary Energy Demand (DHW, Heating, Cooling, Auxiliary and Household Electricity):	**102**	**kWh/(m²a)**		120	kWh/m²a	**Yes**
Specific Primary Energy Demand (DHW, Heating and Auxiliary Electricity):	**32**	**kWh/(m²a)**				
Specific Primary Energy Demand Energy Conservation by Solar Electricity:	**49**	**kWh/(m²a)**				
Heating Load:	**11**	**W/m²**				
Frequency of Overheating:		**%**	over	25	°C	
Specific Useful Cooling Energy Demand:	**0**	**kWh/(m²a)**		15	kWh/m²a	**Yes**
Cooling Load:	**4**	**W/m²**				

In the following table, we can see the distribution of the total net energy demand in heating, cooling, DHW and electricity. This can be compared to the needed primary energy demand.

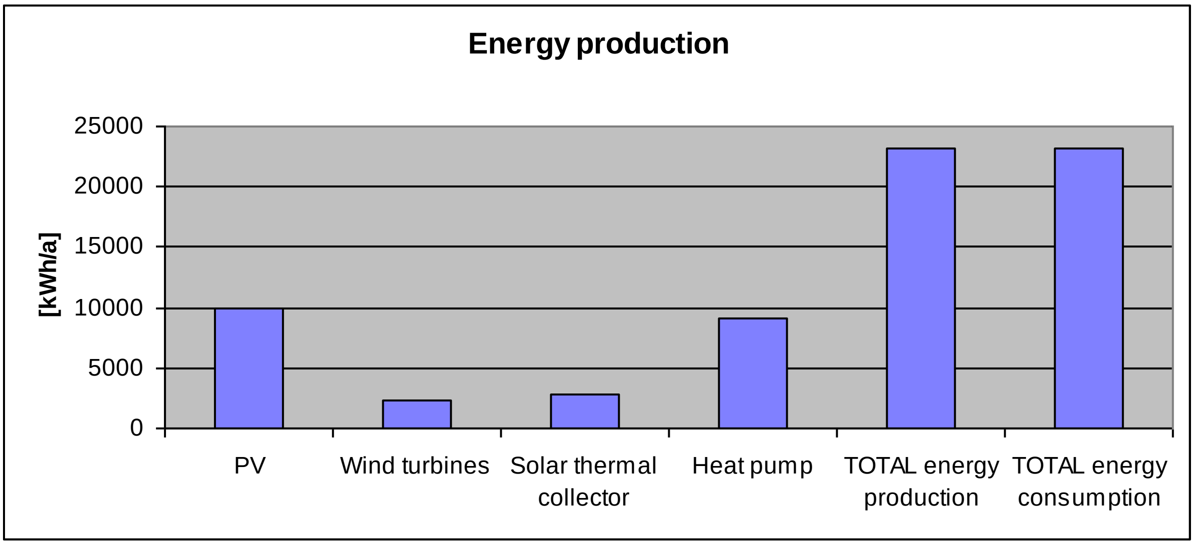
	Specific net energy demand	Primary energy demand
	kWh/(m².year)	kWh/(m².year)
Heating	14,8	14,8
DHW	10,6	15,4
Cooling	0,0	0,1
Electricity	27,8	75,2
TOTAL	53	102



2. Energy production

The active energy strategy is to produce as much energy as the building consumes, on an annual basis. The total specific net energy demand of the building is 23 250 kWh or 53 kWh/m²a, and the same amount of energy has to be generated by the PV, wind turbines, solar thermal collector and heat pump. Then, in this case, the nergy produces as much as it consumes, but the primary energy demand is still much higher than the energy production on site.

	Energy production [kWh/a]	% of electricity demand	% of DHW heating demand	% of space heating demand
PV	9880	81	-	-
Wind turbines	2276	19	-	-
Solar thermal colector	2890	-	42	-
Heat pump	9090	-	58	100
TOTAL	23161			



a) Electricity Production by PV and wind turbines

In order to fulfil the electricity demand of the building, the design integrates PV panels on the roof of the main building and the sunspace. The building already uses low consumption LED devices in order to reduce the electricity consumption. The total net electricity demand of the building is 12 165 kWh/a.

Production of PV panels

130m² of PV panels (including 80m² on the roof of the building and 50m² on the roof of the sunspace), with the average production of 80 kWh/m² can produce 9880[1] kWh/a in Linesoya.

The remaining 2276 kWh will be fulfilled by the production of wind turbines.

Production of the wind turbines

For the calculation of the energy production of a small wind turbine, we consider that the turbine blade has a diameter of 1.2 m, operating efficiency of 20 % and the wind speed is 10 m/sec. (density of air, is 1.2 kg /m. At sea level). If the turbine is run continuously for the whole year, it would produce about 1200 kWh in a year. Hence to fulfil the requirement of 2276 kWh/a, we need 2 wind turbines.

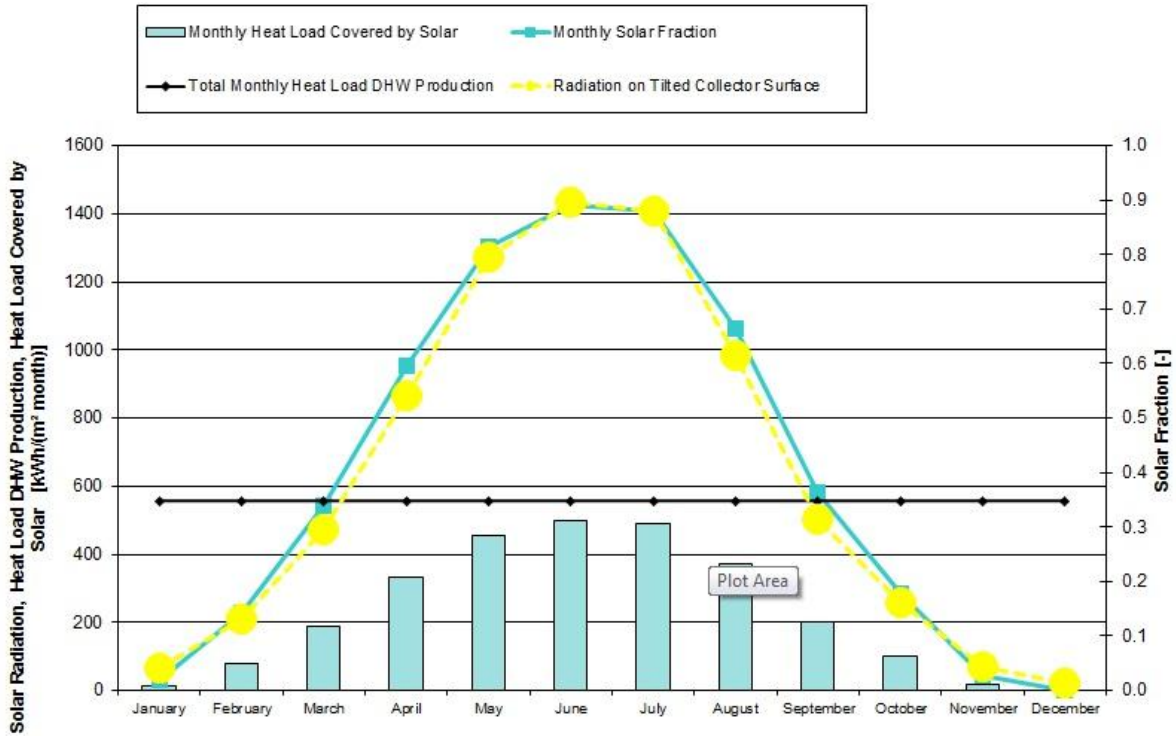
b) Solar thermal collector

In order to fulfill the heating demand, a solar thermal collector and a heat pump are installed.

[1] Value calculated in the website http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php#

In the design, the solar thermal system is placed on the outstanding lift element. This means that the collector is placed on a south facing vertical facade. 4 m² of thermal collectors had ben originally planned, but the PHPP calculations show that it would then only provide 24% of the DHW heating demand. In order to produce 42% of the required DHW energy, a solar thermal collector of 8m² will be used.

The annual primary DHW energy demand is 6724 kWh and 8 m² of vaccum tube collectors can fulfill 2890 kWh of it. All the remaining energy demand for DHW will be furnished by the heat pump. The system includes a simple solar storage tank of 300 liters.

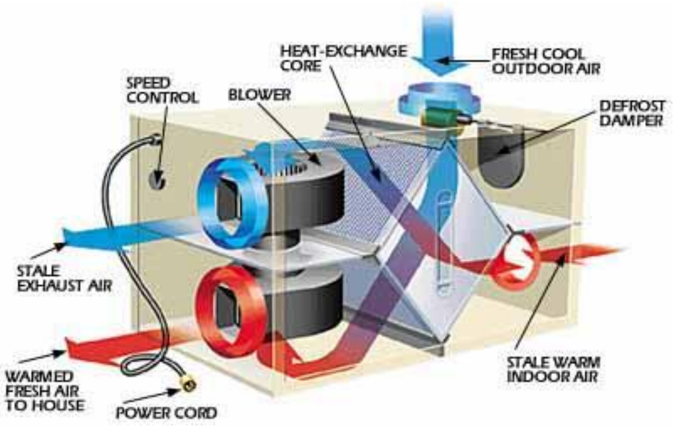


The figure above shows that there is a huge gap between the heat load covered by solar thermal collector and the heat load DHW energy production in the winter. This means that during winter, most of the DHW heating will be provided by the heat pump.

c) Heat recovery system

A heat recovery system is installed in the building to maintain high indoor air quality without excessive additional energy costs. We use thermos 200 DC- PAUL heat recovery unit which has an efficiency of 92 %. This means that the heat recovery system is capable to recover 92 % of heat from the exhaust air and transfer it to the incoming air.

The diagram shows a heat recovery system. It consists of two separate air-handling systems: the first one collects and exhausts stale indoor air, and the other draws in outdoor air and distributes it throughout the home.



d) Heat pump

A heat pump is a device that uses very small amount of electric energy to move heat from one location to another. The heat pumps usually pull heat out of the air or ground and supply it to a living space to heat it. They can be also be switched into reverse to cool a building when required.

In the project, a heat pump is installed for the heating purpose of the building. The heat pump fulfils all the heating demand required for the space heating. It uses 9.4 kWh/m² of electricity for the operation of heat pump, and it will produce 20,8 kWh/m² of heat (with a performance ratio of 0,45)

3. Energy sources and related CO2-emissions

Greenhouse gas emissions related to the energy use in a building depends on: the type of energy source, the embodied energy from production and the disposal of materials that are used in the building.
The table below shows C02- equivalent emission factor for different energy systems in the linesoya project.

Energy system	**CO2 emission factor Kg/m²a**
Electricity demand	18.9
Heat pump	15,3
Solar thermal collector	0,3
PV panels	5,7
TOTAL	40,3

The solar thermal collector and the PV panels also have a CO2 impact: they emit respectively 0,3 and 5,7 Kg/m²a, but the fact they produce energy from renewable sources has the benefit of saving 9,7 kg/m²a of CO2 emissions. As we can see, a supply system of biofuel, PV and wind produce only 40 kg/m² of CO2 emissions per year.

II. Input data

a) General data :

Climate data	**Nb of occupancy**	**Interior temperature** (°C)	**Treated floor area** m²	**Enclosed volume** (m3)
Oslo	12.5	20	437	1766

b) Window type:

Window Type	**g-Value**	**U-Value** W/m^{2}K	Ψ_{Spacer} W/mK	$\Psi_{Installation}$ W/mK
Glass: Low-E 0.51 N 52 - GUARDIAN Flachglas	0,52	0,52		
Frame: Internorm - ed[it]ion passiv fixed glazing - with spacer 'Thermix'		0,63	0,043	0,04

c) Ventilation with heat recovery system:

Ventilation system	**heat recovery efficiency** %	**Average air flow rate** m3/h	**Average air change rate** 1/h	**Infiltration air change rate** 1/h
thermos 200 DC- PAUL	91.6	367	0.3	0.042

d) Heating + DHW

Energy source	**type**	**Area** m²	**Coefficient of performan ce**	**Performance ratio of heat generator**
Solar thermal colletor	Vacuum tube collectors	8	0,83	
Heat pump			3,2	0,45

e) Electricity

Energy source	**Number**	**type**
PV	130 m²	Integrated printed PV cells
Wind turbines	2	Small wind turbines with 1.2m diameter blades

III. Quality control plan.

The main objective of preparing the quality control plan is to ensure that all the solutions developed during the planning period are transferred to the site during the construction process. There are several critical factors that have an impact on the efficiency of the building. Some of such critical factors are thermal bridges, building envelope, air tightness, insulation and integration of technical installation. Special care should be taken about these during construction to ensure the efficiency of the building. Here we discuss some of these points.

a) Continuous Insulation in the thermal envelope.

Structure of the sunspace

The thermal envelope of the project is continuously surrounded by a thick layer of insulation. The thermal bridges are avoided as much as possible. This is the reason why the structure of the sunspace is an independant structure from the main building. This enables to reduce the contact between the cold construction elements of the sunspace and the warm thermal zone which is the main building.

Careful installation of insulation

It is important that the insulation is installed with careful attention, as incorrect installation will result in significant decrease of its performance. An insulation layer should always be a continuos layer. Some of the factors that have to be taken care of while positioning the insulation are listed below[2] :

- Avoid gaps in between the insulation layers.
- Do not compress bulk insulation, that decreases its performance.
- Eliminate thermal bridges as much as possible
- Allow clearance around appliances and fittings
- Protect insulation from contact with moisture
- Provide a sealed air space with reflective insulation
- Provide vapour and moisture barriers to prevent condensation

b) Air tightness of the building

As it is a passive house, the building needs to be very airtight with a low air flow. The high airtightness requirement is an air change rate of less than or equal to 0.6 1/h.

[2] These points com from the website: http://www.sustainability.vic.gov.au/resources/documents/Insulation_installation.pdf

Typical Leakages and Possible Solutions

The aim is to avoid typical leakages (occuring on surfaces, joints and connections, penetrations and other building components). There are several ways to achieve the passive house airtightness requirements[3]:

General construction :

- Check the airtightness of pre-fabricated construction
- Use an impermeable vapour barrier as an air barrier
- Avoid to damage the vapour barrier
- Continually check the quality of construction as the work proceeds

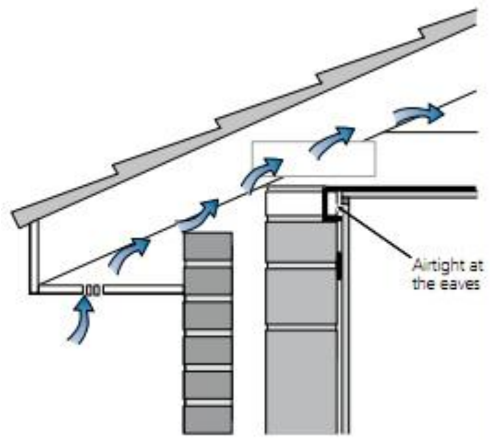
Construction of walls :

- Seal
  - around the edges of the room
  - all junctions between the ground floor slab and the external walls
  - all cavities around windows and external doors.
  - gaps around any pipes and cables passing through external walls, ceilings and ground floors ceiling below the roof space.

- To avoid penetrating the Vapour barrier layer entirely, battens can be added to the room side of the membrane to form a small cavity between the membrane and the plasterboard. Services such as pipes and wiring can be run through this zone.
- Use continuous ribbons of expanding polyurethane foam between the plasterboard sheets and the inner leaf of block walls to reduce air leakage behind dry-lining.

Roof

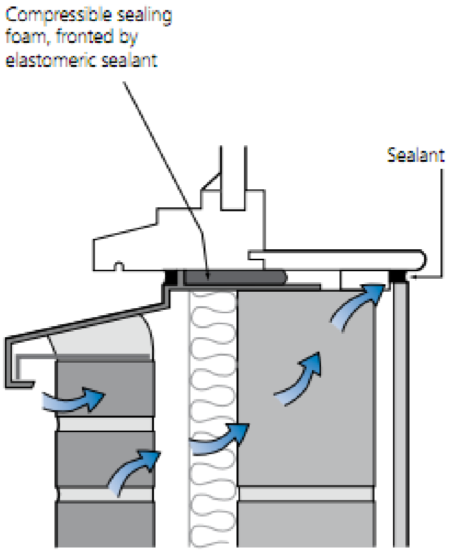
- Check that loft hatches are airtight and surrounds are sealed where they penetrate the air barrier.
- Locate combined air tightness / vapour control layer (VCL) on warm side of the insulation.
- Add battens to the underside of the VCL before covering with plasterboard.
- Use sleeves that are adhered to the foil or the board



[3] Air Tightness in Passive Houses, Dipl.-Ing. Stefanie Rolfsmeier, BlowerDoor GmbH; Design and Detailing for Air tightness, Chris Morgan, SEDA, 2006

Positioning of windows and doors:

- Use compatible gunned in sealant to seal gaps around windows/doors and the surrounding wall externally to prevent air leakage.
- Apply draught-stripping to all gaps between the wall reveals/window boards and door frames.
- Use a pre-compressed flexible expanding foam strip, where the openings are larger.
- Ensure that the airtight membrane meets and overlaps the seal to maintain the airtight layer overall.



c) Optimization of the technical systems

The longer the pipes, the more heat losses will occur. It is important to place the pipes very carefully, and in the shortest way as posssible. This will reduce energy losses, save space and save the material costs of pipes.

Solar thermal collector

There are many different issues that enhance the DHW system performance. In addition to the orientation of the collector and the fact that any source of shading has to be taken away from the collector, there are important things to do during the installation of the system:

- adjustment of the temperature in the storage tank
- insulating plumping: 100 mm of rigid foam
- insulating the storage tank

This will improve the efficiency of the system while reducing the heat losses through the pipes.

Heat recovery system

Here again, it is very important to insulate the pipes, including the exhaust and the intake pipe. The heat recovery system should be entirely placed into the insulated zone, so that the contact between the pipes and outdoor air is as small as possible.

IV. Conclusion

This report presents the results of a PHPP calculation. The project, which was into the passive house requirements according to the formula’s calculations and ecotect results, seemed to have a too high heating demand to be able to be called passive house. This is why some of the design had to be updated. This has mainly be done by improving the U-values: thicker insulation layers and better insulation materials. After this change only, we could reach the passive house requirements with a heating demand of 15 kWh and a total specific primary energy demand of 102 kWh/m²a. Here we can see the limitations of the simulating programs, that don’t give the same results.

Then, it is very important to respect carefully the quality control plan. Special care should be taken while constructing the project on site, as improper installation of the construction elements and equipment may result in less efficiency and increased energy demand and supply of the building. The energy efficiency of the building is determined by the planners and the constructors. This is why it is important to inform very well the constructors about the importance of the quality of their job. This can be done by lectures and sensibilisation actions.

As a plan for follow up, further contribution to the energy saving could be to make the users and the visitors of the project aware about their energy consumption. This can be done by providing daily energy consumption feedback to the users, energy tracking systems...., and providing energy information.

V. References

1.Air Tightness in Passive Houses, Dipl.-Ing. Stefanie Rolfsmeier , BlowerDoor GmbH, Energie- und Umweltzentrum

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3. Energy efficient refurbishment of existing housing CE83, Energy Saving Trust, 2004

4. Improving Air tightness in dwellings GPG224, Energy Saving Trust, 2005

5. Design and Detailing for Air tightness, Chris Morgan, SEDA, 2006

6. A practical guide to building airtight dwellings, NHBC Foundation, 2009

7. http://www.greenspec.co.uk

8. Guidelines for energy efficiency concepts in office buildings in Norway
Matthias Haase, Karin Buvik, Tor Helge Dokka, Inger Anderson, SINTEF Building and Infrastructure, 2010

VI. Appendix

Exterior wall 1st floor		
	Thickness [mm]	
Elements	old	updated
Interior plaster	15	15
Verical wooden wall_timber	60	60
Existing insulation	50	50
OSB	30	30
Insulation	300	350
painted wood cladding	20	20
Total thickness [cm]	**47,5**	**52,5**
U-value	**0,101**	**0,090**

Basement slab		
	Thickness [mm]	
Elements	old	updated
linoleum	30	30
Impact sound insulation	20	20
Concrete	170	170
phenolic Foam	150	250
Plaster Coat	10	10
sand blinding	100	100
Total thickness [cm]	**48,0**	**58,0**
U-value	**0,116**	**0,073**

Roof		
	Thickness [mm]	
Elements	old	updated
Reused tiles, clay	20	20
wood Fiber board	30	30
celloluse insulation btw rafters	100	200
insulation btw rafters	300	300
OSB	20	20
plasterboard	10	10
Total thickness [cm]	**48,0**	**58,0**
U-value	**0,101**	**0,075**

Exterior wall ground floor		
	Thickness [mm]	
Elements	old	updated
interior plaster	5	5
concrete	250	250
Insulation	200	300
Outdoor skin	20	20
Total thickness [cm]	**47,5**	**57,5**
U-value	**0,147**	**0,101**