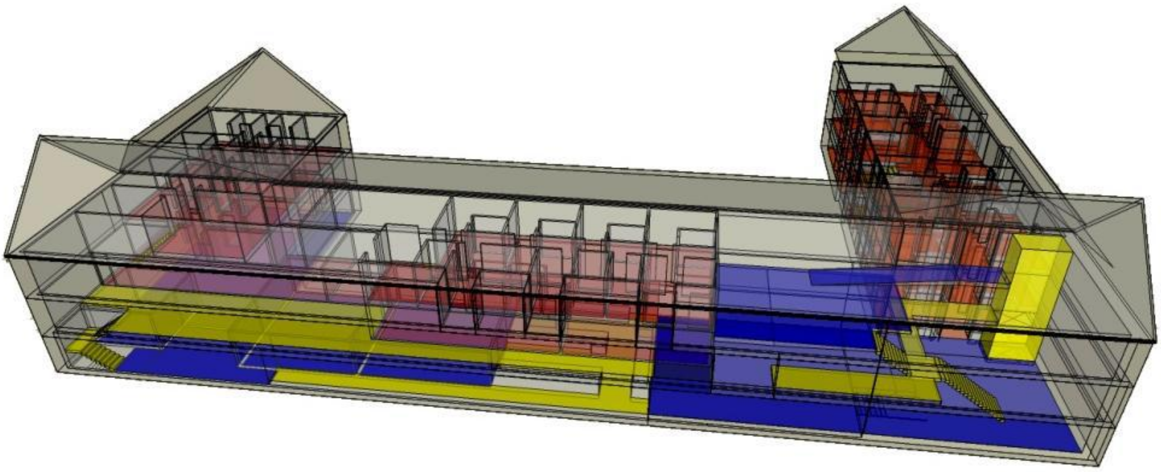
AAR 4926 INTERGRATED ENERGY DESIGN THEORY COURSE

ROTVOLL PROJECT

ASSIGNMENT 3



GROUP 3

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1. Final design

1.1. Assignment description

The purpose of the Rotvoll project is to refurbish a building and at the same time try to preserve most of the old parts as much as we can. The old barn changes to be a residential building for 2 families and 25 students while energy performance should be considered by combining the ecological, economic and social dimension of sustainable architecture into 1 holistic design. The challenge was to refurbish and redevelop the properties of the original building respecting its architectural, historic qualities and local context while creating a multifunctional house.

The assignment 3 is one part of this integrated design process which is to further detail the design concept in order to produce construction documents, along with updated energy budgets and an updated quality control plan.

1.2. Description of original goals

The project group's goal is to plan an energy-efficient building with satisfactory indoor air quality. Through collaboration with the engineer students in part 1 of the project, the students' goal is to make it possible to develop energy-efficient ventilation and heating of the building so that the building will meet the passive house standard.

In assignment one there where two main goals set; Comply with Norwegian passive house standard (NS3700) and reduce CO2-impact by reducing building materials on site

1.3. Description of final design

All along the design process, it was very important to go back and forth between architectural and energetically concepts and decisions. But since the purpose of the Rotvoll project is to refurbish a building we hope we can try to preserve most of the old parts as much as we can.

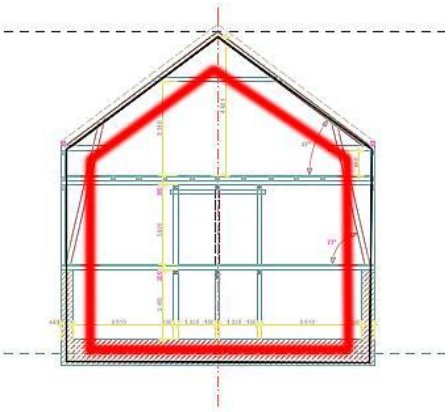


Figure 1 Concept 'house in house'

Having analyzed the different concepts, our main concept will be —house in house , together with the reuse of parts of the facade. With this concept the social and historical values are taken into account, while having enough options to fit the architectural program in the building.

The maximization of the usable space within the existing volume was also important in the project so that we don’t have any stretching out or extension part to keep the building compact. For envelop part, as we have kept the existing part, the concrete at the basement and first floor can be used as thermal mass. In order to reduce the heat loss, we only keep the existing windows and add small windows as few as possible. But the big glazing and open spaces are designed in the south façade.

Different functions are integrated with the thermal zones depending on people’s activity level and requirement for the thermal comfort.

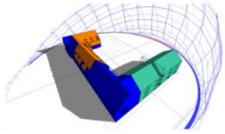
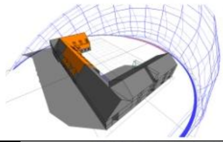
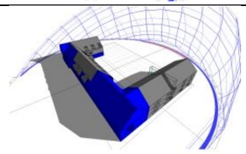
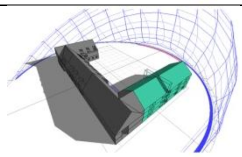
	LOCATION	AREA	THERMAL REQUIRMENT	OPERATION TIME
				
Family part		695.3 m^2	23	4:00pm To 8:am (Mon. to Fri)
Shared big space		778 m^2	18	8:00am To 4:00pm (Mon. to Fri.)
Dormitory part		816.5 m^2	23	4:00pm To 8:am (Mon. to Fri)

Table 1 Different functional zones in the building

The concept can be described in three aspects.

- From the structure view, we hope to keep the outside structure so that we can save the material from cladding for façade, and build an exactly new structure inside.
- From the energy view; we hope the space between the old and new can be used as buffer space without heating and the new insulation has been added on the inner part of the external walls which helps to reduce efficiently all the thermal bridges that existed in the old structure.
- From the space view, we use public space as the connection between family and dormitory.

1.4. Trade-offs and design process

During the working process, we changed the plan by following our original concept "house in house".

For thermal zones, technical room in the southwest part is removed, instead of that is a shared living room for student so that the west wing can be one separate part and insulated separately.

For envelop, at first we considered to use the outside layer as wind barrier so that the air gap between can be used as the ventilation system. However, the air gap doesn't works well because the air ventilated in is actually outside and the existing outside layer is not air tight. That is why we add the new wind barrier inside the existing structure.

Passive and active strategies are integrated with functions of spaces. By choosing the different material for envelop, the wall should reach both thickness we want from architectural view and U-value for the energy view.

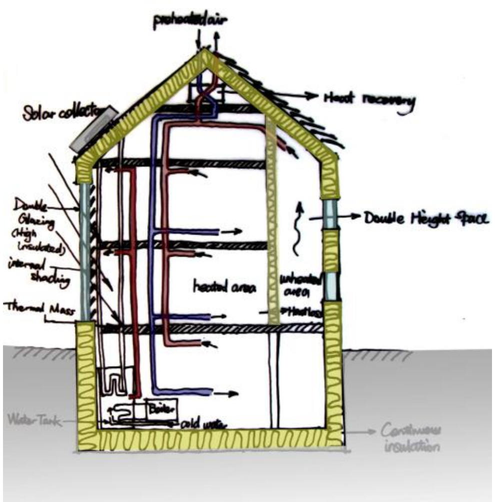


Figure 2 Active and passive strategies

2. Final performance report and energy budget

In this chapter we will describe the calculated energy budget for the final design. Since the start of the assignment, the plan and the façade functions have changed a lot. The expertise of the teachers, Ecotect building simulations and simple hand calculations have guided the design into the final form. This final design is modeled in PHPP to arrive at a final energy budget.

In the first paragraph we will describe the main input that is given for the areas and basic parameters. In the second paragraph we will give the results. In the next chapter we will describe the quality assurance plan. In this assurance plan the minimum U-values and installations are given that ensure that are needed in the construction to reach the calculated result.

2.1. PHPP input for 4 different models

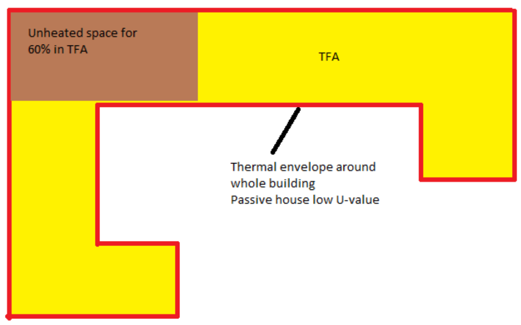
The concept of the building is 'house in house'. In PHPP it is not directly possible to take the effect of a buffer space inside the thermal envelope into account. Therefore we made four different models, in which the buffer space was taken into account in different ways.

The most parameters are the same in all the models. The basic parameters, which are the same in every model, are shown in table 2. They differ in the treated floor area, total thermal envelope area and heated volume. The different models and there results are described in figure 3.

It is important to notice that we chose to model the building as a residential building. In PHPP it is not possible to enter different functions in the same building. In the first floor there will be a school function. So, this part of the building will have a different user type and higher internal gains. It is assumed that the result for the PHPP can be used on the first floor, although there is a different user type. With the school in a part of the building the internal heat gains will be higher, and thus the heating demand will be lower. Special attention should be paid for the overheating in summer, because the PHPP for residential will give a underestimation for this value.

Parameter name	**Parameter value**
Location / climate	Trondheim, Norway
Building function	Residential
Thermal bridges	"thermal bridge-free"
Pressurization test result	0,6 h-1

Table 2 Basic parameters for each PHPP model

<table>
<tr><th>Model 1: Reduction for TFA</th><th>Model 2: Reduction in U-values</th></tr>
<tr><td>


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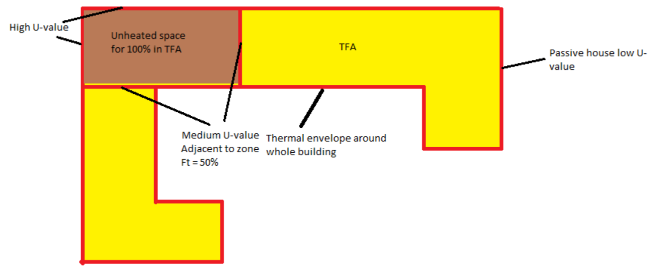
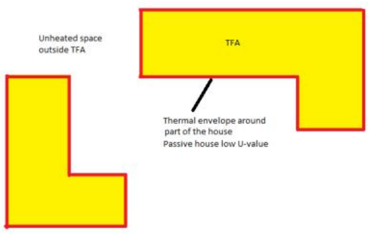


</td></tr>
<tr><td>Model:
- Thermal envelope around the whole building
- Low U-value around the whole building
- Bufferspace for 60% in the TFA (heated)</td><td>Model:
- Thermal envelope around the whole building
- Different U-value for components around the bufferspace
- Bufferspace for 100% in TFA (heated)
- Extra walls between bufferspace and the rest of the building with a reduction factor</td></tr>
<tr><td>Results:
- Heating demand: 37865 kWh (15 kWh/m2a)
- Primary energy demand: 56 kWh/m2a</td><td>Results:
- Heating demand: 44499 kWh (16 kWh/m2a)
- Primary energy demand: 57 kWh/m2a</td></tr>
<tr><td></td><td></td></tr>
<tr><th>Model 3: Unheated space outside</th><th>Model 4: Unheated space outside, reduction factor</th></tr>
<tr><td>


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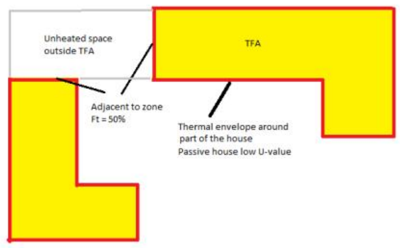

</td></tr>
<tr><td>Model:
- Thermal envelope around heated area
- Bufferspace outside TFA (unheated)
- Low U-values for building components</td><td>Model:
- Same as model 3, but the walls adjacent to the bufferspace have a reduction factor 50%</td></tr>
<tr><td>Results:
- Heating demand: 47923 kWh (24 kWh/m2a)
- Primary energy demand: 58 kWh/m2a</td><td>Results:
- Heating demand: 47302 kWh (23 kWh/m2a)
- Primary energy demand: 57 kWh/m2a</td></tr>
</table>

Figure 3 Schematic view of different models

2.2. PHPP results and conclusion

The results from the models are summarized in the following graph, with two y-axes. On the first y-axis the total annual heating demand is given. On the second y-axis the heating demand per square meter heated floor area is given.

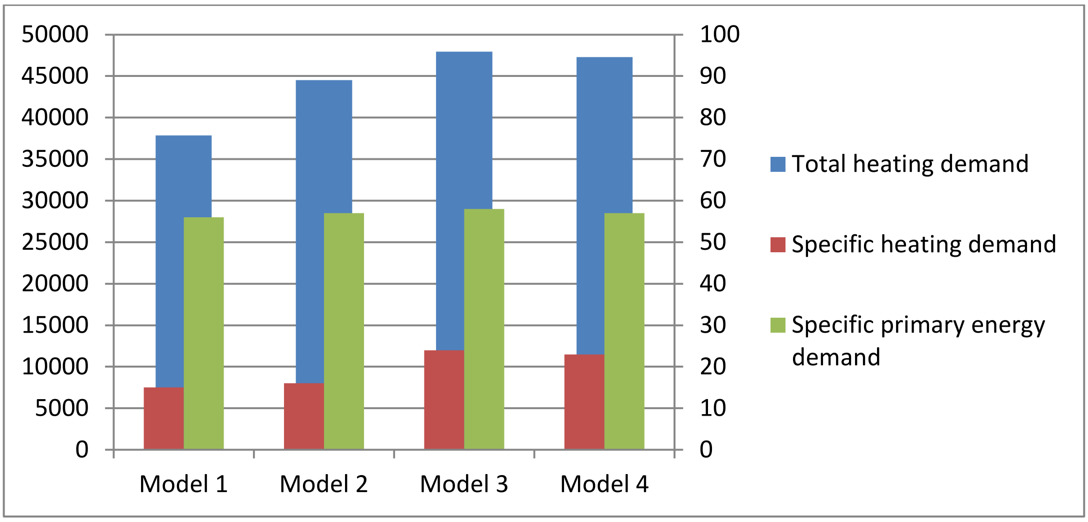

Figure 4 Summary PHPP results for different models

As shown in figure 4**,** model 1 gives the best result, followed by model 2, 4 and 3.

Because the building site is given, and the form factor is not so good for this building, the best result will be reached by exploiting as much space as possible. According to this PHPP it is the best to have a good U-value around the whole building, simply because you exploit more TFA space compared to the losses area. This is also shown in model 1. But this model 1 is in contrast with the architectural concept 'house in house', where the unheated space plays a role as a buffer space, capturing heat losses.

The difference in model 3 and 4 (giving a reduction factor for walls adjacent to the unheated space, and thus giving a reduction in energy demand) shows that the unheated space has at least a positive impact on the total energy demand. The energy demand in this model is much higher than in model 1 and 2, because the solar gains for the large south facing window (10m x 14m) covering the whole buffer space are not taken into account for this model.

Model 2 shows that the real situation (with higher U-values for the unheated space walls) still gives a good result. But in model 2 the whole TFA for the buffer space is taken into account, which is not the real case.

In the end, all the models are not exactly true. Model 1 (and 2) sees the unheated space as heated (over exaggerating the thermal comfort and thermal gains), while model 4 (and 3) see the unheated space as outside space (over exaggerating the thermal discomfort and thermal losses). Model 2 gives the U-values that are closest to reality, and the result is still relatively good. So, the conclusion would be that the result should be in between the values of model 1 and model 4, but closer to model 1.

3. Quality assurance and production documents

In this chapter we will describe the needed installations and U-values to reach the calculated PHPP-limit value. It is possible to change materials in correspondence with the contractor, but it is important to keep an eye on the functional values, because the overall output should be the same. For example if you choose a glazing type with a lower U-value, the heating demand will go down, but the overheating and cooling demand can go up. On the other hand, if you change the glazing types, but the functional values will stay the same, then the outcome will also stay the same.

First, in table 3, the current build-up of the building components are given, together with the U-value. Second, in table 4, the glazing properties are given.

Building component	Current build-up, until ventilated air gap	U-value in PHPP [W/m2K]
Masonry wall (401mm)	- Gypsum board 15mm - Air space 11mm - (Old) masonry wall 200mm - Timber frame element with polyurethane insulation 125mm - VIP panels 50mm	0,059
Wooden wall (268mm)	- Gypsum board 15mm - Air space 3mm - Three layers timber frame element with polyurethane insulation 250mm	0,128
Roof (268mm)	- Gypsum board 15mm - Air space 3mm - Three layers timber frame element with polyurethane insulation 250mm	0,128
Ground floor (415mm)	- Interior finish 15mm - Concrete 100mm - Two layers polyurethane insulation 300mm	0,075
Wall heated space – bufferspace	- Insulation 200mm	0,167
Wall outside air – bufferspace	- Insulation 150mm	0,224

Table 3 Building components used in PHPP

Glazing	Properties
Glazing type	- g-value: 0,5 - U-value: 0,6 W/m2K
Frame type	- U-value: 0,72 W/m2K - Frame dimensions: 0,14m (each direction) - Thermal bridge spacer: 0,04 W/mK - Thermal bridge installation: 0,04 W/mK

Table 4 Glazing components used in PHPP

Besides the U-values of the walls and glazing, it is also important to ensure the quality of the installations. These are given in table 5.

Installation type	Current choice	Properties
Heat exchanger	- Thermos 200 DC – Paul	- Efficiency: 92% - Electrical efficiency: 0,36 Wh/m3
Solar thermal collector	- 100m2 Vacuum tube collector - Oriented on the south, vertical - Stratified solar thermal collector with DHW heat exchanger	- Contributes for 45% to DHW production (model 1) - Contributes 39388 kWh/a to useful heat (model 1)
DHW distribution system	- Pipes inside the thermal envelope	
Heating distribution system	- Pipes inside the thermal envelope	

Table 5 Installation components used in PHPP

Finally, all the other aspects that need quality control are given in table 6**.** These aspects contain properties that do not depend on the work of one person, or the characteristics of a building component. These quality aspects need to be taken into account during the whole construction and planning process.

Other aspects for quality control	Properties
'Thermal-bridge-free'-construction	In PHPP it is assumed that all building details will have a thermal-bridge-coefficient lower than 0,04 W/mK (measured with exterior dimensions). This is called 'thermal-bridge-free construction'. This quality property asks for good building detailing and construction.
Air tightness	0,6 h-1
Air change rate	0,5 h-1
Summer air change rate	Infiltration: 0,5 h-1 Manual night ventilation: 0,5 h-1
Shading	In PHPP it is assumed that the wind protection coefficient is moderate (0,07). Besides this it is assumed that there is no extra shading from trees around the house. So, it is important that the existing surroundings stay the same, or the PHPP should be updated.
Primary energy source	In PHPP the final primary energy source is set to 100% district heating.

Table 6 Other aspects for quality control

4. Evaluation of changes compared to assignment 1

In chapter 3 a description is given about the new quality assurance plan, based on the PHPP models and the final design, as described in chapter 1 and 2. There are some changes in the energy budget and the quality assurance plan that is made before the design process started. In this chapter we will elaborate on the changes.

First the main goals as set in assignment one were slightly changed. The first goals (comply with NS3700) is changed into comply with the German Passive House Standard. In the final stage of the project PHPP is used to verify the energy demand. In this software program it is only allowed to use the German Passive House Standard. This standard sets slightly higher demands than the Norwegian standard, so the change is not from a big influence.

The second goal was to reduce the CO2-emissions on site. Because there was no assessment of the CO2-emissions made during the design process, this goal is changed into 'reuse as much of the elements in the existing building as possible'. In this way the reduction of CO2-emission can be done in a more qualitative manner, instead of calculating all the CO2-emissions.

In the final design this reuse expresses itself in the following way:

- Keep the existing wooden structure in bufferspace
- Keep the masonry in the walls and reuse it as thermal mass
- Keep parts of the wood in the façade as external cladding
- Reuse part of façade in the garden as sun shading
- All the wood that is left, will be delivered to the community as firewood

Then, in table 7 on the next page, a comparison is given between the values in assignment 1 and the new quality control plan. Basically all changes are due to new insight in the design process and changed floor plans. Also, some U-values and efficiency-rates had to be changed, because otherwise the goal of the passive house could not be reached.

Parameter	Assignment 1 value		Assignment 3 value	
	Project report 42/ TEK10	*Chosen*	*Updated (in model 1)*	*Reason*
Heated area	N/A	3589,5 m2	2451,7 m2	Plans changed. In assignment one the assumption was made that all floors would be used. In the final design the buffer space has large multistory rooms, which reduce the TFA.
Heated volume	N/A	9764 m3	8262 m3	A more detailed calculation showed this result. Not so much difference, because the volume did not change so much
Air leakage	0.6 h-1 / 1.5 h-1	0.5 h-1	0,6 h-1	0,6 h-1 seemed to be sufficient
Thermal bridge value	0.3 W/m2K / 0.6 W/m2K	0.03 W/m2K	0	Assignment 1 was made with SIMIEN, which calculates according to the Norwegian Standard. Assignment 3 was made with PHPP (German standard)
U-values walls	0.15 W/m2K / 0.18 W/m2K	0.09 W/m2K	0,06 – 0,08 W/m2K	More insulation seemed necessary. New wall build-up
Floor basement	0.15 W/m2K / 0.18 W/m2K	0.14 W/m2K	0,08 W/m2K	More insulation seemed necessary. New wall build-up
Window	0.8 W/m2K / 1.2 W/m2K	0.7 W/m2K	0,7 W/m2K	No change
Door	0.8 W/m2K / 1.2 W/m2K	0.7 W/m2K	0,7 W/m2K	No change, in PHPP the doors are calculated as windows.
Efficency heat exchanger	80 % / 80 %	86 %	93	93% necessary according to PHPP
SFP-factor	1.5 kW/m3s	1,5 kW/m3s	1,5 kW/m3s	No change
Lighting	1,95 W/m2	1,95 W/m2	1,95 W/ m2	No change
Technical equipment	3,00 W/m2	3,00 W/ m2	3,00 W/ m2	No change
Hot water	5,10 W/m2	5,10 W/ m2	5,10 W/ m2	No change
Heat distribution	N/A	Hot water	Hot water	No change
Heat supply users	1,50 W/m2	1,50 W/m2	1,50 W/m2	No change

Table 7 Comparison of quality values between assignment 1 and assignment 3

5. Commissioning and monitoring plan for owner or contractor

In chapter 5 and 6 the follow up for this design will be described. Because of time limits, this is done in a general way. Chapter 7 and 8 from 'SINTEF projesktrapport 56: Guidelines for energy efficiency concepts in office buildings in Norway' by Haase, Buvik, Dokka and Andresen is used as a guideline for this report.

5.1 Commissioning

In the follow up, the quality plan as described in chapter 3 should be carefully taken into account. In the next phases of the project a contractor and craftsmen have to be selected that want to participate in constructing the building with the high quality demands. It is possible to use the knowledge of the contractor and the craftsmen to get a better result with lower lifecycle costs, but the functional values in the quality plan should always be the main reference. If you change these values, the energy budget can also be changed.

It is important to spend time on checking the references from the builder. The SINTEF report tells on page 14, that there are incidences, where a builder wants to get involved in an environmental friendly building, instead of having real practical experience. Having the right experience is important in all phases of the building planning, so also the constructional phase.

5.2 Monitoring plan

Most parts of the quality control plan are straightforward and can be monitored by using certification. Special attention should be paid on the avoidance on thermal bridging and air tightness. These values are influenced by many persons in the design process. The air tightness can be measured after the construction phase with a 'blower door test', but it is hard to correct the results, so also during the follow up in the planning phase the overall thermal bridge values and air tightness should be taken into account.

It is important to monitor the actual energy consumption after the construction, in comparison with the calculated energy demand in PHPP. This should also be done one year after completion of the building, because then the users are familiar with the building and the real energy usage, with real user patterns can be measured.

6. Construction and operating strategies plan

For the construction, it is important to comply with the advices as described in chapter 5 and to comply with the quality control plan in chapter 3. For the operating, there are several strategies that can be followed, and strategies that follow from the quality control plan:

Operating strategies that should be followed from the quality control plan:

- Use of manual night ventilation to reduce summer overheating
- No planting of new large trees close to the building, to avoid a loss of internal gains
- Use of energy efficient electrical appliances
- Selection of district heating as primary energy source

Operating strategies that can be implemented to reduce the energy consumption (SINTEF report 56):

- Smart energy information technologies, like demand controlled ventilation, lighting or other equipment
- Give (live) feedback on the energy consumption to raise awareness