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AAR4817Design for Zero Emission Building

The Impact of Renewable Energy Supply Systems for Designing Non-domestic Passive Houses in the Progress towards Net Zero Energy Buildings

-With the help of BREEAM Europe energy efficiency issue

Summary

The essay analyzes a further step above the energy efficiency of the building (which is considered as the base line towards Zero Energy Building) to consider the impact of renewable energy supply systems for designing non-domestic low energy building in progress towards net Zero Energy Building (net ZEB). The aim of the essay is to assess that the minimization of delivered energy and CO_2 emissions considerations should go in parallel for developing net ZEB. The essay consists of two parts: theory and case study. To be specific, the essay focuses on comparing different renewable energy supply options to evidence that the choice of renewable energy supply systems have significant impact on delivered energy and CO_2 emission reduction.

Keywords: *energy efficiency; renewable energy supply systems; net ZEB; delivered energy; CO_2 emissions*

1. Introduction

The research topic of the essay is whether the choices of renewable energy supply systems have a significant impact for developing a non-domestic low energy building in progress towards a net ZEB.

The aim of the essay is to assess the minimization of delivered energy and CO_2 emission considerations should go in parallel for developing net ZEB.

The goal of the essay is to analyze how different renewable energy supply options can affect the reduction of delivered energy while not contributing to increase of CO_2 emissions. To evaluate how much further a low energy building has been progressing towards a net ZEB can be assessed by BREEAM Europe energy efficiency issue (Ene 1) [1, 101].

<u>Research Question</u>

Constructions are one of the largest "consumers" of man-made materials flows. It also consuming energy during its operational period and continuously extended to the end of its life – dismantling. Construction provide material base for our daily activities and working environment. If we can assume that climate change is the direct outcome of human activities, then the reduction of building energy consumption should be considered initially. It leads to design of low energy buildings in order to reduce energy use and mitigate CO_2 emissions which are the main portion of green house gas emissions. And further development results in passive house concept with strict limitation of heating and/or cooling demands.

The passive house concept in terms of energy efficiency has assumed a leading position in Europe [2, 17]. In late 2010, this type of construction comprised buildings with over seven million square meters usable area in all Europe. The book "Net Zero Energy Buildings" [2, 12] states: *In Europe, zero energy buildings are considered the logical continuation of a long chain of developments from low-energy houses towards passive houses.* So a ZEB is a passive house whose annual energy consumption and related CO_2 emissions have been completely balanced. This understanding of ZEB also leads to an important issue that a net ZEB should be primarily energy-efficient building. The importance of energy efficiency has been already broadly recognized. The book also states: *Many architectural, structural and technical equipment designs for constructing new, energy-efficient buildings…are already tried and tested.* So it is not hard to imagine why the building sector has been pushing forward from low energy buildings to ZEB. This awareness of energy efficiency has also brought into some current ZEB understanding, such as Torcellini et al. [3, 3]: *ZEB is a residential or commercial building with greatly reduced energy needs through efficiency gains such that the balance of energy needs can be supplied with renewable technologies.*
For the step after being energy efficient, the renewable technologies become the critical points in terms of energy efficiency and CO_2 emissions.

So an initial question has arisen*: do renewable energy systems have impact on energy and CO_2 emissions reduction on the path towards a ZEB from a low energy building?*

Considering the energy consumption from commercial building category is about 60% of the electricity use in Norway. So the scope of the essay has been limited to the office building category. And the renewable energy supply systems have been limited to the combination of three options:

- **Option 1:** utility grid and district heating
- **Option 2:** utility grid and biofuel boiler
- **Option 3:** electricity from photovoltaic (PV) + utility grid exchange and solar thermal collector + ground source heat pump

In order to prevent a local on site storage, the utility grid has been chosen as the feed-in system when on-site production of electricity is exceed.

The research question has been formed based on the information stated above:

Do renewable energy systems have significant impact on delivered energy and CO_2 emissions reduction on the path towards a net ZEB from a low energy building?

<u>Method</u>

The essay is based on theoretical analyses and case study. Theoretical analyses mainly focus on the question why we need to think about CO_2 emissions in parallel with delivered energy of renewable energy supply systems. And then green building certification system – BREEAM has been introduced as a guideline for helping on comparing design options in terms of energy reduction.

In the case study, three options have been calculated respectively with their delivered energy and CO_2 emissions from energy production. In the last stage of the case study, the delivered energy from three options have been assessed according to BREEAM Europe energy efficiency issue (Ene 1) in order to find out the better solution in terms of energy improvement percentage from the national regulation [1, 101].

2. Consideration of Renewable Energy Supply Systems for Net ZEB

This chapter is intended to discuss that after achieving energy efficiency, the choices of renewable energy supply systems will be the important factor influencing the CO_2 emissions of a Net ZEB. Firstly passive house concept and the realization of being energy efficient have been introduced. And the second part aims at describing renewable energy supply systems options and finding out the importance of renewable energy supply systems decision in terms of CO_2 emission. At last, green building certification systems – BREEAM energy efficiency issue (Ene 1) has been introduced as a design guideline [1, 101].

2.1 Being Energy Efficiency as the Base Line towards Net ZEB

The climate is in the progress of warming due to the man-made greenhouse emissions of which CO_2 emissions contain most percentage. These climate changes lead the building sector to a serious of new challenges on: energy needs, environmental technologies and etc. There is a significant potential to reduce CO_2 emissions through improving energy performance of the buildings. The realization of the challenges has been extended into both continental and national. In EU Commission has formulated its 2020 target of a 20% reduction in energy consumption mainly through energy efficiency [4, 1]. And among EU member states, countries propose a comprehensive description of the progress towards very low energy buildings. For instance, Norway has pointed out as a major strategy in cutting CO_2 emissions while proposed passive house standard as the minimum energy performance from 2017[4, 4]. The passive house concept is a successful measure to reduce energy use in buildings. Its definition originally came from Germany: *a passive house is a building, for which thermal comfort can be achieved solely by post-heating or post-cooling of the fresh air mass, which is required to fulfill sufficient indoor air quality conditions - without a need for additional recirculation of air* [5, 5].

In the Norwegian context, the primary requirement for passive house is on the net heating needs (space heating); secondary requirements for overall heat losses and renewable energy share of heating and domestic hot water and the minimum requirements are for components and supply systems [6, 6]. Passive house standard NS3700 for residential building appears first in Norway and still under the development [16]. Since commercial buildings concerned consume 60% electricity in Norway, the development of non-domestic building passive house criteria has been also carried out - *Kriterier for Passivehus-og Lavenergibygg-Yrkesbygg (Prosjekrapport 42)* [7]. For a passive house, operational energy use is reduced through passive measures, such as extra insulation for the building envelope, the use of high performance windows and doors and utilization of solar energy and heat recovering from the ventilation. Applying these high energy efficiency measures can help secure energy and carbon savings through the lifetime of the building. This is because these energy efficiency measures are mainly part of building's fabric and they should have a longer life span than energy supply technologies. In the same time, the efficiency of the building service systems has been also required and taken into consideration in the national building energy calculation method NS3031 [14].

Furthermore, a passive house with a complete balanced annual energy consumption and related CO_2 emissions is called ZEB. A clear definition of ZEB has not been achieved. There are various understandings of ZEB. Torcellini et al. [3, 3]: *ZEB is a residential or commercial building with* *__greatly reduced energy needs through efficiency gains__* *such that the balance of energy needs can be supplied with renewable technologies.*

So we can clearly recognize that a ZEB is primarily energy efficient building.

2. 2 Renewable Energy Supply Systems for Designing Low Energy Buildings towards Net ZEB

Energy efficiency has been already realized as the first step towards ZEB and passive house standard development has been widely spread in many countries in EU in the past few years. In order to achieve the balance of energy needs, renewable energy system should be supplied, see Figure 1.

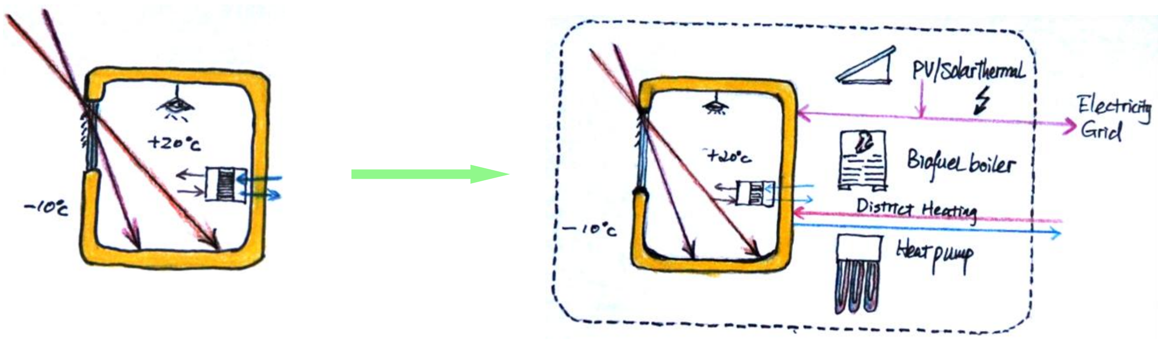

Figure 1: From low energy building towards ZEB with different renewable energy supply systems.

And the renewable sources can be available on the site e.g. sun, wind. It can also be transported to the site e.g. biomass. So we can say there are two types of renewable energy supply options existing: on-site and off-site. “Zero Energy Building – A Review of Definitions and Calculation Methodologies” [13] mentioned: *…the nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby.* Torcellini et al. [3, 5] are one of the first to propose more detailed discussion within above mentioned supply options. They provide ZEB supply-side options respectively to on-site and off-site supply options. For the off-site supply, they proposed that building either uses renewable energy sources available off-site to generate energy on site, or purchases off-site renewable energy sources. For the on-site supply, it consists of two sub-options: using renewable energy sources available within the building foot print, or use renewable energy sources available on site. Torcellini et al. [3, 5] also gives examples of preferred application of renewable energy sources such as PV, solar hot water, biomass and etc, see Table 1.

“From Net Energy to Zero Energy Buildings: Defining Life Cycle Zero Energy Buildings (LC-ZEB)” states [8, 3]: *in current practice, the most common approach to ZEB is to use the electricity grid both as a source and a sink of electricity, thus avoiding the on-site electric storage systems. The term ‘net’ is used in grid connected buildings to define the energy balance between energy used and energy sold, the term ‘net-zero energy’ being applied when the balance is zero.*

Option no.	ZEB supply-side options	Examples
0	Reduce site energy use through low-energy building technologies	Daylighting, high-efficiency HVAC equipment, natural ventilation, evaporative cooling, etc.
On-site supply options		
1	Use renewable energy sources available within the building's footprint	PV, solar hot water, and wind located on the building
2	Use renewable energy sources available at the site	PV, solar hot water, low-impact hydro, and wind located on-site, but not on the building
Off-site supply options		
3	Use renewable energy sources available off site to generate energy on site	Biomass, wood pellets, ethanol, or biodiesel that can be imported from off site, or waste streams from on-site processes that can be used on-site to generate electricity and heat
4	Purchase off-site renewable energy sources	Utility-based wind, PV, emissions credits, or other "green" purchasing options. Hydroelectric is sometimes considered

Table 1: Torcellini et al. proposed ZEB renewable energy supply option hierarchy.

In this essay, the phase - net ZEB will be used. The net ZEB might have the connection to different energy infrastructure; electricity grid, district heating and etc. So it has the possibility of feeding in excess energy production on site and purchasing energy from the energy infrastructure when the production and demands are mismatched. But due to different energy qualities between exported and imported energy, the utility grid is often in a worst case than the building. An example could be the Norwegian electricity grid. Norway has a very long history of hydropower generation. It is considered much greener than other countries. But in the case of importing electricity from European mix grid when the Norwegian production cannot meet the national needs, the CO_2 factor (g/kWh) will be increased. By supplementing with renewable energy, such as solar collectors, solar cells, heat pump or biofuel can help for reduction of CO_2 emissions from delivering the operational energy (certainly, it should also be variable from case to case).

Therefore, on the path towards a net ZEB from a low energy building, renewable energy supply systems will also influence the reduction of CO_2 emissions. They should also be tailored for each individual situation. And some environmental assessment methods such as BREEAM can work as a guideline in the project planning phase to promote energy efficiency of the building and encouraging the choice of renewable energy systems with lower CO_2 emissions from the energy production.

2. 3 BREEAM as a Guideline

BREEAM is the first green building certification system which was published in the UK. The system is being applied in different countries worldwide, such as Norway, Netherlands, Sweden and etc. BREEAM International has been developed for buildings outside UK and includes three different versions:

- BREEAM Gulf (all kinds of buildings within gulf region)
- BREEAM Europe (office and retail buildings)
- BREEAM Communities (urban development)

Due to the language problem, BREEAM Norway will not be chosen as the discussion object. BREEAM Europe commercial building [1] has been chosen as a guideline in this case. Its assessment process has two stages: design and procurement; post construction. And it has the same rating benchmarks as other schemes: unclassified, pass, good, very good, excellent and outstanding. The various assessment sections and their weightings have been shown in Table 2 [1, 37]. The energy section has the biggest weighting and contains 9 indexes.

BREEAM Section	Weighting (%)	
	New builds, extensions & major refurbishments	Building fit-out only
Management	12	13
Health & Wellbeing	15	17
Energy	19	21
Transport	8	9
Water	6	7
Materials	12.5	14
Waste	7.5	8
Land Use & Ecology	10	N/A
Pollution	10	11
Innovation	10	10

Table 2: BREEAM Europe 2009 assessment weighting and environment weighting.

According to the scope of this essay, only the energy efficiency issue (Ene1) in the energy section will be discussed here. The aim of the energy efficiency issue is to recognize and encourage buildings that are designed to minimise their operational energy consumption. There are three options of assessment criteria in energy efficiency issue (Ene 1):

- Option 1: determination of the energy performance of the building using the national calculation methodology.
- Option 2: determination of the energy performance of the building using a dynamic simulation modelling tool.
- Option 3: Energy design features where there is no operational national energy calculation methodology in the country of assessment.

Since in this case, the Norwegian passive house criteria for non-domestic building can be applied, option 1 can be used to determine the energy performance of the building [7]. In order to find out the credits achieved for this issue, the percentage improvement over the requirements of local building regulations has to be defined. Here is an example from BREEAM Europe [1, 102]: *calculation the percentage improvement of the actual Building Energy Performance Index (BEPI) over the Current Standards Building Energy Performance Index (CSBEPI), so the improvement as percentage can be expresses as:*

(CSBEPI- BEPI)/ CSBEPI x 100 = improvement (%)

This simplified calculation method of percentage improvement over the requirement of local building regulation can be a very good method for the designers to check how good the building performance is. And it will encourage designers to design the building with the base of energy efficiency and to choose higher efficiency energy supply systems.

The author has to acknowledge that there is an issue in BREEAM energy sections called low or zero carbon technologies (Ene 5) which might be also very useful guideline [1, 118]. It contains the consideration such as payback time, land use, local planning, energy generated from low or zero carbon energy source per year, life cycle impact, life cycle cost and etc. Due to the limited size of this essay, this issue will not be brought into the case study in the next chapter. But CO_2 emissions from the energy generation systems will be considered.

3. Case Study: Brøset Klima Center

This chapter consists of three parts. The first part is the introduction of the case. It includes case study parameters, method and limitations. The second part is to analyze three design options in order to evidence the big impact on the choices of renewable energy supply systems for designing a low energy building towards a net ZEB in terms of delivered energy and CO_2 emissions. The last part is the conclusion of the case study.

3.1 Case Description, Method and Limitation

The case is taken from author's Design for Zero Emission Buildings course project work. The project is located in Brøset area, Trondheim, Norway. Brøset area is selected by Trondheim authorities to be developed as a sustainable neighbourhood. And this project is aiming at designing a community centre for different social activities and simultaneously promoting the different sustainable technologies and social aspects of the Brøset area.

The project design work focus on designing different two-floor building blocks with various functions and fully developing the outdoor space in order to create a truly ecological area. Figure 2 illustrates the location plan indicates the outdoor area and the building plans. All the buildings have the orientation of counter clock wise 10° from north.

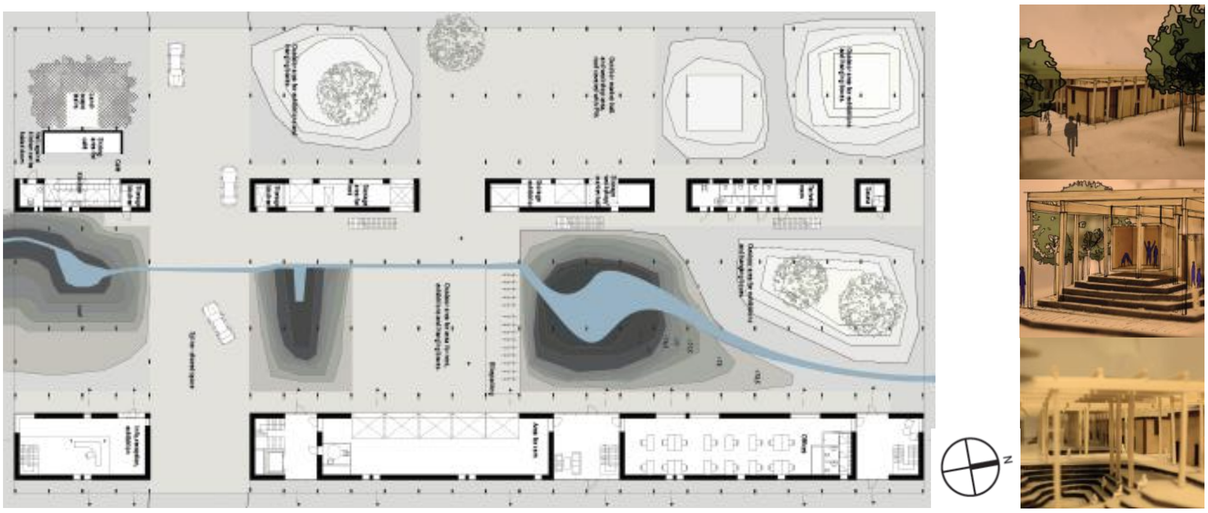

Figure 2: Location plan with building plan and outdoor areas (on the right). Images of the area (on the left side).

The project consists of reception, offices, café, workshop and other functions (sanitary, sauna, and storage rooms). Thermal zones (offices, reception, and café) have been defined for the simulation process, see Figure 3.

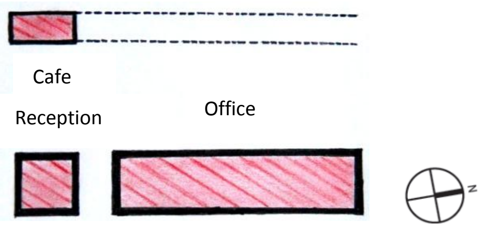

Figure 3: Thermal zones from the project: office, reception and café.

Case study parameters:

Sizes:

- Heated floor area: 542 m^2
- Volume: 3794 m^3

Roof inclination:

- Flat roof with various slope towards roof drainage system
- Stand-alone Photovoltaic (PV) and solar thermal collector with inclination 43°

Standards:

- NS3031 (Norwegian standard) [14]
- NS-EN 15603 (Norwegian standard) [15]

Unpublished non-domestic building passive house standard:

- Kriterier for passivehus-og Lavenergibygg – Yrkesbygg (prosjekrapport 42) [7]

Calculation tool:

- Computer aided: ECOTECT Analysis 2011 for heating demand evaluation
- Manual calculation: according to the standards stated above for delivered energy and CO_2 emission calculation

Method

In this case study, different options of energy supply systems will be compared in terms of delivered energy and CO_2 emissions. The better choices of renewable energy supply systems will be discussed.

In general, the case study has been designed in **two stages**:

- **First stage**: designed according to Norwegian non-domestic passive house criteria [5];
- **Second stage:** three options of energy supply systems will be analyzed based on their respective delivered energy and CO_2 emissions.

More specifically, in the first stage, the energy efficiency measures for building envelope are applied, such as minimizing average U-value (see Attachment 1). Other fixed energy efficiency features:

- Air tightness at 50n Pa: 0.5h^{-1}
- Heat recovery in ventilation system: 83%

In the second stage, three options of energy supply systems are applied:

- **Option 1:** electricity 100% supplied from the national grid (European mixed UCPTE); heating and domestic hot water 100% supplied with district heating (district heating connection is available in Brøset area).

- **Option 2:** electricity 100% supplied from national grid (European mixed UCPTE); heating and domestic hot water supplied with biofuel boiler.
- **Option 3:** electricity from photovoltaic with national grid exchanges; heating and domestic hot water supplied by solar thermal collector and ground source heat pump.

Limitation

Firstly, it should be noted that the building has considered as non-domestic building and designed in order to fulfill the non-domestic building passive house criteria [7]. And there is no available data for required delivered energy in these criteria. The delivered energy requirement is referred from Norwegian energy labelling “A” office category maximum figure – 84kWh/m^{2}a [9, 45].

Secondly, in the following case, the heating demand has been simulated from ECOTECT Analysis 2011 which is not the simulation tool required in the Norwegian context. The tool called SIMIEN has to be used for the energy calculations. Due to the language problem, the required tool cannot be used in this case. But author thinks the result will not have too many differences and a significant influence on the analysis result. The aim of this case study is to further evidence that the choice of renewable energy supply systems should be considered both from delivered energy and CO_2 emissions point of view.

Thirdly, only three options of renewable energy supply systems have been analyzed in this case study. There are various other options can be used to discuss. More precisely, there are more combinations can be analyzed. For instance, the combination of biofuel boiler and PV + utility grid; PV + utility gird and district heating; full electricity supply for heating and electricity demand with PV + utility grid. And it could also be the utilization of wind power. Brøset area is considered as the place where almost constantly receives winds. Author believes that there might be an interesting result from i.e. the combination of wind power and biofuel boiler, since the wind turbine systems has 100 in efficiency factor and 20g/kWh in CO_2 factor [10, 11, 15].

3.2 Calculation Results and Discussion

In order to achieve a passive house standard primary requirement of heating demand in Norway, the energy efficiency measures have been carefully selected as stated in the previous section. Specific heating demand is 25kWh/m^{2}a from the simulation result in ECOTECT Analysis 2011. Annual energy budget is calculated according to NS3031 [14]. The specific annual energy demand is ca. 50kWh/m^{2}a, see Table 3.

Annual Energy Budget	heat		electricity		total
	Net energy demand [kwh/a]	Specific energy demand [kwh/(m^{2}a) (542m^2)]	Net energy demand [kwh/a]	Specific energy demand [kwh/(m^{2}a)(542m^2)]	
heating	10840	20.00			
domestic hot water(DHW)	2710	5.00			
fans					
pumps			1523.02	2.81	
lighting			8455.2	15.60	
technical equipment			3382.08	6.24	
sum	13550		13360.3		26910.3
		25.00		24.65	49.65

Table 3 : Annual energy budget of the case.

In order to find out a relatively better solution for energy supply in this case, three options have been proposed here with their respective efficiency factors and CO_2 factors, see table 4. And CO_2 emission factors are taken from various documents [10, 11, 15].

Supply Systems	Option 1	Option 2	Option 3
Supply of heating and hot water	District heating	Biofuel boiler	Solar thermal collector/heat pump
Efficient factor	0.84	0.84	8.55/2.34
CO_2 factor (kg/kWh)	0.231	0.014	0.051/0.472
Supply of electricity	National grid	National grid	PV/national grid
Efficient factor	0.98	0.98	100/0.98
CO_2 factor (kg/kWh)	0.617	0.617	0.130/0.617

Table 4: Different options of energy supply system and respective efficient factor and CO2 emission.

Calculated with 542m^2 heated floor area	**Specific Calculation Methods**	**Option 1**	**Option 2**	**Option 3**
Specific heating demand (kWh/m^{2}a)	Ecotect Autodesk simulation tool	25	25	25
Annual energy demand	NS3031, P29, formula (39)	50	50	50
Delivered energy (kWh/m^{2}a)	1. Delivered energy of district heating, equipments, lighting, ventilation 2. Calculated according to NS3031, P31-32, formula (40,41,42,43,44,45,46)	72	72	31
CO_2 emission (kgCO_2/m^{2}a)	1. CO_2 emission from district heating and electricity use 2. Be attention that the electricity CO_2 factor is taken as EU Electricity mix UCPTE	26	16	19

Table 5: Delivered energy and CO_2 emission of three different options.

Expressing the figures in Table 5 into column chart, the differences among three options in terms of delivered energy and CO_2 emissions became clear, see Figure 4.

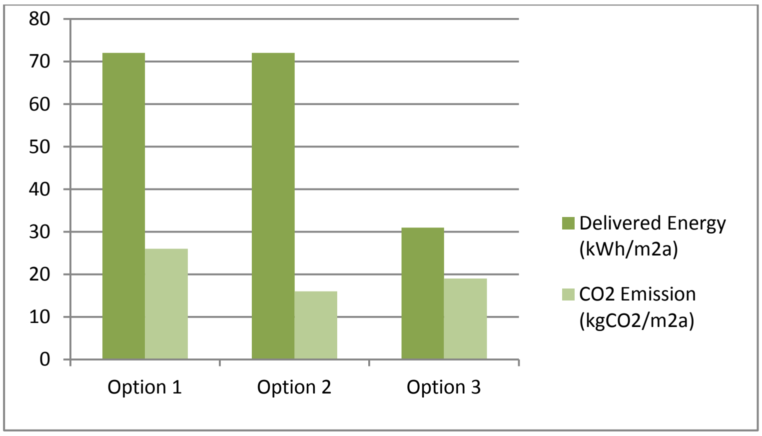

Figure 4: Delivered energy and CO_2 emission comparison among three options.

According to the calculations stated above, in option 1, 100% heating and domestic hot water supplied by district heating have 72kWh/m^{2}a in delivered energy. In option 2, 100% biofuel generating heat and supplying domestic hot water result in the same delivered energy as option 1. And in option 3, heating demand covered by solar thermal collector and ground source heat pump, electricity covered by PV have significant reduction on delivered energy than both option 1 and 2. The reason for this result is high efficiency of PV system.

So in option 3, the biggest portion of delivered energy saving comes from electricity generating system.

In option1, the total CO_2 emissions from generating operational energy use are $26kgCO_2/m^2a$ which is actually much higher than in option 3. This is due to the higher CO_2 factor of district heating in comparison with the systems in option 3. The electricity is fully covered by utility grid is also one of the reason for higher CO_2 emissions from option 1. And even though option 2 has much higher delivered energy, CO_2 emissions are lower than the one in option 3. Finally, option1 and 2 results with same delivered energy, but option 2 has ca.38% of CO_2 emissions reduction from option1.

Now we can use BREEAM as a guideline to evaluate the options in order to discuss and find out a better solution. In order to find out the credits which the case can get from BREEAM Europe Ene 1 - Energy efficiency issue, the percentage improvement over the requirements in Norway should be defined:

- **Option 1:** requirement = $84kWh/m^2a$, actual delivered energy = $72kWh/m^2a$, so the improvement as percentage = (84-72)/84 = 14.3%.
- **Option 2:** the same as option 1
- **Option 3:** requirement = $84kWh/m^2a$, actual delivered energy = $31kWh/m^2a$, so the improvement as percentage = (84-31)/84 = 63%.

Seen from Table 6 [1, 102], options 1 and 2 can receive 5 credits and option 3 can receive 12 credits.

BREEAM Credits	New buildings	Refurbishments
1	1%	-50%
2	3%	-32%
3	5%	-20%
4	7%	-9%
5	11%	0%
6	15%	8%
7	19%	15%
8	25%	21%
9	31%	28%
10	37%	36%
11	45%	45%
12	55%	55%
13	70%	70%
14	85%	85%
15	100%	100%
Exemplar credit 1	*Carbon neutral building*	
Exemplar credit 2	*True zero carbon building*	

Table 6: Percentage improvement over the requirement of local building regulation.

From the delivered energy point of view, option 3 is obviously the best solution in this case. And BREEAM is not only act as a guideline for the designers for comparing the design options. Looking at the improvement percentage, the designers can also realize that the efficiency of the renewable energy supply system and also the combination of different systems have great impact on the further energy reduction from a passive house standard. Comparing the percentage improving or the achieved credits with the level of Carbon neutral building (exemplar credit 1) and True zero carbon building (exemplar credit 2) in Table 6, designers can see how far the building should be developed further in order to achieve a higher goal.

3.3 Case Study Conclusion

In this case study, three options of renewable energy supply systems have been analyzed. The delivered energy from option 3 is much lower than the other options. The CO_2 emissions are higher than in option 2. But in general, option 3 is the best choice due the overall performance (delivered energy and CO_2 emissions).

CO_2 emissions from different renewable energy supply systems are quite critical in this case. Delivered energy in option 3 is 57% lower than in option 2, but option 2 CO_2 emissions are lower than option 3 (even though the different is not much by looking at the specific number). This is because CO_2 factor of biofuel boiler is much lower than the solar thermal collector and heat pump. And solar thermal collector and heat pump has higher efficiency than biofuel boiler. So it seems the renewable energy supply systems in this case can still be improved by other combination of options, just like mentioned in the limitation section above.

From this case study, it is easy to realize that both efficiency and CO_2 factor should be taken into consideration when choosing the renewable energy supply systems. During the design phase, BREEAM energy efficiency issue is a good tool for assess the different design options. As mentioned in section 2.3, the issue of low and zero carbon technology (Ene 5) will not be discussed in this essay. But those two issues have a great potential on helping and/or reminding the designers for choosing renewable energy supply systems with the consideration of both system efficiency and their CO_2 factor.

For developing a low energy house towards a net ZEB, under the help of BREEAM energy efficiency issue, the designers can analyze and compare different design options. Looking at the improvement percentage, the designers can also realize that the efficiency of the renewable energy supply system and also the combination of different systems have great impact on the further energy reduction from a passive house standard.

4. Conclusions and Future Work

<u>Conclusions</u>

The research question of this essay is:

Do renewable energy systems have significant impact on delivered energy and CO_2 emissions reduction on the path towards a net ZEB from a low energy building?

It has been investigated through the theoretical analyses that a ZEB should be primarily energy efficient. This consensus has been broadly recognized. And in order to further develop low energy house towards passive house with complete balanced annual energy consumption and related CO_2 emissions (ZEB), renewable energy supply systems became critical. Different renewable energy supply options and systems for a net ZEB have been introduced. Theoretical evidence shows that the choice of the system has a direct impact on designing a lower energy house towards a net ZEB. And in this situation, green building certification system such as BREEAM can be used as a guideline to help designers with comparison of different design options and encouraging the project design towards a net ZEB.

The case study has further evidenced that the choice of renewable energy supply systems have a significant impact for developing a non-domestic low energy building in the progress towards a net ZEB. From the case study we can observe that both efficiency and CO_2 factor should be taken into consideration when choosing the renewable energy supply systems. Furthermore, BREEAM energy efficiency issue (Ene 1) has been applied for the case study. It has been found that the method of BREEAM energy efficiency issue is a good tool for assess the different design options. It has a great potential on helping and/or reminding the designer for choosing renewable energy supply systems with the consideration of both system efficiency and their CO_2 factor. And the credits in the issue also make the step towards a net ZEB design clear.

Future Work

The aim of this essay is to analyze the importance of renewable energy supply systems consideration during the progress of designing a non-domestic building towards a net ZEB.

The essay can be the base information about providing the necessary consideration of renewable energy supply systems should be analyzed from both energy efficiency and CO_2 emissions point of view during the design stage. It can be used by environmental project designers to get a quick understanding on the important issues for choosing renewable energy supply systems for a non-domestic low energy building.

Within the field of net ZEB development, this research can be also extended with the information of payback period, consideration of renewable energy supply systems life cycle impact. The author has done a rough calculation for the PV payback period used in the case study option 3:

Assumption [12]: PV systems costs: 5€/Wp (installed power); Constant saved energy costs of 0.8NOK/kWh; 1€ = 8NOK
In the case study, 120m^2 stand-alone PV is needed (see attachment 2). So the system cost will be 478190NOK. Then the payback period will be around 44 years in this case. So considered from a client point of view, it might be difficult to convince him/her to invest on the PV systems even though the designers have a clear idea of how green the PV production systems are.

And the author thinks the essay can be also evaluated by the combination of BREEAM energy efficiency issue and low and zero carbon technology issues in order to get a full perspective from environmental surrounding influences, cost of renewable energy supply systems.

Resources

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Attachment 1

Energy Efficiency Measures – Construction and U-values

Building Components	Construction Description	U-value (W/m^2K)
Ground support floor	40mm in-situ cast concrete floor 100mm In-situ cast concrete floor 300mm (4 x100mm) FOAMGLAS floor board FOAMGLAS separating layer 200mm FOAMGLAS gravel *(Strip foundations have been insulated in the same time for preventing heatlosses through the ground)*	0,08
External wall	226x104x60mm bricks 20mm drainage gap, drainage gutter installed 2x150mm wooden fibre insulation 226x104x60mm local recycled red bricks One layer of white paint Brick inner layer and outer layer is connected with wall ties (every third layers of bricks)	0,12
Window	Brick lintels are using on top of the opening for supporting the bricks NORDAN triple glazing 0,7 windows are used with insulated window frame Windows are located in the insulation layer for preventing the thermal loses	0,7
Roof	Two layers of roofing felt 100mm wedge shaped insulation (various thicknesses for creating slope on the flat roof) 15mm OSB board 300mm glulam timber beam resting on the brick inner wall supported with steel brackets 300mm wood fibre insulation Airtight layer 50mm inner insulation layer lay between the wooden battens 15mm wooden board Suspended wooden ceiling (hanging distance depending on the service duct size)	0,1

Attachment 2:

Performance of grid-connected PV by PVGIS

Location: 63°25'20" North, 10°27'29" East, Elevation: 95 m a.s.l.,

Nominal power of the PV system: 12.0 kW (crystalline silicon)
Estimated losses due to temperature: 7.5% (using local ambient temperature)
Estimated loss due to angular reflectance effects: 3.0%
Other losses (cables, inverter etc.): 14.0%
Combined PV system losses: 22.8%

	Fixed system: inclination=43 deg., orientation=0 deg.			
Month	**Ed**	**Em**	**Hd**	**Hm**
Jan	4.60	143	0.45	14.0
Feb	17.70	496	1.74	48.6
Mar	30.20	936	3.07	95.1
Apr	40.00	1200	4.27	128
May	45.10	1400	4.96	154
Jun	46.00	1380	5.20	156
Jul	41.80	1300	4.75	147
Aug	34.90	1080	3.91	121
Sep	25.70	770	2.75	82.4
Oct	15.80	491	1.62	50.1
Nov	7.10	213	0.71	21.2
Dec	1.14	35.2	0.13	4.02
Year	25.90	786	2.80	85.2
Total for year		9440		1020

Ed: Average daily electricity production from the given system (kWh)
Em: Average monthly electricity production from the given system (kWh)
Hd: Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m2)
Hm: Average sum of global irradiation per square meter received by the modules of the given system (kWh/m2)