AAR4817 ZEB Theory

Research Essay

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The applicability of BREEAM energy category for achieving energy efficiency in context of Zero energy buildings.

Summary

The essay analyzes the usefulness of the BREEAM Commercial Europe 2009 scheme as a tool for promoting and achieving high energy performance necessary for the movement towards zero energy buildings. Firstly, based on relevant literature an introduction is given to the current ZEB definitions and calculation methodologies. The life cycle considerations gaining importance in the ZEB concepts are discussed. Moreover the concept of energy efficiency as the essential strategy for the achievement of zero energy balance is analyzed. The reasons for the choice of specific ZEB definition as well as scope and limitations of study are explained in the methodology.

The ZEB concept as well as BREEAM environmental assessment scheme is practically applied on the case study with challenging energy goals. The results show that in the context of net zero site energy definition BREEAM energy efficiency issue is successful in encouraging design choices towards reduced energy demands, renewable energy generation and finally minimized delivered energy. Though for the particular project the ZEB definition itself poses difficulties in achievement of the balance due to the limit of it to the renewable energy production on the site. The future research is proposed to focus on extending energy efficiency issue in BREEAM from operational energy consumption to the whole lifecycle as well as expanding the boundaries of zero energy to all life cycle processes.

1.Introduction

The limited energy resources and climate change are the main drivers of sustainable development. As building sector is responsible for 40% of world's final energy use and 33% of direct and indirect greenhouse gas emissions [4]. Therefore minimizing energy use and thus reducing the emissions associated with it is an urgent priority.

The first step towards climate neutrality is therefore energy efficiency. What is a climate neutral building and what should energy efficiency encompass? According to Net zero energy buildings:"Climate neutrality means that buildings have very low energy demand and remaining demands are covered by renewable energy". This definition takes into account only the energy use during operational phase, as a result energy consumed during all the life cycle phases is not taken into account. Moreover the more operational energy use is reduced the more embodied energy in materials ,energy for construction and maintenance contribute to total energy consumption. The expansion of energy efficiency concept to the whole life cycle will affect the balancing method for achieving a net zero energy building. Which leads in turn to expansion of zero energy concept.

As energy efficiency is the main strategy for achieving zero energy building and ZEB will be the target for all new buildings in Europe in 2020 it is relevant to promote and assist this progress. Green certification systems are the possible ways to increase awareness and encouragement. As the most developed certification system is BREEAM it is worth to investigate it's influence on the achievement of energy efficiency. In the research essay the influence of BREEAM Commercial scheme on the energy performance of the project with the goal of zero energy will be analyzed. Prior to undertaking the assessment of the scheme's applicability it is necessary to understand the difference between ZEB definitions, as well as define the boundary of energy efficiency. Because design goals are so important for achieving high performance buildings the way ZEB goal is defined is crucial to understanding the combination of applicable efficiency measures and renewable energy supply options.

Based on the above mentioned issues the following research questions have been formed:

Does BREEAM energy criteria result in truly energy efficient buildings in context of the development towards Zero Energy Buildings? And what is the extent of its applicability for achieving and promoting energy efficiency?

2. Theory

2.1 Net ZEB definitions and calculation methodologies

Europe is currently leading the way in encouraging ZEB as future energy standard ,having already set targets for zero energy or zero carbon by 2020 [1].

The most applied zeb concept is grid connected Net ZEB. According to [4] Net ZEBs are both energy consumers as well as energy producers, which interact with the national energy infrastructure.

Based on the different approaches to calculating the energy balance shown on Fig.1, following definitions have been formulated. The ZEB definitions can emphasize the demand side or supply strategies [8].

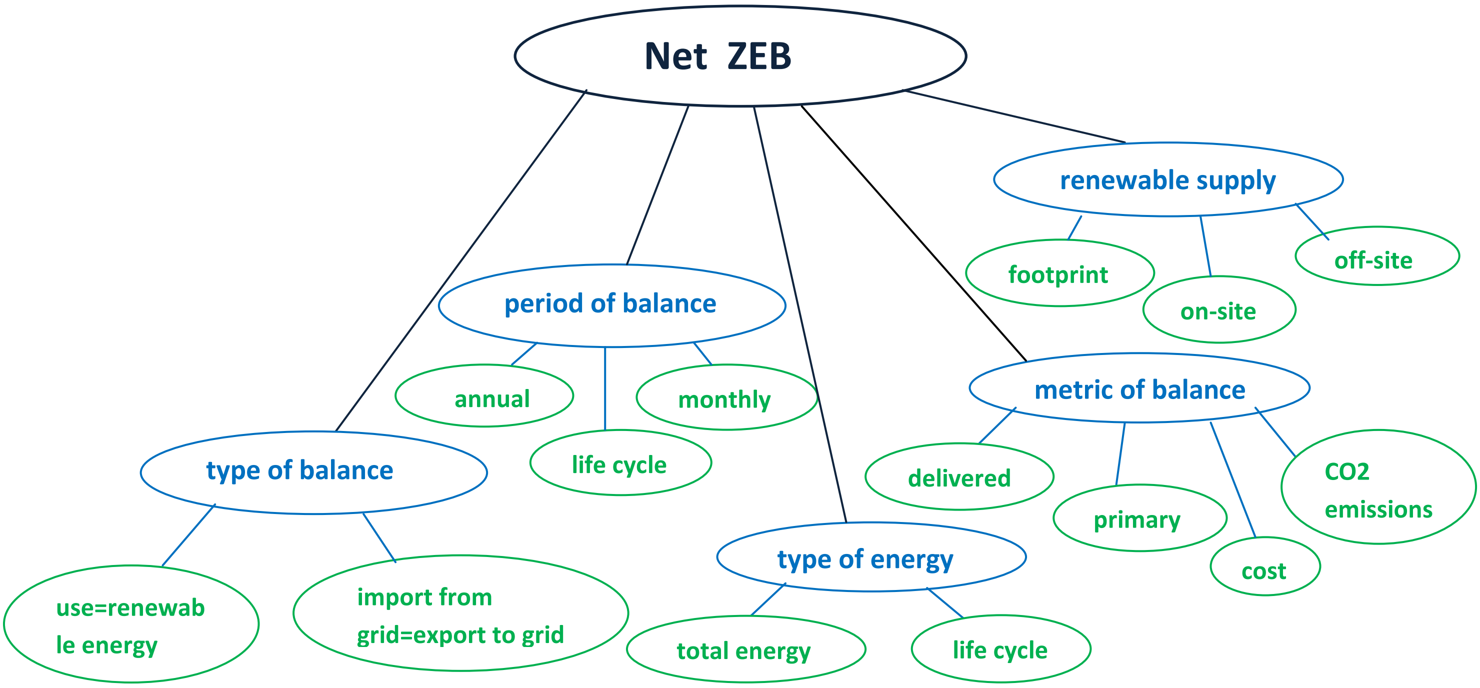

Fig.1 Net ZEB calculation principles

Net zero site energy

The definition is based on the supply option. A site ZEB produces as much energy on site, as it uses in a year (PV, solar thermal, wind).Site zeb encourages energy efficient building design [8].

Net zero source energy

The definition is based on the metric of balance. A source ZEB produces at least as much energy as it uses in a year ,when accounted for at the source . Source energy referrers to primary energy used to generate and deliver energy to the site. Imported and exported energy is multiplied by the appropriate site-to-source conversion multipliers [8].

Net zero energy costs

As in the previous definition the principle difference of balancing method is the metric of balance. In the cost ZEB the amount utility pays the building owner for the energy building exports to the grid at least equal to the amount owner pays the utility for the energy services and energy used over a year [8].

Net zero energy emission.

In this definition the metric of balance are CO2 emissions. A net zero emission building produces at least as much emissions-free renewable energy as it uses from emissions producing energy sources [8]. Zero energy doesn't equal Zero emission, as 100% Green grid is not possible ,so no matter how low is consumption, it has impact on climate [9].

LC Net ZEB

The term ‘net-zero energy’ is frequently used to present the annual energy balance of a grid connected building but it does not consider the energy inputs to deliver the building and its components. In buildings with a ‘zero energy’ balance in use (energy delivered to a grid is equal to energy in use) the life cycle energy is solely due to the process of delivering and maintaining the building and its components [2].

Energy evaluation of buildings typically only considers the energy use in the form of electricity or fossil fuels for the operation of a building without considering the other energy inputs from building construction process as, for example, the manufacturing of materials [2]. LC ZEB is an energy plus building in annual operation balance, as annual surplus of operational energy balances has to offset the energy for construction and maintenance [9]. A LC-ZEB is one where the primary energy used in the building in operation plus the energy embodied within its constituent materials and systems, including energy generating ones, over the life of the building is equal to or less than the energy produced by its renewable energy systems within the building over their lifetime [2].

All the existing concepts of Zero energy buildings decrease energy consumption and increase share of renewable energy [5].

The zero energy definition affects how the buildings are designed to achieve the goal. It can emphasize energy efficiency ,supply side strategies ,purchase energy sources, utility rate structures or whether fuel-switching and conversion accounting can help meet the goal [8].

2.2 Energy efficiency in relation with the ZEB concept

The reduction of energy demands is a central element for any sustainability strategy. NZEB are primarily energy efficient buildings (renewable energy intermittent, limited) [9].

A net zero energy building is a building with greatly reduced energy needs through efficiency gains such that the balance of energy needs can be supplied with renewable technologies. So a good zeb definition should first encourage energy efficiency , and then use renewable energy sources available on site [8].

High energy efficiency standards will help secure energy and carbon savings over the lifetime of the building, without relying on the investment or behavioral choices that occupants will make. This is because energy efficiency measures which are part of the fabric of the home should have a longer lifetime than energy supply technologies such as micro-generation.High energy efficiency means lower demand for heat.

Energy efficiency is essential to minimize credits for balancing of consumption with energy production. As can be seen from Fig.2 without prior reduction of demand the path to zero energy buildings requires very large credits [9].

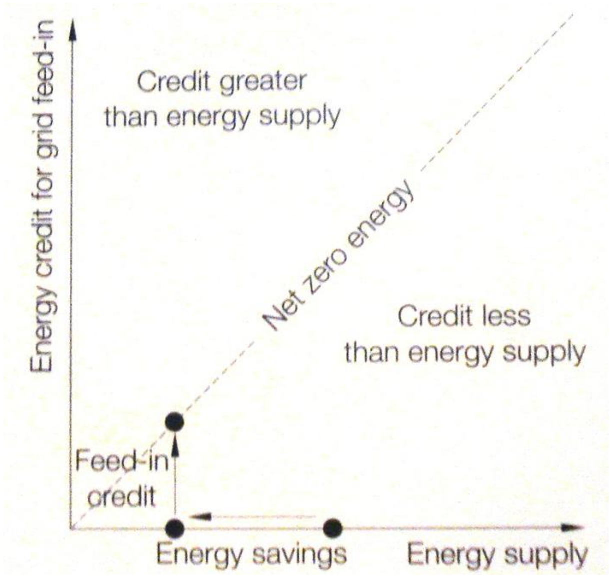

Fig.2 Energy balancing principle

The boundary of energy efficiency might be influenced by the focus of the project on minimizing total net energy demand, total delivered or total primary energy. For example aim of BREEAM in energy efficiency is to encourage buildings that are designed to minimize their operational energy consumption. And in Energy efficient and Passive Houses as operational energy use decreases, construction phase energy use increases [3]. Embodied energy usually comprises 20-40% of the total primary energy expense for energy efficient buildings for an assumed 60 years of service.

Passivhaus concept from Germany is now extending to other parts of the world. While those standards are not zero energy nor zero-heating they do achieve reductions in heating energy demand using a practical and cost-efficient approach, which most experts would consider a good first step towards zero energy building. These solutions also generally use lower quantities of material than more extreme zero energy solutions. According to Hernadez, Kelly 'the true value of a design decision that decreases the annual energy use of a building is after the embodied energy of additional building components and systems are subtracted' [2].

2.3 Methodology

The author of the essay has been introduced to the topic of ZEB and environmental assessment and certification schemes through the lectures given in the course ZEB theory, further knowledge has been gained by acquaintance with state of the art in net zero energy definitions.

The aim of the essay is to analyze the applicability of BREEAM energy criteria for the achievement of high energy performance for the goal of net zero energy building.

Before conducting the assessment it was essential to comprehend the existing methods of zero energy balance to set the scope and define the limitations of the research. The expansion of balance boundaries, balance period ,change in supply options might determine different level of energy efficiency needed for minimizing the effort of balancing consumption with energy production, which in turn affects achievement of zero energy goal.

The scheme chosen as guideline for the case study is the BREEAM Europe Commercial 2009,as the issue weighted most in the energy category is energy efficiency. Focus in the essay is more on Zero Energy Buildings due to importance of energy savings and because affordable, broad scale, "climate-neutral" energy source is not available yet [9]. The net zero site energy concept was selected, due to the fact that it encourages energy efficient design.

3. Case study

3.1 Description of the Brøset Klima Center

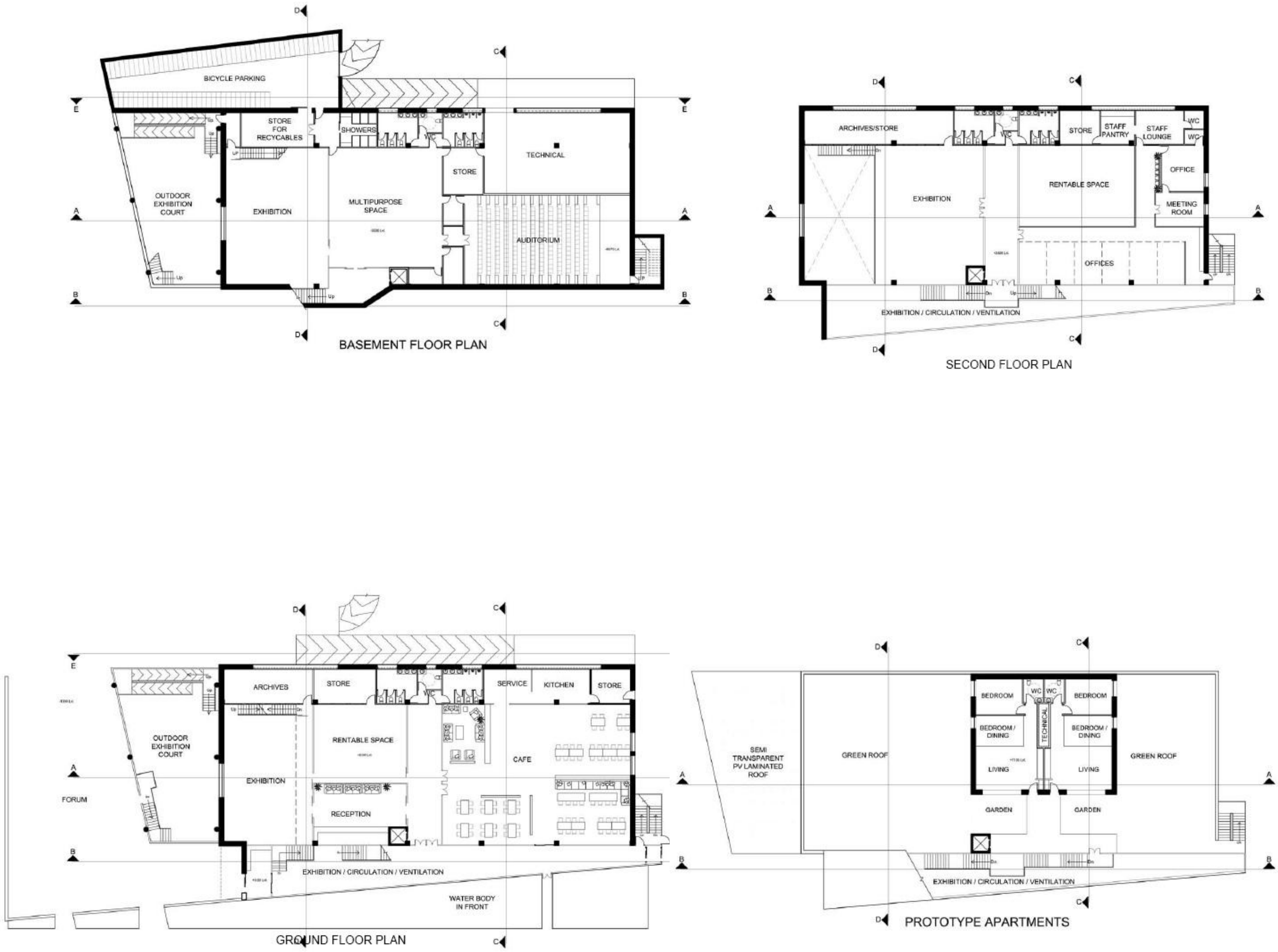

Fig. 3 Floor plans

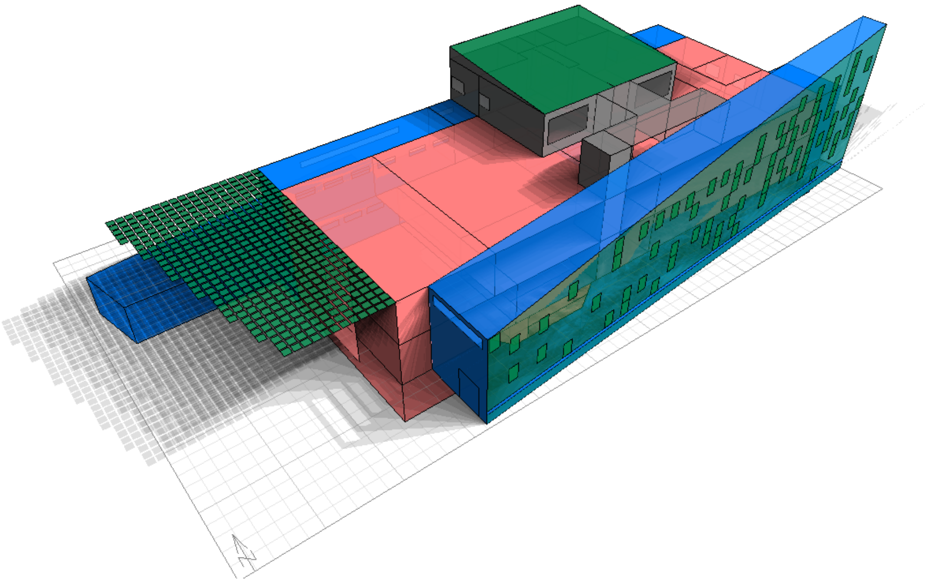

Fig.4 Zoning. Blue- unheated zones, red-heated, grey-autonomous prototype apartments, green-PV electricity generation

The Brøset Klima Centre project was chosen as a case study as the initial energy goals are very challenging - a net zero energy building (during operation) with an energy label of A. Moreover it should be certified as BREEAM Outstanding.

The project was developed with a Norwegian passive house concept for cultural building in order to minimize energy use. The next step was to provide renewable energy supply on site.

Klima Centre is a multipurpose building, providing exhibition, office, rentable area, conference, cafe facilities. In order to minimize the heating demand following *passive strategies* were employed in the design of the building:

- Thermal zoning, with 2 unheated buffer zones, one consisting of service and technical areas on the North and the double skin facade on the South. And exhibition area in the basement with intermittent use.
- Passive solar gains and daylighting through the glazed South facade.
- Natural ventilation strategies: cross ventilation and stack effect in the double skin facade cavity and the chimney.

Active strategies:

- Improved performance of the building envelope according to the passive house minimum requirements for building elements, components and air leakages.(Prosjekt rapport 42)
- Balanced mechanical ventilation with heat recovery.

3.2 Energy calculations and BREEAM assessment

As a result of above mentioned strategies the heating demand of 25kWh/m^2 of Norwegian passive house requirement for cultural buildings has been achieved. The result was acquired by the simulation of the building with the all the thermal zones, occupancy, operating schedules and internal gains in Ecotect.

First step was to determine the energy budget. The heated floor area was defined according to the concept of unheated buffer and heated core zones, and estimation of installed power was done (according to NS 3700/1 and Haase, Novakovic report).The resulted total net energy demand is 54,5 kWhm^2 year.

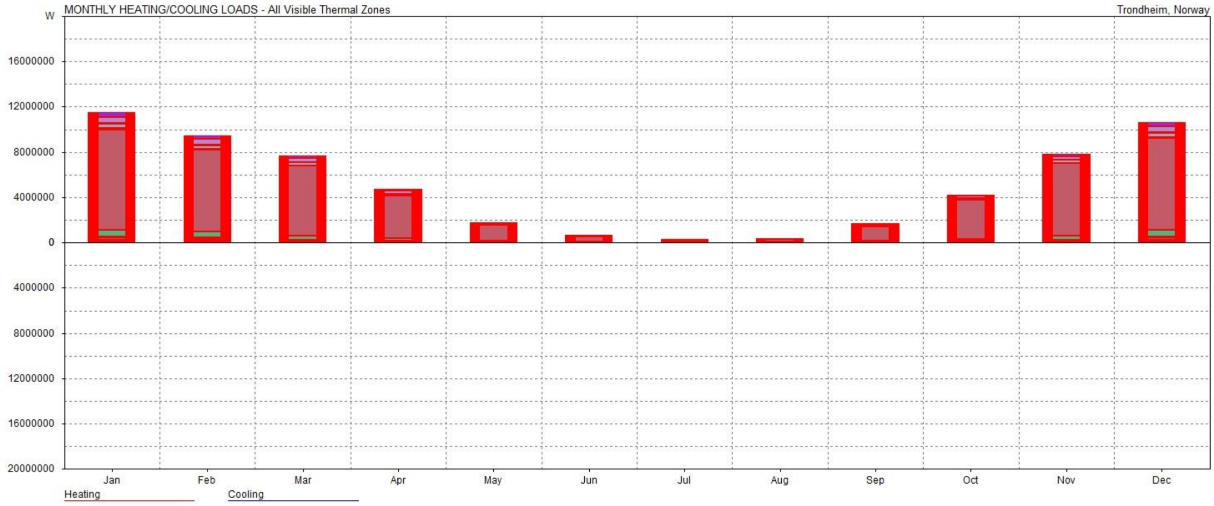

Fig.5 Heating and cooling demands (Ecotect)

Heated floor area 2184 m^2

	Heat (kWh/a)	Electricity (kWh/a)	Total net energy demand (kWh/a)
Space heating			
Ventilation heating	54600		
Domestic hot water	10920		
Fans and pumps		6115	
Lighting		34070	
Equipment		13540	
Cooling		0	
Sum	65520	53725	122521
kWh/m^{2}a (2184m^2)	**30**	**24,5**	**54,5**

Fig 6. Annual energy budget

Next step was to determine renewable energy supply to satisfy the heating and electricity demand. To cover the electricity demand the total area of 402 m^2 PV were integrated in the South facade, plus 114m^2 PV were installed on the canopy. The energy production was calculated in the PVGIS tool. As can be seen from Fig 10. the surplus of electricity produced by PV is sold to the grid in summer months and bought from the grid in winter months-this way grid serves as balancing mechanism. To fulfill the demand for heating and DHW biofuel micro CHP (80% heat) and ground source heat pump were used (Fig. 11). Based on the heat and electricity production values the delivered energy was calculated for each energy supply system.

The total delivered energy is 29 kWh/m^2 ,which is well below the maximum of 105kWh/m^2 for cultural buildings ,thus the goal of A labeled building has been achieved. As the net zero site energy has been applied ,the total annual delivered energy must be covered by annual renewable energy production on site. Therefore achievement of zero energy is complicated by exclusion of other supply systems such as heat pump and CHP from energy balance. The total PV production is 22 kWh/m^2 year ,while the delivered energy is 29 kWh/m^2 year. As a result the building is nearly zero energy. The Fig.12 shows that if off site supply option was chosen for the balance, building would have reached the goal of zero energy.

	Total production per year (kWh/a)	Installed power (kW)
Electricity		
Crystalline PV	23260	36,3
CIS PV	25600	40,8
Sum	48860	
Biofuel micro CHP (20%)	9360	3
Total	58220	
Heat		
Biofuel micro CHP (80%)	31200	10
Ground source heat pump	34320	11
Total	65520	

Fig.7 Energy production

Delivered Energy

Building category	A
	Lower than
	kWh/m2
small house	79
apartment building	67
kindergarden	90
office building	84
school	79
university/ highschool	95
hospital	179
nursing home	136
hotel	135
sport arena / stadium	109
commercial building	129
Cultural / museum	105

Fig. 8 Norwegian energy label A

	Delivered energy (kWh/a)	Specific delivered energy (kWh/m²a)	CO2 emissions (kg)	CO2 emissions (kg/m²)
Electricity	10155,4	4,7	-547,8	-0,23
Heating	53031,6	24,3	10323	4,6
Total	63187	29	9775,2	4,37

Fig. 9 Delivered energy and CO_2 emissions

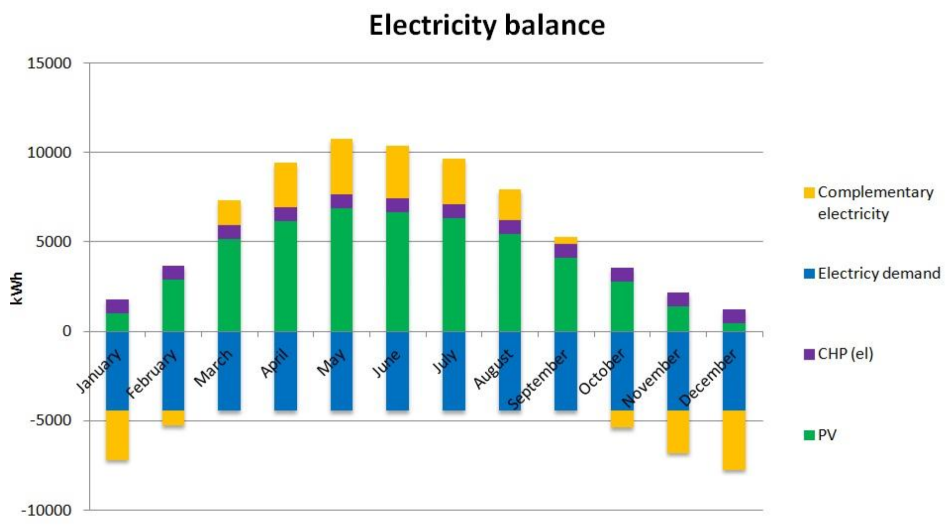

Fig. 10 Monthly electricity balance

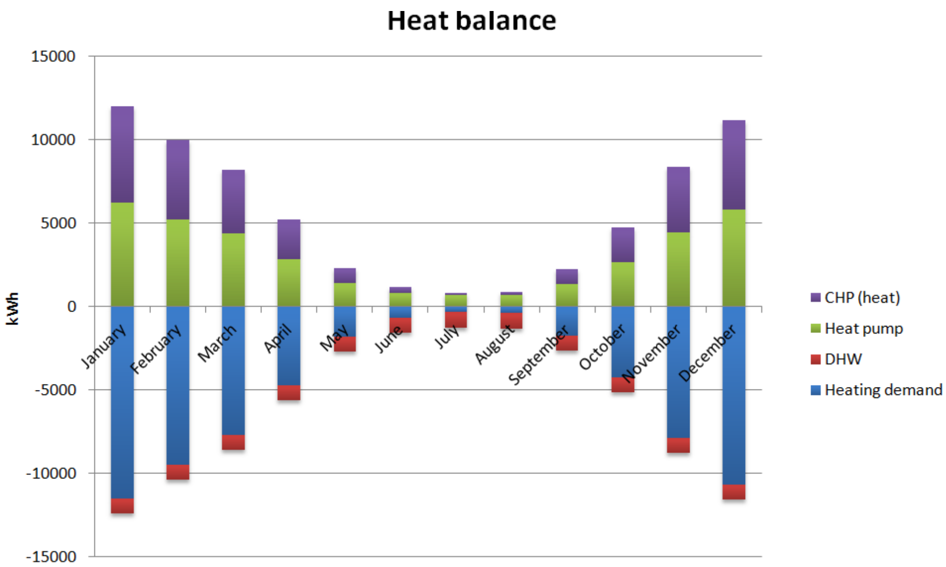

Fig. 11 Monthly heat balance

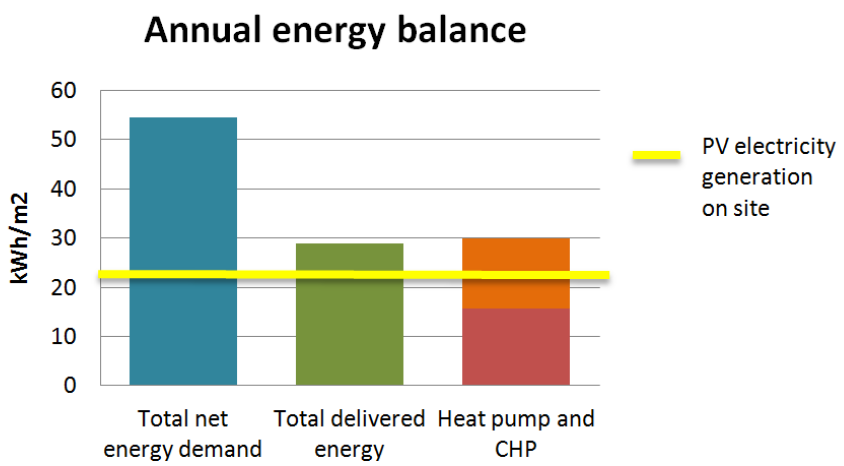

Fig. 12 The coverage of delivered energy by generation on site (PV)

BREEAM issues	Credits	Minimum credits for Outstanding	Influence on Design	Easy credits	Credits achieved
Energy efficiency	15	10	+	-	13
Low zero carbon technologies	3	1	+	-	1
Energy efficient lifts	2	-	-	+	2
Sub-metering of substantial energy uses	1	1	-	+	1
Sub-metering of high energy load areas and tenancy	1	-	-	+	1
External lighting	1	-	-	+	1
Innovation	3	-	+	-	0
					15,70%

Fig.13 Credits achieved in BREEAM Energy category

Finally the credits for energy efficiency have been calculated based on the percentage of the reduction of operational energy consumption over the current national standard. The energy consumption was improved from 105 to 29 kWh/m^2 year, which equals 72 % improvement and 13 credits out of 15.

Furthermore, due to the fact that energy category has the largest 19% in weighting compared to other BREEAM environmental categories, the gained 15,7% in energy played the crucial role for Brøset Klima Centre in being certified as the Outstanding building.

4. Conclusion

Concluding the results of the case and theory study, the initial research question can be answered positively:

Does BREEAM energy criteria result in truly energy efficient buildings in context of the development towards Zero Energy Buildings?

As every project has it is own specifics in terms of realistic energy goals due to the climatic and infrastructural, economical limitations in application of certain energy efficiency measures as well as renewable energy supply options, the above conclusion is true only to the particular case study.

Analyzing the energy performance of the Broset Klima Center, it can be seen that the possibility of getting high credits in the category with the largest weighting, by significant improvement over current standard, has encouraged the use of efficiency measures from the early design stages- passive solar strategies in combination with the high U values of building elements and efficient technical systems. And the reduction of the total net energy demands was understood as the first step towards necessary reduction in operational energy consumption (delivered energy),which is the energy efficiency issue in the scheme.

The next logical step was the generation of renewable energy for covering the demands, preferably with the largest efficiency factor (PV) for minimization of delivered energy.

Viewed in the context of the goal of zero energy or more specifically net zero site energy, the 2 steps taken for achieving high credits directly affected the possibility of reaching net zero, firstly by significant reduction in consumption and provision of onsite renewable energy generation for it's balancing. The result of the energy calculation is the nearly zero energy building which is due to the limitations of the ZEB definition used. As zero energy balance can be influenced by the definitions and calculation methodologies used.

Thus the conclusion can be drawn that BREEAM Commercial European scheme proved to be an effective tool for motivating the energy efficiency required for the goal of net zero site energy building during operation for the ambitious projects. On the other hand due to the absence of minimum requirement on energy efficiency for all the buildings below the exemplary and outstanding level the general effectiveness of the scheme for promoting improved energy performance is significantly decreased.

4.1 Future work

The possible future research can be in looking beyond the limitations of the given study. As was mentioned in introduction and in the theory, the operational energy use that comprises energy demands is only a part of energy consumed by building in its lifetime. Therefore the efficiency measures that focus only on reduction of the energy demands, without taking into account reduction of the energy embodied within materials and systems throughout the whole life cycle are not enough for the achievement of the energy efficiency in the life cycle perspective. Consequently as the ZEB definitions are going in the direction of expanding the boundary of energy to include the life cycle energy use, there will be a necessity in a international guideline that promotes the life cycle approach to energy efficiency. The mentioned considerations might be included in future in the BREEAM energy category.

References

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Figures

Fig.1 Net ZEB calculation principles; made by the author of the essay based on the calculation methodologies explained in Zero Energy Building- a review of definitions and calculation methodologies.

Fig.2 Energy balancing principle; **Voss, Musall;** Net Zero Energy Buildings, International projects of carbon neutrality in buildings; 1st Edition, Architektur-Dokumentation GmbH & Co.KG, Munich, 2011.

Fig.3 Floor plans; made by Group 3 in the course **AAR4546 ZEB-Design.**

Fig.4 Thermal zoning; Ecotect.

Fig.5 Heating and cooling demands; Ecotect.

Fig.6 Annual energy budget; calculated by the author.

Fig.7 Energy production; calculated by the author.