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COMPARISON BETWEEN ECONOMIC VIABILITY OF PASSIVE HOUSES AND CONVENTIONAL HOUSES BASED ON THE COST BENEFITS ANALYSIS

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Abstract

The objective of this article is to compare economic viability of passive houses to conventional houses based on the cost benefits analysis. The passive house concept represents today's highest energy standard with the promise of slashing the heating or cooling energy consumption of buildings. On average passive houses are reported to be more expensive upfront than conventional buildings of equivalent size and layout. For this reason, investors often ask whether passive houses are economically viable: will the extra cost pay back in the long-run through fuel savings? Several studies have offered cost-benefit analyses to address this, usually based on modelled heating or cooling consumption figures and prescriptive approaches to setting values for unknowable variables such as future fuel price rises and the investor's discount rate. Unfortunately, an economic analysis can take into account only quantifiable factors such as the amount of future energy savings. Advantages of quality buildings with significantly higher quality indoor environment cannot be quantified financially. Nevertheless, the quality and comfortable housing is often the most important factor in decision making. The paper offers displays of results which should help investors to choose the best solution for their purpose.

Keywords

Passive house, conventional house, fuel price rises, amortisation time

Introduction

Energy efficient houses began to be widely publicized after the oil crisis of the 1970s that led to an alarming increase in energy prices. This led to the development of concepts related to super-insulation, air tightness of the building, passive design and also the implementation of high efficiency heat recovery. The passive solar design for buildings was promoted by G.F. Keck with the "House of Tomorrow" (1933) and by MIT University with "Solar House 1" (1939) and later, the houses of the 1970s such as "Philips Experimental House" (Germany, 1975), "DTH Zero-Energy House" (Denmark, 1975), "Lo-Cal House" (USA, 1976), "The Saskatchewan Conservation House" (Canada, 1977), "Leger House" (USA, 1977) brought to the forefront issues such as super-insulation "super-glazing" air tightness, heat recovery ventilation [1].

In the 1990s, in Germany a series of energy efficient houses were built, beginning with the building "Kranichstein" from Darmstadt as a result of the concept of "passive house" issued by W. Feist and Bo Adamson. Passivhaus Institut, founded in 1992 by W. Feisthas three basic requirements for the certification of a passive house: the building must not use more than 15kWh/m^2 per year in heating and cooling, pressure test n 50 ≤ 0.6 h−1, and primary energy demand (for all energy services) ≤ 120 kWh/m^2 per year [2]. In addition, window u-value ≤ 0.8 W/m^2/K, ventilation system with heat recovery with ≥ 75 %, thermal bridge free construction ≤ 0.01 W/mK [3].

Passive houses are buildings which assure a comfortable indoor climate in summer and in winter without needing a conventional heating or cooling system. Over the past few years, the use of passive cooling and heating technologies has become more common for reducing the energy consumption of buildings.

In Europe, buildings are responsible for more than 40 percent of global energy use and they emit 40 % of all CO_2 emissions [4]. Data from the U.S. Energy Information Administration shows that buildings are responsible for 48 % of greenhouse gas emissions annually and 76 % of all electricity generated by U.S. power plants goes to supply the building sector [5]. The passive house presents an intriguing option for new and retrofit construction: in residential, commercial, and institutional projects to reduce these environmental impacts of buildings.

Primary energy demand in the world has increased drastically in recent decades. Furthermore, the EU Commission has stated that one of its highest priority tasks is to address global warming, with special focus on reducing greenhouse gases. The Commission states in the directive for energy efficiency in the built environment that the building sector must decrease its use of energy to reduce CO2 emissions. An EU directive issued in 2006 and approved in 2007considered the following three targets for 2020, known as the "20-20-20": reduce 20% of EU greenhouse gas emissions from 1990 levels, raise the share of EU energy consumption produced from renewable resources to 20% and 20% improvement in the EU's energy efficiency [6]. Passive house can be an essential tool on this road how to achieve 20-20-20 EU-goals.

In 2010, the recast of the Energy Performance of Buildings Directive introduced the concept of and obligation for nearly zero energy buildings, particularly for new buildings. The 2010 EPBD obliged all European member states to have all new public buildings built after December 31 2018 and all new buildings (residential and non-residential) built after December 31, 2020 to be nearly zero energy buildings [7]. For the majority of the buildings will be necessary to meet the requirements of the EPBD directive to achieve very high energy efficiency standard as have passive house standard.

The paper offers a method that a prospective helps investors to choose the best solution for their purpose, to decide whether a passive house is a more economical option than a conventional house of equivalent size and layout.

Literature reviews

Over the last few years, there have been a number of works on the topic of passive house and although the requirements and the basic principals are the same, the suggestions and the figures are different. Badescu [8] studied a series of alternative heating solutions and he found that for time periods which are longer than 20 years the geothermal heat pumps solution tends to be the most efficient from an economic point of view. Audenard et al. [9] published the economic analysis of passive houses and low-energy houses compared with standard houses. Study investigates three building types: the standard house, the low-energy house and the passive house, and measures energy savings to perform an economic analysis in order to determine the economic viability of the three building types. In that case, if energy cost remains constant the passive house equals the cost of a standard house in about 30 years and when the cost of electricity would be with an escalation rate of 5 % then the cost equalization period is reduced to 18 years. Versele et al. [10] undertook the life cycle cost and the payback period analysis of a retrofitted one-familiar house in Belgium and he divided the problem into 4 scenarios of fulfilment standard requirements for houses among which the passive house requirement was included. He found that the additional investment to achieve a passive house standard was 27 % higher than the cost scenario for a standard house. Also, he found that the passive house standard is justified economically if energy prices increase with 8% to 10% every year the next 40 years.

In article about cost efficient passive houses, Schnieders and Hermelink [11] suggested that passive houses offer a viable option to meet the remaining energy demand only with renewable sources, within the boundaries of availability of renewable energy and affordability. The authors also argued that building constructed according to the passive house concept fulfils three dimensional sustainability goals, environmental, social and economic expectations. Parker's [12] study indicates that while constructing environmentally profiles building like passive and zero energy buildings, efficiency may be over emphasized, which may result in failing to achieve an economic advantage.

Methodology

Initial assumptions

A financial decision on long-term investments, which an investment in energy savings undoubtedly is, is influenced by time. The funds, which need to be invested immediately, have for the investor usually higher value than the same money received in the future.

The basic comparison

The economic disadvantage of passive houses is that to build them generally cost more than to build conventional houses. On average, passive house in the Czech Republic might cost about 10 % more [13]. This cost differential is likely more in countries where passive house components are not yet readily available. As the number of passive house suitable components on the market increases, however, prices in these other countries will drop. Financial support for passive houses, as currently available in a number of countries, further reduces their cost. In this light then, building a passive house may even be more affordable over the long-term than building a conventional home, especially in light of rising energy costs, but are surprisingly affordable to begin with. The investment in higher quality building components required by the passive house standard is mitigated by the elimination of expensive heating and cooling systems. The cost benefit analysis needs to be performed to show to investors if a passive house pays back through reduced heating costs or cooling costs, within a reasonable amortisation period in order to be economically viable compared to a conventional house. Assuming the annual increase in fuel price is about the same as the homeowner's implicit discount rate, the amortisation time would be the point where the savings in fuel draw equal to the extra building costs, as in [14]:

$$\mathrm{D_E} \times \mathrm{A_N} \times \mathrm{P_E} \times \mathrm{T_A} = \mathrm{B_C} \times \mathrm{A_N} \times \mathrm{C_B} \,/\, 100 \tag{1}$$

where A_N = useable floor area of house (m^2); B_C = building cost of a conventional house (€ /m^2); C_B = percentage difference in cost of building a passive house rather than a conventional house; D_E = difference in primary heating/cooling energy demand of a conventional house compared to a passive house (kWh/m^{2}a); P_E = price of heating/cooling energy (€/kWh) at the time of building; T_A = amortisation time (years) for the extra cost of building the passive house to pay back through fuel savings. Hence, rearranging Eq. (1), the time to amortisation is given by [14]:

$$T_A = \frac{B_C \times C_B/100}{D_E \times P_E} \tag{2}$$

It is noted that the variable A_N, the useable floor area, cancels out in Eq. (2) and subsequent development of the formulae, so it will not be referred to it again.

The values of the two price variables B_C and P_E on the right-hand-side of Eq. (2) depend on the country or geographical zone the passive house is in, while D_E is a physical and possibly behavioural factor which is passive house compared to a conventional house for Europe in general. The outcome depends very much on the local building costs and price of energy. It will be performed analysis using Czech prices, which will hold true in the Czech Republic.

Fuel price rise and discount rate

During the years to amortisation the price of fuel is likely to rise. In case of passive house, it is necessary to estimate the future benefits of lower consumption. The expected annual proportionate increase in the fuel price is represented by a factor F. Further, it is necessary to estimate the fact that money that is expected to be recouped at some time in the future is worth less to an investor today than its face value at that future time, therefore discount rate R. The annual return on investment is modified by an annuity factor [14]:

$$A = \frac{1+F}{1+R} \tag{3}$$

Hence the return on investment after N years, converted to money in the year the investment is made, is given by:

$$V = D_E \times P_E \sum_{1}^{n=N} A^{n-1} \tag{4}$$

As this is the sum of a geometric sequence it can be written:

$$V = D_E \times P_E \left(\frac{A^N - 1}{A-1}\right) \tag{5}$$

For the year of amortisation (when $N = T_A$) this draws equal to the additional costs of the passive house compared to the conventional house, so that:

$$B_C \times C_B/100 = D_E \times P_E \left(\frac{A^{T_{A-1}}}{A-1}\right) \tag{6}$$

Rearranging Eq. (6) to make T_A the subject gives:

$$T_A = \frac{\mathrm{In}\left\lfloor 1 + B_C \times \frac{C_B}{100 \times D_E \times P_E} \times (A-1) \right\rfloor}{\mathrm{In}(A)} \tag{7}$$

Eq. (7) will be used for calculations which include the effects of the future fuel price rise and the discount rate.

Results

The building cost

According the international website The European Construction Cost [15] the residential building cost B_C is approximately 645 €/m^2 in the Czech Republic during the year 2014.

The building cost of passive house

Currently, the building cost of passive house is higher than a conventional house with mean 10% in the Czech Republic, where were built only few hundreds, approximately 700 houses [13]. In some cases, higher building cost could be caused by a disadvantage cost from the building contractor.

Fuel price

For the price of heating fuel P_E, firstly it is considered the price of natural gas. Gas price is converted to energy units, as compared with electricity. To illustrate, 1 m^3 of gas is about 10.5 kWh. Currently in the Czech Republic, gas price is approximately 0.0587 €/kWh [16]. According to Europe's Energy Portal [17], Czech households pay more for gas than the French or British and in a European comparison the price of gas is one of the highest in the Czech Republic.

On the contrary, the price of electricity for households in the Czech Republic is lower than in most European countries. Price of 1 kWh for 2014 varies depending on regions and suppliers in the Czech Republic. The average price of electricity for households is currently about 0.18 €/kWh [18]. Passive houses use electricity, while it will be assumed in the analysis that an equivalent conventional house uses natural gas. However, as it is highly likely that a passive house will also have a photovoltaic unit.

Present day in the Czech Republic, new buildings have the consumption an average 115 kWh/m^2 per year in heating. For a simple illustrative case it is set D_E, the passive house consumption advantage over a conventional house, at 100 kWh/m^2 per year [19], and ignore the effect of future fuel price rises and the discount rate (or, with equal effect, assume that they are equal). Hence using Eq. (2):

$$\mathrm{T_A} = \frac{645 \times 10/100}{100 \times 0.06} = 10.75 \doteq 11 \text{ years}$$

For this case the amortisation time for the extra cost of building the passive house to pay back through fuel savings is 11 years that is less than technical life of thermal components of houses, and with the increasing cost of energy this time significantly decreases. Nevertheless, it is just an illustration and might not reflect a particular household actual consumption patterns. In study that was performed in Germany [14], value of amortisation time was 39 years, which goes beyond the 25-year an assumed technical life of thermal components of houses. Firstly, this very high value is caused by higher building cost of conventional houses in Germany in comparison with the Czech Republic. Secondly, it caused by different value of the difference in primary heating energy demand of a conventional house compared to a passive house. In Germany, conventional houses demand less heating energy. The construction of buildings with low energy consumption is already there long-term trend. Since, in view of the fact that Germans belong to the first pioneers who began to address the issue of sustainability.

It may be examined the relationship between amortisation time T_A and the difference in energy consumption D_E between a passive house and a conventional house according to Eq. (2):

$$\mathrm{T_A} = \frac{645 \times 10/100}{\mathrm{D_E} \times 0.06} = \frac{1075}{\mathrm{D_E}}$$

Figure 1. shows above-mentioned relationship between amortisation time T_A and the difference in energy consumption D_E. In this analysis where amortisation time T_A is displayed as a function of the passive house’s energy consumption advantage over an equivalent conventional house. With an average of 10 percentage difference in cost of building a passive house to a conventional house in the Czech Republic, this graph offers to investors to opt for preferred amortisation time and see what consumption advantage a passive house would need to have, to amortise in that time.

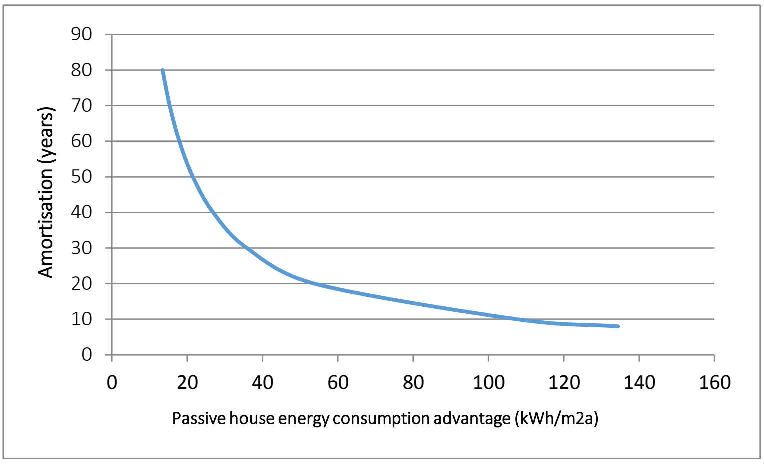

Figure 1: Amortisation times for passive house compared to conventional house

Fuel price rise and discount rate

Figure 2. shows calculations which include the effects of the future fuel price rise and the discount rate according to Eqs. (7) and (3). In graph there are displayed amortisation times for passive house compared to conventional house by three alternatives, when discount rate R is determined by 5 % in all cases [20] and value of fuel price rise F is variable. Factor F is difficult to predict, for this reason there are 3 scenarios: high future fuel price rise F = 10 %, modest future fuel price rise F = 6 % and low future fuel price rise F = 3 %.

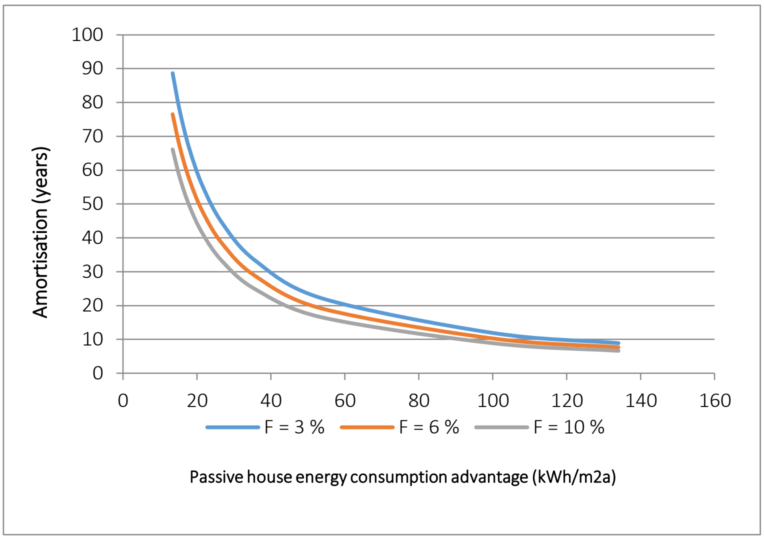

Figure 2: Amortisation times for passive house compared to conventional house, with discount rate R = 5 % and three variable values of fuel price rise F = 3 %, F = 6 %, F = 10 %

Discussion

A fact to be discussed is that how a number of variables affect the energy consumption advantage a passive house would need to have over a conventional house, to make it amortise in a given number of years. Among these variables belong building cost of a conventional house B_C, percentage difference in cost of building a passive house rather than a conventional house C_B, difference in primary heating/cooling energy demand of a conventional house compared to a passive house D_E or price of heating/cooling energy P_E, which tends to increase. Furthermore, the parameters of future fuel price rise F and discount rate R are also involved in viability calculation and it is difficult to predict these factors.

Another problem is that the amortisation time for passive house varies from country to country and also from year to year. Especially, building cost of a conventional house B_C depends on location, a difference in B_C could be more than 1000 €/m^2.

Beyond the interpretation of the results of this research paper, every investor may prepare its own decision based on its expectations. The cost benefits analysis used in this study is able to provide useful information and a new approach to potential investors that can be used in their projects.

Conclusion

Comparison between economic viability of passive houses and conventional houses was conducted based on real and subjective approach for decision making whether it is economically viable to build a passive house rather than a conventional house. It is reality that the economic disadvantage of passive houses is higher initial costs, while on the other side passive house saves money in the medium to long-term by consuming less fuel. Analysis is also subjective because it accepts that the values of some of the parameters in the cost benefit equation are unknowable and must be posited by the perspective of the investor.

The analysis offered displays of results in the form of years to amortisation as a function of passive house consumption advantage. Under conditions that passive house could save about 100 kWh/m^2 per year than conventional house, it would amortise in less than 15 years. In this case, it is less than 25-year technical life, which is often assumed for thermal components of houses. Results are also depended on two final parameters such as the future fuel price increase and the discount rate. The paper offers a method based on which investors can decide whether a passive house is a more economical option for their purpose.

It is very difficult to assess the economic viability of a passive house if it is not possible to estimate the growth rate of fuel price in the future. Therefore, it cannot be clearly defined the payback period of higher investment in passive house. However, it is certain that the fuel price will increase.

The most important is that passive houses present sustainable energy solutions. No matter the climate or geographical region, passive houses stay at a comfortable temperature year round with minimal energy inputs. Include to the long-term energy savings, passive houses belong to one of the solution of the problem with planet's dwindling non-renewable energy resources.

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