Low-energy versus conventional residential buildings: cost and profit

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Abstract

Purpose – The purpose of this paper is to investigate the commercial aspect of "green" building construction and whether increased investment costs are profitable taking the reduction in operating costs into account. The investment viability is approached by comparing investment in conventional and "green" residential building, particularly passive houses, using real construction and post-occupancy conditions.

Design/methodology/approach – The key data were obtained by surveys and personal interviews. The first survey was directed to the companies which had experience of building low-energy housing and the second survey to housing companies that actively manage operation of low-energy houses.

Findings – Findings indicate that low-energy buildings are considered an interesting and sound business opportunity, and investment analysis indicates that low-energy houses (particularly passive houses) can be more attractive investments than conventional residential buildings. The long-term strategy of building low-energy buildings can give competitive advantages. The government initiative and the construction regulations are found to be necessary in eliminating the initial barrier to energy-efficient projects and achieving long-term environmental goals.

Originality/value – This paper provides insights into the investment decisions and contributes to the understanding of the construction, operation and profitability of energy-efficient residential buildings.

Keywords Low-energy buildings, Residential buildings, Cost, Profit, Sweden, Construction industry, Energy

Paper type Research paper

1. Introduction

1.1 Background

Accurately evaluating property is challenging, and seems even more so when sustainability values are involved. Sustainability features are expected to contribute to the property value (Meins *et al.*, 2010), so the sustainable attributes of a building should be included in property valuation models (Lorenz *et al.*, 2007; Lorenz and Lutzkendorf, 2008). On the other hand, uncertainties concerning the financial and environmental potential of "green" buildings contribute to doubt on the part of participants and property investors. Financial and insurance institutions seek strong evidence of profitability in green projects (Nelson *et al.*, 2010) before they are willing to support them. Investors and developers defend this reluctance by expressing concerns about the extra cost of "green" buildings and the highly speculative return on investment and payback period (Issa *et al.*, 2010).

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In seeking empirical evidence, a few research studies have focused on the linkage between cost and income premium in energy-efficient and sustainable properties. Matthiessen and Morris (2004) compared the LEED[1] and non-LEED certified projects and concluded that, though costs vary between building projects, there is no significant statistical difference between LEED and non-LEED certificated buildings; both categories include low- and high-cost buildings. They have also pointed out that a number of factors can influence the economic results, so comparison with an average construction budget yields little information. Schnieders and Hermelink (2006) examined residential energy-efficient buildings in Europe and concluded that constructing a passive house costs 0-17 per cent more than constructing a conventional house; on average, the specific extra investment was found to be 8 per cent of the total building cost. Other research (Miller *et al.*, 2009) has demonstrated that the more environmentally friendly a building is and therefore the higher the LEED certified level, the higher the extra cost of building green. On the other hand, emerging results indicate that green labelled commercial buildings can generate higher rental income (Eichholtz *et al.*, 2009) and that the relationship between green rating level (i.e. LEED) and effective rental premium is significant (Eichholtz *et al.*, 2010).

Exploring the correlation between price premium and "green building" certification appears to be relatively more common in the commercial than the residential market, which might be related to accessibility of data. A few studies have been done in Switzerland where Banfi *et al.* (2008) analysed willingness to pay for energy saving measures in Switzerland's residential buildings, concluding that willingness to pay for energy-efficiency attributes is similar to the cost of implementing those attributes. Values for willingness to pay estimated by the authors are comparable to results received by Ott *et al.* (2006), where they were able to capture the effect of Minergie standards[2] using the hedonic pricing model and conclude that price for Minergie single-family homes in Zurich was 9 per cent (±5 per cent) higher than that of comparable properties. Analysis of the rental market in Switzerland indicates that Minergie tenants are willing to pay a 4.9 per cent increase in gross rent (Salvi *et al.*, 2010).

In Sweden, low-energy houses have been examined in several studies, focusing mainly on life cycle energy assessment (Gustavsson and Joelsson, 2010) and simulation as well as measured values (Karlsson and Moshfegh, 2006; Wall, 2006). Although the general economic assessment of low-energy houses has been approached (Karlsson and Moshfegh, 2006, 2007), the investment viability and life cycle costing analysis of low-energy buildings has yet to be assessed.

1.2 Purpose and significance of the study

The financial rationale of "green" buildings is often questioned by practitioners, who point to the importance of risk, construction complexity, and other real-life conditions that often have considerable effects on investment feasibility. This paper, therefore, compares investments in conventional and "green" residential property (particularly low-energy housing – LEH) using real construction and post-occupancy conditions. The key information was obtained from private and public housing companies in Sweden involved in constructing both types of housing. Furthermore, we also discuss challenges related to constructing energy-efficient housing and incentives that might be needed to accelerate development of the LEH market in Scandinavia.

Accordingly, this paper aims to:

1. Investigate the difference in investment cost between low-energy and conventional housing (CH).
2. Evaluate the profitability of low-energy houses accounting for energy savings.
3. Investigate housing development companies' incentives to construct energy-efficient housing.
4. Explore whether further incentives are needed to accelerate low-energy residential development.

The study is part of a research project investigating the comprehensive value of LEH and its investment potential. The findings should further the development of the low-energy building market and improve present understanding of the construction and operation of energy-efficient residential buildings.

1.3 Scope and limitations

The environmental impact of a building depends on many factors, including energy (e.g. embodied energy, energy used during the building operation, and energy used during construction), materials, use of water and other resources. This research focuses on "green" residential buildings, where special attention is paid to building energy performance; in other words, the investigation focuses on low-energy residential buildings, and particularly in the passive house standard.

We particularly address the cost side of investment and explore whether increased investment costs are profitable, taking the reduction in operating cost into account. The investment costs one defined here as total production cost.

Low-energy buildings require a better insulated envelope, which may increase the thickness of walls, and a reduced ratio between living space and total built area, which in turn influences the number of square meters available for sale, and affects investment viability. This construction aspect of low-energy buildings is not discussed in this paper, but will be explored in further studies.

In this paper, we use term investor to refer to municipal (public) companies that build residential buildings with apartments for rent. The private developer, who builds residential properties with the intention of keeping and managing them as rental property, is also regarded by the authors as an investor. The role of banks and financial companies is not discussed in depth, though the issue and implications of bank strategies towards low-energy construction are significant and worthy of further studies.

The study is limited by data availability and the number of observations, as relatively few low-energy multi-family residential buildings have been built to date in Sweden (Figure 1).

This paper is organized as follows: the theoretical background and local context are reviewed in Section 2, the methodology and data collection are described in Section 3, the results are included in Section 4, investment analysis inputs and results in Sections 5 and 6, respectively, finally, the conclusions are presented in Section 7.

2. Theoretical overview

2.1 The Swedish context: construction standard

The Swedish Building Regulations (BBR) had long emphasized building safety, comfort, and indoor environmental quality, although after the energy crisis of the 1970s the issue of energy used in buildings became a greater priority (Boverket, 2002).

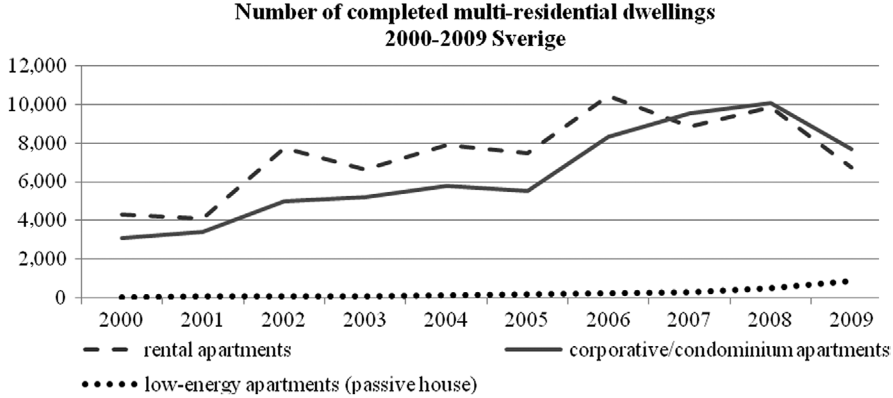

Figure 1.
Housing construction in Sweden (2001-2009)

Source: SCB, Statistics Sweden – www.scb.se; Passivhuscentrum – www.passivhuscentrum.se

The National Board of Housing, Building and Planning in Sweden gradually incorporated energy requirements into its building code. The changes in the Building Regulations not only limited energy consumption in newly built buildings, but also included standards for the average *U*-value of the building envelope and further considered the energy source issue, by tightening rules for buildings using electric heating systems (Elmroth, 2009). Stricter energy requirements and discouraging the installation of electric heating are part of the government's environmental strategy.

These regulations, however, will change again, since EU Directive 2010/31/EU specifies that by end of December 2020 all new buildings should meet the standards for nearly zero-energy buildings. Assuming that construction takes two-three years on average and that post-building assessments need an additional two to three years, meeting the 2020 building standards will require considerable expertise and experience in building energy-efficient buildings. It is crucial to collect information about these experiences now to draw conclusions and learn lessons.

2.2 Low-energy buildings

A strict definition of what constitutes a "low-energy" house or residential building is difficult to find. It is generally assumed that low-energy buildings should consume significantly less energy than the levels specified in the Building Regulations. The key objective of such a building is energy-efficient design that allows the minimization of energy consumption throughout its life cycle (Summerfield *et al.*, 2009). Specifications that facilitate energy-efficiency gains include compact construction, minimum thermal bridge value, an air-tight building envelope, a thermally insulated building and energy-efficient windows, and finally appropriate choice of heating and ventilation systems (Krope and Goricanec, 2009).

Forum för Energieffektiva Byggnader (FEBY – the Forum for Energy-Efficient Buildings), the organization that promotes building and renovation to energy-efficient standards in Sweden, recognizes two types of low-energy houses: passive houses and mini-energy houses, stating that low-energy houses should aim to achieve better (FEBY, 2009b) or significantly better performance (FEBY, 2009a) than stated in the Swedish Building Regulations. A brief comparison of passive house standards according to FEBY (2009a) and the Swedish Building Regulations BBR 16 (Boverket, 2009) is presented in Table I.

2.3 Profitability and investment viability

a. Profit. The objective and the result for most companies is profit (p), which can be presented as difference between (discounted) income (i) and cost (c), $p = i - c, p \rightarrow \max$.

In Sweden, we can distinguish two housing markets: the owned and the rental markets, where municipal (or private) companies own the property and rent out dwellings. In most cases, the separate organization within the company is responsible for maintenance and operation of the building. In this paper, we refer to this organization as the housing management company. In the case of housing owned by municipal or

Standard for various climate zones in Sweden	FEBY Passive house standard, 2009	Swedish Building Regulation BBR16
Specific energy demand$^{\mathrm{c}}$ requirement for zone (I) north	≤ 58 kWh/(m^{2}A$^{\mathrm{f}}_{\mathrm{temp+garage}}$)$^{\mathrm{a}}$ ≤ 34 kWh/(m^{2}A$_{\mathrm{temp+garage}}$)$^{\mathrm{b}}$	≤ 150 kWh/(m^{2}A$^{\mathrm{e}}_{\mathrm{temp}}$)$^{\mathrm{a}}$ ≤ 95 kWh/(m^{2}A$_{\mathrm{temp}}$)$^{\mathrm{b}}$
Specific energy demand requirement for zone (II) central	≤ 54 kWh/(m^{2}A$_{\mathrm{temp+garage}}$)$^{\mathrm{a}}$ ≤ 32 kWh/(m^{2}A$_{\mathrm{temp+garage}}$)$^{\mathrm{b}}$	≤ 130 kWh/(m^{2}A$_{\mathrm{temp}}$)$^{\mathrm{a}}$ ≤ 75 kWh/(m^{2}A$_{\mathrm{temp}}$)$^{\mathrm{b}}$
Specific energy demand requirement for zone (III) south	≤ 50 kWh/(m^{2}A$_{\mathrm{temp+garage}}$)$^{\mathrm{a}}$ ≤ 30 kWh/(m^{2}A$_{\mathrm{temp+garage}}$)$^{\mathrm{b}}$	≤ 110 kWh/(m^{2}A$_{\mathrm{temp}}$)$^{\mathrm{a}}$ ≤ 55 kWh/(m^{2}A$_{\mathrm{temp}}$)$^{\mathrm{b}}$
Heat loss	≤ 0.30 l/s m^2 ± 50 Pa, according to SS-EN 13829 standard	Quantitative values not specified
U-value (W/m^2 K)	U (for windows) ≤ 0.90–0.80 W/m^{2}K according to standards SS-EN 12567-1 U (for building envelope elements) ≤ 0.15 W/m^{2}K	U (average for building envelope) ≤ 0.50 W/m^{2}K$^{\mathrm{a}}$ U (average for building envelope) ≤ 0.40 W/m^{2}K$^{\mathrm{b}}$ U value for windows is not specified
Annual heating load$^{\mathrm{d}}$ for climate zone (I) north	≤ 12 W/(m^{2}A$_{\mathrm{temp+garage}}$) ≤ 14 W/(m^{2}A$_{\mathrm{temp+garage}}$)	Installed electrical power for heating of dwellings with electric heating, ≤ 5.5 kW
Annual heating load for climate zone (II) central	≤ 11 W/(m^{2}A$_{\mathrm{temp+garage}}$) ≤ 13 W/(m^{2}A$_{\mathrm{temp+garage}}$)	Installed electrical power for heating of dwellings with electric heating, ≤ 5.0 kW
Annual heating load for climate zone (III) south	≤ 10 W/(m^{2}A$_{\mathrm{temp+garage}}$) ≤ 12 W/(m^{2}A$_{\mathrm{temp+garage}}$)	Installed electrical power for heating of dwellings with electric heating, ≤ 4.5 kW

Notes: [a]For dwellings without electric heating systems; [b]for dwellings with electric heating systems; [c]specific energy demand: refers to the amount of energy that must be delivered to the building over a certain period of time (i.e. annually) to achieve good indoor climate and building operation; value includes heating, hot water, and energy used for general building operation; domestic electricity is not included; expressed in kWh/m^2; expressed in purchased energy, i.e. end-use energy, measured at final level, purchased from distributor; [d]annual heating load: describes the maximum amount of energy that must be delivered to the building at a particular time (usually the coldest day) to achieve good indoor climate; expressed in W/m^2; [e]Atemp: refers to the area within the thermal envelope where the temperature should be kept over 10°C (www.boverket.se/Kontakta-oss/Fragor-och-svar/Bygg-och-konstruktionsregler/Om-avsnitt-9-i-BBR/Atemp); [f]Atemp + garage refers to the Atemp area and garage area included within the thermal envelope (FEBY, 2009a)

Table I. Brief comparison of passive house standards according to FEBY (2009a) and the Swedish Building Regulations BBR 16 (Boverket, 2009) private companies, i equals rental, c includes initial cost of building design and construction as well as operation and maintenance costs.

In the first case, where buildings are built for sale, i.e. a private person is the owner and the occupant, consequently the interpretation of the profit equation changes and i becomes the selling price of the property. Since the selling price is strongly related to market conditions and the data for market value of LEH is very limited, in this study the focus is on rental housing. The issues related to economic viability of LEH investment on tenant-owned market will be addressed in our further research.

Rents for residential apartments in Sweden are the result of collective bargaining between municipal housing companies and private property owners on one side and the local tenants' union on the other. The rent level is not really dependent on the apartment's quality factors like indoor comfort, but rather related to location, buildings production year or size (Lind, 2011).

Since the rent is not decided by the market, one cannot really observe rent changes caused by market preferences related to property quality or indoor comfort, therefore we can assume that rent $= i$ is constant and equal in conventional and LEH. In such cases, the investor's only strategy for obtaining positive profit is to focus on cost.

b. Investment assessment. An attractive investment is one that offers the investor a satisfactory return on equity (Jaffe and Sirmans, 2001). Whether or not return on invested capital is deemed satisfactory depends on the investor's objectives, but a potentially good investment can be identified using equity investment models, net present value (NPV), internal rate of return (IRR), and payback period (Jaffe and Sirmans, 2001). Generally, the outcome of an investment evaluation of a real estate development project is determined by the total investment cost, net operating income generated on real estate, and the required rate of the return over the expected holding period (Hoesli and MacGregor, 2000; Geltner *et al.*, 2007). NPV can be described by the following function:

$$NPV = \sum_{n=1,i=n}^{n} \frac{NOI_i}{(1+R)^n} + \frac{RV_n}{(1+R)^n} - TIC, \quad RV_n = \frac{NOI_i}{rRV} \tag{1}$$

NPV net present value of equity.

NOI_i net operating income through i periods.

n expected holding period.

RV_n residual value in the nth period.

rRV expected yield from property.

TIC total investment cost.

Consequently, IRR can be described as:

$$0 = \sum_{n=1,i=n}^{n} \frac{NOI_i}{(1+IRR)^n} + \frac{RV_n}{(1+IRR)^n} - TIC \tag{2}$$

IRR internal rate of return on equity.

Input data used in investment models are based on estimates; the more accurate the cost and income valuations, the greater the likelihood an attractive investment can be identified (Hoesli and MacGregor, 2000).

3. Method and data collection

3.1 Investors

Information about low-energy buildings in Sweden was collected through survey and personal interviews.

The survey questionnaire was sent to municipal housing companies that build rental housing and to private construction companies that build housing for sale or rent. The survey was addressed to the companies that took part in the construction of low-energy multi-family buildings over the last decade. It was estimated that approx. 1,000 energy-efficient dwellings had been build in that time (i.e. till 2010). It is appraised that the companies who responded to our survey have been involved in 85-90 per cent of these projects. All respondents were asked to answer questions from the position of an investor (i.e. client) and not that of contractor (some companies might have participated in construction projects as contractor, investor, or both). The number of survey recipients per company varied depending on company size and the number of low-energy projects carried out. The survey was addressed to chief executives (i.e. those responsible for new projects and housing development) and project managers. The notification of survey questionnaires were sent to 34 companies (93 people) that had participated in at least one LEH project in Sweden. Answers were collected using an on-line questionnaire from February to March 2010; 34 completed questionnaires were collected for a response rate of 37 per cent. We have received answers from 24 different companies (i.e. 71 per cent of the contacted companies), 16 respondents represented public and 18 private companies. Some of the biggest construction companies in Sweden took part in the survey, including listed companies (e.g. Skanska, NCC, and PEAB) and large municipal housing companies, such as Svenska Bostäder, whose 2009 turnover was approximately EUR 300 million (http://svenskabostader.se). 12 face-to-face, open-ended interviews were conducted between September 2009 and September 2010 to acquire a better understanding of the technical and economic challenges of building LEH in Sweden. The interviewees represented nine companies, five private (seven interviewees) and four public companies (five interviewees).

3.2 Operation and management companies

Data on the operation and management of low-energy dwellings was obtained by survey and personal interviews. Survey questionnaires were sent to housing companies identified by market research as actively managing low-energy buildings. Only multi-family residential buildings with rental apartments were the subjects of study.

Low-energy buildings were identified in the building stock of 18 public housing companies. The notification of survey questionnaires was sent to the person or people responsible for managing and operating identified low-energy residential buildings (30 recipients) in the 18 companies. The number of survey recipients per company varied depending on the size of the housing company and the number of low-energy buildings in the building stock. Answers to an on-line questionnaire were collected from November to December 2010. Nine people, each representing a different housing company, completed the survey.

Additionally eight interviews were conducted with representatives of housing management companies over a period of approximately one year, i.e. December 2009-February 2010. Four interviews were face-to-face, open-ended interviews and four were scheduled telephone interviews. The interviewees represented two private and four public companies. The goal of the interviews was to acquire a deeper understanding of the different challenges of operating and managing low-energy versus CH.

4. Results and analysis

4.1 Investment cost

Most respondents stated that the total investment cost of LEH was less than 10 per cent greater than that of traditional buildings. Just over half of the public companies estimated that the extra total investment cost was in the 5-10 per cent range, while only one quarter of the private companies gave this answer. Most of the private companies, i.e. approximately 60 per cent, estimated that the extra investment cost of LEH was 5 per cent or lower (Figure 2).

Public and private companies' opinions differ to some extent concerning the cost estimates. This difference may be because private companies tended to have more accurate information about individual cost components (e.g. operation, materials, and design). In addition, private companies may have procurement advantages, and their workers can find savings on site during construction by discovering innovative and practical solutions.

Administration and design. Administration costs in LEH are no higher than in CH, except in the case of "demonstration projects", where the increased costs often relate to organizing lectures and on-site visits. Nearly two-thirds of the respondents said that LEH construction material was more expensive than CH material, which may relate to the higher unit prices of more energy-efficient material (e.g. insulation and windows). Labour and design costs are also higher on LEH budgets. The architect team, installation designer team (e.g. for HVAC), and energy coordinators must work together to deliver a low-energy building design. Collaboration and active engagement throughout the design and construction processes as well as work precision may translate into more hours of work for both the design and building teams.

Private companies (60 per cent) estimate that the design cost tends to be higher by approximately 10 per cent in LEH projects; 40 per cent of public companies agree with this estimate, though 50 per cent of public companies consider the design cost to be about the same as in CH projects.

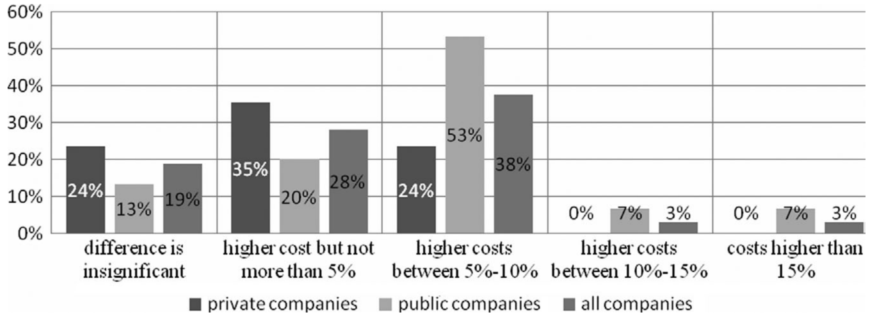

Figure 2.
Total investment cost of green buildings compared with that of traditional residential buildings

Material. Materials are estimated to cost approximately 10 per cent more for LEH construction and installation approximately 5 per cent more. Investors stated that, even though some installation costs (e.g. of a more advanced ventilation system) may be more expensive, savings from not installing a heating system balanced the total installation cost. Other significant material cost components are windows and insulation, which are estimated to cost approximately 10 per cent more in LEH projects. One-third of public companies estimated the insulation cost to be up to 20 per cent more expensive. This cost estimate was not supported by any of the private companies. Moreover, one fourth of private companies disagreed with the window cost estimate, and believed this cost was no higher than in CH buildings.

Labour. According to most respondents, labour costs are approximately 10 per cent higher in LEH than CH projects. Respondents agreed that LEH construction requires more knowledge on the part of the builder, though they did not agree (65 per cent) that there was a greater risk of mistakes in the LEH construction process.

4.2 Operation and maintenance costs

Operation. Regarding the estimated operating cost, most public and private companies expected significant savings in operating low-energy buildings. This belief seems to be confirmed by housing management companies, which also cited cost reductions of at least 20-40 per cent for LEH operation. The reduction in operating cost is based mainly on reduced energy requirements. Investors anticipate that achieving the estimated energy efficiency may require more system adjustments than usual. In practice, the technical installations are not considered to be a particular problem. Housing managers believe that LEH installations require just as much adjustment as do CH installations, though the need for adjustment comes earlier in LEH than in conventional dwellings. Housing managers admit that balancing LEH systems can be challenging, and that the biggest problems are insufficient auxiliary heating efficiency in cases in which air heating systems were installed and adjusting the air flow and temperature in those systems.

Maintenance. One-third of public companies believed that low-energy buildings would require less maintenance in the future, whereas only one fifth of private companies thought the same. This difference in opinion may depend on differences in experience, since municipal companies own, manage, and are in charge of operating and maintaining their building stock, whereas private companies less often assume that responsibility.

Energy consumption. Metering energy consumption in buildings poses some challenges. Individual metering systems for domestic electricity are common in Sweden, though metering heating and hot water, especially when systems are connected to district heating, presents some problems. The difficulty comes partly from the significant cost of installing the most appropriate individual metering system for data collection. According to housing managers, the estimated energy consumption reflects the actually metered energy consumption fairly well. Nonetheless, most newly built LEH are equipped with individual metering systems, so the resident's individual consumption cost is irrelevant to the general investor. Tenants of LEH pay basic rent to the building owner and additional charges for the individual consumption of cold and hot water and domestic electricity. The situation is slightly different in conventional buildings, where rent usually includes hot water and heating (calculated and charged according to commonly used templates) and only domestic electricity is charged according to the individual tenant's consumption.

4.3 Experience and expertise

Survey results suggest that more private (60 per cent) than public (30 per cent) companies noted that prior experience of LEH projects significantly increased efficiency and profitability in ensuing LEH projects. This difference of opinion may be based on the extent of prior construction experience. However, by managing and operating low-energy buildings, municipal companies may gain knowledge and experience that allows them to reduce operation and maintenance costs in LEH and increase efficiency in existing housing stock. Housing managers seem to confirm this hypothesis, since a majority fully or partly agree that experience from earlier LEH projects allows for an increase in efficiency and decrease in operation and maintenance cost in both new built LEH and existing stock (conventional buildings).

The results from our survey suggest that construction companies are in the learning process and are yet to find the optimal solution for benefiting from scale economics, i.e. industrialization and standardization (Figure 3).

4.4 Barriers and incentives

Most investors recognized the business value of low-energy buildings and expressed willingness and readiness to invest in low-energy projects (90 per cent), though many respondents pointed out that the marginal cost of saving 1 kWh of energy is very high if the building space heating should be lower than 50 kWh/m^2.

The survey results indicate that government needs to play a more active role in encouraging low-energy construction. Public companies particularly stress the need for financial stimulants (e.g. tax reductions or subsidiaries) whereas private companies indicate that buildings regulations and standards are not stimulating enough for low-energy buildings development (Figure 4). The last finding is very interesting as it may suggest that building companies underperform due to less demanding standards.

Building low-energy houses is important if one is to be competitive on the market. This is clear for respondents of our survey (particularly private firms) according to whom constructing LEH is good business and, by doing so, the company will strengthen their market position (Figure 5).

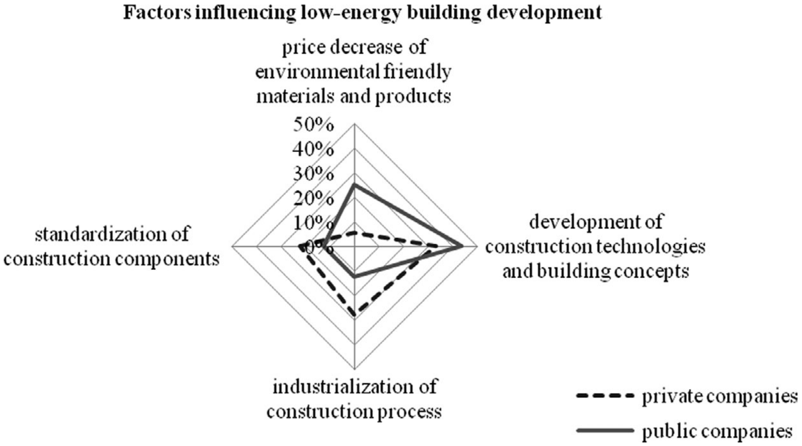

Figure 3.
Factors that have greatest impact on development and growth of low-energy building construction

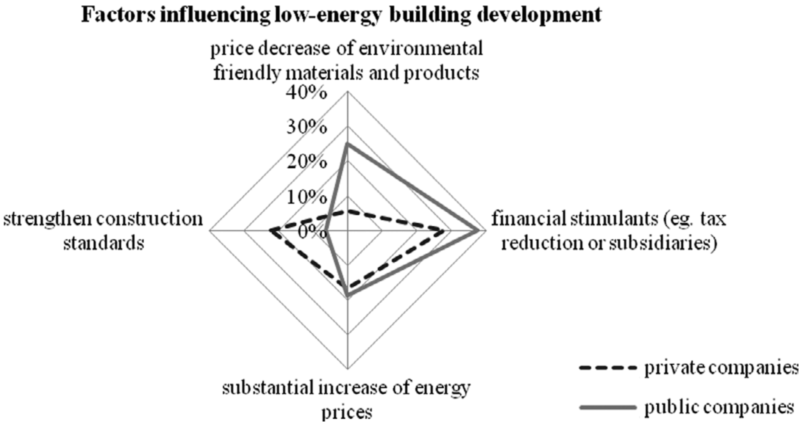

Figure 4.
Decisive factors influencing low-energy building development

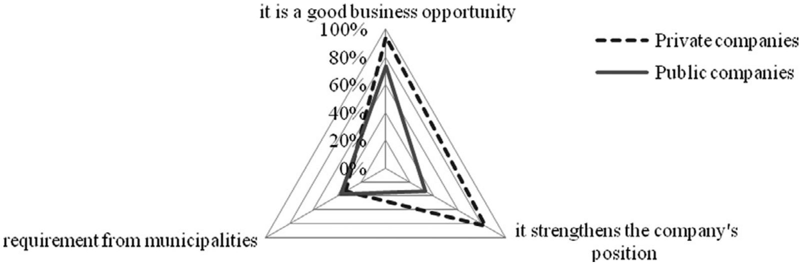

Figure 5.
Rationale for building low-energy buildings

5. Investment assessment: assumptions

5.1 Input data

We attempt to answer the profitability question by evaluating investment in multi-family low-energy building (passive house standard) and the benefits from energy savings. The general assumptions are presented in Table II and the motives behind them are presented below. A sensitivity analysis is carried out to observe changes in results if assumptions are changed. In the economic assessment, the NPV model is used (equation (1)).

Construction cost (average) in multi-family buildings in Sweden in 2009 (EUR/m^2 living area)	3,000
LEH construction cost difference	5%
Real interest rate	3%
Domestic heating (used for hot water and heating) (EUR/kWh)	0.075
Annual energy price increase	2.5%
Energy savings (kWh/m^2), a	60
Holding period	20 years
Exit yield	5%
Additional m^2 value at the end of holding period (EUR/m^2)	143.8
NPV (20 years) (EUR/m^2)	13.1

Table II.
Base case assumptions for live cycle costing analysis

Energy savings. The difference between LEH and CH investments can be expressed by extra investment cost and consequently energy savings. The energy savings are calculated based on the difference between energy requirements for building operation (inclusive space heating) according to Swedish Building Regulations (Boverket, 2009) for conventional houses (CH) and the passive house standard (FEBY, 2009a) for low-energy houses (LEH). The specific energy demand in Sweden varies depending on climate zone and, in southern Sweden for newly built buildings, it should not exceed 110 kWh/m^2 (leavings space) for conventional buildings and 50 kWh/m^2 for passive houses (Table I).

Energy prices. The central question is what energy price is rational to assume? In the last decade, energy prices in Sweden increased by over 325 per cent and within one year the price can increase by 10 per cent (SCB Statistics Sweden – www.scb.se). Since low-energy building owners benefit most from savings resulting from minimum requirement for space heating and since the most common source for heating in multi-family houses in Sweden is district heating (75 per cent, SCB Statistics Sweden – www.scb.se), we use the mean district heating price. Analysis is done with real prices; however, we assume that the energy price trend is going to hold and therefore we include an annual energy price increase of 2.5 per cent in real terms. The assumed base energy price is EUR 0.075 per kWh. The average price growth in the last five years is shown in Figure 6.

Rate of return. The mean for the Swedish ten-year nominal government bond rate in 2010 (1 January 2010-1 January 2011) was approx. 2.9 per cent (Sveriges Riksbank, Central Bank in Sweden – http://riksbank.com) whereas reported inflation for 2010 was 2.1 per cent (HICP[3]), indicating that the real rate was approx. 0.8 per cent. In the calculations below, a real rate of 3 per cent is used. This is higher than the current real government bond rate, which is motivated with addition for risk. The assumption of 2 per cent risk is in line with the generally used risk level for market risk (Adair and Hutchison, 2005; Hutchison *et al.*, 2005; Hordijk and Van de Ridder, 2005; Lorenz *et al.*, 2006). Since the discount rate is based on the risk-free rate and risk premium, it may reflect the risk-reduction potential of sustainable buildings (Lorenz *et al.*, 2006;

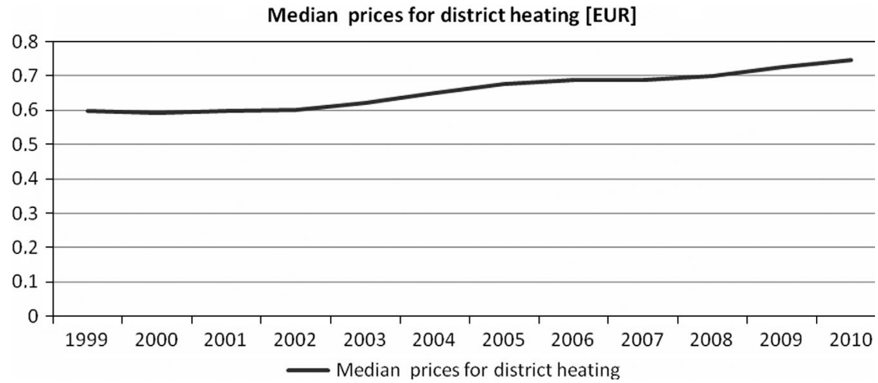

Figure 6.
Annual price change for district heating in dwellings (EUR/kWh), 2000-2010

Source: Based on data from Svensk Fjärrvärme – www. svenskfjarrvarme.se/Statistik –Pris/Fjarrvarmepriser

Lorenz and Lutzkendorf, 2008), which relates to the fact that "green" buildings are less sensitive to changes in energy prices, are characterized by reduced impact on the environment and require lower maintenance cost. On the other hand, there might be uncertainties related to construction technologies, inappropriate solutions and production quality. Those issues should be addressed when assessing specific property projects; however, the calculations presented in this paper are done on the market level and therefore a more general risk value is used, which in order to avoid too optimistic assumptions is set equal for both LEH and CH projects.

Construction cost. The construction cost of conventional buildings is based on the average building total production cost of new-multifamily buildings in Sweden in 2009, which was approx. 3,000 EUR/m^2 living area (SCB, 2010). This cost includes land price, fees for connection of utilities, ground and site works on construction plot and works related to construction of the building. The construction cost of passive houses is estimated based on results from our survey and considered to be 5 per cent higher than the construction cost of CH.

Building residual value. Exit yield is assumed to be 5 per cent; the higher value for exit yield than that for rate of return is motivated by the higher uncertainty when the period is further into the future. The analysis is carried out for holding periods of 20 years.

6. Results from investment analysis

6.1 Base case scenario

In the base case scenario, we assumed the base energy price (EUR 0.075 per kWh) and the extra investment cost 5 per cent (more investment cost than in the conventional residential building). With those assumptions (see Table II for details), in holding periods of 20 years, computed NPV was positive and equal to 13.1 EUR/m^2, indicating that potential energy savings are sufficient to defray the extra investment cost required in LEH and consequently that construction of LEH is an attractive investment alternative. If the owner decides to sell the property after 20 years for a price equal to the estimated residual value (end of holding/calculation period), it is expected that the potential energy savings will generate additional value of 144 EUR/m^2 of LEH building.

6.2 Sensitivity analysis

There are, of course, uncertainties in the assumed values; therefore we have performed a sensitivity analysis (Table III) where one variable is subject to change, keeping other variables constant.

The results of our survey indicate that efficiency increases with experience in LEH construction, which suggests that the extra investment cost will decrease in the future. Sensitivity analysis shows that one point change in extra investment cost has significant impact on computed NPV (Table III). This variable can be controlled by the company to the highest degree.

The investment analysis is very sensitive to assumed base energy price and energy price fluctuation. Even in Sweden, energy price for district heating can vary significantly depending on distributor and region. Investing in low-energy building (passive house standard) in the regions where energy prices are higher is particularly attractive.

	NPV, 20 years (EUR/m^2)
Base energy price (EUR/kWh)	
0.06	−19.50
0.07	2.25
0.08	24.0
0.09	45.8
0.1	67.5
Annual energy price increase (%)	
1.5	−7.6
2.0	2.4
2.5 (base case scenario)	13.1
3.0	24.8
3.5	37.3
Rate of return (%)	
3.5	1.7
3.58 (IRR)	0
4	−8.7
Extra investment cost (%)	
6	−16.9
5 (base case scenario)	13.1
4	43.3
3	73.3
2	103.3

Table III.
Sensitivity analysis, NPV computed at 20 year holding period, one variable was subject to changes, the other as in the base case scenario (Table II)

Investment analysis indicates that if extra investment cost is 6 per cent or higher, or base energy price is 0.6 EUR or less, the potential energy savings are insufficient to cover extra initial investment. This would also be the case if the real energy price increase is lower than 1.5 per cent or if the real interest rate is set to 3.8 per cent or higher.

7. Conclusions

In this paper, we have attempted to investigate investment viability in LEH in Sweden. We have analysed investments in conventional and low-energy residential property using real construction costs and post-occupancy conditions, with consideration to energy savings potential. Key data was obtained by surveys addressed to private and public housing companies, involved in constructing both types of housing, and to housing management companies responsible for maintenance and operation of conventional and low-energy residential buildings.

Quantitatively, the costs of labour (e.g. training, hours worked, and required work accuracy) and of high energy-efficient materials, such as insulation, windows, and more advanced mechanical ventilation systems with heat recovery, add up to a higher investment cost for low energy buildings. At the same time, high accuracy of construction work and energy efficiency material are absolutely necessary for constructing air-tight, well-insulated, and energy-efficient buildings. Achieving qualitative objectives and future energy savings requires the transforming of conventional building processes, changes in work sequencing, the active involvement of all project participants in the building process (e.g. architect, installation team, construction workers, and investor/owner), and understanding of qualitative and quantitative objectives on the part of all project participants.

Despite regarding low-energy residential buildings as more expensive, public and private companies consider this to be a good investment opportunity. This opinion is supported by our investment analysis, which suggests that the present value of potential energy savings is higher than the extra investment cost required in LEH.

Can we expect a reduction of cost in LEH construction? The construction industry particularly benefits by "learning-by-doing": practical experience and spread of knowledge between workers is central for efficient management of construction projects (Styhre, 2009). The survey respondents agreed that experience gained during prior LEH projects improves the efficiency and profitability of ensuing projects. Improvements in construction processes due to experience and learning (Turner, 2010), competence, ongoing monitoring (Turner, 1999) as well as reduction in cost, for example, due to better procurement, technical development, strategic partnerships, and cost driver control (Porter, 1985), allow the investor and developer to control investment costs and improve their market position. Consequently, investment cost for low-energy buildings is expected to decrease, which as the sensitivity analysis shows, significantly improves profitability.

Foreseeable changes in the political and legal environment might be an important argument for LEH construction. The European Council with its latest directive regarding energy performance of buildings (European Parliament and Council, 2010) established new goals for European Union Members. Article 9a Directive 2010/31/EU clearly states that "Member States shall ensure that by 31 December 2020 all new buildings are nearly zero-energy buildings". The fundamental concept "nearly zero-energy building" combines two ideas: first that the amount of energy which must be supplied to the building is very small and second that the source of this energy should come from renewable sources. This means that experience and expertise in building energy-efficient buildings are fundamental and the organizations that choose to be ahead and are quick learners may have an opportunity to benefit from knowledge and cost control in low-energy construction.

What form of action can stimulate acceleration of LEH construction? Experience in low-energy building construction is fundamental for achieving national and European Union environmental goals; promoting and actively supporting building low-energy buildings should be one of the government's priorities. This suggests that construction regulations and financial incentives, such as tax reductions or subsidies, may act primarily as "catalysts" covering, to a certain extent, the extra cost of low-energy construction and eliminating the initial barrier to energy-efficient projects.

Notes

1. LEED is a voluntary certification system which provides third party verification that a building or community was designed and built with the aim to reduce environmental impact; building performance is assessed in five key areas (sustainable site development, water and energy efficiency, material selection and indoor environmental quality) and rated on a point scale whose total determines certification level (www.usgbc.org).
2. Minergie is a label, supported by the Swiss Confederation, Swiss cantons and industry, particularly focusing on building low and very low energy consumption and promoting highly energy-efficient choice of material (www.minergie.ch).
3. HICP – Harmonised Index of Consumer Prices; CPI index which has been calculated using a common methodology across EU countries.

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