Profitable Net ZEBs – How to break the traditional LCC analysis

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Abstract

Global warming and an increasing population needing more buildings are important issues ahead. Hence, Net ZEBs and green buildings is one of many necessary measures for climate change mitigation. Some studies indicate that improved energy and/or green performance in these buildings may not be profitable. However, a short time perspective and narrow concept for evaluation may be wrong. This study presents two different built Net ZEBs in Sweden, with verified plus energy performance in user phase. Furthermore, it presents an economic analysis, based on life cycle costing (LCC), where additional green values are included in the analysis. The study shows that the, discounted, cumulative annual cost reductions due to green values exceed the initial extra cost after roughly five years. More research should be carried out in order to develop the methods and equations presented here and to gain more knowledge regarding reduced employee turnover, reduced sick absence, increased productivity, etc. in green buildings.

Keywords: Net Zero Energy Building; Life Cycle Costing; Net ZEB; LCC

1. Introduction

The IPCCs first working group, states unambiguously through observations and measurements that there is a warming of the climate system [1]. The atmosphere and ocean have warmed, the amounts of snow and ice have diminished, sea level has risen, and the concentrations of greenhouse gases have increased.

Energy use in buildings accounts for 24 % of the generation of greenhouse gases and 40 % of the primary energy use [2]. The population, and the need for buildings, on the planet is increasing. Hence, Net Zero Energy Buildings, Net ZEBs, is one of many necessary measures for climate change mitigation as they may reduce the fossil energy use in the building sector. The number of low-energy buildings and Net ZEBs has increased significantly over the past years in Sweden [3].

Net ZEBs are usually also "green buildings", which here are referred to as buildings with high performance within the aspects of energy, thermal comfort, indoor air quality, building materials etc.

Despite that construction of Net ZEBs and other low-energy and/or green buildings has been proven possible; it was, by the Swedish government, suggested to forbid the possibility for municipalities in Sweden to set tougher energy requirements for new construction, than the requirements in the national building regulations in 2013 [4]. The suggestion was based on a Swedish Government Official Report, "Byggkravsutredningen" [5], stating that calculated incurring additional costs, 10-15 %, are unprofitable. Based on this, the Swedish law: Planning and Building Act (2010:900) were changed in 2015, prohibiting municipalities in Sweden to set tougher energy requirements than the requirements in the national building regulations.

To design and construct buildings with additional insulation, more energy efficient HVAC-systems etc. are usually coupled to increased investment costs. However, several other studies and evaluations estimates the additional costs to 0-10 % [6-8], to design and construct buildings with significantly better energy performance than in the mentioned official report [5].

The energy tariffs in Sweden are relatively low today. Hence, it is usually difficult to justify decisions such as investing in more insulation and energy-efficient HVAC-systems if the measures need to be profitable based on a short time perspective. Furthermore, it may be hard to value other aspects that may be included in green buildings.

A short time perspective and a narrow concept for evaluating profit, only focusing on increased investment costs and decreased energy costs, may be wrong. This may be wrong not only from a socio economic perspective, but also from a strict business perspective. By broadening boundary conditions for the traditional economic framework, the economic conclusion may be completely different compared to the Swedish Government Official Report [5].

This paper presents two green Net ZEBs in Sweden and cost analyses, showing a slightly different way to evaluate the profitability of investment. This study does not claim to verify green value in these buildings. Rather, it shows how these values may be quantified.

2. Added value in green buildings

Quantifying added value in green buildings in monetary terms, except for energy savings, may be complex. Nevertheless, attempts to include increased productivity, reduced turnover and reduced absenteeism has been carried out, for example by James Scott Brew [9]. The calculation procedure in itself may not be complex, but the research on green buildings and environmental and green benefits is still in its early stage. I.e. well proven statistic-based input data for the calculations are not always easy to find. However, studies do exist that may be used as a basis [10-14].

An American study showed that 19 % of 534 tenants/companies in green buildings reported lower employee turnover [10]. Furthermore, roughly 20-25 % of the tenants/companies also reported higher employee morale, easier to recruit employees and more effective client meetings.

Regarding productivity in green buildings, studies show that employees in green buildings perceive a positive effect of their work environment and productivity in green buildings [11-13]. Furthermore, reduced absenteeism has also been found [12, 13]. However, a recent study highlights that social factors are significantly more important from a monetary perspective, than environmental factors [14].

Three additional "values" are worth mentioning. Firstly, it is "publicity for free". The value of a positive news article about a specific building or a specific project should be comparable to advertising costs in the specific source, in which the article is published. Secondly, in Sweden, green incentives may be given from municipalities for projects with high green ambitions, such as the possibility to buy land for development, reduced land prices, reduction of administration costs for building permits and shortened process time for building permits. A recent study [15] found that 40 % of the municipalities in Sweden applies promotion measures in order to increase the share of green buildings and 13 % applies green incentives in monetary terms.

3. Introduction to the case studies

Two Net ZEB case studies are included in this study; one office building and one residential building. The Net ZEB balance is based on the Swedish building regulations, excluding energy use for plug loads and lighting.

The office building is located in the south of Sweden, Väla Gård, see Fig 1. The building consists of two main buildings with double pitched roofs, connected by a smaller building with a flat roof. The smaller building serves as an entrance and reception. The building is designed according to the passive house design principle with an airtight and well-insulated building envelope and balanced mechanical ventilation with heat recovery and variable air volume, based on temperature and CO2. Heat is supplied via a ground source heat pump, GSHP, connected to bore holes. During summer, the boreholes are used as a natural heat sink, free cooling is extracted by circulating the working fluid for the heat pump in the bore holes. Roof sides facing south-west are equipped with PV panels. A summary of the design is presented in Table 1. In addition to the Net ZEB performance, the building is also certified as LEED platinum [16], which includes high focus in indoor environment quality. The projects also had tough green goals for construction materials and waste such as 100 % recycling/reuse of waste from the building site, and 100 % non-hazardous chemicals and building materials. More technical information and results from measurements and verification may also be found in other publications [17-20].

Fig. 1 Väla Gård, Office building in the south of Sweden

Table 1 Summary of technical description, Väla Gård

Technical description	Data
Conditioned floor area	1 670 m^2
U-average, building envelope	U=0.26 W/m^2K
Air tightness, assumed (q_{50}/n_{50})	0.3 l/s, m^2 / 1.0 h^{-1}
Ventilation heat recovery	82 %
COP (heating/cooling)	3/20
PV-panels (area/kWp)	455 m^2/67.5 kWp

The office building, Väla Gård, was taken into use in 2012 and the energy performance has been monitored, see Table 2. The measurements have not been normalized for deviating boundary conditions (e.g. external climate).

Table 2 Summarized energy performance, Väla Gård
(Sim = Simulated results, Meas. = Measured results)

	kWh/m^2a	
Energy use	**Sim.**	**Meas.**
Heating, cooling & auxiliary energy	19	14
Plug loads and lighting	29	26
PV-panels	38	41
Imported electricity	29	23
Exported electricity	19	24

The residential building is also located in the south of Sweden, see Fig 2. The building is one out of seven one-storey terraced houses within the neighbourhood. All buildings are designed according to the passive house design principle with an airtight and well-insulated building envelope and balanced mechanical ventilation with heat recovery. The ventilation system has the capacity to double the air flow, which may be done manually or programmed to do based on relative humidity or temperature. Heat is supplied via a GSHP connected to bore holes. During summer, the boreholes are used as a natural heat sink, free cooling is extracted by circulating the working fluid for the heat pump in the bore holes. Each building was designed with 40 PV-panels mounted on the roof. A summary of the design is presented in Table 3. More technical information and results from measurements and verification may also be found in other publications [20-22].

In addition to the Net ZEB performance, the building is also certified as a “Svanen building” [23], which includes high focus on indoor environment quality, healthy construction materials and 100 % recycling/reuse of construction waste.

Fig. 2 Solallén, Residential building in the south of Sweden

Table 3 Summary of technical description, Solallén

Technical description	Data
Conditioned floor area	258 m^2
U-average, building envelope	U=0.17 W/m^2K
Air tightness, measured (q_{50}/n_{50})	0.21 l/s, m^2 / 0.84 h^{-1}
Ventilation heat recovery	90 %
COP (heating/cooling)	3/20
PV-panels (area/kWp)	66 m^2/10 kWp

The residential building, at Solallén, was taken into use in 2015 and the energy performance has been monitored, see Table 4. The measured results have not been normalized for deviating boundary conditions (e.g. external climate).

Table 4 Summary energy performance, Solallén (Sim = Simulated results, Meas. = Measured results)

	kWh/m^2a	
Energy use	**Sim.**	**Meas.**
Heating, cooling and auxiliary energy	30	28
Plug loads and lighting	30	22
PV-panels	31	36
Imported electricity	45	38
Exported electricity	16	24

4. Methodology

The profitability of the increased costs related to increased energy efficiency and green values related to the building were evaluated. The increased costs for production were be compared to the value of energy efficiency and other green values, quantified as described in this chapter.

The value of reduced energy use and exported energy is described in Eq. 1 which summarizes reduced energy costs (REC). Future value of imported and exported energy is discounted into a net present value. REC is usually evaluated towards the capital expenditures related to the energy measure or measures. Within this model, costs for maintenance and replacement are not included.

$$REC = \sum \frac{EI \cdot \alpha + EE \cdot \beta}{\left(1 + \frac{r - i - \gamma}{1 + i + \gamma}\right)^t} \quad (1)$$

where *EI* is the reduced imported energy, α is its energy tariff, *EE* is the increased exported energy, β is its energy tariff , *r* is the nominal discount rate, *i* is the inflation rate and γ is the increase in energy tariffs.

In order to widen the economic concept, the net present value of five additional values may be quantified according to Eq. 2-6; reduced employee turnover costs (RETC), reduced sickness absence costs (RSAC), increased productivity value (IPV), public publicity value (PPV), reduced sickness absence salary (RSAS). Equation 1 and 6 may be used for a stakeholder who will invest in a residence building to live in. Equations 1-5 may be used for a stakeholder who will invest in a non-residential buildings for its own staff.

$$RETC = \sum \frac{\varepsilon \cdot Emp(RC + IC + RPC + LI + DC)}{(1 + R)^t} \quad (2)$$

where ε is the reduced employee turnover, *Emp* is the quantity of employees, *RC* is the recruitment cost per employee, *IC* is the introduction course for new employee, *RPC* is the reduced productivity cost (new employee and supervisor), *LI* is the lost income during vacancy, *DC* is the decommissioning cost and *R* is the discount rate, as presented in Eq. 7.

$$RSAC = \sum \frac{Emp \cdot 0.8SC \cdot \phi \cdot \kappa}{(1 + R)^t} \quad (3)$$

Where *SC* is the average salary costs per employee, ϕ is the average sickness absence, κ is the reduced sickness absence.

The reason for the reduction of the salary in Eq 3 is due to that wageworkers in Sweden usually get 80 % of their salary when they are on sick leave [24].

$$IPV = \sum \frac{Emp \cdot SC \cdot IP}{(1 + R)^t} \quad (4)$$

where IP is the increased productivity per employee.

$$PPV = \sum AIP \cdot AC \quad (5)$$

where *AIP* is article in press and *AC* is the advertising costs in the specific source (paper, internet, etc.).

$$RSAS = \sum \frac{WW \cdot 0.2S \cdot \phi \cdot \kappa}{(1+R)^t} \quad (6)$$

where WW is the quantity of wageworkers in the household and S is the salary.

The reason for the reduction of the salary in Eq 6 is due to that wageworkers in Sweden usually get 80 % of their salary when they are on sick leave [24].

$$R = \frac{r - i}{1 + i} \quad (7)$$

Furthermore, as mentioned in the previous chapter, the value of lowered land price may also be included in an evaluation. As this usually occurs during the initial phase of a building process, there is no need to discount these values. I.e. no need for an equation to express the net present value.

Väla Gård, the office building, were evaluated by quantifying REC, RETC, RSAC, IPV and PPV. Furthermore, the increased investment costs coupled to these savings were quantified.

Solallén, the residential building, were evaluated by quantifying REC, RSAS and lowered land price (which was the case in this project). Furthermore, the increased investment costs coupled to these savings were be quantified.

In Solallén and Väla Gård, productivity, sickness absence etc. were not measured. In order to enable quantification of green values, input data regarding reduced employee turnover, reduced sickness absence and increased productivity were based on previous studies [10-14]. Increased costs for the case studies, to achieve their green and Net ZEB targets, were gathered from the project managers in each project. Other data is gathered from Swedish literature and databases. The input data and results are presented in the next section. For all input data, except investments and energy performance, a base case data set is defined and presented together with an interval for sensitivity analysis.

5. Results and discussions

Boundary conditions regarding nominal discount rate, inflation, energy tariffs, changes in energy tariffs and period of analysis are presented in Table 5. Regarding nominal discount rate, governmental and municipal organizations usually have rather low requirements, 4-6 % [25]. However, private actors may have higher requirements. In this study we have chosen to set 7 % as the baseline.

The inflation is constantly changing. In Sweden, the national target is 2 % [26]. Hence, 2 % is chosen as a baseline.

Regarding energy tariffs, data show that the increase of energy prices over time in Sweden has been almost 4 %, not adjusted for inflation [27]. I.e. a lower value, 2 % is chosen. Energy tariffs are set to reflect Swedish conditions.

Table 5 Boundary conditions

Boundary condition		**Input**	
Nominal discount rate, r	[%]	7	±2
Inflation, i	[%]	2	±1
Tariff for imported energy, α	[€/kWh]	0.12	±0.02
Tariff for exported energy, β	[€/kWh]	0.10	±0.02
Increase in energy tariff, γ	[%]	2	±1

The office building, Väla Gård, reported increased costs amounting to almost 450 000 € or 268 €/m^2, roughly an increase of 11 % of costs compared to if the office would have been a "normal office". Increased production costs, consultants and certifications costs are included. The GSHP-system is not included in the increased costs, as it would have been required regardless of whether the building was to be green or not. Regarding investment costs, a state grant were given for the PV-panels, amounting to roughly 82 000 € or 49 €/m^2.

The residential building, Solallén, reported increased costs amounting to almost 300 000 €. However, these costs represent increased costs for all seven buildings in the project. The increased cost per building were roughly 42 000 € or 164 €/m^2, roughly an increase of 8 % of costs compared to if it would have been a "normal residential building". The same costs are included as in the costs for Väla Gård. No state grants for PV-panels were given in this case. However, a municipal discount on land was given for projects who were designed as passive houses or better. In this case the discount amounted to 165 000 € for all seven houses or 92 €/m^2.

Reduced energy costs are based on measured values and calculated according to input data in Table 5.

Salary, *S*, and salary costs, *SC*, is based on average salaries in Sweden [28], which is roughly 3 765 €/month. Including costs for employers, the salary costs amounts to 6 325 €/month. No differences in salary for managers and other employees have been included. In total 70 persons are employed to work at Väla Gård and 5 wage workers are expected to live in Solallén.

Regarding reduced costs related to employee turnover for Väla Gård, data is summarised in Table 6.

The average employee turnover in Sweden is 3.5 % [29]. Based on previous findings in reduced employee turnover [10], we assume that a reduced employee turnover of 0.5 % to 3.0 % is reasonable.

Based on an estimation of roughly two days of work, per recruited employee, and costs for advertising for new staff; the recruitment cost is summarised to 6 500 € per new employee. Furthermore an introduction course for each employee is expected to cost 2 000 €.

In order to summarise reduced productivity cost, a reduced productivity of 20% for two persons is expected for 6 months.

One person is the new employee the other person is one experienced co-worker who helps and guides the new employee.

Lost income during vacancy is based on a vacancy of 3 months, salary costs and nominal discount rate.

The decommissioning cost is based on an assumption of reduced productivity of the employee by 50 % after the person resigns for the remaining time of the employment.

Table 6 Basis for quantification of employee turnover costs

Data		Input	
Reduced employee turnover, *ε*	[%]	0,5	±0,1
Recruitment cost, RC	[€x10^3/p]	6.5	±1.5
Introduction course, *IC*	[€x10^3/p]	2.0	±0.5
Reduced productivity cost, *RPC*	[€x10^3/p]	15.1	±5.0
Lost income during vacancy, *LI*	[€x10^3/p]	1.3	±0.3
Decommissioning cost, *DC*	[€x10^3/p]	9.5	±1.5

Average sick absences in Sweden were six days per year in Sweden 2016 [30]. Based on previous findings of reductions of absenteeism [12, 13], we assume a reduced sickness absence of 10%, both for Väla Gård and Solallén.

Table 7 Basis for quantification of sick absence costs

Data		Input	
Average sickness absence, *ϕ*	[d]	6.0	
Reduced sickness absence, *κ*	[%]	10	±2.5

The quantification of increased productivity is based on the reduction of share of time were an employee does not perform value creating work. I.e. increased productivity. Based on previous findings [11-13], we estimate that the productivity may increase by 0.5 %, see Table 8.

Table 8 Basis for quantification of increased productivity

Data		Input	
Increased productivity, *IP*	[%]	0.5	±0.25

Numerous articles were published about Väla Gård. In total, ten publications about Väla Gård were considered to have such a positive value that it could be considered to be equal to advertising. The corresponding cost were estimated to 3 500 € per article.

Based on the input data presented, the recurring cost reductions for Väla Gård (REC, RETC, RSAC and IPV) amounts to roughly 69 000 €/year or 42 €/m^{2}a. Regarding Solallén, the recurring cost reductions (REC and RSAS) amount to roughly 2 730 €/year or 11 €/m^{2}a. The distribution of the summarised green values for the first ten years are presented in Fig 3. As can be seen, the cost reductions (CR) amount to a significant *relative share* in Solallén compared to Väla Gård. This is mainly due to additional values in RETC, IPV and PPV for Väla Gård which is not included in Solallén.

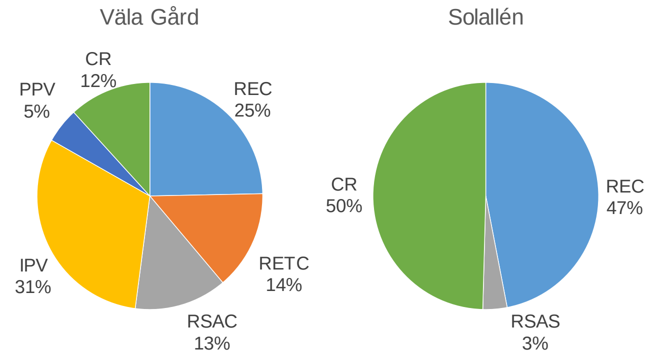

Fig. 3 Distribution of summarised green values for ten years. Väla Gård (left) and Solallén (right)

The accumulated discounted value for the cost reductions in Väla Gård and Solallén, normalised by conditioned area, is presented in Fig 4. For both buildings, a base case is presented together with a best case and a worst case. The accumulated value starts on a negative value which is due to the increased costs for green investments.

The accumulated green values, in the base cases, exceed the initial costs after roughly four and seven years for Väla Gård and Solallén respectively.

The initial green investments, normalised by conditioned area, were roughly 60 % higher for Väla Gård compared to Solallén. When the grants given by the state and the municipality are considered the difference increases to roughly 300%.

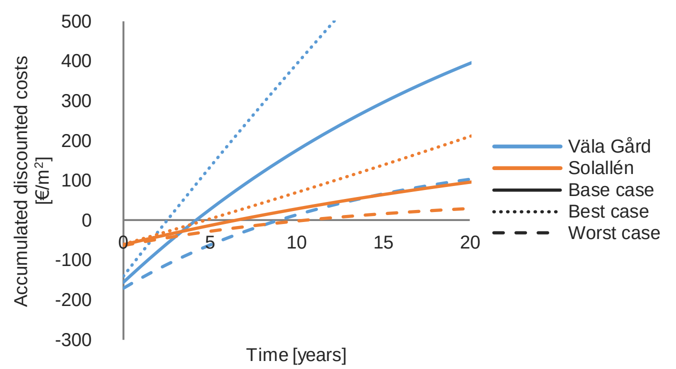

Fig. 4 Accumulated costs for investments and for green values in Väla Gård and Solallén.

Since green values for increased productivity etc. are not included in Solallén, it takes a little longer time for the "payback". Furthermore, one may argue that the cost reduction on the land given by the municipality is very important in this case. However, it would be possible to quantify more green values, which are not included here. E.g. increased value of building, less costs moving/changing homes (if one is satisfied with its home, one should stay there for a longer time) etc.

Previous studies exist for which co-incurring additional costs amounts to 0-15 % [5-8]. Here, the corresponding value is 8-11 %.

Results showing increased costs of 0 % are unlikely to be, due to the lack of investment to achieve "green performance". Probably, these projects have prioritized “green investment” and saved money in other parts of the project. Thus, the projects have not become more costly than expected.

Reduced employee turnover, reduced sick absence and increased productivity in this study is based on assumptions, i.e. should not be mistaken for verified results.

6. Conclusions

In this study we showed examples of how green values could be quantified in monetary terms. The study shows that it may be very profitable to build green buildings if one accounts for green values. Furthermore, it may be easier to find it profitable in non-residential buildings.

However, more research should be done in order to further develop these methods and to gain more knowledge regarding reduced employee turnover, reduced sick absence, increased productivity, etc. in green buildings.

Abbreviations

AC	Advertising cost
AIP	Article in press
DC	Decommissioning cost
EE	Exported energy
EI	Imported energy
Emp	Quantity of employees
i	Inflation
IC	Introduction course for new employee
IP	Increased productivity
IPV	Increased productivity value
LI	Lost income during vacancy
PPV	Public publicity value
r	Nominal discount rate
R	Discount rate
RC	Recruitment cost per employee
REC	Reduced energy costs
RETC	Reduced employee turnover costs
RPC	Reduced productivity cost
RSAC	Reduced sickness absence costs
RSAS	Reduced sickness absence salary
SC	Salary costs
t	Period of analysis
WW	Quantity of wage workers
α	Tariff for imported energy
β	Tariff for exported energy
γ	Increase in energy tariff
ε	Reduced employee turnover
κ	Reduced sickness absence
ϕ	Sickness absence

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