Financial evaluation of energy efficiency in buildings: Social cost-benefit analysis

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One of the main objectives of EU energy policy is to improve the energy efficiency of buildings, because nearly 40% of the final energy consumption is made up of buildings – houses, offices, shops and other buildings – and in addition, buildings have the second largest energy saving potential. It is very difficult to determine the overall economic impact when it comes to energy efficiency testing for public buildings, as there are a number of factors of uncertainty that arise from implementation to operation. Buildings should therefore be treated as capital investments where the best investment scenario is likely to be unclear. There is a need to model trade-off relationships between the factors influencing the investment. One of the tools for assessing cash flows in energy efficiency studies is Cost-Benefit Analysis (CBA), which is called the Social Cost-Benefit Analysis (SCBA) in the public sphere. In this study, besides the revenue and expenditure required for energy efficiency analysis, we explore the potential risk factors that lead to scenario analyses.

Introduction

Energy efficiency is at the heart of the European Union's 'Europe 2020' Sustainable Growth Strategy (EC, 2010). The Union has envisaged 20% savings over the projected energy consumption by 2020, which can potentially be achieved in buildings, transport, production and processing. When designing cost-saving investments, it is an important aspect that businesses which ignore the opportunities offered by the digital economy can face competitive disadvantages (Szekeres & Borzán, 2018a). In the 21st century the technological and digital development are indispensable part of the continuous investment activities related to the investment incentive system in the national economy (Szekeres & Borzán, 2018b). Member States also agree that ICT (Infocommunication Technologies) is necessary for the implementation of an intelligent energy and transport system. The smart electricity grid, a higher level of energy efficiency and the spread of renewable energy sources are essential elements of a modern, competitive economy and the development of the EU.

One of the main objectives of EU energy policy is to improve the energy efficiency of buildings, because nearly 40% of the final energy consumption is made up of buildings – houses, offices, shops and other buildings – and the second largest energy saving potential lies in the buildings after the energy sector (Eurostat, 2011). Based on studies conducted for the EU (Eichhammer et al., 2009; Wesselink et al., 2010), the cost-effective energy savings potential of buildings can be estimated at 65 Mtoe, corresponding to cumulated investment requirements, amounting to 587 billion euros for the period 2011- 2020.This savings potential would cover 60 billion euros of investment needs annually. It should also be noted that the buildings built today will still exist in 50-100 years, so 92% of buildings built in 2005 will still be operational in 2020 and 75% in 2050 (EC, 2012). Beyond energy savings, better efficiency also contributes to cut carbon emissions (Harangozó & Szigeti, 2017), a key element of climate policy (Harangozó, 2008).

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Essential, necessary elements of energy efficiency analysis

It is very difficult to determine the overall economic impact when it comes to energy efficiency testing for public buildings, as there are a number of factors of uncertainty that arise from implementation to operation. Buildings should therefore be treated as capital investments where the best investment scenario is likely to be unclear. There is a need to model trade-off relationships between the factors influencing the investment. As with any other investments, the general model for energy efficiency analysis of public buildings is Cost-Benefit Analysis (CBA). The most typical feature of the energy efficiency analysis of public buildings is the high initial investment and the generally lower operating costs during the operational life cycle. Basics of energy efficiency analysis:

- Assessing and outlining the owner’s investment criteria (available resources, discount rate, expected return time, ownership duration),
- energy costs, escalation rate,
- energy consumption of the building,
- construction and investment costs,
- upkeep and maintenance costs
- planned replacement costs.

Of course, making strategic decisions requires taking into account more extensive factors – tax, capital budget and other – which should be supplemented by the assessment of external impacts[1]. These social cost-benefit analyses regarding the greening process of energy production and use can be of great help in the operation of public institutions (Table 1).

Table 1. Potential institutions in the focus of social cost-benefit analysis

Building types	*Examples*
Administrative, urban public buildings	Offices Town hall Library Court Central Police Station Ambulance Station Churches
Credit institutions	Commercial banks, Savings cooperatives
Educational institutions	Elementary school Secondary school College University
Health institutions	Hospital Multifunctional health centers
Hotels	
Industrial buildings	Warehouses Factories
Offices	
Residential buildings	Private homes Flats
Commercial buildings	Shopping mall Store Shopping center
Social service institutions	Social homes Parking lots Sports and recreation centers

Social cost-benefit analysis

The social cost-benefit analysis is based on the following long-term parity.

[1] The emergence of development programs can also have a significant impact on construction projects (Szabó, 2014).

Full-scale Eco-nomic Impact	=	+	Benefit change (consumer surplus)	+	Changes in operating costs and revenues (producer surplus and government impacts)	+	Changes in external costs (eg. envi-ronmental and health impacts)	-	Investment costs

Determining each item of the above parity requires a careful and wide-ranging analysis and assessment. The income effects (Table 2) can be monetary, non-monetary and quality elements.

Table 2. Possible benefits during investment evaluation

Benefit factors	*Type*	*Content*	*Example*
Monetary	Revenues	Revenues directly or indirectly generated from the project (incremental revenues).	Income from the project, electricity and heating, ie. heat production.
	Avoidable (alternative) costs	Unavoidable without the investment, however, avoidable with the realization of the investment.	
	Cost saving	A measurable decrease in the level of expenditures, in case project implementation is continuous.	
	Residual value of assets		
Non-monetary	Quantitative	Benefits connected to health and environmental impacts, which in many cases can be quantified financially (avoidable external costs).	Lower number of asthma cases, and mortality rate.
Non-monetary	Qualitative	All advantages and benefits that are not quantifiable in terms of quantity.	Increasing skills, abilities and experience of employees.

Source: NEEDS (2009)

The possible cost categories (Table 3) should also be assessed with the same depth.

Table 3. Possible cost elements

Costs	*Type*	*Content*	*Example*
Monetary	Investment costs	Expenditure incurred up to commissioning such as equipment transportation, construction, civil works, pipeline construction, engineering works, consulting, landscaping .	Investment in waste-gas, desulphurization process.
	Fixed costs	Also remains constant in case of different volumes of electricity and heat generation	Maintenance and administrative overheads.
	Variable costs	Varying degrees, according to the changes in the volume of electricity and heat production.	Fuel cost.
Non-monetary	Quantitative	Mainly external costs, which are linked to adverse health and environmental developments.	The institution's loss of income.
Non-monetary	Qualitative	Any other expenditure that cannot be quantified or expressed in physical appearance.	Landscape aesthetic effects of wind parks.

Source: NEEDS (2009)

The energy investments can be evaluated on the basis of their physical and economic lifespan. Firstly, it is necessary to define the term for major repair and reinvestment needs – this is much shorter than the term of the whole project. The planning time horizon for energy efficiency projects is typically 20 to 40 years.

Table 4 shows the results in terms of calculating the cost and benefit components of present value (PV) and net present value (NPV) in case of investment alternatives for increasing project efficiency[2]. The table shows step-by-step how to perform cost-benefit analysis, taking into account an

[2] For project planning, it is necessary and important to properly estimate the return on projects, but this step is often omitted from the planning process (Csiszárik-Kocsir & Varga, 2017a; 2017b, Csiszárik-Kocsir, 2018).

energy producing project and its external costs (environmental and health impacts). NPV calculations allow the ranking of alternative projects.

Table 4. Scoreboard for investment ranking

		Alt.1	Alt. 2	Alt. 3	Alt. "n"
1.	PV Investment costs				
2.	PV Operational costs				
3.	PV External costs				
4.	PV Yields				
5.	Net Present Value (NPV) = PV (Yields) – PV (Total cost)				
6.	Ranking based on NPV, taking into account the external costs				
7.	Net Present Value (NPV) = PV (Yields) – PV (Institutional costs)				
8.	Ranking based on NPV, excluding external costs				

The difference between the 6th and 8th lines of the table is remarkable, since it is in fact signals the difference between taking into account and excluding sustainability principles. The pursuit of sustainability can be costly in the short term – during the initial phase of the investment, which can put heavy burdens on the investor –, in the long term, however, it has a positive effect due to positive synergy effects.

I would also like to note that during the modeling I have taken into account that an institution can not only be an energy user but also an energy producer. Only in this case can we really carry out dynamic evaluations and cost-benefit calculations. If we only model energy consumption, the lines for production are zeroed and in this case we are talking about cost optimization and cost-effectiveness only.

Static and dynamic investment evaluation models

Previously, the most common process of conducting a full evaluation was demonstrated by evaluating cash flows based on NPV. This represents a dynamic assessment, which took into account the time value of money during the calculations.

However, for static investment-economic calculations this is not yet done. When assessing the energy efficiency of buildings, simple payback (SPB) is worth calculating. This is acceptable if the inflation and the discount rate is low and the payback period is very short. Some organizations prefer simple payback and simple cost accounting methods for alternative energy saving programs due to future inflations and unpredictable interest rates.

The calculation of the simple payback can be described by the following specification:

Simple payback (SPB) = one-time expenditure/average annual yield
SPB = (cost of energy-saving proposal)/(annual savings – annual cost of savings)

The applicable *dynamic calculations* cover not only cost-benefit ratios, but also provide a good comparison and evaluation basis for the following indicators: net present value, RNPSS rate, internal returns.

The project is recommended if the NPV is positive. The net present value is equal to the difference in the present value of the benefit (positive cash flows) and the cost (negative cash flows).

$$NPV = PV(B) - PV(C)$$

$$PV(B) = \sum_{t=0}^{N} \frac{B_t}{(1+r)^t} \qquad PV(C) = \sum_{t=0}^{N} \frac{C_t}{(1+r)^t}$$

The cost-benefit analysis is a ratio that is accepted if its value is greater than 1, i.e. the present value of the benefits is higher than the present value of the costs.

$$BCR = \frac{PV(B)}{PV(C)}$$

Determining the discount rate is a key factor. For energy investments, the values envisaged by the EU are the standard, which is 3,5% for EU Member States and 5,5% for Cohesion countries.

RNPSS (Ratio of NPV and public sector support) is a corrective version of cost-benefit analysis which is already used in many advanced economies (UK, Scotland, EU, Switzerland). As a starting point, it is assumed that only positive net present value projects are available but there is not enough funding source. This is a BCR-like ratio, but the denominator and the numerator also show the public sector support. If an investment is privately funded, the grant will only appear in the denominator. Thus, projects that are partially privately funded or fully privately funded (if such a thing exists) become preferable.

IRR (Internal Rate of Return) is the discount rate that makes the discounted profits and discounted costs of a project equal. IRR can also be defined as an internal return with an NPV of a project being zero. The implementation of the project is recommended when the internal rate of return is higher than the discount rate determined on the basis of EU appropriations.

After dynamic investment-economic calculations, due to the high uncertainty factors, it is worth conducting sensitivity analysis. Sensitivity analysis focuses on alternative assumptions that have a significant impact on the results of the study (for instance NPV, or cost-benefit ratio). The goal is to show how risky the project is if some assumptions or factors change.

The sensitivity analysis should identify the most critical variables in the project, where even small changes in their values create significant changes in the NPV and can possibly cross the 'break-even' limit. The sensitivity analysis shows how stable the net present value is, how much it is affected by the cost-benefit factors, the discount rate and the time horizon. Table 5 lists the variables and factors that may be relevant in the sensitivity analyses and the outcome of the investment assessment.

Table 5. Critical factors in the sensitivity analysis

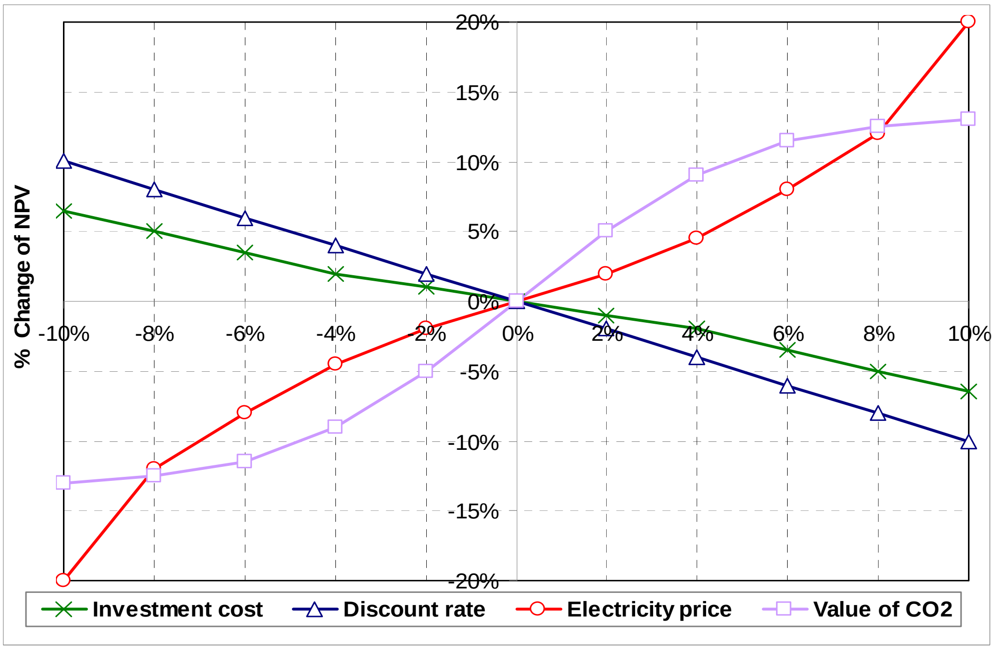
Categories	*Examples*
Operational costs	Cost of goods and use of services: wage, electricity, heating, gas, other fuel, fuel transport costs.
Quantitative parameters in terms of operating costs	Consumption rate of energy and other goods and services; number of employees.
Investment costs	Duration of construction, wages, real estate purchase price, transport costs, concrete and steel costs, turbines and boilers, useful life of equipment.
Output prices	The commercial price of electricity and heating, the price of by-products.
Quantitative parameters in terms of yields	The efficiency of boilers and turbines, the amount of electricity and heat generation, number of users.
Price flexibility	Inflation rate, real wage growth rate, energy price growth rate, price indexes.
Eligibility of prices (costs and yields)	Conversion equivalent of market prices, shadow prices of products and services.
External costs	Value of income loss, cost of construction materials, illness, monetary manifestation of willingness to reduce the morbidity rate, costs to manage or avoid GHG effects, value preservation.
Quantitative parameters in terms of external costs	Emission volume and height management, weather conditions, air quality, population density, radiation / harmful substance inhalation exposure parameters.

Source: NEEDS (2009)

The analysis can therefore be used in all cases where the estimated costs and benefits can be quantified. The aim is to show how risky the project is, in case of favorable and unfavorable conditions.

The analysis can be even more expressive if we graph the project's sensitivity to the most important factors. The following graph shows the sensitivity of the project of an institution engaged in energy production to investment costs, discount rate, electricity prices and CO2 emissions.

Figure 1. Score graph of sensitivity analysis



Source: NEEDS (2009)

After depicting the results of the sensitivity analysis, we will be able to identify the most important factors and their effect on NPV. Figure 1 shows that NPV is very sensitive to changes in electricity prices – if we examine the investment at the producer level. A 20% reduction in the electricity price will lead to a reduction in the net present value of about 20%. On the other hand, NPV is relatively insensitive to the change in investment costs – since we know that the investment period is very long (between 20 to 40 years). The discount rate represents the unit flexibility, which means the amount of percent change generated in the NPV in case of a 1% change in the discount rate.

In addition to conducting sensitivity analysis, scenario analysis can also be made. Instead of examining each parameter individually, it examines the combined effect of the value of critical variables on NPV. We need to create a pessimistic and an optimistic scenario where we can evaluate the parameters of each variable in aggregate, that is, we can analyze the values of the variables together. This process allows to define multiple scenarios for each project opportunity:

- Pessimistic scenario. This represents a combination of 'high' costs and 'low' benefits.
- The most likely or base scenario. This is a combination of the most likely benefits and costs. Keep in mind that the most likely scenario may be different from the base scenario, which contains not the most likely, but the expected values.

- Optimistic scenario. Unlike the pessimistic scenario, this is a combination of 'low' costs and 'high' yields.

Figure 2 shows that this leads to eight scenarios in addition to the primary realistic scenario, based on the two extreme cases, the pessimistic scenario (high costs and low benefits) and the optimistic scenario (low cost and high benefit).

Figure 2. Scenario modelling

			Cost scenarios		
			Low	Realistic	High
			IC -10%, FC -5%	IC -10%, FC -5%	IC -10%, FC -5%
Benefit scenarios	Low	Elec P -10% CO_2 -5%	NPV 95% BS	NPV 80% BS	Pessimistic: NPV 60% BS
	Realistic	Elec P Base CO_2 Base	NPV 110% BS	Realistic: NPV 100% BS	NPV 85% BS
	High	Elec P +10% CO_2 +5%	Optimistic: NPV 135% BS	NPV 125% BS	NPV 105% BS

Remarks
ElecP - Electricity price
CO2 - Damage of CO_2 avoided (Avoidance of the harmful effects of CO_2)
IC - Investment costs
FC - Fuel costs
BS - Base scenario (Realistic scenario)
NPV - Net present value

Source: NEEDS (2009)

Summary

In determining the theoretical framework for the above building energy efficiency analysis, it can be seen that the known calculations must be thoroughly and carefully developed according to the specific data. The cost and benefit factors should be individually defined for the duration of the entire operating and investment cycle. In addition to the discount factors corresponding to EU standards, only investment-specific factors can make the analysis complete – tax effects, inflation indexation or with the help of integrating residual value.

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