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# Methods of evaluating the long-term financial effects of energy efficiency projects*

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**Abstract:**

Are investments in energy efficiency profitable? The answer largely depends on the applied methodology within investment analysis, but because of their wide impact energy efficiency investments should not be evaluated only by "normal" investment criteria. After a comprehensive literature review, we establish a new conceptual framework for the analysis of energy efficiency methodology and exhibit three main factors of evaluation: scope, timing, and approach. Stakeholders of energy efficiency projects can employ this framework when choosing the appropriate methodology for their investment analysis.

**JEL Classifications:** C18, C49, Q40, Q51

**Keywords:** Energy efficiency, profitability, evaluation methods, financial effects

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## 1. Introduction

Energy drives the economy. The importance of dedication to efficient production and use of energy arises not only from the (legitimate) pursuit of profitability (which is well documented, see FS & UNEP, 2016), but from severe damages society has caused to our environment due to an inefficient and inconsiderate use of energy and its resources. The aim of this paper is to investigate the methods of evaluation of long-term financial effects arising from energy efficiency projects, and to present a literature overview of energy efficiency projects' capital budgeting tools. As a literature overview paper, it is bound to be limited and non-exhaustive - it is unfeasible to encompass in an article the entirety of previous research in this field. Therefore, the focus will be on some of the pillars, broadened with selected contemporary work.

Energy-efficiency evaluation (EEE) from the perspective of financial analysis is quite straightforward, as it attempts to answer the following central question: are investments in energy efficiency profitable? Even though the question is simple, the answer to it is anything but straight-forward. It depends on the selection of financial factors and capital budgeting tools which are used when energy efficiency investment decisions are made. There is no single, correct answer: different methods provide different answers. The question then becomes: which methods, financial factors, and capital budgeting tools were used in EEE?

This article is organised in three sections. After the introduction, the second section presents a brief overview of the foundations in "standard" investment evaluation (i.e. unrelated to energy efficiency). The third section analyses idiosyncrasies of investments in energy efficiency projects, and shows how they differ from standard investment

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evaluation. The conclusion summarizes the most important findings, while the appendix provides an introduction to capital budgeting tools which are most often used.

## 2. "Standard" investment evaluation

Be it in the context of energy efficiency or otherwise, the "standard" financial evaluation of a projects' profitability is a central part of the overall cost-benefit analysis (e.g. EC, 2015). The distinction is that a cost-benefit analysis is usually done ex-ante, before investing (OECD, 2015), while EEE is carried out both before and after. Long-term investing (capital budgeting) has its established framework (see Appendix) which is based on the concept of time value of money (Helcké, 1981; Peterson & Fabozzi, 2002; Dayananda et al., 2002; Goel, 2015, etc.). Time value of money states that in a typical environment, where money has its price (the price being the interest rate), the time when money is available determines its value (Ruegg & Marshall, 1990, pp. 107-134). This is significant because capital is budgeted over longer periods of time. Furthermore, after a recent introduction of negative interest rates it no longer holds that money is more valuable today than tomorrow, which contrasts to the "classic" time-value concepts (such as Short, Packey & Holt, 1995, p. 5).

Equating future flows of money to a consistent (present) level is achieved through discounting, which reverses the future cash inflows and outflows of the project during every year of its lifetime and summarizes it in an amount (net present value; NPV) at the starting point of the project's life. While calculating NPV there are many assumptions about the future of the major variables that may determine the outcome. Assumptions are made because the future is unknown, however it must be predicted (to a degree) in order to provide a statement about the profitability of investment. Different assumptions constitute different scenarios about the possible development of the major determinants of the NPV. Scenario analyses can be automated via Monte Carlo simulations of the NPV's sensitivity to different assumptions (e.g. Žiković et al. (2015) used Monte Carlo simulation in calculating the profitability of a wind-powered electric generation plant).

Dixit & Pindyck (1994, p. xi) provided a new theoretical approach to ex-ante capital investment decisions. They emphasised the irreversibility of most investment decisions and the uncertainty of the environment in which investment decisions are made. This approach recognizes that there is a value in postponing the investment decision; waiting for better information can yield profit. Dixit & Pindyck provided a parallel with the option valuation theory (*options* as derivative financial instruments), which is why the framework they instituted is known as "real option investment analysis" (with the synonym "sequential investment analysis").

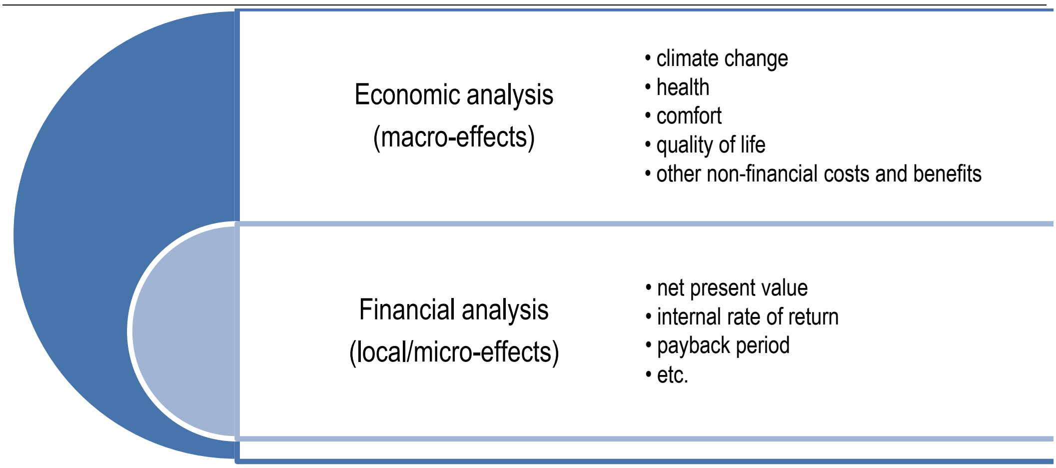
## 3. Specifics of investments in energy efficiency projects

Deciding on investing large amounts of money into anything is a complex process; made even more difficult when considering the complexities of energy efficiency related projects. Howarth & Sanstad (1995) state that the energy market abounds in market failures - asymmetric information, bounded rationality, and high transaction costs. EEE has its own peculiarities which make calculations of financial effects additionally challenging. Having in mind their importance, effects, and their overall impact, it should be clear why energy efficiency investments are considered "non-standard", and why they should not be evaluated by "normal" investment criteria. The "non-normality" of energy efficiency projects is also identified by UN: *"[Are] energy efficiency projects profitable under* normal *investment criteria? Clearly not. (…) Many energy efficient technologies are likely to remain unprofitable for some time, at least until environmental damages are properly priced"* (UNIDO, 2011, p. 7). Which criteria should then be used? The answer is determined mainly by how we classify the evaluation within the categories of scope, timing, and approach.

### *3.1 Scope*

The effects of energy efficiency projects are extensive (see e.g. Yang & Yu, 2015). An inclusive economic analysis of the energy efficiency project differs from its financial payoff (profitability) analysis because it is significantly broader, and should consider wider perspective than just individual financial effects on a local/micro-level. It should strive to estimate the environmental and societal benefits such as pollution reduction, increases in the levels of comfort, improvements in health and other non-financial costs and benefits (see Figure 1). Similar reasoning, albeit in a different form, was presented by UNIDO (2011, pp. 5-7), where *economic*, *environmental* and *social* benefits of energy efficiency projects are considered. *Economic* benefit is defined by the individual profitability, *environmental* benefits include reductions in emissions and pollution, and preservation of natural resources, while *social* benefits come from increases in competitiveness, productivity growth, employment and wages. All of these benefits have contributed to the promotion of investing in energy efficiency ex-ante, on an institutional level (e.g. Taylor et al. 2008).

FIGURE 1. ANALYSIS OF ENERGY EFFICIENCY PROJECTS' EFFECTS




Source: Author's representation.

However, estimating the environmental and societal benefits of energy efficiency projects is more than challenging. These effects are extensively explored in the field of climate change economics, but presenting them here extends beyond the aim and scope of this article. Introductions to the field of economics of climate change can be found at Griffin (2003), Hanley & Owen (2004), Stern (2008), etc.

Clinch et al. (2001) provide an example of encompassing the bigger picture when examining the profitability of energy efficiency projects. They analysed results from the implementation of various energy-saving retrofit measures across the domestic sector in Ireland. They also included mortality benefits (the proportion of excess winter deaths associated with poor thermal housing standards), morbidity benefits (increased exposure to cold and damp cause the majority of the seasonal variation in morbidity), and comfort (improved housing conditions). Other "co-benefits" of energy efficiency projects according to NAPEE (2007, pp. 3-8) include trade balances, increased tax revenues, and national security impacts.

Going beyond the local effects shifts the financial analysis to another level where it becomes progressively more complex. Such meta-disciplinarity, of course, makes way for confusion and disorder: "*In researching the role of energy efficiency policies, we quickly encountered data problems; limits to information; and deep-seated methodological challenges and debates about how to properly measure and predict the costs, benefits, and effectiveness of past and future policies*." (Gillingham et al. 2006, p. 186). Nevertheless, ignoring broader effects, retreating, and focusing on the local financial effects, can lead to profound effects such as climate change, a gradual deterioration of our ambient, and other harmful consequences to humanity and the environment (see Boyd, 2014, pp. 1-8). Ultimately, ethical considerations and moral obligations (however unquantifiable they might be) should also bear weight in EEE, whether economists are comfortable with them or not.

### 3.2 Timing

Temporal perspectives of EEEs are essential in resolving the evaluation methods of energy efficiency projects' long-term financial effects. When is the analysis of the profitability being done? The answer to this question largely determines the choice of the evaluation methods. EEE can and should be performed both:

a. before (ex-ante; a priori; as an investment study) the implementation of energy efficiency measures, and:

b. after it (ex-post; a posteriori); as an examination of the energy efficiency measures impact and effectiveness.

The Energy Efficiency Benefits Calculator (EEBC), provided by the United States Environmental Protection Agency (US EPA, 2006), is a tool that demonstrates the benefits of implementing energy efficiency programs. Cappers et al. (2009) performed a quantitative analysis of energy efficiency incentive mechanisms using EEBC. They showed that such an analysis can produce both an a priori estimate of the net resource benefits if the utility successfully implements energy efficiency programs, and an ex post quantification of the actual achieved change in bills, retail rates, shareholder earnings, and return on equity (Cappers et al., 2009, p. 15).

TABLE 1. EPISTEMOLOGICAL BREAKDOWN OF IMPORTANT VARIABLES REGARDING ENERGY EFFICIENCY PROJECTS

| IMPORTANT VARIABLES (SELECTION) | EX-ANTE (INVESTMENT ANALYSIS) | EX-POST (EFFECTIVENESS EVALUATION) |
|---|---|---|
| - FUTURE ENERGY PRICES<br>- FUTURE ENERGY CONSUMPTION<br>- FUTURE CONSUMER BEHAVIOUR<br>- EXOGENOUS FACTORS (FUTURE WEATHER, INTEREST RATES, ETC.) | UNKNOWN, TO BE ESTIMATED | KNOWN, MEASURED OR MEASURABLE |
| - ENERGY-RELATED EXPENDITURE THAT WOULD HAVE TAKEN PLACE IF ENERGY EFFICIENCY MEASURES HAD NOT BEEN IMPLEMENTED | UNKNOWN, TO BE ESTIMATED | UNKNOWN, TO BE ESTIMATED |

Source: Author's representation.

Both ex-ante and ex-post studies carry a burden of uncertainty about the level of savings from the implementation of an energy efficiency project, but for ex-ante analysis, understandably, that weight is much heftier because it additionally relies on estimates (see Table 1). It should be noted that ex-post econometric analyses usually find lower energy savings than those that rely on ex-ante methods. Joskow & Marron (1992) suggest that public utility companies tend to overstate the cost-effectiveness of energy efficiency programs by a factor of at least two.

As previously stated, one of the key questions in EEE (at least from a financial analyst's standpoint) is the question of profitability. The profit considered originates from a positive difference between energy efficiency related savings and costs. However, savings cannot be directly measured because they represent the absence of consumption or demand. Instead, in ex-post evaluation savings are usually determined in two ways:

1. by comparing measured consumption (or demand before and after the implementation of an energy efficiency program,) with adjustments for changes in conditions, such as weather. A savings calculation will typically be done by subtracting the energy measured after a project installation from the baseline consumption. In the lack of baseline data analysts use expert estimates (e.g. Bukarica, 2012, p. 6). Baseline consumption is the estimated energy consumption that would have occurred if the measures had not been applied (estimated avoided costs). The savings calculated relative to prior energy usage are usually labelled as the gross savings; see CADMAC (1998); CPUC (2004); NAPEE (2007); SEE Action (2012); Slote (2014), etc.;
2. net savings are the savings calculated relative to a comparison (control) group which serves as a proxy for what the participants would have done in the absence of the energy efficiency program.

If both gross and net savings are obtainable, a net-to-gross ratio (NTGR) can also be expressed. Gross savings may be estimated by one method and net savings estimated by another; in that case, an estimate of the net-to-gross ratio (NTGR) should be used in EEE. There are four approaches for determining the NTGR (NAPEE, 2007):

1. self-reporting surveys; in which information on savings are reported by participants and non-participants without an independent verification or review;
2. enhanced self-reporting surveys; the self-reporting surveys are combined with interviews and an independent documentation review and analysis which may also include an analysis of market-based data;
3. econometric methods; in the context of calculating net energy savings statistical models are used to compare participant and non-participant energy and demand patterns, these models often include survey inputs and other factors such as weather and energy costs (rates);
4. deemed net-to-gross ratios; NTGR is estimated using information available from the evaluation of other similar programs.

### *3.2.1 Un/reliability of ex-ante savings estimates*

In order to provide an answer to the question of profitability, an ex-ante analysis must estimate both (a) an expected future consumption after the simulated implementation of energy efficiency measures, as well as (b) the adverse scenario of future consumption without the simulated implementation of energy efficiency measures. The ex-post analysis, as presented in Table 1, is faced with the estimation of only (b). Clinch & Healy (2001) provided a template for ex-ante economic evaluations of energy efficiency programmes, but clearly stated that there are *"a number of weaknesses in the analysis"* (Clinch & Healy, 2001, p. 122) which mostly arise from the need to make various assumptions to predict future prices and to estimate other benefits. This explains why EEE is sometimes regarded as "*an attempt to measure the unmeasurable*" (Kushler et al., 1992, p. 7.6).

Because a priori and a posteriori analyses differ substantially, the respective frameworks for the financial analyses also differ. The unavailability of accurate, true data for most of the important variables in ex-ante EEE limits the possibility of applying particular evaluation methods and guides the investment analysis towards simulation (e.g. Verbeeck & Hens, 2005). Some of the building energy simulation programs commonly used in evaluation and building science research are *DOE-2*, *Micropas,* and *EnergyPlus* (CPUC 2004, pp. 129-133). For example, when estimating ex-post savings obtained from energy efficiency projects Scheer et al. (2013) used the difference-in-difference method to measure the effect of a treatment (i.e. energy efficiency measure) by comparing the change in the consumption of participants in an efficiency upgrade scheme with the change in consumption of a group of non-participants. By having two groups - one of which was involved in an energy efficiency project, and the other that was not - the financial effects could be estimated by measuring differences between them. Such an analysis is impossible to perform a priori. By having some reliable, measured, non-estimated data over time one can also employ other contemporary econometric techniques (e.g. panel data analysis; Loughran & Kulick, 2004), which is - again - unfeasible when doing an investment analysis before the implementation of some energy efficiency measure. In conclusion, without true data, an ex-ante EEE depends heavily on assumptions about the future which are much too often reduced to idealisations and/or wishful thinking.

### *3.2.2 Common effects which distort ex-post savings estimates*

Having data at hand does not shield one from other challenges, as estimating financial effects in an ex-post analysis has its own difficulties. Specific factors negatively affecting the correct assessment of positive financial effects (savings) in EEE include (based on Mills, 2006, p. 89):

- inadequate time or methodology to establish accurate baseline consumption;
- the inability to monitor common effects which distort savings estimates;
- the inability to monitor and mitigate actions that could decrease the efficiency of the assets, such as poor maintenance;
- the volatility of future energy rates, currency exchange rates, interest rates, etc.

The work on defining effects which mislead EEE is in progress and the list of them expands with time. At present, the most common are the rebound effect, free riders, and spillover effects.

There are number of definitions of the "rebound effect" (see Berkhout et al., 2000), but most of them focus on the increase of energy use after investing in energy efficiency. The effect describes an escalation in the energy consumption after implementation of energy efficiency measures due to lower relative energy prices, which then weakens the financial effects of energy efficiency investments. For example, during winter in a poorly insulated building a user sets the thermostat to a lower setting to reduce heating expenditure. After investing in insulation his heating bills reduce notably, which means that there is now a decrease in the price he pays for a unit of energy needed for heating (lower relative energy prices). He then increases the desired interior temperature on the thermostat. This increase in energy consumption lessens the effect of the implemented energy efficiency measure (see Hens et al., 2010). Literature review on rebound effect can be found at Greening et al. (2000), while Sorrell et al. (2009) give an overview of the theoretical and methodological issues regarding the estimation of the effect For further studies of the rebound effect see Loughran & Kulick (2004), Gillingham et al. (2006), UNIDO (2011), etc.

Sunikka-Blank & Galvin (2012) introduced another concept based on the rebound effect which they labelled "the prebound effect". It refers to the situation where the actual energy consumption before the implementation of energy efficiency measure is lower than the calculated. In EEE, estimates of savings are often based on calculated preimplementation consumption, not on actual consumption. Sunikka-Blank & Galvin (2012) found actual consumption to be 30% below the calculated levels, which leads to the overvaluation of savings as one cannot save energy that was not even consumed.

Along with (p)rebound effects EEE should monitor and account for "free riders". These are the consumers who participate in the energy efficiency program but would have saved energy regardlessly. Keeping in mind the different paths to interpret the cost-effectiveness of energy efficiency, *"the strongest concerns have been over free ridership"* (Gillingham et al., 2006, p. 173). Some estimate that up to 80% of energy savings come from free riders (Krietler, 1991, according to Gillingham et al., 2006, p. 173). Similar findings are presented by Train (1988, p. 125) who states that 30% of reported energy savings in a local energy efficiency program is attributable to the program itself, which means that the remaining 70% would have occurred even in the absence of the program. Grosche & Vance, C. (2009) calculated that, in Germany, up to 50% of estimated savings may be lost due to free riders. The issue of free riders is explicated at Joskow & Marron (1992), Malm (1996), Grosche & Vance (2009), Rosenow & Galvin (2013), etc.

An opposite correlate to "free riders" are the "free drivers." They contribute to the goals of the energy efficiency program and increase savings, but formally they aren't program participants (Kushler et al. 1992; Nelson & Hydro, 1994). Free drivers are a subset of the "spillover effects" into the non-participant population. Another spillover effect of investing in energy efficiency is the creation of new jobs. These are often new workplaces required to implement and maintain energy efficiency equipment. Nonetheless, investing in energy efficiency can also lead to the destruction of jobs (e.g. by switching from one energy source to another, workers in the maintenance and management of the previous source can lose their positions) which offsets job creation. These issues are yet to be explored in detail. Joskow & Marron (1992, p. 43) claim that there is *"little evidence that* [free drivers] *are a significant side benefit*" of energy efficiency programs, while on the other hand a more recent study by NYSERDA (2011) shows that spillover effects can outweigh and counterbalance most of the free rider effects.

These complexities - (p)rebound effects, free riders, spillover effects, etc. - should be taken into account when performing an ex-post EEE. Specifically, to evaluate the savings of an energy efficiency measure one should strive to identify unrelated factors that could affect savings, such as changes in weather patterns from year to year; changes in disposable income and in energy costs (which might cause consumers to use more or less energy); changes in the number of building occupants, or the number of hours/timing of their occupancy; etc (SRC Int., 2001, p.50).

### *3.3 Approach*

Both ex-ante and ex-post evaluations without some sort of quantitative data would be little more than literary exercises, even though they rely on estimations. Handling quantitative data is at the centre of measurement and verification (M&V) of energy savings; see CPUC (2004, pp. 147-204); NAPEE (2007); EVO (2012); SEE Action (2012); EVO (2016), etc. The primary purpose of M&V is to establish and report an energy efficiency projects' benefits and savings. Based on the sources of the data and its characteristics, M&V procedures include two main methodological approaches: top-down and bottom-up (EU, 2006; Bukarica et al., 2012; WICEE, 2017).

The top-down approach to EEE is based on national and sector-aggregated energy statistics, where a set of energy efficiency statistical indicators ("top-down indicators") and averages are used as the starting point to evaluate savings. It begins with macro data such as national statistics for energy consumption, and then works down to disaggregated data, correlating the achieved energy savings with energy efficiency measures.

A bottom-up approach means that the savings obtained through the implementation of a specific energy efficiency project are measured in non-monetary terms (kilowatt-hours, Joules, or kilogram oil equivalent) and added to the energy savings results from other specific energy efficiency measures to obtain an overall impact. It begins with data at the level of a single energy efficiency measure and aggregates results from all measures to assess total energy savings in a specific field. The required data can be attained by billing statistics, direct measurement, expert calculations or estimates (ex-ante or ex-post; with or without on-site inspection).

Both approaches have their advantages and downsides. Analysts must balance between accuracy and the costs of evaluation. In comparison to the top-down approach, the advantage of the bottom-up evaluation is the availability of data which means that savings can be directly monitored. This yields better accuracy and it enables the development of benchmarks, as well as better programme control. A disadvantage of bottom-up evaluations is the higher costs of data collection.

The difference between lower energy demand joined with higher energy efficiency (foreseen by bottom-up energy efficiency evaluators), and higher demand with lower efficiency (foreseen by top-down evaluators) is known in the literature as the *energy efficiency gap*. Further reading on the efficiency gap can be found at Wilson & Swisher (1993), Jaffe & Stavins (1994), Koopmans & te Velde (2001); Jaffe et al. (2004), Allcott & Greenstone (2012); Gillingham & Palmer (2014), etc.

Combining the top-down and the bottom-up evaluation could lead to higher accuracy and/or lower costs, and to a successful evaluation of the energy efficiency policies and the impact of the specific energy efficiency measures.

The European Commission recommended detailed measurement and verification methods regarding energy efficiency (EC, 2010). Within the top-down approach, it recommended that specific energy efficiency indicators be divided into four sectors: household, service, transport, and industry. Regarding the bottom-up approach, it separated three categories of energy efficiency measures:

a. the replacement of existing equipment with new, more energy efficient ones;
b. the energy efficient retrofitting of existing equipment (or buildings) without replacing them;
c. additional new energy efficient equipment, or the construction of new energy efficient buildings.

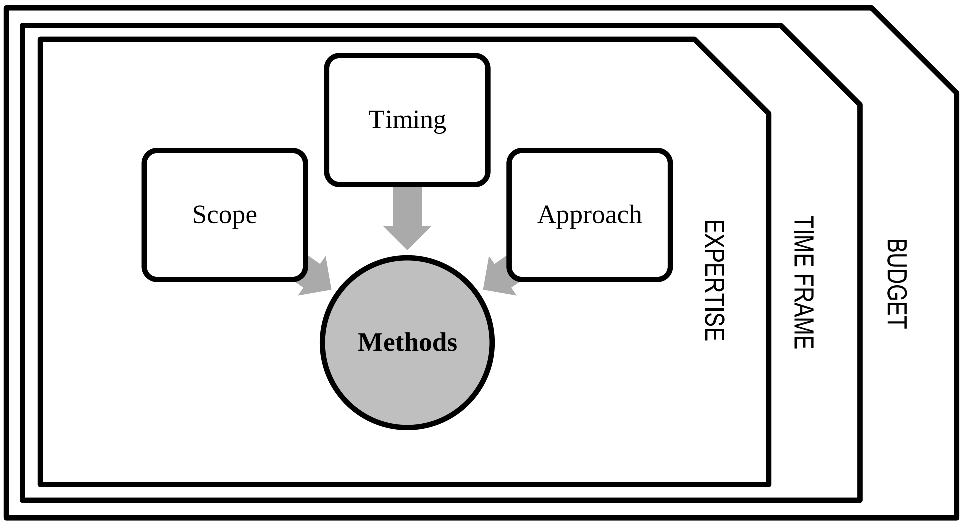
For each of the above categories EC provided formulas to calculate the annual unitary final energy savings (UFES) per participant or per unit. However, declaring energy savings in physical, non-monetary measures (kWh/unit/year, kWh/m$^2$, or similar) avoids the issue of time value of money (and defining appropriate discount rates), which is essential for a financial analysis.

### *3.4 Methods*

After gaining a wide perspective of energy efficiency evaluation methods from the here cited (and uncited, but consulted and studied) publications, in this paper we suggest a conceptual framework that could be used to assess and compare methods for energy efficiency evaluation.

The obtainable budget, time-frame, and expertise of EEE analysts constitute the primary resources available for EEE. The resources are in most cases unobservable and opaque to the end-user of evaluations, as only the analysts (and their financiers) are familiar with their detailed specifications. Desired and required accuracy is a function of resources; evaluations with abundant resources are expected to provide more accurate savings estimates. The resources shape the accuracy of the savings estimates and frame the scope, the timing and the approach to the evaluation. As such they constitute the three main categories which determine the methods that are used in EEE (Figure 2). Every evaluation can be classified within these three categories, and for each EEE it can be stated whether it assesses micro and/or macro effects (*scope*), whether it is ex ante and/or ex post (*timing*), or top-down and/or bottom-up (*approach*).

FIGURE 2. CONCEPTUAL FRAMEWORK FOR INVESTMENT ANALYSIS OF ENERGY EFFICIENCY




Source: Author's representation.

Having the presented framework in mind, the basic categories of statistical methods applied in a financial analysis within EEE are (SRC Int., 2001, pp. 49-54):

1. simple comparison (subtracting costs before and after the implementation of an energy efficiency measure; or subtracting costs of participants and non-participants in the programme);
2. weather-adjusted comparison (similar to simple comparison but includes adjustments to account for the effects of weather on energy savings);
3. multivariate analyses (relatively advanced, complex methods based on the regression analysis and/or other econometric methods).

A simple comparison of costs and benefits can be (and usually is) expanded with an introduction of the time value of money. They are most often used for evaluating micro, ex-post, bottom-up effects.

Weather adjusting (or weather normalization) is performed using the cooling and heating degree days data (CDD and HDD), which is a metric that reflects the amount of energy used to cool or heat a building, and/or data collected from weather services (Fels, 1986). Weather normalization sets a certain historical period as "normal" and measures savings in comparison to that period. However, this could lead to erroneous conclusions due to climate change and unstable, non-stationary weather metrics. Being an expansion of the simple comparison, they too are most often used for evaluating micro, ex post, bottom-up effects.

Estimating macro, ex ante and ex post, top down effects requires more intricate methods. There is an extensive variety of more or less complex econometric methods used in EEE. The application of regression analysis has a long and successful track record. Princeton

Scorekeeping Method (PRISM; Fels, 1986) is a widely used (IPMVP, 2003; CPUC, 2004; NAPEE, 2007, etc.) standardized tool for estimating energy savings which applies regression when using energy meter readings before and after the energy efficiency measure installation, together with average daily temperatures, to determine ex-post total energy savings as the difference between pre- and post-installation periods. The California Evaluation Framework (CPUC, 2004) which was set up with a primary purpose to document effects of local energy efficiency programs, established a framework for the application of regression analysis - ordinary least squares, generalized least squares, or other forms of maximum likelihood estimation. It also displays an analysis of covariance models (CPUC, 2004, p. 110) used in EEE (e.g. Megdal et al., 1995).

Since the effects of investments in energy efficiency evolve over time and could have long lags, time-series econometric techniques can be employed (e.g. Arimura et al., 2011). On the issue of EEE timing and its complexities, pooled cross-section time series (i.e. panel data) econometric models can - by their design - tackle the issues of rebound effects, free riders and spillover effects (Horowitz, 2011, p. 45). Panel-data based analysis (such as data envelopment analysis) also allows EEE on the macro-level, because it can measure economy-wide energy efficiency changes in multiple countries over time (e.g. Vlahinić-Dizdarević & Šegota, 2012; Vlahinić Lenz & Prša, 2015). Many studies use time series or panel data models to study energy demand, such as Hirst et al. (1991), Samiullah et al. (1996), Loughran & Kulick (2004), Horowitz (2007), Metcalf (2008), and Horowitz (2011). Arimura et al. (2011) estimated ex-post effects of the energy saving policies using non-linear least squares assuming no endogeneity and generalized method of moments. To estimate long-term effects of investments in energy efficiency measures, they used the probability density function of a Gamma and Weibull distribution in a panel-data analysis.

When differentiating between long- and short-term effects for an ex-ante evaluation, one of the first elements to consider is the variation in uncertainty. Ex-ante investment analyses outcomes rely heavily on forecasting future energy prices (and other variables such as temperature, humidity, precipitation - all of which are in flux with the change of climate), which becomes progressively more unreliable as "long-term" becomes longer - as the future is more distant. The uncertainty increases with the expansion of the time frame of evaluation and is closely related to risk: higher uncertainty indicates higher risk (ceteris paribus). This is particularly accentuated when evaluating investing in buildings as they are typically expected to be in use for many decades. Since money is at the core of finance, financial analysis is aimed at the quantification of profitability, even though other non-monetary measures of energy savings also exist, such as "megawatts" (a theoretical unit of power representing an amount of electrical power saved; see e.g. Joskow & Marron, 1992) and UFES (EC, 2010). This introspection of uncertainty, risk, and quantification logically streams toward risk assessment techniques. The probability-based methods most often used in EEE are (Goswami, 2007, pp. 3.8-3.16): the expected value analysis, the mean-variance criterion and coefficient of variation, the risk-adjusted discount rate technique, the certainty equivalent technique, the Monte Carlo simulation, decision analysis, real options, and sensitivity analysis. When applying Value at Risk (VaR) - a widely-used risk measure in the financial industry - and extending it to EEE, Jackson (2008) created another risk-based method: Energy Budgets at Risk (EBaR). Instead of deciding upon a strictly estimated internal rate of return, the EBaR introduces a confidence level on the realization of the internal rate of return. For example, an EBaR (IRR - Internal Rate of Return, 95) of 25% means that there is no more than a 5% probability that the internal rate of return will be less than 25% (Jackson, 2008, p. 12).

It is obvious that most contemporary econometric methods can be (and are) used in EEE (depending on the availability of data and other resources). Whatever the method/model being used, the following concerns should be accounted for as part of the EEE (CPUC, 2004, pp. 113-117; CADMAC, 1998, pp. 11-14):

a. model misspecification (omission of a relevant explanatory variable; disregard of a qualitative change in one of the explanatory variables; the inclusion of an irrelevant explanatory variable; an incorrect mathematical form of the regression equation; and/or an incorrect specification of the way in which the disturbance enters the regression equation);

b. random error term (violation of OLS assumptions);
c. non-random measurement error (variables are measured with a non-random error that has a correlation with other variables in the model; multicollinearity issue);
d. heteroscedasticity (non-constant error variance; e.g. large buildings have the likelihood of having greater variance and error variance in variables with a greater potential size. A common correction in GLS is to use weighted least squares);
e. autocorrelation (serial correlations in time-series);
f. collinearity among repressors;
g. influential and missing data (outlier identification and handling, substitution, dropping and filling of the missing data);
h. weather effects (the handling of weather normalization);
i. precision (reporting standard errors);
j. other issues (depending on data and model).

It should be noted that, when discussing methods in EEE, one should distinguish data collection and data analysis methods. Data collection includes engineering calculations, modelling, metering, the collection of bill data, etc. Data analysis contains engineering methods, basic and advanced statistical models, and integrative methods which combine two or more approaches (Vine & Sathaye, 2000, p. 197). In general, when evaluating the effects of energy efficiency programs, methodologies can be divided into a statistical analysis or an engineering analysis (Vine, 1996, p. 991). Engineering methods estimate energy savings based on the equipment's technical information and on the operating characteristics of the equipment. Economists normally delve into statistical methods and rarely deal with engineering; this paper is no different.

## 4. Conclusion

Energy efficiency should not be thought of as an *l'art pour l'art* endeavour. It must entail a sound financial analysis as local/micro savings do not necessarily add up to positive global effects, and because the profit-making ability of energy efficiency investments is often perceived as a dominant factor. On the contrary, the strategic character of an investment is the most important factor when deciding on investments, and financial return is not the major driver of investment decision-making. Deciding on investing in energy efficiency projects should be done more according to a strategical approach (by evaluating each project's role in raising a competitive advantage), and less by financial factors (Cooremans, 2011). Nevertheless, financial factors eventually need to be estimated, regardless of their priority.

After reviewing the extensive literature in different scientific fields, it is clear that (within given resources) the methods used for estimating the financial effects of energy efficiency projects are determined by the three main factors: the scope, the timing, and the approach to evaluation. The contribution of this paper is in providing a conceptual framework which can be used to position every energy efficiency evaluation within these categories.

When the question whether to estimate the broader effects of energy efficiency investments is answered, the decision as to the breadth and the scope of the examination can be made. The present, standard methods of evaluating long-term financial effects of energy efficiency projects are still incapable for the precise calculation of individual (lower-level) profits coming from global effects and efforts (e.g. ozone-layer preservation, pollution reduction, etc.). The scientific community needs to establish and strengthen the link between local investments and global effects because without the scaling and the long-term additivity of financial effects many energy efficiency investments appear to be unprofitable. In practice, these difficulties often prevent the endeavour of estimating macro effects.

Estimation techniques depend on the availability of data. Since we do not have reliable, true data about the future, EEE methods differ in relation to whether the evaluation is made before and/or after the investment. Either way, savings and profitability arising from energy efficiency cannot be directly measured because they represent the absence of energy inefficiency. The timing of EEE determines if the estimation process will - in general - be broader (before investing in energy efficiency) or narrower (after investing in energy efficiency).

The approach to the EEE is also controlled by the characteristics of the data collected. The methods are conditional on the level of collected information; macro/national/industry/sector, or billing/metering data. The path to evaluation will be shaped by the starting point.

Consequently, systematically analysing methods of energy efficiency evaluation and its financial effects requires conceptualising the research within the above categories. To simplify: methods are driven by data; availability and characteristics of data will determine the methods used. In this manner, within the energy efficiency context, no contemporary econometric method is off limits.

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## Appendix

The capital budgeting tools used most often to evaluate ex-ante profitability of any kind of investment (including energy efficiency oriented), are: 1. payback time, 2. net present value (*NPV*) and 3. internal rate of return (*IRR*). Payback time is the time (in years) needed for cash flow to cover the capital costs. *NPV* and *IRR* both have the same basis equation (Eq. 1):

$$x = \frac{CF_0}{(1+y)^0} + \frac{CF_1}{(1+y)^1} + \cdots + \frac{CF_n}{(1+y)^n} \qquad (1)$$

Where $CF_i$ are cash flows, $x$ is defined as *NPV* when $y$ equals predetermined discount rate, or $y$ is defined as *IRR* when $x$ equals zero, $y$ is therefore either the discount rate or the internal rate of return, and $n$ is project lifetime (number of periods).

Hence, *NPV* is an amount of money - positive or negative - calculated as the difference between the discounted cash inflows and discounted cash outflows during the life of the project. Negative *NPV* conveys that the investment is not profitable.

When *NPV* equals zero the investor is undecided (ceteris paribus), because the investment yields nor profit nor loss. In transposition, if *NPV* is defined as zero and discount rate as an unknown variable, then solving for $y$ provides the internal rate of return. Discounting future cash flows requires selecting an appropriate discount rate and nuancing real discount rates (excluding the effect of inflation) and nominal rates (including the effect of inflation).

It should be noted that there is no generally accepted norm for adjusting for inflation in EEE (SRC International, 2001, p. 58). Selecting discount rate at the level of weighted average cost of capital - WACC (see e.g. Sandeep Goel, 2015, pp. 117-126, etc.) is a common practice (Short, Packey & Holt, 1995, p. 8; Cappers et al., 2009, p. 68, etc.). Martin L. Weitzman (1998) shows that, when discounting the far-distant future of any investment project, the lowest possible interest rate should be used, and that "*it may be essential to incorporate declining discount rates into any benefit-cost methodology for evaluating long-term environmental projects*" (Weitzman, 1998, p. 207).