Economic Evaluation of the Energy Efficiency Improvement Projects

Miloš Gasić[1*], Tatjana Jurenić[2] and Ivana Rakonjac[3]

* Corresponding Author
1 Faculty of Architecture, University of Belgrade, Serbia, email: misko@arh.bg.ac.rs
2 Faculty of Architecture, University of Belgrade, Serbia, email: tanja@arh.bg.ac.rs
3 Faculty of Architecture, University of Belgrade, Serbia, email: i.rakonjac@arh.bg.ac.rs

ABSTRACT **The process of adaptation of the buildings in architectural projects is codified by a set of energy efficiency regulations that are mandatory and which affect designers. To fulfil these requirements certain investments are necessary, which influence the economic performance of the project in construction phase, as well as in the long run over the building's exploitation period. Therefore, an analysis of the economic effectiveness of the project is needed, which would also take into consideration the operation phase of the project, to include the whole life cycle. The methodology of the life cycle costs and savings analysis is presented in the following sections, which would be adjusted to the specific preconditions of the energy efficiency improvement projects, availability and possibility to gather relevant input data, as well as the perspective and understanding of architects as prospective analysis practitioners. The format of the proposed study is created to comprise several steps or phases, and their contents would be further elaborated. The methods that are applied include analytical procedure, comparisons, deduction and elaboration of the existing tools, and techniques and methods in the field of economic analyses in architecture and building construction. The resulting procedure allows for practical and theoretical implementation in actual projects. It is simple and straightforward to conduct, easy to understand, and open for expansion.**

KEYWORDS life cycle, evaluation, energy efficiency, costs and savings

1 Introduction

The adoption of the new energy efficiency regulation in building codes of Serbia in 2011 brought about a new aspect in design practice. Parameters for dimensioning outer envelopes of the object and the adjoining thermal insulation that were previously widely used and proven through professional experience have since been changed. This is also the case in terms of other widely used façade elements, such as windows and doors that are made of wood, plastic, or metal alike. On the other hand, it has been formally acknowledged that the energy available for the normal functioning of the buildings is getting scarce, and the costs associated with it are getting higher. The problems of energy resources, ecological implications, and the quest for sustainable alternatives have all been growing over the last decades. All the interventions on the building that require the issuing of a building permit, including adaptation works, are linked with the obligation to upgrade the energy efficiency category according to the regulatory rulebook. It is therefore implied that the appropriate systems and elements of building envelope have to be designed. At the same time, these requirements have implications on the capital investment for the client, affecting the life cycle costing. Through a well-balanced building intervention and the selection of heating and cooling systems, possibilities emerge to optimally achieve both regulated EPC (energy performance certificate) and the positive investment outcomes for client.

The global aim of the life cycle study would be to achieve a balance between cost and energy efficiency benefit on adaptation projects. To achieve this end, it will be necessary to define and explore which capital investments provide the best results during the life cycle, making savings that prove the investment profitable in the long run. Various methods and techniques of calculating costs and savings during the life cycle can be used in the process, as well as some of the economic performance measurements. It is also necessary to make choices regarding the study period, as well as dealing with the time value of money through the discount rate and currency expression in constant or current terms. However, above all, the analysis is based on the manner and creation of the design cases that would be considered.

Bearing in mind the needs of architects as practitioners, the prevailing types of projects, the availability of relevant information and data, and especially the global aims of the applied life cycle cost analysis, a seven steps model has emerged. These seven steps transform into seven chapters of the life cycle study in a project for building energy efficiency improvement.

2 Project Description

Even though the proposed model can be adjusted to a potentially wide array of projects, the most common form of energy efficiency project is the adaptation of an existing building. According to the regulations,

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complete design documentation is needed for adaptation, which does not necessarily include the life cycle analysis study. Therefore, there is no code by which to regulate its contents, but it would be recommended that the project and the building information remain within a relevant scope for the life cycle study. This would start with a description of the project under consideration, consisting of three generic parts, which are as follows:

- *Basic information on the project to be analysed.* In the short table format, some information should be given that creates a specific ID of the building: location, function, year of construction, the kind of intervention that is planned, the form of ownership, and the potential financing that is expected (private, public, partnership, etc).

- *Project description summary*. Comprising approximately one written page, the project should be described in terms of function, form, materials, construction, equipment and other relevant features. Such chapters are standard for new projects, and should also be followed in all other projects. This description should encompass both existing buildings and planned interventions.

- *Building illustration*. The life cycle study is not regulated by any code for project documentation. Therefore, it is advised that a reference be made within the life cycle study to the adaptation project documentation under analysis, and that an illustration of the building be added through an appropriate set of photographs and/or drawings. This should not exceed the length of one page.

3 Formulation of Project Options

Life cycle costs are meaningful in terms of decision making only when a project option is compared to a basic or reference case, also known as the zero option. In the case of an existing building, the reference case typically requires no investment. In this case, life cycle costs contain the use costs only, afterwards compared to the combined investment and use costs for other options.

In the case of the life cycle study of a new construction, the reference case is usually set as the one with the lowest investment costs, or the minimal acceptable performance level according to the regulations.

There are three key points to consider when the options are to be selected. The most important one is to bear in mind that a good project decision directly depends on the quality of options chosen for analysis. An analysis based decision cannot be better than the best option considered, no matter how good economic evaluation is. This is all about a creative choice that precedes rigorous analytical procedure.

The second point of interest would be to take into consideration only the options that meet the performance standards. Furthermore, other possible constraints should be considered, such as the availability of energy sources, or the regulation requirements. It is not sensible to perform an economic evaluation on the option that would otherwise be rejected for other reasons.

Finally, in some cases, it is only required that the minimal performance level be met, whereas, in other cases, options that exceed the required threshold and bring additional advantages are favoured. If so, they should be observed, or, if they are of non-monetary nature, the benefits they allow should be noted and included in the documentation text.

3.1 Description of the Reference Case

In cases of the adaptation of existing buildings, the reference case is the zero option, without intervention.

The reference case description principally relates to the systems and elements of the object, which can be broken down in the following way:

- HVAC systems;
- building envelopes and its layers;
- façade, roof, and other elements and products with thermally insulating functions;
- building structure with structural and partition elements.

After the building systems and elements definition, the next step would be to calculate energy losses and establish the energy category for the object.

3.2 Description of the Project Options

Following the reference case, a description of the proposed alternative systems and elements should be made, mainly in the form of text with some illustrations. Then, the calculation of energy losses is carried out and the energy category for the building established. Finally, it should be determined whether the object has achieved an upgrade in its energy efficiency category, which is a legislative prerequisite for building adaptation.

To make the decision based on an analysis meaningful, the fundamental minimum is to have at least two project options that can be compared to the reference case. The more project options we have, and the more elaborate they are in terms of the combined use of systems, materials, and products, the better educated the decision will be. However, it is common for all the analyses and studies to have an optimal level of effort, time, and cost allocated to the work. It is preferable not to surpass nor fall short of this optimal level to any great extent.

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4 Input Analysis Parameters

Costs and savings in the project life cycle occur at different times, at different periods, and under the influences of all mechanisms that are associated with the time value of money. From the point of view of the analysis credibility, it is of paramount importance to consistently apply the accepted suppositions concerning money management in time. The accuracy of the suppositions can even be considered to be of lower priority than the uniformity of its application to all the project options.

There are three basic input parameters for the life cycle analysis: the discount rate to be applied, the study period that is suitable for the planning horizon, and the manner of monetary expression of costs and savings incurred.

4.1 Discount Rate

Before summary costs that take place at different times within the study period can be compared, they have to be converted to a common point in time to reflect the time value of money. This conversion procedure is called discounting. It is customary to discount future costs and savings to the present value, so that they could be directly set against the investment cost.

There are several conventions to show money flow that can be adopted when discounting future costs to present value. One-time costs are usually discounted from the actual time of occurrence. Annually recurring costs, which occur once a year at approximately same amount, are typically discounted from the end of the year. Costs that occur at the start of the study period are not discounted because they already take place at present time.

A discount rate that is used to adjust future costs to the present value is, in fact an interest rate at which it is equal for the investor to reclaim his investment at that time or any other. The discount rate reflects an investor's appreciation of time and money, or the return rate of the best option investment. The discount rate is also often referred to as the minimal acceptable rate of return (MARR). It is important to understand that each investor has preferences about money and therefore his own discount rate.

When life cycle cost analysis is carried out, there are three types of future money flows that arise, and each one is associated with a particular type of present value index (Fuller and Boyles, 2000).

- One-time money flow is multiplied by the single present value index (SPV) to obtain the present value. Examples of these sorts of money flows are replacement costs or the residual value at the end of the study period.

- Annual equal amounts are multiplied by the uniform present value index (UPV) to obtain the present value. Examples for these are annual operation and maintenance costs.

- Annual changing amounts that differ from year to year at the known rate are calculated by multiplying the amount from the base year with the modified uniform present value index (UPV^*) to obtain the present value. An example of this is the energy consumption for which it is estimated that it would remain at the same annual level, but the prices of energy sources would escalate at their own projected rate.

The calculation formulas for corresponding discounting indices are standard compound interest formulas, used on discount rates instead of interest rates, but are conveniently readily available for widespread use in form of discount index tables.

Inflation decreases the buying power of money through time. Money spent in different years, with different buying power, cannot be directly compared to provide a relevant result. When the economic evaluation of capital investments over time is performed, following the discounting procedure, both the changing buying power of money and the real earning power of money have to be taken into consideration.

There are two basic methods of accounting inflation in the economic analysis (Fuller and Boyles, 2000):

- Estimating future costs and benefits in the current currency, and discount them with the nominal discount rate, which means that the discount rate includes inflation rate; or
- Estimating future costs and benefits in the constant currency, and discount them with the real discount rate, which means that the discount rate doesn’t include inflation rate.

The methodology of life cycle cost analysis allows money flow to be presented either way. Analyses done in constant or in current currencies result in the same present value, and therefore support the same conclusions. Choosing constant currency is, however, usually more suitable because there is no need to predict future inflation rates. Prices in constant currency are not influenced by general inflation rate.

As mentioned before, prices of particular commodities and products escalate at rates that are not identical to the general inflation rate. These individual escalation rates are especially important for the prices of energy sources, which are known to have considerable deviations from the general inflation rate. This can be noticed from historical data. To deal mathematically with escalation rates, the same rules are applied as for discount rates. The resulting present value will be identical if the costs of the basic year are:

- Escalated to the future value by using current currency and nominal prices escalation rate (E, inflation excluded), or discounted back to the present value using nominal discount rate (D); or

– Escalated to the future value by using constant currency and real prices escalation rate (e, which is differential rate), or discounted back to the present value using real discount rate (d).

If correctly conducted, both procedures finally show the same result.

The price escalation is considered to be constant over the years, as suggested by the basic equations and indices that derive from them. If that rate changes, which is the case in real life, future costs must be calculated with the compound rate. There are sources and publications that provide an estimation of the price escalation of energy sources. Nevertheless, it is clear that the analytical process is constrained by a number of assumptions which, in the long run, diminish its reliability.

For practitioners in the field of energy efficiency in architecture who are not professional economic analysts, it is most appropriate to adopt the real discount rate from which the inflation rate is excluded and to disregard relative escalation rates for individual energy sources. To remedy the setbacks that develop from these simplifications, it is advised to perform some of the risk analysis techniques.

The Directorate-General for regional and urban policy at the European Commission recommends the use of relevant real discount rates in cost-benefit studies for investment projects. Bearing in mind that energy efficiency improvement projects are not developed for investors for whom it would be possible to calculate a weighted average cost of capital (WACC) that would represent the personal discount rate, it is advised to accept the financial discount rate of 4%, for member countries and the whole of the euro zone, as instructed by the Commission Delegated Regulation (EU) No 480/2014 of 3 March 2014. Apart from the financial rate, a social discount rate is set by this publication, within which a wider social view on future costs and benefits is taken into account. To apply the proper social discount rate, countries are differentiated both as member countries of the EU, for which the recommended rate is 3%, and so-called cohesion countries (which include Serbia) for which the rate is 5%, according to the Commission Implementing Regulation (EU) No 1011/2014 of 22 September 2014. The latter rate is therefore suggested for use in the analyses of energy efficiency improvement projects. These recommendations are given for the years 2015-2020.

4.2 Study Period

The study period is the time during which the effects of the decisions are of interest to decision makers. There is no such thing as the correct study period, but it should be long enough to enable the accurate estimation of long term economic performances. The expected lifespan of a system under analysis is often taken as the study period. However, the study period of the maximum of 25 years from the start of operation is limited by specific regulations in the field of energy consumption (European Commission, Directorate General for Regional and Urban Policy, 2015). This constraint is due to growing uncertainties in price

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estimations if the period is longer. In addition, the duration of the study period is limited according to the conditions for the realistic financing arrangements for the project.

Besides the limitation for the maximum duration, some other factors determine the length of the study period, such as:

- All the options should be compared against the same time period. Discounted cash flow diagrams for one period cannot be compared with the ones calculated for longer or shorter periods of time.
- All the measurements of economic evaluation should be calculated for the same study period. If not, they would not be consistent.
- Investor's planning horizon should be taken into consideration. For instance, the study period could be either shorter or longer depending on whether the investor is the building's user or the developer only.
- The analysis should be adjusted to different expected life spans of the systems or the buildings. To fit various life spans into one study period, residual values (i.e. sale, demolition, remaining) are used to level the differences.

Practitioners in the field of energy efficiency in architecture in the region of the western Balkans are advised to adopt a study period of twenty years. Any longer-term financing is not available, and this period may be considered as long enough to examine the relevant effects of costs and savings over the life cycle.

4.3 Monetary Expression

As previously noted, future costs and benefits can be evaluated in the current currency and discounted with the nominal discount rate, which includes the inflation rate, or evaluated in constant currency and discounted with the real discount rate, which doesn't include the inflation rate. Since we have already given the reasons for the acceptance of the social real discount rate offered by the latest recommendation of the European Commission, it is implied that the monetary expression through constant currency in the zero year of the analysis is selected, without counting the individual escalation rates of the energy sources.

5 Cost Analysis

Cost analysis is the key step in a cost study. It consists of the estimation and documentation of the costs, classified by their types, character, frequency, and magnitude. During the cost analysis, one relies on the breakdown, which principally starts from the initial or investment costs versus in-use or life cycle costs.

In energy efficiency improvement projects, investment costs are comprise all the construction or renovation works, as well as the purchase and installation of the systems. For economic analysis

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purposes all of these costs take place in present time and hence the effects of time value of money are not applied. Most of the challenges that generally appear in the use of data sources for cost estimation are applicable for this analysis. The most reliable source is the personal database of the cost analyst, who is best acquainted with the specific condition under which the information is generated. Thus, the analyst can avoid the danger of using the same cost data in different real-life conditions. Aside from the personal archive, the best source of information about purchase and installation costs would come from the local supplier or contractor. Furthermore, it is also possible to use price books, contract information, commercial publications, or information from a third party (Gasic et al, 2012). All methods of information gathering can be beneficial in combination with the experience and skill of the analyst, provided that quite enough resources are assigned to the operation. The obtained data has to be documented by stating the reference, which can range from the publication of any sort, to the quotation of a website or a person (i.e. contractor).

Cost analysis principles for life cycle costs don't differ from the ones that are applied on the analyses of the initial costs. However, the information that can be used for analysis is even less available and less reliable, because the cost occurrence is expected far into the future. During the process, the life cycle cost breakdown must be noted as below (International Standard ISO 15686-5, 2008).

- By the cost carrier:
    - owner of the building;
    - user of the building.
- By the cost origin:
    - ownership costs;
    - use costs.
- By the time of the occurrence of the cost:
    - regular costs;
    - cyclic costs;
    - random costs.
- By the cost magnitude:
    - fixed costs;
    - changeable costs.

The most difficult task is to obtain the data for the life cycle cost analysis concerning the estimation of the maintenance and repair costs. It is possible to get manufacturers recommendations on maintenance, warranty, and service periods for some products and systems, which is a good basis for life cycle cost estimation. However, it is often not possible to find objectively grounded information. In such a case it is necessary to set aside a fund for maintenance and repairs, as a lump sum or as a percentage from the total investment.

In an architectural project for energy efficiency improvement, costs can be divided into four groups, which would form four chapters in the life cycle cost study.

5.1 Analysis of the Energy Sources Prices

Data on the prices of the energy sources are openly available via websites and publications of communal companies. Therefore, this set of information is the simplest for price analysis purposes. Some particularities, however, should be noted. Measurement units for energy sources differ and there are special charge rates in some cases, due to either social policy to protect the poor population, or as a stimulus for economy or specific social groups (i.e. for a branch of industry). In these cases, it is not possible to precisely ascertain which of the tariffs shall be applied, but it can be foreseen with a satisfactory level of accuracy, based on some average consumption values.

It is also useful to gather data on the prices of energy sources from the immediate and more distant surrounding countries, for the purposes of comparison and interpretation of trends. For an economy in transition it is safe to assume that the prices of the energy sources are at least partially undervalued, and that their future trend is comparable to the ones that are in a more advanced phase of transition. Besides, the trends in developed economies provide good indications of the presumed future global evolution.

The prices of the energy sources should then be applied to the expected consumption level during the life cycle, which results in the energy sources cost. These costs fall to the group of the regular costs, as to their time of occurrence, and to the use costs by their origin. For the majority of energy sources, there is the fixed starting charge set, which doesn't depend on the consumption level, although this minimum charge does not move the group into ownership costs.

In the discounting process, the multiple present value index is used, unless the prediction of the relative price escalation for the energy sources is considered for the sake of calculation.

5.2 Analysis of the Systems and Equipment Prices

The purchase and installation of the materials, products, elements, equipment, and systems also fall into the investment costs, which is previously set by the project options. The cost of the associated construction works is also included, such as the addition of the thermal insulation on the building envelope, or replacement of openings, as well as the installation or replacement of the air and water heating, cooling, ventilation, and conditioning systems.

When estimating the systems and equipment costs, it should be observed that the most commonly available price sources indicate the acquisition but not the fitting cost. From the cost analysis point of view, it is necessary to consider so-called built-in prices, together with purchase cost. When certain engineering systems are analysed, manufacturers or suppliers often offer an installation service, which makes the total cost data easily available. This is also the case with façade elements, but it should be noted that the installation service doesn't always include the treatment of surrounding walls, which is needed. In cases of acquisition of thermal insulation for the façade or other envelope elements, it is more common that only the purchase price of material is available. The estimate in this case should include consultation with contractors, or other accessible data sources to derive the price of the full installed element.

While the systems and equipment costs can be considered as investment costs, discounting is not applied on them, since they take place in the present time.

5.3 Maintenance Cost Analysis

Systems and elements need to be maintained in some way over the life cycle. When purchasing, some of the building systems suppliers provide manufacturers' instructions for maintenance, which can be used as a basis for the cost estimation. It is important not to confuse these costs with repair and replacement costs. In most cases, it would be useful to create a fund for elements and systems maintenance, which can be set as a percentage of the buying price, or as a lump sum based on certain presumptions. The data source on the maintenance cost could consist of the manufacturers' catalogues, the price list of the specialised maintenance companies, service providers, etc.

Multiple present value index is used for discounting of the maintenance costs, because it is presumed that the amounts needed for maintenance would be evenly distributed throughout the life cycle, similarly to the energy consumption costs. In reality, of course, maintenance costs rise according to the elements and systems age, but calculating with an average value is more practical and deemed to be sufficiently accurate.

5.4 Analysis of the Repair and Replacement Cost

Unlike maintenance of the built-in elements and systems, repair and replacement cost occur in incidents, as one-time costs. The occurrence of these costs is forecasted based on the presumed lifetime duration and the experience of services. Calculating repair and replacement cost into the life cycle cost analysis requires two types of assessment – the first one is the estimation of the actual repair and replacement cost, and the second one is the estimation of the periods in which they would occur.

To reach this goal, the first step would be to determine the lifespan of the systems and equipment designed based on the project options. In most cases, the lifespan of the built-in systems and equipment exceed the study period. Therefore, it is adequate to consider the residual value at the end of the study period. Building elements that are constructed for the purposes of energy efficiency improvement are not likely to have any residual value that would be applicable to the life cycle study. However, for some systems it would be possible to determine a residual value that could be calculated in the study, with the appropriate amortisation rate taken into account.

The periods of repair and replacement of the systems and equipment can be determined based on the instructions of the manufacturer or the service provider, as well as the duration of the warranty. With insufficient information on the repair and replacement periods it is acceptable to set up a repair and replacement fund, as a lump sum or a certain percentage of the capital investment sum.

Repair and replacement costs are one-time and changeable by nature. Therefore, for life cycle study purposes they can be considered to be regular. For discounting procedure, a multiple present value index should be used instead of a single present value index.

6 Life Cycle Analysis

After certain presumptions considering economic, monetary, and time parameters are adopted, and cost analysis conducted according to the previously set project options, one can proceed to the life cycle analysis. The choice of the type of the analytical procedure depends on the economic indicator that can be considered as primary, with a major influence on the project stake holders and specific project. This indicator, in a mathematical sense, represents the result of the whole life cycle analysis, but essentially it is better described as the basis for the analysis interpretation and decision making, which would consequently follow.

Each of the life cycle analysis procedures is simple to conduct, and sometimes those procedures are no more than a variation of another. In life cycle analysis, the focus is on the costs and savings. When benefits occur in the form of increased income (i.e. from rent) or from an improved level of service (i.e. more net floor area) it is usually referred to as cost-benefit analysis, which aims for selection of the project option with the highest profit (in the private sector) or the highest net benefits (in the public sector). On the other hand, when benefits take place primarily in the form of reduced exploitation cost, with little or no service level change, the life cycle analysis is applied and the case with the lowest life cycle cost is sought. The analyses, linked with the energy preservation, are mostly related to the investment and in-use costs, and therefore the life cycle model is applied (Davis Langdon LLP, 2014).

6.1 Calculation of the Life Cycle Cost by Options

General algebra for a life cycle cost calculation shows that the life cycle cost is the sum of all the project costs, without benefits, over the years of the study period. Both investment and in-use costs are included. Investment costs take place in the present time, while for the other costs principles of money time value are applied. The sum is as follows:

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$$LCC = I + Rp - Rs + E + OMR$$

where the abbreviations stand for:
I: present value of investment cost
Rp: present value of replacements cost
Rs: present value of residual value
E: present value of energy consumption cost
OMR: present value of operation, maintenance and repair cost

The mathematical procedure is simple and straightforward after the assumptions on the study period, type and degree of the discount rate, and the cost analysis results are considered, evaluated, and adopted. The rule for decision making certainly means that the project option with the least life cycle cost shows the best economic performances.

6.2 Calculation of Net Savings by Options

Net savings are a measurement of the long-term profitability of an option in comparison to the reference case. The net savings method is a variation of the net benefit method, used when benefits occur primarily in the form of a reduced cost. Net savings result in a sum expressed in present time, which describes how much savings have been made during the study period by the specific option case. It is especially important to note whether the sum of net savings outweighs the sum that would have been achieved through the minimum acceptable rate of return (MARR) which is, in fact, equal to the discount rate.

Net savings can be calculated as an extension of the life cycle cost method to show the difference between the total life cycle cost for the reference case and the total life cycle cost for the option case. Net savings can also be directly calculated from the differences in cashflows between the reference case and the alternatives.

The net savings method can be used to determine the cost effectiveness of a project. If a project is to be considered as cost effective, it means that its net savings are positive. For instance, if there is a positive present value of the net savings for an alternative system of the building, it means that by choosing this system a saving would be achieved during the study period, which would be over and above the savings that would have been made at a minimal acceptable rate of return.

Mathematically explained, net savings equal the difference between the present value of the operating cost savings and the present value of the additional investment cost:

$$NS = (\Delta E + \Delta OMR) - (\Delta I_0 + \Delta Rp - \Delta Rs)$$

where the abbreviations stand for:
ΔE = difference in energy cost in favour of the alternative (reference minus option case)

ΔOMR = difference in the values of the operation, maintenance, and repair costs in favour of the alternative (reference minus option case)
ΔI_0 = difference in the values of the additional investment cost (option minus reference case)
ΔRp = difference in the values of the additional replacement cost (option minus reference case)
ΔRs = difference in the residual values (option minus reference case)

6.3 Calculation of the Savings/ Investment Ratio by Options

Savings/investment ratio (SIR) is an evaluation indicator that describes the relation of the savings versus costs. It is a variation of the cost/ benefit index (BCR), used in those cases when benefits take place in the form of a cost reduction.

Savings displayed in the formula relate to those associated with the building use (i.e. energy consumption reduction, and differences in operation, maintenance, and repair costs). A denominator shows the rise of the investment costs (i.e. the rise of the capital investment, differences between the replacement costs and residual values).

Savings/investment ratio as a measurement can be used to determine the cost effectiveness of a project. The index of 1.0 and above generally shows that the project is cost effective. The higher this index is, the higher are the savings for the invested money, and also over and above the sum that would have been saved at the minimal acceptable rate of return. Also, the savings/investment ratio is recommended for setting priorities between the projects when the budget is insufficient to support all the cost-effective options. If the project cost is approximate, which means that the budget cannot be used with great accuracy, the net savings method provides better decision guidelines than the savings/investment ratio. Total net savings can be calculated for the test combinations to find the set of the options that will maximise the total net saving while remaining within the budget framework.

The calculation of the savings/investment ratio (SIR) is conducted by dividing the discounted savings value by the in-use costs, compared with the reference case, and discounted value of the additional investment costs.

6.4 Calculation of the Payback Period by Options

The payback period shows how long it would take the initial investment cost to be recovered by the savings. The measurement is calculated as the number of years between the capital investment and the moment at which the aggregated savings (from which all costs are deducted) have accumulated sufficiently to compensate the investment cost.

The payback period method that is used involves time value of money by discounting cash flows and it is therefore known as the discounted payback period, as opposed to the simple payback period.

Both simple and discounted payback periods as measurements are gravely deficient, due to the fact that all the costs and savings that take place after the achieved balance (or the payback) are neglected. For this reason, it is possible that an option with a shorter payback period turns out to be a worse investment, if entire life span of the project is considered. Where projects for energy efficiency improvement are concerned, it often happens that applied systems need more maintenance and repair as time goes by, and so the in-use costs tend to rise.

The discounted payback period can be used as a supplementary measurement for the following purposes:

- preliminary grading to support the decision to accept or reject;
- assessment of the minimal required life cycle of the project to protect the initial investment funds from uncertainties; and
- determination of cost effectiveness when potential benefits beyond a certain point in time are irrelevant.

A mathematical procedure is conducted by deriving the minimal value of N, for which the following formula is used:

$$\sum_{t=1}^{N} \frac{(S_t - \Delta I_t)}{(1+d)^t} \geq \Delta I_0$$

where symbols stand for
S_t- savings in the use costs that could be attributed to the project option in year t
ΔI_t - additional investment cost in year t, over the initial investment cost
ΔI_0 - additional investment cost for the specific option.

7 Sensitivity Analysis

Risk is defined as the probability of the occurrence of an event or an error, as well as the consequences and the impact of this event or error. Unlike uncertainty, which is characterised by the lack of reliable deterministic values that could be used as the input variables for analysis, risk is subjected to an array of analytical methodologies described and tested in the theory and practice of project management.

Major risks in the life cycle cost study for energy efficiency improvement projects can be identified within the group of adopted input data for the analysis, and from the results of cost analyses. The recommended discount rate results from the various macroeconomic analyses and it is published by the relevant international institution. Of course, this can also be proven wrong under certain circumstances.

Cost analysis is a part of a study in which most of the wrong assumptions can infiltrate, because they are based on estimations that, for numerous reasons, do not necessarily come true. As far as the assumed periods and time of the cost occurrence in the future is concerned, it is more important to consistently apply the assumptions for all options than to predict them with any great precision.

Given that the analyses previously presented are simple from a mathematical point of view, the sensitivity analysis method enables a fast, clear, and understandable way of including the risk factor treatment into the analysis. This method is based on the variation of input data and examination of the changes in results and the consequential conclusions obtained from the life cycle study. Even though it is applicable to all the input data, including the study period and the discount rate, the most interesting domain of its employment would be in the energy sources prices.

By adopting the real social discount rate of 5%, which doesn't include the effects of inflation, it becomes possible not to estimate future costs and benefits, but to use their present time values. The need for complex forecasts and assessments of future events is thereby eliminated. When leaving out the energy sources' respective escalation rates from the calculation, a simplification is made that is unrealistic by nature, but enables the comparison of the options on equal terms. Sensitivity analysis should primarily be directed towards this segment, that is, to alternate energy sources prices in order to observe the consequences that might show up for different economic efficiency indicators of the project options. In the conditions of the transition economy, the obvious approach would be to choose to alternate input data using the energy prices from the closer and more distant surrounding economies. The economies in closer surroundings include countries in a more developed phase of transition, while more distant surrounding countries include developed economies whose overall performances a transition country generally aspires to reach. In this way, it would be possible to observe the trends, presumably reflecting some likely future developments.

The conclusion that follows a sensitivity analysis doesn't have to be straightforward and definite, because the tendencies that are examined through the analyses don't always come true. Whether something will happen or not is influenced by too many factors that cannot be ascertained. However, this procedure gives us the ability to determine which input data can be considered to be more important and more influential in the determination of the results of the final analyse. This can and should be made a part of the concluding considerations of the study.

TOC

8 Conclusions

The proposed procedure for the study development is based on an analytical approach on one hand, but also on the adoption of some simplifying assumptions on the other hand. Those assumptions enable us to create a study with an optimal balance of effort, time, and even cost, against accuracy and precision. It would be expedient to make a distinction between the concepts of accuracy and precision. Accuracy describes how well a statement or a data relate to the truth of factual condition, while precision describes how fine is the deviation that is made. The accuracy of an estimate is measured by its closeness to the measurements achieved, whereas its precision relates to the level of refinement, details, and articulation. Obviously, to reach a high level of precision requires a higher level of investment into the study itself, both in terms of money and time. Of course, the ideal achievement would be to have as much accuracy and precision as possible. However, for the sake of the study's credibility, the fact of how true the adopted assumptions are is less important than the consistent usage of all the assumptions and input data for all the project options.

The concluding chapter of the study should provide a summary of the answers to the basic questions that the study was supposed to address:

- Has the higher category of energy efficiency been reached and all the other regulation prerequisites been fulfilled, for all the project options respectively?
- Has the criterion for energy efficiency been fulfilled for all the project options respectively, according to the selected measurements for the particular analysis (costs, net savings, savings/investment ratio, payback period)?
- Do the results of the sensitivity analysis indicate that there is a higher level of risk to question the reliability of the conclusions of the life cycle analysis?
- Recommendation for the selection of the project option.

Even though the results of the study as a whole are measurable and conclusive by nature, their interpretation is still free to some extent, and the analyst can and should present his own criteria and reflections in a certain form. Sometimes, this might be done by adding appendices to the analysis, comprising documentation of various kinds, but in most cases it would be of great use to describe and support in narration what were set as primary criteria, and for what reason have certain measurements been given advantage while the others have been disregarded. Even though we aspire to the automation of the data processing, and inclusion of as many parameters and measurements as possible into analysis, interpretation and decision-making still remain the principle task of the analysts and those who make decisions based on the study results.

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