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APPLICATION LCA FOR ECO-EFFICIENCY ASSESSMENT OF INVESTMENTS PROJECTS

Abstract
Eco-efficiency which takes into account the life cycle idea is a relatively new concept described by ISO International Standard 14045:2012. It can be used in environmental management by integration environmental considerations with economic analysis to improve products and technologies. Nowadays, eco-efficiency is a strategic tool and it is one of the key factors of it sustainable development. In the investment decision-making process, to assess new technology solutions and to choose the best options, the eco-efficiency account should be introduced. Life Cycle Assessment (LCA) as a method used to assess environmental aspects and quantified impacts of investment project is proposed. Life cycle cost analysis being the combination of Net present value (NPV) with life cycle cost (LCC) was chosen for quantifying their financial effects. The eco-efficiency analysis based on LCA can be recommended not only as a decision support tool for individual investors, but also for ranking of investment projects when applying of financial support from structural or other national funds, as well in sustainable public procurement.

Key words
eco-efficiency, environmental protection, investment project, Life Cycle Assessment (LCA)

Introduction
In economic policy of many countries, and in the strategies of institutions and international organizations (European Union, United Nations), along with the increase in consumer awareness, attention paid to the issue of product quality improvement and environmental protection has begun to grow. Consequently, economic operators, particularly from the EU countries, must meet specific requirements for high quality products, applying the technologies intended to further reduce environmental impacts [1]. The environmental technology sector is perceived worldwide as one of the most dynamically developing areas of the economy. Currently, the investments in environmental protection project registered an increasing trend all around the world. Studying their efficiency provides insights for further developing of new investments. The investments efficiency issue is very complex, based on a large number of generated effects. It covers three distinctive concepts:
- economic efficiency of investments;
- environmental (or ecological) efficiency of investments;
- social efficiency of investments [2].

This work is focused on economic and environmental efficiency of investments concepts. It has to be mentioned that environmental performance can, and should be used to assess the planned investment projects, especially those designed to protect the environment. In the investment decision-making process, to assess new technology solutions, the eco-efficiency account should be introduced. In the present paper, Life Cycle Assessment (LCA) as a method used to assess environmental aspects and quantified impacts of investment project is proposed.

Eco-efficiency of investment projects
In the literature, the term ‘eco-efficiency’ has been given a range of different meanings [3], e.g. in Cicea et al. studies, an environmental efficiency is found as ecological efficiency or eco-efficiency [2]. A general definition of eco-efficiency is contained in the report of the World Business Council for Sustainable Development [4]. Eco-efficiency is considered as a management philosophy that focuses on reducing environmental intensity and increasing environmental productivity while also reducing costs and creating value [5-8]. It has been recognized

that for many of consumer products, a large share of the environmental impacts is not only in the use of the product but in its production, transportation or disposal. Therefore, in choosing an investment project, environmental impacts generated by all parts of a product's life cycle, from acquisition of materials through manufacture a recovery or disposal, must be considered. In ISO 14045:2012 it was proposed to take into account the whole value chain in eco-efficiency assessment, including environmental and product-system-value assessment. The key objectives of ISO 14045 are to present clear terminology and a common methodological framework for eco-efficiency assessment, practical use of eco-efficiency assessment for a wide range of product (and service) systems, including interpretation of eco-efficiency assessment results and transparent and informative reporting of eco-efficiency assessment results. Environmental assessment in eco-efficiency evaluation shall be based on Life Cycle Assessment (LCA) according to ISO 14040:2006.

In practice, eco-efficiency is best understood as an efficient use of natural resources, minimization of waste and pollution at every stage of production while ensuring quality of delivered goods and services, and providing cost-effectiveness. Nowadays, eco-efficiency is one of the key goals in corporate environmental management, which brings together economic and ecological issues [9-11]. It is worth to note that in the countries of the European Union in recent years the dynamic growth of expenditures on environmental protection was observed. According to EUROSTAT database (2015) in EU (28 countries) between 2004 and 2011 expenditures on environment protection increased from 133.4 to 171.0 EUR per inhabitant [37]. Environmental fees and penalties as well as access to EU funds allowed to accumulate significant resources to finance investment and ecological activities. Initially, the criteria for the granting of financial assistance were very mild, but over time more and more attention has been paid to the selection of investment projects, which meet both economic and ecological criteria. Given the importance of public procurement, there is certain that increased focus on environmental performance in the public sector will have a great impact on business. The companies that are not able to provide information about the environmental performance and the life cycle costs (LCC) of products have face difficulties in getting contracts with the public sector now and still in the future. Consequence of this is steadily more common measures of eco-efficiency in industry [12]. For example, an evaluation of the economic and ecological feasibility of new and existing mining projects using a combination of environmental goals expressed in life cycle assessment (LCA) results with economic goals expressed within life cycle costing (LCC) was proposed in [35] study. The authors emphasize that mining producers can reasonably expect that implementation of LCA and LCC will lead to minimisation of environmental impact of their activities and to more effective environmental, cost and waste management. This means savings through reducing the amount of waste emissions and a decrease in fees and fines [35].

In Poland, environmental performance (cost) is defined as the discounted net benefit streams, attributed per unit of physical environmental effects, for example on the pollution reduction. In this perspective, it can be a tool for ranking and evaluation of protective projects, according to the relationship:

$$EE = \frac{NPV}{eWC}$$

where:
EE - environmental performance,
eWC - ecological material effects in natural units,
NPV - net present value (discounted cash flows).

The condition of efficiency should be at least zero and positive NPV value, and a similar value per unit of environmental effects. In case of difficulty in assessing the value of the cash inflows (or profits) of the proposed investment, the analysis can be limited to comparing the discounted value of the expenses (costs), which includes external costs, per unit of environmental effects [13]. In the Adeoti et al. study, the discounted cash flow micro-economic assessment to evaluate the 6.0 m^3 family-sized biogas project in Nigeria, based on the NPV values was used. The results shows that the 6.0 m^3 family-sized biogas project using cattle dung as substrate in Nigeria has a good economic potential [33]. In another work, the authors indicated that addressing social and environmental concerns makes financial sense in the analyzed investment project (Camisea project). In present value terms (based on NPV values), the benefit of managing these concerns was expected to surpass the cost investment by approximately US$50 million [34]. It need to be noticed that using the life cycle net present value (LCNPV) method it is possible to compare different investment options, and this method can be treated as a tool that can help producers to make better decisions pertaining to environmental protection. Study of the influence of the environmental cost of projects should be based on long-term analysis of environmental investment [35].

Implementation of eco-innovative technologies

The dissemination and implementation of eco-innovative technologies is essential because of growing legal requirements and increased competition [14]. In this respect, technologies increasing productivity, minimising the amount of recycling and waste, reducing energy and material consumption (low-input technologies) should be sought and implemented [15]. Implementation of such measures will depend on business strategy and environmental, economic and social objectives set out therein. Integration and effective identification of those objectives usually requires conducting additional activities relating to:

- extension of corporate financial reporting by environmental protection aspects, and identifying the environmental protection costs of individual unit processes,
- application of investment effectiveness calculation from the perspective of the life cycle of the object, i.e. the investment phase, service phase (e.g. greater capital expenditures on buildings can result in a significant reduction in operating costs such as heating), and post-production phase (such as closing costs, rehabilitation and monitoring of waste disposal facilities),
- inclusion of environmental aspects in the design phase, i.e. the implementation of innovation technologies based on the eco-balance of the entire life cycle of the product (eco-design),
- incurring higher costs for research and implementation of new and innovative technological solutions and marketing costs to market new products (e.g. in the case of those derived from waste, it is necessary to demonstrate that they have no longer the status of waste according to law).

External factors pose also some difficulty to the entrepreneurs, namely:

- lack of system solutions relating to the environmental protection and rapidly changing legal provisions,
- diversity of multiple indicators to assess the ecological effects, in the absence of universally accepted, standardised model of ratio analysis for their quantification,
- lack of support mechanisms that would promote seeking comprehensive solutions, taking into account environmental, economic and social aspects.

Although, in Poland for years there have been grants or loans for environmental project available from the national funds (such as the National Fund for Environmental Protection and Water Management), and, recently, also from the EU funds (e.g. Structural Funds), the business operators fund the majority of such projects with their own resources. Supporting eco-innovative projects designed to reduce negative environmental impacts, at every stage of the product life cycle, requires the development and implementation of rules for their evaluation, taking into account the technical feasibility, economic and ecological efficiency, and consideration to social aspects. The selection of such investment solutions should be made based on:

- analysis and assessment of possible technological solutions, such as with the cumulative account method, the technological quality, best available techniques (BAT),
- assessment of environmental impacts of the project, based on the eco-balance developed,
- assessment of potential environmental impacts of various processes, including pre-production activities (so called upstream, for example transportation of raw materials), and post-production activities (so called downstream, such as the operation phase of a manufactured product), this way, transfer of environmental effects from one phase process to another (e.g. from the production to operation phase), from one region to another, or from one preserved area (water) to another (air), is avoided. The LCA method could be applied for that,
- account of project eco-efficiency, taking into account the synchronisation of economic and environmental effects [13].

Taking into account the above considerations, for the assessment of new technology solutions during the investment decision-making process, the eco-efficiency account should be introduced. It uses dynamic methods, combined with eco-balance methods, particularly the LCA and LCC. Such approach allows the assessment of eco-efficiency of the planned projects by quantifying their financial and environmental effects, and then, their prioritisation, depending on the adopted criterion.

Life Cycle Assessment method (LCA)

Currently, different approaches for eco-efficiency analysis are suggested: cost-benefits analysis CBA, life-cycle analysis LCA, contingent valuation CV [16]. According to the International Organization for Standards (ISO), Life Cycle Assessment is a method used to assess environmental aspects and impacts of products [17]. According to the official definition given by the European Commission, LCA is the process of collecting and evaluating data "input" and "output" of the product, as well as the potential impact on the environment throughout its life cycle: production, use and disposal (Figure 1) - estimating environmental effects caused by products and processes from 'cradle to grave' or 'cradle to cradle' [18]. In recent years, the perspective that LCA provides on the environmental performance of products had been made it a central concept for both environmental management in industry and environmental policy-making in public government [19]. The development and harmonization has occurred resulting in an international standard (ISO), complemented by a number of guidelines and textbooks. This has increased the maturity and methodological robustness of LCA. However, this method is still under development [20, 21].

Introduction of LCA in investment projects will allow taking into account all the factors that could potentially affect the environment and which are associated with the product. However, it should be noted that in LCA analysis the product can be a particular item/ product, an entire or part of a production process or use of the product, as well as the particular service or even an economic system [20]. Analyses with the LCA method involve quantification and assessment of the environmental effects during the entire life cycle, based on the developed material and energy balance [23].

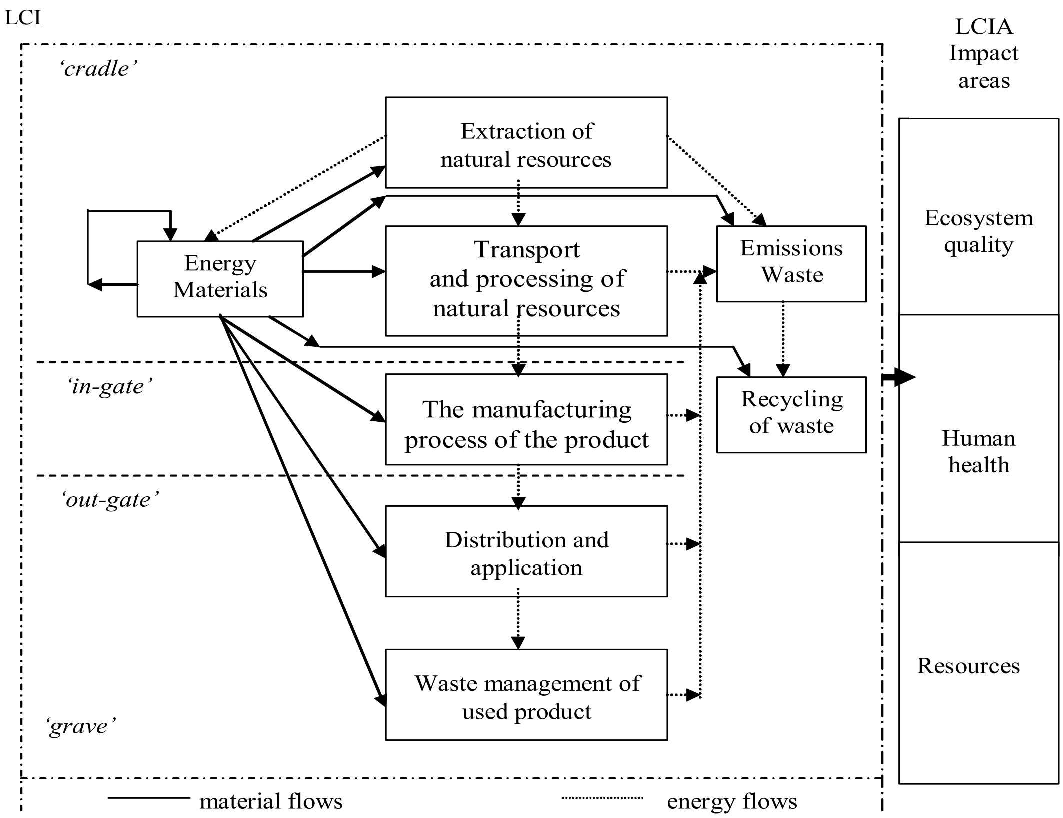

Fig. 1. LCA life cycle scheme
Source: [13]

The magnitude and significance of environmental, economic or social costs associated with specific life cycle activities are identified during the Life Cycle Impact Assessment (LCIA) phase. According to analyze the existing impact assessment methods, Society of Environmental Toxicology and Chemistry (SETAC) and the European Platform on Life Cycle Assessment (EPLCA) have made initial selection of 11 different categories of impact – Figure 2 [13, 24]. LCA includes impact categories on a global scale (climate changes, ozone layer depletion) as well as on a regional or even local scale (acidification, eutrophication, photochemical oxidation). Various temporal horizons of impact modelling enable to recognise the phenomenon of impact accumulation in time [25]. For each category of impact, based on scientifically valid models, the value of indicators is developed. However, their value is determined in another unit (kg of CO_2 equivalent, kg of PO_4 equivalent, kg of SO_2 equivalent), therefore it is not possible to directly compare them. However, they allow for assessing the impact of the product/process on the environment by determining the share of each emissions and each of the unit processes analyzed in this impact category. LCA, as one of the techniques of environmental management, is recognized and recommended in the EU as a tool for assessing environmental projects in many areas of economic activity [13].

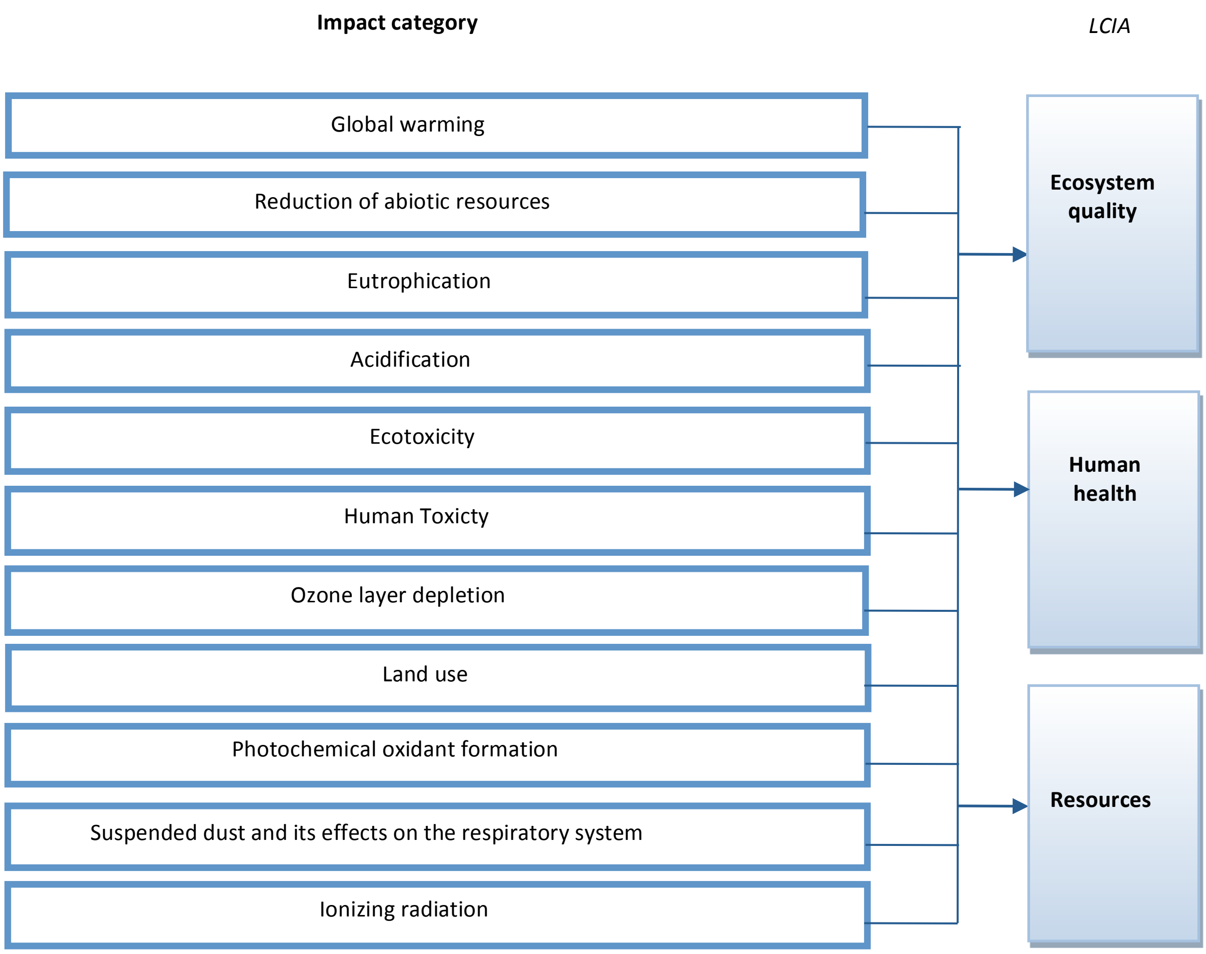

Fig. 2. The 11 different categories of impact
Source: [24]

The LCA results are presented in figures in specified categories of impact or on the basis of the calculated eco-indicator. This allows to compare the environmental impact of the proposed activity, e.g. a variant of omission or any other defined effect (such as a competitive manufacturer), which may be used to determine the ecological effect of the planned investment activities [26].

Cost efficiency assessment - using a dynamic unit cost method to evaluate the efficiency of environmental investments

Environmental performance can and should be used to assess the planned investment projects, especially those designed to protect the environment. Entities providing financial support usually define it as the relationship between the set ecological targets and expenditures incurred to reach them [27]. This approach defines the purpose as a selected area of the environment such as air protection and does not take into account the efficiency (cost-effectiveness) of planned economic development projects. However, when the eco-efficiency is defined as the relationship between discounted net benefits and environmental effects (e.g. reduction of pollution), there are clear difficulties in interpreting the results, especially for products/processes with significantly different impacts on the environment, but the same calculated indicator. Moreover, evaluation of the environmental effect is carried out in a protected area, such as air, which may cause an environmental problem in another area. Therefore, introduction of the eco-efficiency method of Life Cycle Assessment assesses the impact on the environment in integrated terms and allows the quantification of the results, is proposed. The combination of the methods of economic evaluation of the effectiveness of investment (discount method) enables the assessment of the eco-efficiency for both planned (*ex ante*) and made (*ex post*) investments.

It should be noticed that the use only the cost-benefit analysis is not a relevant method for making economic appraisal of investments that respond to compulsory ecological standards. Since the ISPA (Instrument for Structural Policies for pre-Accession) serves as a measure that helps accession countries to comply with EU ecological standards, the appraisal procedure should rely rather on the cost-effectiveness analysis [28]. To evaluate the effectiveness of environmental protection investments it is proposed to use cost-effectiveness ratio, created on the basis of cost per unit of dynamic methods (DGC - Dynamic Generation Cost) [29]. This is an indicator developed and used in the German bank KfW [28]. It determines the relation between the costs of the project and the effects coming from its use. This cost is equal to a price which allows for discounted revenues equal discounted costs. DGC shows what is the technical cost of obtaining environmental effect unit (product), expressed in local currency (e.g. EUR euro, US dollars, PLN zloty) per unit of environmental effects. It takes into account the current value of the investment and running costs. The obtained results are expressed in natural units, while the lower cost of obtaining environmental effect unit means more cost-effective investment. The mathematic notations of eco-efficiency as a combination of economic performance as DGC and ecological performance as LCA are expressed by the ratio as follows:

$$Eco-efficiency = \frac{1}{DGC \cdot LCA}$$

DGC indicator can be used at various stages of preparation and selection of investment projects, especially at:

- comparing alternative solutions for a given problem;
- limiting the scope of the investment,
- selecting of investment projects.

DGC ratio can be calculated from formula [13, 29]:

$$DGC = p_{EE} = \frac{\sum_{t=0}^{t=n} \frac{KI_t + KE_t}{(1+i)^t}}{\sum_{t=0}^{t=n} \frac{EE_t}{(1+i)^t}}.$$

where:

KI_t - capital costs incurred during the year;
KE_t - operating costs incurred during the year;
PEE - production in the year;
i - discount rate;
t - year, ranges from 0 to n, where 0 is the year of the first bear the costs, while ‘n’ is the last year of installation.

DGC indicator can be considered from two points of view:

- company, which wants to achieve a certain goal and considers choosing the best option; analysis of the technical cost allows to sort the options (from cheapest to most expensive);
- society, which as an investor can support the selected project.

The main problem in resolving the discussed issues are:

- determine the measurement of the environmental effect, which has a significant impact on the surrounding of the planned investment. E.g. an environmental impact of 1m^3 of wastewater discharged into the lake, in which there is no outflow, is quite different than when the receiver is large river. In practice, only a few areas of environmental protection selection of projects may be based only on the cost-effectiveness indicator. It is possible, e.g. in the case of climate protection (global warming), because it does not matter the place of emission but only the amount of greenhouse gases enter into the atmosphere.
- selection the environmental effect indicator – there is no generally accepted methodology for assessment of the integrated environmental effect, and focus on indicator characterizing just one area of protection.
- approval the discount rate at the same level for environmental effects and financial effects. It is assumed that the environmental effects expressed in physical quantities can and should be discounted, but the discount is much lower than adopted in financial terms. This is due to the fact that the ecological effects of property are not subject to the same rules as the amount of capital used in economic processes. Here it is important to answer the question whether the resulting environmental effect in future years is worth less than that achieved in the current year. In the literature there is no

consensus on this issue, but generally lower levels of environmental or social discount rate are offered in comparison to those taken into account in the financial assessment. For example, the Stern report on climate change (i.e., the costs of CO_2) [30] proposed a discount rate of 1.4% with 1.3% due to the expected growth and 0.1% of the possible annihilation of mankind.

The analysis of alternative solutions for investments should be carried out in practice only during the formulation of the concept. Therefore, the design office, preparing the concept of investment, should describe all possible options to achieve the objective set by the investor and the estimate for each investment and operating costs. As a result, DGC pointer enables the cheapest solution to be chosen. Therefore, comparison of alternative solutions is the best use of the DGC pointer. Selection and qualification of projects for funding is a difficult task. The DGC pointer allows the creation of a ranking of projects for groups of homogeneous environmental effect, so projects may be prioritized according to their size and value. This procedure will ensure the lowest cost of obtaining the environmental effect [13]. Czaplicka-Kolarz et al. [36] were conducted eco-efficiency analysis on the basis of LCA and DGC of high density polyethylene (HDPE) and low density polyethylene (LDPE) production. Using DGC and LCA analysis, which allows to compare production technologies of chosen polyolefins, and it was adopted methodology for eco-efficiency calculating. The results allow a statement, which technology is more eco-efficient. Eco-efficiency indicators presented in this paper could be used as a benchmark for eco-efficiency assessment of polyethylene production by chosen technologies in existing installations [36].

The assessment of the profitability projects co-financed by the Structural Funds are carried out on the basis of detailed recommendations, e.g. for investment in environmental protection, described in the publications developed for the European Commission in the form of guides. For large infrastructure project, in accordance with Art. 26 of Council Regulation 1260/99/EC (Journal of Law 161 of 26 June 1999) laying down general provisions on the Structural Funds, preparation of cost analysis and benefits (CBA), analysis of risk factors, environmental impact assessment (EIA), and evaluate the impact of investments on equal opportunities and employment, is required. The aim of CBA is to demonstrate whether the project leads to an increase in welfare of the community affected by its consequences. The widely understood socio-economic CBA should take into account not only the financial costs and benefits expressed as cash flows, but also provide information about the impact of these aspects of the project that are not subject of the transaction on the market. For such projects, both (real) financial rate of return of the total investment and economic rate of return, taking into account social and environmental aspects through the use of shadow prices account, is calculated [31]. The CBA method is appropriate for the assessment of economic efficiency and in some extent - an integrated economic efficiency, environmental and social - but only for investment project [32].

While at the EU level, there are generally accepted guidelines for financial analysis economic and investment projects, as well as the detailed requirements for the preparation of the EIA, the method of calculating the ecological effects for the evaluation and implementation of various programs is determined at the level of individual country or region. This approach allows for the prioritization of national or regional authorities, which are subject to specific financial support from designated areas of environmental protection. The choice of the method of determining how the effect will be calculated should be based on ecological principles and objectives of the environmental policy of the country and provide a basis for the implementation of the principles of sustainable development [13].

Summary

According to ISO International Standard 14045:2012, eco-efficiency assessment is a necessary management tool to decrease the overall environmental impact and is increasingly becoming a key requirement for success in business. Eco-efficiency is the function of life cycle assessment and life cycle cost and it connects the basic business target (profit) and the basic production system target (costs) with environmental approach. This allows to the possibility to create innovative products fulfilling environmental criteria by decision-makers in companies. In this paper, environmental assessment in eco-efficiency evaluation based on Life Cycle Assessment (LCA) according to ISO 14040:2006 was proposed. Moreover, it was highlighted that environmental performance should be more frequently used to assess the planned investment projects, especially those designed to protect the environment.

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