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The use of LCC method in running cost analysis of a single-family house

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Abstract: In the process of making decisions on building a single-family home, many variables of a cost nature should be taken into consideration, which will affect the total level of costs of use of the building in the long-term perspective. Life Cycle Costing (LCC) is a method that can support this process, which is why the main purpose of this article is to analyze the cost of using a single-family home using the LCC method, taking into account environmental aspects that are important in shaping the quality of life of individual households and local communities. In this context, an answer to the following research problem is sought: How to calculate and reduce the costs of using a single-family home in the perspective of its life cycle, taking into account the current and prospective energy and environmental conditions? In order to accomplish the above research objectives, the first part of the article presents the theoretical basis for calculating the costs of maintaining single-family buildings together with a description of use of the LCC method. Next, a case study was presented, within which the long-term costs of maintaining a single-family building were calculated and the pro-ecological possibilities of their reduction were indicated.

Keywords: product life cycle cost, present value of cash flows, running cost, total cost

JEL codes: O14, O31, O32

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1. Introduction

Together with the increase in wealth of society there appears a consumer trend which consists in a desire to possess a single-family home that is supposed to replace living in a block

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of flats. Such behavior comes from a lower cost of rent in a single-family home compared with an apartment with a similar usable area. Another reason for these changes is the desire to be close to nature, in a quiet area, possessing one's own garden. The objective of this paper is to present a process of optimal variant selection of investing in a single-family home using Life Cycle Cost (LCC) methods, taking into account the environmental aspects. When the subject of interest is the cost of constructing a residential building for a family, the LCC method becomes helpful. It is a method that incorporates the already known ways of product cost estimation with a defined length of its life cycle. In this way, the decision to build or purchase a single-family home can be made on the basis of rational financial premises that take into consideration the long-term perspective of exploitation, in which, apart from the costs of construction/purchase and current use, it is also important to reduce the costs in the life cycle at the stage of choosing a single-family home structure. The rationalization of such a choice is also driven by environmental reasons related to the need to minimize energy consumption from non-renewable sources dictated by both the limited sufficiency of non-renewable resources and the high level of environmental pollution associated with their use.

The life cycle of a single-family home lasts 40-60 years. In many cases an average consumer focuses only on the initial investment costs, forgetting running costs presented in Figure 1.

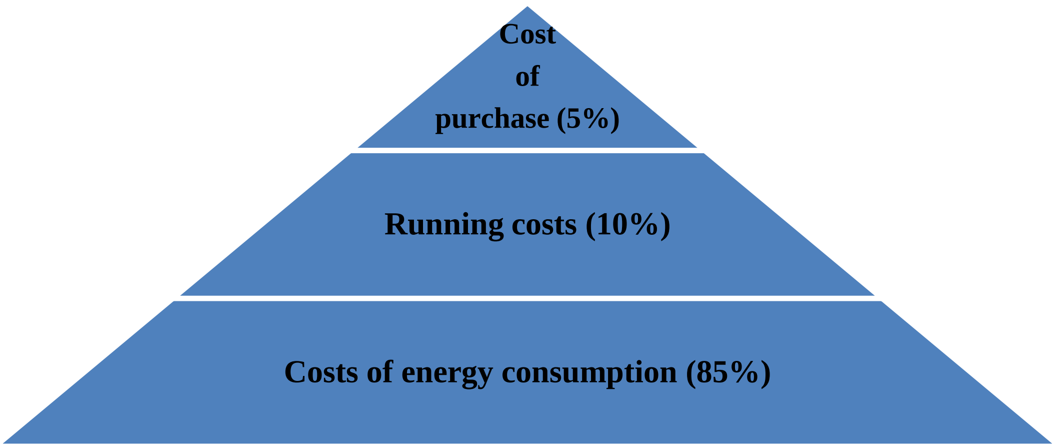


Figure 1. Pyramid of costs

Source: Skowron M. *Zielone Zamówienia Public*zne II Podręcznik, Warszawa 2012, p. 8

Based on the information in Figure 1, it may be stated that if we assume several dozen years of product life cycle, the initial investment costs only constitute 5% of the total. Next, running costs (that also include the cost of repair and modernization) amount to 10%. The remaining part of total costs belongs to the cost of energy consumption. In connection with the above, the average consumer omits 95% of the investment costs in their calculation. Therefore, when considering offers we should pay attention to the most beneficial ones in terms of the total life cycle, not only choosing the cheapest offers concerning purchase run cost estimate of buildings based on the current prices of materials necessary for construction. The cost estimate for purchase often becomes the basic document that a mortgage is granted for (Stec, 2015). However, the cost estimate of repair and modernization is made by construction companies, which, before making a decision, should know the scale of construction works, and what follows it, an approximate amount of the initial costs (Myna, 2016).

The cost structure, in which the costs of energy consumption predominate, should lead decision-makers to choosing energy-saving technical solutions that in future will reduce the total cost of using a single-family home. Nevertheless, analyzing the costs only from the current perspective of purchase/construction hinders making such far-reaching decisions. Therefore, the LCC method, by which the long-term operating costs of using a single-family home are analyzed in this article, may be helpful in making the potential buyer aware of their consequences while trying to answer the following research question: How to calculate and reduce the costs of using a single-family home in the perspective of its life cycle, taking into account the current and prospective energy and environmental conditions?

2. Life Cycle Costing in the light of literature studies

In order to achieve the objective of this paper, the method of cost assessment of product life cycle (Life Cycle Cost) was applied, taken from the standard PN-EN 60300-3-3, which defines the total cost of product as a sum of purchase, possessing and liquidation costs (Kiss, 2016). The LCC method was invented in 1960s. The US Department of Defense introduced it in practice of public procurement. These days this method is commonly used in various branches of industry, in particular in power, infrastructure and construction industry (Epstein, 1996). In the literature of the subject, a lot of space has been devoted to this topic (Badea et al., 2014; Han et al. 2014; Heck, 2010). Due to the fact that 85% of the costs of functioning of single-family buildings are those of energy consumption, a great deal of attention is devoted to these issues in the literature, focusing on the analysis of case studies of the use of various thermal and energy solutions and the level of carbon dioxide emissions, as an ecological boundary condition, associated with their use.

Based on the literature review, the following conclusions concerning the life cycle carbon emission assessment of a residential building may be drawn (Karimpour et al., 2016):

– life span is different for various types of building size and insulation,

- depending on the type of heating and other energy costs, the life cycle ranges from 40 to 100 years,
- in order to calculate energy cost, usually conversion factor is used.[1]

Referring to the experience of other authors using life cycle carbon emission assessment, a relevant mathematical model of development should start with 3 main assumptions facilitating the choice of optimal variant (Heck, 2010), including:

- assumption that after the end of life cycle the installations should be replaced,
- assumption that in order to reduce the possibility of failure, the installation inspection should be conducted according to the scheme provided in building heating characteristics,
- assumption that the energy prices do not change in the whole life cycle (the use of capital recovery factor -CRF-).

3. Methodology

In the course of the research, the above-described LCC method was used to estimate the costs of maintaining single-family buildings, which was applied to three buildings with different surface area. Subsequently, these costs were compared, and the initial investment option was selected based solely on the level of total costs, assuming that the same thermal and energy technologies were used in all the buildings. In the second part of the analysis – assuming the choice of pro-ecological technological solutions – a re-evaluation of the costs of using the building with the largest surface area was made, thus identifying the possibilities of reducing energy costs that constitute the greatest load in the life cycle.

In the case study 3 cost estimates of residential buildings of residential area of 99-114 m^2 were made. Based on the literature review included in Table 1 and the method adopted it was assumed that:

- life span of a residential building amounts to 40 years,
- discount rate (d) in the year 2016 amounts to 2.83%[2],
- total costs covered in the life cycle are composed of initial costs, running costs and liquidation costs. They are calculated according to the formula:

[1] Conversion factor – calculation of primary energy (necessary for manufacturing of energy product) in relation with electricity. For example, conversion factor of 2.5 indicates that power is provided with effectiveness of 40% (100%/2.5=40%).

[2] Data obtained from website: https://www.uokik.gov.pl/stopa_referencyjna_i_archiwum.php

$$K_c = K_z + K_u + K_r \tag{2}$$

where: K_c - total costs; K_z - cost of purchase (initial, not discounted), K_u=K_e (energy costs, discounted for 40 years) + K_f (financial costs, discounted for 30 years), K_r - (liquidation costs, discounted for 40 years).

$$K_e = \frac{K_{e(t)}}{CRF_{(t)}} \tag{3}$$

$$K_f = \frac{K_{f(t)}}{CRF_{(t)}} \tag{4}$$

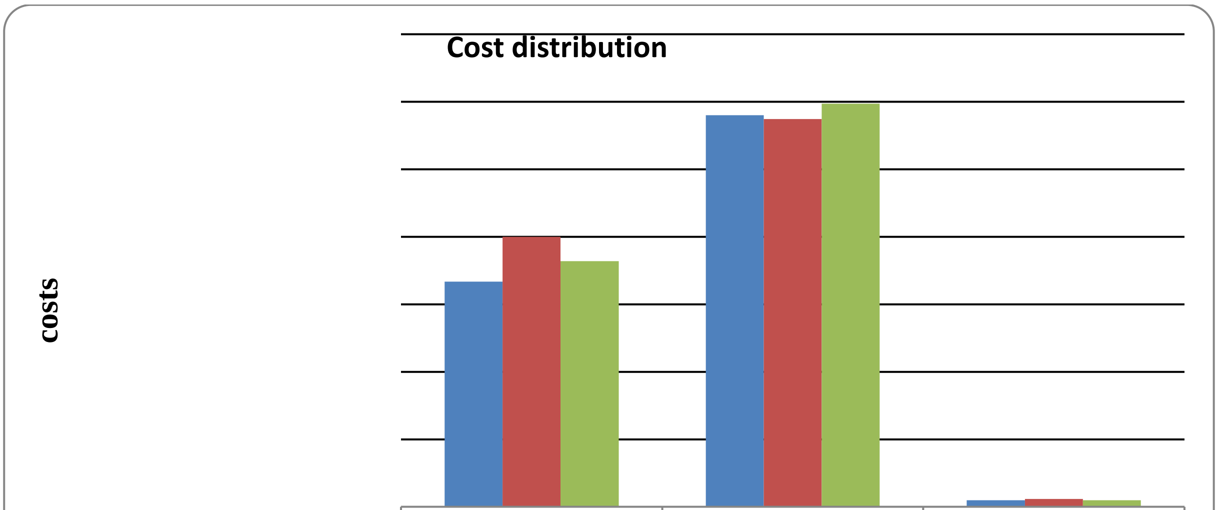
$$K_r = \frac{K_{r(t)}}{CRF_{(t)}} \tag{5}$$

$$CRF_{(t)} = \frac{d}{1-(1+d)^{-t}} \tag{6}$$

We understand the cost of purchase to be bringing the house to the so-called state of practical completion. Running costs are meant as the sum of energy costs, land tax, repairs, waste removal, gas consumption for central heating and water heating (Islam et al., 2014; Pasierb, 2010; Skowron, 2012). It is also assumed that a family building a residential home takes a mortgage for its construction at the amount of PLN 300 000 with a nominal rate of 5% over the period of 30 years. The aforementioned financial costs are added to running costs. Liquidation costs are understood as a present value of cash flows in 40 years. It should be emphasized that all the costs should be understood as discrete variables and considered at a given time and with strict assumptions of the methods.

4. Research results

Based on Figure 2, it may be stated that the largest share in the cost structure goes to the sum of financial and running costs. The lowest share corresponds to liquidation costs as they will be covered only after the completion of the life cycle of a residential building. Figure 2 is also a reference to the aforementioned iceberg syndrome, since it illustrates that running costs constitute about 68-72% of the total costs covered in the whole life cycle; however, the initial costs are only about 26-30%, and the share of the liquidation costs is scarce (1%). The liquidation costs are much lower than others because they are discounted throughout the life cycle of the building. It was also assumed that the house will be built of materials that will not hinder its demolition in the future.



	initial costs	running costs + financial costs	liquidation costs
house with area of 99 sq.m.	333434,05	579914,18	9824,892847
house with area of 114 sq.m.	400073,04	574122,05	11462,37
house with area of 105 sq.m.	363851,45	597175,82	9824,89

Figure 2. Chart of cost distribution for different variants

Source: author's own elaboration

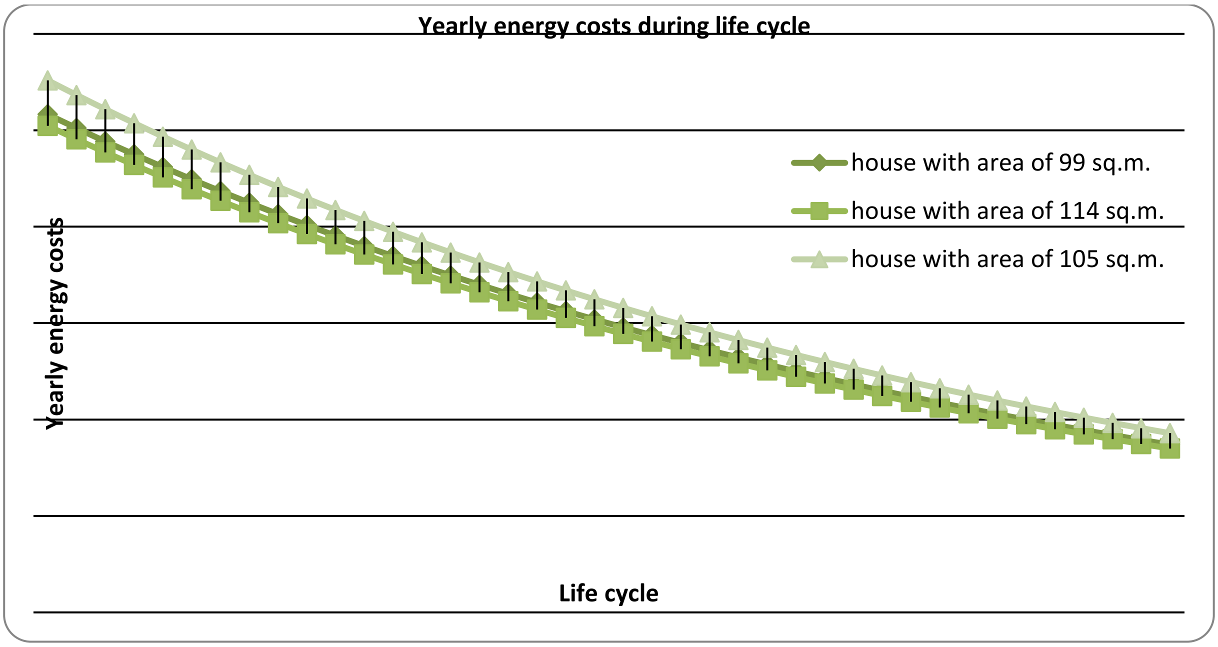


Figure 3. Yearly running costs depending on the selected variant

Source: author's own elaboration

In Figure 3, a yearly share of energy costs is discounted at a fixed rate of 40 years. Based on the information included in Figure 3, it may be stated that Variants 1 and 2 have similar running costs. Furthermore, running costs in Variant 3 are higher and it is caused by the largest usable area of the building. Taking the total cost encompassing the whole life cycle of a residential home into account, the most beneficial choice is Variant 1, that is specific for the smallest usable area (99 m^2). As it was mentioned before, the investor is interested in the lowest total cost. Due to an obvious conclusion concerning the relation of cost and usable area, the case study was extended with an attempt to answer the question how to reduce running costs of a house with a greater area – in the analyzed case – a house with the area of 145 m^2. The numeric data for this part of analysis are presented in Table 1.

Table 1. Comparison of construction and heating costs

House of area 145m^2	House in a traditional technology	Energy efficient house "Izodom"	Passive house "Izodom"
Construction cost	PLN 227 638	PLN 230 905	PLN 278077
Heating cost for 25 years	PLN 152 913	PLN 99 559	PLN 44 145
Savings	PLN 0	PLN 53354	PLN 108 768

Source: http://www.pasywnedomy.eu/assets/katalog_projektow_domow.pdf

Based on the information included in Table 2, it may be stated that the most expensive house to build (home of the largest area) may be the cheapest in maintenance provided that it is a passive house.

A passive house has to possess the following five features (Kuklauskas, 2015; Pasiecki, 2013; Żurawski, 2013):

- heating demand index does not exceed 15kwh/m^2/year,
- primary energy demand index does not exceed 120 kwh/m^2/year,
- heat transfer coefficient amounts to U ≅ 0,1W/m^2K,
- ventilation systems have been inserted,
- thermal bridges have not been used.

Walls and windows in the passive house are characterized by the most effective thermal insulation (low U index). Passive house constitutes a construction without places that the heat could go away through and where water liquefies. Such a type of house also possesses ventilation systems that are aimed at retrieving heat from the environment at the level of 75%. Figure 4 presents a visualization of passive technologies.

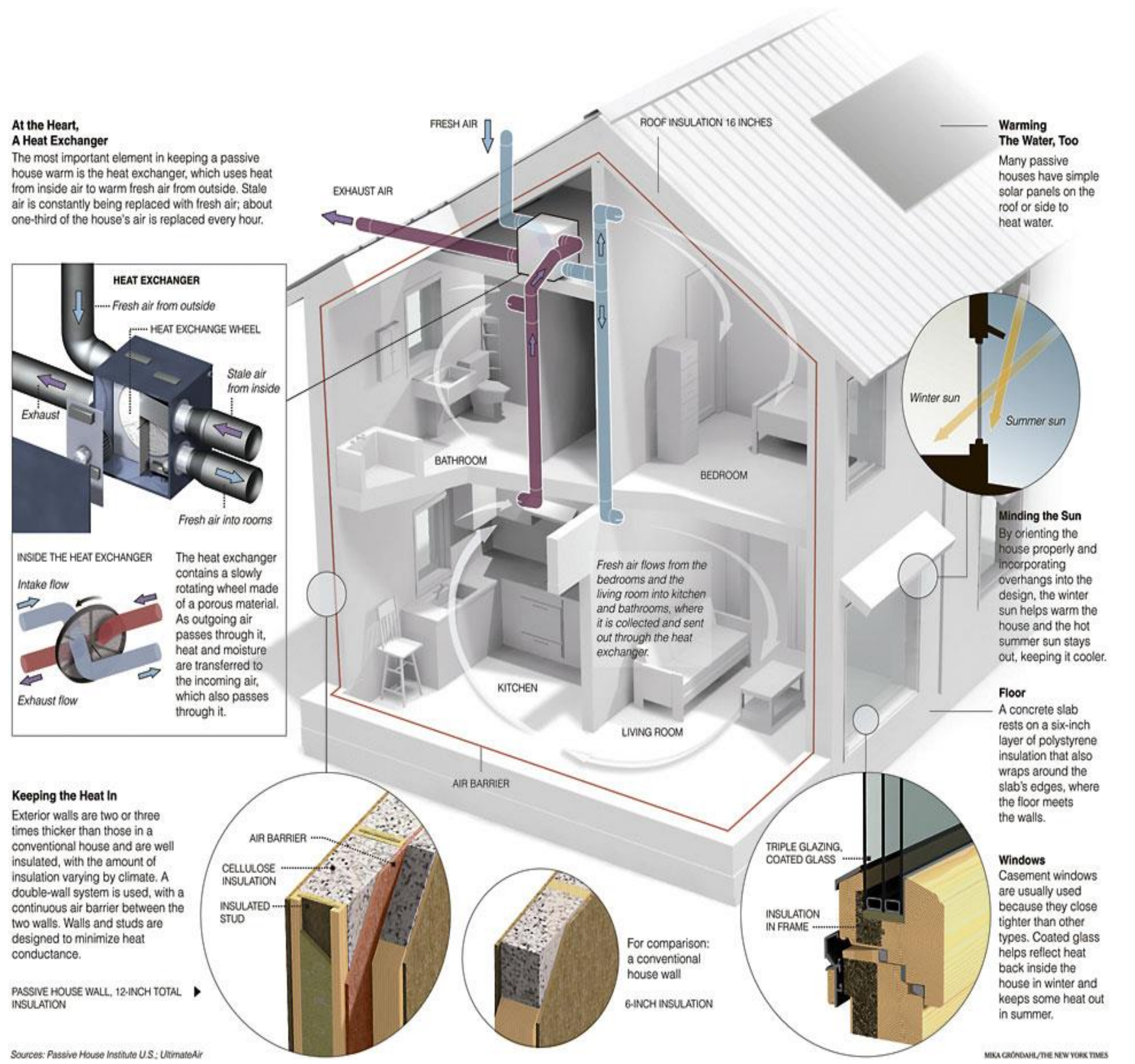


Figure 4. Technologies used in a passive house

Source: https://www.intuswindows.com/passive-house/ (12.11.2016).

The use of passive construction is the most efficient method of energy costs rationalization in terms of savings in the whole life cycle. Furthermore, financial costs should be selected in such a way that the total cost of mortgage is minimized. The investor, before making a decision about building a particular type of a residential building, should therefore consider the following aspects:

– life span of the building,
– total costs, savings resulting from the use of passive technologies (Kiss, 2016; Minne et al., 2015).
– share of particular costs in the structure and possibility of their covering from the perspective of the whole cycle.

5. Conclusions

Responding to the research question raised in the introduction, it should be stated that the costs of maintaining single-family buildings should be calculated taking into account the long-term perspective using the LCC methodology. Such an approach allows the decision-maker to be made aware of the complexity of cost issues and provides full information about the costs that is necessary for a rational decision to purchase or build a single-family house. In addition, the analysis shows that a significant part of financial burdens in the life cycle of a residential building are energy costs, which, however, can be effectively minimized while maximizing environmental effects by designing and using the so-called passive house. Passive houses are characterized by a high construction cost, but they have low demand for energy. The consequence of low energy demand are definitely lower energy and heat costs, which allows reducing costs in the life cycle of a single-family building. When making decisions, outside the lowest total cost criterion, the investor should, therefore, take into account the savings that it can have if it chooses a passive house.

The method of life cycle cost assessment (LCC) presented in the paper was supposed to analyze the particular variants of a one-floor, single-family residential building. In the paper, the investment analysis was applied using discounted cash flows (NPV). The adopted assumptions described in the case study impose some limitations on the method:

– it does not include price changes that may occur during the house life cycle,
– it assumes that the family would obtain an income allowing covering the costs over the whole house life cycle without incurring additional debt,
– mortgage taken for the building is paid off in time and in even installments,
– discount rate does not change depending on investment year.

The use of LCC method allows the investor to research the types, share and approximate amount of costs borne during the life cycle. The advantages of the approach adopted are as follows:

– simplicity of the mathematical model obtained thanks to numerous initial assumptions,
– making the investor aware that the initial costs only constitute about 20% of the total costs,
– enabling recognition of the cost structure,
– facilitation of cost planning and control,
– acknowledging the benefits from using the method of energy costs rationalization.

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ZASTOSOWANIE METODY LCC W ANALIZIE KOSZTÓW EKSPLOATACJI DOMU JEDNORODZINNEGO

Streszczenie

W procesie podejmowania decyzji o budowie domu jednorodzinnego należy uwzględnić wiele zmiennych o charakterze kosztowym, które będą wpływać na całkowity poziom kosztów użytkowania budynku w długiej perspektywie czasowej. Metodą, która może wspomóc ten proces jest Life Cycle Costing (LCC), dlatego też głównym celem niniejszego artykułu jest przeprowadzenie analizy kosztów użytkowania domu jednorodzinnego z wykorzystaniem LCC przy uwzględnieniu aspektów środowiskowych, które mają istotne znaczenie w kształtowaniu jakości życia indywidualnych gospodarstw domowych oraz społeczności lokalnych. W tym kontekście poszukuje się odpowiedzi na następujący problem badawczy: W jaki sposób kalkulować i obniżać koszty użytkowania domu jednorodzinnego w perspektywie cyklu jego istnienia przy uwzględnieniu obecnych i perspektywicznych uwarunkowań energetycznych i środowiskowych? By zrealizować powyższe zamierzenia badawcze w pierwszej części artykułu przedstawiono teoretyczne podstawy kalkulacji kosztów utrzymania budynków jednorodzinnych wraz z opisem wykorzystania metody LCC. Następnie zaprezentowano studium przypadku, w ramach, którego skalkulowano długoterminowe koszty utrzymania budynku jednorodzinnego oraz wskazano proekologiczne możliwości ich obniżenia.

Słowa kluczowe: koszty cyklu życia produktu, wartość teraźniejsza przepływów pieniężnych, koszty użytkowe, koszty całkowite

Kody JEL: O14, O31, O32

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