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Environmental impact analysis of windows made from wood and PVC using LCA

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Abstract: The aim of this study was to compare environmental impact generated during the manufacture processes of windows made from wood and PVC based on methodological assumptions of the LCA technique. Manufacture of 100 windows of 1000 x 1000 mm in size each was assumed as a functional unit. Environmental impact assessment was performed using the Ecoindicator 99 method (H/A). The LCA for windows made from wood and PVC windows was based on information coming from their manufacturing plants. A higher value of the cumulative indicator, i.e. a markedly greater negative environmental impact was found for the production of windows from PVC (+530 Pt). The value of the cumulative index for wooden windows was (-236 Pt). A positive environmental effect recorded for wooden windows results mainly from the capacity to absorb CO_2 from the atmosphere by trees during their growth.

Keywords: Life Cycle Assessment, wooden windows, PVC windows, environmental protection

INTRODUCTION

Windows as inherent elements of every building are very popular products manufactured by many companies. Customers may choose from windows made from PVC, wood, wood and aluminum, or aluminum alone. Widows made from wood are considered to be environmentally friendly. Such opinions are presented in many reports, although frequently these claims are not based on research or analyses. Life Cycle Assessment (LCA) is a methodological tool facilitating environmental impact assessment of products and thus verifying popular opinions. In accordance with the methodological assumptions of LCA environmental impact is determined and evaluated for all potential actions throughout the entire life cycle of the product or during its individual stages. The LCA analytical procedure was specifically discussed in a series of the ISO 14040-14043 standards.

METHODS

Aim and scope of assessment

The LCA was conducted in order to compare environmental impacts generated during manufacturing stages of windows made from PVC and windows made from wood and with the aim to identify window frames with better environmental characteristics, i.e. safer for the environment. It was performed following methodological assumptions presented in the ISO 14040-14043 standards.

Geographical, time and technological aspects

Data concerning consumption of materials and energy in the manufacturing process of windows and semi-finished products (PVC profiles and scantlings) came directly from Polish producers. Information was collected in 2010. Data on the collection and production of such raw materials as wood, aluminum, PVC, EPDM or steel was obtained from the data base attached to the SimaPro 6.0 software.

The analysis did not include environmental impacts connected with the use of glass units in windows or the packaging process of these windows, since they were treated as elements common to both types of analyzed window systems. Environmental impacts

connected with the production and application of paints, adhesives or silicone were also excluded from analyses.

Functional units

Manufacture of 100 single-frame window units of 1000 x 1000 mm in size was considered to constitute a functional unit.

Life cycle Impact Assessment (LCIA)

The impact of life cycle for the tested window systems was analyzed using the Ecoindicator ’99 (H/A) method (Goedkoop and Spriensma 2000). The applied method made it possible to provide assessments within eleven categories of environmental impact, which according to the adopted assessment procedure are grouped into three categories of damage (table 1). The analysis consisted in the stages of characteristic, standardization and weighing of environmental impacts as well as presentation of results in the form of a cumulative result.

At the standardization stage recorded results were referred to the number of residents in Europe in accordance with the assumptions of the Eco-Indicator ’99 method. The weighing stage resulted in the presentation of impacts within individual categories using the Eco–Indicator points [Pt]. The value of 1 Pt represents one thousandth of the yearly environmental load of one average European inhabitant [Goedkoop et al., 2000].

The last stage consisting in the presentation of results in the form of the so-called cumulative ecoindicators is of particular importance. Based on these indicators it is easy to make comparisons and inferences on the global environmental impact of the entire product system.

Tab. 1 A list of investigated categories of impact and categories of damage

Impact Category	Damage Category
Carcinogenic effects	**Human health**
Respiratory effects caused by organic substances	
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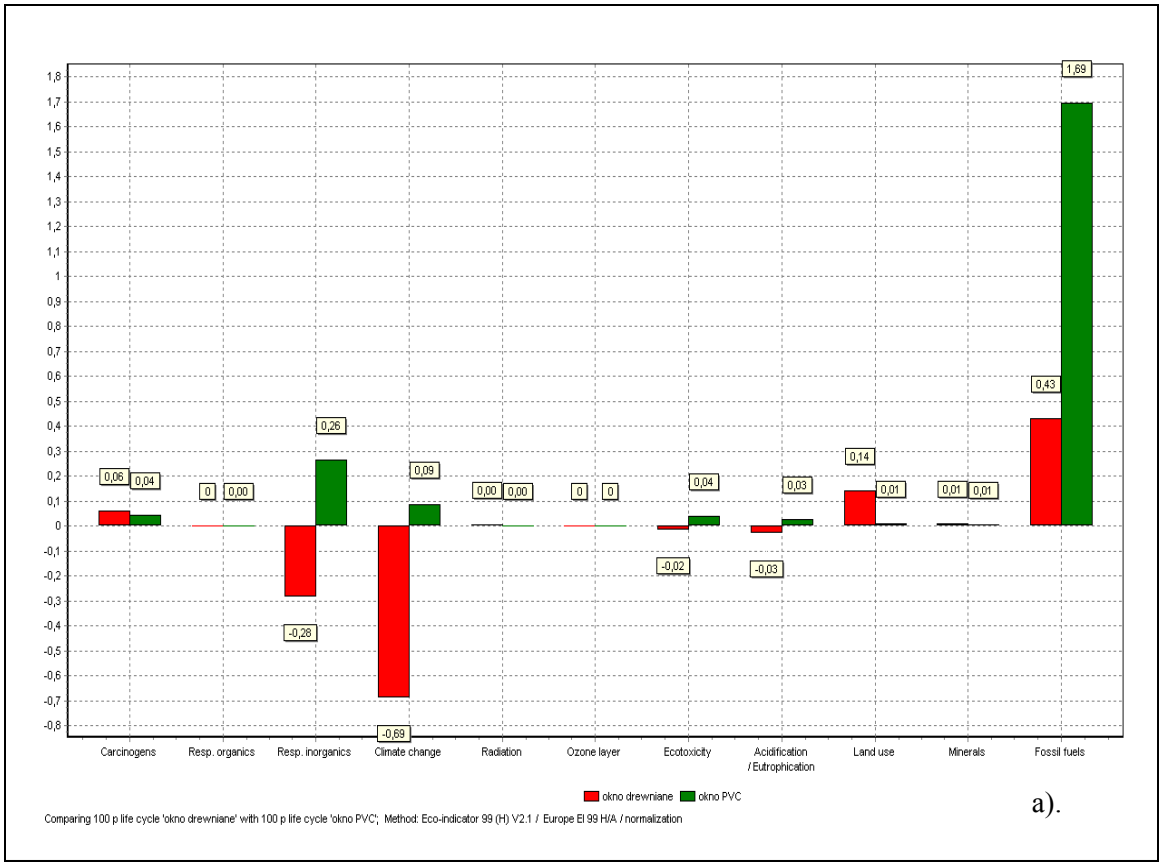
Climate change	
Radiation	
Ozone depletion	
Ecotoxicity	**Ecosystem Quality**
Acidification/ nutrification	
Land use	
Minerals	**Resources**
Fossil fuels	

DISCUSSION OF RESULTS

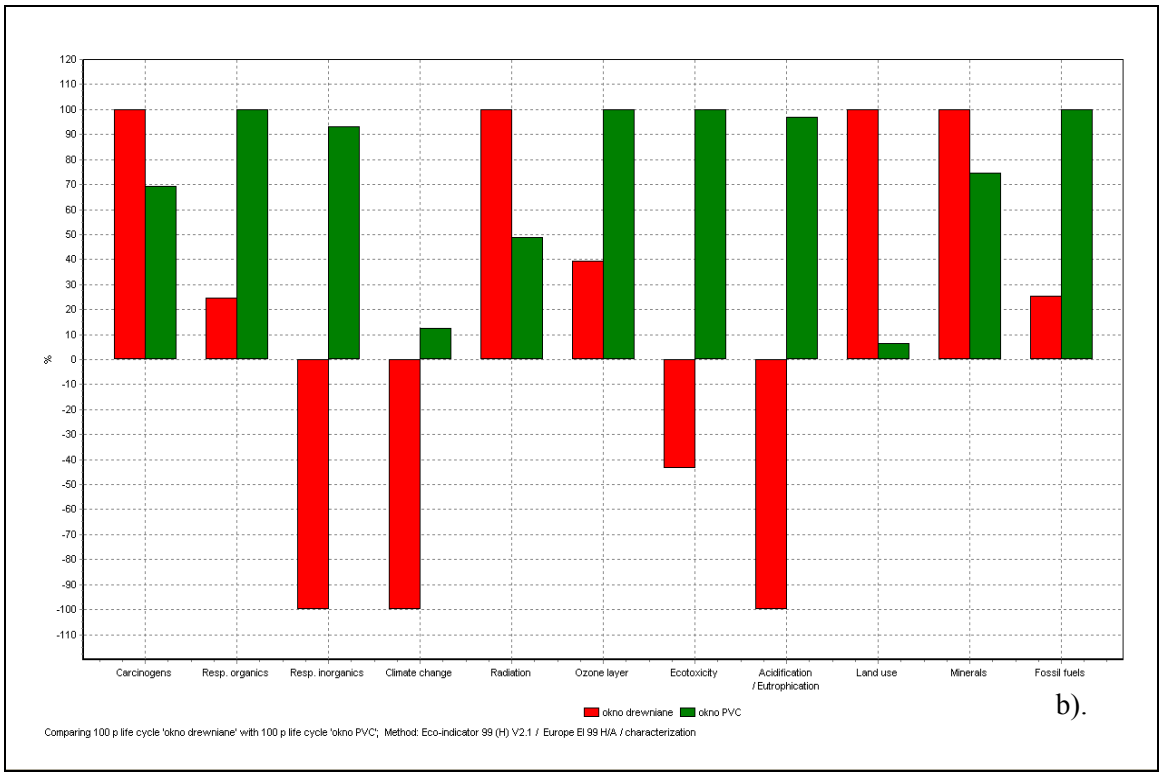
Figure 1 presents results of analyses in terms of eleven environmental impact categories recorded for the characteristics, standardization and weighing stages.

As it results from Fig. 1a, the manufacture process of windows from PVC has a negative effect on the environment within all analyzed impact categories. The manufacturing process of wooden windows is attributed higher values, i.e. it has a more negative effect on the environment than the production process of PVC windows only in four impact categories, i.e. carcinogens (development of cancer), radiation, land use and minerals. Within four other impact categories, i.e. diseases of the respiratory tract caused by inorganic compounds, climate change, ecotoxicity as well as acidification and eutrophication the manufacturing process of wooden windows generated positive impacts. This is connected with positive phenomena occurring during life cycle of trees and their environmental impact.

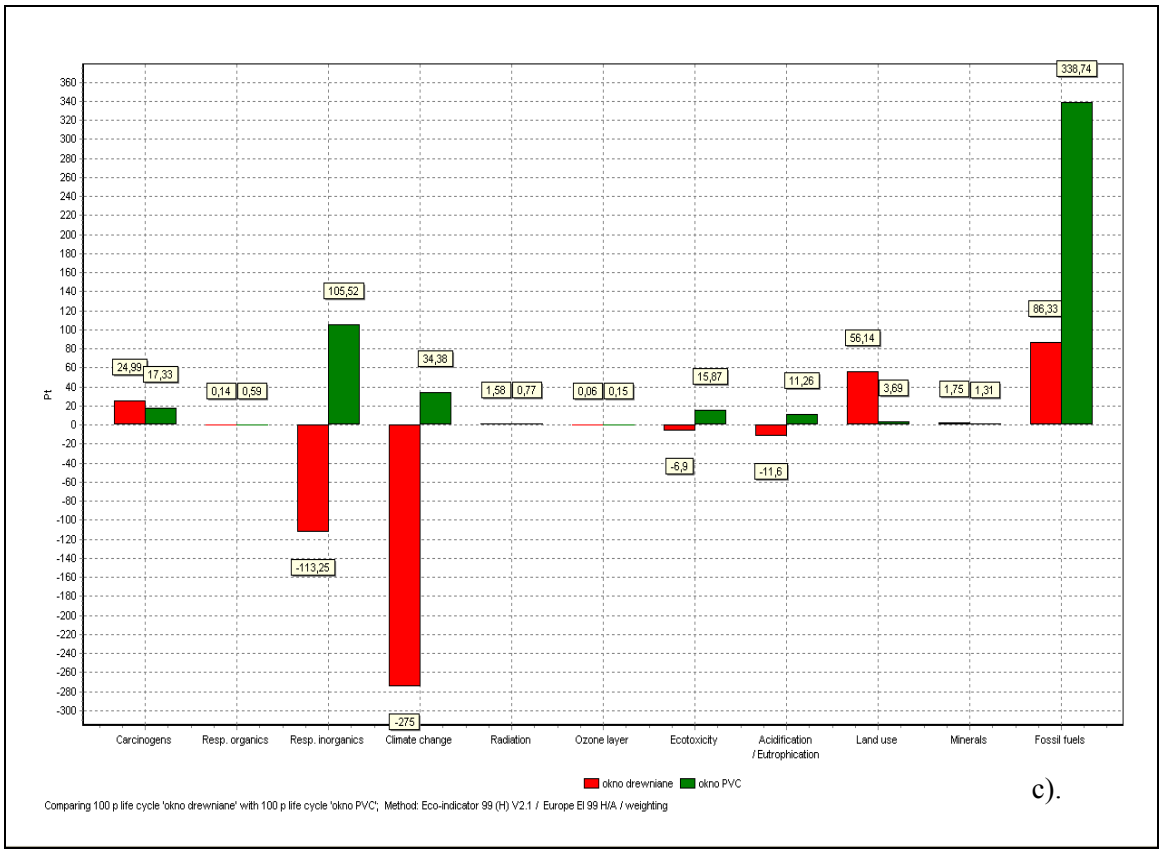
After incorporation at the standardization stage (Fig. 1b). of data concerning environmental statistics per 1 resident of Europe it may be observed that the production process of wooden windows causes a significant increase in the environmental impacts within such impact categories as carcirogens, land use and fossil fuels, while the production process of PVC windows has a significant effect on the environment through emission of pollutants causing respiratory problems due to inorganics, climate change, ecotoxicity and fossil fuels. The impacts on fossil fuels generated by the window systems made from wood and those from PVC are markedly greater in the case of PVC windows. However, windows from wood to a greater extent than windows from PVC result in an increase of cancer incidence rates (carcirogens).



a).



b).



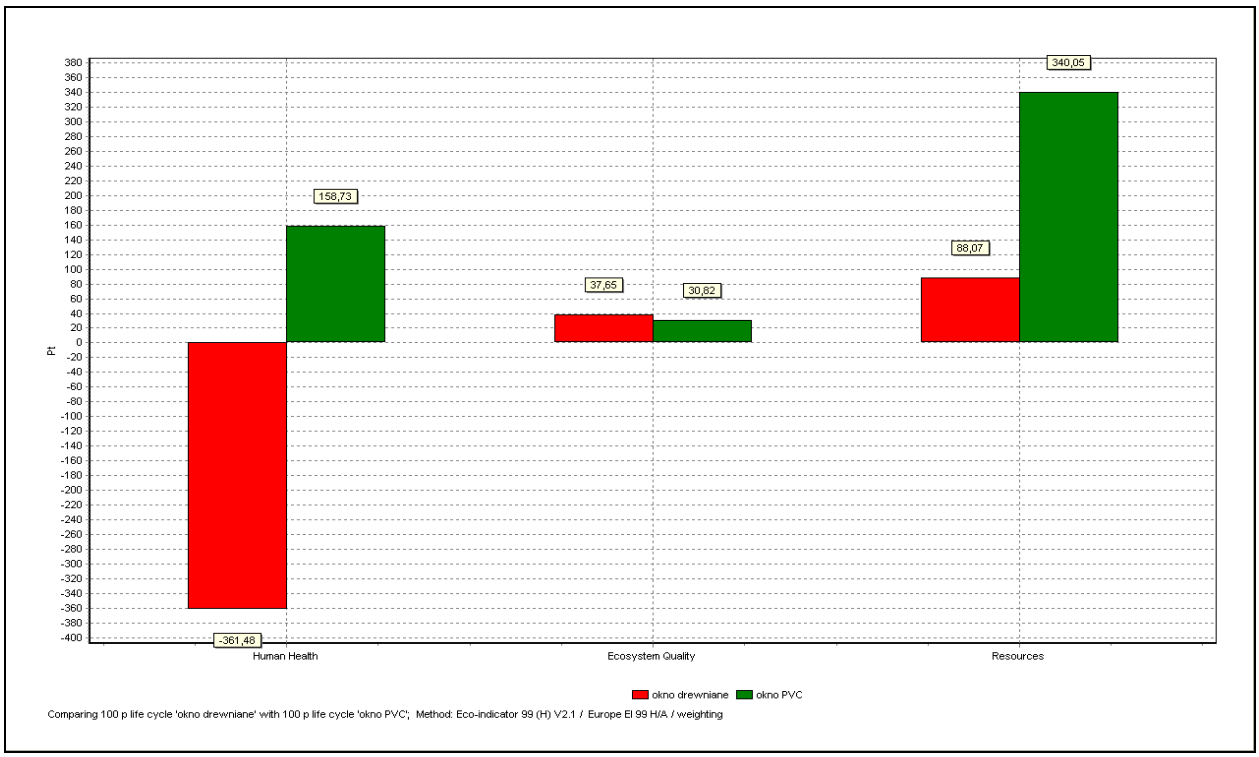
c).

Fig. 1 A comparison of production stage of windows from wood and PVC in terms of 11 impact categories: a). the characterization stage; b). the standardization stage; c). the weighing stage

As a result of the weighing stage (Fig. 1c). values within each category increased considerably, but the total effect of impacts was not changed.

The manufacturing process of wooden windows and the required semi-finished products was characterized by significant effects within the category of carcinogenicity (+24.99 Pt), land use (+56.14 Pt) and depletion of fossil fuels (+88.33 Pt). In turn, the manufacturing process of windows and window profiles from PVC had an effect on the environment through emission of carcinogens (+17.33 Pt), inorganic compounds causing respiratory tract diseases (+105.52 Pt), climate change (+34.38 Pt), ecotoxicity (+15.87 Pt), acidification and eutrophication (+11.26 Pt) and depletion of fossil fuels (+338.74 Pt).

Within positive impacts generated solely by window systems from wood significant impacts were found in terms of the category of climate change and diseases of the respiratory tract caused by inorganic compounds at (-275 Pt) and (-113.23 Pt), respectively. The positive impact of window systems from wood on ecotoxicity as well as acidification and eutrophication was markedly lower, as it amounted to (-6.9 Pt) and (-11.6 Pt).



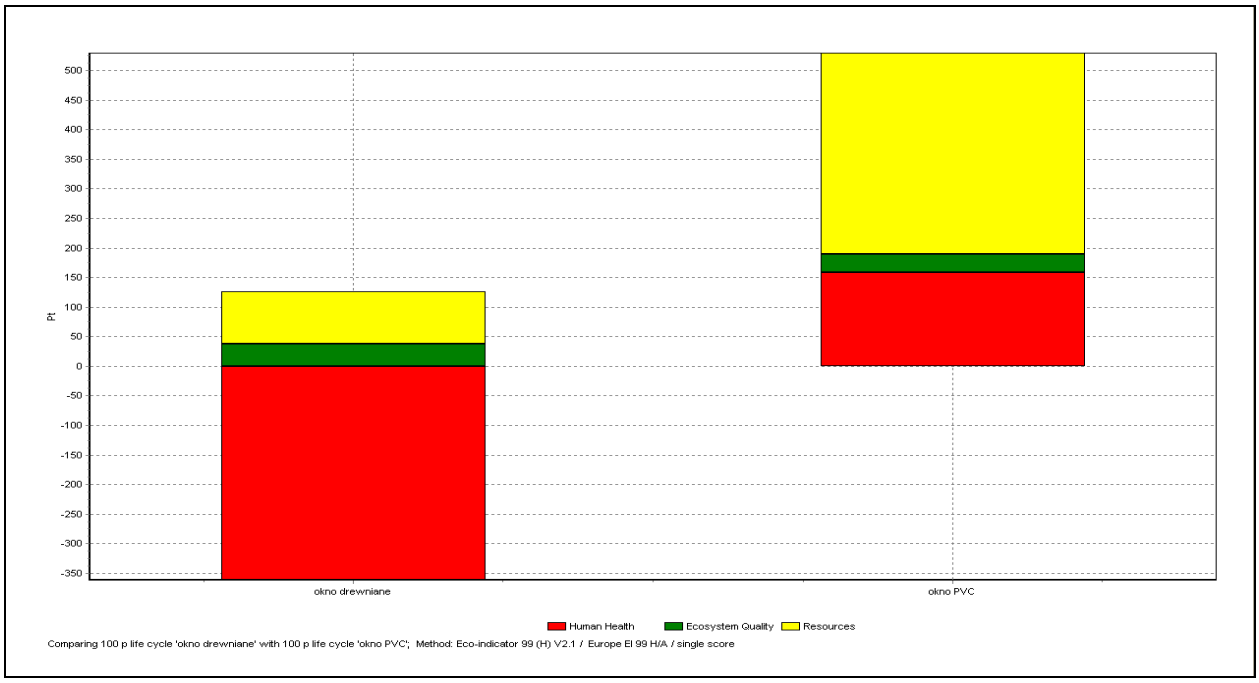


Fig. 2 A comparison of production of wood and PVC windows within 3 damage categories: a). the weighing stage, b). cumulative effect

After grouping of individual impact categories into the investigated damage categories (Fig. 2a) it may be stated that the production process of the tested wooden window system has no negative impact on human health. It is characterized by positive impacts (-361 Pt). In turn, the manufacturing process of PVC windows has a negative impact on human health at (+159 Pt). Within the other damage categories both product systems have negative impacts. Within the category of ecotoxicity wooden windows have slightly higher negative environmental impacts than PVC windows. This difference amounts to (+7 Pt). The impact of both window systems on depletion of fossil fuels is markedly more diverse. In the case of window systems made from wood it is (+88.07 Pt), while those from PVC is markedly higher and amounts to (+340.05 Pt).

a) b)

After summing up environmental impacts determined for analyzed damage categories we obtain values of the so-called cumulative indicators (Fig. 2b), which with one number determine the total environmental impact of tested product systems. A higher value of the cumulative indicator was found for the production of windows from PVC (+530 Pt). The value of the cumulative indicator for the manufacturing stage of required semi-finished products and windows from wood is (-236 Pt). The negative result in the case of the wooden window system is connected with the positive environmental impacts of wood, generated at its stage of growth.

CONCLUSIONS

Thanks to the comparative analysis information was obtained on the environmental impact of the manufacturing stage of two most popular window frame systems. It was found that windows produced from wood are more environmentally-friendly than PVC windows. This is evidenced by the determined values of cumulative indicators. Moreover, the conducted analysis made it possible to identify main environmental hazards represented by the analyzed impact categories and damage categories.

Production of windows from wood, which is frequently more expensive, but - as it was shown by this analysis - safer for the natural environment and human health, should be

supported by marketing instruments, using the environmentally friendly aspect of these products in order to emphasize their attractiveness to consumers.

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Streszczenie: *Ocena środowiskowa okien z drewna i PVC za pomocą LCA*. Celem niniejszej pracy było porównanie w oparciu o założenia metodologiczne techniki LCA wpływów środowiskowych powstających podczas procesu produkcji okien z drewna i okien z PVC. Jako jednostkę funkcjonalną przyjęto wyprodukowanie 100 sztuk okien o wymiarach 1000 x 1000 mm. Oceny wpływów środowiskowych dokonano za pomocą metody Ekowskaźnik 99 (H/A). Podstawą do przeprowadzenia analiz LCA dla okien z drewna i okien z PVC były informacje pochodzące z zakładów produkujących wyroby. Wyższą wartością wskaźnika skumulowanego, czyli zdecydowanie większym negatywnym wpływem na środowisko charakteryzowała się produkcja okien z PVC (+530 Pt). Wartość wskaźnika skumulowanego dla okien z drewna wynosiła (-236 Pt). Pozytywny efekt środowiskowy odnotowany dla okien z drewna wynika głównie ze zdolności przyswajania CO_2 z atmosfery przez drzewa w trakcie ich wzrostu.

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