ANALYSIS OF LIFE CYCLE ASSESSMENT OF WOODEN CONSTRUCTION

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Summary:
Unfortunately, rapid development of new products and manufacturing processes in the modern world, generate more and more negative impact on the natural environment. Therefore, there is a necessity for comprehensive methods of environmental impact assessment, based on the methodology adopted by the international organizations. One of such a methods is Life Cycle Assessment (LCA). This is a relatively new technique of environmental management, which involves particular product assessment in terms of environmental effects, during its entire life cycle. The main goal of this method is a comparative analysis and optimization of production to minimize negative environmental impacts in different phases of product's production, exploitation and elimination. Life Cycle Assessment concerns many areas of human activity, including the civil engineering, which is one of the largest sectors of the economy and of raw materials flow as well.
In this thesis an analysis of life cycle of small wooden construction using the environmental Life Cycle Assessment method has been presented. The scale and type of negative environmental impacts generated during the life cycle of the construction have been analyzed. The analysis has been carried out by using the computer program Sima Pro 7. In this program all particular elements and production processes of wooden construction have been verified. The stages starting from the growth of trees in the forest, treatment of wood, through assembly, till demolition and waste utilization, have been taken into consideration. The processes with the most adverse environmental effects were found. Conclusions concerning the performed analysis have been formulated.

Key words: Life Cycle Assessment (LCA), sustainable development, sustainable civil engineering, wooden construction

Introduction

Sustainable development is a social and economic development, which should satisfy the needs of today's society and simultaneously guarantee the ability to satisfy the needs of future generations. The concept of "sustainable development" – was first defined in the report "Our Common Future" (1987), formulated by the World Commission on Environment and Development, United Nations. Sustainable development was defined as a process, which has been taken in order to meet developmental aspirations of present and future generations as well.

Sustainable development is a necessity of technological and civilization development. This is the effect of taking care of future generations, which someday will manage the environmental resources. The main requirement for sustainable development, the necessity for care of the environment is also a constitutional requirement. Moreover general principles of sustainable development are following:

- renewable resources should not be consumed faster than they can be regenerated,
- non-renewable resources should not be consumed faster than it could be replaced by renewable substitutes,
- pollution and waste should not be formed faster than the nature can absorb and neutralize it (Czarnecki, Kapron 2010).

From the beginning of the seventies of the last century, a significant increase of interest in issues related to environmental protection, natural resources and in particular material and energy consumption of individual manufacturing processes, has appeared. From that time research and studies in this area have been started. Obtained results has been taken into account for creating environment-friendly policies of countries and regions.

One of the methods, which allows to estimate the potential impact on the environment is a Life Cycle Assessment (LCA). This name was introduced in 1990 at a conference in Vermont, where it was found, that for each product subjected to analysis, it is necessary to quantify the materials and energy consumption used during each of product stage (Fig. 1). Only on the basis on such a collected data would be possible to assess the product impact on the environment.

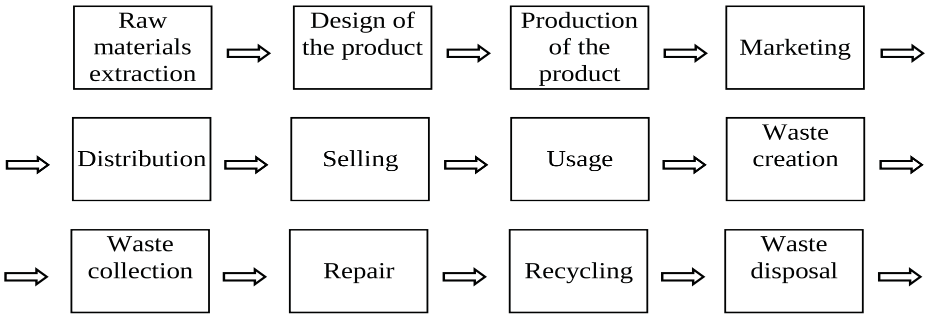

Fig. 1. The main phases of product life cycle (Gorzynski 2007).

General issues for sustainable development in civil engineering

Civil engineering industry consumes more than 40% of produced energy, about 50% of processed materials and emits 35% of greenhouse gases. This is the reason that civil engineering is one of the most important sectors of the economy, where sustainable development is required. The increase in social awareness of the civil engineering impact on the environmental protection and the energy saving, makes more important necessity to fulfill certain conditions and criteria for buildings. Therefore it is necessary to harmonize the European requirements in this scope. The basic rules for harmonization process are going to be standards, developed by the European CEN Technical Committee, which deals with:

- impact assessment of buildings on the environment,
- environmental declaration of building products,
- entire life cycle assessment of buildings and building constructions (Czarnecki, Kapron 2010).

The concept of "sustainable civil engineering" has gained a reputation as one of the most promoted ideas. Described earlier, principles of sustainable development are the basis for this new idea. It could be clearly concluded that sustainable civil engineering for the keynote has the motto "satisfy present needs with thinking about the future". In other words, sustainable development in civil engineering industry need to take into account future generations especially concerning consumption of raw materials (Karbowski 2010).

Meaning of wood as a raw material

Wood is a material obtained from fallen trees and formed into various assortments. It is necessary to distinguish a tree as a living plant and wood as a material made from tree. Wood is a material used for fuel, constructions, people daily life and also in the arts. From other building materials wood has fundamentally different structure. In fact, it is a band of cells that were part of the living body wood. The technical characteristics and the possibility of the use of wood depends on the arrangement and structure of these cells.

Wood next to coal, iron and oil is the raw material which has a large effect on economic development. A very wide range of applications makes that this material does not leave a man over a lifetime, even despite the increasingly rapid development of technology. It is proved by the continuous increase of consumption and the rising price of wood. Nowadays there is a necessity to replace wood by other materials. The reason of it, is the increasing scarcity and the need for efficient management of this scarce resource. On the other hand, compared with fossil fuels, the advantage of wood is the ability to be produced in a continuous manner, without running out of resources. This is achieved by proper acquisition of timber without disturbing the production potential. All these mentioned issues are the reasons why wooden elements have been chosen as an object of LCA analysis (Krzysik 1976).

Life cycle analysis of a wooden construction in the program SimaPro 7

LCA analysis has been carried out using the computer program SimaPro 7, delivered by Pre Consultants (Dutch company). This program is based on modeling the various components of the product, in order to create the entire product life cycle. As a component may be treated a single element or whole product, consisting of several components. The program allows to analyze and assess the environmental impact of factors common to all the successive stages of a product's life, beginning from its production, through the use until to waste disposal. Analysis using the SimaPro 7 is performed according to methodological assumptions of LCA. Therefore includes four successive stages:

1. Goal and scope,
2. Inventory,
3. Impact assessment,
4. Interpretation (Nowak 2008).

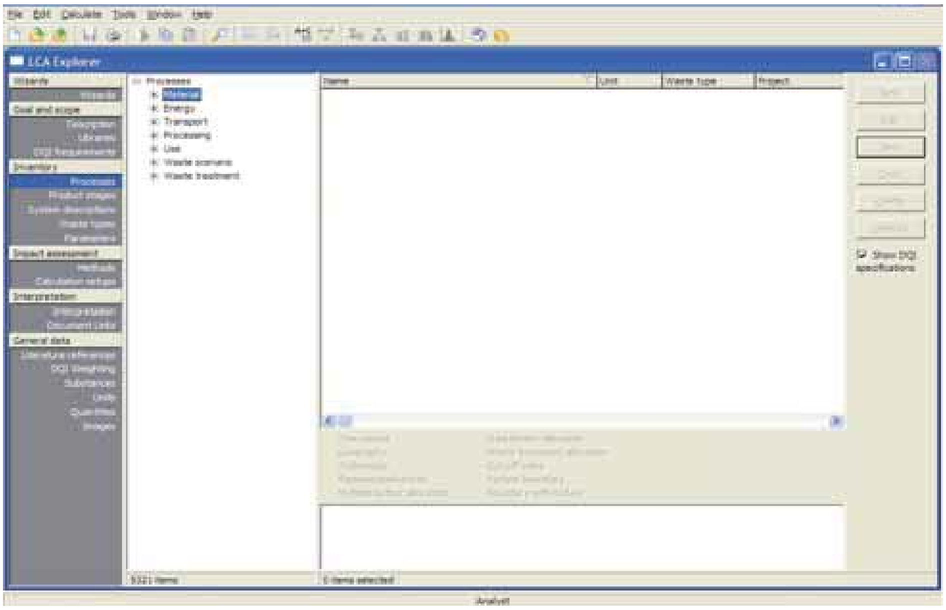

Fig. 2. SimaPro 7 – main menu (LCA Explorer).

Assumption of the life cycle analysis in the program SimaPro 7

According to an example (http://www.pre.nl – "SimaPro 7 Tutorial") as a subject of the environmental analysis was taken a wooden construction in form of bower with a very simple design, which could be placed in a private garden. It is made of wooden planks and a small amount of metal fasteners. Wood is not impregnated and painted. The bower does not have windows and doors. There is no heating and electricity connection. The view and dimensions of bower have been presented in the Figure 3 and Figure 4. For analysis it has been taken 150 kg, as a needed amount of wooden elements.

Fig. 3. View of analyzed wooden construction (bower).

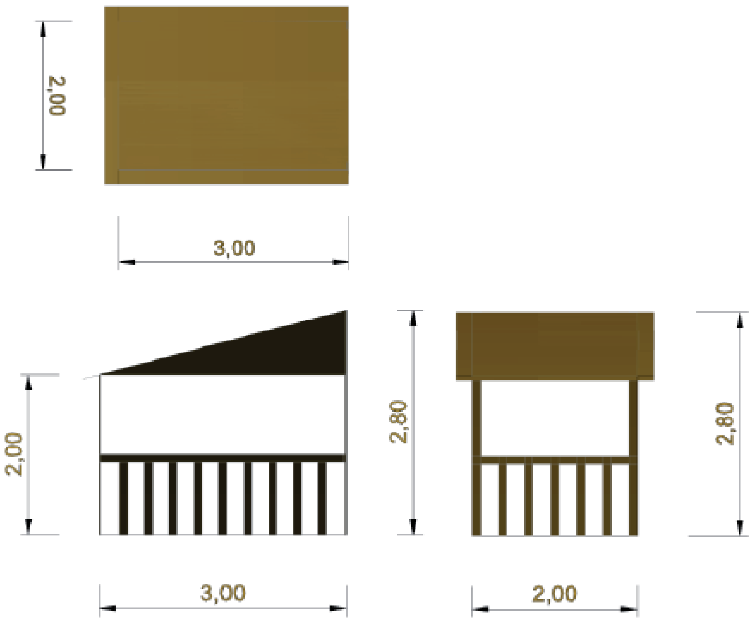

Fig. 4. The dimensions of analyzed wooden construction (bower).

Life cycle of a typical wooden construction consists of the following steps, shown in the Figure 5 (Strykowski et al. 2006).

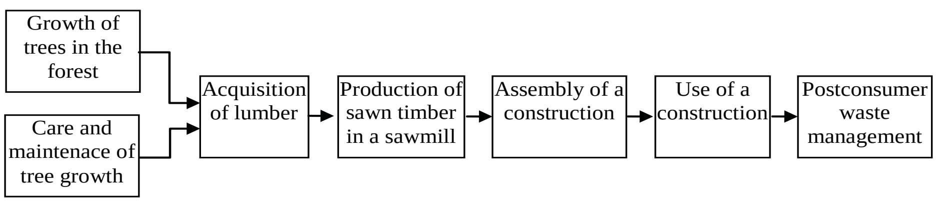

Fig. 5. Diagram of life cycle flow of a wooden construction.

Differently from the order of a typical life cycle phases (Fig. 5), the analysis carried out in the SimaPro 7 successively consists of three basic stages (http://www.pre.nl – "SimaPro 7 Tutorial"):

1. Entering processes, that describe the growth and care of trees in the forest, cutting trees and cutting sawn timber in a sawmill.
2. Entering the end processes of the life cycle. Several advanced capabilities of the SimaPro 7 in implementation of waste management have been used. It has been assumed that 40% of the wood is burned in home fireplaces and 60% is stored in a specially adapted landfill.

3. After entering all production processes and the final waste management, it has been carried out assembly and then entire life cycle of the bower.

It should be mentioned that LCA analysis of a wooden construction has been done without taking into account stage “use of a construction”. It has been neglected because in the construction there was no electricity and heat consumption. Successive stages of wood preparation have been described below in the article.

Analysis in the program SimaPro 7 – creation of production processes

Growth of trees in the forest

The beginning of the life cycle of the analyzed construction is associated with preparation of the materials. Because the object is made entirely from wooden elements, should be examined various stages of preparation of wood and its treatment. The first stage of the analysis in case of wood as a building material is “Growth of trees in the forest” and is created in the “Processes” – “Material” – “Wood”. In the inventory table, the amount of carbon dioxide absorbed from the air, solar energy necessary for growth and necessary area for forest cultivation have been taken into account.

Care and maintenance of tree growth

This step could be treated as an existing at the same time with the previous process. During creation of the table inventory, attention should be paid to the problem, which is the use of land for timber production. In environmental life cycle assessment there are two kinds of ground usage: “land occupation” and “land transformation”. Transformation means a change in the quality of the forest ecosystem. The measure of this change are two indicators of biodiversity: the accumulation of species and abundance of species. The benchmark of ecosystem quality is the accumulation and abundance of species assigned to the primary forest. Silviculture is a disturbance of the highest quality and means the conversion from primary forest (“Transformation from forest”) to the secondary forest (“Transformation to forest”). This type impacts are expressed in surface units, for example m^2. It is assumed that the transformation can take place in an extensive way, for example by enlarging the surface of the culture, and intensive way, by increase the efficiency of culture. In case of timber production, it has been assumed that there is both extensive and intensive land transformation. The second form of surface use is land occupation. There is no change in the quality of the ecosystem, as in the case of the transformation, but there is no possibility for a given area to return to its original form. The impact of the land occupation is determined in units of area and time, for example m^2year.

In the process “Care and maintenance of tree growth”, the participation of man, such as planting and cultivation of seedlings, saplings treatments, cleaning and thinning treatments, has been taken into account. Therefore has been considered the type and time of forest equipment use (e.g. chain saws, transport vehicles), fuel consumption (e.g. diesel) and the use of the area (e.g. forest roads).

Acquisition of timber (Cutting trees)

To create the table of inputs and outputs (the table inventory) for the timber acquisition stage (menu “Processes” – “Material” – “Wood”), two previously created processes have been taken into account. It has provided inputs and described forestry processes both with and without human intervention. An additional input to the process is necessity to use a chainsaw to fell trees. From the process there is about 250 kg of waste, in form of branches left in the forest.

Production of sawn timber in a sawmill

The next process, which must be defined in the life cycle analysis of a wooden construction is a cutting roundwood in a sawmill. Creating this process is similar to the three previous processes, in the menu “Processes” – “Material” – “Wood”. In the outputs to technosphere, instead of process name, finished products should be listed:

• planks – as 50% of the output, that is 500kg,
• sawdust – in the amount of 40% of output, which is 400kg,
• bark – as 10% of the output, that is 100kg.

After a treatment of one ton of timber in a sawmill, three different products have been created. Therefore, there is a problem of so-called allocation, it means distribution of environmental loads, generated by all processes together, between three final products. All adverse impact and energy used during the cultivation of trees in the forest and in the process of cutting, must be allocated between the planks, sawdust and bark. The analysis has been carried out on the basis on allocation according to weight of the output materials. Thus it is assumed that 50% of the environmental impact is addressed for planks, 40% for sawdust and 10% for bark.

The input to the process from the technosphere is the previous process of “Acquisition of timber”, in the amount of 250 kg more than the overall weight of the starting materials (planks, sawdust and bark). This surplus has been used for burning in the sawmill to allow the drying of wood. The results of wood combustion obviously are air emissions. In this process the transportation between place of cutting down trees in the forest and the sawmill, and the electricity needed for mechanical treatment (cutting sawn timber in sawmill) have been also included.

Analysis in the program SimaPro 7 – waste disposal and postconsumer waste management

After creating a production system of the main components of analyzed construction, that is wooden planks, arrangements for the end of the life cycle of wood products need to be considered (http://www.pre.nl – “SimaPro 7 Tutorial”). Even though there was not yet analyzed the assembly stage of bower, it is already possible to predict how the waste will be used at the end of its life. Postconsumer waste management has been considered for two main materials:

• Wood products – planks,
• Metal auxiliary elements – nails, screws.

For simplification of the analysis, the following assumptions have been done:

- 40% of wood waste is burned in home furnaces. It is assumed, however, that the heat from the combustion was not spent on heating any room.
- 60% of the waste is stored in a modern landfill. In this case, it is assumed that the storage was equipped with a special system for methane collection. Some collected methane is used as a fuel.

In the analysis of postconsumer waste management it has been necessary to separate waste into different streams for further processing. As the first separation it has been divided on 40% of waste for incineration and 60% for storage. As the second it has been separated the wood from the metal connectors. In fact, it is difficult to assume that all metal items will be carefully removed during dismantling. However, in case of the analysis seems to be justified by the fact that during the combustion, steel behaves differently than wood. In order to perform this separation should be made different types of waste. The SimaPro 7 has the proper tool called "Waste scenario". It can be used both for overall separation of waste and for separation into properly defined types of waste, such as wood and steel. But before creating a detailed postconsumer waste management system, first must be considered how emissions coming from each waste management will be treated.

Waste management, called "Waste scenario" is used for indicate the main flow of waste, but does not consider the emissions emitted during the removal or waste disposal. For this purpose there is a tool called "Waste treatment". It includes data about all compounds emitted during the process of waste dispsal, such as incineration or storage. Therefore it is necessary to establish:

- Emission of compounds during the combustion of wood products.
- Emission of compounds during the combustion of the metal parts, if necessary.
- Emissions of compounds during waste storage.

Looking at the final waste management for wood products, it should be taken into account that there may be also found a positive phenomenon. As a positive effect in the analysis should be taken the acquisition of emitted methane. Wood components located on the landfill during the first 150 years are slowly degraded. As a result of this process, methane and carbon dioxide is produced. The emitted methane (in an amount of about 56% of all emissions), can significantly affect global warming. The magnitude of this effect could be demonstrated by the fact that the release 1kg of methane into the environment contributes nearly 20 times more to climate change than 1kg of carbon dioxide emission. Therefore it was assumed, that most of emitted methane is collected on the landfill by a special equipment. This gas can be used as a fuel or simply be burnt, because the emission of carbon dioxide has much less impact on the environment than methane emission. Using collected methane as fuel reduces the consumption of natural gas and this is certainly a positive phenomenon. To model the positive benefits of waste management in the SimaPro 7, option called "Avoided products" is used.

Waste treatment – characteristic of waste storage on the landfill

To model the process of wood products storage as the end of their life cycle, must be used the option named “Waste treatment”, which is located in the “Inventory” – “Processes” – “Waste treatment” – “Landfill” (Storage). Entering procedure is similar to the previously created production processes. The table inventory must include the name of the postconsumer process ”Storage on the landfill” specify the type of waste , that is “Wood” (Wood) and the amount of 1kg. As the “Avoided products” should be entered “Natural Gas B300” in the amount of 0.007 kg. It means that collected methane will reduce natural gas consumption in other processes. Necessity of waste transport between the place of the municipal waste collection and landfill at a distance 20 km, should be considered as an input to the technosphere in the amount of 0.02 tonne-kilometers. The output is methane emission that have not been completely captured by collection equipment and the total emission of carbon dioxide.

Waste treatment – characteristic of wood incineration

For creation of process ”Incineration of wooden elements” shall also be used the tool “Waste treatment” in the “Inventory” – “Processes” – “Waste treatment” – “Incineration” (Burning). In this case, there is no any benefits coming from the process, so there is no “Avoided products”.

Postconsumer waste management

After completing the processes of the waste treatment, should be enter the processes of postconsumer waste management, which define exactly how much waste is addressed to a particular waste disposal. For analysis three following managements need to be created:

1. Storage.
2. Incineration.
3. Separation of waste between landfill (storage) and incineration.

Waste scenario – waste disposal on the landfill

In fact, it can be expected that the materials supplied on the landfill are not sorted. However, in the analysis to separate metal and wood elements, the tool “Waste scenario” has been used. In this case, it is sure that the wood and metal will go separately to the corresponding disposal operations, which is “Waste treatment”. Entering has been done in the “Inventory” – “Processes” – “Waste scenario” – “Landfill” (Storage). A new process called “Management – Storage of wooden elements” should be created with the amount of 1kg. Then in the “Materials and/or waste types separated from waste stream”, earlier created process of waste disposal named “Storage of wooden elements” should be written. The process of waste disposal for storage of steel elements, already existing and just taken from the program SimaPro7 should be written as well. After entering the data into the table inventory, the program automatically separates waste types and directs them to the appropriate disposal processes. Wood and metal parts are sent into separate storage, and all the other materials are sent to an unspecified treatment.

Waste scenario – waste disposal for wood incineration

Entering the characteristic of the process takes place in the “Inventory” – “Processes” – “Waste scenario” – “Incineration” (Burning). It is created a new process “Management – Incineration of wooden elements” for waste incineration, which is similar to the storage process and includes the combustion of elements coming from disassembled bower, including metal parts as well.

Separation of waste between landfill (storage) and incineration

The final stage of waste management is division of waste stream into:

• 60% for storage,

• 40% for incineration.

Entering the characteristics of the process for waste separation takes place in the “Inventory” – “Processes” – “Waste scenario” – “Others”. Should be put the name as “Final waste management” and the amount of 200 kg. In the process, transportation of parts from disassembled bower to the place of municipal waste collection has been taken into consideration. There is no taken into account any remaining waste, because all waste has been properly allocated to specific disposal processes.

Analysis in the program SimaPro 7 – Assembly of a wooden construction

After entering the operation and processes of final waste management for wooden bower, it is impossible to display the schematic tree showing the unit processes and the relationships between them. The program does not know yet, which materials should be put in the right waste stream. Therefore it must be defined the following two stages of product (“Product stages”):

• Assembly (“Assembly”) to define finished construction,

• Life cycle (“Life cycle”) to connect assembly phase (the production of wooden elements) with final waste management.

In the SimaPro 7 it is done by using the tool “Product stages” in the “Inventory”. A characteristic feature for the creation of both assembly and life cycle is the fact that at these stages, there is no entered any environmental data. Only appropriate references to the previously developed processes need to done.

In the “Inventory” – “Product stages” – “Assembly” must be created a new assembly process and named: “Assembly of a wooden construction”. Successively the table with reference to the appropriate materials and processes should be filled in.

Basic assumptions for assembly process have been adopted with some simplifications:

• Wooden bower is made of 150 kg of planks. There is no waste. Package of the products (planks) is not required.

• About 2 kg of metal elements in form of nails and screws have been used.

• The owner of the bower has to transport the planks from the shop by his own car. The shop is located at a distance of 5 km from his home (http://www.pre.nl – “SimaPro 7 Tutorial”).

After editing and saving the assembly process it is possible to check the preview of process tree (Nowak 2008). The program will automatically display a tree with the option, that not all partial processes must be shown on it. The so-called limiting function (“cut-off level") gives opportunity to not display the partial processes for which contribution is less than the threshold value. However, for the calculation, the contribution of all processes is taken into account. Helpful is also the option of showing the scale of the environmental impact of the processes by using the thickness of the line ("Show flow indicator in line width").

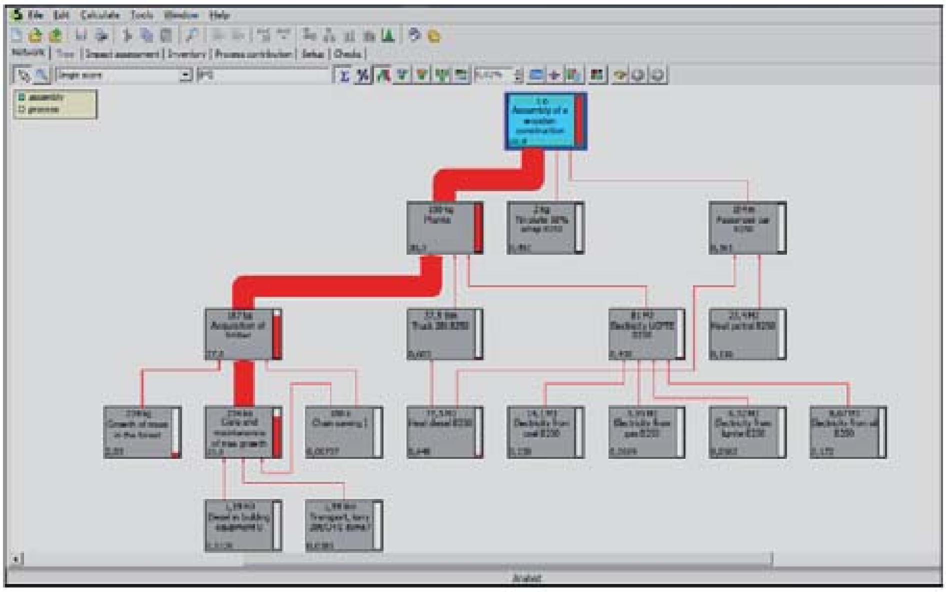

Fig. 6. SimaPro 7 – Network/tree of the process "Assembly of a wooden construction".

Analysis in the program SimaPro 7 – Life cycle of a wooden construction

The life cycle of the wooden bower is created similar to previously described assembly process. In the "Inventory" – "Product stages" – "Life cycle" must be opened a new process and named "Life cycle of a wooden construction". Then, must be entered a reference to a previously created assembly process and to the process of postconsumer waste management. On the view of life cycle tree, all the participated processes has not been displayed. Of course, there is possibility to show all processes, but then the scheme gets more unclear. Therefore, the option limiting the number of displayed processes ("cut-off level") is helpful especially in the visual assessment of analyzed process according to flows tree (Nowak 2008).

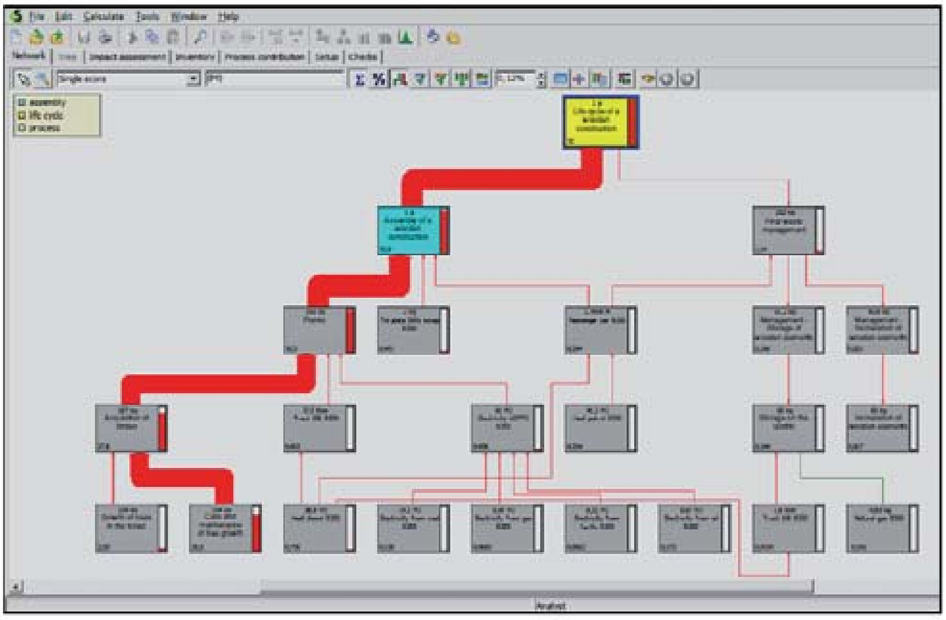

Fig. 7. SimaPro 7 – Network/tree of the life cycle “Life cycle of a wooden construction”

The results of the environmental life cycle analysis in the program SimaPro 7.
The indirect way for checking the results is a view of tree of processes. However in the SimaPro 7, there are many options to display results according to the research needs.

Inventory results
To show the results in a table with a detailed list of all chemical substances and compounds involved in the life cycle should be in the “Product stages” – “Life cycle” opened a previously created life cycle and pressed the “Analyze” button in the top bar menu. Then should be exposed the “Inventory” bookmark. Table with a comprehensive compilation of all the components involved in the analysis is displayed. The data enclosed in the table can be sorted alphabetically according to name or to quantity of given component contents or according to units.

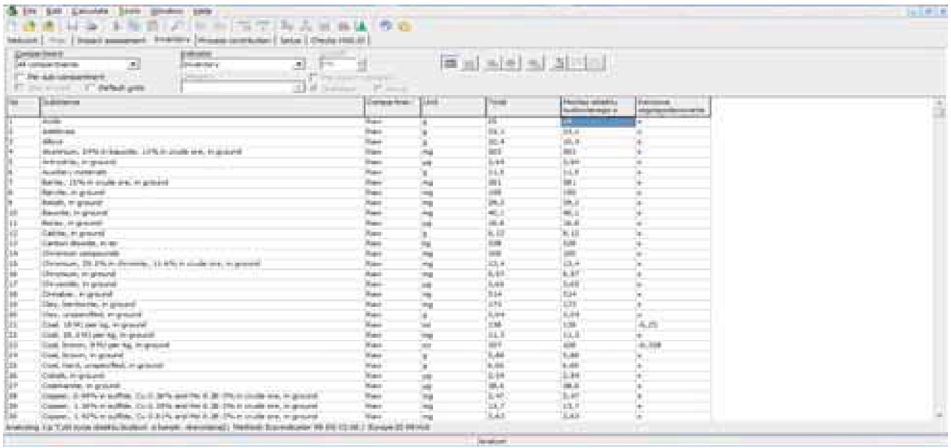

Fig. 8. SimaPro 7 – Results table with a inventory list of all substances and materials involved in the life cycle.

Impact assessment results (LCIA)

The calculation process in the SimaPro 7 is based on the operation defined as a classification. During this process, the values (information) listed in the table inventory are assigned to the corresponding impact categories. After classification results must be converted to comparable values by following processes:

1. Characterization,
2. Normalization,
3. Weighing.

Summary of the results

In the Table 1, the results of Eco Indicators expressed in the unit [Pt] after weighing have been presented. If these data were presented for example for characterization results, it would be expressed in general units of the appropriate impact and damage categories. Presentation of all results in the same unit, the points [Pt], makes the results more transparent and much better described the cross-sectional structure of the whole environmental impact.

Tab.1. The most important results of the life cycle assessment analysis of a wooden construction.

Issue of analysis		**Indicator [Pt]**	**Percentage part in the result of the entire life cycle [%]**
1. Environmental impact of the life cycle of a wooden construction			
Final result – Eco Indicator		32,00	100
2. Environmental impact of the life cycle phases			
Assembly of a wooden construction		30,90	96,40
Final waste management		1,14	3,56
3. The processes with the greatest environmental impact			
1. Care and maintenance of tree growth		25,70	80,40
2. Growth of trees in the forest		2,03	6,33
3. Planks (Acquisition of timber)		1,39	4,35
4. Incineration of wooden elements		0,817	2,55
5. Oil for heating (Heat diesel B250)		0,726	2,27
6. Tinned steel (Tin plate 50% strap B250)		0,451	1,41
7. Storage on the landfill		0,267	0,833
8. Heating fuel (Heat petrol B250)		0,204	0,636
8. Electricity from oil (Electricity from oil B250)		0,172	0,538
9. Others		0,214	0,67
4. Damage Categories			
1. Ecosystem Quality		29,80	93,00
2. Human Health		1,31	4,09
3. Resources (Consumption of resources)		0,943	2,95
5. Impact Categories			
1. Land use		29,60	92,30
2. Resp. inorganics		1,79	5,59
3. Fossil fuels		0,628	1,96
4. Minerals		0,315	0,984
5. Acidification / Eutrophication		0,164	0,513
6. Resp. organics		0,0582	0,182
7. Carcinogens		0,0539	0,168
8. Ecotoxicity		0,0332	0,104
9. Ozone layer		0,000316	0,000987
10. Radiation		0,0000193	0,0000602
6. Positive Impact Categories			
11. Climate change		-0,594	-1,86
7. LCI results with the greatest environmental impact			
1. Transformation of forest area, forest road. (Transformation, to traffic area, road embankment.)	13,10 m^2	25,80	80,50
2. Occupation as a forest area. (Occupation, forest, intensive, normal.)	445 m^2 rok	3,82	11,90
3. Carbon dioxide. (Carbon dioxide, biogenic.)	185 kg	1,01	3,15

5. Transformation to forest area. (Transformation, to forest, intensive, normal.)	3,18 m^2	0,817	2,55
6. Particulates. (Particulates, <10µm.)	81,10 g	0,792	2,48
7. Petroleum. (Oil, crude, 42.6 MJ per kg,in ground.)	142 oz	0,586	1,83
8. Nitrogen dioxide.	195 g	0,537	1,68
9. Nitrogen oxides.	157 g	0,432	1,35
10. Non-methane volatile organic compounds. (NMVOC, Non-methane volatile organic compounds, unspecifed origin.)	60,90 oz	0,313	0,978

Interpretation of the results

Obtaining results from the LCA analysis do not mean the end of the task. There is a problem, if these results are reliable. Taken into account the fact that almost every stage of analysis has specific sources of uncertainty and is affected by them each level of results aggregation, the key role plays the degree of reliability. To finish the task of the analysis, phase of interpretation, which is responsible for statistical determining the uncertainty and sensitivity of the final results, should be done.

Conclusions

In the paper the main phases of LCA analysis of wooden construction using the computer program SimaPro 7 have been presented. The example of creation a production processes and final waste management have been explained. The overall environmental impact from the life cycle of a wooden construction is 32.00 points [Pt]. This impact is the most accumulated in the damage category named as "Ecosystem Quality", because it represents 93% of total value of Eco Indicator. Analyzing two basic stages of life cycle (assembly and waste management), it is clear that greater environmental impact has an assembly stage equal 30.90 [Pt] (96.40%). This exceeds the stage of final waste management, whose the environmental impact is 1.14 [Pt] (3.56%).

According to the results presented in the Table 1, the main source of environmental impact from the entire life cycle is the process "Care and maintenance of tree growth", which represents the value of 25.70 [Pt] (80.40%). The second is "Growth of trees in the forest" with a value of 2.03 [Pt] (6.33%). The impact category with the greatest environmental impact is "Land use". The rate for this category is 29.60 points [Pt], which represents 92.3% of total value of the indicator. The next impact categories are "Resp. Inorganics" (Effects of breathing / inorganic compounds) and "Fossil fuels". Result as an indicator for the first category is 1.79 points [Pt], which represents 5.59% of the total result. In case of fossil fuels result is 0.628 points [Pt] and covers 1.96% of the Eco Indicator.

According to performed statistical analysis of the obtained results, variability of the data used in the study is quite significant. The standard deviation is 11.50 [Pt], which represents 35.94% of the final result of Eco Indicator. Sensitivity of the obtained results on the changes in value election is much less than sensitivity on the variability of weighing criteria.

For more accurate presentation of the environmental impact scale of a wooden construction, it should be carried out a similar analysis of a similar construction, for example, made of a different material. Then it would be possible to carry out a comparative analysis and draw conclusions about differences in the size of the environmental impact for different materials (e.g. wood and steel).

The presented life cycle analysis of a wooden construction has been modeled without taking into account the phase of use the construction. An important addition to the analysis would be certainly taking into account this phase, expressed as a consumption of electricity, heat, water, etc. It can be expected that stage of use the construction would be an important part of the total environmental impact. However, the purpose of this study is not an evaluation of a different ways of use, so any assumptions related to the phase of use have been omitted. This applies, for example, the assumptions associated with various methods of heating and the power savings.

During carrying out of the analysis, an essential problem has been observed. A significant difficulties in accessing the data, characterizing certain manufacturing processes from the point of view their environmental impact have been found. In particular there is no domestic sources, which would define a detailed quantity of material and energy inputs to individual processes. An even greater problem is with the information about outputs from the processes. This applies in particular difficulties in measuring the emission to the environment.

References:

1. Czarnecki L., Kapron M. (2010), *Defining of the sustainable civil engineering.* Building Materials. Monthly Technical and Economical. Technology, Market, Execution. No. 1/2010. (in polish)
2. Gorzynski J. (2007), *Introduction to environmental analysis of products and objects.* Scientific – Technical Publishing Houses, Warsaw. (in polish)
3. Karbowski A. (2010), *Sustainable civil engineering.* Construction, Technology, Architecture. Polish Cement No. 1/2010. (in polish)
4. Krzysik F. (1975), *The science of wood.* The Polish Scientific Publishers, Warsaw. (in polish)
5. Nowak A. K. (2008), *Ph.D. thesis Environmental and technical aspects of the process of obtaining zinc and lead concentrates*. Krakow. (in polish)
6. Strykowski W., Lewandowska A., Wawrzynkiewicz Z., Noskowiak A, Cichy W. (2006), *Environmental Life Cycle Assessment (LCA) of wood products*. Institute of Wood Technology Publishing House, Poznan. (in polish)