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Technical note

APPLYING THE LIFE CYCLE ASSESSMENT METHOD TO AN ANALYSIS OF THE ENVIRONMENTAL IMPACT OF HEAT GENERATION

M. DZIKUĆ
University of Zielona Góra, Faculty of Economics and Management
Chair of Security Management
65-001 Zielona Góra, ul. Podgórna 50, POLAND
E-mail: M.Dzikuc@wez.uz.zgora.pl

The paper presents a method of Life Cycle Assessment (LCA) to determine the impact of the heat produced on the environment. In addition, the usefulness of this method to assess the energy sector has been shown.

This paper presents the impact of heat generation on the environment in coal power plants. A detailed analysis by the method of LCA is made to compare the environmental impact of heat generation in the Legnica Power Plant and Polkowice Power Plant.

It is pointed to the difference in the results obtained. Moreover, the causes of the reported environmental impacts are discussed. Measures are identified which will help to reduce in the future the impact of the electricity produced on the environment during the production of heat.

Key words: life cycle assessment, energy, ecology, heat, power plant.

1. Introduction

The last couple of years have brought some important changes in the electric power industry that can be observed in most EU countries. Energy strategy of the EU has become one of the most important factors influencing the development of the member states. Poland is a country with electric energy produced predominantly in hard and brown coal-fired power stations.

All coal-fired power stations affect the environment in a negative way. As a result of the rising levels of environmental pollution, ways of limiting the negative human impact on the environment are being sought. Novel solutions, aimed at reducing the negative impact on the environment, are being introduced as a reaction to the rising awareness of the society and increasingly more stringent requirements imposed by laws.

One of the ways allowing an evaluation and comparison of the environmental impact of different means of energy generation is the Life Cycle Assessment method (LCA). The LCA can be applied to products, processes (encompassing full life cycle) as well as to entire branches of industry (Dzikuć, 2013). In connection with the growing importance of energy efficiency in industry, the paper provides examples of the LCA applications to two electric power plants: the Legnica Power Plant and Polkowice Power Plant.

2. Description of the LCA method

Ecological Life Cycle Assessment is a research method aimed at an analysis of environmental problems. Such an analysis is based on identifying and determining the amount of used up materials and energy, as well as on determining the pollution levels, and on a subsequent evaluation of the impact these

elements might have on the environment. This method can be used to identify potential problems and help to determine ways of improving environmental quality (Dylewski and Adamczyk, 2012).

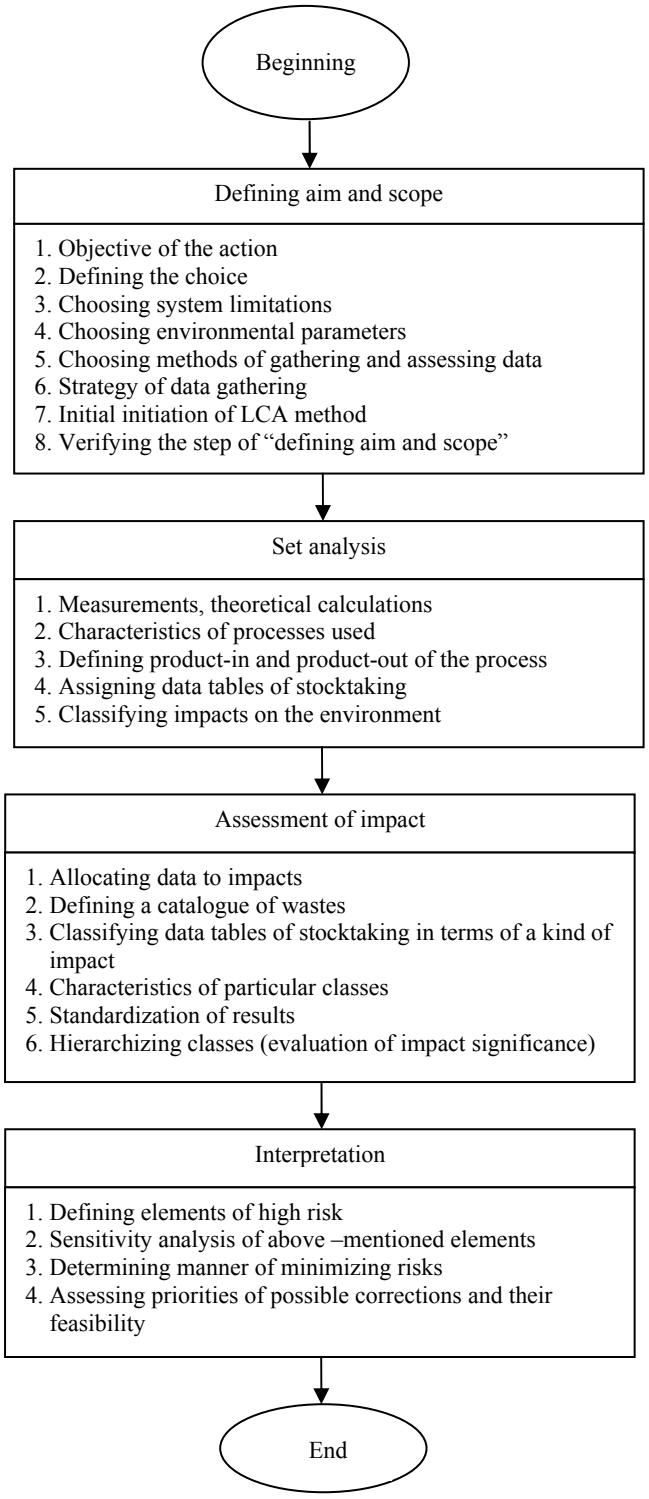

Fig.1. The procedure of LCA.
Source: Wach, 2002

One of the main goals of the Life Cycle Assessment method is to analyse the potential impact of production processes on the environment and to determine ways to improve the quality of the environment (Łasiński, 2012). The possibility of the "cradle-to-grave" product analysis is an important feature of the LCA method. It is also possible to determine the environmental impact of a product not only during the production or resources acquisition phases but also during the product usage and utilisation phases (Dylewski and Adamczyk 2011). The LCA method allows an effective management of limited resources, since it is based on real input and output data of a given process.

The International Standard Organization (ISO) defines the LCA as a method allowing an analysis of environmental aspects and of a potential production impact, divided into four phases (Fig.1.):

1. determining the aim and scope of the analysis,
2. an analysis and evaluation of the production system inputs and outputs,
3. an analysis of a potential environmental impact of system inputs and outputs,
4. interpretation of the results of analysis of the sets and phases of impact evaluation in relation to the research aim (Polski Komitet Normalizacyjny, 2009).

The Life Cycle Assessment can be greatly simplified with the use of a dedicated computer software, such as SimaPro, designed by PRe Consultans B. V. (the Netherlands) or Umberto, designed at the Institute of Energy and Environmental Research in Heidelberg. In our research we used version 7.1 of SimaPro (Zarębska, 2013), which uses the Eco-indicator 99 in the process of the environmental analysis. This indicator has the advantage that it takes into account the diminishing resources problem, which is very important in an analysis of environmental impact of various energy generation methods, since energy generation requires the use of a great amount of non-renewable energy resources (Björklund, 2011).

The analysis following the above steps renders is possible to picture the impact and divide it into eleven main categories: carcinogenic compounds, organic compounds, inorganic compounds, climate change, radiation, ozone hole, ecotoxicity, acidification/euthropication, land use, fossil fuels and three damage categories: human health, ecosystem quality, resources consumption including the type (Dzikuć, 2013), normalisation and a final score (weighting) that measures the environmental impact of a product in Pt (ecoindicator point) units, where 1 ecopoint (Pt) expresses a value representing one thousandth of a yearly environmental impact of one inhabitant of Europe (Dąbrowski and Dzikuć, 2012). The use of methods such as the LCA can save the amount of energy resources consumed. Lower resource consumption helps to ensure energy security (Polski Komitet Normalizacyjny, 2009).

3. Applying the LCA method to energy generation analysis of the Legnica Power Plant and Polkowice Power Plant

The Legnica Power Plant and Polkowice Power Plant are parts of the company "Energetyka" Ltd., which is engaged in the production of heat and electricity. The owner of "Energetyka" Ltd. is KGHM Polish Copper SA, The Power Plant in Legnica produced in 2010, 1 025 460 GJ, while the Power Plant in Polkowice produced in 2010, 1 271 528 GJ and 45 818 MWh. Both power plants are powered by coal.

Table 1. The LCA Results – the three damage categories.

Impact categories	**Unit**	**Legnica Power Plant**	**Polkowice Power Plant**
Human health	Pt	*1.041*	*0.494*
Ecosystem quality	Pt	*0.072*	*-0.126*
Resources	Pt	*3.431*	*2.294*
Total	**Pt**	***4.544***	***2.662***

Source: Compiled on the basis of the result obtained with SimaPro 7.1.

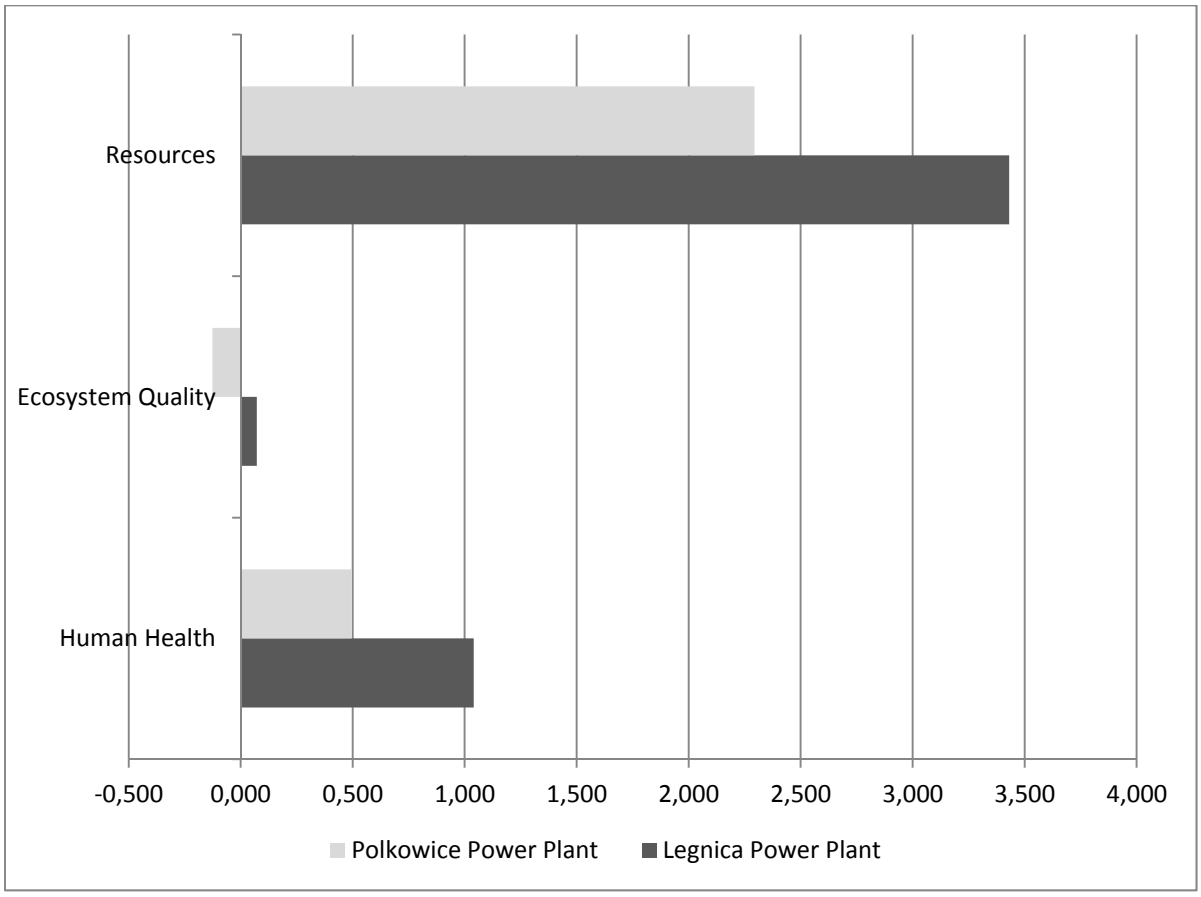

Fig.2. The LCA results – the three damage categories.
Source: Compiled on the basis of the result obtained with SimaPro 7.1.

Table 2. The LCA results - eleven impact categories.

Impact categories	Unit	Legnica Power Plant	Polkowice Power Plant
Carcinogenic compounds	Pt	*0.032*	*-0.148*
Organic compounds	Pt	*0.000*	*0.000*
Inorganic compounds	Pt	*0.536*	*0.272*
Climate change	Pt	*0.472*	*0.370*
Radiation	Pt	*0.000*	*0.000*
Ozone hole	Pt	*0.000*	*0.000*
Ecotoxicity	Pt	*0.022*	*-0.106*
Acidification/Eutrophication	Pt	*0.050*	*-0.020*
Land use	Pt	*0.000*	*0.000*
Minerals	Pt	*0.000*	*0.000*
Fossil fuels	Pt	*3.431*	*2.294*
Total	**Pt**	***4.544***	***2.662***

Source: Compiled on the basis of the result obtained with SimaPro 7.1.

The objective is to determine and compare the environmental impact of thermal energy based on coal using the LCA, using a computer program SimaPro 7.1. 1 GJ is used as a functional reference unit of the system which describes the impact of the product on the environment (e.g.:1 ton of coal, covering the area of *1* m^2 with paint).

The data that were used to study come from 2010 and include the elements included in the system used in the production of electricity, such as coal, water, electricity and outgoing parts of the production system, the amount of produced electricity and heat, and any resulting contamination during production.

The results of the LCA applied to the three damage categories (Tab.1 and Fig.2) show that the category "resources" has the highest environmental impact, with energy production from hard coal. This can be explained by the fact that the hard coal reserves are scarce. The next important factor affecting the environment in relation to the three damage categories is the "human health" category. Here the impact of energy production from coal is several times greater. The reverse can be observed in relation to the „ecosystem quality" category but here the difference is much smaller. However, the result in the case of the Legnica Power Plant is positive (*0.072 Pt*). This means that the impact on the environment in the case of this category of damage is small. In the category of "quality" services the result of *-0.126 Pt* achieved by the Power Plant Polkowice can be interpreted as a premium for the use of cogeneration.

All three categories of damage indicate a higher impact on the environment in the event of the Legnica Power Plant. This is a clear impact reaching several dozen of percent. A less negative impact in the case of the Polkowice Power Plant results from the application of cogeneration in it. Production of electricity and heat in combination allows significant savings of energy resources. It also renders it possible to achieve lower indicators of emissions per unit of energy produced.

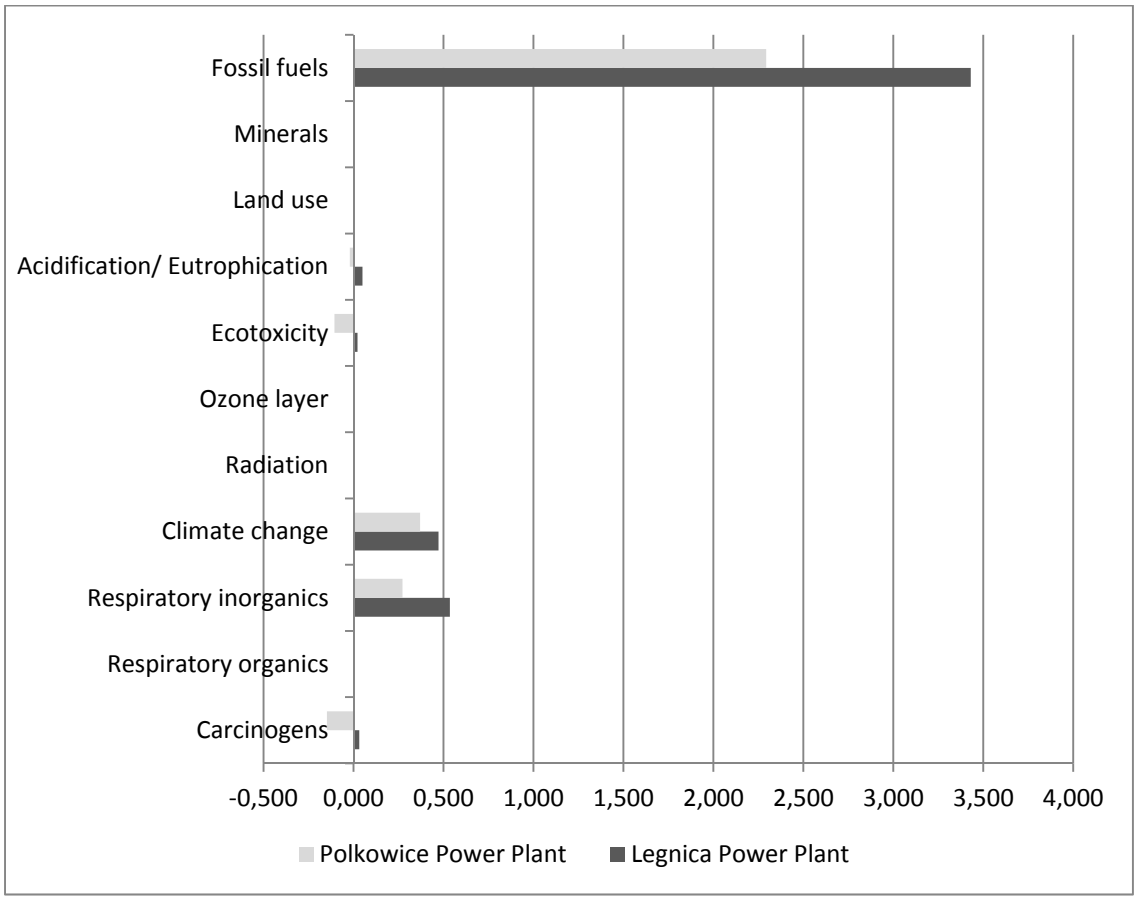

Fig.3. The LCA results - eleven impact categories.
Source: Compiled on the basis of the result obtained with SimaPro 7.1.

The results of the LCA applied to the eleven impact categories (Tab.2 and Fig.3) show that the category “fossil fuels” has the highest impact, in the case of hard coal, which is the main factor influencing the final score. The total environmental impact 1 GJ of energy production is almost *2 Pt* higher in the Legnica Power Plant than the Polkowice Power Plant.

Definitely the highest impact on the environment in the case of the eleven categories of impact has the category "fossil fuels". A higher environmental impact is observed in the Legnica Power Plant. Other categories of impact exert a limited effect on the environment. It should also be observed that the categories of “climate change” and “inorganic compounds” have a limited impact in the range of *0.272* to *0.536 Pt*. In both cases, the higher impact on the environment is the production of energy in the Legnica Power Plant.

Other categories of impact achieve significantly lower scores that do not exceed *0.15 Pt*. Noteworthy, however, are the negative results obtained by the Polkowice Power Plant. Negative results in the category of “carcinogenic compounds” (*-0.148 Pt*), “ecotoxicity” (*-0.106 Pt*) and “acidification/eutrophication” (*-0.020 Pt*) should be interpreted as an environmental benefit. This does not mean, however, that burning coal has a positive effect on the environment. It is a kind of indication of what can be achieved by cogeneration of the production of heat and electricity.

4. Conclusions

It should be noted that there is a significant difference between the environmental impacts of energy production in the Polkowice Power Plant and the Legnica Power Plant. Poland as a country having large coal reserves will use this source of energy for decades. It is therefore important to develop energy technologies based on coal. However, as studies show it is possible to minimize the negative environmental impacts of energy production.

Generation of electricity in coal-fired power plants have a negative impact on the environment. Looking for solutions that will help reduce the environmental impact related to energy production is of great significance. The difference in the analyzed results of the several dozen percent shows that it is possible to effectively reduce the negative impact on the environment by introducing more efficient technologies. The Polkowice Power Plant by generating electricity and thermal energy is able to provide less environmental impact per unit of electricity generated. Calculated environmental burdens indicate that technologies using coal, which will have a smaller impact on the environment, should be sought.

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