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Original Research

Life Cycle Assessment as an Eco-Management Tool within the Power Industry

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Abstract

The following paper presents how life cycle assessment (LCA) helps to establish the environmental impact of energy production of three Polish power plants. Ecological differences between discussed power plants as well as reasons for such differences have also been pointed out. The calculations were based on the assessment procedure of Eco-indicator 99, which allows for the presentation of the impact results with respect to three damage categories. The study also determines actions which, if undertaken, will reduce the negative environmental impact of energy production. Even though coal-fired energy production is ecologically harmful, implementation of modern technologies allows for reduction of raw material consumption and limits greenhouse gas emissions.

Keywords: coal, ecology, energy, life cycle assessment (LCA), power plants

Introduction

Recent years have seen many changes in the Polish energy sector. Changes have been especially profound with regard to energy production based on traditional raw materials, including the introduction of modern methods of purifying coal before burning and the removal of harmful admixtures during the burning process. The European Union's climate and energy policies pose a huge challenge to Poland, particularly with regard to the energy sector's dependence on fossil fuels.

One of the most effective methods allowing for evaluation and comparison of the environmental impact of energy production of different power plants using the same fuel is life cycle assessment (LCA). The method allows for evaluation and comparison of environmental impact of different power plants using the same fuel [1]. LCA analysis is applicable to evaluation and comparison of both the product and its full life cycle as well as entire industry branches [2]. Every action that helps in energy production evaluation and points out energy raw materials saving methods contributes to the improvement of energy security [3].

The following study is of a cognitive and methodological nature. The paper outlines problematic aspects of ecological management in the power industry and presents the results of LCA analysis, i.e., evaluation and comparison of energy production of three heat and power plants (in Chwałowice, Legnica, and Polkowice). Our research was carried out with the assistance of SimaPro software. The SimaPro uses the Eco-indicator 99, which allows for accounting for the issue of non-renewable resources and which is of great importance when discussing the environmental impact of the power plants' energy production. This aspect is important for the study of the environmental impact of electrical production in Polish coal-fired power plants. LCA analysis enables the presentation of the results of the environmental impact in relation to 11 impact categories that can be grouped into three damage categories. Relationships between categories of damage and impact are

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Table 1. Categories of damage and impact in the Eco-Indicator 99 method.

Damage category	Human health	Ecosystem quality	Resources
Impact category	Carcinogens	Ecotoxicity	Minerals
	Respiratory organics	Acidification/ Eutrophication	Fossil fuels
	Respiratory inorganics	Land use	
	Climate change		
	Radiation		
	Ozone layer		

Source: own study based on computer software SimaPro.

presented in Table 1. The LCA analysis results are expressed in ecoindicator points (Pt), with 1 ecoindicator being the equivalent of one-thousandth of annual energy use per European citizen capita [4, 5].

Environmental management, from both scientific and more practical approaches, is an important matter for the energy sector. From the scientific perspective, the management of environmental issues – due to their complex nature – requires solutions from various academic fields. Even though environmental economics is considered to be the most influential, the power industry also grasps from ecological economics and management.

As of today, the literature describes environmental management as the management of resources use, environmental protection, and all the actions aimed at reaching sustainable development [6]. The Polish energy sector is based primarily on fossil fuel, and the conversion of primary energy into more refined forms impacts the natural environment. Poland's primary source of energy is coal-fired power plants. The coal-burning process is the single biggest source of air pollution, including solid, gas, toxic, and non-toxic incineration effects. On that account Poland's energy production (especially coal-based) should be monitored with great care [7].

Bearing in mind all energy source materials, hard coal is considered to be the one with the highest emissions rate as well as the one producing the highest amount of CO_2. In the above context, environmental management is the substantial part of energy and climate policies. The reduction of greenhouse gases is one of main issues addressed by the Climate and Energy Package [8, 9]. In this regard a number of various changes is required: changes in energy production (including clean coal technologies such as biomass and coal co-incineration or carbon capture and sequestration), legislative changes, promoting climate- and ecology-friendly actions, and support instruments. In addition, economic instruments (emission allowance markets), which the literature on the subject defines as emission permits, have also been in development [10]. Also, it is possible to mitigate air pollution-related problems by implementing efficient emission-reduction technologies [11].

The Polish energy sector is undergoing major changes, including ongoing ecologization of parties producing and distributing electrical and thermal energy [12]. As a market practice, the environmental management of the largest power industry entities is an integral part of the management system, including PN-EN ISO 9001:2008 and PN-EN ISO 14001:2009. Hard coal is currently considered the main, providing energy security. Still, the share of renewable sources continues to grow, with the increase in the production of agricultural biogas being the best example [13]. Within the commercial power industry biomass and hard coal co-incineration has been gaining in importance. As the hard coal – which negatively impacts the environment – is the main source of thermal energy, one should aim at the development of relatively small, local installations allowing for cogeneration and the reduction of energy transmission loss. Achieving sustainable development with the assistance of currently available tools requires the employment of rational environmental management. At this place the LCA method might be exceptionally valuable [14-16].

LCA as a Tool for Environmental Analysis and Management

LCA is the well-established research method allowing for the identification of environmental threats [17]. LCA determines the amount of used raw materials and produced energy, as well as the amount of impurities, discharged waste, and their environmental impact [18].

The LCA helps in identifying potential threats and establishing new ways of improving environmental quality standards [19]. The LCA helps to identify the environmental impact of a certain product not only during its production process and the acquisition of necessary raw materials, but also during its exploitation and reprocessing. Since it is based on both input and output of actual data of any given process, the LCA technique facilitates the management of limited resources [20].

The International Standard Organization defines LCA as an assessment technique that evaluates the environmental factors and potential interactions with the given product. The technique consists of four stages [21-24]:

1. Identification of the aim and scope of the study
2. Stocktaking of input and output data within the selection system
3. Evaluation of the potential environmental impact of input and output data
4. Interpretation of the data set and stages evaluation with regard to the aim of the study

The studies conducted by LCA show that the negative environmental impacts of energy generation are dependent mainly on the fuel used in its manufacture. But the scale of energy production has no significant environmental effect, assuming it is analyzed in power plants of at least medium size. In Poland, a significant part of the energy is generated using hard coal. The use of indigenous energy resources is economically justified. However, it is necessary to search for solutions that will reduce greenhouse gas emissions to the atmosphere [24].

Table 2. LCA results of three power plants in three damage categories.

Damage category	Unit	Chwałowice Power Plant		Polkowice Power Plant		Legnica Power Plant	
		2010	2011	2010 [7]	2011 [7, 23]	2010	2011 [23]
Human health	Pt	0.49	0.45	0.49	0.55	1.04	0.91
Ecosystem quality		-0.10	-0.11	-0.13	-0.14	0.07	0.06
Resources		2.86	3.08	2.30	2.51	3.43	3.54
Total		3.25	3.42	2.66	2.92	4.54	4.51

Source: own study based on computer software SimaPro.

LCA Analysis of Thermal Energy Production in Power Plants

The main focus of our study is to determine and compare via LCA analysis the environmental impact of the hard coal-based thermal energy production. One GJ of generated thermal energy was selected as the functional unit, which should be clearly defined and easily measurable as it provides a point of reference for standardization of input and output within the given frame of reference. The scope of the study covers two years of power plant operations (2010-11). LCA analysis holds the account of production systems input components, such as hard coal and thermal energy, as well as production's output components, including generated thermal and electrical energy or undesired impurities (e.g., CO_2, SO_2, NO_x).

The system boundaries for the analyzed heat sources include generating a particular unit of thermal energy (fuel consumption and material and energy emissions) without the environmental impact of the production of boilers and the later stage of recycling. The environmental impact related to the production, construction, and arrangement of the infrastructure necessary to transport and/or store fuel was omitted as well. The study also included an average calorific value of hard coal used to produce energy. The LCA analysis data had to come from the power plants.

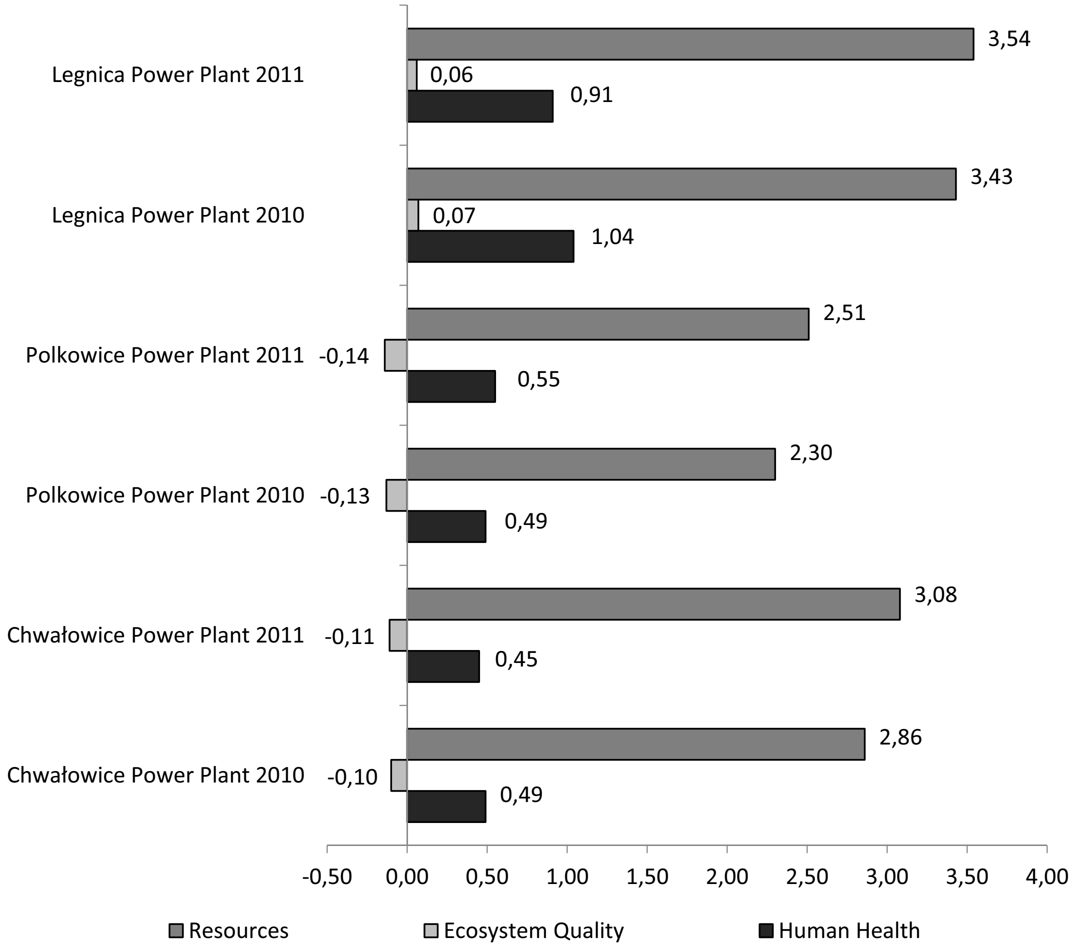

Fig. 1. LCA results of three power plants in three categories of damage in [Pt].
Source: own study based on computer software SimaPro.

When analyzing, LCA does not take into account the environmental impact of the construction of power plants and power plant hard coal production due to the unavailability of the data needed for the study [5]. Distribution losses were not taken into account when assessing the impact of energy production on the environment. The articles took into account the impact of energy production.

The breakdown of LCA analysis with respect to three damage categories (Table 2 and Fig. 1) indicates that the greatest negative environmental impact characterizes damage in the category "raw materials." It should be stressed that, within the given timeframe, the energy produced in the Legnica Power Plant had been the most impactful.

Another environmentally influential category is "human health." Again, the Legnica Power Plant turned out to be the most harmful. The difference is considerable and requires additional explanation. The discrepancy arises from the technological differences that had to be included in the LCA analysis. The Legnica Power Plant generates thermal energy only, whereas reimaging two power plants produces energy in a cogenerative manner. Cogeneration allows for reduction of vast coal quantities, which is not without the effect on the "raw materials" category. As the result, the Chwałowice and Polkowice power plants emit less harmful gases per generated thermal energy unit (GJ). Also, in the "eco-system quality" category both the Chwałowice and the Polkowice power plants achieved better results. Even though the Legnica Power Plant scored low (0.07 Pt in 2010 and 0.06 in 2011), power plants in Chwałowice and Polkowice achieved negative numbers. Negative numbers in the damage category "eco- system quality" are the result of implementation of highly functional installations enabling cogeneration of thermal and electric energy, thereby conserving fuel.

Conclusions

It should be noted that energy production based on hard coal negatively impacts the environment. Reasons are twofold: depletion of natural resources and emission of harmful gases into the atmosphere. One of the main factors holding back the development of other than coal-based energy productions is the high cost of renewable resources exploitation. While considering the financial cost of energy production from hard coal, it should not be forgotten that due to CO_2-related fees, Poland's obligation to pay its profitability is only going to decrease. As Poland has large resources of hard coal, replacing coal as a major source of thermal energy is a long process that will be spread over many decades. Therefore, it is crucial to limit the environmental impact by implementation of innovative technologies and the modernization of currently existing facilities. This issue is particularly important as the development of renewable resources in Poland usually comes down to co-firing biomass in coal-heated boilers. The delay in implementation of Directive 2009/28/WE of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources does not contribute toward the increase of renewable resources energy production.

The implementation of innovative and eco-friendly solutions allows for significant reduction of the negative impact of energy production from burning hard coal. What should be stressed is the fact that the reduction of negative environmental impact results in limiting both the amount of needed coal as well as a pollution decrease. Presented LCA analysis indicate that modern technologies reduce the emissions of harmful gases into the atmosphere. Among other positive effects are massive savings resulting from the reduction of CO_2-related fees that Polish entities have been obliged to pay since 2012. In addition, cogeneration substantially reduces the consumption of hard coal in energy production. Further investigation of this issue will be the subject of our future work.

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