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Technical note

TECHNICAL AND ECONOMIC ASPECTS OF BIOMASS CO-FIRING IN COAL-FIRED BOILERS

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

K. ŁASIŃSKI*
University of Zielona Góra, Faculty of Mechanical Engineering
Department of Systems Security Engineering
65-516 Zielona Góra, ul. Szafrana 4, POLAND
E-mail: K.Lasinski@eti.uz.zgora.pl

The article presents the analysis of the potential of using biomass and coal co-firing in the Polish electro energetic system and shows the benefits resulting from an increase of biomass amount in electricity production in one of the largest Polish power stations.

The paper discusses the most often used technologies for biomass co-firing and the potential of using biomass in electricity production in Poland. It also emphasises the fact that biomass co-firing allows a reduction of greenhouse gases emissions to the atmosphere and helps decrease consumption of energy resources.

The article also emphasises the economic meaning of increasing the share of renewable energy resources in energy balance, including biomass, due to costs related to greenhouse gases emissions charges. Finally, conclusions from using biomass and coal co-firing in electricity production are presented.

Key words: biomass, coal, co-firing, energy, economy.

1. Introduction

Negative impact on the environment resulting from the use of coal in energy production is an incentive for Poland to take actions aiming at increasing renewable energy resources in this process (Dzikuć and Urban, 2014). Co-firing biomass with coal for electricity production is a cost-efficient possibility which allows a reduction of CO_2, NO_x, and SO_2 emissions (Nussbaumer, 2003). One of the possibilities supporting coal use reduction is biomass co-firing in large coal-fired power stations. At present, biomass co-firing is perceived as one of the most economically advantageous possibilities of reducing the consumption of non-renewable energy resources (Kati, 2003).

The aim of the article is to present biomass and coal co-firing during the electricity production in Poland (Dąbrowski and Dzikuć, 2012). The article shows technical and economic aspects of biomass and coal co-firing during the process. It also presents an analysis conducted with the use of the LCA (Life Cycle Assessment) method on the basis of data obtained from Dolna Odra Power Station. The LCA method shows the influence of electricity production based on coal burning on the environment (Dzikuć, 2013a), as well as environmental and economic benefits that can be achieved through an increase in biomass amount in one of the largest Polish power stations (Dzikuć and Dzikuć 2013).

* To whom correspondence should be addressed

2. Methodology

The LCA method used in the article can be defined as a technique of assessing environmental hazards present during commodities production and services provision. The assessment concerns the whole life cycle of a product or activity, starting from extraction and processing of raw materials, product manufacturing process, distribution, use, reuse, maintenance, recycling, final management and transport (Adamczyk and Dzikuć, 2014).

LCA channels the research on the product system impact on the environment into areas of the ecosystem, human health, and consumed resources. LCA is a technique, whose aim is recognition, stocktaking, and evaluation of environmental hazards resulting from the analysis of a given manufacturing process (Dzikuć, 2013c). The analysis is based on identification and determination of the amount of consumed materials, energy, amount of emissions and waste in the environment, and then assessment of the impact of these elements on the environment. Life cycle assessment is defined as a method which gives rise to the identification of elements helpful during determining ways to improve the environment quality.

One of the main tasks of LCA is to determine the influence of the manufacturing process on the environment with division into individual processes. LCA renders it possible to investigate the effect of the product on the environment not only during manufacture or extraction of raw materials but also during use and disposal. With LCA it is also possible to determine the environmental benefits that result from recycling of materials destined for disposal. In addition, life cycle assessment can help to effectively manage limited resources because it is based on real input and output data of the process (Dzikuć and Zarębska, 2014). An effective use of non-renewable energy resources contributes to improving energy security (Dzikuć, 2013b). An important objective of the life cycle assessment method is the analysis of a potential impact of manufacturing processes on the environment and defining methods to improve the environment quality (Łasiński, 2012).

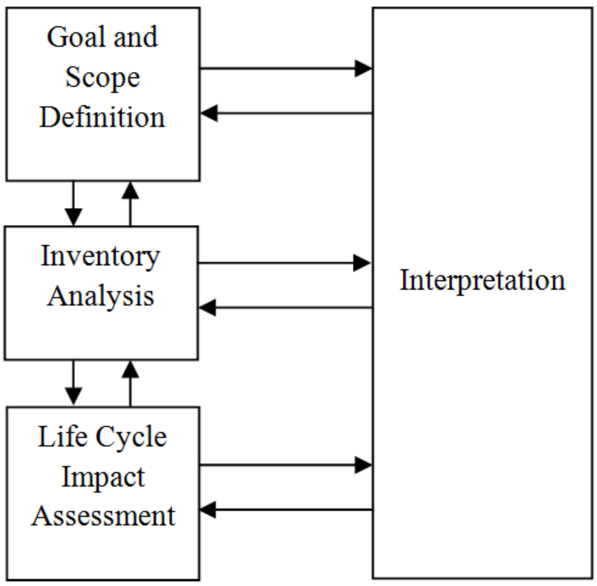

Fig.1. LCA framework based on ISO 14040.
Source: PN-EN ISO 14040, 2009

The International Organisation for Standardisation (ISO) defines LCA as a technique of evaluation of environmental aspects and potential impacts associated with the product (PN-EN ISO 14040, 2009; PN-EN ISO 14044, 2009), which consists of four phases shown in Fig.1.

LCA allows presentation of the results of the environmental impact in relation to three categories of damages, which include: Human Health, Ecosystem Quality, and Resources (Dzikuć and Piwowar, 2013). The presentation of the LCA results is expressed in Eco-indicator points (Pt), where 1 Pt is the value of one-thousandth of the annual environmental burden per capita in Europe. Eco-efficiency can be expressed as the amount of value-added effects (eg revenues from energy production) divided by the environmental pressures, understood as the emissions or the amount of material inputs (eg energy consumption, raw materials, materials, water, emissions). The definition of eco-efficiency can be written as follows (Zarębska, 2013)

$$E = \frac{\mathrm{IEPP}}{IE} \tag{2.1}$$

where E is the eco-efficiency, IEPP is the intentional effect of the production process and IE is the impact on the environment.

3. Techniques and potential of co-firing of biomass use

Biomass co-firing in the production of electricity in Poland has a large impact on the development of renewable energy resources. It is confirmed by a number of investments carried out in the country and aimed at improving or commencing biomass burning. Around the world, and especially in Europe, there are a lot of installations where biomass is burned. As many as two-thirds of all the power stations which use biomass co-firing are located in Europe. This is partly because biomass co-firing in coal-fired power stations is funded by EU countries (Luschen and Madlener, 2013).

The use of biomass for electricity generation is a particularly attractive form of energy production from the climate viewpoint. This is one of the reasons why biomass is the most widely used renewable energy resource in Poland (Tab.2).

Table 1. The volume and structure of the electricity production in Poland.

Specification	2010		2011		2012	
	GWh	%	GWh	%	GWh	%
Coal	*87 941*	*55.8*	*87 326*	*53.4*	*80 596*	*49.7*
Lignite	*48 651*	*30.9*	*52 529*	*32.1*	*54 054*	*33.3*
Natural gas	*4 797*	*3.0*	*5 821*	*3.6*	*6259*	*3.9*
Biomass	*6 305*	*4.0*	*7601*	*4.6*	*10094*	*6.2*
Other fuels (oil and gas, liquid gas)	*4 812*	*3.0*	*4305*	*2.6*	*3923*	*2.4*
Water	*2 920*	*1.8*	*2331*	*1.4*	*2037*	*1.3*
Wind	*1 664*	*1.1*	*3205*	*2.0*	*4747*	*2.9*
TOTAL	*157 658*	*100.0*	*163 548*	*100.0*	*162 139*	*100.0*

Source: The Energy Market Agency www.cire.pl 25. 04. 2014.

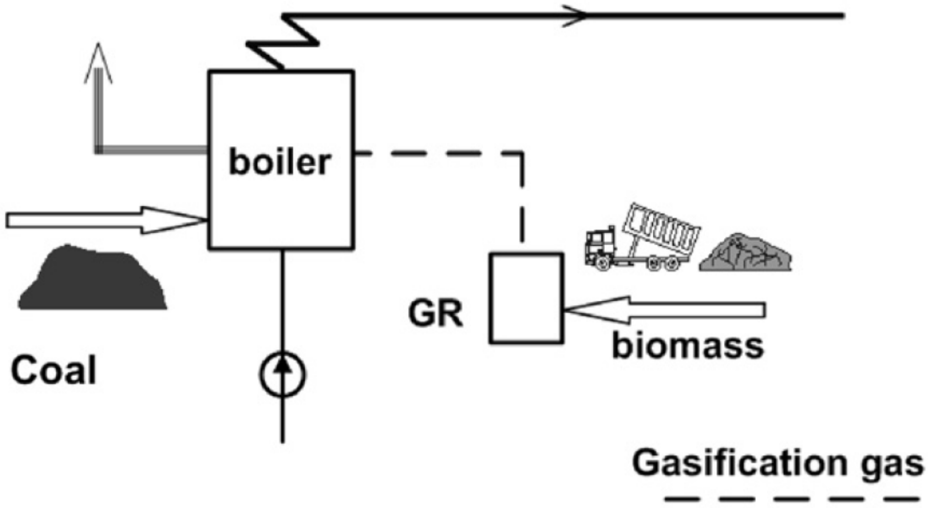

Fig.2. Technology indirect co-firing of biomass.
Source: Al-Mansour and Zuwala, 2010

It should be emphasized that during biomass combustion CO_2 is released. However, taking into account that the emitted CO_2 was previously removed from the atmosphere during the growth of plants, it is assumed that the balance of carbon dioxide emission during biomass combustion is neutral.

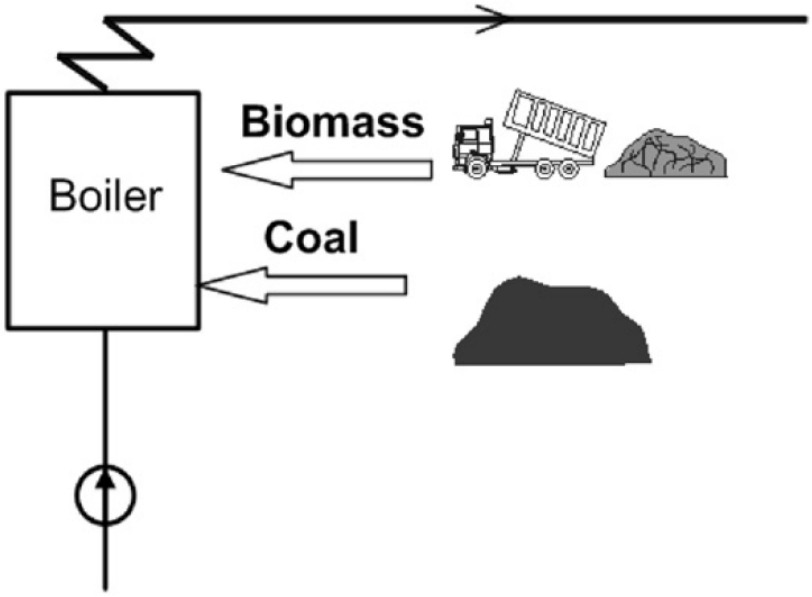

Fig.3. Technology direct biomass co-firing.
Source: Al-Mansour and Zuwala, 2010

There are three basic methods of co-firing biomass with coal, these are (Al-Mansour and Zuwala, 2010):

- Indirect co-firing, which is possible after installation of a gasifier used to convert solid biomass into gas. Figure 2 shows a diagram of the indirect biomass co-firing which can be performed in coal boilers. This solution allows a high degree of flexibility of the gaseous fuel used, which can be purified prior to combustion in order to minimise the negative impact of emissions formed during combustion of the gaseous fuel.

- Direct co-firing is the cheapest and simplest method of using biomass for energy production in coal power stations. Biomass is burned in the coal furnace, often using the same mills and burners, as shown in Fig.3. It is a frequently used method of co-firing, allowing the use of up to *3*% of biomass without incurring significant capital costs.
- Parallel co-firing is carried out by installing two separate boilers, a biomass-fired one and a coal-fired one. Figure 4 shows installations for the production of energy, which utilise steam generated in the use of coal and biomass. Each of the fuels is burned in a separate boiler.

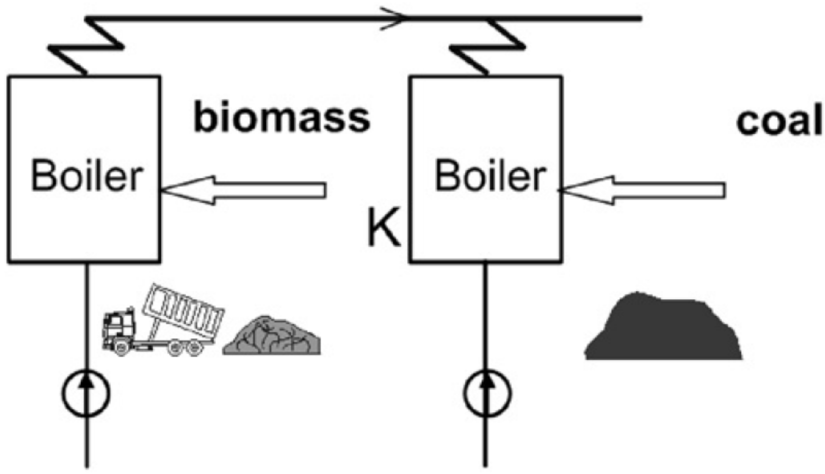

Fig.4. Parallel technology biomass co-firing Parallel co-firing.
Source: Al-Mansour and Zuwala, 2010

4. Environmental benefits resulting from the co-firing of biomass with coal

Biomass co-firing can contribute to reducing the negative impact of electricity generation on the environment. During the study, Dolna Odra Power Station was used as an example. This power plant currently generates electricity using biomass co-firing with coal. Data analysed with LCA comes from 2012. In 2012 in Dolna Odra Power Plant 5 503 784 MWh of energy were produced and the generation of electricity consumed 2 252 722 Mg of coal and 124 777 Mg of biomass (Polish Energy Group, 2013).

Table 2. LCA Results – the three damage categories.

Impact categories	**Dolna Odra Power Plant** 5% share of biomass (results in Pt)	**Dolna Odra Power Plant** simulation-7% share of biomass (results in Pt)
Human health	*8.0*	*8.0*
Ecosystem quality	*1.0*	*1.0*
Resources	*25.0*	*24.4*
Total	***34.0***	***33.4***

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

The results of the LCA analysis are shown in Tab.2. They indicate that the increase of biomass in the production of electricity significantly reduces the negative impact on the environment. With the proportion of biomass amounting to *5*%, which took place in 2012, the impact of electricity generation on the environment amounted to *34.0* Pt. After an increase of biomass share to *7*%, as assumed by the authors, the negative impact on the environment decreased to *33.4* Pt (Dzikuć, 2014). This change is mainly due to the lower consumption of non-renewable resources. Although the difference may seem slight (approximately *1.8*%), it must be noted that the difference relates to the generation of only *1* MWh of electricity, and only multiplying this value by the amount of power generated in the whole year of 2012 to assess what environmental benefits could be achieved during a year as a result of increasing makes it possible biomass share in the production of electricity.

During the research with the LCA method computer software SimaPro version 7.1. was employed. During the simulation the appropriate amount of coal was removed and replaced by biomass. When calculating the amount of coal, the calorific value and moisture content of coal and biomass were taken into account, which made it possible to estimate more precisely the amount of biomass needed to produce a similar amount of electricity. The simulation also takes into account the reduction of harmful emissions (mainly NO_X and SO_2), which in the case of restricted consumption of coal replaced by biomass would be decreased. It is difficult to accurately determine exact values that could be achieved in this way because it must be remembered that the simulation does not take into account any changes in fuel combustion technologies. Nevertheless, basing on studies conducted to date it can be assumed that the results are affected by an insignificant error (*4-6*%) and the difference, expressed in Eco-indicator points, between electricity generation with biomass share equal to *2*% and the share equal to *7*% would be close to *0.6* Pt.

5. Conclusions

Installations using biomass co-firing are characterised by a lower negative impact on the environment. The uptake of renewable energy resources depends on factors such as: legal considerations associated with energy production utilising biomass co-firing or resources amount. Biomass and coal co-firing in generation of electricity has some disadvantages, such as reduction in boiler efficiency while increasing the share of biomass, and increased corrosion of certain elements located in energy units. However, despite the mentioned flaws, co-firing biomass with coal can reduce the consumption of non-renewable energy resources and reduce the amount of harmful emissions during energy generation.

The analyses of environmental burdens carried out in the article indicate that such solutions should be sought that will be less damaging for the environment. Not only due to the increasing environmental requirements, but also because of the charges related to the emission of greenhouse gases into the atmosphere. Energy infrastructure existing in Poland allows to the use of the potential of biomass, which is a relatively cheap fuel, at a low cost.

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