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MACIEJ DZIKUĆ
ARKADIUSZ PIWOWAR

LCA analysis as a tool to assess the impact of electricity production on the environment

1. Introduction

From the point of view of generating energy management practices is necessary to estimate the amount of required energetic resources, materials, the amount of emitted dust, solid wastes (ashes), which is generated in the course of production as well as electricity, which is also necessary during energy production. It is also crucial to consider the distance energetic resources take while being transported from the place of extraction to the power station as well as means of transport used. In recent years there has been a substantial increase of requirements concerning the very manner of energy production and its impact on the environment. There appeared a need for finding such a tool, which would take into consideration many aspects of the issue. The main objective of this paper is to present the Life Cycle Assessment method (called Life Cycle Assessment - LCA), which is an effective tool helping provide a complex evaluation of particular manners of energy production.

The validity and timeliness of the discussed in this paper define the issues of climate change and diminishing energy resources,

Ph.D. Maciej Dzikuć
University of Zielona Gora,
Faculty of Economics
and Management
Scholar in Sub-measure 8.2.2 „Regional Innovation Strategies", Measure 8.2 „Transfer of Knowledge", Priority VIII „HR Regional Economy" Human Capital Operational Programme, co-financed by the European Social Fund, the European Union and the state budget
Ph.D. Arkadiusz Piwowar
Wroclaw University of Economics
Faculty of Engineering and Economics

which in turn are the determinants of the introduction of new instruments of environmental management. According to International Energy Agency, the world demand for electricity will double until 2030, from present 16 to 31,6 thousand TWh. This implies the need to build new power plants with power of 4800 GWe. However, these new power plants need energetic resources or more effective use of renewable energy sources. The reserves of energetic resources on the Earth are limited. According to the forecasts of the experts from the World Energetic Council, at the present level of use the world reserves of energetic resources will be sufficient for: coal – 205 years; lignite coal – 247 years; petroleum – 44 years; natural gas 55 years (Survey of Energy Resources 2004). Therefore, it is so important to assess accurately the impact of energy production on the environment, which will be able to recognize more effective manners of energy production on the basis of limited energetic resources supplies.

2. Life Cycle Assessment Assessment

The notion of „ Life Cycle Assessment" was first introduced at the conference of Society of Environmental Toxicology and Chemistry inVermont in 1990. With the use of LCA analysis it is possible to decrease environmental loads already at the stage of designing a particular product. For regard of conducting the assessment of all stages of the product it is possible to make comparisons, which clarify various kinds of risks emerging in the course of a particular article production (Wach 2002).

The Life Cycle Assessment has been mentioned in few documents of the European Union as well as in domestic ones as an effective tool for the evaluation of the impact on the environment. LCA definition was described in ISO norms (International Organization for Standardization) and also on the official pages of the European Commission, which defines LCA as a process of gathering and evaluating data-in and data-out as well as the potential impact on the environment in the whole period of life cycle and concerns production, use and utilization of products.

The use of this conception of assessment in production processes allows for the optimum choice of technologies not loading the environment during the production of articles or selection of technology influencing the environment in a much less degree (Dylewski, Adamczyk 2012, pp. 88-95).

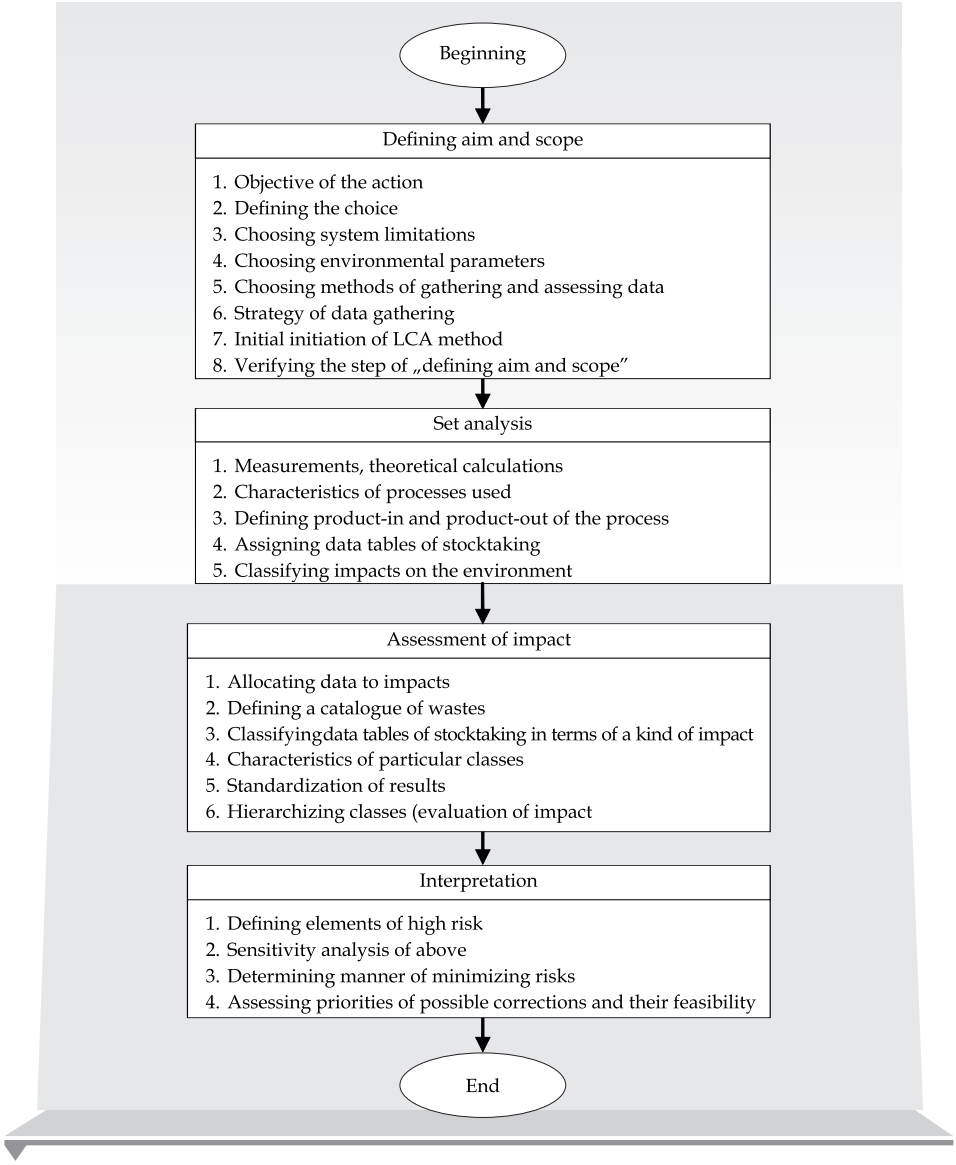

Figure 1. The procedure of LCA

Source: Wach 2002, p. 92

ISO norms clarify requirements in relation to conducting LCA. The Life Cycle Assessment concerns environmental aspects and possible impacts on the environment in the period of product life starting from gathering resources, through production, use, processing after being removed from exploitation, recycling, up to the final disposal (i.e. "from the cradle to the grave"). There are four stages of LCA analysis distinguished (http;//lca.jrc.ec.europa.eu 2012):

- stage of defining the aim and scope,
- stage of analyzing the in and out set,
- stage of assessing the impact and
- stage of interpretation.

The scope, together with borders of the system and the level of accuracy of LCA, depends on the object and intended use of the studies. The profoundness and extent of LCA studies can differ substantially depending on the aim of a particular LCA analysis.

The Life Cycle Assessment is supported by specialist computer programmes, such as SimaPro elaborated by PRe Consultans B. V. in Holland or Umberto elaborated in the Institute of Energy and Environmental Research in Heidelberg as well as by less popular programmes, such as: ECO-it, EcoManager, EcoPro, EcoScan (Zarębska 2013, pp. 106-110). The software differs from each other mainly in terms of the number of processes and models of materials being implemented to the base as well as methods of assessing the impacts. An interesting solution used in SimaPro programme in version 7.1 is the implementation of Eco-Indicator 99 for the environmental assessment, whose advantage is the fact that it includes the problem of supplies of resources reduction (Kowalski 2007), which is very important in case of examining the impact of different manners of energy production on the environment for regard of using substantial amounts of non-renewable energetic resources in the process of energy production.

The analysis includes: consumption of resources, emissions of harmful and poisonous substances, soil contamination. As a result of such activities it is possible to minimize environmental loads before making decisive decisions concerning the reduction of expected effects already at the stage of designing a power plant.

LCA Life Cycle Assessment analyzes environmental risks connected with the product in the time of its whole life, whereas the product in LCA method is not only a particular object, but also production process or service (Dylewski, Adamczyk 2011, pp. 2615—2623).

The most important tasks of LCA are the following:

- documentation of possible impacts of a product (service) on the environment during its whole life cycle,
- analysis of probability of appearing mutually connected environmental impacts in such a way as protective means used not lead to the appearance of next problems,
- agreement of preferences in improving products,
- possibility of comparing heterogeneous solutions of the same issue or different methods of realizing the same process.

Figure 1. presents the procedure of conducting the Life Cycle Assessment, whose first stage is to define the aim and scope of the studies. The aim of the research should define clearly the intended use, reasons for whose the studies are carried out and also the receiver of the results. The aim of the research defines the level of accuracy of LCA and the range of research is described by individual processes, its borders and functional unit. A functional unit is the smallest unit accepted for the research, which becomes the quantitative effect of LCA system. Its main task is to provide a reference point for standardizing data-in and data-out of a particular system, which causes that it should be defined explicitly and be measurable. In case of the assessment of the impact on the environment of producing energy through burning different energetic resources or generating energy from renewable sources, it can be 1 MWh.

The set analysis in life cycle is based on gathering data and selecting calculating procedures, it defines ins and outs for the examined product in the period of its life cycle. The data is gathered in order to prepare a balance of all energetic and chemical elements absorbed from the environment.

ISO norms recommend the following support actions in a suitable system of a product:

- preparing detailed diagrams of processes' transfers together with existing individual processes and relations between them,
- elaborating a description of all individual processes together with a list of the categories of data related to particular processes,
- preparing a description of methods for gathering data and methods of calculating,
- elaborating instructions regarding the places of gathering data,
- elaborating a catalogue which includes measuring units (PN-EN ISO 14044 2009, p. 33).

Table 1. Categories of environmental impact

No.	Category	Description
	Abiotic impoverishment	Extraction of non-renewable ores of mineral resources
	Energy impoverishment	Extraction of non-renewable energy carriers. This category can be included in category 1.
	Greenhouse effect	Atmospheric absorption of radiation leading to the increase of global temperature
	Ozone hole	Increase of ultraviolet radiation reaching the surface of Earth caused by impoverishment of ozone layer
	Water and soil contamination	Exposing biota to toxic substances
	Acidification	Increase of water and soil acidity
	Contamination of humans	Exposing human health to toxic substances appearing in water, air and soil, mainly with food
	Creating photochemical oxidants	Emergence of atmospheric particles causing photochemical smog
	Eutrophication	Reduction of oxygen amount in water or soil by emission of substances causing increase of biomass production

Source: Clift 1997, p. 294

Interpretation is a phase of Life Cycle Assessment, whose task is to analyze conclusions, check completeness, analyze sensitivity, other analyses, recommendations and report. Moreover, this phase allows to define elements of great risk, analysis of sensitivity of above mentioned elements, to define the manner of minimization of threats as well as assess priorities of possible corrections and their feasibility. The impact assessment allows for defining trustworthiness of results at a high level and formulated conclusions and elaborated recommendations become a complete and objective report from the research. The assessment conducted according to the mentioned procedure allows to present the results of impact in relation to nine impact categories included in table1. The presentation of the result of environmental interference of electricity, as well as other products subject to the assessment, takes place in the form of Pt units (point of eco indicator), where 1 point of eco indicator (Pt) is a value, which represents one thousandth of annual environment load of one citizen in Europe.

LCA method is especially useful for analysis to determine the impact on the environment during the production of energy. In Poland, more than 90% of electricity is produced by burning coal and lignite. Consumption of non-renewable energy resources has a negative impact on the environment. When it comes to the energy of emission of toxic gases into the atmosphere. Through an analysis of LCA is possible to evaluate and compare the various energy technologies and exhaust after-treatment. LCA method takes into account the amount of energy consumed, which also is of great importance when comparing the impacts on the environment, which takes place during the production of electricity (Dzikuć 2013, pp. 33-36).

LCA method allows you to specify the least aggravating environmental technology at the design stage power. Information on the amount of emissions generated may prove crucial to the profitability of the investment due to rising CO_2 emissions charges.

3. Reasonableness of LCA analysis for energy sector in Poland

In order to find the answer to the question whether LCA analysis for energy sector is reasonable, it is necessary to familiarize with the latest reasons determining the policy of our country in the nearest years.

The estimates of Poland's energetic policy until 2030 define crucial aims of energetic policy. The document „Energetic policy of Poland until 2030" prepared in the Ministry of Economy assumes a long-term strategy of development of energetic sector. Moreover, it includes a forecast of demand for fuels and energy as well as a programme of actions until 2012. The document specifies six basic directions of development for domestic power industry:

1. The issue of increasing the energetic effectiveness is treated as a priority and as a consequence the reduction of energy intensity of Polish economy to the level of so called „old EU".
2. The next fundamental direction of actions is energetic security of Poland determined by own resources of energetic supplies such as coal and lignite coal (Dzikuć 2013, pp. 56-61). Such a solution gives a guarantee of a stable production of electricity. It is necessary to underline that such a solution does not cause a necessity of importing energetic resources and it can totally cover domestic demand for electricity, but also it allows to produce a substantial part of heat based on own resources. An important direction is a continuation of actions allowing for the diversity of supplies of energetic resources, such as petroleum or natural gas, and also as a result of diversifying technologies

of petroleum and natural gas production. Moreover, it is also assumed that the support of technologies, which will allow to obtain fuels from domestic resources. „Poland's energetic policy until 2030" also assumes the change of regulations defining responsibility of local governments for elaborating local plans of providing with electricity, fuels and heat.

3. The next step is the diversity of the structure of generating electricity, which nowadays is mainly based on coal or lignite coal-fired power plants. Nuclear power industry is planned to be implemented, indispensible tasks have been defined, whose undertaking in the following years will enable the initiation of nuclear plants.
4. The fourth direction is the development of the use of renewable energy sources. The essential idea is to build a plan of reaching the realization of targets included in the climate package. The intentions of the document for 2020 are the following:
   - 15 percent of share of renewable energy sources in the consumption of final energy,
   - 10 percent of share of bio fuels in the transport fuel market. "Poland's energetic policy until 2030" also assumes the development of bio fuels of II generation.
5. The document also forecasts the development of competitive markets of fuels and energy. The enhancement of competition on the energy market is also predicted.
6. The last direction is to reduce the impact of the power industry on natural environment, which is a consequence of accepted obligations connected with the climate package. The limitations of CO_2, SO_2, NO_X emissions are assumed. In order to improve these actions, the system of managing domestic levels of greenhouse gases and other substances emissions will be elaborated (Polityka energetyczna Polski do 2030 roku 2009, pp. 4-6).

The realization of the above mentioned assumptions can be supported by Life Cycle Assessment, whose aim can be to define the impact of energy production on the environment. The essential issue seems to be the evaluation of obtaining energy from ultimate sources in domestic conditions. Energy in Poland is mainly produced from coal, lignite coal and in a far smaller degree from natural gas as well as petroleum, which is used for reason of its specificity particularly in transport. The studies should also include the energy produced with help of renewable energy sources, despite the fact that their impact on the environment is much smaller because the "resource" itself used for energy production in renewable energy sources, i.e. wind, sun, water has the unnoticeable influence

on natural environment. In case of renewable energy sources, the critical impact on the environment takes place in the very preparing process (investment) for obtaining energy from these sources, i.e. for example while windmills are being built. At the stage of exploitation of renewable energy sources (obtaining energy) the impact on the environment in comparison with traditional production of energy is minimal. It is worth analyzing the influence on the environment in the time of working of water power station or gathering biomass with use of machines consuming e.g. petroleum, but although in this case the impact on the environment is bigger than for example in case of obtaining energy from wind, there is still however a large disproportion between the impact on the environment in case of obtaining energy from conventional sources.

As mentioned earlier, the implementation of LCA studies in the energy sector and draw conclusions, can bring tangible benefits to society. It is worth to emphasize the benefits for manufacturing companies in the energy sector. LCA results of the analysis allow you to choose the right solutions that minimize the impact on the environment and can be an important aspect of the social responsibility of businesses. It is worth noting that in recent years the issue of corporate social responsibility has become an important, increasingly hot topic of public debate and policy (Piwowar 2010, pp. 493-501). Due to the nature and extent of the impact of energy companies on corporate social responsibility environment is particularly important. The implementation of corporate social responsibility strategy by energy companies may be basic for new sources of competitive advantage in the energy market.

4. Conclusion

LCA evaluation is an important element of a complex approach, taking into consideration the whole life cycle of a particular product and can be an effective tool supporting decision-making in the energy sector. Due to the benefits described in this article, the method of LCA can be used to identify the strategic direction of the energy sector in Poland.

Moreover, due to LCA results it is possible to select proper solutions minimizing negative impact on the environment of individual companies in the energy sector. It is very important for the social and environmental aspects of their operations. Considering manners of obtaining energy from accessible analyzed resources there are many aspects, as not only economic reasons and environment protection against pollution become essential, but also other numerous important factors, such as e.g. the amount of existing non-renewable

energy resources. The use in this regard LCA may be an important determinant of corporate social responsibility energy sector.

Summary

LCA analysis as a tool to assess the impact of electricity production on the environment

The paper presents a method for Life Cycle Assessment LCA (Life Cycle Assessment) to evaluate the ecological characteristics of products, presents a procedure for the implementation of the LCA with an overview of the various stages. Moreover the validity of using this method to evaluate the energy sector. The article also points to the directions of the Polish energy sector and pointed to the need to determine the environmental risks associated with the production of energy. Energy industry in Poland, the structure of energy production requires special supervision. The use of coal and lignite as a primary fuel results in significant the environmental impact.

***Keywords**: Life Cycle Assessment, ecology, energy.*

Streszczenie

Analiza LCA jako narzędzie służące do oceny wpływu produkcji energii elektrycznej na środowisko

W pracy zaprezentowano metodę oceny cyklu życia LCA (Life Cycle Assessment) służącą do oceny właściwości ekologicznych wyrobów, przedstawiono procedurę realizacji LCA wraz z omówieniem poszczególnych etapów. Ponadto wskazano zasadność wykorzystania tej metody w sektorze energetycznym. W artykule wskazano również na kierunki rozwoju polskiego sektora energetycznego oraz wskazano na konieczność określania zagrożeń środowiskowych związanych z wytwarzaniem energii. Przemysł energetyczny w Polsce z uwagi na strukturę wytwarzania energii wymaga szczególnego nadzoru. Wykorzystanie węgla kamiennego oraz brunatnego jako podstawowego paliwa powoduje znaczne obciążenie środowiska.

***Słowa kluczowe:** Ocena Cyklu Życia (LCA), ekologia, energia.*

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