The use of the life cycle assessment (LCA) conception for Mittal Steel Poland SA energy generation – Krakow plant case study

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Abstract

Life cycle assessment (LCA) is an environmental methodology for assessing the environmental effects associated with a product, process or activity and is useful as an information tool for the examination of different scenarios for future decision support strategies. This paper provides an overview of LCA and life cycle inventory (LCI) techniques for energy production proposed for the Power Plant of Mittal Steel Poland in Krakow, Poland. In this paper, an energy medium generation scenario is presented, including electric energy, technology practice steam, blast to iron blast furnace, hot water, demineralizing and degassing water for hot rolling mill, BOF blast oxygen furnace (BOF), cokery, as well as steel continuous casting and BOF. In this paper LCA is limited to the inventory analysis., i.e. the determination the environmental interventions. Environmental interventions are defined within the LCA-methodology as "the exchanges between the anthroposphere (economy) and the environment including resources use, emission to air, water, or soil" [5].
Keywords: life cycle assessment (LCA), life cycle inventory (LCI), boundary system, Environmental Management Standard, energy generating.

1 Introduction

Krakow, a city with a population of 850 000, is the old capital of Poland and an important centre of European science and culture. Mittal Steel Poland consists of four plants located in Dabrowa, Krakow, Sosnowiec and Swietochlowice. It boasts a full production system – from pig iron to final, highly processed steel products – producing around 6.5 million tons of crude steel annually. Today,

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Mittal Steel is the only truly global steel maker - with operations in the USA, Canada, Mexico, Trinidad, France, Germany, Czech Republic, Poland, Romania, Bosnia, Macedonia, Kazakhstan, Algeria and South Africa [12]. The program of improvements in the soil, water and groundwater, as well as the effectiveness of waste water treatment, was implemented in the period 1999-2002.

This research was conducted with the cooperation of representatives from the Water Department of Mittal Steel Poland in Krakow.

2 Methodology

2.1 Mittal Steel Poland, Krakow Power Plant structure

This case study will focus on the Power Plant located in the Mittal Steel Poland in Krakow, Poland. In this paper, LCA is limited to the inventory analysis i.e. the determination of the environmental interventions. Environmental interventions are defined within the LCA-methodology as “the exchanges between the anthroposphere (economy) and the environment including resources use. emission to air, water or soil” [5].

The Power Plant, the branch of the Energy Plant, has four departments:

- Boiler-House,
- Engine Room,
- Heat Power Department,
- Electric Department.

The Power Plant process produces:

- electric energy,
- blast to iron blast furnace,
- technological steam -1.6 MPa/400^{o}C;
- technological steam -0.8 MPa/260^{o}C;
- hot water;
- softening water for rolling mills, BOF, and cokery;
- water after demineralization for continuous casting and BOF.

The energy process is based on the coal dust, as well as coke-oven gas and blast–furnace gas fired in the steam boilers. Five of the steam boilers have a capacity of 230 tons per hour, and the other (two) of the steam boilers have a capacity of 220 tons per hour. The temperature in the boilers varies between 510 and 540^{o}C, and the output pressure of the steam is 9 MPa.

Currently, the ISO 14001 Environmental Management Standard is being used in the Power Station. On the basis of the ISO 14001 guidelines the Mittal Steel Power Plant:

- implement, maintain and improve an environmental management system;
- ensure compliance with environmental laws and regulations;
- implement Pentol-Vahlko flue gas conditioning system;
- make selective waste disposal.

A general view of the Mittal Steel Poland Power Plant is presented in Figure 1 [11].

2.2 Description of LCA methodology

Several LCA studies have been proposed in the literature to present and to compare the potential environmental impacts due to greenhouse gases (GHG) emissions from several Coal-fired Power Plants. Kannan *et al* present an empirical relation between plant efficiency and life cycle energy use in addition to a scenario for electricity cost with varying gas prices and plant efficiency in Singapore [7]. In presentation [13] the life cycle inventory (LCI) of GHG emission was developed for electricity power plants in Thailand using the LCIA:*NETS NETS* (*N*umerical *E*co-load *T*otal *S*tandardization). Heller *et al* [6] highlighted the study aimed at using the LCA for demonstration that electricity generation with willow energy crops, either by cofiring with coal or in dedicated biomass power plants, leads to significant reductions in many of the environmental impacts of coal-based electricity production.

The International Organization for Standarization (ISO) has adopted work carried out by SETAC and has incorporated it into a series of standards focusing on Environmental Management. These standards include the ISO 14040 series on LCA as follows:

- ISO 14040, Environmental Management - Life Cycle Assessment, Principles and Framework (ISO 1997)
- ISO 14041, Environmental Management - Life Cycle Assessment, Goal and Scope Definition and Life Cycle Inventory Analysis (ISO 1998)
- ISO 14042, Environmental Management - Life Cycle Assessment, Life Cycle Impact Assessment (ISO/FDIS 1999)
- ISO 14043, Environmental Management - Life Cycle Assessment, Life Cycle Interpretation (ISO/FDIS 1999) [8].

The concept of LCA first emerged in the late 1960s, but did not receive much attention until the mid-1980s [2]. In 1989, the Society of Environmental Toxicology and Chemistry (SETAC) became the first international organization to begin oversight of the advancement of LCA. In 1994, the International Standards Organization (ISO) began developing standards for the LCA as part of its 14000 series standards on environmental management. The standards address both the technical details and conceptual organization of LCA [10, p. 41].

As defined by the U.S. Environmental Protection Agency,
"LCA is a technique to assess the environmental aspects and potential impacts associated with a product, process, or service by compiling an inventory of relevant energy and material inputs and environmental releases; evaluating the potential environmental impacts associated with identified inputs and releases; and interpreting the results to help make a more informed decision" [3].

The functional unit is the central concept in LCA. The goal and scope definition is designed to obtain the required specifications for the LCA study.

During this step, the strategic aspects concerned questions to be answered and identifying the intended audience are defined [13]. The life cycle inventory analysis (LCI) collects all the data off the unit processes, and is the phase of the LCA. Our case study will focus on the Power Plant located in Mittal Steel Poland Plant in Krakow, Poland and this paper is only concerned with the presented LCI for the energy generation in the Mittal Steel Poland, in Krakow.

2.2 Purpose of the LCA study and system boundaries

The aim of this study is to analyze the environmental performance of the energy generation to determine its present status. Therefore the LCA study must be organized by carefully dividing the energy generation process into phases to identify which parts of the process are responsible for each environmental effect [14 p. 44]. The system boundaries are drawn in the initial stages of a study, as part of the scope and goal. Consider a given power plant that produces a given quality and quantity of energy. Figure 7 depicts the system boundaries around the “core system”, composed of the simplified process flow diagram, which also includes all power generation processes. The subject of this paper is only an overview of the LCI technique, the tool helping to make decisions that will results in more efficient environmental management. It was not possible to develop the full results of the inventory analysis, because of lack of data availability and knowledge about the energy consumption, air emission and water emission.

In this case study, the system evaluated does not include anything upstream from the sludge production.

Figure 1: General view of the Mittal Steel Poland Power Plant in Krakow.

Reports of LCA or inventory studies are superior sources of data since they typically contain the complete set of inventory data and are more transparent in terms of the methods used. Baseline emission data for energy process operation reported and provided by Mittal Steel Poland Energy Department is shown in Table 1 [11].

Table 1: Emission data to the atmosphere.

Year	Dust	SO_2	NOx	CO	Coal consumption	Ash emission from 1 tonne of coal	Effectiveness
			Value units: tonnes/year				
1985	29825	11894	7361	0	971960	30.69	87.80
1988	14639	9272	7971	0	809100	18.09	92.00
1991	7553	9719	4484	804	711730	10.61	94.60
1993	4377	11182	4611	769	686450	6.38	95.00
1995	2634	9646	5064	438	705760	3.73	97.90
1996	1471	7891	5224	521	692980	2.42	98.80
1997	1341	5810	4024	193	562720	2.38	98.70
1998	1155	5608	4048	47	513750	2.25	9860
1999	887	5239	3769	56	487320	1.82	98.90
2000	781	4815	3324	171	440220	1.77	98.90
2001	697	4442	3072	0	393600	1.77	99.00
2002	587	3543	2634	0	334100	1.76	99.02
2003	439	2817	1933	0	306080	1.44	99.03

Figures 2, 3, 4 and 5 demonstrate how Mittal Steel Poland Power Station energy processes provide a significant reduction in SO_2, NOx, and ash emissions from one tonne of coal [11]. This reduction changes with coal consumption (Table 1). On the other hand, dust removal effectiveness across the study period (from 1995 to 2003 year) increases from 87.80 to 99.03% (see Figure 5).

The system boundaries are drawn in the initial stages of a study, as part of scope and goal. Figure 6 [11] depicts the extending LCI system boundaries around the "core system," include all the processes from the energy and material resources for the energy generating process to final products. Consequently, the following processes are considered: transport of the coal from coal deposit and blast-furnace gas to steam boilers, water demineralizing station, water supply degassing facility, water softening station, evaporator and heat network degassing installation, heat powers banks and turbogenerators. The subject of this paper is only an overview of the LCI technique, the tool helping to make decisions that will result in more efficient environmental management.

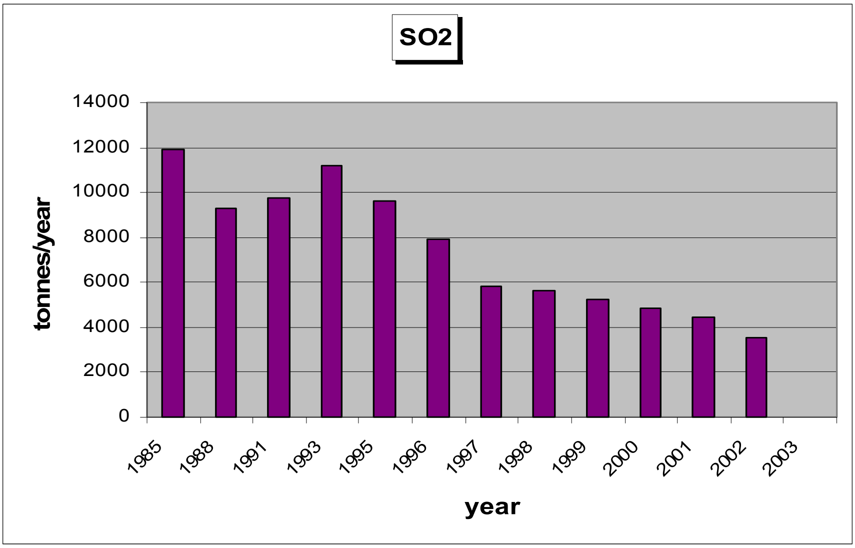


Figure 2: Distribution of SO_2 emissions across life cycle stages for energy production.

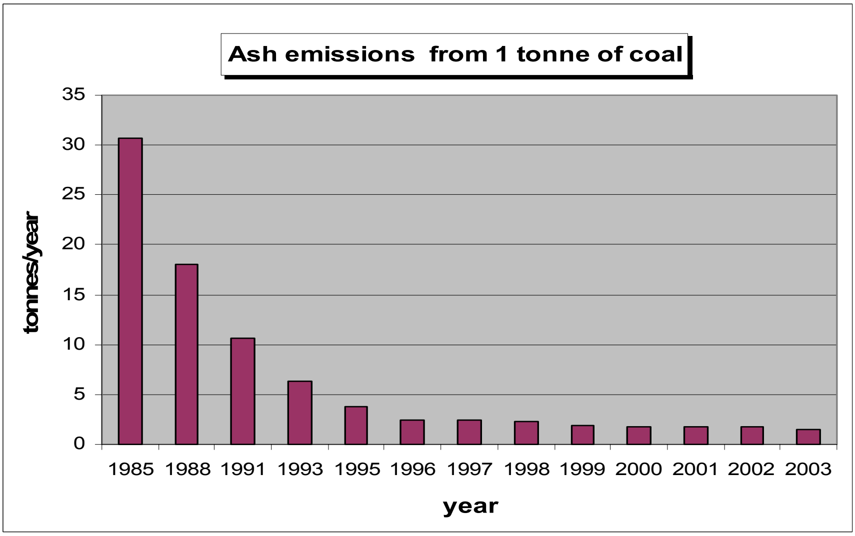


Figure 3: Ash emissions from 1 tonne of coal across life cycle stages for energy production.

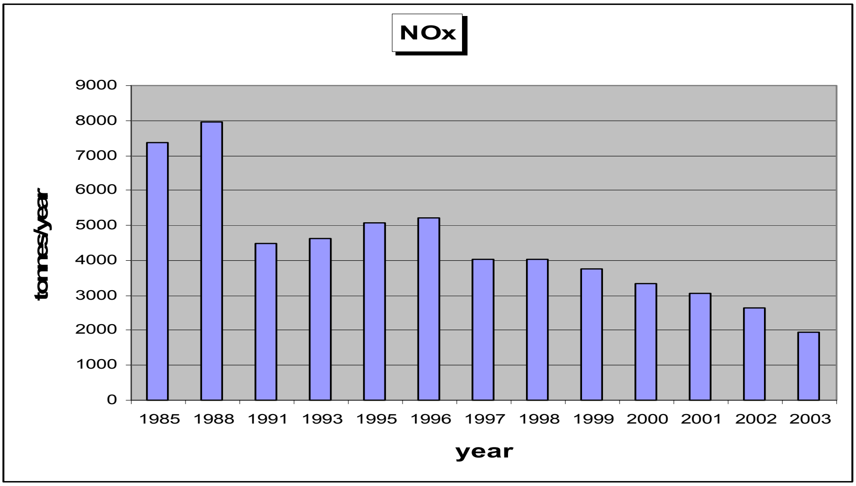


Figure 4: Distribution of NOx emissions across life cycle stages for energy production.

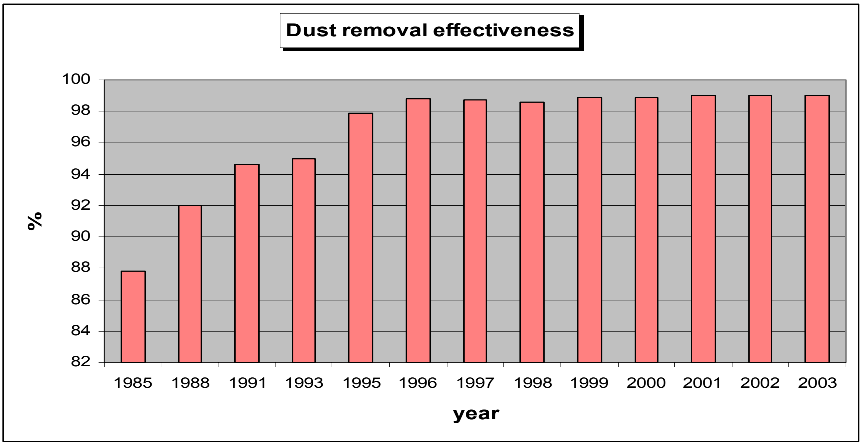
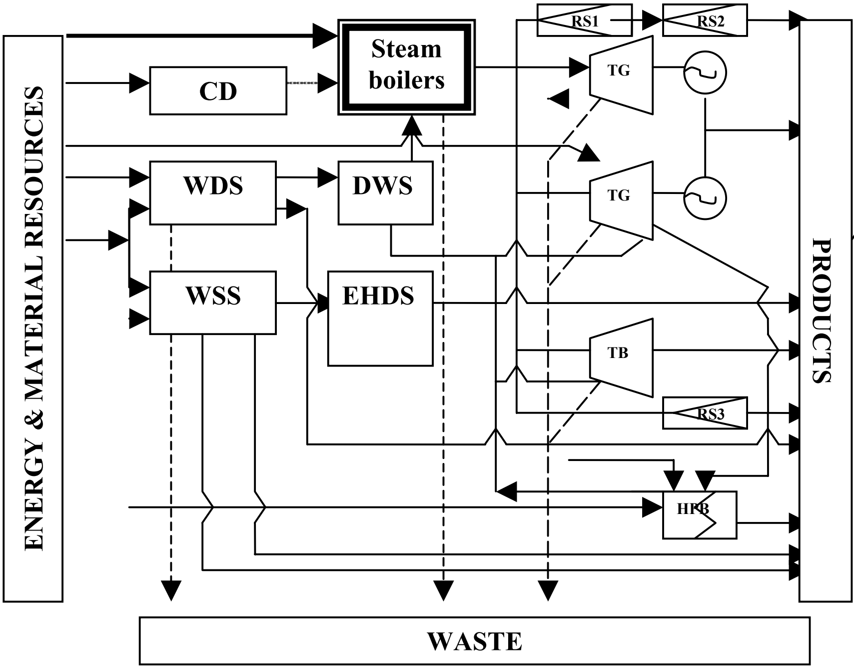


Figure 5: Dust removal effectiveness across life cycle stages for energy production.

The baselines presented in this study use deterministic input values. A probabilistic LCA of coal and natural gas electricity generation using Monte Carlo simulation will help make decisions under uncertainty. In a deterministic model, all data are known, or assumed to be known, with certainty. In a probabilistic model, some data are described by probabilistic distributions [4].



Legend

CD – Coal Deposit (yard)
WDS - Water Demineralizing Station
DWS – Degassing of the Water Supply
WSS – Water Softening Station
EHDS - Evaporator & Heat network Degassing Station installation
TG - Turbogenerator
RS1- Reducing Station nr 1
RS2 - Reducing Station nr 2
RS3 - Reducing Station nr 3
TB – Turbo blower
HPB – Heat Power Blanks

Figure 6: Processes considered in the LCA study within the boundaries of the system.

LCA can be a very effective tool for relative comparisons, particularly if a mix of energy-related, material application-related and process-related aspects plays a role [16]. LCI, part of a LCA, is the inventory of materials, energy requirements, and environmental emissions associated with a product or process from the time of the original recovery of raw materials used to build the product (“cradle”) to the time of its ultimate disposal to earth (“grave”) [15].

3 Concluding remarks

1. The research described in this paper can also serve as the basis for future work. The potential directions for future research is to use risk assessment for analysis in LCI models for energy generation management decision support systems under uncertainty, because this technique accounts for uncertainties in the assumptions, and to introduce the sensitivity analysis in LCI data collection to aid in the optimization of design aspects in the energy generation management systems. Due to very limited data availability and knowledge about the specific weighting factors this is an omission from the modeling that needs to be acknowledged and taken into consideration when making decisions on using the LCA methodology in the energy generating management.

2. An interesting extension of this study would be the incorporation of environmental impact assessment. Within LCA, LCI is considered the step in which all the environmental loads or environmental effects generated by a product or activity during its life-cycle are identified and evaluated [16]. Relation between an emission identified in the inventory and the impact on the environment is not a component of this work.

3. Several LCI models for energy generating processes are in advanced stages of development [1].

4. LCI models do not make the decisions [10].

5. Several simplifying assumptions were made to narrow the focus of this study.

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