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THE USE OF LIFE CYCLE ASSESSMENT (LCA) CONCEPTION FOR ARCELORMITTAL STEEL POLAND S.A. ENERGY GENERATING – KRAKÓW PLANT CASE STUDY

WYKORZYSTANIE OCENY CYKLU ŻYCIA (LCA) DO OCENY PROCESÓW WYTWARZANIA ENERGII W ARCELORMITTAL STEEL POLAND S.A. KRAKÓW

A b s t r a c t

Life Cycle Assessment (LCA) is an environmental methodology for assessing the environmental effects associated with a product, process or activity and it is useful as an information tool for the examination of different scenarios for future decision support strategies. This paper provides an overview of Life Cycle Assessment (LCA) and Life Cycle Inventory (LCI) techniques for energy production proposed for the Power Plant of the ArcelorMittal Steel Poland in Kraków, Poland. This paper presents an energy medium generating scenario, including the electric energy, technological steam, blast to iron blast furnace, hot water, demineralizing and degassing water for hot rolling mill, BOF (Blast Oxygen Furnace), cokery, as well as steel continuous casting and BOF. In this paper LCA is limited to the inventory analysis, i.e. the determination of the environmental interventions. The 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” [6].

Keywords: Life Cycle Assessment (LCA), Life Cycle Inventory (LCI), hydrated sludge disposal, ferrous sludge disposal

S t r e s z c z e n i e

Ekologiczna Ocena Cyklu Życia (LCA) jest techniką zarządzania środowiskowego opisaną w międzynarodowych normach ISO. W artykule przedstawiono ogólny zarys techniki LCA oraz jej pierwszy etap obejmujący analizę bilansową systemu LCI (*Life Cycle Inventory*). Przedmiotem opracowania jest instalacja energetycznego spalania paliw – siłownia należąca do ArcelorMittal Steel Poland S.A. o. w Krakowie. Siłownia zlokalizowana jest w północno-wschodniej części Krakowa, w centralnej części zakładu ArcelorMittal Steel Poland S.A. Głównym przedmiotem działania siłowni jest produkcja energii elektrycznej, dmuchu wielkopiecowego, pary technologicznej (1,6 MPa oraz 0,8 MPa), ciepła w wodzie grzewczej oraz produkcja odgazowanej i podgrzanej wody zmiękczonej i podgrzanej wody zdemineralizowanej. Produkty te są zużywane głównie na potrzeby własne ArcelorMittal Steel Poland S.A. Zgodnie z opisanymi w normach zaleceniami ocena techniką LCA dokonywana jest przez identyfikację i określenie ilości zużytych materiałów, energii oraz odpadów wprowadzanych do środowiska, a następnie ocenę wpływu tych procesów na środowisko i interpretację wyników [6].

Słowa kluczowe: Ekologiczna Ocena Cyklu Życia (LCA), analiza bilansowa systemu (LCI), składowisko odpadów uwodnionych, składowisko materiałów żelazonośnych

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1. Introduction

Kraków, a city with a population of 850,000, is the old capital of Poland and an important centre of European science and culture. ArcelorMittal Steel Poland consists of four plants located in Dąbrowa, Kraków, Sosnowiec and Świętochłowice. 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, ArcelorMittal Steel is the only truly global steel maker with operations in the USA, Canada, Mexico, Trinidad, France, Germany, the Czech Republic, Poland, Romania, Bosnia, Macedonia, Kazakhstan, Algeria and South Africa [10]. The program of improvements in the soil, water and groundwater, as well as the effectiveness of wastewater treatment was implemented in the period of 1999–2002. The ArcelorMittal structure is shown in Figure 1.

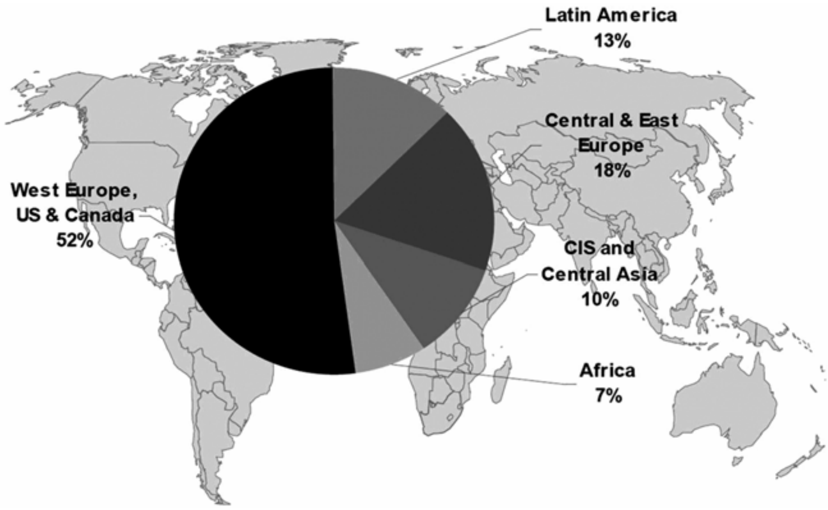

Fig. 1. Overview of the ArcelorMittal Structure

Rys. 1. Struktura Kombinatu Stalowniczego ArcelorMittal

2. Methodology

2.1. Mittal Steel Poland, Kraków Power Plant structure

This case study will focus on the Power Plant located in the ArcelorMittal Steel Poland in Kraków, Poland. In this paper LCA is limited to the inventory analysis, i.e. the determination of the environmental interventions. The 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” [6].

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

1. Boiler-House,
2. Engine Room,

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3. Heat Power Department,
4. Electric Department,
5. The Power Plant process produces:
   - electric energy,
   - blast to iron blast furnace,
   - technological steam –1.6 MPa/400°C,
   - technological steam –0.8 MPa/260°C,
   - hot water,
   - softening water for rolling mills, BOF, and cookery,
   - 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 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°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 ArcelorMittal Steel Power Plant:

- implements, maintains and improves an environmental management system,
- ensures compliance with environmental laws and regulations,
- implements Pentol-Vahlko flue gas conditioning system,
- makes a selective waste disposal.

The general view of the ArcelorMittal Steel Poland Power Plant is presented in Fig. 2 [9].

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]. The presentation [12] developed the life cycle inventory (LCI) of GHG emission for electricity power plants in Thailand using the LCIA: *NETS* (Numerical Eco-load Total Standardization). Heller et al. highlighted the study aimed at using the LCA to demonstrate 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.

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" [2].

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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 concerning questions to be answered and identifying the intended audience are defined [13]. The life cycle inventory analysis (LCI) collects all the data of the unit processes and is the phase of the LCA. Our case study will focus on the power plant located in ArcelorMittal Steel Poland Plant in Kraków, Poland, and this paper is only concerned with the presentation of LCI for the energy generation in the ArcelorMittal Steel Poland in Kraków.

Fig. 2. General view of the ArcelorMittal Steel Poland Power Plant in Kraków

Rys. 2. Ogólny widok Siłowni Kombinatu Stalowniczego ArcelorMittal Steel Poland S.A. w Krakowie

2.3. Purpose of the LCA Study and System Boundaries

The aim of this study is to analyze the environmental performance of 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 [13]. The system boundaries are drawn in the initial stages of the study as a part of scoping and goal. Consider a given power plant that produces a given quality and quantity of energy. Figure 6 depicts the system boundaries around the "core system", composed of the simplified process flow diagram which also includes all the power generation processes. The subject of this paper is only an overview of the LCI technique, a tool helping to make decisions that will result in a more efficient

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environmental management. The complete inventory was integrated by 31 main environmental loads (inputs, outputs): energy and raw materials consumed, wastes produced, and emissions to air, water and soil. The baseline emission data for energy process operation reported and provided by Mittal Steel Poland Energy Department is shown in Table 1. Table 2 presents the inventory corresponding to the Mittal Steel Poland power plant generation processes based on the Mittal Steel Poland Environmental Report [11].

Table 1

Emission to atmosphere data

Year	Dust	SO_2	NO_x	CO	Coal consumption	Effectiveness
	Tonne/year	Tonne/year	Tonne/year	Tonne/year	Tonne/year	%
1985	29 825	11 894	7361	0	971 960	87.80
1988	14 639	9272	7971	0	809 100	92.00
1991	7553	9719	4484	804	711 730	94.60
1993	4377	11 182	4611	769	686 450	95.00
1995	2634	9646	5064	438	705 760	97.90
1996	1471	7891	5224	521	692 980	98.80
1997	1341	5810	4024	193	562 720	98.70
1998	1155	5608	4048	47	513 750	98.60
1999	887	5239	3769	56	487 320	98.90
2000	781	4815	3324	171	440 220	98.90
2001	697	4442	3072	0	393 600	99.00
2002	587	3543	2634	0	334 100	99.02
2003	438.8	2816.5	1933	0	306 080	99.03

Figures 3, 4, 5 and 6 demonstrate how ArcelorMittal Steel Poland Power Station energy process provides a significant reduction in SO_2, NO_x, and ash emissions from 1 tonne of coal. This reduction changes with coal consumption (Tab. 1). On the other hand, dust removal effectiveness across the study period (from 1995 to 2003) decreases (Fig. 6).

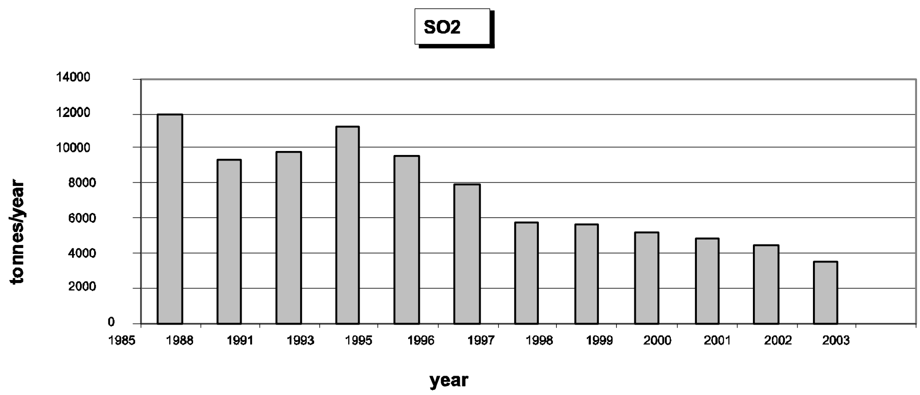

Fig. 3. Distribution of SO_2 emissions across life cycle stages for energy production

Rys. 3. Emisja tlenku siarki

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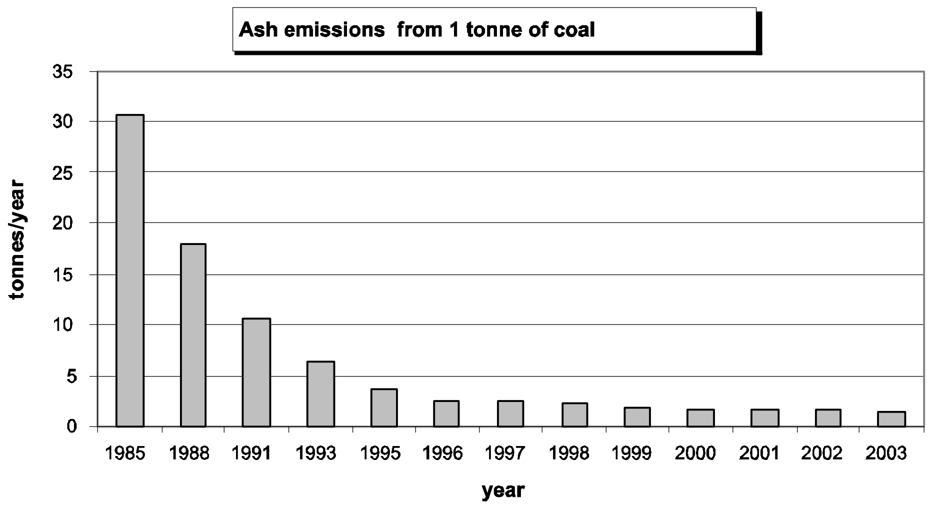

Fig. 4. Ash emissions from 1 tonne of coal across life cycle stages for energy production

Rys. 4. Emisja popiołów

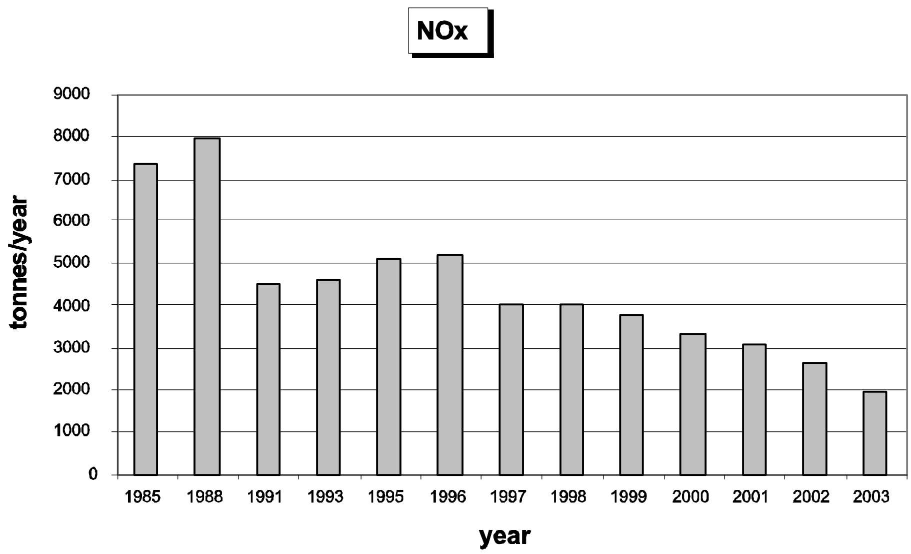

Fig. 5. Distribution of NO_x emissions across life cycle stages for energy production

Rys. 5. Emisja tlenków azotu

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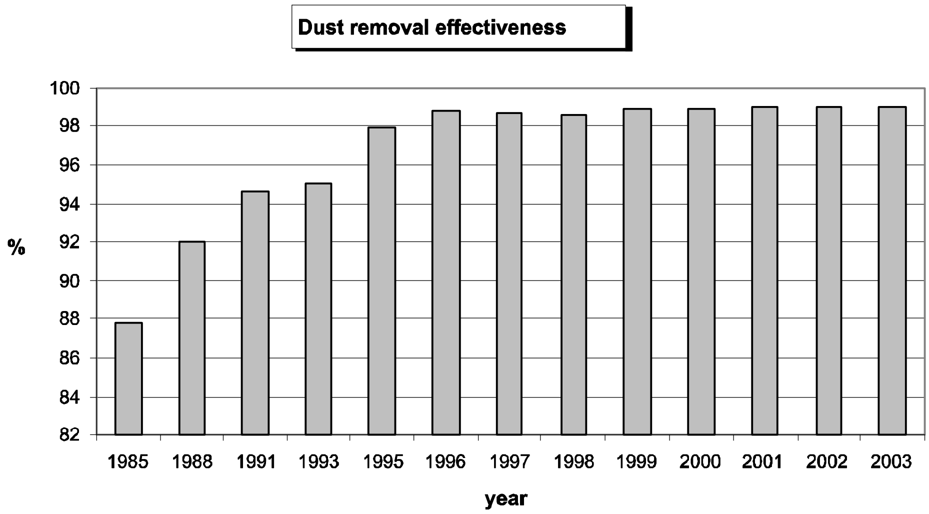

Fig. 6. Dust removal effectiveness across life cycle stages for energy production

Rys. 6. Skuteczność odpylania

The system boundaries are drawn in the initial stages of the study, as a part of scoping and goal. Figure 7 [11] depicts the extending LCI system boundaries around the "core system," including all the processes from the energy & material resources for energy generating process to final products. Consequently, the following processes are considered: transport of coal from coal deposit and blast–furnace gas to steam boilers, water demineralizing station, water supply degassing facility, water softening station, evaporator & heat network degassing installation, heat power banks and turbogenerators. The subject of this paper is only an overview of the LCI technique, a tool helping to make decisions that will result in a more efficient environmental management.

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 in case of 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 [3]. Simulation models are generally easier to understand than many analytical approaches [3, p. 12]. The LCI analysis usually needs a large amount of data. Usually the overall uncertainty as to LCI is dominated by a few major uncertainties [1]. The use of stochastic model helps to characterize the uncertainties better, rather than pure analytical mathematical approach. In this case, one of the most widespread stochastic model uncertainty analyses is the Monte Carlo simulation [13, p. 174]. 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 [15]. LCI, part of LCA, is an 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") [14].

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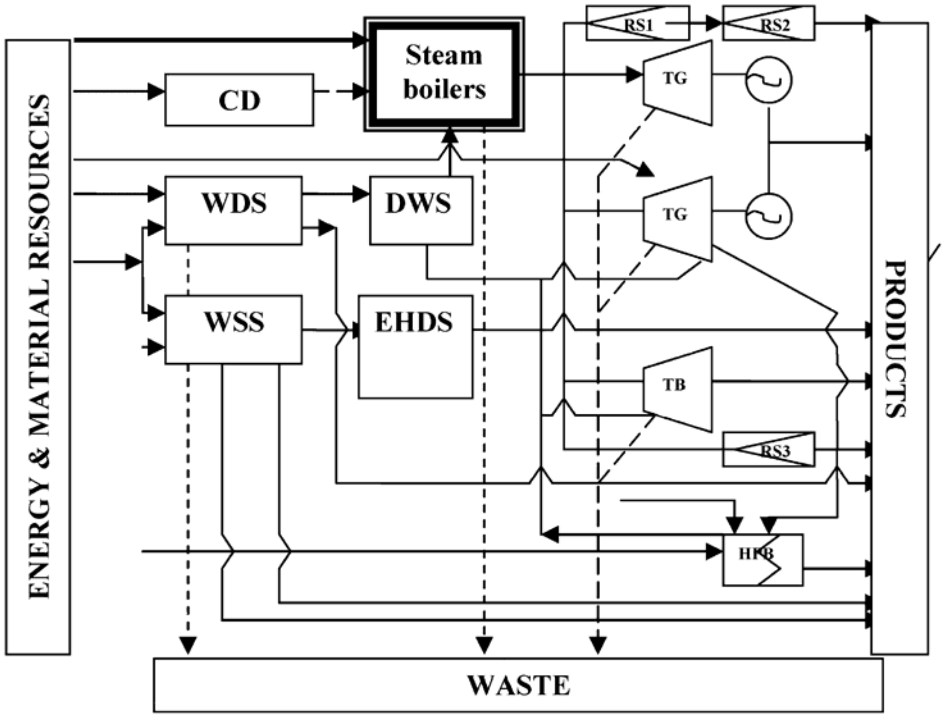
Inventory corresponding to the ArcelorMittal Steel Poland power generation processes is summarized in Tab. 2 [11].



Legend
CD – Coal Deposit (yard)
WDS – Water Demineralizing Station – output: demineralizin water
DWS – Degassing of the Water Supply – inputŁ condensation water from turbogenerators
WSS – Water Softening Station – outputŁ softening water
EHDS – Evaporator & Heat network Degassing Station installation – output: degassing softening water
TG – Turbogenerator – output U = 6 KV
RS1 – Reducing Station nr 1 – output: steam 3 MPa
RS2 – Reducing Station nr 2 – output: steam 1.6 MPa
RS3 – Reducing Station nr 3 – output: steam 0.8 MPa
TB – Turbo blower – output: blow to blast furnace
HPB – Heat Power Blanks – outputŁ Steel Plant & Kraków city heating
Steam boilers – output: steam 9 MPa

Fig. 7. Processes considered in the LCA study within the system boundaries for the power generation processes

Rys. 7. Schemat uproszczony produkcji Wydziału Siłownia

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Table 2

Inventory corresponding to the Mittal Steel Poland power generation processes

Raw materials & emissions (input/output)	Quantity
Hard coal	315,680 Mg
Blast furnace gas	4.16 million GJ
Coke oven gas	0.80 million GJ
Natural gas	0.08 million GJ
Electric energy	133,628 MWh
Industrial water	12,384,404 m^3
Drinking water	30,205 m^3
Gear oil	0.80 Mg
Calcium hydroxide	284.2 Mg
S	100 Mg
HCl	215 Mg
NaOH	219 Mg
Band conveyors	500 m
Land using	93,055 m^2
SO_2	3,138.1 Mg
NO_2	248.5 Mg
Dust	622.1 Mg
Cr	10.4 kg
Cd	1.0 kg
Cu	21.3 kg
Pb	22.8 kg
Ni	19.6 kg
Mn	274.0 kg
CO_2	48.1 Mg
F	9.6 Mg
Aliphatic hydrocarbons	67.5 Mg
Used water	3,316,958 m^3
Decarbonization water sludge	2,289.5 Mg
Ion exchanger sludge	1,528.7 Mg
Other sludges	10.0 Mg
Other oils (gear lubricant, etc.)	15.24 Mg

3. Concluding remarks

1. The research described in this paper is the conception for future work. The potential directions for future research are to use risk assessment for analyses in LCI models for energy generation management decision support systems in case of 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.
2. An interesting extension of this study would be the incorporation of the environmental impact assessment. Within LCA, LCI is considered a step in which all the environmental

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loads or environmental effects generated by a product or activity during its life-cycle are identified and evaluated [15]. The relation between an emission identified in the inventory and an 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 decisions.
5. Several simplifying assumptions were made to narrow the focus of this study.
6. The research described in this paper can also serve as the basis for future work. The potential direction for future research is to continue using risk assessment for the analysis in LCI models for waste management decision support systems in case of 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 waste management systems. The data for future work are presented in Tab. 2.

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