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Preface

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PREFACE

The Faculty of Engineering of Universitas Negeri Semarang, Indonesia organized the 11th EIC. The conference this year, with the theme "Applied Green Technology for Environment Conservation Through Continuous Engineering Innovation," was successfully held on September 22nd, 2022. This year's annual conference was also held digitally through Zoom meeting and streamed on YouTube like in the previous year due to the effects of COVID-19 and government travel limitations.

The Academic Vice Rector of Universitas Negeri Semarang launched the conference and provided a quick overview of the institution. Next, in the plenary session, four keynote speakers from Taiwan, Malaysia, and Indonesia gave their speeches. Each of them spokes for 45 minutes, followed by a 15-minute Q&A period. Each speaker attended the Zoom meeting in order to present their speech. Also, this session was facilitated by knowledgeable and skilled moderators from the Faculty of Engineering at UNNES. From the beginning of the opening ceremony to the conclusion of the plenary session, more than 900 attendees enthusiastically joined a Zoom meeting.

Following the plenary session, nine Zoom meeting rooms were assigned to the 128 presenters from Indonesia, Malaysia, Thailand, and Taiwan depending on the contents of the manuscript in order to hold a parallel session presentation. A moderator ran the presentation and the Q&A session in each room. Presenters were allotted 10 minutes for their presentation and 5 minutes for questions and answers. All of the presenters and participants in each room had excellent discussions thus increased participants' understanding of the subject delivered. Idea sharing was also promoted through the sessions.

The committee, partner, keynote speakers, presenters, participants, and everyone else who helped make this virtual conference a success were all thanked deeply despite the pandemic circumstances. Without any notable issues, all of the attendees joined in and participated throughout the entire session. The best presenter from each parallel room was named at the conclusion to recognize their tremendous effort in organizing the presentation. All keynote speakers, presenters, and conference attendees received a certificate from the committee following the conference as identification of their involvement.

This document is a compilation of the 53 presenters' accepted manuscripts. It presents the findings from research as well as concepts, data, and applications pertaining to green technology theory, design, development, implementation, testing, and evaluation. In this proceeding, various engineering-related subjects are presented. The following areas are where green technology is used:

1) Biodegradable Materials
2) Biomass Conversion
3) Biotechnology and Bioprocess
4) Disaster Resilience Infrastructure
5) Energy Efficiency
6) Energy Management System
7) Environmental Monitoring
8) Green Chemicals
9) Green Construction
10) Green Materials

11) Green Technology in Building
12) Green Technology System
13) Green Transportation
14) Intelligent Control System
15) Natural Disaster Mitigation
16) Renewable and Sustainable Materials
17) Renewable Energy
18) Renewable Resources
19) Sustainability in the Built Environment
20) Sustainable Architecture
21) Waste Treatment

The goal of this proceeding is to contribute to the advancement of green technology. Also, we wish everyone reading this proceedings pleasure and success in expanding an understanding of engineering research. We value everyone's dedication and hard work and anticipate that the conference will be even more successful the following year.

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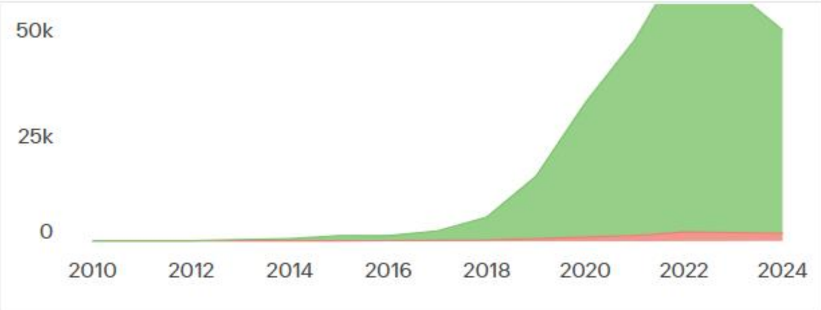

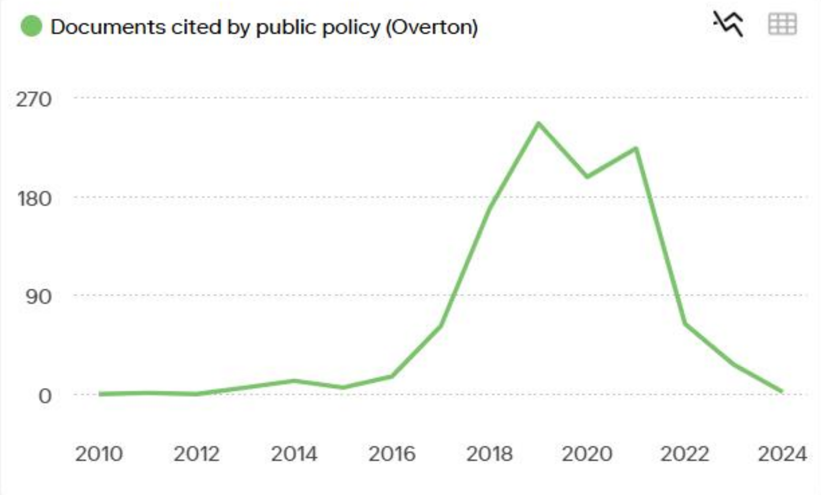

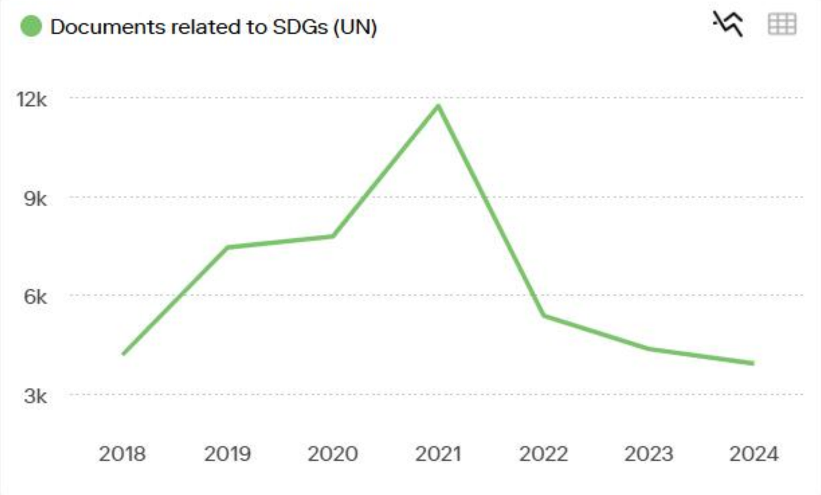

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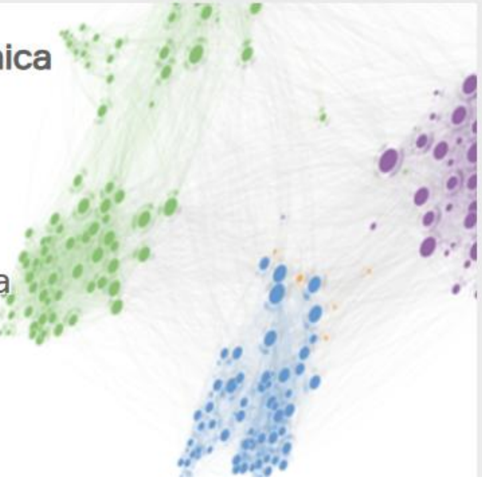

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Environmental Impact Assessment of Steel Production in Indonesia : A Case Study

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Abstract. One of the biggest energy consumers and CO2 emitters in the world is the steel sector. With the growth in infrastructure construction, steel output has risen year over year. Therefore, a life cycle assessment of inputs and outputs at each stage of the steel manufacturing process is necessary to enable the adoption of life cycle management and offer sustainable production and consumption. The Life Cycle Assessment method is employed in this study to assess the environmental effects of steel manufacturing in Indonesia. The CML-IA baseline method, which assesses several impact categories including global warming, ozone layer depletion, acidification, and eutrophication, and others impact was used in this study and SimaPro 9.2 software was used to calculate the environmental impact of steel production. According to the findings, the largest contributors to the overall impact are the electric arc furnace, rolling mills, ladle furnaces, which use chemicals, and reheating furnaces, which use LPG. The entire impact of the steel manufacturing process on global warming, using a functional unit of 1 ton steel, is 1215.17 kg CO2 eq, of which the Electric Arc Furnace (EAF) contributes 477.37 kg CO2 eq, or 39% of the total CO2 emissions. Based on these findings, an effort is therefore required to reduce the consumption of fuel in the reheating furnace as well as electricity in the EAF and rolling mills.

1. Introduction

One of the industrial items that finds extensive application throughout a range of industries, including transportation, construction, and building, is steel [1]. After the chemical sector, the iron and steel industry consumes the second-highest amount of energy globally and ranks among the top emitters of CO2 [2]–[4]. 3.2% of the emissions of greenhouse gases come from the steel industry. 15% of industrial emissions come from this category of business [5]. Climate change can be brought on by greenhouse gas emissions from industrial operations, hence this issue needs to be addressed [6]. A total of 84.26 million tonnes of crude steel were produced in 2019, more than double the amount produced over the previous three decades [7]. A difficulty is that, in addition to the anticipated rise in infrastructure development and demand for construction steel, there may also be significant environmental risks from the steel manufacturing process. While there are potential environmental hazards that cannot be avoided, infrastructure development is expanding. This illustrates the need for actions to lessen the effects of the steel-making process on the environment. In order to determine how the steel production process affects the environment, one way that can be used is the Life Cycle Assessment (LCA) method.

LCA is an assessment of the life cycle of a product system by compiling and evaluating inputs, outputs and potential environmental impacts. The input in question is the flow of raw materials,

materials, or energy that enters the process unit, while the output is the flow out of the process unit, which can be in the form of emissions into the air and discharge to water and soil. or still in the form of materials or materials to enter the next process unit [8]. LCA evaluates the environmental impacts associated with collecting raw materials from the earth, until the materials return to the earth, including all by-products to the air, water, and soil. LCA describes all activities and environmental impacts comprehensively [9]. LCA results can be used to develop better production processes, foster initiatives to innovate products or processes, design products, improve environmental management systems, and assist companies in setting corporate strategies for sustainable development [10].

Impact assessment of steel products using LCA has been studied in a number of countries. Li investigated the CO2 emissions from the iron and steel industry in China [11]. This study investigated direct and indirect CO2 emissions, and the findings showed that the primary direct emission sources are coke and coal, while indirect emissions are produced by the transportation sector, petroleum processing, mineral production, and coal mining. Another study that analyzed the environmental effects of steel manufacturing in Italy [1] came to the conclusion that using the slag from steel production as a raw material in construction and agriculture can lessen the environmental impact of steel production. Backes [2] used a 1 kg hot-rolled coil functional unit to undertake a cradle to gate examination of the steel production process. According to this study, power plants, which have a 48% global warming potential (GWP) value, are the biggest emitters, followed by blast furnaces, which have a 22% GWP value. To ensure the sustainability of the steel industry in Indonesia, a life cycle evaluation of steel products must be performed as there has been very little research done on the examination of the environmental impact of steel manufacturing in Indonesia. With the help of LCA, this study examine the effects on the environment of producing one type of steel product in Indonesia. In order to optimize that process, hotspot detection is used to identify the step that affects the steelmaking process overall the most.

2. METHODS

SimaPro software was used to process the LCA data. According to ISO 14040 and 14044, the attributional LCA processes were carried out and followed:

Goal and scope definition: The process with the greatest environmental impact from steel production activities in one of the steel companies in Indonesia is identified by this study using the life cycle assessment method. The research's objectives were accomplished within its parameters and purview. The input and output of each step of production are converted in accordance with the functional unit of 1 ton of steel in 2020, which serves as the measurement or functional unit in this study. The steel manufacturing process is covered by this study, which comprises the electric arc furnace (EAF), ladle furnace (LF), continuous casting machine (CCM), reheating furnace (RF), rolling mills (RM), and finishing mills (FM) (see Figure 1). This analysis excludes transport between processes. Global warming potential (GWP), abiotic depletion (ADP), ozone layer depletion (ODP), human toxicity (HT), freshwater aquatic ecotoxicity (FAETP), terrestrial ecotoxicity (TETP), photochemical oxidation (POP), acidification (AP), and eutrophication (EP) are among the effect categories that are assessed using the CML-IA baseline technique.

Life Cycle Inventory: Inventory analysis gathers data on physical flows for product systems, including inputs of resources, materials, semi-products, products, emission outputs, and waste products. At this point, data input is recapitulated in the form of electrical energy, raw materials, and chemicals, and the outputs take the form of the goods produced by each unit that processes products.

Life Cycle Impact Assessment (LCIA): process for assessing potential environmental effects by categorizing LCI outcomes. Characterization is done during the environmental impact evaluation stage by directly comparing the results (LCI) in each effect category that is investigated based on the method used.

Interpretation: conclusions, constraints, and recommendations are all part of interpretation.

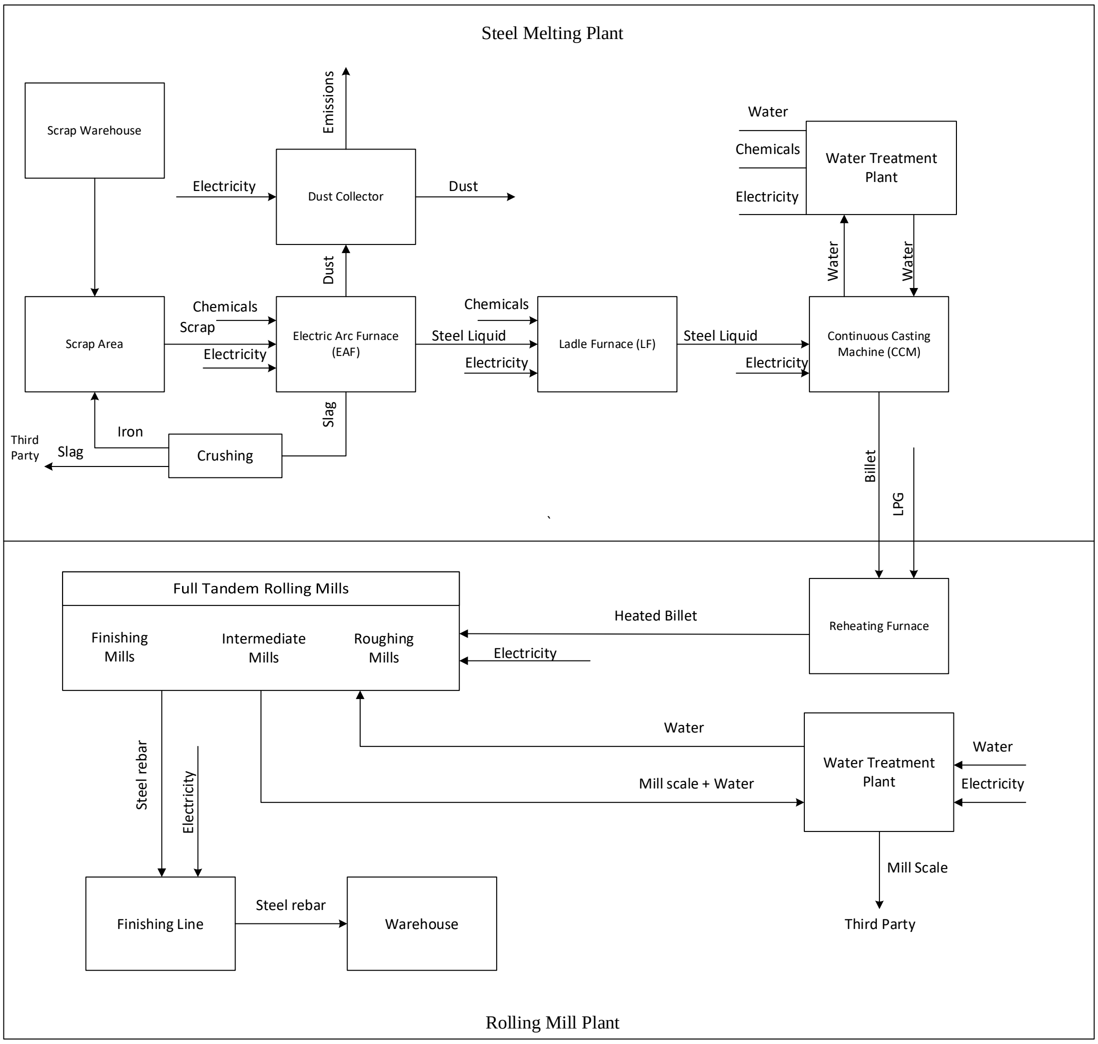

Figure 1. The system boundaries of steel production

3. Results and Discussion

The initial stage carried out is the Life Cycle Inventory, which is a data recapitulation of electrical energy, raw materials, chemicals and products produced from each product processing unit. The data obtained from the data recording of the Steel Melting Department and the Rolling Mills. For units that are not the same, a unit value conversion is carried out for each unit to facilitate data input and processing in the Simapro software. After entering the process, as well as the number of inputs and outputs from each process, analysis is carried out which will quantify the inputs that have been entered so that the magnitude of the impact is obtained. The following is the table of inflow and outflow of each process of steel production.

The life cycle impact evaluation was calculated by characterizing using the ISO 14040 process, so the results are not normalized. By multiplying LCI results by the characterisation factor and grouping the conversion results into the same impact category, one can calculate indicator outcomes (characterization).

Table 1. The life cycle inventory of steel production (1 ton)

Input			Output		
Material	Amount	Unit	Material	Amount	Unit
Electric Arc Furnace					
Scrap	1,101	tons	Liquid steel	1,011	tons
Electricity	390.82	KwH	Slag	0.064	tons
CaO	0.036	tons	Dust	0.064	tons
Carbonizer	0.002	tons			
LNG	101.8	MJ			
Oxygen	8.07	Nm^3			
Electric Dust Collector	24.68	KwH			
Ladle Furnace					
Liquid steel	1,011	tons	Liquid Steel	1.03	tons
Carbonizer	0.003	tons			
FeSi	0.001	ton			
SiMn	0.011	ton			
FeCrom	0.002	ton			
CaO	0.007	ton			
Argon	34,784	kg			
Nitrogen	1,491	ppm			
Electricity	47.86	KwH			
Continuous Casting Machine					
Liquid steel	1.03	ton	Billets	1.03	ton
Electricity	13.06	KwH			
Water	0.879	m^3			
Oxygen	0.183	m^3			
LPG	0.382	kg			
Reheating Furnace					
Billets	1.03	tons	Heated billets	1.03	tons
LPG	47,127	m^3			
Rolling Mills					
Heated billets	1.03	ton	Deformed Steel	1	ton
Electricity	363.57	KwH	Mill scale	0.03	ton
Water	0.310	m^3	Water	0.310452864	m^3
Finishing Line					
Deformed Steel	1	ton	Deformed Steel	1	ton
Electricity	18.49	KwH			

The ISO 14040 standard approach was used to determine the environmental effect data up until the characterization stage, hence the results are not normalized. According to the classification and characterization processes of the impact analysis per functional unit, the impact of each category for each lifecycle phase is represented in Table 2 as absolute values.

Based on the Table 1, it can be seen that 1 ton of steel produces an impact on Global warming of 1215.165 kg CO_2 eq, with the process that has the greatest contribution to the category of Global warming impact is the Electric Arc Furnace with an impact contribution of 477.36 kg CO_2 eq, followed by Rolling Mills with a contribution of 395.55 kg CO_2 eq, Ladle furnace with a contribution of 174.37 kg CO_2 eq, and Reheating Furnace with a contribution of 132.99 kg CO_2 eq. The cause of the large contribution to Global Warming from the Electric Arc Furnace, and Rolling Mills process is the result of indirect emissions resulting from large electricity consumption. Meanwhile, the Reheating Furnace is caused by the use of LPG fuel to reheat the billet before entering the Rolling Mills. Characterization can also be displayed in graphic form. Figure 2 displays the quantification and characterisation of each step of the manufacturing process in relation to the impact category.

Table 2. Characterization of Steel Product

Impact category	Unit	EAF	LF	CCM	RF	RM	FM	Total
GWP	kg CO2 eq	477.37	174.37	14.26	132.99	395.44	20.73	1215.17
ODP	kgCFC-11-eq	$2.95x10^{5}$	$7.69x10^{-6}$	$4.17x10^{-7}$	$1.65x10^{-5}$	$1.16x10^{-5}$	$6.07x10^{-7}$	$5.77x10^{-5}$
HT	kg 1,4-DB eq	356.91	96.52	8.44	11.56	234.09	12.27	719.81
FAETP	kg 1,4-DB eq	447.78	86.10	12.90	9.28	357.87	18.76	932.69
ADP	kg Sb eq	$3.6x10^{-3}$	$2.2x10^{-4}$	$1.2x10^{-5}$	$1.7x10^{-4}$	$3.3x10^{-4}$	$1.75x10^{-5}$	$4.3x10^{-3}$
TETP	kg 1,4-DB eq	0.96	0.29	0.03	0.045	0.83	0.04	2.21
POP	kg C2H4 eq	0.073	0.052	0.002	0.013	0.057	0.003	0.200
AP	kg SO2 eq	2.22	0.82	0.063	0.11	1.77	0.09	5.07
EP	kg PO4--- eq	2.37	0.47	0.08	0.02	2.17	0.11	5.23

The contribution of each production step to the effect category is depicted in Figure 2. Overall, Electric Arc Furnace contributes the most to all impact categories, with very little help from scrap, lime, and other additives, with the majority of this contribution coming from the high energy usage. Due to the lack of certain materials added to either production process, as well as the comparatively low quantity of electricity needed, finishing mills and continuous casting machines contribute the least overall to all impact categories. Except for the effect category for the ozone layer depletion, where the usage of LPG makes the reheating furnace the second largest contributor after the electric arc furnace, production activities associated to rolling mills are the second largest contributor in every impact category. Due to the employment of chemicals as a material in the Ladle furnace process to generate the required steel requirements, the contribution of ladle furnaces to the impact of photochemical oxidation has a value that is practically equivalent to Rolling mills.

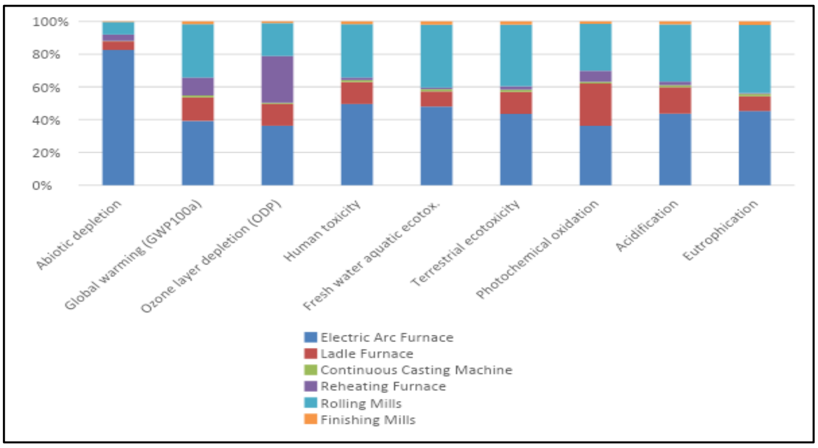

Figure 2. Classification of the product lifecycle according to impact category – analysis of the contribution of the steel production stages for all impact categories

Based on the results of previous studies on a steel melting industry in Poland [12], it is known that the contribution to Global Warming from electricity consumption in the EAF is 469 kg CO_2 eq. In addition, an LCA study on a steel industry in China found that the total impact on the global warming category was 1042.8 kg CO_2 eq, slightly lower than the total impact on global warming in this study. However, in that study, the steel melting process used the basic oxygen furnace [13]. Figure 3 show the impact contribution of each raw material in the steel production process. It is known that the process that has the largest contribution is electricity. So based on the results, an effort is needed to minimize the use of electricity in the EAF and rolling mills, as well as the use of fuel in the reheating furnace.

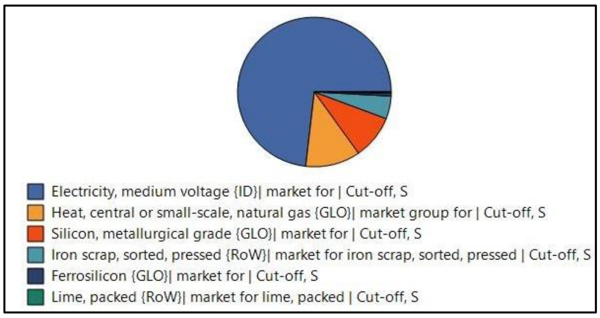

Figure 3. Characterization distribution of materials

4. Conclusions

Utilizing the LCA method, an environmental impact analysis of the steel production process in Indonesia was conducted. Using Simapro software and the CML-IA baseline method, the environmental impact was calculated. GWP, ADP, ODP, HT, FAETP, TETP, POP, AP, and EP are among the effect categories that were examined. A ton of steel has a functional impact of 1215.17 kg CO2 eq, and 39% (477.37 kg CO2 eq) of the total CO2 emissions from the steel manufacturing process come from EAF. The reason EAF and rolling mills have such a significant influence on global warming and each category of impact is because of how much electricity they require. LPG is utilized for billet reheating, which in turn fuels the reheating furnace process. Due to the extensive and intensive use of power in the steel smelting and processing business, electricity consumption is the most significant effect category. Based on these findings, an effort is therefore required to reduce the use of fuel in the RF as well as power in the EAF and rolling mills. By presenting multiple scenarios for the steel production process, more research may be done by using LCA to analyze each scenario's environmental impact. The ideal scenario for enhancing the manufacturing process that can reduce the environmental impact of the steel production process can be used by steel producers based on the findings.

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Environmental Impact Assessment of Steel Production in Indonesia : A Case Study

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Abstract. One of the biggest energy consumers and CO2 emitters in the world is the steel sector. With the growth in infrastructure construction, steel output has risen year over year. Therefore, a life cycle assessment of inputs and outputs at each stage of the steel manufacturing process is necessary to enable the adoption of life cycle management and offer sustainable production and consumption. The Life Cycle Assessment method is employed in this study to assess the environmental effects of steel manufacturing in Indonesia. The CML-IA baseline method, which assesses several impact categories including global warming, ozone layer depletion, acidification, and eutrophication, and others impact was used in this study and SimaPro 9.2 software was used to calculate the environmental impact of steel production. According to the findings, the largest contributors to the overall impact are the electric arc furnace, rolling mills, ladle furnaces, which use chemicals, and reheating furnaces, which use LPG. The entire impact of the steel manufacturing process on global warming, using a functional unit of 1 ton steel, is 1215.17 kg CO2 eq, of which the Electric Arc Furnace (EAF) contributes 477.37 kg CO2 eq, or 39% of the total CO2 emissions. Based on these findings, an effort is therefore required to reduce the consumption of fuel in the reheating furnace as well as electricity in the EAF and rolling mills.

1. Introduction

One of the industrial items that finds extensive application throughout a range of industries, including transportation, construction, and building, is steel [1]. After the chemical sector, the iron and steel industry consumes the second-highest amount of energy globally and ranks among the top emitters of CO2 [2]–[4]. 3.2% of the emissions of greenhouse gases come from the steel industry. 15% of industrial emissions come from this category of business [5]. Climate change can be brought on by greenhouse gas emissions from industrial operations, hence this issue needs to be addressed [6]. A total of 84.26 million tonnes of crude steel were produced in 2019, more than double the amount produced over the previous three decades [7]. A difficulty is that, in addition to the anticipated rise in infrastructure development and demand for construction steel, there may also be significant environmental risks from the steel manufacturing process. While there are potential environmental hazards that cannot be avoided, infrastructure development is expanding. This illustrates the need for actions to lessen the effects of the steel-making process on the environment. In order to determine how the steel production process affects the environment, one way that can be used is the Life Cycle Assessment (LCA) method.

LCA is an assessment of the life cycle of a product system by compiling and evaluating inputs, outputs and potential environmental impacts. The input in question is the flow of raw materials,

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materials, or energy that enters the process unit, while the output is the flow out of the process unit, which can be in the form of emissions into the air and discharge to water and soil. or still in the form of materials or materials to enter the next process unit [8]. LCA evaluates the environmental impacts associated with collecting raw materials from the earth, until the materials return to the earth, including all by-products to the air, water, and soil. LCA describes all activities and environmental impacts comprehensively [9]. LCA results can be used to develop better production processes, foster initiatives to innovate products or processes, design products, improve environmental management systems, and assist companies in setting corporate strategies for sustainable development [10].

Impact assessment of steel products using LCA has been studied in a number of countries. Li investigated the CO2 emissions from the iron and steel industry in China [11]. This study investigated direct and indirect CO2 emissions, and the findings showed that the primary direct emission sources are coke and coal, while indirect emissions are produced by the transportation sector, petroleum processing, mineral production, and coal mining. Another study that analyzed the environmental effects of steel manufacturing in Italy [1] came to the conclusion that using the slag from steel production as a raw material in construction and agriculture can lessen the environmental impact of steel production. Backes [2] used a 1 kg hot-rolled coil functional unit to undertake a cradle to gate examination of the steel production process. According to this study, power plants, which have a 48% global warming potential (GWP) value, are the biggest emitters, followed by blast furnaces, which have a 22% GWP value. To ensure the sustainability of the steel industry in Indonesia, a life cycle evaluation of steel products must be performed as there has been very little research done on the examination of the environmental impact of steel manufacturing in Indonesia. With the help of LCA, this study examine the effects on the environment of producing one type of steel product in Indonesia. In order to optimize that process, hotspot detection is used to identify the step that affects the steelmaking process overall the most.

2. METHODS

SimaPro software was used to process the LCA data. According to ISO 14040 and 14044, the attributional LCA processes were carried out and followed:

Goal and scope definition: The process with the greatest environmental impact from steel production activities in one of the steel companies in Indonesia is identified by this study using the life cycle assessment method. The research's objectives were accomplished within its parameters and purview. The input and output of each step of production are converted in accordance with the functional unit of 1 ton of steel in 2020, which serves as the measurement or functional unit in this study. The steel manufacturing process is covered by this study, which comprises the electric arc furnace (EAF), ladle furnace (LF), continuous casting machine (CCM), reheating furnace (RF), rolling mills (RM), and finishing mills (FM) (see Figure 1). This analysis excludes transport between processes. Global warming potential (GWP), abiotic depletion (ADP), ozone layer depletion (ODP), human toxicity (HT), freshwater aquatic ecotoxicity (FAETP), terrestrial ecotoxicity (TETP), photochemical oxidation (POP), acidification (AP), and eutrophication (EP) are among the effect categories that are assessed using the CML-IA baseline technique.

Life Cycle Inventory: Inventory analysis gathers data on physical flows for product systems, including inputs of resources, materials, semi-products, products, emission outputs, and waste products. At this point, data input is recapitulated in the form of electrical energy, raw materials, and chemicals, and the outputs take the form of the goods produced by each unit that processes products.

Life Cycle Impact Assessment (LCIA): process for assessing potential environmental effects by categorizing LCI outcomes. Characterization is done during the environmental impact evaluation stage by directly comparing the results (LCI) in each effect category that is investigated based on the method used.

Interpretation: conclusions, constraints, and recommendations are all part of interpretation.

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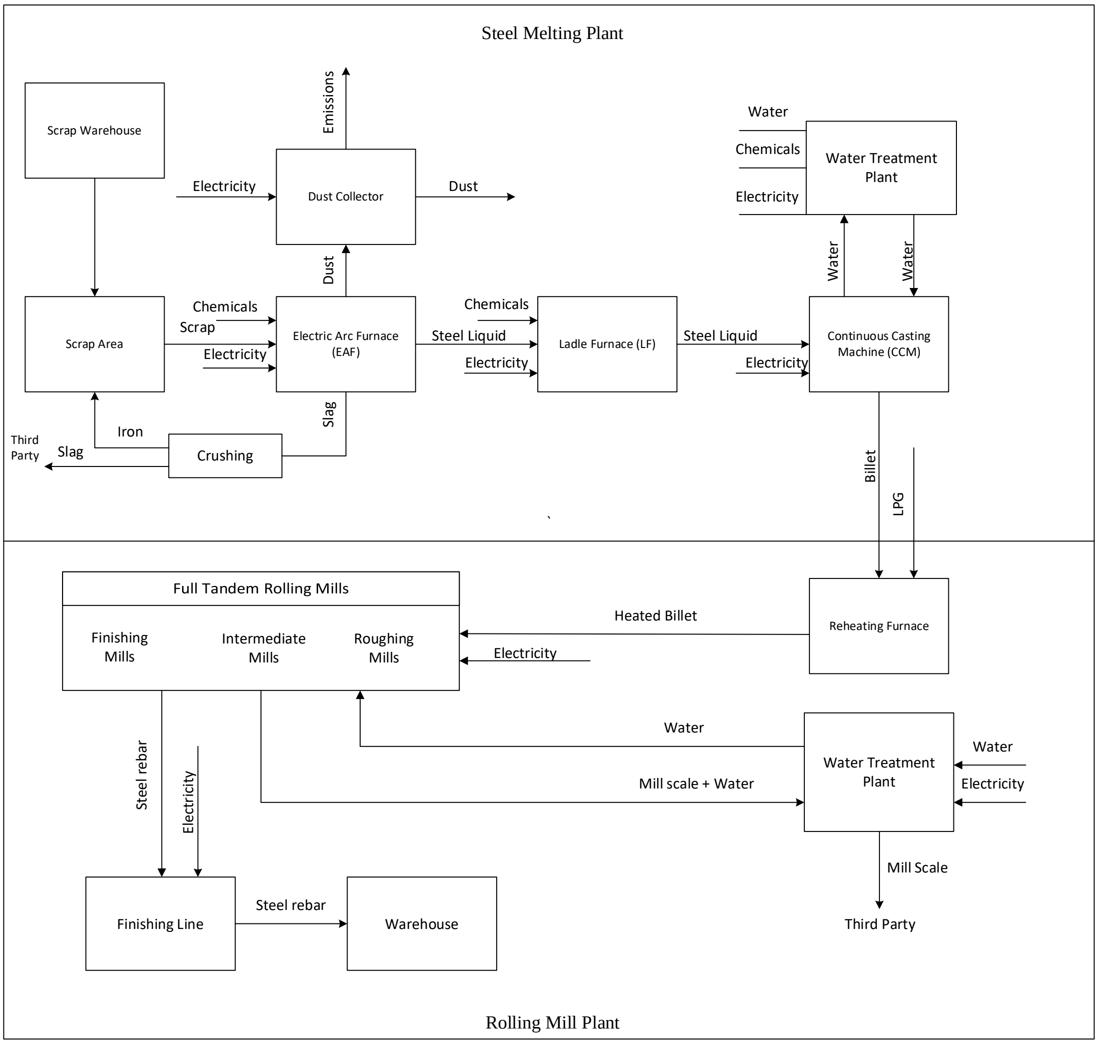

Figure 1. The system boundaries of steel production

3. Results and Discussion

The initial stage carried out is the Life Cycle Inventory, which is a data recapitulation of electrical energy, raw materials, chemicals and products produced from each product processing unit. The data obtained from the data recording of the Steel Melting Department and the Rolling Mills. For units that are not the same, a unit value conversion is carried out for each unit to facilitate data input and processing in the Simapro software. After entering the process, as well as the number of inputs and outputs from each process, analysis is carried out which will quantify the inputs that have been entered so that the magnitude of the impact is obtained. The following is the table of inflow and outflow of each process of steel production.

The life cycle impact evaluation was calculated by characterizing using the ISO 14040 process, so the results are not normalized. By multiplying LCI results by the characterisation factor and grouping the conversion results into the same impact category, one can calculate indicator outcomes (characterization).

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Table 1. The life cycle inventory of steel production (1 ton)

Input			Output		
Material	Amount	Unit	Material	Amount	Unit
Electric Arc Furnace					
Scrap	1,101	tons	Liquid steel	1,011	tons
Electricity	390.82	KwH	Slag	0.064	tons
CaO	0.036	tons	Dust	0.064	tons
Carbonizer	0.002	tons			
LNG	101.8	MJ			
Oxygen	8.07	Nm^3			
Electric Dust Collector	24.68	KwH			
Ladle Furnace					
Liquid steel	1,011	tons	Liquid Steel	1.03	tons
Carbonizer	0.003	tons			
FeSi	0.001	ton			
SiMn	0.011	ton			
FeCrom	0.002	ton			
CaO	0.007	ton			
Argon	34,784	kg			
Nitrogen	1,491	ppm			
Electricity	47.86	KwH			
Continuous Casting Machine					
Liquid steel	1.03	ton	Billets	1.03	ton
Electricity	13.06	KwH			
Water	0.879	m^3			
Oxygen	0.183	m^3			
LPG	0.382	kg			
Reheating Furnace					
Billets	1.03	tons	Heated billets	1.03	tons
LPG	47,127	m^3			
Rolling Mills					
Heated billets	1.03	ton	Deformed Steel	1	ton
Electricity	363.57	KwH	Mill scale	0.03	ton
Water	0.310	m^3	Water	0.310452864	m^3
Finishing Line					
Deformed Steel	1	ton	Deformed Steel	1	ton
Electricity	18.49	KwH			

The ISO 14040 standard approach was used to determine the environmental effect data up until the characterization stage, hence the results are not normalized. According to the classification and characterization processes of the impact analysis per functional unit, the impact of each category for each lifecycle phase is represented in Table 2 as absolute values.

3 Based on the Table 1, it can be seen that 1 ton of steel produces an impact on Global warming of 1215.165 kg CO_2 eq, with the process that has the greatest contribution to the category of Global
3 warming impact is the Electric Arc Furnace with an impact contribution of 477.36 kg CO_2 eq, followed
7 by Rolling Mills with a contribution of 395.55 kg CO_2 eq, Ladle furnace with a contribution of 174.37 kg CO_2 eq, and Reheating Furnace with a contribution of 132.99 kg CO_2 eq. The cause of the large contribution to Global Warming from the Electric Arc Furnace, and Rolling Mills process is the result of indirect emissions resulting from large electricity consumption. Meanwhile, the Reheating Furnace is caused by the use of LPG fuel to reheat the billet before entering the Rolling Mills. Characterization can also be displayed in graphic form. Figure 2 displays the quantification and characterisation of each step of the manufacturing process in relation to the impact category.

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Table 2. Characterization of Steel Product

Impact category	Unit	EAF	LF	CCM	RF	RM	FM	Total
GWP	kg CO2 eq	477.37	174.37	14.26	132.99	395.44	20.73	1215.17
ODP	kgCFC-11-eq	2.95×10^{5}	7.69×10^{-6}	4.17×10^{-7}	1.65×10^{-5}	1.16×10^{-5}	6.07×10^{-7}	5.77×10^{-5}
HT	kg 1,4-DB eq	356.91	96.52	8.44	11.56	234.09	12.27	719.81
FAETP	kg 1,4-DB eq	447.78	86.10	12.90	9.28	357.87	18.76	932.69
ADP	kg Sb eq	3.6×10^{-3}	2.2×10^{-4}	1.2×10^{-5}	1.7×10^{-4}	3.3×10^{-4}	1.75×10^{-5}	4.3×10^{-3}
TETP	kg 1,4-DB eq	0.96	0.29	0.03	0.045	0.83	0.04	2.21
POP	kg C2H4 eq	0.073	0.052	0.002	0.013	0.057	0.003	0.200
AP	kg SO2 eq	2.22	0.82	0.063	0.11	1.77	0.09	5.07
EP	kg PO4--- eq	2.37	0.47	0.08	0.02	2.17	0.11	5.23

The contribution of each production step to the effect category is depicted in Figure 2. Overall, Electric Arc Furnace contributes the most to all impact categories, with very little help from scrap, lime, and other additives, with the majority of this contribution coming from the high energy usage. Due to the lack of certain materials added to either production process, as well as the comparatively low quantity of electricity needed, finishing mills and continuous casting machines contribute the least overall to all impact categories. Except for the effect category for the ozone layer depletion, where the usage of LPG makes the reheating furnace the second largest contributor after the electric arc furnace, production activities associated to rolling mills are the second largest contributor in every impact category. Due to the employment of chemicals as a material in the Ladle furnace process to generate the required steel requirements, the contribution of ladle furnaces to the impact of photochemical oxidation has a value that is practically equivalent to Rolling mills.

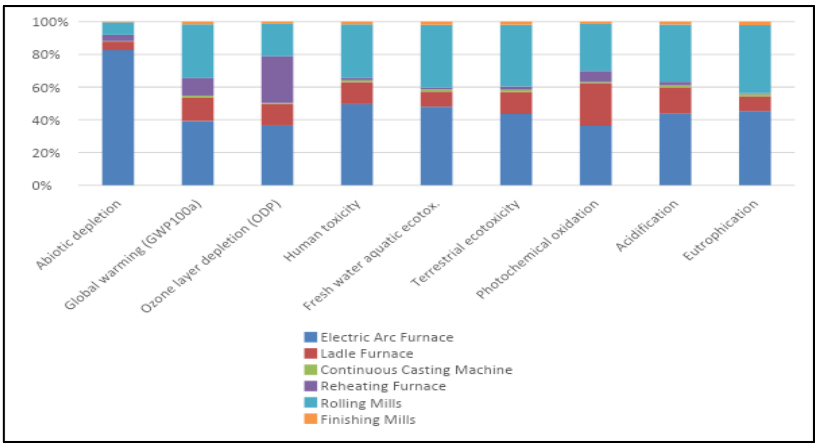

Figure 2. Classification of the product lifecycle according to impact category – analysis of the contribution of the steel production stages for all impact categories

Based on the results of previous studies on a steel melting industry in Poland [12], it is known that the contribution to Global Warming from electricity consumption in the EAF is 469 kg CO_2 eq. In addition, an LCA study on a steel industry in China found that the total impact on the global warming category was 1042.8 kg CO_2 eq, slightly lower than the total impact on global warming in this study. However, in that study, the steel melting process used the basic oxygen furnace [13]. Figure 3 show the impact contribution of each raw material in the steel production process. It is known that the process that has the largest contribution is electricity. So based on the results, an effort is needed to minimize the use of electricity in the EAF and rolling mills, as well as the use of fuel in the reheating furnace.

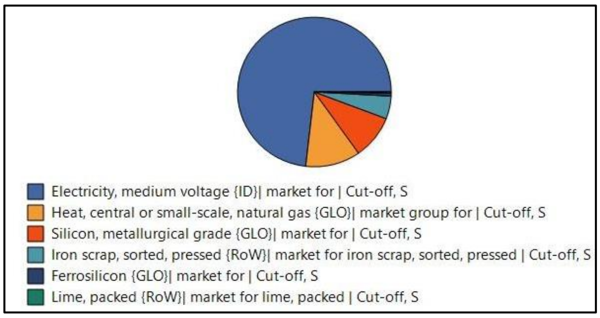

Figure 3. Characterization distribution of materials

4. Conclusions

Utilizing the LCA method, an environmental impact analysis of the steel production process in Indonesia was conducted. Using Simapro software and the CML-IA baseline method, the environmental impact was calculated. GWP, ADP, ODP, HT, FAETP, TETP, POP, AP, and EP are among the effect categories that were examined. A ton of steel has a functional impact of 1215.17 kg CO2 eq, and 39% (477.37 kg CO2 eq) of the total CO2 emissions from the steel manufacturing process come from EAF. The reason EAF and rolling mills have such a significant influence on global warming and each category of impact is because of how much electricity they require. LPG is utilized for billet reheating, which in turn fuels the reheating furnace process. Due to the extensive and intensive use of power in the steel smelting and processing business, electricity consumption is the most significant effect category. Based on these findings, an effort is therefore required to reduce the use of fuel in the RF as well as power in the EAF and rolling mills. By presenting multiple scenarios for the steel production process, more research may be done by using LCA to analyze each scenario's environmental impact. The ideal scenario for enhancing the manufacturing process that can reduce the environmental impact of the steel production process can be used by steel producers based on the findings.

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