"Environmental costs estimation and mathematical model of marginal social cost: A case study of coal power plants"

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NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
47	7	1

BUSINESS PERSPECTIVES

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ENVIRONMENTAL COSTS ESTIMATION AND MATHEMATICAL MODEL OF MARGINAL SOCIAL COST: A CASE STUDY OF COAL POWER PLANTS

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Abstract

An increase in electricity production is proportional to environmental risks due to continuous energy production. The paper aims to quantitatively estimate the environmental costs and mathematically model the marginal social cost associated with the lifespan of the coal power plants. Results revealed South Africa Tier 1 company optimum level of electricity production per annum at around 2.15 gigawatts, considering the emission costs and reasonable profit. 85% of the total emissions during the combustion phase average cost of the C02 emission discharged by coal is calculated as 0.23c/KWh, 0.085c/kWh is calculated for NO2, while SO2 is 0.035c/KWh. Total emission cost represents 69.2% of the total cost of producing 1 MGW of electricity. The results confirmed the company losses to be insignificantly considerable to the evaluated environmental costs and capital investment. However, the use of this newly developed mathematical model depends on the source of energy production to confirm the feasibility and profitability of investment in coal-powered stations using environmental management accounting and marginal social cost approaches.

Keywords	energy, South Africa, fossil fuel, greenhouse gas, emission
JEL Classification	Q56

INTRODUCTION

Energy production is a critical infrastructure that contributes greatly to economic growth in any part of the world. The availability of sustainable and affordable energy determines the rate of economic growth that will be achieved by any nation around the globe. South Africa's economy is facing growing challenges in the recent time, many factors contributing to the challenge is the energy shortage (Lipton, 2013). Energy availability is one of the critical factors of any economy because of its impact on production and the real economy (Hagens, 2020). Energy demand and consumption for both business and household activity needs have increased, largely due to urbanization and the growth of the South African economy. In the process of generating electricity, ESKOM is a significant user of South Africa's natural resources, namely coal and fresh water. Given its current power generation mix, it has a considerable carbon dioxide (CO_2) footprint and is a large emitter of sulfur dioxide (SO_2), nitrogen (NO_2), and particulates. During the 2011 financial year, the company used 327bn liters of fresh water and emitted 230 Mt of CO_2, 1 810 kt of SO_2, and 977 kt of NO_2 (ESKOM, 2020). South Africa is positioned among the world's first 15 biggest carbon dioxide producers, due to the country's substantial reliance on coal supplies at 92% of the nation's electricity power (Eberhard et al., 2016).

Coal produces emissions that contaminate the atmosphere which hurts human health. In this regard, the United Nations and South African government have been designing ways of reducing carbon emission, leading to the signatory of the Kyoto Protocol and Paris Agreement's Article 2 in 2015. South Africa adopted the use of a greenhouse gas (GHG) inventory-based approach for all sectors of the economy to reduce its CO_2 emissions. The challenges of meeting the nation's environmental change moderation objectives, National Treasury in 2013 proposed the introduction of carbon emission taxes. Target levels set to consider these will be accounted for using global warming potential (GWP) values to reduce the upper range targets of the country to 17% by 2025 and 28% by 2030 specified in the Annex to decision 18/CMA.1 (IPCC, 2019). Coal as a primary source of energy input in electricity generation produces harmful environmental emissions that are hazardous to human, aquatic and agricultural activities (Munawer, 2018). The significant emission generated by coal activities includes CO_2, NO_2, and SO_2 (Nazari et al., 2010). These emissions are needed to be accounted for and subsequently internalized. At the moment, ESKOM does not include the cost of these emissions in its cost of electricity production (Chakamera & Alagidede, 2018), but paid emission tax for the limit exceeds the minimum limit. For emission to be included in the cost of production, they needed to be giving monetary value (Nkambule & Blignaut, 2017). The household electricity segment creates the majority of its yield from coal-powered plants that contribute huge CO_2 discharge and will be at the receiving end of the proposed carbon tax. The carbon discharges of various innovations can be differentiated using CO_2 emissions per kilowatt-hour of electricity produced. This mirrors the aggregate of CO_2 produced during the useful life of the generating plants.

In the evaluation and appraisal of capital budgeting investment, the demands of a detailed analysis of projected costs in the long term and the proposed investment projects revenues were identified (Mellichamp, 2019). The decision-making for investments in electricity generation as explored (Trianni et al., 2017) justified the motivation with obstacles to ensure environmental costs estimation and compliance with social costs adoption for profitability, and organizational behaviors, which serve as obstacles to having long-term decisions on energy investment. The triad of environmental, social, and governance aspects (ESG) is a basis for forming investment standards, institutional investment, environment, and market in developing countries, and regulation as an investment policy mechanism (Fakoya, 2013). The ESG criterion to improve companies' activity best practices in indexes surveys, and ratings based on investor decision-making was presented by SHIFT (2017).

Consequently, the problem related to quantifying environmental risk costs due to continuous energy production has been clearly stated. Therefore, this study explores the need to quantitatively measure the environmental risk and associated hazard to the environment using an environmental costs estimation and mathematical model of marginal social cost to enhance the completeness and accuracy of making capital investment decisions in the aspect of electricity generation.

1. LITERATURE REVIEW

The theory of political economy accounting in economics, sustainable growth, and community was developed by Parker (1993) based on accounting for social and environmental aspects. It was believed that social support is essential to the existence of any corporate organization and ideal regulation of sustainable growth to an acceptable social level was suggested. Hamidu et al. (2015) postulated that an organization must ensure that its activities do not endanger society; otherwise, a business entity will lose societal support. The legitimacy theory was formed from the paradigm of political economy, which is of the assumption that corporations should discharge their social responsibility role by giving back to the community and meeting up with societal demands (Zyznarska-Dworczak, 2017). Over time, the primary goal of a business entity is to maximize profit, which serves as a benchmark of its performance, which has been recently overtaken by a more important indicator of been socially responsible to the host community. Legitimacy theory explains the rea-

son behind the reporting of environmental information (Alikhani et al., 2014). Beneficiaries' theory attempts to differentiate beneficiaries from the issues of the society; it suggests the use of guidelines to examine the organizational responsibility to the society through environmental information reporting (Ozili, 2020). The ethical pathway of this theory stated that beneficiaries such as investors have the right to access the information regarding the environment as disclosed by the organization (Alikhani et al., 2014). The organizational theory examines the structure and the operation of the organization concerning political, cultural, and social forces that surround the corporation. The organization needs to interact with these forces to ensure its stability. This theory assumes that several factors must be considered when reporting environmental accounting. These include impending dangers to the environment, organizational responsibilities towards these dangers, reviewing of the interaction between the organization and the environment and the utilization of the natural resources (coal), assessment of dangers to the environment, and reporting of environmental costs. Adenuga et al. (2020) presented these issues to include terrestrial habitats disturbance, water quality, air quality, emission of greenhouse gases (GHGs), and other pollutants impacts on the local community. This review suggested accounting theory as mitigation measures to address the potentially significant impacts on coal for electricity generation on the environment in addition to the entity's needs to respond to external expectations.

With the use of burners and fuel, coal is being converted into fossil fuel to generate electricity. 70% of the world's electricity is being generated by coal, and South African is ranked 7th in the world among the countries that generate electricity through coal. South Africa has coal abundance with an estimated 100bn tons of coal which includes reference coal provides around 85% of electricity generation in South Africa. 13 of 15 coal power stations operates by ESKOM are in full operation, with Medupi partially completed and Kusile is under construction. The total installed capacity of all the coal power station is more than 44,000 megawatts, which account for 93% of total installed capacity of all the power stations in South Africa. There are many reasons coal is being used as a primary and major source of elec-

tricity generation in South Africa. It is regarded as the cheapest source of energy and the largest deposit of hard coal resources in the country. As of 2013, South Africa's coal reserve is estimated at 32.1 billion tons. In the process of converting coal to fossil fuel, emissions are generated. This has been the shortcoming of coal technologies of electricity generation. Carbon emission is a global concern due to its adverse impact on human health, plants, and the environment (De Marco et al., 2019). South Africa is regarded as among the highest in carbon emittion (Okolo et al., 2019). It operates a highly energy-intensive economy with considerable dependency on fossil fuels to meet its energy needs. This, together with a relatively small population, means that South Africa is a significant contributor concerning per capita emissions of CO_2 on a global scale (Oke et al., 2017). Considering electricity production alone, 92% of electricity produced in South Africa is from coal combustion, complemented by nuclear energy (Oyewo et al., 2019). South Africa emits about 440 Mt. of CO_2 per annum and is responsible for over 40% of CO_2 emitted in the African continent. South Africa accounts for about 1% of global emissions and is ranked 11th highest CO_2 emitter in the world (Oke et al., 2017). This is a result of energy generation through coal utilization, which produces harmful emissions such as CO_2, NO_2, and SO_2 (Yang et al., 2019). Currently, South Africa's economy is facing growth challenges as a result of instability in energy production (Mohammed et al., 2013). Energy availability is one of the critical factors of production in any economy, and this is because of its impact on production and the real economy (Nkomo, 2005).

Due to the utilization of coal in electricity generation, South Africa has become a significant contributor to CO_2 emission in the world (Zhang et al., 2019). It accounts for 25% of carbon emissions in the world. CO_2 causes harmful effects on human health, such as respiratory diseases and lung infections, as a result of air pollution, which affects the quality of air intake (Munawer, 2018). It also brings about global warming, which affects aquatic lives and causes drought that has a negative impact on agricultural production, which would impact food security. According to ESKOM (2019), the process of electricity production involves the emission of 960g of CO_2 per kilowatt-hour (kWh)

produced; estimated to 194,000 kg of CO_2 emitted during the period. Carbon emission also accounted for 960 kg of CO_2 in every one MW of electricity produced by coal. Sustainable energy is the bedrock of economic growth worldwide (Awodumi & Adewuyi, 2020). The slow growth that is being witnessed in the South African economy can be directly attributed to the challenges faced by ESKOM in the area of production and supply of electricity required to stimulate the economic growth of the country (Kessides, 2014). One of the causes of these problems is the method employed by ESKOM to generate electricity, which is majorly by coal (Donnelly, 2019). Currently, coal is the highest method of generating energy worldwide and is utilized extensively in the production of electricity in different countries (Huaman & Jun, 2014). The use of coal as a significant source of energy production can be traced to the availability of coal as a natural resource in the country. Despite its abundant availability, using coal to generate electricity creates emissions such as carbon dioxide (CO_2), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) that damages the environment and causes health challenges to human (Munawer, 2018). According to Riekert and Koch (2017), the monetary value of each of the emissions discharged by coal are: CO_2 costs 0.23c/KWh; NO_2 costs 0.085c/kWh while SO_2 costs 0.035c/KWh. Despite that, these costs have been determined by several pieces of literature, none have been able to include these costs in the evaluation of capital investment of ESKOM prospective projects such as Medupi and Kusile power stations (Nkambule & Blignaut, 2017). The costs of these emissions are high and needed to be taken into consideration when determining the costs of producing electricity and even during the capital investment evaluation stage. There is no indication in the literature of ESKOM taking into account the environmental costs of using coal to generate electricity either during the evaluation of the capital investment or during the determination of costs of producing electricity through coal. The reason for these can be traced to lack of information about the costs of these emissions, these costs are regarded as external costs which are borne by the society and do not form a part of the private cost of ESKOM (Dwivedi, 2015). The impact of energy supply on the growth of any economy cannot be overemphasized; therefore, an investigation is required in this area of study. A steady energy supply has a direct impact on the development of any economy in the world. Therefore, there is a need to determine the costs of these emissions when determining the costs of producing electricity through coal, which can be subsequently included in the evaluation of capital investment of ESKOM in coal power stations which is the focus of this study. There is strong evidence that NO_2 respiratory exposure can trigger and exacerbate existing asthma symptoms, and may even lead to the development of asthma over more extended periods (Munawer, 2018). It has also been associated with heart disease, diabetes, birth outcomes, and all-cause mortality, but these nonrespiratory effects are less well-established. The other environmental impact of the use of coal to produce electricity is the emission of SO_2. SO_2 is one of the major pollutants derived from coal combustion processes; and this substance when treated concomitant with a Particulate matter (PM10) results in synergistic injury in terms of human cell survival and apoptosis occurrence (Yun et al., 2015).

Marginal social cost theory is the use of marginal cost to determine the externality of a cost that is borne by the society or third party apart from the manufacturer and consumer example is the emission that is produced by coal-powered electricity (Santos et al., 2010). The marginal social cost can also be used to determine the optimum production level that will achieve a desired profit for the firm and also maintain social benefit to the society (Nooij, 2011). This theory was considered based on its suitability and relevance in achieving the set objectives. Marginal social cost theory is the use of marginal cost to determine the externality of a cost that is borne by the society or third party apart from the manufacturer and consumer (Lipsey, 2018). The emission produced by coal-powered electricity is the representation the marginal social cost that can be used to determine the optimum production level to achieve a desired profit for the firm and also maintain social benefit to the society (Dwivedi, 2015).

Abella and Bayacag (2013) discovered a 10% increase in revenue leading to a 5.42% increase a disease rate, which will no doubt lead to worse health conditions in the Philippines subject to environmental emission. The relationship between economic development and environmen-

tal degradation is defined by the variable of operationalized environmental degradation as the emissions of CO_2 and SO_2 gauged by kilograms per capita. The use of quadratic and cubic terms was used to achieve a realistic representation of the relationship between the environment and economy (Sulemana et al., 2017; Gupta et al., 2016; Katircioglu et al., 2014). Investments in environmentally-friendly energy production may lack being placed above other projects due to the inability to be linked to the core business (Owusu & Asumadu-Sarkodie, 2016). The assessment requirement for investigated energy generation investments in relation to a successive application of net present value (NPV) and particularly the payback technique (PB) for electricity production projects (Emmanuel et al., 2010; Cooremans, 2012). A paradigm for social reality through philosophical assumptions in the form of epistemology, ontology knowledge, and axiology-belief system (Mukhalalati & Awaisu, 2019) leads to the positivism evidence interpreted by the mathematical model developed for this study. The post-positivist research principles mean the creation of new knowledge that can support committed social movements to aspire the world to change and contribute towards social justice (Mukhalalati & Awaisu, 2019).

Given this, the estimation of environmental risks due to continuous energy production to determine the accurate costs of electricity production using coal is the main purpose of this study. Therefore, a novel mathematical model was developed from the knowledge of environmental costs estimation associated with coal power plants' lifespan following the mathematical model of the marginal social cost approach.

2. METHODOLOGY

The marginal social cost model utilized data obtained from ESKOM operation the external cost (environmental costs) being borne by the consumer. The determination of tonnes of coals in each power plant according to available data estimated at 17 million tonnes of coal per annum to generate the install capacity. The CO_2 generated by 1 ton of coal is 2.17 tonne, 0.32kg of SO_2 and 0.18kg of NO_2 (Riekert & Koch, 2017). The cost per kg of each

emission as determined by the total environmental cost of two power generation investigated are estimated to be between R31bn to R60 billion per annum (R45bn on average). 70% of these costs are attributed to water damage, therefore the remaining 30% can be allocated to emissions (CO_2, NO_2, and SO_2) (Munawer, 2018).

This section explains the mode of data collection and subsequent analysis for this study. Secondary data over the past 20 years were obtained from ESKOM and are quantitative in nature. Statistics South Africa (2017) was contacted for data on sources of environmental damages and hazards as a result of electricity generation by ESKOM using coal and its capital budgeting practices and techniques adopted. Table 1 displays the information used for the regression analysis, pulled from the data set.

Table 1. Total costs and total revenue of electricity produced for the past 20 years

Source: ESKOM (2019).

Year	Total electricity sold (GWh)	TSC (Incl Ce) in R'Bill	TSB/TPB/TR (R'Bill)
2019	217508.22	R239.78	R197.45
2018	217199.67	R232.00	R184.75
2017	216561.00	R228.89	R181.04
2016	216417.50	R228.83	R165.00
2015	216274.00	R220.70	R146.87
2014	217903.00	R223.51	R136.89
2013	216561.00	R213.59	R126.67
2012	258856.00	R221.51	R130.13
2011	251121.50	R214.23	R57.88
2010	243387.00	R210.77	R53.26
2009	235652.50	R202.06	R48.81
2008	227918.00	R199.76	R44.55
2007	220183.50	R193.70	R40.46
2006	212449.00	R186.52	R36.56
2005	256959.00	R189.66	R41.22
2004	204714.50	R171.46	R35.33
2003	196980.00	R163.76	R31.67
2002	187957.00	R144.11	R28.16
2001	181511.00	R139.97	R24.98
2000	173776.50	R151.30	R21.79

As of March 2019, ESKOM operates 31 power stations located across the country, 1 of which is partially completed, and one is under construction. 31 power stations utilize different technologies to generate electricity such as coal, gas turbine, hydro, nuclear, and wind energies. This paper aims to estimate coal power generating plants data that was

used to determine the amount of emissions discharged in form of CO_2, NO_2, and SO_2. Marginal cost method was applied to determine the types of emissions that are produced in process of coal electricity generation. As a form of manufacturing entity uses direct inputs termed as variable costs, the relevant costs in relation to the production of electricity are coal and water. The quantity (tonnes) of coals consumed in each power station to generate a particular amount of electricity at the install capacity is important to know. According to data obtained, 530g of coal was used to produce 1 Megawatt per hour (MWH) of electricity; 1.46 kiloliter of water was used in the process. The CO_2 emitted by 1 ton of coal was 2.17 tonne; 0.32kg of SO_2 and 0.18kg of NO_2. The cost per kg of each emission was determined, as the total environmental cost of generating electricity using coal is estimated to be between R31bn to R60 billion per annum (R45bn on average). The total cost of producing 1MWh of electricity without taking the environmental costs of coal into account is:

$$TC = f(I). \tag{1}$$

Input costs are coal and water, and they can be referred to variable cost/relevant cost, therefore the equations can be explicitly presented as:

$$TC = f(coal, water). \tag{2}$$

$$TC_i = \beta_{i1}Coal_i + \beta_{i2}Water_i. \tag{3}$$

Since environmental costs are associated with using coal to generate electricity, the equation then becomes:

$$TC = f(I + C_e), \tag{4}$$

where C_e stands for the emissions of CO_2, NO_2, and SO_2 respectively as producing electricity through coal have negative externalities.

$$TC_i = \beta_{i1}Coal_i + \beta_{i2}Water_i + \\ +CO2_i + \beta_{i5}NO2_i + \beta_{i6}SO2_i. \tag{5}$$

$$TC_i = \beta_0 + \beta_{i1}Coal_i + \\ +\beta_{i2}Water_i + \beta_{i4}CO2_i + \\ +\beta_{i5}NO2_i + \beta_{i6}SO2_i + \mu. \tag{6}$$

Apriori Expectation:

$$\beta_1 - \beta_6 > 0. \tag{7}$$

Marginal social cost model was applied to determine the optimum production level for the desired profit to maintain social benefit to the society. The quantity/level of production where marginal social benefit is equal to marginal social cost is the optimum production level. Assuming that there is no external cost (negative), the market equilibrium is achieved at the point where marginal private cost (MPC) intersects marginal social benefit (MSB). This derives the profit/market surplus at this intersection, which connotes the average profitable point of electricity generation capacity. With the inclusion of environmental cost/marginal social cost (MSC), it is expected to shift the equilibrium point, as this will affect the cost of production:

$$TSC = TC_i. \tag{8}$$

$$TC_i = TC = f(I + C_e). \tag{9}$$

Therefore marginal social cost is:

$$MSC = \frac{\Delta TSC}{\Delta Q}. \tag{10}$$

$$MSC = \frac{1}{\Delta Q}\Delta(\beta_{i1}Coal_i + \beta_{i2}Water_i + \\ +\beta_{i4}CO2_i + \beta_{i5}NO2_i + \beta_{i6}SO2_i). \tag{11}$$

Total social benefit (TSB) will be equal to total private benefit (PB) which can also be equal to total revenue (TR) where the externalities are negative. The externalities caused by coal electricity production will give rise to negative externalities. TSB=TPB=TR, TPB=quantity produced/sold multiply by selling price per unit:

$$TPB = \beta_{i4}Q(SP). \tag{12}$$

Marginal social benefit:

$$MSC = \frac{\Delta TSB}{\Delta Q}. \tag{13}$$

Therefore the optimum quantity/production level is:

$$\frac{\Delta TSC}{\Delta Q} = \frac{\Delta TSB}{\Delta Q}. \tag{14}$$

The data obtained had some missing information, which has been completed using the moving average techniques, which is a well-known and accepted scientific forecasting method. Moving average is a technique that averages several most recent actual values, which is updated as new values become available (Stevenson, 2012).

This moving average is calculated using (15):

$$Ft = MA_n = \frac{\sum_{i=1}^{n} A_{t-i}}{n} = \tag{15}$$
$$= \frac{A_{t-n} + \ldots + A_{t-2} + A_{t-1}}{n},$$

where Ft – forecast for period t, MA_n – n period moving average, A_{t-i} – actual value in period $t-i$, n – number of periods (data points) in the moving average, which was set to 3 for this purpose of this study.

3. RESULTS AND DISCUSSION

As the first descriptive, Figure 1 shows that the production has been increasing with a fairly constant rate up to 2012, where the graphs display a drop in the quantity produced; the average production quantity is 218,494 GWh. On the other side, the cost of electricity produced kept a constant increase from 2000 to 2019 with a maximum

cost of R339/MWh. The second descriptive analysis was about the carbon footprint of coal usage in the generation of electricity. This analysis is displayed in Figure 2. The CO_2 emission is displayed in Mt and NO_2 and SO_2 emission are displayed in Kt to understand the quantity of these particles that were emitted every year during the generation of electricity using coal.

Regression analysis was done considering the total social cost of electricity as the dependent variable and the total amount of electricity sold as the independent variable. The scatter plot graph of this analysis is displayed in Figure 3, and this regression modeling has yielded a polynomial regression model displayed in equation 16. The polynomial regression model has been selected over other trend line options because it presents a higher R-squared value, which is an indication of a good fit regression model. R-squared or coefficient of determination is a statistical measure that is mostly used to measure the goodness of fit of the equation; it describes how well the model fits the data and indicates the percentage of the variance of the dependent variable that the independent variable explains correctly in the model.

$$TSC = -2 \cdot 10^{-8} Q + 0.0113 Q - 1107.2. \tag{16}$$

The second regression consisted of the statistical model of the total social benefit (total revenue) of the electricity sold against the total electricity sold. Similarly to the previous model, the scatter plot of this regression modeling is displayed in
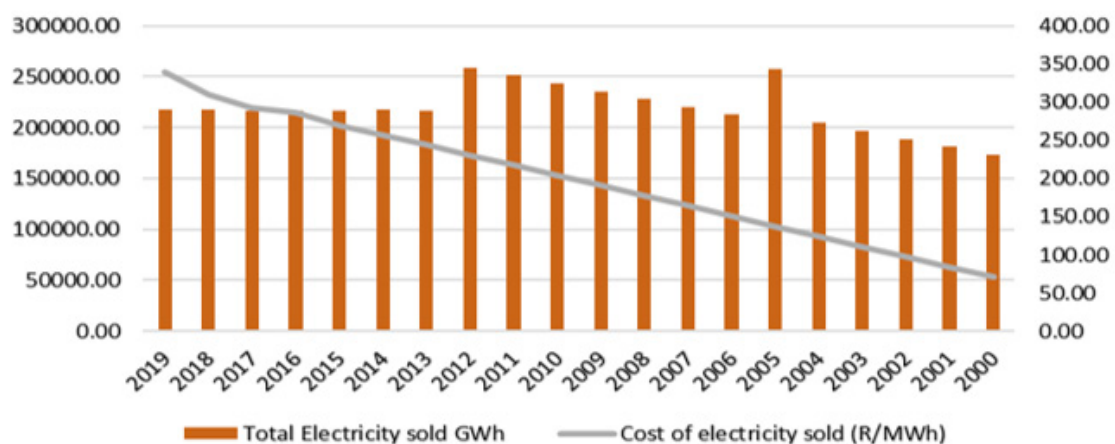

Figure 1. Electricity generation quantity and cost of production
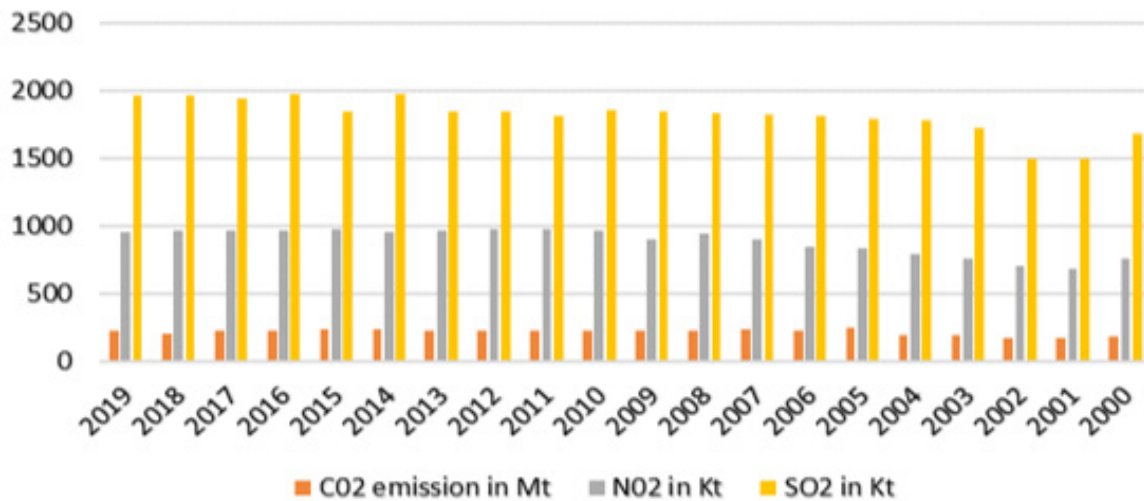
Figure 2. Environmental impact of electricity production

Figure 4, and the predictive equation of the total social benefit in terms of the total quantity Q is given in equation 17:

$$TSB = -4 \cdot 10^{-8} Q^2 + 0.0199Q - 2120.3. \qquad (17)$$

Marginal social cost seeks to find an equilibrium point where marginal social benefit is equal to marginal social cost. The result shows that for ESKOM to be able to make a profit, there must be an optimum level of production – 2,150,000 Gigawatts per annum. The range of present capacity of ESKOM is 229,200 gigawatts annually (ESKOM, 2015). The important revelations from the regressions analysis between electricity generation and environmental emissions are summarised in Figures 5, 6, and 7.

The emission discharges show that air pollution of CO_2 emissions was estimated at approximately 6,648 million tons over the coal power plants shown in Figure 5, 28,680 kilotons of NO_2 shown in Figure 6, and SO_2 emissions at 59,040 kilotons shown in Figure 7. Over 85% of the air pollutants emanated from the combustion phase.

Allocating monetary values to the emissions yielded a base case total coal-power plants emission cost over the lifespan at ZAR7193.4 billion or 330.72c/kWh. The emission costs of coal power plants
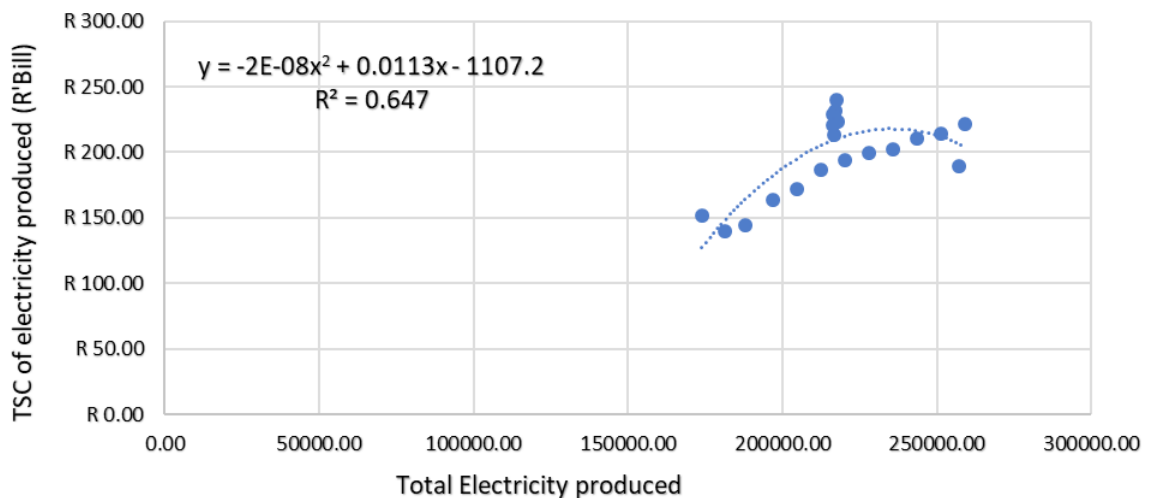

Figure 3. Scatter plot of cost of electricity vs Total electricity produced (sold)
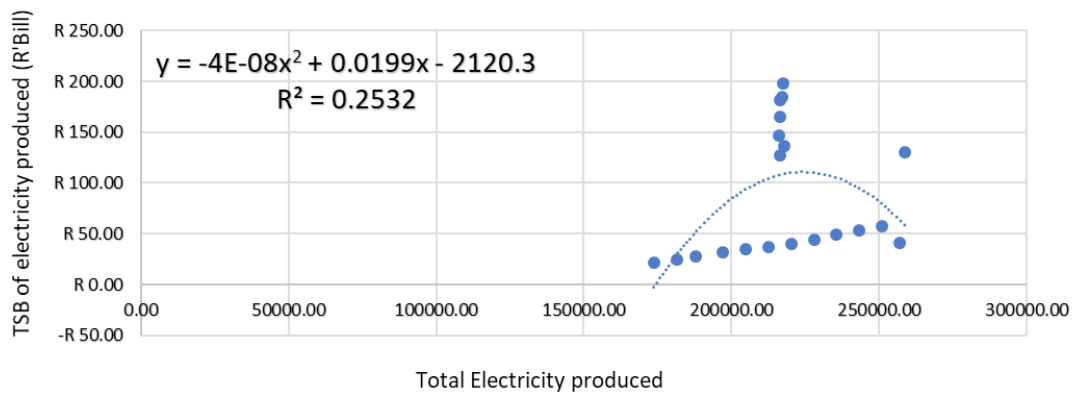
$$y = -4E\text{-}08x^2 + 0.0199x - 2120.3$$
$$R^2 = 0.2532$$

Figure 4. Regression analysis of the TSB of electricity vs Electricity sold

$$y = 0.0008x + 44.523$$
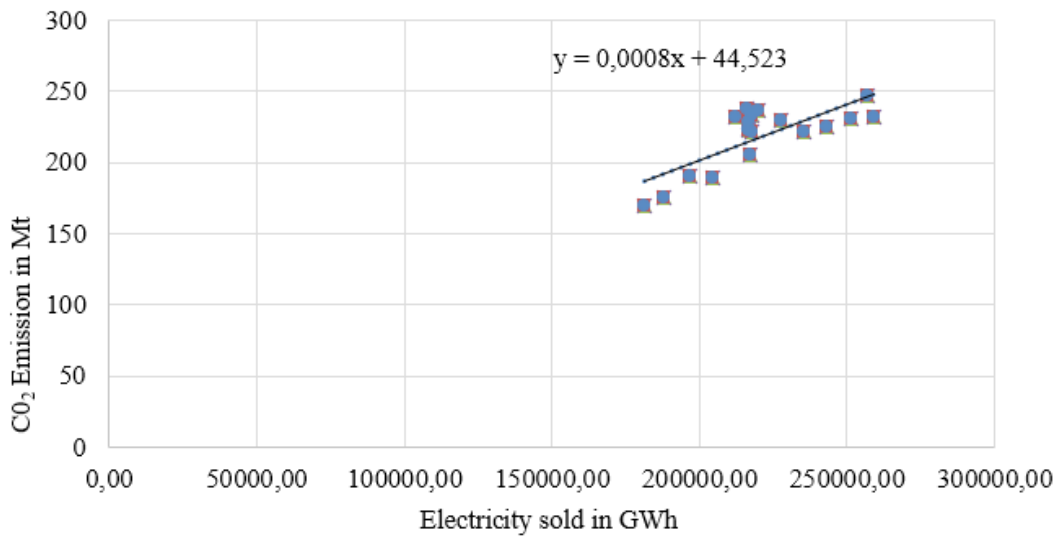
Figure 5. CO_2 emission in Mt Vs Electricity sold in GWh (2020)
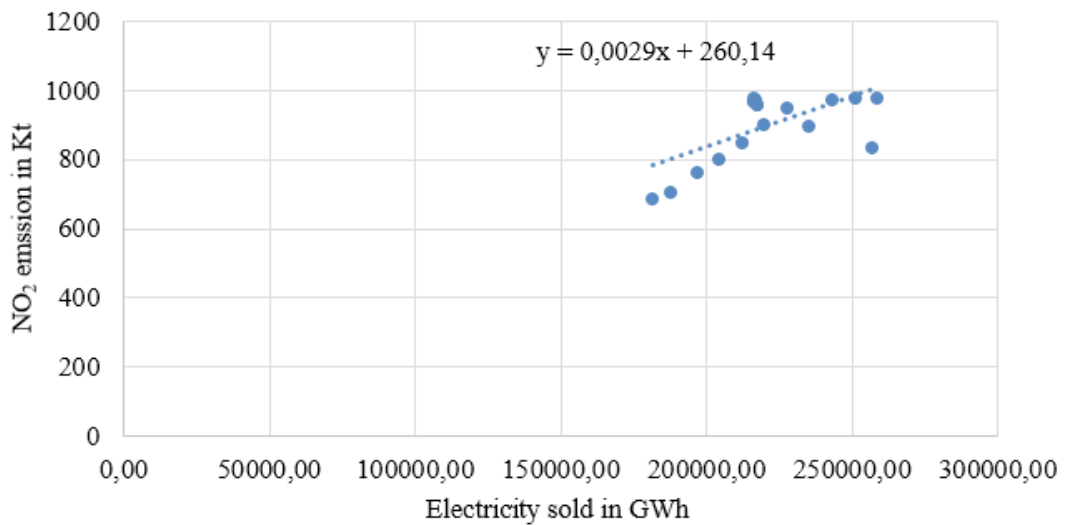

$$y = 0.0029x + 260.14$$

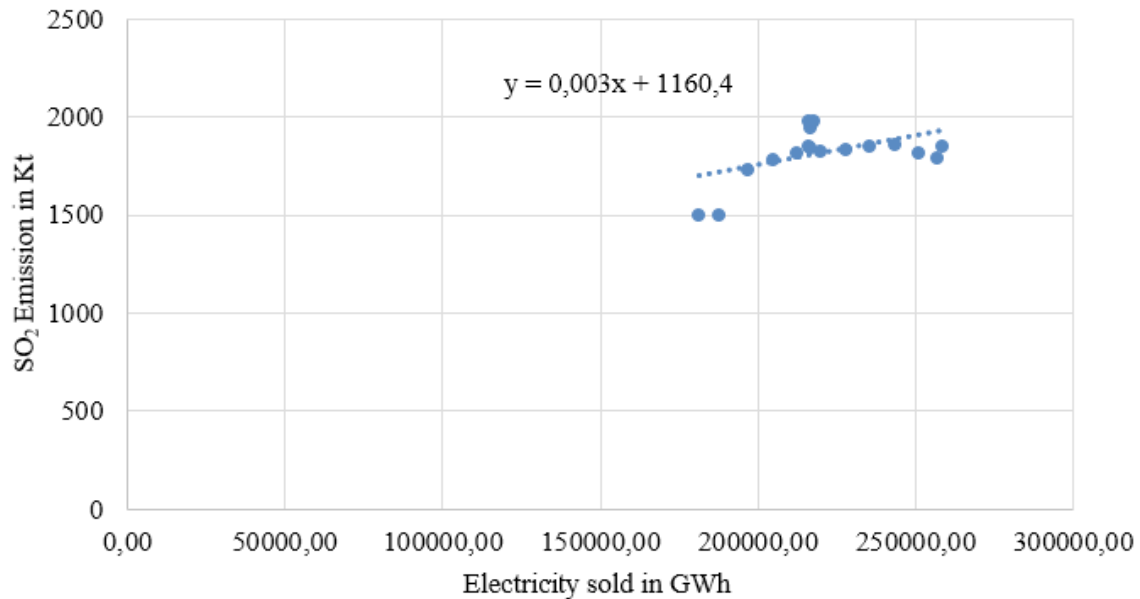**Figure 6.** NO_2 emission in Kt Vs Electricity sold in GWh (2020)

Figure 7. SO$_2$ emission in Kt Vs Electricity sold in GWh

ranged from ZAR139.04 to ZAR166.04 per KWh. Nkambule and Blignaut (2017) arrived at the same amount in their previous study on emission cost. Considering the emission cost in this study, the results show tripling the current electricity costs.

The coal power plants emissions or external cost estimated for this study is the lowest costs because other externalities such as road damage, particulates, and noise pollution were not taken into account.

CONCLUSION

In this study, the knowledge of environmental costs associated with coal power plants' lifespan was used to develop a mathematical model of marginal social cost. The reliability of this study is ensured by the fact that data used for analysis come mainly from reports and no survey was conducted. The secondary data remove the chance of biases in data collection and analysis, hence ensure a reliable study. This study can be applied in any coal power generating organization across different countries and regions. This paper has contributed to knowledge in three major aspects. Firstly, it has provided insight into various emissions being discharged by coal power plants. Secondly, the study diverted the attention from phasing out coal power plants due to its perceived negative environmental impact. However, through the application of the mathematical model of marginal social cost, coal power plants can still be operated at an optimum level of production. Thirdly, the study includes environmental costs or emission costs into capital investment evaluation decisions on coal power plants. The direct labor costs in the power generation considered the determination of true costs of electricity such as operating expenses, depreciation, and other production expenses included when evaluating capital investment decisions.

AUTHOR CONTRIBUTIONS

Conceptualization: Toyese Oyewo.
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Formal analysis: Toyese Oyewo, Olukorede Tijani Adenuga.
Funding acquisition: Odunayo Magret Olarewaju, Melanie Bernice Cloete.
Methodology: Toyese Oyewo, Olukorede Tijani Adenuga.
Resources: Toyese Oyewo, Odunayo Magret Olarewaju, Melanie Bernice Cloete, Olukorede Tijani Adenuga.

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