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The external costs of coal mining: the case of collieries supplying Kusile power station

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Abstract

The aim of this paper was to quantify the external costs of mining and transporting coal to the Kusile coal-fired power station in eMalahleni. Monetary values were estimated for a number of impacts including its contribution to climate change, human health effects of classic air pollutants, mortality and morbidity, impacts of water pollution and water consumption. The results of the study disclosed that coal mining and transportation will inflict costs to both the environment and humans of between R6 538 million and R12 690 million per annum, or between 20.24 c/kWh and 39.3 c/kWh sent out. The external effect of water consumption (opportunity costs of water) constitutes over 90% of the total cost, followed by global warming damage costs and ecosystem services lost due to coal mining. The estimated externality cost is approximately between 50% and 100% of the current average electricity price.

Keywords: external costs, coal mining, coal transportation

1. Introduction

Cheap coal and electricity are considered to be comparative advantages for South African industry (Department of Energy, 2010). However, the mining, transportation and combustion of coal for the purposes of electricity generation produce harmful environmental and health effects that are not only borne by South African society, but by people around the world. Some of these effects include the impact of air pollution on human health, the impact of climate change, and the environmental impact on water quality and biodiversity. South African researchers have been investigating a number of these effects and their associated external costs, with the emphasis on the combustion process (Van Horen, 1997; Blignaut & King, 2002; Spalding-Fecher & Matibe, 2003).

In the past, researchers have noted that the entire coal fuel cycle is associated with dire impacts on both the environment and human health. They have, therefore, called for the consideration of all stages in the life cycle of coal-based electricity supply, including coal mining, processing and transportation (Bjureby *et al.,* 2008; Mishra, 2009; Epstein *et al.,* 2011). The consideration of all stages, instead of focusing only on coal combustion, is paramount to revealing the true cost of coal-based electricity generation and is necessary to inform public policy and private investment (Bjureby *et al.,* 2008; Epstein *et al.,* 2011). More research on the environmental and health costs of coal mining and transportation in South Africa (SA) is, therefore, needed (Munnick *et al.,* 2009). Furthermore, most of the studies are relatively old and need to be updated (for example, Van Horen, 1997; Goldblatt *et al.,* 2002; Van Zyl *et al.,* 2002). There are also no studies that extensively quantify the external costs of transporting coal to a power station in South Africa. This paper aims to advance the understanding of the measurable and quantifiable external costs of coal mining and transportation by quantifying these costs in relation to the Kusile coal-fired power station, which is currently being constructed in eMalahleni. It should be noted that this analysis excludes the contribution to climate change of other parts of the coal chain, water, aspects which are captured elsewhere (Riekert and Koch 2012, Inglesi-Lotz and Blignaut 2012, and Nkambule and Blignaut 2012).

Table 1: Coal mining and transportation impacts

Activity	*Accidents*		*Air pollution*		*GHG emissions*	*Damage to roads*	*Bio-diversity*	*Water quality*
	Morbidity	*Mortality*	*Morbidity*	*Mortality*				
Coal mining	x	x	x	x	x		x	x
Beneficiation							x	x
Coal transportation	x	x	x	x	x	x	x	

2. The environmental and health impacts associated with coal mining

In general, coal mining stresses the environment during the extraction, beneficiation and transportation of coal to a power station (Mishra, 2009). A summary of the health and environmental hazards associated with these processes is shown in Table 1. Coal mining produces negative externalities, primarily in the form of air pollution, global warming from greenhouse gas (GHG) emissions, accidents, biodiversity impacts and water pollution (Goldblatt *et al.,* 2002). In addition to these externalities, coal transportation produces noise pollution, congestion and damage to roadways (Jorgensen, 2010) and uses fuel. Coal beneficiation, a process mainly done using wet cleaning methods, leaves behind coal slurry which may contaminate water. Also, some of the chemicals used and generated in processing coal are known to be carcinogenic and some cause heart and lung damage (Epstein *et al.,* 2011).

3. Literature review: external costs of coal mining and transportation

Environmental and health impacts in the life cycle of coal (mining, transport, processing and combustion) have been assessed using a range of methods since 1982 (Mishra, 2009). The literature discloses two broad categories of methods that have been used by researchers to estimate the external costs: the abatement cost approach and the damage cost approach. The abatement cost approach uses the costs of controlling or mitigating damage as a proxy for the damage caused by an externality. Alternatively, the damage cost approach estimates the actual external burdens and assigns a monetary cost to them, using valuation techniques. The damage cost approach can be executed in either a top-down or a bottom-up manner.

The top-down approach estimates external costs of pollutants based on national or regional damages. The bottom-up approach – also known as the impact pathway approach – traces pollutants and other burdens from their initial source, quantifies impacts and monetises impacts using valuation techniques, such as the contingent valuation method (for example, through directly eliciting willingness-to-pay or willingness-to-accept) or indirect valuation methods (for example, replacement cost technique or hedonic pricing method). The bottom-up approach is the most preferred approach, but it is data intensive (Sundqvist, 2002). In most developing countries such as South Africa, primary valuation studies that are linked to the environmental impacts of energy are also lacking. For this reason, researchers adjust monetary estimates of externalities from previous studies and transfer them to new contexts (i.e. benefit transfer technique) (Van Horen, 1997; Spalding-Fecher & Matibe, 2003). Various researchers have used a number of approaches to place a value on the impacts of coal mining, depending on the nature of the externality.

A number of international studies have attempted to quantify the external costs of coal mining and transportation (for example, Bjureby *et al.,* 2008; Sevenster *et al.,* 2008; Yushi *et al.,* 2008; Epstein *et al.*, 2011). These studies are summarised in Table 2 below, highlighting how the various researchers studied, quantified and monetised the environmental and health effects of coal mining and transportation.

In summary, the international studies cover three main impacts related to coal mining and transportation that is climate change impacts from GHG emissions, human health burdens due to air pollution and fatalities due to coal transportation. For climate change impacts, the most recent values used by the researchers range between \$10 and \$100/t of CO_2e (carbon dioxide equivalent) (2008 values) based on either the prevention costs for CO_2 or the valuation of damages due to emissions of a ton of carbon (damage cost approach). Specifically, Epstein *et al.* (2011) and Yushi *et al.* (2008) monetised climate change impacts using the damage cost approach, while Bjureby *et al.* (2008) and Sevenster *et al.* (2008) used values based on the approximate prevention costs for CO_2. To estimate human health damages due to air pollution, researchers generally estimate the specific air pollutants' quantities obtained from databases and then multiply these numbers with adjusted damage costs per ton of emission figures from other studies. For fatalities due to coal transportation, they generally estimate fatality rates for transportation and multiply these with the adjusted value of statistical life (VSL) or value of life year (VOLY). The externality values were converted to 2010 US\$ for comparative purposes (see last column of Table 2). However, in-depth comparisons are still hindered by the fact

Table 2: Summary of international studies on external costs of coal mining and transportation

Author	*Country*	*Method*	*Impacts investigated*	*Values in:*	*Units*	*Value*	*Value 2010-US$*
Yushi *et al.* (2008)	China	Human capital approach; Willingness-to-pay; Travel cost	*Coal mining:* - Airborne pollution - Soil pollution - Biodiversity loss, etc.	2005	RMB/t	69.47	12.05
			Coal transportation: - Emissions, noise - Damage to roads - Overloading - Accidents		RMB/t	8.73	8.73
Epstein *et al.* (2011)	United States	Benefit transfer	*Coal mining:* - Climate change	2008	$/kWh	0.03-0.34	0.03-0.34
			- Public health burden		$/kWh	4.36	4.55
			Coal transportation: - Public fatalities		$/kWh	0.09	0.09
Sevenster *et al.* (2008)	Global	Benefit transfer	Mining & transportation: - Air pollution (GHG and classic air pollutants)	2007	€ mil/yr € mil/yr	673 0.0073	946.45 0.01
Bjureby *et al.* (2008)	Global	Benefit transfer	*Coal mining:* - Climate change - Human health impacts from air pollution	2007	€ mil/yr € mil/yr	674 0.007	947.85 0.01
			Mining accidents		€ mil/yr € mil/yr	161 0.0017	226.42 0.0024

Table 3: Summary of South African studies on external costs of coal mining

Author	*Impact investigated*	*Units*	*Low*	*Central*	*High*	*1990/1*	*1995/6*
Van Zyl *et al.* *(1999 values)* (2002)	Methane	R million R/t	180 0.98	540 2.93	1260 6.83		
	Sulphate pollution	R million R/t				8.56 0.11	17.13 0.19
Van Horen (1997) *(1994 values)*	Accidents	R million R/kWh	16.8 0.01	24.5 0.02	34.5 0.02		
Pretorius (2009)	Acid mine drainage	R/kWh		0.38			

that the units of analysis vary between the studies (for example, some report cost per ton and some report cost per kWh). In general, the external costs of coal mining and transportation reported in the global studies look similar (Bjureby *et al.,* 2008; Sevenster *et al.,* 2008) due to the use of similar methodologies and the consideration of more or less similar externalities.

Locally, owing to the importance of coal to South Africa, there are studies that have attempted to quantify the external cost of coal mining and these are summarised in Table 3. Van Zyl *et al.* (2002) estimate the climate change impact of methane (CH_4) emissions produced during coal mining to range between R180 million and R1.260 billion (R0.98 – R6.83/t). They further estimate the impact of coal mining on the quality of water in the eMalahleni catchment to be between R8.56 million and R17.13 million (R0.12 – R0.23/t). Pretorius (2009), however, estimates the water damage externality for Eskom's coal mining needs to be R0.38/kWh. Additionally, Van Horen (1997) estimates the occupational health effects of coal mining (accidents: morbidity and mortality) to range between R16.8 and R34.5 million (R0.01–R0.02/kWh) (1994 values). The cost-of-illness approach was used to value injuries. To attach an economic value to premature mortality (fatalities), Van Horen (1997) adjusted valuations of a changed probability of death from international studies.

External costs of road transport are estimated by Gaffen *et al.* (2000) at a national level so external cost estimates for coal transportation destined for power generation were not distinguished.

Jorgensen (2010) mainly focuses on rail transport, while Coaltech (2009) quantifies CO_2 emissions from coal transportation. These studies highlight a lack of data in South Africa in terms of emissions and valuation studies, among other issues.

In conclusion, local studies highlight the need for more research on coal mining and coal transportation externalities. No studies were found attempting to quantify the external costs of transporting coal to a power station, and the local studies seem to be relatively old and need to be updated.

4. Research method and data

The specific impacts that are considered in this study, as well as the sources of data that enabled the computation of the external costs of coal mining and transportation, are presented in Table 4. The impacts investigated in this study are climate change impacts, the human health effects of classic air pollutants, mortality and morbidity, the impacts of water pollution, water consumption and the loss of ecosystem services due to coal mining.

4.1 Coal mining global warming damages

The main GHG associated with coal mining is CH_4 (methane), which is released during coal extraction when coal seams are cut. The global damage cost from methane emissions was computed as a product of the annual amount of CH_4 released in meeting Kusile's annual coal requirement and the damage cost estimate for CO_2 adjusted for inflation and to reflect the global warming potential of CH_4 compared to CO_2. For the amount of CH_4 emitted per ton of coal in surface mines, estimates from Lloyd and Cook (2005) were used. About 17 million tons of coal will be transported to Kusile annually (Wolmarans & Medallie, 2011). A range of damage cost estimates for CO_2, computed by Blignaut (2012) were adopted in this study (2010 values) (i.e. \$0.80/tCO_2 (low), \$15/tCO_2 (market), \$14.33 tCO_2 (median), \$24.29/tCO_2 (high), \$82.02/tCO_2 (very high) and \$112.01/tCO_2 – Stern (2007 and 2008) base value).

4.2 Coal transportation global warming damages

The GHGs associated with transportation include CO_2, CH_4 and N_2O (nitrous oxide) (Gaffen *et al.*, 2000). To calculate the global damage costs of CO_2 emitted during coal transportation, the following procedure was followed: First, the amount of diesel that is required to transport the 17 million tons of coal to Kusile was estimated. This necessitated determining the amount of coal to be transported by road, the truck capacity (based on Coaltech, 2009), annual distance travelled and the truck's fuel

Table 4: Coal mining and transportation impacts investigated in this study and the sources of data

Impact investigated	Method	Data requirements	Data source
Coal mining climate change impacts	Benefit transfer	1. Social cost of carbon 2. Methane emission factor 3. Coal mined for Kusile 4. CH_4 global warming potential	1. Blignaut (2012) 2. Lloyd and Cook (2005) 3. Wolmarans and Medallie (2011) 4. IPCC (2001)
Coal transportation climate change impacts	Benefit transfer	1. Total diesel consumption 2. Carbon emission factor for diesel & diesel oxidation factor 3. Social cost of carbon	1. Wolmarans and Medallie (2011) 2. IPCC (1996) 3. Blignaut (2012)
Accidents: mortality and morbidity	Benefit transfer	1. Fatalities and injuries during coal mining and transportation 2. Monetary valuation estimates for mortality 3. Monetary valuation estimates for morbidity 4. Coal produced in various years	1. DME (2010) 2. NEEDS (2007), AEA Technology Environment (2005) 3. Van Horen (1997) 4. WCA (2006-2009)
Water pollution	Benefit transfer	1. Coal mined for Kusile 2. Water pollution damage cost	1. Wolmarans and Medallie (2011) 2. Van Zyl *et al.* (2002)
Water consumption	Benefit transfer	1. Annual water requirements for mining coal for Kusile power station. 2. Opportunity cost of water	1. Pulles *et al.* (2001), Wassung, (2010) 2. Inglesi-Lotz and Blignaut (2012)
Human health impact due to air pollution	Benefit transfer	1. Emission factors for various classic air pollutants 2. Damage cost estimates	1. Stone and Bennett (n.d.) 2. NEEDS (2007), Sevenster et al. (2008)
Loss of ecosystem services	Opportunity cost	1. Land use 2. Market price of maize and value of ecosystem services provided by grasslands	1. Wolmarans and Medallie (2011) 2. Blignaut *et al.* (2010)
Impacts not investigated due to lack of data: noise pollution, damage to roads and traffic congestion			

consumption (based on Odeh and Cockerill, 2008); Second, the total amount of diesel consumed was converted to terajoule (TJ); Third, the carbon emission factor for diesel was determined, based on the IPCC (1996); Fourth, the carbon content of the diesel used was estimated by multiplying the total amount of diesel consumed with the diesel carbon emission factor (t/TJ); Fifth, the fact that not all carbon is oxidised during combustion was accounted for by using the diesel oxidation factor – which is 99% according to IPCC (1996); Sixth, the estimated total carbon emissions were converted to CO_2 by multiplying the carbon emissions with the molecular weight ratio of CO_2 to carbon; Last, the global warming damage cost of CO_2 emissions during coal transportation was computed as a product of the total CO_2 emissions calculated above, multiplied with the damage cost of CO_2 (\$/t CO_2), as computed by Blignaut (2012).

4.3 Accidents: monetary estimates for mortality and morbidity

To compute both the injury and fatality rates for the annual amount of coal needed by Kusile, the following procedure was followed: First, the fatalities and injuries per million tons of coal mined in South Africa from 2006 to 2009 were calculated based on estimates reported by the Department of Minerals and Energy (2010); Second, to calculate the total number of people that are likely to die or be injured by Kusile's annual coal requirement, the respective computed rates were multiplied by the amount of annual coal needed by Kusile (i.e. 17 million tons), which yielded 14 injuries and one death per annum; Third, valuation estimates for morbidity and mortality were computed and multiplied with the respective number of people that are likely to be injured or die.

For morbidity, cost estimates (estimated using the cost-of-illness approach by Van Horen (1997)) from public health practitioners were transferred to this study by adjusting the values for inflation. For fatalities, due to a lack of valuation studies in South Africa, estimating the economic value for mortality was based on valuation of changed life expectancy, obtained from the NEEDS (2007) and AEA Technology Environment (2005) studies. The valuation of changed life expectancy, like the valuation of a changed probability of death, entails the use of individual preference approaches. These approaches are generally preferred in the literature to values yielded by the human capital approach, which values a lost life at the discounted value of future income which that person might have been expected to generate (Van Horen, 1997). Basing the value for mortality on the change of life expectancy, as opposed to a change in the probability of death as noted by Rabl (2006) and NEEDS (2007), is more appealing because the approach considers the constraint that humans die only once, and also because respondents (i.e. surveyed individuals) show difficulty in understanding small probability variations. The values for mortality were adjusted to reflect the disparity in income levels between the European Union and South Africa. This adjustment is essential because, theoretically, individual valuations of the risk of death are dependent on income levels. The income adjustment factor was therefore calculated and used to adjust the values for mortality. The adjusted values were then inflated to ZAR and multiplied by the number of people that are likely to die, yielding the total value for mortality.

4.4 Water pollution

Coal mines can affect water quality through mine water discharges, leachate from discard dumps or acid mine drainage (AMD). AMD is highly acidic water that forms when pyrite, a sulphur-bearing mineral, and other sulphide minerals present in coal and associated strata, reacts with water and air to form sulphuric acid and dissolved iron (Ochieng *et al.,* 2010; Singh, 2008). This acidic run-off dissolves heavy metals such as lead and copper (WCA, 2010). For these reasons, AMD is characterised by a low pH (potential Hydrogen) and high concentrations of sulphate and heavy metals (Neculita *et al.,* 2007; Manders *et al.,* 2009).

AMD is a crucial and costly environmental problem linked to both coal and gold mining in South Africa (Council for Geoscience, 2010; Naicker *et al.,* 2003). Direct damage cost estimates of water pollution from coal mining in the eMalahleni catchment were computed by Van Zyl *et al.* (2002). As already noted, AMD is characterised among other attributes by high concentrations of sulphate. For this reason sulphate was chosen by the researchers as a best available indicator of overall salinity and a major concern in the area. Damages to the industrial and domestic sectors were estimated using preventative expenditures while those to the agricultural sector were estimated using preventative expenditures necessary to maintain yield and lower yields due to pollution.

The drawbacks of the Van Zyl *et al.* (2002) study are its focus on i) sulphate and not all pollutants, ii) impacts in the catchment and not downstream, and iii) lack of address of natural/environmental uses. The estimates computed are thus considered conservative. The direct damage cost imposed on other water users in the eMalahleni catchment from sulphate pollution by coal mining was estimated to range between R0.11 and R0.19/t of saleable production (1999 ZAR). These damage cost estimates from sulphate pollution are used in this study. These estimates are inflated and then multiplied with the annual amount of coal required by Kusile to arrive at an estimate of the annual damage costs that are likely to be imposed by mining coal for Kusile.

4.5 Water consumption

Water is used in a number of activities in coal mines. Primarily, it is used for dust control, extraction and coal washing. It is also lost through evaporation (Wassung, 2010). In order to compute the society-wide cost of water consumption by the proposed New Largo Colliery that will supply coal to the Kusile coal-fired power station, the following procedure was followed: First, the annual water requirements of a surface mine with a beneficiation plant that produces 17 million tons of coal for electric power generation were computed based on figures reported by Pulles *et al.* (2001) and validated by Wassung (2010); Second, it was necessary to establish the opportunity cost of water to society when engaging in coal mining. Estimating such, if time and resources allow is imperative, as the administered price of water for coal mining or for coal-fired electricity generation in South Africa in general does not reflect the actual loss of welfare to society due to the presence of externalities (Spalding-Fecher & Matibe, 2003). However, since the opportunity cost of water to society when engaging in coal mining has not been computed in South Africa, the opportunity cost of water to society when engaging in coal-fired electricity generation will be used, as the coal produced by the proposed coal mine will be 100% dedicated to coal-fired power generation.

Inglesi-Lotz and Blignaut (2012) estimated the opportunity cost of water to society for the Kusile coal-fired power station and their values were used in this study. First, the society-wide loss of water use at the Kusile power station computed was divided by the water requirements of the power station to arrive at the opportunity cost of water per cubic meter. The values that were yielded (in R/m^3) were then multiplied by the annual water requirements of mining coal for the Kusile power station, thereby yielding a society-wide cost (opportunity cost) of water use in the New Largo Colliery for the purposes of supplying the Kusile coal-fired power station.

4.6 Human health damages due to air pollution

Air pollution (classic air pollutants) in coal mines is mainly caused by coal dust and particulate matter generated during coal mining, burning discard dumps and underground fires (Goldblatt *et al.,* 2002). To estimate human health damage due to air pollution coming from coal mining and transportation, the methodology used by Sevenster *et al.* (2008) and Bjureby *et al.* (2008) was adopted. This was done owing to the lack of studies in South Africa that link human exposure to classic air pollutants produced during coal mining and transportation to human health. First, the amount of classic air pollutants emitted was calculated using emission factors from the literature. For coal transportation, this involved computing the total annual distance travelled by the truck and multiplying it with the emission factor for each pollutant considered. Emission factors were sourced from the study by Stone and Bennett (n.d.). This was followed by transferring damage cost estimates per ton already linked to air pollutants from the NEEDS project (NEEDS, 2007; Sevenster *et al.*, 2008) and from the AEA Technology Environment (2005) study.

The damage cost estimates needed adjustments before these could be multiplied with the estimated emissions. The adjustment was done by first transferring the VOLY estimates for the EU ($VOLY_{EU}$) and adjusting the $VOLY_{EU}$ values for differential levels of income between the European Union and South Africa. An adjustment factor was then obtained ($VOLY_{EU}/VOLY_{SA}$) and was used to adjust all the original damage costs per ton of emission. Finally, to estimate human health damages due to air pollution, the respective adjusted values per ton were multiplied by the estimated emissions. The classic air pollutants that were considered were nitrogen oxides (NO_X), sulphur dioxide (SO_2) and particulate matter ($PM_{2.5}$).

4.7 Loss of ecosystem services due to coal mining

The new opencast mine that is proposed to supply coal to the Kusile power station will mine coal from the New Largo coal reserve. The New Largo coal reserve signifies the extent of the area that could be mined and covers an area of 6 817 hectares (Wolmarans & Medallie, 2011). The area is mainly used for maize cultivation and a substantial part fall into grasslands. Extraction of the coal resource in this area will therefore lead to loss of both farmlands and grasslands. The opportunity cost of coal mining in this area is therefore the forgone benefits derived from agricultural production and ecosystem services generated by grasslands.

Loss of agricultural potential was calculated as a product of the number of hectares of land under maize production, productivity of maize (t/ha) and the market price of maize. Concerning grasslands, there are numerous services provided by them, including carbon storage, drought and flood mitigation, sediment reduction, biodiversity maintenance, wildlife habitat provision, aesthetic beauty provision, protection of watersheds, stream and river channels, nutrient cycling and movement, waste detoxification and decomposition, and control of agricultural pests (USDA, 2010). Three of these, namely carbon storage, drought mitigation and sediment reduction, were valued in a study by Blignaut *et al.* (2010) for a fire-prone grassland ecosystem in the Maloti–Drakensberg mountain range in South Africa. These three ecosystem services were considered immediately viable and marketable, thus the

Table 5: Summary of annual damage costs due to coal mining and transportation (2010 values)

Damage estimated	*Central estimate (R million)*	*High estimate (R million)*	*% of total*
Global damage cost: coal mining	477	722.4	
Global damage cost: coal transportation	2.4	3.9	~ 6
Human health damages due to accidents	0.7	1.3	< 1
Human health damages due to air pollution	10.5	15	< 1
Water pollution damages	6.1	7.7	< 1
Water consumption external effect	5 964.18	11 862.41	> 90
Loss of agricultural potential	76.4	76.4	
Loss in ecosystem services	1	1	~ 1
Total	**6 538.28**	**12 690.11**	

others were excluded to avoid selling services with no immediate market.

In this current study, however, only the carbon storage value could be adapted from Blignaut *et al.* (2010), not drought mitigation or sediment reduction. The reason for this is that the water values are for a high rainfall mountain catchment and cannot be equated to highlands low productive grasslands. Also, the carbon sequestration estimate adapted from the Blignaut *et al.* (2010) study is considered conservative. The loss in carbon sequestration was computed as the product of the number of hectares under grasslands and an estimate of the value of carbon storage generated by grasslands.

5. Results and discussion

Table 5 shows a summary of the annual external damages of mining coal and transporting coal to Kusile for electricity generation purposes. The overall costs ranged between R6 538 million and R12 690 million per annum. The external effect of water consumption (opportunity costs of water) makes up over 90% of the total cost, followed by global warming damage costs (~6%) and ecosystem services lost due to coal mining (~1%).

Based on an annual coal usage of 17 million tons, the costs translates into an externality value of between R385 and R746/t, which is considerably higher than the earlier South African studies (shown in Table 3). This is due to the higher (global) price of carbon and the fact that this study includes more externality aspects. It is estimated that the net power generation output of Kusile is 32.3 million MWh (net capacity of 723 MW per unit x 6 units x 8 760 hours x a load factor of 85%) which translates to an estimated damage cost of between R6 538 million and R12 690 million and an externality cost of between 20.2 and 39.3 c/kWh. The estimated externality cost is between 50% and 100% of the current average electricity price, which is approximately R0.41/kWh (2010 value) (RSA, 2011).

6. Conclusion

The aim of this study was to quantify the external costs of coal mining and transportation related to the Kusile coal-fired power station currently being constructed in eMalahleni. The results of the study disclosed that coal mining and transportation will inflict costs to both the environment and humans of between R6 538 million and R12 690 million per annum, or between 20.24 c/kWh and 39.3 c/kWh sent out. The estimated externality cost is between 50% and 100% of the current average electricity price. These costs are considered to be a lower bound estimate since some externalities were not investigated (for example, noise pollution, damages to roads and the damage caused by ash lagoons on water resources) due to unavailability of data.

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