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Clean and energy efficient technology as green economy transition mechanism in South African gold mining: case of Kusasaletu

Abstract

The decline of easily accessible gold reserves at Harmony Gold Limited's Kusasaletu gold mine meant the firm had to be innovative to access deeper ore bodies. In principle, accessing deeper ore has higher cost implications as more energy, particularly electricity is consumed. Such energy is needed for ventilation, cooling, longer shafts traveling time as well as drilling and blasting harder rock. In South Africa where electricity is largely coal generated, increased energy consumption leads to increased greenhouse gas (GHG) emissions, a move that undermines green economy and low carbon transition. This paper examines environmental and financial impacts of clean and energy efficient technology transition at Kusasaletu gold mine by tracing trends from 2004 to 2012. The findings show significant declines in energy consumption and GHG emissions and operational costs although clean and energy efficient technology transition resulted in increased capital expenditure.

Keywords: clean technology, energy efficiency, South Africa, gold mining, green economy.

JEL Classification: Q56.

Introduction

This paper deliberates on clean and energy efficient technology as a green economy and low carbon transition mechanism in the South African gold mining sector. The focus is on Harmony Gold Limited's Kusasaletu mine. The mining sector, specifically gold mining is one of the biggest energy consumers in South Africa (South African Chamber of Mines, 2007). Records from the national power utility company, Eskom show that mining consumes 15% of electricity produced in the country with gold mining taking up 47% of this total (Eskom, 2013). This makes gold mining the highest electricity consumer in the sector. To this end, gold mining is deemed one of the worst environmental polluters from a GHG emission point of view. This is so given that the bulk of Eskom electricity is generated from coal. Kirsch (2011) argues that "sustainable mining" is an oxymoron as mining houses usually use the term to claim 'greenness' that they do not achieve. However, an intensive analysis of sustainability in gold mining reveals that the key to sustainable mining depends on a number of complex factors including exploration and production, economics, technology, as well as legal, social and environmental issues (Mudd, 2007).

The ever tightening environmental, social and political regulations on mining practices are a major driver for clean and energy efficient technology adaptation by gold mining companies. Warhurst and Bridge (1996) observed that there is a growing recognition that technological innovation can be stimulated by an environmental regulatory framework in which compliance costs are offset by production gains. However, this is not the view of all corporations. Ngwakwe and Msweli (2013) note that there is an apparent carbon reduction phobia fuelled by the seemingly capital intensive na-

ture of GHG (carbon) emissions reduction. These are critical concerns in a global economy that is now preaching green economy transition that will result in low carbon emissions through energy efficiency and use of renewable energy.

Chapple (2008, p. 1) defines green economy as "clean energy economy, consisting primarily of four sectors: renewable energy (e.g. solar, wind, geothermal); green building and energy efficiency technology; energy-efficient infrastructure and transportation; and recycling and waste-to-energy". This way, green economy is therefore aligned to sustainable development. There are no conflicting ideas between sustainable development and green economy on how they seek to positively address social life, economic growth and environmental wellbeing.

In a green economy context, a mine's competitive advantage is highly linked to its ability to acquire and assimilate clean and energy efficient technology. Theoretically, cleaner and energy efficient technologies should be able to reduce environmental impact and production costs. Innovations in the mining sector may include investment in micro-electronics, process control technology and process improvement leading to energy savings and improved profit margins. Warhurst and Bridge (1996) give an example of Homestake Mine, a USA based mining company that was forced by high costs of production to find ways to reduce production costs.

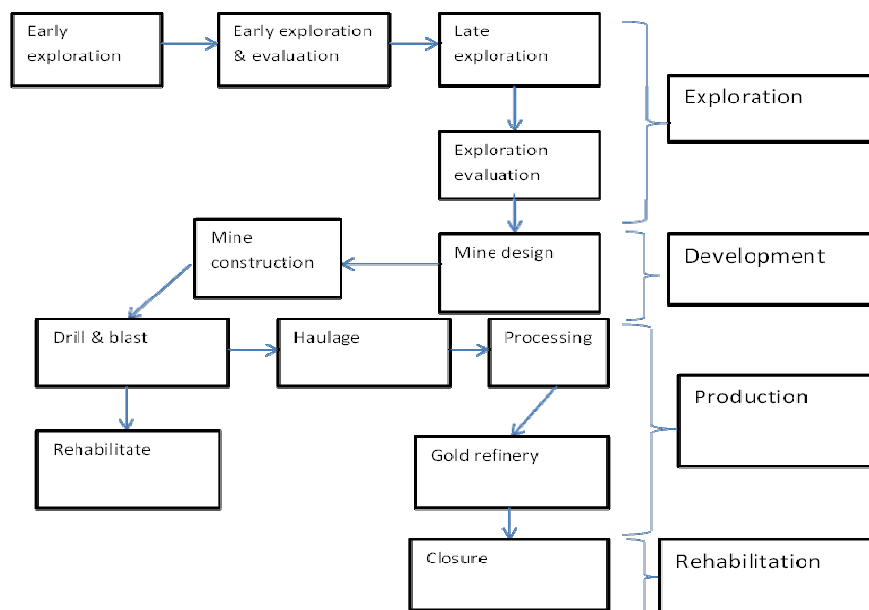
Given the foregone, this paper seeks to show practical evidence that there are genuine efforts to reduce a company's carbon footprint through clean and energy efficient technologies that in turn lead to reduced operation costs and possibly increase profitability. The question that motivated this paper is: can South African gold mines still be profitable while reducing their carbon footprint in the face of declining gold ores and high energy demands that follow as a result of deepening projects? The objec-

tive of the paper is mainly to examine the impact of clean and energy efficient technologies on environmental performance of South African gold mines using Kusasalethu as a case study. The paper is significant given the value of gold mining in South Africa's economy and the environmental threats these mines present. The search for co-existence between mines, ecology and society suggests that there be an implementation of new and cleaner mining innovations to mitigate the negative environmental impacts of mining activities, particularly under green economy transition (ICMM, 2011).

1. Methodological orientation and the study site

The study evaluates clean and energy efficient technology transition at Harmony Gold Limited's Kusa-

salethu mine in South Africa. The study further determines trends in energy consumption and GHG emissions following clean and energy efficient technology transition from the identified mine. This is done under two regimes, namely: the Business as Usual (BAU) that projects electricity consumption and GHG emissions without clean and energy efficiency technology intervention and the Business Unusual (BU) scenario that takes into consideration clean and energy efficient technology interventions that intensified in 2009. The analysis traces the gold value chain (Figure 1) and is centered on tonnes of ore milled and energy consumed annually as units of measurement and analysis. The analysis is done using the stated units for energy intensity drawing data from 2004 to 2012.



Source: Adapted from Mjimba (2011).

Fig. 1. Gold value chain

Data was generated from a range of sources that covered Harmony Gold Ltd annual financial and sustainability reports, raw data from fieldwork visits, Eskom annual reports (for electricity grid emissions factors) and other verified sources. Based on energy consumption data, computations were made for GHG emissions BAU and BU scenarios in order to expose environmental stewardship from reduced energy consumption. The major limitation on the approach, however, is that we mainly considered energy savings from technologies which focus on underground activities.

As highlighted in the introduction, Kusasalethu is located in Gauteng Province of South Africa. Harmony Gold Ltd Group acquired Elandrand mine in February 2001, together with the adjacent Deelkraal mine from Anglo Gold for a cash price of one billion rand¹. These two mines are collectively known

as New Elandstrand/Kusasalethu. Kusasalethu's development will add a further 18 years of life to the operations. The mine produced 180,334 ounces of gold in 2011 (Harmony, 2011). Since then, production has been on the rise annually, and full production was expected to be more than 300,000 ounces by end of 2013 (Harmony, 2012).

After the acquisition, Harmony Gold Ltd continued with the deepening project. Apart from deepening the sub-shafts and developing access to the mine, a variety of other aspects had to be addressed. This included raising the reef and waste ore pass system, installing new rock hoisting facilities and integrating the two mines' ore pass systems. In addition, the work called for the construction of two settling dams, together with the provision of underground pumping stations, a refrigeration chamber, two service shafts and a turbine chamber and dam. Based on a feasibility study undertaken in 1990, Anglo

¹ The exchange rate averaged \$1 = R10 rand during the second half of 2013.

Gold decided to extend the life of the mine by exploiting operations beyond 3,000 metres (m) to 3,500 m below datum. The plan was to deepen both the sub-vertical and sub-ventilation shafts by around 500 m (Harmony, 2011). However, Anglo Gold's feasibility studies indicated that such efforts did not make sustainable (economic) business sense due to the estimated and guaranteed high costs of energy and the special shaft design and technologies for the increased underground cooling. As such, Anglo Gold sold the mine to Harmony Gold Ltd.

Given the operational profile of Kusasalethu and its inherent challenges, the mine decided to invest in clean and energy efficient technologies for sustainable and profitable mining starting 2009 (Harmony, 2010). The company committed to employing energy efficient technologies which are in line with its energy efficiency and its climate change strategy policy (Ibid).

2. Literature review

2.1. Drivers for clean and energy efficient technology transition in gold mining. Drivers pertaining to clean and energy efficient technology transition come in two major forms: risks and opportunities. These two drivers can be further split into categories including financial, regulatory, physical, environmental and reputational. Economically, end-of-pipe technologies and approaches are much more attractive for mines with limited funds as they appear affordable. The South African National Treasury (2013) concurs. It notes that the long term return period of clean technology investment discourages business from making upfront investments as end-of-pipe technology requires less capital investment, less development and maintenance than cleaner technologies and approaches.

After studying the Tanzanian gold mining sector, Cooksey (2011) concluded that mining companies in Tanzania incur a range of 'compliance costs' to meet international safety, environmental, accounting and corporate social responsibility (CSR) standards. These standards are set by international stock exchanges and other industry umbrella organizations such as the International Council on Mining (ICMM). The implementation of CSR programmes that includes mitigating the environmental impact of mining activities increase the cost of gold mining significantly. A marginal mine could easily prove to be unprofitable if these costs are not managed (Cooksey, 2011).

One of the biggest challenges faced by South African gold mining companies is the increasing demand for energy in the country and the high cost of electricity. Ruffini (2013) noted that electricity alone cost South Africa's biggest gold mining company Gold Fields, one billion rand in 2009. This figure increased by 60% in 2010/11 to R1.6 billion in

2011/12 and was estimated to rise to 3 billion rand in 2012/2013 financial year. To mitigate this cost, Gold Fields have pro-actively sought to adopt and adapt to clean and energy efficient technology to reduce costs and subsequent environmental damage.

According to Hilson (1999), the first mining environmental legislation was passed in North America and Europe in 1970. Since then, the mining industry has been improving the manner in which pollutants are managed and are focusing on how to prevent pollution from happening at the first place. Toxic pollutants in air emissions have dropped dramatically globally. The methods used to monitor and control waste streams have also been upgraded significantly. This has been achieved partly by integrating cleaner technologies and cleaner processes into several polluting areas of operations. In South Africa, the White Paper on Mining and Minerals of October 2008 addresses broader constitutional rights and environmental protection in the mining industry (Department of Minerals and Energy, 2008). The possible introduction of a carbon tax in South Africa was discussed during COP17, held in Durban, South African in 2011. South Africa reaffirmed President Jacob Zuma's 2009 Copenhagen (COP15) pledge to reduce GHG emissions by 34% by 2020 and 42% by 2025 (National Treasury, 2013).

In his 2013 budget speech, the finance minister, Pravin Gordhan announced that South African will price carbon by way of a carbon tax from 1 January 2015 starting with R120 per tonne of carbon dioxide rising by 10% annually thereafter (Gibson, 2013). This policy position directly puts pressure on gold mines and other big GHG emitters to do something. Thurlow (2011) views carbon tax as a tax that is based on economic principles of negative externalities. These externalities relate to the unpaid costs or benefits generated in the production of goods and services. Businesses produce products that are generated from fossil fuels, consumers contribute to this carbon footprint by consuming these products, thus supporting business practices that pollute the environment. Thurlow (2011) further argues that a carbon tax will pose serious economic development challenges since South Africa's economy is founded on energy intensive industry such as mining which is supported by cheap coal generated electricity. Reducing the country's carbon footprint needs serious economic transformation. Carbon emissions are strongly linked to discourses on climate change (Wingart et al., 2000). Nhamo (2011) notes that debates on whether climate change was happening or not and its effect on the environment were laid to rest by the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report published in 2007.

A transition to clean and energy efficient technology presents a range of opportunities that the South African gold mining sector needs to take advantage of. Creamer (2012) notes that the development, acquisition and integration of new technologies may be an increasingly important determinant of a mine's competitiveness in the context of market growth and adhering to regulatory pressures, particularly under green economy transition. Opportunities presented by a transition to the green economy include; innovation and competitiveness, opening up of new markets, and the creation of green jobs. Clean technology supported by managerial capacity in the area of environmental performance can further bring new markets and a new profit center for some mining companies.

A favorable reputation can be gained by harnessing of clean and energy efficient technology. "Reputation is driven by social, environmental and economic outcomes of corporate activity and the quality and structure of the relationship that exist between a company and its stakeholders (Svendsen et al., 2002, p. 1). From Tuk et al. (2005), good reputation is important for mines seeking entry and operating licenses in communities and to explore further business markets in new environments such as those demanding environmental stewardship in green economies. The scholars further argue that a good reputation creates financial gains, and leads to improved economic performance and sustainable business. Warhurst and Bridge (1996) note that credit providers and insurance companies are increasingly becoming aware that poor environmental performance can hamper productivity and profitability of the debtor company resulting in the debtor running a risk of non-financial returns and failure to repay loans. Warhurst and Bridge (1996), present an example of this scenario in a case of Grasberg Mine in Iran Jaya. In the 1990's an overseas private Investment Corporation decided to withdraw \$100 million worth of risk insurance from the Grasberg mine in Iran Jaya on the grounds of ecological damage to forest and river system (Ibid).

2.2. Clean and energy efficient technology transition in the gold value chain. According to Mjimba (2011), modern gold mining typically follow four stages which are: (1) exploration that deals with locating and proving a deposit; (2) mine development section dealing with the construction of a mine to access a proven reserve; (3) production section dealing with the extraction of the minerals from the ore body and processing the ore – including blasting of the ore rock and underground transportation of ore also known as haulage); and (4) rehabilitation that is conducted after the closure to allow for further pro-

ductive use of land after mining. These different stages employ different technologies that are now subject to clean and energy efficient technologies. For the purposes of this paper, the authors focus on the first three energy intensive stages.

Exploration technology has assisted gold mines in saving time, energy consumption and operational costs. The majority of international and South African gold mining companies have adopted the use of the 3D technology and the Geographical Information System technology (GIS) for exploration. Goldfield in Tanzania uses ArcGIS as its main platform for exploration and uses Geosoft Target for drill hole plotting. Geosoft's ability to map out and locate exact ore body location for precise drilling and analysis of minerals save Goldfield time, energy and money. The main technological advantage of Geosoft is its ability to present data in 3D visuals and making data sharing between different software of different formats possible and easy. The current Geosoft 3D technology is a transition from the older ArcView which used 2D technology (Viewpoint, 2010). The 3D, and Geosoft technology can be classified under clean and energy efficient technologies and methods because of their ability to locate gold ore deposits precisely, thus helping mining companies avoid "trial and error" drilling that often use energy, water and cost a lot of money.

Mine development involves mine construction and design. South Africa is home to the deepest mines in the world – "Mponeng" meaning look at me in *Sesotho* language. The mine has reached a 4.5 km depth (Bleby, 2012). DRDGOLD (2012) reported that the average depth of their mines is between two to four kilometres below surface. To mine successfully at these depths, such mines need to employ the most resource efficient technologies. Gold Fields (2010) reported that around 48% of electricity in the mine is used for ventilation, cooling and pumping water. The cooling requirements intensify in proportion to the deepening of the mine.

At present, most South Africa's deep-level gold mines use handheld pneumatic drills to bore holes in the underground rock face. In pneumatic drills, compressed air drives the drill bit. Explosives are then inserted into the holes to blast the rock. The problem with pneumatic drilling is that it is energy-intensive. A compressor which compacts air for the drill is on the surface, which can be thousands of meters above the actual drilling site. The distance between the surface area where the compressor is based and the actual location of the drill makes this technology energy inefficient as there are often leaks in the pipes leading to the drill. These leaks lead to only 1% of the electricity intended for the drills being of productive use (Creamer, 2012). To save energy,

Gold Fields has commissioned the newly improved Peterstow drills. The Peterstow drills employ a patented closed-loop water hydraulic system in conjunction with modular power packs, which are taken underground. The design drastically reduces electricity usage. It also decreases the chance of flooding, meaning that mines do not have to install and pay for addi-

tional facilities to pump water back to the surface which would result in high electricity consumption. To support industrial electricity saving initiatives through clean technologies in South Africa, Eskom has developed guidelines that include a schedule of clean and energy efficient technologies for the (gold) mining sector (Table 1).

Table 1. Eskom’s recommendations on clean technology in the (gold) mining sector

	Area of implementation	Technology function	Technology usage methods
Motors and motor systems	Driving pumps, electric motors, fan systems, compressed air systems, processing plants, ventilation fans, conveyor belts	Electricity convention	Avoid rewinding motors as this cost energy. Rewind vendors must be SABS certified. Devise an electric motor management strategy.
Compressed air systems	Drilling	Controlling heavy drills, replace electric usage	Manage air leaks; compressor should not leak 5% of compressor capacity. Discourage the use of air compressors as cooling systems.
Pumps	Underground and hostels	Pumping drinking water, washing, underground process application	Pumps must be selected to operate close to their best efficiency zone. For multiple arrays, consider a modular arrangement with smaller and larger pumps to allow for each pump to run within its best efficiency zone.
Fans	Underground	Ventilation, extraction of flammable gases, provide fresh air underground	Where possible run multiple pumps into different columns to reduce friction loss. Install variable speed drives to reduce demand.
Lighting	Interior and exterior lighting	Miner’s residences, administration offices, security, processing and extraction facilities	Switch off lights where they not necessary. Use the automatic controls including photo cells occupation sensors and time switches. Electronic Control Gear (ECG) consumes less electricity than Conventional Control Gear (CCG). The latter need to be retrofitted.
Heat pumps and solar heating systems	Outside walls of mine residential buildings or at ground level depending on configuration	Minimize electricity usage; reduce conventional water heating by two-thirds	The storage tank must have a minimum operating pressure of 100 kPa. The storage tank must be rated for interior or exterior installation. All storage tank components must be SABS certified.
Refrigeration	Miner’s residence	Food storage at miner’s residence. Air-conditioning	Minimize the temperature lift, reduce the cooling mode, regular monitoring.

Source: Eskom (2012).

Haulage and transport machinery are an important aspect in the gold mining cycle. From excavation to mine closure and rehabilitation, large-scale mines utilize sophisticated haulage trucks and loaders. Cripple Creek and Victor Gold Mining Company (CC&V) which is owned by AgloGold Ashanti and based in Colorado invested in F-Series of the Caterpillar fleet of haulage trucks. The F-Series truck employ Vital Information Management System (VIMS) technology that collects and transmit machine data and turns it into useful information used to track productivity, machine performance, service scheduling, trends, diagnosis and equipment condition monitoring (Viewpoint, 2010).

Gold bars are transported to the metal refinery for further processing where gold reaches 99.9% purity levels. This is the level acceptable by the London Bullion Markets Association that gives buyers assurance that the gold bar is of the highest standard as stamped on the bar. Hilson (2000) states that the need to prevent and minimize environmental pollution in the gold refinement phase has led to the emergence of a number of cleaner technologies and strategies. These technologies are efficient in reduc-

ing and detoxifying wastes and pollutions released from point sources. Examples of such technologies include high-tech flue gas desulphurization known as acid gas scrubbers, and chemical detoxification. Gas scribes use lime slurries that routinely remove 90% of sulphur dioxide from flue gases and up to 99% can be achieved by using magnesium-enhanced lime and by operating on appropriate pH and liquid-to-gas ratios. Gas scribe technology has widely been adopted by mining companies that have realized that the cost and burden of remedying soil, water and ecosystems are higher than preventing or minimizing these pollutions at the first place (Hilson, 2000).

3. Presentation of data and discussion of key findings

Results from fieldwork revealed that there are three major drivers for investing in clean and energy efficient technologies at Harmony Gold (including Kusaalethu) namely: (1) the need to reduce operational costs and increase profits; (2) complying with government environmental legislation; and (3) creating a positive reputation for the mine. These confirm the claims from the literature. Whilst it is desirable to meet the highest standards in all the

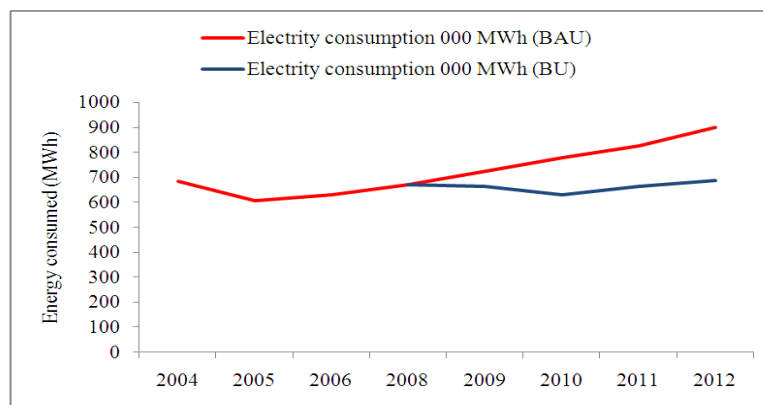
three drivers, the high costs associated with new technology and process changes to meet the desired outcome pose a challenge.

Energy cost contributed 10% of Kusasaletu's operational costs and this cost has been increasing annually due to annual electricity tariff increases (Harmony, 2010). A saving in electricity costs in an era of annual tariff increases has the potential to improve the financial performance of Kusasaletu, *ceteris paribus*. This saving can be achieved through adopting clean and energy efficient technology. However, as revealed in the literature section, adopting clean and energy efficient technologies comes at a cost.

The planned carbon tax for South Africa to be effective in January 2015 was singled out as a "very important" driver to the adoption of clean and energy efficient technology that will significantly reduce electricity consumption, and effectively GHG emissions. If not mitigated, high GHG emissions will translate into higher tax and operational cost for Kusasaletu. For Harmony Gold Ltd, voluntary reporting as a member of the Carbon Disclosure Project (CDP) introduced in South Africa in 2007 played a major role in the mine's decision to reduce its carbon footprint, compete with other mining companies and take advantage of the reputation that comes with being seen to care about the environment. In 2010, Harmony Gold Group was amongst

South African companies who reported on the CDP (CDP, 2013). The sum of these drivers played a role in Kusasaletu's decision to adopt clean and energy efficient technology in all stages of its value chain. Although clean technology acquisitions pose a temporal high capital cost, deep mining poses high energy demands which perhaps pose higher operational and environmental cost.

Harmony Gold Ltd (including Kusasaletu) took a decision to embrace clean and energy efficient technology in 2009. This witnessed heavy investments in this area as a mechanism to respond to the government's call to engage the green economy and business call to be part of the CDP. To verify Kusasaletu's clean and energy efficient technology transition, data was gathered to determine trends in energy consumption and GHG emissions for the period 2004 to 2012. Figure 2 shows the trends in energy consumption. From Figure 2, two scenarios are painted: the BAU and BU. The BAU trend line was plotted taking into consideration the year 2008 as base year. From this base year, the energy intensity factor (a measure from the ratio of energy consumed per tonne of gold ore milled) was adopted to complete the plots. The energy intensity factor stood at 0.751685 in 2008. This figure was then by the total tonnage of gold ore milled in each year to come up with the total electricity that would have been consumed under the BAU scenario.

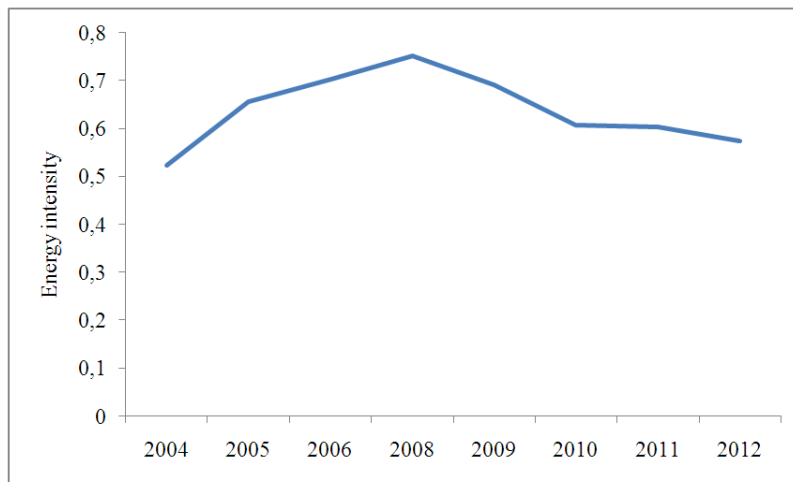


Source: Authors (Data supplied by Harmony Gold Ltd, 2013).

Fig. 2. Trends in electricity consumption at Kusasaletu (2004-2012)

It emerges that Kusasaletu's measures that embraced clean and energy efficient technology yielded positive results in terms of electricity consumption over the years under consideration. There is a clear reduction in energy consumption from the financial years 2009-2012 under the BU scenario that measures actual consumption. This is in sharp contrast to the plotted trends under the BAU scenario that would have witnessed a

continued rise in energy consumption to 2012. Under the BAU scenario, the mine's energy consumption would have risen from 669,000 MWh in 2008 to 900,000 MWh in 2012. Cumulatively, there was a reduction in consumption of 581,985 MWh during the period under review. This reduction in energy consumption is further verified by the decreasing trend in energy intensity from 2009 to 2012 (Figure 3).



Source: Authors (Data supplied by Harmony Gold Ltd, 2013).

Fig. 3. Kusasaletu energy intensity trends (2004-2012)

The BU electricity savings were realized from the following initiatives: cooling auxiliary project, water supply optimization technologies, Eskom's demand side management (DSM) and the two water efficient turbines installed at Kusasaletu. The DSM strategy monitors pumping systems and time them to make sure they consume suitable electricity during off peak periods, resulting in efficient use of Eskom's tariffs that rewards load-shifting. DSM also improved the efficiency of pumping operations. Pumping is energy intensive in underground mining and its energy intensity increases with increasing depth.

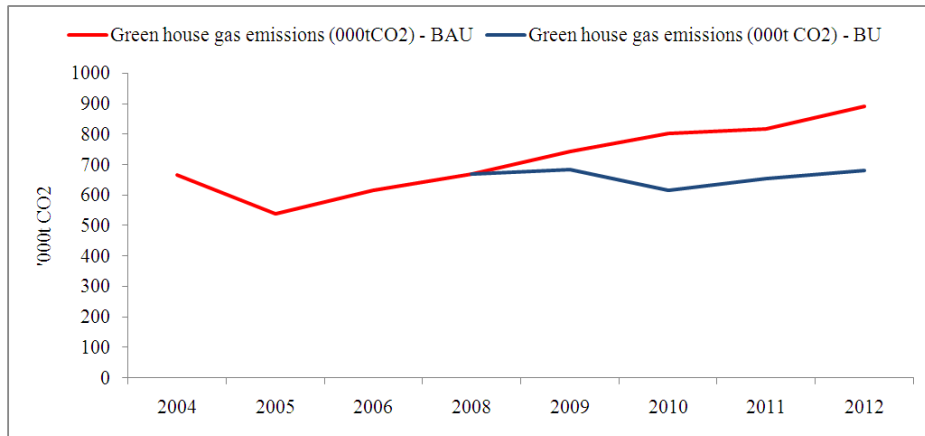
Despite electricity consumption savings realized by adopting clean and energy efficient technology at Kusasaletu, there are still a number of areas that need attention in order to realize additional savings. This paper identified two areas. First, Kusasaletu needs to improve its underground technology particularly the means of energy supply to pumping systems. At the moment Kusasaletu is using hydraulic rock drilling technology, which are both energy and water inefficient than electronic drills. The hydraulic pumps are both water and energy inefficient as they often allow for water leakages between the pipes connecting the pump and the driller. The leakages result in 99% energy wastage.

There are suggestions that Kusasaletu adopts the energy efficient compressed air drilling technology to replace the current hydraulic drilling technology. A CSIR respondent supported the claim made by Business Day (2013) by identifying compressed air technology as being both highly energy intensive. The respondent noted:

The old technology [hydraulic rock drillers] meant that machines such as pumps and other systems had to be manually adjusted. This meant that, if unattended, these machines would unnecessarily continue operating at high velocity, thus waste energy. These older technologies have however been replaced by energy efficient automated water pumps, air optimization and refrigeration which automatically regulate the amount of energy needed and the duration of pumping needed, thus saving energy (Excerpt from telephone interview with a CSIR respondent, 2013).

Other new developments in underground energy efficient technology that Kusasaletu could adopt include the use of thermal scanning to detect potential 'hot connections' on electrical panels which protect relays and prevent power outages while monitoring the central systems for all pumps. Whilst Kusasaletu still has a lot of additional technologies to adopt to become 'greener' there is no denying the positive impact of the technologies adopted thus far on energy consumption. This impact also has a bearing on the GHG emissions, the focus of the next section.

The decision to implement a carbon tax in 2015 has been cited as one of the major drivers for Kusasaletu to invest in clean and energy efficient technology. Projections are that a carbon tax is going to add to financial burdens for South African companies (South African National Treasury, 2013; Gibson, 2013). The aspect of GHG emissions is also central to this paper. Since GHG emissions are also directly linked to electricity consumption, we took time to calculate GHG emissions from electricity consumption (indirect or scope 2 emissions). Once more the BAU and BU scenarios were plotted (Figure 4).



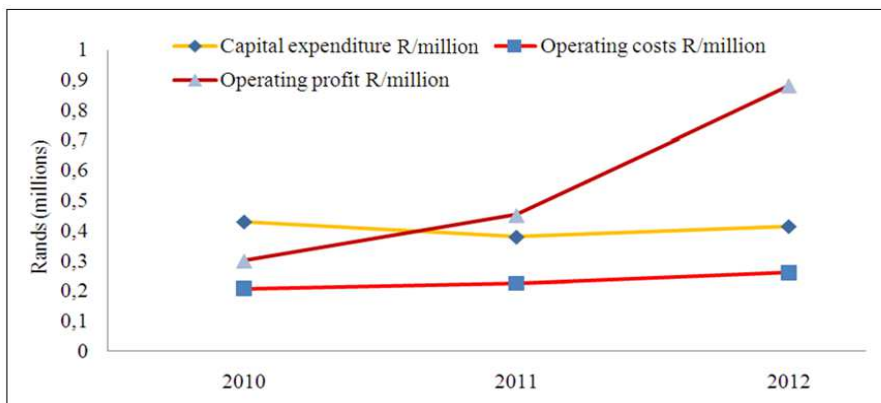
Source: Authors (Data supplied by Harmony Gold Ltd, 2013).

Fig. 4. GHG emissions at Kusasalethu (2004-2012)

It emerges that Kusasalethu’s decision to commission clean and energy efficient technology yielded positive results with regards to GHG emissions reduction over the years under consideration. There is a clear reduction in GHG emissions from the financial years 2009-2012 under the BU scenario that measures actual GHG emissions. This is in sharp contrast to the plotted trends under the BAU scenario that would have witnessed a continued rise in GHG emissions to 2012. Under the BAU scenario, the mine’s GHG emissions would have risen from 669,000t CO₂ in 2008 to 891,000t CO₂ in 2012. Cu-

mulative, there was a reduction in GHG emissions of 616,000t CO₂ during the period under review.

So what with clean and energy efficient technology transition and the economic bottom line at Kusasalethu mine? This is the question we attempt to answer in this last part of the findings. Kusasalethu has made multimillion rand investments in clean and energy efficient technologies. This confirms findings and propositions from the literature. The benefits associated with these investments are shown and discussed from Figure 5.



Source: Adapted from Harmony (2010, 2011 & 2012).

Fig. 5. Annual financial performances at Kusasalethu

Figure 5 shows that capital expenditure was at its highest in of 2010 amounting to R430 million rand. The reason for higher capital expenditure in 2010 was attributed to the development and investment in clean and energy efficient technology as well as the appointment of new senior environmental executive. The total cost was R266 million, while maintenance of existing equipment for efficient performance took up R34 million. In 2011 further capital expenditure amounting to R380 million was made. In 2012 capital expenditure was R415 million (US\$53 million).

In 2011/2012 financial year, Kusasalethu also entered into a co-funded energy saving partnership with Eskom which resulted the approval of three air optimization projects (pumping systems), Kusasalethu contributed R20.1 million towards these projects. From these investments, the mine witnessed a rise in operating profits by 33% from R301 million in 2010 to R453 million in 2011. From the profits earned partly from clean and efficient technologies in 2010/2011, Kusasalethu invested in the cooling auxiliaries’ technologies in 2012. This re-

investment had a further positive impact on the 2012 operational profits that rose by 48% to R881 million (US\$114 million) compared to 2011. Other factors, including favorable exchange rate and increased gold outputs also contributed to the bottom line.

Overall, Kusasaletu's financial performance in relation to the acquisition and implementation of clean and energy efficient technology confirms that investment in clean and energy efficient technology can temporarily result in high capital expenditure as noted by the South African National Treasury (2013) and Hillson (2000). The only cost that can continue to rise is the operating cost because it is largely dependent on external factors outside the mine's control such as energy costs, nature of rand/dollar exchange rate and labor costs and the price of gold. However, operating costs can be managed by the implementation of clean and energy efficient technologies which should manage to bring down energy consumption.

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Conclusion

Based on the key findings, we conclude that transition to and investment in clean and energy efficient technology has potential to minimize resource consumption and limit environmental damage, particularly reduce electricity consumption and GHG emissions. We therefore encourage the Harmony Gold Group and other South African gold mines to continue moving in this direction. In addition, economic, environmental and social reputation should be treated as mutual aspects in the South Africa's gold mining sector in order for such companies to be competitive globally. The reputational damage of not going greener, possibly leading to economic loss may be huge. Hence doing nothing in terms of energy efficiency measures that result in the reduction of harmful GHG emissions result in global warming and climate change will be detrimental to the environment, society and the country's economy.

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