

## CHAPTER 2

### Literature Study

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#### 2.1 SOUTH AFRICAN ENERGY POLICY ENVIRONMENT

##### 2.1.1 National Growth Path (NGP) and its dependency on mining

In 2010, Government announced its plans to create 5 million jobs in the South African economy by 2020 via the National Growth Path that outlines the sector contribution for achieving these targets. This followed President Jacob Zuma's speech at the inaugural state of the nation address in 2009:

*"It is my pleasure and honour to highlight the key elements of our programme of action. The creation of decent work will be at the centre of our economic policies and will influence our investment attraction and job creation initiatives. In line with our undertakings, we have to forge ahead to promote a more inclusive economy."* (Zuma, 2009).

In the NGP it was stated that several sectors are targeted to create new job opportunities from increased exports, research or innovation strategies up to 2030. Amongst these are mining; in jobs driver section 2 of the report it is envisaged to create 140 000 direct jobs by 2020 and should grow to 200 000 jobs in 2030 (New Growth Path, 2010). Direct implications towards the sector are also captured under section 1 that focusses on the new build program of infrastructure implying Eskom and Transnet under the Department of Public Enterprises and also innovation in sector 3 for renewable energy. As mentioned in chapter 1, revenue streams of these companies are generated by sales so mining under industry would have to carry the bulk of this financing cost accounting for about R 450 billion (EIUG, 2012).

Governments' vision in the NGP is job creation, albeit from several sectors some of the biggest expectations are on mining. This is understandable when considering our vast mineral resources but careful review in the following sections will indicate the pressure this is pushing into the industry as we look at operating costs drivers and how these have outgrown the Consumer Price Index (CPI) over the past decade.

### 2.1.2 Energy Price Path and IRP energy model

Over the recent past, Eskom's average electricity price has tripled from approximately 20c/kWh in 2007 to 60c/kWh in 2012. This has placed a considerable financial burden on all electricity consumers and is contributing to inflationary pressure. Despite this, Eskom maintains that tariffs are still not cost-reflective and has suggested in various statements that further increases are required to reach target cost-reflective tariff levels (Lund, 2012).

In his 2012 State of the Nation address, President Zuma reiterated his concern with fast rising electricity prices. The government has recognised that sharply increasing electricity tariffs have a significant impact on both the poor, and on the productive sector of the South African economy hampering our ability to drive growth and create sustainable jobs (Zuma, 2012).

It is likely that South Africa will continue to see significant price increases over the next MYPD period, albeit limited by the government's commitment to restraining the rate of increase. This view is corroborated by Eskom's latest stakeholder consultation, in which Eskom has indicated its intention to pursue a 5-year application under MYPD3. Eskom has indicated the need for increases of around 14.6% per annum under their baseline scenario (to appease political pressure) and up to 19% per annum under their additional options scenario, depending on policy decisions in respect of key power sector responsibilities and obligations (e.g. new build, carbon taxation, rural electrification and others) (Eskom, 2012).

Despite deteriorating economic performance in the primary and secondary sectors of the economy, these are still major contributors in terms of economic growth and employment and continue to offer the best opportunity for job creation in the short to medium term. These sectors also rely heavily on electricity as an input cost. With South Africa's major export partners in Europe suffering from an on-going recession and the softening of demand from China and India, the country will need to become even more competitive if it wishes to maintain economic growth and stability (Steyn, 2013a).

It is worth noting that the Electricity Pricing Policy mandates the development and maintenance of a long-term pricing model by the Department of Energy (DoE). This is particularly important given the shortcomings identified and acknowledged in the IRP2010 pricing model (EIUG, 2012). In order to ensure the viability of the sector, a more precise price path is required to:

- Manage Eskom's funding requirements and its bid to achieve a "stand-alone" credit rating

- Provide a benchmark for Independent Power Producers (IPPs) and private off-takers
- Provide an indication to energy intensive (and other) users for future business planning

As the country approaches the MYPD3 submission and the first revision of the IRP2010, it is critical that this more precise path serves as a basis for informed and constructive consultation in both areas. To this end, prompted by the EIUG, the DoE and NERSA have made a request to Eskom to have access to its comprehensive pricing model. This would allow the DoE and NERSA to carry out independent modelling and analysis. To date Eskom have not made the model available (EIUG, 2013). According to Snell (2013), the implications of this is, it leaves an uncertain outlook on the energy price path and security of supply going forward, Figure 2.1 shows work done by the independent consultants for the EIUG and presented at their Annual General Meeting (AGM). It shows that the expected energy unit cost varies almost 200% from a low of R 80 c/kWh in 2033 to R 1.50 c/kWh in 2043 with multiple variations in-between. Further it is stated that from a financial perspective on capital funding this adds enormous risk towards a project that increases the expected return that investors require.

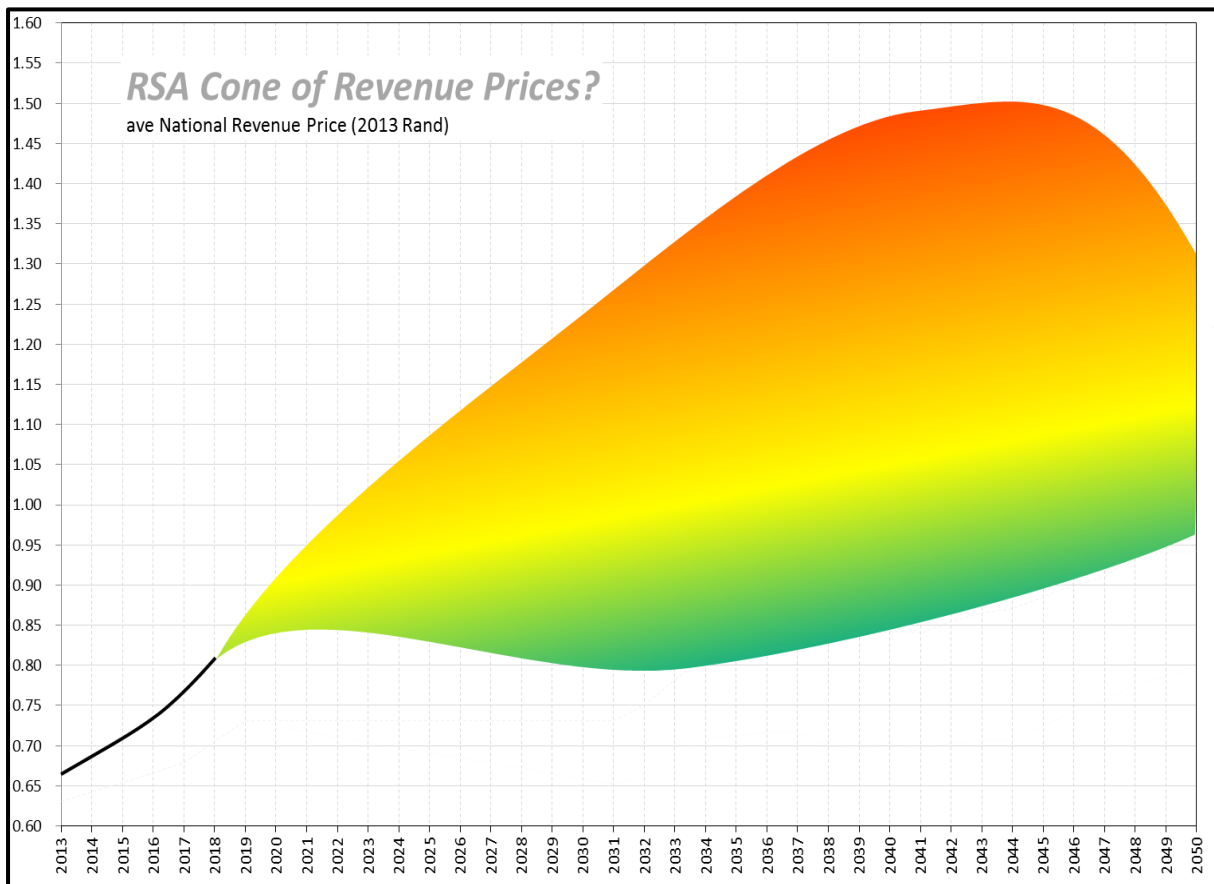


Figure 2.1: Energy cost outlook for South Africa (Snell, 2013).

### 2.1.3 Other industry constraints on operational costs in mining

On 10 August 2012, the South African mining sector witnessed the start of industry wide strikes that brought the sector to a standstill as workers demanded increases from employers (Nicholson, 2012). The industrial action that initially started at the platinum mines quickly spread to other precious metal groups and by end October 2012, costing the industry an estimated R 10bn in lost gold and platinum production (SAPA, 2013).

*“An additional R180 million was lost in coal production during the same period. The total value of production lost across all sectors of mining amounted to R15.3bn,”* South African Institute of Race Relations spokeswoman Boitumelo Sethlatswe said in a statement (SAPA, 2013).

In 2013 the challenges have not subsided as there are again talks of strike actions by labour unions AMCU (Association of Metal and Construction Union) and NUM (National Union of Mine Workers). According to Janse van Vuuren (2013), NUM members that represent approximately 64% of the mining workforce will down tools after the Chamber of Mines (Collective bargaining counsel in South Africa that represents employers) failed to meet the 60% pay demand increase. This is over and above the 11% to 22% increases passed by the Chamber in 2012.

Strategic importance of this is indicated in the AngloGold Ashanti annual financial statements under risk and internal control (AngloGold Ashanti, 2010). It is mentioned that the largest components of operational cost in the gold mining industry is labour and energy. As mentioned, both of these costs have increased in the recent past above the CPI index and pressures for further increases from unions and the sole utility Eskom will directly affect cash costs. It is of such importance that AngloGold Ashanti has put special measures in place to monitor and control these risks in dedicated energy departments that constantly monitor the security of the Eskom supply (AngloGold Ashanti, 2008).

Providing the aforementioned background it is hard to imagine that more expectations will be placed on the mining sector as it tries to weather what could only be described as an insurmountable storm. Government in 2012 from the DoE and Treasury put forward draft legislation for taking South Africa to a green economy under the following initiatives: Carbon Tax, National Energy Efficiency Strategy (NEES) and its implementation under the National Energy Efficiency Action Plan (NEEAP) in drafts for public comment.

#### 2.1.4 Carbon Tax

During the annual budget speech in February 2013, Minister of Finance Pravin Gordhan announced the introduction of carbon tax for South Africa that will start in 2015 (Gibson, 2013). The first draft of this proposed tax was published in May 2013 by the National Treasury in the policy paper for public comment (National Treasury, 2013) with the following key implications toward the mining industry according to Lyn Staib – Global Vice President for Energy, Water and Sustainability at AngloGold Ashanti (Staib, 2013):

##### *Proposed Tax Design Features:*

- Tax will be introduced on 1 January 2015.
- Tax rate – R120/tCO<sub>2</sub>-e on direct emissions only above 100,000tCO<sub>2</sub>-e per year.
- All entities with direct or indirect emissions over 100,000tCO<sub>2</sub>-e per year will be required to report emissions performance to Department of Environmental Affairs (DEA).
- Tax will apply to electricity generators (including Eskom).
- Tax rate will increase 10% per year (nominally) for first 5 years (until 2019).
- Tax will be determined on the consumption of fuel inputs used for mining purposes albeit generation or daily operational activities (with emissions calculated using factors to be approved by DEA and aligned with the Intergovernmental Panel on Climate Change (IPCC) determinations).
- Tax rate escalation from 1 January 2020 will be announced by the time of the South African budget papers in February 2019, but without any public participation or comment stages.
- Industry will be allowed a 60% tax concession that will be applied at start up and remain in place for the next 5 years until 2019.
- **Additional tax concessions will apply as follows:**

##### *Mining industry:*

- Maximum 10% for trade exposure.
- Maximum 10% for offsets (verified under internationally recognised standards).

##### *Electricity generation:*

- Maximum 10% for offsets (verified under internationally recognised standards).

- Further adjustment for all sectors (concession or penalty) – maximum 5% either way - for total emissions (direct and indirect) performance against benchmark.
- All of the tax concession provisions will be reviewed after 5 years and reduced. They may be replaced with absolute emissions thresholds (linked to carbon budgets). If this occurs, the mining industry could be subject to a carbon cap on emissions or penalties for exceeding an imposed cap.

*Additional Policy Support Proposed (as advised in the Policy Paper):*

- Support for poor and low income households, it is required that a free basic electricity initiative be strengthened so implying that some low income users will receive a portion of energy free of charge.
- National Liquids, Petroleum and Gas (LPG) strategy to provide access to safe and cleaner alternative fuel for household use (Department of Energy, 2011).
- Renewable and cogenerated energy that focusses on channelling international climate funding into small renewable energy projects, special feed-in tariffs and cogeneration.
- Energy pricing that will provide further support for renewables and phasing out of high emissions intensive power stations.
- Electricity levy found in the current Megaflex (Megaflex, 2013) tariff structure for large consumers to be phased down out of the current electricity levy. This could be considered as the carbon tax rate is increased and double taxation could occur.

General comments for mining industry:

- Since the carbon tax is to apply to direct emissions only, the mining industry is at greatest risk of exposure to Eskom pass-through.
- The maximum benchmark penalty of 5% would be applied to Eskom on current an indication that is likely that concessions would be reduced to 55%.
- Since the tax escalates over time, most likely ahead of inflation as was seen in Australia (Burn, Reed & Toth, 2013) and since it is designed to eventually mesh with carbon budget controls on emissions (that is, emissions caps), the mining industry should thoroughly understand each provision of the tax and its potential longer term implications.
- National Treasury is relying on effective parallel and complementary policy processes across the whole policy spectrum in South Africa. These include:

- Renewable energy industrial development through Industrial Policy Action Plan (IPAP) (Industrial Policy Action Plan, 2012).
- The National Growth Path (NGP), which promotes job creation through the green economy via technology innovation, expanded public employment schemes to protect the environment, renewable energy and biofuels.
- The Electricity Integrated Resource Plan (IRP), which has some take up of renewables and nuclear power.
- Renewable Energy Policy, including the Renewable Energy Independent Power Producer (REIPP) program that could initiate 2.6GW of renewable energy projects.
- Energy Efficiency Strategy promoting 15% reduction in absolute energy consumption in the mining sector by 2015.
- Integrated Energy Security Master Plans and Integrated Energy Plan that encourages diversification to renewables and natural gas as sources of power generation.
- National Development Plan (NDP), which supports a managed transition to a low-carbon economy, including the introduction of a carbon price but indicates that the electricity sector could qualify for a rebate of the carbon tax.

As mentioned in chapter 1 and shown in Figure 1.2, Government must be careful with the goals of new policies and the expectations that its departments have towards the mining industry. To this point it is shown that there is a substantial need for growth and job creation and it is largely dependent on industry and mining to cater for it. An article by Bloomberg news mentions the need that such a growing economy will have for water and power resources (Bloomberg, 2013). Over and above points mentioned thus far the DoE have placed into circulation the National Energy Efficiency Strategy (NEES) and National Energy Efficiency Action Plan (NEEAP) that targets as mentioned by Staib (2013) a 15% reduction in energy consumption by 2015 from the mining sector.

### **2.1.5 National Energy Efficiency Strategy (NEES)**

The National Energy Efficiency Strategy (NEES), published in Government Gazette No. 35920, by the then Minister of Energy Ms Dipuo Peters outlines as mentioned the pathway for South Africa to a greener economy and initial steps towards reducing 15% of all energy consumption in several sectors that include mining by 2015 from the base load consumption profiles in 2000 (Government Gazette, 2012). In the foreword it is mentioned that the new legislation comes at a time when the world is still recovering from the aftermath of the 2008

global financial crisis with many companies reducing on labour cost and also the vision from Government for new job creation. The strategy with its sole purpose to align with international trends on climate mitigation is outlined as follows:

### *Energy Efficiency*

Energy Efficiency is defined by the World Energy Council as “*efficiency improvements that refer to a reduction in the energy used for a given service or level of activity*”. This reduction is normally associated with changes from either behaviour or technology (World Energy Council, 2013). The technology available for implementation could be split into several different alternatives but according to the NEES was separated into the following categories for consideration as solutions in achieving the set targets:

- *Energy Substitutions*: Alternative products that reduce the level of energy requirement to provide the same level of service. Energy office (Energy Office, 2013) states that this is a level of energy management and is supported in their statement by Capehart, Turner and Kennedy (2007) in that efficient and effective use of energy is a form of energy management with the sole purpose to minimize costs and to try and enhance a company's competitive position. The NEES in section 4.3 states that there will be an expected energy efficiency improvement from the mining industry of 15% by 2015. An argument from the EUIG states that industry cannot be expected to achieve this target if the base load consumption from where the improvement is suggested to be made remains unknown (EIUG, 2012).
- *Renewables*: According to Dictionary.com (2013) renewable energy is any natural form of energy that is inexhaustible by nature and as examples will include sun, wind and wave energy forms. Gritsevskiy (2013) argues that renewables are any form of energy that is naturally occurring and sustainable, in her report to the United Nations (UN). South Africa's Karoo has some of the best solar radiation areas when compared to European nations, and is one of the biggest untapped energy sources globally based on research findings by the DoE's renewable energy section (Renewables, 2013). Figure 2.2 illustrates the radiation levels per meter squared ( $m^2$ ) as found in South Africa. Remarkable is the fact that almost all the provinces except for the coastal regions have radiation levels that exceed the global average of 6500 MJ/ $m^2$  annual radiation.

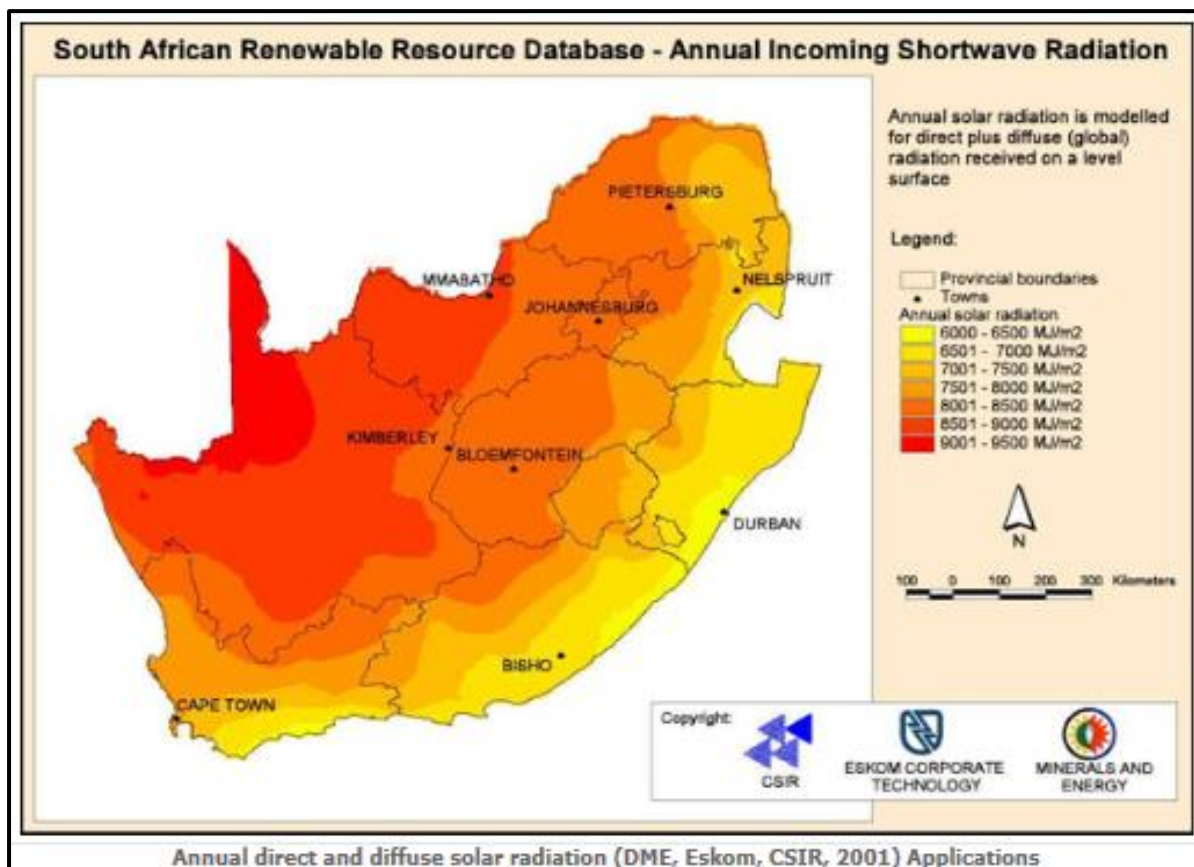


Figure 2.2: Annual Solar Radiation for South Africa (Solar Distributors Africa, 2013).

- *Fuel Switching:* From the NEES (Government Gazette, 2012) fuel switching is simply described as alternative fuels source from what was the norm, so the conversion from conventional Diesel to Biodiesel. Diesel comes from non-sustainable processes that have an infinite lifespan whereas Biodiesel is produced from fatty acids that are found in common food such as Corn, Sunflower, Soya Beans and Peanuts to mention but a few (Mandjiny, Periera & Tirla, 2009). These are all agricultural products currently available and have a larger life expectation that that of oil sources.
- *Re-Generation / Own Generation:* According to Mortensen (2004), Co- or Regeneration is the process of delivering energy in more than one form from a single energy source. This implies that available energy could be used to regenerate for other purposes via turbines or heat sinks.

Mentioned above is a brief explanation of what technologies the NEES targets to achieve industry goals. In a reply by industry it's indicated that technical challenges and capital availability for proper feasibility studies alone would take industry past the 2015 target and therefore the ambitions of the NEES was out of line with achievable targets (EIUG, 2012). Therefore, Government soon realized that the goals as set out in the NEES were ambitious and somewhat unrealistic. The timeframe provided and the funding mechanism to allow industry and mining to achieve these targets was unrealistic but still required input. This

paved the way to what is known as the National Energy Efficiency Action Plan (NEEAP), collaboration between all stakeholders to understand their abilities to comply with the requirements as set out in the NEES but to do it in such a manner that job security is ensured and that the NEES with its requirements do not counteract the NGP.

### **2.1.6 National Energy Efficiency Action plan (NEEAP)**

Advancing from the NEES, public consultation sessions with relevant stakeholders indicated to Government that several opportunities or critical path items exist to fast track industry and mining in: 1. establishing their base load profiles and 2. energy reduction methods that will assist in achieving allocated targets (Unlimited Energy, 2013). The critical path items included:

- *Energy Audits:* According to Hasanbeigi and Price (2010, 7), energy audits is a “*systematic, documented verification process of objectively obtaining and evaluating energy audit evidence, in conformance with energy audit criteria and followed by communication of results to the client.*”. By completing energy audits on the companies that make up the largest consumption profiles of each industry Government will be capable of establishing a base load of current activities and how they have increased or decreased since the initial base year of 2000 (Unlimited Energy, 2013). Problem in this specific area is that not all companies have energy data dating back to the base year and extrapolation would be required to estimate the figures.
- *Technology information and best practice:* Collaboration between companies towards this single project could identify industry best practices and share lessons learned in order to achieve quick savings.
- *Energy Saving Companies (ESCO'S):* Eskom since the start of its Integrated Demand Management Program (IDM) to build a virtual power station from energy savings have worked in partnership with ESCO's. The program since its inception in 2001 has collectively saved about 2,495 TWh's of energy that is equivalent to almost the same demand reduction as Medupi or Kusile in the current build program (Etzinger, 2013). The cost of the program is a fraction when compared to the new power stations but energy efficiency projects are becoming scarcer as all the low hanging fruits have been plucked.
- *Energy Modelling:* It is clear from the NEEAP that the biggest shortfall in the NEES was the assumptions made without accurate energy modelling. It is also emphasized that accurate forecasts from industry is lacking and that focus should be placed on energy modelling and the development of energy forecasts that would assist

Government in understanding the energy requirements. These forecasts are critical for the IRP projections and cost structures for financing (Unlimited Energy, 2013).

Based on the above critical path items scenarios were provided in the NEEAP for respective stakeholders to model their industries and predict to unknown accuracies what their energy requirements could be. Illustrated in Figure 2.3 below are the suggested modelling paths as outlined in the NEEAP for stakeholders. An in-depth study was completed with the EIUG on both these paths and will be discussed in section 2.3.

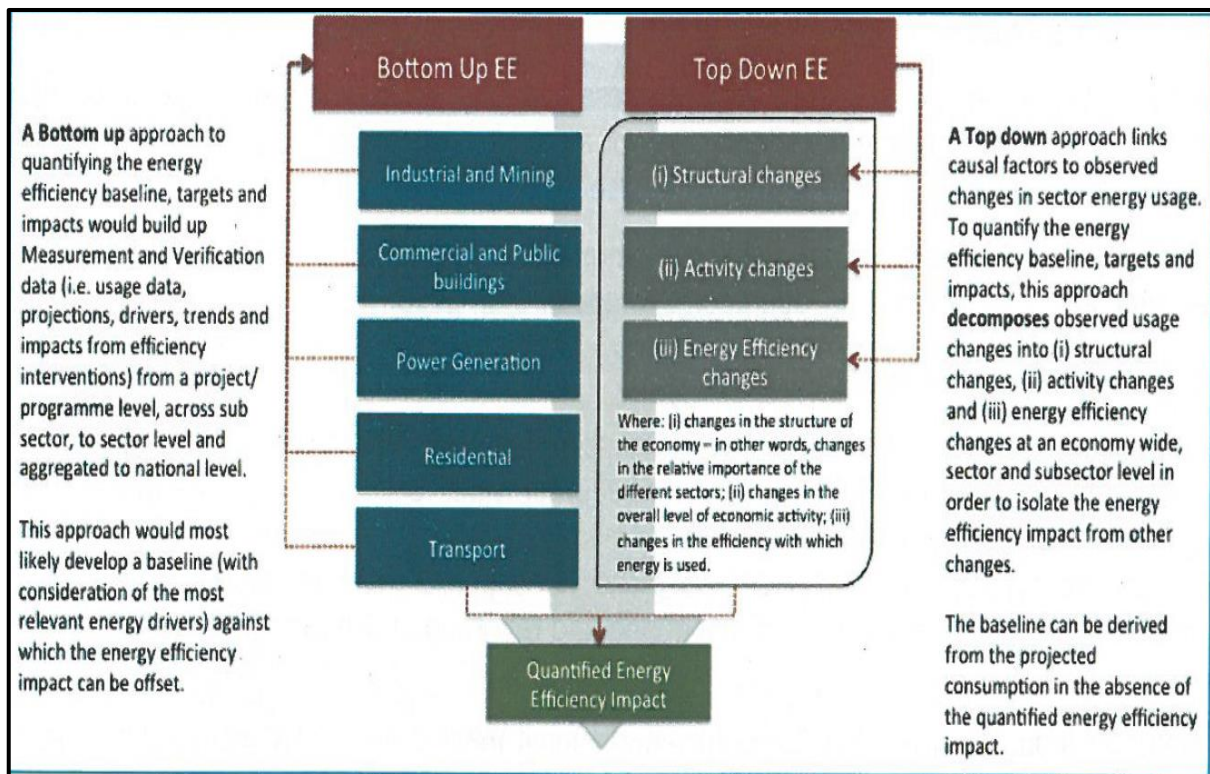


Figure 2.3: Energy modelling as suggested in the NEEAP (Unlimited Energy, 2013:25)

Up to now it is clear that there are significant pressures placed on stakeholders in both industry and mining to reduce energy numbers and increase jobs. To some extent there is assistance in funding mechanisms introduced by Government, Independent investors and Treasury to alleviate some but not all of the capital requirements as discussed below.

### 2.1.7 Funding

Work done by McKinsey and Company in 2010 showed that from the inception of the Kyoto Protocol and its research findings in international studies which speculate the effects of carbon emissions on Earth's atmosphere; that requirements globally indicate without funding incentives little work would be feasible to offset carbon emissions (McKinsey & Company, 2010). The report shows the benefit of having an international carbon trade mechanism that

allows for the selling of carbon credits in geographical areas that could provide funding incentives towards reducing emissions. The findings are supported by Palmer, Walls and Gerarden (2012) that show that energy savings could be done via capital borrowing mechanism as they provide good returns on invested capital if proper financial programs are in place. Energy efficiency projects require substantial upfront invested capital as they normally coincide with process variations or upgrades instead of typical retrofit programs.

In South Africa there are 2 funding options for energy efficiency programs that are active with an additional measure being legislated by National Treasury on tax incentives. For the purpose of this report we will only consider the active mechanisms that exist in Governments Eskom Integrated Demand Program (IDM) and the international Clean Development Mechanism (CDM).

#### **2.1.7.1 Eskom and Integrated Demand Management (IDM)**

Eskom Integrated Demand Management (IDM) was established in 2001 with the sole purpose to build capacity in the constraint energy supply utility. The program had several funding mechanism depending on the type of technology used and its ease of installation. The models used will evaluate the difficulty of the energy saving initiative, its installation period and the projected saving to allocate funds (Etzinger, 2013). As mentioned in section 2.1.6 the program has saved in magnitude the same amount of demand (MW) as a new power station like Medupi and Kusile. Available information (IDM, 2013) indicate that funding would typically vary from R 3.8m/MW to R 6.7m/MW and that it is significantly lower than the new build program for power stations with an outlook of R 18m/MW based on the Eskom media statement in July 2013 (Eskom, 2013).

#### **2.1.7.2 Clean Development Mechanism (CDM)**

Finding its origin in the Kyoto protocol the Clean Development Mechanism was established so that Certified Carbon Emission Reductions (CER's) could be claimed and made available for trading under the carbon trading platform between geographical areas (Winkler & Van Es, 2007). The incentive that drives the CDM and how it separates itself from the IDM program is that it wants to incentivise projects that do not necessarily provide payback terms on capital funding that is shorter than three years. The additional benefit of having carbon credits available for trading is the fact that trading prices work on an open market system (Niemack & Chevallier, 2010) that could benefit any holder of carbon credits given future price uncertainty. The research further indicates that the future of this funding option is unknown from targets on emission reductions that are stated to be ambitious for developing countries like South Africa with its high emission profile and mineral energy complexity.

Funding for energy efficiency is therefore very limited as both the above mentioned options may take up to two years of waiting for approval on new projects under the IDM or CDM mechanisms. Eskom's MYPD3 (2013) application was limited to an increase of 8% instead of the initial 16% with indications from NERSA that energy efficiency funding in the IDM program will be reduced.

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## **2.2 ENERGY FORECASTING AND MODELLING**

### **2.2.1 Background**

The Oxford dictionary defines forecasting as “*a calculation or estimate of future event*” (Oxford, 2013). The Business Dictionary defines it as “*a planning tool as it attempts to deal with the uncertainty of the future*” (Business Dictionary, 2013) and Investopedia (2013) describes it “*as a process of looking at historical data to predict future trends*”. There is a commonality in this literature that forecasting deals with a level of uncertainty and therefore by no means is fixed and firm but should rather be seen as an indicative tool that uses historical information to estimate the future values.

Work done by Sterman (1986) shows that historically there has always been a need for energy forecasting, and to have models that would to some extent predict what future energy requirements should look like. His work also shows via a gap analysis that the forecasting was never in line with actual trends at the time and considerable errors were made when comparing actual versus outlook energy profiles based on variable assumptions. A decade later his findings was again proven by Smil (1999), on work done by Weinberg (Weinberg, 1979) who showed that the newly developed DYNAMO model from the Massachusetts Institute of Technology (MIT) was inaccurate. DYNAMO was intended to provide an energy profile of 20 years for the United States of America (USA) and in some years was out by more than 7% on sector level (mining or industry) but not the total aggregated level (total USA) that averaged on 0.5%.

A study by Winebrake and Sakva (2006) showed energy forecasting in the USA when looking at the period of 1982 to 2003 was out by 0.1% on aggregated level but some 4.9% on sector level. They further state the importance of accurate energy forecasting as it provides a policy outlook for capital investment from Government. Research by Sheffield (1997) showed that global consumption of oil with a total human population of 6 billion was at 9 000Mtoe/a and will increase to between 15 000Mtoe/a and 21 000Mtoe/a when the numbers double to 12 billion. It is also shown that there is no direct correlation between population growth and energy required as assumptions are made that renewable energy

streams form part of power generation. Figure 2.4 below illustrates variation in energy requirements for population growth and commercial energy requirements and it is evident that assumptions will form part of energy forecasting. It's therefore inevitable that assumption will lead to errors and that it will transfer onto the client of the utility as mentioned in section 2.1.2.

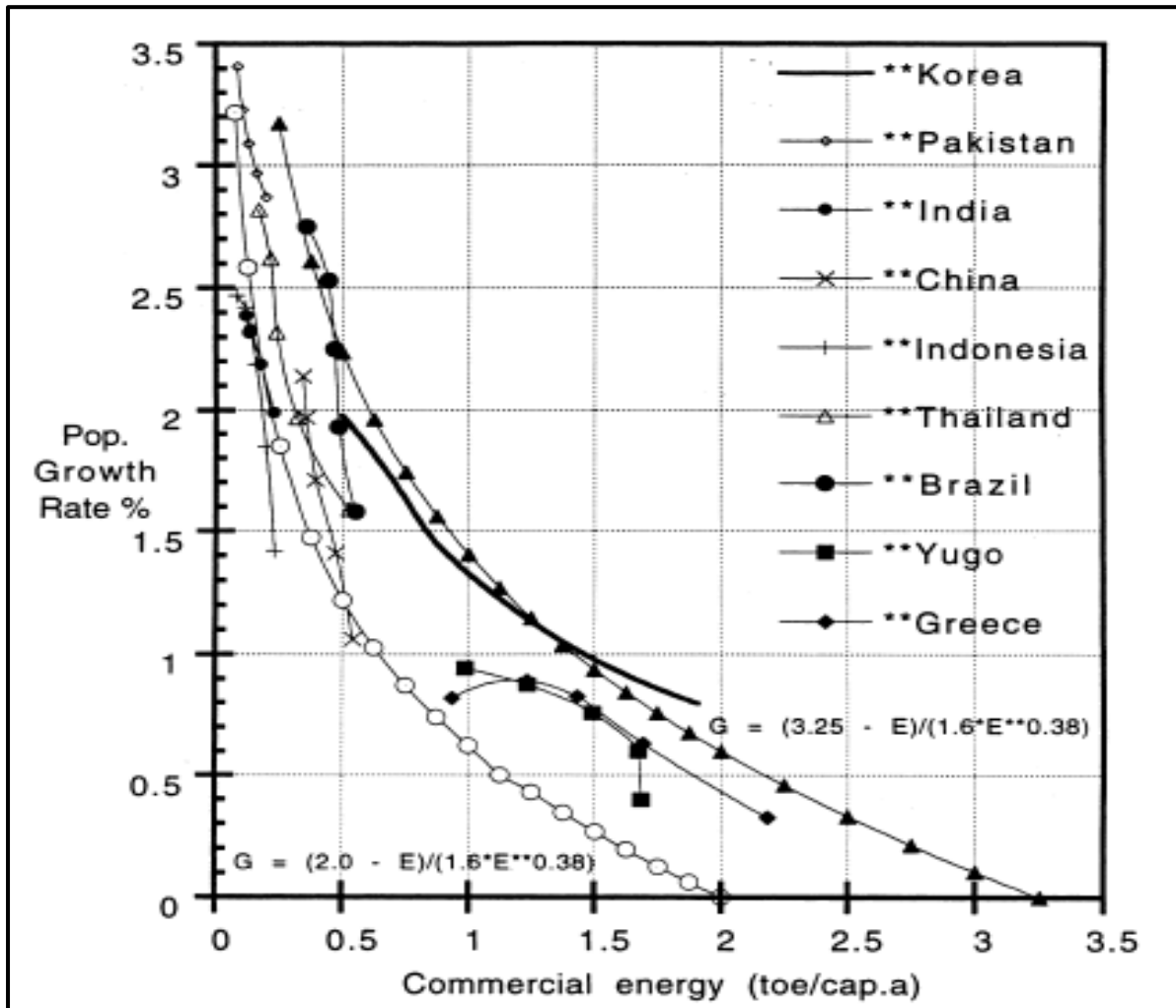


Figure 2.4: Population growth rate versus annual energy per capita (Sheffield, 1997:8)

Given the aforementioned background it would be expected that there are vast amounts of studies that show the implication of energy outlooks and their cost implications on mining. Unfortunately international models developed are either at aggregated (national) level and are utility based. For South Africa work done by Inglesi (2009) provided an aggregate electricity demand forecast to 2030 from a process similar to that of a time based regression model. The regression is extrapolated based on the historical information and forecasted energy requirements in the not so distant future at 130 TWh in 2016. This is in complete contradiction to the work done by Surtees (1998) for Eskom where he predicted a consumption of between 200 TWh to 250 TWh for the same period. Methodologies by both

differ and based on the 2012 published generation results from Eskom both were out by some 80 TWh, Figure 2.5 below shows the squared and linear outlook approaches used by Inglesi and Surtees.

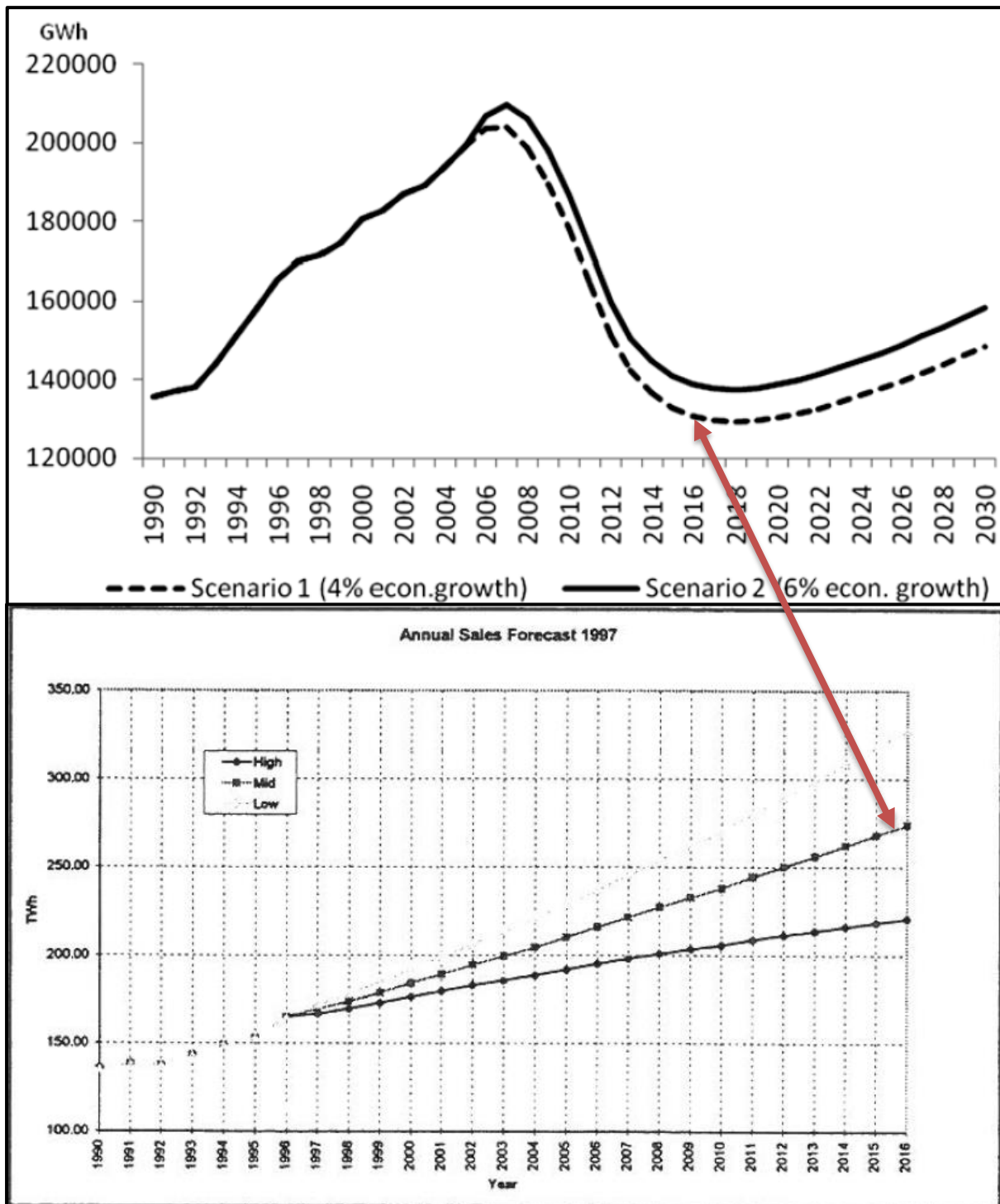


Figure 2.5: South African energy forecast according to Inglesi (top) and Surtees (bottom).

For the purpose of this study key fundamentals used by both Inglesi and Surtees will be used for further research to try and establish energy forecasting principles that would be applicable in mining applications. Work done by Nelson (1989) on demand forecasts in

South African Coal mines followed a regression approach but with limited statistical data interpretation and it is aligned with research outcomes in a study by Delport and Lane (Delport & Lane, 1996). General trends from all the research found show a regression as an initial starting point for capturing historical data which is then combined or adjusted to the specific case study variables. An investigation by Deloitte on the expansion of the regression model to a full Monte Carlo Analysis is also included in section 2.4. All these are compared with work done by the EIUG on energy models as they are proposed by the NEEAP in section 2.1.6 to indicate future uncertainty and to what sort of risk level they alleviate for investors as proposed by Ahsan and Uddin (2005).

### 2.2.2 Regression model

According to Vardeman (1993) a regression or linear regression is a statistical model where a response variable (Y) is directly or indirectly correlated to an input variable (X). This could also be described as a model where the (Y) variable is statistically calculated based on a normal distribution of (X) given the associated confidence level of the normal distribution as shown by Figure 2.6 below and mathematically in equation 1.

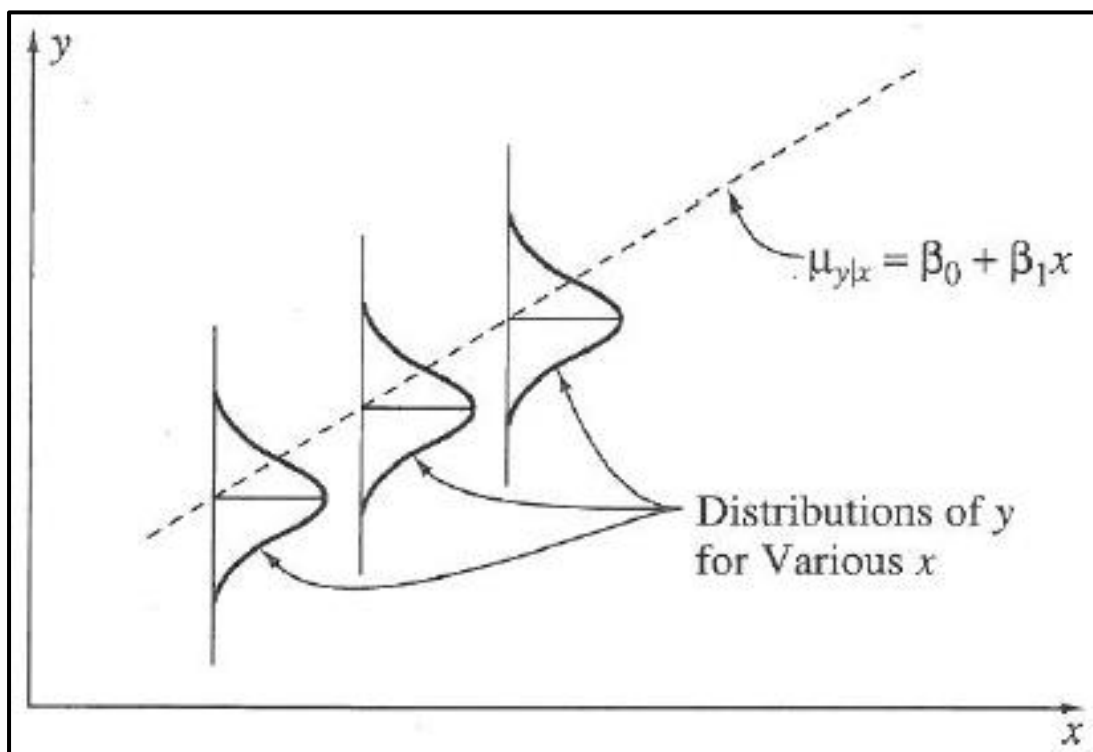


Figure 2.6: Regression model of a response variable Y and its input variable X

$$Y_i = \beta_0 + \beta_1 X_i + \varepsilon_i \text{ with } i = 1, \dots, n \quad (1)$$

The constant ( $\beta_0$ ) is the point that the response variable (Y) intersects the vertical axis and could be considered the base value. Equation 1 shows the regression equation for a single

variable (X) and therefore ( $\beta_1$ ) is the slope of the regression line. Epsilon ( $\epsilon$ ) captures the random error (residual) in variable (Y) depending on the number of observations (i). According to Levine, et al., (2011:554) equation 1 could simply be expanded for additional variables. For the purpose of this report no more than 3 variables are used to show simplicity in linear expansion techniques and shown below by equation 2.

$$y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \epsilon_i \quad (2)$$

When adding variables (X, i...n) to the equation a constant ( $\beta_i$ ) must be added that represents the slope of the variable (X) at the point if the rest remain constant. The same technique is used in work by Cerda and Westermann (2009) that predicted the electrical load for an energy efficiency scheme in expanding electrical systems. Variables used looked not only at electrical system expansion but also included what the effects of macroeconomic drivers could be on the network. When referring back to the model by Surtees commonality is shown in the linear expansion of the graph. The work done by Inglesi however shows that a multiple squared regression was used based on the same variables with a quadratic response as in Figure 2.5. The fundamental difference to equation 2 to cater for the quadratic curve fitting is the expansion of constant ( $\beta$ ) with the same variables (X1) to (X3) as shown by equation 3.

$$y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_3 X_1 + \beta_5 X_3 X_2 + \beta_6 X_2 X_1 + \epsilon_i \quad (3)$$

Levine, et al., (2011:561) suggests that a coefficient of multiple determination ( $r^2$ ) be used to measure the proportion of the variation in variable (Y) that is explained by the variables (X, i...n). The application of this is it provides the user with a confidence in the regression and indicates how accurately the variables (X, i...n) represent the response variable (Y). When expanding to multiple variables an Adjusted ( $r^2$ ) must be used to reflect both the number of independent variables (X, i...n) and the sample size.

Finally a residual analysis should be included to evaluate the actual response variable (Y1) against the regression response variable (Y2). The residual is equal to the difference between the actual and the regression variables as shown in equation 4.

$$\epsilon_i = y_{1i} - y_{2i} \quad \text{with } i = 1, \dots, n \quad (4)$$

The requirements for model verification based on the residual analysis are Levine, et al., (2011:516-519):

- *Linearity* – A plot of the response variable (Y) against the input variable (X) with a visual inspection if there is a linear relationship between the data or not.

- *Independence* – By plotting the residual in equation 4 against the input variables (X, i...n) it establishes if consecutive residuals are independent or not. Should there be a cyclic pattern in the data the residuals are not independent.
- *Normality* – By plotting the residuals in a normal distribution there should be normality between them if evaluated in a frequency distribution i.e they should not depart substantially from the normal distribution.
- *Equal Variance* – An evaluation is done when plotting the residuals against input variables (X) and evaluating the homogeneity (their variability) of the data points, if it has an equal variance to the reference point it is valid for each level of X.

Levine, et al., (2011:536) mention that the pitfalls of a regression model are:

- Lacking awareness of the assumptions of least-squares regression.
- Not knowing how to evaluate the assumptions of least-squares.
- Extrapolating outside the relevant range

The last mentioned point is further discussed in section 2.2.4 on future predictions of statistical models.

### **2.2.3 Monte Carlo Analysis**

Mentioned above, there exists several pitfalls in a linear regression model, that increase the error percentages when extrapolating outside a certain data range. A solution to this problem comes in what is known in statistics as a Monte Carlo Analysis when the underlying distribution and parameters are known. According to Mooney (1997:1) a Monte Carlo Analysis is applied when the response variable (Y) interference cannot be interpreted by the input variable (X) in a regression analysis, to name but a few possibilities the error term ( $\epsilon$ ) is correlated with an independent variable or might be skewed. This could lead to the least squares ( $r^2$ ) to be off the mark. Therefore Monte Carlo Analysis is applied as it provides:

- Exploration of parameters in estimating a variety of distributions.
- It can be applied to determine estimator properties in multi equation systems.
- Results from valuable statistics that are calculated from a mean and absolute averages.

Mohr's (1990) view for a Monte Carlo Analysis is that the centre principle of sampling a distribution is the range of values that are taken from a sample to build a population with its associated probabilities. The statistical bias could be assessed by drawing observations in its behaviour; the user of the Monte Carlo Analysis is creating an artificial world also known

as a *pseudo-population* that represents the real world. The procedure therefore of a Monte Carlo Analysis according to Moody (1997:2) is:

- Specify the pseudo–population in symbolic terms so that it could be used to generate samples. This entails the development of a computer based algorithm for data generation.
- Sample from the pseudo–population such that it reflects the population of interest.
- Calculate theta ( $\theta$ ) distribution from the pseudo–population and store it in a vector.
- Repeat these steps ( $t, i \dots n$ ) times where ( $t$ ) represents the trail numbers.
- Finally, construct a frequency distribution of the theta ( $\theta$ ) values which will then be the Monte Carlo estimate of the sampling distribution.

#### **2.2.4 Future Predictions**

Statistical model analysis by McCullagh (2002) showed that data extrapolation to some extent is valid if there is certainty that future events will follow the same patterns as historical data. However future uncertainty will increase the error percentage depending on the period of extrapolation that goes outside the historical data. For our interpretation this means, if we are looking to predict with a statistical model an event in 20 years there must be certainty that the data we have will represent that event with limited uncertainty. In a study by Lange (2005) for onshore wind farms power generation in Europe it was found that no clear pattern exists in predicting wind intensity from weather prediction data and that generated electricity exceeded the required load by almost 200% based on a couple of days forecasts, thus emphasising the uncertainty in future predictions.

Economies rely on Government investment for growth (Barro, 1990) and this is determined by policy that is based on info provided on future requirements, a future that as shown must not be too far ahead and should react to some level of historical certainty and trends. Given the South African requirements and the new build program with mining and industry having to cater for a substantial portion of the funds as mentioned in Chapter 1 will require both industries to have accurate models that illustrate expected energy patterns.

Both industry and mining have partnered with the EIUG to provide insight and predictions towards the NEEAP as submitted by the DoE and their proposed models. Section 2.3 provides an overview and detailed analysis of this process with comments on the findings.

## **2.3 MINE ENERGY FORECASTING**

### **2.3.1 Background**

As mentioned in section 2.2, very limited research exists for energy forecasting with regards to the mining sector not only in South Africa but globally. The assumption is therefore made that it never really impacted on costs to the extent that it has seen in recent years as indicated by Staib (2013). When focus is placed on the annual published reports from mining houses and more specifically mining as a sector, publications from the CoM showed energy as input cost have grown to 25% of OPEX as in section 2.1. Work done by the EIUG on the modelled approach as suggested by the NEEAP will be used to evaluate the predictions of the IRP for industry and mining in the following sections.

There are 2 key elements required from a modelling perspective, companies need to know what their energy (kWh) will look like in future and what the associated cost (c/kWh) will be. Going forward, the following sections will therefore focus on the cost (c/kWh) on the work done by mining and industry alongside the EIUG, and a final section on the energy outlook at a mine from work done by Deloitte sets the foundation for discussions in chapter 3.

### **2.3.2 South African Cost Studies (Mining & Industry)**

To date, the majority of the “independent” (non-Eskom) price path modelling has been done using a model developed during the first iteration of the IRP. This model is not considered appropriate as a long-term model; however, it is a useful starting point. In previous work undertaken by the EIUG, this model has been audited and adjusted. The outputs have also been compared to the expected international price paths of various tariffs of key international competitors, such as Russia, China, and India.

In July 2012, Sasol procured electricity pricing models from Fieldstone and McKinsey in order to provide an objective view of the potential price path in the future. This model and its outputs are further detailed in the “Bottom-Up” approach described below.

The EIUG was not given access to the Fieldstone model and the model was not reviewed for the purpose of this report. The outcomes from the model have been assumed to be representative based on Fieldstone’s description of the model’s structures and operations.

Whilst it is useful to benchmark Eskom’s outputs using independent models – it is critical that these models use a similar methodology in order to ensure the results are comparable. The Fieldstone model uses a different methodology from the Rate of Return methodology currently employed by NERSA to calculate average electricity tariffs. That is not to say that

the model is wrong or that its outputs are not representative; rather it is different and difficult to verify that its outputs are comparable.

### **2.3.3 Current Cost Models**

The approach adopted in this analysis has largely been informed by previous work undertaken by the EIUG as well as the access to publicly available capacity, performance and costing data for the power sector.

#### *Overall Approach*

In broad terms the approach entailed a basic top down determination of the price path based on various estimates on what annual increases will be applied for by Eskom and/or approved by NERSA, for the next five years. This is informed by various views on pricing presented in the past and proposed by the NEEAP in section 2.1.6.

In addition a more comprehensive longer term bottom-up pricing analysis was also undertaken based on a basic capacity expansion and costing model that derives a long term revenue price path from underlying technical, operational and commercial assumptions for the South African power market. The results of the two approaches were then compared to assess the degree of convergence on a projected average price path.

In considering electricity pricing, it is recognised that there is a vast range of electricity tariffs paid by different customers depending on their respective tariff categorisations (that is, industrial, commercial, residential, rural and so on) as well as their respective suppliers (that is, Eskom versus municipal distributors). In order to simplify the analysis and deal with the top priority pricing issues in a pragmatic way, the analysis presented here has focused on the overall average pricing level for Eskom expressed in pure energy terms (that is, c/kWh).

This approach provides a rational basis for meaningful debate on the overall average price level of electricity supply without necessarily getting bogged down in the additional complexities around tariff structures and different tariff components or around municipal tariffs.

This does not, however, diminish the importance of careful review of tariff structures, particularly given Eskom's stated intention of proposing material changes to retail tariff structures as part of the MYPD3 application and approval process. Moreover, there is widespread recognition of the complexities associated with municipal electricity tariffs. Municipal electricity tariffs vary substantially by virtue of different pricing methodologies employed and the application of a range of disparate non-electricity related levies and

surcharges that arguably do not fall under the jurisdiction of NERSA. The complexities around municipal electricity tariffs are further exacerbated by ageing power infrastructure, maintenance backlogs and the level of financial distress that many municipal distributors are experiencing. These aspects are not analysed and addressed herein, but should form the focus of additional work undertaken by the EIUG in order to develop informed EIUG positions on all the key issues affecting energy intensive users.

### **2.3.3.1 Price Path Considerations**

Notwithstanding the simplification noted above, it is still necessary to define the different “average” pricing levels presented to highlight the key issues and avoid confusion and misinterpretation. These are:

- *Revenue Price Path* - This provides an indication of the overall average level of electricity prices from Eskom, incorporating the existing Eskom generation fleet, new Eskom capacity, IPP capacity and Eskom transmission and distribution costs. As such, the municipal electricity pricing is not addressed.
- *Megaflex Tariff/Price path* - This provides a view on the indicative level of prices for large industrial users, based on a selected target market (typical large customer load profile)
- *Megaflex Variable/Energy Price Path* - This provides a reference price for non-Eskom generators either co-located at the off-take site or wishing to wheel to bilateral third part off-takers.

### **2.3.3.2 Top-Down Approach**

Eskom has indicated on various occasions that the next MYPD period should be extended from the standard three year to a five year determination. This, it is argued, will provide a slower glide path and associated relief for consumers. This will simultaneously provide greater certainty to ratings agencies and lending institutions that cost-reflective tariff levels will be reached within a defined timeframe.

Eskom’s MYPD3 application will thus cover the period 2013/14 to 2017/18. The top-down analysis is limited to the proposed five year MYPD3 period. This is the period which is of primary concern to energy intensive users and potential developers of private generation capacity. Although the longer term price path is clearly also important, there is much uncertainty concerning the key demand, capacity and cost assumptions beyond 2017. In particular, the extent to which the rising prices will suppress demand and reshape the South

African economy is not clear; the price elasticity of demand is not well understood. The focus of the top-down analysis has thus been limited to the MYPD3 period to 2017.

One of the greatest challenges in attempting to examine and assess Eskom's assumptions underlying a projected price path is the degree of information asymmetry that prevails: Eskom will inevitably have more accurate information than NERSA or the public. As a general matter, this makes it difficult for NERSA to simultaneously ensure exact cost recovery and provide optimal incentives for cost minimisation. The top down analysis thus draws on a few data sources.

- The 2010 MYPD2 cost reflective tariff level - Under the MYPD2 application and determination Eskom and NERSA made reference to indicative longer term cost-reflective pricing levels. These provide a helpful perspective to compare and evaluate the proposed MYPD3 application, particularly in respect of the early MYPD3 years.
- The original and adjusted IRP2010 price path model – Used, in the first instance to determine the IRP price path published with the IRP 2010 promulgated in 2011 and subsequently revised by the EIUG.
- Stakeholder communiqués on the Eskom MYPD3 application – salient aspects of the Eskom proposed MYPD3 application shared with both government and some of its key clients in recent months.

Key observations from the model indicated that:

The analysis indicated that increases of 25% per annum for 5 years reached an average tariff level of 82c/kWh (real 2010) by 2014/2015, which delivered manageable financial ratios as well as no cash flow shortfall. This was deemed to represent the full cost-reflective target tariff level. Inflating at 6% per annum gives a target average price level of 92c/kWh (real 2012) by 2017. In conclusion, 92c/kWh is therefore the first indicator that can be used in benchmarking what a cost-reflective tariff would be for Eskom.

### **2.3.3.3 IRP2010 Price Path and EIUG modelling**

The IRP2010 was promulgated in May 2011 and presented a long term price path based on the IRP pricing model. This price reached an average price level of around 97c/kWh (2010) in 2017. Inflating this at 6% per annum gives an average price level of 1.09c/kWh in 2012 terms. In late 2011, the EIUG undertook an assessment of the IRP price path model in order to establish its integrity and accuracy. Certain structural aspects and assumptions in the model were corrected and a revised set of IRP price path outputs were produced.

The base case price level in 2017 from this revised modelling was determined to be 89c/kWh (2010) or, if inflated at 6% per annum, 99c/kWh in 2012 terms. It is noted that the IRP price path modelling includes the implications of full build for the IRP2010, which takes account of additional funding requirements for new capacity beyond Kusile as shown by Figure 2.7.

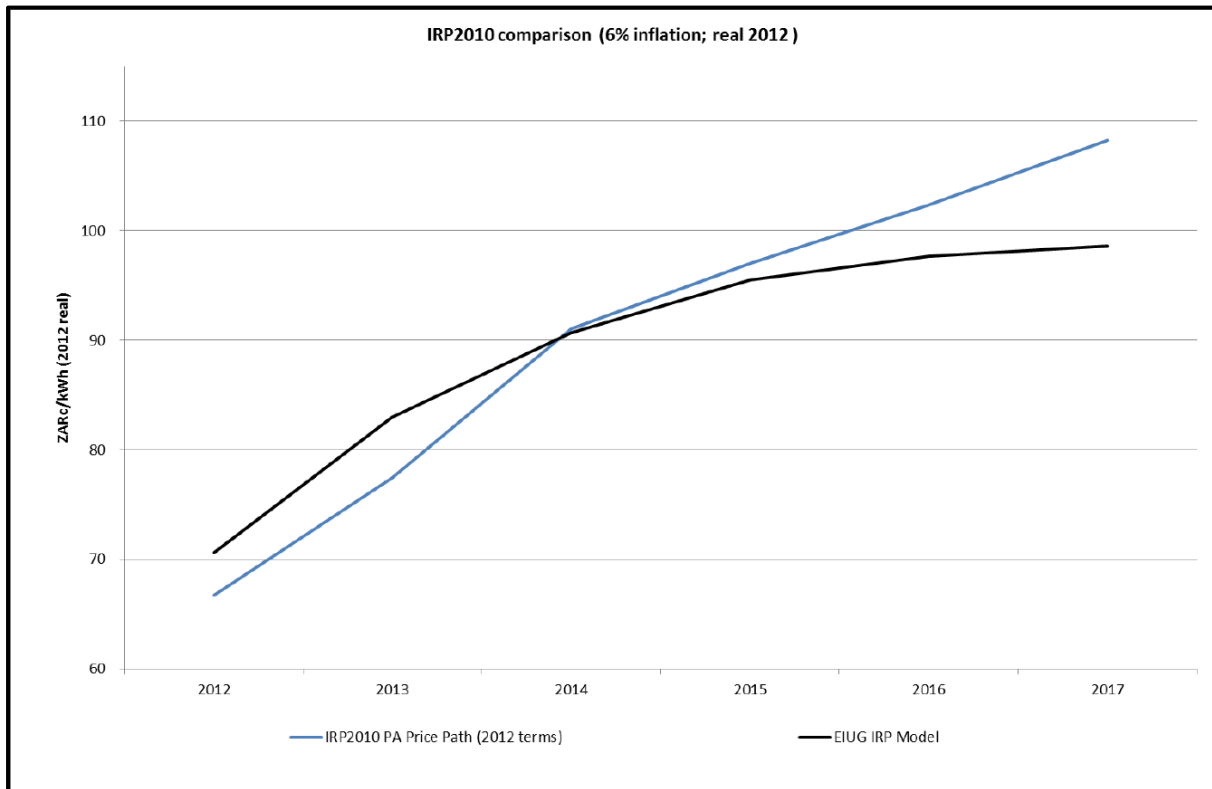


Figure 2.7: IRP2010 energy price path versus EIUG top down study

### 2.3.3.4 Bottom-Up Approach

The bottom-up approach essentially entailed the application of a pricing model developed by Fieldstone Africa (Pty) Ltd (“Fieldstone”) and procured by Sasol Ltd (“Sasol”). The model and assumptions were adjusted by Sasol in conjunction with Fieldstone to reflect a rational view of South Africa’s electricity supply market into the future.

The pricing model is Microsoft Excel-based. Short and long-term electricity demand, supply and cost estimates are derived by applying a set of economic, technical and financial inputs and assumptions in order to forecast future annual electricity demand and supply as well as average electricity pricing for the period 2011 to 2040. This pricing represents the “Revenue Price Path” described above.

The model takes account of the existing portfolio of Eskom power stations and brings additional new capacity on line as set out in the IRP2010 (Policy Adjusted Scenario) with

some adjustments as noted below. In the event of a supply shortfall the model assumes that additional reference plant coal-fired capacity is brought on line to meet demand. System peak (MW) and energy (MWh) demand is forecast based on a projected growth rate taking account of a required minimum reserve margin. The model thus delivers “capacity and production plans” that comprise anticipated annual system capacity and energy supply profiles for the modelling period (2011 to 2040).

In order to determine the average price path, the model determines the fixed capacity and variable (energy) charges required by each power plant within the plans. These charges are, in turn, determined on the basis of the costs associated with each power plant (or power plant grouping).

- *Capacity charges* are derived to cover the fixed costs associated with each plant/grouping. These cost elements typically include interest payments and principal repayments on debt, the fixed cost portions of fuel and operating/maintenance expenditure and the required equity return.
- *Variable (energy) charges* are derived to cover the variable costs associated with each plant/grouping. These variable costs typically include the variable fuel and variable operating and maintenance costs.

These capacity and variable (energy) charges are used to determine the total generation costs of meeting the peak capacity and peak energy demand as per the system capacity and energy supply profiles and as per the individual capacities and load factors of the different power plants. The transmission and distribution network and customer service costs are then added to the generation costs based on historic benchmark cost data for Eskom. Provision is made for technical losses as well as non-payment “losses” which also increases the tariff required. The environmental levy also gets added and its forecast makes provision for the introduction of a carbon tax which is phased in until 2020, and then increased with inflation.

The combined generation, transmission and distribution costs then broadly equate to the annual system revenue requirement for supply to meet demand and to be economically viable. This total annual system revenue requirement is then divided by the annual energy production to deliver the annual average revenue price for each year in the model. This is collated to define the long-term price path. It is noted, further, that in order to emulate the current NERSA methodology applied to Eskom (whereby a return on work under construction is provided for), the model incorporates appropriate capacity payments prior to the defined commercial operations dates for a new Eskom-built plant.

In addition to the Revenue Price Path, the model delivers the required annual tariff escalation. This is based on a simple comparison between the average prices between one year and the next. An option is included in the model to limit the price escalation, where an escalation ceiling is imposed. The various indicative Megaflex Price Paths are from the Revenue Price Path based on the prevailing (2012) ratio between the average pricing levels and the Megaflex tariff, taking into account the variable and energy elements contained in the tariff structure. To simplify the analysis this is done for a typical Megaflex customer with a summary of findings shown in Figure 2.8.

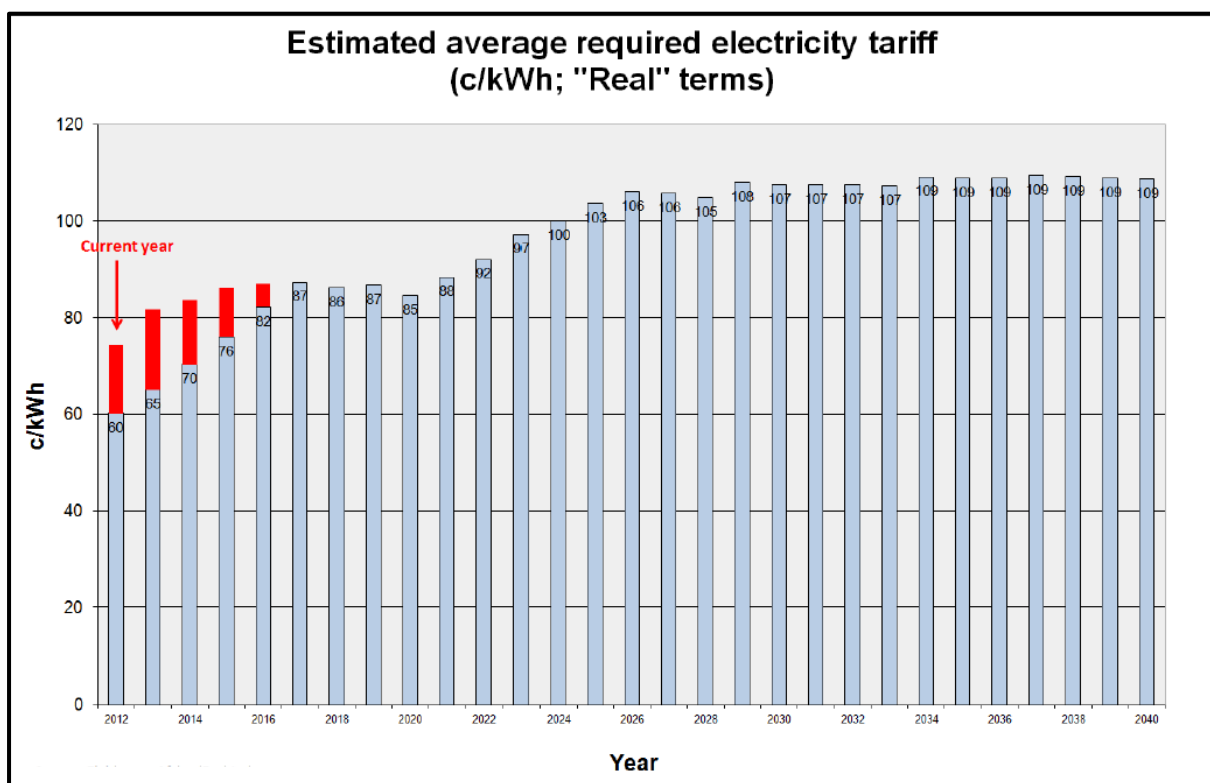


Figure 2.8: Bottom up approach price path

### 2.3.3.5 Megaflex Price Path

The average Revenue Price Path presented and discussed above provides a valuable indication of the overall average level and trend in electricity prices for South Africa. It is, however, noted that in practice no customers pay the average price. For energy intensive users the Megaflex tariff provides a better indication of the level of prices that large industrial customers will face in future.

As noted above, the indicative Megaflex price path is derived from the Revenue Price Path based on the prevailing (2012) ratio between the two pricing levels. To simplify the analysis this is done for a typical Megaflex customer profile (that is, 80% load factor, connected at 66 to 132 kV, located < 300 km from Johannesburg). The results of this analysis are shown in

Figure 2.9, indicating the average Revenue and indicative Megaflex Price Paths respectively.

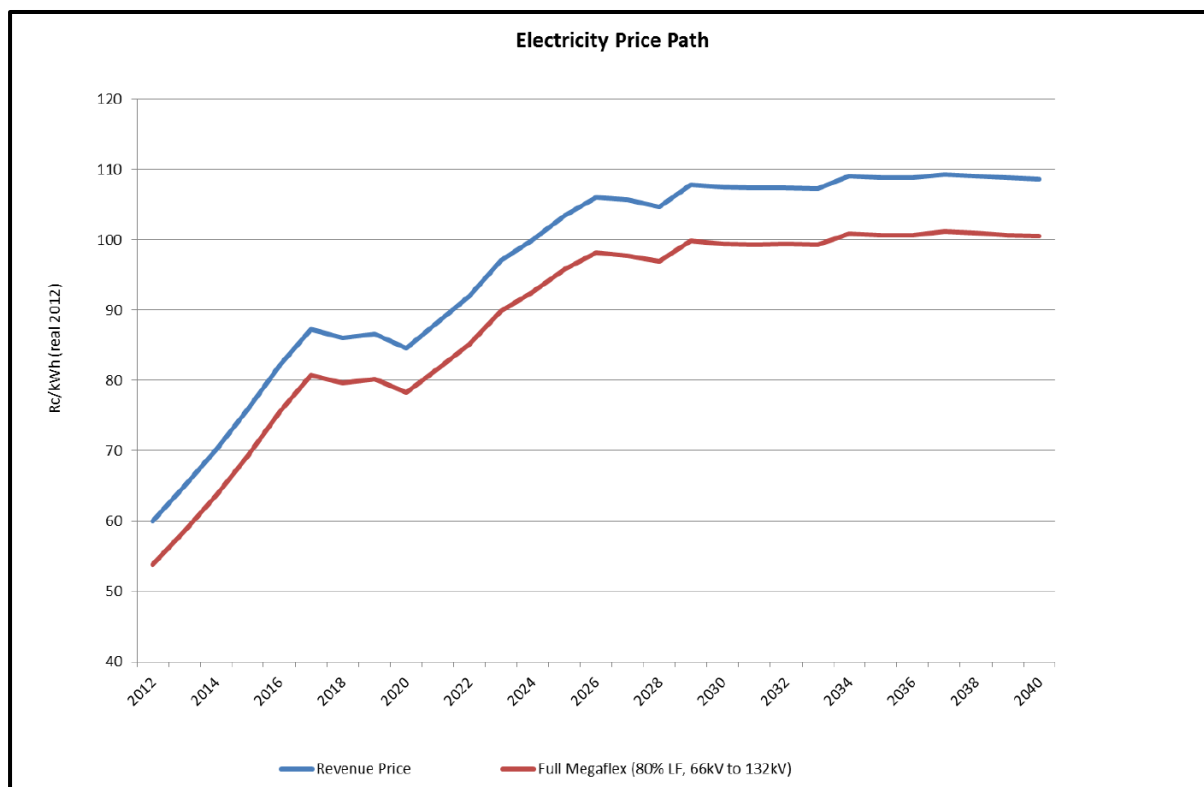


Figure 2.9: Megaflex price path

### 2.3.3.6 Megaflex Variable and Energy Price Paths

There are various own generation, co-generation and IPP initiatives under way within the power sector with large users seeking to mitigate the risks around supply security and the substantial increases in Eskom tariffs. It is important for the developers of these projects as well as the potential off-take customers to understand the extent to which power generated can be offset against Eskom charges. The full variable and energy components of the Megaflex tariff are relevant in informing this view respectively.

As was done for the overall Megaflex Price Path, the indicative Megaflex Energy Price Path is derived based on the prevailing (2012) ratio between the Revenue Price Path and the Megaflex tariff, but taking account of only the energy tariff components, namely the (peak, standard and off-peak) energy charges and the environmental levy. Similarly, the Megaflex Variable Price Path incorporates the energy charges noted above plus the Distribution Network Demand charge (which is levied on actual Maximum Demand and thus deemed to be variable) and the Electrification and Rural Subsidy. Figure 2.10 shows the results of the Megaflex Variable and Energy Price path study.

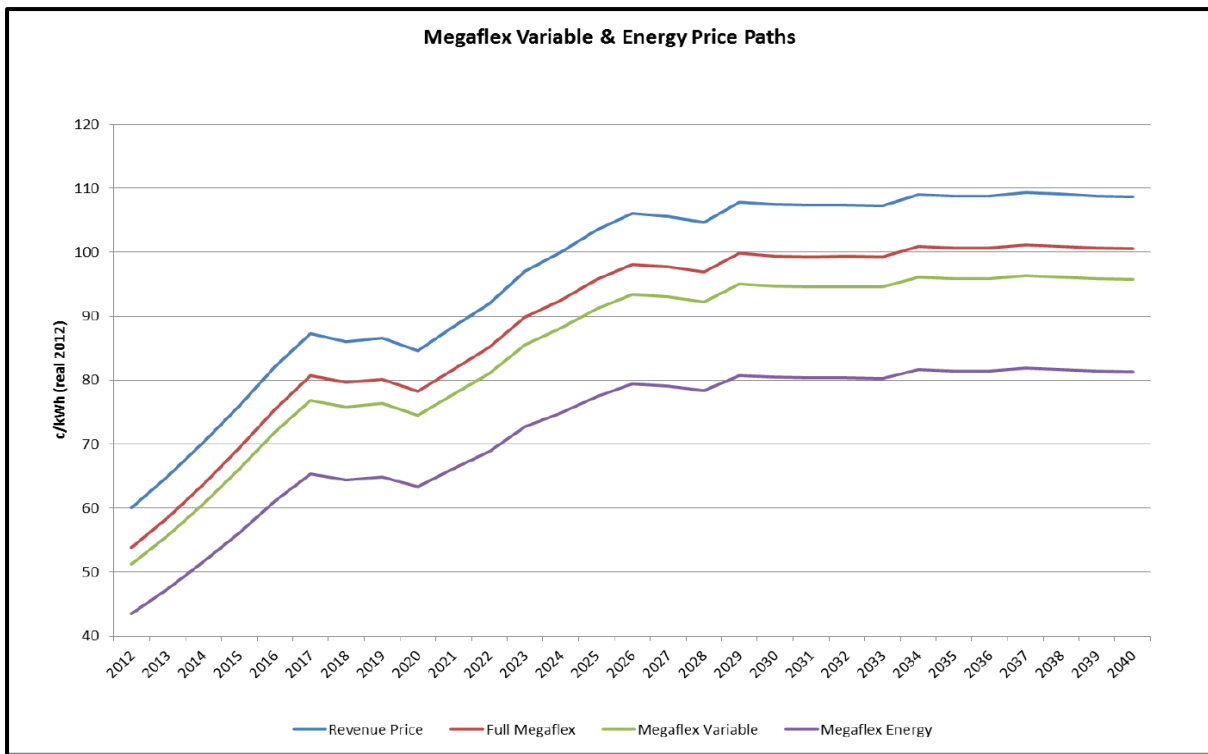


Figure 2.10: Megaflex variable and energy price path

### 2.3.3.7 Summary of Price Path Studies

It is recognised that average electricity price levels in South Africa have not been cost-reflective for some time. This has posed major challenges to funding much needed expansion. Under MYPD2 and MYPD3 it has been proposed that South African electricity price increases be phased in to reach full cost-reflectivity by a defined future date. Analysis by various parties on where this full cost-reflective level lies has led to a diversity of future price paths. The analysis presented herein has sought to unpack some of this analysis and provide a basis for further engagement on MYPD3 and the longer term price path underpinning the IRP.

#### *Short Term*

The government has indicated that during the period to 2017, it will ask Eskom and Nersa to limit price increases to less than 15% per annum. Based on Eskom's prevailing average selling price of around 60 c/kWh this provides a landing point of 90c/kWh (2012 real) in 2017. Eskom has responded in its MYPD3 stakeholder communication process by providing a number of scenarios which trend towards this price. This is, however, based on a number of critical provisos, including no further new build from the IRP2010 or carbon taxation applied. The validity of this path is thus questionable. Nonetheless a 5-year target level of 90c/kWh can be taken as reflective of the current cost of supply including Medupi, Kusile, Ingula and the current transmission strengthening projects. Eskom's assumptions regarding

this number need to be tested further to ensure that it is in fact cost reflective and that the risk associated are properly understood and managed.

Eskom have also made it clear to government that if there is additional build required post Kusile that the tariff may need to raise further to fund these new projects. This is based on the premise that the build is as per the IRP2010 and contains more “expensive” (than coal fired plants) technologies including renewable options and nuclear.

### *Long Term*

In the longer term, there is considerable variation in the price paths projected, ranging from 99 c/kWh to 109 c/kWh in the EIUG IRP modelling and the Fieldstone modelling respectively. The EIUG IRP price modelling sees the price path reach its plateau level of 99 c/kWh by 2017 and flatten off beyond that, implying that the costs additional IRP capacity are incorporated into the price. By contrast, the Fieldstone model only reaches 87 c/kWh by 2017 and shows sustained increases beyond 2020 until the price flattens off at around 109 c/kWh by 2026. These differences are the result of the different pricing approaches applied and cost assumptions adopted in the models. For example the capital cost assumptions for nuclear capacity are materially higher in the Fieldstone model (deemed to be understated in the IRP).

Without the availability of an independent longer term pricing model that has been properly specified and built according to the Rate of Return methodology applied and tests the viability and fundability of supply options, it is difficult to be sure that the price paths are being compared on an equitable basis. As noted in previous EIUG correspondence it is vital that the DoE and Nersa have access to a comprehensive pricing model in order to be able to engage effectively on MYPD determinations and on IRP revisions with associated long term price paths. It is not clear from Eskom’s communication what increases it anticipates would be required to support the IRP build programme beyond the MYPD3 period. As such we do not have view from Eskom on the longer term price path envisaged.

Notwithstanding the reservations noted, the analysis has highlighted a number of key considerations in evaluating the Eskom MYPD3 application and in considering the long term price path emanating from the IRP and subsequent revisions. In addition, the analysis around projected Megaflex tariff levels, including the variable and energy components, provides a basis for further engagement on issues around IPP market entry, bilateral trading and network wheeling.

## 2.4 DELLOITE ENERGY MODEL STUDY

### 2.4.1 Overview

Deloitte was approached by AngloGold Ashanti (AGA) to perform an assessment of the electricity consumption rates that will be used in the capital estimate and business plans for a new deepening project. The Deloitte personnel provided the approach and skills to support the above effort. Technical insights were provided by relevant AGA personnel in order to validate the rates. A first-principles approach was followed to obtain an independent view of the primary consumption drivers and applicable rates (Van Antwerpen, 2011:5).

Based on the methodology that was applied and the approach that was followed, the Life of Mine (LOM) forecast for Level 1, Phase 2 and Phase 3 to 6 are illustrated below. The forecast will change when Basic Mining Equations (BME) forecasted production profiles change and when additional equipment requirements are updated.

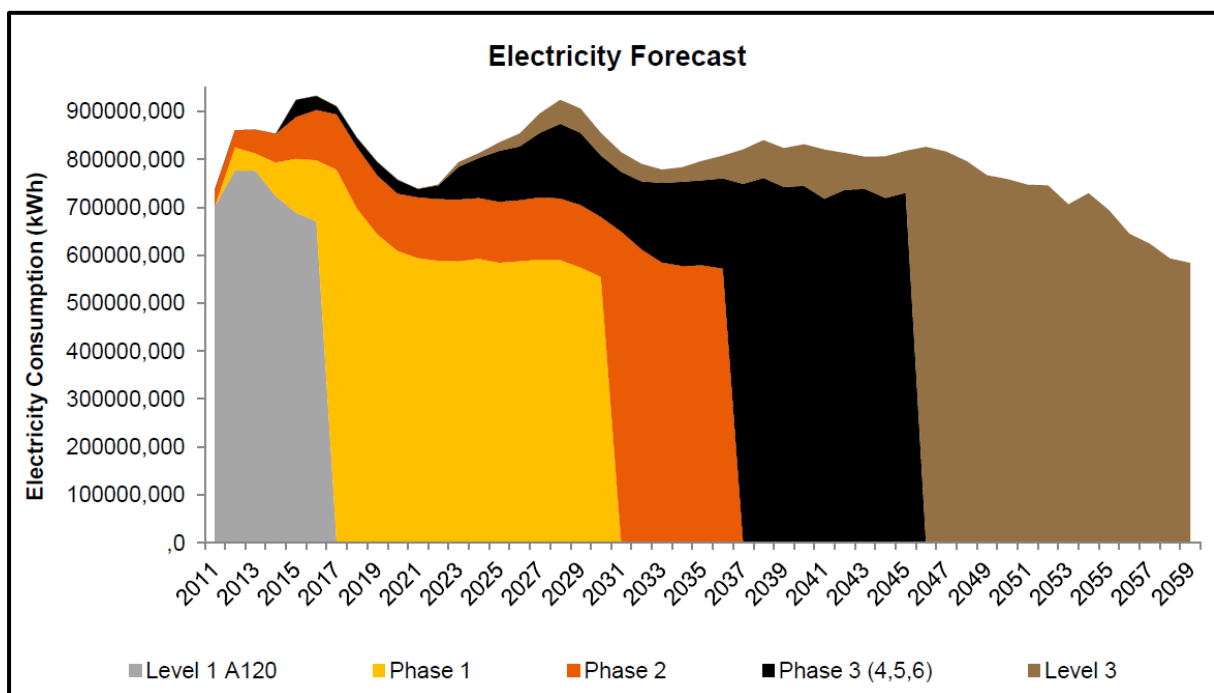


Figure 2.11: LOM profile as calculated from a Monte Carlo Analysis of available data.

The load profile was calculated in a Monte Carlo analysis based on a pseudo-population of 9531 data points for various processes that make up the total mining load. The forecast was done based on the following tonnage profiles as provided by AGA and illustrated below for the different phases as mentioned previously.

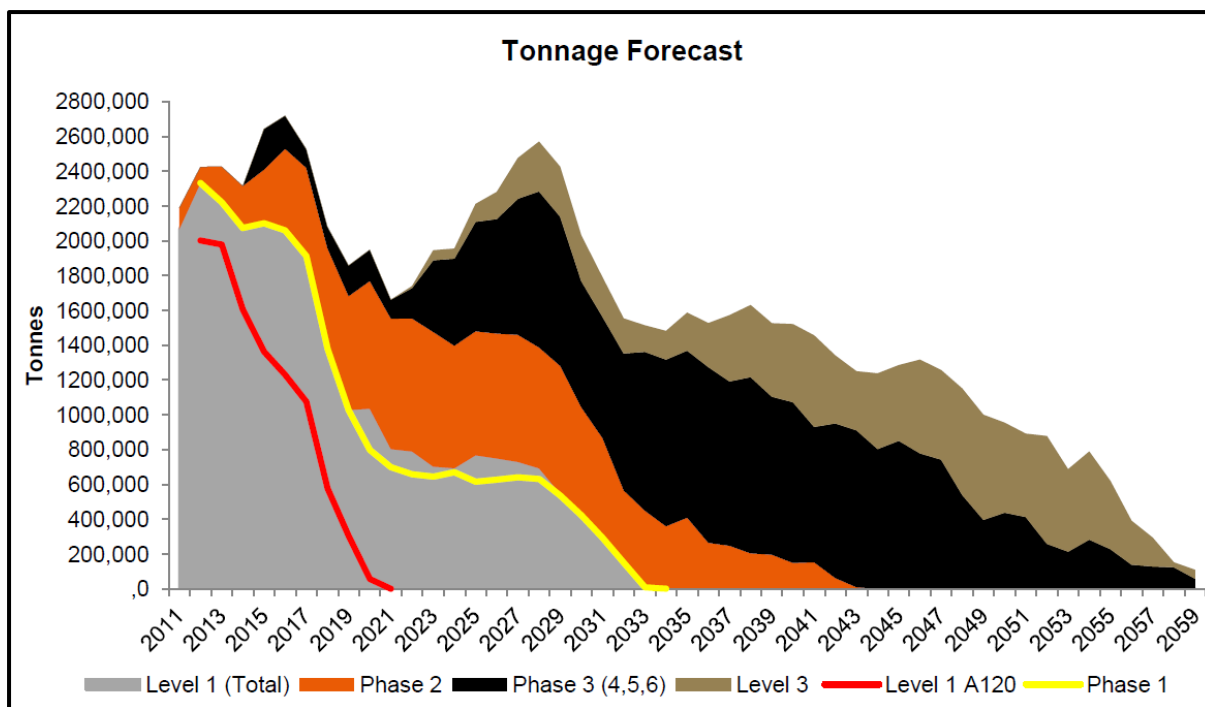


Figure 2.12: LOM tonnage profile based on available BME data

## 2.4.2 Background

With an annual production of more than 5-million ounces of gold through twenty-one operations globally, AGA is one of the largest producers of gold in the world. AGA has continuously shown improvement in the performance of current assets through cost management and increased labour productivity, as well as seeking out value-adding growth opportunities through exploration and acquisition. AGA has devised a strategy which should see the company obtain a Return on Invested Capital (ROIC) in excess of 15% over a 5-year period (Van Antwerpen, 2011:10). This strategy includes, amongst other things, the following key initiatives:

- Business process framework (BPF);
- Pathway to value (P2V); and
- Changes in corporate governance processes.

Capital Projects are critical to the growth and sustainability of AGA's long-term strategy of maintaining an annual production of 5-million ounces of gold produced. A robust development of the business case and the identification of value-add opportunities for these projects can add to the strength of the capital projects. The scoping and pre-feasibility studies for the new deepening project were conducted by the Strategic Project Planning (SPP) team at an AGA mine during 2010 and early 2011.

The project is currently at feasibility phase, and the intention is to complete the study for the Business and Technical Development (B&TD) review. In past capital efficiency projects conducted on deep level mines, it was found that the electricity contribution to OPEX is in the order of between 30% and 40%, in some instances only second to labour. In recent times, Eskom has increased its tariffs as charged to end users in the range of 22% to 30% per annum. If the incorrect application and allocation of electrical usage is forecasted, it would affect the investment case evaluation and subsequent decision-making that would further be exasperated by the expected future tariff increases.

Mining is generally composed of the following processes:

- Ventilation – Air that is circulated into and out of the mine for environmental and cooling purposes.
- Refrigeration – This is the medium of cooling with either direct or indirect interaction towards the ventilation process.
- Pumping – The transport of the refrigeration medium is most commonly done by water and the pumping process is therefore required to remove the water from the underground working areas.
- Compressed Air – The most common medium for breaking rock still found today, compressed air is used in the pneumatic pressure release process to drill into the rock face.
- Underground (Mining) load – On level production fans, pumps, lighting systems and scraper winch operations are captured in this process.
- Winding – The surface and underground hoisting systems that allow for the transport of people, material and rock to and from working places.
- Surface load – The load captures all the administrative building located on surface along with the water heating loads at change houses.

In the study it was found that these loads make up 99% of the total energy requirement of a typical mine. Although all these processes have different variables that affect the process performance the only available forecasting tool for models is the tonnage prediction from the BME LOM profile. A process of data filtration found that each process has a substantial base load associated with its performance (found when applying a simple Regression or Monte Carlo Analysis). By understanding the base loads and the remaining variable load percentages estimations were done as to the future LOM profile as shown in Figure 2.11. A summary of the base load study is shown in Figure 2.13 for the processes mentioned above, and the establishment of the applicable values discussed below.

### 2.4.3 Base Load Analysis

An analysis was performed on the various electricity elements and their consumption at Mponeng to determine whether these were subject to any drivers which would impact the rate of consumption in kWh. Based on this analysis, it was determined that the electricity consumption for some of the elements correlated well to the production tonnages profile for the same period in which other elements had little to no correlation. This was due to the fact that the consumption profiles of some elements are dependent on tonnages (that is, Rock Hoisting), whereas other elements such as surface areas reflected fairly consistent consumption profiles regardless of the tonnages hoisted, or other factors such as seasonal demand, depth levels mined, and more.

Electricity consumption will therefore only be variable over and above the respective base load. To isolate the base load portion of total consumption, a decision was taken to measure the average electricity consumption per element over the annual December shutdown period per day and reflect this as a percentage of the average electricity consumption per day for the rest of the calendar year. This was performed over a four-year period, from 2007 to 2010. The offline or base load period each year was not kept constant due to the varying dates that the mine was shut down for the Christmas break, but it was generally for the period of 23 December to 2 January each year. The same date for the year was kept constant across the various elements for that year though. Variances were seen in the results across the sub-elements and from year to year. After consulting with mine electricity stakeholders, it was agreed that some of the factors leading to these variances in base loads were inefficiencies. Typical examples given were of pumps that were kept on at a rate higher than was required for that period, as well as compressors which were not utilised efficiently.

To provide an overall viewpoint of the electricity base load, a project decision was taken to use a four-year average of the electricity base load per element to try to achieve an encompassing base load that was not subject to fluctuations year on year and would be more reflective for forecasting purposes. For an element, where the base load percentage for a certain year was classified as an outlier, that year was ignored and a three-year average was used. Based on this methodology, the base load percentage for the represented mine was identified as 63% of total electricity consumption.

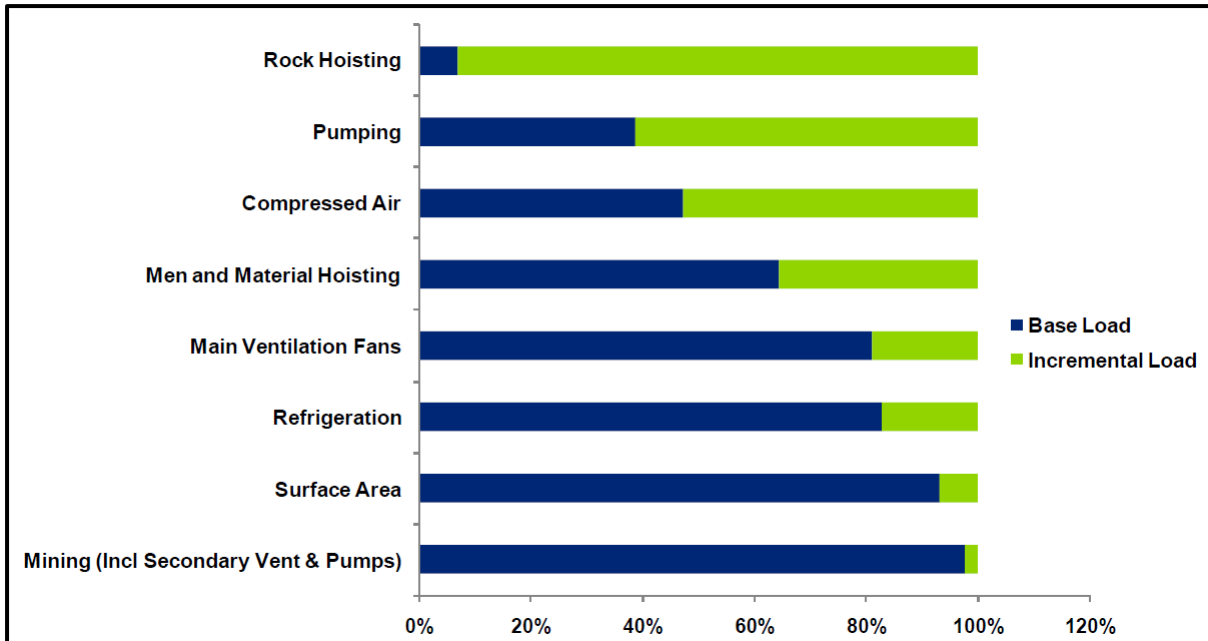


Figure 2.13: Base Load Analysis Results

#### 2.4.4 Variable Load Analysis

The variable portion was divided by the production tonnages to obtain a kWh/t rating. An illustration of such a graph is shown in Figure 2.14. For a constant slope the data was used as is to obtain a statistical distribution.

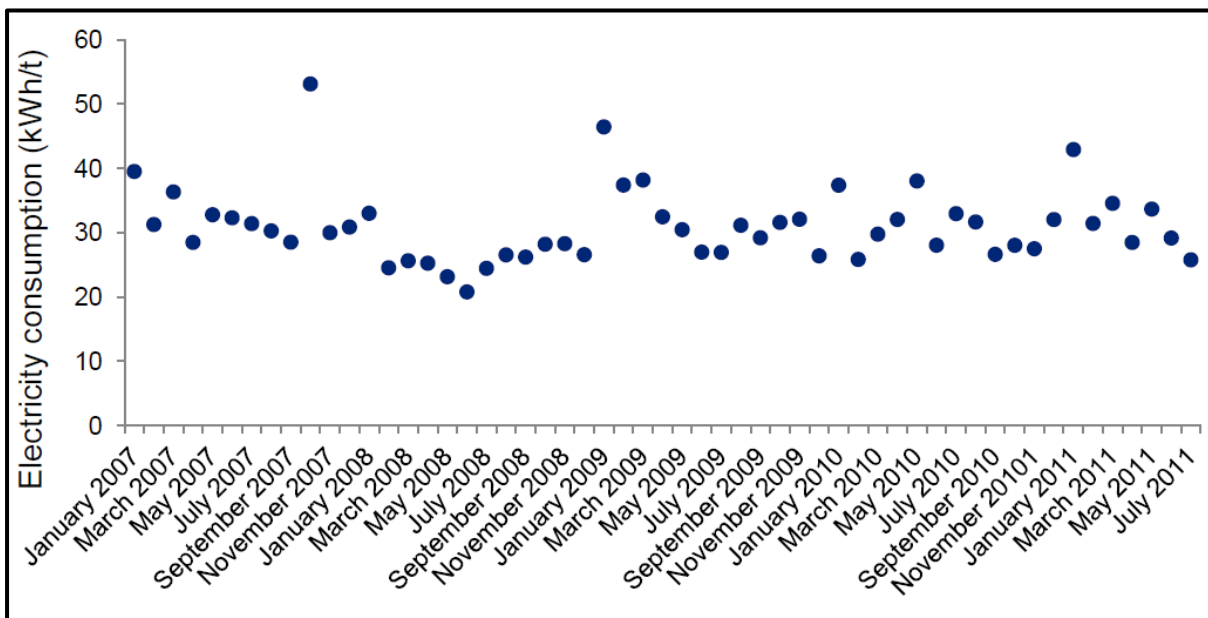


Figure 2.14: Variable Load Analysis Results

It was found that some processes had an increase in kWh/t over a specific period, as displayed in Figure 2.15. This increase in variable load had to be first corrected by the

equation obtained by the regression analysis to obtain a suitable distribution. Thereafter, the distribution was multiplied again by the slope to follow the same trend as displayed below.

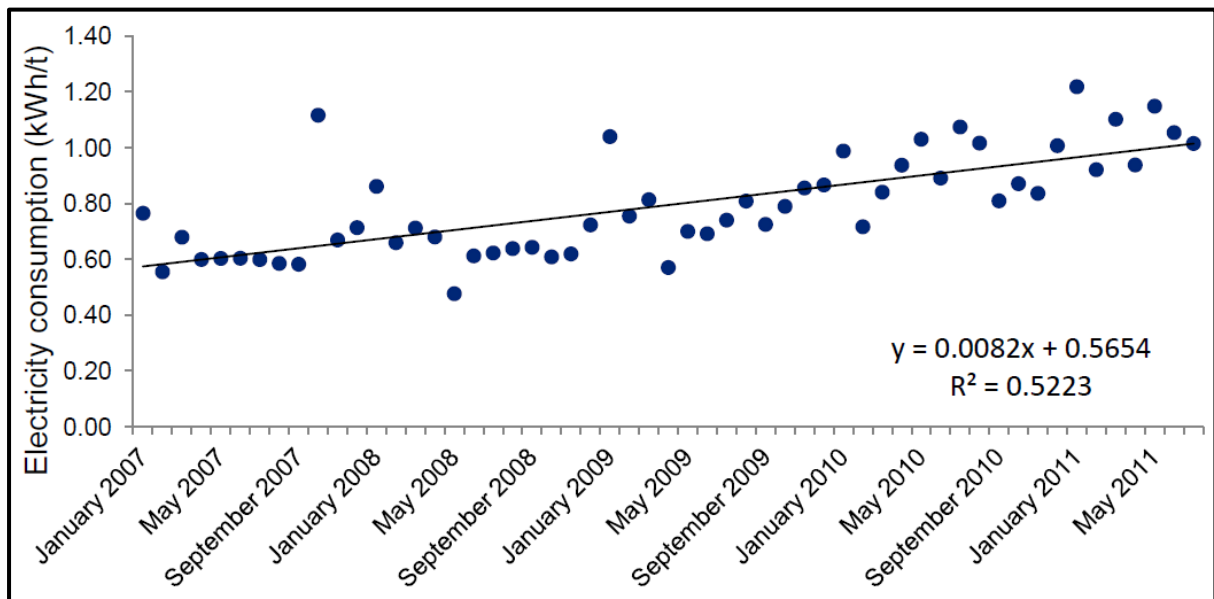


Figure 2.15: Increased Variable Load Result

The discussion to this point will form the basis of chapter 3, to illustrate the concept of base and variable load and their importance towards energy forecasting in the mining environment for deep level mining applications.