Measurement and verification of energy efficiency impact at gold mines

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AngloGold Ashanti has been proactive in the field of energy management for many years. AngloGold Ashanti is a signatory to South Africa’s National Energy Accord of 2005 calling for a 15% reduction in energy consumption by 2015 for the mining sector. This target also supported our internal targets that were already set. AngloGold Ashanti’s seven South African mines consume on average 440 MW. Due to the dynamics of gold mines, and the large numbers of relatively small energy efficiency initiatives and awareness campaigns made measurement and verification of energy efficiency very difficult at a macro level since some initiatives could get lost in the fluctuating load profile.

This paper will discuss the methodology and process followed to quantify the impacts of the combined energy efficiency initiatives at macro level. It will quantify the energy efficiency impacts in megawatt-hours (MWh), financial, and equivalent carbon emissions (CO2e) reduction with reference to our baseline year, 2004, for the Vaal River and West Wits mine clusters.

Background

AngloGold Ashanti (South Africa) has been proactive in the field of energy management for 30+ years. In 2005 the Department of Minerals and Energy introduced the National Energy Efficiency Accord as part of SA’s energy efficiency strategy. The accord target is set at a national reduction of 12% by 2015, expressed as a percentage reduction against the national projected energy use in 2015. The final energy demand reduction for the industry and mining sectors is 15% by 2015, which aligned with the internal targets already set by AngloGold Ashanti in 2003/4. AngloGold Ashanti is one of many companies who are signatories to the accord indicating their voluntary commitment to achieving the set target.

As early as 2003 it was acknowledged by the National Utility (Eskom) and National Energy Regulator of South Africa (NERSA) that the peak demands would soon start exceeding the peak generating capacity of SA’s electricity supply networks. The Demand Side Management (DSM) initiative was launched and AngloGold Ashanti was of the first to access this project funding mechanism. Initially our priorities were peak clipping and load shifting projects to address the system peak balance. More recently we have put greater priority on energy efficiency projects since it has become evident that there is in reality a base generating capacity shortage as well as peaking constraints. To this end NERSA together with Eskom and other stakeholders have put together the Power Conservation Program (PCP).

AngloGold Ashanti was an early starter in the field of real-time measurement (1994) and control of electricity demand (in the 1970s by using telephones and in the 1980s automated radio telemetry). Working closely with IST Otokon (Now Powertech IST Otokon), a supplier of metering, logging equipment, and software developers, measurement and analysis tools were put in place on all our South African mines to report half-hourly demand profiles for every medium voltage feeder out of the consumer substations. In most instances this enabled us to have demand profiles down to process level.

To determine the energy efficiency progress made since the signing of the Energy Accord it was decided to contract Energy Cybernetics Pty Ltd, a company specializing in Measurement and Verification, Strategic Energy Management and Energy Management Training, to independently calculate our energy savings based on the Energy Accord requirements. This required comparison of actual consumption and production profiles of the Accord base year (2004), projected (business as usual) energy levels, with current energy and production levels. The current energy and production period was defined to align with the PCP base period (October 2006 to September 2007) so that it would provide AngloGold Ashanti with information relevant to the proposed PCP rules. The principle of determining the percentage reduction for the accord is illustrated in Figure 1.

The mining industry currently has an allocated allowance of 90% under the proposed Energy Conservation Scheme (ECS) that forms part of the PCP. This implies that AngloGold Ashanti will need to sustainably reduce its electricity consumption by 10% based on electrical energy use between October 2006 and September 2007, a period chosen for the ECS baseline and at which time some energy efficiency gains had already been achieved. The baseline developed under the interim rules will consequently fail to take the impacts already achieved due to AngloGold Ashanti’s energy efficiency activities from January 2005 to September 2007 into account. The ECS baseline will consequently be much lower than would have been the case had AngloGold Ashanti not been actively implementing energy efficiency.

This could put the company at risk in achieving the allocated allowance and vulnerable to the punitive tariffs of
PCP. It will also effectively penalize AngloGold Ashanti for having been proactive in achieving energy efficiency prior to September 2007. The purpose of quantifying and verifying the achieved energy efficiency impacts are to provide a basis to apply for an adjustment to the PCP baseline to incorporate ‘proactive’ energy efficiency activities prior to the PCP Baseline period.

It is, however, important to note that the reduction in electrical energy use between the business-as-usual baseline and the actual profile is due not only to energy efficiency, but also due to operational changes that fall under business-as-usual. The methodology must therefore take account of these reductions in energy use due to operational changes and consider only the energy efficiency component of the reduction, illustrated in Figure 2.

**Analysis methodology**

The base year of 2004 was selected for this analysis since that was prior to AngloGold Ashanti’s drive for energy efficiency under the Accord. The basic methodology is to obtain a relationship between the monthly electrical energy use and the monthly service level (production, tons hoisted, tons treated) for 2004 as shown in step 1 of Figure 3.

The monthly service level (production, tons hoisted, tons treated) during the PCP baseline period (October 2006 to September 2007) is then applied in respect of how much energy the system would have consumed under 2004 conditions before energy efficiency impacts arose (steps 2, 3 and 4). This energy use is then compared to the energy use of the PCP baseline period and the difference between the two sets of data is equal to the energy efficiency achieved (steps 5 and 6). This process is the same process that is applied during the measurement and verification of DSM projects with an energy efficiency component and is in line with the International Measurement and Verification Protocol.

In the situations where production or service level are not measureable or recorded, like business services and residential areas, but energy efficiency impacts have occurred, the average monthly performance of the base year (2004) is used as the baseline when compared to the PCP baseline data without reference to service levels.

**Analysis data and layout**

The quantification of the energy efficiency achievements for our two main measurement centres and utility accounts, West Wits and Vaal River, based on the above-mentioned methodology was not possible purely from the Eskom billing data alone. The service levels also had to be brought into consideration where applicable. Electricity use and production data recorded were consequently used in the analysis.

In order to increase the accuracy of the analysis, the project team also decided to split West Wits and Vaal River into their respective business units and perform the analysis separately for each business unit, as shown in Figure 4.
Although compressed air is seen as a separate business unit by AngloGold Ashanti, its disaggregated components were allocated to the relevant shafts, plants and third-party users for the purpose of this analysis to result in energy efficiency attributable to each business unit.

Business Services for West Wits and Vaal River do not have a measurable service level or production component that could be used during the analysis. They were handled in the alternative manner as described earlier. Wedela (a village in the West Wits area) did not form part of this analysis since it is an Eskom third-party fed off AGA distribution network and thus is not AGA responsibility for the accord.

The data used for this analysis consists of monthly total kWh electricity consumption for each business unit shown in Figure 4. The service level in the form of tons hoisted for the shafts, and tons treated for the plants, are available in total tons per month.

All these data were available from January 2004 to July 2008. These service levels were adequate to use since there were no changes in shaft depth. If the depth changes significant energy (business-as-usual) would have to be added for hoisting and refrigeration. The electrical data recorded was calibrated and adjusted where needed to correspond with the Eskom billing data. For the purpose of this paper the Savuka Gold Plant was selected as an example to illustrate the application of the methodology.

**Step 1 and 2 input data**

Collect energy and related production data for the business unit to be analysed. From this graphic representation in Figure 5 it is not immediately evident that anything different happened over the period.

**Step 3 and 4**

Plotting tons treated per month against energy (kWh) per ton per month starts to reveal the energy efficiency shift under different production levels. The resulting plot and linear regression lines are illustrated in Figure 6.
Steps 5 and 6 service level adjusted energy

Using the base 42 kWh/ton per month one can calculate the service level adjusted (SLA) energy, what it would have been had there been no efficiency; Figure 7 shows both SLA and actual energy consumed per month.

The difference between the adjusted service level energy in the PCP baseline year and the actual energy consumed in the PCP baseline year is the energy efficiency achieved, which for Savuka plant is 3,754 MWh.

To convert this to equivalent CO₂ emissions simply multiply by the country kg/kWh emission factor, which in the case of SA has been reported as 1 kg/kWh. Thus Savuka plant is emitting 3,754 tons less CO₂ than in the baseline year, even if the factor changes with time as is normally the case. In 2004 it was 0.89 kg/kWh and in 2006/7 somewhere between 0.978 and 0.958 kg/kWh. Applying the current factor will always give the difference between business-as-usual emissions and emissions after energy efficient initiatives.

Results

This section provides the summary results that were obtained from the analysis of West Wits and Vaal River.

The detail results per business unit can be obtained from the presenter of this paper.

Energy efficiency at AngloGold Ashanti

Figure 8 shows the actual electrical profile for West Wits against the service level adjusted baseline profile. The service level adjusted profile shows what the energy use of West Wits would have been if no energy efficiency initiatives had been implemented. The difference between the two profiles during the PCP baseline period is equal to the energy efficiency achieved for that period. In the case of West Wits this was 60 GWh.

Figure 9 shows the actual electrical profile for Vaal River against the service level adjusted baseline profile. The service level adjusted profile shows what the energy use of Vaal River would have been if no energy efficiency initiatives had been implemented. The difference between the two profiles (as shown in Figure 9) is equal to the requested energy efficiency achievement to the PCP baseline for Vaal River.

The annual energy efficiency achievement during the PCP baseline period for the Vaal River operations was 240.6 GWh.
Figure 7. Service level adjusted energy and original actual energy consumed per month

Figure 8. Actual monthly electricity consumption of West Wits together with the service level adjusted baseline

Figure 9. Actual monthly electricity consumption of Vaal River together with the service level adjusted baseline
Verified energy efficiency accord achieved

Figure 10 shows the performance of both West Wits and Vaal River in their Energy Efficiency Accord target of 15% to be achieved by 2015. West Wits managed to achieve an annual energy efficiency impact of 0.81% in 2005. This grew to 3.54% in 2007. A total of 10.26% of electrical energy was saved as at July 2008—the date to which the data were available. Vaal River, on the other hand, achieved an annual energy efficiency impact of 7.79% in 2005. This grew to 10.54% in 2007. A total of 13.77% of electrical energy was being saved as at July 2008 compared with the 2004 baseline year.

It can clearly be seen that both West Wits and Vaal River are on their way to achieving, and possibly exceeding, their commitments towards the Energy Efficiency Accord.

Verified other impacts of energy efficiency

Figure 11 provides the savings in electrical energy consumption that was achieved per year at West Wits and at Vaal River. For West Wits the savings grew from 14.2 GWh in 2005 to 59.1 GWh in 2007. West Wits saved 97.9 GWh in the first seven months of 2008.

For Vaal River the savings grew from 178.6 GWh in 2005 to 249.1 GWh in 2007. Vaal River saved 184.1 GWh in the first seven months of 2008. In total, West Wits saved 217.6 GWh between January 2005 and July 2008 through energy efficiency, whereas Vaal River saved 826.6 GWh over the same period. This is a staggering total of 1 044.3 GWh saved at AngloGold Ashanti through effective energy efficiency.

The cost savings associated with the energy efficiency activities on West Wits have increased from R2.16 million in 2005 to R10 million in 2007. The electricity cost saving between January 2008 and July 2008 was R18.86 million. The energy efficiency activities at West Wits implemented between January 2005 and July 2008 have saved AngloGold Ashanti a total of R38.5 million in electricity cost.

Similarly, Vaal River’s electricity cost savings has increased from R27.4 million in 2005 to R42.1 million in 2007. The electricity cost saving between January 2008 and July 2008 was R34.98 million. The energy efficiency activities at Vaal River implemented between January 2005 and July 2008 have saved AngloGold Ashanti R138.8 million.
million in electricity cost. The total electricity cost savings achieved by AngloGold Ashanti since January 2005 to July 2008 is R177.4 million, all due to energy efficiency.

AngloGold Ashanti did not only achieve substantial impacts in terms of electricity consumption and cost reductions due to energy efficiency, but also achieved a significant environmental impact. The carbon dioxide emission reductions associated with the reduction in electricity consumption is shown in Figure 13. A total of 195,890 tons of CO₂ emission reductions have been achieved purely due to the energy efficiency activities of AngloGold Ashanti at its West Wits operations. For Vaal River this environmental impact was 743,950 tons of CO₂ emission reductions. In total, AngloGold Ashanti achieved CO₂ emission reductions to the total of 939,840 tons between January 2005 and July 2008.

How was it achieved?
While this is not the main subject of this paper it may be useful to select a few main contributing factors that led to this achievement.

- Measurement and targeting. One cannot control what one does not measure and it is important to have targets set by management with support and result indicators to monitor progress. Part of the measurement system generates regular reports on use compared to the target. The other advantage of measurement is that one can hold the end user accountable and any efficiency achieved is attributed to the source.
- Energy planning forms part of the business planning process each year. Business units are responsible for developing energy plans in line with the production plan, with energy efficiency targets included. Part of the business plan is a list of activities that are targeted to achieve the improvement.
- Through the years old plant has been replaced with more modern processes with resulting impacts to the energy intensity. This has been done on a greater scale at Vaal River than at West Wits, which would account for slightly better results there.
- Energy awareness has played a role for a number of years. While the power is still flowing it is not the easiest task but when the lights go out everyone knows the importance of managing energy.

Figure 12. The annual electricity cost savings achieved at West Wits and Vaal River since 2004

Figure 13. The annual carbon dioxide emission reductions achieved at West Wits and Vaal River since 2004 due to electrical energy efficiency
Summary of results
A detailed analysis of the electrical data and service level data for the various business units of AngloGold Ashanti’s West Wits and Vaal River operations was conducted by Energy Cybernetics (Pty) Ltd.

Substantial impacts have been achieved at both West Wits and Vaal River due to various energy efficiency initiatives implemented by AngloGold Ashanti between January 2005 and September 2007. The methodology used is based on the principles of the International Performance Measurement and Verification Protocol, which also forms the foundation of the M&V methodologies used in the DSM programme.

The analysis determined that West Wits operations were already achieving 10.26% energy efficiency impacts by the middle of 2008 compared with the 15% target under the Energy Efficiency Accord. A total of 217.66 GWh of electrical energy was saved between January 2005 and July 2008, which was an electrical energy cost saving of R38.5 million for AngloGold Ashanti. A total of 195 890 tons of CO₂ emission reductions have also been achieved.

The analysis determined that Vaal River was achieving 13.77% energy efficiency impacts by the middle of 2008 when compared to its 15% target under the Energy Efficiency Accord. A total of 826.61 GWh of electrical energy has been saved between January 2005 and July 2008, which was an electrical energy cost saving of R138.8 million for AngloGold Ashanti. A total of 743 950 tons of CO₂ emission reductions have also been achieved.

Through the results that were independently quantified and verified, AngloGold Ashanti was able to prove that they were proactive in implementing energy efficiency since January 2005. An upwards adjustment to the PCP baseline could consequently be motivated to Eskom. This adjustment was approved, which meant that AngloGold Ashanti would not be penalized by means of a lower PCP baseline due to implemented energy efficiency. This also affected the PCP targets for AngloGold Ashanti, which effectively reduced the risk of punitive penalties for AngloGold Ashanti.

Acknowledgements
AngloGold Ashanti acknowledges the contribution made by Energy Cybernetics (Pty) Ltd. in preparing this paper.

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Started work at Vaal Reefs Exploration and Mining in 1972, qualified as an Electrician with a HNDT. Worked as a shaft electrician for 2 years before becoming a junior engineer and passed GCC in 1997. Worked as a relieving engineer and shaft engineer on shafts for 2 years before becoming the Electrical Engineer at Vaal Reefs followed by a period of Control and Instrumentation Engineer until 1996 when I was appointed Energy Engineer for Vaal Reefs. AngloGold was established in 1998 and I was appointed Energy Engineer for South African operations. Expansion of AngloGold Ashanti and structural changes led to my current position as Energy Engineer for Africa operations.