MEASUREMENT & VERIFICATION OF THE ESKOM IRRIGATION PUMPING STANDARD PRODUCT PROGRAMME: EVALUATION OF CROP LOAD FACTORS

SAEEC 2013

ME Storm, R Gouws and LJ Grobler
School of Electrical, Electronic and Computer Engineering, Potchefstroom Campus, North-West University

ABSTRACT

Eskom Integrated Demand Management (IDM) also included irrigation in the Standard Product Programme (SPP) to cater for smaller irrigation Energy Efficient (EE) projects. The irrigation sector is a large energy consumer in South Africa and may have a large EE potential. The unique characteristics of irrigation projects create significant challenges for Measurement and Verification (M&V) under the SPP. Previous M&V studies assessed a large sample of irrigation pumping Variable Speed Drive (VSD) SPP projects. These assessments were conducted to verify project impact availability, project viability and achieved savings credibility. A further study was required to quantify attainable project impacts over the whole project life by incorporating crop Load Factors (LF). This paper focuses specifically on the evaluation and validation of crop LFs as well as its applicability and use in SPP irrigation projects. The evaluation was conducted through a comprehensive crop LF analysis. The aim of this analysis was to determine the typical LF of a large sample of real world pumps and compare these with the Eskom proposed crop LFs.

1 INTRODUCTION

The South African irrigation sector is a significant energy consumer with around 60 000 centre pivots. These may have a large potential for Energy Efficiency (EE), without even considering other irrigation methods such as sprinklers and micros. However, the average irrigation pump is relative small, which makes the attainable EE impacts also small. This makes normal M&V too expensive on such projects. An M&V case study was performed to evaluate the potential and applicability of SPP on the irrigation sector [1].

As part of the case study, the challenges with applying SPP to irrigation sector were investigated. Compared to other SPP technologies like lighting and heat pumps, irrigation projects is difficult and have a multitude of yearly varying variables that will influence the possible savings [1].

In older irrigation projects, the M&V of normal demand shifting already proved to be very difficult and complicated [2]. Applying SPP takes this complexity even to the next level by implementing EE and not demand shifting [1]. In addition, no continues M&V metering will be done and the savings will be determined using a deemed approach - implying an informed estimated saving will be used for the life of the project. [1,2,3]

An M&V assessment was performed to verify project EE improvement impact availability, project viability and achieved savings credibility assessment on 19 sample sites [1]. From the assessment it was verified that definite and significant demand reductions were achieved with the implementation of VSDs to optimize the irrigation systems. The lowest demand reduction measured was 7.1% and the highest demand reduction measured was 71.6%. From all 19 case study sample pumps measured, the average demand reduction was 42.2%. [1]

With potential demand reduction impacts verified, the next step was to establish what the yearly average impact will be. The demand reduction results captured shows the attainable impact when the pump is running. However, the question now is how much that pump is operational during the year? This can be determined through crop LFs.

2 CROP LOAD FACTORS

The Eskom Irrigation Energy Advisor team [4] considered several methods to establish a representative LF for an irrigation pump. The troubling issue is the many factors and variables influencing the LF of an irrigation pump.

Considering an ideal situation with a single irrigation pump with one type of crop for a three year period, among other the following needs to be considered:

- Soil type (Sand soil requires much more water for instance);
- Climatic region;
- Typical rainfall for the specific farm (this is essential since it is commonly found that irrigation farms, only a few kilometres apart, can have significant average rainfall differences) – ‘barbwire phenomenon’ ;
- Irrigation practices of the farmer - this differs between farmers;

- Issues such a water restrictions; certain areas sometime experience green draughts although there is sufficient irrigation water available, but irrigation control boards still restrict water allocations; and
- Crop variants may also influence the amount irrigation water required; for instance certain sunflower variants are much more resistant to draughts than other variant types.

By considering the above only for a single pump and a single crop already stages a daunting task to establish the pump load factor. Typical irrigation setups are far from ideal with one pump irrigation several different crops with the switch of valves. Some irrigation lands are also planted with two types of crops in a year. With this, crop rotation practices are critical for healthy crop lands.

A specific method researched and tested by an Eskom Energy Advisor [5] was to use crop load factors. Through a specialised irrigation software programme SAPWAT incorporating 50 years the typical water requirements for a specific crop in a specific area and soil type can be calculated.

Calculations are done on comprehensive crop data and are used as an irrigation guidance tool by farmers across South Africa. Having the crop load factor and the irrigation system setup and characteristics for that crop, the load factor, typical power use and average demand required for that crop can be calculated.

Now, even if a single pump irrigates multiple crops, the overall (yearly average) LF of the pump can be calculated by combining the crop LF of each crop. This also allows for multiple crops on one irrigation land in a single year.

Apart from irrigation system characterisation, it was required from M&V to independently verify the application of crop LFs. M&V normally does verification by doing representative period measurements on a system establishing a typical baseline. Also, crop load factors can only be really tested when measuring the LF of a pump over several years.

In this case, it was out of the question. Even more so, SPP allows no measurements over the project life. An intuitive way is needed to evaluate the calculated crop load factors for an area without installing expensive metering.

3 EVALUTION OF CROP LOAD FACTORS

The evaluation was done through a comprehensive crop LF and pump LF analysis. The aim of this analysis was to determine the typical LF of a large sample of actual irrigation pumps and compare these with the Eskom proposed crop LFs.

The critical outcome of the analysis was to verify if the Eskom crop load factors are representative and conservative.

3.1 SAMPLE PUMPS AND DATA USED

It was a significant challenge to obtain the required kW demand profile data of enough sample pumps. Data (30min, kW profile data) was collected from M&V meters on old irrigation projects and Ruraflex points through the Eskom MV90 system.

Through much effort from the Eskom personnel [6,7], more than enough data was collected. The period used for the analysis is Sep 2008 till August 2012.

The period was respectively broken into the following four data year sets:

- Aug 2008 till Sep 2009;
- Sep 2009 till Aug 2010;
- Sep 2010 till Aug 2011; and
- Sep 2011 till Aug 2012.

Data in Mpumalanga and the Eskom Eastern region (KZN) were collected.

3.1.1 Mpumalanga Data

In Mpumalanga, M&V are involved with various irrigation projects since 2005. Of these projects the required info and kW profile data have been collected for more than four years. The irrigation projects included river pumps alongside the Crocodile River spanning from Machadodorp to Komatipoort and pump stations alongside the Lomati and Komati River. A few borehole pumps were also included in the total of 65 pumps/pump-stations that formed part of the study.

3.1.2 KZN Region Data

In Eastern Region (KZN) only data of Ruraflex points were available. From all the data collected, M&V was able to use 104 MV90 metering points for the LF analysis. The points included pumps stations in amongst other the following areas: Pietermaritzburg, Kokstad, Pongola, Greytown, Estcourt, Bergville, Colenso, Eshowe, Marina Beach, Harding, Underberg; Ixopo, Newcastle, Paulpietersburg, Ingagane, Nottingham Road, Empangeni and Margate.

3.2 DATA PROCESSING

Data was consisted of four year 30min demand profiles in Microsoft Excel files and text documents. The vast amount of data sets were scrutinised to check for faults and missing timestamps. Data credibility with sanity checks were also done, since data sets are in some cases corrupted due to metering faults. In cases were data were questionable, some periods or the complete measured points were discarded. [8,9]

The four year data of each point was processed in order to deliver average weekday, Saturday and Sunday daily profiles. The daily profiles were generated for each calendar month and each calendar month was accordingly allocated to the four data year sets. [8,9]

The daily data were also used to determine the weekday, Saturday and Sunday LF for each calendar month. From the three day types, the weighted average LF was determined. Having the LFs per day type, the farmer's pumping tendencies can also be evaluated. For instance, some farmers tend to only pump over weekends part of the year to benefit from the lower weekend tariffs on Ruraflex and Nightsave. Although not immediately relevant, the results from the daily LFs can be used to evaluate the typical available demand during the weekdays.

An important aspect to note is that instead of the installed capacity, the maximum operational capacity (utilization capacity) was used to calculate the LFs - thus the maximum demand of a pump station. Therefore, the study boundary was set around the power measured by the metering point since:

- In many cases the installed capacity information was not available or unreliable. Information of some pumps stated it to be a specific size (kW) although it was observed from the measured data to have a maximum demand of twice the installed capacity. Motors are often run above 100% of the nameplate installed capacity;
- Resistance is often experienced from the farmers on the supply of data and information of pump stations;
- Most of the MV90 point captures a whole pump-station and not individual pumps. These pump-stations frequently contain backup pumps and other less used maintenance pumps. Adding the installed capacities of these much less used pumps to the total installed capacity of the pump station will result in an inaccurate LF for the pumps that are actually used; and
- Details of changes to the pump stations over the four year period are not always available. The farmer may have changed the installed pump with another pump being a different size or expanded the station to contain more pumps.

The maximum operation capacity of a pump (or pump-station) was calculated on a monthly basis, yearly basis and for the whole four years. From this, changes in the operational capacity of each pump (or pump station) can be easily observed.

The final LF calculations were based on the yearly maximum operational capacity. Where installed capacities of individual measured pumps were available and reliable, the LFs were also calculated on the installed capacities.

4 MPUMALANGA LF AND CROP LF ANALYSIS

The first area considered for evaluation was Mpumlanga, specifically the Lowveld where several old Eskom DSM load shifting projects were implemented. The Mpumalanga evaluation was later followed by the Eastern region (KZN) analysis. The following sections give the results for Mpumalanga.

4.1 MPUMALANGA LF ANALYSIS RESULTS

Table 1 provides the results of the LF analysis performed on the 65 points over the four year period. A breakdown was made to distinguish between the results of Ruraflex and non-Ruraflex points (Landrate and Nightsave). It is important to note that only 16 non-Ruraflex points were measured and therefore not statically representative of all Mpumalanga non-Ruraflex points. However, it does give an indication of the typical LF that can be expected. On the Ruraflex points an average LF (based on maximum demand) of 0.248 (24.83%) for the whole period September 2008 to August 2012 was calculated. The LF (also based on maximum demand) of the non-Ruraflex points were considerably lower at 0.155 (15.5%). The weighted averages of all the points were 0.227 (22.65%).

Table 1: Mpumalanga yearly LFs calculated

Period	Ruraflex	Non-Ruraflex	All
Sep 2008 to Aug 2009	0.260	0.150	0.231
Sep 2009 to Aug 2010	0.257	0.137	0.228
Sep 2010 to Aug 2011	0.233	0.142	0.211
Sep 2011 to Aug 2012	0.267	0.200	0.251
Whole Period	**0.249**	**0.155**	**0.226**

Here it is important to note that due to the large sample of pump stations evaluated; statistically the variety of crops irrigated in the area is probably addressed through random pump selection. The next steps are to treat the Eskom proposed LFs and the calculated pump station LFs as comparable commodities.

This can be done by dividing LFs found into a scale. This scale is divided into 0.1LF increments. For instance if a LF of 0.03 was found, it was divided into the 0 to 0.1 increment. All LFs above 0.6 were allocated to one increment. Figure 1 to Figure 4 gives bar charts, visually displaying in which LF increment the amount of calculated LFs (of the different points) fall. Figure 1 shows that 8.3% of all the measured LFs are in the range 0 to 0.1 and 36.7% is in the range between 0.1 and 0.2. In the 0.2 to 0.3 range 36.7% of the pumps LFs are seen.

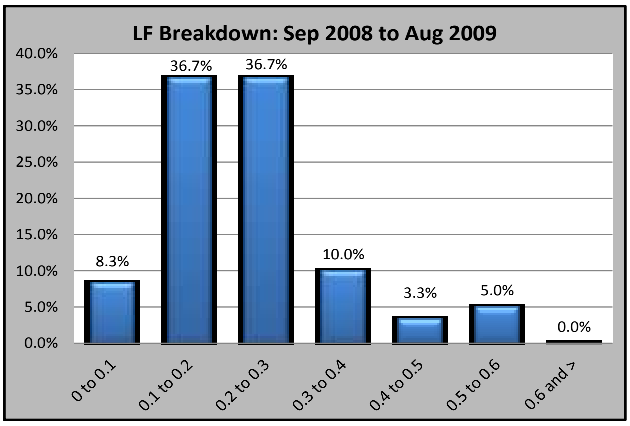


Figure 1: LF breakdown for Sep 2008 to Aug 2009

In the year Sept 2008 to Aug 2009 no LFs above 60% was seen. Figure 2 to Figure 4 gives the results of the three other year sets while Figure 5 provides a summary of the whole four year period.

From Figure 5 it can be seen that for the whole four year period, 34% of the pump LF's fell in the range 0.1 to 0.2 and 32% in the range 0.2 to 0.3. Only 11% of the LFs were below 0.1, while 23% where above 0.3. Less than 1% on average was above 0.6.

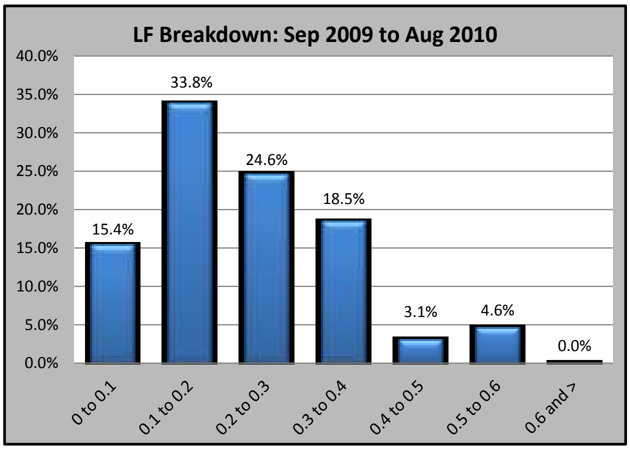


Figure 2: LF breakdown for Sep 2009 to Aug 2010

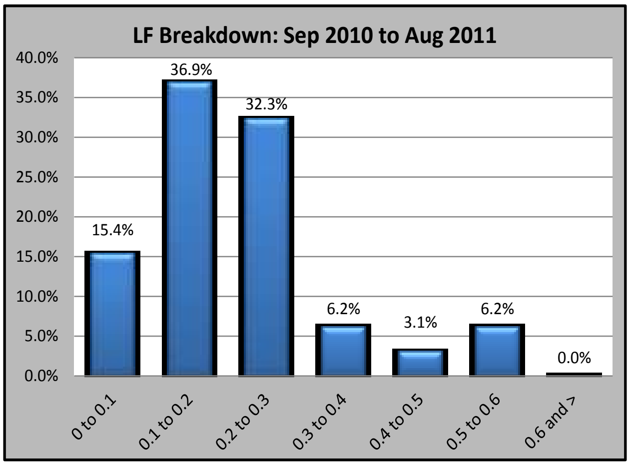


Figure 3: LF breakdown for Sep 2010 to Aug 2011

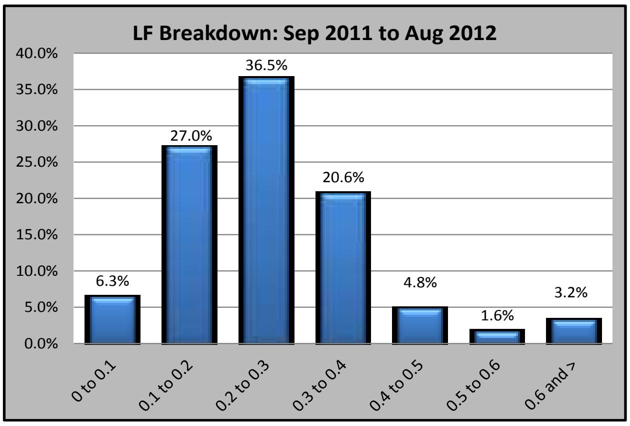


Figure 4: LF breakdown for Sep 2011 to Aug 2012

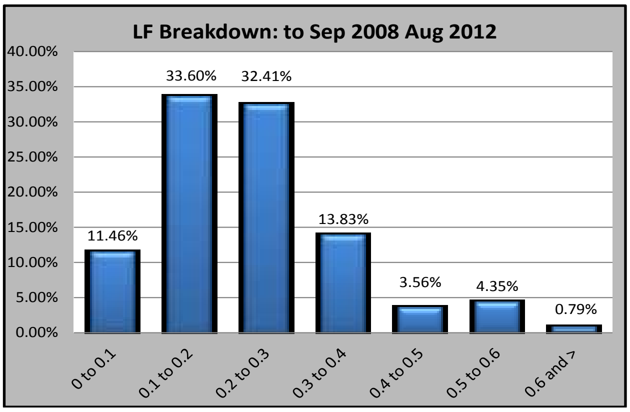


Figure 5: LF breakdown for Sep 2008 to Aug 2012

4.2 ESKOM PROPOSED CROP LOAD FACTORS

Table 2 list the Eskom proposed crop LFs for different type of crop planted in Mpumalanga. Figure 6 shows an analysis of the percentage of crop LFs that falls in the different 10% increments. This bar chart also compares the Eskom proposed crop LFs and the measured MV90 LFs. Evaluating the bar chart, it is seen that 50% of the proposed crop load factors conservatively fall within the 0.1 to 0.2 range.

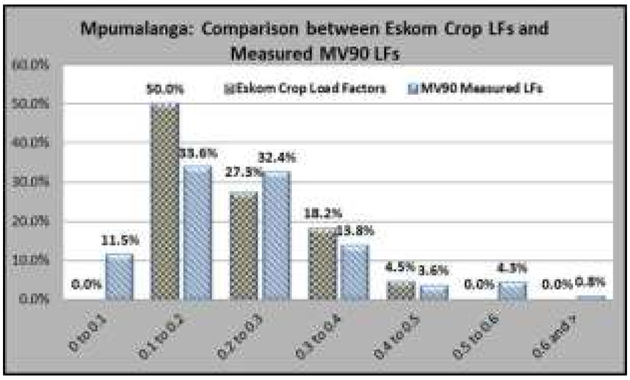


Figure 6: Mpumalanga Eskom Crop LFs and MV90 LFs

Further, 27% fall within the 0.2 to 0.3 range and only 23% is above 0.3. The biggest proposed LF, according to Figure 6, is 0.4 for tomatoes. Overall, the results show that the proposed Eskom LFs are representative, but conservative of the typical LF (according to max demand) seen in the field. The overall weighted average measured LF in Mpumalanga is 0.231, while the overall proposed Eskom crop LF is 0.226.

Table 2: Eskom crop load factors for Mpumalanga

CROP LOAD FACTORS - MPUMALANGA	
Crop	**Annual Load factor with rain**
Beans	0.18
Cabbage Crops (Summer)	0.13
Cabbage Crops (Winter)	0.13
Citrus & Subtropical Fruit	0.35
Cotton	0.19
Grapes	0.25
Green Peas	0.13
Groundnuts	0.20
Lucern	0.28
Maize	0.18
Nuts - Almonds	0.21
Nuts - Pecan	0.15
Onions	0.21
Planted Grazing (Perennial)	0.22
Planted Grazing (Seasonal)	0.28
Potatoes	0.31
Soft Fruit (Ave)	0.35
Soya Beans	0.16
Tendril crops	0.11
Tomatoes	0.40
Vegetables	0.36
Wheat	0.18

5 KZN LF AND CROP LF ANALYSIS

Similar to Mpumalanga, a LF analysis was also conducted for the KZN province.

5.1 KZN LF ANALYSIS RESULTS

Table 3 provides the results of the LF analysis performed on the 104 point over the four year period. Unlike the Mpumalanga analysis, only data from Ruraflex points were available. Therefore no analysis was performed on Landrate points. Of all the Ruraflex points an average LF (based on max demand) of 0.213 (21.29%) for the whole period September 2008 to August 2012 was calculated.

Table 3: KZN yearly LFs calculated

Period	Ruraflex
Sep 2008 to Aug 2009	0.223
Sep 2009 to Aug 2010	0.228
Sep 2010 to Aug 2011	0.183
Sep 2011 to Aug 2012	0.234
Whole Period	**0.213**

5.2 ESKOM PROPOSED CROP LOAD FACTORS

Table 4 lists the Eskom proposed crop LFs for different types of crops planted in KZN. Just as for Mpumalanga, Figure 7 shows a bar chart breakdown of the measured MV90 percentage crop LFs compared with the Eskom proposed crop LFs. Only looking at the MV90 LFs, it can be seen that 8% is in the 0 to 0.1 range and 59% of the proposed crop load factors conservatively fall within the 0.1 to 0.2 range. Further 33% fall within the 0.2 to 0.3 range and no LFs above 0.3.

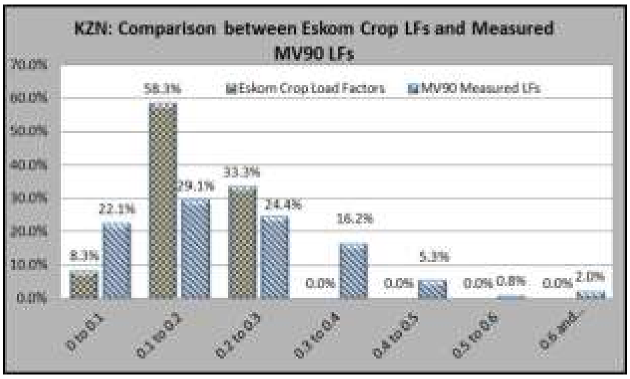


Figure 7: Bar-chart comparing Eskom Crop LFs and measured LFs

The biggest proposed LFs according to Table 4 are 0.27 for cassava and potatoes. The overall average measured LF in Mpumalanga is 0.213, while the overall proposed Eskom crop LF is only 0.174.

Table 4: Eskom crop load factors for KZN

CROP LOAD FACTORS - Eastern Region	
Crop	**Annual Load factor with rain**
Beans	0.17
Cabbage Crops (Summer)	0.08
Cabbage Crops (Winter)	0.12
Cassava	0.27
Citrus & Subtropical Fruit	0.23
Cotton	0.15
Grapes	0.17
Green Peas	0.11
Groundnuts	0.15
Lucern	0.21
Maize	0.15
Nuts - Almonds	0.17
Nuts - Pecan	0.06
Planted Grazing (Perennial)	0.19
Planted Grazing (Seasonal)	0.23
Potatoes	0.27
Soft Fruit	0.22
Soya Beans	0.15
Sugar Beet	0.19
Sugar cane	0.21
Tendril crops	0.12
Tomatoes	0.15
Vegetables	0.24
Wheat	0.15

By comparing the Eskom crop LFs and the MV90 measured LFs, overall the results show that the proposed Eskom LFs are representative but conservative. The Eastern region Proposed LFs is more conservative than Mpumalanga proposed LFs.

6 CONCLUSION

The South African irrigation sector is a significant energy consumer which may have a large potential for Energy Efficiency (EE). However, these are all small EE impacts making normal M&V too expensive for these projects. Therefore an M&V case study was performed to evaluate the potential and applicability of SPP on the irrigation sector and the M&V thereof. An M&V assessment on 19 irrigation sample sites verified that definite and significant demand reductions can be achieved with the implementation of VSDs. The next step was to determine how much a pump is operational during the year?

A specific method researched and tested by an Eskom Energy Advisor was to use crop LFs through a specialised irrigation software programme called SAPWAT. It was required from M&V to independently verify the application of crop LFs to SPP. Normal M&V measurements was not an option and an intuitive way needed to be found, to evaluate the calculated crop load factors for an specific area. This evaluation was done through a crop LF and pump LF analysis determining the typical LF of a large sample of actual irrigation pumps and comparing these with the Eskom proposed crop LFs. The critical outcome of the analysis was to verify if the Eskom crop load factors are representative and conservative.

In Mpumalanga a total of 65 pumps and in KZN a total of 104 pumps and or pump-stations formed part of a LF study. A total of four years data of each point was processed in order to determine the weekday, Saturday and Sunday average LF for each calendar month. Comparing the Eskom crop LFs and the MV90 measured LFs, the results show that the proposed Eskom LFs are indeed representative, but conservative. The overall average measured LF in Mpumalanga is 0.213, while the overall proposed Eskom crop LF is only 0.174. The KZN proposed LFs is more conservative than Mpumalanga proposed LFs.

7 BIBLIOGRAPHY

[1] Storm, M.E. "M&V of the Eskom irrigation pumping SPP Programme" *ICUE conference proceedings*, Cape Town, Aug 2013. pp. 249-254.

[2] Storm, M.E. "M&Vof an irrigation pumping project: Case study," *ICUE conference proceedings*, Cape Town, May 2008. pp. 333-336.

[3] Van der Merve, C.A. "The Measurement and Verification Guideline for the Standard Product Programme," NWU, Potchefstroom, 2012.

[4] Eskom IDM EIEA Team - Scheepers,W.H. Gordijn, R. Rossouw, P. Bezuidenhout, N. Horlock, K.

[5] Bezuidenhout, N. Eskom, 2013.

[6] Vermaak, J. Eskom, 2013.

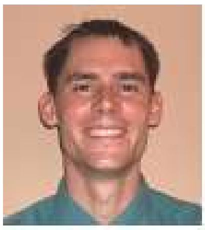
[7] Govender, M. Eskom, 2013.

[8] De Jager, G. NWU M&V Team, 2013

[9] De Waal, B. NWU M&V Team, 2013

8 AUTHORS

Principal Author: Markus E. Storm holds a B.Eng and M.Eng degree in Electrical & Electronic Engineering. The degrees were obtained at the North-West University, Potchefstroom, South Africa. He is certified by the AEE as a CMVP (Certified Measurement & Verification Professional) and a CRM (Certified Carbon Reduction Manager). Currently he is involved in M&V projects varying from irrigation pumping to CDM CFL projects and measurement system development



Co-author: Rupert Gouws holds a Ph.D. degree in Electrical and Electronic Engineering from the North-West University (Potchefstroom campus). He consulted to a variety of industry and public sectors in South Africa and other countries in the fields of energy engineering and engineering management. Currently he is appointed as a senior lecturer specialising in energy engineering, electrical machines and control at the North-West University. The Engineering Council of South Africa (ECSA) registered him as a Professional Engineer and the AEE certified him as CMVP.

Co-author: LJ Grobler holds Ph.D. degree in a mechanical engineering and is a professor at the School for mechanical and materials engineering, and also the North-West University engineering faculty Dean. He specialises in M&V and in energy management and process energy optimisation. He is certified by the AEE as a Certified Energy Manager (CEM) and a CMVP.

Presenter: The paper is presented by Markus Storm