Department of Minerals and Energy, Pretoria

Capacity Building in Energy Efficiency & Renewable Energy

Report No. 4.1 Measuring & Verification

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REPUBLIC OF SOUTH AFRICA

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Abbreviations and Acronyms

BEE	Black Economic Empowerment
CaBEERE	Capacity Building in Energy Efficiency and Renewable Energy
CB	Capacity Building
CEF	Central Energy Fund
DANIDA	Danish International Development Assistance
DDG	Deputy Director-General
DEAT	Department of Environmental Affairs and Tourism
DK	Kingdom of Denmark
DKK	Danish Kroner
DME	Department of Minerals and Energy
DPW	Department of Public Works
DTI	Department of Trade and Industry
EE	Energy Efficiency
EMO	Energy Management Opportunity
ESCO	Energy Service Company
ESETA	Energy Sector Education Training Authority
FIDIC	Industrial Federation of Consulting Engineers
IDC	International Development Corporation of South Africa
NT	National Treasury
NER	National Energy Regulator
NGO	Non-Governmental Organisation
PDI	Previously Disadvantaged Individual
PM	Project Manager
PQ	Pre-Qualification
PSC	Project Steering Committee
PTT	Project Task Team
QA	Quality Assurance
RE	Renewable Energy
RSA	Republic of South Africa
SA	South Africa / South African
SALGA	South African Local Government Association
SANGOCO	South African Non-Governmental Organisations' Committee
SARS	South African Revenue Service
SMME	Small, Medium and Micro Enterprises
SP	Service Provider
ST	Short Term Adviser
TA	Technical Assistance
TOR	Terms of Reference
VAT	Value Added Tax
ZAR	South African Rand

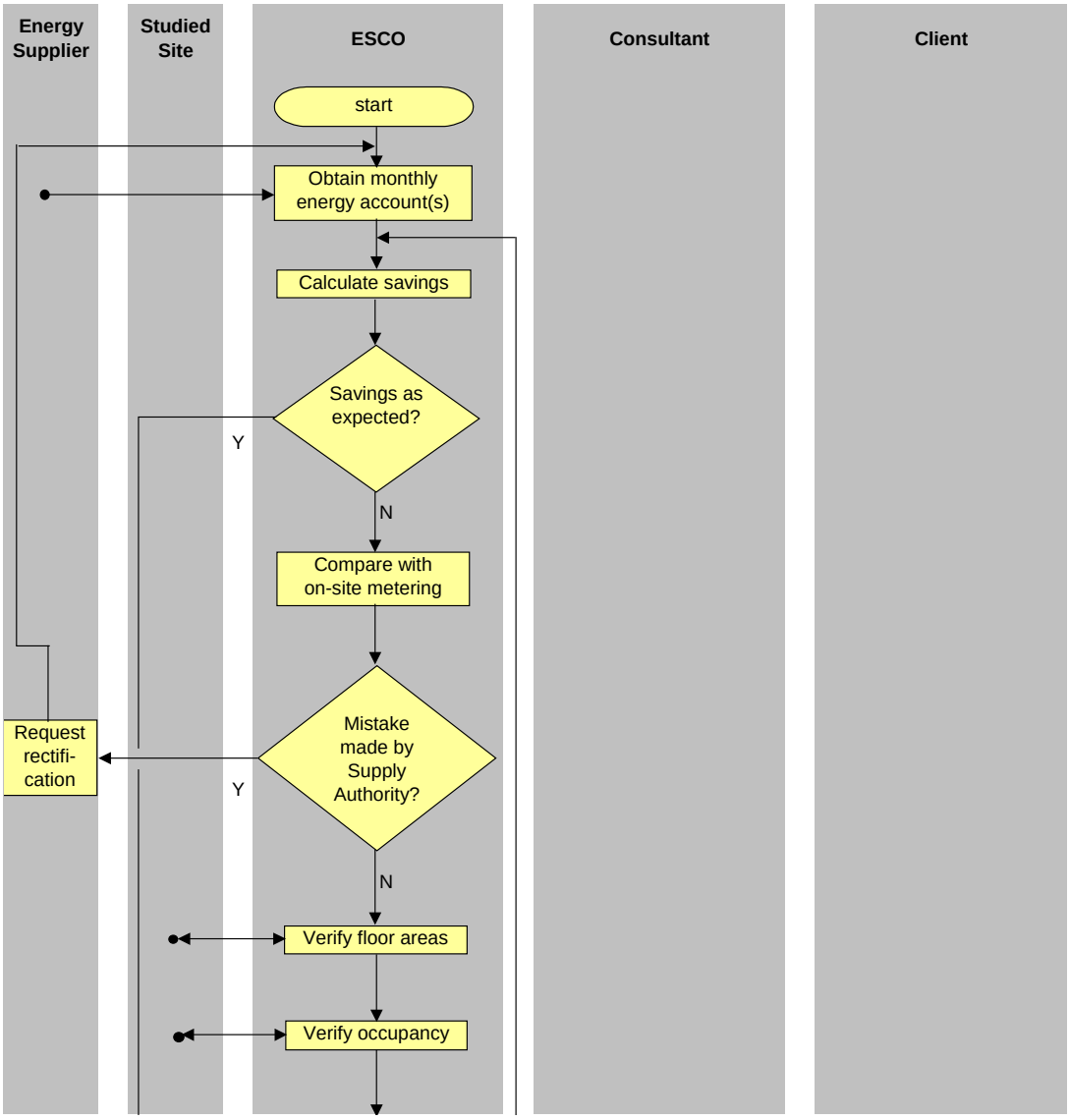
1 Introduction

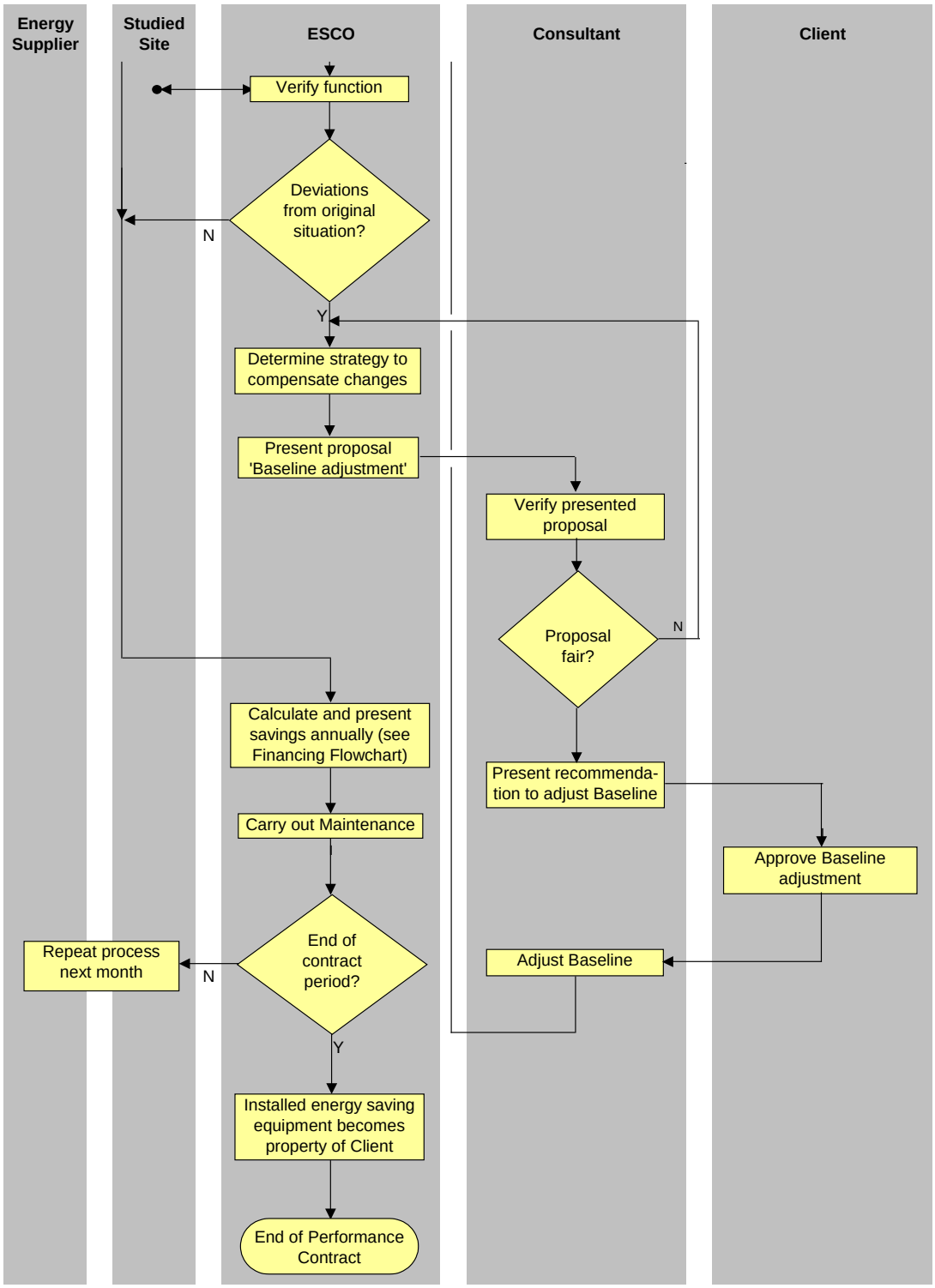
Measuring and Verification are actions that have to be taken after energy saving strategies have been implemented. These are required to ensure that savings have actually been achieved and to check that they are being maintained. Experience teaches that without this continuous check, energy consumption will slowly crawl back to the level of the Baseline or worse. The other main reason for Measuring and Verifying is to determine the quantity of savings obtained, in order for all parties involved to claim their share of the savings.

This document also deals with procedures that have to be followed to adjust Baselines. Changing a Baseline is sometimes required if a site expands, in which case the Baseline needs to be corrected to ensure savings are calculated correctly.

2 Flow Chart for Measuring & Verification

The following Flow Chart summarises the process of Measuring & Verification as described in more detail in this document.




Energy Supplier
Studied Site
ESCO
Consultant
Client
Verify function
Deviations from original situation?
N
Y
Determine strategy to compensate changes
Present proposal 'Baseline adjustment'
Verify presented proposal
Proposal fair?
N
Calculate and present savings annually (see Financing Flowchart)
Present recommenda-tion to adjust Baseline
Carry out Maintenance
Approve Baseline adjustment
End of contract period?
Repeat process next month
N
Adjust Baseline
Y
Installed energy saving equipment becomes property of Client
End of Performance Contract

3 Measuring

The aim of measuring is to check constantly the energy consumption and what savings are being obtained in order to ascertain at an early stage whether the site's energy consumption is acceptable or abnormal. The instruments and methods for measuring are given in this chapter.

3.1 Energy consumption

3.1.1 Electricity

The supply authority measures the electricity consumption and demand. The monthly invoices are therefore the main source for calculating savings. The consumption and demand should be compared to the Baseline.
Although the supply authorities' duty is to invoice for the correct consumption and demand, problems can occur:

- Meters are read by people (meter readers) and sometimes they make mistakes (e.g. decimal point wrongly placed).
- Electricity meters are electronic devices (sometimes mechanical) and can therefore malfunction. They should be tested and calibrated regularly, which is rarely done.
- Meter readings often have to be corrected with a multiplication factor due to the size of installed current transformers (CTs). If this multiplication factor is wrong (often after a meter has been replaced), the invoices will contain wrong figures.

For the above reasons it is recommended that the ESCO performs its own metering. This could be done by taking the pulses (kW/kVA and kVAr) from the authority meter and logging them (e.g. with a computer). The logs can be converted to graphs showing the electricity profiles. This does not eliminate the problems that can occur because of lack of calibration. Experience teaches us that this method is usually sufficient. If the meter malfunctions, this will be picked up in the readings either on the logging device or on the electricity invoices.

3.1.2 Other fuel sources

Except for a few situations where natural gas is metered, all other fuel sources are delivered in bulk and consumed at a different rate. Metering is difficult or impossible. For all unmetered fuels, logbooks will have to be filled in on site, or alternatively, the supplier should send through delivery quantities when they occur.

3.1.3 Direct measurement of energy savings

In some cases the energy savings can be measured directly. The methods of measurement have to be agreed on before the energy saving strategy is implemented. Measurement of energy savings is a preferred approach when the historical energy consumption fluctuates and implemented energy savings are smaller than the fluctuations. This also applies to sites where there is insufficient consumption history (i.e. newly occupied buildings) to establish a Baseline.
Examples of measuring energy savings are:

- Newly occupied office building where lights have been retrofitted with a more energy efficient type. The old situation will have to be measured for a short time to know what the energy consumption is. After the retrofit the energy consumption has to be measured again for a short time; after that the amount of time the lights are on, multiplied by the reduction in power, is the energy saving.

- When a heat exchanger is installed as energy saving strategy, the temperature difference over the heat exchanger multiplied by the flow indicates the energy saving. By logging these quantities, the energy saving can be calculated.
- If more efficient motors (on pumps, fans, etc) or Variable Speed Drives are to be installed, the energy consumption of the old situation has to be recorded for a week. When installing the motors with higher efficiency or VSDs the energy consumption can be recorded using a simple kWh meter. The difference in consumption is the energy saving.

Other methods of measuring energy savings are available, but require a more custom made approach. The ESCO proposing these alternative measuring approaches must provide enough information on the method used. The Consultant has to verify if the method and can only approve the proposed approach if both parties agree.

3.2 Installation

The modifications made within installations on site have to be checked regularly in order to guarantee the energy savings they were designed for.

In cases where fuels sources have been changed, the performance of the newly installed equipment has to be measured regularly to ensure the equipment maintains the designed efficiency.

3.3 Function of site

In order to make sure the Baselines used are valid, the ESCO and Consultant must constantly check the variables that influence the Baseline.
Keeping track of occupancy numbers (in prisons, hospitals, schools, etc.) is the main priority. If these numbers change dramatically and influence the energy consumption of a site, adjusting Baselines should be investigated (see Chapter 5)

Also, if additions are made to the site (i.e. new buildings or extensions to existing buildings), the impact on the energy consumption has to be measured. Sub-metering is the solution; the readings will be taken monthly (around the same date as the supply authority does). These readings, taken by the ESCO with the Consultant as a witness, will be added to the Baseline. The ESCO submits a proposal to the Consultant to adjust the Baseline (see Chapter 5)

4 Verification

4.1 Energy consumption

In 3.1 the various methods of measuring the energy consumption are described. Once this data is gathered, it must be verified. Comparing to the Baseline is the first action. If unexpected deviations from the Baseline are discovered, action needs to be taken.

4.1.1 Metering

- Determine whether the energy supplier has misread any meters or used wrong multiplication factors.
- Did the supply authority actually read the meter or has it estimated the consumption?
- Does the metering period coincide with the period used in the Baseline? Reading the meter 3 days later will increase the consumption for a month by 10% !
- Could the meter be faulty? Verify by measuring at the same point as the meter and compare the measurements.

4.1.2 Installation

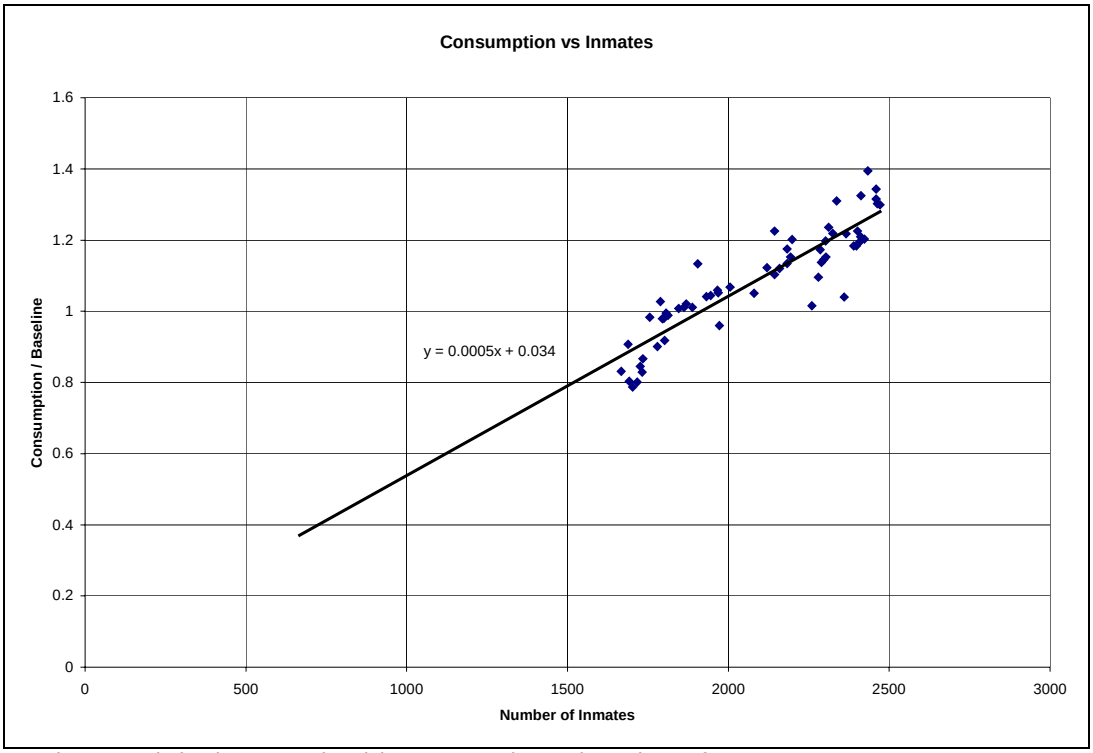
- Are all energy management opportunities still in place. Inspect on site whether lighting retrofits are still in place, all timers are set to designed setpoints, PFC is working properly (blown capacitors?), etc.
- Are deviations a result of different weather circumstances? Verify the climate data of that month with the data used in Energy Saving calculations.
- Has any equipment been added to the site? Especially equipment that is using a different fuel source will have a serious impact: for example electrification of a kitchen that used to have steam as a heat source.
- Discussions with maintenance personnel on-site will reveal most of the additions and/or modifications. Having a good relationship with this Department helps a lot; modifications will be mentioned before they will take place, giving the ESCO enough time to study the impact of the modifications and additions.

4.2 Function of site

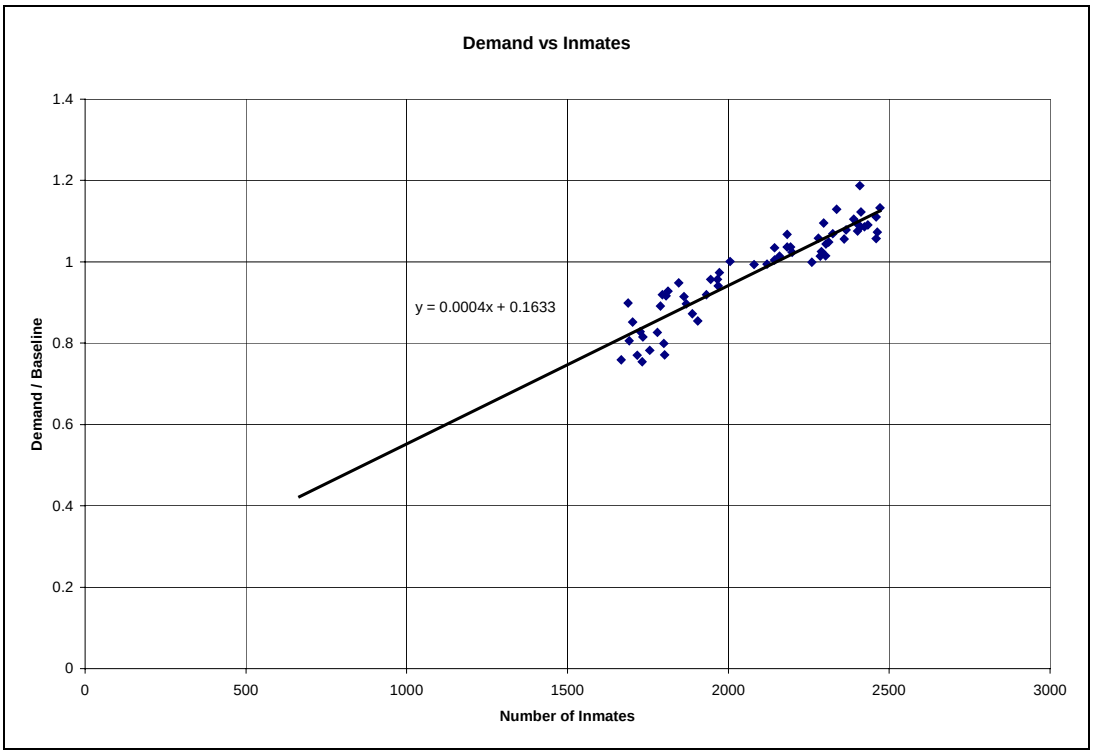
If occupancy numbers vary, it is likely that the energy consumption will, too.
Variables that have an influence on the energy consumption are:

- Occupancy numbers
- Floor areas (see definition in Auditing document Appendix C)
- Function of building/site

Finding a correlation between occupancy numbers or floor areas and energy consumption is a complex issue. The engineering and statistical rules will have to be followed and the ESCO must have a well-founded correlation to present to the Consultant when it discovers energy savings are not taking place because of either one of the first-mentioned variables. The ESCO can then request to change the Baseline according to the increase of occupants or floor areas (see Chapter 5). Also see Graphs 1 and 2 for examples of finding correlations between, in this case, number of inmates in a prison and the increase in electricity consumption and demand. Note that these examples show the correlation after energy saving strategies were implemented. The numbers of inmates increased over the years, increasing the consumption and demand.



Graph 1. Correlation between Electricity Consumption and Numbers of Inmates



Graph 2. Correlation between Electricity Demand and Numbers of Inmates

If a (part of a) site changes function (e.g. old ablution block refurbished to an office building) the difference in energy consumption and demand has to be calculated by the ESCO and verified by the Consultant. Also, this proposed change in Baseline has to be well-founded in order for both parties to agree, which is required.

5 Baselines

5.1 Calculation of Baseline

The Consultant has to compile the Baseline at an early stage of the Detailed Audit. Before the Baseline is official all parties (Client, User and ESCO) will need to give their approval. Once approved, the Baseline will be handed over to the ESCO, so it has a reference point from which to calculate potential savings.
To calculate a Baseline, the Consultant will require 3 years of historical energy consumption data. This can be obtained from the Client or directly from the energy supply authority. It is important to obtain figures for all forms of consumed energy.
The consumption will be averaged for every month and has to be converted to the universal energy unit MJ. If only electricity is used, the unit kWh can be used. In the case of a demand tariff, the demand figures have to be averaged for every month, and form part of the Baseline.
Extremes in historical data have to be omitted. This is done to make sure misreadings and malfunctioning of meters are not included in the Baseline. The accuracy of the meter has to be established on-site by measuring independently at the supply incomer.
Other variables that can possibly influence the energy consumption (e.g. occupancy numbers) will be filed, but no attempt to find a correlation should be made at this stage.

As mentioned in the Auditing document, the CO_2 emissions should be included in the Baseline. These emissions are calculated back to the source; electricity is generated in power plants that are mainly coal fired, the energy of the coal is transformed into electricity with a certain efficiency. All these variables have been taken into account in Table 1.

Energy sources	**kg CO_2 / unit fuel**	**kg CO_2 / GJ***
Electricity	0.77 kg CO_2/kWh (Eskom) 0.89 kg CO_2/kWh (EIA)	213.89 kg/GJ (Eskom) 247.22 kg/GJ (EIA)
Distillate Fuel (No.1,2,4 fuel oil and diesel)	2.68 kg CO_2/litre 3.14 kg CO_2/kg fuel	69.38 kg/GJ
Residual Fuel Oil (No. 5 and 6 fuel oil)	3.12 kg CO_2/litre 3.12 kg CO_2/kg fuel	74.77 kg/GJ
LPG	1.54 kg CO_2/litre	59.78 kg/GJ
Propane	1.52 kg CO_2/litre	59.84 kg/GJ
Natural Gas	1.93 kg CO_2/m^3_n	50.34 kg/GJ
Bituminous Coal	2465.61 kg CO_2/ton fuel	88.27 kg/GJ
Sub-Bituminous Coal	1857.91 kg CO_2/ton fuel	91.45 kg/GJ

Table 1. CO_2 emission of energy sources for South Africa
* GJ values are based upon Higher Heating Values

Table 1 was compiled using the following sources:
- GHG Protocol, Eskom environmental report, 2000 figures, Agama
- CO_2 calculation tool from www.ghgprotocol.org (Energy Information Agency EIA)

5.2 Baseline adjustment

Both the ESCO and the Consultant can request to change the Baseline if a site is performing below expectations and if a cause can be found. The request must include a technical report stating what the cause of energy increase (or decrease) is, including all documents that prove that in fact a change in occupancy, floor areas or function did occur. Correlations between the increase in energy consumption and above-mentioned variables have to be included, based on mathematical formulae.

If any equipment has been added to the site, measurements (preferably logged consumption over a period of time) have to be carried out, and the results must be included in the request.

If the ESCO and Consultant agree that there is sufficient proof that the Baseline should be changed, the Consultant will write a proposal to the Client and User. Once all parties have agreed on the Baseline changes, the new Baseline will come into effect.

In the case of addition of installations (e.g. extra geysers or air conditioning units) the ESCO can request to sub-meter these additions. A simple electricity meter needs to be installed, and the meter readings need to be taken at the first working day of the month. The readings have to be taken by the ESCO, and the Consultant has to be witness. The readings can only then be added to the Baseline.
After a period of time (3 years), the average monthly meter readings can be used to make a permanent adjustment to the Baseline and the meter can be removed.

6 Quality Assurance

Auditing, Financing, Implementing and Monitoring & Verification are the four cornerstones on which a successful Energy Management programme is based. If these four aspects are not integrated properly within each other, the programme is doomed to failure.

To ensure Quality Assurance within the M&V section, the following steps should be taken into account:

- As the Consultant has compiled the historical energy accounts into a Baseline, only the Consultant can change a Baseline. The ESCO will submit a proposal, which shall be judged by the Consultant. If found fair and correct, the Consultant will recommend a Baseline adjustment to the Client and User. When all parties have approved, the Baseline will be officially changed by the Consultant.
- If the guaranteed savings are not achieved, the ESCO will have to investigate immediately. If at the end of the year, the savings achieved are lower than the guaranteed savings, the ESCO will have to pay in the difference.