Achieving Electrical Load Reductions and Cost Savings in Commercial Buildings

By

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Abstract

The power crisis that has been thrust on the country requires an immediate 10% reduction in load. If this is achieved it will eliminate disruptive load shedding and allow Eskom to rebuild capacity for the future. A 10% reduction in load could be seen as a threat to production and business. This is however a huge opportunity for most businesses and property owners to reduce their utility bill and become more efficient. This paper will discuss how a comprehensive energy measurement and control strategy can be used to identify inefficiencies and reduce energy consumption with no negative business impact. Case studies will be presented that achieved savings of up to 75% with a return of investment of more than 120%. This paper will be of value to business and property owners, consultants and facilities management personnel and will present a viable alternative to using costly generators.

Introduction

According to the US Environmental Protection Agency (EPA), buildings in the USA account for:

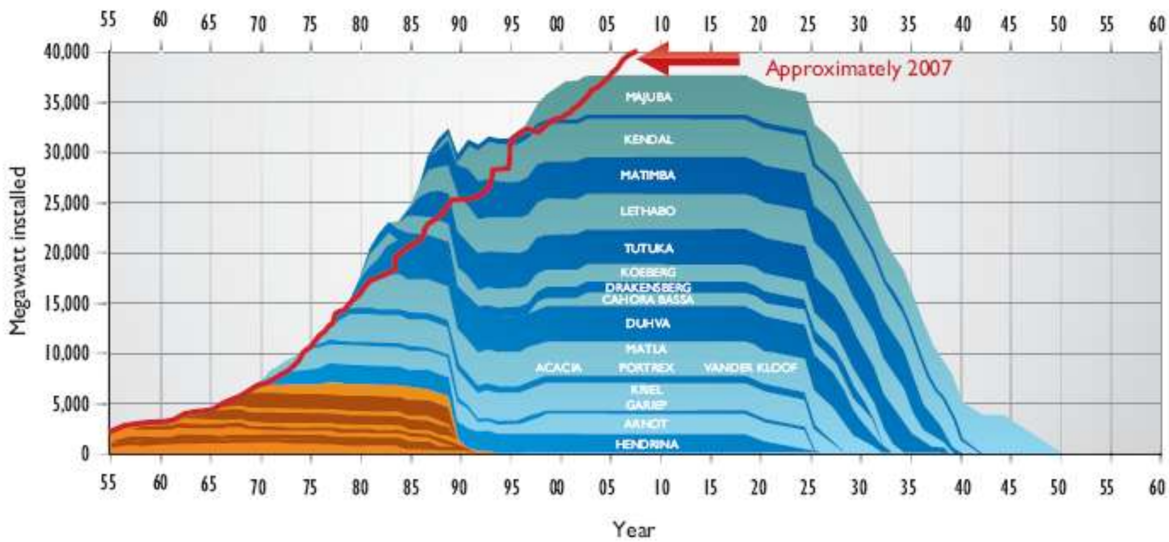
- 65% of electricity consumption,
- 36% of energy use,
- 39% of greenhouse gas emissions,
- 30% of raw materials use,
- 30% of waste output (136 million tons annually)
- 12% of potable water consumption.

Buildings represent a huge opportunity for reducing electricity consumption which provide significant benefits to owners, tenants and the environment. Few buildings constructed prior to the 1990's considered energy efficiency due to the lower cost of electricity and unavailability of energy efficient technologies.

Reductions in energy consumption also enable companies to deliver products and services at a lower cost. These increased profits accrue directly to the bottom line. Potential savings from an integrated approach to energy-efficient upgrades can be 35% or greater. According to the US EPA, energy bills for existing US commercial buildings of approximately 7.3 billion m^2, total $110 billion annually. The US EPA estimates that increasing the energy efficiency of this space could save more than $25 billion.

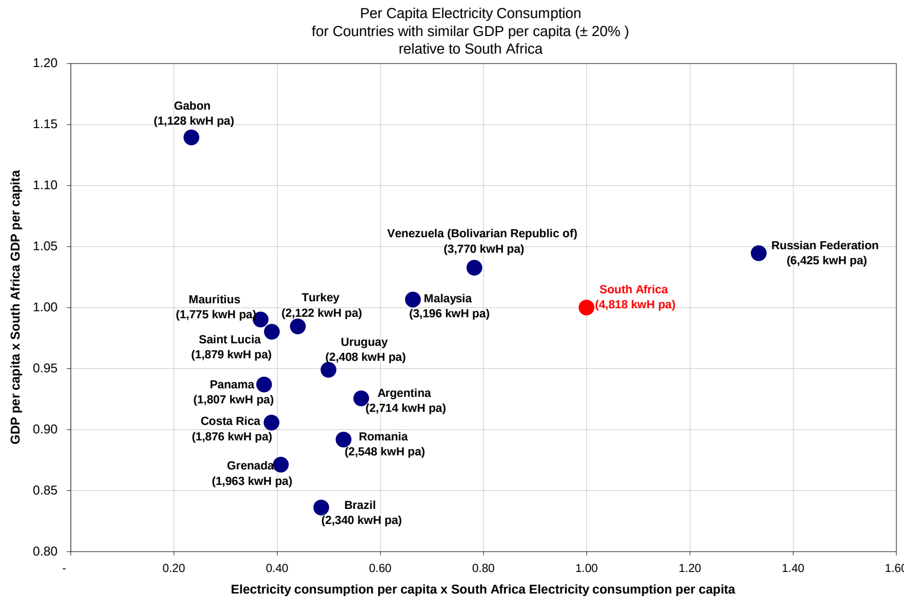
The SA Electricity Scenario

At present electricity prices in South Africa are among the lowest in the world. This has made it uneconomic to introduce energy saving technologies. In order to incentivise consumers, Eskom DSM has had projects running to reduce energy & pay towards costs since 1994.The authorities have realised since 1998 that rising electricity demand with fixed generation capacity would eventually result in shortages. This is illustrated by the following graph from Eskom DSM.



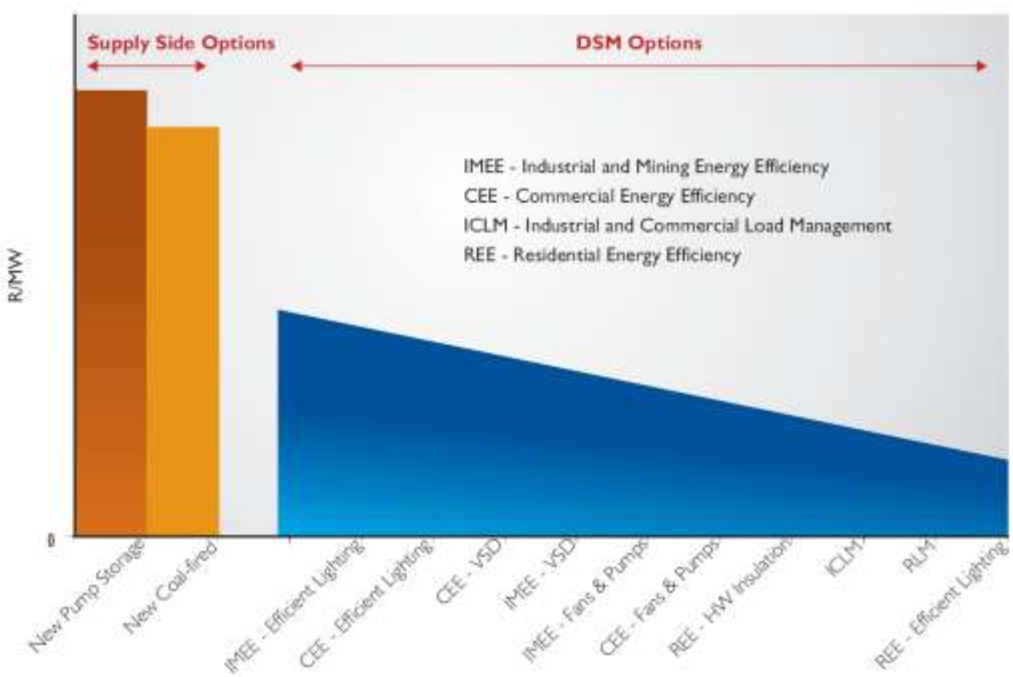
This shortage of generation capacity triggered the electricity crisis starting during late November 2007. In order to stabilize the electricity network Eskom effectively require an immediate 10% reduction in load profile. This should not be achieved by load or demand shifting. At present (April 2008), South Africa is in a power rationing phase where consumers are load shed according to a published schedule. From July 2008, Eskom is moving to the next phase where they hope to achieve the necessary savings by using penalties and incentives For example a R0.02 / kWh additional charge for customers who do not reduce their current consumption by at least 10%.

When South Africa is compared with other developing countries, it can be seen in the figure below that the electricity consumption per capita is one of the highest normalised to the per capita income. The inevitable increased electricity prices will provide a challenge for businesses to use energy in a more efficient manner.



Source: UN (United Nations). 2007d. The 2004 Energy Statistics Yearbook. Department of Economic and Social Affairs, Statistics Division. New York.

The following Eskom DSM graph compares the cost of generation and implementing more energy efficient consumption.



Management Options

Good businesses always anticipate change and make contingency plans to cope with new circumstances. In response to the current electricity crisis there are three responses:

1. Do nothing. The business is either unable or unwilling to make contingency plans. There could also be a false belief that the ESCO will sort out the problem or there will be sufficient savings from other consumers. There will be no additional capital expenditure (CAPEX). If the business is dependent on electrical power for operations it will suffer production losses. At present the load shedding is 12 hours per 2 weeks or 15 percent.

2. Invest in independent generation or backup equipment. The business identifies equipment critical to the operation and then purchases or rents generators, UPS's and inverters to supply critical power during the load shedding. This may require CAPEX and additional operating expenses (OPEX).

3. Identify energy savings opportunities in the business to save at least 10 percent. This option may require some CAPEX but will immediately reduce OPEX. The projects with the greatest impact and best return of investment (ROI) could be chosen.

Most businesses will already have critical business equipment on standby or backup supplies in order to ensure security of supply. A combination of options 2 and 3 could be pursued.

What is a 10% Saving?

Existing, non energy efficient commercial buildings typically use between 250kWh/m2 and 350kWh/m2 per annum. This is for lighting, heating, ventilation and air conditioning (HVAC) as well as equipment. A savings of 10% will amount to between 25 kWh/m^2 and 35 kWh/m^2 per annum. Using a figure of 30kWh/ m^2 will require a reduction of 15W per m^2 for a business operating 8 hours per day / 5 days per week. The load reduction can be achieved by a combination of the following:

- Recommissioning existing equipment to improve efficiency
- Using more energy efficient equipment
- Reducing the operating time of equipment
- Removing superfluous equipment

Note that energy savings are only affected by a reduction in load. Shifting a load to another time period does not save energy – it merely postpones it to another period. Although there is no energy saving, there could still be a financial benefit due to the consumption taking place at a more favorable tariff or reducing the maximum demand charge.

Green and High Performance Buildings

Wikipedia describes Green Buildings as the practice of increasing the efficiency with which buildings use resources — energy, water, and materials — while reducing building impacts on human health and the environment, through better siting, design, construction, operation, maintenance, and removal — the complete building life. The concept of green buildings has been taken further and some practitioners now refer to High Performance Buildings.

The US Department of Energy defines a high-performance commercial building as *"a building with energy, economic, and environmental performance that is substantially better than standard practice. It's energy efficient, so it saves money and natural resources. It's a healthy place to live and work for its occupants and has relatively low impact on the environment. All this is achieved through a process called whole-building design".* Benefits of whole-building design include:

- Reduce energy use by 50% or more
- Reduced maintenance and capital costs
- Reduced environmental impact
- Increased occupant comfort and health
- Increased employee productivity

The design and upgrade guidelines for high performance buildings can be used to improve energy efficiency in any building.

Energy Audits and Building Surveys

The above design concepts can be used when designing and constructing new buildings such as the FNB Fairlands Office complex in Gauteng. Most existing buildings will be relatively energy inefficient, so it will be necessary to conduct an energy audit to determine how the building is currently using energy. This is the first task to be performed in the accomplishment of an effective energy cost control program

The Audit Consists of:

- A detailed examination of how the facility uses energy
- What the facility pays for that energy
- Recommended program for changes in operating practices or energy-consuming equipment that will cost-effectively save money on energy bills

The basic steps in the audit are:

- Collect information
- Analyse how energy is used (or wasted)
- Identify specific changes known as energy conservation opportunities or ECO's
- Analyse the costs & benefits of ECO's
- Devise an action plan

Success depends on using an integrated approach and depends on the following factors:

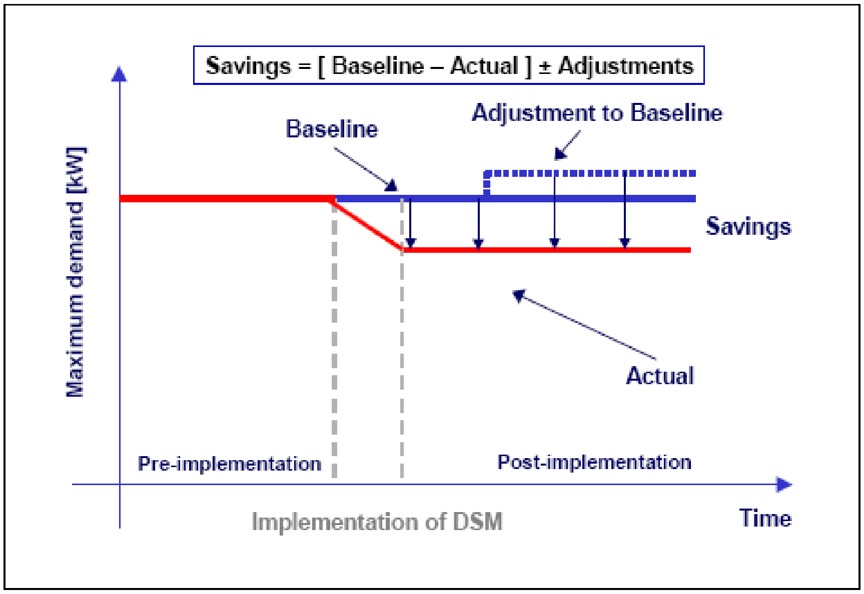
- Involving the right people in your organization —The audit must have the support and commitment of top management. It should target top level executives to promote energy performance.
- Benchmarking energy performance to optimize energy use and achieve maximum energy and cost savings, and using proven energy-efficient technologies and an integrated approach for building upgrades
- Communicating results to increase awareness of the benefits of energy performance

The audits should be part of a continuous process to improve energy efficiency as shown below:

Measurement & Verification

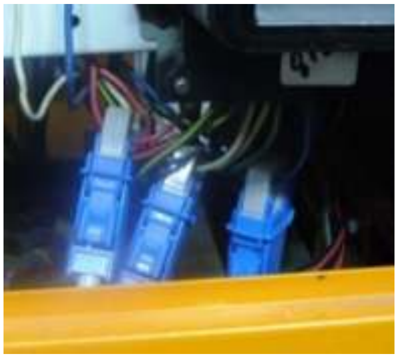
Implementation of successful energy reduction projects depends on measurements before and after the implementation of any improvements. This process is known as measurement and verification (M&V). The objectives of M&V are to provide an impartial, credible and transparent process that can be used to quantify and assess the impacts and sustainability of energy-efficiency projects.

An energy-efficiency project has three basic stages. The first stage is the pre-implementation phase, where measurements are taken and opportunities identified. The second phase is the implementation of the energy reducing plan and the third phase is monitoring and analyzing the results. Graphically this is shown below:



Monitoring equipment is recommended to establish the baseline electrical consumption. Data is usually available from the bulk supply meters to the site. However these provide aggregated totals so it is not easy to identify the ECO's in the building.

Where possible key individual loads should be measured. These would consist of lighting, HVAC and equipment loads at a number of representative building floors. The equipment can be installed in distribution panels or the substation. The measurement units at a typical site are shown below:

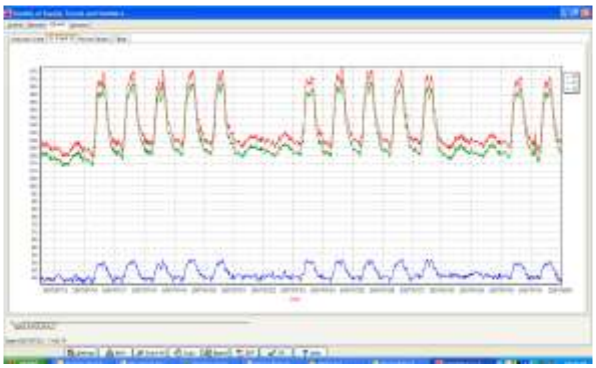


M & V Equipment

The electrical measurement equipment used for the M&V of a building should be capable of the following:

- Inputs for at least one 3 phase load (3 voltage and 3 current)
- Sample interval from 10 to 30 mins
- Save data for up to 12 months
- Remote data collection (GSM is preferred)
- Current inputs should use clamp-on or split-core current transformers

Examples of data collected from a sample building are shown below:



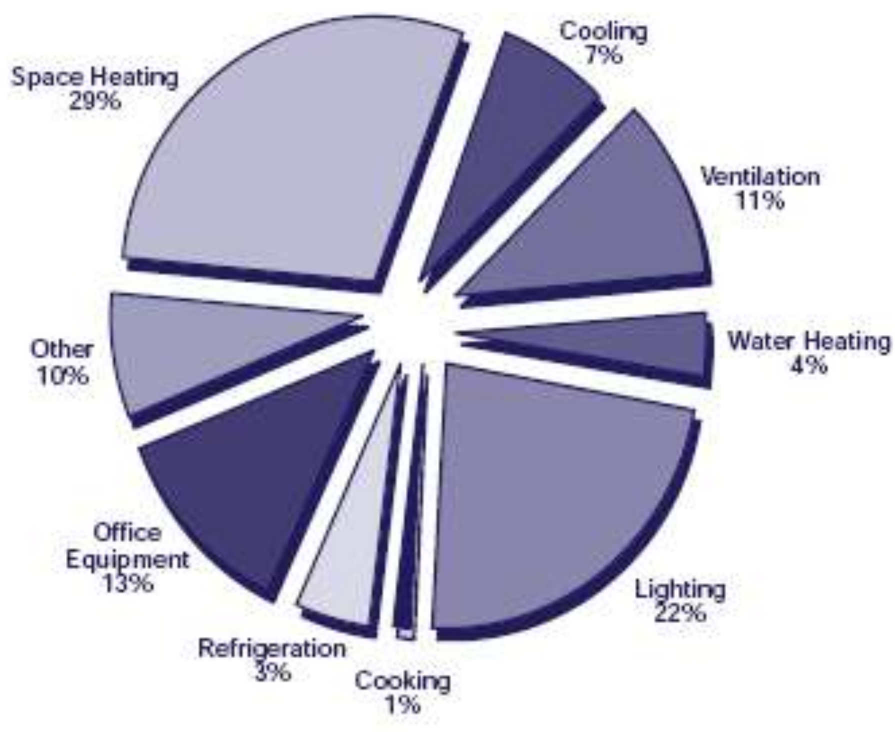
The data from the building can then be analysed to identify opportunities for savings. The savings can then be compared with the required investment and the projects can be ranked by return on investment, ease of implementation etc. Following implementation, it is essential to continue the monitoring process to ensure the projected savings are achieved.

Building Energy Profile

Each building has an energy profile or envelope that determines the electrical energy that will be required. Most of these are determined by the design of the building and are not easy to change. It is useful to understand how heat flows in a building in order to identify ECO's. This is illustrated by the following figure:

Heat Flow In Buildings: Building Systems Interactions

Heat flow, lighting and equipment consume most of the electricity in a building. Typical electricity use in a commercial building is shown below:



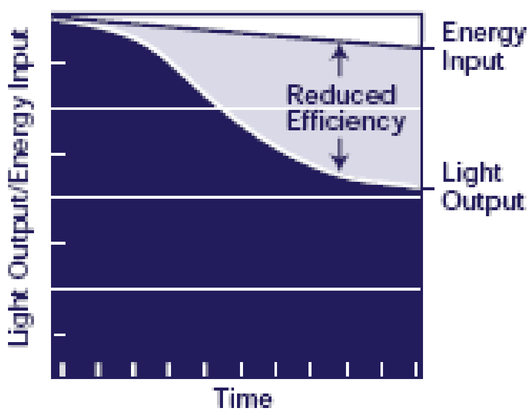
Lighting – Opportunities for Saving

Lighting often represents greatest immediate energy savings opportunity. Optimum lighting levels must be determined for each office or workspace. Often work areas are incorrectly illuminated as the lighting fixtures are installed for “general” use. The energy efficiency of lights vary substantially and where possible older technologies such as incandescent lights should be changed to new energy efficient lamps such as compact fluorescent (CFL) and LED. The ballasts in the older fluorescent fixtures can be upgraded to the energy efficient electronic ballasts.

Lights that need to stay on permanently such as emergency lighting in stairwells and exit signs should be changed to the highest possible efficiency lamps as there is no duty cycle.

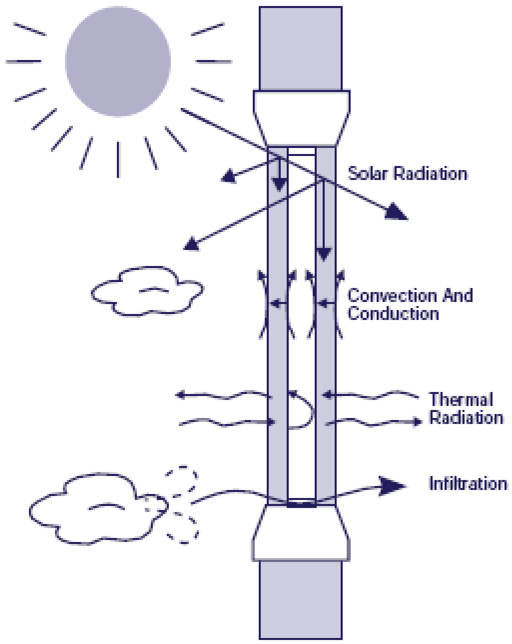
Timers or motion sensing devices can be used to automatically control lights which are on after hours or when offices are unoccupied

Light output can be significantly reduced when the lamps are dirty. Periodic maintenance and cleaning of lamps and fixtures should be instituted. It should also be noted that lamp efficiency changes with time as shown below. It may be economical and more energy efficient to use fewer lamps and change the globes before failure when the light output is below a certain threshold.



Heating Ventilation and Air Conditioning (HVAC) – Opportunities for Saving

HVAC can consume 50% or more of the electricity used in a building. The figure illustrating building heat flow has already been presented above. The following figure illustrates how the external environment affects the heat flow into and out of a building.



Evaluating commercial building loads is complex and time consuming. A number of software programs are available to help designers perform this evaluation. The following factors influence building heat loads:

- Solar. Solar radiation can have an enormous influence on the heating and cooling required in a space. Standard double-glazed windows can let up to 75 percent of this energy penetrate the building, where it becomes a cooling load. Additional window treatments such as tinted and reflective glazing, shading and draperies can further reduce solar gains.
- Lighting. Typically, 70 to 80 percent of the electrical energy used by lighting ends up in the conditioned space as heat. Lighting power is often about 20 W/m^2 in office buildings but can be as high as 40 to 50 W/m^2
- Equipment. The equipment load (also called plug-load) is often in the 2- to 5-W/m^2 range but can be as high as 15 to 20 W/m^2
- Windows. Heat can also be radiated out of the building through the windows in winter if outdoor temperatures are much lower than room temperature.
- Outside air temperature and types of insulation. Heat gains or losses through walls, floors and roofs.
- Internal gains from occupants (including latent heat for cooling purposes): Each adult will typically generate about 75 W of sensible energy and 55 W of latent energy

Other energy efficiency considerations include the use of a central chiller and air handling unit vs. wall mounted & split air conditioning units. Wall mounted units are less efficient for the total building but can be used to condition small spaces more efficiently.

When the building is unoccupied the building temperature can be adjusted to save energy. In addition wall mounted / split units are often left on when offices are unoccupied. A timer or remote control can be used to turn these units off when not required.

The HVAC equipment in many buildings is old, inefficient or poorly maintained. These units can consume considerably more electricity than necessary. A calculation can be made to determine the economic point for replacement and maintenance.

Equipment

Equipment powered by electricity directly affects your electrical loads. It should be noted that for many types of equipment, much of the electrical consumed will ultimately end up in that space as heat. Thus, improving the efficiency of your electrical equipment not only reduces your electrical loads but also reduces your cooling load. The following factors influence electricity consumption by equipment:

- Nameplate rating. Most electrical equipment will be fitted with a nameplate that specifies the wattage or current consumption of the equipment. Faulty equipment can consume significantly more power and periodic checks should be done to ensure correct operation.
- Efficiency at various loads. Equipment such as electric motors operates at a much lower efficiency at lower speeds. Ensure that equipment is operating at the correct speed to ensure the highest efficiency.
- Operating time. Energy use is directly proportional to operating or ON time. Where possible, unused equipment should be switched off automatically by a timer or control system. The running time for some equipment is different during summer and winter. The appropriate adjustments should be made.
- Energy Efficiency. Equipment should comply with one of the recognized energy efficient branded products such as ENERGY STAR®
- Off or "On Standby". When possible switch OFF equipment not in use. Surveys indicate that equipment in left on standby consumes between 5% and 13% of the ON power

Automatic Control of Loads

The control of energy consuming devices for the purpose of minimizing energy demand and consumption is known as energy management. This can be achieved by manually switching equipment on and off. Automatic control systems are an integral part of many energy related systems e.g. a heater thermostat. Automatic Controls can be used as a tool to achieve energy savings.

The following factors should be considered:

- Sensors and Monitoring. Automatic control may require feedback from the building to make intelligent decisions. This will require sensors (temperature, motion, etc) as well as a monitoring instrument to provide the necessary real-time information.
- Business Rules. A set of business rules needs to be integrated in the control system to ensure that electrical loads are switched on and off to ensure proper business operation within the energy efficiency targets
- Local vs. Central Control. The central control of loads is more expensive but it can ensure that the energy efficiency program is optimized. Simple local control using manual on/off or timers can be just as effective at a significantly lower cost. They are however easy to override or misuse.
- Individual vs. Group Loads. The cost of controlling individual loads may be prohibitive. The incremental energy cost of leaving a load on until a larger group can be switched off must be compared with the const of controlling individual loads.
- Overrides. These may be necessary for health and safety purposes as well as equipment failure.

Energy Management Control Systems should ideally be able to:

- • Manage demand (need for energy at a specific time)
- • Manage length of time a device consumes electricity
- • Set alarms when a device fails or malfunctions
- • Monitor HVAC and other building systems
- • Provides information for equipment maintenance
- • Provides building owners and managers with data for making future decisions and plans

Case Study 1: Adobe Systems (Existing Building)

Energy efficiency upgrades began in 2001 with the help of Cushman & Wakefield, a global commercial real estate brokerage and services company. During the next five years, Adobe spent US$1.4 million on 64 separate, energy-efficiency improvement projects in the Towers. After rebates totaling US$389,000, the net cost of all these projects was only US$1.11 million. Adobe now saves US$1.2 million per year in reduced energy operating expenses, which translates into a 121 percent return on investment and an average payback per project of 9.5 months.

Building Type:	**Office high-rise; Computer Data Center**
Recognition Status:	**Energy Star label, LEED for Existing Buildings v2.0 Platinum**
Gross Sq. Footage:	**West Tower: 391,000 sq. ft. (119,200 sq. m.); 18 stories East Tower: 325,000 sq. ft. (1,030 sq. m.); 16 stories Almaden Tower: 273,000 sq. ft. (25,400 sq. m.); 17 stories**
Total Retrofit Project Cost:	**US$1.4 million (total invested to date)**
Cost Savings:	**US$1.2 million/yr**
DOE Climate Zone:	**Zone 4 (2,400 HDD, 500 CDD)**

Case Study 2: BP Head Office, V&A Waterfront (New Building)

BP Southern Africa’s new Portswood office complex is situated at the V&A Waterfront. The building is a Resource Efficient Design (RED) which has the following characteristics:

- Low-rise campus type sustainable building set in a green environment with open plan office space
- The environmental performance of any building is largely determined by the design of its envelope. The T-shaped building is orientated at a 45-degree angle to the north with the main entrance on the southeast corner.
- Annual energy consumption target was set to be 115kWh/m2, 10 percent of the overall energy had to come from renewable sources.

- Lighting energy savings in two ways, firstly by cutting down on the actual electricity consumption of lights and by drastically reducing the amount of heat the lighting produces. Optimum use is made of natural light.
- Lighting installation was 40% more expensive than a standard installation, but will effect a 65% operational cost saving
- Solar water heaters on the roof supplement hot-water cylinders and photovoltaic cells on the roof and entrance canopy designed and supplied by BP Solar (France) can generate 10% of peak electricity demand

Conclusion

The purpose of this paper is to demonstrate that electricity savings of 10% or more are readily achieved in older commercial buildings. Reducing load profiles are a viable alternative to providing additional supplemental generation and standby capacity. The savings achieved by load reduction directly improve overall profitability of the business. Energy savings and load reduction is an ongoing process. South African businesses need to become more energy aware and ensure that the kWh per unit of production is driven lower as more energy efficient technologies provide cost effective opportunities.

References

1. The SA Demand Side Management Programme – an Operational Guide for Energy Services Companies , Eskom DSM

2. Grobler, Prof. LJ & den Heijer, Willem. The Measurement and Verification Guideline for Clients of Demand-Side Management, Eskom M&V

3. ENERGYSTAR® Building Upgrade Manual, US Environmental Protection Agency , 2004

4. Wulfinghoff, Donald R. ENERGY EFFICIENCY MANUAL, Energy Institute Press, 1999

5. Hordeski, Michael F. New Technologies for Energy Efficiency, THE FAIRMONT PRESS, INC, 2002

6. Turner, Wayne C. & Doty, Steve. ENERGY MANAGEMENT HANDBOOK SIXTH EDITION, THE FAIRMONT PRESS, INC, 2007

7. Barley, D., Deru, M., Pless, S. and Torcellini, P. Procedure for Measuring and Reporting Commercial Building Energy Performance, National Renewable Energy Laboratory, 2005

8. Etzinger, Andrew .Presentation to SAIEE breakfast from Eskom, 2008

9. High Performance Building : Perspective and Practice, Adobe Systems Corporate Headquarters, RMI

10. Robertson, Alex and de Beer, Inge. Report on BP Head Office, V&A Waterfront

11. Energy Star Guidelines for Energy Management, US Environmental Protection Agency

12. US Green Building Council Website – www.usgbc.org

13. Australian Green Building Council Website – www.gbca.org.au

14. Wikipedia Web Site - http://en.wikipedia.org/wiki/Standby_power

15. Rocky Mountain Institute Built Environment Web Site - http://bet.rmi.org

16. National Fuel Cell Research Center Web Site - http://www.nfcrc.uci.edu/2/

17. US Department of Energy, Office of Energy Efficiency Web Site - http://www.eere.energy.gov/buildings/highperformance/design_approach.html

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