**Proceedings of the Second IASTED Africa Conference**
**Power and Energy Systems (AfricaPES 2008)**
**September 8-10, 2008 Gaborone, Botswana**

# ACHIEVING SUSTAINABLE ELECTRIC POWER FOR SOUTHERN AFRICA: ISSUES AND OPTIONS

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**ABSTRACT**
Due to a combination of factors including unprecedented growth in demand for electric power driven in part by the favourable investment climate in Southern Africa, existing generation capacity will not be able to meet demand in the short to medium term. This is already evident from the ongoing load shedding in many countries in the region. It goes without saying that failure to meet demand for electric power will undermine the regional economy and its future growth. Poor economic prospects will inevitably reverse any poverty reduction gains that have been achieved. Moreover the continuing reliance on top-down load shedding regimes as the primary mechanism to match supply and demand leads to undesirable economic and social outcomes. While it is generally accepted that investment in new large power stations is a major part of the solution, this by itself will not be enough to create truly sustainable power systems. This paper presents a qualitative analysis of the main challenges facing the electric power sector in Southern Africa ranging from technical through to commercial and regulatory aspects. The paper also suggests approaches and polices that could be considered in order to achieve sustainable electric power systems in region.

**KEY WORDS**
Sustainability, renewable energy, energy efficiency, organisation restructuring

## 1. Introduction

The Southern Africa region is experiencing a period of deficiency in electricity supplies. In particular there have been serious shortages and consequently (and unfortunately) load shedding in South Africa, Botswana, Zambia and Zimbabwe. The load shedding is unfortunate because of the consequent economic losses and inconveniences suffered by customers.

Table 1 shows the installed capacities, the available capacity and the peak demand in Southern African countries in 2006/7 [1], [2]. With a peak demand of 44GW and available capacity of 46GW, the operating reserve margin was a mere 4.5%. Although the total installed capacity exceeded peak demand by some 9GW, it was insufficient to meet the growing regional demand from 2007 onwards. The projected energy balance for the Southern African Power Pool (SAPP) members is shown in Figure 1 [1]. It worth noting that in the period up to 2010, the forecast energy consumption exceeds the planned energy production. The situation will normalise after 2011 when the planned energy production is projected to be greater than the forecast energy consumption.

Table 1
SAPP Demand and Supply Outlook

| Country | Utility | Installed Capacity MW | Available Capacity MW | 2006 Peak Demand MW |
|---|---|---|---|---|
| Angola | ENE | 1127 | 943 | 476 |
| **Botswana** | **BPC** | **132** | **120** | **434** |
| Congo | SNEL | 2442 | 1170 | 1075 |
| Lesotho | LEC | 72 | 70 | 109 |
| Malawi | ESCOM | 302 | 246 | 240 |
| **Mozambique** | **EDM**<br>**HCB** | **307**<br>**2250** | **2075** | **343** |
| Namibia | NAMPOWER | 393 | 390 | 449 |
| **South Africa** | **ESKOM** | **43061** | **37258** | **36513** |
| Swaziland | SEB | 51 | 50 | 196 |
| Tanzania | TANESCO | 897 | 680 | 635 |
| Zambia | ZESCO | 1632 | 1630 | 1468 |
| Zimbabwe | ZESA | 2045 | 1125 | 1758 |
| | **Total** | **54711** | **45757** | **43755** |

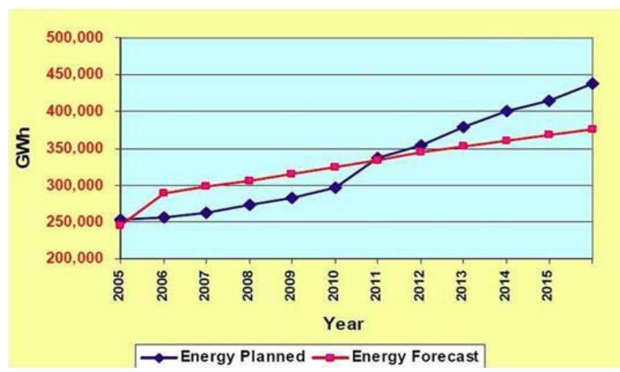

Figure 1. Planned versus forecast energy in SAPP

The region as a whole has a capacity constraint although Mozambique and Angola have available capacities greater than their peak demands. Of the two, Mozambique is interconnected to the grid of SAPP and exports to South Africa, Zimbabwe and Botswana. Over the years the countries of Southern Africa have developed a tradition of cooperation which led to the formation of SAPP. As result of this history of cooperation, there is a common understanding that they should work together to resolve the current regional energy crisis, through the structures of the Southern African Development Community (SADC) and the SAPP.

In addition to capacity deficiencies, the utilities are also facing other infrastructure challenges such as plant outages and coal supply challenges in Eskom affecting 4,500 MW [2]. This in part accounts for some of the unavailable installed capacities. Furthermore, some transmission routes consist of single transmission lines leading to poor security of supply. For example at the end of 2007 and in the early part of 2008 Botswana experienced power shortages that were due to the failure of the transmission line between Mozambique and Zimbabwe.

Most of the solutions to the electricity supply crisis have focused on development of additional generation capacity as well as demand side management strategies. These tend to forecast demand based on current usage and trends. In many cases other measures that could be instituted to alleviate the electricity shortages are not explored. These other measures are discussed in this paper.

In the short to medium term the major infrastructure projects that have been proposed in the region, and are ongoing include Inga 3 Development (4300 MW) and the Mmamabula Energy Project (2400 MW). South Africa has recently signed Agreements with the French Government for a series of nuclear power stations that will in the long term (next two decades) be expected to meet the projected demand [3], [4], [5].

While countries in the region are cooperating in finding solutions to the power crisis, each country has its own plans for managing this challenge. In the case of Botswana, the demand in the medium to long term has been reviewed. The revised five year forecast beginning 2008/9 is shown in Table 2 [1]. It is worth noting that there are shortfalls in each year with that in 2010/11 being the largest and hence giving cause for concern. Given these projected shortfalls, it is important to consider other measures that could have an impact on the forecast demand.

Table 2
Five Supply and Demand Plan

| Year | 2008/9 | 2009/10 | 2010/11 | 2011/12 | 2012/13 |
|---|---|---|---|---|---|
| Total Supply (MW) | 560 | 555 | 455 | 655 | 805 |
| Forecast Demand (MW) | 587 | 645 | 683 | 707 | 740 |
| Surplus/shortfall (MW) | **-27** | **-90** | **-228** | **-52** | 65 |

Table 3 [1] shows that in 2007, mining, at 43% of total energy consumption, constituted the largest load component in Botswana followed by commercial, domestic and government. It is important to note that domestic and commercial loads accounted for about 57% of the energy sales.

Table 3
Composition of Botswana Load

| Year | 2005 | | 2006 | | 2007 | |
|---|---|---|---|---|---|---|
| | GWh | % | GWh | % | GWh | % |
| Mining | 1,046.6 | 43.3 | 1,184.3 | 45.1 | 1,199.0 | 43.2 |
| Domestic | 539.3 | 22.3 | 584.4 | 22.3 | 681.7 | 24.6 |
| Commercial | 613.1 | 25.4 | 631.1 | 24.0 | 634.0 | 22.8 |
| Government | 216.9 | 9.0 | 226.6 | 8.6 | 262.0 | 9.4 |
| Total | 2,415.9 | 100.0 | 2,626.4 | 100.0 | 2,776.7 | 100.0 |

Other countries in the region also have substantial domestic and commercial/industrial loads. Measures aimed at reducing the reliance of these load categories on supply from the grid would have a major impact on the electricity industry in Botswana and the region as whole. This paper therefore suggests that in parallel with the major infrastructure developments that have been proposed, the region needs to consider other measures (such as use of solar power for water heating and electricity supply, and use of energy efficient appliances) that would have a significant impact on the peak demand and the overall cost of providing electricity. However, for these additional measures to be successful and play a role in the creation of sustainable electricity supply in the region there are many issues that must be considered and challenges that must be overcome. These issues and challenges are discussed in the next section.

## 2. Issues and Challenges for the Electricity Industry in Southern Africa

The major issues that must be addressed as part of the process of creating sustainable electricity supply in Southern Africa include the following:

### 2.1 Structure and level of tariffs

Electricity utilities aim to recover their investment and operating costs through the tariffs charged to their customers. Determination of tariffs is however a complex procedure due to the mass of technical detail involved including constraints imposed by available metering technology and the need to take into account various conflicting standards of fairness and functional efficiency in the choice of the tariff structure. One of the major challenges in setting tariffs is establishing the trade off between various objectives of tariff setting. These include the ability to reflect accurately cost streams, efficiency in responding to changing demand and supply conditions, effectiveness in delivering appropriate revenue requirements, stability and predictability of revenue and tariffs themselves, and finally simplicity in terms of their practical implementation. In particular it is important to consider affordability of the tariffs, especially with regard to disadvantaged groups in society. The primary objective of applying time-of-use tariffs is to encourage customers to change their consumption patterns shifting demand from peak to off-peak periods.

A typical load profile for Botswana is shown in Figure 2. Note that there are two peaks; one in the morning between the hours 7 and 11and the other in the afternoon between the hours 19 and 23. The morning peak is a combination of domestic, commercial and industrial loads while the evening peak could be mostly commercial and domestic loads as most of the industries are closed. If time-of-use tariff levels are set optimally there is a real prospect that implementing such tariffs could change consumption patterns resulting in overall reduction in system peak demand.

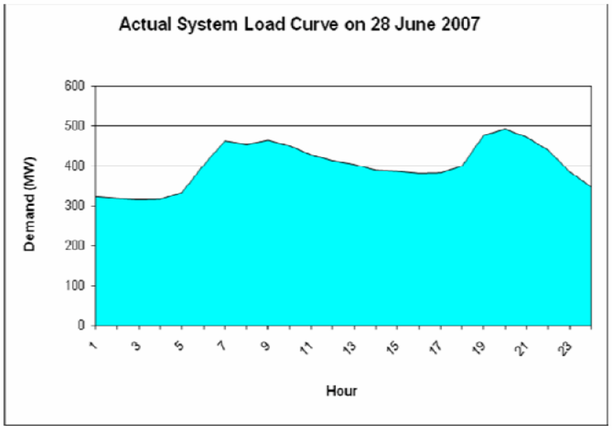


Figure 2. Typical daily load distribution

**2.2 Organization structures that may no longer be fit for purpose**

Most utility problems both technical and non-technical originate from distribution and retail (supply) segments of the business. While there has been a discernible trend to unbundle the predominantly vertically integrated utility business into generation, transmission, distribution and retail segments, for some countries commercial separation of the business units has remained a mere aspiration. It is important for these countries to find ways to improve the technical and commercial operation of the distribution and retail segments of the utility business where, as noted above, most of the utility problems are experienced.

**2.3 Review of Energy Efficiency programmes in the region**

Most countries have identified energy efficiency as a cornerstone of demand side management. In particular energy efficient lighting has been adopted as a short to medium term measure that can contribute significantly to reducing peak demand. The region needs to look into possibilities of shifting water heating from electricity to solar and also incorporate aspects of solar electricity for domestic use even in urban areas. It could well be cost effective to channel investments in generation capacity to installation of solar systems. In general, greater efforts must be directed towards educating customers on the need to save electricity and the measures that they can take.

**2.4 State of deregulation**

Most utilities in the region are owned by their Governments. There is a realizations that this may not necessarily be the best set up and that the private sector should be brought in. Initially the main target has been to interest private investors in the generation segment of the electricity business. It is likely that in future private sector participation in the distribution and retail will follow. The current energy crisis might provide the necessary motivation for change.

**2.5 Estimate on cost of power deficits**

The power deficit affecting the region has brought into sharp focus the fact that failure to meet existing and future electricity demand has severe economic and social consequences. However more needs to be done to model and quantity the effects of power deficits and load shedding in all countries in the region. This will put into proper perspective the opportunity costs of the failure to make timely generation capacity investments.

**2.6 Challenge of Commercialisation**

Commercialisation in the context of this paper refers to operation of a state owned utility as a business that is expected to make a profit in much the same as any private enterprise. Electric utility companies are usually viewed as vehicles for national development ultimately answerable to the political hierarchy. This attitude to electric utilities especially in developing countries has lead to economic inefficiency as well as unsatisfactory financial performance in general as uneconomic projects and operations are forced on utilities, often for political expediency. Well intentioned attempts at commercialisation have been thwarted by political expediency. While it is accepted that for developing countries it is necessary for Governments to focus on development, this paper supports the view taken by many others that a more effective governance framework is needed for commercialisation to be effective in the absence of privatisation.

**2.7 Investment Climate**

Various measures are required to solve the power crisis. Most of the solutions require massive injections of capital from the private sector and the international community. Any investor would however be wary of putting their money in the region unless some of the following factors are satisfactorily resolved: -

**2.7.1 Perceived risk**

Investors need assurance that their investment will yield the required return and that legal as well as regulatory arrangements are stable to enable externalisation of profits without undue restrictions or government interference. The latter is a major concern for some countries in the region due to prolonged political instability.

**2.7.2 Skills shortage**

Major infrastructure investments require a skills pool from which to draw the personnel who will man the infrastructure. The region does not have a large pool of skilled labour to draw from. This may cast doubt on the success of power projects beyond the construction and commissioning phase. While there is usually an influx of foreign experts into the region at the start of a major project it is unlikely that this would be sustainable over the long term. It is therefore critical for human resource development (capacity building) to be included as integral part of all major projects.

### 2.8 Poverty Levels

The poverty levels in the region have a bearing on the investment climate because they affect the levels of tariffs that can be realistically charged. The electricity tariffs have to be afforded for a project to stand a chance of success. Targeted subsidies for vulnerable groups might be the answer to this challenge.

### 2.9 Strategies

The countries in the region have different strategies for attracting investment. Moreover investment opportunities also tend to be different. Successes for one country may therefore not be easily replicated in another country. Investment opportunities therefore have to be looked at on a country by country basis.

### 2.10 Lack of research

Not much research on power shortages has been carried out in the region. This is in part because resources are not readily available to undertake the required research. Perhaps this was because up to the current crisis, there was sufficient capacity available in the region, except during the drought in the late nineties when Zambia and Zimbabwe had insufficient water in the Kariba Dam. The current power shortages should lend credence to the clear imperative to develop research capabilities within the region to deal with electricity supply issues.

## 3. Creating sustainable electricity systems - Options for the future

The various options that can be considered in the creation of sustainable electricity systems are discussed below. It is acknowledged that some of the options are already being implemented by some of utilities. They are presented here to show the complementary actions that utilities can embark upon.

### 3.1 Promoting efficient use of energy

The power crisis has demonstrated that when demand exceeds supply then there is no alternative to taking the hard decision of switching customers off. Measures such as having energy efficient bulbs become very attractive in that the lighting load can be substantially reduced. Some of the utilities have taken the decision to supply free energy efficient light bulbs in order to realize this benefit. Power factor is another important issue. As most motoring and rectifier loads tend to operate at low power factors it is important for utilities to send the correct message to the customers regarding need to improve power factor. In Botswana for example the maximum demand billing is based on kW not kVA. While this may be justified for a lightly loaded system, there is need to review this pricing policy in the context of loss performance of long transmission lines and distribution systems.

### 3.2 Encouraging mass deployment of photovoltaic and other renewable energy devices

Studies need to be undertaken to demonstrate the benefits of using small scale PV and other renewable generation technologies to meet some, if not all, of the electricity demand (especially for domestic and rural loads). As a pilot project, Government institutions could provide the lead in transferring some of their loads from the grid to local PV systems. Ways of encouraging the use of PV systems by domestic customers need to be explored and implemented. In addition micro-hydro schemes should also be developed in those areas where there is potential for such schemes.

### 3.3 Encourage mass deployment of solar thermal systems

Most houses in the region use electric geysers for water heating. These devices could be replaced by solar thermal systems with electric boosters for cloudy days. Given that electric geysers consume a lot of power (typically of the order of 2000W) mass replacement of these devices would release a significant load from the grid. With the right incentives and cost reflective electricity prices, it is conceivable that in the long run electric geysers could be fully replaced by solar thermal water heaters.

### 3.4 Role of distributed generation

The electricity supply industry developed from small generating stations to large central power stations due to efficiency and economies of scale considerations. However, in the last two decades, due to technological developments that have lead to production of efficient small scale generation, penetration of distributed generation is expected to grow driven by environmental and many other benefits [6]. It is proposed that more serious attention should accrue to the role that distributed generation could play in the creation of sustainable electricity systems in Southern Africa.

### 3.5 Development and implementation of incentives for consumers to take up solar system

The promotion of solar systems for electricity and water heating should be accompanied by incentives which will entice the consumers. For example the initial investment costs could be subsidized through government grants as is the case in “Low Carbon Buildings Programme” in the UK [7]. Support could also be provided on basic PV and solar thermal installation and maintenance knowhow. Governments could also grant tax and VAT concessions or waivers on solar equipment. In addition innovative financing arrangements, such as micro financing, could be encouraged to make the solar systems affordable. Furthermore donor agencies could be encouraged to support, or provide subsidies for solar projects on grounds that they are environmentally friendly and contribute to poverty reduction. More ideas on ways of making solar power affordable can be found in [8].

### 3.6 Facilitate customers with surplus power to sell back to the utilities

There are some industries that generate electricity as part of their operations and use it to supply part or their entire load. Utilities could purchase any excess electricity from such industries or indeed domestic customers. This would encourage those who invest in PV systems to sell energy to the utility at those times when their demand will be less than their generation. In most countries, this would require governments to enact legislation to allow customers to sell power back to the utilities, as was done in South Australia [9], [10], [11].

### 3.7 Promote cost reflective tariffs with at least peak and off-peak rates

Electricity tariffs should reflect the cost of generating and delivering electricity to customers. Power consumed during the peak periods is more expensive than that consumed at off-peak times because the marginal cost of generation is highest at peak times when more expensive generators are used [12], [13] [14]. Time of use tariffs allow the time dynamic generation costs to be reflected in the tariffs. Electricity consumers could then shift their consumption to off-peak times motivated by the incentive to save money. A successful time of use tariff would lead to peak demand reduction (load lopping) as more and more consumers shift their loads to off-peak periods. In addition, demand charges must be configured so as to encourage industrial consumers to install power factor improvement apparatus.

Tariffs in most countries in Southern Africa do not have a time of use feature. Monthly tariff rates in Botswana shown in Table 4 are a typical example of such rates.

Table 4
Botswana tariff rates

| Type of User | Description | Fixed charge (Pula) | Energy charge (Pula/kWh) | Demand Charge (Pula/kW) |
|---|---|---|---|---|
| TOU 4 | Domestic consumers | 11.11 | 0.4 | Nil |
| TOU 6 | Small Business | 29.74 | 0.4579 | Nil |
| TOU 7 | Medium Business | 29.74 | 0.2348 | 56.21 |
| TOU 8 | Large Business | 29.74 | 0.2117 | 52.91 |
| TOU 2 | Government | 29.74 | 0.5935 | Nil |
| TOU 1 | Water Pumping | 29.74 | 0.4669 | Nil |

Exchange rate: I Pula = 0.1471 USUS$

### 3.8 Implement smart metering

Current metering is primarily aimed at recording energy units used and/or the maximum demand for billing purposes. The meter is locked up either in a metering kiosk or in the distribution board to be read by a utility employee. Alternatively for those on prepaid metering the pre-paid meter may give an indication of the energy remaining. None of these arrangements gives the consumer additional information such as rate of consumption which could be used to adjust consumption. It is proposed that utilities in the region consider introducing smart metering that would display features such as cumulative billing showing rate of charge In addition where consumers have the option to sell electricity back to the utility, the meter would also display the import and export information. The main intention of smart metering is to give the customer live information about the state of the billing that may be used to make decisions on how best to manage their electricity consumption. The UK Government has recently completed a consultation on smart metering as route to changing customer behaviour [15].

### 3.9 Deal with non technical losses

Non-technical losses refer to the energy that is unaccounted for after sales and actual/estimated technical losses. Non-technical losses can be quite high in some utilities in the region, and estimates are in the range 10% to 20%. Non-technical losses can be due to theft of electricity, wrong billing or fraudulent billing. It requires considerable effort to accurately account for and eliminate non-technical losses.

## 4. Proposed approach

In order to give confidence to policy makers on the potential benefits of the various interventions for achieving sustainable electricity systems that have been discussed in this paper, it is necessary to undertake studies to quantify these benefits. The studies should preferably target countries rather than utilities in order to quantify the benefits that would accrue to the whole region.

Based on the discussions in Section 3, the studies that must be undertaken so as to quantify the impact of the proposed measures on regional energy demand as well as system peak include the following:

- Replacing inefficient electrical appliances with energy efficient ones
- Promoting Liquefied Petroleum Gas (LPG) for cooking replacing electric cookers
- Introduction of cost reflective and time-of-use pricing
- Allowing customers to sell surplus electricity back to the utility at peak and off-peak times. In addition to legislative/regulatory changes to allow customers to sell electricity to the utility, changes to distribution grid codes to allow easy connection of distributed generation will also be needed.

It will be particularly important to commission studies to quantify the opportunity cost of failure to meet growing demand and reliance on load shedding to match supply and demand. This should be aimed at showing the impact of power shortages on economic growth and GDP, impact on employment generation, impact on customers; domestic, commercial, industrial, agricultural and mining.

For some of the utilities it will also be essential to carry out organizational restructuring to achieve effectiveness and efficiency. This would include rationalization of labour to make commercialization a success where such a policy exists.

Another important aspect is capacity building to deal with the effects of HIV/Aids, changing technologies, aging workforce and labour migration.

Radical approaches to the management of the perennial problems in the distribution part of the utility business should be considered including ownership of distribution business by customers and workers.

Ensuring effective generation planning and implementation across the region will be very important going forward. There is need to clearly set out the responsibility for generation planning and implementation especially in regard to opening up the region to independent power producers. There is also need to encourage small scale generation, including renewables (small hydros, Photo-voltaics, bio-mass etc). This will require revision of the role of Electricity Regulators to include responsibility for promoting renewable generation.

## 5. Conclusion

This paper has presented the main challenges facing the electric power sector in Southern Africa ranging from technical through to commercial and regulatory aspects. The paper has also suggested approaches and polices that would be conducive to the creation of sustainable electric power systems in Southern Africa. The power crisis is a wake up call to energy planners in the region to institute holistic approaches to the issue of energy planning. Promoting energy efficiency and deployment of renewable energy should be a key part of the strategic response to this crisis. Energy pricing is the primary mechanism through which both supply side and demand side participants can be persuaded to make economically efficient decisions. Perhaps the era of cheap energy is over and cost reflective pricing must now be fully embraced. Where subsidies are deemed necessary these must be provided in ways that will not undermine efficient decision making.

## Acknowledgments

The authors are grateful for the contribution of SAPP, regional utility engineers and energy planners as well as Regulators for their insights into the challenges of energy planning in Southern Africa.

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