# ENHANCING ELECTRIFICATION IN KENYA – THE ROLE OF NEW RENEWABLE TECHNOLOGIES

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## 1 Background

### 1.1 Historical Perspective

The origin of Kenya's electricity supply industry can be traced to the introduction of electricity in East Africa in 1875. That is the year that the Sultan of Zanzibar, Seyyied Bargash, while on a visit of Europe, acquired a generator to light his palace and the nearby streets. The generator was later sold to Harrali Esmailjee Jeevanjee, a wealthy merchant in Mombasa, who transferred it to the Mombasa Electricity Power & Lighting Company in 1908.

At around the same time, a Mr. Clement Hertzel was given the exclusive right to supply electricity to the then district and town of Nairobi. This led to the formation of the Nairobi Power & Lighting Syndicate.

The two utilities in Nairobi and Mombasa were later merged under a new company known as the East African Power & Lighting Company (EAP&L) which was incorporated in 1922. Ten years later, the company extended its operations to East Africa by acquiring a controlling interest in the Tanganyika Electricity Supply Company Ltd. (TANESCO) and, in 1936, obtaining generating and distribution licenses for Uganda.

In 1948, the government of Uganda formed the Uganda Electricity Board, which took over the distribution of electricity in that country. The Board and EAPL signed an agreement for EAPL to purchase power in bulk from the Board. In order to do this, the government of Kenya created the Kenya Power Company (KPC), which was managed by EAP&L, for the purpose of raising money to construct the Tororo - Juja transmission line, and to enter into a supply agreement with the Uganda Electricity Board.

Reference to the map of Kenya vis-à-vis the electrification indicates that grid coverage closely follows the railway network.

In 1964, EAP&L sold its majority stockholding in Tanesco to the government of Tanzania. With its operations confined only to Kenya, EAP&L was subsequently renamed The Kenya Power & Lighting Company Ltd. (KPLC) in 1983.

The important lesson from the foregoing is that electrification started with localised distribution networks, with captive generation facilities, which were later interconnected for various reasons. Indeed it is instructive that to date KPLC is still the holder of distribution licences, with respect to these inaugural networks, issued in the 1950s. In accordance with the Act, these licenses are valid.

## 1.2 Electrification Today

As at 30 June 2001 Kenya had 537,079 electricity consumers comprising of 465,365 KPLC customers and 71,718 Rural Electrification Fund (REF) customers. This translates to about 10% of the population who have taken supply of electricity and an estimated 15% of the population with access to electricity.

Kenya's rate of electrification can be put into perspective by comparing it with those achieved in other countries/regions given in Table 1.

**Table 1: World Population Access to Electricity[1]**

| Country/Region | Proportion of Population With Electricity |
|---|---|
| OECD, EE, FSU | 100% |
| China | 95% |
| Other DC | 78% |
| Pakistan | 40% |
| Bangladesh | 35% |
| Indonesia | 33% |
| India | 30% |
| Sub-Sahara Africa | 20% |

Further, as at the end of 2001 South Africa is reported to have achieved 66% electrification[2] (i.e. proportion of population with access to electricity). Additionally Ghana is said to have achieved 80% electrification.

## 1.3 Principal Sources of Generation

Kenya's principal sources of generation comprise hydro, thermal and geothermal. Table 2 shows the 2000/1 contribution of the alternative sources of generation to the current interconnected system capacity, while Table 3 shows the annual gross generation by source for the period 1997/8 to 2001/2[3].

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[1] Dr. Malcolm Kennedy, "Power in the Sun" IEE Power Engineering Journal, December 2000

[2] It is instructive that this level of electrification has been achieved on the background of connection of 2.5 million households since 1995 under ANC's Reconstruction and Development Programme following the country's independence.

[3] 2001/2 are preliminary and have not been audited.

**Table 2: Current (2000/1) Installed Interconnected Capacity (MW)**

| Source | Installed Capacity (MW) | Proportion (%) |
|---|---|---|
| Hydro[4] | 707.2 | 60.8% |
| Thermal | 399.5 | 34.3% |
| Geothermal | 57 | 4.8% |
| Wind | 0.4 | 0.0% |
| **TOTAL** | **1,164.1**[5] | **100.0%** |

**Table 3: Gross Generation (GWh) by Source (1997/8-2001/2)**

| Sources | Year | | | | |
|---|---|---|---|---|---|
| | **1997/8** | **1998/9** | **1999/2000** | **2000/1** | **2001/2** |
| Hydro[6] | 3,405 | 3,414 | 2,590 | 1,523 | 2,588 |
| Thermal | 713 | 799 | 1,458 | 2,099 | 1,512 |
| Geothermal | 366 | 390 | 383 | 429 | 459 |
| Wind | 1 | 0 | 0 | 0 | 0 |
| TOTAL | 4,485 | 4,603 | 4,431 | 4,051 | 4,559 |

A significant feature of Table 3 is the wide variation (from 38% to 76%) in contribution by hydro in the generation mix. Accordingly thermal generation also varies (16% to 52%) as system managers attempt to supplant the energy shortfall created by unavailability of hydro usually occasioned by poor hydrological conditions.

In addition to the interconnected system capacity by the principal power stations, there are a number of embedded generating plants mainly in the sugar belt (co-generation using bargasse). Kenya also has 9MW isolated generating capacity providing about 20GWh of energy to the off-grid towns of Garissa, Lamu, Lodwar, Mandera, Marsabit and Moyale

[4] This includes the non-firm 30MW imports from Uganda

[5] Of this capacity 16% is provided by independent power producers, namely Iberafrica, OrpOwer 4 Inc., Tsavo Power Company and Westmont

[6] This includes the non-firm 30MW imports from Uganda

## 1.4 Transmission and Distribution Systems

Once dispatched, power is conveyed from the principal generating stations to load centres via transmission and distribution networks.

Kenya's transmission network comprises of 132 and 220 kV systems with total circuit lengths of 2,032 km and 885 km respectively (as at 30 June 2001). For the corresponding period the distribution network comprised 576 km for 66 kV; 126 km for 40 kV; 4,639 km for 33 kV; and 10,397 km for 11 kV. Low voltage supply is at 415/240 volts**.**

## 1.5 General Overview

Admittedly Kenya's current level of access to electricity can at best be described as meagre and at the current annual rate (based on number of new connections) of electrification (6-7%) it is unlikely that a significant proportion of population will access, and take supply of, electricity in the near future. This situation is particularly poignant considering the extent to which electrification improves the economic well being and quality of life in general of the population. Accordingly, it is therefore imperative that ways of enhancing electrification must be pursued.

# 2 Enhancing Electrification in Kenya – Cross Cutting Issues

I firmly believe that enhancement of electrification can be achieved through a combination of grid extension and off-grid systems. However, before delving into these two approaches, it is important to understand some cross-cutting issues, as described herebelow

## 2.1 Role of Government

The general world-wide paradigm, and there is general consensus of this, with respect to the provision of infrastructure services is that governments' role should be confined to creation of an enabling environment for greater participation by the private sector in the development and provision of these services. This thinking is premised on the private sector's recognised expertise in improving efficiency, both in operating performance as well as mobilisation and application capital. Additionally, this would potentially focus the governments' efforts on areas less amenable to private sector participation, e.g. health and education.

The creation of an enabling environmental principally revolves around promulgation of laws and formulation of appropriate policies and establishment of suitable regulatory regimes. For instance in early-mid 1990s, unable to meet growth in electricity demand due to budget constraints East Asia governments formulated policies that reformed their industries, including creating regulatory agencies, which fostered the involvement of the private sector in development of new generation and transmission capacity, thereby alleviating chronic power shortages. In South Africa policies under ANC's Reconstruction and Development Programme have seen the connection of 2.5 million households since 1995 while in Uganda the Electricity Act, 1999 promises much in terms rural electrification due to its Act clear articulation of the roles of government, private sector and donors. In fact today, Uganda has not only attracted US$500 million for rural electrification from the Global Environmental facility (GEF) but has also awarded concessions, to the private sector, for the development of off-grid systems. Implementation Agreements and Subsidy Agreements clearly stipulating the role of the Government of Uganda and the concessionaires support these concessions.

Further, the success of China's micro-hydro programme, reputed to be the largest in the world with 15,000 MW is attributed to the strong technical and financial support from the central government to the local electricity companies which operate the off-grid systems.

Here at home, the liberalisation of the power sub-sector following the enactment of the Electric Power Act, 1997 and the subsequent establishment of the Electricity Regulatory Board (ERB) has seen the entry of the private sector in generation. Independent power producers currently in operation in Kenya, Iberafrica, OrPower, Tsavo Power and Westmont produce about 16% of the country's energy requirements. The role that IPPs play in diversifying the country's generation mix cannot be overstated. In addition the Act, set a 5% rural electrification levy. Further, policies affecting regional integration of economies, including power trading, would contribute towards enhanced electrification.

I would be naïve if I stood here and pretended that the current Act and policies would support an ambitious electrification effort. In my opinion therefore, appropriate policies need formulated (and supported by relevant revision of the Electric Power Act) with respect to *inter alia* the following areas:

- Embedded generation; Combined Heat and Power (CHP), wind generation, etc. In this regard it barriers to entry should be removed;
- Rural Electrification. A more comprehensive coverage would be required addressing pertinent issues such as subsidies, approach to grid/off-grid electrification and roles of government (e.g. in undertaking feasibility studies to establish siting of small hydro plants, in developing rural electrification plans, etc.); or its agents
- Standards of embedded generation plants and off-grid systems. With regards to off-grid systems this would facilitate cost reduction through bulk purchases, in manufacturing, etc.
- Electricity pilferage otherwise referred to as commercial losses; etc.

## 2.2 Electricity Tariffs

The electricity industry (comprising grid and off-grid operators) requires tariffs that generate adequate revenue to finance their activities and earn an appropriate return on their assets whilst ensuring reliability of supply. These activities include efficient operation and maintenance of existing plant as well as generation and network expansion in order to cater for future growth in demand. It is therefore crucial that the electricity tariff policy be able to adequately address the conflicting issues of subsidies and recovery of cost of service.

In order to appreciate the extent of likely conflict these issues, consider the case of isolated diesel stations in Kenya and Indonesia[7], where uniform national electricity tariffs apply. What this means is that but for heavy cross-subsidisation by grid customers, consumers supplied by isolated grids would otherwise be subjected to much higher tariffs. On the other hand the subsidisation of diesel generation supplying the isolated grids would act as an entry barrier to penetration by alternative sources of off-grid electrification.

### 2.3 Ability and Willingness to Pay

Whether with respect to centralised or off-grid supply, one of the key drivers for electrification is the ability and willingness to pay for electricity. This is what distinguishes access and taking of supply.

Whether in the proximity of the grid or far away, people not connected to the grid already use electricity in one form or other. For instance some people use car batteries for lighting and perhaps a television while others use dry cell batteries. Still others use kerosene and candles for lighting. When designing grid-based electrification programmes, those concerned must therefore establish the level of penetration of the alternative forms of electric power with a view to determining the ability and willingness to pay. This is because there is a strong correlation between these attributes and the form of electric power or energy used in households. Although I do not know whether this has been finalised, not the specific terms of reference, I am aware of an on-going World Bank funded study, whose Final Report has been recently been submitted to the Ministry of Energy, on Household Energy Demand and Supply. The findings of this study, which are likely to be discussed at a stakeholder workshop, are likely to be a significant input into any future electrification strategy.

## 3 Enhancing Electrification in Kenya – The Role of New Renewable Technologies

Much has been written about how Kenya intends to meet growth in demand for electricity, in an affordable manner, through conventional sources of generation whilst ensuring reliability of supply. I therefore beg your indulgence in highlighting the following measures being pursued in this regard.

- Diversification of sources of power in order mitigate hydrological risks. In this regard geothermal and medium-speed diesel generation dominate future planting programme;
- Enhanced import of power from Uganda and interconnection with Tanzania and by extension the South African Power Pool;

[7] Lao PDR, Institutional Development for Off-Grid Electrification, ESMAP Report 215/99, June 1999

- Continued reinforcement of the transmission, and distribution networks;
- Raising of Masinga dam; and
- Endeavouring to ensure timely completion of committed generating plants, namely Olkaria II (64MW), Olkaria III (48MW) and Sondu Miriu (60MW), and transmission line additions.

Although these do not feature in the country's generation plans, embedded generating plants also have potential for complementing the conventional sources of generation, thereby enhancing electrification. Some thoughts on the potential role of new renewable technologies in embedded generation are given herebelow. In addition, cognisant of the fact that in many cases grid electrification is simply uneconomical, the potential role of new renewable technologies in off-grid electrification is also explored.

The term *new renewable technologies* with respect to generation refers to production of electric power using biomass, small (mini and micro-) hydro, wind, municipal waste to energy, landfill gas and solar photovoltaics. Brief overviews of selected technologies is presented herebelow:

***Wind Power Plants***

Wind turbine operate by extracting the kinetic energy from the wind passing through the rotors. Wind turbine technology has developed very fast over recent years and to date turbines with ratings of upto 2 MW exist.

Wind turbines are normally located away from habitation and therefore the associated well developed distribution network. Indeed there are wind farms located off-shore. As a result of the location, wind turbines are usually integrated with relatively weak distribution networks, which leads to concerns voltage fluctuation (which may be manifest to the human eye as flicker). Other concerns include importation of reactive power by wind turbines with uncompensated induction generators as well as harmonic generation (especially with thyristor starting wind turbines). In order to establish the technical feasibility of wind farms these concerns must to be addressed.

In addition to the technical challenges, issues regarding the responsibility for extending and upgrade the grid in order to off-take the output from wind turbines would need to be addressed.

***Small Hydro Plants***

Small hydro systems (mini and micro) capture the energy in flowing water and convert it to electricity. Systems can be either run-of-the-river or with pondage. The potential for small hydro-electric systems depends on the available water flow. Accordingly, unless with significant pondage, the output of these plants vary widely and low (of the order of 30%) load factors are common-place. It is therefore important that adequate data on hydrology be gathered.

Like wind turbines, small hydro plants are connected on weak networks, and therefore raise similar concerns on power quality.

***Biomass Power Plants***

Biomass utilizes the energy content of agricultural residue, wood waste, animal wastes or energy crops. These materials are either combusted in boilers to produce steam and/or heat, or converted into combustible gases and subsequently used to generate electricity..

Examples of application of this technology in Kenya is the combustion of bargasse to generate electricity in the sugar belt. When, well structured bargasse projects can provide truly competitive power.

***Solar Photovoltaic Generation***

Photovoltaic (PV) generation, or direct conversion of electricity, is a well established technology. However, although a number of large (MW scale) demonstration projects have been constructed in the past, interest is now focused on incorporating the photovoltaic modules into the fabric of buildings to reduce overall cost and space requirements[8]. Therefore, unlike wind and small hydro plants which are connected at 11 kV, PV installations would be connected directly into the LV distribution network, thereby making them truly embedded.

## 3.1 Grid Extension – Role of New Renewable Technologies

Outside the conventional sources of generation, where power from large power plants are fed into the interconnected transmission grid through generator transformers, the next feasible potential source of reasonable amounts of power is embedded or dispersed (as opposed to centrally dispatched) generation, whereby the power is fed directly to the distribution network. Recently there has been considerable revival in interest in embedded generation with the key policy drivers including:

- Environmental considerations; in particular the Kyoto Protocal which requires countries to substantial reduce $CO_2$ emissions to help counter climate change;
- Energy efficiency;
- Power industry deregulation or competition policy;
- Diversification of energy sources. And
- Commercial considerations including availability of modular plant, short construction times, lower capital costs and the ability to site the plants closer to the load.

Embedded generation plants are not planned by the utility but are developed by entrepreneurs (usually to provide captive power to industrial complexes) and are

[8] NickJenkins, Ron Allan, Peter Crossley, Danbiel Kirschen and Goran Strabac, “Embedded Generation” Institution of Electrical Engineers 2000

not centrally despatched. Another unique feature of this type of generation is that production only occurs whenever the energy source is available.

Co-generation or Combined Heat and Power (CHP) schemes, which make use of the waste heat of thermal generating plant for either industrial processes or space heating dominate embedded generation although new renewable technologies are becoming increasingly popular.

In terms of the level of generation that can be absorbed onto the distribution system is determined by many factors, such as[9]:

- Voltage level;
- Voltage level at the primary sub-station;
- Distance from the primary sub-station;
- Size of conductor
- Demand on the System;
- Other generation on the system; and
- Operating regime of the generation.

Another major concern with embedded generation is that lack of information on the day-to-day operation of, in aggregate, relatively large amounts of small embedded generation causes the grid system operator to schedule more centrally dispatched units than might otherwise be required. The costs of this are borne by the consumer[10].

## 3.2 Off-Grid Systems

As alluded earlier it is sometimes technically difficult and financially unattractive to rely on conventional grid-based extension for providing electricity services to rural population, particularly those remote from the grid. Alternatives, including isolated diesel and new renewable based systems may therefore be considered.

A somewhat surprising observation, but which is true, is that people in areas without grid electricity spend more on electricity and its alternatives than their counterparts with access to grid supply. This implies that subject to lifting of entry barriers, people remote from national grids would be able, and willing to pay for electricity generated from new renewable technologies.

Wind generation, in combination with diesel plants or small hydro schemes are suitable for off-grid electrification. On their own right, small hydro schemes are also particularly suitable off-grid electrification. It is however important to note that for the potential of off-grid electrification to be realised, small networks (sometimes referred as micro-grids) must be developed and operated in a

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[9] C. L. Masters, "Voltage Rise – The Big Issue When Connecting Embedded Generation to Long 11 kV overhead Lines, IEE Power Engineering Journal, Vol.16 No. 1, February 2002

[10] I. P. Burton, "Gas and The Current Generation Mix in England and Wales", IEE Power Engineering Journal, Vol.14 No. 2, April 2000

sustainable manner. In this regard institutional issues to facilitate development of such systems as well as issues pertaining to availability of reasonable demand centres, payment, safety and standards of construction must all be addressed.

For stand-alone purposes, perhaps the technology with the most potential is the photovoltaic generation, principally because of the modular nature of construction. World-wide PV demand is reported to be growing at 15-20% each year[11]. In Kenya, as in other developing countries, the barriers to the penetration of PV technology are perceived to be high upfront costs, taxation and lack of enabling policies. In the case of Kenya I am aware of a recent World Bank study that was commissioned to address these issues.

# 4 Conclusions

Kenya's current level of access to electricity can at best be described as meagre and at the current rate of electrification (6-7%) it is unlikely that a significant proportion of population will access, and take supply of, electricity in the near future. In order to enhance electrification alternative approaches to grid extension and off-grid systems must be considered. In this regard, new renewable technologies would be expected to play an increasing role. However, for the full potential of these technologies to be realised legal, policy (e.g. taxation, tariffs, subsidy, etc.), technical and institutional issues must be addressed in order to lift barriers to the penetration of these technologies.

## *Disclaimer*

*It must be emphasized that the views expressed in this paper are my personal views and in no way reflect the corporate attitudes or views of the Electricity Regulatory Board.*

[11] USEA/USAID Handbook of Climate Change Mitigation Options for Developing Country Utilities and Regulatory Agencies, Version 1.0, June 1999