GIS AND RURAL ELECTRICITY PLANNING: A CASE STUDY UGANDA

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Abstract

Sustainable development is literally fuelled by the electricity sector. In Uganda, the electricity sector has experienced dramatic market liberalization changes in recent years. The *Power Sector Reform* was characterized by the unbundling of the main government utility, Uganda Electricity Board (UEB), which had a monopoly, into three companies that were created to introduce competition and liberalize the electricity industry. This led to the creation of a regulatory body. A rural electrification fund, agency and board were also formed to subsidize rural electricity investments. This is part of the Government of Uganda's new holistic approach to long-term energy planning.

This paper discusses the use of Geographical Information System (GIS) in the planning process for rural electrification. The aim is to identify patterns of demand and priority areas of need. By creating a demand-side scenario, electricity can then be supplied to targeted areas. A cross-sectoral view is taken to examine the energy demand patterns using physical data and available country statistics that are then incorporated into a GIS master database. The initial priority demand-side sectors targeted, in terms of energy needs, are education and health. As a result of this preliminary work, areas can be identified and targeted for rural electricity investment, which include off-grid renewable energy plants such as small-scale hydropower schemes.

Introduction

The pace of rural electrification over much of the developing world is painfully slow, and Uganda is no exception. This comes as no surprise since rural communities not only have low population densities but they are often the poorest, which results in high capital and operating costs for electricity companies. Attracting investors for rural electrification projects, especially in politically uncertain, least developed countries (LDCs), is the overriding challenge.

Typically, in a LDC like Uganda, before even arriving at a technological solution, the financial and economic costs first have to be justified. New innovative technologies come after cost considerations since the means justify the end. Trends show that a project will last only as long as its financing,. making financial viability one of the first priorities for rural electrification projects. Although necessity is the mother of invention, scarce resources do not leave any room for expensive options, however innovative they may be. So before any new renewable energy technologies (RETs) can be adopted in Uganda, a host of cost-benefit decisions have to precede the final technology selection, which certainly has to be the least-cost option.

The planning process firstly needs a defined 'Rural Electrification Criteria' that is specific for the country's situation. In Uganda, the proposed indicative rural electrification master plan can broadly be condensed into three steps:

1. In the first instance, a case has to be made for grid-based or off-grid planning.
2. This would be justified by a financial and economic cost/benefit analysis in order to identify and prioritize possible electrification projects.

Finally, a technology selection can be made to suit these specific conditions.

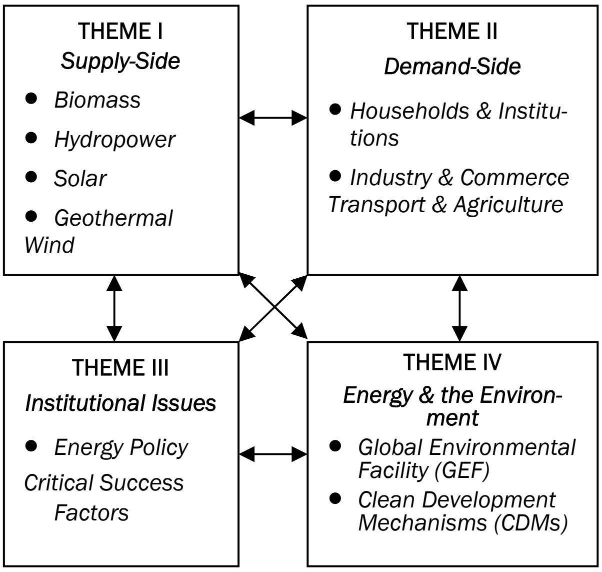
Positive political will is crucial to the success of the planning process and this has already been addressed in Uganda's 'Rural Electrification Strategy and Plan Covering the Period 2001 to 2010' by the Ministry of Energy and Mineral's Development. Currently, grid electricity access in rural areas stands at less than 2% with grid access of 5% for the whole country. The minimum aim for the Rural Electrification Strategy and Plan is a rate of 10% by 2012 which translates to 400,000 new rural consumers (Ministry of Energy and Minerals Development, 2001). The primary objective is to reduce inequalities in access to electricity and associated opportunities for increased social welfare, education, health and income generation.

Regarding global impacts, Uganda completed an inventory of it greenhouse gas emissions and is therefore obliged to meet its commitments as a signatory to the UN's Climate Change Convention (UNCCC). The promotion of renewable energy is therefore another important element of the Government of Uganda's rural electrification strategy and this gives it the opportunity to benefit from internationally sponsored projects via organizations like the Global Environmental Facility (GEF).

Methodology

A rational and systematic approach is needed for rural electricity planning in Uganda. With GIS this can be provided in the form of geo-referenced data, using Global Positioning System (GPS) coordinates, that allows displays of tabular and spatial information to assist decision-makers. The planning process is very complex and multifaceted so a simplified approach needs to be taken. For the purposes of this study, consider the whole problem in its entirety to be divided into four interrelated themes, which contain the following topics:

This paper presents the demand-side aspect of rural



infrastructure in Uganda for electricity planning. Taking a country-wide view, the initial demand-sectors targeted are health centers, schools, households and rural trading centers. These could then provide a priority-ranking pattern based on estimated load profiles and/or benefit points allocated to each 'demand center'.

Many other inter-related aspects arise out of the four themes during this process, and it is within this context that the following questions are applied to rural electricity planning in Uganda:

- **What are the institutional structures set up for rural electrification?**
- *(Theme III – Institutional Issues)*
- **What are some of the critical success factors affecting the planning process?** *(Theme III – Institutional Issues)*
- **What are the energy demand patterns in Uganda?**
- *(Theme IV – Demand Side)*
- **What are the possible off-grid renewable energy options?**
- *(Theme II – Supply Side)*
- **Institutional Structures**

Uganda's Electricity Act of 1999 aims at reforming the power sector by introducing competition and liberalizing the electricity industry Ministry of Energy and Minerals Development, 2002). In order to make electrification affordable to the rural population, the government will subsidize electrification projects, however, the criteria and level of subsidization are still in the process of being determined. The project is being financed by the World Bank and the GEF through a multi-sectoral program called Energy for Rural Transformation (ERT) and its overall goal is to increase electricity access in rural areas from 1% to 10% by 2012.

It is therefore planned that the electricity tariffs will reflect the supply costs in order to guarantee the financial viability of rural electrification investments, and this is to be regulated by an Electricity Regulatory Authority (ERA). An autonomous body, the Rural Electrification Agency (REA) has also been set up, under the Ministry of Energy and Minerals Development (MEMD), to implement rural electrification policies and manage the Rural Electrification Fund (Government of Uganda, 1999). They are responsible for awarding subsidies to investments in rural electrification projects in Uganda. Under this ERT program, the role of the Ministry is one of overall coordination, monitoring and evaluation. The Private Sector Foundation will play the role of the facilitator who will develop business plans and after the business plans have been developed, they will then apply to REA for a subsidy. In this way, the Government of Uganda is looking to achieve their goal through a public/private partnership.

Critical Success Factors

Critical Success Factors (CSFs) are described by the Energy Technology Support Unit (ETSU) (part of the UK Government's Department for International Development (DFID)), as key features of renewable energy programs that need to be put in place to maximize the possibility that a project will succeed. They use their experience and knowledge of various energy projects worldwide to categorize these CSFs. Universal CSFs are the ones which form essential features which include: the use of proven designs or performance guarantees; the existence of an acceptable economic and financial package; thorough market surveys and clear indication of social need. They state that checks should be put in place to determine project compatibility with the medium-term energy strategy and to ensure that legislative, political and regulatory frameworks are favorable (Department for International Development, 2005).

Some more specific CSFs that can be applied to Uganda's case during the electricity planning process are cost recovery and community involvement:

2.1. Cost recovery

Cost recovery is one of the most decisive and crucial factors determining long-term effectiveness of rural electrification programs. The whole operation needs to be profitable in the long-term in order to be ultimately sustainable. Dependence on high initial subsidies in investment costs might lead to eventual extortionate tariffs for the unsuspecting and poor rural customer in order for the supplier to recover the loss incurred by reduced or no subsidy. In Uganda, Priority Rural Electrification Project (PREP) packages are initially being prepared for bidding to the private sector in order to test the market before embarking on countrywide schemes.

2.2. Community involvement

Cost-saving opportunities, therefore, need to be exploited from the beginning of the planning process. In order to create a win-win situation, a two-way approach needs to be taken such that increased income generating activities would be created as a consequence of improved access to electricity. That way, the rural consumer will be able to afford to pay his/her electric bills and the supplier can in turn afford to provide a decent service and make a modest profit. Rural communities in Uganda could be mobilized under their Local Councils to brainstorm new income-generating activities that would arise from electrification based on their natural resources and workforce.

Energy Demand Patterns

In Uganda, the ever-growing demand for electricity exceeds actual consumption and this is suppressed by limited supply. The situation is exasperated further by recurrent load shedding that is imposed almost daily on urban consumers in the capital city, Kampala, where demand is greatest. Their electric supply is rationed while their electricity bills are on the increase thus they are forced to pay more for a lesser service. It would therefore make practical sense to look at the demand that already exists in the country then design a targeted supply system to match it.

A cross-sectoral view is taken to examine energy demand patterns for Uganda using geo-referenced data, and to get a literal picture of the situation on the ground. A 'demand center' can be interpreted as any physical structure that would require electrification. With a goal of kick-starting development, the initial focus is on prioritizing provision of electricity to schools and hospitals, powering a few small enterprises, mobile telecommunications, as well as providing domestic electricity. This analysis is based on available country statistics from the Uganda Bureau of Statistics (UBOS) and physical data that are then incorporated into a GIS database to create a base-case demand scenario. (At this stage of the analysis, agricultural productivity and business activity input would be useful to add but that data is not yet readily available).

As shown on the maps developed (Figure 1 to Figure 7), the existing demand pattern for Uganda is clear: most activity in the country clusters along the existing electric grid as a lifeline for power.

Figure 1. shows the electric transmission network and some 33 kV distribution lines including some of the proposed extensions for the suggested PREP (Priority Rural Electrification) areas.

Figure 2. shows this electricity grid and the road network combined. We can see that the power lines roughly follow the road network, and this is particularly true in the rural parts. Ideally, under full coverage, these two networks should match.

Figure 3. shows the population distribution by region. From this we can see that there are a few isolated pockets of densely populated areas. Kampala, being the capital city, is the most densely populated region and North-Eastern Uganda is the least populated because it is a semi-desert region.

Figure 4. shows the population distribution along the grid and we can see that there are still many highly populated areas out of reach from the grid. Such areas would therefore be good candidates for off-grid planning.

Figure 5. shows some energy demand centers such as schools and village trading centers.

Figure 6. shows distribution of health centers (HC) around the country which have been aggregated into four levels. At the highest level, there are hospitals, which take the highest energy load priority; then HC IVs, which would use powered medical equipment; down to HC IIIs and HC IIs which require basic electricity supply.

Figure 7. shows the distribution of energy demand centers along the electric grid, including population density, schools and village trading centers. Their combined demand pattern shows the congestion along the electric grid.

These preliminary results could then provide the basis for a priority-ranking pattern. Once the demand scenario has been set, estimated load profiles or benefit points can then be allocated to each 'demand-centre'. These points could then be summed up within each administrative boundary at either district, county or parish level to give a priority pattern.

Supply Options

4.1. A case for off-grid options in rural Uganda

On the ground, the rural terrain and settlement patterns in Uganda are some of the major obstacles to electricity infrastructure planning. Typically, a village is identified by its trading center where most business activity is centered. These trading centers are usually along the main road and are often distributed sparsely and randomly, with many miles between villages. Beyond the road network and in between the trading centers, are the rural households, which are buried in the midst of farmland or plantations or natural vegetation following no particular layout plan. The natural terrain can also sometimes be mountainous and seem impenetrable. In these remote, hard to reach areas where grid supplies are impractical, people generally meet their energy needs for lighting and cooking by using wood fuel or charcoal.

These areas would almost certainly benefit from small-scale off-grid renewable energy plants such as mini-hydro. Their standards of living would be elevated to socially and politically acceptable levels, and it would also be environmentally beneficial by removing the dependence on woody biomass.

4.2. Potential small-scale hydro schemes

Uganda is at the heart of the Great Lakes region of East Africa. Not only does it co-host the world's biggest freshwater lake, Lake Victoria, it also boasts the source of the mighty River Nile that starts at the waterfalls in Jinja and runs all the way through the country, up to Egypt. In addition, there are plenty more rivers and lakes that spill over from these making it a very lush and fertile country. Hydropower is an abundant natural resource over much of rural Uganda.

Consequently, Uganda's electricity supply system is dominated by hydropower nearly 100 times greater than any other source. The total estimated electric potential for hydropower in Uganda is estimated to be in excess of 2000 MW compared with the current power generation of less than 250 MW (Government of Uganda, 1999). There are therefore plenty of potential sites for small-hydro schemes, which are, as yet, under-developed.

Small-scale hydro installations in rural areas could then offer considerable financial benefits to the communities served, particularly where careful planning identifies income-generating uses for power. Their simplicity means that small-hydro schemes not only provide renewable energy, they are also extremely cheap to maintain, given basic training.

The main advantage of a small hydro-scheme is that it does not require a dam or storage facility to be constructed; it simply diverts water from the river, channels it into a valley and 'drops' it into a turbine via 'penstock' (pipeline). This type of hydro generating would thus avoid the damaging environmental and social effects that larger hydroelectric systems can cause. It would seem that for Uganda's rural population who are materially poor but have a great wealth of nature at their disposal, this most basic, self-sustaining and least-cost method of power generation could prove to be the most innovative of all.

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She has received several awards including the 'Individual Bursary Award' (1999) by the British Royal Academy of Engineering for outstanding candidates, a gold 'CREST' award from Imperial College, London for Creativity in Science and Technology and an Academic Scholarship. She hold a bachelors and Master's degree in Engineering Science, Oxford University

Figure 1: The electricity grid - Transmission Network and some 33kV Distribution lines plus proposed extensions.

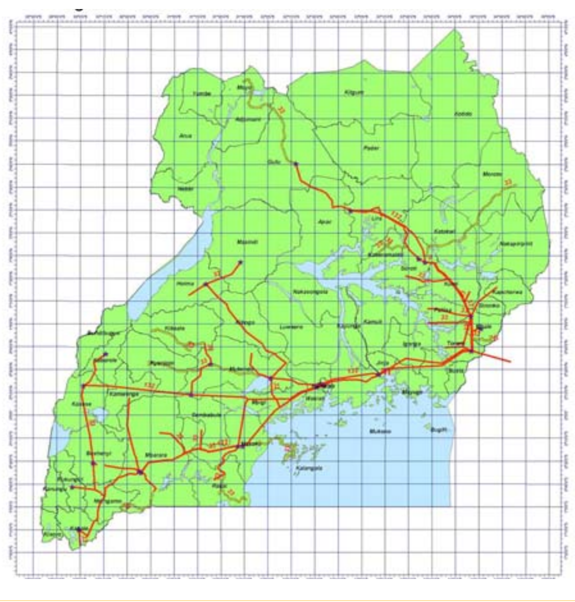


Figure 2: The electricity grid roughly follows the road network; under full coverage these should ideally match.

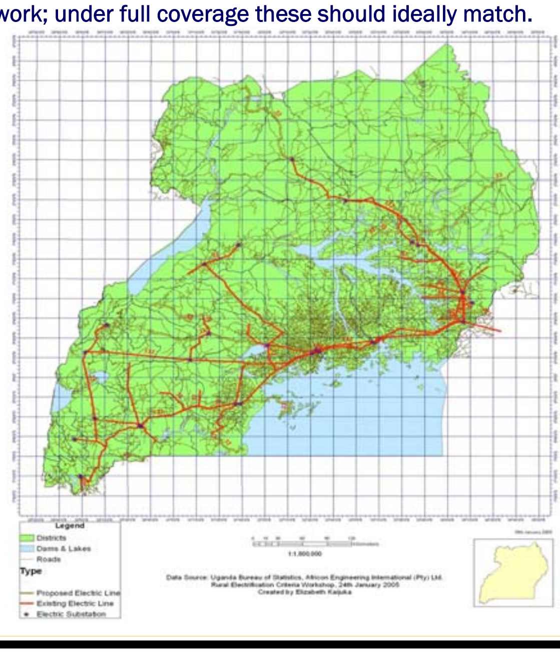


Figure 3: Population Distribution - a few pockets of densely populated areas; Kampala is the most densely populated region, Eastern Uganda the least densely populated region.

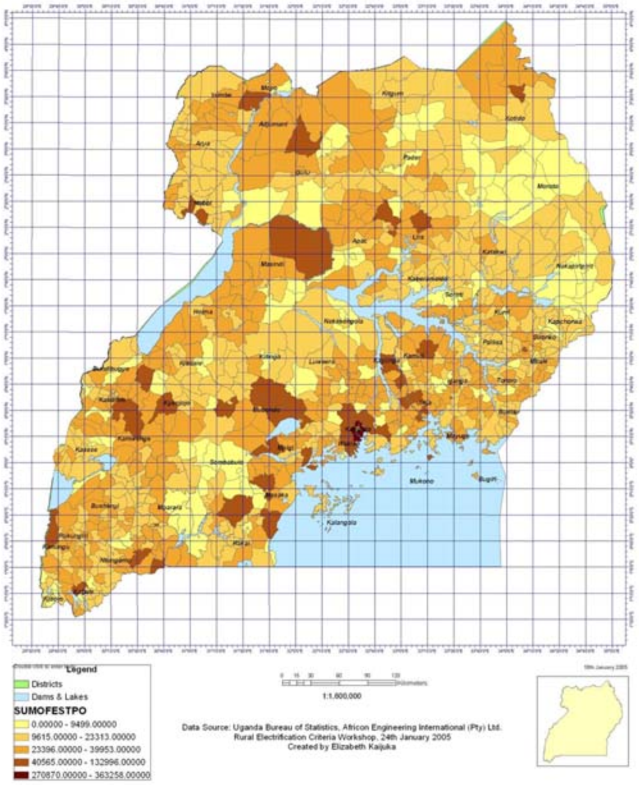


Figure 4: Population density is highest along the electricity grid; still many highly populated areas out of reach.

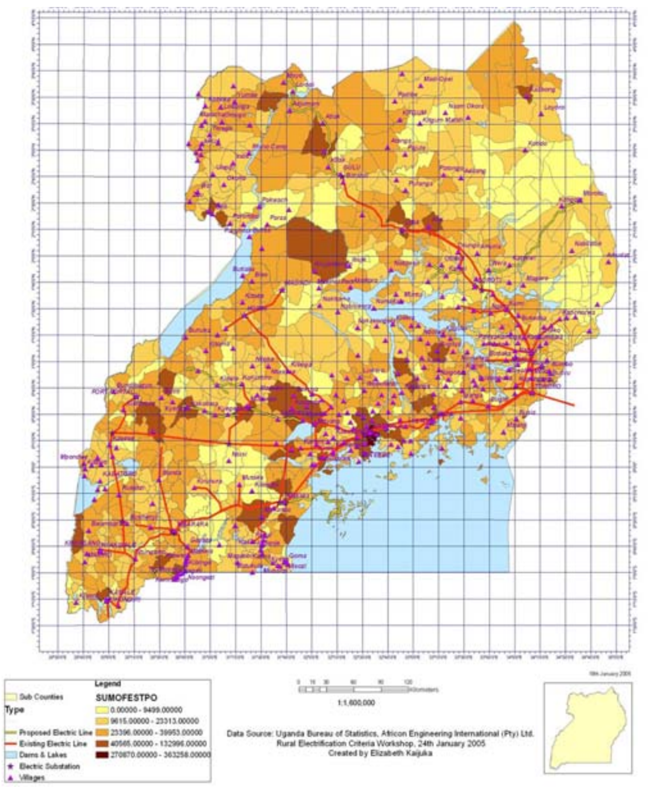


Figure 5: Some demand centers - schools and village trading centers

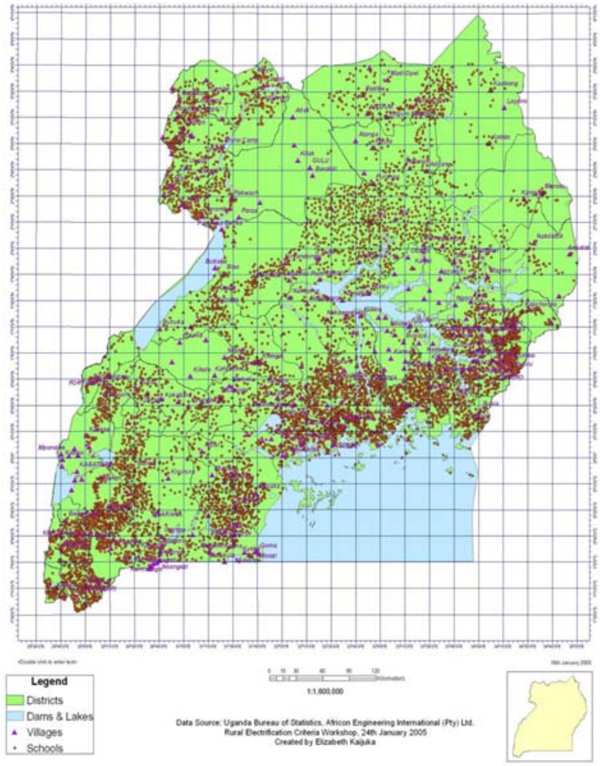
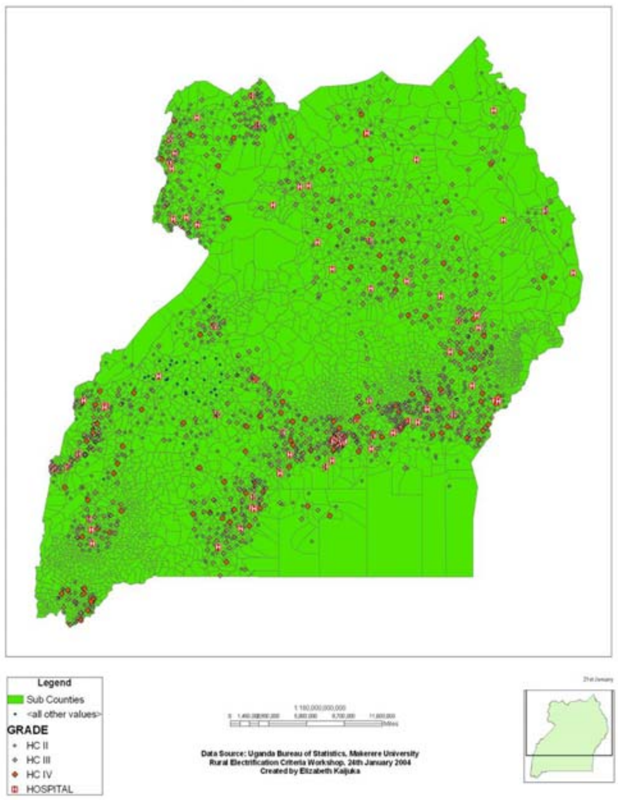


Figure 6: Health Centers



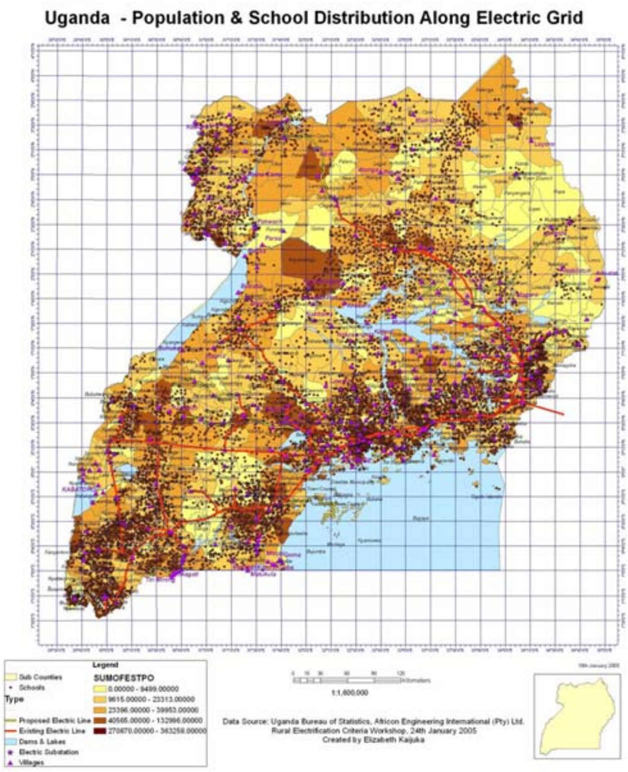


Figure 7: The Demand Pattern - most activity congregates along the Electricity Grid

The Akosombo dam, one of Africa's large hydropower plants is both a reminder of Africa's aspirations to industrialize and untapped potential. Its contribution to the economy of Ghana may not be disputed but not all its promises: transport, irrigation and fishing, to name afew, are yet to be realized.

ENERGY CONFERENCE ANNOUNCEMENTS

The Power Generation Summit.

19-21 September 2005,

Grand Hotel Huis ter Duin,

The Netherlands

For information:

http://www.powergenerationsummit.com/

PowerAfrica

24-26 October, 2005

Sandton Convention Centre

Johannesburg, South Africa

For information:

http://www.powerafrica.co.za

4th World Wind Energy Conference & Renewable Energy Exhibition

Melbourne, Australia, 2-5 November 2005

presented by WWEA and REGA

For information:

http://www.wwindea.org/

INTERNATIONAL SOLAR COOKERS CONFERENCE AND FOOD PROCESSING

Granada, Spain, 12th to 14th of July 2006.

http://www.solarconference.net/

Oil Africa 2006

The 2nd Sub-Saharan OIL, GAS, PETROCHEM Exhibition and Conference

Cape Town International Convention Centre

March 22-24, 2006, Cape Town,

South Africa