8TH SOUTHERN AFRICA REGIONAL CONFERENCE

14 - 17 NOVEMBER 2017

"Electricity Supply to Africa and Developing Economies …. Challenges and opportunities."

Enabling Universal Access to Electricity in Developing Countries

The Cost of Sustainable Energy

Charles Odoi Chibambo (C.O, CHIBAMBO)

Electricity Supply Corporation of Malawi (ESCOM)

Malawi

cchibambo@escom.mw

1. SUMMARY

Based on the analysis conducted by the International Energy Agency (IEA) in their special report on Sub-Saharan Africa, it is expected in the Africa case scenario that household electrification will grow from the current 32% to 70% in 2040 with an estimated cost of $205 billion .To reach 100% electrification, there's need to find new strategies that can optimise financing and reduce implementation time frames.

In analysing the report, one of the problems with the current electricity sector is the dominance of domestic consumers, the majority of which are in urban areas whilst population growth will be in rural areas which makes it financially unjustified to invest in 100% electrification.

This paper proposes to have the household electrification campaign, stem off of supply to productive centres in rural areas. These centres will be chosen based on land use plans and resource availability to form ecosystems whose components will be bid out in phases. This approach will allow for pre-approval of sites to reduce the timelines for implementation and allow for better vetting of offtaker projects.

Power projects scope should be less than 100 Megawatts (MW) to allow more private sector interest. These smaller projects also give government utilities the opportunity to invest, by raising finance through a special escrow account replenished through the automatic diversion of their current revenues.

2. KEYWORDS

Ecosystem – An interconnected system

Off-taker – Large Electrical Power Consumer

Soft-Energy – An easily convertible energy source

Hard-Energy – An energy source that needs complex technology to convert

3. BACKGROUND

Despite global interest in improving sub-Saharan Africa's Electricity Supply and its low electrification rate over the last couple of decades, most of the region is still plagued with persistent blackouts and has a total electrification rate of around 32%, of which approximately 80% of those lacking access to electricity are based in rural areas.

Studies by the International Monetary Fund (IMF) show how poverty levels in sub-Saharan Africa are higher in countries with low quality electricity infrastructure; the correlation is higher than for other types of infrastructure or for general structural variables, such as levels of health or education (IMF, 2014a), which makes access to electricity key to poverty reduction [1].

Although there has been substantial improvement in development of Policies and increased spending over the last decade, with annual investments estimated at around $8 billion per year, resulting in an increase in electricity access from 23% in 2000 to 32% in 2012 there remains a stark contrast to North Africa which has 99% electrification rate with a gross domestic product (GDP) per capita which is around two-and-a-half times that of sub-Saharan Africa.

The continent itself is the size of the United States, China, India and Europe combined. As of 2012, almost half of those around the world without access are on the African continent and with population growth in sub-Saharan Africa pegged against progress in other parts of the world, it is estimated that sub-Saharan Africa will have 75% of people in the world without access to electricity compared with the 50% in 2012 even after spending $205 billion in investments. The map extract in figure 1 below from the IEA Report [1] shows the different levels of electrification in Africa in 2012.

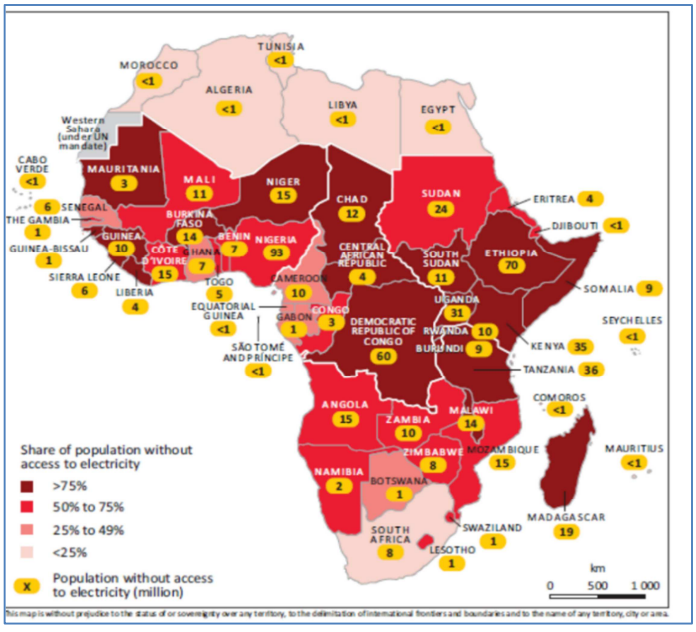

Figure 1 Electrification Rates in Africa

The recent approach to increasing rural and peri-urban electrification has been based on social fund financing from Governments and through various development agencies targeted at connecting extending distribution networks or by setting up micro-grid and off-grid systems for consumers too far from the main grid.

The grid extension programs are not coordinated with the necessary investments in both Generation & Transmission projects which are slower to implement and require years of complex multi-stakeholder studies and approvals. These projects are also more reliant on third party finance (loans or guarantees have their own set of conditions and timelines before disbursement occurs.

The micro-grid and mini-grid systems have lacked sustainability because the communities fail to raise financing to effectively and continuously service the key components of the installed systems.

Building off the in depth analysis conducted by the International Energy Agency (IEA) in the special report on sub-Saharan Africa, it's clear there is a need to develop new strategies that can help overcome the issues highlighted, to further develop the continent and support the increase of access to electricity in the region [2].

4. THE CURRENT ENERGY MARKET

In many sub-Saharan countries, economic development is at an early stage, a point reflected by the fact that two-thirds of total energy use in the region occurs in the residential sector compared with an average of 25% in other developing countries and just 20% across the Organisation for Economic Co-operation and Development (OECD) [1][2].

The extract in figure 2 below [1] shows the current energy consumption profile of Africa.

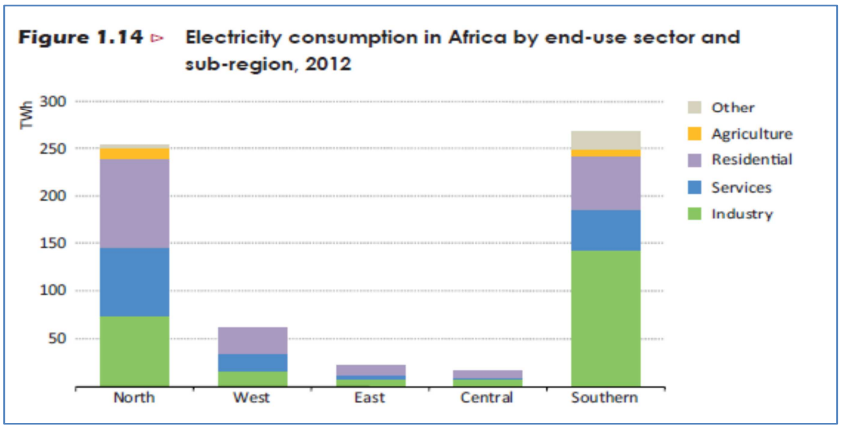

Figure 2 Electricity Consumption in Africa

Within the region, South Africa accounted for 41% and Nigeria for 19% of total sub-Saharan energy consumption for productive uses, while the other countries had their energy consumption profiles largely dominated by domestic use.

These variations in energy use profiles result in significant differences and interests in energy development needs and strategies. This is one of the problems faced in getting coordinated effort towards developing regional projects. Governments have to justify why they must expose their countries to substantial amounts of financial debt for projects that might have more cross border electrification benefits, while their domestic markets remain underserviced

Figure 3 below further illustrates the breakdown of the domestic consumer's profile

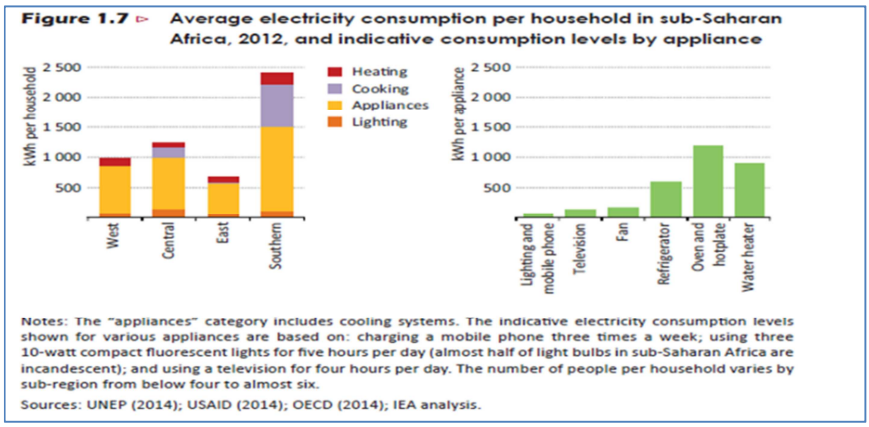

Figure 3 Domestic Consumption Profile in sub-Saharan Africa

As shown in figure 3, domestic profiles are dominated by appliances, while cooking only features highly in Southern Africa. The appliances with the highest usage are the water heaters, refrigerators and the oven/hotplates which are not readily available in rural homes due to the cost of the appliances, the economic state of the country, the people's cultures and their hierarchy of needs.

In 42 countries, more than half of the population relies on solid biomass (fuelwood, straw, charcoal or dried animal and human waste) for cooking needs and in 23 of these the share is above 90%, however these biofuels have adverse environmental consequences and health effects resulting in 4.3 million premature deaths, of which nearly 600 000 are in Africa [1].

The collection of solid biomass for cooking in rural areas requires people (mostly women and children) to devote hours of each day to collect fuelwood. This also affects the potential for these people to focus on more nationally regulated, financially viable endeavours which could have an impact on GDP per Capita growth. Replacing fuelwood with electricity would require a cultural transformation coupled with the availability of cheap electricity and strong regulation of the fuelwood resources.

The current general domestic electricity consumer profile is the reason why most rural off grid systems have been designed to provide basic lighting with some other basic appliance use, but even if cooking is added to the mix, the model would still be financially unsustainable because income in households is mostly dependent on external factors.

5. THE SOLUTION

"Spend 80% of your effort towards optimising your existing systems and the remaining 20% on innovation"

The issues of Policy and Governance are critical in making any strategy on sub-Saharan Africa work. Policy development and co-ordination at continental and regional level is undertaken by the African Union (AU) and the New Partnership for Africa's Development (NEPAD).

This paper, however, aims to assess the possibilities of linking increased electrification rates through the designing of financially sustainable energy systems, targeted at supplying value adding processes around key economic driving areas that are mutually beneficial to private investors as well as the Government and its societies. If this approach is successful, it should also help limit the rates of urbanisation to the current existing major cities, whose electrical network infrastructure can barely provide quality service to its current inhabitants [2].

As shown in the previous sections, the energy profile for rural and peri-urban areas in sub-Saharan Africa is expected to largely constitute consumption in residential sectors but the IEA's African Century Case, requires more rapid energy development, to give a 30% boost to GDP by 2040, which would require higher growth in markets that generate income.

5.1 CREATING A NEW MARKET

As noted before, the concept of building business models for power projects off of an overall "higher cost reflective tariff" in an energy profile dominated by domestic consumers is not sustainable, because the state of the economy among other factors will determine the people's capacity to pay. In a stagnant or regressing economy, growth in consumption would be based on new entrants from rural areas (through government initiatives) or peri-urban customers that have migrated to urban areas due to poverty.

For older, relatively more stable economies like in South Africa, energy expenditures account for around 3.5% of total income, while in Malawi, where income levels are typically much lower, the share is more than double [1]. Large disparities in electricity consumption are also evident: in countries with intermediate levels of income, the wealthiest 20% of households tend to account for around 40% of consumption while, in the extreme case of Malawi, the richest 20% consume more than 80% of the total.

Figure 4 below [1] shows results of assessing the relationships between income levels and expenditure on electricity.

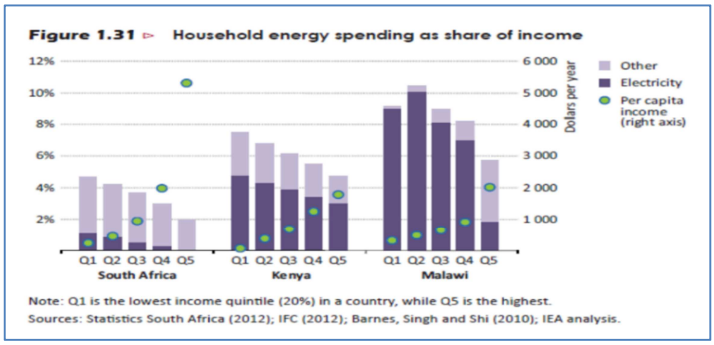

Figure 4 Energy Expenditure relative to Income

Even though there is no direct correlation between income and electrification rates, the capacity to spend can affect how much electrical energy is consumed in each country.

There are generally two approaches to dealing with access to electricity and economic growth/ industrialisation, with one side stating that you need to have the electricity projects upfront to industrialise and the other stating that the industries must exist to justify the costs of constructing Generation, Transmission and Distribution networks.

Selection of Power Generation and offtaker projects should be a delicate balance that can support the transition of consumption patterns to include a larger share and need for electricity in productive uses, like mining, cement production, iron and steel processing as well as the mechanisation of agricultural processes especially in rural areas. These centres of production will form the nuclei for the next set of households to grow around, increasing their probability of getting access to electricity, especially since the initial capital investment costs are covered in the productive sector supply models.

In terms of productive sectors, Agriculture remains a large sector in many economies, accounting for around 20% of regional GDP (compared with a 6% share globally) and around 65% of employment (AfDB, OECD and UNDP, 2014) [1]. But it also remains largely unmodernised, with huge scope for productivity and personal development gains through the application of modern energy [2]. Mining (energy and non-energy commodities) also features highly in several sub-Saharan economies, both as an employer and as a source of export

revenue, with mining output typically exported in a raw or semi-processed state previously, due to lack of strong domestic markets. Before creating new innovative centres, optimisation of the electricity requirements for these sectors could provide the drive towards converting the regional consumption profile into a more financially sustainable one.

5.2 PROJECT SELECTION & IMPLEMENTATION

There are several areas that need to be reviewed in the selection of Power Projects for development. Currently project selection and scoping in feasibility studies is done independent of most of the other national projects within and outside the energy sector.

Projects from a country's Integrated Resource Plan (IRP) are selected without a detailed project management assessment, leading to unrealistic owner requirements, improper quantification of deliverables, little to no risk analysis, poor projection on implementation timelines, poor resource breakdown, limited outage management planning and incomplete procurement plans.

In developing a nation, governments have to take different forms of foreign and local financing to provide for (i) the generation project (ii) the transmission systems with wayleave and compensation (iii) tax exemptions for the large mining and manufacturing offtakers (iv) subsidies for the domestic customer with each part being assessed, financed and developed separately.

Development systems are interdependent and are supposed to be assessed simultaneously based on Government's land use plans. Combined value chain analysis creates a financial ecosystem, which can inform a country's development and investment strategy.

The concept of ecosystems is not new, as it has actually been done on a larger and more complex scale in Denmark [3], where four companies (a power plant, a refinery, a gypsum facility for producing wall board, and a pharmaceutical plant) formed an energy ecosystem and effected the exchange shown in Figure 6. The "waste" products from the power station (including heat in the form of warm water) are used to warm the greenhouse and other facilities. Such a co-generation system provides an industrial network with a much higher efficiency for overall energy use than if any of the organizations had organized independently for their material and energy needs.

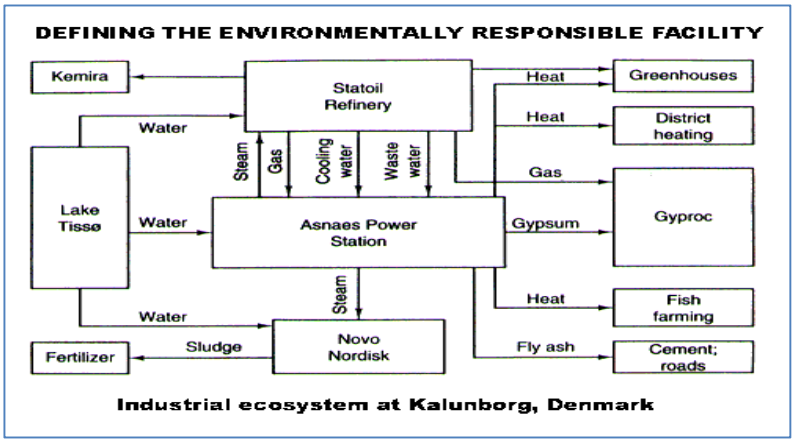

Figure 5 Industrial Ecosystem

The financial ecosystem program in sub-Saharan Africa will have governments bid out components (including the power Project) in various combinations ranging from full Private Sector bids, Public Private Partnership's (PPP's) or through government finance.

The first role of Government, its Parastatals and Utilities in these ecosystems is to provide access to the land and resources (cost of which can be capitalised as part of their investment) and in setting up the requirements for future integration of any external systems.

The IEA Report highlights that for power projects, small-scale options, commercialised by the private sector, may be the only way forward where there are shortcomings in public policies or institutions. The types of power projects selected for supply in these ecosystems can be off-grid systems, micro-grid systems, extension of central grids or cross border supplies that can be mobilised quickly.

5.3 ENERGY SOURCES

The choice of energy sources including the role of electricity in the defined ecosystems is as much based on its range of uses as it is on its availability and capacity to transport to the end user. The extract in figure 7 below shows current energy resource use in the region.

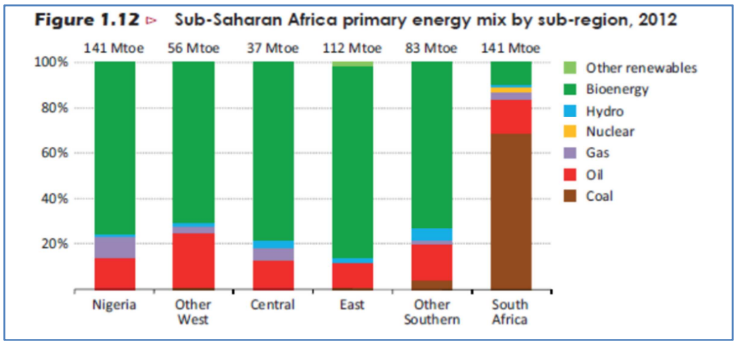

Figure 6 Primary Energy Mix

Though renewables feature low in the energy mix, they can provide the most viable option (in terms of fast approval) and should be prioritised for use in the ecosystems. Depending on the type of renewable source available, the projects can be developed as standalone systems or utilise hybrid networks that can best meet the demand requirements.

Oil, Coal and Biomass feature highly in sub-Saharan Africa's energy source mix. Half of sub-Saharan oil demand is currently being met by imports and, and it is projected that even if existing refining capacity was able to be fully utilised, the region would still be reliant on imports. Oil products have a strong logistics network that has grown over the decades allowing it to still feature highly as a short to medium term source of energy.

Coal is expected to still feature high in Southern Africa [1], but because of its high CO2 emissions, is expected to face competition from the new natural gas finds in Mozambique and Tanzania dependent on the development of an effective logistics network [4].

The unregulated fuel wood source and the mastery of the people to convert it into usable energy has made it more attractive compared to the other energy sources making biofuels rank highly in the current and possibly future energy sources, resulting in mass deforestation. The EU Energy Initiative Partnership Dialogue Facility is poised to help countries to develop their own Biomass Energy Strategy Plans to sustain the use of the resources. With the right technology, this could also feature as a potential source of energy for power plants which can provide cheaper electricity to households as a competitive alternative to the direct use of biofuels for cooking.

Since fuel is such a critical component of the electrification process, the risk (which varies with fuel types) should neither be sitting with the Energy Conversion Company, the utility nor the government. A competitive process between various fuel suppliers can be offered through medium term contracts to provide the necessary fuel in a particular area [5].

5.4 TECHNOLOGY

"*What we have is not an energy problem, what we have is an energy conversion problem"*

In the ideal use of energy, we would distinguish between the needs requiring high or low "quality" energy. Using energy at the appropriate level and from renewable resources is what is referred to by Amory Lovins as a "soft energy path." One soft technology philosophy argues that we adapt our life styles to suit the energy available to us [3]. The soft energy path is the path that most rural areas follow, but to enhance modernisation there is need for hard energy which requires conversion technologies.

Energy loss is inevitable [3], however the designs and technologies selected to dispense the energy at various levels of the ecosystem should focus on optimising efficiency to increase return on investments. It is estimated that, on average, around 18% of grid-based electricity generated in sub-Saharan Africa (outside South Africa, where losses are lower) is lost in transmission and distribution, a very high figure by international standards. Following the conventional approach developing power systems would lead to an additional electricity requirement of around 10 gigawatts (GW) of generation capacity by 2040 for losses, costing the order of $7 billion [1]

The efficiency problem needs to be resolved through close coordination between System Engineers, Design Engineers and selected Research and Development centres. There is substantial amount of work already being carried out in some Utilities in Africa and Electrical Engineering groups like Cigre. For example, Cigre group B3.43 is working on optimising the design process for substations in areas with low electrification to reduce the required costs of investment. Because these specialist groups spend more time researching technologies and systems they should take an active role in advising Governments on how best to build their ecosystems.

5.5 TARRIFS AND PROJECT FINANCING

If projects are assessed together, governments can take into careful consideration the absorptive capacity of the domestic economy to guard against investments that generate poor returns.

Early determination of the financing structures after the project concept phase and during the pre-feasibility and feasibility assessments enhances the chances of securing better project financing for implementation [6] [7]. The complexity of financing deals requires dedicated units with the right expertise in financial and contract management, to select viable investments and ensure the right type of contracts are signed. Poorly structured deals in the region have been one of the biggest problems in proper utilisation of the available finances.

The Southern African Power Pool (SAPP) Project Assistance Unit (PAU) is currently working with utilities in preparation and scoping of large scale regional projects. However in most democratic states there is a limitation on how quickly these projects can move from preparation to implementation, which affects the timeline in which the governments expect to reap the benefits and commit to provision of finance or guarantees.

With the increase in interest from the private sector, the bottlenecks to increase in investment appear to arise more from considerations of project preparation, policy's and procurement methods rather than financing.

The typical power generation project attracting the attention of private investors (even in South Africa) is small-to-medium size with capacity of around 10 megawatts (MW) to 100 MW, i.e. a scale [1]. These would fit well with the power requirements in a start-up ecosystem.

Government utilities can also invest in such smaller scale projects by diverting a percentage of their current revenues into an escrow account in a currency of their choice.

This account should be specifically for Capital Investments and completely separate from their operations and maintenance accounts. Disbursement of the money in this account should be managed by an investment group which can help guide utilities on which projects offer the best returns [7].

Small scope projects with smaller capital requirements, mean smaller levels of debt against the project revenues, which could provide a better debt/service ratio for financiers and allow the utility to generate extra profit for investment in other projects and improve the utilities credit rating.

Having several projects in one area, also means a combined risk analysis can be done and the power project returns can be developed based on a desegregated financial recovery model from multiple offtakers whose development plans are available and project execution has high certainty [7]. New electricity tariffs can be structured around these instead of domestic consumers who would be secondary beneficiaries with a tariff aimed at encouraging greater electricity use in the households so that profits are generated from user numbers and not high tariff rates.

There are several financing structures that can be considered, a few of which are described below:

PPP Financing – Through Public Private Partnerships, governments focus more on social economic benefits while the private sector gains in profits from providing the capital. A Special Purpose Vehicle (SPV) [6] with limited liability is responsible for managing the project, collecting revenue and paying taxes.

EPC & Finance – This is becoming common because of lack of readily available finances to Governments. Selection is through a tendering process where contractors are evaluated based on their technical capacity as well as their capacity to raise finance.

Commercial Loans – Almost all large debt contains a commercial component, the variation in banking strategies also offers a large variation in the interest rates and repayment terms. Defining the correct Debt/Equity ratio is critical to sustainable economic growth.

The selection of a financing method is fully dependent on the fiscal policies of individual countries but governments should conduct preliminary review of all financing sources available and allocate the best type of finance to individual projects within their systems.

6. CONCLUSION

Economic analysis of a country's tradeable resources and its financial position have a critical role in developing land use and investment plans. Through coordination with project managers governments can select the sequence in which to implement projects within a defined ecosystems with the aim of limiting their financial exposure, getting good returns and increasing the probability for successful implementation.

System and Design Engineers can work within financial boundaries to provide scalable solutions within the networks that can optimise resources and sustainably deliver services required within each Geographic ecosystem.

The age of wasteful, desegregated development strategies needs to come to an end, strategic interdependent growth is the key that will drive nations towards poverty reduction and attain 100% electrification rate in sub-Saharan Africa.

7. BIBLIOGRAPHY

[1] F.Birol “Africa Energy Outlook – A focus on Energy Projects in sub-Saharan Africa” (IEA Special Report, 2014, all pages)

[2] G.Mills, O.Obasanjo, J.Herbst & D. Davies “Making Africa Work” (A Handbook for Economic Success, 2017, pages 68-86)

[3] Environmental Decision Making, Science & Technology (Carnegie Mellon University, 2003, all pages)

[4] Power Africa “Understanding Natural Gas and LNG Options” (U.S Department of Energy, February 2017, pages 89-105).

[5] Power Africa “Understanding Power Purchase Agreements” (Creative Commons Attribution- Noncommercial-Share Alike 4.0 International License, February 2017, pages 89).

[6] Power Africa “Understanding Power Project Financing” (Creative Commons Attribution-Noncommercial-Share Alike 4.0 International License, 2016, pages 12-37, 60).

[7] B. Graham “The Intelligent Investor” (Harper Collins, 2006, pages)