The role of unmet demand in the dynamics of energy supply forms: The case of electricity market structures in sub-Saharan Africa

Alexis Vessat

To cite this version:

Alexis Vessat. The role of unmet demand in the dynamics of energy supply forms: The case of electricity market structures in sub-Saharan Africa. French Association for Energy Economist (FAEE) 10th Winter Student Workshop, FAEE & Ecole Supérieure de Commerce de Paris (ESCP Europe Business School), Nov 2017, Paris, France. hal-01944317

HAL Id: hal-01944317
https://hal.umontpellier.fr/hal-01944317

The role of unmet demand in the dynamics of energy supply forms: The case of electricity market structures in sub-Saharan Africa

---

Author: Alexis VESSAT (ART-Dev, Université de Montpellier)[1]

Abstract

The energy sector in sub-Saharan Africa is in a state of flux. Based on an approach borrowed from industrial economics, using historical examples that point to three successive transformations of electricity market structure, our analysis differs from previous studies by looking at demand as a consequence of supply. Our results show, an extremely fragmented demand for energy in sub-Saharan African countries, within which a very dynamic unmet demand drives change in how supply is offered. New forms of energy provisioning introduced on the electricity market put into question the initial on-grid network model. The appearance of decentralized electricity production shows that there is a potential for going beyond current limitations and moving away from a supply structure focused on the maintenance and improvement of on-grid networks without consideration of the needs of rural populations on one hand, and on the other hand, the establishment of expensive mini-grids that provide inferior energy services to rural populations. New territorial linkages focus on mechanisms seen in energy demand.

Keywords: Centralized electricity production, electricity market reform, sub-Saharan Africa, decentralized mini- and off-grid production systems, demand fragmentation, supply dynamics and changes, rural electricity demand, access to electricity

JEL Classification: Q40, Q42, Q49

---

[1] Email : alexis.vessat@umontpellier.fr, Actors, Resources and Territories in Development, (ART-Dev), Université de Montpellier 1, Economics department, avenue Raymond Dugrand, site de Richter, C.S. 79606, 39460 Montpellier Cedex 2, France.

Section 1. Introduction

Since the beginning of the 2000s, sub-Saharan Africa has experienced sustained economic growth at a faster rate than the rest of the world economy, despite growing demographic pressure. Nevertheless, this growth rate is not homogeneous (UNCTAD, 2014; World Bank, 2017). These fluctuations in growth can have external causes such as variations in the price of petroleum, but also internal causes such as inadequacies in the energy infrastructure (African Energy Outlook, 2014; Eberhard & al, 2014). Sub-Saharan Africa (SSA) can thus be characterized by both its wealth in energy resources and its poverty in the production and consumption of electricity. Even though the African continent contains a little more than 14% of the world's population, it consumes less than 4.5% of primary energy (World Energy Outlook, 2017).

The inadequacy of the electricity sector in SSA represents a cost of about 2 points of GDP in economic growth (World Bank, 2017). Currently the combined electrical production capacity of the 48 countries of Sub-Saharan Africa adds up to 80 GW, half of which is for South Africa. The per-capita production capacity is only 0.08 GW (versus 1.94 GW for France). Over the past 20 years, capital growth, or the electric power installed in the principal on-grid network, has only increased about 1.7% per year (Eberhard & al, 2011). In a simulation, the International Energy Agency has determined that to reach the objective of universal access to electricity, $630 billion would need to be invested over a period stretching from 2014 to 2040 (source??). A similar study carried out by the World Bank's Infrastructure and Local Development Project finds a need for $400 billion invested through 2030 (World Bank, 2014). All of these simulations have been developed in a context where over 25% of energy production facilities (outside of South Africa) are not considered operational.

In sub-Saharan Africa, electricity is provided through centralized networks that primarily supply urban areas. The power infrastructure, a remnant of post-colonial decisions on organizing the electricity market, is mostly based on market demand and passes through the main on-grid network. There are many deficiencies in how the development of power infrastructure has been structured.

The introduction of private energy supply as part of a trend towards deregulation in the electricity sector in the 1990s has improved the centralized supply, but there remains a substantial gap between supply and demand. The demand for energy increased by 45% between 2000 and 2012 (African Energy Outlook, 2014), while production capacity only increased by 19% over the same period (Eberhard & al, 2014). Current supply therefore only covers part of overall demand.

Demand in sub-Saharan Africa is fragmented into at least three components:

- *Market-based demand*, served by the on-grid network. While this demand is met by current offerings, it is coming up against the limits of the networks;

- *Unmet non-grid market demand,* power customers outside the on-grid centralized network. These households buy extremely expensive energy resources (kerosene or diesel) for decentralized energy production that is both inefficient and expensive. This demand mechanism leads to the search for new models and thus an increase in decentralized solutions like mini-grids, made possible by the overall drop in the production costs of renewable energy systems. The new organizational modes for decentralized supply (mini-grid and, since the 2000s, off-grid) transfer households' willingness to pay a monthly fee to decentralized networks, which allows new consumers to have access to electricity without going on-grid. This transfer puts into question the electricity production model initially adopted by African governments. The perspectives for developing the mini-grid are encouraging; for example, the IEA envisages the installation of 100 to 200,000 mini-grids in SSA by 2040 (source ???);

- ❖ *Out-of-market demand* includes all the households that use primary biomass as their main source of energy. Biomass remains the biggest energy source, especially for household needs like cooking, for most rural households in Sub-Saharan Africa (African Energy Outlook, 2014): more than half of total primary energy demand. These households have no access to electricity. This out-of-market demand represents 580 million people and 310 terrawatt hours of potential electricity consumption (Bazilian, 2012).

This demand fragmentation coincides with the many upheavals seen throughout the power system: the on-grid supply is seeing competition from decentralized production solutions like mini-grid and off-grid systems. Even though these technologies are a considerable step forward compared to conventional electricity production methods, they remain inaccessible for a large number of households, especially those in rural areas, where the power services offered are limited.

This article thus focuses on the demand mechanisms in a situation where the rise of renewable energy sources (solar, small hydropower, wind, bioenergy) in electricity production enables decentralized solutions that were previously inaccessible and stimulates demand with a retroactive effect on the organization of supply.

This article uses an industrial economics approach with historical examples throughout Sub-Saharan African countries. It is organized as follows. **Part 2** presents the contributions and limits of the vertically integrated centralized supply system that dominated the electricity sector in Sub-Saharan African countries from 1945-1990. **Part 3** presents two very important and completely independent changes in supply beginning in the 1990s. The first change is related to new entrants (independent private producers or IPPs) whose goal was to create competition in the market. The second change was the introduction of the mini-grid, which, due to its greatly reduced price, created an alternative to conventional means of electricity production. The emergence of decentralized solutions stimulated non-grid demand, which encouraged their further development. **Part 4** contextualizes the emergence of new forms of off-grid energy supply since the 2000s, in combination with the distancing of certain rural populations, which led to a second stimulation of energy demand. Finally, **Part 5** looks at a set of theoretical propositions that illustrate the dynamics of unmet demand and the changes in forms of supply that these dynamics bring about, aligning demand functions with the capacity limitations of the different networks.

Part 2. From 1950 to 1990, establishment of a vertically integrated monopoly with the objective of on-grid electricity access for urban areas

Due to their inherent characteristics, network industries are natural monopolies (Chevalier, 1995). In Sub-Saharan Africa, electricity has primarily been distributed through centralized grid systems. The electricity companies set up vertically integrated systems, integrating production, transportation, distribution, and sales of electricity within the same entity (Percebois & Girod, 1998; Percebois & Hansen, 2010). This electricity market structure model remains extremely common: it is still used in half of SSA countries (Eberhard & al, 2014).

These choices were dictated by former colonial capitals during the 1950s to imitate the structures established in developed countries. Vertical integration was justified by several techno-economical efficiency arguments:

- The development of new production capacity (Percebois & Girod, 1998),
- State or external support[2] necessary to develop a sector requiring high capital intensity

---

[2] Public funds: FIDES (Investment fund for economic and social development) and FAC (Funds for aid and cooperation); External funds (European Development Fund, USAID, or CRID).

(Varashin, 2002) and participating in the development and extraction of a range of energy resources in order to enhance certain productive activities (like hydroelectricity, which encouraged agricultural development),

- Gains realized from economies of scale (due to activities with a growing scale of production), transactions costs, or range (Gratwick & Eberhard, 2008).

2.1. Economic characteristics of vertical organizations in SSA

Vertical integration has three major assets:

- **Growth in electrical production capacity**

With high demographic pressure in urban areas, growth in electrical production capacity was made possible by using energy resources (petroleum, coal, diesel) and imported power plants (Coquery-Vidrovitch, 2002 ; Varashin, 2002), as well as through an emphasis on the region's hydroelectricity potential (Coquery-Vidrovitch, 2002).[3] In the 1960s, four major dams were built in SSA: Akosombo in Ghana (1962-1964), Kainji in Nigeria (begun in 1969), Mount Coffee in Liberia, and Kossou in Côte d'Ivoire (1969-1971). This increase in nominal output is illustrated in Table 1 below:

Table 1: Growth in nominal output and energy produced by several SSA power plants

Country	**Côte d'Ivoire**	**Cameroon**	**Gabon**	**Ghana**	**Kenya**	**Madagascar**	**Senegal**
State monopoly	Côte d'Ivoire Electrical Energy (EECI)	Cameroon Electrical Energy (ENELCAM), later Cameroon National Electrical Company (SONEL)	Gabon Power and Water Company (SEEG)	Volta River Authority (VRA)	Kenya Electricity Generating Company (KPLC)	Jiro sy rano Malagasy (JIRAMA)	Senegal National Electricity Company (SENELEC)
Additional	67 -	911 million	20 million	476-5276	102-466 MW	98 million	110

MW output or GWh of energy produced	1750 GWh produced between 1960 and 1980	additional kWh produced from 1946 to 1960	additional kWh produced from 1946 to 1960	GWh produced from 1978 to 1980. Mostly hydroelectric power plants	in 1978	additional kWh produced from 1946 to 1960	million additional kWh produced from 1946 to 1960
Sales of electrical power from these companies	**Abidjan:** 13 million kWh (1955) 57, 064 533 million kWh (1960) (Varashin, 2002)	-	-	-	-	-	**In the Dakar-Rufisque-Thiès region:** 37 million kWh (1952)

Sources: Kansara & Walkade (1983); Percebois & Girod (1998); Saupique (2002); Varashin (2002)

- **Supply of electricity to main urban centers**

Urban households were first provided electricity through the grid network (Saupique, 2002)[4]. Several lines were thus maintained:

- This would respond to the rapid growth in urban household demand stemming from colonial populations residing in the territory (Lappara, 2002; Mehyong & Ndong, 2011).

Many European households used appliances imported from Europe (fans, telephones, refrigerators, lamps). These households drove intensified electrification efforts (especially in Côte d'Ivoire).[5] Similarly, in 1972, in N'Ndjamena (Chad) two major arteries in the colonial districts were provided electrical power.

---

[4] A notable difference can be seen between the centralized planning preferred by the French High Commission for West Africa (AOF) and the self-government methods used by the British (Mazrui & Wondji, 1998).

[5] See the comment by Verteuil, former administrator of the EECI (Côte d'Ivoire Electrical Energy).

- It provided better quality electricity, [6]
- It encouraged growth in industrial textile production

The priority given to providing electricity to urban areas completely excluded rural areas from access to electricity; moreover, most of the urban households on the grid were wealthier. [7]

- **Development of a grid system providing a low-cost link from the energy resources to be extracted to the areas where they are consumed (Saupique, 2002; Segreto, 2002).**

In certain territories, the extension of railroad lines coincided with the development of electricity (Coquery-Vidrovitch, 2002). The industrial needs of certain colonies (mining regions) involved access to electricity.[8] Certain plans, especially those developed in France, depended on modernizing production equipment of the grid system to (i) promote mining and energy operations and (ii) economically integrate the colonies.

The development of the grid system in fact allowed for the extraction of fossil fuels (coal and petroleum in Nigeria and South Africa) and mined resources (aluminum from bauxite in Ghana, copper in Zambia, uranium deposits in Niger).

2.2. Limitations of vertical integration

A broad consensus has now arisen as to the productive and allocative inefficiencies of vertical integration in SSA. The arguments that have been made (World Bank, 1993; Joskow, 1997; Bacon, 1999; Bacon & Besant-Jones, 2002) are as follows:

1. The lack of appropriate scale and lack of investment in maintenance and the development of new production units

The first event was the drying up of domestic funds, leading to low domestic savings as well as financial difficulties in the power companies themselves, which was exacerbated by bad payment behavior by several actors, especially the states themselves (Wamukonya, 2003). These difficulties were

---

[6] Enhancing the hydroelectric potential of Douala (Cameroun) resulted in the production of 7700 MWh of electricity in 1952.

[7] The Akosombo dam (Ghana) was launched in 1960, giving preferred access to urban households, while rural households had to wait until 1987 to gain very reduced access to electricity.

[8] Especially in South Africa for the power needs of (gold and diamond) mines (Coquery-Vidrovitch, 2002).

combined with an outsized power infrastructure, often referred to as white elephants (Lappara, 2002).[9]

This phenomenon was followed by a lack of external financing (Naudé & Krugell, 2007, Wernick & al, 2014), due to both the lack of transparency in many SSA countries, as indicated by the Mo Ibrahim Foundation (Mauro, 1995, Tanzi & Davoodi, 2002a) and multiple deficiencies seen at the governance level (institutional and regulatory frameworks, operation patterns, and fee structures).

These two weaknesses forced the power companies to look for other sources of financing[10] (Wamukonya, 2003).

2. Unfamiliarity with the technology, as symbolized by the spread of thermal energy, often to the detriment of local resources

This can be seen in large power main losses (representing 20-30% of total electricity production), insufficient load factors, substantial waste of resources, and productivity slowdowns (up to 40%), leading to numerous cuts in electricity production and the use of back-up generators, which can make up 50% of total electricity production and cost $0.20-0.30 per kWh produced (Karekezi, 1994; Chevalier 1995; Plane, 1997; Sambo, 2009). This unfamiliarity resulted in the limiting of production plants, which in most SSA countries do not exceed an output of 500 MW.

3. The financial state of the public monopoly, subject to numerous deficits, put into doubt the ability to ensure power service

The pace of growth in the urbanization rate did not allow the development of a critical mass of paying end users for the power companies. Consequently, the power companies' debt skyrocketed within a context of successive economic crises that could be seen in a rise in interest rates and in the price of petroleum, which were not accounted for in the companies' fee structures.

In 1990, when the Ivorian electricity company was almost $300 million in debt (World Bank, 1995), this was due to multiple errors in revenue collection (70-85%) (World Bank, 1995; ANARE, 2005). For

---

[9] This was the case, for example, of the hydroelectric plant on the Turkwel river in Kenya during the 1980s; from 1945 to 1990, Nigeria built up a production capacity of 5 GW when its domestic demand was only at 2 GW.

[10] This is the case of the Volta River Authority (VRA) in Ghana (Edjekumhene & al, 2001, Turkson & Wohlgemuth, 2001).

the same reason, the Kenyan KPLC built up $300 million in debt between 1945 and 1990 (Wamukonya, 2003, 2005).

4. The impossibility of meeting emerging rural demand while improving the quality of electricity furnished to urban and peri-urban households

Electricity supply was focused on developing access to electricity in urban areas. Between 1970 and 1990, the rate of urban access in SSA increased from 28% to 38% (Turkson & Wohlgemuth, 2001). However, this notable progress looks weak in comparison to other developing countries in Latin America and South and East Asia, where much higher access rates have been achieved[11].

It is due to these limitations that private solutions began emerging in the 1990s. Two innovations appeared: one organizational (private producers) and the other technological (mini-grids), which engendered new demand dynamics.

Part 3. From 1990 to mid 2000s, deregulation and demand segmentation

In the 1990s, two major changes considerably weakened the traditional forms of power supply.

3.1. A uniform deregulation process opposing several demand segments: Monopsony as applied to the electricity sector

The introduction of private producers who would establish real competition on the electricity market took place in a context of deregulation of infrastructure industries.

- **The introduction of new producers able to compete on the market**

Organizational forms copied from developed countries (unbundling, third-party access to the grid, vertical and horizontal separation of the grid) were confronted with the intrinsic characteristics of the electricity sector in SSA: immature grid systems and rapid growth in demand (Plane, 1996; Bacon, 1999; Turkson, 2000).[12]

---

[11] Over the same period, urban access grew from 67% to 82% in Latin America, from 39% to 53% in South Asia, and from 51% to 82% in East Asia (Turkson & Wohlgemuth, 2001).

[12] Only a few SSA countries (Kenya, Uganda, Nigeria, Ghana) have dealt with questions related to third-party access or vertical or horizontal separation of networks (Bacon & Besant-Jones, 2002).

Deregulation was thus limited to the entry of independent private producers (IPP), whose goal was to establish competition on the market. These IPP were mostly funded by multilateral lending agencies[13]; investment in these projects has grown considerably over the last few years (Izaguirre, 2000; Castellano, 2015; Eberhard, 2017).

The electricity market thus hinges on a hybrid structure combining the former operator, now buyer, with the new entrants. The structure functions with competitive calls for tender. Any accords between the two parties are regulated by electricity buying agreements entered into over long periods (World Bank, 1993; USAID, 1994). Several specific clauses (amount of energy allocated; amount of fees to be invoiced for fuel and insurance; *force majeure*; transfer, cancellation, and modification of legal, refinancing, and revenue stream provisions) are set in advance to guarantee financial viability for the state-owned utilities while securing revenue streams for the new entrants.

Over 20 IPPs were established between 1990 and 2011, producing a total of 4 GW (Eberhard, 2011).

The IPPs have made several contributions:

- **Growth in existing production facilities**

In some cases, IPPs exceeded the production capacities of the state-owned utilities (Karekezi & Kimani, 2002; Eberhard & Gratwick, 2008). In Togo, the IPP in Lomé (CTL) increased the country's total installed capacity from 149 to 249 MW, supplying the equivalent of 67% of the country's total nominal capacity. in Uganda, Bujagali, an IPP established in the 1990s, increased total production capacities by almost 30% (or 250 additional MW), going so far as to make up 45% of total production in 2013. In Kenya, IberAfrica built a plant that produced 109 MW between 1996 and 2008 (Eberhard & Gratwick, 2008).

Some IPPs also use renewable energy: hydroelectricity in the Bugajali plant in Uganda with a nominal capacity of 250 MW; geothermal in the Kenyan IPP Or Power; wind power in two IPP plants in Lake Turkana in Kenya that produce 300 MW, and another in Kinangop province that was in the 60 MW category; biomass using bagasse in Mauritius that powers a 110-MW IPP plant. On the other hand, the state-owned utilities have not chosen to utilize renewable energy.

---

[13] The International Finance Corporation (IFC), a member of the World Bank, financed about one-third of private energy projects in Sub-Saharan Africa (Hoskote, 1995; Eberhard & Gratwick, 2008).

A complete list of IPPs can be found in a table in Appendix 1.

- **Improved urban access**

Electricity supplied by IPPs has considerably improved access to the grid (Eberhard & al, 2011). This access increased from 23% in 1990-1995 to 27% in 1996-2000 to 30% in 2000-2005.

- **Improved financial situation for the state-owned utilities**

IPPs considerably improved the techno-economic performance of the state-owned utilities in terms of revenue collection, better customer billing, and decreased system losses. In Côte d'Ivoire, for example, the revenue collection rate of the EECI approached 98%. Similarly, in Eritrea, power outages dropped to nine hours per year after the market was privatized (United Nations Economic Commission for Africa, 2006). NamPower, the Namibian public power company, considerably reduced its system losses in electricity transportation and distribution, from 14% in 1998 to 8% in 2004 (United Nations Economic Commission for Africa, 2006). And in Senegal, SENELEC increased sales by 5.7% (United Nations Economic Commission for Africa, 2006).

- **Renewable-energy IPPs are competitive with state-owned thermal plants**

This can be seen in several examples. The Bugajali hydroelectric station in Uganda (250 MW) produced power at $0.10/kWh, much less than the thermal power produced by the state-owned utilities ($0.24-0.27/kWh). Similarly, the OrPower geothermal station in Kenya produced power assessed at $0.09/kWh, much less than the thermal plants ($0.20-0.33/kWh)

However, IPPs have several disadvantages:

- **Over-concentration in certain SSA countries**

This is especially true in South Africa, which over four years saw 6327 MW of independently produced power (Eberhard & Kåberger, 2016; Eberhard, 2014, 2016). Due to competitive tenders for renewable energy, the cost of this energy has decreased by 46% for wind power and 71% for solar (Eberhard & Kåberger, 2016; REN21, 2016).

In the rest of Sub-Saharan Africa, only 21 power projects were funded, with a total investment of less than $2 billion (Izaguirre, 1998). The guaranteed electricity buy-back programs in Kenya and Uganda were not attractive enough (BNEF & &l, 2014).

- **IPP plants generally continue to use thermal energy, ignoring the whole range of renewable energy**

In 2014, 82 % of IPPs used thermal energy: heavy fuel oil (HFO) and natural gas (Karekezi & Kimani, 2005).[14] Very few IPP plants use renewable energy exclusively. For example, in 1998, less than 5% of these plants used hydropower. The thermal IPPs widely reinforced the lack of technological proficiency: only 41% of them were still operational in 2001 (Financial Times Energy, 2011a-c).

IPPs are also vulnerable to fluctuations in the price of HFO: from the 1990s to the mid 2000s, its price was over $40 per tonne, which greatly reduced these plants' competitiveness (Ormat, 2009).

Finally, from an organizational point of view, the overdependence on thermal energy led to long and costly transactions among the various stakeholders (Agence Française de Développement, 2012).

- **The buyer structure faces multiple organizational problems**

This is especially due to delays in certain IPP projects (GTI Dakar, Bui Hydro's Kounoune plant in Ghana, Bugajali in Uganda, and the Lomé Thermal Plant in Togo) leading to substantial changes in the clauses in IPP fixed contracts (e.g., AES Barge's Okpai plant in Nigeria and Independent Power Tanzania Limited's (IPTL) Songas plant in Tanzania).

Organizational problems linked to overly generous contract clauses should be emphasized. Many IPPs have been accused of artificially inflating their costs (e.g., IberAfrica, an IPP in Kenya). Many state-owned utilities therefore needed to renegotiate their contracts, especially in terms of end-use fees (in the case of the Power 4 and Songas IPPs in Kenya and the AES in Nigeria).

The creation of IPPs was limited, in the end, by the lack of transparency throughout the countries of Sub-Saharan Africa. It should be noted that quite often IPP contracts were hastily negotiated in crisis situations, beginning in the 1990s, when many competitive calls for tender were cancelled (Gratwick & Eberhard 2008).

- **IPPs target the urban consumption niche, mostly ignoring rural demand**

In Africa, IPP plants were mostly established close to the grid system to reach a critical mass of urban users while mostly ignoring rural demand.

---

[14] This trend is likely to continue due to the development of Combined Cycle Gas Turbine plants (CCGT).

The introduction of private producers was accompanied by a second change that affected electricity supply throughout Sub-Saharan Africa. Mini-grids created a new demand dynamic at a time when HFO prices were rising and the cost of renewable energy was trending downward.

3.2. A novel demand mechanism: mini-grids in Sub-Saharan Africa.

- ❖ **A technological innovation,** based on the new and more decentralized mini-grid system offering an alternative to conventionally produced on-grid power.

Mini-grids can be connected to either local thermal production or hybrid production including renewable energy, if available and depending on local demand, which varies widely. Mini-grids have certain advantages:

- ❖ **Because of the sparseness of supply, mini-grids have spread throughout SSA, using mostly renewable energy sources**

In comparison with grid systems, renewable mini-grids seem to be an unbeatable option given the decentralization of rural electrification. The technological developments attributed to mini-grids led to upheavals in the organizational and contractual frameworks of upcoming projects (Agence Française de Développement, 2012). We should also consider industrial auto-production, with excess power sold at a fixed rate. Power production through small independent producers requires setting a rate structure for electricity (Agence Française de Développement, 2012).

- ❖ **The development of mini-grids was spurred by the reduction in renewable energy costs and the increase in petroleum prices**

The cost of solar panel production has dropped significantly in terms of its primary components like the module, converter, and wiring, making it more competitive (Agence Française de Développement, 2012), especially given the parallel rise in the price of imported petroleum.

Moreover, this technology can be used in hybrid configurations combining diesel with renewable energy. Diesel is now no longer used as the main production fuel but as a back-up (IRENA, 2016).

Many such mini-grids have thus been created, substituting for diesel plants connected to the main grid system in, for example, South Africa, Sudan, Kenya, Nigeria, and Senegal. In sub-Saharan Africa, there is no less than 19.7 MW of installed capacity in the form of hybrid mini-grids combining diesel and renewable energy (IRENA, 2016).

Mini-grids are becoming more competitive. At the beginning of the 2000s, each kWh they produced is estimated to have cost $1.90-5.90 (for a baseline 200 KW system), while the cost of a hybrid system was estimated at $2.50-10.90 per watt (IRENA, 2017).

- **The rapid growth in renewable mini-grids can be explained by financial support to the entire industry**

The boom in mini-grids can be attributed to numerous aid programs established through many countries in sub-Saharan Africa providing subsidies to encourage the emergence of these systems. For example, AMADER (the Malian agency for the development of domestic energy and rural electrification) set up 150 mini-grids in Mali; the Senegalese agency for rural electrification had a similar initiative. Similarly, over 200 renewable mini-grids are owned and operated by village electricity consumer societies.

This subsidy policy is still necessary. It can also be accompanied by cross-subsidization, when the mini-grids set up include small urban clusters or large villages with a concentration of economic activity, as in the Sava Valley in Madagascar.

- **Mini-grids a new form of supply, help stimulate demand, especially in rural households**

Due to their decentralized nature, these technological options meet the needs of rural power demand. Demand for electricity is low in SSA, characterized by power needs mostly related to lighting (Agence Française de Développement, 2012). Consumption generally peaks sharply in the evening (3-4 times the rate in the morning) and is otherwise very low throughout the day. This demand needs to be developed in order to ensure that decentralized production systems can be profitable, and to create return on investment by avoiding low usage rates when rural demand is saturated due to a low connection rate (Agence Française de Développement, 2012). The combined demand of rural households can only grow with the help of appropriate household appliances, which requires income growth. The dynamics around demand involve a progressive increase in productive and commercial use of electricity in combination with increase in rural incomes, thus ensuring the profitability of rural electrification programs.

Their development is still hindered by certain limits, however.

- **Mini-grids are still subject to the costs of compensating for intermittency in renewable energy**

Intermittency brings up the question of calibrating production to meet demand in order to avoid under-utilization of equipment and the ensuing rise in cost per kWh. One of the main problems with solar mini-grids is that production needs to be during the day, while demand in most rural communities tends to be nocturnal. These technologies thus need to store their electricity in expensive batteries.

With renewable mini-grids, the cost of compensating for intermittency are so high that some customers, especially those in rural or peri-urban areas, decide to go on-grid to have guaranteed access to electricity. Such is the example of Sri Lanka, where electricity from renewable mini-grids built and managed by VECS (village electricity consumer societies) was extremely expensive as compared to that from the state-owned CEB (Ceylan Electricity Board), which provided better-quality and more reliable electricity (Tenenbaum & al, 2015). Rural and peri-urban households, moreover, tend to compare the basic-needs electricity rate offered by the state-owned utility, about $0.025-$0.03/kWh, to mini-grid prices at $0.25/kWh.

- **Mini-grid power is prohibitively expensive for rural populations, given the inferior power services they offer**

The costs for a solar mini-grid, mostly related to batteries and photovoltaic modules, make them financially inaccessible for most rural communities. [15]

It should be noted that existing mini-grids are often linked to small distribution networks of less than 11 kilovolts (KV) that only produce a low installed capacity of about 8 to 10 MW (Tenenbaum & al, 2014). Despite examples that point to the possibility of developing larger mini-grids, such as the solar systems connected to industrial activities in the South Deep mine in South Africa, the power that these systems provide is still extremely limited due to intermittent energy production (Tenenbaum & al, 2014).

- **Mini-grids are in competition with thermal plants on the grid**

In many cases, renewable mini-grids rare extremely expensive. For example, in Uganda, one kWh of power from a renewable mini-grid costs about $16.40. The rates offered to residential customers are currently $0.50/kWh, two to three times higher than the preferential rates offered to low-income customers by the state-owned companies. Renewable mini-grids create strong tariff differentiation, to the point at which they end up being connected to the national power network to eliminate this large disparity between state power customers and mini-grid customers (Tenenbaum & al, 2014).

---

[15] A breakdown of the average costs of a solar mini-grid: 27% battery, 20% for the photovoltaics, 7% for the converter, 5% for the wiring and 4% for installation and transmission of electricity (IRENA, 2018).

The appearance of off-grid power in the 2000s led to a new demand dynamic as these solutions targeted rural populations who had been excluded from both the main power grid and mini-grids.

Part 4. Supply forms in the early 2000s: The emergence of off-grid power

4.1. Market fit of new off-grid forms of electricity production

- **Due to its versatility, off-grid power meets a segment of rural demand by exploiting the potential of renewable energy**

Off-grid power made its appearance in the 2000s, forcing public services to reconsider other institutional agency models (Ackermann & al, 2001). According to the IEA, 60% of future access to electricity will pass through off-grid systems (IEA, 2010; Mandelli & al, 2016).

The main advantage of off-grid power is that it aims to satisfy rural demand, which has been unmet up to now. More specifically, it makes it possible to monetize a latent willingness to pay that has not been satisfied by on-grid solutions. Many studies have highlighted that this population pays much more than do on-grid customers, or $10.00 per resident per month (IEA, 2012; African Energy Outlook, 2014).

Off-grid power has come to rural areas through solar home systems[16]. These innovative systems are based in local businesses that want to invest in rural electrification. In terms of supply, the technology appears to be flexible, using small home solar power systems that generate 20-100 watts. In terms of demand, off-grid power aims to satisfy the power needs of rural households by providing them with lighting and a way to charge their phones. Baurzhan and Jenkins (2016) show that under certain conditions, home solar systems would allow a 5-person household to save the equivalent of $31.20 per year if they own one mobile phone, $62.40 for two, and $93.60 for three (Baurzhan & Jenkins, 2016).

- **Solar off-grid power is becoming competitive due to the sharp fall in the cost of solar power components**

In 2016, off-grid solar installations produced electricity that cost $0.83/kWh, using the 10% discount rate in 2016 (Baurzhan & Jenkins, 2016; Quansah, 2016).

---

[16] Kenya, South Africa, Zimbabwe, and Tanzania are the countries on the cutting edge of off-grid solar power: they have developed 320 000, 150 000, 113 000, and 65 000 home solar systems respectively (IRENA, 2015b).

There are two categories of cost reduction depending on installed capacity. For systems with an installed capacity of 1 kW or more, cost reductions are mainly related to the photovoltaic array (14.5 to 17.5 %), batteries (11 to 21 %), converters (11 to 22 %), and other materials (29 to 36 %).

For systems under 1kW, total installation costs vary from $20.00 for a 20W system to $1270 for a 100 W system. Because of the small size of the off-grid solar system, the main cost is replacing the battery, which varies between $56 and $214 per year. This cost, however, is falling sharply. Current home solar systems are based on deep-cycle lead-acid batteries, but a new generation of lithium-ion batteries are about to come onto the market (IRENA, 2016), making these systems even more affordable.[17]

- **Off-grid power is competitive with kerosene lamps, driving the demand function for rural households**

The competitiveness of off-grid solar installations should be examined in terms of the power services provided to households. Currently, households with no access to the grid pay between $84 and $270 per year for lighting and phone charging needs (BNEF, Lighting Global, World Bank & Gogla, 2016 & IRENA, 2016). Very small home solar systems are still very affordable in comparison to traditional lighting solutions such as candles, kerosene lamps, and battery-operated flashlights. The cost of an off-grid solar installation was estimated to be $51 in 2016, which is 2.3% of average household income. In comparison, rural households can spend $56 on kerosene lamps, or 2.6% of average household income.

Off-grid solar power remains competitive with kerosene lamps because it offers a better quality of light. For example, a 2W LED bulb produces about 380-400 lumens of light as opposed to 8-40 lumens emitted by a kerosene lamp.

4.2. The limits of off-grid power

- **It is expensive for most of the rural population**

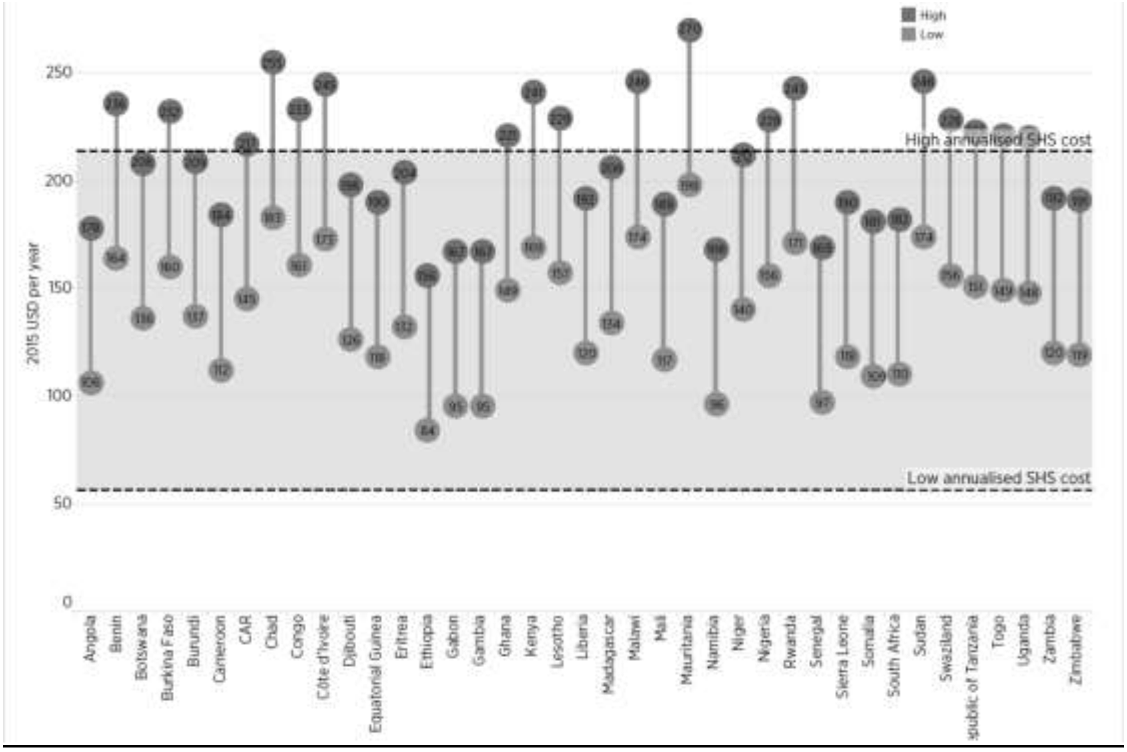
Three-quarters of those living below the poverty line live in rural areas (Eberhard, 2014). The monthly energy expenses of these households rarely exceed $2. Therefore, an off-grid solar installation remains extremely expensive for these households (Karekezi & Kithyoma, 2002), representing 100-

---

[17] The average cost of a 1 kW home solar system with a storage capacity of 20-220 ampere hours (Ah) is about $2 per Ah. There is a wide variance in the cost of batteries, on a scale from $2.10 to $6.8 per watt produced (IRENA, 2016).

200% of their average annual income (Karekezi, 2005; African Energy Outlook, 2014). Despite a general tendency towards lower costs for solar installations, they would currently make up a large portion of household budget (estimates vary from 22 to 61%).

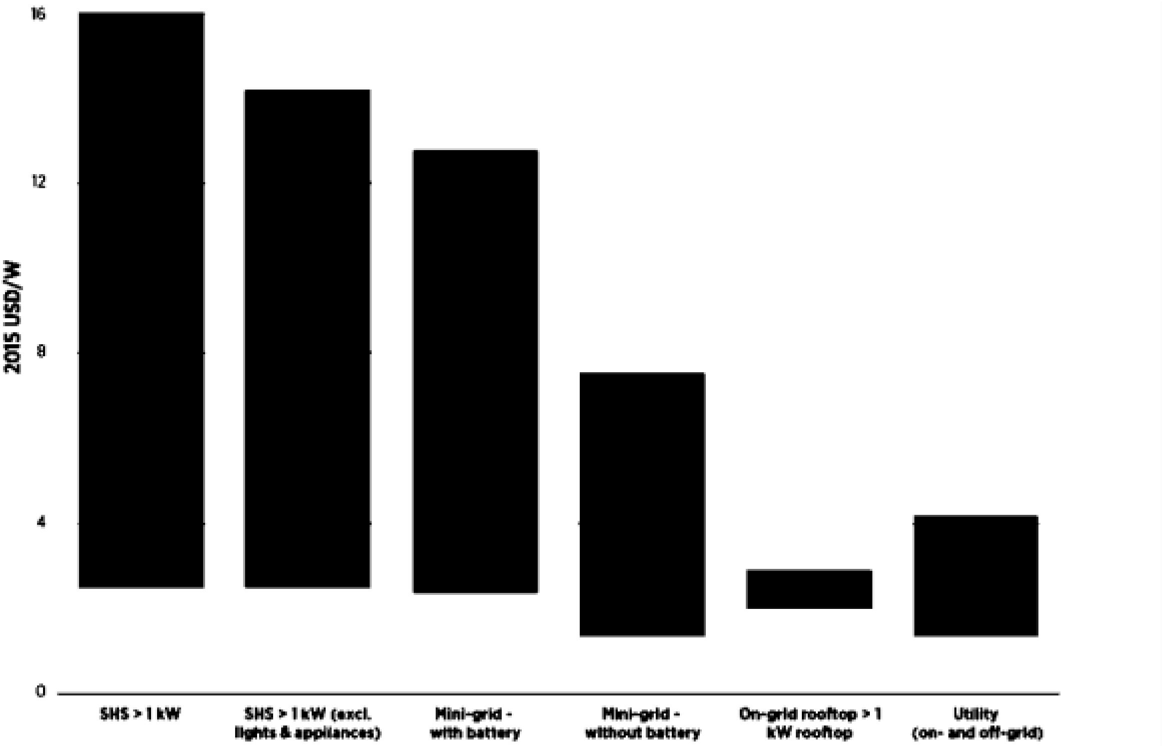
Figure 1. Comparison between annual expenses of an African household and the cost of a home solar system (less than 1 kW) in 2015



Source: IRENA, (2016)

Note: The blue strip represents the range of annual costs for a solar home system (SHS), while the circles represent the high and low annual household expenses for off-grid power for lighting (kerosene, batteries, candles) and phone charging.

Figure 2. Cost of solar home systems in sub-Saharan Africa (2009-2016)



Source: IRENA (2016a)

The reduction in cost for off-grid solar technology is thus insufficient. Baurzhan and Jenkins (2016) confirm this hypothesis in their analysis of solar energy in sub-Saharan Africa. Using their calculations of the levelized cost of energy (LCOE) of off-grid solar technology ($0.83/kWh) and considering an annual rate of cost reduction in solar arrays of 4% and 7.67% respectively, the authors find that it would take between nine and seventeen years for solar home system to be competitive with conventional diesel plants.

❖ Off-grid power must still compete with thermal plants

In forecasted scenarios, off-grid access to electricity is a dominant solution (African Energy Outlook, 2014; World Energy Outlook, 2017). By the year 2030, the cost of these technologies will have continued to fall sharply (African Energy Outlook, 2014; World Energy Outlook, 2017).

Nevertheless, due to their high initial costs, off-grid solutions must still compete with on-grid thermal systems, often backed up with diesel generators. Diesel and petrol are subsidized in some SSA countries that produce and export them (Nigeria, Angola, Gabon). These low fuel prices are attractive to consumers, who are more likely to choose low-cost fossil fuel solutions over renewable off-grid options (African Energy Outlook, 2014; World Energy Outlook, 2017).

- **Off-grid power still provides inferior power service to customers, who take on the problem of intermittency**

Off-grid solar solutions (Pico solar lanterns, solar home systems) have low installed capacities (between less than 3 watts and 2 kW). While they are ideal in the sense that they provide access to electricity to people far from the main grid, these solutions are still limited in terms of the power service they can provide to end consumers (African Energy Outlook, 2014). This is particularly true for solar kits (Agence Française de Développement, 2012), which, despite the 50% drop in price over the last 15 years, still produce only 50 watts and only produce energy for light, phone charging, and audiovisual use for only 3-6 hours for even the most powerful systems. Consequently, these off-grid systems cannot offer sufficient energy services to rural and peri-urban populations (Agence Française de Développement, 2012), making grid access remain relevant.

In sub-Saharan Africa, the power system is still characterized by major changes in electricity supply. Starting with an inadequate grid system, production solutions focused on more decentralized solutions (mini-grid and off-grid), which are, however, limited and expensive (for example, some developers lock their off-grid supply). These various changes are the results of shifts in electricity demand. In fact, there are many levels of demand across sub-Saharan Africa, with all electricity systems hinging on the baseline price of on-grid electricity. All of these changes can be illustrated through theoretical propositions showing the dynamics of unmet demand and their impact on the forms of electricity supply production.

Part 5. The dynamics of unmet demand and their consequences on the major changes in supply types observed in electricity production.

The appearances of new forms of electricity supply following the development of the mini-grid in the 1990s and off-grid power in the 2000s led to different dynamics at the demand function level. We will analyze them through several theoretical propositions:

Proposition 1. Two limitations to natural monopoly are free-riding and back-up costs, the first of which is internalized and the second not;

Proposition 2: Supply- level dynamics: decentralized solutions emerge as a response to inadequacies in the centralized on-grid supply and become competitive (decentralized technology based on renewable energy) with conventional means of production under certain conditions;

Proposition 3. Demand dynamics depend on the type of power (on-grid, mini-grid, off-grid),

Proposition 4. All these dynamics throughout the electrical network move in a cobweb curve, spinning demand around a new equilibrium price.

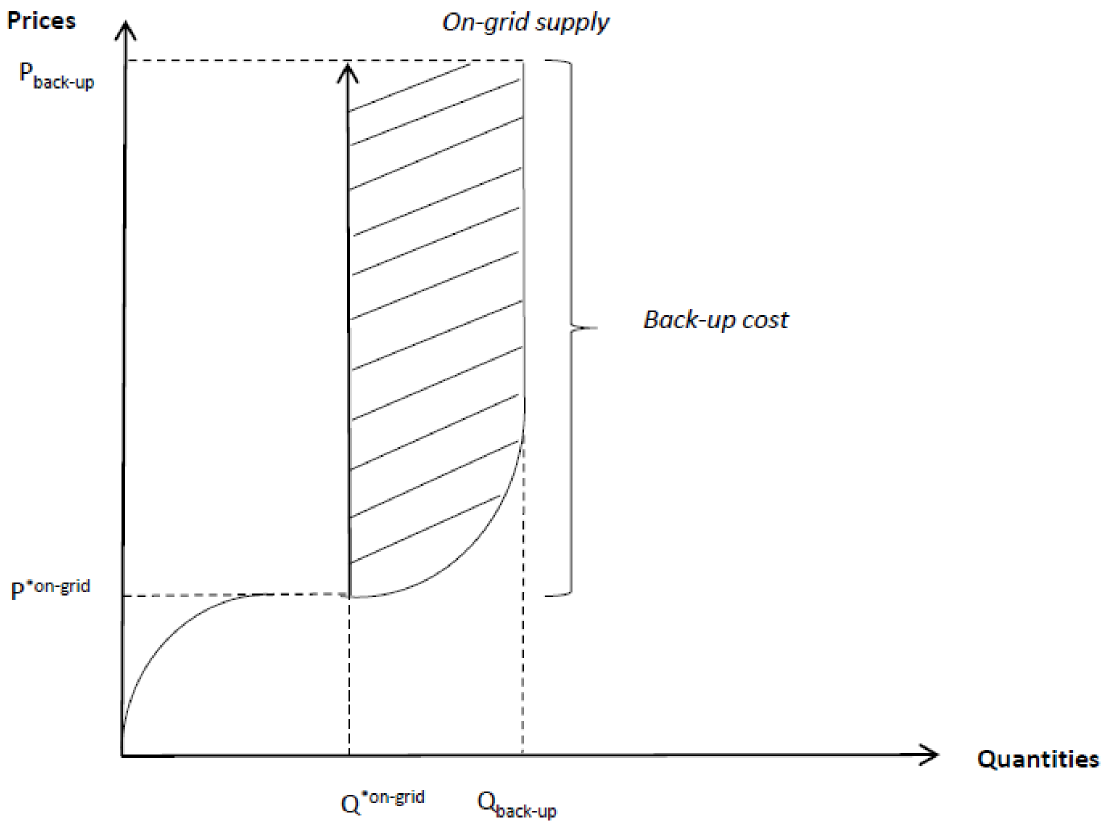
Proposition 1. Illustration of the inadequacy inherent in natural monopolies

Natural monopolies use conventional means of production to meet the demand that they encounter. The point of natural monopolies is to be able to increase the number of beneficiaries without rationing by spreading costs among the growing number of consumers. In the case of SSA, this principle finds its first limit in consumers who do not pay for power, or free-riders. This limit can be internalized by a natural monopoly.

On the other hand, natural monopolies in SSA are faced with another limit that is not internalized: technical weaknesses that cause a discontinuous distribution of electricity. To deal with this, the natural monopoly needs to offer a back-up supply.

The increase of on-grid demand shifts the supply curve, making the cost of back-up power visible. Within the equilibrium of supply and demand, the two limiting principles of natural monopolies can be summarized by free-riding and unmet demand that cannot be covered by the main grid system.

Figure 3. The cost of back-up power



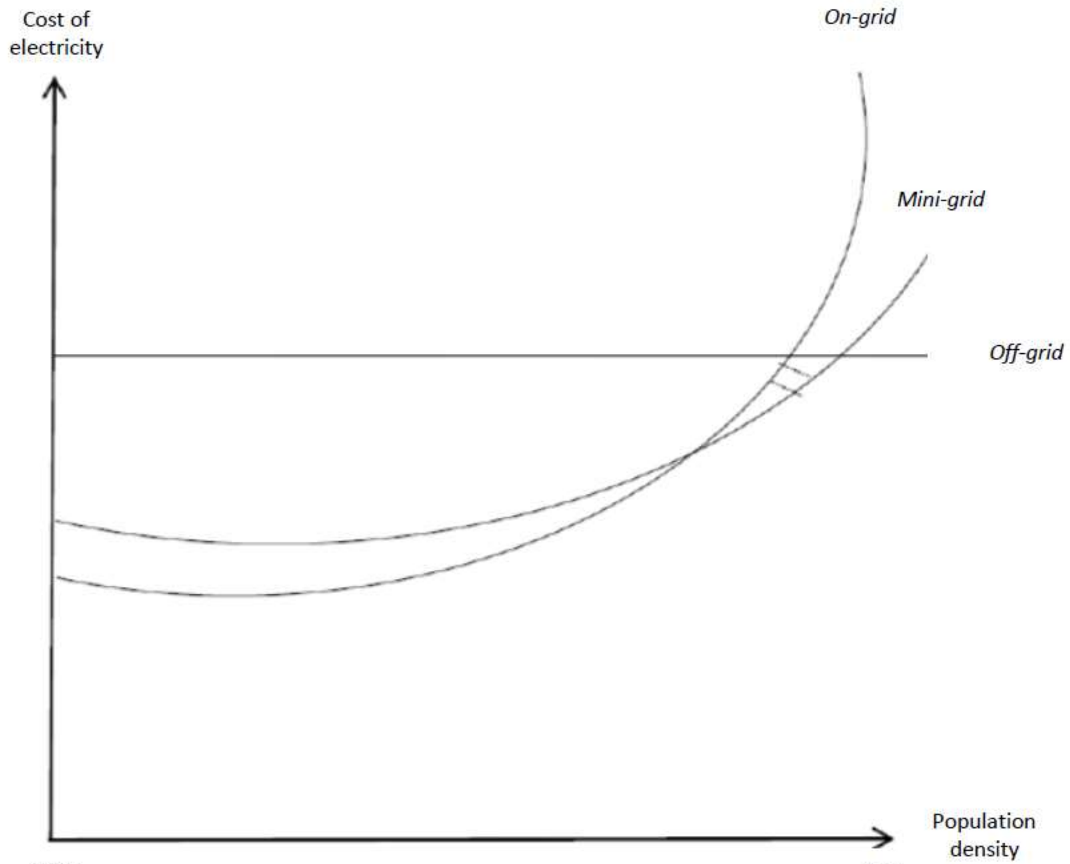
The equilibrium point for the grid system is at ($P^{*on\text{-}grid}$; $Q^{*on\text{-}grid}$). The cost of back-up power is prohibitive (Cross-hatched section with high $P_{back\text{-}up}$). This shows the inability of the natural monopoly to resolve inadequacies observed in the grid system. As a result of demand pressure, new decentralized systems, mini-grid and off-grid, arise in the attempt to compete with conventional means of grid production.

<u>Proposition 2.</u> Decentralized supply forms and how they fit with on-grid, mini-grid, and off-grid systems

New decentralized supply types appeared in SSA as a result of the inadequacies of the grid system and the large unmet demand in rural areas. The emergence of these supply types was encouraged by technical progress in renewable energy.

However, these two technologies are not mature; mini-grid power faces competition from on-grid power at short distances and from off-grid at long distances.

Figure 4. Cost comparison between on-grid, mini-grid, and off-grid power



We assume that price elasticity of demand for the quantity demanded is identical for each network. For off-grid power, since the cost of a solar kit is equivalent to the cost of electricity, it is seen as a vertical line.

Mini-grids are more profitable in dense communities sufficiently far from the grid network, where the consumer price of grid electricity is high, and in areas with reliable supplies of renewable energy (cross-hatched area). Mini-grids are most cost-effective for applications requiring average quantities of electricity.

On the other hand, in very densely populated areas or very remote areas, on-grid and off-grid power are more competitive.

Proposition 3. Demand characteristics for on-grid, mini-grid, and off-grid power

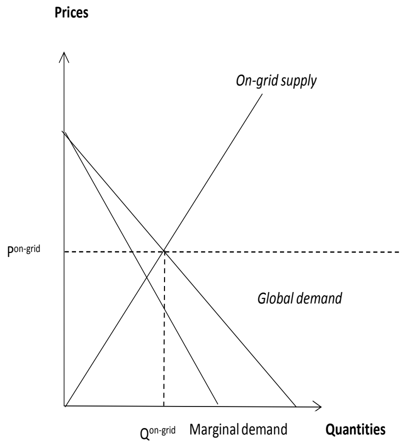


Figure 5. **On-grid demand**

Supply does not ration demand. The whole network hinges on the equilibrium of quantities offered by the grid and prices that match these quantities ($P_{on\text{-}grid*}$; $Q_{on\text{-}grid*}$). Quantities consumed may vary from several megawatt hours to several gigawatt hours.

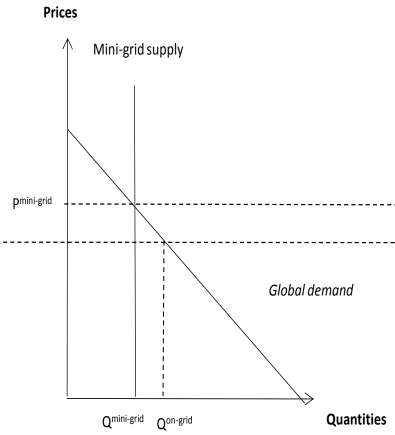


Figure 6. **Mini-grid demand**

Supply rations demand. Demand is constrained by the capacity the mini-grid can supply; the curve thus becomes vertical. Quantities consumed (Qmini-grid) are distinctly lower than those on the grid (only a few kilowatt hours consumed). The price of mini-grid power (Pmini-grid) is higher than that on the grid (Pon-grid).

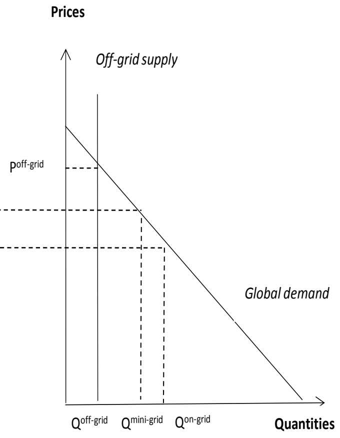


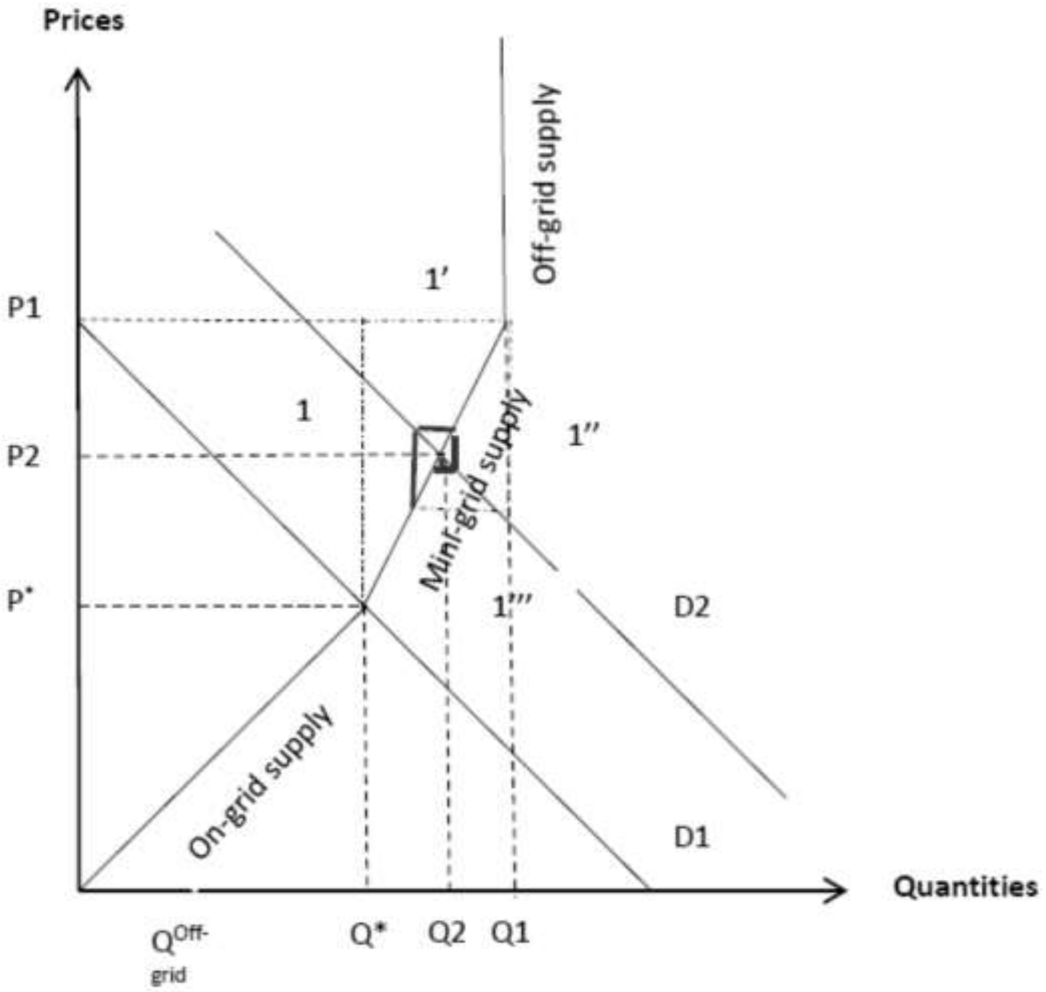
Figure 7. **Off-grid demand**

Supply rations demand. Off-grid prices are higher than both mini-grid and on-grid prices.

Proposition 4. Cobweb shift of the network ensemble and spinning of demand around a new equilibrium price

This proposition takes into account that different types of demand, served by different supply forms, are not indifferent to each other. The growth in demand makes consumers more aware of different prices for electricity. The electricity market will incite consumers to obtain the best price.

Figure 8. Cobweb model of the network ensemble



where D_1 is on-grid demand and D_2 is aggregate demand (on-grid + mini-grid + off-grid). The supply function is also aggregate, represented by a bent curve. Two movements can be seen. Movement 1 takes place when $Q^*_{D1} = Q^*_{D2}$. Variations in demand lead to an increase in price, from p^* to p_1. In response to Movement 1, Movement 2 translates a variation in demanded quantity, moving from Q^* to Q_1 (1'' on the graph). The price then falls (1''). The ensemble of networks tends to converge at an equilibrium set at P_2 (1'''). These decentralized solutions converge towards this equilibrium without ever attaining it because of characteristics inherent in these immature networks.

Conclusion

In sub-Saharan Africa, centralized on-grid power supply has not been able to respond to the challenges of access to electricity for a large portion of the population. Privatization, which took place in the 1990s, was supposed to expand access by extending the networks that the older public companies were incapable of financing. This privatization was accompanied by two movements: one was competition in the electricity segment with IPPs and the second was the appearance of mini-grids based on renewable energy (solar, small hydroelectric, and wind). These mini-grids, the result in a change in supply coming from demand mechanisms, was an undeniable economic opportunity for rural households that had been excluded from access to electricity from conventional centralized means of production. The fairly rapid emergence of mini-grid power can also be explained by the considerable drop in installation costs and electricity pricing that remained competitive compared to the thermal production sources that had been the norm. Beginning in the 2000s, a second change took place with the appearance of off-grid power. All of these decentralized systems, however, share the problem of the inferior power services they deliver and their cost. Due to reasons inherent to these decentralized solutions, access to electricity through the grid has become relevant again, since the grid remains more economically sustainable.

In sub-Saharan African countries, electrification depends on innovative plans for developing electricity supply, leading to a co-existence, at a growing cost, of centralized and decentralized networks. It would be useful to examine the state of the current networks as well as the potential of joining decentralized networks to each other or to the central grid, leading to rural electrification. This new meshing of supply stemming from demand dynamics makes it possible to imagine new designs in energy policy that go beyond the current limitations: supply oriented towards the maintenance and improvement of the grid system without responding to the needs of rural populations and mini-grids supplying small amounts of expensive power to those rural populations.

References

Adamientes, A. G. & Besant-Jones, J.E. & Hoskote, M. (1995). *Power sector reform in Developing Countries and the role of the World Bank.* Paper presented at the 16th Congress of the World Energy Council, Tokyo, October 8-13.

Ackermann, T. & al. 2001. Distributed generation: a definition, Electric Power Systems Research; 57.

African Energy Outlook. 2014. *A focus on energy prospects in Sub-Saharan Africa*. World Energy Outlook Special Report, International Energy Agency

Agence Française de Développement. 2012. *Accès à l'électricité en Afrique Sub-Saharienne : retours d'expérience et approches innovantes*. Document de travail.

Autorité Nationale de Régulation du Secteur de l'Electricité. 2005. *Rapport d'activités.*

Bacon, R.W. 1999. *A scorecard for energy reform in developing countries*. Finance Private Sector and Infrastructure Network, the World Bank Group.

Bacon, R.W. & Besant-Jones, J. 2002. *Global Electric Power Reform, Privatization and Liberalization of the Electric Power Industry in Developing Countries*. Energy and Mining Sector Board Discussion Paper Series Paper n°2, the World Bank Group.

Banque Mondiale. 1993. *The World Bank's role in the Electric Power Sector*. Washington D.C. Banque Mondiale. 1995. *Bureaucrats in Business*. Washington D. C.

Banque Mondiale. 1995. *Bureaucrats in Business*. Washington D. C.

Banque Mondiale. 2017. Africa's Pulse : une analyse des enjeux façonnant l'avenir économique de l'Afrique. Volume 16.

Baurzhan, S. & Jenkins, G. 2016. *Off-grid solar PV: Is it an affordable or appropriate solution for rural electrification in Sub-Saharan African countries?* Renewable and Sustainable Energy Reviews, Vol.60, pp: 1405-1418.

Bazilian, M. Nussbaumer, P. Rogner, H.-H. Brew-Hammond, A. Foster, V. Williams, E. Howells, M. Niyongabo, P. Musaba, L. Gallachóir, B.Ó. Radka, M. Kammen, D. 2012. *Access scenarios to 2030 for the power sector in sub-Saharan Africa*. Utility Policy, vol. 20, pp. 1-16.

Bloomberg New Energy Finance. Lighting Global & Gogla. 2016. *Off-grid solar market trends report 2016*. World Bank Group.

Castellano, A. Kendall, A. Nikomarov, M. Swemmer, T. 2015. Brighter Africa: McKinsey & Company Monthly Journal.

Chevalier, J.M. 1995. *Les réseaux de gaz et d'électricité : multiplication des marchés contestables et nouvelle dynamique concurrentielle*. Revue d'économie Industrielle, Vol.72 (2), pp : 7-29.

Commission économique des Nations Unies pour l'Afrique & Commission UNEP (United Nations Environment Programme). 2006. *Making Africa's Power Sector Sustainable: An Analysis of Power Sector Reforms in Africa*. New York: United Nations.

Coquery-Vidrovitch, C. 2002. *La politique de réseaux d'électrification en Afrique. Comparaison Afrique de l'Ouest, Afrique du Sud ou comment faire de l'histoire sociale à partir de sources économiques*. Outre-Mers, 334-335, pp. 71-84.

CNUCED. 2014. *Le développement en Afrique, rapport de 2014, catalyser l´investissement pour une croissance transformatrice en Afrique*. Nations-Unies.

Eberhard, A. & Gratwick, N.K. 2008. *Demise of standard model for power sector reform and the emergence of hybrid power markets*. Energy Policy, pp. 3948-3960.

Eberhard, A. & Malgas, I. 2011. *Hybrid power markets in Africa: Generation planning, procurement and contracting challenges*. Energy Policy. Vol. 39, pp. 3191-3198.

Eberhard, A. Rosnes, O. Shkaratan, M. Vennemo, H. 2011. *Africa's Power Infrastructure: Investment, Integration, Efficiency. Directions in Development*. World Bank. https://openknowledge.worldbank.org/handle/10986/2290.

Eberhard, A. & Shkaratan, M. 2012. *Powering Africa: Meeting the financing and reform challenges*. Energy Policy, Vol. 42, pp 9-18.

Eberhard, A. Gratwick, K. Morella, E. & Antmann, P. 2014. *Independent Power Projects in Sub-Saharan Africa: lessons from Five Key Countries"*. World Bank Group, Directions in Development, Energy and Mining.

Eberhard, A. & Kåberger, T. 2016. *Renewable energy auctions in South Africa outshine feed-in tariffs*. Energy Science and Engineering 4(3)

Eberhard, A. Gratwick, K. Morellac, E. Antmann, P. 2017. *Independent Power Projects in Sub-Saharan Africa: Investment trends and policy lessons*. Energy Policy, Vol. 108, pp. 390–424

Edjekumhene, I. Amasdu, M. B. & Brew-Hammond, A. 2001. *Power sector reform in Ghana: The untold story*. KITE, Ghana.

ESMAP. 2000. *Introducing competition into the electricity supply industry in developing countries: lessons from Bolivia*. Washington D.C.

Girod, J. & Percebois, J. 1998. *Reforms in sub-Saharan Africa's power industries*. Energy Policy, Vol. 26, No.1, pp. 21 -32.

Hansen, J.P., & Percebois, J. 2010. *Energie, Economie et politiques*. Préface de Marcel Boiteux, Avant-propos de Jean Tirole, Aux éditions De Boeck.

Hoskote, M. 1995. *Independent Power Projects (IPPs): An Overview*. Energy Note 2. In Energy Themes, ed. R. English. Washington, DC: World Bank

International Energy Agency.2002. *World Energy Outlook: Energy & Poverty Special Issue*. OECD/IEA, Paris.

International Energy Agency. 2010. World Energy Outlook.

International Energy Agency. 2017. World Energy Outlook.

Ikeme, J. Ebohon, O.B. 2005. *Nigeria's Electric Power Sector Reform: What should for the key objectives*? Energy Policy, Vol. 33, pp. 1213-1221.

IRENA. 2015. *Off-grid renewable energy systems: Status and Methodological issues*.

IRENA. 2015. *Prospects for the African Power Sector*.

IRENA. IEA. Energy Technology Network. SAREC. & REN 21. 2015. *Renewable energy solutions to power Africa: bridging the gap for off-grid renewable energy deployment*.

IRENA. 2015b. *East African Power Pool: Planning and Prospects for Renewable Energy*.

IRENA. 2016. *Solar PV in Africa: Costs and Markets*.

IRENA (2018). *Renewable Power Generation Costs in 2017*.

Izaguirre, A.K. 1998. *Private Participation in the Electricity Sector*. Viewpoint 154. World Bank, Finance, Private Sector, and Infrastructure Network, Washington D.C.

Izaguirre, A.K. 2000. *Private Participation in Energy*. Note No. 208. Viewpoint 21464. World Bank.

Joskow, P.L. & Schmalensee, R. 1997. *Markets for Power: An Analysis of Electric Utility Deregulation*. MIT Press, Cambridge.

Kansara, M. & Walkade, N.S. 1983. *Forty years of electric power development in Kenya*. Energy, Vol.8 (4), pp 317-321.

Karekezi, S. 1994. *Energy Policies Issues in Africa*. Resources, Conservation, and Recycling. Vol. 12, pp 23-29.

Karekezi, S. & Kithyoma, W. 2002. *Renewable energy strategies for rural Africa: is a PV led renewable energy strategy the right approach for providing modern energy to the rural poor of Sub-Saharan Africa?* Energy Policy, Vol.30, pp 11-12 (107186).

Karekezi, S. & Majoro, L. 2002. *Improving modern energy services for Africa's urban poor*. Energy Policy, Vol.30, pp 1015-1028.

Karekezi, S. & Kimani, J. 2005. *Have power sector reforms increased access to electricity among the poor in East Africa*. African Energy Policy Research Network (AFREPEN).

Laparra, M. 2002. *Enelcam – Alucam : l'énergie hydroélectrique du Cameroun à la rencontre de l'aluminium*. Outre-Mers, 334-335, pp. 177-200.

Mandelli, S. Barbieri, J. Mereu, R. Colombo, E. 2016. *Off-grid systems for rural electrification in developing countries: Definitions, classification and a comprehensive literature review*. Renewable and Sustainable Energy Reviews, Vol. 58, pp. 1621-1646

Mauro, P. 1995. *Corruption and Growth*. The Quartely Journal of Economics, Vol. 110, issue 3, pp. 681-712

Mazrui, A.A. & Wondji, C. 1998. *L'Afrique depuis 1935*. Comité scientifique internationale pour la rédaction d'une Histoire générale de l'Afrique (UNESCO).

Mehyong, S.W. & Ndong, R.E. 2011. *L´ électrification de l'Afrique équatoriale française (AEF) dans la période de l´ après Seconde Guerre mondiale : aménagements hydro-électriques et rivalités interterritoriales*. Revue historique, n 657, p. 93-118.

Naudé, W.A. & Krugell, W.F. 2007. *Investing geography and institutions as determinants of foreign direct investment in Africa using panel data*. Applied Economics, Vol.39 (10), 1223-1233. Plane, P.

1996. La privatisation dans les pays en développement : déterminants et conséquences macro-économiques. Economie & prévision, 125, pp. 19-36.

Plane, P. 1997. *La privatisation de l'électricité en Côte-d'Ivoire : évaluation et interprétation des premiers résultats*. Revue Tiers Monde, 152, pp. 859-878.

Quansah, D.A. Adaramoral, S.A. & Mensah, L.D. 2016. *Solar Photovoltaics in Sub-Saharan Africa – Addressing Barriers, Unlocking Potential*. Energy Procedia, Vol. 106, pp. 97-110.

REN21. 2016. *Renewables 2016: Global Status Report*. Paris, France

Sambo, A.S. 2009. *Renewable Energy for Rural Development*. The Nigerian Perspective. ISESCO Science and Technology Vision 1, pp 12-22.

Saupique, T. 2002.*L´ électrification de la ville de Dakar après 1945*. Outre-mers, tome 89, n334-335, L'électrification d'outre-mer de la fin du 19ème siècle aux premières décolonisations, pp 85-104.

Segreto, L. 2002. *Electrifier un rêve : l´ industrie électrique dans les colonies*. Outre-Mers, tome 89 n°334-335, L´ électrification outre-mer de la fin du XIXème siècle aux premières décolonisations, pp. 235-249.Tanzi, V. & Davoodi, H.R. 2002a. *Corruption, growth, and public finances*. In G.T. Abed and S. Gupta, eds., Governance, Corruption, and Economic Performance. Washington, DC: IMF, 197-222.

Tanzi, V. & Davoodi, H.R. 2002a. *Corruption, growth, and public finances*. In G.T. Abed and S. Gupta, eds., Governance, Corruption, and Economic Performance. Washington, DC: IMF, 197-222.

Tenenbaum, B. Greacen, C. Siyambalapitiya, T. Knuckles, J. 2014. *Quand la lumière vient d'en bas : Comment les petits producteurs d'électricité et les mini-réseaux peuvent promouvoir l'électrification rurale et les énergies renouvelables en Afrique*. Directions in Development--Energy and Mining; Washington, DC: World Bank. https://openknowledge.worldbank.org/handle/10986/16571.

Turkson, J. & Wohlgemuth, N. 2001. *Power sector reform and distributed generation in Sub-Saharan Africa*. Energy Policy, Vol.29, pp 135-145.USAID & World Bank. 1994. *Submission and Evaluation of Proposals for Private Power Generation Projects in Developing Countries*. IEN Occasional Paper 2. World Bank, Washington, DC.

Varaschin, D. 2002. *EDF et l'Outre-mer, de 1946 au début des années 1960*. Revue d'histoire, 334-335, pp. 387-408

Wamukonya, N. 2003. *Power sector reform in developing countries: mismatched agendas*. Energy Policy, 2003, vol. 31, issue 12, 1273-1289

Wamukonya, N. 2005. *Power Sector Reforms in Sub-Saharan Africa: Some Lessons*. Economic and Political Weekly, vol. 40, No. 50 (Dec. 10-16, 2005), pp. 5302-5308

Wernick, A. Jerry, Haar. Latika, S. 2014. *The impact of governing institutions on foreign direct investment flows: evidence from African nations*. International Journal of Business Administration, Vol.5, No 2. C

Appendix

Appendix 1: List of IPPs in sub-Saharan Africa

Country	Project name	Installed capacity (MW)	Commissioning date	Consortium (Foreign holdings)	Power source	Type of contract	Lifespan (years)
Angola							
	Chicapa Hydroelectric Plant	16	2008	ALROSA Co. Ltd. (55 %) (yes)	Hydroelectric	BOT	40
	Biocom (Malange)	30	2014 (Financial closure)	Unknown	Cogeneration	Unknown	-
South Africa							
	Sasol	240	2010	Sasol (100 %) (non)	Open-Cycle Gas Turbine (OCGT)	MTPPP	5
Cameroon							
	Dibamba	88	2009	AES (56%), Cameroon government (44%) (yes)	HFO	BOT	20
	Kribi	216	2012	AES (56 %), Cameroon government (44%) (yes)	Combined-Cycle Gas Turbine (CCGT)	BOT	20
Côte d'Ivoire							
	CIPREL	210	1993	SAUR International (88 %); BOAD (12 %) (yes)	Natural gas	BOOT	20
	Azito	288	1996	CInergy (65.7 %); CDC and Globeleq (11	Natural gas	BOOT	20

				%); IPS-AKFED (23 %) (yes)			
Ghana							
	Takoradi II	220	1998	CMS (90%) then TAQA (90 %), VRA (10%) (yes)	Unknown	BOOT	25
	Suson Asogli	200	2007	Shenzhen & Togbe Afede XIV (100 %) (yes)	Incojn	BOO	20
	Bui Hydro	400	2005	Sinohydro (100 %) (yes)		BOO	Unknown
Kenya							
	Westmont	46	1997	Westmont (100%) (yes)	Kerosene / condensed gas / gas turbine	BOO	7
	IberAfrica	108.5	1997; 2000; 2009	Union Fenosa (80%); KPLC (20%) (yes)	HFO + Diesel (DDO)	BOO	7, 15, 25
	OrPower	48	2000; 2009	Ormat (100%) (yes)	Geothermal	BOO	20
	Tsavo	74	2001	Cinergy and IPS (49.9%); CDC and Globeled (30%); SFI (5%) (yes)	HFO + Diesel	BOO	20
	Rabai	90	2009	Aldywch-International (Netherlands, 34%), BWSC	HFO	BOOT	20

				(Danish, but owned by Mitsui of Japan, 25.5%), FMO (Netherlands, 20%), IFU (Danish bilateral lender, 20%) (yes)			
Nigeria							
	AES Barge	270	1999	Enron (100%) (yes)	Combined-Cycle Gas Turbine (CCGT)	BOO	13
	Okpai	450	2005	Nigerian National Petroleum Corporation (60%); Nigerian Agip Oil Company (Italy, 20%); Phillips Oil Company (20%) (yes)	Combined-Cycle Gas Turbine (CCGT)	BOO BOO	20
	Afam VI	630	2008	Nigerian National Petroleum Corporation (55%); Royal Dutch Shell (30%); Elf (Total) (10%); Agip (Italy, 5%) (yes)	Combined-Cycle Gas Turbine (CCGT)	BOO	20
	Aba Integrated	140	2005	Geometric Power Limited (100	Unknown	Unknown	15-20

				%)			
Uganda							
	Namanve	50	2008	Jacobsen (100%) (yes)	HFO	BOOT	6
	Bugajali	250	2011	Sithe Global (USA, 58%), IPS-AKFED (32%), Government of Uganda (10%) (yes)	Hydroelectric	BOT	30
Senegal							
	GTi Dakar	52	1999	GE Capital Structured Finance Group (SFG) (USA), Edison (Italy), IFC (yes)	Diesel/Nafta (DDO)	BOOT	15
	Kounoune I	68	2008	Mitsubishi (Japan), Matelec S.A.L (Lebanon) (yes)	HFO	BOO	15
Tanzania							
	IPTL	100	1998	Mechmar (70%), VIP (30%) (yes)	HFO, diesel (DDO)	BOO	20
	Songas	189	2004	TransCanada, Globeleq then AES (100 %) (yes)	Combined-Cycle Gas Turbine (CCGT)	BOO	20
Togo							
	Centrale Thermique	100	2010	Contour Global (USA, 80%%), IFC	Natural gas, HFO, Diesel	BOOT	25

	de Lomé			(20%) (yes)	(DDO)		
Zambia							
	Itezhi Tezhi	120	2014	Tata, (India, 50%), Zesco (Zambia, 50%) (yes)	Hydroelectric	BOOT	25

Sources: Eberhard & Gratwick, 2008; The Infrastructure Consortium for Africa (ICA), 2011; Eberhard, 2017

Glossary: DDO: Distillate Diesel Oil; HFO: Heavy Fuel Oil; OCGT: Open-Cycle Gas Turbine; CCGT: Combined-Cycle Gas Turbine: CCGT; BOOT: Build, Own, Operate, Transfer; BOO: Build, Own, Operate; MTPPP: Medium-Term Power Purchase Program.

SAUR International: joint venture between Bouygues Telecom and Electricité de France; BOAD: West African Bank for Development, Agence Française de Développement (AfD), and the IFC; Ci-energy: joint venture between Swiss company ABB and Globeleq.