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Beyond the grid: engineering, institutions and finance

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The production, distribution, and consumption of electricity in Africa is a disaster that blights the continent's economic and social prospects. And it has the potential to become much worse. The twentieth century power systems at the heart of the present supply infrastructure are inadequate to meet present day demand for reliable power. For the future the projected growth of both population and GDP per capita in Africa implies expanding demand resulting in worsening shortfalls unless radical strategies of expansion and change are implemented.

ENGINEERING ADVANCES FOR THREE STRATEGIC TASKS

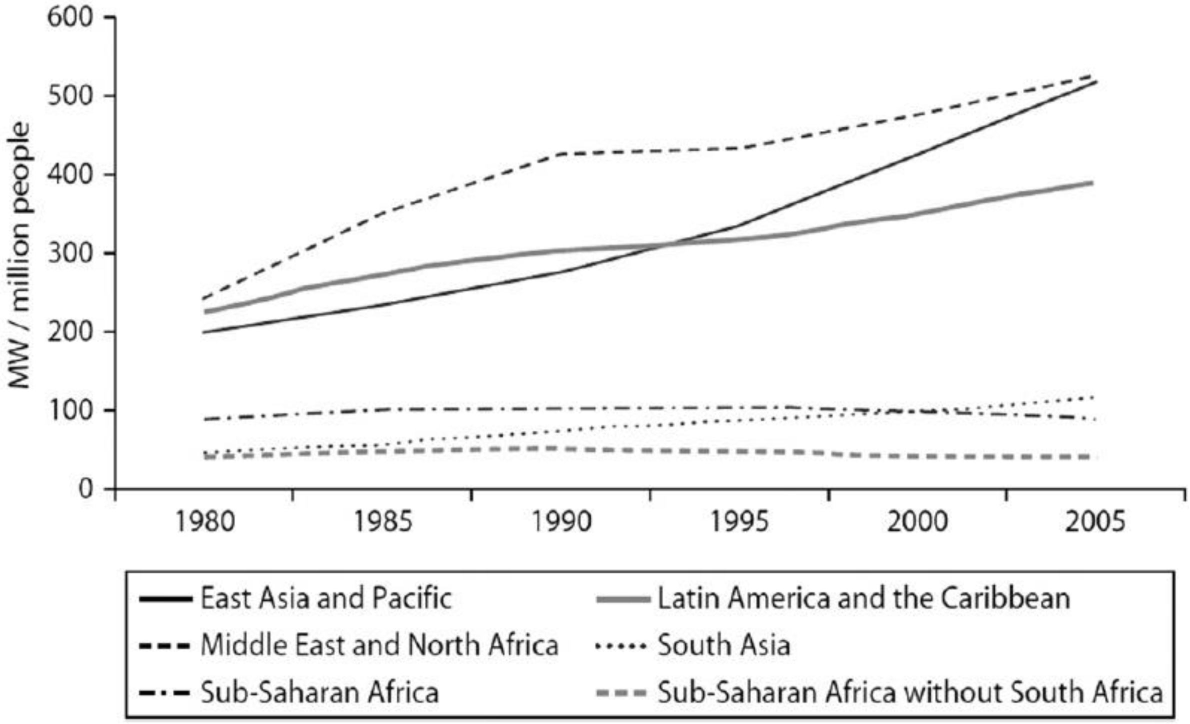
Strategies for 'electrifying Africa' have to address three great tasks:

Task 1. Expanding both the output and reliability of existing power systems.

These **centralised** systems for power generation, transmission and distribution, inherited from the twentieth century, involve large scale generation and transmission through centralized grids. Investing in their expansion is fundamental to Africa's electrification. But investment has to encompass major, challenging change of two types. New and upgraded capacity incorporating new generating and transmission technology is required; and the institutional and market structures that characterized the systems historically – utilities as state owned, vertically integrated, monopolies in poorly regulated and subsidized markets – are not generally sustainable without major change.

The capacity of sub-Saharan Africa's centralised systems was far below those of other regions of the global south in 1980 and has not matched population growth since then, falling further behind those of the other regions. (Figure 1) .

Figure 1 Megawatts installed per million people



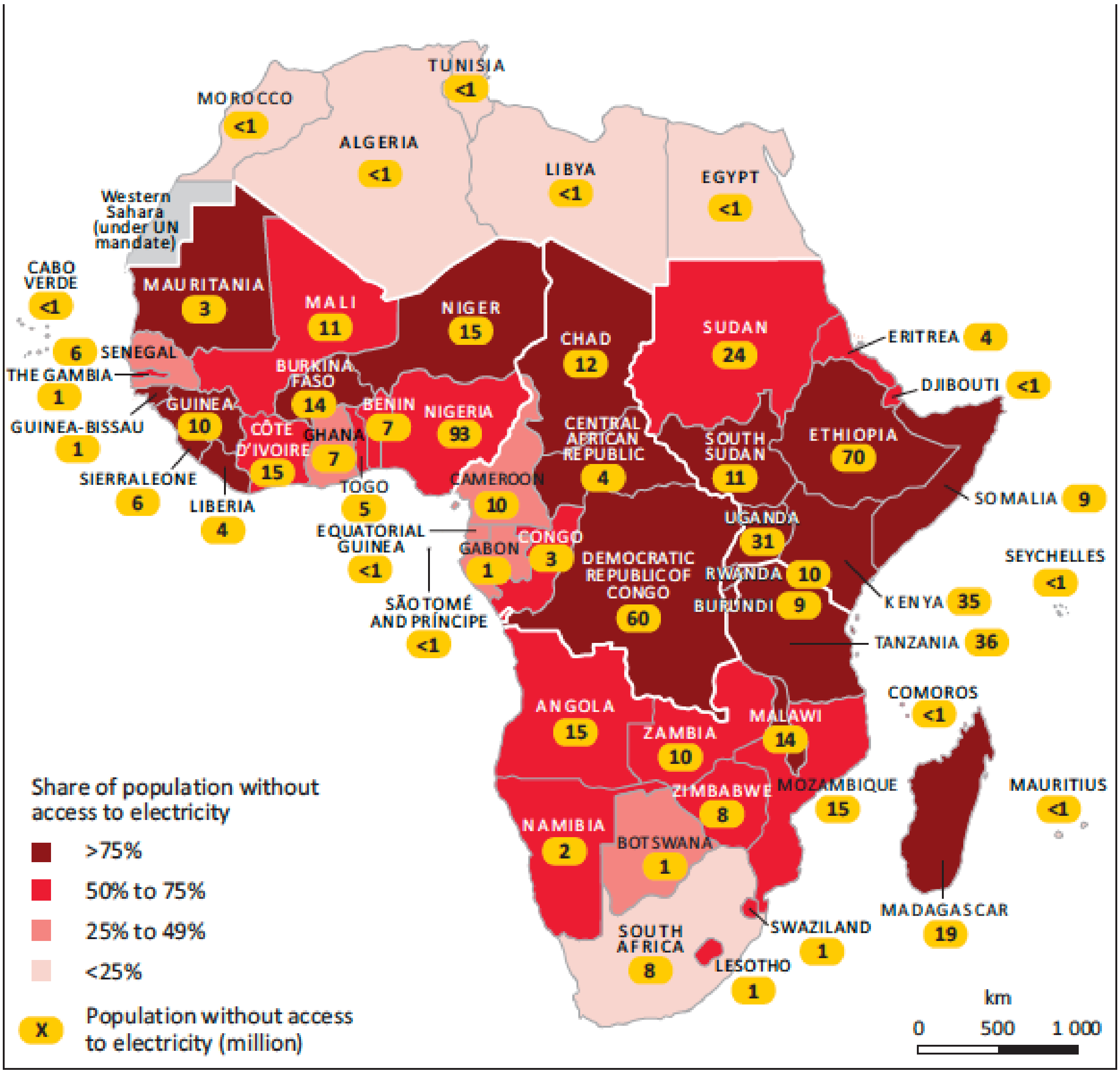
Source: Eberhard et.al., 2011

Investing in the centralised systems principally addresses the currently unsatisfied and future growth of demand for reliable power from existing, connected consumers. Capacity and grid expansion can also increase the numbers connected but cannot quickly provide coverage for large numbers in unconnected rural areas far from established grids.

Task 2. Increasing access to electricity by connecting the unconnected.

More than 50 per cent of sub-Saharan Africa's population has no access to power from the centralised system (Figure 2).

Figure 2 Share of population without access



Source: International Energy Agency. Africa Energy Outlook, 2014, Figure 1.6

Partly because lack of access is particularly acute for rural populations spread over large distances, in some countries investment in grid expansion is not a cost-effective means to reduce it substantially and rapidly (Szabo et.al., 2011). Even South Africa, which inherited an extensive, large capacity centralised system in 1994 and embarked on a successful programme of extending grid connections to provide access for the unconnected, found by 1999 that grid extension could not efficiently and quickly connect more than 80 per cent of the population. (Lemaire, 2011). Consequently much recent attention has focused on the development of **decentralized** small systems in which distributed local generation is linked to mini-grids.

The feasibility of decentralized systems has been greatly increased in recent years by recent developments in hardware and digital control systems. Their benefits include their relative cost effectiveness in locations distant from a centralised grid; their flexibility in being able to speedily supply new industrial or residential locations; their short development period and potential for early revenue streams; their scalability through linking both mini-grids and additional local generators; and the possibility of linking distributed generation to the centralised grid.

The technological advances that have made decentralised systems feasible and attractive are linked to advances in the use of renewables in generation, for decentralised systems can be seen sourcing energy locally from solar, wind, biomass, and local hydro, while being autonomous from commercial supply chains of fossil fuels (or partly autonomous in the case of hybrid source decentralized systems). Thus they are generally analysed as decentralised clean power systems enabling countries (partially) to develop twenty-first century power by 'leapfrogging' twentieth century centralised fossil fuel based systems. But, since renewable distributed generation can, subject to geography, be linked to existing and extended fixed grids investment in both should be seen as complementary (Murphy et.al. 2014). With a feasible objective of achieving hybrid power over linked grids, decentralised clean systems are sometimes regarded as transitional systems for the decades before previously unconnected regions are connected to hybrid centralised systems.

Task 3. Energy mix

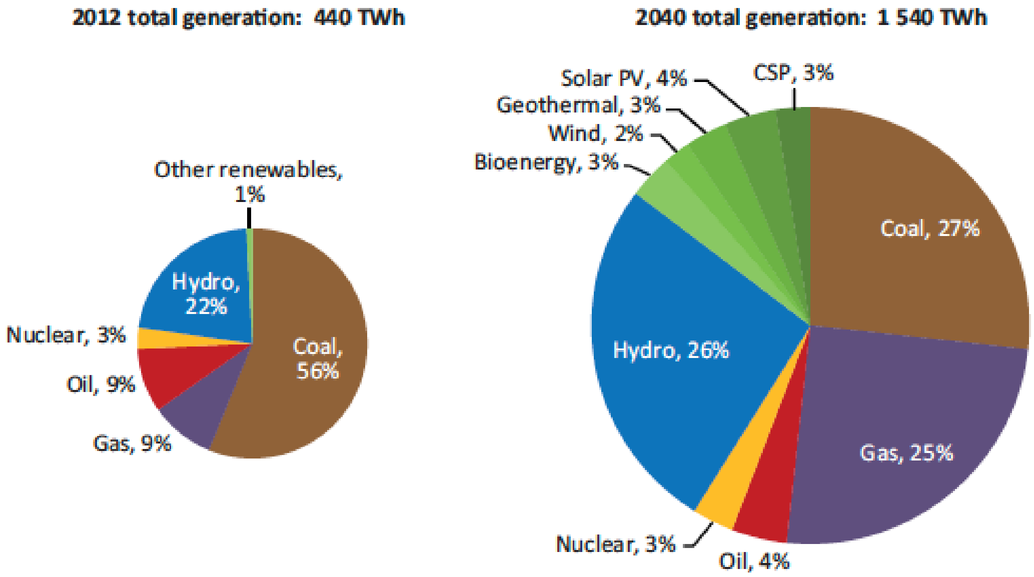
Sub-Saharan Africa, in line with global obligations, has the task of shifting its energy mix further towards a low carbon emissions average. Within COP21's 'ground-up' process of 'intended nationally determined contributions', in the Paris agreement several African countries committed to significant reductions in emissions. For example, compared to business-as-usual levels Angola pledged to reduce emissions unconditionally by 35% by 2030, with an additional 15% reduction conditional upon support, and Nigeria pledged to reduce emissions by 20% unconditionally and 45% conditionally. Investing in Africa's electrification in ways that increase the proportion of clean energy sources is required to support those goals. So is investment in the centralised grid to reduce wasteful energy transmission losses that currently occur in sub-Saharan countries at a rate much higher than the global average through old and poorly maintained grids.

Apart from climate change emission-reducing changes in the region's energy mix is also seen as being in African countries' interests partly because of the cost that climate change imposes on the region; partly because of the negative public health impact of high emission fuels; and possibly within an energy security strategy insofar as it reduces dependence on international supplies of fossil fuels.

Fossil fuels accounted for 74 per cent of Sub-Saharan Africa's power generation sources in 2012, with coal accounting for 54 per cent and oil 9 per cent (Figure 3). The overall figures mask great variations with, at one extreme, South Africa's generation being almost entirely coal based while generation in Central Africa and Mozambique is predominantly from hydro sources.

A leading scenario for a changed energy mix envisages increasing the share of hydro to 26 per cent (from 22 per cent) and other renewables such as solar PV and wind to 15 per cent (from 1 per cent) by 2040 (Figure 3). Within it, a move toward cleaner fossil fuels involves a switch from oil and coal towards gas.

Figure 3. Electricity generation by fuel in sub-Saharan Africa in the New Economic Policies Scenario, 2012 and 2040



Source: International Energy Agency (2014) *African Energy Outlook: World Energy Outlook Special Report* Figure 2.6

To achieve electricity sector transformation in Africa that addresses those three tasks – and the many sub categories of tasks they involve – requires strategic advances in two distinct spheres: engineering and investment. Rapid technological advances, particularly in system design, now offer solutions to most of the engineering challenges for centralised, decentralised and hybrid systems, but investment lags far behind.

Engineering advances have transformed power generation through advances in the design of solar photovoltaic cells and their large scale manufacturing process, by the design of wind turbines and by technologies for efficient use of gas and oil. At the same time, storage technologies have developed fast, especially in the mass production of lithium-ion batteries. Costs depend on the mode in which they are used, ranging from large capacity energy storage systems within utilities to meet peak demands to household battery storage to overcome the variability of supply from solar PV panels. According to a recent estimate median costs of lithium-ion battery storage decreased by between 11 per cent and 12 per cent between 2015 and 2016 (Lazard, 2016)

But of equal or greater significance are engineering's technical advances in system design. Generating electricity with PV cells, wind turbines or fossil fuels is relatively simple, but systems that make the output usable and enhance operational efficiency pose complex problems. The output of centralised utilities has to be transmitted and distributed across wide area grids and local connections while the output of local generators has to be distributed to consumers across mini-grids, and ultimately connected to a centralised grid permitting two way flows. 'Smart grids' that integrate generation and storage from a range of (decentralised and central) sources, and manage both demand and supply to minimise fluctuating and costly imbalances, are now feasible (Welsch et. al., 2013). Digital technology enables netwoks to move electricity from high to low voltage systems and to control feed-ins, and the design of systems that combine different sources, storage, and controls efficiently is now routine. The associated new hardware technology of automated controls that ensure rapid switching between sources, control of supply surges, and supply responsiveness to demand changes is now established. Meanwhile, mobile phone technology, particularly the techniques of mobile money transfer pioneered by M-PESA in Kenya, have led to the development of payment systems designed to suit low income consumers of decentralised clean electricity.

While engineering advances have opened new routes to Africa's electrification recent investment trends have fallen well short of the high rates of real investment that would be required to implement the strategies that they make feasible. Focusing on Task 2 alone, connecting the unconnected, the International Energy Agency calculated that the additional investment required between 2010 and 2030 to achieve universal access in sub-Saharan Africa would be USD 389 billion (constant 2010 USD) (International Energy Agency, 2011), but the region's total annual investment in power (for both connected users and new connections) is well below the annualized rate required for that scenario.

This paper outlines some selected issues in financing the costs of the investment needed for Africa's electrification.

A FINANCING SYSTEMS FRAMEWORK

'How can investment in Africa's electrification be financed?' is susceptible to simple, broad brush answers. One approach is to calculate the (total or annualized) capital cost of reaching a target level of megawatts per person for sub-Saharan Africa over a certain period and compare it with an estimate of funds that could be available from various sources.

But such calculations do not take us far, for the devil is in the detail. Analyses that grasp key details from a conventional perspective on finance focus on the risk-return implications and risk sharing characteristics of financial instruments; the optimal combination of a variety of debt instruments and equity finance. Similarly, important studies concern the range of combinations of state, concessional foreign, and 'private' finance, their implications for risk-sharing, cost and revenue sharing, and, hence, the cost of capital invested.

This paper is founded on a more holistic approach to financing. The approach, a *Financing Systems Framework*, treats finance as a connected set of quantities, prices and choices linked in a many-stepped process from financial source to implementation of real investment. It is a process that occurs within institutional constraints that can either hinder or facilitate it and which demand policy interventions.

Seeing finance for investment in Africa's electrification as a process differs from the static approach of calculating pools of funds available; it enables us to consider key issues at each stage of the process. Those include, fundamentally, the risk-return characteristics of actors' portfolio allocation decisions. They include the institutional constraints affecting the process, stretching all the way from financial market structures, through financial and energy market regulations to African countries' governance, stakeholder interests, and incentive structures, and, further, to the financial literacy and customs, of retail customers as well as their income level and volatility. Thus, the financing systems framework enables us to identify financing problems at key points, from the conditions of global financial markets through the many intermediate stages to the capacity of African countries, communities, and individuals to use finance for electricity investment.

The need for a financing system approach to complement existing studies of specific financing mechanisms is illustrated by simple 'failure' scenarios. Imagine the consequences for sustained investment if new financial instruments are devised that improve the return risk ratio for international investors in African electricity projects (such as those in Arezki et. al. 2017; World Economic Forum, 2013; and others) but the projects' expected revenue streams fail to materialize because local politics or culture, that had not been taken into account, undermine payment of electricity fees. Illustrative examples are the past experience of South Africa in collecting payments for municipal electricity and, in respect of a different infrastructure category, the South African revolt against fees for use of Sanral's debt-financed upgraded road network. Focusing only upon the design of suitable instruments for channeling wholesale finance to African power projects can be followed by unpleasant financial surprises unless complemented by measures to address institutional issues across the whole financing system.

Since Africa's electrification involves three major tasks, financing systems differ according to the task: investment and finance for modernising and expanding centralised utilities and grids differs from that needed by decentralised power, and some specific financing systems relate to investment for emissions reduction. Instead of a comprehensive analysis of issues at all points of different types of financing systems this paper the following sections focus on some illustrative points. I first discuss some key aspects of financing systems for investment in centralised systems, followed by distinctive financing system aspects applicable to investment in decentralized systems.

INFRASTRUCTURE FINANCING OF CENTRALISED SYSTEMS' REAL INVESTMENT: MACROECONOMIC FUNDAMENTALS

Financing investment in utility and grid power is broadly similar to financing other large, long-term infrastructure projects. Desirable levels of global investment in infrastructure as a whole would generate a large demand for funds and financing the upgrading of Africa's centralized generation and grid systems has to compete globally against the world's infrastructure projects. One scenario calculation is that the global infrastructure investment required to support currently projected global economic growth would absorb USD 3.3 trillion per annum on average from 2016 through 2030 or a cumulative total of USD 49.1 trillion of which USD 14.7 is allocated to power projects (McKinsey, 2016).

Taking that as a starting point for African electrification's financing process it may be argued that the first step is to consider how to attract finance into infrastructure from institutional investors' portfolios. Although infrastructure assets, with their long and stable income steams (post development) are compatible with the liability structure of many institutional investors such as pension funds, the main asset classes for institutional investors as a whole are public equity and other financial market assets (Çelik and Isaksson 2013). For example, in McKinsey (2016, p23) it is argued that institutional investors have some USD 120 trillion under management which governments and other stakeholders can attempt to attract for investment in infrastructure. To the extent that institutional investors switch into infrastructure financing the issue is how to make fund allocations into African electrification at least as attractive in terms of risk and return as infrastructure projects in the countries of developed and other developing regions (when risk and return are judged broadly to include such factors as the cost and risk of institutional obstacles).

Attracting funds from global investment portfolios is at one end of a financing process. I focus on it here to highlight that if studies calculate such financial resources but neglect macroeconomic fundamentals they obscure some basic issues that have to be faced by strategies for African electrification.

Increased investment in expanding and upgrading the infrastructure absorbs real resources that must be matched by real domestic or foreign saving. Without an increase in domestic saving or a reallocation of domestic saving from other investment projects, the real resources come from an increased inflow of foreign saving. In national income accounting terms a large investment programme from 2016 to 2030 implies higher current account deficits on the balance of payments matching the excess of domestic real investment over domestic real saving.

Thus, financing of electrification investment is fundamentally a macroeconomic problem. One financial implication of that macroeconomic constraint, neglected in most writing on electrification strategy, is that funding it from foreign saving through loans or debt adds to the country's foreign liabilities and complicates its debt management. Ultimately the sustainability of the country's debt depends on the macroeconomics of the growth rate and macro policy's management of domestic sectors' saving and investment rates. Attracting foreign saving to match electrification investment requires more than a capital budgeting assessment of each project or programme; assessment of its implications for the country's debt management and the macroeconomic policies it requires should not be neglected.

Macroeconomics also underlines the value of distinguishing between stocks and flows at this stage of the financing process. Calculations of the amount of wealth potentially available in the portfolios of institutional investors refer to an accumulated stock of past saving that, in global accounting, is, in principle, matched by a stock of already existing physical capital. Investment in Africa's electrification is a flow to be calculated over a planning horizon period. In recent years a high proportion of the foreign saving being invested in sub-Saharan Africa's centralised electricity systems originates from China's flow of new resources measured by the country's excess of domestic saving (current account surplus).

For sub-Saharan Africa China is the largest national source of investment in the sector's expansion and upgrading. Financing is tied to Chinese contractors designing and carrying out the projects. It is estimated that between 2010 and 2020 China will have completed 145 sub Saharan Africa projects for new capacity in generation, transmission and distribution

(Table 1). Of these it is estimated that 78 per cent are financed wholly by Chinese entities and another 10 percent are partially financed by China in tandem with multilateral development banks and other sources (International Energy Agency, 2016).

Table 1. Overview of Chinese power projects in sub-Saharan Africa, 2010-20

	Generation capacity			T&D capacity		
	Completed projects	Under construction	Planned and financed	Completed projects	Under construction	Planned and financed
East Africa	14	9	5	10	10	1
West Africa	17	4	2	6	2	2
Central Africa	8	5	2	5	1	2
Southern Africa	15	7	8	4	5	1
Total	**54**	**25**	**17**	**25**	**18**	**6**
	96			**49**		

Source: International Energy Agency, 2016. Table 1

FINANCIAL INSTRUMENTS AND INSTITUTIONS

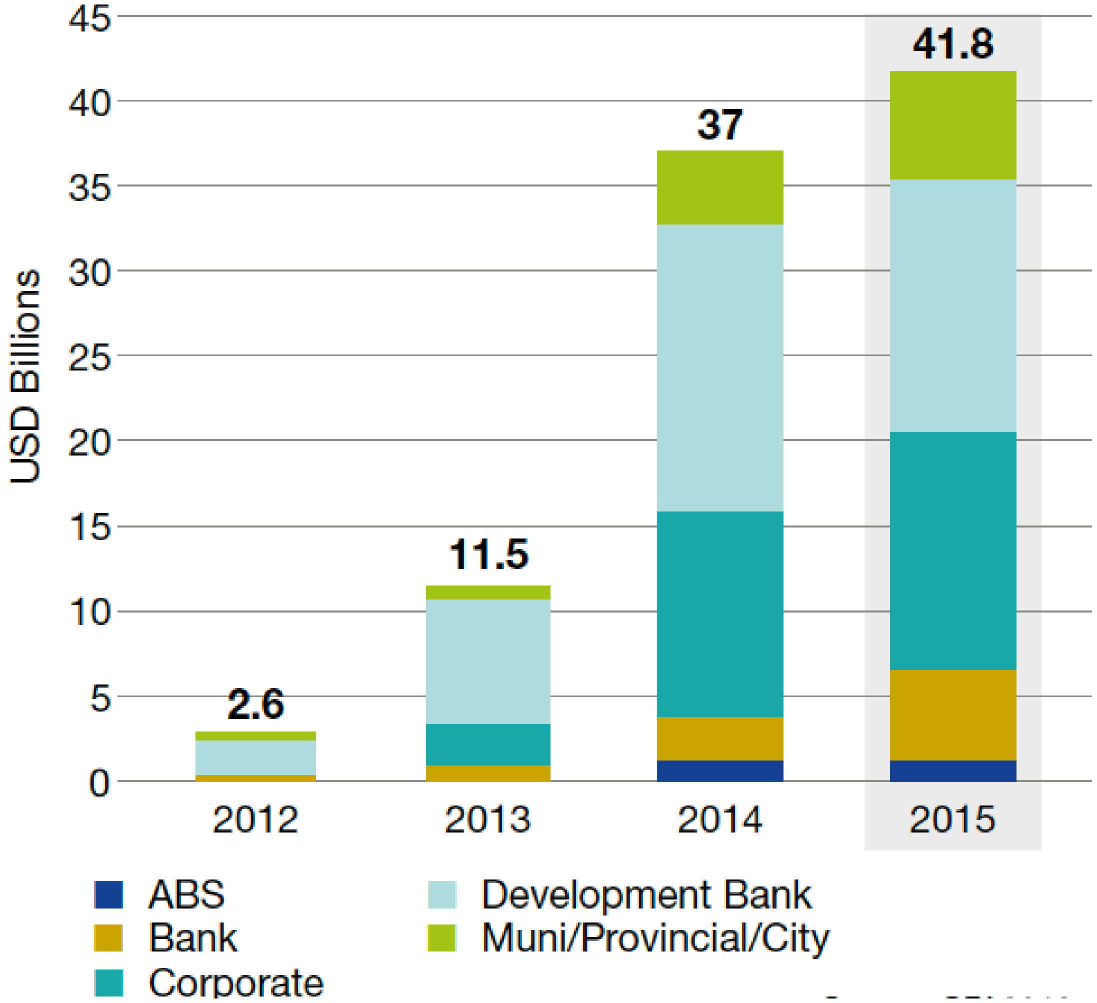
Whatever the ultimate source of savings for investment in African electrification, the financing process may be strengthened by designing financial instruments tailored to increase investors' return- risk ratios. Such innovations imply associated institutional changes to create new markets, new financial intermediation, or new principal-agent relations, as is illustrated by two recent examples.

The proposal of Arezki et. al. (2017) for increasing institutional investors' financing of infrastructure such as African centralised electricity systems envisages a transformation of public-private partnerships (public agency and private developer/operator) into fourfold partnerships that additionally have development banks and institutional investors as partners. Although the entities involved are not unusual in project financing this proposal places them on a partnership footing with a new, proactive agency role for development banks as initiators and coordinators. The proposed financing mechanism associated with the institutional change is for development banks to create pools of infrastructure assets that are the basis for asset backed securities sold to investors.

A different innovation in this space is the fledgling market in green bonds that could be a channel for funding clean electricity projects in Africa as well as other climate change mitigation projects.

Although the market is very small, annual new bond issues have initially grown at a fast rate, principally due to issues by development banks and corporations (Figure 4). Chinese entities, international and regional development banks, and US borrowers have dominated issues, but, with the exception of a small amount of green bonds issued by the African Development Bank, green investment in Africa has not had a significant presence. (Climate Bond Initiative, 2017). The potential contribution of green bonds, their attraction as an asset class for institutional investors, is twofold.

Figure 4: Green Bond Issuance Diversification



Source: Shishlov et.al. (2016)

Inclusion in institutions' portfolios may increase their attractiveness to a growing class of savers who value environmental benefits, and they act as a hedge against the climate change risks (such as the risk of stranded assets) to which other securities in their portfolio are subject (Shishlov et.al. 2016).

Although increasing numbers of institutional investors are announcing strategies for increasing their portfolios' green hue, the creation of a significant market in green bonds requires associated institutional changes in order to establish and monitor rigorous standards for classifying funded projects as green. While the Climate Bond Initiative is committed to achieving such transparent standards, experience with other climate related finance mechanisms suggests that it will be difficult to achieve the degree of standard setting required for a well-functioning market.

FINANCING DECENTRALISED CLEAN ELECTRICITY

So, can we envisage sub-Saharan Africa being transformed in the near future by decentralised clean power? Among the obstacles that have to be faced is the readiness of unconnected end users to make use of access to a local clean power supply. Adoption of the supply innovation is an example of an issue encountered in more general studies of diffusion of innovations as suggested in an analysis of decentralised clean energy in Uganda (Eder et.al., 2015). It is at the opposite end of a financing process compared to international finance sources; it involves matters at ground level.

The experience of Brazil suggests possible difficulties, for legislation in 2012 intended to promote small scale (household level) solar energy has not resulted in significant adoption. For African countries, some insight into the challenges facing adoption of local clean electricity can be gained at a granular level from case studies.

Interviews of actors involved in renewables-based local systems in rural areas of Uganda, Tanzania, and Mozambique, including local residents who have had the opportunity to access that electricity have revealed numerous difficulties. (Eder et.al., 2015; Ahlborg and Hammar, 2014). They include lack of local management skills, difficulty of ensuring maintenance of installed systems, the need for organisations and individuals promoting the system to obtain local trust, and finance.

Financing installation costs is an obstacle for adoption by households. Evidence from case studies suggests that financial innovations that enable cost recovery while lowering the financial threshold reduces the obstacle to adoption by low-income consumers with low savings for such investment. A range of financial models have been used within African programmes promoting decentralised clean electricity systems models. All use fee-for-service payments that enable adopters to spread the cost in very small, affordable payments related to use.

In Tanzania, Uganda and elsewhere recent 'Paygo' systems use mobile payments systems and remote monitoring . By contrast early fee-for-service systems for decentralised solar electricity in Zambia involved monthly visits by the electricity scheme's company's technicians to collect the fees, check on maintenance and provide a two way channel for information and feedback (Lemaire 2009). The Zambian schemes' success is likely due in part to such 'outreach' – parallel to the experience of microfinance schemes where 'outreach' based schemes outperform others. The outcome of those Zambian cases is also due partly to its subsidy from foreign aid. A case study of South Africa's programme to roll-out household clean power systems with fee-for-service cost recovery through local service delivery enterprises (concessions) operating forms of outreach finds that the programme's success depends on the continuity and predictability of subsidies to the concessions (Lemaire 2011).

Fee-for-service methods of financing decentralised supplies rest on business models where local agents, operating concessions granted by a central authority supply installations and maintenance and recover costs from subsidies and fee-for-service customer payments. Since the long run financial sustainability of that model is not yet known, it is too early to say that it can successfully reduce the obstacles to adoption and have a significant impact on increasing access to electricity.

CONCLUSION

Considering the current situation of electricity availability and use in sub-Saharan Africa and the prospects for transformation, this paper introduces some key concepts and issues. Its limited scope requires the omission of many features and issues in Africa's electrification and the paper contains no direct policy recommendations. The paper is one part of an on-going project that comprehensively examines the institutions, broadly defined, affecting investment in Africa's electrification and yields direct conclusions for policy. At present, the broad policy implication is that policies to address institutional obstacles at different points in the financing process are necessary.

Treating the financing process of electrification at the level of sub-Saharan Africa as a whole obscures the wide variety of national experiences and prospects in the region. It diverts attention from the lessons that can be learned from countries' varied problems and policies.

Within the region's variety South Africa's electricity sector is an outlier not only because of its size and its situation within an industrialised society with large coal reserves, but because of the institutional framework that has enabled long term strategic planning. Notwithstanding faults in corporate and political governance affecting the sector, South Africa's opening of the sector to independent power producers introduced private enterprises that changed the energy mix by producing a significant expansion of clean energy. It is a world-leading example of institutional change – including strategic change in regulations and tendering processes -- facilitating a change in market structure to enable new financing processes and an effective shift in the country's electricity provision (Eberhard et.al. 2014).

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