

## Working Paper

# Building Electricity Supplies in Africa for Growth and Universal Access

Andrew Scott

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## Executive Summary

Although Africa has enormous energy resources, more than half of the continent's population do not have any access to electricity and generation is often unable to meet the demand of those who do. Growth and poverty reduction will be constrained if this deficit continues. The purpose of this paper is to outline the nature of the opportunities and challenges for expanding the supply of electricity to meet development objectives, taking into account recent reductions in the costs of renewable energy.

### Access to electricity

Under business as usual scenarios, over 600 million Africans would still lack access to electricity two decades from now. The example of Morocco and a number of other countries indicate that in Africa, faster rates of electrification are possible. The global goal of universal access to electricity by 2030 would add about 3% to the expected total demand and could be delivered with a small increase in the capacity that is already expected to be built. For about 60% of the population, mini-grids and stand-alone systems would be the best means to provide access.

Addressing the lack of access to electricity in sub-Saharan Africa needs to recognise opportunity in the significant amounts already spent by households on lighting and communications. If households spent this amount, around US\$50 a year, on electric lighting, they could purchase more electricity than the average African household currently connected to the grid.

Even where there is a supply of electricity, many people may not connect to the service because they cannot afford to. In most African countries there is a connection charge for new consumers. These are high by international standards, ranging from US\$2 to US\$400, and can make access to electricity unaffordable for households, even if the monthly tariff can



Photo credit: Flickr/Solar Electric Light Fund

## About this working paper

This paper was prepared as an input to the 2015 Africa Progress Report *Power, People, Planet: Seizing Africa's energy and climate opportunities* produced by the Africa Progress Panel led by Mr. Kofi Annan which can be found at: [www.africaprogresspanel.org](http://www.africaprogresspanel.org).

The Africa Progress Report (APR) is the annual flagship publication of the Africa Progress Panel. The APR draws on the best research and analysis available on Africa and compiles it in a refreshing and balanced manner. The Panel makes policy recommendations for African political leaders and civil society who collectively have the primary responsibility for spurring Africa's progress. In light of the continent's dynamic links with the rest of the world, the APR also highlights critical steps that must be taken by leaders in the international public and private sector.

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**New Climate Economy**  
c/o World Resources Institute  
10 G St NE  
Suite 800  
Washington, DC 20002, USA  
+1 (202) 729-7600

**New Climate Economy**  
c/o Overseas Development Institute  
203 Blackfriars Road  
London, SE1 8NJ, UK  
+44 (0) 20 7922 0300

[www.newclimateeconomy.report](http://www.newclimateeconomy.report)  
[www.newclimateeconomy.net](http://www.newclimateeconomy.net)



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be afforded. Connection charges could be made affordable by enabling consumers to spread the cost over time, rather than incurring it as an up-front cost. For tariffs for electricity supplied through the grid, the tariff structure can be used to cross-subsidise low-income consumers. For off-grid supplies, credit and financing schemes would enable access.

## Electricity for growth

Economic growth is closely associated with the production and consumption of electricity, though the relationship is complex. The impact of growth on the demand for electricity will be felt through expanded industrial and service sectors, and higher incomes. Under business as usual assumptions, the International Energy Agency (IEA) expects the total demand for electricity in Africa to increase at an average rate of 4% a year to 2040, and the demand from the industrial sector to more than double. Generation capacity in Africa needs to expand rapidly to meet this expected growth in electricity demand.

The bulk of Africa's electricity will continue to be delivered to industrial and commercial consumers connected to the grid. By one estimate, industrial and commercial consumers will account for 68% of the demand in 2030. The supply of electricity to the grid is expected to be predominantly from large-scale generating units. Substantial investment in transmission and distribution will also be necessary.

The current level of investment in sub-Saharan electricity systems (about US\$8 billion a year) is inadequate to overcome the existing shortcomings of the region's electricity systems, to expand coverage and to meet the growth in demand. The region has under-invested for a number of years. The total additional investment required to meet expected demand, estimated to be US\$46 billion a year by the IEA, is beyond the capacity of Africa's public finance. Policy frameworks that attract inward investment will be necessary.

In 2012, 82% of Africa's electricity was generated from fossil fuels. By 2040, another 81 gigawatts (GW) of thermal capacity will have been built in sub-Saharan Africa, under business as usual assumptions. However, for both grid and off-grid electricity, the levelised cost of electricity (LCOE) from most renewable options is now at the same level or lower than the cost of fossil fuel options. This change in relative costs, combined with the expected future reduction in the cost of renewables, suggests the need to review plans for expanding fossil fuel generation.

The quality of Africa's electricity supply is poor. On average there is a power outage about every four days in sub-Saharan countries, and in some countries outages are a daily occurrence. The economic impact of unreliable electricity is felt through lost or reduced output, lower productivity, and the higher cost of electricity for consumers. These losses have been estimated to reduce Gross Domestic Product (GDP) by around 2%. At the firm level, unreliable electricity has been found to have a significant negative impact on productivity. Improving the reliability of electricity supplies, by expanding generation capacity and investing in transmission and distribution, would contribute to economic growth.

The vertically-integrated state-owned utilities have become an excessive burden on limited government budgets in some countries, amounting to 1.4% of GDP in 2010 in sub-Saharan Africa. Their weak financial performance affects their ability to maintain the electricity infrastructure, reinforcing inefficiencies in the system, and is a barrier to investment in the expansion of electricity supply.

Structural reform of the electricity sector, combined with privatisation, has been part of the conventional approach to addressing the inefficiencies of state-owned utilities, often with a presumption that private sector companies will be inherently more efficient. The lessons from the past two decades suggest that power sector reform needs to be adapted to the local context and implemented over a long period of time. In the hybrid electricity systems that have evolved, comprising vertically-integrated utilities supplemented by private power producers, effective regulation of the electricity market is a critical question.

## Recommendations

The two challenges of expanding electricity generation and distribution for economic growth, and extending electricity supplies to those who do not yet have access, are inter-related but require different policies and interventions.

To achieve universal access to electricity, governments should:

- Raise the level of their ambition for electrification, especially in countries where universal access is currently envisaged only for the next generation.

- Target all electricity consumer subsidies more directly at the poorest households.
- Promote credit schemes for low-income households to enable access to off-grid supplies and remove the barrier of connection charges for access to the grid.
- Include off-grid electricity (mini-grids and stand-alone systems) as an essential component of power sector plans.
- Support the design and implementation of mini-grids.

To address the challenge of expanding electricity to enable growth, governments should:

- Reform electricity utility companies to make them more efficient and financially sustainable.
- Ensure that tariff setting in the power sector is transparent, based on actual costs and able to cover operating costs and contribute to future investment.
- Review national power plans to ensure they take advantage of recent dramatic reductions in renewable energy costs.
- Build African institutional and technical capabilities to develop and disseminate renewable energy technologies.
- Improve the reliability of electricity supplies by ensuring adequate generation capacity (or imports) and improving maintenance of electricity infrastructure.

## 1. Introduction

The African continent has enormous energy resources, far beyond its own needs. Yet Africa has an electricity deficit. More than half of the continent's population do not have any access to electricity, and generation is often unable to meet the demand of those who do. Per capita consumption of electricity is lower in Africa than in all other major regions of the world.<sup>1</sup> South of the Sahara, it has stayed at about the same level for two decades, according to World Bank statistics.<sup>2</sup> The rise of Africa heralded by recent growth rates will be constrained if this deficit continues and the demand from growing population and economies is not met.

The purpose of this paper is to outline the nature of the opportunities and challenges for expanding the supply of electricity for economic growth and poverty reduction in Africa.<sup>3</sup> The focus is on sub-Saharan Africa, where the electricity deficit is greatest. The paper draws from recent literature and identifies developments that will influence future investment in electricity systems, as well as the key areas of action for policy-makers and planners.

The need to increase electricity supply in order to match the current and growing demand is one of Africa's major energy challenges. Another is the need to enable over 620 million Africans to gain access to electricity for the first time. The number of high profile initiatives to increase investment in the provision of electricity in Africa, including the New Partnership for Africa's Development's (NEPAD) Africa Power Vision, which pursues the energy priorities of the Programme for Infrastructure Development in Africa (PIDA), and the International Renewable Energy Agency's (IRENA) Clean Energy Corridor, which aims to exploit the continent's renewable energy potential, demonstrates that these challenges are recognised by African governments.

The UN Secretary-General's Sustainable Energy for All (SE4All) initiative, launched in 2011, is building support for an approach to energy policy and planning that addresses energy access and climate change together. SE4All's targets are the universal provision of access to modern energy services by 2030, a doubling of the rate of improvement in energy efficiency and a doubling of the share of renewables in the global energy mix, also by 2030. The Conference of Energy Ministers of Africa endorsed these objectives in 2012,<sup>4</sup> and they are incorporated in the Sustainable Development Goals agreed in September 2015.

Energy policy has conventionally focussed on how to meet expected demand in a timely way and at least cost. Electricity consumption in Africa has increased by around 5% a year over the past decade, and electricity demand is expected to double between 2012 and 2030.<sup>5</sup> To meet the growth in demand, and satisfy current unmet demand, installed generation capacity needs to double by 2030 and increase by almost another one and a half times by 2040.<sup>6</sup> This calls for much higher levels of investment than have been experienced recently.

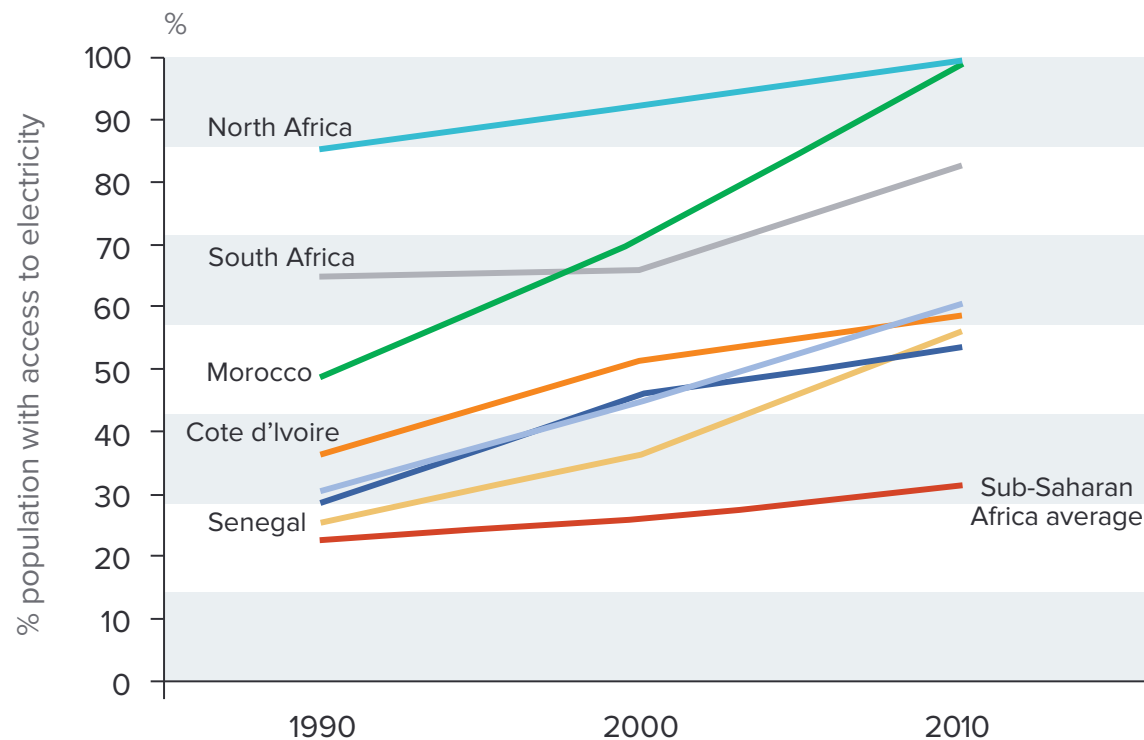
For electricity, energy policy implementation in Africa has often resulted in investment in thermal electricity generation,<sup>7</sup> and in a transmission and distribution (T&D) grid. Large-scale hydropower has also been developed (supplying 15% of the electricity generated in 2012),<sup>8</sup> but with a very long lead time, it can be unresponsive to rapidly growing demand. The relative costs of generating electricity from different energy sources are changing, however, as renewable energy technologies mature. Solar photovoltaic (PV) electricity generation is now a lower cost option than fossil fuels in many places,<sup>9</sup> while decentralised generation and distribution alternatives are becoming technically and economically more feasible. These developments challenge the conventional wisdom of energy planners and existing power sector plans. This paper suggests that plans for expanding generation capacity should be reviewed to take advantage of these changes.

The paper first discusses the extension of access to electricity in sub-Saharan Africa, outlining the scale of the challenge and measures that would enable the goal of universal access to be achieved. The third section considers the expansion of electricity production and distribution to enable economic growth, and meet expected demand. Summary recommendations for measures to address both challenges are presented in the final section.

## 2. Achieving universal access to electricity

Since 2000, 145 million people in sub-Saharan Africa have gained access to electricity.<sup>10</sup> This equates to an increase in the access rate from 23% to 32%.<sup>11</sup> A few countries are achieving faster rates of improvement in access to electricity than others. Five African countries (Cameroon, Côte d'Ivoire, Ghana, Morocco and Senegal) increased access by more than one percentage point a year over the period 1990 to 2010 (see Figure 1), compared with a global average of 1.2 percentage points a year.<sup>12</sup> The example of Morocco and other fast movers indicates that substantially faster rates of electrification are possible.

Figure 1  
Change in electrification rates, selected countries and regional averages, 1990-2010



Source: SE4All database.

There is a marked difference between electrification rates in North Africa and sub-Saharan Africa. North African countries had a 99% average electrification rate in 2012. The island states of Cape Verde, Reunion, Mauritius and the Seychelles had also reached close to universal access. In sub-Saharan Africa, the average electrification rate was a third of this (32%), ranging from 85% in South Africa to under 10% in six countries (Chad, Central African Republic, DR Congo, Liberia, Malawi and South Sudan).<sup>13</sup> Electrification rates in sub-Saharan Africa also differ greatly between urban and rural areas. On average, 59% of the urban population has access to electricity, while 16% of the rural population do.

Across sub-Saharan Africa, however, the increase in access to electricity has typically not managed to keep up with population growth. The number of people without access has increased by around 200 million, since 2000.<sup>14</sup> More than half of Africa's population – more than 620 million people – did not have access to electricity in 2012.<sup>15</sup> Boxes 1 and 2 describe the different approaches to electrification in Ghana and Senegal.

The millions of Africans who lack access to electricity are disadvantaged in a number of ways. The absence of electricity limits the opportunities open for people to improve their productivity and earn higher incomes. It limits their education, denying them opportunities to read during hours of darkness and constraining the quality of educational facilities and services. In sub-Saharan Africa only 35% of primary schools have access to electricity.<sup>16</sup> Lack of electricity prevents people from accessing good-quality health services, with an estimated 30% of health facilities having no electricity.<sup>17</sup> Electric lighting would also improve people's health, by eliminating the household air pollution and burns from accidents that are associated with kerosene lighting.<sup>18</sup> Without electricity, opportunities to obtain information, knowledge and entertainment from the radio or television are more limited, and the absence of street lighting reduces people's sense of personal security. Lack of electricity also disadvantages people by requiring them to spend a higher proportion of their income on less-efficient lighting and communications than can be provided by electricity.<sup>19</sup>

## Box 1

### **How rapid rural electrification was achieved in Ghana**

Ghana has one of the fastest rates of rural electrification in sub-Saharan Africa. The proportion of the rural population with access to electricity increased from 6% in 1990 to 52% in 2012. This progress has been driven by the National Electrification Scheme (NES), which began in 1989 with the aim of extending access to electricity to all communities of 500 people or more, by 2020. A major component of the NES is the Self-Help Electrification Programme (SHEP). By 2009, the SHEP had connected 2,837 communities.

The purpose of the SHEP is to connect villages and towns within 20km of the grid. They must apply to be included in the programme, and to be eligible the community itself has to provide materials and finance for the low voltage distribution network, as well as evidence that at least one-third of households are wired and ready to be supplied with electricity. The government provides conductors, pole-top arrangements and transformers, and covers the other installation costs. The Ministry of Energy is responsible for vetting and selecting the communities to be included in each phase of the programme.

In 2010, only 64.2% of households in electrified communities were connected. Access to electricity in communities connected by SHEP has been facilitated by the use of lifeline tariffs and the cross-subsidisation of poorer consumers by more affluent and high-usage electricity consumers. Measures to ensure monthly electricity charges are affordable to the poorest will be necessary to realise the government's current goal of achieving universal access to electricity by 2020. The performance of utilities and the shortage of electricity in the country will also be a challenge.

Source: Abavana, 2012; Ghana, 2012; <https://energypedia.info>

Outside the residential sector, lack of access to electricity can limit the productivity and opportunities for micro-, small- and medium-scale enterprises (MSMEs). Electrification, however, does not necessarily lead to enterprise growth, increased productivity, and higher returns.<sup>20</sup> Electrification and the number of MSMEs are correlated, suggesting that the creation of new, often informal, home-based micro-enterprises follows electrification. However, electrification has been found to have a variety of effects on established micro-enterprises, including a small but significant effect on sales,<sup>21</sup> and no systematic effect.<sup>22</sup>

The existing conditions in areas undergoing electrification help determine the kind and scale of impacts that electricity can be expected to bring,<sup>23</sup> and the full potential economic impact of electricity can be exploited only if essential preconditions are met, such as firms' endowment of adequate capital, access to markets and transport infrastructure. Decisions by MSMEs to connect to an electricity supply when it does become available reflect their assessment of the expected returns, and are influenced by the costs involved.<sup>24</sup>

## Box 2

### **Achieving rural electrification in Senegal through concessions**

The electrification rate in Senegal more than doubled between 1990 and 2010. By 2012, 90% of urban households had access to electricity, and in rural areas 28% of households were electrified, compared with just 2.2% in 1990. The approach of the Senegalese Rural Electrification Agency (Agence Sénégalaise d'Électrification Rurale; ASER) in contributing to this progress, with support from the World Bank, has attracted the attention of other countries.

Before 1998, rural electrification was managed through a number of agreements between the government and the national utility, SENELEC (Société Nationale d'Electricité du Sénégal). In 2001, ASER was established and given the responsibility to promote rural electrification. This has been pursued through several channels. The principal one focusses on the allocation and operation of 25-year rural electrification concessions. ASER also supports locally initiated rural electrification projects and multi-sector projects to support business productivity and social service delivery.

The country has been divided into 18 different rural electrification concession areas, to be awarded to private operators by ASER through a competitive bidding process. Each concession area is to have its own electrification plan, covering 5,000-10,000 potential electricity consumers. The concessionaires are contractually required to connect a given number of households, including a number living more than 20km from the grid.

The maximum tariffs for defined levels of service in each concession are set by the independent regulator, the Commission de Régulation du Secteur de l'Electricité (CSRE). Tariffs can vary between different concessions but not within concession areas. In addition, consumers pay a monthly charge that allows their up-front connection and wiring costs to be repaid over time.

ASER's concessions approach provides a way to ensure private investment in rural electrification. Concessionaires are required to provide at least 20% of the investment. Up to 80% of the investment cost can be provided as a subsidy by the government, through the World Bank support, but disbursements are tied to performance milestones and the number of connections made. The first six concessions secured a total of US\$52 million of private finance, amounting to 49% of the total investment and more than double the minimum 20%.

While the financing model, entailing private sector investment and an element of output-based aid, has been successful, the concessions' progress in expanding the number of connections has been slower than anticipated. Increases in rural electrification in Senegal before 2012 cannot be attributed to them. Nevertheless, ASER's objective was to increase the national electrification rate to 30% by 2015 and 60% by 2022, and the 2015 target has been surpassed. On current projections, the target for 2022 may be narrowly missed.

Sources: de Gouvello and Kumar (2007); Mawhood and Gross (2014); <https://energypedia.info>.

## **SUPPLYING ELECTRICITY FOR UNIVERSAL ACCESS**

Under business as usual scenarios, a significant proportion of the sub-Saharan population would still lack access to electricity two decades from now.<sup>25</sup> The global goal of universal access to electricity, endorsed by African energy ministers,<sup>26</sup> implies the expansion of electricity generation and distribution to meet this additional demand, as well as the growth in demand from existing consumers, industry and services.<sup>27</sup> The additional electricity consumption in 2030 that would result from universal access to electricity in sub-Saharan Africa is estimated to be approximately 35 terawatt hours (TWh) (see Box 2). This is equivalent to an additional 3% on total demand, and 12% on residential demand.

The additional generation capacity that will be required to enable universal access to electricity depends on how the electricity will be supplied and the energy sources that will be used. Mini-grid and stand-alone systems would together supply an estimated 57% of the additional demand from ensuring universal access and 43% would be supplied from the grid.<sup>28</sup>

On the basis of IEA and Joint Research Council estimates of the proportions of off-grid electricity that would be supplied from different energy sources (Figure 2), the off-grid generation capacity required would be approximately 7.2 gigawatts (GW) (details in Table 1). About 87% of this capacity is in renewable energy generation capacity.<sup>29</sup> The total additional capacity in 2030 for universal access is estimated to be 11 GW, which is equivalent to 4% of IEA’s expected total sub-Saharan capacity. In other words, the ambition of universal access to electricity could be delivered by 2030 with a small increase in capacity above what is already expected to be built, bringing electricity to almost one third of the population of sub-Saharan Africa.

Box 3

**Estimating the demand for grid and off-grid electricity**

The IEA’s assumptions (IEA, 2014) indicate that approximately 48% of the total population who currently lack electricity in sub-Saharan Africa, would be best served by grid extension and just over half by mini-grids (34% of the population without access) and stand-alone systems (18%). By 2030, when 45% of the sub-Saharan population will be living in urban areas, compared to 35% now (UN Population Division) and 635 million people will still lack access to electricity (under current policies), the proportion of the population best served by mini-grids and off-grid systems will be slightly higher, 37% and 20%, respectively.

Another estimate of the relative contributions of grid extension and off-grid systems in providing universal access in Africa has been provided by the Joint Research Council (JRC). Using a combination of spatial mapping and social and economic data, this research found that 39% of the total population would be best served by grid extension (Szabó et al., 2011), about three-quarters of the IEA’s estimate and a difference of about 60 million people. There is considerable variation between countries and the balance between grid extension and off-grid systems will be subject to local geographical, economic and policy conditions.

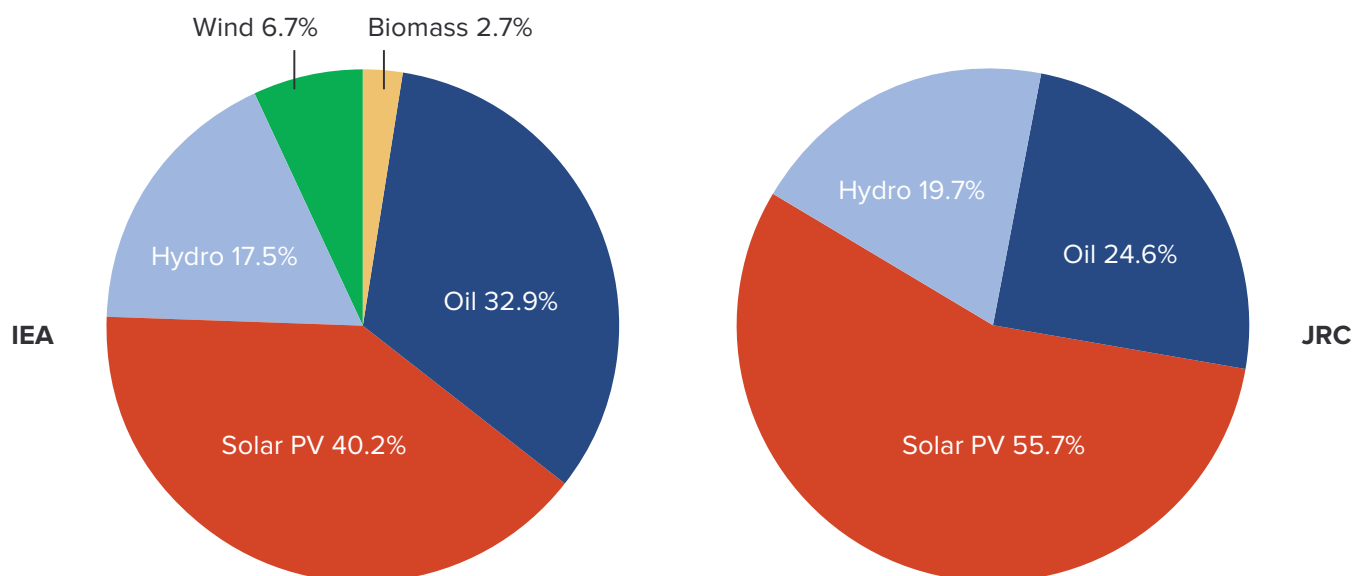
The JRC did not distinguish between mini-grid and stand-alone systems for the population best served by off-grid options, but did look at technical options and found that 34% (of the total population without electricity) would be best served by solar PV, 12% by mini-hydro and 15% by diesel generators (Szabó et al., 2011).

The additional demand for electricity to be met through off-grid systems can be estimated using assumptions about the basic level of electricity consumption of newly-connected households. Although average electricity consumption in the sub-Saharan residential sector is 317 kilowatt hours (kWh) per capita a year (IEA, 2014), or 1585 kWh per household per year, consumption by most households gaining electricity for the first time is likely to be much lower than this. Unfortunately, data on the actual consumption of electricity by newly-connected households is unavailable. The IEA assumes a minimum rural consumption level of 250 kWh per household per year, enough for a couple of light bulbs, phone charging and a fan (IEA, 2014). This is comparable to Tiers 2 and 3 of the SE4All Global Tracking Framework (2013), which entail electricity consumption of 100 kWh and 365 kWh a year, respectively. Sanchez (2010) considered a higher level, 600 kWh per household per year, to be the minimum acceptable level of consumption. Using the IEA’s minimum consumption figures, the total estimated additional consumption of electricity from universal access is shown in the table below.

MWH	2010	2012	2030
Grid extension urban	11465354	13740334	6213750
Grid extension rural	7160941	5875160	8592938
Mini-grids	10860760	8910659	13032622
Off-grid	5848102	4798047	7017566
Total without access	35335157	33324200	34856875



Figure 2  
Sources of electricity for off-grid systems (% MWh by source)



Source: SIEA, 2014; Szabo et al., 2011.

Table 1  
Generation capacity required to meet off-grid demand from universal access

	GWh	Capacity factor	GW
Oil	6627	0.8	0.945575
Solar PV	8120	0.2	4.634889
Hydro	3449	0.5	0.787359
Wind	1323	0.2	0.755315
Bioenergy	531	0.5	0.121308
<b>Total</b>	<b>20050</b>		<b>7.244446</b>

Source: Author's own estimates.

## MAKING ELECTRICITY AFFORDABLE

The challenge of addressing the access to electricity deficit in sub-Saharan Africa is not just a question of providing a supply, from the grid or through off-grid systems. Even where there is a supply of electricity many people may not connect to the service because they cannot afford to. After electrification in rural areas, many households do not immediately connect to the supply and take-up rates are often lower than anticipated. In urban areas, Eberhard et al. (2011) found that 93% of the population lived close to an electricity supply from the grid, while 75% had a connection. More than half of this difference was attributed to a gap in demand. In other words, when electricity supplies are extended to new areas, a lack of effective demand can result in some households remaining without a connection.

To understand how to address the demand gap, it is important to understand what households use electricity for and how they meet these needs without electricity. The *Poor People’s Energy Outlook 2010* (Practical Action, 2010) identifies six services that energy provides to households – lighting, cooking and water heating, space heating, cooling, communications, and earning a living. Electricity could be used to provide all of these services. In practice, the evidence indicates that most households with an electricity supply in Africa use it primarily for lighting and communications (including radio and television).

Households without an electricity supply do not go without lighting or modern communications. Indeed, they often spend a significant proportion of their limited incomes on these services. Kerosene is currently the most common source of energy for lighting across sub-Saharan Africa, used by more than two-thirds of households. Market surveys conducted in 2008 for Lighting Africa, in five countries, found that the great majority of households use a paraffin (kerosene) lamp of some kind for lighting, except in Zambia (see Table 2). Household surveys in Kenya and Uganda have also found that kerosene was the main source of lighting for, respectively, 76% and 85% of households.<sup>30</sup> The proportion of households using kerosene for lighting in urban areas is lower than in rural areas, however.

Table 2  
**Types of lighting devices used by households (%)**

Devices	Ethiopia	Ghana	Kenya	Tanzania	Zambia
Paraffin lamp with no cover	69	5	30	30	8
Paraffin lamp with cover	14	72	67	60	6
Firelight /moonlight	11			7	5
Torch	10	12	10	8	3
Light bulb in socket or lamp	8	6		10	6
Candles		18	5	19	79
Lantern (battery or solar)		4			

Source: *Lighting Africa*.

Other sources of lighting, for households without an electricity supply, include candles and dry cell batteries (for torches or lamps).<sup>31</sup> The very poorest households do not use any lighting device, but rely on firelight or moonlight during the hours of darkness. Incidence of the use of electricity as the main source of lighting corresponds with the level of electrification.

The cost of purchasing and running different lighting devices varies, as does the quality of light provided. Lighting Africa’s market surveys provide information about how much different lighting devices cost to run. The monthly cost of running a kerosene lamp ranged from about US\$3.20 to over US\$8.00, depending on national kerosene prices, while the monthly cost of candles ranged from less than one dollar to US\$4.65 (Table 3).

Estimates of total annual household expenditure on lighting vary, in part because of survey methodology, but all show that households spend a substantial amount on a service they regard as a necessity. A survey of households in selected Millennium Villages found an average annual expenditure of US\$48.27 on lighting and electricity. More than half of this was on kerosene (55.3%), 39% was on batteries and 0.3% on candles.<sup>32</sup> Lighting Africa’s market surveys estimated the average annualised costs of purchasing and running lighting devices at US\$57 per household per year, while en.lighten’s estimates across 45 sub-Saharan countries suggest average annual expenditure of US\$102 on kerosene, candles and batteries.<sup>33</sup>

Addressing the lack of access to electricity in sub-Saharan Africa needs to recognise the significant amounts already spent by households on lighting and communications. This expenditure presents an opportunity to increase access and pay for extended electricity services. If households spend around US\$50 a year on electric lighting, an amount many are already spending on lighting, at an average price of US\$0.10 per kWh,<sup>34</sup> this would purchase 500 kWh a year. This is more than current African

Table 3  
**Monthly cost of running lighting devices**

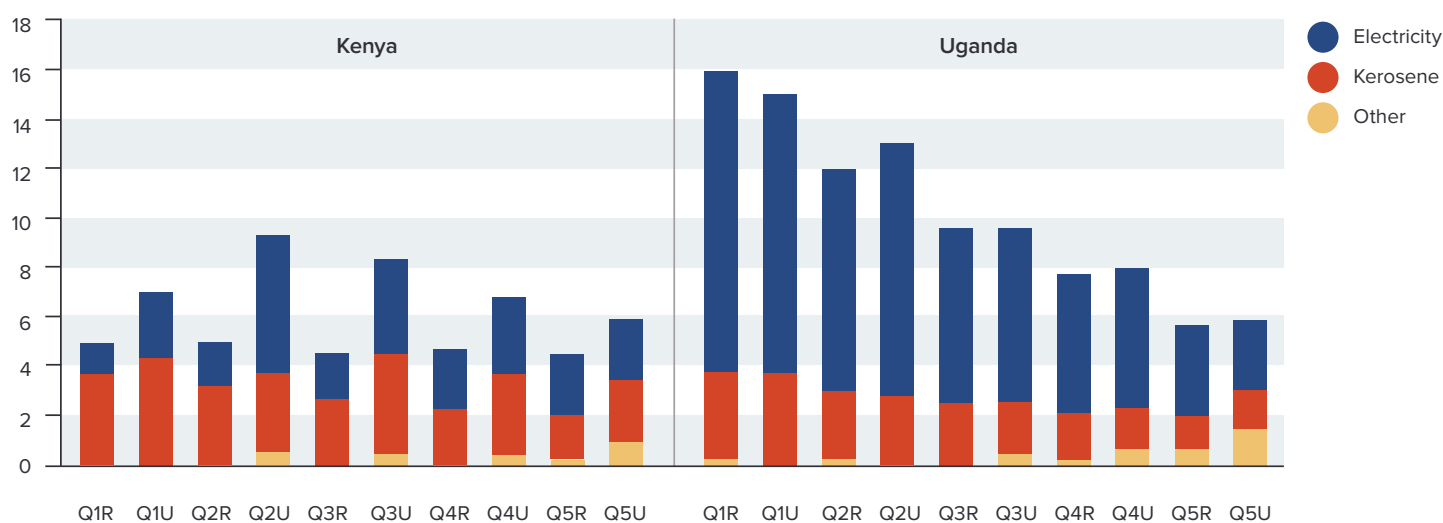
	Ethiopia US\$	Ghana US\$	Kenya US\$	Tanzania US\$	Zambia US\$
Paraffin lamp with glass cover	3.30	3.20	8.06	5.10	3.54
Paraffin lamp with no cover	0.90	2.40	2.80	2.40	4.65
Bottle gas lamp	0.80	n/a	n/a	0.85	n/a
Candles	0.30	1.44	0.77	1.50	4.74
Torch batteries	0.90	2.31	1.38	2.30	2.34
Battery powered lantern	n/a	7.80	n/a	5.00	10.21

Source: Lighting Africa.

average residential consumption. Households in the lowest income quintiles that have access to electricity tend to consume less than this. At a price of US\$0.40 per kWh, around the cost of generating off-grid electricity, US\$50 would purchase 125 kWh a year which would still be enough to meet the need for lighting and communications in low-income rural households.

Poorer households tend to spend a larger proportion of their income on energy than richer households. Analysis of household survey data from 30 African countries found that the poorest quintile spent 15% of their total expenditure on energy, compared with 9% by the richest.<sup>35</sup> Household survey data from Uganda showed that the poorest quintile there spent 16% of their total expenditure on energy, and the richest quintile 5.7%.<sup>36</sup> These proportions also vary between rural and urban areas, as shown in Figure 3.

Figure 3  
**Proportion of household expenditure on energy by rural and urban income quintiles in Kenya and Uganda 2005/06**



Source: Bacon et al. 2010.

These figures do not distinguish between energy for lighting and energy for other uses, including cooking, which is the largest single use of energy by nearly all households. However, the proportions in Figure 3 for electricity and kerosene can be regarded as a good indication of the share of expenditure on lighting by different income quintiles.

Similarly, the use of electricity varies with income group. In Uganda, for example, where electrification rates are low, 0.2% of households in the lowest income quintile used electricity in 2005/06, compared with 15% in the highest quintile.<sup>37</sup> The international goal of universal access to electricity calls for the eradication of these differences and the supply of electricity to all households, across all income quintiles and in both urban and rural areas.

To ensure universal and equitable access, and to maximise the benefit from electrification, low-income households may still need support to use electricity for essential services, such as lighting. For electricity supplied through the grid, the tariff structure is commonly used to cross-subsidise low-income consumers.

An analysis of tariffs in the mid-2000s found that about two-thirds of the residential tariff structures in sub-Saharan Africa were increasing block tariffs (IBTs), which have a different unit price for each of a number of defined blocks of consumption. One-third of tariffs had the same unit price irrespective of the level of consumption.<sup>38</sup> Half of the tariff systems also had a fixed monthly charge, US\$1 to US\$3 in most cases. IBTs lend themselves to cross-subsidisation by setting the tariff for the first, or 'lifeline', block at a lower level. In most cases this block was 50 kWh per month, but the lifeline tariff varied from US\$0.009 (Nigeria) to US\$0.266 per kWh (Mali). In sub-Saharan Africa, most countries recover costs through higher unit prices for high consumption level blocks, but in a small number of countries the tariff structures would not be able to recover operating costs.<sup>39</sup>

Some countries also set a social tariff, providing a bigger subsidy for households that meet certain eligibility criteria. South Africa, for example, introduced Free Basic Electricity in 2004, aiming to provide 50 kWh a month free to low-income households connected to the grid.<sup>40</sup> The initiative has been implemented unevenly, and a review in 2012 found that a quarter of those eligible did not receive free basic electricity.<sup>41</sup>

Nevertheless, many households are able to afford tariffs which recover costs, and it is clear that monthly tariffs need not be a barrier to access to grid electricity. At the same time, tariff structures can be designed to allow cross-subsidisation for the lowest-income households.

Tariffs are not the only cost incurred when gaining an electricity connection. In most countries there is also a connection charge for new consumers, and investment is required for wiring and fittings within the home. Connection charges vary across sub-Saharan countries, both in the amount of the charge and its rationale. In some cases, it is intended to cover administrative costs, in others it is meant to cover the full cost of extending the grid to a particular house. Connection charges in Africa are high by international standards, ranging from US\$2 to US\$400, and averaging US\$168 (across 15 countries with information available).<sup>42</sup> In five countries they exceed, by a good margin, average monthly incomes. High connection charges can, therefore, make access to electricity unaffordable for households, even if the monthly tariff can be afforded.

There are two ways to make connection charges more affordable. The first is to reduce the costs, by adopting less expensive technical specifications.<sup>43</sup> This would also be a way to reduce the costs of internal wiring incurred by new consumers. Connection charges could also be made affordable by spreading the cost over time, rather than incurring it as an up-front cost before the supply is connected. This would allow any savings in energy expenditure from the substitution of electricity for kerosene and batteries, to be used to cover the cost of the initial connection. In Senegal, monthly bills include a charge that allows their up-front connection and wiring costs to be repaid over time,<sup>44</sup> and a number of credit schemes have been introduced, such as in Cote d'Ivoire, Kenya and Botswana, to enable payment of connection charges to be spread out over time.<sup>45</sup> These credit schemes have been linked to the electricity provider or government, rather than provided by commercial financial institutions.

For off-grid electricity consumers, there is less scope within tariff structures to subsidise access for low-income households. Mini-grids can use technical means, such as load limiters, to ensure a household's consumption does not go above a predetermined maximum, and charge differential tariffs for different levels of consumption. Costs can also be reduced by the use of appropriate technical standards. For stand-alone systems, a variety of credit and payment systems has evolved, often initiated by the supplier of the equipment (see Box 4.) Prepayment and mobile payment technologies make revenue collection less costly and more efficient.

#### Box 4

### **Access through pay-as-you-go solar electricity: the example of Azuri Technologies**

Although the cost of solar technologies has fallen in recent years, solar lighting remains out of reach for many low-income families. At US\$70, the typical price of a lighting device is too high to be affordable without credit, but this is often not available for their purchase. The suppliers of lighting devices are therefore innovating payment methods that allow resource-poor households to pay the purchase cost over a period of time. One of the most successful is Azuri Technologies.

Azuri produces solar home systems that incorporate a pay-as-you-go controller. This is activated by a code which is obtained by purchasing a scratch card and is then sent by SMS to Azuri. Azuri sells its solar home systems to dealers who install the system, provide after-sales support and sell the scratch cards, which can be physical cards or scratch card numbers bought using a mobile payment system.

Customers pay an initial fee of about US\$10 for the installation of the lighting system in their home, comprising a 2.5 Watt-peak (Wp) PV module, battery, two light-emitting diode (LED) light bulbs, and a USB socket for phone charging. They pay about US\$1.50 for a weekly scratch card, which is about half of the typical US\$3 a week spent on kerosene for lighting. After 18 months, users can pay a fee of about US\$5 to have the system permanently unlocked or they can upgrade to a larger system.

Following a pilot in 2011, Azuri began commercial sales in Kenya the following year and by March 2013, 2,400 systems had been installed. By 2015, the system is available in 11 African countries.

An impact study in 2014 found that the main use of the lighting provided by the solar home systems was studying, and that mobile phone charging was the second most important use of the systems. Most users also reported working more, and saving time on travelling to purchase kerosene or charge their phone.

Source: Ashden; Azuri (<http://www.azuri-technologies.com>)

## **3. Electricity for growth and production**

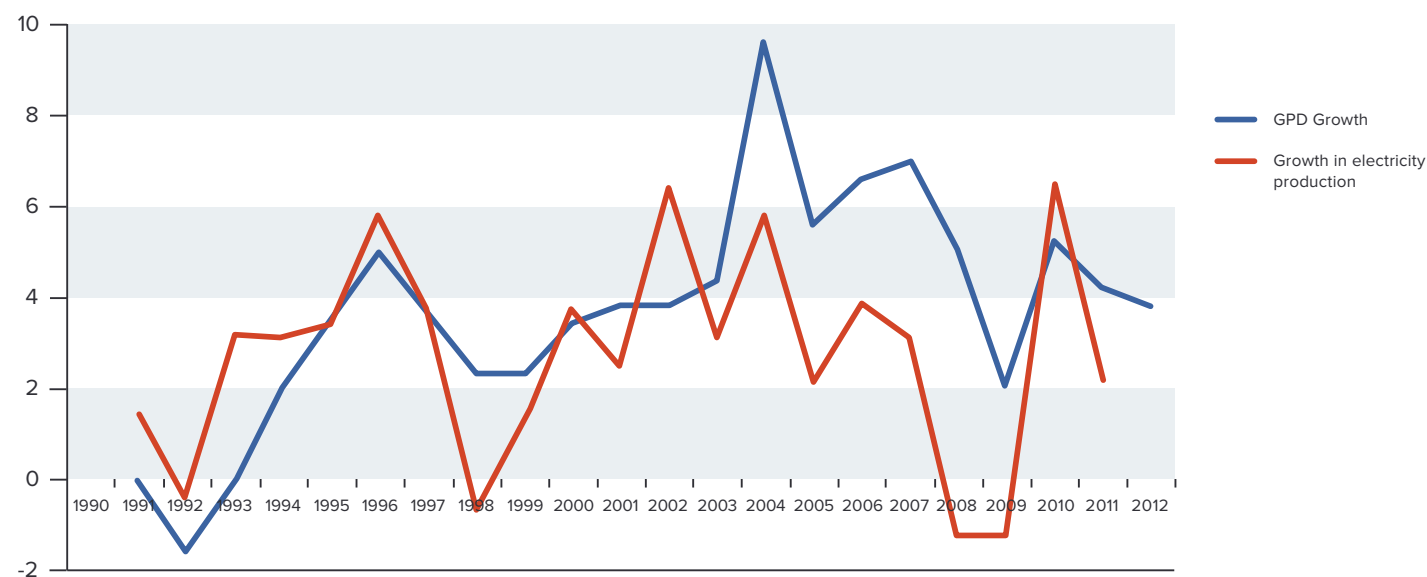
Economic growth is closely associated with the production and consumption of electricity, though the relationship is complex and context-specific. Some studies have found no causal relationship between growth and electricity (or energy consumption), while others have concluded that electricity is a factor that determines growth, or vice versa, or the causal relationship is in both directions.<sup>46</sup>

This variation in the findings from statistical analysis is partly due to differences in methodology and the data used (e.g. different countries and time periods). The evidence from sub-Saharan Africa suggests that electricity is a factor that does contribute to economic growth.<sup>47</sup> In different countries the causal relationship has been found to be in both directions and in one direction.<sup>48</sup> There is also evidence that electricity infrastructure is a significant factor explaining differences in industrial development between countries.<sup>49</sup> Whether as a causal factor or enabler of growth, it is clear that electricity consumption is linked to economic growth. Figure 4 shows how the annual rates of growth in GDP and electricity consumption in sub-Saharan Africa have followed a similar pattern.

The impact of economic growth on the demand for electricity will be felt through higher incomes, allowing higher levels of consumption in the residential sector, and through expanded industrial and service sectors. Industry consumes the largest share of electricity, accounting for half of all electricity consumed in sub-Saharan Africa in 2012 (IEA database). This was largely for mining and mineral processing, and concentrated in South Africa, Nigeria, Ghana and Mozambique.<sup>50</sup>

Under business as usual assumptions, the IEA expects the total demand for electricity in Africa to increase at an average rate of 4% a year, until at least 2040 (Table 4).<sup>51</sup> The demand for electricity from the industrial sector will more than double between 2012 and 2040, according to IEA estimates. A substantial part of this additional demand is from the mining sector, whose demand is expected to be 142-155% higher in 2020 than in 2012, and will consume 30% of sub-Saharan Africa's electricity by 2020.<sup>52</sup>

Figure 4  
**Pattern of annual growth rates in GDP and electricity consumption, sub-Saharan Africa, 1990-2012**



Source: World Development Indicators.

Table 4  
**Electricity demand by main sectors 2010-2040 (TWh)**

	2010	2020	2030	2040
<b>Residential</b>	91	163	283	463
<b>Industrial and commercial</b>	331	516	760	1107
<b>Total</b>	423	679	1043	1570

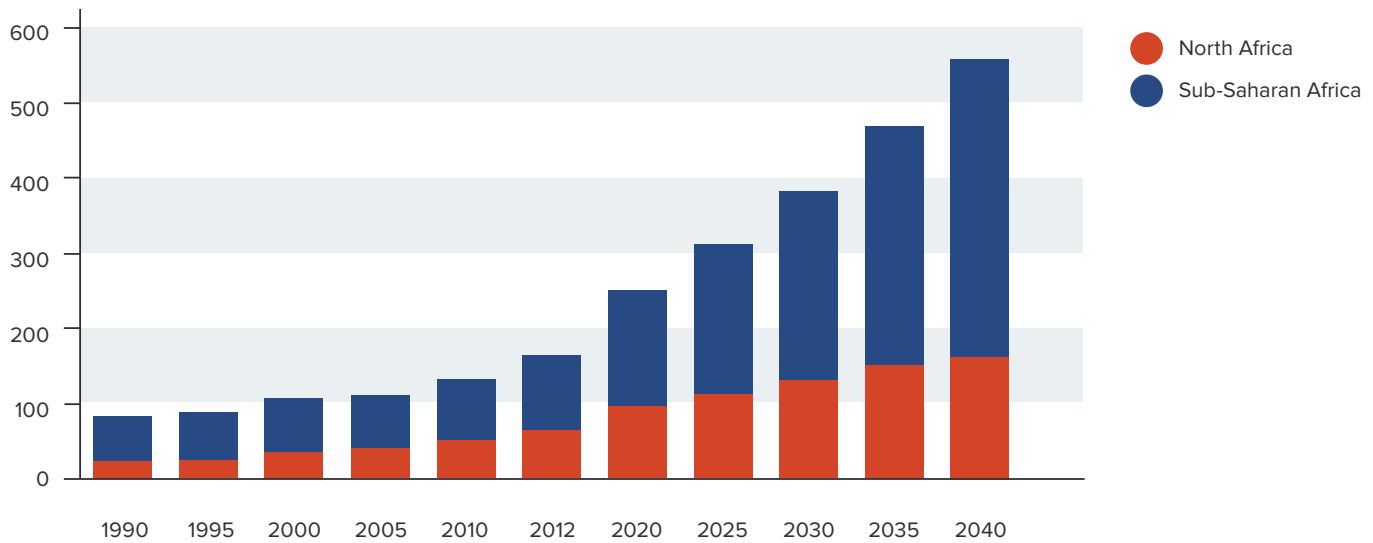
Source: Castellano et al., 2015.

### EXPANDING GENERATION CAPACITY

The total installed generation capacity in Africa was 165 GW in 2012. The five countries of North Africa accounted for around 40% of this. Sub-Saharan Africa’s share, totalling 97 GW, was dominated by Nigeria (18 GW) and South Africa (46 GW).<sup>53</sup> The installed capacity in around half of sub-Saharan countries is less than 500 megawatts (MW).

Generation capacity in Africa needs to expand rapidly to meet expected growth in the demand for electricity from existing consumers, from additional consumers gaining access and from growth in the industrial and services sectors. The IEA estimates that installed generation capacity will more than double from 165 GW in 2012 to 384 GW by 2030, and increase by almost another one and half times to 558 GW by 2040 (under the business as usual or New Policies Scenario).<sup>54</sup> As shown in Figure 5, this will require a much faster expansion in capacity in sub-Saharan Africa than was achieved over the past two decades.

Figure 5  
**Installed generation capacity estimates 1990-2040**



Sources: 1990-2010, SE4All database; 2012-2040, IEA (2014).

The broad options to expand the supply of electricity, and access, are (a) to extend the national grid, (b) build mini-grids, and (c) promote decentralised stand-alone systems. Within each of these categories a variety of techniques can be used to generate and distribute electricity. The IEA's projection assumes that all urban areas would be best (i.e. most economically) supplied through grid extension.<sup>55</sup> According to the IEA, grid extension would also be the best option for 30% of rural areas; mini-grids would be best for 45.5% of rural areas and off-grid (stand-alone) systems<sup>56</sup> best for 24.5%.<sup>57</sup>

Though more individual consumers might be best served by off-grid supplies, their relatively low consumption means that the bulk of Africa's electricity will continue to be delivered to industrial and commercial consumers connected to the grid. By one estimate, industrial and commercial consumers will account for 68% of the demand in 2030, and about 7% of this is expected to be through off-grid generation.<sup>58</sup>

The supply of electricity to the grid to meet this demand is expected to be predominantly from large-scale generating units, such as fossil fuel plants, nuclear power plants and hydropower plants, which have significant economies of scale but require an efficient T&D network to serve consumers. Indeed, according to the IEA, investment in T&D will need to be nine-times higher than it is today, and proportionally greater than investment in generation capacity.<sup>59</sup>

Distributed electricity generation, such as rooftop solar PV and localised wind farms feeding into the distribution network, could also help increase the supply of electricity to the grid. The potential for distributed small-scale generation is not well understood, however, and it rarely features in power sector plans. Only 9 countries in Africa have a feed-in tariff policy to encourage it.<sup>60</sup> Small generation units may not provide all the economies of scale in electricity production, but they have the advantages that they require smaller amounts of capital investment and they contribute to the resilience of the electricity distribution system in the face of technical breakdowns and extreme weather events.

Mini-grids comprise a generator of electricity and a low-voltage distribution network (grid), usually serving a single community, village or small town. The source of electricity may be a diesel generator, a solar PV system, a micro-hydro scheme or a combination (hybrid) of these or other sources. Mini-grids are not connected to the national grid, though may be seen as a precursor or step towards this. Mini-grids may be community owned (e.g. by local authorities or cooperatives), operated by a utility company, operated by a commercial business, or some combination of these (e.g. community owned but privately operated).<sup>61</sup> More detail about the variety mini-grid models found in Tanzania is presented in Box 5.

## Box 5

***There is a variety of possible models for mini-grid development: examples from Tanzania***

Mini-grid development in Tanzania demonstrates the diversity of possible models for mini-grid design and operation as well as their potential for enabling access to electricity in rural areas. Over 30 mini-grids are operating in the country and electricity from mini-grids may be the best option in 1,600 other locations, according to the Rural Electrification Investment Prospectus. Renewable energy mini-grids are a cost-effective electrification option for an estimated 20% of the population, over 9 million people.

TANESCO, the state-owned utility, operates 21 diesel and gas-fuelled mini-grids, with capacities ranging from 400 kW to 12 MW. The initial investment came from public funds and donors. The generators for these mini-grids are expensive to operate (the costs in 2012 were US\$0.40-0.45 per kWh), but TANESCO is required to charge households the same tariff as consumers with grid connections. This means that TANESCO loses around 30 cents per kWh consumed by customers on its isolated mini-grids.

Private sector mini-grids in Tanzania are operated by commercial organisations, co-operatives and non-governmental organisations. The mini-grid scheme operated by the Urambo Electric Consumers Co-operative Society was established in 1993. This mini-grid has two diesel generators (193 kW capacity), serving about 240 customers. The tariff in 2002 reflected actual costs, but was more than 15 times higher than the TANESCO tariff. This has resulted in a limited connection rate.

Rift Valley Energy, a commercial company, set up the 4 MW Mwenga hydro plant with a mini-grid to provide electricity to rural areas. At the same time, it is able to sell the bulk of the produced power to TANESCO via connection to the main grid. The scheme established a utility company for the local customers, Mufindi tea and coffee factories, 14 villages and some industries.

The Njombe Catholic Church Mission operates small hydro plants (about 150kW each) in three villages. Ownership and responsibilities are shared between the Mission, the local community and donors, but the Mission manages operations. Metered and flat rate tariffs are used, and in 2013 the tariffs were lower than the TANESCO tariff.

The non-governmental organization, TaTEDO has installed mini-grids in 16 rural communities. The generators use either liquid biofuels or mineral diesel, and can provide mechanical power as well as electricity. The average net revenue, after all operating costs, for these mini-grids may amount to Tshs 25.6 million (Tanzanian shillings) (about US\$13,000) per month.

At the end of 2014, the Sustainable Energy Fund for Africa approved a grant of US\$420,000 to Jumeme Rural Power Supply Ltd., for the preparation of plans to develop a portfolio of solar hybrid mini-grids. The Jumeme project aims to expand rural electrification to 16 villages, in the first phase, serving 11,000 households, 2,600 businesses, 42 public offices, 32 schools, and 12 health centres.

The Renewable Energy Agency has over 90 projects in the pipeline and the country has one of the most advanced policy and regulatory frameworks for small power projects supplying both the main grid and off grid mini grids in Africa.

Source: IED (; World Bank; <http://www.afdb.org/en/news-and-events/article/sefa-to-support-solar-hybrid-mini-grids-in-rural-growth-centres-in-tanzania-13897/>)

Stand-alone systems include a source of electricity (e.g. diesel generator, pico-hydro or solar home systems) and distribution or wiring within a single property (home or firm). The system operator is the consumer of the electricity generated. Although stand-alone systems do not require conventional electricity infrastructure, their diffusion and operation requires an effective market for energy devices and services. For the operations of industrial and commercial consumers, stand-alone systems may be essential in locations not connected to the grid, or as a back-up in case of grid failure.



When planning to meet the expected rapid growth in electricity demand, planners and policy-makers should assess all of the technical options before arriving at an appropriate balance between options that best serve their country's or region's needs.

Sub-Saharan Africa currently invests about US\$8 billion a year in electricity generation and T&D, equivalent to 0.5% of GDP.<sup>62</sup> This level of investment is inadequate to overcome the existing shortcomings of the region's electricity systems, to expand coverage and to meet the growth in demand. Indeed, the region has under-invested for a number of years. Analysis for the Africa Infrastructure Country Diagnostic (AICD) suggested that between 2005 and 2015, the annual investment requirement was more than three times higher than this, at US\$27 billion a year.<sup>63</sup> Of this, 15% was just to rehabilitate existing infrastructure and maintain capacity. Looking ahead, the IEA's business as usual scenario (the New Policies Scenario) requires annual investment to average US\$46 billion a year between 2014 and 2040, roughly half for generation and half for T&D.<sup>64</sup> This is more than five times higher than current levels, but the IEA suggests that policy and project preparation barriers may be more of a hurdle than the availability of finance.<sup>65</sup>

The IEA estimates that the capital cost of increasing the electrification rate in sub-Saharan Africa, from 32% in 2012 to 70% in 2040, will be US\$205 billion.<sup>66</sup> This is equivalent to about US\$7.5 billion a year, and less than 20% of the total investment in the power sector expected over the same period. SE4All estimates that US\$17 billion a year will be required to provide universal access to electricity in sub-Saharan Africa.<sup>67</sup> Capital invested in the electricity sector can be from several sources. The financial state of the utilities means that self-financing from revenue is quite limited. The two main sources, therefore, are public finance and external financing, the latter including foreign direct (equity) investment, commercial bank lending, and multilateral and bilateral development assistance.

The total additional investment required is beyond the capacity of sub-Saharan public finance, and even small grid-connected generation plants are likely to be beyond the scope of domestic equity investors. Though development finance institutions will continue to be important, it will be necessary to attract more international commercial lenders and foreign equity to invest in sub-Saharan electricity systems. This will depend on the costs and returns of investing in electricity generation and T&D and on the perceived risks for investors.<sup>68</sup> The main risks are in the regulatory and policy frameworks of countries in the region, and risks related to economic or political instability. Governments in the region are in a position to reduce these risks and create conditions that are attractive to investors.

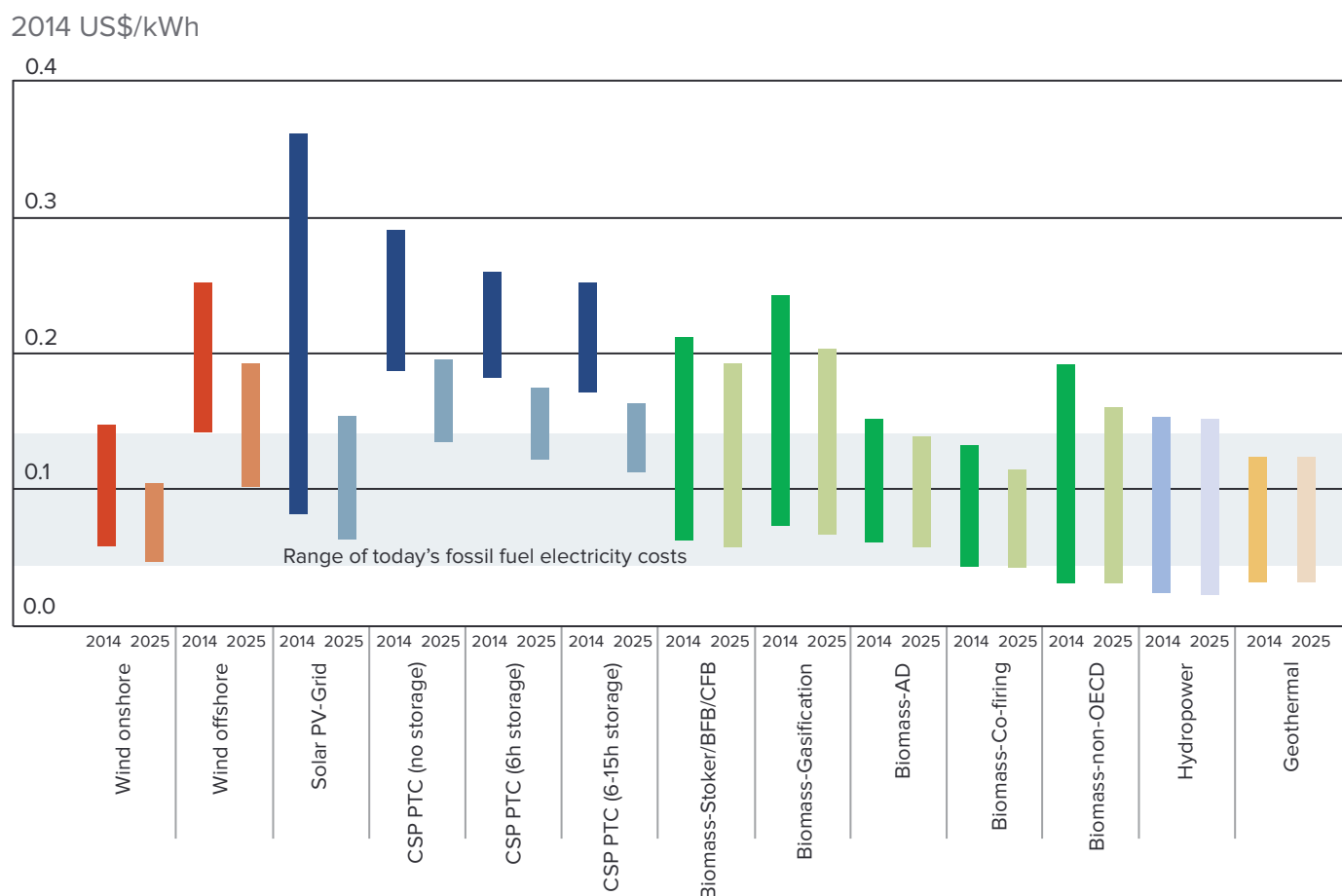
## COMPARING COSTS

The levelised cost of energy (LCOE) is used to compare the costs of different options for supplying electricity. The LCOE takes account of costs, capital and operating, over the life of the infrastructure. The cost profiles of fossil fuel technologies and renewable energy technologies are quite different, the former having low capital and high recurring costs, while the latter has high initial capital costs and low operating costs. The LCOE allows comparison on the same basis.

The lifetime of some electricity infrastructure can be three or four decades, so estimation of the LCOE calls for assumptions about future prices. Some energy prices may change significantly. The price of oil, for example, was on the increase until mid-2014, but has since fallen dramatically and there are varied views about whether and when it will return to previous levels. The capital costs of renewable energy technologies, except hydro, have been declining rapidly in recent years and are expected to reduce further. Energy prices also vary between countries, often influenced by the regulatory environment, and the capital costs vary according to the specific conditions of their location. Nevertheless it is useful to compare the costs of generating electricity from different sources, using the most recent figures available.

Figure 6 summarises the latest (2014) worldwide LCOE estimates compiled by IRENA.<sup>69</sup> A range of costs is shown for each technology, reflecting differences due to location and other factors. Figure 6 shows that, globally, except for off-shore wind and concentrated solar power (CSP), the LCOE of renewable options is at the same level or lower than the cost of fossil fuel options.

Figure 6  
LCOE ranges by generation technology 2014 and 2025



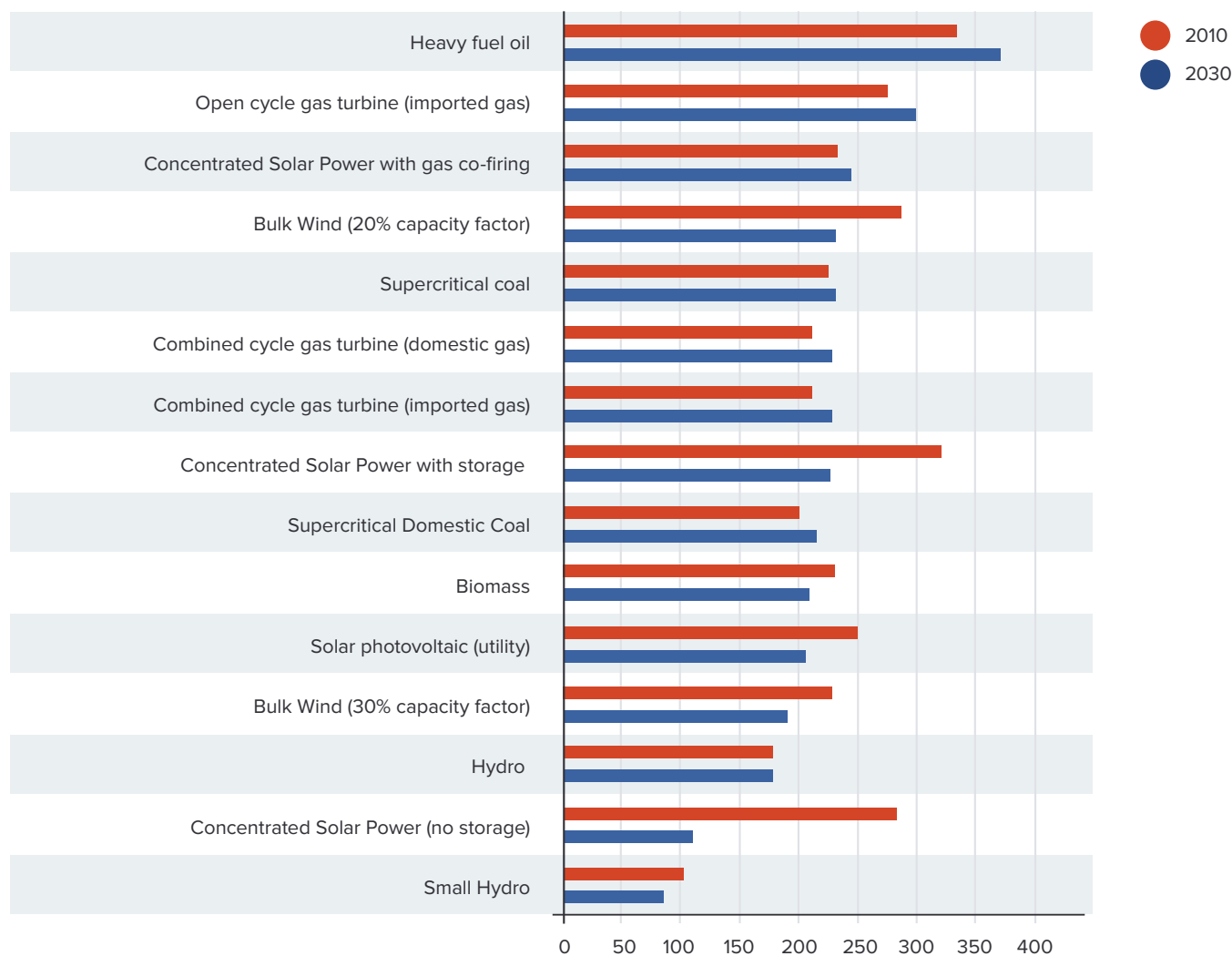
Sources: IRENA, 2015, Figure 10.1.

Given the influence of location on these cost estimates it is also useful to consider LCOE estimates specifically for Africa. Estimates for 2010 and 2030, compiled by IRENA, are summarised in Figure 7, and present a similar picture to international costs. These estimates also suggest rising fossil fuel costs and falling renewables costs. Estimates from the IEA, in Figure 8, include some of the less efficient fossil fuel technologies (sub-critical coal and gas turbines), which are lower than renewable LCOEs, but which do not take pollution and emission costs into account.

Accurate estimation of the costs of pollution from the generation of electricity in sub-Saharan Africa is difficult. The main cost is on human health. Fossil fuel power generation contributes to atmospheric air pollution,<sup>70</sup> which causes 176,000 deaths a year, imposes costs on Africa's stretched health services, and reduces people's productivity through ill health.<sup>71</sup>

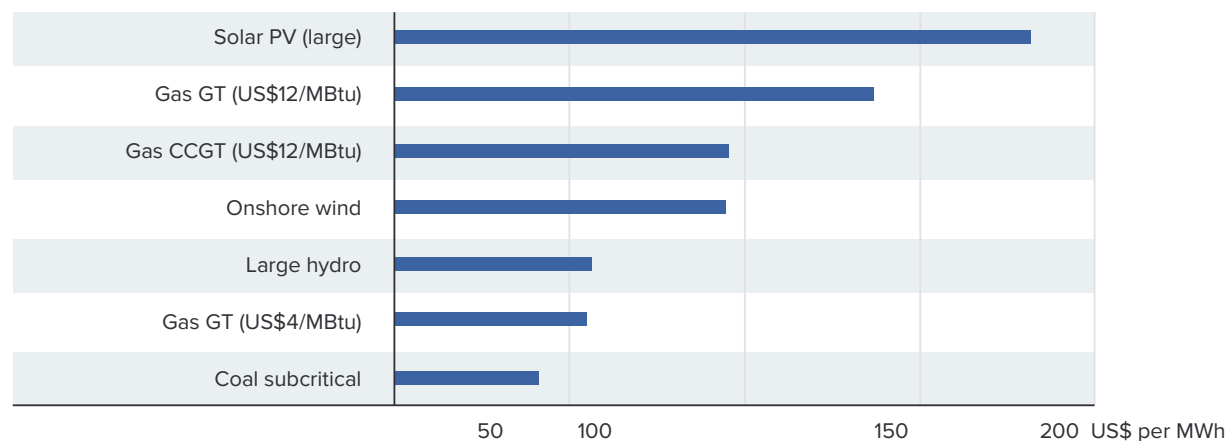
Factoring in environmental costs, by putting a price on carbon, would make LCOE estimates favour renewable electricity options even more. The price of carbon in international carbon markets is currently low, does not fully reflect the costs of pollution, and therefore may be unsuitable for LCOE estimates. South Africa is introducing a carbon tax in 2016, levied at about US\$10 per tonne CO<sub>2</sub>e, but with an effective rate of US\$1 to US\$4 per tonne.<sup>72</sup> At this rate, fossil fuel electricity generating 1-2 tonnes CO<sub>2</sub> per MWh,<sup>73</sup> depending on the technology, could add US\$1-US\$8 per MWh to the LCOE.

Figure 7  
**LCOE of electricity generation in 2030 (US\$/MWh)**



Source: IRENA, 2013a, 2103b, 2015.

Figure 8  
**The IEA's LCOE estimates for Africa**



Source: IEA, 2014

Off-grid electricity generation tends to have a higher cost than large-scale generation for the grid. Table 5 below shows the off-grid LCOE estimates from two sources, IRENA’s planning tools for West Africa and Southern Africa<sup>74</sup> and Innovation Energie Développement’s (IED) mini-grid estimates.<sup>75</sup> The table shows that off-grid generation from diesel or petrol is relatively more expensive than renewable alternatives.

Table 5  
**Levelised costs of alternative off-grid technologies in Africa**

	IRENA US\$/MWh	IED US\$/MWh
Diesel 100 kW	320	300-600
Diesel/gasoline 1 kW	604	
Small hydro	102	100-300
Solar PV without storage	152	
Solar PV with 1 hour storage	250	
Solar PV with 2 hour storage	163	
Biomass gasifier		100-300
Biomass	74-127	
Wind hybrid		200-400
Solar hybrid		400-600

Sources: IRENA, IED (2013)

In 2012, 82% of Africa’s electricity was generated by the combustion of fossil fuels. By 2040, this proportion is expected to have reduced to 62% (under business as usual), although the quantity of electricity generated from fossil fuels will more than double.<sup>76</sup> Another 81 GW of thermal capacity will have been built in sub-Saharan Africa to supply this. The cost comparisons for electricity from different sources and the expected future reduction in the cost of renewables (shown in Figure 7), suggest the need to review plans for expanding gas- and coal-based generation in some countries. Forecasters may also need to review their assumptions for business as usual scenarios.

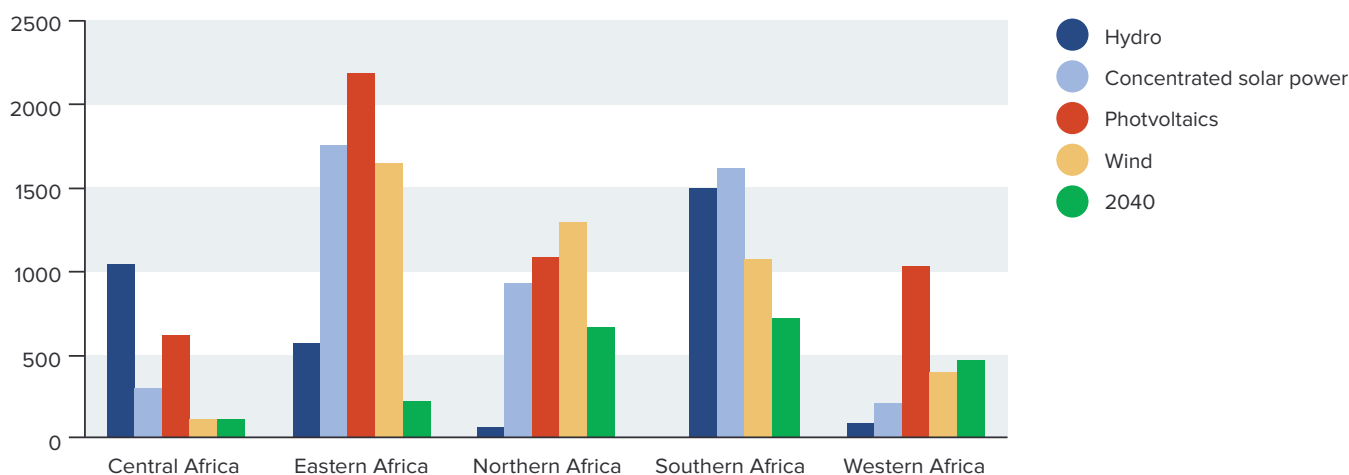
As well as potential savings in costs, renewable energy could benefit sub-Saharan countries in other ways. The development of renewable energy could create jobs for Africans, through manufacturing, installation and maintenance services, and in businesses that use the electricity generated. For every MW of renewable electricity installed, 27 jobs could be created.<sup>77</sup> One study has estimated that in South Africa, more jobs could be created through the development of renewable energy than an energy system based on fossil fuels.<sup>78</sup>

Investment in renewable electricity generation would also reduce the impacts of volatility in the prices of fossil fuels. The international market price of oil can change rapidly and unpredictably. In 1979, 1986 and 1990, for instance, there were price rises.<sup>79</sup> Between mid-2014 and January 2015, the price fell from US\$115 per barrel to US\$50 per barrel, and there is uncertainty about the future price. This volatility delays investment, reduces consumption and slows growth.<sup>80</sup> With 78% of sub-Saharan Africa’s electricity currently dependent on fossil fuels, price volatility can have a direct impact on the financial performance of the power sector. The costs of renewable energy, however, are falling and have low volatility. The diversification of energy sources for electricity in sub-Saharan Africa would reduce the impact of oil price changes on the sector.

## EXPLOITING RENEWABLE ENERGY POTENTIAL

Although renewable energy sources can provide least-cost options for the supply of electricity in Africa, their distribution across the continent is varied. Hydropower, for instance, is the least-cost source of electricity but there is only enough hydropower potential to meet the expected total demand for electricity in 2040 in Central and Eastern Africa, largely in the Congo and Nile river basins (see Figure 9). Overall, however, Africa's renewable energy resources are more than adequate to supply the future demand for electricity. Indeed, the demand expected in 2040 (under business as usual scenarios) could be met by about 12% of the technical potential of the continent's renewable energy resources.

Figure 9  
**Renewable energy potential and expected demand in 2040 (TWh)**



Source: IEA, 2014

Solar energy has the greatest potential across the continent. The technical potential for solar PV has been estimated to total 6,567 TWh a year, almost three times the expected total demand in 2040.<sup>81</sup> In addition, the total potential for CSP is an estimated 4,719 TWh a year, mainly in the arid and semi-arid areas of the north, east and south of Africa.

Wind energy, which has been used for many years to pump water in many rural areas, has been little exploited so far for electricity generation. The continent's total technical potential has been estimated at 3,800 TWh a year. Though it is concentrated in the coastal zones of northern, eastern and southern Africa, it is one of the most reliable wind energy resources in the world.

The geothermal energy resource is concentrated in eastern Africa and, with a total potential between 10 GW and 15 GW, is likely to make a significant contribution to electricity supply in the region. It is competitive with thermal generation and unlike other renewables, its supply is not variable. Kenya regards geothermal as the preferred choice for investment in generation capacity, and is aiming to increase this from 250 MW to 5 GW by 2030.<sup>82</sup>

Figure 9 shows that the renewable energy potential in some parts of Africa, eastern and central Africa in particular, far exceeds foreseeable demand. This offers the prospect in some countries (e.g. DRC and Ethiopia) of investing to export electricity to neighbours or even further afield. Cross-border trading of electricity has been taking place in Africa since the 1950s, under bilateral arrangements,<sup>83</sup> and the potential advantages for managing demand by creating regional or continent-wide markets for electricity have long been recognised. The Southern African Power Pool was formed in 1995. The proposal for a 'Clean Energy Corridor' through eastern and southern Africa is intended to exploit the continent's renewable energy potential for the benefit of the widest number of countries.<sup>84</sup> The formation of regional power pools has been a slow process, building on inefficient and financially constrained national utilities, in countries where there may not be enough power for domestic consumption.

## THE RELIABILITY OF ELECTRICITY

The quality of Africa's electricity supply is poor. On average there is a power outage about every four days in sub-Saharan countries, and in some countries outages are a daily occurrence. Only four African countries are above the world average for

the quality of their electricity supply in the World Economic Forum's competitiveness index, and five African countries<sup>85</sup> appear among the ten lowest-scoring countries.<sup>86</sup>

The reliability of electricity supplies is affected by two main factors: whether the available generation capacity is enough to meet the demand, particularly peak demand, and the quality of the T&D infrastructure (largely determined by its age and maintenance). When the reserve margin (i.e. the difference between peak demand and capacity) falls below 15%, electricity systems may be forced to practice load shedding, temporarily cutting the supply to some consumers. In some African countries the reserve margin is in deficit (i.e. capacity is lower than peak demand), including ten of the twelve countries in the Southern Africa Power Pool.<sup>87</sup>

Technical faults in the T&D network, as a result of poor maintenance, installation and design, are another cause of outages. The quality of the T&D system is usually measured by the losses incurred once electricity has been dispatched to the grid, and in the most efficient system, losses of around 6% can be expected.<sup>88</sup> In sub-Saharan Africa average losses, at 18%, are more than double the world average.<sup>89</sup> A World Bank study for the period 1999-2006 found average losses in the region to be 27.5%, with significant variation in losses between countries, ranging from 14.5% in Angola to 68% in Swaziland.<sup>90</sup> According to one estimate, these losses usually represent more than 0.5% of GDP.<sup>91</sup>

When losses are high, a significant proportion can be due to non-technical factors, such as a failure to collect revenues and the theft of electricity. Reliable estimates of these non-technical losses are available for only a few countries. In South Africa, up to 40% of the losses in Eskom's network have been found to be due to theft, mostly by businesses.<sup>92</sup> The cost of electricity theft in South Africa has been estimated as US\$450 million a year.<sup>93</sup> In Uganda, where overall access is less than 10%, electricity theft costs an estimated 60 billion shillings a year (US\$20 million).

The economic impact of unreliable electricity is felt through lost or reduced output, lower productivity, and the higher cost of electricity for consumers. Outages cause African firms to lose 4.9% of annual sales, on average, and much more in some countries.<sup>94</sup> For the wider economy, these losses have been estimated to reduce GDP by around 2%.<sup>95</sup> At the firm level, unreliable electricity has been found to have a significant negative impact on productivity,<sup>96</sup> though not always for small and medium-scale manufacturing enterprises.<sup>97</sup> The impact of unreliability in electricity supplies depends on geography, the economy's structure, and the overall business environment, but lower productivity appears to be associated with more frequent and longer outages.<sup>98</sup>

Electricity losses add roughly US\$35 per MWh to the cost of electricity for consumers in sub-Saharan Africa.<sup>99</sup> Costs are increased again when firms, and households, use back-up diesel generators during grid outages. Close to half of all firms (45.8%) in sub-Saharan Africa own or use a back-up generator, with the greatest incidence in Nigeria (85.7% of firms).<sup>100</sup> The cost of electricity from small generators is about four times higher than from the grid, and in 2012 an estimated US\$5 billion was spent on fuel for back-up generators.<sup>101</sup> Generator ownership is affected by firm characteristics (including size, sector, and firm structure), and the probability of ownership is higher amongst large firms. Small-scale and micro-enterprises tend not to have generators.<sup>102</sup> Generators provide 12.6% of the electricity consumed by firms.<sup>103</sup> These generators account for a significant proportion of total installed generation capacity, averaging 6% across sub-Saharan Africa, according to Foster and Steinbuks (2008). Self-generation is more expensive than electricity from the grid, but when used for a small proportion of total operating hours, does not affect the average cost of power.<sup>104</sup>

## THE PERFORMANCE OF UTILITIES

In most African countries the basis for the development of the electricity system has been a vertically-integrated state-owned utility, responsible for generation and T&D. The natural monopoly that characterises the supply of electricity and its perception as a public service, notwithstanding low electrification rates, have resulted in the inefficient management of many electricity utilities, over long periods of time. Setting tariffs at below cost, failure to collect revenues, overstaffing and poor maintenance of infrastructure are all symptoms of this inefficiency.<sup>105</sup> The result has been that utilities have become an excessive burden on limited government budgets, amounting in sub-Saharan Africa to 1.4% of GDP in 2010.<sup>106</sup> In some countries, the losses incurred by the electricity utility amount to more than this – 2.8% of GDP in Senegal.

The weak financial performance of utility companies affects their ability to maintain the electricity infrastructure, reinforcing inefficiencies in the system, and it prevents or constrains investment in the expansion of electricity supply.<sup>107</sup> Their poor financial performance also inhibits private investors who would depend on the utility for their market.

Structural reform of the electricity sector, combined with privatisation, has been part of the conventional approach to addressing the inefficiencies of state-owned utilities, often with a presumption that private sector companies will be inherently more efficient. In Africa the complete unbundling of vertically-integrated utilities into separate private generation, transmission and

distribution companies, has been the exception rather than the rule. A review of 49 sub-Saharan countries in 2006 found that a vertically-integrated state-owned monopoly continued to operate in most countries (35). Only 8 countries had opened generation to independent power producers (IPPs).<sup>108</sup> More recently, in the 22 countries of eastern and southern Africa, 17 have systems dominated by a vertically-integrated utility, and in 10 of these it is state-owned (see Table 6).<sup>109</sup> The lessons from the past two decades suggest that power sector reform needs to be adapted to the local context and implemented over a long period of time. In the hybrid electricity systems that have evolved, comprising vertically-integrated utilities supplemented by private power producers, effective regulation of the electricity market is a critical question.<sup>110</sup>

Table 6

### Structure of power sector in countries of Eastern and Southern Africa

Vertically integrated state-owned utility	Vertically integrated	Unbundled
Angola	Burundi	Ethiopia
Botswana	Cong DR	Kenya
Lesotho	Djibouti	Sudan
Malawi	Egypt	Uganda
Mozambique	Libya	
Namibia	Rwanda	
South Africa	Tanzania	
Swaziland		
Zambia		
Zimbabwe		

Source: Castellano et al., 2015.

## 4. Conclusions and recommendations

It seems clear that the forecast rapid growth in the demand for electricity in sub-Saharan Africa will be driven by industrial expansion and the higher incomes of Africans who already have access to electricity. The consumption of those gaining access to electricity will add only a small proportion to overall demand. The two challenges of expanding electricity generation and distribution for economic growth, and extending electricity supplies to those who do not yet have access, are inter-related but require different policies and interventions.

Removing sub-Saharan Africa’s electricity deficit is a critical challenge for governments in the region. Electricity producers and suppliers of equipment for distributed generation in the private sector, as well as commercial financial institutions, have a critical role in building Africa’s electricity systems. The public sector will also continue to have a major operational role in most countries. A necessary condition to address the deficit will also be governments’ creation of appropriate policy and institutional frameworks. This section outlines key policy measures to address the challenges of electricity access and electricity to enable economic growth.

### ACCESS

The goal of universal access to electricity by 2030 has been accepted in principle by African leaders, though current plans in many countries fall short of this. Rapid progress on electrification has been achieved in some African countries over the past 15 years, and in other regions of the world rapid progress has also been made where governments make access a policy priority.<sup>111</sup>

**Governments should raise the level of their ambition for electrification, especially in countries where universal access is currently envisaged only for the next generation,** as an essential element of strategies for equitable development and for achieving the Sustainable Development Goals in Africa.

Making electricity affordable for the poorest households will be necessary to achieve universal access. For grid electricity, the tariff structure offers a means to subsidise them, and subsidies for connection charges will be necessary. **Governments should target all electricity consumer subsidies more directly at the poorest households.** As African countries gain middle-income status and start to introduce wider social protection measures, lessons from South Africa's Free Basic Electricity policy should be considered as a way to link electricity access and social protection.

**For off-grid supplies and grid connection charges, credit schemes for low-income households could be expanded.** These need to be managed efficiently, but not necessarily by organisations within the power sector. Subsidies for off-grid supplies (e.g. solar home systems) and grid connections should be targeted at the poorest households (e.g. through eligibility criteria, voucher schemes or cash transfers).

The extension of electricity services to all rural areas, where the great majority of people without access to electricity live, is constrained by the limited demand of each consumer, the high marginal cost of connections and high operating costs (maintenance and revenue collection). For these reasons, off-grid generation and distribution offers a more cost-effective option than grid extension in most rural areas. **Governments should include off-grid electricity (mini-grids and stand-alone systems) as an essential component of power sector plans.** Public support for the development of mini-grids and stand-alone systems should focus on the development of markets for these services and the goods to deliver them, rather than investment directly in infrastructure.

Mini-grids are a solution to a collective action market failure, where it is not in the interests of an individual household or firm to invest in supplying to other consumers, but a system that supplies multiple consumers would have economies of scale and be more cost-effective. **Public support for the design and implementation of mini-grids will be required if the number of new mini-grids is to be scaled up significantly.**

## GROWTH

Efficient institutions in the power sector will be essential to ensure that electricity contributes fully to growth and poverty reduction. Whether under public or private ownership, separate institutions for generation, T&D, and regulation, would allow focussed attention on each essential element of the electricity supply chain. **Governments should reform electricity utility companies to make them more efficient and financially sustainable.** This should include providing a framework to ensure that regulators have a strong mandate and an independent authority to implement and enforce the rules governing the sector.

The cost of generating a unit of electricity in sub-Saharan Africa is often not covered by the unit price charged to consumers. The level of tariffs is sometimes not enough to cover even recurrent operating and maintenance costs. **Governments and regulators should ensure that tariff setting in the power sector is transparent, based on actual costs and able to cover operating costs and contribute to future investment.**

For large-scale power projects the time between the initial feasibility study and commissioning is often several years. During this period costs can change (and often over-run), resulting in lock-in to infrastructure that may no longer be cost-effective. Some projects may be identified and included in plans for years before financing is in place and construction begins. **Energy sector planners should review national power plans to ensure they take advantage of recent dramatic reductions in renewable energy costs.** Given the global imperative of decarbonising electricity, feasibility analysis should factor in realistic carbon costs. Support from donors will be required by some countries to review and revise their power plans.

**Governments, individually and collectively, should build African institutional and technical capabilities to develop and disseminate renewable energy technologies.** The new renewable energy technologies, such as solar PV, wind power and geothermal energy, have huge potential in sub-Saharan Africa. Large-scale investments are already taking place, and in the off-grid section of the electricity market the number of companies is growing. Many of these initiatives depend on imported technologies and expertise, and the participation of foreign companies. African countries are potentially missing out on the wider economic benefits of greater domestic value-added in the development of renewable electricity.

The demand for electricity from the grid is affected by the reliability of the supply. Households and firms can be deterred from connecting because the benefit is outweighed by the cost of connecting and the risk of being dependent on an unreliable, unpredictable service. Low-income households and small enterprises cannot afford back-up generators. **The reliability of electricity supplies should be improved by ensuring adequate generation capacity (or imports) and improving maintenance of the infrastructure,** benefitting existing consumers and encouraging more people to invest in a connection.



## ACRONYMS

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ASER	Agence Sénégalaise d'Électrification Rurale
CO <sub>2</sub>	Carbon dioxide
DRC	Democratic Republic of Congo
GDP	Gross domestic product
GW	Gigawatt (1,000 megawatts)
GWh	Gigawatt hour
IBT	Increasing block tariff
IEA	International Energy Agency
IPP	Independent power producer
IRENA	International Renewable Energy Agency
JRC	Joint Research Council
kWh	Kilowatt hour
LCOE	Levelised cost of electricity/energy
LED	Light-emitting diode
MSME	Micro-, small- and medium-scale enterprise
MW	Megawatt (1,000 kilowatts)
MWh	Megawatt hour
NEPAD	New Partnership for African Development
ODI	Overseas Development Institute
PIDA	Programme for Infrastructure Development in Africa
PV	Photovoltaic
SE4All	Sustainable Energy for All
SHEP	Self-Help Electrification Scheme
T&D	Transmission and distribution
TANESCO	Tanzania Electric Supply Company
TaTEDO	Tanzania Traditional Energy Development Organisation
TWh	Terawatt hour (1,000 gigawatts)

## ENDNOTES

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- 1 Sub-Saharan Africa has the lowest per capita consumption of any major region in the world. Average per capita electricity consumption in 2012 was below 100 kWh in 16 countries, according to IEA *Africa Energy Outlook 2014*, Paris: International Energy Agency, 2014. Available at: <http://www.worldenergyoutlook.org/publications/weo-2014/>
- 2 World Development Indicators, Electric power consumption (kWh per capita): 537 kWh in 1990, 535 kWh in 2011. Available at: <http://data.worldbank.org/data-catalog/world-development-indicators>
- 3 Electricity is one form of energy necessary for growth and poverty reduction. It provided 9.4% of the energy consumed in Africa in 2012, according to IEA statistics (<http://www.iea.org/statistics/>). Biomass energy for cooking, which accounted for over half of all energy consumed in 2012, is addressed in another background paper for the 2015 Africa Progress Panel report.
- 4 Available at: <http://www.eu-africa-infrastructure-tf.net/attachments/CEMA/resolution-on-sustainable-energy-for-all-initiative.pdf>
- 5 IEA, 2014.) *Africa Energy Outlook 2014*.
- 6 IEA, 2014. *Africa Energy Outlook 2014*; Castellano, A., Kendall, A., Nikomarov, M. and Swemmer, T. *Brighter Africa: The growth potential of the sub-Saharan electricity sector*, London: McKinsey & Company, 2015. Available at: <http://www.icafrica.org/en/knowledge-publications/article/brighter-africa-the-growth-potential-of-the-sub-saharan-electricity-sector-276/>
- 7 In 2012, 82% of Africa's electricity came from the burning of coal, oil and natural gas (IEA, 2014).
- 8 IEA, 2014.) *Africa Energy Outlook 2014*.
- 9 IRENA. *Renewable Power Generation Costs in 2014*, Abu Dhabi: IRENA, 2015. Available at: <http://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=36&CatID=141&SubcatID=494>
- 10 IEA, 2014.) *Africa Energy Outlook 2014*.
- 11 The access rate for the whole continent was 43%. SE4All, *Global Tracking Framework*, Washington: Sustainable Energy for All, 2013. Available at: <http://www.worldbank.org/en/topic/energy/publication/Global-Tracking-Framework-Report>
- 12 SE4All, 2013. *Global Tracking Framework*.
- 13 IEA, 2014. *Africa Energy Outlook 2014*.
- 14 IEA, 2014. *Africa Energy Outlook 2014*, p.30, 40.
- 15 i.e. the proportion of the population who have access. There is no standard definition of 'access to electricity'. In some cases 'access' is used to mean that electricity is available at a particular location, irrespective of how many people actually use it. Increasingly, 'access' is interpreted as having an electricity supply in the home. It remains a binary measure, however – either there is a supply or there is not – with no indication of how reliable the supply is, how many hours in the day it is available, nor how much electricity is consumed, and what for.
- 16 Practical Action, *Poor People's Energy Outlook 2013*, Rugby: Practical Action, 2013. Available at: <http://practicalaction.org/ppeo2013>
- 17 Practical Action, 2013. *Poor People's Energy Outlook 2013*.
- 18 Lam, L., Smith, K., Gauthier, A. and Bates, M. Kerosene: A review of household uses and their hazards in low- and middle-income countries, *J Toxicol Environ Health B Crit Review*, 15(6), 396-432, 2012. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/22934567>
- 19 The actual savings will vary from country to country. The Country Lighting Assessments undertaken for en.lighten, for 45 African countries, suggest that around US\$100 a year per household could be saved by a switch to solar PV and LED lighting.
- 20 Attigah, B. and Mayer-Tasch, L. *Productive use of Energy (PRODUSE): The Impact of Electricity Access on Economic Development: A literature review*, Eschborn: GIZ, 2013. Available at: <http://www.produce.org/?lang=eng&page=5>

- 21 World Bank *The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits*, An IEG Impact Evaluation, Washington, D.C.: The World Bank, 2008. Available at: <https://openknowledge.worldbank.org/handle/10986/6519>
- 22 Grimm, M., Hartwig, R. and Lay, J. *How Much Does Utility Access Matter for the Performance of Micro and Small Enterprises?* Washington, D.C.: The World Bank, 2012. Available at: [http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2013/05/24/000333037\\_20130524141223/Rendered/PDF/779350WP0P11510BLIC00PublicServices.pdf](http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2013/05/24/000333037_20130524141223/Rendered/PDF/779350WP0P11510BLIC00PublicServices.pdf)
- 23 Pueyo, A. *The Evidence of Benefits for Poor People of Increased Renewable Electricity Capacity: Literature Review*, Brighton: Institute of Development Studies, 2013. Available at: <http://www.ids.ac.uk/publication/the-evidence-of-benefits-for-poor-people-of-increased-renewable-electricity-capacity-literature-review>
- 24 Neelsen, S. and Peters, J. *Productive use of Energy (PRODUSE): Micro-enterprise Electricity Usage in Two Export-Oriented Fishing Communities at Lake Victoria, Uganda*, Eschborn: GIZ, 2013. Available at: <http://www.produce.org/index.php?lang=eng&page=5/>; Scott, A., Darko, E., Lemma, A. and Rud, J-P. How does electricity insecurity affect businesses in low and middle income countries? London: ODI, 2014. Available at: <http://www.odi.org/publications/9184-electricity-energy-security-sme-economic-growth>
- 25 IEA, 2104. *Africa Energy Outlook 2014*; Castellano et al. 2015. *Brighter Africa: The growth potential of the sub-Saharan electricity sector*.
- 26 Available at: <http://www.eu-africa-infrastructure-tf.net/attachments/CEMA/resolution-on-sustainable-energy-for-all-initiative.pdf>
- 27 The Sustainable Energy for All initiative and the proposed Sustainable Development Goals have a target of universal access by 2030. Currently, many African governments are not planning to achieve this electrification target.
- 28 This estimate is based on the assumptions in Box 1.
- 29 The capacity factor for diesel generators is higher than for renewable energies, making the installed capacity proportion lower than the proportion of electricity generated.
- 30 Bacon, R., Bhattacharya, S. and Kojima, M. *Expenditure of Low-Income Households on Energy: Evidence from Africa and Asia*, Washington, D.C.: The World Bank, 2010. Available at: <https://openknowledge.worldbank.org/handle/10986/18284>
- 31 Estimates for 45 countries, for the en.lighten initiative, give average household consumption of candles at 22 per month, and of batteries 0.44 per month (<http://www.enlighten-initiative.org>).
- 32 Adkins, E., Ooppelstrup, K. and Modi, V. Rural household energy consumption in the millennium villages in Sub-Saharan Africa, *Energy for Sustainable Development*, vol. 16, 249-259, 2012. Available at: <http://www.sciencedirect.com/science/article/pii/S0973082612000221>
- 33 UNEP, *Modelling Methodology for Energy and Financial Savings Potential from Switching to Solar LED lanterns*, UNEP/GEF en.lighten Initiative, 2013. Available at: <http://map.enlighten-initiative.org/docs/Off-Grid%20Country%20Lighting%20Assessment%20Model%20Methodology%20for%20web%20Feb%202013-%2003-06.pdf>
- 34 Tariffs for low consuming households vary from one US cent per kWh to US\$0.42 per kWh (Cape Verde).
- 35 Banerjee et al. *Access, Affordability and Alternatives: Modern Infrastructure Services in Africa*, Washington, D.C.: The World Bank, 2008. Available at: <http://documents.worldbank.org/curated/en/2008/02/16281440/africa-access-affordability-alternatives-modern-infrastructure-services-africa>
- 36 Bacon et al., 2010. *Expenditure of Low-Income Households on Energy: Evidence from Africa and Asia*.
- 37 Bacon et al., 2010. *Expenditure of Low-Income Households on Energy: Evidence from Africa and Asia*.
- 38 Briceño-Garmendia, C. and Shkaratan, M. *Power Tariffs: Caught between Cost Recovery and Affordability*, Policy Research Working Paper 5904, Washington, D.C.: The World Bank, 2011. Available at: <http://documents.worldbank.org/curated/en/2011/12/15536521/power-tariffs-caught-between-cost-recovery-affordability>
- 39 Briceño-Garmendia and Shkaratan, 2011. *Power Tariffs: Caught between Cost Recovery and Affordability*.

- 40 For households not connected to the grid, a subsidy of up to 80% of the monthly service fee would be provided for non-grid systems.
- 41 Oxfam, 'You Can't Eat Electricity', Oxfam Discussion Paper, Oxford: Oxfam, 2013. Available at: <https://www.oxfam.org/en/research/you-cant-eat-electricity>
- 42 Golumbeanu, R. and Barnes, D. *Connection charges and electricity access in Sub-Saharan Africa*. Policy Research Working Paper 6511. Washington, DC: World Bank, 2013. Available at: <http://documents.worldbank.org/curated/en/2013/06/17933875/connection-charges-electricity-access-sub-saharan-africa>
- 43 Golumbeanu and Barnes, 2013. *Connection charges and electricity access in Sub-Saharan Africa*.
- 44 de Gouvello, C. and Kumar, G. *OBA in Senegal : Designing Technology-Neutral Concessions for Rural Electrification*. Washington, DC: The World Bank, 2007. Available at: <https://openknowledge.worldbank.org/handle/10986/11034>
- 45 Golumbeanu and Barnes, 2013. *Connection charges and electricity access in Sub-Saharan Africa*.
- 46 Pueyo, 2013, *The Evidence of Benefits for Poor People of Increased Renewable Electricity Capacity: Literature Review; Economic Consulting Associates, Correlation and causation between energy development and economic growth*, Evidence on Demand, London: Department for International Development, 2014. Available at: [http://dx.doi.org/10.12774/eod\\_hd.january2014.eca](http://dx.doi.org/10.12774/eod_hd.january2014.eca)
- 47 See for example: Wolde-Rufael, Y., Electricity consumption and economic growth: a time series experience for 17 African countries, *Energy Policy* 34, 2006; Wolde-Rufael, Y. Energy Consumption and Economic Growth: The African experience Revisited, *Energy Economics* 31, 2009; Menyah, K. and Wolde-Rufael, Y. Energy consumption, pollutant emissions and economic growth in South Africa, *Energy Economics* 32, 2010; Odhiambo, N. Energy consumption, prices and economic growth in three SSA countries: A comparative study, *Energy Policy* 38, 2010; Adebola, S. Electricity Consumption and Economic Growth: Trivariate investigation in Botswana with Capital Formation, *International Journal of Energy Economic and Policy*, Vol. 1, No. 2, 2011; Adom, P. Electricity Consumption-Economic Growth Nexus: The Ghanaian Case, *International Journal of Energy Economic and Policy*, Vol. 1, No. 1, 2011; Eggoh, J., Bangake, C. and Rault, C. Energy consumption and economic growth revisited in African Countries, CESifo Working Paper, *Energy and Climate Economics*, No. 3590, 2011; Fowowe, B. Energy consumption and real GDP: Panel co-integration and causality tests for sub-Saharan African countries, *Journal of Energy in Southern Africa*, Vol. 23 No. 1, 2012; Ziramba, E. Hydroelectricity Consumption and Economic Growth Nexus: Time Series Experience of three African Countries, *European Scientific Journal*, Vol. 9 No. 1, 2013; Dogan, E. Energy Consumption and Economic Growth: Evidence from Low-Income Countries in Sub-Saharan Africa, *International Journal of Energy Economics and Policy*, Vol. 4, No. 2, 2014; and Dlamini, J. Balcilar, M. Gupta, R. and Inglesi-Lotz, R. Revisiting the Causality between Electricity Consumption and Economic Growth in South Africa: A Bootstrap Rolling-Window Approach, University of Pretoria, 2013.
- 48 Kirubi, C. and Jacobson, A. and Kammen, D. M. and Mills, A. Community-Based Electric Micro-Grids Can Contribute to Rural Development: Evidence from Kenya. *World Development*, 73, pp. 1208–1221, 2009. Available at: <http://www.sciencedirect.com/science/article/pii/S0305750X08003288>
- 49 Isaksson, A. *Energy Infrastructure and Industrial Development*, Research and Statistics Branch Programme Coordination and Field Operations Division UNIDO, Working Paper 12/2009, 2009. Available at: [http://www.unido.org/fileadmin/user\\_media/Publications/Research\\_and\\_statistics/Branch\\_publications/Research\\_and\\_Policy/Files/Working\\_Papers/2009/WP%2012%20Energy%20Infrastructure%20and%20Industrial%20Development.pdf](http://www.unido.org/fileadmin/user_media/Publications/Research_and_statistics/Branch_publications/Research_and_Policy/Files/Working_Papers/2009/WP%2012%20Energy%20Infrastructure%20and%20Industrial%20Development.pdf)
- 50 Banerjee, S., Romo, Z., McMahon, G., Toledano, P., Robinson, P. and Arroyo, I. *The Power of the Mine: A Transformative Opportunity for Sub-Saharan Africa*. Directions in Development. Washington, DC: World Bank, 2015. Available at: <https://openknowledge.worldbank.org/handle/10986/21402>
- 51 Castellano et al. *Brighter Africa: The growth potential of the sub-Saharan electricity sector* (2015) estimate a 4.5% annual growth in demand, using a different model and assumptions.
- 52 Banerjee et al., 2015. *The Power of the Mine: A Transformative Opportunity for Sub-Saharan Africa*.
- 53 IEA, 2014. *Africa Energy Outlook 2014*.
- 54 IEA, 2014. *Africa Energy Outlook 2014*.
- 55 IEA.) *World Energy Outlook 2011*. Paris: International Energy Agency, 2011. Available at: <http://www.worldenergyoutlook.org/publications/weo-2011/>

- 56 The terminology for off-grid electricity systems is not universal. Here the IEA's category of 'off-grid' is interpreted as stand-alone, and 'off-grid' is used to describe all systems that are not grid extension.
- 57 IEA, 2011. *World Energy Outlook 2011*.
- 58 Castellano et al. (2015) *Brighter Africa: The growth potential of the sub-Saharan electricity sector*.
- 59 IEA, 2014. *Africa Energy Outlook 2014*.
- 60 REN21 (2014) *Renewables 2014 Global Status Report*, Paris: REN21. Available at: <http://www.ren21.net/status-of-renewables/global-status-report/>
- 61 GVEP. 'The history of mini-grid development in developing countries,' Briefing Paper, London: GVEP International, 2011.
- 62 IEA, 2014. *Africa Energy Outlook 2014*.
- 63 Anton Eberhard, Orvika Rosnes, Maria Shkaratan and Haakon Vennemo. *Africa's Power Infrastructure: Investment, Integration, Efficiency*. Washington, DC: The World Bank, 2011. Available at: <https://openknowledge.worldbank.org/handle/10986/2290>
- 64 IEA, 2014. *Africa Energy Outlook 2014*. Estimates of the investment required vary. Foster and Briceno-Garmendia (2010) suggest US\$37.2 billion is required (Foster, V., & Briceno-Garmendia C. *Africa's Infrastructure - A Time for Transformation*. Washington, DC: The World Bank, 2010. Available at: <http://www.icafrica.org/en/knowledge-publications/article/africas-infrastructure-a-time-for-transformation-9/> ; A number of estimates are reviewed by Bazilian, M. et al. Bridging the Energy Poverty Gap, *Geopolitics of Energy*, 32 (10/11), 2011. Available at: [http://blogs.cfr.org/levi/files/2010/11/Bazilian\\_2010\\_Geopolitics\\_Vol32.pdf](http://blogs.cfr.org/levi/files/2010/11/Bazilian_2010_Geopolitics_Vol32.pdf)
- 65 IEA, 2014. *Africa Energy Outlook 2014*.
- 66 IEA, 2014. *Africa Energy Outlook 2014*.
- 67 SE4All. SE4All Finance Working Group Report, 2014. Available at: <http://www.se4all.org/wp-content/uploads/2014/12/Finance-Committee-Report.pdf>
- 68 IRENA. *Rethinking Energy 2014*, Abu Dhabi: IRENA, 2014. Available at: <http://www.irena.org/rethinking/>
- 69 IRENA *Analysis of Infrastructure for Renewable Power in Eastern and Southern Africa*, Abu Dhabi: IRENA, 2015. Available at: [http://www.irena.org/DocumentDownloads/Publications/IRENA\\_Africa\\_CEC\\_infrastructure\\_2015.pdf](http://www.irena.org/DocumentDownloads/Publications/IRENA_Africa_CEC_infrastructure_2015.pdf)
- 70 These emissions averaged an estimated 0.736 kg CO<sub>2</sub>/kWh in 2011, higher than the world average of 0.623 kg CO<sub>2</sub>/kWh. In South Africa electricity-related emissions are estimated to be 1.069 kg CO<sub>2</sub>/kWh. Brander, M., Sood, A., Wylie, C., Haughton, A. and Lovel, J. (2011) Electricity-specific emission factors for grid electricity, Technical Paper, *Ecometrica*. Available at: <http://ecometrica.com/assets/Electricity-specific-emission-factors-for-grid-electricity.pdf>
- 71 WHO. Burden of Disease from Ambient Air Pollution for 2012, Summary of Results. Geneva: WHO, 2014. Available at: [http://www.who.int/phe/health\\_topics/outdoorair/databases/FINAL\\_HAP\\_AAP\\_BoD\\_24March2014.pdf?ua=1](http://www.who.int/phe/health_topics/outdoorair/databases/FINAL_HAP_AAP_BoD_24March2014.pdf?ua=1)
- 72 Available at: <https://www.cgcsa.co.za/resources/articles/environment/the-implementation-of-carbon-tax>
- 73 South Africa's electricity produces 1.069 tCO<sub>2</sub>e per MWh on average and off-grid electricity has an estimated emission factor of 1.0 ton CO<sub>2</sub>e per MWh (Brander et al., 2011. Electricity-specific emission factors for grid electricity, Technical Paper; UNDP, 2013.).
- 74 IRENA *West African Power Pool: Planning and Prospects for Renewable Energy*, Abu Dhabi: IRENA, 2013. Available at: <http://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=36&CatID=141&SubcatID=333>; IRENA *Southern African Power Pool: Planning and Prospects for Renewable Energy*, Abu Dhabi: IRENA, 2013. Available at: <http://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=36&CatID=141&SubcatID=332>
- 75 IED *Low Carbon Mini Grids: Identifying the gaps and building the evidence base on low carbon mini-grids*, Support study for DFID, Innovation Energie Développement, 2013. Available at: <https://www.gov.uk/government/publications/support-study-on-green-mini-grid-development>
- 76 IEA, 2014. *Africa Energy Outlook 2014*.

- 77 Based on estimates in IRENA *Renewable Energy Jobs & Access*. Abu Dhabi: IRENA, 2012. Available at: <http://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=36&CatID=141&SubcatID=228>
- 78 Rutovitz, J. *South African Energy Sector Jobs to 2030: How the Energy [R]evolution will create sustainable green jobs*, Greenpeace, 2010. Available at: <http://www.greenpeace.org/africa/en/Press-Centre-Hub/Publications/South-African-Energy-Sector-Jobs-to-2030/>
- 79 Kilian, L. *The Economic Effects of Energy Price Shocks*. University of Michigan and CEPR, 2007. Available at: <https://ideas.repec.org/p/cpr/ceprdp/6559.html>
- 80 Klevnäs, P., Stern, N. and Frejova, J. *Oil Prices and the New Climate Economy*, London: New Climate Economy, 2015. Available at: <http://www.sei-international.org/publications?pid=2748>
- 81 IEA (2014) *Africa Energy Outlook 2014*.
- 82 Government of Kenya (GoK) *Updated Least Cost Power Development Plan: Study Period 2011-2031*, Nairobi: Government of Kenya, 2011. Available at: <http://www.renewableenergy.go.ke/index.php/content/44>
- 83 Available at: <http://www.afdb.org/en/blogs/integrating-africa/post/power-trade-in-africa-and-the-role-of-power-pools-12101/>
- 84 IRENA *Analysis of Infrastructure for Renewable Power in Eastern and Southern Africa*, Abu Dhabi, IRENA, 2015.
- 85 Angola, Burkina Faso, Chad, Nigeria, and Guinea. Available at: <http://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=36&CatID=141&SubcatID=500>
- 86 World Economic Forum *Global Competitiveness Report 2014-2015*, World Economic Forum, 2014. Available at: <http://www.weforum.org/reports/global-competitiveness-report-2014-2015>
- 87 IRENA (2015) *Analysis of Infrastructure for Renewable Power in Eastern and Southern Africa*
- 88 Smith, T. Electricity Theft: A Comparative Analysis. *Energy Policy* 32 (18):2067–76, 2004. Available at: <http://www.provedor.nuca.ie.ufrj.br/eletrobras/estudos/smith1.pdf>
- 89 IEA, 2014. *Africa Energy Outlook 2014*.
- 90 Tallapragada, P., Shkaratan, M., Izaguirre, A., Helleranta, J., Rahman, S. and Bergman, S. *Monitoring Performance of Electric Utilities: Indicators and Bench-marking in Sub-Saharan Africa*, Washington, D.C.: The World Bank, 2009. Available at: <http://documents.worldbank.org/curated/en/2009/01/16338434/sub-saharan-africa-monitoring-performance-electric-utilities-indicators-benchmarking-sub-saharan-africa>
- 91 Antmann, P.) *Reducing Technical and Non-Technical Losses in the Power Sector*, Background Paper for the World Bank Group Energy Strategy, Washington, D.C.: The World Bank, 2009. Available at: <http://documents.worldbank.org/curated/en/2009/01/20382190/reducing-technical-non-technical-losses-power-sector>
- 92 *The Africa Report*, 13 August 2014. Available at: <http://www.theafricareport.com/East-Horn-Africa/electricity-theft-on-an-industrial-scale.html>; *Engineering News*, 17 May 2013. Available at: (<http://www.engineeringnews.co.za/article/businesses-responsible-for-bulk-of-electricity-theft---eskom-2013-05-17>).
- 93 Available at: <http://www.weforum.org/best-practices/creative-good/operation-khanyisa-south-africa>
- 94 The most recent Enterprise Surveys show lost sales of 11.4% in Ghana (2013) and almost double this (22.1%) in Central African Republic (2011).
- 95 Andersen, T. and Dalgaard, C-J. Power outages and economic growth in Africa, *Energy Economics* 38, 19–23, 2013. Available at: <http://www.sciencedirect.com/science/article/pii/S0140988313000406>; Foster, V. and J. Steinbuks *Paying the Price for Unreliable Power Supplies: In-House Generation of Electricity by Firms in Africa*, Working Paper, Washington, D.C.: The World Bank, 2008. Available at: <https://ideas.repec.org/p/wbk/wbrwps/4913.html>
- 96 Arnold, J., Mattoo, A. and Narciso, G. *Services Inputs and Firm Productivity in Sub-Saharan Africa Evidence from Firm-Level Data*, World Bank Policy Research Working Paper 4048, Washington, D.C.: The World Bank, 2006. Available at: <https://openknowledge.worldbank.org/bitstream/handle/10986/9285/wps4048.pdf?sequence=1>; Escribano, A. and Guasch, J.L. and

---

Pena, J. *Assessing the Impact of Infrastructure Constraints on Firm Productivity in Africa*. Working Paper 9, Africa Infrastructure Sector Diagnostic, Washington, D.C., 2009: The World Bank. Available at: <https://openknowledge.worldbank.org/bitstream/handle/10986/19901/WPS5191.pdf?sequence=1> ; Moyo, B. Do Power Cuts Affect Productivity? A Case Study Of Nigerian Manufacturing Firms, *International Business & Economics Research Journal*, Vol 11, Number 10, 2012. Available at: <http://www.cluteinstitute.com/ojs/index.php/IBER/article/view/7262>

97 Scott et al., 2014. *How does electricity insecurity affect businesses in low and middle income countries?*

98 Scott et al., 2014.) *How does electricity insecurity affect businesses in low and middle income countries?*

99 IEA, 2014. *Africa Energy Outlook 2014*.

100 World Bank Enterprise Surveys. Available at: <http://www.enterprisesurveys.org/>

101 IEA, 2014. *Africa Energy Outlook 2014*.

102 Scott et al., 2014. *How does electricity insecurity affect businesses in low and middle income countries?*

103 World Bank Enterprise Surveys. Castellano et al. (2015) estimate that 7% of industrial electricity consumption was from stand-by generators in 2010, and 10% from companies' own power sources.

104 Steinbuks, J. and V. Foster. When do firms generate? Evidence on in-house electricity supply in Africa, *Energy Economics* 32 505–514, 2010. Available at: <http://www.sciencedirect.com/science/article/pii/S0140988309001959>

105 Eberhard et al., 2011. *Africa's Power Infrastructure: Investment, Integration, Efficiency*.

106 IMF *Energy Subsidy Reform in Sub-Saharan Africa: Experiences and Lessons*, Washington, DC: International Monetary Fund, 2013. Available at: <https://www.imf.org/external/pubs/cat/longres.aspx?sk=40480.0>

107 Eberhard et al., 2011. *Africa's Power Infrastructure: Investment, Integration, Efficiency*.

108 Besant Jones, J. *Reforming Power Markets in Developing Countries: What Have We Learned?* Washington, DC: The World Bank, 2006. Available at: <http://documents.worldbank.org/curated/en/2006/09/7440330/reforming-power-markets-developing-countries-learned>

109 IRENA, 2015. *Analysis of Infrastructure for Renewable Power in Eastern and Southern Africa*

110 Eberhard et al., 2011. *Africa's Power Infrastructure: Investment, Integration, Efficiency*.

111 Bazilian, M. Power to the Poor: Provide energy to fight poverty, *Foreign Affairs*, March/April 2015. Available at: <https://www.foreignaffairs.com/articles/africa/2015-02-16/power-poor>

## ABOUT THE NEW CLIMATE ECONOMY

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The Global Commission on the Economy and Climate, and its flagship project The New Climate Economy, were set up to help governments, businesses and society make better-informed decisions on how to achieve economic prosperity and development while also addressing climate change.

In September 2014, the Commission published Better Growth, Better Climate: The New Climate Economy Report. Since then, the project has released a series of country reports on the United States, China, India and Ethiopia, and sector reports on cities, land use, energy and finance. In July 2015, the Commission published Seizing the Global Opportunity: Partnerships for Better Growth and a Better Climate. It has disseminated its messages by engaging with heads of governments, finance ministers, business leaders and other key economic decision-makers in over 30 countries around the world.

### The authors

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**Authors:** Andrew Scott, Research Fellow, ODI

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The findings and conclusions in the paper are those of the author and do not necessarily reflect the positions or policies of the Overseas Development Institute, Africa Progress Panel or the New Climate Economy.