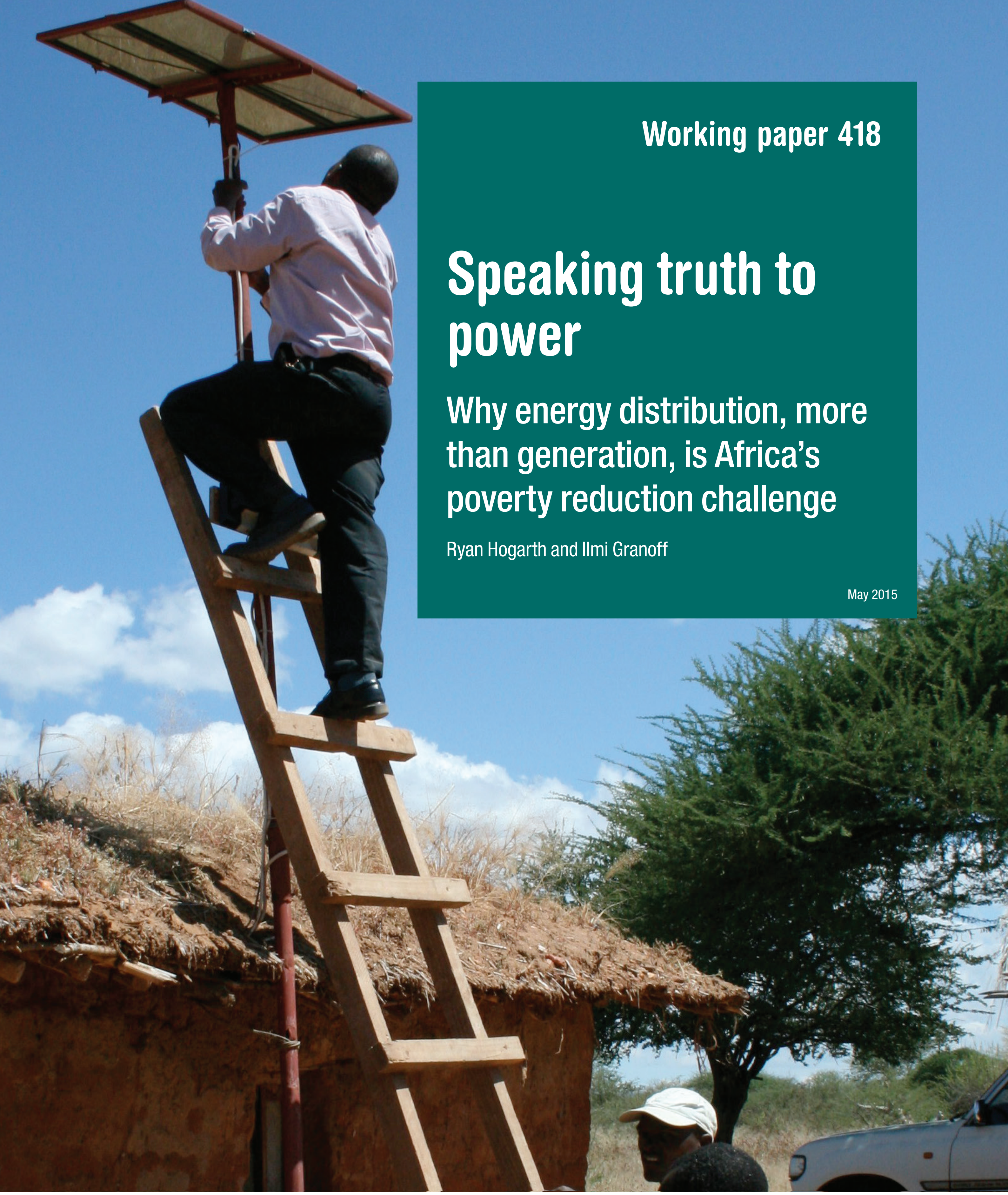

Working paper 418

Speaking truth to power

Why energy distribution, more than generation, is Africa's poverty reduction challenge

Ryan Hogarth and Ilmi Granoff

May 2015

ODI | OXFAM

Overseas Development Institute
203 Blackfriars Road
London SE1 8NJ

Tel. +44 (0) 20 7922 0300
Fax. +44 (0) 20 7922 0399
E-mail: info@odi.org.uk

www.odi.org
www.odi.org/facebook
www.odi.org/twitter

ISSN (online): 1759-2917
ISSN (print): 1759-2909

Cover photo: EEP Energy and Environment Partnership Programme - EEP Southern and Eastern Africa

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Abbreviation

CAPP	Central African Power Pool
CFL	Compact fluorescent light
EAPP	Eastern Africa Power Pool
ICT	Information and communication technology
IEA	International Energy Agency
JRC	Joint Research Council
kWh	Kilowatt hour
LPG	Liquid petroleum gas
MJ	Megajoule
MW	Megawatt
PV	Photovoltaics
SAPP	Southern Africa Power Pool
TFC	Total final consumption
TWh	Terawatt hour
USAID	United States Agency for International Development
WAPP	West Africa Power Pool

Acknowledgements

We are grateful to all those who contributed to and commented on the draft of this report. Special thanks go to our team of co-collaborators and commentators at Oxfam America, led by Heather Coleman and including Sasanka Thilakasiri, James Morrissey, Ruth Mhlanga and John Magrath, and to ODI's Caroline Haywood for her role in editing and producing the report. We would also like to thank Aaron Leopold of Practical Action, and Andrew Scott and Tom Mitchell from ODI for their review and invaluable comments. Responsibility for the content of the report rests solely with the authors. This publication has been made possible by the generous support of the C.S. Mott Foundation.

Executive Summary

A vast number of people in sub-Saharan Africa live in energy poverty. Over two-thirds of the region's population, 620 million people, lack access to electricity – a number almost twice that of the population of the United States. Four-fifths, or 750 million people, lack access to clean and modern methods of cooking their food – a number equivalent to the entire population of Europe (IEA, 2014). Around 65 per cent of primary schools and over 30 per cent of health facilities in sub-Saharan Africa also lack electricity (Practical Action, 2014).

Not surprisingly, energy poverty is a major theme on the international development agenda. Given the scale of the problem, many are calling for a dramatic scale-up of the region's power generation capacity. World Bank president Jim Kim has gone so far as to call Africa's energy gap 'energy apartheid'.

It is true that Africa has far less energy supply, particularly of power generation, than any other continent. However, evidence indicates that even dramatically expanding such supply will leave many in energy poverty. Even the International Energy Agency's (2014) ambitious scenario for expansions in Africa's power supply leaves 530 million individuals in the region without electricity in 2040 and 653 million without modern cooking services.

The reason is that most investment in power generation in Africa is not geared towards serving the basic energy needs of the poor; it is rather geared towards industrialization and the rising demands of existing consumers. In fact, two-thirds of the energy investment in Africa is devoted to producing energy for export. Approximately half of current electricity consumption in Africa is used for industrial activities – mostly mining and refining (IEA, 2014).

The 'energy access gap' – the number of people without access to modern energy services – is largely distinct from the 'industrial energy gap' – the massive gap between installed electricity generation capacity in the industrialised and unindustrialised world. Greater ambition to close the industrial energy gap will not necessarily resolve the broader energy access gap.

This paper revisits the roles that energy plays in poverty reduction. First, while energy does not reduce poverty itself, it delivers *energy services*. These services can improve poor people's welfare both directly by enhancing their own productivity, education and health, and indirectly by changing the economy around them. The paper provides a simplified framework for thinking about these energy services, and then reviews the literature on their importance to poverty reduction (see Figure 1).

From this framework, we draw a series of three important conclusions about energy priorities and their implications for poverty reduction and development.

1) Tackling energy poverty will have less to do with ambitious expansion of electricity capacity, and more to do with ambitious distribution of energy services to poor people

At its most technical level, energy access means delivering energy to households above a base threshold. The lack of modern cooking services accounts for the largest share of incidences of energy poverty (see Figure 11), and addressing that lack has the clearest and most immediate benefits for human welfare (Bailis, Ezzati, & Kammen, 2005; WHO, 2014). Policies that promote and underwrite access to improved cookstoves and fuels, for example, will be the most important for delivering modern cooking services. For this aspect of energy access, electricity supply will play a minimal role in their delivery (World Bank, 2008). Figure 11 also shows that cooking technologies, while not expensive, face a significant shortfall in the investment needed to achieve universal access to households.

Delivering electricity services to households also generates rapid and immediate poverty reduction, as does the delivery of such services to schools, primary health clinics, and micro- and small-scale business enterprises (Pueyo, Gonzalez, Dent, & DeMartino, 2013; World Bank, 2008). For each of these end-users, easily distributed energy technologies, even if they deliver relatively small amounts of electricity, are frequently the most cost-effective options for securing access to those services most important to poor people (Practical Action, 2014; Szabó, et al., 2011; USAID, n.d.). Figure 11 shows that a smaller proportion of the total incidences of energy poverty would be most cost-effectively treated through grid connections. More than 2.5 times additional investment is required to secure energy access through distributed systems than energy access through grid connections (IEA, 2011).

Incremental increases in poor people's access to energy services reduce poverty and improve lives. If there is anywhere that 'energy apartheid' can be said to exist, it is the absence of basic energy services for very poor people. Closing this energy access gap will require ambitious investment in distributing energy services to households and communities.

2) Expansion in centralized power generation serves industry, the services sector and already-connected households, before it serves the poor.

Greater centralised generation is necessary to enable energy services that are valuable for industrialization. Powering industrial growth has the potential to reduce poverty through employment, and through greater government revenue, but its track record in doing so in Africa is mixed. A long chain of transformations must take place to ensure that the benefits of industrial growth reach poor people effectively. The dominance of the extractive sectors in Africa's industrial growth makes this all the more challenging (IEA, 2014). Extractive industries have a weaker track record than other forms of industrial growth, such as manufacturing, in catalyzing poverty reduction. In fact, Africa's energy input into non-industrial sectors like services and agriculture has historically produced more jobs than when input into industry (Practical Action, 2012).

It also cannot be assumed that the energy services most important to poor people would be delivered as a by-product of ambitious expansions in electricity generation capacity, or even the expansion of both generation capacity and electrification. Even in communities that gain access to the electricity grid, connection tends to occur regressively: poor households often remain without electricity for years, even decades, as they are unable to afford the connection charges (World Bank, 2008). Hence, the challenge is not predominantly the technical one of radically expanding generation capacity; it is orienting policy to deliver electricity to those who need it most.

High 'ambition' to close the industrial energy gap risks neglecting the formidable policy task of providing energy access to all. Ambition is not merely about the number of megawatts installed, but the number of people reached.

3) Distributed, clean energy interventions are best suited to tackling energy poverty – and poverty more generally.

Many of the services that are important for poverty reduction would be most cost-effectively fulfilled by lower carbon technologies. Wherever the harvesting of biomass is unsustainable, a shift to more efficient biomass stoves, kerosene or LPG will tend to reduce greenhouse gas emissions (Bailis, et al., 2005). Moreover, most households, schools, clinics, and micro- and small-scale enterprises located away from the electricity grid will best gain access through distributed renewable energy technologies. Solar photovoltaic (PV), wind, biomass, and micro-hydro would be the most cost-effective option for between 67.1 and 75.4 per cent of off-grid and mini-grid household connections (IEA, 2014; Scott, forthcoming; Szabó, et al., 2011). These technologies solve some of the core delivery problems of getting key services to poor people.

For the electricity poor that will gain access through the grid, large-scale renewable technologies can easily meet this demand. Distribution will remain the challenge. Evidence suggests that large-scale renewable technologies can also help to close the industrial energy gap. While closing this gap will be less useful to delivering energy access and energy services to the poor, their contribution to increased centralized capacity is important.

1. Energy poverty, revisited

Energy poverty is a major theme on the international development agenda. The UN General Assembly has declared 2014 to 2024 as the international decade of 'Sustainable Energy for All', and the UN Secretary General has a flagship programme bearing the same name. The number of people that live without access to energy – in energy poverty – is substantial: 1.3 billion people lack basic access to electricity and 2.6 billion lack access to clean and safe energy for household cooking. Energy poverty is most pronounced in sub-Saharan Africa, where around 620 million people – more than two-thirds of the population – lack access to electricity. About 730 million people in the region – or four-fifths of the population – lack access to modern cooking services (IEA, 2014). To put these figures into some context: the number of people living without electricity in sub-Saharan Africa is almost double that of the entire population of the US, and the number living without modern cooking services equals the entire population of Europe.

These statistics highlight formidable challenges. The international agenda calls for high megawatt generation projects and transmission schemes to rapidly close the 'energy gap' between sub-Saharan Africa's per capita installed electricity capacity and the capacity in the industrialised world. At the 2014 Africa Leaders' Summit, World Bank President Jim Kim referred to the region's vast energy gap as 'energy apartheid', and, alongside leaders of several African nations, cited a moral mandate to invest in power. Furthermore, the United States Agency for International Development's (USAID) Power Africa programme commits $7 billion to the region between 2013 and 2018 to add 30,000 megawatts (MW) of additional electricity capacity in a bid to boost capacity by approximately one third. The stated aim of Power Africa is to double access to electricity. Some commentators have noted, however, that a massive expansion in power capacity to end energy poverty could conflict with efforts to address climate change (Bazilian and Pielke, Jr., 2013).

But what if the thinking of the development community on energy poverty is wrong? What if, in our race to close the energy access gap quickly and at scale, we fail to solve it at all? Does framing the energy access problem as one of prioritising generation create a false paradox between access and sustainability?

The International Energy Agency's (IEA) New Policies Scenario (2014) forecasts energy supply based on planned policies and investments. It projects that on-grid generation in sub-Saharan Africa will increase 350 per cent by 2040, from 440 to 1,541 terawatt hours (TWh)[1] (IEA, 2014). Despite this rapid growth in supply, the IEA also projects energy poverty in 2040, with 530 million people still without electricity and 653 million without modern means of cooking their food. In absolute terms, this represents only a small reduction in the current numbers of people living in energy poverty. Factoring in population growth, 30 per cent and 37 per cent of sub-Saharan Africans will remain without electricity and modern cooking services, respectively.

Why is it that so many people will not benefit from the projected massive increase in on-grid generation?

In reality, the biggest barrier to universal energy access is not the capacity to generate electricity, but rather the ability to get energy to those who need it most. The concept of energy poverty and access tends to focus on very small, incremental shifts in the delivery of energy to poor people. The total energy demand of these shifts constitutes only a small fraction of the 'gap' between electricity supply in much of Africa versus more industrialised countries, or the gap between the region's current and projected electricity supply.

There are distinct energy gaps that require different interventions if they are to be bridged. The 'industrial energy gap', representing the massive gap of installed energy capacity between the industrialised and unindustrialised world, is not the same as the energy access gap, i.e., the cumulative deficit of energy access faced by those who are living in energy poverty.

1 A terawatt hour is equal to the sustained power of approximately 114 megawatts for a period of one year.

Indeed, a forthcoming ODI report calculates that it would require the generation of only an additional 35 TWh above the levels that are being projected to provide universal electricity access to the region's population by 2030 – only 6 per cent of current annual consumption and an even smaller fraction of the levels that are being projected (Scott, forthcoming).

Most current and projected investment in power production in sub-Saharan Africa aims to close the industrial energy gap. In 2012, industry consumed almost 70 per cent of all electricity used for productive purposes (industry, agriculture, and services) in the region, and about half of all electricity consumed in general (IEA, 2014).[2] Most of this consumption was dominated by extractive industries, particularly mining and refining. In the future, the majority of projected expansion in electricity generation is expected to supply industry and the service sector and to meet growing demand from households that already have access to electricity.[3]

While the industrial energy gap is expected to narrow or close in sub-Saharan Africa, the energy access gap is projected to remain wide open. By most evidence, energy poverty is not likely to be resolved as a mere corollary of the expansion of energy capacity (or even grid extension) across the region. Building a power plant does not guarantee greater energy access unless transmission, electrification, and connection policies are all aligned to bring energy services to those that lack them, and at a price that they can afford.

In 2012, industry consumed almost 70 per cent of all electricity used for productive purposes (industry, agriculture, and services) in the region, and about half of all electricity consumed in general (IEA, 2014).[4] Most of this consumption was dominated by extractive industries, particularly mining and refining.

Box 1. Glossary of terms relating to energy and poverty

Energy services. The tangible benefits obtained from energy consumption, such as lighting, heating, communications or cooking.

Energy poverty. The inability to meet basic energy services with reliable, affordable, legal and safe energy technologies.

Energy access. The inverse of energy poverty. Having sufficient energy to meet basic energy services. Often measured along a spectrum.

Electricity access. Having access to reliable, affordable, legal and safe electricity in sufficient quantity to meet basic electricity-related energy needs, such as lighting, a fan and communication technologies.

Energy access gap. The cumulative deficit of energy access for those living in energy poverty.

Income poverty. The state of having a level of income that is insufficient to meet basic consumption needs. This is measured using a narrowly defined indicator of poverty that is focused on income and consumption.

Industrial energy gap. The gap between the generation capacity and consumption of industrialised and unindustrialised countries. Coined to distinguish between this (very large) energy deficit and the energy poverty gap.

Multi-dimensional poverty. Poverty as measured by multiple indicators of human deprivation (or its inverse, welfare), including the lack of basic material possessions (food, water, sanitation, shelter, clothing), combined with social and political exclusion and a lack of economic opportunity. Typically this is measured using indices with multiple indicators, such as the multi-dimensional poverty index, that take into account such factors as health, education and living standards.

2 The services sector – led by telecommunications – consumes 23% of energy and 28% of electricity for productive purposes, while the agricultural sector consumes only 6% and 3%, respectively (IEA, 2014).

3 Industrial electricity demand will more than double from 220 TWh in 2012 to over 440 TWh in 2040. The service sector, primarily telecommunications and a variety of small enterprises, accounted for 20% of electricity demand in 2012, or 88 TWh. Projections for the service sector are not provided, but increases in consumption are likely to be substantial. Although only 20% of the projected increase in electricity demand will be the result of new households gaining access to the electricity grid, residential electricity demand, driven by growing demand by already connected households, will expand more than five-fold from 94.4 TWh in 2012 to 520 TWh in 2040 overtaking industry to become the largest end-consumer of electricity (IEA, 2014).

4 The services sector – led by telecommunications – consumes 23% of energy and 28% of electricity for productive purposes, while the agricultural sector consumes only 6% and 3%, respectively (IEA, 2014).

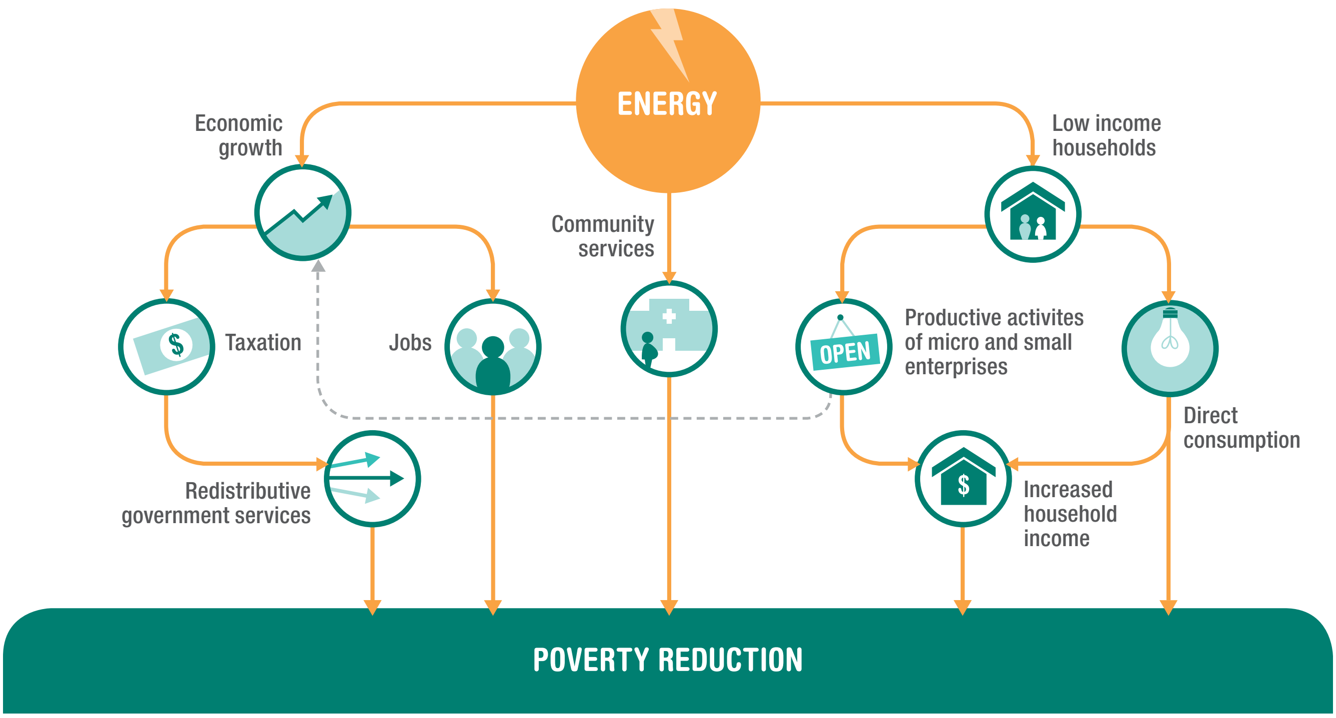
Addressing energy poverty primarily through the traditional model of grid expansion would require substantially more time (decades) and financial capital than one based primarily on decentralised technologies. Furthermore, the latter would be likely to create far more jobs. For example, Practical Action (2014) estimated that electricity generated through solar photovoltaics (PV) creates between 8 and 10 times more jobs for every gigawatt hour (GWh) it generates than electricity generated through coal or natural gas.

Bazilian and Pielke Jr. (2013) contend that efforts to promote incremental shifts in energy access, such as those delivered through distributed electricity generation or clean cookstoves, suffer from a failure of ambition. They are not alone in this view, and quote the most striking articulation of it – from Kandeh Yumkella, the United Nations' head of the Sustainable Energy for All (SE4All) agenda: 'The provision of one light to poor people does nothing more than shine a light on poverty…' (Yumkella, 2009, quoted in Bazilian and Pielke, Jr., 2013).

Yumkella, Bazilian, and Pielke make an important point: delivering energy services to reduce poverty means more than just delivering energy to households. Energy is an indispensable input for activities outside of the household – including business enterprises and community services – that can also result in poverty reductions. Closing the industrial energy gap may also reduce poverty by growing the economy. Nevertheless, incremental shifts of energy services to poor people who currently lack access are also critically important. Figure 1 untangles the distinct but interlinked ways in which improved energy provision may have an impact on poverty.

This paper brings these linkages to the fore. Section 2 includes a typology of energy services, i.e. the tangible benefits derived from energy consumption (Kowsari & Zerriffi, 2011, p. 7513). Energy services range from the most basic household needs, such as cooking, to large-scale industrial activities. In each case, services are evaluated to determine their impact on energy poverty in particular, and poverty in general. The paper then considers how those energy services can best be delivered to achieve the twin objectives of alleviating both energy poverty and wider poverty. A mix of secondary quantitative and qualitative sources from academic journals, multilateral and development organisations, and governments were used in this analysis. Section 3 concludes with a discussion of the implications of the analysis for the larger debate about delivering sustainable energy access for all.

Figure 1. Energy's pathways to poverty reduction



2. Energy services for poverty reduction

Understanding energy poverty requires an understanding of the different services that energy can provide, and the relationship of each of these to poverty. The energy services that are often discussed in relation to poverty can be divided into five categories:

- modern cooking services
- household lighting, communications, and electrical appliances
- energy services demanded by micro or small enterprises
- energy services demanded by schools and health facilities
- energy services for industrialisation.[5]

Empirical evidence suggests that each type of energy service affects human welfare, and therefore fights poverty, in different ways. There is also variation in the amount and form of energy needed to deliver each service, and the technologies available to provide them. In order to make broader statements about energy and poverty, it is necessary to trace the pathways between the two.

This section examines how each of these services relates to poverty, and the implications of this relationship for delivering that service in ways that help poor people. Inadequate access to modern cooking technologies, which represents the most widespread form of energy poverty, is analysed first. The section then considers the relationship between electricity and poverty, both in terms of basic household access and access for schools and primary health clinics. The energy services most important to micro- and small-enterprises, which provide the primary source of income for low-income households, are also explored. The section concludes by exploring the relationship between energy, industrialisation and poverty.

Indoor air pollution is the fourth largest cause of death worldwide, contributing to 4.3 million deaths each year, and is the biggest environmental killer, ahead of unsafe water and sanitation and diseases like HIV/AIDS and malaria (Lim et al., 2012; WHO, 2014).

2.1 Modern cooking services

2.1.1 Relationship with poverty

Most incidences of energy poverty come in the form of lack of access to clean and modern cooking services. In sub-Saharan Africa, the vast majority of households cook with biomass – either fuelwood in rural areas or more energy-dense charcoal in cities – using relatively basic fires or stoves, often indoors. Improving energy services related to cooking provides welfare benefits to poor households, and there are compelling reasons to believe that it also improves incomes.

There is copious evidence that modern cooking services can improve the welfare of low-income households by improving health, particularly by reducing household air pollution (Bailis, Ezzati, & Kammen, 2005; WHO, 2014).

The World Health Organization (2014) estimates that household air pollution causes around 600,000 premature deaths each year in Africa. It also attributes 2.6 per cent of the global toll of ill health to household air pollution from solid fuels, with nearly all of this proportion found in poor regions (Desai, Mehta, & Smith, 2004).[6]

The disease burden falls disproportionately upon women, who are more exposed than men because they tend to spend a greater period of time cooking,[7] and on children under the age of five, who account for 13 per cent of deaths related to household air pollution (WHO, 2014).

Modern cooking services may also reduce risks to personal security during fuelwood collection (Elias &

5 In common with much of the energy access community, we do not include energy services related to transportation as part of the 'energy poverty' discussion. This is something of an arbitrary exclusion, but this paper maintains it so that it can focus on the poverty implications of the various services discussed in the energy poverty context.

6 Specific health issues associated with the inhalation of fumes from burning biomass include asthma, chronic obstructive lung disease, acute respiratory infections, tuberculosis, perinatal mortality, low birth weight and cataracts (Smith, Samer, Romieu, & Bruce, 2000; WHO, 2002).

7 With the WHO's recent inclusion of strokes in the list of diseases caused by household air pollution, the number of deaths attributed to the hazard increased substantially. However, the strong gender bias against women disappeared as a result, presumably because pollution-induced strokes were more prevalent among men.

Victor, 2005; Holdren & Smith, 2000) although the magnitude of both the risks and their reduction is less clear.

Beyond health benefits, improved access to modern cooking technologies can, in principle, reduce income poverty by enabling households to make more productive use of their time. The IEA (2014) estimates that households without modern cooking technologies spend between one and five hours every day collecting fuelwood. Improved energy access could allow this time to be spent on activities such as education or commerce that can increase household income (Elias & Victor, 2005). Of course, having more time can also have direct benefits for the quality of life, regardless of any change in income.

Less directly, improved access to modern cooking methods is also thought to benefit the poor by reducing deforestation and forest degradation. Wood is renewable (and carbon neutral) when harvested at sustainable rates, but the rate of today's overall consumption of biomass for cooking is unsustainable. For example, fuelwood collection accounts for more than 75 per cent of wood removal from forests in sub-Saharan Africa (FAO 2010). There is, however, some debate on the degree to which biomass consumption for cooking leads to deforestation. Generally speaking, the wood gathered and used by rural residents for personal consumption comes largely from dead trees, as they wish to preserve the forest stock. In contrast, the wood converted to charcoal for use in urban areas comes predominantly from felled trees (Practical Action, 2014). Therefore, while fuelwood collection tends to contribute to forest *degradation*, the charcoal industry tends to contribute to *deforestation*. Chidumayo and Gumbo (2013) estimated that charcoal production caused 14 per cent of total deforestation in sub-Saharan Africa in 2009. The impact of deforestation can include the scarcity of fuelwood around villages and urban areas, which increases the distances people have to travel to find fuelwood and the time they have to spend collecting it (IEA, 2014). Furthermore, deforestation and forest degradation result in increased erosion and reduced watershed maintenance, leading to an increase in droughts and floods (Chidumayo & Gumbo, 2013), with obvious implications for household poverty and well-being.

2.1.2 How do we provide modern cooking services to households?

In general, cooking is the first energy service used by households, coming even before lighting. For the poorest households, cooking can represent up to 90 per cent of their total energy consumption. Improved cooking technologies are often described using the metaphor of an 'energy ladder': with traditional biomass fuels and primitive technologies on the lower 'rungs', and kerosene, liquid petroleum gas (LPG), natural gas and electricity (among other energy sources) on the higher rungs. Despite its importance for health and expenditures, households are slower to change their cooking technology than they change other household technologies: '[…] traditional fuels and technologies tend to exit more slowly than new ones arrive; modern transistor radios exist alongside primitive cookstoves' (Elias & Victor, 2005, p. 5).

Among solid fuels, cost appears to be the biggest factor in household choices about the cooking technology choices along the energy ladder. In general, the cheapest method of cooking is the use of efficient cookstoves, charcoal or fuelwood. As explained by Sanga and Jannuzzi (2005, p. 13), 'Charcoal is the cheapest alternative when compared to other commercial fuels and for this reason it will continue to be the most preferred cooking fuel for some time in the future.' Table 1 displays the fuel and stove costs associated with different methods of cooking in US dollars per megajoule (MJ).

Households continue to cook with solid fuels after gaining access to electricity, even in grid-connected areas where, in effect, there is unlimited power supply (Figure 2). This is primarily because of cost: 'households are conscious of the rapidly spinning wheel of the electricity meter if a heating ring is turned on' (World Bank, 2008b, p. 33). Cooking is a relatively energy intensive service. It takes 0.44 kilowatt hours (kWh) of electricity to bring a two litre pot of water to a boil (Eskom, 2010) – enough electricity to keep a ceiling fan (25 W), light bulbs (15 W), and TV (70 W) running for four hours. According to Elias and Victor (2005, p. 4), 'the first kilowatts of electricity acquired by households are commonly used for lighting, entertainment and communication services, while

Table 1. Indicative costs of cooking with different technologies

Stove type	Monthly amortised costs of stove [$]	Useful energy cost [$/MJ]	Monthly costs for household consumption of 320 MJ [$]
Firewood	n/a	0.031 or free	9.92 or free
Charcoal (traditional)	0.051	0.031	9.971
Charcoal (efficient)	0.285	0.018	6.045
Kerosene	0.076	0.033	10.64
LPG	0.475	0.05	16.475
Electricity	1.044	0.035	12.244

Source: based on data from Sanga & Januzzi, 2005. Values in this table are only indicative and may vary substantially by region and over time with changing technologies and fuel prices. The calculations by Sanga and Jannuzzi (2005) were based on surveys in Dar es Salaam, Tanzania, in 1990 and 2002; [b] *Note that the costs provided for cooking with electricity reflect only those of households already connected to the grid.*

many households continue to cook and heat the home with traditional fuels long after modern energy enters the household.' In general, households also have capital invested in 'traditional' cooking technologies, and lack the finances to invest in electric stoves that can cost from $100 to $500 (Elias & Victor, 2005).

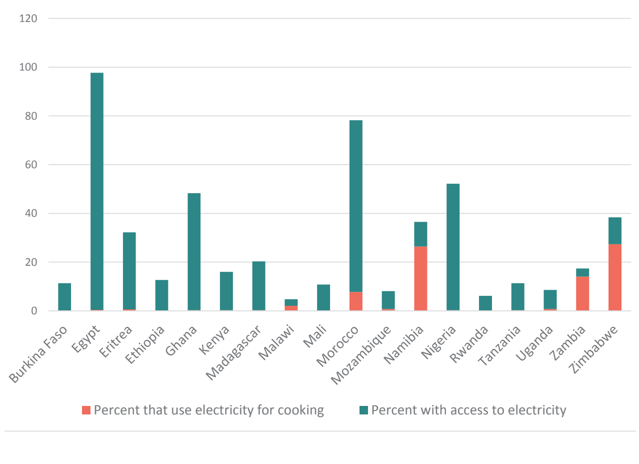
Given the high upfront costs of electric stoves, it is more likely that low-income households will shift from open-fires and traditional charcoal stoves to other modern methods of cooking, such as LPG or kerosene. This is born up by the low penetration rates of electric cooking relative to electricity access as a whole, shown in Figure 2 below.

Factors other than cost can also play a role in cooking choice. Chakrabarti and Chakrabarti (2002) argued that the shift to modern cooking services is driven by the desire to free up time spent on collecting fuelwood and reduce the adverse health effects of household air pollution. Sanga and Jannuzzi (2005, p.13) stated that 'Charcoal substitution by LPG or kerosene will occur not for economic reasons, but for individuals' desire to improve quality of life, in the context of modernisation (Sanga & Jannuzzi, 2005, p. 13).' When health benefits and time savings are monetised, Jeuland and Pattanayak (2012) argue that kerosene and LPG become the most attractive options. Further evidence suggests that LPG poses fewer health costs than kerosene, making it a more attractive option for many.[9]

Even after they adopt modern cooking technologies, households will often engage in 'fuel stacking' (the use of multiple fuels) as a result of both cultural preferences for biomass cooking (people say they prefer the taste of food cooked with wood or charcoal) and as a way to address the unreliable supply electricity, LPG and kerosene supply (Elias & Victor, 2005). Other evidence suggests that a lack of consumer education on energy choices could play a role, as some people believe that cooking with electricity is dangerous (World Bank, 2008b).

As a result of these factors, the push for universal access to modern cooking services will be driven much more through the diffusion of advanced biomass cookstoves, LPG stoves, and biogas systems (IEA, 2011).[10] Electricity is predicted to play a much smaller role in delivering such services.

Figure 2. Proportion of those with electricity who use it for cooking



Source: data from World Bank, 2008b.

2.2 Basic electricity for households: lighting, communications and other electrical appliances

2.2.1 Relationship with poverty

The welfare and income benefits of basic electricity access at the household level appear to be substantial. Even relatively low levels of electricity consumption can greatly improve the welfare of low-income households by powering lighting and other energy services, such as mobile phones, fans, radios, televisions, refrigerators and water pumps (GTZ and NL Agency, 2010; Pueyo, Gonzalez, Dent, & DeMartino, 2013).

As seen in Table 2, the quantity of electricity necessary to provide these energy services varies. The IEA (2014) uses a two-tiered threshold of electricity poverty: 250 kWh of electricity per year for rural households, which is enough to power a mobile telephone, a fan, and two compact fluorescent light bulbs (CFL); and 500 kWh per year for urban households, which could, in addition, power a refrigerator, a second mobile phone and another appliance.[11]

These may seem, at first glance, to be a meagre set of appliances that can be powered by a relatively low level of service, especially to those are already accustomed to plentiful electricity. Indeed, critiques sometimes imply that a focused on the delivery of electricity in the 250 or 500 kWh range somehow 'caps' electricity services and thereby precludes users from ever obtaining more electricity. Why focus on a mini-fridge, for example, when a bigger fridge would be far nicer? When measured against the energy services that very poor people are consuming already, however, even relatively small amounts of power can deliver material services.

8 The data for this figure range from 1999 to 2005.

9 Kerosene use presents the risks of toxic emissions, burns, and ingestion, particularly among children.

10 However, because of the predominantly extensive (rather than intensive) livestock systems in Africa, and the frequent scarcity of water, it is likely that biogas will play a more marginal role than the LPG and advanced biomass cookstoves. We were unable to find comparable data on the costs of cooking with biogas systems.

11 Both of these thresholds assume a household of five individuals. The IEA does not explain its justification for the differentiation between rural and urban households. Presumably, it is based on differences in consumption levels once electricity access is attained.

Table 2. Indicative consumption of different household electricity appliances

Appliance	Power (watts)	Daily use (hours)	Daily	Yearly
Mobile phone	4	2	0.08	29.2
Each light	20	5	0.1	36.5
Fan	50	5	0.25	91.25
Microwave	1000	0.25	0.25	91.25
TV	70	3	0.21	76.65
Laptop computer	100	4	0.4	146
Desktop computer	150	4	0.6	219
Kettle	1500	0.5	0.75	273.75
Mini fridge	150	12	0.75	273.75
Small water pump	200	6	1.2	438
Electric hob	1500	1	1.5	547.5
Water heater	500	3	1.5	547.5

Source: Appliance wattage was sourced from a variety of different online sources. Values should be considered as indicative only. Energy consumption will vary according to the efficiency of the devices and the hours of use per day.

The value that poor people place on basic energy services is illustrated by their willingness to pay for them. The hundreds of millions of households in Africa that lack electricity do not sit idly in the dark. Instead, they fulfill their lighting needs with a variety of technologies including candles, simple wick lanterns and numerous types of oil lamps. Evidence suggests that poor households often only use electricity for a few final consumption-related purposes, especially immediately after gaining access. As noted by a World Bank (2008b) study, 'Lighting and TV account for at least 80 per cent of rural electricity consumption and thus the bulk of the benefits delivered by electrification.'

Mills and Jacobson (2011) estimated that the world's off-grid households spend approximately $40 billion per year on lighting – around 20 per cent of all global lighting expenditures – but receive only 0.1 per cent of the lighting service consumed by the electrified world in total.

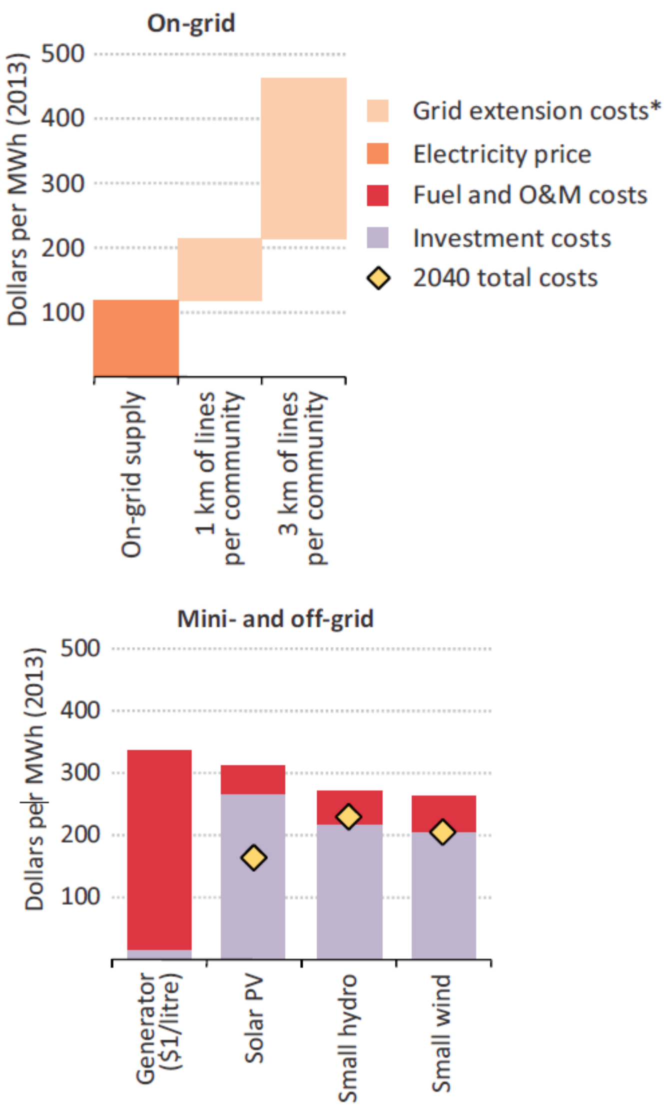
These technologies may not lead directly to an increase in income, but the World Bank (2008b) has found that they do have substantial welfare benefits. In a review of nine rural electrification programmes, including some in Ghana and Senegal, the World Bank (2008b) found that increased access to TV and radio increased knowledge about health and contraception, which, in turn, improved health outcomes and reduced fertility rates. Access to electricity was associated with reduction in fertility rates by 1.06 children per family in Ghana and 2.00 in Senegal. Child nutritional status also improved with electricity access, but the causal mechanisms are not fully understood in this case.

Furthermore, the World Bank (2008b) found that electricity access was associated with an increase in the number of years that children spend in school. Two potential explanations are provided for this relationship. First, there is evidence that the presence of household electricity in rural areas attracts more effective teachers, encouraging students to stay in school for longer (or enabling them to, through improvements in their grades) (Cabraal, Barnes, & Agarwal, 2005). Electricity within the schools themselves is important, and addressed in Section 2.3 below. Second, electric lighting allows students to study during the evening, resulting in better grades and, again, more time spent in school. Indeed, the World Bank (2008b) found that access to electric lighting increased the reading/studying time of children and adults by an average of 77 minutes and 27 minutes respectively per household per day – but only if they chose to study and read. Otherwise, it had no significant impact. In some cases, access to electric lighting even led to less reading and studying.

While welfare improvements alone justify prioritising the reduction of energy poverty, there is strong evidence that household electricity access could also reduce income poverty, given households' inelastic demand for basic services like lighting and mobile phone charging. Final consumption of modern forms of energy can allow households to reallocate resources that were once spent on these energy services to more productive uses.

Surveys conducted by the Lighting Africa (2011) programme in Ethiopia, Kenya, Tanzania, and Zambia revealed that a typical off-grid household in these countries will spend $57 annually on fuel and lantern costs. Furthermore, a large and growing number of households lack access to electricity, but do have a mobile phone. In Kenya, for example, only 15 per cent of households have electricity, but over 50 per cent have mobile phones (Legros, Havet, Bruce, & Bonjour, 2009). These households often pay to charge up their phones (and people often walk many kilometres to do so). In rural Uganda, the price for charging a mobile was UGX 500 ($0.17) per charge in 2010. At two charges per week, this represents a further cost of $17.68 per year (Hogarth, 2012). A rough estimate would, therefore, put a rural household's total annual expenditure

Figure 3. Indicative levelised costs of electricity for on-grid, mini-grid and off-grid technologies in sub-Saharan Africa, 2012



Costs of grid extension are calculated as the average of extending the medium-voltage grid a certain distance (e.g. 1km) to each community on a levelised cost basis.

Notes: costs are indicative and could vary significantly depending on local conditions such as electricity tariffs, population density and the delivered cost of diesel. The quality of service for the different technologies also varies: additional investment in batteries or back-up power may be needed to compensate for the variability of renewables or intermittent grid supply. O&M = operation and maintenance.

Source: IEA, 2014, p. 128.

on services that could be provided through electricity access at around $75. To put this in perspective, in Uganda, a D.Light Nova solar lantern with a mobile phone charging function costs UGX 95,000 ($31.93) (Hogarth, 2012). Given these potential savings, improved household electricity access could free up significant income.

Improved electricity access is also thought to reduce income poverty by enabling the consumption of new energy services that raise the productivity of household labour and capital. For example, the education benefits associated with household electricity access can, in theory, increase income levels, because education has proven links with lifetime earnings (Cabraal, et al., 2005).

It is a compelling story, but proving that it is true is more challenging. While there is a strong correlation between income levels and electricity consumption, the direction of causality is complex. The relationship is attributable, in part, to the fact that a relaxation of household budgetary constraints fuels demand for new energy services such as entertainment, refrigeration and other higher-wattage uses (Elias & Victor, 2005).

A 'light bulb in a hut', therefore, does far more than shine a light on poverty. That small amount of electricity can signal a dramatic shift in direct well-being, a major cost saving and, in all likelihood, a productivity boost.

2.2.2 How do we provide electricity to new households?

There are three broad technological options to provide electricity to homes: (1) grid extension, (2) mini-grids and (3) off-grid (stand-alone) systems. Very often, options 2 and 3 are the most cost-effective for providing the levels of electricity required by rural households, given the high costs of extending the electricity grid. Figure 3, from the IEA (2014), provides an indicative estimate of the cost of providing one megawatt hour (MWh) of electricity from different on-grid, mini-grid and off-grid technologies in sub-Saharan Africa. It shows that the cost of providing electricity access through grid connections depends on how far the grid must be extended.

The on-grid costs on the left of Figure 3 do not reflect the cost of connecting a household to the electricity grid or internal wiring, and the value given for the cost of extending the electricity grid is sometimes substantially higher. Szabó et al. (2011) examined the cost of providing electricity access across Africa, and found that '[…] in cities where the grid already exists, the cost of a connection may start at €140 [$153], while in areas where there is no grid, construction and connection costs can exceed €1050 [$1149] and the extension cost [per km] can be ten times these values.'

The infrastructure for transmission and distribution in sub-Saharan Africa is sparse, as is the region's population. Almost 60 per cent of its people live in rural areas and with just 36.9 inhabitants per km^2, its population density is less than one-third that of Europe's (Mandelli, Barbieri, Mattarolo, & Colombo, 2014). Belward et al. (2011) concluded, 'In areas where household density is low (<50 cap/km^2), any investment in larger grid infrastructure would never be cost competitive.'

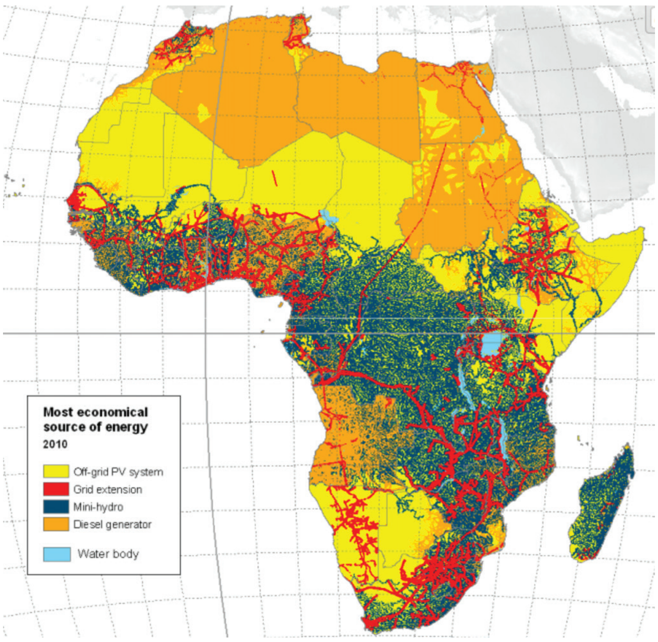
For this reason, the IEA (2011) estimates that, although grid connections are preferable for all urban residents, only

30 per cent of unelectrified homes in rural areas would be most cost-effectively served through centralised grids. A forthcoming ODI paper estimates that 48 per cent of the people in the region who will not have electricity as of 2030 would be served most economically by an extension of the grid (Scott, forthcoming). Over half would best be served through mini-grids (34 per cent) and off-grid systems (18 per cent).

A study by the European Commission Joint Research Council (JRC) found distributed electricity technologies to be the most cost-effective option for electricity access for an even higher proportion of households. The study developed a spatial electricity cost model to determine the most economical option for providing electricity to different areas (Figure 4). Based on this analysis, the study found that only 39 per cent of the population would be served most

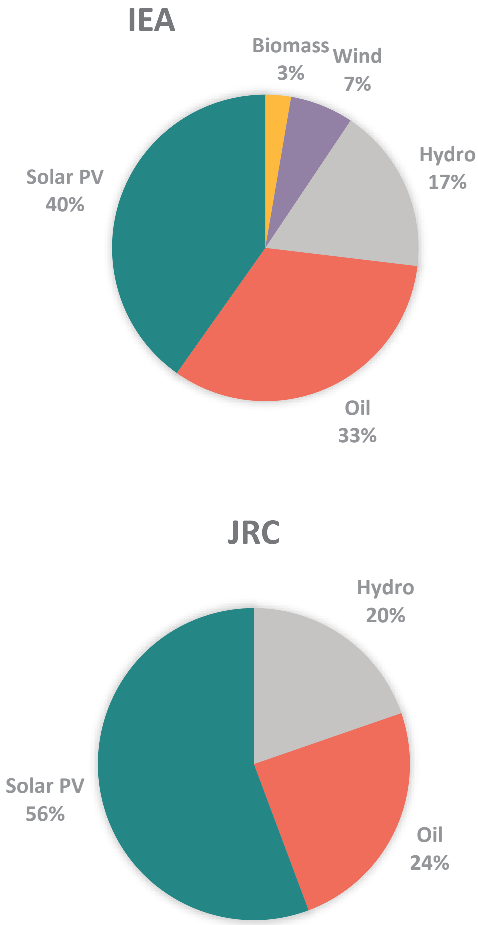
Of the households that would be supplied most economically through off-grid and mini-grids systems, according to IEA and the JRC estimates, renewable energy technologies – including solar PV, wind, biomass, and micro-hydro – would be the most cost-effective sources of electricity for between 67.1 and 75.4 per cent (Figure 5).

Figure 4. Most economical source of energy by area



Source: (Szabó, Bodis, Huld, Pinedo, et al., 2011).

Figure 5. Sources of electricity for off-grid and mini-grid systems (percentage of MWh by source)



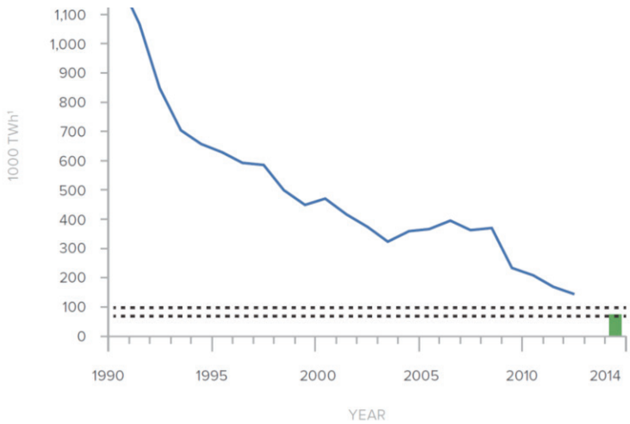
Source: Scott, forthcoming.

economically through grid extension, and the remaining 61 per cent would be best served by off-grid and mini-grid systems (Szabó, Bodis, Huld, & Moner-Girona, 2011).

This figure does not reflect, however, the potential synergies between different technologies. For example, to deal with the intermittent nature of wind and solar power, mini-grids often combine these sources with diesel generators to ensure a reliable supply of electricity. Households, in contrast, generally address the problem of intermittent supply by using car batteries.

These two studies are also likely to underestimate the proportion of the population that would best be served by mini-grid or off-grid technologies. There are two reasons for this: first, the capital cost of renewable energy technologies (except hydro) has been falling in recent years. Figure 6 shows the dramatic decline in the price of solar PV electricity – a trend that is expected to continue (Carbon Tracker Initiative, 2014). If it continues to fall, any utility-scale generation and distribution infrastructure projects that begin now will have to compete against even lower renewable energy prices by the time these projects come online.

Figure 6. Indicative levelised costs of solar PV electricity over time, and estimated lowest utility-scale costs



Source: Carbon Tracker Initiative, 2014, p. 40.

Second, as discussed above, the IEA data do not consider the costs of connecting individual households to the grid. Even those households in close proximity to the electricity grid may find the cost of connection beyond their reach. As a result, grid connection tends to occur regressively, with better-off households connected first and reaping most of the benefits from grid expansion (Pachauri, Scott, Scott, & Shepherd, 2013; World Bank, 2008b). Governments could subsidise the connection charges, but, given their limited finances, there is generally a trade-off between subsidising pro-poor grid connections and investing in further grid expansion. The high costs also mean that grid connection tends to occur over a long time period. A World Bank (2008b, p. xv) study found, 'Even in villages that have been connected for 15-20 years, it is not uncommon for from 20 to 25 per cent of households to remain unconnected.' Even when they are connected, the tariffs for electricity may remain too high for households living on very low incomes (African Progress Panel, forthcoming).

This is not to say that low-income households are not willing or able to pay for electricity. As discussed, unelectrified households already spend a significant portion of their income on lighting and charging their mobile phones. Rather, it indicates that solar lanterns or smaller PV systems are often more affordable options for such households, even in urban areas. This also means that policies that facilitate small incremental shifts of energy consumption to poor people may, in reality, be more progressive, rather than, as they are so often labelled – 'under-ambitious.'

2.3 Energy services for schools and healthcare facilities

2.3.1 Relationship with poverty

Education and healthcare, both considered essential for poverty reduction, can be improved tremendously by electricity access. As mentioned, electricity access for households, schools, and health facilities can help to attract and retain qualified teachers and medical professionals (Cabraal, et al., 2005; Practical Action, 2014; World Bank, 2008b). Beyond this benefit, the energy services that are enabled when schools and health clinics gain access to electricity can be vital to their effective functioning.

Electricity can improve schools through better lighting; the use of fans to control temperature; more efficient administration through computers and other information and communication technology (ICT); and tuition that is enhanced by a variety of different electrical appliances. Practical Action (2013), however, has estimated that 65 per cent of primary schools in sub-Saharan Africa, accounting for a total of 90 million pupils, lack access to electricity. There are wide variations in the proportion of primary schools without electricity, from just over 10 per cent in South Africa to 98 per cent in Burundi.

In Africa, not only has education been demonstrated to increase income levels, it has also been shown to have a positive impact on other indicators of development: health, female participation in politics, and political stability (Gyimah-Brempong, 2010).

There are also strong links between healthcare and poverty reduction. Ill health can reduce earning capacity and entail significant costs for treatment, sometimes driving a household below the income poverty line. The poor account for a disproportionate share of those burdened with disease, and this is, in part, because of the failure of health services to reach them (Wagstaff, 2002).

Electricity can improve the services delivered by all health facilities tremendously. Basic health facilities – the kind that are the most important for poverty reduction – have electricity demands that differ from those of larger clinics and hospitals. Small clinics or health posts in rural areas demand electricity for lighting; for ICT for administration, information, and aftercare services and for laboratory equipment and for refrigeration, which is particularly important for the storage of vaccines, blood and other medical supplies. Larger clinics, of the type found more commonly in medium-sized towns and cities, while requiring electricity for all of these purposes, also need it for more energy-demanding medical equipment, such as ultrasound and X-ray machines, equipment for HIV/AIDS diagnosis, and incubators for premature babies (USAID, n.d.).

Smaller, less energy intensive health facilities are the most important for poverty reduction. Despite this, over 30 per cent of all health facilities in sub-Saharan African, serving approximately 255 million people, lack electricity. In Uganda and Tanzania, respectively, only 42 per cent and 50 per cent have electricity (Practical Action, 2013).

2.3.2 How do we provide electricity for schools and healthcare facilities?

Schools, health clinics and hospitals require higher quantities of electricity than households, but many of these services still benefit from electricity supply in relatively small increments, which can be delivered by a range of technologies.The (USAID, n.d., p. 5) provided two scenarios for the supply of electricity to health clinics of different sizes in Africa using electricity from different sources. Their data can be used to consider, in particular, the demands of education and health services that focus on poor people.

The first scenario featured a health clinic with up to 60 beds that used electricity for lighting, limited surgical procedures (e.g. suturing), refrigeration and basic laboratory equipment – the type of facility that can be seen as typical of those found in rural areas of sub-Saharan Africa.[12] USAID calculated that the electricity needs of such a clinic ranged from 5 to 10 kWh per day.

Practical Action (2013) estimated that the electricity needs for a 60-bed rural clinic would be similar to those for a primary school with approximately 100 students and four classrooms, at around 5 kWh per day.

The school would use electricity for lighting, electric fans and basic ICT including a stereo and computer for administrative purposes.

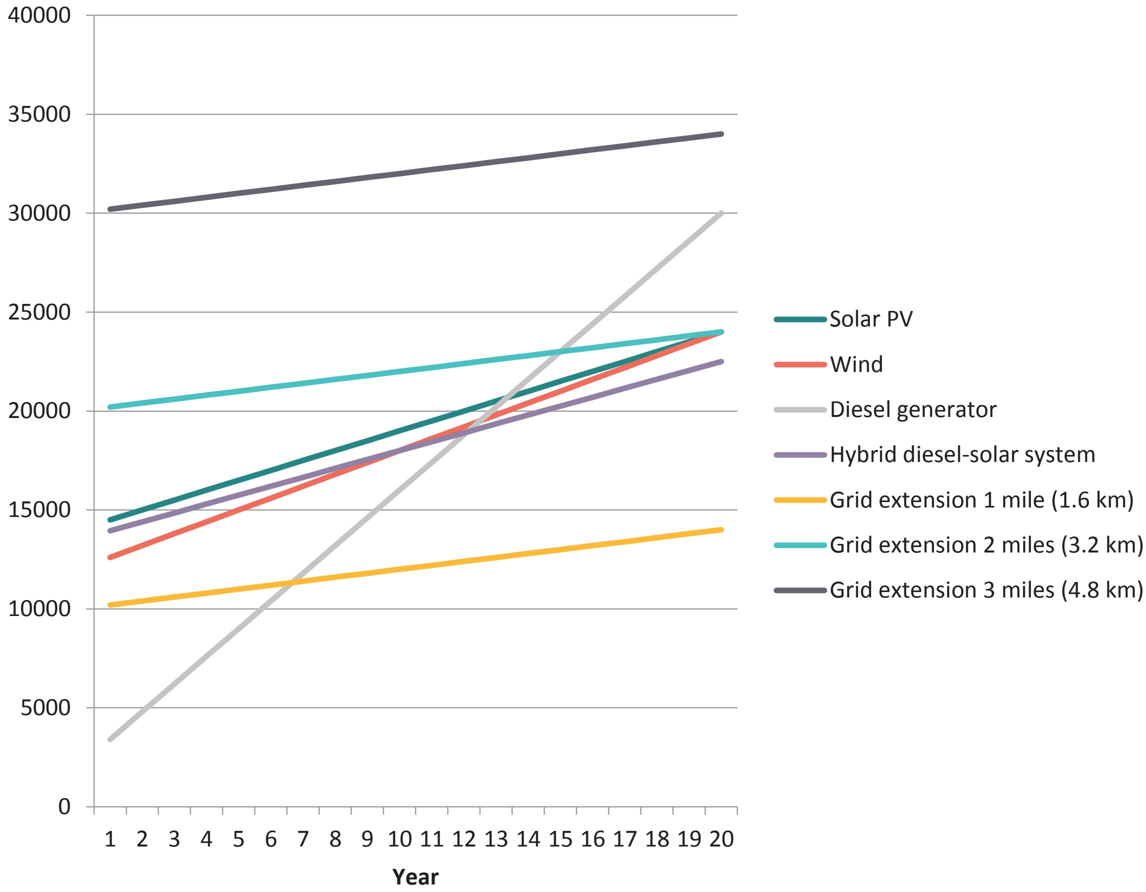
Figure 7 compares the cumulative fuel, maintenance, and technology costs of supplying 5 kWh of electricity per day using different technological options over a 20-year time period.

It shows that over this time period off-grid technologies – wind solar, or hybrid diesel-solar systems – tend to be more cost effective than the electricity grid in providing 5 kWh per day (or 1,825 kWh per year) to schools and small clinics in rural areas that are more than 3.2 km from the electricity grid.

USAID's (n.d., p. 5) second scenario examined the energy needs of a larger clinic (120 beds or more) that would make significant use of ICT and possess sophisticated devices such as X-ray machines and other diagnostic machinery. It estimated that such a facility would demand 20-30 kWh per day, because of its higher-powered medical devices.

For this quantity of energy, grid extension would more commonly be the most economical option for the delivery of the electricity. Realistically, however, such a facility would not be located in rural areas away from the electricity grid. It would be located in towns or cities,

Figure 7. Comparison of technological options to supply 5 kWh per day or 1825 kWh per year



Source: based on data from USAID, n.d., p.5

12 In fact, it is more accurate to say a 60-bed clinic is well beyond the facilities of most rural clinics throughout much of Africa, but represents an ideal scenario for the delivery of rural health services, and is, therefore, a 'generous' estimate of electricity demands.

and could serve as 'regional referral center and coordinate communication between several smaller facilities and hospitals in large cities' (USAID, n.d.).

2.4 Energy services for micro and small enterprises

2.4.1 Relationship with poverty?

Though definitions for micro and small enterprises vary, the terms are used in this paper to refer to those enterprises that rely primarily on family or household members. In sub-Saharan Africa, agriculture and micro and small enterprises (largely informal) represent the largest source of employment.[13] Therefore, their production levels are tied intrinsically to rates of income poverty.

The energy needs of such enterprises vary substantially across different types of economic activities. It is reasonable, for the sake of simplicity, to categorise these enterprises within agriculture, services, and manufacturing sectors.[14]

Agriculture uses energy during land preparation, planting and transplanting, weed control, harvesting, transport and irrigation. In sub-Saharan Africa, these processes are still powered primarily by human labour (Karekezi & Kithyoma, 2002).

Modern energy services have been seen to greatly improve the productivity and dependability of crops (Cabraal, et al., 2005). Irrigation pumps, for example, could lengthen the growing season and end the need to fetch water and irrigate fields by hand (Practical Action, 2012). Land that has irrigated systems is, in general, more than twice as productive as non-irrigated land, yet only 4 per cent of agricultural land is thought to be under irrigation in sub-Saharan Africa (World Bank, 2008a). Refrigerators and food dryers could reduce the waste of agricultural produce. Finally, mechanised land preparation, planting and harvesting could replace human traction as the dominant source of energy in agriculture (Karekezi & Kithyoma, 2002).

Even where energy supply can improve agricultural productivity, however, it will be only one element among a range of more complex interventions. There is evidence suggesting diminishing returns to energy inputs in agriculture, and that excessive inputs (i.e. mechanisation) may reduce employment and have harmful consequences for the environment (Practical Action, 2012). Complicating the issue still further, a growing body of evidence suggests that, in some contexts, non-mechanised agricultural techniques such as no-till systems, which consume less energy and have more labour inputs, can often be more productive.

Enterprises in the services sector have energy needs that are qualitatively similar, but often larger, than the needs of households. They include services such as lighting, batteries, mobile phones, computers, radios, televisions, sewing machines and refrigerators. Restaurants also demand heat energy for cooking (Practical Action, 2012).

In the manufacturing sector, enterprises are often more energy intensive and often require heat energy (brewing, baking, and pottery) and motive power (woodworking and construction tools, grain mills, and other agro-processing machinery) (Karekezi, Kimani, & Onguru, 2008).

There is anecdotal evidence that improvements in electricity access can increase the productivity of micro and small enterprises outside of agriculture. James et al. (1999) found that electrified stores in Namibia were able to stay open longer while spending, on average, less money on lighting and refrigeration than non-electrified stores. In Mali, the United Nations Development Programme found that improved access to electricity allowed women to increase production of shea butter by over 300 per cent (from 3 kg to 10 kg per day) in one community and between 35-45 per cent in another (UNDP, 2004).

Statistically, firms with access to electricity tend to have higher productivity than firms without. However, access to electricity seems have a lower impact on the productivity of micro enterprises than on small or medium ones, as it appears that smaller enterprises are more likely to adapt to unreliable electricity through more labour inputs than through the purchase of expensive back-up generators (Grimm, Hartwig, & Lay, 2011; Scott, Darko, Lemma, & Rud, 2014; World Bank, 2008b).

There is also statistical evidence that households with electricity are more likely to receive an income from a micro enterprise. However, these benefits tend to accrue in a regressive manner, with wealthier households receiving a higher boost in income than households that are poorer (Pachauri, et al., 2013). In Bangladesh, for example, Khandker et al. (2009) found that while electrification increased household incomes by 12.2 per cent on average, the impact on the poorest households was negligible.

Pachauri et al. (2013) argued that the regressive distribution of the income benefits of electrification indicates that access to electricity alone is not enough to drive growth in production or the formation of new micro and small enterprises. If low-income households are to take advantage of the productive opportunities created by improved electricity access, electricity provision often needs to be combined with other interventions that aim

13 Agriculture represents over half of all employment, and, according to the International Labour Organisation (2002), informal employment represents 72% of non-agricultural related employment in sub-Saharan Africa (ILO, 2002).

14 Common services include small shops, restaurants, guesthouses, beer halls, mechanical and electrical repair workshops and mobile phone and battery charging centres. Manufacturing enterprises include pottery, weaving, brick making, charcoal production, soap making, beer brewing, leather treatment, bakeries, candle wax manufacturing, tinsmiths, blacksmiths, saw mills, grain mills, edible oil processing, fish smoking, dairy processing, tobacco curing and other agro-processing enterprises (Karekezi & Kithyoma, 2002).

to, for example, improve access to markets, road and communications infrastructure, as well as the introduction of electrical machinery and tools. When such interventions were included in combination with a community-owned and managed diesel-powered mini-grid in Mpeketoni village, Kenya, the productivity per worker and the gross revenues of carpentry and tailoring microenterprises increased by over 200 per cent. As people were paid on the basis of their production, their incomes increased accordingly (Kirubi, Jacobson, Kammen, & Mills, 2009; Pachauri, et al., 2013).

2.4.2 How do we deliver energy services to micro and small enterprises?

As seen in the previous section, the energy services demanded by micro and small enterprises vary significantly between agriculture, services, and manufacturing sectors. A variety of different technologies are available to meet these demands.

Regarding agriculture, one of the most important energy services demanded is water pumping for irrigation. Electricity offers one option to power irrigation pumps, and where available, grid-connections can provide the source. However, there are also a number of options that do not require electricity. In fact, depending on the proximity and depth of the water source, human-powered treadle pumps are generally the cheapest option for small-scale subsistence agriculture at $100-300. Small, motorised pumps powered by petrol or diesel are also relatively competitive, at $250 plus fuel costs, and are becoming increasingly common. Likewise, solar PV powered pumps offer an increasingly competitive alternative. Given their high capital costs, these are typically implemented by groups of farmers, rather than individuals (Burney, Naylor, & Postel, 2013).[15]

The mechanisation of the land preparation, planting and harvesting process requires tractors, rotovators, rototillers and threshing machines powered by petrol- and diesel-fuelled internal combustion engines (not to mention material, political and legal changes to, for example, property law and land use policy). However, as discussed in the previous section, non-mechanised systems such as no-till agriculture, are more productive per hectare in some contexts (IFAD and UNEP, 2013).

In the services sector, as discussed, electricity-related services such as lighting and ICT can be fulfilled largely by off-grid and mini-grid technologies as well as grid connections. For restaurants, biogas digesters, LPG stoves and improved institutional biomass cookstoves offer clean and affordable methods of modern cooking (Karekezi & Kithyoma, 2002).

'Since 2000, two out of every three dollars invested in sub-Saharan African energy has gone to produce energy for export.' IEA.

Enterprises that demand heat energy for such activities as charcoal-making, brewing, baking and pottery-making meet these needs primarily by burning biomass (Practical Action, 2012). There are significant opportunities for greater fuel efficiency through the use of more efficient kilns and boilers in micro- and small-scale pottery, charcoal production and agro-processing industries. For example, the prevailing method of converting fuelwood to charcoal uses earth-mound kilns, which have a highly inefficient conversion rate of 8 per cent to 12 per cent. Industrial kilns have a conversion rate of over 25 per cent but are less popular because of their high upfront costs, and because they increase the unit costs of charcoal production (IEA, 2014).

For the other small enterprises that require motive power, and that are commonplace in rural parts of sub-Saharan Africa, the cost-effective supply of that power is context specific, with a vast range in the quantity of energy they demand. Basic woodworking and construction equipment ranges in power from around 750 to 1200 W, which is within the range of solar PV systems. The energy demand of small agro-processing enterprises, on the other hand, is often higher than 10 kW (Karekezi & Kithyoma, 2002). This quantity of energy is typically beyond the capacity of affordable solar PV systems. Where available, however, wind and micro-hydro technologies offer attractive options to fulfill these energy needs, both for electrical and mechanical power. Where none of these technologies are available, then diesel generators (and grid connections if in close proximity) are generally the most cost-effective.

2.5 Energy services for industrialisation

2.5.1 Relationship between industrialisation and poverty

Energy is also an indispensable input for many energy services that are thought to be necessary for the macro-economic growth that is driven by industrialisation. Industrialisation is thought to reduce poverty in two ways. Most directly, the jobs created through the increased

15 For example, Burney et al. (2010) compared the costs of implementing a PV and diesel powered irrigation system for a 0.5 hectare garden in Benin. The garden was split between 40 farmers, each with 120 m^2 plots. The PV system cost $18,000 while the diesel system cost $9,000 with fuel costs of $684 to $2,053 per annum.

16 Mining operations include those in Botswana, Democratic Republic of Congo, Ghana, Guinea, Liberia, Namibia, Sierra Leone, South Africa and Zambia.

17 Refining operations include those in Angola, Cameroon, Chad, Congo, Democratic Republic of Congo, Côte d'Ivoire, Eritrea, Gabon, Ghana, Kenya, Madagascar, Mauritania, Niger, Nigeria, Senegal, South Africa, Sudan, Tanzania and Zambia.

productivity of larger firms can enable households to work their way out of poverty. Less directly, the wealth created by industrialisation can be mobilised as public revenue for spending on social services, employment programmes, cash transfers and other 'equalising' policies.

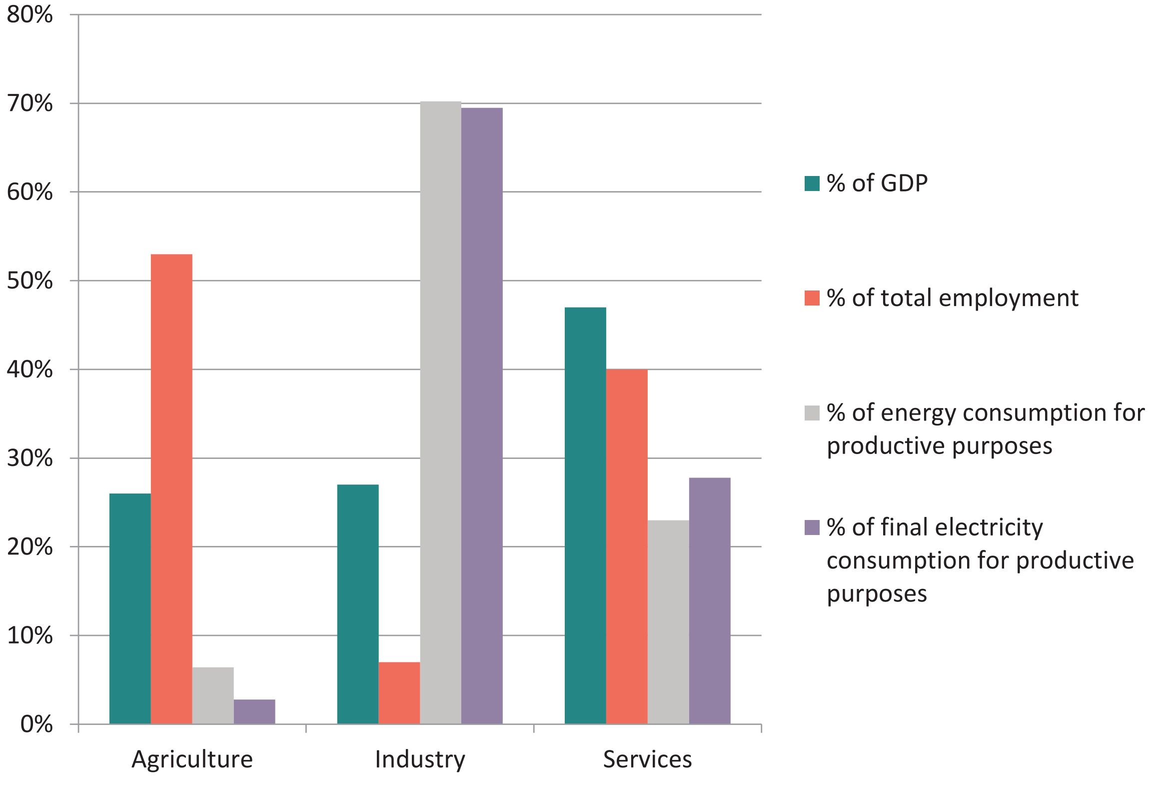
This is a compelling narrative, as industrialization has been effective in reducing poverty in many parts of the world. However, just as some forms of industrialization can create jobs and expand the tax base, other forms are associated with inequality and the persistence of poverty. In Africa, the track record on industrialization is mixed, at best.

The largest existing industries in Africa are the extractives, particularly minerals[16] and hydrocarbons.[17] Fossil-fuel production is so dominant in the regional economy that, according to the IEA (2014, p. 161), 'Since 2000, two out of every three dollars invested in sub-Saharan African energy has gone to produce energy for export.' Other energy intensive industries include cement production, led by the Dangote plant in Nigeria; petrochemical production in South Africa and Nigeria; aluminium smelting, led by the Mozal plant in Mozambique[18]; iron and steel production in South Africa; and the automotive industry in South Africa. Overall, there are few actual manufacturing operations in the region at present.

The empirical evidence on the impact of industrialisation on poverty reduction is complicated (Fredderke & Bogetic, 2006; Scott, et al., 2014). There has been the odd success story: the prudent and transparent management of revenues from diamond mining in Botswana has been credited with reducing the proportion of people living in poverty rates from one third to one fifth over the past two decades (IEA, 2014).

There have, however, been many failures. In 2013, fiscal revenues from hydrocarbon extraction in sub-Saharan Africa totalled over $100 billion. Almost half of these were levied in Nigeria, the region's largest economy, where they represented over 75 per cent of the government's budget. Cumulative revenues from oil export in Nigeria have amounted to over $1 trillion[19] since 1980 (IEA, 2014). Yet, despite the windfall to public coffers, Nigeria performs no better than the average sub-Saharan African country on human development indicators ranging from life expectancy to education levels. Experiences like Nigeria's led the IEA (2014, p. 162) to conclude:

Figure 8. Average employment percentage per sector versus average GDP percentage in 11 sub-Saharan African countries, and proportion of energy and electricity consumption for productive purposes across sub-Saharan Africa



Sources: IEA, 2014; Practical Action, 2012.

18 Aluminium smelting at the Mozal plant accounts for half of Mozambique's energy demand.

19 In 2013 $.

"Sub-Saharan Africa has ample energy resources, both fossil fuels and renewable, but the opportunities that these offer to support sustained economic growth are often missed. A glaring example is the way that deficiencies in essential infrastructure in many countries are perpetrated by inefficient or corrupt misuse of revenues from fossil fuel extraction."

Industrial growth in Africa has also created relatively few jobs. Figure 8 compares the contributions that the industry, agriculture, and services sectors each make to GDP, employment, and the total energy and electricity consumed for productive purposes. While industry is represented by large corporations, much of the employment in the agriculture and services sectors comes from the micro and small enterprises discussed in the previous section.

As seen, while industry and agriculture provide similar contributions to GDP, agriculture employs more than seven times as many people. Also, and of particular importance to this paper, the amount of energy and electricity consumed by each sector does not correspond with its contribution to GDP or employment. The energy consumed by industry represents far fewer jobs than the energy consumed by the agriculture and services sectors.

Industrialization may be crucial to sustain poverty reductions over the long-term – particularly if it is based on manufacturing, which has driven poverty reduction through job creation in other regions. Extractives-led industrialization in Africa has had a comparatively weak relationship with poverty reduction. For this relationship to be improved many steps are required that are unrelated to the expansion of energy capacity. For example, under the existing extractives-heavy industrial model, it will depend on governments implementing progressive fiscal policies and states possessing the technical capacity to provide efficient management and service delivery. A transition to a new industrial model, on the other hand, would require additional industrial policy to usher in a transition to new growth sectors. More broadly, it would also likely depend on governments being held accountable to low-income households to avoid the capture of the benefits by the elite.

Harnessing industrialisation for poverty reduction is a worthwhile policy goal. Focusing on energy services for industry, as a route to poverty reduction, may warrant more careful consideration when it is contingent on a much broader transformation (and given that other energy services are tied more closely to poverty reduction). This is all the more striking when (as shown in Figure 8) agriculture and services may drive growth and employment-based poverty reduction more effectively. Meanwhile, expanding capacity associated with the demands of industrialization, by all forecasts, fails to deliver actual energy services directly to poor people, either through direct access to households or even through community services and benefits to micro and small enterprises.

Table 3. Total installed capacity and key indicators for sub-Saharan African power pools

	CAPP 2009	EAPP 2008	WAPP 2010	SAPP 2010
Installed capacity (GW)	6.07	28.37	14.09	49.88
Hydropower share	86%	24%	30%	17%
Thermal share	14%	73%	70%	83%
kW/1000 habitants	49	74	54	311

Source: Mandelli et al., 2014, p.662.

Table 4. Sub-Saharan Africa's renewable electricity generation potential in TWh/year and as a share of current total final consumption of electricity (% TFC*) for each region

	Middle Africa		Eastern Africa		Western Africa		Southern Africa	
		% TFC		% TFC		% TFC	TWh /year	% TFC
Wind	120	688			394		852	416
Solar	915						3128	
Hydro			578		105	292	26	13
Biomass			642		64	178	96	47
	0	0	88	198	0	0	0	0

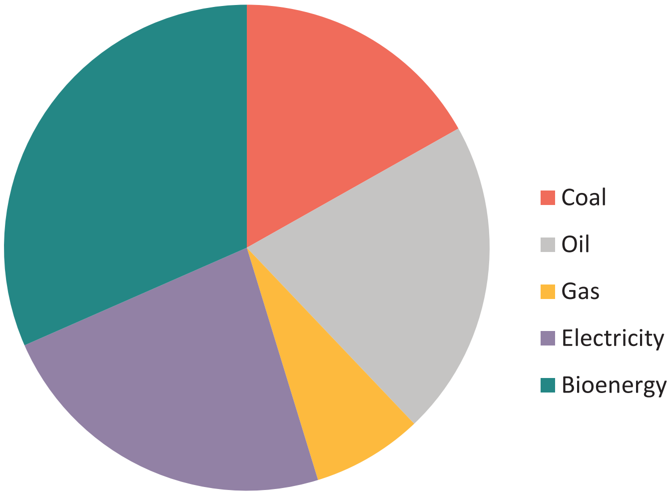
*Source: Mandelli et al., 2014, pp. 665-666. * TFC = Total final consumption.*

2.5.2 How do we provide energy for industrial energy services?

The relationship between energy supply and industry becomes clearer when we analyse how energy services are delivered to industry, as we have done with other energy services. Of the energy consumed for productive purposes, industry consumes approximately 70 per cent, or 66 million tonnes-of-oil-equivalent. Figure 9 provides a breakdown of the different sources of this energy consumption across all productive purposes. More than half of this consumption occurs in only two countries: South Africa (41 per cent) and Nigeria (19 per cent).

Notably, only 22 per cent of all energy for productive purposes comes from electricity. Large-scale production in mining, refining, cement, and iron and steel – all of them of particular importance in sub-Saharan Africa – requires

Figure 9. Mix of energy used for productive purposes, 2012



Source: IEA, 2014

significant motive power and heat energy for industrial processes. Across the region, this energy is supplied largely through the combustion of biomass, coal, oil, and, to a lesser extent, natural gas. The IEA (2014) New Policies Scenario projects that consumption of fossil fuels for productive uses will increase by 96 per cent in sub-Saharan Africa by 2040, while consumption of biomass will increase by 123 per cent.

While electricity accounts for only a small part of industry's total energy demand, industrial is still the greatest source of such demand and consumed most of Africa's supply. As seen in Figure 10 (overleaf), extractive industries, in particular, consume an overwhelming proportion of the power produced in many sub-Saharan African countries (Banerjee, Romo, McMahon, Toledano, & Robinson, 2014). Individual industrial plants dominate consumption in some countries: the Mozal aluminium smelter alone accounts for over half of all electricity consumed in Mozambique. Industry's demand for electricity in sub-Saharan Africa is projected to double between now and 2040 (IEA, 2014).

In general, industrial processes require a stable baseload supply and a larger quantity of electricity than can be provided through small-scale off-grid renewable technologies alone. For this reason, most electricity consumed by industry is supplied through grid connections. Castellano et al. (2015) estimated that the self-generation of electricity (primarily through diesel-fuelled generators) accounted for 10 per cent of industrial electricity demand in 2010, and projected that this will decline to 7 per cent by 2040.

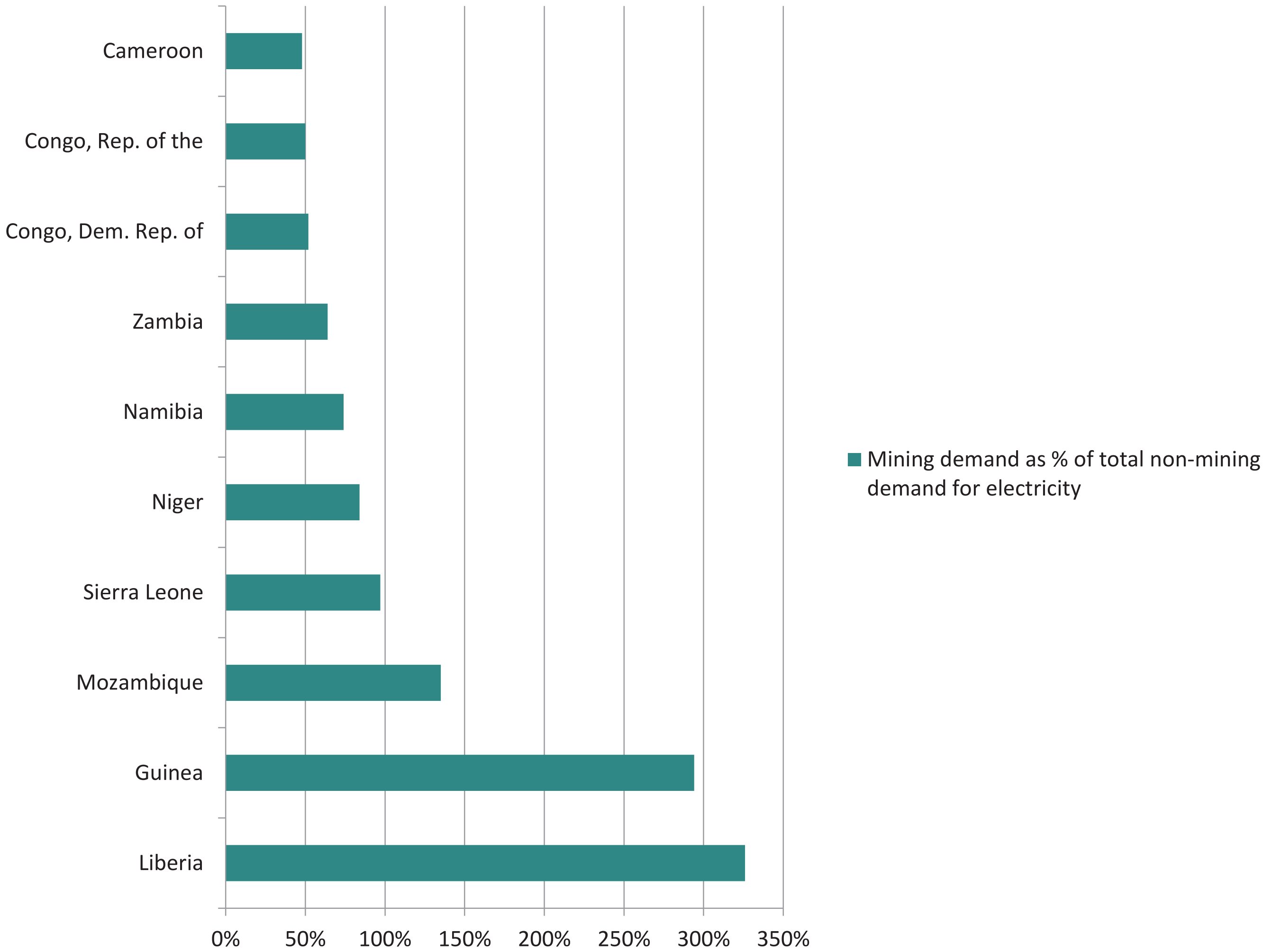
In sub-Saharan Africa, utility-scale electricity is transmitted and distributed primarily through national utilities. Four power pools provide the potential for transboundary transmission: (1) the Central African Power Pool (CAPP), (2) the Eastern Africa Power Pool (EAPP), (3) the West Africa Power Pool (WAPP), and (4) the Southern Africa Power Pool (SAPP). Although little transboundary trade occurs, the power pools offer a useful unit for regional analysis. The installed capacity of each power pool is displayed in Table 3.[20] While hydropower contributes a significant share of the power produced in the regions with the most current and projected industrial production – West and Southern Africa – the electricity grids are dominated by fossil-fuelled thermal generation (Mandelli, et al., 2014).

Technically, it is possible for the entire current and projected industrial electricity demand of sub-Saharan Africa to be met through renewable energy. Mandelli et al. (2014, p. 666) argued that wind, solar, hydro and biomass resources are so abundant in Africa that each one of them could supply the entire continent's electricity demand. Table 4 provides estimates of the potential of each renewable electricity source. Each sub-region has at least one renewable resource in extreme abundance: solar in Southern, West, and Eastern Africa; wind in Eastern Africa; and hydro and biomass in Western Africa (Mandelli, et al., 2014, p. 665). Despite this potential, in the IEA's New Policies Scenario over half the supply is projected to come from fossil fuels in 2040, and over a quarter from coal power alone (IEA, 2014).

Of course, this analysis of delivering industrial energy focuses on the demands under a 'business-as-usual' scenario. In this context, it is worth noting once again that the extractives-heavy industrial sector in Africa is particularly energy intensive. In the larger discussion of Africa's industrialisation, it is important to note that alternative industrialisation models will have different energy demands, and that these may be met by an array of technologies and energy systems.

20 Note that Egypt contributes 78% of generating capacity in EAPP, and South Africa contributes 82% of generating capacity in SAPP.

Figure 10. Mining demand as percentage of total non-mining demand for electricity



Source: Banerjee et al., 2014, p. 9.

3. Implications for universal and sustainable energy access

The analysis outlined in the previous sections lead to three main conclusions about the energy access agenda:

- Tackling energy poverty will have less to do with ambitious expansion of electricity capacity, and more to do with ambitious distribution of energy services to poor people.
- Expansion in centralised power generation serves industry, the services sector and already-connected households, before it serves the poor.
- Distributed, clean energy interventions are best suited to tackling energy poverty – and poverty more generally.

3.1 Tackling energy poverty will have less to do with ambitious expansion of electricity capacity, and more to do with ambitious distribution of energy services to poor people

Energy poverty and its inverse, energy access, pose specific and pernicious challenges that will not be resolved as a byproduct of the expansion of generation capacity or even by the expansion of capacity plus electrification.

This conclusion has emerged from analysis of what it would take to deliver basic energy access. For the most part, improving basic electricity access does not result in modern cooking services, even where households suffer from a lack of both. Just as different illnesses often require different treatments, so too do different types of energy poverty. Therefore, we can consider there to be a total 1.35 billion 'incidences' of energy poverty in sub-Saharan Africa, with some incidences occurring in the same households. Most of these – 730 million – relate to individual people who lack access to clean and safe methods of cooking. They will be best serviced, primarily, through modern cooking technologies, such as LPG, biogas digesters and improved cookstoves. Of the remaining 620 million incidences (those people who lack access to electricity), between 52 per cent and 61 per cent would best be serviced through off-grid and mini-grid connections (IEA, 2014).

As seen in Figure 11, only approximately 20 per cent of incidences of energy poverty in sub-Saharan Africa could be addressed by expansions in utility-scale power generation and extension of the grid. Even within this 20 per cent, initial consumption levels are likely to be low because of the inability of consumers to afford tariffs and electric appliances. To supply each of these households with 500 kWh per household would require an increase in on-grid generating capacity of only 6.8 per cent.[21] The challenge is not generating this electricity; it is getting it to households living on very low incomes.

Tackling energy poverty, therefore, has little to do with expanding generation capacity. Instead, it requires an entirely different set of targeted policy interventions to (1) improve the availability, cost and adoption of cleaner stoves and cooking fuels and (2) provide incremental electricity services to people without them.

The barriers preventing low-income households from accessing modern cooking technologies include their relative cost compared to fuelwood and charcoal, as well as cultural preferences for food cooked over open flames. Time spent collecting fuelwood and the health consequences of household air pollution (once households are aware of them) are often motivating factors for switching fuels.

Policies to promote modern cooking technologies could target these issues directly, while social marketing campaigns could increase awareness of the health and time impacts of traditional cooking methods. Where the charcoal trade is leading to deforestation, the regulation of fuelwood harvesting could ensure that the price of biomass reflects these negative impacts. In turn, the increased cost would incentivise fuel switching or investment in more efficient biomass stoves and charcoal kilns, although the 'subsidy' provided to poor households through free fuelwood collection would need to be replaced with incentives for cleaner cooking options.

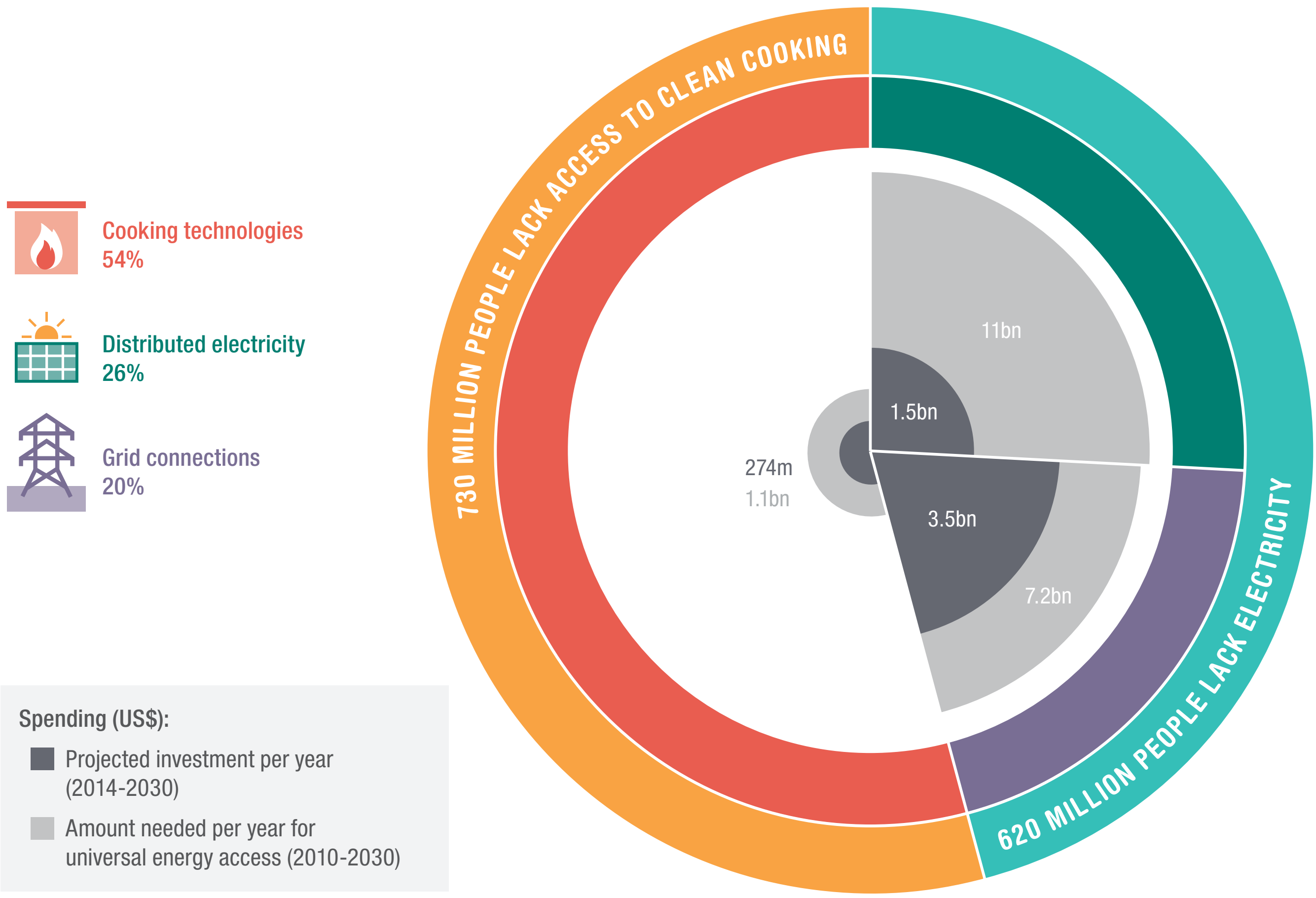
21 At 500 kWh per year, these households would consume less than 30 TWh as a whole.

As shown, low-income households already spend a relatively large proportion of their income on kerosene for lighting and on fees for charging their mobile phones. In comparison to these expenditures, some renewable energy technologies, such as solar PV and solar lanterns, are actually cheaper options. The primary barrier to electricity access is often the limited purchasing power of low-income households, rather than the cost of the technologies. Policies could aim to improve access to consumer finance to enable these upfront costs to be smoothed out over time, although a number of renewable energy suppliers are already developing innovative payment methods without policy guidance (Hogarth, 2012). There is also a dearth of market infrastructure and technical capacity for off-grid and mini-grid technologies in rural Africa. To overcome these barriers, policies could aim to increase the workforce of renewable energy engineers and incubate enterprises that sell off-grid electricity technologies (Miller, 2009).

Finally, where grid connection is the most cost-effective option, the high cost of household grid connection fees and electricity tariffs still inhibit the access of the poorest households. Policies must prioritize these barriers. For example, Ethiopia's Accelerated Access Expansion programme provided loans to rural consumers to cover the $98 connection fee. In Tunisia, consumers using less than 50 kWh per month are charged a low-cost 'lifeline tariff' (World Bank, 2008b).

Acknowledging that the 'industrial energy gap' is largely separate from the 'energy access gap' this paper argues that a focus on poverty reduction requires prioritising energy access. Policies, finance and technical support should target off-grid renewable sources of electricity, LPG, biogas, and clean cookstoves to achieve the energy access aims they set out to deliver. Even beyond "direct" access of households, many of the electricity services that benefit poor people most directly—services consumed by health clinics, schools, and micro and small enterprises— are

Figure 11. The total incidences of energy poverty in sub-Saharan Africa and the technologies and investment needed to secure universal access



This figure breaks down incidences of energy poverty and the technologies and investment needed to treat each incidence. Many households will suffer from both forms of energy poverty, but households with clean cooking will still need electricity (and vice versa).
Source: based on data from IEA, 2011 and IEA 2014

served by ambitiously scaling up the distribution even of relatively small amounts of electricity, rather than ambition on generation capacity. Importantly, distributed renewable energy technologies can help solve this distribution question, and require financing at scale. In a significant portion of cases, *renewable energy is the most economically efficient option for the reduction of energy poverty*.

3.2 Expansion in centralised power generation serves industry, the services sector and already-connected households,

The expansion of centralised power capacity will, in the absence of fairly radical political and institutional shifts, be geared towards supplying three growing areas of demand: (1) growing demand from households already connected to the electricity grid, (2) industry, and (3) urban-based enterprises in the services sector – primarily telecommunications, but also other types of micro-, small- and medium-scale enterprises.

The debate on how best to close the large gap between present and forecasted demand is not simply one of energy 'access'. Indeed, improving electricity access would narrow only a small portion of this gap.

This does not diminish the importance of supplying electricity to these three areas. Growth in the electricity consumption of economic groups that already have access to electricity is, of course, a worthwhile policy goal. And growth in the services sector is likely to contribute to poverty reduction through job creation and, possibly, through greater tax revenues for public services.

It is important to recognise that industrialisation may be crucial to sustain poverty reductions over the long-term. One can understand the intuitive appeal of building on historic models that have defined the economic transition of other regions. Some industries are better than others at creating jobs, and industrialisation could, in theory, sustain a base for economic growth that funds public revenue and equalises policies over the long term.

As in the rest of the world, sub-Saharan Africa faces hard choices on how to fulfil the energy demands of its industry and its growing middle-class in a carbon-constrained world. For this reason, it is important to focus on the development of Africa's substantial on-grid renewable electricity potential. As argued by a recent African Development Bank (AfDB) report, 'Africa's reserves of renewable energy resources are the highest in the world, and the continent has enough renewable energy potential to meet its future energy needs' (Mukasa, Mutambatsere, Arvanitis, & Triki, 2013, p. 1).

That being said, just as poverty reduction is not the purpose of constructing a thermal coal power plant, it is not the purpose of policies that promote on-grid wind and solar. Grid connections will play an important role in supplying energy services that help to combat poverty, but the vast majority of on-grid electricity cannot be 'assumed' to achieve poverty reduction.

Meanwhile, many of the energy services that are most important for poverty reduction – consumed at the household level, and even at the community and small enterprise level – require incremental, but widespread, energy access. If the aim is universal and sustainable poverty reduction, these opportunities should be given greater priority.

3.3 Distributed, clean energy interventions are best suited to tackling energy poverty – and poverty more generally

A co-benefit to closing most of the 'energy access gap' through distributed, clean energy technologies lies in avoided greenhouse gas emissions. In fact, addressing the largest component of energy poverty – inadequate access to modern cooking services – will have climate benefits. Bailis et al. (2005) estimated that annual net emissions from residential energy use in sub-Saharan Africa amounted to 79 million tonnes of carbon in 2000 (61 per cent from wood, 35 per cent from charcoal, 3 per cent from kerosene and 1 per cent from LPG). Furthermore, the paper projected that in the absence of systematic shifts in fuel use, cumulative emissions between 2000 and 2050 will be an estimated 6.7 gigatonnes of carbon – 5.6 per cent of Africa's total emissions. For this reason, even though cooking with fossil fuels produces greenhouse gas emissions, a shift to kerosene or LPG or wherever the harvesting of biomass is unsustainable tends to represent a reduction in net emissions relative to traditional biomass cookstoves.[22]

The climate implications of achieving universal access to electricity depend on how that electricity is generated, with different effects for on and off-grid generation. However, in both cases, very few emissions would be produced. This holds true even if we look beyond basic access to households, and include the pro-poor delivery of energy services via schools, clinics, and micro and small enterprises.

Most households, schools, clinics, and micro and small enterprises in rural areas that would be supplied most economically through off-grid and mini-grids systems will gain access through renewable energy technologies. As for the 50 to 60 million electricity-poor households that would be served most cost-effectively through grid connections: their initial consumption will produce very few greenhouse gas emissions. Much could easily be fulfilled through the scale up of on-grid renewable energy technologies, such as small-scale hydro, geothermal, and wind.

To be clear, not all energy services that are important for rapid poverty reduction would best be fulfilled with zero-carbon energy sources. In areas where wind and hydropower are not available, diesel generators and solar/

22 Kerosene is a more carbon-intensive fuel than LPG. Its net impact on emissions depends on the severity of deforestation and forest degradation in the area. The impact of a shift to electricity for cooking depends on how that electricity is generated (Jeuland & Pattanayak, 2012).

diesel hybrid systems may provide the most cost-effective options for firms that need significant motive power. Urban-based micro and small enterprises, particularly in the services sector, will consume a notable quantity of electricity through grid connections, which may result in greater greenhouse gas emissions depending on how that electricity is generated. Even if the electricity were provided to these users through polluting technologies, the quantity of electricity demanded is relatively low. The same can be said for the 300 thousand unelectrified schools and 39 thousand unelectrified clinics. Providing access to these users is not where the climate challenge lies. These emissions will be minimal compared to those produced in fulfilling the energy services associated with industrialisation, which dominate the emissions associated with modern forms of energy consumption.

3.4 What does this mean for energy and poverty?

While an ambitious scale-up of clean centralised power supply is laudable, reducing poverty requires advancing energy services for households, schools, primary health facilities, and micro and small enterprises.

When poverty reduction is a primary aim of development spending, then energy access should make up a greater share of energy portfolios. Figure 11 showed that cooking technologies, while not expensive, face a significant shortfall in the investment needed to achieve universal access. However, the largest shortfall in investment to achieve universal energy access relates to distributed electricity systems. Over 2.5 times more additional investment is required to secure energy access through distributed systems than energy access through grid connections (IEA, 2011).

These needs stand in stark contrast to current trends in development spending. A recent Sierra Club and Oil Change International report (2014, p. 3) found that, 'With the exception of the African Development Bank at 38 per cent of its energy portfolio (by dollar amount), the MDBs' overall energy portfolios largely did not target energy access for the poor. None of the banks' current approaches to energy access were aligned with the IEA scenario in which 64 per cent of additional energy access funding flows to distributed energy solutions.' The World Bank's spending on energy access was as low as 8 per cent of its energy portfolio in 2013 (Sierra Club and Oil Change International, 2014).

If there is anywhere where "energy apartheid" can be said to exist, it is the absence of energy services for very poor people. In addressing the industrial energy gap, the formidable task of achieving energy access to all could be lost. Ambition is not merely about the number of megawatts installed, but the number of people reached.

References

African Progress Panel (forthcoming). Power, People, Planet.

Bailis, R., Ezzati, M., & Kammen, D. (2005). Mortality and Greenhouse Gas Impacts of Biomass and Petroleum Energy Futures in Africa. *Science, 308*(5718), 98-103.

Banerjee, S. G., Romo, Z., McMahon, G., Toledano, P., & Robinson, P. (2014). *The Power of the Mine: A Transformative Opporunity for Sub-Saharan Africa*. Washington, DC: World Bank.

Bazilian, M., & Pielke Jr., R. (2013, 21 November 2013). Making Energy Access Meaningful. *Issues in Science and Technology*, from http://issues.org/29-4/making-energy-access-meaningful/

Belward, A., Bisselink, B., Bódis, K., Brink, A., Dallemand, J., de Roo, A., et al. (2011). *Renewable Energies in Africa*. Brussels: European Commission Joint Research Centre.

Burney, J., Naylor, R., & Postel, S. (2013). The case for distributed irrigation as a development priority in sub-Saharan Africa. *PNAS, 110*(31), 12513-12517.

Burney, J., Woltering, L., Burke, M., Naylor, R., & Pasternak, D. (2010). Solar-powered drip irrigation enhances food security in the Sudano-Sahel. *PNAS, 107*(5), 1848-1853.

Cabraal, R., Barnes, D., & Agarwal, S. (2005). Productive Uses of Energy for Rural Development. *Annual Review of Environment and Resources, 30*, 117-144.

Carbon Tracker Initiative (2014). *A guide to why coal is not the way out of energy poverty*. London.

Castellano, A., Kendall, A., Nikomarov, M., & Swemmer, T. (2015). *Brighter Africa: The growth potential of the sub-Saharan electricity sector*. McKinsey & Company.

Chakrabarti, S., & Chakrabarti, S. (2002). Rural electrification program with solar energy in remote region - a case study on an island. *Energy Policy, 30*, 33-42.

Chidumayo, E. N., & Gumbo, D. J. (2013). THe environmental impacts of charcoal production in tropical ecosystems of the world: A synthesis. *Energy for Sustainable Development, 17*(2), 86-94.

Desai, M., Mehta, S., & Smith, K. (2004). *Indoor smoke from solid fuels: Assessing the environmental burden of disease at national and local levels*. Geneva: World Health Organization.

Eberhard, A., & Van Horen, C. (1995). *Poverty and Power: Energy and the South African State*. Rondebosch, South Africa: UCT Press.

Elias, R., & Victor, D. (2005). *Energy Transitions in Developing Countries: A Review of the Concepts and Literature*. Stanford, CA: Center for Environmental Science and Policy, Stanford University.

Eskom (2010). *Now you're cooking: Switch to gas for easier, more cost effective and eco-friendly cooking*. Johannesburg: Eskom Holdings Limited.

Fredderke, J., & Bogetic, Z. (2006). *Infrastructure and Growth in South Africa: Direct and Indirect Productivity Impacts of Nineteen Infrastructure Measures*. Washington, DC: World Bank.

Government of South Africa (2012). *Education Statistics in South Africa, 2010*. Pretoria: Department of Basic Education, Government of South Africa.

Grimm, M., Hartwig, R., & Lay, J. (2011). How much does utility access matter for the performance of micro and small enterprises?

GTZ and NL Agency (2010). *Energizing Development: Report on Impacts*. Eschborn: Gesellschaft für Technische Zusammenarbeit and Netherlands Enterprise Agency.

Gyimah-Brempong (2010). *Education and Economic Development in Africa*. Paper presented at the 4th African Economic Conference. from http://www.afdb.org/fileadmin/uploads/afdb/Documents/Knowledge/Session%20II.2.1_2.%20Education%20and%20Economic%20Development%20in%20Africa.pdf

Hogarth, J. (2012). Promoting diffusion of solar lanterns through microfinance and carbon finance: A case study of FINCA-Uganda's solar loan programme. *Energy for Sustainable Development, 16*, 430-438.

Holdren, J., & Smith, K. (2000). Energy, environment, and health *Energy and the Challenge of Sustainability*. New York: United Nations Development Programme.

IEA (2011). *World Energy Outlook 2011: Energy for All*. Paris: International Energy Agency.

IEA (2014). *Africa Energy Outlook - A focus on energy prospects in sub-Saharan Africa*. Paris: International Energy Agency.

IFAD and UNEP (2013). *Smallholders, food security, and the environment*. Rome: International Fund for Agricultural Development and United Nations Environment Programme.

ILO (2002). *Women and Men in the Informal Economy: A Statistical Picture*. Geneva: Gender and Employment Sector, International Labour Organization.

James, B., Nakatana, M., & Rudek, B. (1999). *Socio-economic Impacts of Rural Electrification in Namibia: The Impact of Electrification on Rural Health Care Facilities, Education and Small Businesses. Report No. EDRC/99/R2*. Cape Town: Energy Development Research Centre.

Jeuland, M., & Pattanayak, S. (2012). Benefits and Costs of Improved Cookstoves: Assessing the Implications of Variability in Health, Forest and Climate Impacts. *PLoS ONE, 7*(2), 1-15.

Karekezi, S., Kimani, J., & Onguru, O. (2008). Energy access among the urban poor in Kenya. *Energy for Sustainable Development, VII*(4), 38-48.

Karekezi, S., & Kithyoma, W. (2002). Renewable energy strategies for rural Africa: is a PV-led renewable energy strategy the right approach for prividing modern energy to the rural poor of sub-Saharan Africa? *Energy Policy, 30*, 1071-1086.

Khandker, S., Barnes, D., & Samad, H. (2009). *Welfare Impacts of Rural Electrification: A Case Study from Bangladesh*. Washington, DC: World Bank.

Kirubi, C., Jacobson, A., Kammen, D., & Mills, A. (2009). Community-based electric micro-girds can contribute to rural development: Evidence from Kenya. *World Development, 37*(7), 1208-1221.

Kowsari, R., & Zerriffi, H. (2011). Three dimensional energy profile: A conceptual framwork for assessing household energy use. *Energy Policy, 39*, 7505-7517.

Lam, N., Smith, K. R., Gauthier, A., & Bates, M. N. (2012). Kerosene: A review of household uses and their hazards in low-income countries. *Journal of Toxicology Environmental Health, 15*(6), 396-432.

Legros, G., Havet, I., Bruce, N., & Bonjour, S. (2009). *The energy access situation in developing countries. A review focusing on the least developed countries and sub-Saharan Africa*. New York: United Nations Development Programme and World Health Organization.

Lighting Africa (2011). *The Off-Grid Lighting Market in Sub-Saharan Africa: Market Research Synthesis Report*. Washington, DC: World Bank.

Lim et al. (2012). A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet, 380*(9859), 2224-2260.

Mandelli, S., Barbieri, J., Mattarolo, L., & Colombo, E. (2014). Sustainable energy in Africa: A comprehensive data and policies review. *Renewable and Sustainable Energy Reviews, 37*(656-686).

Miller, D. (2009). *Selling Solar; The Diffusion of Renewable Energy in Emerging Markets*. Oxford: Earthscan.

Mills, E., & Jacobson, A. (2011). From carbon to light: A new framework for estimating greenhouse-gas reductions from replacing fuel-based lighting with LED systems *Energy Efficiency, 4*, 523-546.

Mukasa, A., Mutambatsere, E., Arvanitis, Y., & Triki, T. (2013). *Development of Wind Energy in Africa*. Tunis: African Development Bank (AfDB).

Pachauri, S., Scott, A., Scott, L., & Shepherd, A. (2013). *Energy for All: Harnessing the Power of Energy Access for Chronic Poverty Reduction*. London: Chronic Poverty Advisory Network.

Peck, M., Gerebreg, E., Kruger, G., van der Merwe, A., Godakumbura, W., & Ahuja, R. (2008). Burns and fires from flammable non-electric domestic appliances: Part I. The scope of the problem. *Burns Journal, 34*(3), 303-311.

Practical Action (2012). *Poor people's energy outlook 2012: Energy for earning a living*. Rugby, UK: Practical Action Publishing Ltd.

Practical Action (2013). *Poor People's Energy Outlook 2013*. Rugby, UK: Practical Action Publishing.

Practical Action (2014). *Poor people's energy outlook 2014*. Rugby, UK: Practical Action Publishing Ltd.

Pueyo, A., Gonzalez, F., Dent, C., & DeMartino, S. (2013). *The Evidence of Benefits for Poor People of Increased Renewable Electricity Capacity: Literature Review*. Brighton: Institute of Development Studies.

Sanga, G. A., & Jannuzzi, G. D. (2005). *Impacts of efficient stoves and cooking fuel substitution in family expenditures of urban households in Dar es Salaam, Tanzania*. São Paulo: International Energy Initiative.

Scott, A. (forthcoming). *Building electricity systems for growth, access and sustainability in Africa. Background paper for the Africa Progress Panel 2015 report: Climate change - an agenda for Africa's future*. London: Overseas Development Institute.

Scott, A., Darko, E., Lemma, A., & Rud, J.-P. (2014). *How does electricity insecurity affect businesses in low and middle income countries?* London: Overseas Development Institute.

Sierra Club and Oil Change International (2014). *Failing to Solve Energy Poverty: How Much International Public Investment is Going to Distributed Clean Enegy Access?*

Smith, K., Samer, J., Romieu, I., & Bruce, N. (2000). Indoor air pollution in developing countries and acute lower respiratory infections in children. *Thorax, 55*, 518-532.

Szabó, S., Bodis, K., Huld, T., & Moner-Girona, M. (2011). Energy solutions in rural Africa: mapping electrification costs of distributed solar and diesel generation versus grid extension. *Environmental Research Letters, 6*, 1-9.

Szabó, S., Bodis, K., Huld, T., Pinedo, I., Tromboni, U., & Moner-Girona, M. (2011). *Energy options in rural Africa: solar and diesel distributed systems vs grid extension*. Ispra: Joint Research Centre, European Commission.

USAID (n.d.). *Powering Health: Electrification options for rural health centers*. Washington, DC: United States Agency for International Development.

Wagstaff, A. (2002). Poverty and health sector inequalities. *Bulletin of the World Health Organization, 80*(2), 97-105.

WHO (2002). *Reducing Risks, Promoting a Healthy Life*. Geneva: World Health Organization.

WHO (2013). Global Health Observatory Data Repository, from http://apps.who.int/gho/data/view.main.30000

WHO (2014). *Burden of disease from household air pollution for 2012*. Geneva: World Health Organization.

World Bank (2001). *Dying for Change: Poor people's experience of health and ill-health*. Washington, DC: World Bank.
World Bank (2008a). *Groundwater in rural development facing challenges of supply and resource sustainability.* Washington, DC: World Bank.
World Bank (2008b). *The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits. An IEG Impact Evaluation.* Washington, DC: World Bank.
WRI (2014). Climate Analysis Indicators Tool 2.0 Retrieved December 3, 2014, from http://www.wri.org/our-work/project/cait-climate-data-explorer