LIGHTS POWER ACTION

ELECTRIFYING AFRICA

An in-depth follow-up to the Africa Progress Report 2015 "Power, People, Planet: Seizing Africa's Energy and Climate Opportunities"

AFRICA PROGRESS PANEL

CONTENTS

6 ACKNOWLEDGEMENTS

9 FOREWORD BY KOFI ANNAN

14 INTRODUCTION

22 PART I: OFF-GRID SOLAR – CLIMBING THE POWER LADDER

- **Solar products offer an energy ladder**
- **Solar home systems: Powering families**
  - Box 1: Rwanda national off-grid programme
  - Box 2: "Impact investors" bring solar energy to African homes
- **Advancing access beyond the home**

43 PART II: MINI-GRIDS – SERVING "THE MISSING MIDDLE"

- **Mini-grid models**
  - Box 3: Africa can learn from mini-grid experience in Asia and America
- **Accelerating mini-grid development**

60 PART III: MENDING AND EXTENDING THE GRID

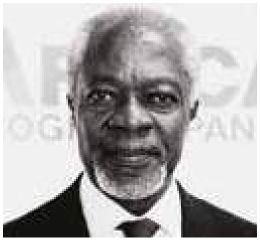
- **National grids are failing Africans**
- **Making power sector reforms work for all**
  - Box 4: In Côte d'Ivoire and South Africa, reforms encounter success and challenges
  - Box 5: Coal's future in Africa
- **Unleashing Africa's renewable power potential**
  - Box 6: African Renewable Energy Initiative: Creating energy systems for the future
- **Transmission and distribution – the weak link**
  - Special Section: Preventing electricity losses and theft
  - Box 7: The Grand Inga Dam – promises and pitfalls
- **Regional power trade could transform Africa**
- **Getting the finances right: Making power sustainable**

94 PART IV: POLICY INSIGHTS

100 REFERENCES

107 END NOTES

ABOUT THE AFRICA PROGRESS PANEL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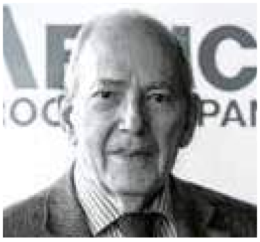
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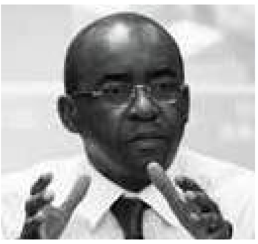
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The Africa Progress Panel consists of ten distinguished individuals from the private and public sectors who advocate for equitable and sustainable development for Africa. Kofi Annan, former Secretary-General of the United Nations and Nobel laureate, chairs the Africa Progress Panel and is closely involved in its day-to-day work. The other Panel members are Michel Camdessus, Peter Eigen, Bob Geldof, Graça Machel, Strive Masiyiwa, Linah Mohohlo, Olusegun Obasanjo, Robert Rubin and Tidjane Thiam.

The Africa Progress Panel brings about policy change through a unique combination of cutting-edge analysis, advocacy and diplomacy. The life experiences of Panel members give them a formidable capability to access the worlds of politics, business, diplomacy and civil society at the highest levels, globally and in Africa. As a result, the Panel functions in a unique policy space with the ability to influence diverse decision-makers.

The Panel builds coalitions to leverage and broker knowledge and to convene decision-makers to create change in Africa. The Panel has extensive networks of policy analysts and think tanks across Africa and the world. By bringing together the latest thinking from these knowledge and political networks, the Africa Progress Panel contributes to generating evidence-based policies that can drive the transformation of the continent.

ABOUT THIS POLICY PAPER

This policy paper is a follow-up to the Africa Progress Panel's annual flagship report *Power, People, Planet: Seizing Africa's Energy and Climate Opportunities*, published in June 2015. The 2015 report explored the links between energy, climate and development in Africa. It documented the risks that would come with a business-as-usual approach and highlighted the opportunities for African leaders. As a global community, the report stated, we have the technology, finance and ingenuity to make the transition to a low-carbon, renewable energy future, but so far we have lacked the political leadership and practical policies needed to break the link between energy and emissions. The report concluded that Africa is well placed to be part of that leadership.

Power, People, Planet, was circulated widely among policymakers, business leaders, civil society and heads of state, globally and in Africa. Since its publication, the Panel has carried out high-level advocacy for the report's recommendations on climate and energy policy, working closely with a wide range of partners.

This new paper seeks to build on the political momentum that has been created over the past year to increase energy access in Africa. Its main aim is to provide additional policy-relevant information and insights to support the implementation of ambitious new public and private initiatives now underway that aim to increase energy access swiftly across Africa, especially the New Deal on Energy for Africa, spearheaded by the African Development Bank. In light of the continent's dynamic links with the rest of the world, the paper also highlights critical steps that must be taken by leaders in the international public and private sectors.

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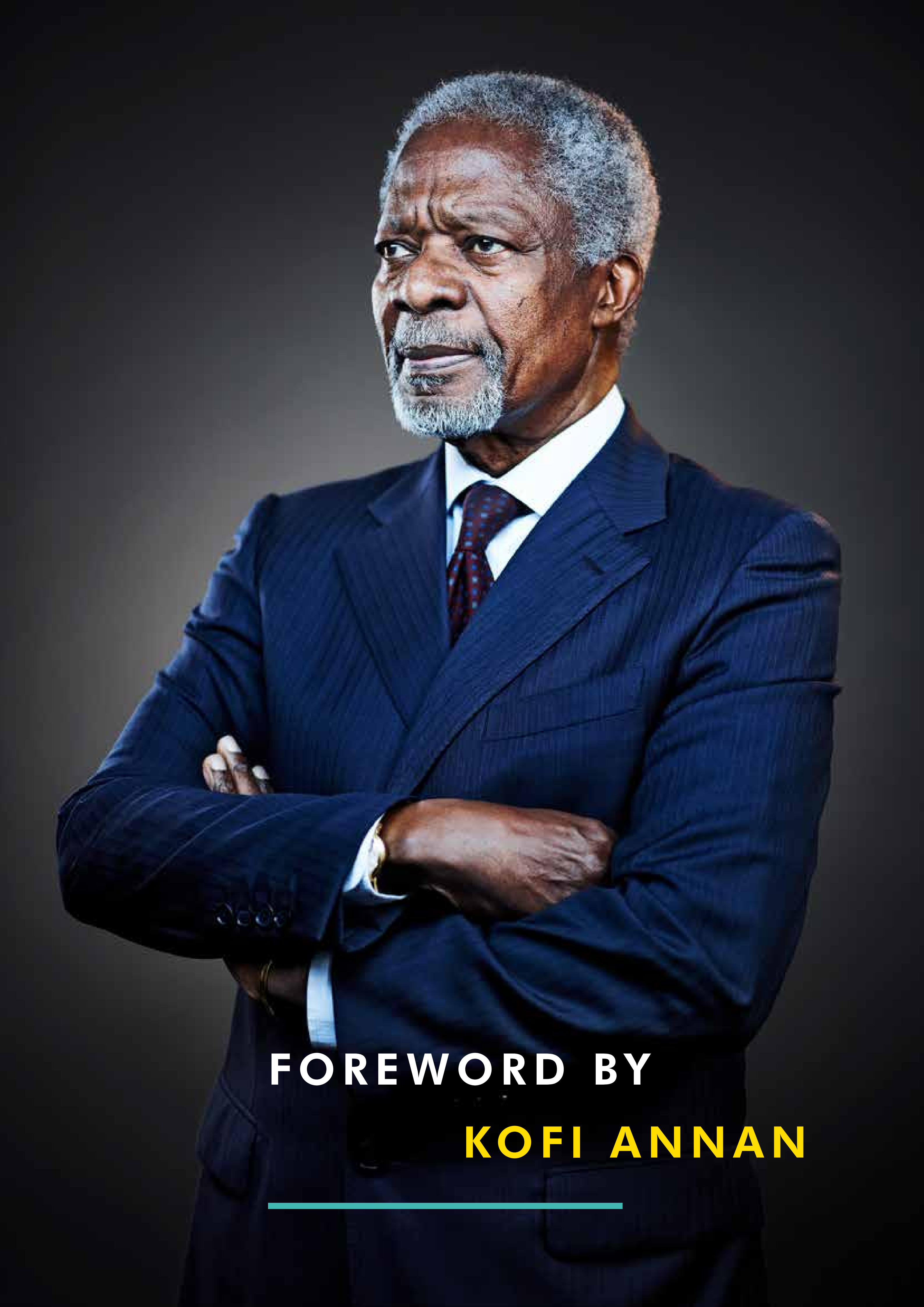

FOREWORD BY KOFI ANNAN

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WE KNOW WHAT TO DO. EVERY GENERATION TO COME DEPENDS ON US GETTING IT RIGHT.

Africa's energy needs are massive. They are also urgent. The traditional way of expanding energy access – increasing electricity generation capacity and extending the grid – is still vital. But it is slow. We have to electrify Africa faster.

To bring modern energy to all their citizens as soon as possible, African countries are exploring every available means. This report shines the spotlight on two promising options – off-grid solar power and mini-grids – while also outlining the steps to put Africa's grids back on track. It sharpens the vision we laid out 2015 Africa Progress Report, *Power People Planet: Seizing Africa's Energy and Climate Opportunities.*

The cost of not taking action is clear. Economic growth, industrialization, jobs, business, sustainable agriculture and social development all depend on governments making energy a top priority. And our ability to limit global warming depends crucially on making the transition to renewable energy.

Meeting the double energy imperative – to increase both the scale and the pace of electrification – is a huge task. But it's also an exceptional opportunity, as we show in this report.

It's an opportunity for countries to kick-start the social and economic transformation they need. It's an opportunity for entrepreneurs and investors, African and non-African. It's an opportunity for the continent to show what it can do by combining the latest technology with African ingenuity.

Africa can lead the world in low-carbon power development, by embracing the revolution in clean energy and using the latest tools to manage energy demand and increase efficiency. Africa can lead in creating markets for renewable energy, fostering the growth of mini-grids, building diversified modern grids and interconnecting them across the continent.

It's a huge task, but we know it can be done – because it's happening already.

Many countries have set ambitious targets for increasing energy access or for advancing other elements of the energy transition. At the core of Africa's electricity system, the utilities that manage national grids are following an international path towards greater efficiency and accountability, by separating generation, transmission and distribution. Governments are amending electricity laws and improving regulatory frameworks, clearing a path for investors. Independent power producers are increasing the involvement of the private sector and showing how to scale up renewable power generation capacity.

Building and extending grid infrastructure can be slow, however. Even before the work can start, legal, financial and technical frameworks have to be adjusted or created from scratch. The 620 million Africans who lack electricity can't wait – and shouldn't have to wait. Luckily, mini-grid and off-grid energy solutions are plentiful. Africans are rapidly adopting and adapting them, particularly to meet the needs of areas that are remote or neglected by the grid.

Off-grid and mini-grid power by renewable sources of energy has a crucial role to play in meeting the three great energy challenges that African governments face: providing all their citizens with access to secure and affordable energy services; building the energy infrastructure needed to drive inclusive growth and create jobs; and limiting carbon emissions.

To meet these challenges, governments must also look beyond their own borders and think on a continental scale. Africa is rich in energy resources but they are not all evenly distributed, so cross-border power trade is essential.

Here, too, we know what to do, and much is being done already. Major interconnection projects are under way. Five regional power pools have been created that cover the continent. But so far, only 8 per cent of electricity is traded across borders – and those power pools are not connected to one another. To unlock Africa's energy potential for all Africans, governments must cooperate to ensure regional power trade thrives.

Fortunately, the future looks promising for African energy cooperation, with several new frameworks emerging. In 2015, the New Partnership for Africa's Development (NEPAD) established the Africa Power Vision, and the African Development Bank launched its New Deal on Energy for Africa. Both reflect the increased commitment to ensuring universal access to modern energy, and adequate power to enable economic growth and prosperity. The African Development Bank has made energy one of its five top priorities.

Africa's energy and climate needs are rising up the global development agenda. In September 2015, the world's governments adopted the Sustainable Development Goals, which include a goal to ensure access to affordable, reliable, sustainable and modern energy for all. This energy goal includes objectives advocated by the Sustainable Energy for All (SE4All) initiative and endorsed by Africa's energy ministers at their conference in 2012.

Africa made its voice heard at the 21st Conference of Parties to the UN Framework Convention on Climate Change (COP21) in Paris, where governments came together to agree a far-reaching, legally binding deal aimed at keeping global warming below 2°C. New measures were agreed to support international cooperation and build the resilience of communities affected by climate change.

The Paris agreement was a triumph of multilateralism in an era marked by a worrying trend towards unilateralism and away from international cooperation. That trend has since continued and deepened, restoring some of the pessimism that preceded the Paris accord. But the agreement remains a strong, indispensable, global commitment. African governments must now play their full part in delivering on their Paris pledges. They made their commitment clear in Paris by launching the Africa Renewable Energy Initiative, an unprecedented effort to give all Africans access to energy that is based on renewable sources by 2030.

In return, Africans have a right to expect more and better international support for low-carbon energy. After all, they have contributed least to the underlying problem.

That support should include technical and financial assistance for developing renewable power, on-grid and off-grid.

Bilateral and multilateral donors have pledged billions of dollars to Africa's energy transition, but little of that money is moving yet. If funds don't start arriving in 2017, countries may lose heart, and leaders who fought for the Paris agreement may face attack at home and be undermined. Donors need to realize that Africa's energy imperative is urgent – not just for Africa but for the world. Investing in the continent's clean energy is a key way to put the planet on a low-carbon growth path.

At home, African governments have a vital task to do, one that goes to the heart of the continent's energy problems: fixing national energy grids that are unreliable and financially fragile. Many energy utilities suffer from mismanagement and inefficiency, reflected in failures to set tariffs, collect revenue, support private partnerships and investments in energy and stem major energy losses in transmission and distribution. A lack of accountability and transparency nurtures corruption. In our report, no finding brings this home more forcefully than the fact that some electricity theft – a problem across the continent – is carried out by a few government organizations, including the armed forces in some countries.

At the same time, renewable sources of energy because of their flexibility, modularity, and adaptability are the basis of Africa's new modern electricity systems. Africa's electricity future is emerging today where consumers are becoming producer and the monopoly and centrality of electricity is being challenged.

There are serious and persistent problems, yet they are solvable. The will exists to solve them, as many countries are demonstrating. Governments are showing leadership. But they need support to put in place the necessary integrated plans and policies, to overcome market barriers, and provide incentives for the business models and finance that can scale up Africa's energy transition. I hope that this report will be a catalyst for further action.

Across the continent, there is a general acceptance that modern energy is an indispensable ingredient of the growth and progress that Africa needs to bring prosperity to every citizen – women and men, rural and urban, of every ethnicity and every origin. **(See infographic: The Sustainable Development Goals will only succeed if they succeed in Africa)**

Africa stands at a crossroads. There is global attention and support for fixing Africa's energy problems, interest from investors, and demand from Africans for rapid expansion of reliable and carbon-friendly power. There are successes to build on. It's time for African leaders to act.

We know what to do. Every generation to come depends on us getting it right.

KOFI A. ANNAN

Chair of the Africa Progress Panel

THE SUSTAINABLE DEVELOPMENT GOALS WILL ONLY SUCCEED IF THEY SUCCEED IN AFRICA:

URGENTLY POWERING AFRICA TO DELIVER THE GLOBAL GOALS

AFRICA UNPLUGGED

SDG 1 Africa's poorest people are paying among the world's highest prices for energy

SDG 2 The challenge is food loss and waste. More than enough food is being produced. Up to 1/3 of all food is spoiled or squandered rather than being consumed

SDG 3 36,000 women die in childbirth each year in Nigeria. Lifesaving medical care is hampered by a lack of lighting

SDG 4 In 9 African countries more than 80% of primary schools have no electricity

SDG 8 Energy-sector bottlenecks and power shortages cost the region 2-4% of GDP annually undermining sustainable growth, jobs and investment

SDG 5 600,000 Africans are killed every year by air pollution caused by the use of firewood and charcoal for cooking. Women and children are the primary victims

SDG 9 60% of operator network costs for mobile-phone operators are spent on diesel fuel

SDG 11 50% of Africans will be living in cities by 2030, placing a huge strain on energy infrastructure

SDG 10 The energy gap between Africa and the rest of the world is widening

SDG 15 Collecting firewood and producing charcoal are the main causes of deforestation in Africa

SDG 13 No region has contributed less to climate change. Yet Africa pays the highest price for failure to avert a global climate catastrophe

SDG 17 Climate finance is fragmented and poorly governed. African countries are unable to leverage the finance needed to manage climate risk and deliver energy for all

620 MILLION
unconnected Africans

Energy is the 'golden thread' connecting growth, equity and sustainability. Energy access is essential to ensure that all SDGs succeed.

- No Poverty
- Industry, innovation & infrastructure
- Zero Hunger
- Reduced inequalities
- Good health & well-being
- Sustainable Cities and Communities
- Quality Education
- Climate Action
- Gender Equality
- Life on Land
- Decent work & economic growth
- Partnership for the Goals

AFRICA CONNECTED

SDG 7 Affordable and Clean Energy

EFFECTIVE INTERNATIONAL COOPERATION can increase investment in Africa's renewable energy. A global movement is growing around an energy transition that is clean and affordable

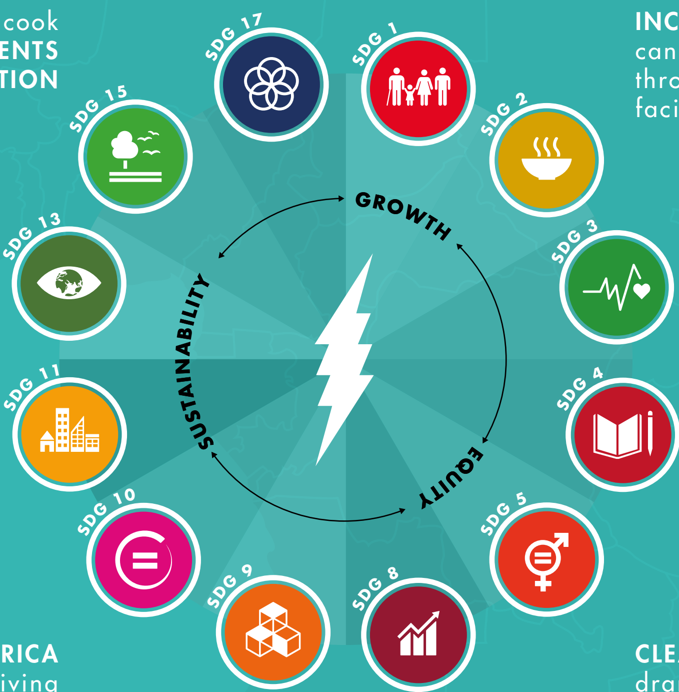
CUTTING THE COST OF ENERGY generates savings that can be invested in productive activities, health and education

The use of clean cook stoves **PREVENTS DEFORESTATION**

INCREASING ACCESS TO POWER can help reduce food loss through improved refrigeration facilities

Climate change presents Africa with a unique 'leapfrogging' opportunity to become a **GLOBAL LEADER IN LOW-CARBON DEVELOPMENT**

ACCESS TO RENEWABLE ENERGY SOLUTIONS can help save lives. In Uganda, the use of solar-powered radios to contact traditional birth attendants led to a reduction of maternal mortality by 54%



INNOVATIVE ENERGY SOLUTIONS in and around cities and rural communities will reduce pressure to migrate and make all areas more sustainable

ACCESS TO SOLAR ELECTRICITY in primary and secondary schools in Sudan and Tanzania improved completion rates from less than 50% to almost 100%

A MORE CONNECTED AFRICA will reduce inequalities. Giving poorer Africans greater equality of opportunity will make it possible to achieve all the SDGs

CLEAN COOKING STOVES dramatically reduce household and ambient air pollution and improve resource efficiency

GREEN POWER ALTERNATIVES could save more than 80% of what is spent on powering the 145,000 off-grid telecom sites in Africa

The renewable energy market is booming. Affordable electricity and clean cooking facilities **PROMOTE GROWTH AND JOBS**

INTRODUCTION

Across Africa, lack of electricity prevents many children from doing their homework at night. Evariste Akoumian, from Côte d'Ivoire, decided to solve this problem by creating backpacks with built-in solar panels that collect energy while children walk to school. During the day, the solar panels can absorb enough energy to power a lamp for four to five hours at night[1].

On the other side of the continent, in East Africa, the company M-Kopa provides rural households with home solar-energy systems that provide three lights, five connections for phone charging and a portable radio. Customers pay US$35 upfront then US$0.50 daily for a year. M-Kopa has already reached 275,000 homes and plans to reach 1 million homes by the end of 2017[2].

Evariste's backpacks and M-Kopa's solar household systems offer three striking lessons about Africa's energy story: Demand for electricity is huge; every source of electricity, on-grid and off-grid, will be needed to meet it; and African ingenuity is already matching supply and demand.

Universal access to reliable, affordable, low-carbon electricity is the key to Africa's socio-economic transformation. The continent has enormous potential to generate the energy which it needs to drive inclusive growth and create jobs. Yet most of Africa is mired in an energy crisis. In this report, we examine a range of ways to solve that crisis as quickly as possible.

Accelerating access to electricity in Africa is urgent. Although 145 million Africans have gained access to electricity since 2000, in many places electrification has not kept pace with population growth. Currently 620 million Africans do not have access to electricity, almost two-thirds of the population, and unless the electrification rate increases, the number of Africans without access in 2030 will increase by 45 million. **(See infographic: Mind the gap: Africa's energy deficit is large and growing)**

Alongside the access deficit is a wider power deficit. The average American consumes over 13,000 kilowatt hours (kWh) of electricity a year and the average European somewhat less. The average African (excluding South Africa) uses just 160kWh.

Africa could lead the world in building sustainable energy systems that couple efficiency and equity, as we showed in the 2015 Africa Progress Report, *Power People Planet: Seizing Africa's Energy and Climate Opportunities*. Demand for modern energy is set to surge in Africa, fueled by economic growth, demographic change and urbanization. As the costs of renewable energy sources fall, Africa could leapfrog into a new era of power generation. New energy and electricity systems (including utility reform), new technologies and new business and energy/electricity delivery models could be as transformative in energy as the mobile phone has been in telecommunications.

To achieve this vision and solve Africa's energy problems, it seems logical to focus on big projects such as large dams and power pools that will scale up national and regional infrastructure. But these projects are expensive, complex and slow to implement, particularly in rural areas. Africa's 600 million households cannot wait for the rollout of a grid that offers affordable connections for all.

The challenge for governments, their development partners and the private sector is how to move faster to bring the millions of African households, remote communities and small-scale entrepreneurs into the energy loop as quickly as possible. To meet that challenge, countries need to be able to choose from a menu that offers all options, including off-grid household systems and mini-grids as well as the national grid. Of the 315 million people who will gain access to electricity in Africa's rural areas by 2040, it is estimated[3] that only 30 per cent will be connected to national grids, and most will gain access to electricity through off-grid household or mini-grid systems.

This report is not advocating a shift in policy emphasis away from on-grid solutions, which will always form the base of energy supply in Africa. It is promoting a broadening of perspective to include new technologies and systems, some of them unproven, that offer promising ways to close Africa's energy gap more quickly than would be possible by relying on grid connections alone. The current static system can evolve into a dynamic, resilient system with many options and possibilities for expansion – from smart grids, mini-grids and hybrid grids to cross-border "super-grids". **(See infographic: Africa's energy transformation)**

National governments and regional groupings can aim for holistic energy plans that embrace every way of expanding supply, and they can make sure they are integrated with one another. If the policy framework and investment climate are adjusted to support integration of centralized and decentralized energy, the energy transitions will be cheaper and faster.

Off-grid solar technology and mini-grids are breakthrough technologies that have vast potential to advance access to electricity in Africa. Off-grid solar products – including super-efficient appliances designed for low-access environments – can act as rungs on an "energy ladder", providing a range of energy services to households and enterprises with different energy needs and incomes. Technological innovation means that mini-grids can also offer sustainable permanent alternatives to connecting to the grid, especially as reliable and affordable products come on-stream that are attractive to small and medium-sized enterprises operating far from the national grid.

These systems present households with an opportunity to access lighting and power for charging phones and fridges, to reduce household spending on less efficient fuels and to enjoy health benefits from clean home energy. New business models and pay-as-you-go systems are extending the reach of renewable markets, creating investment opportunities for investors in the process.

Governments can put in place the incentives needed to encourage investment in such systems, protect consumers, and facilitate demand among disadvantaged groups. More than that, governments need to support the development of an enabling environment through which African companies can enter energy generation, transmission and distribution markets, climb the value chain, and build the investment partnerships that can drive growth and create jobs.

To bring power to the two-thirds of Africans who lack access to modern energy, renewable energy development needs to accelerate significantly.

African countries have shown a strong willingness to shift from fossil fuels to low-carbon energy. So what is holding Africa back from exploiting its renewable potential? It is vital that governments implement policies that foster the expansion of Africa's renewable power supply.

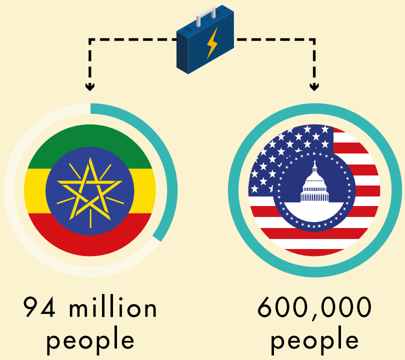
Africa's river systems could support the development of regional hydropower grids. This is already happening in Eastern Africa, where Ethiopia is tapping into its

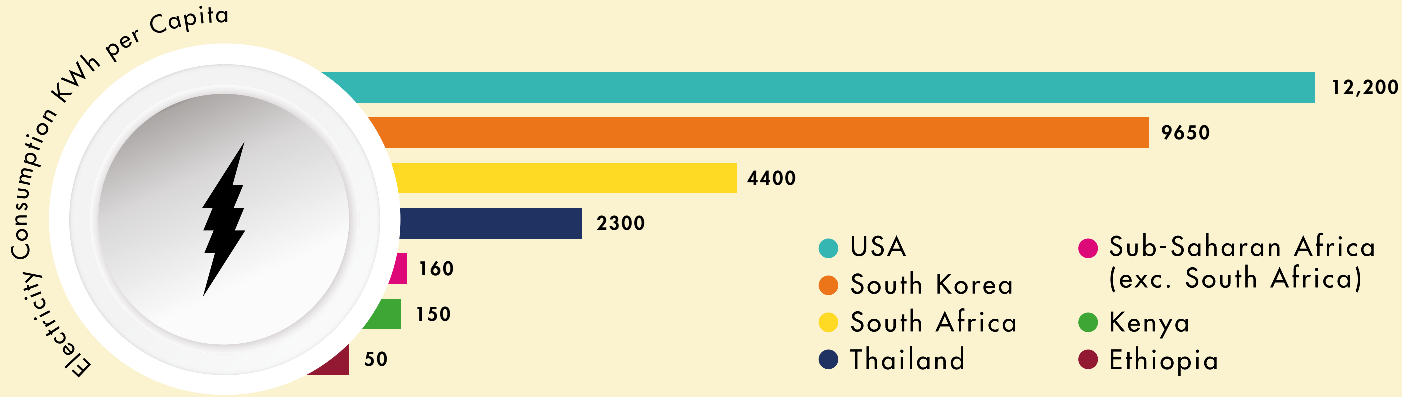
MIND THE GAP

AFRICA'S ENERGY DEFICIT IS LARGE AND GROWING

Energy consumption in Africa is shockingly low

Ethiopia (population 94 million) consumes one-third the electricity of Washington DC (population 600,000)



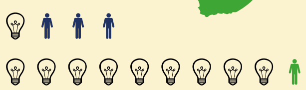


By 2030 the energy gap between Africa and other regions will widen

SUB-SAHARAN AFRICA is the only region in which the absolute number of people without access to modern energy is set to rise.

2016
2030

Energy gaps between African countries are marked

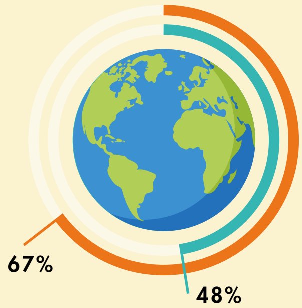


South Africa consumes 9 times as much energy as Nigeria despite having one-third of its population

In the Democratic Republic of the Congo, Liberia, Malawi and Sierra Leone, fewer than one in 10 people have access to electricity

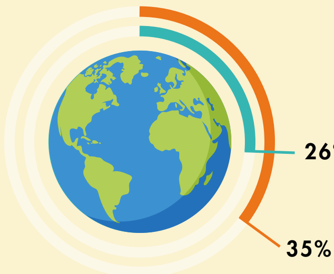
Africa's share of the world population without clean cooking facilities

In 2030, an additional 84 million people will not have access to clean cooking stoves



Africa's share of the world population without electricity

In 2030, an additional 45 million people will not have access to electricity



Within African countries, the electricity grid serves the wealthiest and urban areas

Among the poorest 40% of the population, coverage rates are well below 10%. Connection to the grid exceeds 80% for the wealthiest one-fifth of households vast hydropower potential to expand access, drive new industries and meet the demand of neighbouring countries.

In the short term, African governments cannot rely solely on renewable energy resources. The abundance of natural gas also presents opportunities to develop integrated regional grids across Southern, Eastern and West Africa. Integration can help close the access gap.

Outside South Africa, coal plays a residual role in power generation in Africa – and governments across the region would be wise to keep it that way. Leaving aside the profoundly damaging consequences of coal-fired power for climate change, this is a 20th century fuel exploited through technologies that are becoming increasingly dated. The smart investments in Africa, as in other regions, are being directed towards the more innovative and dynamic renewable energy fuels of the future. However, the transition to clean energy must be managed carefully. For countries with large deposits of coal, it is still the cheapest source of power. They must choose carefully which technologies to use to mitigate use of coal.

While oil and gas will remain prominent in Africa's energy landscape over the medium term, their shares in the energy mix are likely to decline in the face of technological breakthroughs and continuous improvement in energy efficiency that are disrupting the renewable industry and the whole global energy system. Sustained political and financial commitment from global, regional and national frameworks will be key in facilitating the continent's transition to a cleaner energy infrastructure.

If Africa is to exploit the new opportunities fully as they emerge in the energy sector, governments have to tackle old policy challenges. While some encouraging reforms are under way, all too often energy utilities are still opaque, unaccountable and inefficient. Despite its abundance of energy resources and potential, Africa is home to some of the world's worst-functioning grid systems, which have suffered from decades of neglect and mismanagement.

Many of the problems are well-known. Revenue streams are insufficient to cover basic operating costs, let alone new investment, in part because of a failure to collect bills and prevent electricity theft, most of which is carried out by individuals and organizations that consume large amounts of electricity and can afford to pay for it. There is an ongoing challenge to supply basic power and connections that are affordable to poor Africans.

The failure of regulatory authorities to provide secure off-take agreements and predictable prices undermines independent power producers and deters foreign investors. Africa must address these problems to attract the energy-infrastructure investments needed to tackle the power crisis – and to take advantage of the low international interest rates now available to support public investment.

To realize Africa's energy potential and accelerate the continent's wider integration agenda, cross-border power trade is crucial. Yet less than 8 per cent of power is traded across borders in Sub-Saharan Africa. Increasing this figure will require up-grading the grids and harmonizing standards across countries. Cost-effective generation and trade of electricity at the regional level would help to resolve the African energy "trilemma" of ensuring affordable, reliable and sustainable energy.

The ultimate goal should be to bring together and interlink Africa's numerous and fragmented power initiatives to create a single pan-African power grid. To achieve this goal, African countries will have to commit to a much deeper level of cooperation and overcome the dearth of financing for supranational interconnection projects.

In Africa and around the world, there is a deepening awareness not only of Africa's energy crisis but also of the ways to resolve it – through on-grid, mini-grid and off-grid solutions. In this report we explore all three ways of increasing access to electricity.

AFRICA'S ENERGY TRANSFORMATION

CURRENT SYSTEM

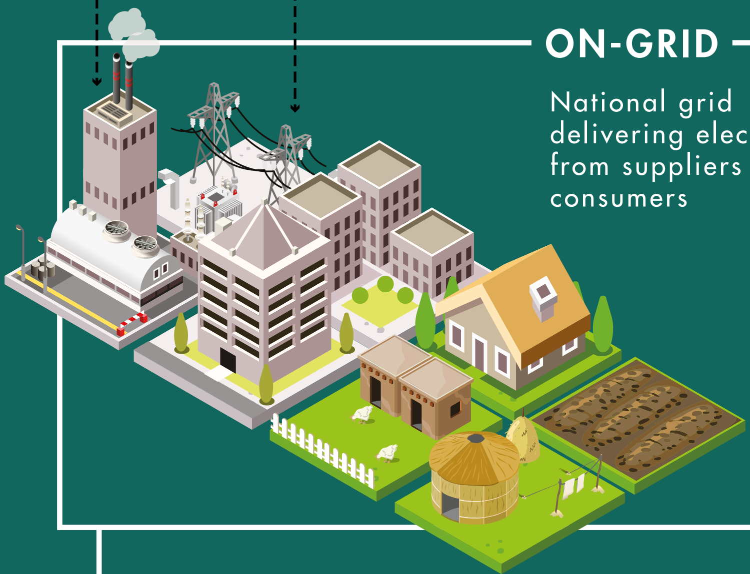
Linear and Static

Small number of big producers

One-way passive agreements with consumers

ON-GRID

National grid delivering electricity from suppliers to consumers



- Inefficient supply system
- Intermittent power supply
- The utility is the only supplier
- Corrupt and heavily subsidized utilities
- Energy losses and theft

620 MILLION
unconnected Africans

TRIGGERS

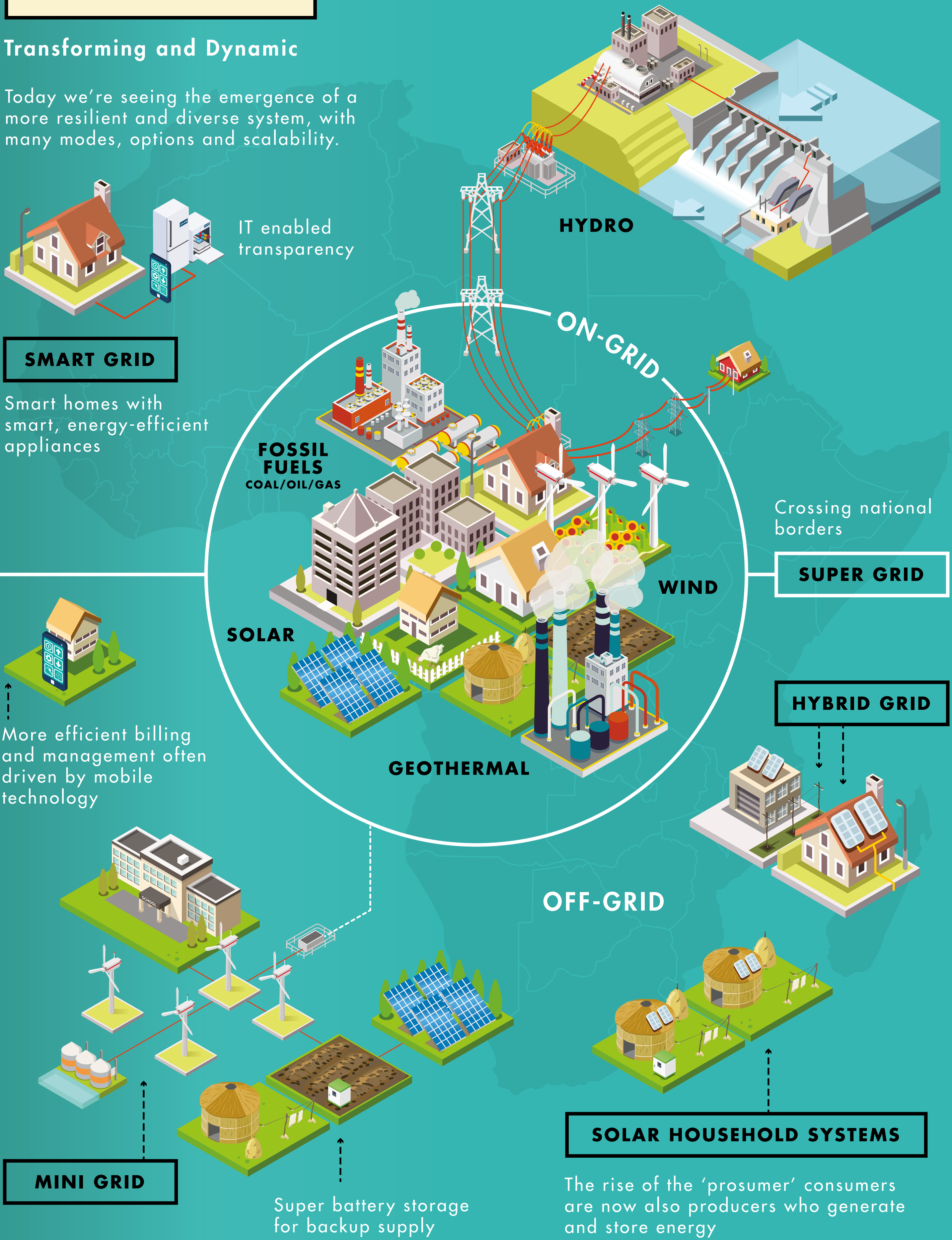
for Transformation

- Decline in the price of renewables
- Decline in energy storage prices
- Increase in awareness of climate change
- Near universal internet access and a shift from the Internet of People to the Internet of Things
- Innovation in technology, business models and payment structures
- Ever-increasing demand for electricity due to a rising middle class, increasing population and urbanization
- The rise of Africa's energypreneur

EMERGING SYSTEM

Transforming and Dynamic

Today we're seeing the emergence of a more resilient and diverse system, with many modes, options and scalability.



Several key factors influence the choice of a particular energy solution, including the target level and quality of energy access, population density, local grid connection characteristics, the availability of local energy resources and the cost of the technology necessary to exploit them[4]. African countries grappling with limited financial resources, weak energy planning and rapid economic growth need to choose the energy technologies that increase access fastest while offering the best value for money. A comparative assessment of off-grid, mini-grid and on-grid systems is therefore critical to help countries make those choices. This report is divided into three parts that consider the advantages and disadvantages of all three options.

Part I charts the spectacular rise of off-grid solar products in Africa, and shows how off-grid consumers can advance up an "energy ladder" of progressively more high-powered solar household systems. In conclusion, we lay out some concrete measures that African governments and their partners can take to help the continent meet its fast-growing electricity needs. Part II examines the role of mini-grids – whether they are connected to the grid or not – in meeting the needs of the "missing middle", the energy consumers who lie between grid-connected power and small off-grid solutions. The story of how mini-grids can fast-track inclusion of large numbers of Africans who have never had grid access is told. Part III looks at why Africa's grids are performing so poorly and what is being done to fix, extend and interconnect them – as well as how to integrate Africa's huge renewable energy potential.

PART I: OFF-GRID SOLAR – CLIMBING THE POWER LADDER

In Africa, off-grid electricity generation used to be regarded as a stop-gap measure – a way to power a few lights during the long wait for a grid connection. In recent years, that situation has changed radically. The number of households connected to off-grid power has soared, improving millions of lives while relieving a chronic shortage of power. In this part of the report we focus on off-grid solar power because of its dramatic growth on the continent – and the "energy ladder" it offers to families who would otherwise have little chance of increasing their level of access. **(See infographic: Africa's energy ladder: Accelerating access)**

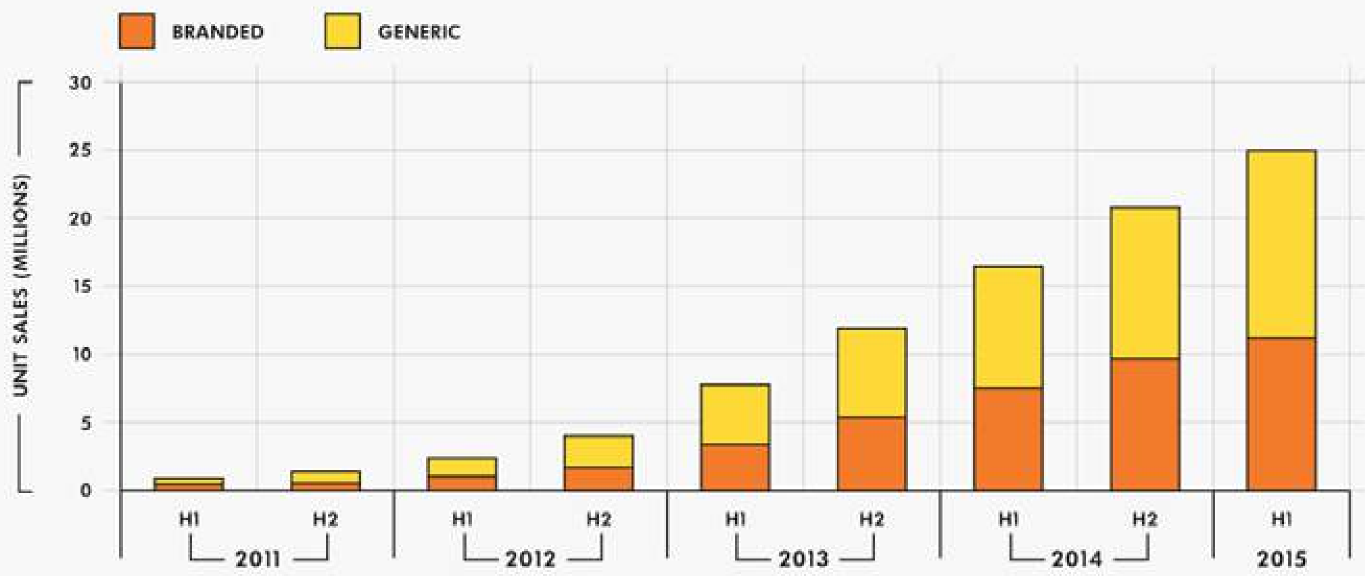
Off-grid solar photovoltaic (PV) systems are now the most economical sources of electricity for more than one-third of the African population who lack access to electricity. Solar PV systems for use by single households or businesses come in a wide range of sizes and costs, from small portable solar lights to large home systems able to power several high-powered appliances[5]. Small solar lanterns can now bring electric light to poor families at a lower cost than ever before.

Some argue that efforts to promote incremental shifts in energy access through solar lanterns suffer from a failure of ambition, because solar lanterns provide inadequate energy access for a decent standard of living[6]. Kandeh Yumkella, the former head of the Sustainable Energy For All (SE4All) initiative, said: "The provision of one light to poor people does nothing more than shine a light on poverty." These concerns are warranted: to fight poverty, more energy services will be needed than lighting and mobile phones. However, recent research[7] shows that small amounts of electricity can greatly improve the lives of low-income families: "Overall, the first few watts of power mediated through efficient end-uses lead to high marginal benefits in household health, education and poverty reduction." They have a key role in expanding access as even ambitious power-generation scenarios[8] would leave over half a billion Africans without access to electricity in 2030[9].

In the past five years, the African market for off-grid solar PV has grown spectacularly, as demand for electric lighting and mobile-phone charging has soared; prices of PV modules, LED lights and efficient appliances have fallen; and innovative models of financing and distribution have spread. Growth has been particularly rapid in sales of the smallest units, known as pico-solar products, which range from single-light lanterns to small solar home-systems of 10W or less that can power multiple lights and a mobile-phone charger. At the beginning of 2011, fewer than half a million brand-name pico-solar lighting products had been sold in Sub-Saharan Africa[10]. By the second half of 2015, this figure had grown to 11.3 million **(Figure 1)**. But growth of brand-name products tells only half the story: unbranded "generic" products could now represent more than half the market[11].

FIGURE 1: DEMAND FOR SMALL-SCALE SOLAR PRODUCTS IS HUGE AND GROWING

Estimated cumulative sales of pico-solar lighting products in Sub-Saharan Africa

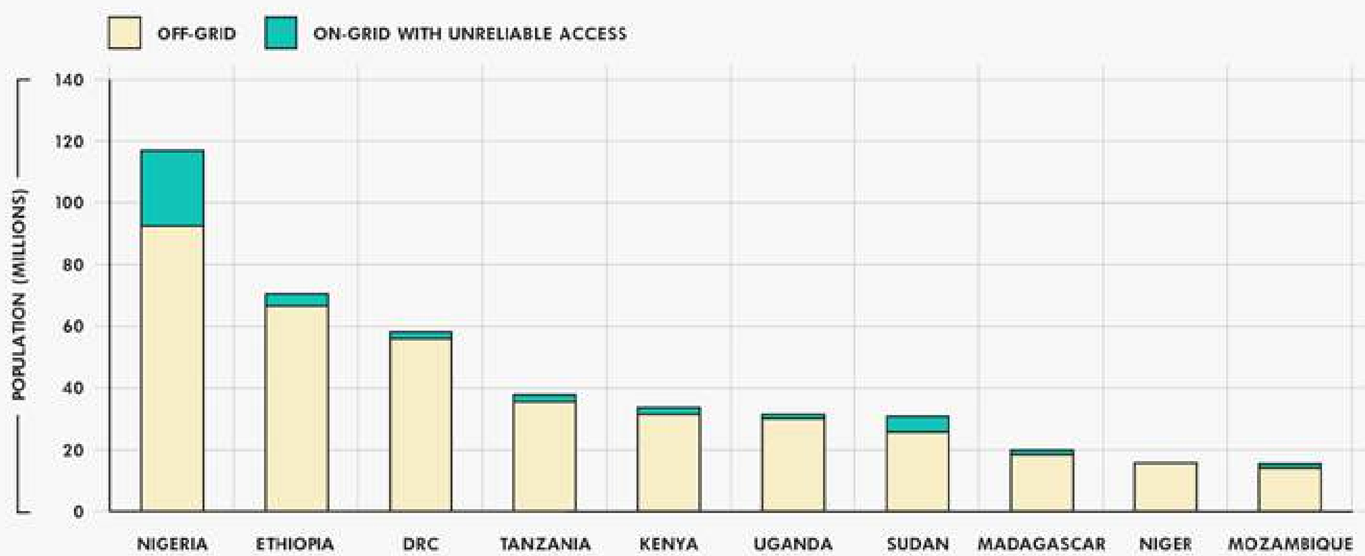


Note: Figures are for solar lanterns and small solar home systems of 10W or less[12]. Source: Orlandi, Tyabji and Chase (2016)

Even among urban dwellers, off-grid solar products are finding a market. Many urban families are unable or unwilling to pay high connection charges[13]. Solar lanterns or smaller solar home systems are often more affordable and immediately available. For the minority of Africans who do have a connection, solar home systems and solar lanterns can offer stop-gap measures to cope with unreliable grid power, which leads to frequent power cuts **(Figure 2)**[14].

FIGURE 2: MOST PEOPLE IN AFRICA LIVE BEYOND THE GRID

Populations living off-grid or with unreliable grid access (millions)



Source: Orlandi, Tyabji and Chase (2016)

AFRICA'S ENERGY LADDER

ACCELERATING ACCESS

STEP 6: VERY HIGH POWER

Off-grid, grid and mini-grid, very large hybrid (combination of solar and diesel) solar household systems, and solar farms

STEP 5: HIGH POWER

Off-grid, grid and mini-grid, large hybrid (combination of solar and diesel) solar household systems

STEP 4: MEDIUM POWER

Mini-grids and large solar household systems
Schools, health facilities and enterprises

STEP 3: LOW POWER

Solar household systems, fans, radios, TVs and fridges

STEP 2: VERY LOW POWER

Pico solar lanterns

STEP 1: NO POWER

No access to electricity. Use of kerosene, candles and battery powered torches

Consumers with different levels of income are able to jump up the ladder several steps at a time

SALES OF PICO SOLAR ARE INCREASING

UP BY OVER ↑10 MILLION

In just four years, sales have risen from 500,000 in 2011 to 11.3 million in 2015.

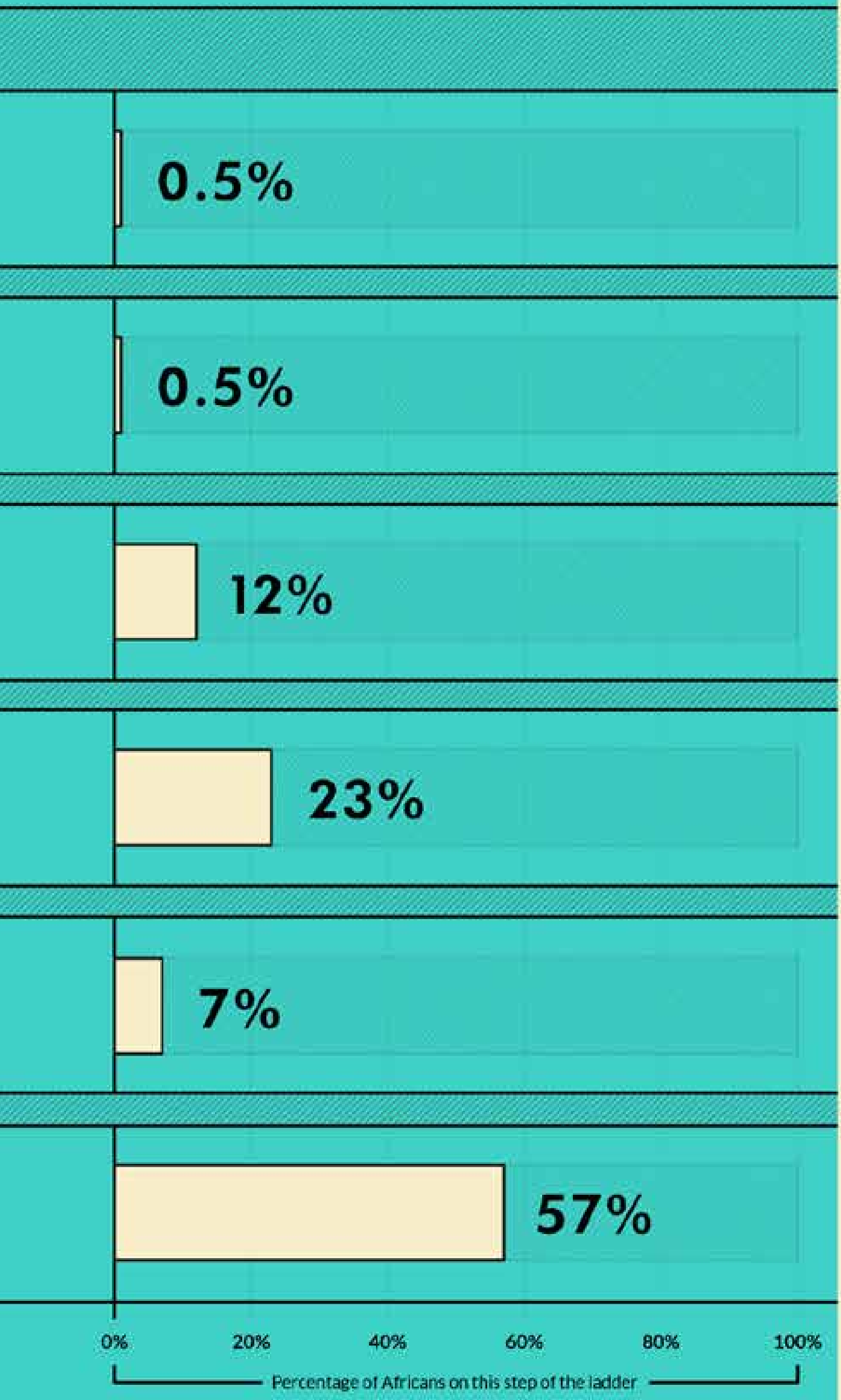
COST OF SOLAR HOUSEHOLD SYSTEMS ARE FALLING

$1000

2009

$200

2020 (projected price)



COMPANIES AND ENTREPRENEURS

HELPING PEOPLE MOVE UP THE LADDER

M-KOPA, BBOXX, AKON LIGHTING AFRICA, SolarAid, azuri, STEAMACO

MARKET BARRIERS

PICO-SOLAR

- Lack of consumer finance
- Debt and equity finance for solar distribution companies
- Consumer awareness
- High import duties and VAT
- Rigid currency exchange policy

SOLAR HOUSEHOLD SYSTEMS

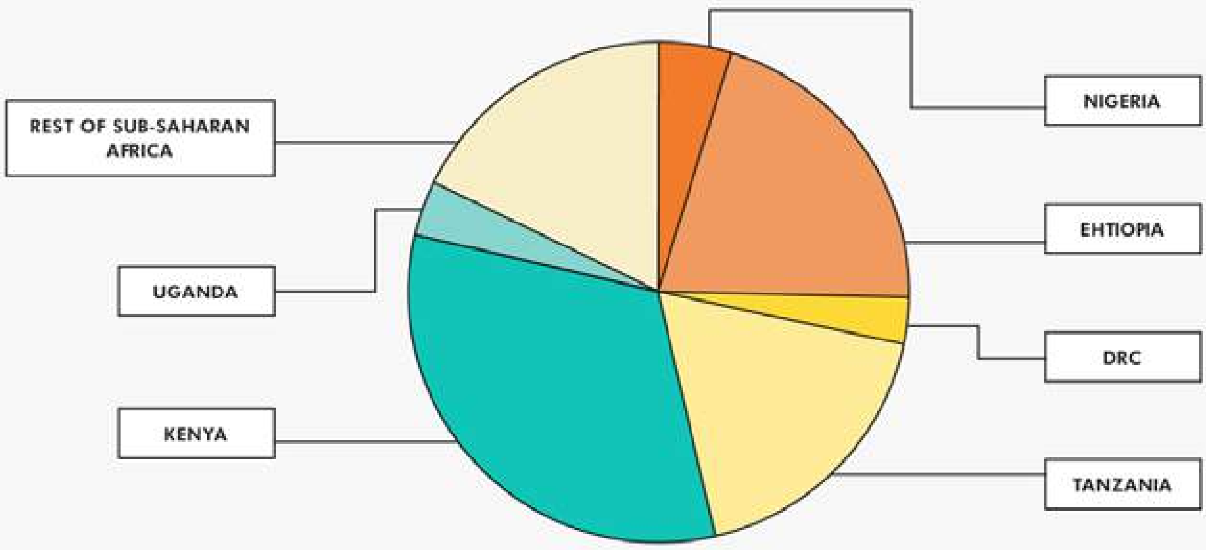
- High upfront costs
- Lack of an array of innovative consumer financing
- Installation and servicing needs
- Need to develop distribution networks
- Training of sales agents and services technicians, financing constraints (lack of working capital, consumer financing)

MINI-GRIDS

- Lack of proven commercial business models
- Lack of adequate and appropriate forms of financing, and implementation capacity
- Inadequate and uncertain policy frameworks for mini-grids
- Inexperience and dispersed knowledge of mini-grids amongst developers and operators
- Tariff design and collection, maintenance and contractor performance, theft management, demand management, training of local staff, high upfront and transaction costs, high business risks in remote areas (low income)

The growth in pico-solar sales is highly concentrated in Kenya, Tanzania and Ethiopia, which accounted for two-thirds of branded product sales between July 2014 and July 2015[15] **(Figure 3)**. Whereas 15-20 per cent of off-grid households in these countries have been reached by pico-solar products, market penetration in Sub-Saharan Africa as a whole is around 3 per cent[16].

FIGURE 3: GROWTH IN PICO-SOLAR SALES IS CONCENTRATED IN ONLY THREE AFRICAN COUNTRIES

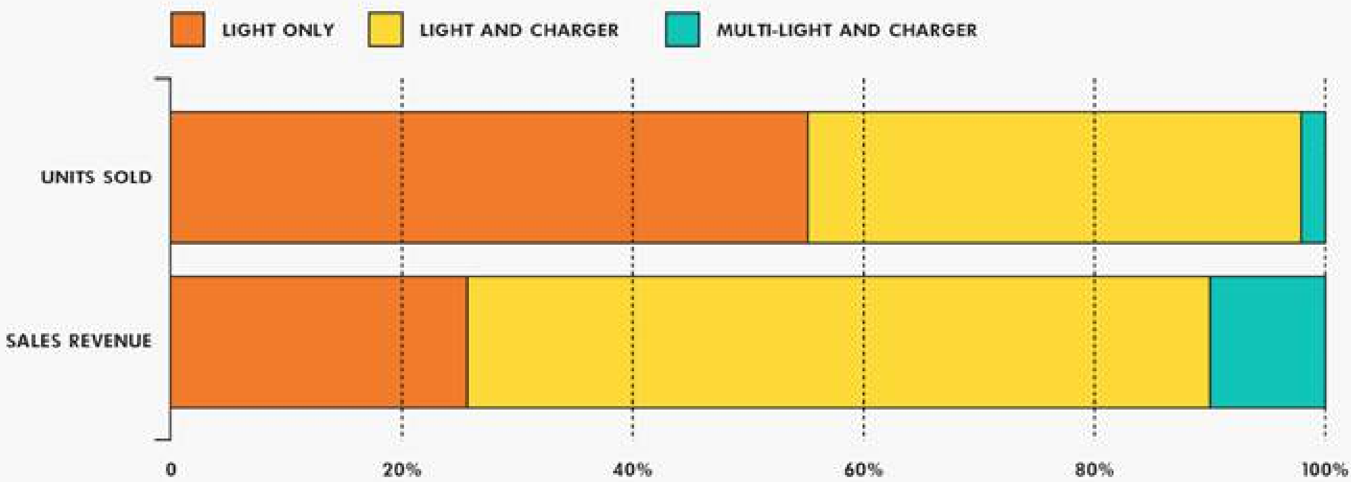


Note: Reported sales of Lighting Global quality-verified products in Sub-Saharan Africa, July 2014–July 2015 (thousands of units). Source: Orlandi, Tyabji and Chase (2016)

The most popular solar products in Africa are solar lanterns. Light-only systems made up more than half the branded units sold in 2014. Systems with one light and a phone charger made up another 43 per cent and earned most of the revenue **(Figure 4)**. Only 2 per cent of units sold were multi-light systems with a phone charger and sometimes a radio. The African solar market is dynamic, with new business and product innovations emerging all the time. Cheaper solar home systems and new pay-as-you-go business models promise to bring solar home systems to increasingly lower-income families. The solar market is now splitting into two: one for entry-level solar lanterns and another for solar home systems that can power small appliances such as radios, fans and televisions.

FIGURE 4: LIGHTS ARE THE POPULAR SOLAR PRODUCTS IN AFRICA

Pico-solar sales by product category – units and revenue (2014)



Source: Scott and Miller (2016)

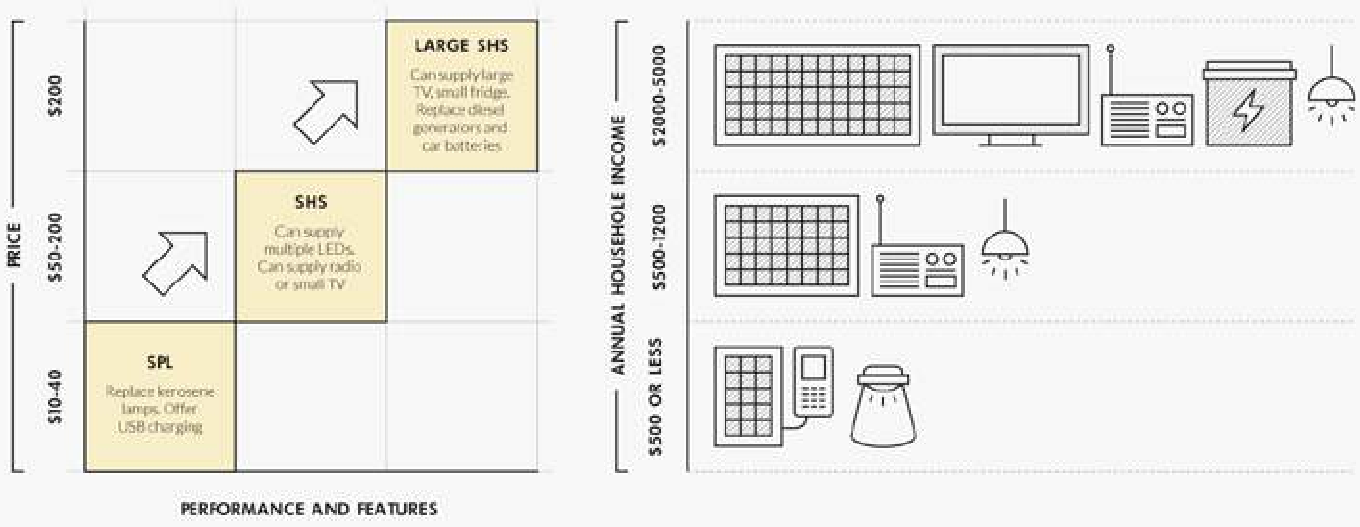
SOLAR PRODUCTS OFFER AN ENERGY LADDER

The multi-tier framework developed by SE4All represents how a family's level of electricity access corresponds to the types of energy services it receives, and the quality, reliability and affordability of those services[17]. The framework's tiers of electricity access are likened[18] to rungs on a ladder: "with high-value/low-power services acquired first (mobile phone charging, lighting) followed by a prototypical stack including fans, television, refrigeration, heating, motive power and others that all provide services contributing to quality of life."

Solar home systems and pico-solar lanterns apply to different tiers of this framework **(Figure 5)**. Most solar products sold in Africa fall either just below or within tiers 1 and 2. Wealthier homes, small enterprises and community services demand higher levels of access that can only be fulfilled through larger solar home systems.

Some argue that obtaining the first tier of electricity access through solar technology enables households and businesses to progress to higher tiers. Given the youth of the solar industry in Africa, most evidence supporting this argument is anecdotal. Nevertheless, the logic of the metaphor of the solar-energy ladder is sound, especially in the context of households. Families with different levels of income can afford different-sized solar systems **(Figure 5)** and eventually will be able to jump up the ladder several tiers at a time.

FIGURE 5: THE SOLAR ENERGY LADDER: AS THEIR INCOME RISES, FAMILIES CAN AFFORD LARGER SYSTEMS

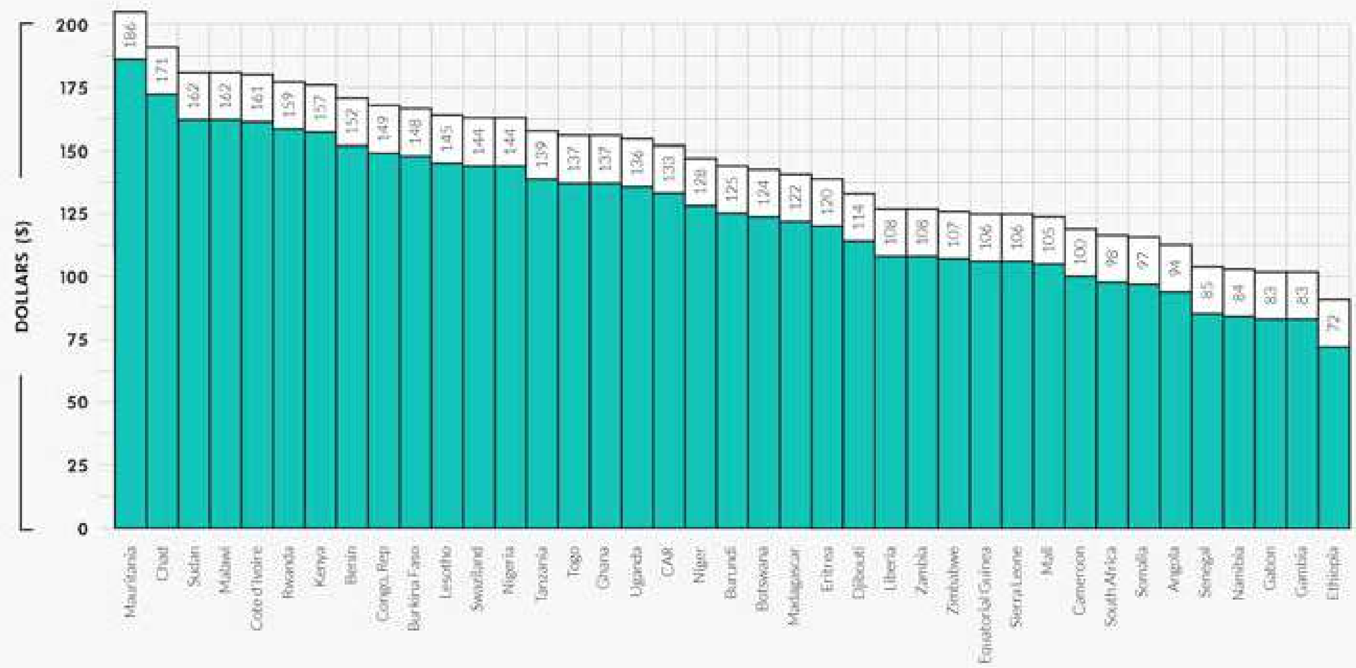


Sources: A.T. Kearney and GOGLA (2014); Harrison, Scott and Hogarth (2016)

For all tiers, solar lighting is cheaper than fuel-based lighting. Energy-poor people are often obliged to spend meagre incomes buying high-priced, low-quality lighting from candles, kerosene lamps and battery-powered torches. The amount that off-grid families spend on lighting ranges from US$186 per year in Mauritania to US$72 in Ethiopia **(Figure 6)**. Most African off-grid families spend more than US$140 per year on lighting[19]. Solar lanterns that produce light comparable to that of a pressurized kerosene lamp can now be purchased for under US$5, a decline from US$20 in 2010. A mid-sized lantern offering superior light costs under US$20, less than half its price in 2009; by 2017, it is projected to cost US$10[20] **(Figure 7)**.

FIGURE 6: AFRICA'S ENERGY POOR FACE HIGH PRICES FOR LIGHTING

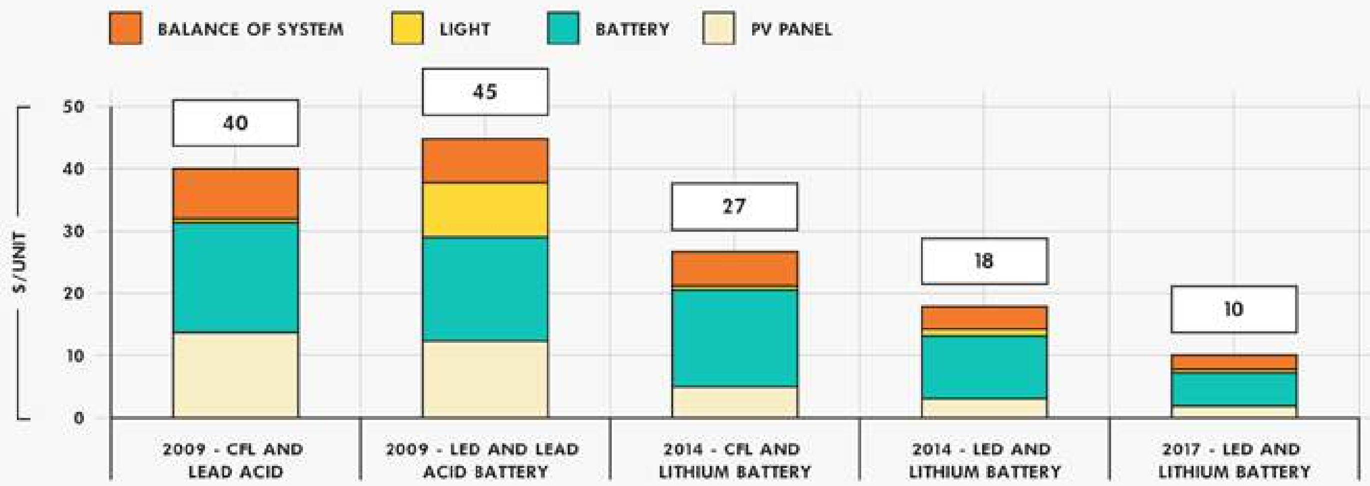
Estimated average annual lighting expenditure by off-grid households ($, 2012)



Source: Orlandi, Tyabji and Chase (2016)

FIGURE 7: THE COSTS OF SOLAR LANTERNS ARE FALLING DRAMATICALLY

Estimated annual expenditure ($/unit)



Note: A mid-sized lantern can provide 120 lumens of light for up to four hours a day. Source: Orlandi, Tyabji and Chase (2016)

Income saved by using electric lighting (instead of kerosene lamps, candles or battery-powered torches) and charging phones at home (instead of at public kiosks) can be spent on more energy-intensive appliances, grid connections or bigger off-grid systems. Those who purchase solar products with consumer finance (or pay-as-you-go models) generate a credit history and assets that can unlock loans for additional products[21].

Finally, families that own a solar system would even be better prepared to connect to the electricity grid when it becomes available, because they will be likely to own energy-saving appliances and a back-up power supply and battery pack to safeguard against power cuts[22].

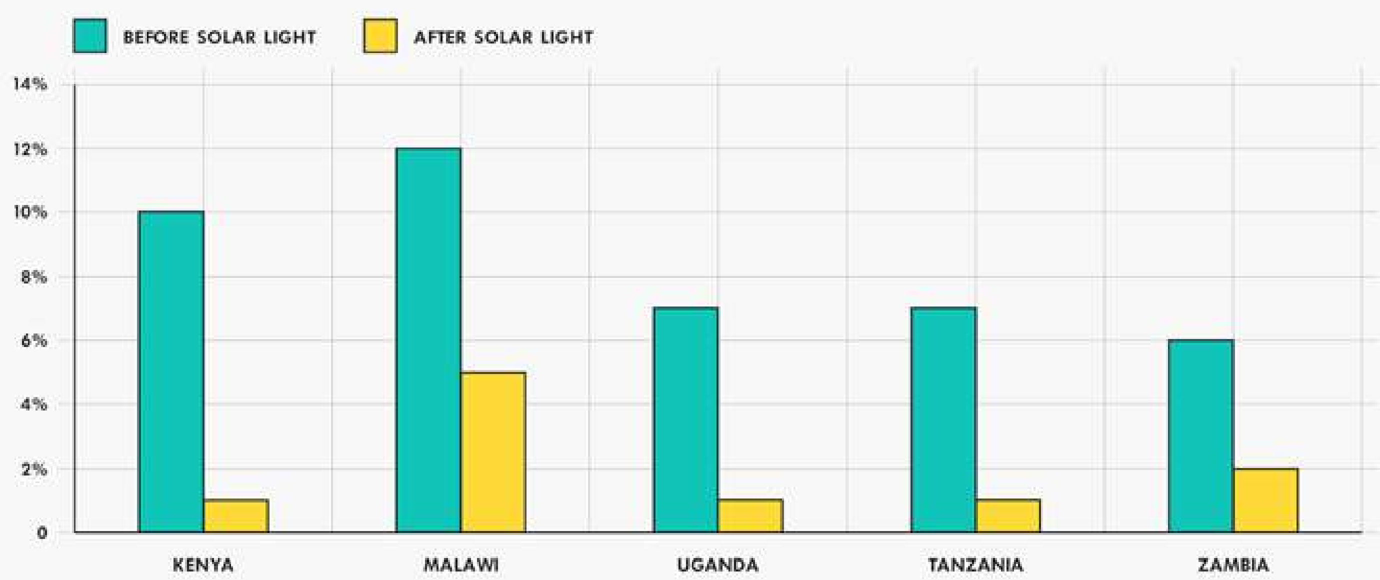
PICO-SOLAR LANTERNS: THE FIRST STEP UP THE ENERGY LADDER

A person with a basic solar lantern has one foot on the first rung of the energy ladder; two feet if that lantern also has a phone-charging function. Quality-certified solar lanterns are estimated to provide tier 1 energy services for 13.5 million people in Africa[23].

A survey by the British non-profit group SolarAid in Kenya, Malawi, Tanzania, Uganda and Zambia found that families that purchased a solar lantern reduced their average lighting expenditure from roughly 9 per cent to 2 per cent of their total income, saving over US$60 a year **(Figure 8)**[24]. The research firm Bloomberg New Energy Finance estimated that every US$1 spent on solar lighting in Africa saves consumers US$3.15. The savings from a US$13 solar light will exceed its costs within three to four months[25].

FIGURE 8: PURCHASING A SOLAR LANTERN CAN REDUCE LIGHTING EXPENDITURE SIGNIFICANTLY

Portion of average household spending devoted to lighting

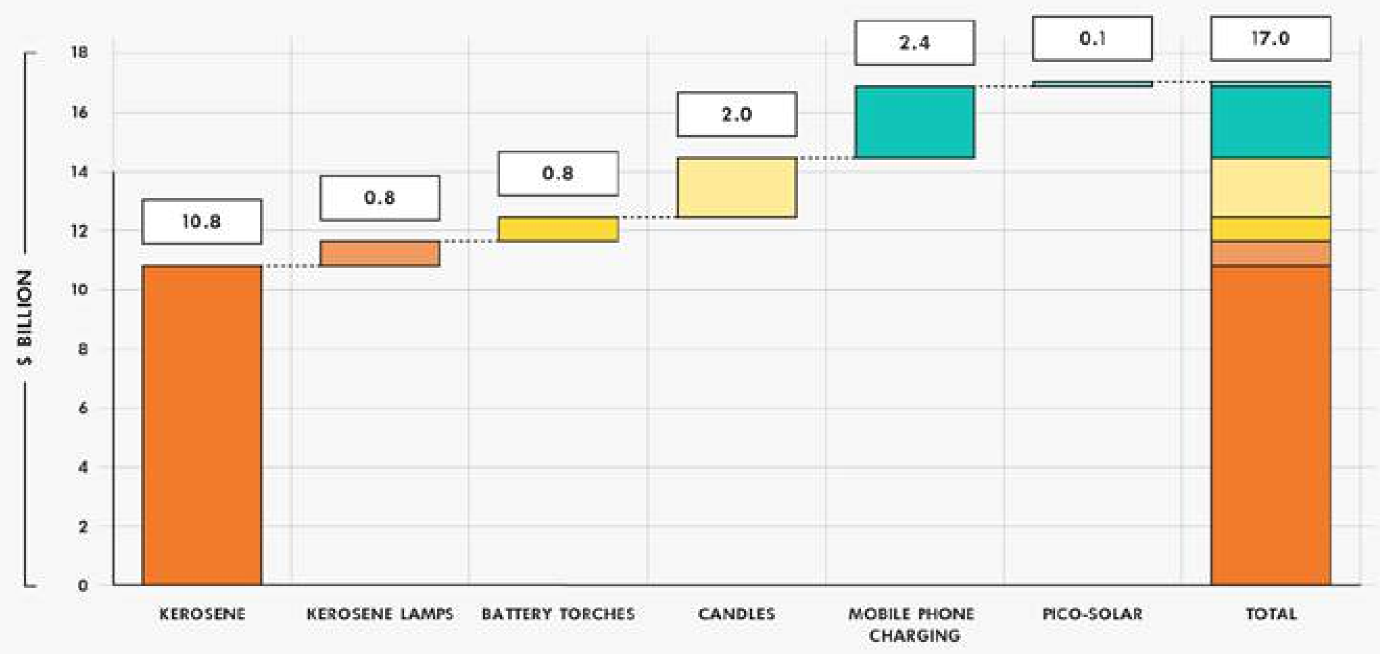


Source: Harrison, Scott and Hogarth (2016)

If the solar product also charges a mobile phone, the savings can be even greater. SolarAid found that off-grid families in Africa spend on average US$0.66 a week charging mobile phones at kiosks, and travel 28 minutes each way to the nearest station to do so. In total, Africa's off-grid population spends around US$17 billion a year on lighting and phone charging **(Figure 9)**[26]. Savings can be re-directed to other important need[27].

FIGURE 9: AFRICANS ARE SPENDING BILLIONS ON OFF-GRID LIGHTING AND PHONE CHARGING

Estimated annual spending ($ billion)



Source: Orlandi, Tyabji and Chase (2016).

Replacing candles and kerosene lanterns with solar lighting also offers health benefits. Improved light can reduce eye problems. Solar lighting significantly reduces the risk of burns and fires[28] and reduces toxic fumes emitted by kerosene lanterns[29,30]. Electric lighting also removes the serious risk that children will accidentally ingest lighting fuel, which is commonly stored in soft-drink containers[31].

Better access to lighting enables children to increase the quality and quantity of time spent on homework, and shift study to the evening hours. A SolarAid survey found that schoolchildren in Kenya, Malawi, Tanzania and Zambia rated limited lighting as their main barrier to learning and doing homework. After obtaining a solar light, children increased their study time on average from 1.7 to 3.1 hours each night[32]. Solar lighting can also improve security, at home and in public spaces. In Liberia and Uganda, families with solar lighting reported feeling safer at night[33].

Despite the clear benefits of solar lighting, the market for solar lanterns remains undeveloped across much of Africa. Bloomberg New Energy Finance noted: "Solar product sales seem not driven by household expenditures and incomes nor the product payback economics alone"[34]. Countries where solar lighting is ubiquitous include ones where expenditure on household lighting is high (Kenya at US$163 a year) and low (Ethiopia at US$72 a year), suggesting there is significant market potential for solar lighting across the region, irrespective of a country's household incomes and lighting expenditure.

The three countries with the largest markets for pico-solar products – Ethiopia, Kenya and Tanzania – have supportive policy environments, with low or zero value-added tax (VAT) or tariff rates on solar products and programmes to raise consumer awareness and build markets.

Three prominent market-building programmes in the region are SolarAid's SunnyMoney, Ignite Power in Rwanda[35] and the World Bank Group's Lighting Global (formerly Lighting Africa). Efforts to raise consumers' awareness of the cost savings and health benefits of solar lanterns have been shown to increase their willingness to pay for the technology[36].

SunnyMoney was established in Tanzania in 2009 and expanded to Kenya, Malawi, Uganda and Zambia. SunnyMoney's School Campaign works alongside education ministries and teachers to raise awareness in schools about solar lighting. Parents are encouraged to purchase solar lights for their homes, particularly for their children to use for homework. SunnyMoney's school-based programme has helped to sell more than 1.7 million pico-solar products.

Ignite Power, launched in 2016 in Rwanda, is the largest solar deployment in East Africa[37] **(Box 1)**. The electrification project has turned the home-solar market on its head in two main aspects. First, it approaches deployment of solar home systems in a similar way to developing a large solar project in terms of structure, financing and incorporation into the national energy planning. Second, Ignite secured a widespread deployment network creating hundreds of solar entrepreneurs as well as attracting four new suppliers to the country. As a result Ignite provides solar home systems for 40 per cent less cost than was previously offered in the market.

Lighting Global was launched in 2007 in Ethiopia, Ghana, Kenya, Tanzania and Zambia. It has now expanded to Burkina Faso, Democratic Republic of Congo, Liberia, Mali, Senegal, South Sudan and Uganda, as well as three Asian countries. Lighting Global initially focused on market research, support for business development and consumer-awareness campaigns. In 2009, it launched a quality-assurance framework to help consumers choose quality pico-solar products. By mid-2015, Lighting Global had tested 152 pico-solar products and verified the quality of 103, and it continues with 54 quality-verified products. Lighting Global's testing framework has been adopted nationwide in Ethiopia, Kenya and Liberia, and informed a new quality framework for the Economic Community of West African States (ECOWAS).

Despite these quality-assurance efforts, the pico-solar product market has been flooded by generic products with lower prices, but often of poor quality, more so than the market for larger solar home systems. It is still unclear whether this is positive or negative for Africa's solar industry. On the one hand, it is a sign of a mature market, and is driving down costs for consumers[38]. On the other hand, poor-quality generic products can break within weeks, undermining consumer confidence in solar technology. SolarAid research showed that while 80 per cent of traders in Tanzania were aware of fake or poor quality products, only one-quarter of customers were aware that such products existed[39].

Some generic products imitate the look and feel of well-known brands, but use inferior technology. To protect consumers, regulatory measures that promote high-quality products will be needed[40]. However, the portion of generics that are counterfeits is low, perhaps 2 per cent[41]. The majority are simply unbranded.

Consumer-awareness activities will remain the key to building markets for solar lanterns across Africa – to inform people about the benefits of solar lighting, and to help them choose the best products.

SOLAR HOME SYSTEMS: POWERING FAMILIES

Solar lighting is just a starting point. Many off-grid families already demand – and can afford – solar home systems that can power small appliances such as a fan, radio, television or refrigerator. The Global Lighting and Energy Access Partnership (Global LEAP) surveyed[42] industry, policy and development stakeholders to determine the importance of different appliances to off-grid families and small and medium enterprises (SMEs). Respondents were asked to rank the five appliances that they felt would have the highest consumer demand and impact over the next three to five years. First were room-lighting and mobile-phone charging, then the highest demand would be for televisions, radios, fans and refrigerators.

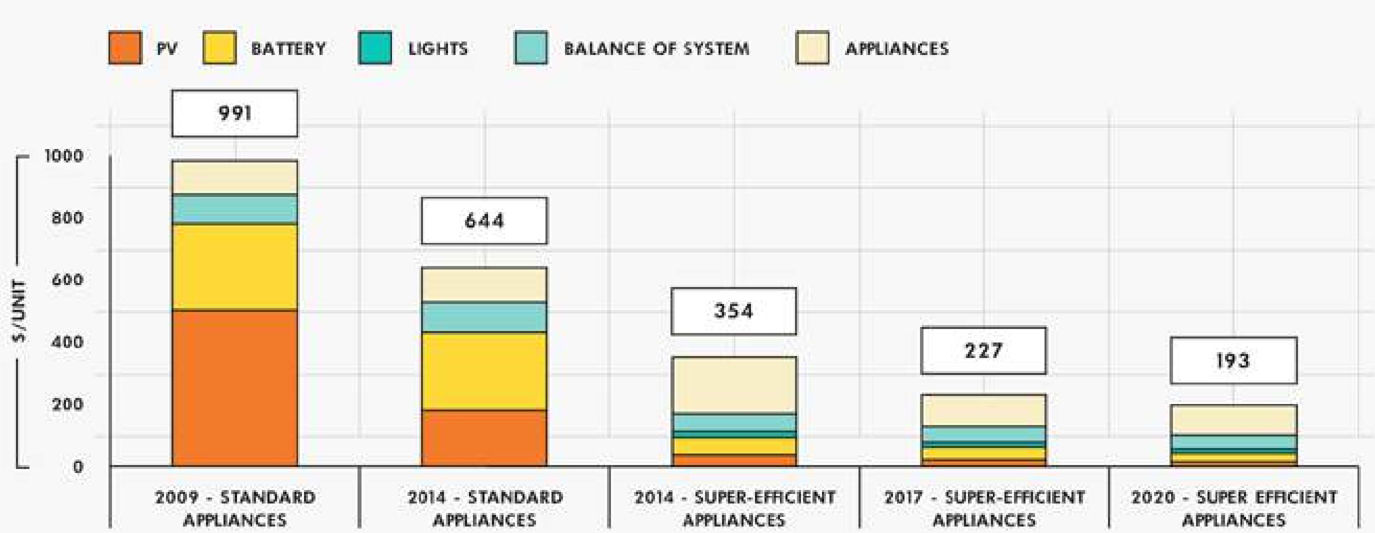
These energy services can significantly improve the quality of life for off-grid families. In hot and humid climates, the comfort provided by a fan could improve household productivity. Refrigerators are particularly beneficial in hot climates, where food storage is a challenge. Television and radio provide not just entertainment but also access to important information about weather and natural disasters, financial planning, family planning and health[43,44].

Building a market for solar household systems

Solar home systems currently provide only a small fraction of African off-grid families with Tier 2 energy services (i.e. television and a fan, in addition to lighting and mobile-phone charging). Only 2 per cent of the solar products sold in 2014 whose quality had been verified by Lighting Global were small solar home systems capable of powering multiple lights, a phone-charger and sometimes a radio. Ownership of appliances such as televisions, fans and refrigerators also remains low in rural areas. Penetration rates vary by country and are tied to income levels and electricity access[45].

FIGURE 10: COSTS FOR SOLAR HOUSEHOLD SYSTEMS ARE DECLINING RAPIDLY

Cost trends of solar home systems with 19" TV, radio and two lights (US$/unit)



Source: Orlandi, Tyabji and Chase (2016)

Sales of solar home systems and appliances are primarily inhibited by their costs **(Figure 10)**. In 2014, a solar home system capable of powering a 19" television, radio and two lights cost US$354. This is down two-thirds from nearly US$1,000 in 2009, but still more than half the average annual income of the 389 million Sub-Saharan Africans who live on less than US$1.90 per day.

The emergence of pay-as-you-go models will transform the market. They enable customers to pay the upfront costs of a solar home system in affordable instalments over time, while the solar provider can deactivate the product if a payment is overdue[46]. Beyond making the technology more affordable, pay-as-you-go increases consumer confidence by shifting the risk of faulty technology to the supplier. It promises to unlock solar home systems for tens of millions of Africans who live above the extreme poverty line but lack an electricity connection. In several African countries – particularly Ethiopia, Kenya, Rwanda and Uganda – this potential market is substantial.

Off-grid is also changing the perception of governments of what is possible. In 2016, as a result of the scale-up of the Ignite project, the government of Rwanda updated its targets to include solar home systems as a main pillar of the energy strategy.

BOX 1: RWANDA NATIONAL OFF-GRID PROGRAMME

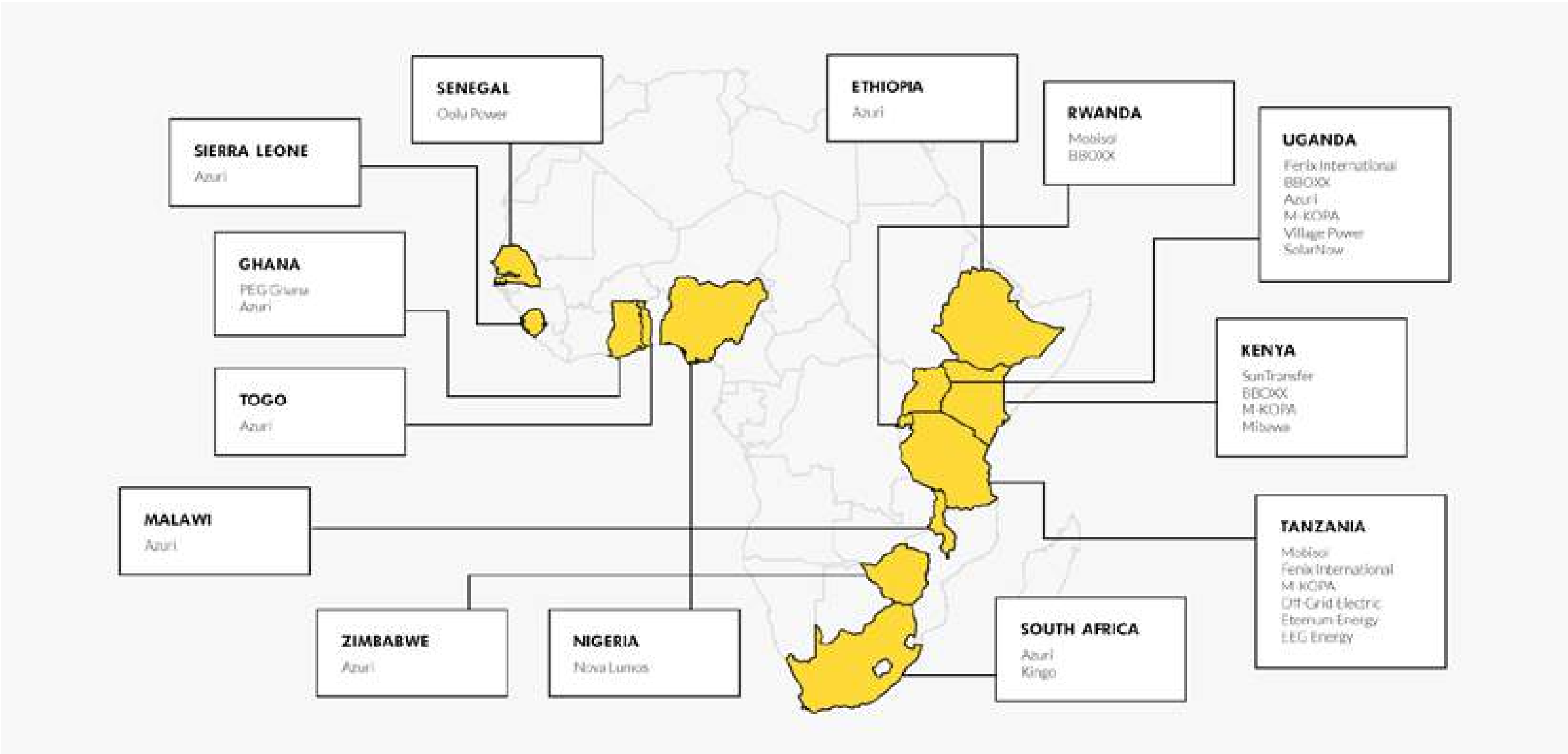
In our last report, we highlighted Ignite Power's national programme for Rwanda, which was underway. The programme was built to connect 250,000 homes in Rwanda using close collaboration with the government and local utilities. The programme is now in full speed, connecting close to 300 homes every day (1,500 people) and scaling up to 500 daily. It continues to grow rapidly, 6 months ahead of target, influencing both the market and the economy. Hundreds of solar entrepreneurships have been created and four new suppliers have been attracted to the country. As a result, the products under the Ignite programme are 40 per cent more affordable than any comparable product in the market that is not in the programme, doubling the total addressable market for solar home systems in the country.

Analysts expect the pay-as-you-go market to grow rapidly. Pay-as-you-go products represent only a small fraction of the solar products sold to date, but pay-as-you-go companies attracted nearly US$160 million in investment in 2015, more than all cash-sale solar companies in Africa combined. Off Grid Electric, a pay-as-you-go solar company, was able to raise US$45 million in debt in one fundraising round[47]. Market leaders are concentrated in East Africa, but pay-as-you-go businesses now operate in a growing number of West and Southern African nations **(Figure 11)**.

Continued product innovation will also help make solar home systems accessible for lower-income markets. The same solar home system that cost US$354 in 2014 is projected to cost less than US$200 by 2020. Price declines are driven not only by the falling cost of solar PV modules, but also by improvements to other system components.

FIGURE 11: PAY-AS-YOU-GO SOLAR LIGHTING IS SPREADING ACROSS AFRICA

Examples of solar lighting services currently available



Note: The list represents a sample and is not intended to be comprehensive. Source: Source: Orlandi, Tyabji and Chase (2016)

Batteries are a critical component of solar home systems, enabling them to continue delivering electricity at night and on cloudy days. In the past five years, the range of batteries available has increased, along with their lifespan and storage capacity, and their capital cost has fallen. Continued innovation is needed to further reduce the cost of batteries and improve their performance and reliability[48].

However the greatest decline in the cost of solar-powered energy services is expected to come from innovation in energy-efficient appliances[49]. Though energy-efficient appliances are still more expensive than their power-hungry alternatives, they reduce the cost of a whole solar system because they allow more energy services to be powered by a smaller PV unit and battery. Energy-efficient televisions, fans and refrigerators are expected to be available soon at prices many off-grid families can afford **(Table 1)**.

TABLE 1: PRICES AND WATTAGE OF SUPER-EFFICIENT APPLIANCES ARE EXPECTED TO FALL SIGNIFICANTLY

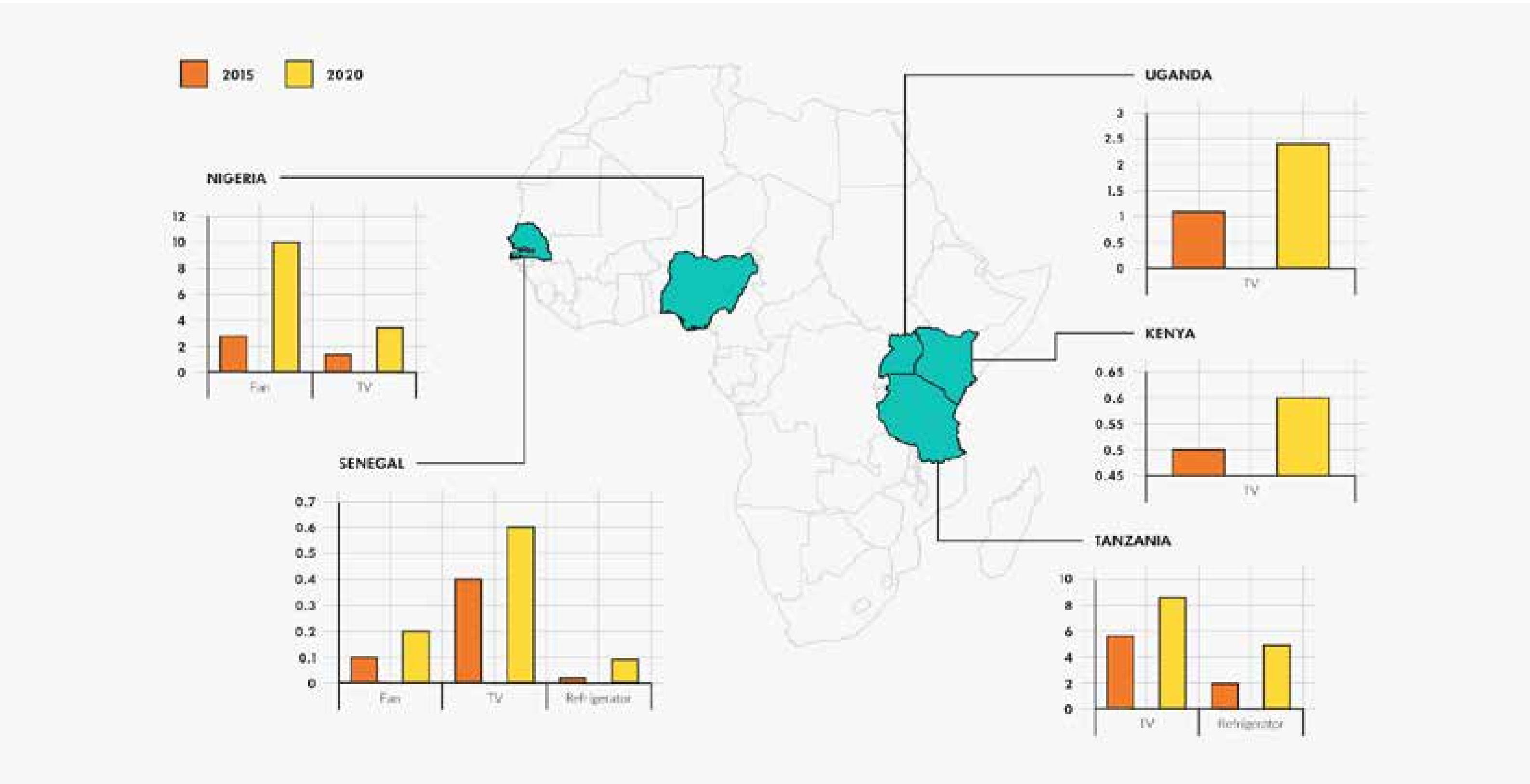
	TV (19")		Fan (12")		Refrigerator (50-80L)	
	2015	**2020**	**2015**	**2020**	**2015**	**2020**
Retail price	$104	~$85	$18	~$12	$300	~$200
Wattage	15W	8-10W	10W	8W	45W	35-40W

Source: Global LEAP (2016)

As the cost of energy-efficient appliances declines, the market for them is projected to grow rapidly **(Figure 12)**. Global LEAP[50] projects that 7 million off-grid families in the developing world will use solar-powered fans and 15 million will watch solar-powered televisions by 2020.

Energy-efficient refrigerators are currently too expensive for most off-grid families. To enable a viable off-grid market, refrigerators will need to cost less than US$200 and consume less than 40W of power – targets that Global LEAP predicts are obtainable by 2020[51].

FIGURE 12: THE GROWING MARKET FOR OFF-GRID APPLIANCES (MILLIONS OF HOUSEHOLDS)



Note: The market is represented by the estimated number of off-grid households and those living in areas where the national grid is unreliable in different African nations that are currently able to afford off-grid appliances and that are predicted to be able to afford them in 2020. Source: Global LEAP (2016)

Solar home systems face a series of market barriers beyond those of pico-solar products. Unlike lanterns, solar home systems require installation and servicing, and therefore a continued local presence. It is costly and time-consuming for providers of solar home systems to develop distribution networks and to train sales-agents and service-technicians.

Markets for solar home systems and energy-efficient appliances are also constrained by limited supply, with a large portion of current demand going unmet. Substantial investment will be required from both existing suppliers and new entrants to meet growing demand and to expand into new markets[52]. Providers of both solar lanterns and larger solar home systems suffer from a lack of working capital. However, financing constraints are a much greater challenge for solar home systems providers, given that solar home systems are much more capital-intensive. Swedish company Trine has shown that "impact investors" – who seek social and environmental benefits as well as return on investment – offer a promising source of finance for solar home systems providers and other small-scale solar solutions **(Box 2)**.

BOX 2: "IMPACT INVESTORS" BRING SOLAR ENERGY TO AFRICAN HOMES

One of the major barriers to uptake of solar home systems is the high upfront costs – not only for consumers but also for providers. The Swedish company Trine seeks to bring down that barrier. Using crowd-investing, the company helps people to support solar energy projects while also delivering a return on investment.

The foundation of Trine's approach is a digital platform that allows the company to target "impact investors". Such investors tend to be younger and driven by a desire to achieve positive social and environmental impact. For them, the return on investment is a bonus rather than the main motivation. Investment amounts typically range from €500 to €10,000. In time, as the approach matures, Trine intends to also approach more traditional investors.

Trine's first pilot project involved a mini-grid installation in Sidonge, Kenya. Since then, seven other projects have been fully funded, in Kenya, Senegal, Tanzania, Uganda and Zambia. A large pipeline of solar entrepreneurs in emerging markets is lined up for future consideration.

In addition, some pay-as-you-go models require the existence of mobile-money networks, which many African nations lack. Some argue that pay-as-you-go could help to open new markets for mobile money and thus widen people's access to banking services[53]. This is evidenced by Ignite Power's work in Sierra Leone, where the company built a mobile-payment platform that is independent from the mobile carrier and has universal reach. Once pay-as-you-go systems are in place, pay-as-you-go companies collect data on consumers' payment performance and this positions them well to help consumers progress up the energy ladder. With a credit history, pay-as-you-go clients could secure loans more easily for upgrades to larger solar home systems and new appliances (as well as non-electricity products).[54] Some investors see value in the consumer data itself, as it can aid retail financing and marketing. The value of such data highlights the need for pay-as-you-go companies to ensure that consumers' privacy and data are protected[55].

ADVANCING ACCESS BEYOND THE HOME

Powering community services

Energy access tends to be measured in terms of individuals and households. However, off-grid solar can deliver some of its most important benefits by powering community services, such as health clinics and schools, or by improving the productivity of farms and small enterprises.

Electricity access can tremendously improve community services such as education and healthcare. In many rural areas of Sub-Saharan Africa, the electricity needs of a primary school or a health clinic would be most economically supplied through solar power or solar-diesel hybrid generators[56,57].

All community services benefit when they have electric lighting, phones and computers[58]. Health facilities also benefit from specialist off-grid medical equipment. Experts anticipate that the most important off-grid appliances for healthcare will be: refrigerators for medicines, blood and vaccines; sterilization equipment; patient monitors to measure vital signs; portable ultrasound machines; oxygen concentrators; cautery machines; and infusion pumps to inject fluids, medication or nutrients into a patient's circulatory system.

A shocking number of community services in Africa lack electricity, despite its importance. An estimated[59] 65 per cent of primary schools in the region, educating 90 million pupils, lack electricity. In Burundi, the Democratic Republic of the Congo, Guinea and Togo, over 90 per cent of primary schools do not have electric lighting. Roughly one-third of health facilities in Sub-Saharan Africa, serving approximately 255 million people, also lack electricity[60]. In Tanzania and Uganda, this figure is more than half[61]. Every year, millions of women have to give birth by candlelight. Nearly half of all vaccine delivered to developing countries is wasted due to unreliable electricity supplies[62]. As the 2015 Africa Progress Report highlighted, in a region where around 105 million children have not been vaccinated, energy shortfalls can cost lives.

Powering farms and small enterprises

Across Africa, the majority of people are employed in agriculture and small service and manufacturing enterprises. Nearly 50 per cent of firms in the region identify inadequate access to electricity and poor quality of supply as serious constraints to production[63]. Owners of small businesses and farmers rank inadequate access to electricity as one of the greatest obstacles they face[64]. A Gallup poll surveyed 17 African countries; in 13 of them, over half of all respondents reported that their workplaces have no access to electricity at all **(Table 2)**. The figure ranged widely, from 12 per cent in South Africa to over 90 per cent in Burkina Faso, Mali and Niger[65].

TABLE 2: THE ENERGY DEFICIT IN THE WORKPLACE IS SIGNIFICANT

Workplace electricity access in selected African countries

	No electricity at place of work (%)	At least 1 day in the last 7, but with outages (%)	Always had electricy (%)
Median	**69**	**25**	**6**
Mali	92	5	3
Niger	92	7	1
Burkina Faso	91	9	1
Central African Republic	89	10	1
Sierra Leone	87	9	4
Liberia	77	14	10
Chad	72	27	1
Uganda	70	25	5
Ghana	69	21	10
Kenya	58	24	18
Cameroon	58	35	7
Tanzania	54	39	7
Zimbabwe	53	41	6
Senegal	48	41	11
Nigeria	41	59	0
Botswana	14	58	29
South Africa	12	29	59

Source: Tortora and Rheault (2012)

Solar power systems can help improve the earnings of these enterprises[66]. Like households, businesses that shift from fuel-based to solar lighting frequently save money. Improved lighting after dark also increases the time available for productive work and allows users to shift the timing of productive tasks[67].

Larger solar PV systems can also displace costly diesel generators and power appliances that enhance productivity. Electricity alone is not enough to drive productivity gains. However, when it is combined with new machinery, access to markets and the right training, the productivity of farms and small enterprises is likely to rise[68].

The larger PV systems can power a broader range of appliances that enhance productivity **(Table 3)**. Many pay-as-you-go companies sell solar power systems in the necessary range **(Figure 13)**.

TABLE 3: LARGER SOLAR POWER SYSTEMS ARE TRANSFORMING PRODUCTIVITY

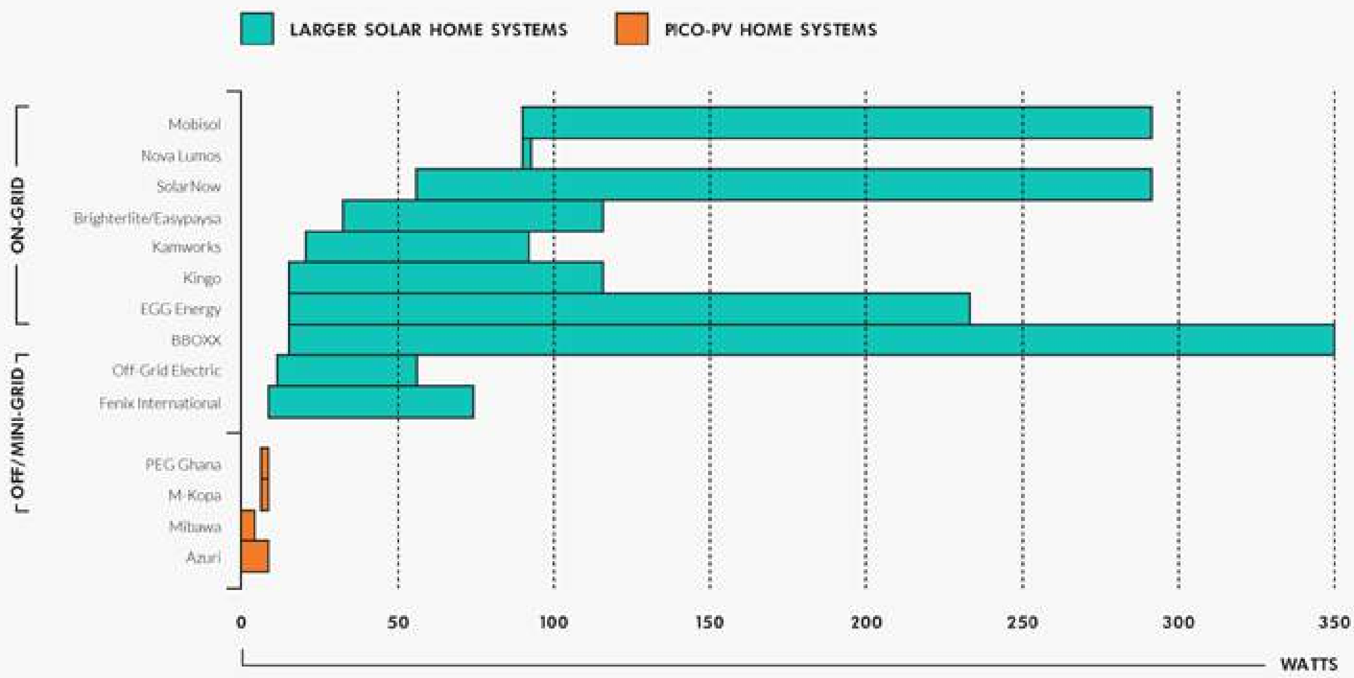
Energy-efficient off-grid machinery and appliances for productive use

Appliance	Solar panel	Estimated cost	Description of output
Egg incubator	40-120W (included)	$287-775	42-200 chicken eggs or 168-500 quail eggs
Milking machine	230W (included)	$798-1,083	10-25 cows per day
Solar electric fencer	Included	$71 -342	3-30 miles
Solar irrigation system	80W (included)	$405	Plots of 1 acre with access to surface water or a well of maximum 24 feet of head
Husker, sheller, grater, polisher	240W (2x120W)	$855-2,508	35-40kg per hour
Rice polisher	Included	$1,003	60kg per hour
Maize thresher	Included	$502	250kg per hour
Cassava grater	250W (included)	$1,756	100kg per hour
Freezer	75W (not included)	$701	165 litres capacity
Large refrigerator	180W (included)	$1,482 – $2,052	50 litres capacity
Portable charging station	30W (included)	$684	4 DC outlets, 2 AC outlets
Barber kit	20W (included)	$342	
Sewing machine	60W (not included)	$279	100 stitches per minute

Source: Tortora and Rheault (2012)

FIGURE 13: CONSUMERS CAN BUY SYSTEMS IN A WIDE RANGE OF SIZES

Energy-efficient off-grid machinery and appliances for productive use



Source: Orlandi, Tyabji and Chase (2016)

Medium-sized solar home systems can enable numerous rural services, such as hair salons, tailoring and movie screenings on television. Solar-powered phone-charging stations are increasingly common. In Tanzania, phone-charging businesses can earn US$100 a month, paying off a US$480 solar PV system in under five months[69].

Farmers can improve productivity through solar-powered egg incubators, milking machines, electric fences for rotational grazing, and water pumps for livestock and irrigation. Irrigation lengthens growing seasons, reduces risk and, in general, doubles agricultural yields. Yet in Sub-Saharan Africa, only 4 per cent of cropland is thought to be under irrigation. Given their high capital costs, solar irrigation systems remain out of reach for most smallholder farmers[70]. However, costs are declining. The World Bank recently reported that smaller solar irrigation pumps are now more cost-effective than diesel-powered ones in India[71].

Larger systems can power basic woodworking and construction equipment[72]. Although energy-efficient appliances for productive uses are becoming more widely available and increasingly cost-effective, supplies are still severely limited, as with residential appliances[73]. Further investment will be required to meet demand and build supply-chains in new markets. Further innovation will also be required, both to drive down costs and to diversify the lines of energy-efficient off-grid appliances on offer[74].

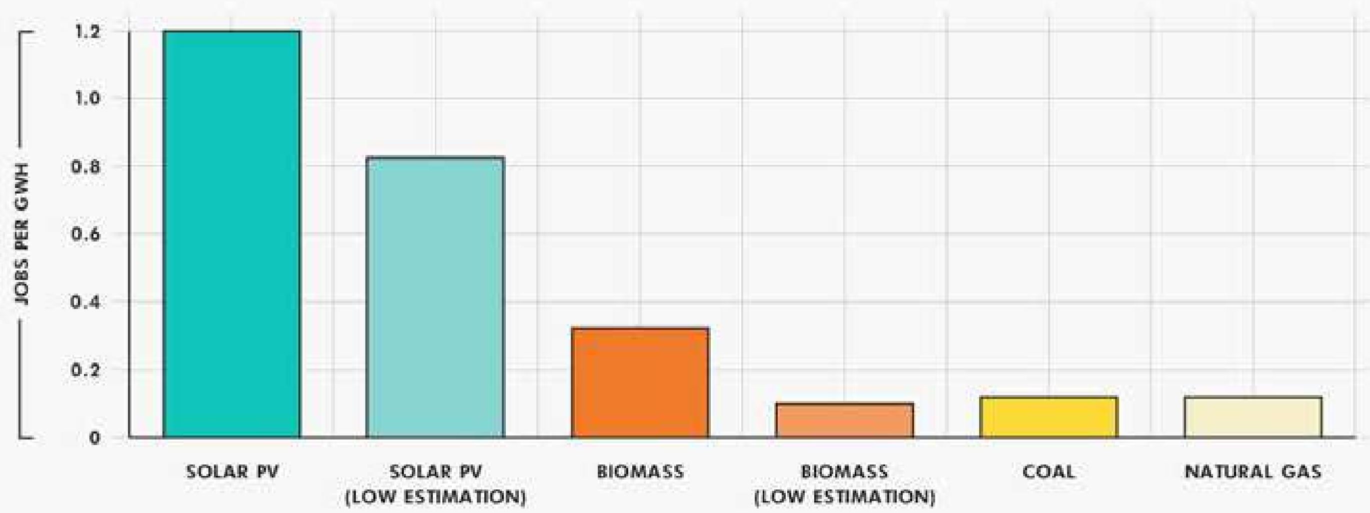
The capital costs of energy-efficient appliances remain beyond the reach of many small enterprises and farmers. Where they can afford them, consumers often do not trust the new technologies, are unaware of their existence, or do not have experience in operating and maintaining them. Training, information campaigns and consumer finance – through banks, microfinance institutions or pay-as-you-go models – are vital to ensure that productivity-enhancing off-grid appliances become mass-market goods[75].

Africa's off-grid solar industry can create many jobs

Africa's solar industry employs a growing number of sales representatives, technicians and managers. Solar PV creates significantly more jobs than fossil fuels or biomass, relative to total energy produced[76] **(Figure 14)**.

FIGURE 14: THE POTENTIAL SOLAR JOB BOOM

Estimated jobs created per GWh



Source: Practical Action (2014)

In 2013, 15,000 people in Sub-Saharan Africa were already employed in the off-grid electric lighting sector[77]. However, employment was highly concentrated in a few countries, such as Kenya, and focused on the sales and distribution end of the value chain[78]. Solar manufacturers have sprung up in several countries, including Ghana, Kenya, Mozambique, Nigeria and South Africa[79] but most solar products continue to be imported. Energy-efficient appliances are also generally imported, except for a few small-scale initiatives, including a partnership between electronics firm LG and charity World Vision Kenya to manufacture and donate 20 solar refrigerators for vaccines and food storage[80]. To reduce import duties, some companies import solar products and appliances as individual components and assemble them in-country.

Further employment gains could come from increased domestic manufacturing of solar-power systems and of energy-efficient appliances such as televisions, refrigerators and fans. Lower labour costs and reduced transport costs would offer African manufacturers a competitive advantage. The Africa Progress Panel[81] found that Bangladesh's solar boom, from 25,000 to 3.5 million systems in 10 years, created 114,000 home-grown jobs in assembly of solar panels.

The overall employment potential of Africa's off-grid solar industry is large. Throughout the value chain, alternative technologies produce roughly 30 jobs per 10,000 people living off-grid, according to an estimate by the United Nations Environment Programme (UNEP). Full market penetration of these technologies in Sub-Saharan Africa could lead to 1.8 million jobs.

PART II: MINI-GRIDS – SERVING "THE MISSING MIDDLE"

Conventionally, extending the national electricity grid has been seen as the way to provide access. Other options have been regarded as inadequate or interim measures[82]. However, there are several reasons why relying on the grid to provide access is not always the best approach. The rate of grid-based electrification is slow, off-grid options are cheaper in rural and remote areas, and off-grid technology is advancing rapidly.

Off-grid solar household systems and mini-grids can be used to provide energy services across the full range of levels of access, reflecting different households' needs and incomes **(Figure 15)**.

FIGURE 15: TIERS - OFF-GRID SYSTEMS MEET MANY LEVELS OF ENERGY NEED

	TIER ○	TIER ●	TIER ●●	TIER ●●●	TIER ●●●●	TIER ●●●●●
ENERGY SERVICES		Task lighting and phone charging	General lighting, television and fan	Tier 2 and any medium-powered appliances	Tier 3 and any high-powered appliances	Tier 4 and any very high-powered appliances
CAPACITY		Up to 12 Wh	Up to 200 Wh	Up to 1 kWh	Up to 3.4 kWh	Up to 8.2 kWh
SOLAR PRODUCT	LIGHT ONLY	LIGHT ONLY / LIGHT & CHARGER	SMALL SHS	LARGE SHS	LARGE SHS	LARGE SHS
MINI GRID			MINI GRIDS	MINI GRIDS	MINI GRIDS	MINI GRIDS

Many efforts to bring power to Africans who do not have sufficient access are focused on large-scale grid-power development projects and small off-grid solutions, leaving a sizable "missing middle" in the dark. While rural electrification constitutes a top priority for most African governments, little has been done to try to meet the power needs of the missing middle.

Mini-grids – which can be grid-connected or independent – lie in the middle, between off-grid systems and grid connections. They comprise an electricity generator and a distribution network that supplies several users, such as households and businesses. The International Energy Agency (IEA) estimates[83] that 140 million people in Africa will gain access to electricity through mini-grids. This would require the installation of 4,000 to 8,000 mini-grids a year for the next 25 years, a number that far exceeds all current estimates of mini-grid investments in Africa[84]. While initiatives to promote off-grid household systems and investment in centralized grids have taken off, the promotion of mini-grids appears to lag.

Mini-grids offer a number of advantages over grid extension and off-grid household systems. They allow flexibility in design and scale, as well as in business or operational model. They can provide electricity in rural and remote areas, where populations are dispersed and per capita electricity consumption is low, at much lower cost than grid extension[85]. In terms of tiers of access, mini-grids can provide up to tiers 4 and 5 **(Figure 15)**, though most[86] deliver tiers 2 and 3. They require smaller capital investment than grid expansion, making it easier to secure finance. Mini-grids can provide electricity in remote areas for productive uses such as farm machinery, which usually require more power than an off-grid household system can provide. They also allow economies of scale to be exploited where houses, businesses and public services in remote areas are physically close to one another.

Despite these advantages, mini-grids are expanding in Africa at a slower rate than in other regions and more slowly than off-grid household systems. There are several reasons for this limited progress. Proven commercial business models are lacking, as are adequate and appropriate forms of financing and implementation capacity[87]. In addition, policy frameworks for mini-grids are inadequate and uncertain, and many developers and operators lack the requisite experience and knowledge of mini-grids[88].

> **MINI-GRIDS OFFER A NUMBER OF ADVANTAGES OVER GRID EXTENSION AND OFF-GRID HOUSEHOLD SYSTEMS.**

On the positive side, the context is rapidly changing for both solar household systems and mini-grids. Opportunities are increasing because policymakers are paying greater attention to electricity access and because more funding is available from development finance institutions and donors. Off-grid electricity is becoming more attractive worldwide because of falling costs of renewable-energy options, more efficient technologies for generation and electrical appliances, and innovations in the use of digital technology for the management of electricity services. Africa has the potential to be at the forefront of this off-grid electricity transformation.

There is no universally accepted definition of a mini-grid, except that it is a system that combines generation capacity and a distribution network. Sustainable Energy for All (SE4All) uses a definition that embraces a variety of systems or models, mainly to distinguish them from stand-alone household systems and extensions of the main grid. This definition includes mini-grids that are unconnected to the main grid (i.e. off-grid) and systems that are connected but able to operate independently. In the current report, mini-grids that are unconnected to the main grid are called isolated mini-grids[89].

The range and variety of mini-grids have given rise to a number of different categorizations, usually based on the capacity of the system. For example, the International Renewable Energy Agency (IRENA) has proposed[90] that they be called pico-, nano-, micro- and mini-grids according to capacity (under 1kW, under 5kW, under 100kW and under 100MW, respectively). The UK Department for International Development (DFID)[91] has suggested the following categorization, combining criteria on capacity and whether they are isolated or connected to the national grid:

Grid-connect/proximate – (> 1MW)
Isolated – (100kW – 1MW)
Very small isolated (micro) – (< 100kW)

The great majority of mini-grids in Africa fall in the capacity range between a few kilowatts and 10-15MW; some are isolated, some are connected to the main grid.

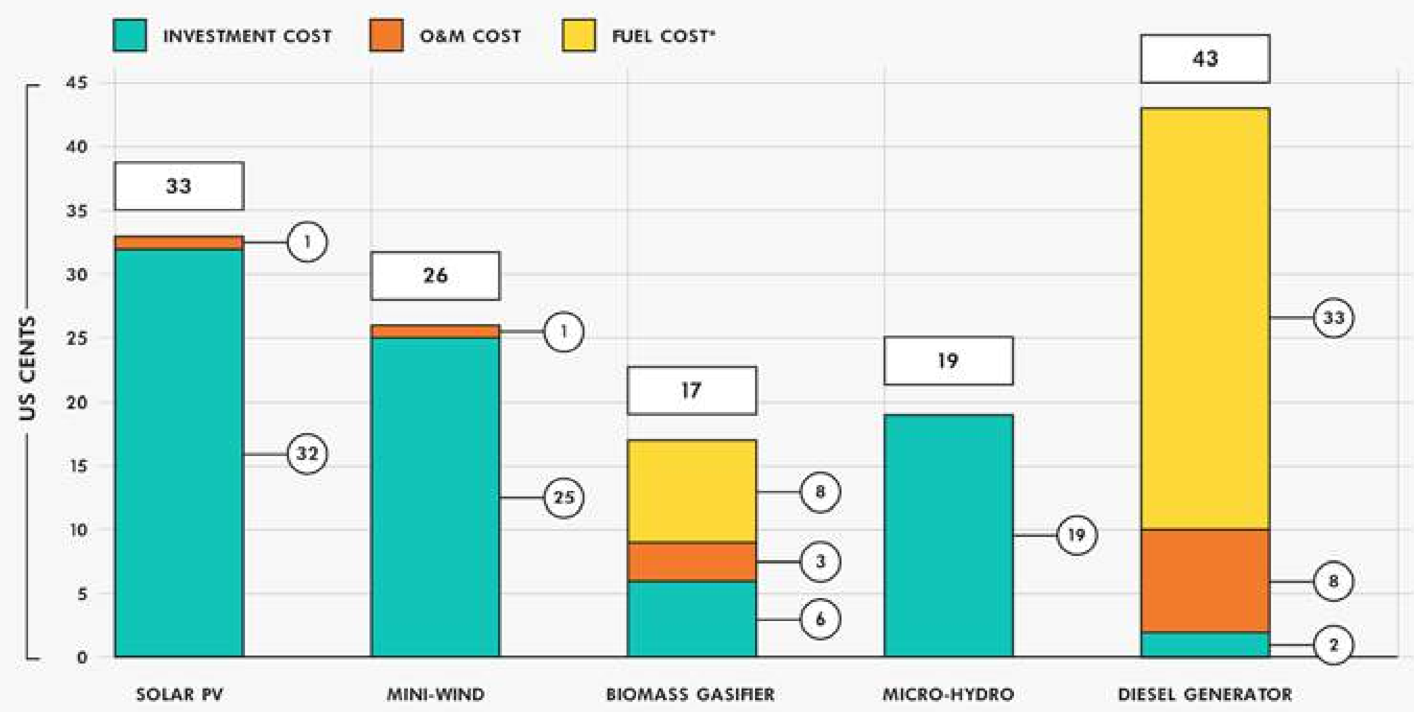
Around 5 million households worldwide are supplied by mini-grids using renewable energy sources[92]. The installed capacity of mini-grids globally includes 75GW of hydropower, 23GW of diesel generators and several thousand solar-powered systems.

Mini-grids have been installed in almost every African country, although detailed information is often unavailable, including whether the programmes are still operating. In some countries, including Mali, Senegal and Tanzania, mini-grids are already an established part of the delivery of electricity services and integral to efforts to extend access to electricity. The total installed capacity of mini-grids in Africa is currently around 1.2GW, or 0.7 per cent of the continent's on-grid installed capacity in 2012[93].

Existing mini-grids in Africa are mostly diesel or hydropower systems, though the number of solar PV and hybrid systems is growing. The International Energy Agency has estimated that almost one-third of the mini-grids needed to provide off-grid access to electricity in Africa will be diesel or petrol-fuelled systems, with the other two-thirds relying on renewable energy sources. Solar PV mini-grids will grow rapidly and will have the largest share (37 per cent) by 2040, followed by hydropower (20 per cent), wind (8 per cent) and bioenergy (3 per cent)[94].

Mini-grids that use diesel or petrol generators have the advantage of low capital costs. This makes them an attractive option where incomes are low and the cost of finance is high. They have the added advantage that the technology is widespread, making repairs and maintenance easier. Diesel generators, however, depend on a regular supply of fuel, which can be interrupted in remote areas and is subject to price fluctuation. Fuel accounts for most of the cost of electricity from diesel generators **(Figure 16)**.

FIGURE 16: GLOBAL COST OF ELECTRICITY GENERATED BY MINI-GRID SYSTEMS



Source: Clean Energy Ministerial (2014)

Note: * Dependent upon the price of diesel

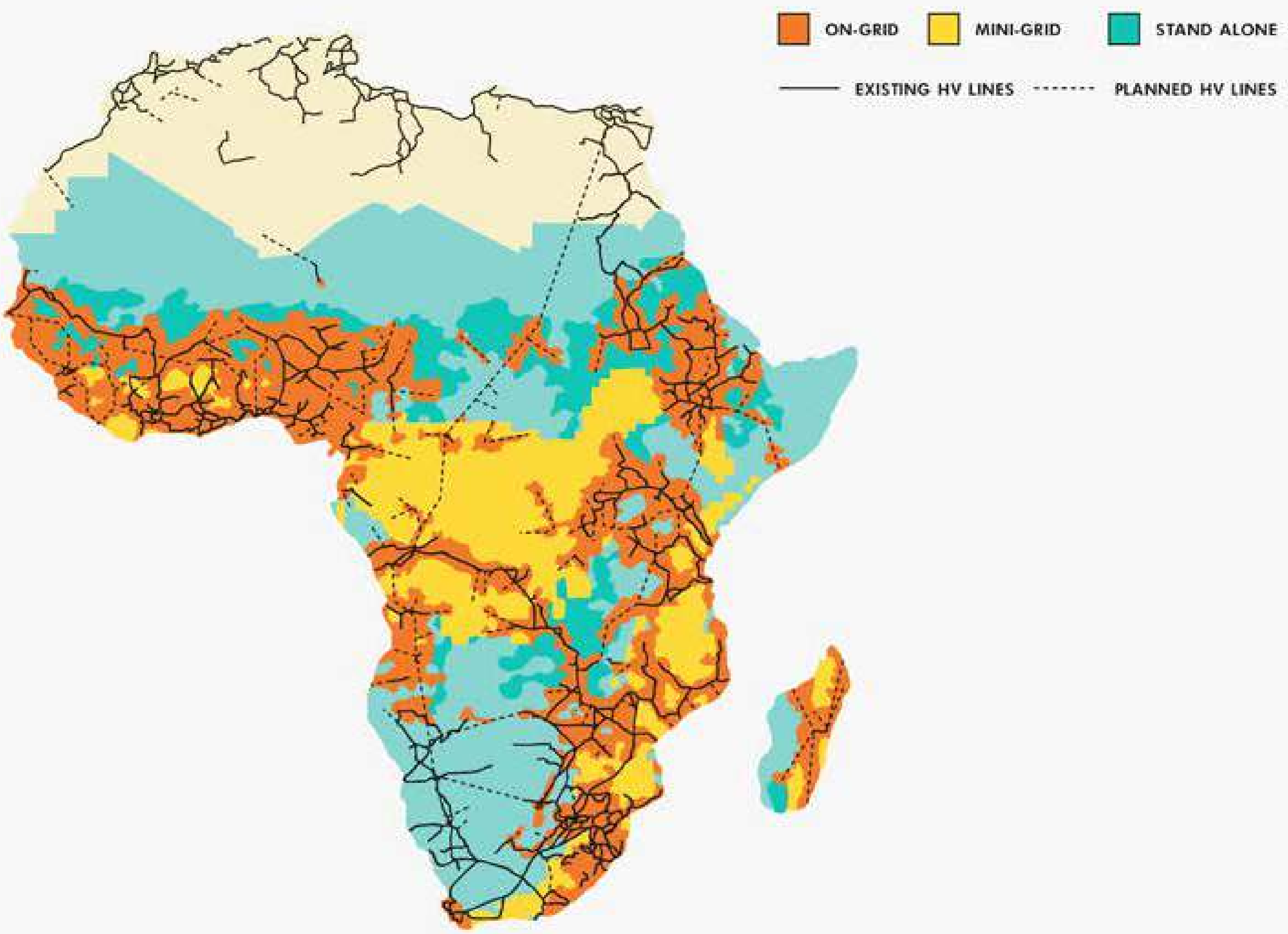
Figure 16 also shows that, on average, renewable energy mini-grids produce electricity at: US$0.19-0.33 per kilowatt-hour (kWh) which is lower cost than diesel systems which produce at US$0.43/kWh (depending on the price of diesel). The cost of electricity supplied by renewable-energy mini-grids is determined by the initial investment cost, with the exception of biomass-fuelled systems. The higher investment cost and longer payback period presents a challenge for the financing of renewable energy systems (see below).

Though most renewable energy mini-grids do not face the risk of interrupted fuel supply or fuel-cost increases, their effective generation capacity may vary according to weather and season. Electricity storage, in batteries, is one way to overcome this variability, particularly for solar and wind systems. Another way is to combine different sources of energy in "hybrid" schemes, commonly solar or wind combined with diesel; hybrid solar-wind and solar-biomass systems can also be found. Hybrid renewable-diesel systems are more economic than diesel only[95,96].

The potential of isolated mini-grids to increase access to electricity has been assessed in several modelling studies, based largely on cost comparisons[97]. The most recent of these is the model developed by the United Nations Department of Economic and Social Affairs[98], which provides a graphic description of where mini-grids (or grid extension, or stand-alone systems) are likely to be the least-cost electrification option under different sets of assumptions **(Figure 17)**.

FIGURE 17: THE MINI-GRID POTENTIAL

Areas best suited to grid, mini-grid and stand-alone systems, Sub-Saharan Africa



Source: UNDESA (2016)

MINI-GRID MODELS

Four kinds of model for the operation of mini-grids are usually distinguished: utility, private, community and public-private. Each has its own advantages and disadvantages **(Table 4)**.

Utility model

In the utility model, a large or medium-sized state-owned or private utility company is responsible for the installation and operation of mini-grids[99]. The utility operates the mini-grid in the same way as the main grid, generating electricity and distributing it to consumers. When the tariffs for consumers are the same as on the main grid, the utility cross-subsidizes the tariff for those connected to the mini-grid (because the unit cost of electricity from mini-grids is higher). The mini-grid investment is likely to be financed by the government, as utilities tend to operate mini-grids only at government instigation and not to regard them as core business or an important source of revenue.

The Tsumkwe mini-grid in Namibia is an example of a utility model mini-grid. This PV-diesel hybrid mini-grid, with a capacity of 202kW, supplies power to 3,000 residents of the Tsumkwe settlement area, as well as 35 commercial and public-service customers. The mini-grid was financed by public and donor finance, and is owned by the regional government, Otjozondjupa Regional Council, and operated on their behalf by the Ministry of Public Works. The regional government manages revenue collection and finances fuel purchases[100].

Private model

In the private model, a private company develops, installs and operates the mini-grid, generating electricity and selling it to connected customers[101]. This is distinguished from the utility model because the company tends to be small or medium-sized and does not also operate the main grid. Finance for the investment may come from a variety of sources, including grants, commercial or concessional loans, and equity. Most privately operated mini-grids have received some form of public support, but purely private mini-grids do exist, such as those operated by American company Powerhive and German company Inensus[102].

Powerhive has been granted a concession to generate and distribute electricity in Kisii and Nyamira, Kenya. The company currently operates four solar PV mini-grids, supplying over 1,500 customers in Kenya. These mini-grids use information technologies to manage the mini-grid management and collect payments. The company used project finance for the first mini-grids, and has recently secured US$11 million in equity finance and US$20 million in venture-capital finance to extend its electricity services to 90,000 people[103].

Community model

When the community served by a mini-grid owns and operates it, the design and installation has often been done by a third party, contracted by the community or on its behalf by an non-governmental organization (NGO) or development agency. Rural communities rarely have the expertise to plan and build mini-grids themselves. The investment finance is generally from grants, supplemented by a cash or in-kind contribution from the community. The operation of a community mini-grid, including revenue collection, is usually managed directly by a village committee formed for this purpose or by a cooperative, but in some cases is contracted to an entrepreneur[104].

Four hydropower mini-grids in Kenya, at Thima, Kathamba, Tungu Kabiri and Kipini, illustrate the community model. In each case the community is responsible for the operation and maintenance of the system, from generation to transmission and revenue collection. The community schemes have elected management committees for this purpose. Kathamba, Thima and Kipini supply mainly households (55, 115 and 120 households, respectively)[105], while Tungu Kabiri serves small businesses.

Community-owned mini-grids are generally initiated by the communities themselves. The initial capital is usually raised through contributions from community members interested in the project. In the case of Tungu Kabiri, 200 members of the community each bought a US$50 share in the company specially formed to own and operate the plant. The schemes also received donor support, in the form of technical support (Kathamba and Tungu Kabiri), equipment (Kipini) and applications for grant funding (Kipini and Tungu Kabiri).

Inadequate power supply has been a challenge for these community-owned mini-grids. This has been managed partly by limiting the hours of service and by varying tariffs for different levels of consumption. The community schemes in Kenya, however, demonstrate that communities can organize themselves to build and operate mini-grids and that they are willing to invest their own time and money to ensure a supply of electricity.

Public-private model

The public-private model can exploit the advantages of the other models and minimize their risks by dividing ownership and operation of a mini-grid among different public and private organizations (as is increasingly being done with national power systems). For instance, generation might be the responsibility of a private company, under a concession from the utility, and distribution of the electricity might be the responsibility of a community organization, which contracts a private business to provide technical support. There are numerous variations of the public-private model, but all require contractual arrangements between the different organizations involved.

Senegal, for example, has boosted rural electrification through a model in which the government retains ownership of the mini-grid and a private company is awarded a 15-year concession to operate and maintain it. This approach, under the Renewable Energy for Senegal (ERSEN) Off-grid Solar Energy Programme, has been followed for 18 mini-grids powered by solar PV and diesel generators. These supply electricity to over 38,000 households, 88 schools and 88 clinics, as well as businesses and public buildings[106].

The Dutch-German Partnership Energising Development (EnDev) and the European Union have provided 80 per cent of the investment cost, with 10 per cent coming from the private operators and 10 per cent from the communities served. Tariffs, which cover operation and maintenance costs, are negotiated by the private operator and vary among schemes. Community involvement has been organized through representative project-management committees in each location.

TABLE 4: ADVANTAGES AND DISADVANTAGES OF MINI-GRID MODELS

	Advantages	Disadvantages
Utility model	• Utilities have experience in electricity generation and distribution, as well as administrative processes • Utilities are likely to have access to policymakers and public and donor funds, and require little additional regulation • Implementation of uniform tariffs across the electricity sector is straightforward • The model enables economies of scale for spare parts and maintenance	• Utilities lack incentives for a decentralized approach and may not give priority to mini-grids in rural areas • Power utilities are often inefficient, financially precarious and subject to political interference and corruption • Utilities may not have capacity for the complexity of planning, implementing and operating multiple mini grids • Utilities may be unresponsive to local circumstances and unable to innovate • The model may only be able to attract public finance
Private model	• Companies may have good technical competence, ability to manage risks and capacity to offer efficient operation and management • There is an incentive to pursue financial sustainability when driven by market dynamics rather than government subsidies • Private companies can better quantify project benefits (and costs) and thus improve pricing and tariff collection • Decentralized implementation and management reduces risk and administrative capacity requirements • Companies can attract private investment and make efficient use of limited capital	• Upfront financial support may be required to ensure that mini-grids are financially attractive • The African private sector lacks experience and technical capacity • Tariffs are needed to cover costs • Companies need to manage relations with communities served • The model requires a stable policy and regulatory framework that is well defined and supportive
Community model	• The model enables community buy-in and increases ownership among electricity consumers, which can improve operation and maintenance • There is a higher chance that the system is appropriate to the community's circumstances and priorities • The model supports community self-sufficiency and empowers local people • Management can be pragmatic and more efficient than large, distant, bureaucratic utilities	• Communities may lack the necessary technical and business skills • Local governance of mini-grids needs to be clear and well managed • Community decision-making can slow implementation and be affected by conflicting social interests
Public-private model	• The model combines the advantages of the other models and may mitigate their challenges and increase opportunities for mini-grids • Responsibilities can be configured to maximize advantages (e.g. if the utility is the distributor, uniform tariffs across the sector can be more easily applied; if the private sector is involved, private investment may be facilitated)	• Differences in the management systems of each entity can increase transaction costs • A strong framework is required to balance the interests of different actors and establish the interface between them

Sources: GVEP (2011b), Seguin (2014), RECP (2013)

Mini-grids in Africa are generally conceived as a means to supply electricity in areas remote from the main grid. The models described above all apply to such isolated mini-grids. In practice, mini-grids may be connected to the national grid from the start of their operation or later. Taking this option into account, four kinds of scheme can be distinguished:

- Isolated small power producer selling directly to retail customers (this is the conventional mini-grid)
- Small power producer connected to the national grid, selling directly to local retail customers and selling surplus power to the grid (or drawing power from it)
- Small power producer connected to the national grid and selling wholesale to the utility or electricity wholesaler (i.e. the conventional independent power producer, IPP)
- Small power distributor, purchasing electricity from the grid and retailing it to localized customers.

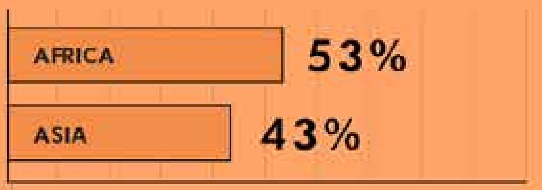
Given the challenges facing the power sector in most African countries, all of these models could be considered in the development of electricity systems. By allowing diversity in the way electricity is generated and distributed, African countries could leapfrog to a new model for the sector, as argued by Jim Rogers, the former chief executive of Duke Energy, one of the world's largest utility companies. The new model "is one in which power is no longer solely delivered through a complex and expensive grid of base load generation and fixed wires, but through a mix of renewable technologies that are more affordable, smaller and decentralized"[107].

Mini-grid experience in Asia and North America offers African governments and their partners some valuable lessons, notably about finance, regulations and innovation **(Box 3)**. **(See infographic: Mini-Grids: Africa versus Asia)**

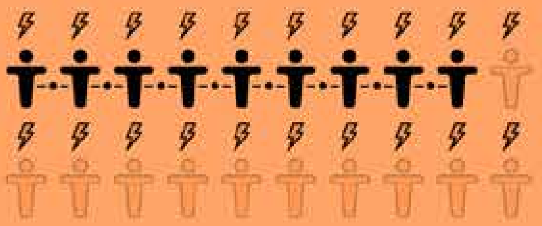
MINI-GRIDS: AFRICA VERSUS ASIA

OVERVIEW

1.2 billion people (17% of the global population) live without electricity. The vast majority are in Sub-Saharan Africa (53%) and the Asia-Pacific region (43%).



315 million Africans in rural areas will gain access to electricity by 2040, 45% of them from mini-grid systems



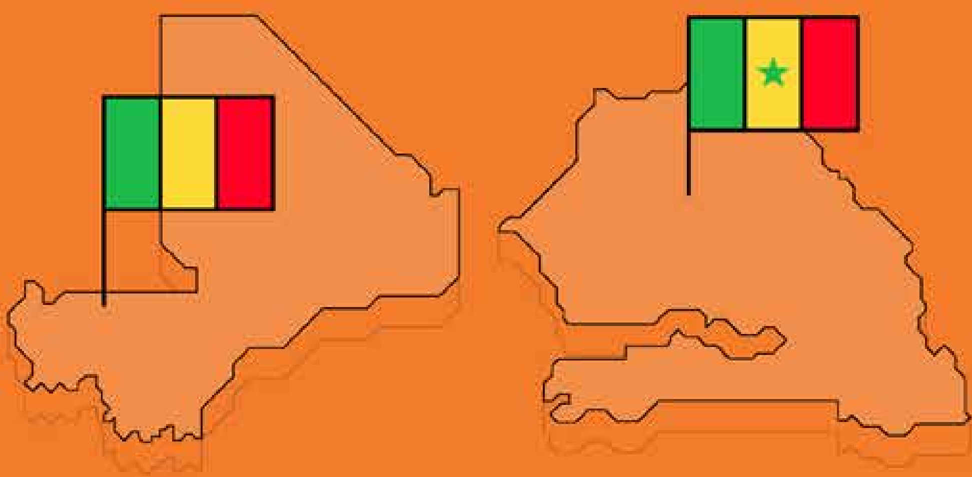
HYBRID SYSTEMS

Small-scale hydropower is the largest source of electricity generation for mini-grids in countries such as Nepal, with diesel coming in second.

Many small islands, for example in Indonesia, the Philippines and China, rely on diesel generation for electricity. Mali uses diesel more than any other African country, with 200 mostly small mini-grids in operation.

These diesel-powered mini-grids are undergoing hybridization to integrate renewables.

↓ SUCCESS STORIES: AFRICA



MOROCCO

Morocco is an African leader in electrification using village-scale mini-grids. By 2010, 3,663 villages had been electrified with solar energy.

MALI

Access to electricity in Mali's rural areas jumped from 1% in 2006 to 17% in 2012. Mali has the largest number of solar **PV/diesel hybrid mini-grids** in Africa.

SENEGAL

Senegal has installed 35 hybrid mini-grids (solar PV and diesel) and plans 41 more. It is one of Africa's most active proponents of **hybrid mini-grids.**

↓ SUCCESS STORIES: ASIA

INDONESIA

In 2015, more than 600 micro-hydro plants were providing off-grid electricity to rural areas of Indonesia.

INDIA

In early 2016, the state of Uttar Pradesh offered incentives for mini-grids. By the end of 2016, 500 solar mini-grids were to be installed.

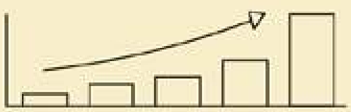
NEPAL

In Nepal, around 1,300 micro-hydro plants and 1,600 pico-hydro systems were in operation in 2015.

TYPES OF TECHNOLOGY USED IN MINI-GRIDS IN BOTH AFRICA AND ASIA: SOLAR, HYDRO, BATTERY, DIESEL, BIOGAS

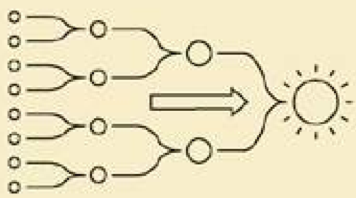
SUCCESS FACTORS

HOW TO PROMOTE MINI-GRIDS

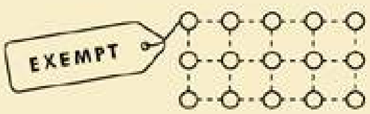


Foster a stable, long-term policy environment to boost investors' confidence.

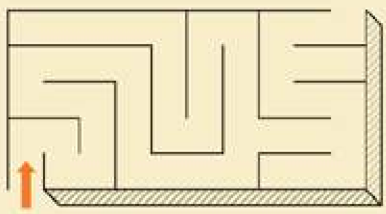
Set clear guidelines, requirements and tariffs through robust, transparent policies and regulations.



Make it easy for mini-grid developers to obtain permits, finance and other necessities.



Exempt very small mini-grids from some regulations.



CHALLENGES FACING MINI-GRID DEVELOPMENT

- Many mini-grids have so far relied on subsidies, which may not continue.
- Higher tariffs
- Lack of a clear framework for mini-grid policies and plans.
- Delays and bureaucracy
- Lack of business focus
- Limited private sector involvement

BOX 3: AFRICA CAN LEARN FROM MINI-GRID EXPERIENCE IN ASIA AND AMERICA

In 2015, North America and Asia had the two largest shares of the world's installed micro-grid capacity, and over half of that (54 per cent) was off-grid[108]. Africa and the Middle East together accounted for only 1 per cent of the market.

Asia: Favourable policy and regulation is vital

Rural electrification in Asia has been pursued mainly through grid extension, as in Africa[109]. Where this approach is too expensive, off-grid electricity systems have been promoted, in some places for more than three decades [110]. Most of these mini-grids are based on either solar PV or micro-hydropower. Diesel systems are also found, notably in the Philippines[111].

Most mini-grids in Asia provide limited electricity services for household use, and are difficult to establish and sustain. To be successful, models need to combine public and private finance, and aggregate investments at a scale that reduces the transaction costs and operation and maintenance (O&M) costs for each scheme. Mini-grid programmes should be able to adapt to a variety of environmental and social contexts.

In South Asia, mini-grids have mainly followed a community model and been financed by grants[112]. But many community mini-grid projects in South Asia have struggled to become financially viable. They have been more successful when they have promoted productive uses of the electricity and enabled consumers to purchase appliances.

A review of seven micro-grids (six in Asia and one in Haiti) identified seven key considerations for mini-grid development: tariff design, tariff-collection mechanisms, maintenance and contractor performance, theft management, demand growth, load limits, and local training and institutionalization[113]. Experience in Asia also shows that all mini-grid models require favourable government policy and regulations, including capital subsidies, in order to be viable.

One key question for developers is what will happen if the main grid is extended to a mini-grid location. The publication of grid-extension plans and a clear policy for the future of mini-grids when the main grid arrives would help reduce the risk of uncertainty for investors.

Tariff regulations are another area of concern for mini-grid developers. Mini-grid programmes that rely on revenue from consumers to cover costs (capital and operating and maintenance costs) need tariffs that reflect these costs. If regulations do not allow these tariffs there should be subsidies for the producers or the consumers.

North America: Resilience, renewables and innovation

The first electricity-generation and distribution systems in the United States, introduced in the 1880s, were mini-grids; these were interconnected later. In recent years, there has been a return to such systems, now usually called micro-grids. Most have a capacity of 1MW or less. They are usually connected to the main grid, but can operate separately when necessary. Aggregate installed capacity is expected to exceed 1.8GW by the end of 2017[114] and 2.8GW by 2020[115].

One reason for this return to small networks is the need to increase the resilience of the electricity supply. On an extensive main grid supplied by large generation plants, power cuts can affect a very large number of businesses and households[116] and it can be difficult to restore services quickly. Micro-grids can continue to supply consumers when the main grid suffers interruptions.

Micro-grid investment has also increased because there is greater interest in exploiting renewable energy resources for lower-cost distributed generation. In 2014, 90 per cent of micro-grid installed capacity was based on fossil fuels. By 2020, the share of renewables is expected to reach 26 per cent[117].

Growth in micro-grid investment has been facilitated by public finance, directly in the form of grants and indirectly through tax breaks[118]. This has enabled innovation in the use of digital technologies to manage generation and distribution.

Recent experience of mini-grids in the United States offers two lessons for Africa. First, early adoption of technical innovations, particularly of digital management tools (for generation, distribution and revenue collection), could enable mini-grid business models to be more efficient and financially viable. Second, new technologies and approaches are introducing new organizational models for electricity systems that may prove more efficient and resilient than the conventional utility-based approach.

ACCELERATING MINI-GRID DEVELOPMENT

System management

Managing demand

In all African countries, the power sector faces the challenge of reliably balancing electricity supply with demand; failure leads to power crises, as Nigeria and Ghana are experiencing. In most countries there is both unmet demand and rapidly growing demand from existing consumers. Mini-grid operators need to be able to match the supply of electricity with demand during the day, as consumers vary their consumption. They also need enough overall demand to ensure that the system is financially viable. In addition, renewable energy mini-grids need to manage generation from solar PV, wind and hydropower, which varies with the weather or the season.

Operators can manage demand in several ways. They can promote energy-efficient appliances and lighting, such as light-emitting diode lamps (LEDs); they can restrict the use of electricity by individual consumers; and, where regulations permit, they can vary the tariff. Technologies such as electricity storage (batteries), current limiters, load controllers and meters can help to manage demand.

Recent innovations with digital technologies, similar to those used in micro-grids in the United States, are also being tried in Africa, increasing the spread of "smart micro-grids". Smart meters offer the potential to measure consumption, facilitate payments and automatically manage a mini-grid's overall load.

In Kenya, for example, the automatic system deployed by Powerhive at Kisii includes distributed meters that use wireless communication to transmit electricity-consumption data and customers' credit balances (on prepaid accounts) to the company[119]. The SharedSolar systems installed in Millennium Villages in Mali and Uganda also combine prepaid metering with central monitoring and control, with up to 10 households connected to each meter. Customers have a daily consumption limit and a maximum power limit, and purchase credit by SMS message[120].

When most of a mini-grid's customers are households, electricity consumption reaches a peak in the evening when people have stopped work for the day. This means that for a large part of the day the mini-grid's installed capacity is under-utilized and the unit cost of electricity consumed is higher. The load factor – the proportion of electricity generated that is consumed – can affect the viability of a mini-grid. Many schemes are designed with an "anchor load", such as a school, health centre, commercial business, manufacturing enterprise or mobile-phone mast that can consume a significant and stable proportion of the power generated. In the planning and design of mini-grids, the capacity of the scheme also needs to take account of expected increases in demand (load factor) over the life of the plant.

Tariffs and revenue collection

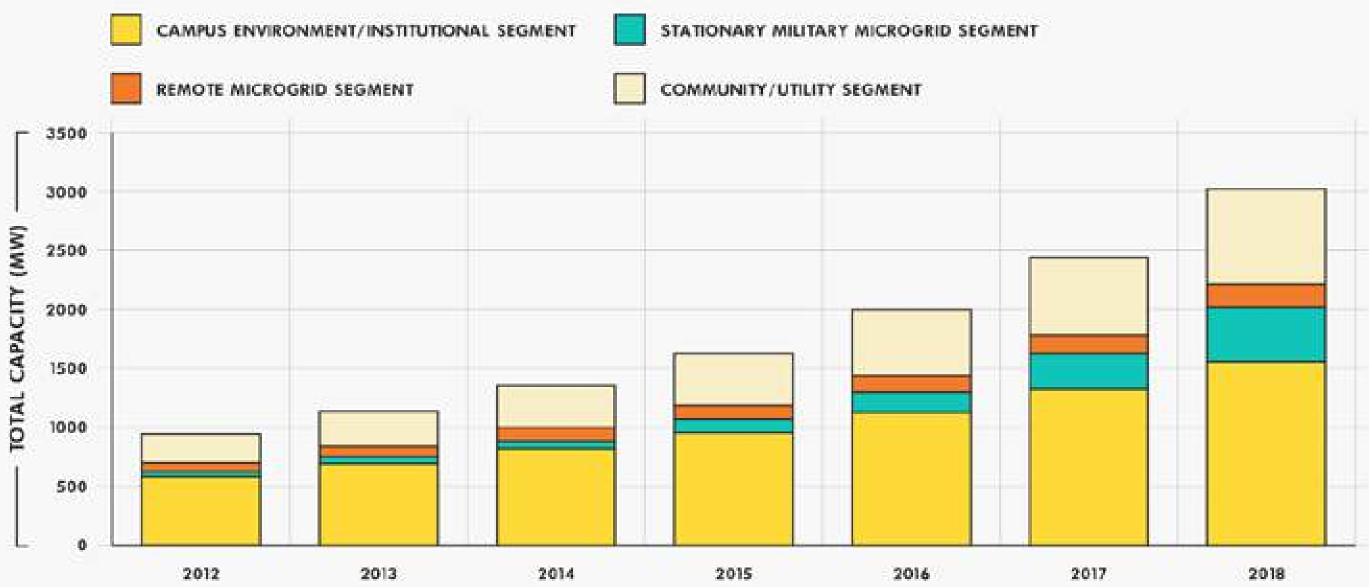
The financial viability of mini-grids depends on their ability to collect enough revenue to cover at least their operating and maintenance costs. A grant or subsidy may provide the initial capital for utility and community-operated schemes, so that they only need to cover operating and maintenance costs. By comparison, private, commercial schemes may also need to recover financing costs and to ensure a profit for the equity-holders.

Mini-grids that provide an alternative to grid extension are likely to be located in rural and remote areas where population density and per capita incomes are low, reducing the prospects for collecting revenue. This disincentive for commercial investment in mini-grids can be mitigated by an anchor load, but often public finance will be necessary for the initial investment.

In addition, although the total cost of extending the grid to a particular location may be higher than the cost of installing a mini-grid there, the unit cost of electricity (e.g. in dollars per kilowatt hour) on the main grid is usually lower **(Figure 18)**. This indicates that the consumer tariff on the mini-grid should be higher than the tariff on the main grid, if tariffs are to cover costs. Government regulations, however, may determine what can be charged (see below).

FIGURE 18: THE COST OF ELECTRICITY IS LOWER ON-GRID THAN OFF-GRID

Levelized costs of on-grid and off-grid electricity in Sub-Saharan Africa, 2012



Source: IEA (2014)

Tariffs do not necessarily have to be based on units of electricity (kWh). In some cases, the tariff is based on the power consumption (in Watts) of consumers, setting a monthly charge and a maximum power limit. Alternatively, tariffs can be applied on a fee-for service basis, using units of service, such as hours of lighting or the avoided cost of kerosene. Variations include flat-rate tariffs, time-based tariffs (e.g. higher rates during peak hours) and tariffs set by customer category (i.e. residential, commercial, industrial). Advanced metering, digital technologies and mobile communications can facilitate setting tariffs and managing payments.

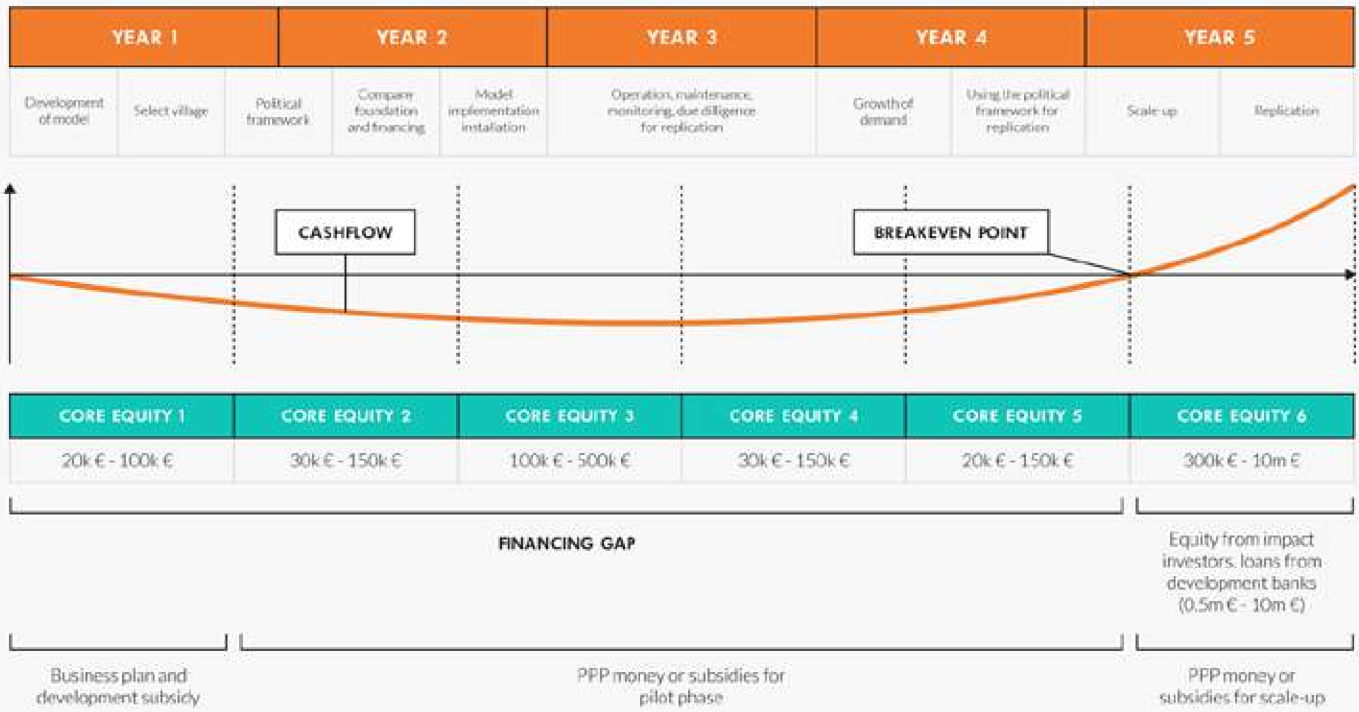
Financing mini-grids

Financing the operation of mini-grids is largely a question of setting tariffs that reflect costs and collecting revenue efficiently, as described above. This section focuses on financing the up-front costs of mini-grids from public and private sources. Initial financing is a particular constraint on developing mini-grids that use renewable sources **(Figure 19)**.

The capital cost of mini-grids varies according to the capacity of the system to be installed, the size of the distribution network, the source of energy for generating electricity and the specific location. This leads to variation in estimates of the total investment required for mini-grids in Africa, as well as in the costs for individual countries. The International Energy Agency, for instance, estimates[121] that over US$300 billion globally would need to be invested in mini-grids to achieve objectives for access to electricity. Its estimate of total off-grid investments in Africa[122] to 2040 is US$61.5 billion, but more would be required to achieve universal access to electricity.

FIGURE 19: THE RENEWABLE MINI-GRIDS INVESTMENT CHALLENGE

Early year cash flow for a renewable mini-grid



Source: RECP (2013)

Where will this initial finance come from? In practice a combination of public finance (from governments and donors) and private finance (equity and debt) will be required to overcome the risks and transaction costs [123], and to reach the scale of investment needed to ensure access to electricity in rural areas. Based on its experience in East Africa, Energy 4 Impact (formerly known as GVEP International) suggests that local commercial banks would provide only 60-70 per cent of the total investment cost. Grants, equity and in-kind community contributions would have to make up the balance.

Most public finance for mini-grids has been provided by international donors, through government and non-governmental organizations. Utilities and rural electrification agencies have been reluctant to finance mini-grids because they are not perceived as core business and may not provide substantial revenues. But the availability of donor finance for mini-grids is increasing, particularly for renewable energy mini-grids, for example from the Solar Energy Finance Association, UK Department for International Development (DFID) and the Africa-European Union Renewable Energy Cooperation Programme (RECP).

Private investors perceive mini-grids as a high risk. In rural or remote areas, infrastructure and the business environment may be under-developed, and markets are constrained by low incomes. Few developers or businesses have experience of investing in or operating mini-grids.

Diesel-fuelled mini-grids pose risks of variations in the fuel price and interruption to supply. The high initial investment cost of renewable energy mini-grids requires a long pay-back period, posing a market or demand risk from changes in demand or the arrival of the main grid. Political risks from changes in the policy and regulatory environment can be mitigated by a strong sustained policy framework, and good design and management.

Because of regulatory weaknesses (see next section) and because they are unable to exploit the economies of scale of national grids, mini-grids can have high transaction costs[124]: project design and development, licensing, due diligence, even financing costs – which are necessary irrespective of the size of a system – can be disproportionate to a mini-grid's overall investment cost.

Transaction costs can be reduced by aggregating mini-grid projects into larger programmes for financing. Several developers are taking this approach, including Inensus, Africa Power, Synchronicity and African Solar Designs. At the same time, development finance institutions such as the African Development Bank, Islamic Development Bank and Department for International Development are looking at mechanisms for investing into portfolios of mini-grid projects. Providing grants or concessional loans for the early stages of mini-grid development, complemented by equity investment (including from the communities to be served), would address the transaction-cost barrier and make mini-grids more attractive to private investors[125].

PART III: MENDING AND EXTENDING THE GRID

MAKING NATIONAL SYSTEMS WORK BETTER

The cheapest way to bring sufficient power to meet most Africans' daily needs is through connection to the national grid, the centralized system of generators, transmission and distribution. This is the cheapest option where people want to use a large or continuous amount of energy, such as for air conditioners or other equipment, and in places where there are many houses or industrial users, and where an existing grid connection is near. As Africans increasingly move into cities and as small settlements grow, often the best way to get them effective power is to ensure that the national grid is working well and that the many inefficiencies are tackled. This section will follow the traditional breakdown of the national grid into:

- Generation – power stations that create the electricity
- Transmission – grid power lines that move electricity around the country
- Distribution – connecting power to users and collecting revenues.

Each of these components can be made to work better through reform, liberalization, public-private partnerships, restructuring, improved management and investment.

We also look at the potential of renewable energy and the vital role of regional cooperation in enabling cross-border power trade.

NATIONAL GRIDS ARE FAILING AFRICANS

Despite its abundance of energy resources, Africa is home to some of the world's worst-functioning grid systems, which have suffered from decades of neglect and mismanagement. Sub-Saharan Africa's power situation is particularly acute, with an electrification rate of just 32 per cent – the lowest in the world[126]. Only Cameroon, Côte d'Ivoire, Gabon, Ghana, Namibia, Senegal, South Africa, and island states such as Cape Verde and Seychelles have electricity access rates over 50 per cent[127].

Unreliable power supply is cited as the main hurdle for businesses in Africa[128]. Thirty countries in Africa South of the Sahara experience regular power shortages and blackouts, costing their economies on average 2 per cent of their GDP, and up to 5 per cent[129] in some cases.

> **UNRELIABLE POWER SUPPLY IS CITED AS THE MAIN HURDLE FOR BUSINESSES IN AFRICA.**

To make matters worse, the continent's overall demand for power, projected to grow by 4 per cent annually, is likely to continue to outpace power supply, pushing electricity access rates further down by 2050[130]. The resulting energy deficit is expected to reach almost 400GW of generation capacity by 2030[131].

Africa faces a daunting energy "trilemma": to fuel its socio-economic transformation it needs to provide electricity that is reliable, clean and affordable[132]. How can Africa turn around its ailing grid sector to improve and scale up grid power supply, while accommodating renewable energy? Making the best use of existing resources and new investments requires old and new planning approaches.

A coherent approach: The power value chain

An increase in power supply capacity is not enough on its own to raise energy access. Countries also need to build an extensive transmission and distribution infrastructure, revise electricity tariffs, enhance power efficiency and introduce smart technologies. Determining strategy, planning and investment need is best handled through a coherent, holistic approach. The Power Value Chain concept developed by the professional services company KPMG is one such example[133].

The KPMG concept helps to visualize all stages through which energy flows, from natural resources all the way to energy delivery to end-users. In doing so, it seeks to capture the requirements at each stage properly and to understand the linkages and interactions among the various elements of the value chain. The aim of the concept is to provide guidance to energy stakeholders on policy and strategy design.

Holistic energy planning can avoid serious drawbacks: Angola failed to plan the connection of three independent electric grid systems and is unable to dispatch surplus power from the North to the centre and South. Uganda's recently completed hydropower plants are sitting idle for lack of a transmission and distribution network[134].

According to KPMG, many countries in Africa have placed a high premium on power generation at the expense of all the other elements along the value chain. The focus on generation has shifted the emphasis of investments away from transmission and distribution, which remain largely underdeveloped, and which, in turn, undermine efforts to increase supply capacity.

An efficient transmission and distribution network is essential. It optimizes power-generation capacity. As African countries move from state monopolies to partnerships, from a single energy resource to energy mixes, from on-grid versus off-grid solutions to integrated power-supply systems, they should also consider taking a long-term, holistic view of their power value chains. They should lift constraints along the value chain and ensure that every obstacle, such as the lack of adequate transmission and distribution, is removed so they can achieve their goal of energy access.

Experience in other regions sheds light on the importance of a coherent approach. Vietnam's electrification story would not have been successful without the deployment of high-quality transmission and distribution infrastructure[135]. Vietnam went even further by linking energy access to a wider socio-economic development agenda[136].

MAKING POWER SECTOR REFORMS WORK FOR ALL

Restructuring of African power utilities

Power utilities across Africa have embarked on a series of reforms in recent years. The reforms are intended to unlock the full potential of the power sector by improving its efficiency and profitability. Governance and organizational structural reforms can redress inefficiencies, mobilize and leverage investments for expansion, and accommodate emerging forms of energy.

Although the need for an overhaul is indisputable, the reforms must be relevant to Africa's fast-evolving energy space and need to support the continent's electrification efforts.

In most countries, the main thrust of the reforms is to curtail government intervention, which is often thought to distort the energy market, and open up the power sector to private operators. This has led to the gradual unpacking of state-owned, vertically integrated utilities (VIU) through restructuring, breaking the vertically integrated utilities into separate entities, and privatization. The United Nations Industrial Development Organization (UNIDO) has identified[137] five categories of power-sector reforms in Africa: management contracts, corporatization, electricity law amendments, unbundling and independent power producers (IPPs).

Management contracts include a private entity contracted to undertake the operational management of the utility, while assets remain owned by the utility. This has been adopted in several countries, especially in West Africa. Corporatization or commercialization is the transformation of the state-owned utility into a corporate entity with limited liability, in which the government is the major stakeholder. This usually entails an increase in electricity tariffs, primarily to recover costs.

Amendments to electricity laws include restructuring utilities' governance systems and creating an independent regulatory body to oversee the power sector and subsequently to include private-sector participation. Almost all African countries have amended their electricity laws, improving the regulatory framework of the power sector, and 27 Sub-Saharan countries have established independent regulatory bodies[138].

Unbundling, otherwise known as restructuring, is a major step towards full liberalization of the power sector. Horizontal unbundling seeks to decentralize power generation, transmission and distribution at the provincial level. Vertical unbundling unpacks national utilities into autonomous generation, transmission and distribution entities. Unbundling occurs later in the reform process, since it requires that several conditions are fulfilled, such as establishing new institutions and completing asset-transfer procedures. Vertical unbundling is more common: Examples of a higher degree of vertical unbundling include Ghana, Nigeria, Sudan and Uganda[139]. Only a few countries have considered horizontal unbundling: Ghana, Nigeria and Tanzania. Private-sector participation grows with the introduction of independent power producers (IPPs), which are power generators set up by private investors (see below).

Restructuring and privatization processes in Africa have improved the operational and financial efficiency of public utilities[140]. But the shift from state monopoly to liberalized market systems has not always been focused on bringing energy access to all and supporting the broader development agenda.

Emphasis has been on unbundling the power-generation segment, leaving transmission and distribution in the hands of the government. As a result, energy generation has benefited from considerable investment, while transmission and distribution have remained largely underdeveloped. This tends to hinder all development and expansion efforts.

Privatization is desirable but not necessary

Despite the push for liberalization, no African country has fully privatized its power sector. African governments' pick-and-choose stance reflects the inadequacy of prescriptive reform models. Countries have preferred to err on the side of caution by selecting options that best suit their needs and circumstances.

Egypt, Mauritius and South Africa are examples of African state-owned public utilities which have, on the whole, performed impressively, although some now face management and maintenance challenges. Increasingly, the dominant structure is hybrid governance whereby the government is the major stakeholder and operates alongside a multitude of energy players.

Tying the performance of the power sector solely to its financial viability ignores the larger electrification and development needs of African countries. A negative experience with reforms forces countries to reconsider privatization, as was the case of Mali and Senegal, where the power sectors reverted to state ownership.

Given the limitations of the privatization model, new arrangements have emerged. African countries and the international development community are gradually shifting to the public-private partnership model[141]. This option makes more sense for African countries, particularly as it relates to the capacity constraints and the need to balance efficiency with improved access to the poor.

GENERATION

African governments' strong recent push to increase generation capacity has boosted deployment of power infrastructure, both traditional and renewable. From a low base, Africa´s grid-based installed capacity has grown steadily to reach 194GW in 2015[142]. Gas accounts for the largest share with 38 per cent, followed by coal (24 per cent), oil (18 per cent), renewable energy (17 per cent, all sources included) and nuclear (1 per cent). Still, the continent requires additional generating capacity of 250GW by 2030, which means a two-fold increase in current growth rates to 7GW a year.

Much of the new capacity comes through independent power producers (IPPs), as in Côte d'Ivoire and South Africa **(Box 4)**. Investors set up power-generation plants after detailed examination of the legal framework and the promised prices for the power they generate, which are usually sold to the transmission and distribution networks through off-take agreements covering many years. The transmission network is often still a state-owned utility, and several IPP developments have been hampered by concerns over how capable these are at paying bills on time.

In recent years, the number of IPPs has grown rapidly. At present, South Africa comes top (6,376MW procured from renewable energy IPPs under the REI4P programme[143], plus energy from other IPPs), followed by Nigeria (1,521MW), Kenya (1,066MW), Côte d'Ivoire (866MW), Ghana (656MW) and to a lesser extent Tanzania and Uganda[144]. The IPP model has tended to focus on large power projects that require significant financial and infrastructure investment outlays. New modalities are needed for smaller projects and participation by the local private sector in generation.

Figures on installed capacity do not tell the full story. Nigeria, Africa's most populous nation with more than 170 million people and economic growth of 7 per cent a year, has an installed capacity of 12.5GW but only 4.5GW of this is available and working[145] (in contrast, South Africa has an installed capacity of 50GW for a population one-third that of Nigeria's). More often than not, power-supply systems across the continent operate well below their installed capacity due to a host of physical and governance-related constraints, including ageing infrastructure, outdated technology, poor maintenance, disruptions to energy supply, transmission and distribution losses, and insufficient power coverage[146].

BOX 4: IN CÔTE D'IVOIRE AND SOUTH AFRICA, REFORMS ENCOUNTER SUCCESS AND CHALLENGES

Côte d'Ivoire was one of the first countries in Africa to privatize its power sector, starting in 1990[147]. Since then it has gone through several phases of reforms, including management contracts, corporatization and independent power producers (IPPs), which led to a rapid increase in private-sector participation. The trend is likely to continue: of the 1,500MW in power-plant projects scheduled for development by 2020, the country plans to award 85 per cent to IPPs. Côte d'Ivoire has been able to boost its power generation capacity, increase national electricity coverage and meet growing domestic demand, while becoming a net electricity exporter in the subregion.

Côte d'Ivoire's privatization experience has succeeded because of the attractiveness of the regulatory and business environment provided to IPPs. There is a danger, however, that some reform provisions will constrain development prospects, particularly the Take-or-Pay clause that guarantees the priority purchase of power generated by IPPs, as well as the government's involvement in the deployment of transmission and distribution infrastructure and its role as the major risk off-taker. There is a risk of customer dissatisfaction over tariff hikes, especially during economic hardships.

South Africa epitomizes the success of the IPP option because of an institutional set-up that allowed partial liberalization of the power market[148]. As a result, IPPs have been able to raise close to US$43 billion in private investment over the last four years. The reforms also helped boost the utility's capacity to plan, procure, contract and regulate the power market. Perhaps the most notable achievement is South Africa's flagship initiative, the Renewable Energy Independent Power Producer Procurement Programme (REI4P). This auction system has been hailed as a model for other countries for its success in providing a clear and transparent policy and regulatory framework, in promoting competition among energy stakeholders, in leveraging substantial investments and in ensuring the rapid execution of energy projects at no extra cost to end-users[149].

South Africa's reforms are still falling short, however. The power sector is facing a growing number of challenges: rising costs and tariffs, the utility's looming financial crisis that is threatening to derail the REI4P, the lack of investment in maintenance and service delivery at the municipal level, and the utility's control over power purchase from IPPs and over energy transmission[150]. As the South African model evolves, there are calls to widen the scope for IPPs by amending the Electricity Regulation Act, to deepen the reform process to unbundle the utility further into separate entities, and to decouple the utility from political interests.

BOX 5: COAL'S FUTURE IN AFRICA

Africa has abundant reserves of coal and other fossil-fuel resources[151]. Coal is the primary energy resource for several countries and accounts for 24 per cent of all grid-installed capacity, second only to gas (38 per cent), followed by renewables (17 per cent) and nuclear (1 per cent). While African countries are far down the list of the world's biggest consumers of coal, any credible scenario for achieving Sustainable Development Goal 7 by 2030 needs to factor in the extent to which a handful of countries, most of them with high coal deposits, depend on the fossil fuel to generate electricity.

Over 90 per cent of the continent's coal is used in Southern Africa, predominantly in South Africa, which has historically relied heavily on coal for its power production and where coal still provides an estimated 80 per cent of the energy supply. South Africa is the fourth largest producer of coal in the world, representing close to 30 per cent of its exports. Coal mining is the country's third highest employer and generates more income for the economy than gold[152].

Countries with proven coal reserves (such as Nigeria and Southern African countries) view coal as a cheap option to expand energy access. Countries such as Morocco, Kenya and Ghana, which harness cheap coal imports to power their economies, see the continuing slump in international coal prices as a bonanza. Several African countries – Botswana, Zambia, Zimbabwe, Mozambique and Namibia in Southern Africa; Nigeria, Ghana and Senegal in West Africa; Kenya and Tanzania in East Africa; and Egypt and Morocco in North Africa – are scaling up or building coal-fired power plants.

This has raised concerns that scaling up the use of coal might contravene the countries' respective commitments to the Paris Agreement. Pressure is mounting to leave Africa's coal in the ground and to limit coal-fired generation projects. However, given the enormity of the energy challenge, African countries are opting to strike a balance between their emission commitments and their development priorities. Often, this means using more coal and less oil.

South Africa has spelled out its plans in an Intended Nationally Determined Contribution (INDC) document. It aims for a peak in CO2 emissions by 2025, with a fall expected a decade later. Coal will continue to play a major role in power generation, with coal projects planned for implementation over the medium term. The country also plans to use clean coal technologies as part of its mitigation contributions[153].

Elsewhere in Southern Africa, efforts to bolster thermal-energy capacity by increasing the share of coal in the energy mix – for example in Zambia and Zimbabwe – come in response to the severe energy crisis that has hit the hydropower sector. Implementation of a 600MW, US$1 billion coal-fired power-plant expansion project in Hwange, Zimbabwe, was due to begin in late 2016, subject to financing. Botswana, a coal-dependent country, has declared its intention to cut emissions by 15 per cent, including going ahead with its plan to increase its coal capacity and reduce oil-fired power generation by 2025. (continued)

In West Africa, the Nigerian Bulk Electricity Trading Agency (NBET) recently signed a 300MW 20-year power purchase agreement with Zuma Power, following the same rationale. Nigeria is Africa's fourth largest emitter of CO2 and there are fears that the proposal to meet 30 per cent of energy needs using coal could jeopardize the country's Intended Nationally Determined Contribution commitment, which sets out a 20 per cent emission reduction by 2030. Senegal has committed to reducing emissions by 5 per cent by 2030, including turning to coal to expand generation capacity and meet growing domestic demand. The Sendou 125MW coal power station is expected to come on-stream in 2018.

Egypt, despite its Intended Nationally Determined Contribution commitment to increase the share of renewables in its energy mix and phase out energy subsidies, is considering increased use of coal as an alternative to dwindling reserves of natural gas, particularly to power its cement industry. Morocco, which relies on imported coal to generate 40 per cent of its electricity, has set an ambitious target of generating 50 per cent of its power from renewable sources and cutting its emissions by 13 per cent by 2030. However, it just completed the 700MW extension of the new 693MW Jorf Lasfar coal-fired plant, set to become operational in 2018.

Despite recent restrictions imposed on international financing in relation to coal projects, driven by the high carbon content of the energy, there is an influx of Chinese investments in coal projects in Botswana, Mozambique and Zimbabwe. Coal has attracted support and financing from multilateral institutions such as the New Development Bank established by the BRICS states (Brazil, Russia, India, China and South Africa) and the African Development Bank, which considers coal a priority.

For many countries, the transition to clean energy will not be as swift as previously thought, since current levels of growth in generating energy from renewable sources are not sufficient to displace fossil fuel and retrofitting installed electricity-generation capacity involves considerable cost. In reality, coal will only be phased out from the overall energy mix gradually and incrementally.

Aggressive promotion of renewables would help reduce the carbon intensity of Africa's power generation more rapidly. On one estimate, increasing installed grid capacity of renewables by 24 per cent through to 2040 would reduce CO2 emissions by 21 per cent, from 625 Mt to 495 Mt a year, but would increase the capital cost of generation by around US$108 billion. Given the investment constraints faced by governments in Africa, the case is compelling for international cooperation to expand the choices available to energy planners through incentives rather than penalties.

UNLEASHING AFRICA'S RENEWABLE POWER POTENTIAL

Integrating renewable energy into the grid system

African countries are very willing to shift from fossil fuels to renewable and low-carbon energy. Many have very significant resources, including hydropower, solar, geothermal and wind, and are successfully injecting renewable energy, albeit in small amounts, to boost the national grid using an array of regulatory and policy mechanisms, including setting tariffs for off-take agreements[154] which favour energy generated through diversified renewable sources.

Challenges in integrated renewable energy as a major part of the national grid include variability, which calls for greater flexibility of energy sources, technologies and systems; and limitations of existing grid infrastructure[155]. In the context of weak transmission and distribution infrastructure, some developers recommend the integration of modest renewable energy capacities, in the range of 5-10MW, for easy deployment across the grid[156].

In 2015, global investments in renewable energy reached a record US$329 billion, signaling that the world has reached an energy turning point[157]. Africa is at the forefront of this movement towards clean power. In December 2015, African countries launched the Africa Renewable Energy Initiative (AREI), an unprecedented effort to give all Africans access to energy that is mostly based on renewable sources by 2030 **(Box 6)**.

South Africa already features among the world's top 10 destinations for clean energy investments, attracting US$4.5 billion in 2015 – up from US$1 billion a year ago – to make it the continent's largest renewable power producer. Morocco comes in a close second with US$2 billion, while Kenya, Uganda and Ethiopia also attracted sizeable investments[158]. Renewable energy represents 17 per cent of total power generation in Africa, and 95 per cent of this comes from hydro resources[159]. With a marginal contribution of only 1 per cent, the potential of clean power excluding hydroelectricity is yet to be unlocked.

> **AFRICAN COUNTRIES ARE VERY WILLING TO SHIFT FROM FOSSIL FUELS TO RENEWABLE AND LOW-CARBON ENERGY.**

BOX 6: AFRICA RENEWABLE ENERGY INITIATIVE: CREATING ENERGY SYSTEMS FOR THE FUTURE

The Africa Renewable Energy Initiative (AREI) was launched in December 2015 at the 21st Conference of Parties to the United Nations Framework Convention on Climate Change (COP21). It charts a course for the continent that is climate-compatible and caters to the needs of all of its people.

The key goal is to enable 1 billion more people to access energy by 2030 than would do so on a business-as-usual trajectory. It envisages that most of the required new generation capacity will be met by renewable energy – at least 300GW from a range of renewable energy sources. And it shows how Africa, by doubling its capacity to generate energy using renewable sources, can leapfrog to smart, distributed, people-centred, renewable energy systems.

The initiative outlines how African countries can avoid locking in fossil-fuel energy systems and bring renewable energy to people where they live. It envisages a highly diversified ownership base that will secure energy for productive sectors – small-scale agriculture, small and medium-sized enterprises, and larger companies – and for the public sector. As more households, communities, cooperatives, companies and public institutions become both producers and consumers of electricity, thriving local economies will create jobs.

African leaders and institutions are putting the initiative into operation by establishing accountable and transparent governance structures, and an Independent Delivery Unit to undertake concrete work and coordinate with other actors and initiatives. International partners have shown great interest and have committed US$10 billion for the initiative's first phase (2017-2020).

Success will depend on addressing critical issues:

African ownership: The Africa Renewable Energy Initiative can only prosper and deliver on its goals if African governments exercise real ownership and their populations are actively engaged in shaping their energy futures through locally appropriate solutions. It offers a unique change from the usual donor-driven model. International partners should be genuine allies and allow the initiative to engage thoroughly with all African governments and their multiple stakeholders, and respond to their requests and plans. Funding from within Africa is crucial to bolster financial support from partners.

Ensuring real, additional action: The initiative outlines a number of core work areas and concrete actions that are necessary to deliver its bold goals. These must truly add to what would otherwise have happened and means that all actions and activities must be carefully assessed and scrutinized to make sure that the initative brings extra value.

Ensuring social and environmentally sound solutions: Social and environmental safeguards must be put in place from the outset. Renewable energy solutions that are effective, appropriate and people-centred must be chosen, with measures to ensure that harmful and short-sighted vested interests do not prevail.

Independence of its delivery unit: Particularly because of the unconventional and transformative approach of Africa Renewable Energy Initiative, its Independent Delivery Unit must be ensured the space and freedom to pursue its work unhampered by bureaucracy, institutional interests and inertia. As a continent-wide effort that transcends the many initiatives and programmes that already exist, the Africa Renewable Energy Initiative needs to be able to function as a non-partisan body that coordinates ongoing work and can put forth bold new ideas for countries to consider.

African governance structures: The governance structures of the initiative will be formed based on summit decisions taken by the Assembly of Heads of State and Government of the African Union. The Board will represent the whole continent, and must have full independence, which means having its own legal personality with power to organize and institutionalize the work of its Independent Delivery Unit and other structures in the most effective way possible. The Africa Renewable Energy Initiative offers a promising path to a prosperous low-carbon future. Like all new initiatives, however, it is fragile and vulnerable to a range of challenges and competing interests.

Hydropower dominates energy market

Hydro and solar power, which have increased their capacity and secured large shares of clean power investments in recent years, will continue to dominate Africa's energy market. Even so, Africa has harnessed less than 10 per cent of its huge hydropower potential. With an installed capacity of 28GW and an additional 17GW in the pipeline, large-scale hydropower initiatives – notably the Grand Inga Dam in the Democratic Republic of the Congo and the Grand Renaissance Dam in Ethiopia – are being developed to improve affordable energy access[160] dramatically. However, growth in hydropower and other renewable power may be subdued, due to inadequate financing to support the deployment of extensive infrastructure and grid networks.

Climate change and competing demands for water threaten to constrain the performance and prospects for growth of hydropower. Diversification of the renewable power portfolio is vital to improve energy security.

Solar power has become the energy of choice for many

From a low base, solar power has grown spectacularly across Africa over the last five years, attracting the bulk of renewable energy investments[161]. Solar power's share of electricity generation soared as installed capacity jumped from 127MW in 2009 to 1.3GW by the end of 2014. Solar became an energy of choice for clean power generation for many countries because of a combination of the continent's unique potential, the flexibility of technology and the wide range of solar-power generation solutions.

In particular, the solar photovoltaic (PV) market expanded rapidly as the cost of PV modules fell by 75 per cent, lowering the cost of electricity from solar PV and making the segment especially competitive. Utility-scale, grid-connected solar power is on the rise across the continent, with the development of projects including a recently completed 8.5MW solar-power plant in Rwanda, the Nzema solar plant under construction in Ghana and a 100MW solar plant planned for Northern Nigeria[162].

Alongside solar PV, concentrated solar power (CSP) is also spreading, from mature energy markets in South Africa, Algeria, Morocco and Egypt to planned installations in Botswana, Namibia and Sudan. The six concentrated solar power plants already existing in Africa have combined installed capacity of 180MW. The launch in early 2016 of the first phase of Morocco's Ouarzazate concentrated solar power plant – destined to become the world's largest – added another 160MW[163] to the capacity.

Beyond hydro and solar power

The exponential growth in energy demand creates plenty of scope to exploit and scale up other forms of renewable energy, including wind and geothermal power, natural gas and less conventional power sources such as biomass and methane.

Wind power has considerable potential in Africa. With medium- to large-scale wind-power projects coming on line in Cape Verde (whose share of wind energy has reached 20 per cent)[164], Egypt, Kenya, Morocco and South Africa, among others, the sector is slowly but surely gaining prominence[165]. Recent undertakings such as the 300MW Lake Turkana plant in Kenya and the 225MW Ayitepa wind farm in Ghana, which mobilized US$525 million in investments, will boost the continent's wind-power generation capacity[166].

Geothermal energy offers a promising form of power generation in the Rift Valley[167]. The current share of geothermal power in renewable energy generation is 210MW of installed capacity[168]. The Olkaria plant in Kenya is an example of geothermal generation with utility-scale capacity. Geothermal power is poised to contribute a greater share of Africa's power. Kenya plans to increase the share of geothermal to 26 per cent by 2030[169]. Ethiopia is going ahead with its 1GW Corbetti project, and Tanzania recently announced a US$350 million investment plan[170].

Natural gas is not renewable but is lower in carbon emissions and pollution than other fossil fuels. Africa is discovering substantial onshore and offshore gas reserves. Gas-fired power capacity has reached 40 per cent and the outlook for gas power generation is bright[171]. Few countries have initiated gas-to-power development plans so far, but the sector is likely to expand if initiatives are properly planned and adequate gas infrastructure investment is available.

Ghana's gas-to-power initiative is expected to add 2.5GW of power-generation capacity[172]. Egypt will start exploiting the Zohr gas field from 2017 to boost the country's gas production and consumption. Morocco is developing infrastructure for gas imports and processing to meet its growing demand for gas in power generation. In Southern Africa, gas fields in Mozambique, Tanzania and, to a lesser extent, South Africa are due to come online in the near future[173].

Biomass is emerging as a promising renewable power option. The use of biomass has so far been limited to more advanced African economies. More than 50 per cent of the continent's capacity is installed in Southern Africa[174]. Mauritius' successful experience in cogeneration using bagasse — a byproduct of sugar production from sugarcane — has led to a 40 per cent share of bagasse in electricity generation[175].

Other countries are following the example set by Mauritius. Manulis Energy in Uganda is an African-led initiative that seeks to unleash the biomass potential of agri-waste, estimated at more than 1.6GW[176]. It plans to develop a 20MW biomass-to-grid project and deploy hybrid (solar-biomass) micro-grid systems with a generating capacity of 8MW in rural areas. Another example is a 12MW biomass power-to-grid project under way in Baringo County, Kenya[177]. This innovative scheme uses biomass gasification technology to process the invasive Juliflora plant and generate electricity that feeds into the national grid.

Methane has recently entered the power market as a possible option for expanding grid-power supply[178]. A pioneer project in Rwanda aims to extract methane from Lake Kivu to generate affordable electricity. The first phase of the 100MW project was launched in December 2015, producing an initial 25MW[179]. If risks are properly managed, the initiative could become a game-changer given its potential to increase Rwanda's power supply dramatically to 1GW by 2020.

How can African countries expand renewable power?

To foster the expansion of Africa's renewable power supply, it is vital that governments implement measures that create conducive conditions. African countries are already deploying a vast array of policy instruments and public-private partnerships to support the development of power generation from renewable sources. South Africa's Renewable Energy Independent Power Producer Procurement Programme (REI4P) is very successful. Other countries wishing to adopt a similar model will need to adapt it to their own specific needs and conditions.

Increasing energy supply: Policy measures aimed at boosting the clean power sector and the supply of renewable energy include clear targets. Rwanda, for example, aims to obtain 22 per cent of its energy from renewable sources by 2018. Feed-in tariffs (FiTs) compensate renewable energy producers for the higher cost of generating clean power, thus helping to mobilize financing in renewables. Uganda's GET FiT programme has generated significant donor interest and support. Energy market auctions encourage producers to reduce their operating costs so they can offer lower power prices. In the 13 countries where the auction system has been implemented, including Morocco and South Africa, the result has been major expansion in large-scale power generation capacity[180]. Other countries have relied on tax waivers and reductions, mostly targeting solar technology.

Increasing energy demand: Energy demand is not generally an issue in Africa, given the huge gap between the amount of power available and the large number of Africans who do not have access to modern energy. But efforts to expand renewable power need to take into account the high upfront costs of clean energy and the limited ability of many consumers to pay for it. Subsidized pricing, widely used elsewhere in the world, is often unfeasible in countries with limited financial capacity. Alternative policy tools are needed to help stimulate and support demand for renewable power.

Some policy measures prove more successful than others. Ghana's feed-in tariff programme resulted in large investment inflows for wind and solar initiatives, including more than US$500 million for the Ayitepa wind farm. Building on this success, Ghana is planning to shift to the auction system, considered a more attractive way to increase investments in renewable power[181].

Different countries have succeeded through creating programmes that best suit their own resources and the local environment and needs, including legislative, policy, investment and other frameworks; and end-consumers' ability to pay. Examples across the continent include the support of two successive Kenyan governments for the Lake Turkana wind power project[182]. In Mauritius, the bagasse cogeneration success story bears a strong testimony to the need for continuous political commitment and close collaboration with all stakeholders[183].

REI4P: South Africa's renewable energy success story

South Africa's Renewable Energy Independent Power Producer Procurement Programme has not only scaled up capacity to generate power from clean sources – mainly wind and solar PV – to 1.4GW[184], it has also produced numerous socio-economic benefits over the course of successive bidding rounds since its launch in 2011[185]. The programme succeeds by introducing competition, which has driven down the costs of renewable energy, making it an attractive alternative to traditional forms of power and boosting the business case for investing in renewables compared to coal[186]. Sustained political commitment has been also instrumental to the solid track record of delivering clean power projects.

The programme's success hinges on creating backward and forward linkages with the rest of the economy, complementing African countries' industrialization agenda and their quest to ensure that the windfalls of clean power initiatives are distributed fairly.

The programme's local-content requirement (LCR) aims to build local manufacturing capacity and skills, so that a significant share of investments into renewable energy– at least 45 per cent – benefit the local economy[187]. The requirement sets out the ambitious target of manufacturing and sourcing locally 75 per cent of components used in clean power generation, such as solar PV panels, wind towers and turbines – up from 35 per cent in 2011. Over the first three bidding rounds, South Africa has been able to capture more than 30 per cent of total clean power investment[188].

In the Western Cape, for example, solar PV manufacturing industries have been established. The solar manufacturing sector generated 26,000 jobs in the fourth round of bidding, double the amount in the first round. Furthermore, an innovative joint venture, I-WEC, is planning to manufacture wind turbines and blades locally. Several international companies are also setting up manufacturing sites for clean-power components in South Africa[189].

"

SUSTAINED POLITICAL COMMITMENT HAS BEEN INSTRUMENTAL TO THE SOLID TRACK RECORD OF DELIVERING CLEAN POWER PROJECTS.

Elsewhere on the continent, Egypt aims to expand local manufacturing of components for wind and concentrated solar power generation, while Algeria plans to manufacture solar PV equipment[190].

Several countries, at varying stages of clean power development and uptake, are seeking to emulate South Africa's experience with the Renewable Energy Independent Power Producer Procurement Programme[191], but they will need to exercise caution when adapting it to their specific contexts. In South Africa, the local content requirements are critical to boost and sustain the expansion of renewable power. Technical capabilities to design and implement similar policy tools need to be strengthened to help expedite clean energy procurement processes[192].

Overcoming the limitations of the REI4P model

Despite the huge success of the Renewable Energy Independent Power Producer Procurement Programme, persistent problems need to be overcome as the model evolves:

- Unrealistic local content requirements heighten the risk of non-compliance, forcing the programme to consider a termination strategy. Policymakers need to ensure that the requirements are compatible with available capacity
- Eskom, South Africa's public electricity utility, faces budgetary constraints that threaten to limit financial allocations beyond the third round of bidding
- Job creation and social benefits have fallen short of expectations
- A lack of sufficient consultation with local government structures sometimes results in delays and disputes (over land, for example, as in the case of the Lake Turkana wind development project in Kenya)
- The concentration on local content requirements can divert attention from the need to develop all elements along the renewable power value chain.

South Africa's programme has been instrumental in shaping the development of independent power producers in South Africa and elsewhere. New models are emerging, such as municipality power procurement. In South Africa, Tombolo Energy seeks to develop independent power producer agreements between municipalities and large consumers, following the example of the agreement between Amatola Green Power and Nelson Mandela Bay Municipality[193]. However, regulations are needed that allow municipalities to purchase power directly from independent producers without having to go through public utilities such as Eskom. In addition, there is a need to strengthen the financial position of municipalities so they can take on the role of guarantor, which South Africa's National Treasury does[194] in the case of the Renewable Energy Independent Power Producer Procurement Programme.

Key factors that determined the successful outcome of South Africa's programme provide important lessons for policy-making and planning[195]. The following were instrumental in building market confidence and fostering competition, as well as generating significant interest and investment into the renewable sector: strong political will and sustained commitment; clear policy and regulatory frameworks; transparent bidding procedures and processes; proper allocation of risks; an adequate tariff-setting system; incremental increase of the target on local content requirements; and structured and timely implementation. This new direction in public-private partnerships can be applied to other infrastructure development programmes. Each country will tailor its energy-procurement programmes according to the requirements, capacities and level of development of the domestic market.

Expanding the clean power space for African investors

High transaction costs of and the lack of adequate financing for smaller players tend to crowd out African investors, despite efforts to involve small and medium enterprises (SMEs). In a recent 100MW tender in Zambia, for example, only one African company (from South Africa) qualified but no Zambian companies qualified. Suggestions to resolve the financing challenges include using pension funds to provide long-term financing to smaller players and mobilizing impact investors in search of positive financial and social outcomes[196].

A small but significant development is the recent expansion of South African companies in Africa[197]. A few compete alongside international companies on the African renewable market, largely driven by the prospects of higher power tariffs elsewhere on the continent as prices for clean power are declining on the domestic market.

Renewables still face technical challenges

To expand significantly, renewable power needs to be connected to the national grid. However the grid needs constant or baseload power, while power from renewable sources such as solar and wind varies according to weather and daylight. Current technological limitations make it difficult for clean energy to play a central role in power supply. A handful of African countries are using energy-storage systems, but these are an expensive way of dealing with the variability of renewable power.

Pumped hydro storage can prove effective for load management and balancing, while thermal storage has the potential to considerably increase the reliability of concentrated solar power[198]. The unique potential of geothermal energy lies in its ability to provide cost-effective baseload power, making it particularly suited for power balancing, as is the case with the Ethiopia-Kenya hydropower connection project[199].

TRANSMISSION

Transmission and distribution - the weak link

Losses are incurred in electricity transmission and distribution (T & D) because of physical and technological deficiencies, known as technical losses, and because of non-technical losses, mostly in the form of electricity theft[200] (see special section). Africa's high transmission and distribution losses, well above the world's average of 7 per cent, represent a major challenge. The impacts are felt throughout the power chain[201], severely affecting the quantity and quality of energy supply and causing attendant economic costs. Corruption and mismanagement, in addition to theft and vandalism, exacerbate the problematic power situation. A classic example is Nigeria's notorious grid-power supply chain[202].

Progress is being registered. Senegal, for example, has managed to reduce its losses significantly[203]. These successes can be attributed to major reforms aimed at enhancing the efficiency of power-supply systems.

In addition to policy measures and technological solutions for improving revenue-collection systems and protecting power-supply infrastructure, existing transmission and distribution infrastructure is being revamped and new grid networks are being deployed. Ghana has been leading the race in expanding grid connectivity to rural areas[204]. Even the Democratic Republic of the Congo, which has one of the lowest electrification rates in Africa (9 per cent), invested in 2014 in the rehabilitation of its transmission line linking Inga Falls to Katanga, a copper-mining district[205].

Strong political commitment, backed by financial support from multilateral banks and the private sector, has helped move major transmission and distribution network development plans from the drawing board to effective implementation in countries such as Kenya, Ethiopia, Mozambique, Ghana and Nigeria. Most of these investments are directed towards regional transmission and distribution infrastructure projects, however, and are not specifically intended to connect the underserved. To accelerate the pace of energy access for all, African countries must ensure that all urban and rural areas within the power grid's reach are included in the planning and development of transmission and distribution networks.

Although current efforts are commendable, the crisis in the power supply chain persists. African countries need to redouble their investments in transmission and distribution lines, which currently fall very short[206]. The huge network losses and the need to expand grid coverage require investments to the tune of US$800 billion through 2040[207].

DISTRIBUTION

Scaling up the grid

Experience shows that even where the grid could be connecting people, for instance people living in rural areas close to power-generation sources and on the periphery of cities, the policymakers behind grid energy tend to overlook them. One major reason is that the power supply, overly strained physically and financially, is unable to cope with additional demand from these areas.

Lack of access to energy is particularly severe in peri-urban areas — home to Africa's urban poor and often unplanned and growing rapidly. Close to 200 million Africans, most of whom have migrated from rural areas or been displaced by the urban housing markets, are forced to live in poorly planned and ill-equipped settlements. West Point in Monrovia, Liberia, and Kibera in Nairobi, Kenya, are among the biggest slums in Africa[208]. Left to fend for themselves, slum dwellers usually resort to illegal connections to the grid, as small off-grid devices do not meet their energy needs[209].

A range of quick-fix solutions, which require limited or no transmission and distribution infrastructure, have sprung up to bridge the energy gap, as is the case of the flourishing market for diesel generators[210]. However, developing the grid is the best way to scale up affordable energy access in such areas.

A novel approach to grid extension by a private utility company in India, Tata Power Delhi Distribution Limited, has successfully extended grid connectivity to 217 slums (175,000 customers) in New Delhi. The model, premised on community engagement, was able to expand grid extension by linking energy access to a wider socio-economic development agenda[211]. Over the last five years, the utility company has been able to reduce its non-technical losses, expand its customer base and improve its revenues from a mere US$0.3 million to US$17 million.

Quick fixes are no guarantee of a lasting solution. In the Democratic Republic of the Congo, power-supply systems set up by mining companies have rarely benefited neighbouring communities and businesses. However, the Indian model of energy access could be replicated and adapted to African contexts, especially for grid-extension projects in peri-urban areas where the majority of the urban poor resides.

SPECIAL SECTION

PREVENTING ELECTRICITY LOSSES AND THEFT

Electricity losses, including electricity theft, are a problem for distribution companies worldwide, but nowhere more so than in Africa. **(See infographic: Africa's Energy Theft and Losses)** Total losses in industrialized countries are typically between 7 per cent and 10 per cent[212]. The Africa Infrastructure Country Diagnostic found that transmission and distribution losses were as high as 50 per cent in some African countries.

Technical losses occur when power is lost in transmission and distribution lines, transformers and meters. Poorly maintained or low-quality infrastructure and equipment increase the level of technical losses. The World Bank's suggested benchmark for technical losses in Africa is 10 per cent of total power produced.

Non-technical losses are caused by individual actors, either purposely (theft) or unintentionally (for instance through errors in accounting), and by faulty equipment that is not directly used to supply power (e.g. meters). The World Bank's suggested benchmark for non-technical losses in Africa is also 10 per cent of total power produced, but losses are more than two or three times higher than this in some countries.

Most non-technical losses are caused by electricity theft, usually by tampering with or by-passing meters, sometimes in collusion with corrupt utility officials[213]. Electricity theft also occurs through the systematic non-payment of bills. Globally, electricity theft costs US$89.3 billion a year[214]. In the United States, the world's biggest consumer of electricity, US$6 billion a year is lost through the theft of electricity.

In Africa most electricity theft is not carried out by people too poor to afford electricity, but by people and organizations that consume large amounts of electricity and could pay for it, including government, corporate, industrial and commercial groups. Power sectors are often inefficient and unable to deliver adequate or reliable electricity supplies. Theft, fraud and corruption compound the problems facing companies responsible for electricity distribution.

The theft of electricity reduces the revenues of financially stretched utilities, which reduces their ability to invest in system improvements and extend services to those without access and increases the cost of electricity for African consumers. Reduced revenue and profits also make the sector less attractive for private-sector investment.

Electricity theft can contribute to power outages by placing an unmanageable load on the system, and by damaging transmission and distribution infrastructure. Outages can affect large numbers of consumers. Similarly, the inability of distribution companies to invest, because of poor revenue, affects all consumers.

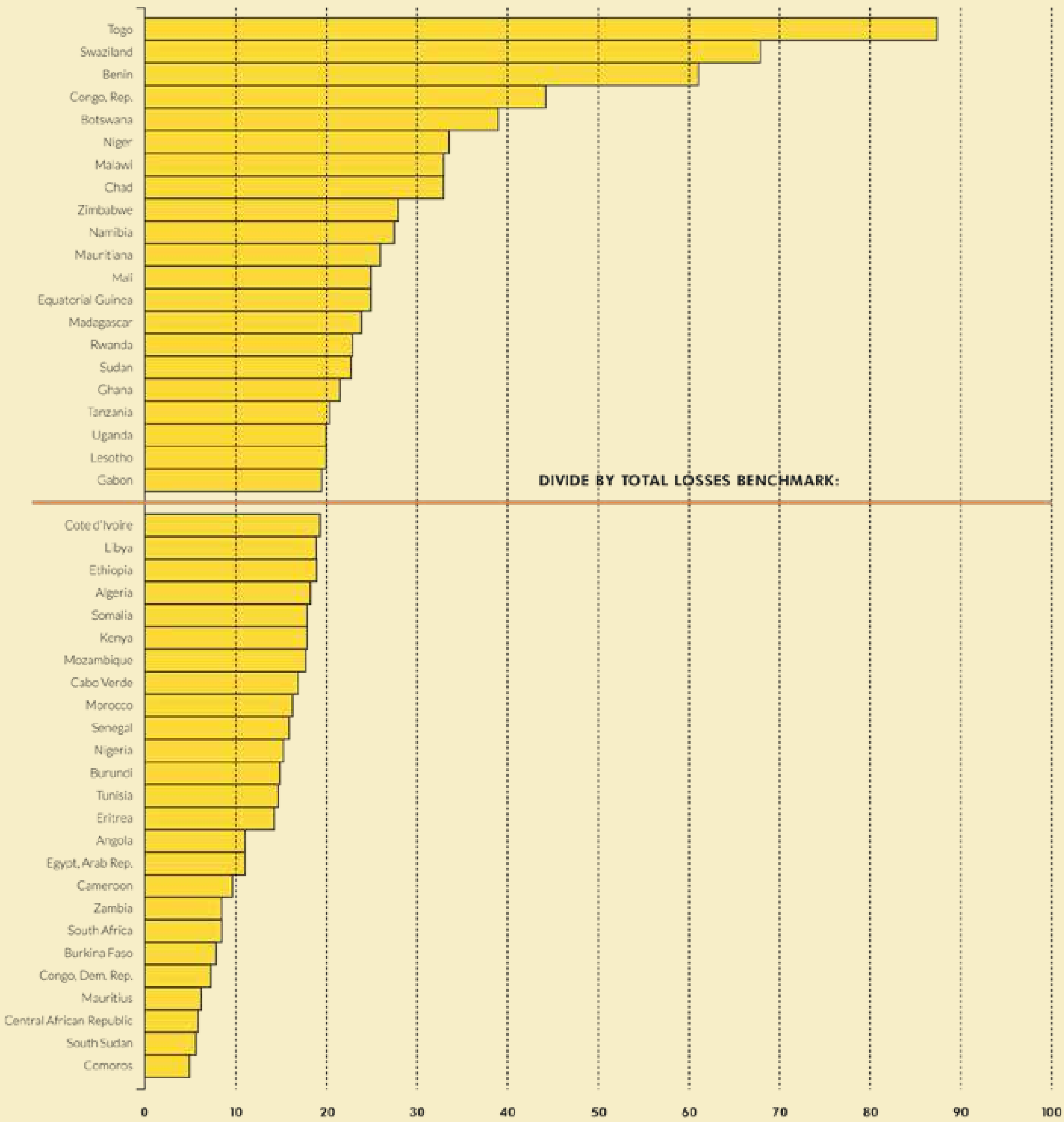
How pervasive is electricity theft?

Data on electricity losses in Africa are neither comprehensive nor up-to-date, but transmission and distribution losses in Africa in 2000 were estimated to be about 20 per cent of total power generated[215]. Other estimates have put the average at 27.5 per cent[216] and distribution losses alone to average 23 per cent[217]. These regional averages conceal the wide variation between countries **(Figure 20)**. Angola, Botswana and Burundi, for example, had losses of 15 per cent, while Swaziland's losses were 68 per cent.

The non-payment of electricity bills accounts for the more than half of electricity theft. Annually, US$1.73 billion is not collected across the region, compared with US$1.48 billion in system losses[218]. In economic terms, the under-collection of electricity bills was equivalent to 0.4 per cent of the region's gross domestic product (GDP) and system losses were equivalent to 0.34 per cent.

FIGURE 20: TOTAL ELECTRICITY LOSSES BY COUNTRY

% of total generation, most recent year available



Sources: Eberhard and others (2011); World Development Indicators

AFRICA'S ENERGY THEFT AND LOSSES

HOW IS ELECTRICITY LOST?

- **Technical losses** take place during transmission and distribution due to energy dissipation and weak infrastructure.
- **Non-technical** losses are due to theft, vandalism, non-payment of bills and accounting errors.

WHY IS ELECTRICITY STOLEN?

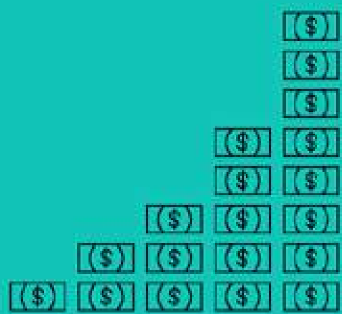
- The greatest proportion of electricity theft is by individuals and organisations that consume large amounts of electricity and can afford to pay for it.
- Some people are unable to pay because they are too poor. Many Africans live below the poverty line.
- Non-payment of bills may be due to a lack of trust between customers and suppliers.

IMPACT

Electricity theft is more significant in Africa than in most other regions.

Electricity theft:
Reduces revenue for financially stretched utilities, which...

lowers investment in system improvements and the extension of services to those without access, and...



increases the cost of electricity for paying consumers.

HOW ELECTRICITY IS STOLEN

The **non-payment of electricity bills** accounts for more than half of electricity theft.

Annually, nearly **US$2 billion** is not collected across the region

NEARLY $2 BILLION

Illegal connections:

- Illegal connections to overhead wires overload the system and lead to blackouts.
- Illegal connections to bare wires or underground cables make up 80% of global power theft.

Meter tampering: Meter is intentionally altered so that it doesn't record correct usage.

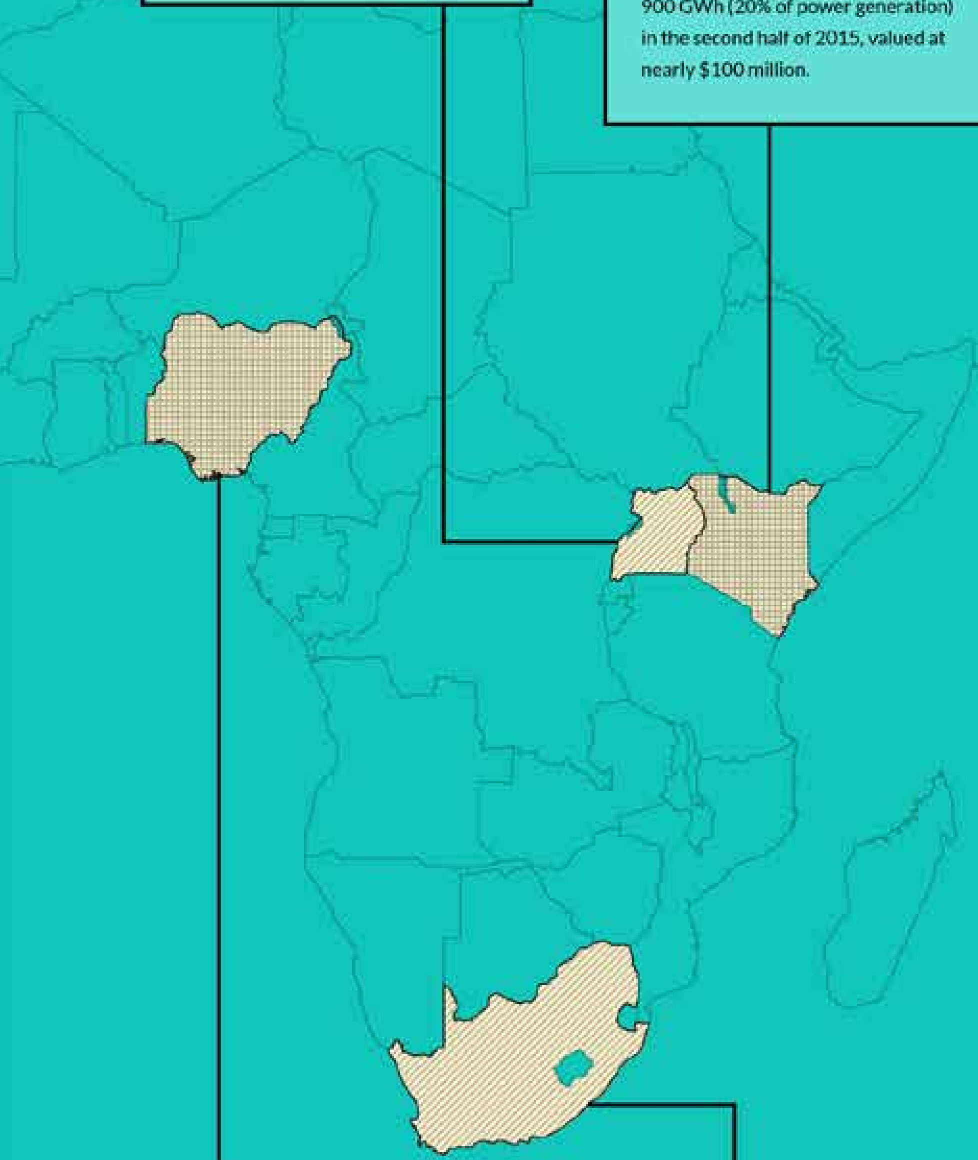
Meter by-passing: The input and output terminals of the meter have been shorted

UGANDA

Uganda's main distribution company, Umeme, estimated losses in 2009 to be 35%. Umeme loses $30 million a year to electricity theft.

KENYA

The main distribution company lost 900 GWh (20% of power generation) in the second half of 2015, valued at nearly $100 million.



NIGERIA

The Port Harcourt Distribution Company estimates that 60% of its customers do not pay their electricity bills, including a large proportion of customers with prepaid meters.

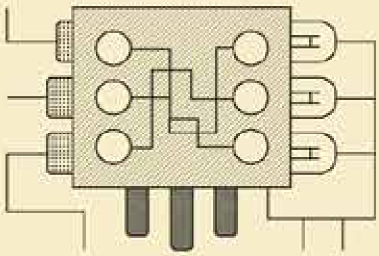
SOUTH AFRICA

Eskom's non-technical losses in 2015/16 were over $350 million, largely due to theft.

HOW IT'S BEING TACKLED

TECHNICAL/ENGINEERING METHODS

The Kamata, used in Uganda, measures current flowing through the mains cable and detects any attempt to by-pass the meter. If tampering is detected, it automatically cuts the power and sends details of the customer and location to the electricity distributor.

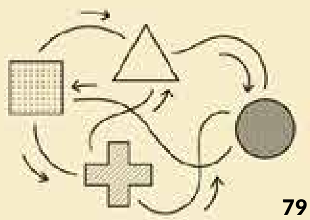


MANAGERIAL METHODS

Management contracts for state-owned utilities have been introduced in several countries to improve the efficiency of electricity services. These have increased collection rates and reduced losses.

SYSTEM CHANGE

- Restructuring the power sector and opening it up to commercial private sector actors.
- Building a relationship of confidence, greater transparency and trust between customers and distribution companies.
- Consumer education and information campaigns that build an understanding and awareness of electricity theft and its consequences.



Why is electricity stolen?

Most electricity theft is by individuals and organizations that consume large amounts of electricity and can afford to pay for it. In South Africa, two-thirds of collection losses were found to be by corporate, industrial and commercial customers. In Uganda, theft by large users accounted for 65 per cent of the collection losses of the largest distribution company[219]. Government organizations were among the biggest non-payers, owing US$19 million. Similarly, in Nigeria, where collection losses amount to 40 per cent of the power distributed, government organizations owed the distribution companies over US$390 million in unpaid bills at the end of April 2016, more than half of it owed by the army[220]. This shows a lack of accountability for non-payment within the public sector.

If poverty or inability to pay is not the driver behind most of the theft, the largest form of theft - non-payment of bills - may be due to a lack of trust between customers and suppliers[221]. This arises because customers mistrust the personnel who read meters and collect revenue; they mistrust bills, particularly estimated bills; they lack information and knowledge about their own electricity consumption; and they are frustrated by the poor reliability of the electricity supply. Distribution companies, for their part, may not be customer-oriented, having evolved out of the public sector, and may not trust their customers because of meter tampering and non-payment.

Both businesses and individuals steal electricity because they feel it is worth taking the risks of being caught and sanctioned. There may be little likelihood of disconnection or other sanction because of inefficiencies, corruption or the use of patronage relationships.

How is it being tackled?

Approaches to reducing electricity theft include technical and engineering methods, managerial methods and system change[222]. Utility companies and governments prefer technical approaches to reducing losses[223]. When losses are very high, it is clear that these alone will not be enough.

Technical and engineering methods: Pre-payment meters, introduced to Africa during the 1980s when power supplies were being extended to low-income families in South Africa[224], are a way to reduce non-payment. They are now in use in many countries including Ghana, Kenya, Nigeria, Sierra Leone and Uganda. Customers benefit from greater control over electricity expenditure and use, and avoidance of debt. Companies that distribute electricity benefit from improved revenue collection.

Revenue collection rates can also be increased through the use of bulk meters for supplies to groups of micro- and small enterprises. In Uganda, the use of bulk meters relies on the relationship between the enterprise operators and the individual responsible for the bulk meter and the group's payments to the electricity company.

In Nigeria, however, where a large proportion of customers do not have any kind of meter, the use of bulk meters is to end[225]. The high level of distrust with electricity billing throughout Nigeria may have contributed to this decision.

Increasingly, electronic "smart meters" are being deployed, which both record electricity consumption and communicate this information to the distribution company. Smart pre-payment meters record and display the amount of credit a customer has, and provide a way for customers to add credit to their account.

In Kitwe, Zambia, for example, pre-payment meters were introduced for all customers in 2010. Credit can be purchased from the state electricity utility, licensed vendors, banks and mobile-money systems. The customer receives a 12-digit number to enter into the meter[226]. In this way, customers have direct control over how much they spend on electricity.

The introduction of pre-payment meters does not reduce all electricity theft. Meters, including digital meters, can be bypassed, at the meter or by illegal connections directly to a low-voltage overhead line. Smart meters themselves can be subject to hacking and fraud.

Managerial methods: Switching to pre-payment instead of billing customers after they have consumed electricity is a management change made possible by meter technology. In some pre-payment systems, customers face difficulties or extra costs (such as transport) when purchasing credit. Digital systems can automate the monitoring of consumption and tracking of payments, which both reduces costs for the electricity company and eliminates opportunities for theft. Digital systems also allow electricity companies to analyse the flow of electricity through their distribution network to understand where theft may be taking place, automating the task of inspection. It does, however, require new technical capabilities within the company to take advantage of this.

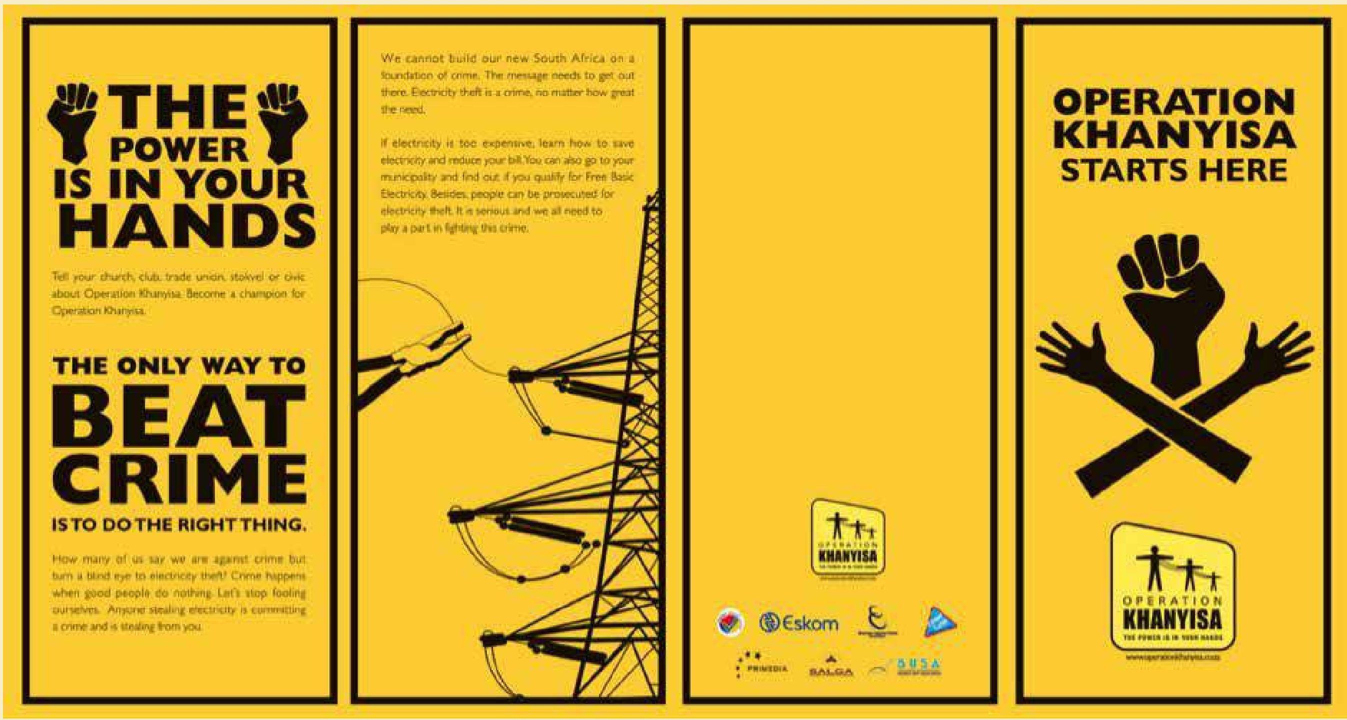
Management contracts for state-owned utilities have been introduced in several countries to improve the efficiency of electricity services. These have increased collection rates and reduced losses. In Tanzania, collection rates increased from 67 per cent to 93 per cent between 2002 and 2005 under a management contract[227].

In Kenya, management reforms increased revenue-collection rates from 81 per cent to 100 per cent between 2004 and 2006[228]. Since then, the main distribution company Kenya Power (Kenya Power & Lighting Company) has adopted a community-based approach to reduce the number of illegal connections in informal urban settlements. This includes actively promoting the advantages of a legal connection (safety, reliability, and affordability), backed by subsidized connection fees and tariffs[229].

System change: Power-sector reforms can help to reduce losses. Prevailing cultural and governance environments shape how sector reform has been undertaken and help determine the extent of electricity theft and the effectiveness of measures to tackle it. Restructuring needs to be accompanied by improved transparency and availability of information, which contribute to better governance within the sector[230]. The reduction of electricity theft also requires building confidence and trust between customers and distribution companies.

Consumer education and information campaigns can also help tackle electricity theft. An example is Operation Khanyisa, which was launched by Eskom in 2010 to address the problem of electricity theft in South Africa **(Figure 21)**. The campaign builds understanding and awareness of electricity theft and its consequences, educates consumers about energy efficiency and how to deal with electricity theft, and encourages the public to report electricity theft. Between 2010 and 2014, Operation Khanyisa recovered 689 million rand (about US$52 million) and led to over 138,000 disconnections[231].

FIGURE 21: OPERATION KHANYISA BROCHURE



Source: http://integratedreport.eskom.co.za/bec-customer.php

The restructuring of public utilities through privatization has not resolved the theft. Part of the answer lies in setting up effective governance and accountability systems to ensure that government ministries and agencies are held accountable for payment defaults of their energy bills, and to oversee private energy companies' activities and protect consumers against predatory practices.

Electricity theft can never be totally eradicated[232]. The challenge for many African power systems is to reduce theft to manageable proportions. Where systems are efficient by the standards of regional or international benchmarks, the efforts to control theft can focus on technological and managerial measures. In countries with very high losses, where the power system is inefficient and governance is likely to be poor, technological and managerial approaches will have more limited effects in cutting losses and increasing revenue.

BOX 7: THE GRAND INGA DAM – PROMISES AND PITFALLS

The Grand Inga Dam project in the Democratic Republic of Congo could generate almost half of the current power consumption of Sub-Saharan Africa[233]. The finished project, with a total capacity of about 40GW, would be able to generate at least 200 TWh. With an estimated generation cost of just US$0.03 per kWh, it encapsulates the ideal solution to Africa's energy trilemma of reliability, affordability and sustainability.

It involves a series of dams at the Inga site on the Congo River to be built in phases. It aims to connect regional power pools covering most of Africa, with transmission lines stretching as far as South Africa and Egypt.

The Democratic Republic of the Congo will be the main beneficiary. Although it accounts for half of Africa's technically exploitable potential hydropower, only 2.5 per cent of its hydro capacity has been developed. Tapping into even a fraction of the potential is likely to transform the energy-poor country into an international powerhouse, on the scale of China and Russia.

The scale and potential of the Grand Inga initiative is not complex from a technical and engineering perspective. It has captured the imagination of African governments and the international development community for decades. The first two dams at Inga were completed in 1972 and 1982. However, only 20 per cent of their initial 2GW total generating capacity is currently operational. The project's failure to deliver is the result of huge debts contracted during construction coupled with low utilization rates and insufficient revenues, which fuelled a constant cycle of poor performance. Rehabilitation is under way but has repeatedly been delayed amid financing and governance concerns.

These can be overcome through building political consensus and implementing Grand Inga as a pan-African project. It has strong support and backing from the African Union, its New Partnership for Africa's Development (NEPAD), the African Development Bank and the multi-agency Programme for Infrastructure Development in Africa (PIDA), as well as the leaderships of Nigeria, South Africa and the Democratic Republic of the Congo.

The substantial capital outlays necessary, US$80 billion-$100 billion, with a lot more needed to deploy transmission and distribution networks, make Grand Inga one of the world's most costly projects. China's growing interest in Africa's infrastructure development could provide a significant boost.

The first phase, Inga III, with generating capacity of 4.5GW, is expected to cost US$5 billion to US$12 billion, with financing structured as a public-private partnership. In August 2016, a Chinese consortium of China Three Gorges Corporation and Sinohydro was competing against a Spanish consortium of Actividades de Construccion y Servicios and Eurofinsa. If expected financing comes from China's Exim Bank and state-owned banks, Grand Inga could become the largest Chinese-funded infrastructure project.

The risks are too high for most international investors. One way to mitigate the risks is to build adequate demand for generated electricity. The Democratic Republic of the Congo and South Africa have signed an agreement on the off-take of 2.5GW of electricity by 2020[234] and the construction of transmission lines. (continued)

Agreements are being reached with Egypt and Nigeria. However, supplying a large volume of electricity to regional markets without developing the domestic market could heighten the country's political risks. To build domestic demand, the mineral-rich country could develop energy-intensive industries such as aluminium and copper refining. Investors would need to be convinced that they have sufficient risk-adjusted return, especially with regard to certainty of power delivery.

The Grand Inga project will be executed in multiple phases over a span of many years, so only a portion of the total capital will be required each year and cash-flow from earlier phases should be able to inject a meaningful amount of capital for later phases, with the likelihood that the project would eventually become "self-financed".

Cross-border coordination is vital, as the execution of Grand Inga will entail building and managing a matrix of grid systems across several countries. There should be comprehensive planning at national and regional levels, inter-regional rule-setting and close coordination among partner countries throughout the project's lifetime. NEPAD can serve as the credible authority, working through political consensus to manage cross-border issues and ensure mutual benefits for all partners.

Domestic political uncertainty had threatened the viability, but seems to be ebbing with the recent agreement on a political transition in late 2017. Strengthening national governance systems and finding solutions to shared problems using continental platforms could prove critical to ensure execution and protection of Grand Inga as a common African public good.

Concerns have been raised over the environmental, social and economic costs. The diversion of the Congo River will affect natural habitats, agricultural land, communities and livelihoods, and could displace 30,000 people. The World Bank has assessed the impacts as minimal, however the concerns are legitimate and taking them into account will maximize the project's benefits. The World Bank later suspended technical assistance funding in July 2016[235] citing "a different strategic direction".

It is urgent to secure financing for a comprehensive environmental and social impact assessment, expected from the NEPAD Infrastructure Project Preparation Facility (IPPF) and the African Development Bank.

The Grand Inga initiative is achievable, provided that it is well structured and risks are mitigated. Strong political impetus at the national and regional levels can mobilize financing, structure and build the project, and transform Africa's power landscape.

REGIONAL POWER TRADE COULD TRANSFORM AFRICA

Cross-border power trade is needed to ensure Africa can provide affordable energy and that new energy-generation and transmission projects can be viable, as well as accelerating the continent's wider integration agenda. Cost-effective generation and trade of electricity at the regional level would help to resolve the African energy trilemma of affordability, reliability and sustainability[236]. Yet less than 8 per cent of power is currently traded across borders in Africa.

The ultimate goal should be to bring together and interlink Africa's numerous and fragmented power initiatives to create a single pan-African power superhighway. To achieve this goal, African countries will have to commit to a much deeper level of cooperation and overcome the lack of financing for supranational interconnection projects.

Power trade provides the opportunity to export surplus electricity from countries in excess to those experiencing power deficits, within and across regions. The pooling and optimization of resources promises US$50 billion[237] savings in generation expenditure. Similarly, levelized costs of energy are expected to drop by 6 per cent in Southern Africa and 10 per cent in East Africa, making cross-border electricity cost-competitive.

Over the years, various cross-border initiatives have been implemented in a bid to improve regional interconnection and power trade. As a result, Africa's power-interconnection capacity nearly doubled between 2005 and 2011, from 5.4GW to 9.3GW[238]. Most recently, major regional power projects under way are likely to boost the continent's interconnection capacity significantly in the near future once they come online.

A continental framework for power trade already exists

Massive power projects have the potential to unlock economies of scale and make business sense only when shared among countries. Cross-border power initiatives therefore stand to benefit from effective regional power-sharing arrangements and cooperation. This is true for Africa's flagship power projects such as the Grand Inga Dam **(Box 7)** and the Grand Renaissance Dam in Ethiopia (6GW), but also holds true for initiatives such as the Manantali Dam in Mali and the Rusizi III hydropower project straddling Burundi and Rwanda.

The Programme for Infrastructure Development for Africa, which was endorsed in 2012 by the summit of the Assembly of African Union Heads of State and Government, provides the strategic underpinning to guide the development of cross-border power infrastructure and drive investments in Africa. It is a collaboration between the African Union Commission, the NEPAD Secretariat and the African Development Bank, the latter acting as the executing agency of the programme.

The programme serves to accelerate regional power projects, particularly those for regional interconnections. Under this framework, 15 energy projects, including 9 hydropower projects, 4 transmission corridors and 2 pipelines (one gas, one oil) with a total price tag of US$40.5 billion, have been prioritized for implementation between 2012 and 2020[239].

Many of Africa's energy resources are shared (for example, water resources) and persisting weaknesses exist at regional levels, especially in terms of cooperation and financing. There is an increasingly glaring need to adopt a continental approach to power infrastructure development and management. The objective is to build and strengthen strategic infrastructure, increase the flow of cross-border power trade and shield continental public goods from uncertainties and risks[240].

The leading Pan-African institutions have particular roles to play in increasing cross-border power trade[241]. These are the African Union, the African Development Bank and the Economic Commission for Africa, as well as the eight continental regional economic communities that are recognized as the building blocks of the African Union.

Regional power trade has yet to overtake bilateral deals

There are currently five regional power pools, set up on the basis of existing regional economic communities[242].

- Southern African Power Pool (SAPP), to which all mainland countries in the Southern African Development Community (SADC) are connected, with the exception of Angola, Malawi and Tanzania
- West African Power Pool (WAPP) connects 14 countries in the Economic Community of West African States (ECOWAS)
- Central African Power Pool (CAPP) links 11 countries in the Economic Community of Central African States (ECCAS)
- East African Power Pool (EAPP) connects countries in the Common Market for Eastern and Southern Africa (COMESA) and Nile Basin Initiative member states (including Egypt and Tanzania)
- North African Power Pool (NAPP) links countries in the Arab Maghreb Union (AMU).

By and large, these power pools are in a developmental state, which explains the limited power flows within regions. Most of them are in the process of developing their respective master plan, which will be their guiding tool for coordinating regional interconnection and integration efforts. Furthermore, there are very limited links between the power pools[243].

Accordingly, only 8 per cent of power flows across borders in Africa. The bulk of regional power trade (7.5 per cent) takes place almost exclusively within the Southern Africa Power Pool, which traded close to 5.3 TWh of electricity in 2012-13. As the main producer, South Africa exports power to Botswana and Namibia and it imports electricity from the Cahora Bassa Dam in Mozambique to re-export it to provide power to the mining sector in southern Mozambique. Elsewhere, less than 1 per cent of power flows within the Central African and East African power pools. There are few interconnections between countries in the North African Power Pool.

Regional power integration and trade has been constrained by the lack of an efficient infrastructure network for transmission and distribution. Much of the power flows between neighbouring countries on the basis of bilateral agreements. In many cases, this has proved to be a successful arrangement in lieu of weak regional connectivity. In West Africa, this is the case with the long-standing two-way power trade flows between Ghana and Côte d'Ivoire. Additional examples include the one-way bilateral agreements between South Africa and Namibia and South Africa and Botswana, as well as Kenya's power import from Uganda[244].

In recent times, Ethiopia is emerging as a major player in power trading in East Africa. Interconnection lines include the region's first power connector with Djibouti in 2012[245] and the roll-out of transmission lines to connect with Kenya, with further big expansion plans.

Recent developments

In a bid to address weaknesses and accelerate regional power integration, African countries have agreed to strengthen existing and prospective interconnections within and across power pools. They call for greater regional coordination in planning initiatives and harmonizing policies, procedures, standards, systems and market frameworks, among others[246]. A range of concrete measures have been put in place in order to create and improve interconnections and high-voltage transmission backbones.

Power corridors: The Programme for Infrastructure Development in Africa has prioritized the development of four corridors[247]:

- The North-South transmission link from Egypt to South Africa
- The central corridor from Angola to South Africa
- The North African transmission link from Egypt to Morocco
- The West African power transmission corridor from Ghana to Senegal

The aim of these corridors, with branches extending in each of the regions, is to strengthen interconnections across the various power pools.

Power interconnections: Africa is moving towards greater regional power connectivity and launched several interconnection initiatives in recent years. Examples include the 2GW capacity, 500kV transmission line linking Ethiopia to Kenya, expected to become operational this year, and the 400KV transmission line underway to link Kenya, Uganda and Rwanda, with capacity to accommodate 500MW of cross-border power trade[248].

Prospects for increased regional power integration look bright for East Africa. Projects planned for development between now and 2020 are Sudan-Ethiopia, Egypt-Sudan, Rwanda-Tanzania, Uganda-South Sudan, Libya-Egypt and Kenya-Uganda interconnectors[249]. Supply agreements have been reached and work on grid codes is already underway.

In West Africa, the 225kV transmission line linking Côte d'Ivoire, Liberia, Sierra Leone and Gambia (CLSG) is one of the priority projects of the West African Power Pool and will connect to the existing Côte d'Ivoire-Benin-Togo-Nigeria interconnection. It will cost US$500 million and is expected to come online in 2017. Projects in the next three years include the 225kV interconnector spanning Guinea and the subregion, which has a transfer capacity of 800MW and a price tag of close to US$900 million, as well as plans to connect Ghana's grid to those of Burkina Faso and Côte d'Ivoire.

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AFRICA IS MOVING TOWARDS GREATER REGIONAL POWER CONNECTIVITY.

In Northern Africa, a 400MW one-way interconnector already links Morocco to Spain[250]. A further 4.5GW of interconnection will be added through the North Africa power transmission corridor linking Egypt, Libya, Tunisia, Algeria and Morocco. Other proposed projects include 400KV interconnection project with a capacity of 4GW, which will link the southern part of the Mediterranean Basin (Algeria and Tunisia) to the northern part (Italy and Spain), partly in the context of the DESERTEC power project[251].

The Southern African Power Pool uses many existing interconnectors. The Southern African Development Community (SADC) is building the first power interconnector between regions, linking Zambia, Tanzania and Kenya. The first phase was due to start operations at the end of 2016[252]. The US$1.4 billion project was implemented on the basis of a tripartite cooperation among three regional groupings – the Common Market for Eastern and Southern Africa (COMESA), East African Community (EAC) and Southern African Development Community (SADC). Under the agreement, each country is required to build infrastructure within its borders, with Zambia as the lead coordinator, and to establish trading mechanisms.

Another flagship project under construction is the Zizabona interconnector, linking Zimbabwe, Zambia, Botswana and Namibia, which is expected to accommodate the flow of 600MW of electricity generated by existing and prospective hydropower plants in Zambia and Zimbabwe[253]. Given the high financial costs involved (US$5 billion), SADC is urging its member states to transition to cost-reflective tariffs by 2019 in order to stimulate private investors' interest in the project. Nine other priority transmission projects with a price tag of US$4 billion are in the pipeline. South Africa's agreement to purchase 2,500MW of generated electricity from the Grand Inga dam has given the project a much-needed boost. What remains now are decisions concerning the best route for transmission lines between the two countries. Interconnectors could also be set up to link the dam to Nigeria and Egypt.

Current initiatives

Transmission lines: East Africa is investing heavily in the roll-out of high voltage lines in an effort to integrate regional power markets[254]. It is expected that between 2016 and 2018, a number of transmission lines will be completed, linking Kenya to Uganda, Ethiopia to Kenya and Tanzania to Kenya. Some of the financing will come from Chinese sources, as in the case of the Ethiopia-Kenya power connection project. A major complaint has been that projects have been consistently falling behind schedule for lack of proper planning and coordination, adequate financing and other issues such as land disputes.

Generation capacity: In East Africa, the Rusizi III hydropower plant recently secured US$138 million in financing (out of the total of US$625 million) from the African Development Bank, as a priority project[255] of the Programme for Infrastructure Development in Africa. The regional initiative, which straddles the Democratic Republic of the Congo and Rwanda and feeds into the East African Power Pool, will add 147MW to the regional power-generation capacity. This project is the first in the region to be built under a public-private partnership arrangement, with the Great Lakes Energy Organization responsible for overseeing the project development.

Power projects underway in Southern Africa were to add 3GW of new capacity to the regional grid[256] in 2016. South Africa was expected to contribute the largest share with the commissioning of at least three power plants with a combined output of over 1.5GW. Other significant contributions to the Southern African Power Pool come from Zambia (300MW) and the Democratic Republic of the Congo (430MW). Angola has announced massive investments in power projects at a time when it is hard hit by plunging oil prices. It was expected to increase the region's generation capacity by 780MW in 2016, although it was not not yet connected to the regional power pool.

Trends in power trading

Some experts contend that electricity will become the most traded commodity in the near future, particularly in the Southern Africa market[257]. Power trading has increased within the Southern African Power Pool: trading was valued at US$50 million between April 2014 and March 2015[258]. The traded volume exceeded 900,000MWh, up from 508,000MWh a year before, as a result of short-term power trading by power-pool countries in order to reduce black-outs and load-shedding. Investment in regional interconnectivity will be sustained.

Hydropower will continue to dominate regional power trade, especially in East Africa. Its share in the energy mix is likely to rise in the Southern African power market with 430MW generated by the Democratic Republic of the Congo to be added to the Southern African Power Pool during 2016. Gas is fast emerging as a major commodity, particularly in Southern Africa, with plans to implement the African Renaissance Gas Pipeline (ARPG) linking Mozambique to South Africa[259]. Tanzania, itself a major gas producer, is making preparations to commence work on a gas pipeline connection with Uganda. A portion of the generated power will cater for the electricity needs in both countries.

When it comes to regional gas pipeline initiatives, Ghana's experience offers warnings. Following the completion of the 680 km West African Gas Pipeline (WAGP) in 2005, gas supply reached Ghana only in 2008. Even then, supply has been intermittent with incidents of vandalism further upstream in Nigeria, coupled with damages and irregularities elsewhere. The situation soon became dire and regular gas shortages forced Ghana to ration power[260]. But, with recent discoveries of offshore gas fields, Ghana is exploring alternative ways to resolve its gas issues. As the West African pipeline dried up, the country is seeking to develop its own gas fields and commission new gas-power plants to offset the lack of regional gas supply[261].

A novelty in regional power trading is the commercialization of power generated by Kenya's Olkaria Geothermal Plant, which will feed into the Eastern African Power Pool. The initial agreement signed was a 30MW power sale by Kenya to Rwanda, transiting through Uganda by July 2015. This year, Kenya, Uganda and Rwanda will start trading 15MW of power, in spite of delays in the execution of the 400kV transmission line, which has a transfer capacity of over 500MW between the three countries[262].

Diversifying the energy mix and reducing dependence on hydropower in the context of climate change and recurrent drought will go a long way towards strengthening regional power pools and flows. However, experts in the SAPP region caution against an increase in clean energy uptake by regional power pools, because of rising load and back-up problems, as was the case for Cape Verde for instance.

Challenges

Despite encouraging progress, the road leading towards Africa's power superhighway is fraught with challenges. A number of bottlenecks and weaknesses are constraining the development of regional power initiatives. A different approach is required to mitigate and reduce risks when dynamics emerge that are beyond the competence of regional power pools.

Power infrastructure and markets: Lack of infrastructure is often cited as a primary constraint to regional power cooperation. An efficient and reliable cross-border transmission network is a pre-requisite for the integration of energy markets. One muted issue is that individual countries adopt a protectionist stance with regards to their national power plans and are uneasy about relying on power imports, for fear of becoming energy-dependent. Another cause for concern is the limited size of regional power markets, as this tends to raise the costs of electricity generation instead of driving them down. There is a need to develop demand for power when developing large-scale projects and large anchor projects are deemed necessary to justify the scale and cost of large infrastructure developments[263].

Regional cooperation: Strong regional cooperation is essential to the success of large-scale regional projects and should be governed by a robust regulatory framework. Countries must coordinate all activities pertaining to the project throughout its lifetime and address issues as they arise, in particular related to energy security[264]. A typical example of failed cooperation is Egypt's recent pull out from the East African Power Pool over the use of the Nile waters[265]. The master plan signed by all member states with the exception of Egypt will go ahead as planned, but Egypt's announcement is likely to delay the delivery of the Libya-Egypt and Egypt-Sudan interconnections.

Governance: Governance arrangements should be determined for clarity and expediency of regional power initiatives[266]. These include whether it is privately or state-owned or a public-private partnership, defining the collaboration among various regional blocs and groupings, explaining the auction systems, and clarifying the number of entities to be involved and the sharing of benefits from power-purchase agreements.

Financing: Regional projects require substantial investments and financing is a persistent challenge. Multilateral banks, and in particular the African Development Bank, provide a portion of the financing usually complemented with other sources, such as the United States of America, China and the European Union. Although revenues derived from power exports help, African countries have to look for alternative ways to mobilize financing, often in the form of budgetary allocations.

Developing a viable business model: One study on interconnections in the Mediterranean Basin argues it is crucial to develop the right business model for regional interconnections[267]. It suggests that the key features for a successful business model include:

- Incentives for investment and efficient operation
- Management of risk and uncertainties
- Coordinated planning and governance

Since African regional power pools have varying levels of interconnection and market structures, it is not straightforward to choose between a regulated system and a market-based system.

GETTING THE FINANCES RIGHT: MAKING POWER SUSTAINABLE

Many African countries are working to ensure universal access to energy for all by 2030, in line with Sustainable Development Goal 7, despite their severe budget constraints. How do planners decide which option – including stand-alone or off-grid, mini-grid and national grid – offers the best value for money, given circumstances such as location, power sources and consumers' incomes and power usage? Financial assessment is a vital tool that enables planners to compare, select, finance, execute and maintain power projects across generation, transmission and distribution.

Location-specific costs: Four key parameters are considered in each location: i) how much and what quality of energy is required, ii) what is the population density, iii) is there a grid connection nearby, and iv) what other local resources are available and what is the cost of the technology to make them supply electricity?[268] Assessing how much and what quality of energy is required involves the six-tier framework **(Figure 15)**, from Tier 0 (only torch and radio or less than 3kWh per household per year), up to Tier 5 (heavy or continuous appliances such as air conditioning, in addition to heating water, ironing, pumping, cooking rice and refrigeration, which uses more than 2,121kWh per year). Lower population densities mean higher cost per household connected and influences transmission and distribution choices. Distance to the nearest grid influences both connection cost and transmission losses, and the cost of grid electricity is also important. Alternative local power sources could include a nearby good location for wind, solar, hydropower, or biomass resources. The cost and availability of diesel also needs to be considered.

Using these parameters can determine the best technology and connection in each case, based on two measures: the total cost per household connected between 2015 and 2030, and the levelized cost of electricity (LCOE), which determines whether a project could break even over its lifetime.

It is possible to use geographic information systems (GIS) or other geo-referencing software both to explore local solutions and to build complex regional studies. Researchers have produced maps of different connection types for different parts of Nigeria and Ethiopia, based on anticipated expansion of main transmission lines and the power plants operating, being built, planned or under consideration. They suggest that grid-based power is the least-cost solution for 85 per cent of newly electrified households in Nigeria and 93 per cent in Ethiopia, but that mini-grid and standalone are both significant in areas with low population density, which in Ethiopia means large areas of the country.

Affordability: One-third of all people in 22 surveyed Sub-Saharan African countries use electricity and they are disproportionately urban and rich[269], although two-thirds of households are in rural areas. Even in communities where there is a connection, lack of affordability is the main reason why other households cannot access electricity. Only six of the countries offered very low prices for low usage (30kWh a month or less), and affordability is exacerbated by sharing meters between households and high connection costs.

Electricity was defined as affordable if households that use 30kWh or less a month, spend less than 5 per cent of their monthly consumption spending on electricity. Grid electricity even at the subsistence level is out of reach for the poor in 11 countries, and this was worse after connection charges were considered. Some households pay too little or nothing, through fraud (tampering with meters), stealing (illegal connections), billing irregularities and not paying their bills. Steps identified to help the poor access electricity include individual meters, subsidizing installation, encouraging prepaid metering, reformulating minimum usage ("lifeline") rates, and stamping out corruption to eliminate bribes. Prepaid meters encourage small frequent transactions, which are more suited to poor households than a monthly billing cycle, remove reconnection costs and discourage unpaid bills.

Similarly an earlier study[270] showed that two-thirds of 27 African countries used increasing block tariffs, and some added extra subsidies for the poor, although some had relatively high fixed charges of US$1-$3 a month. Average effective tariffs were affordable for 90 per cent of the existing customers but would be affordable to only 25 per cent of households that were not yet connected. Nearly 80 per cent of countries fully recovered their operating costs, but only 30 per cent fully recovered capital costs.

Connection costs are particularly significant for off-grid renewable energy supplies, such as household solar. Low income customers usually do not have the capital for these and rolling them out depends on innovative[271] business models.

Financing gap: Nearly half the US$8 billion spent in 2013 on financing Africa's energy infrastructure is thought[272] to have come from domestic public financing, with the rest coming from private participation in infrastructure, official development finance and Chinese investments. As mentioned in the Africa Progress Panel's 2015 report Power, People, Planet, the total cost of financing energy infrastructure needs was US$63 billion in 2013 alone, leaving a US$55 billion gap.

Official development finance was the main source of external infrastructure finance in the 1990s and remained significant at nearly 35 per cent of all finance in 2012, when US$3.5 billion was invested in energy projects. Private participation in infrastructure is growing fast, but electricity financing was only 19 per cent of the total in 2005-2013. Generation attracted most of the private and Chinese finance, while transmission and distribution were mostly financed by governments and China. Over 2010-2015, China financed US$13 billion or a fifth of all investments in power in Africa. Renewable energy accounted for 56 per cent and of the generation capacity (including 49 per cent on hydropower). The Power Africa initiative of the United States committed US$7 billion over four years and acted as a focal point for a range of US agencies and the private sector. The European Union is deepening its energy cooperation with Africa through the Africa-EU Energy Partnership.

Initial costs to set up large-scale renewable energy projects are usually higher than for carbon-intensive projects, including where generators are built for coal or other supplies. Appropriate incentives need to be devised if the mix is to take a longer-term and global approach, including benefiting the world through lower carbon impact.

Governments can improve the efficiency of their investment processes, for instance up to 40 per cent of public investment in low-income countries[273] is lost through delays, cost overruns and inadequate maintenance. Domestic capital markets can be a useful channel for raising local-currency long-term infrastructure finance, either through bonds or other investments. Effective domestic capital markets would also encourage long-term institutional saving, such as pension and insurance funds, and foreign investors using local-currency instruments.The African Development Bank and the International Finance Corporation are boosting local-currency financing.

A bigger pipeline of bankable feasibility studies can encourage the flow of investment. These can be created by national governments, regional economic communities, financiers and multilaterals, experts and specialist project-preparation units. Established risk-mitigation mechanisms, including the World Bank's Multilateral Investment Guarantee Agency (MIGA) and its International Development Association Partial Risk Guarantees, are key to launching many projects and to reducing their costs.

Investment and development banks can specialize in developing and building projects and handing them over, once cash-flows are more predictable, to other institutions such as pension funds[274]. At the same time, having a partner such as the African Development Bank or the World Bank in a consortium encourages private investors who believe these can apply soft pressure to governments to honour commitments.

Challenges to be addressed to attract more private and international investors include reducing political and country risk, ensuring the profitability of projects is commensurate with the risks, and the legal and regulatory environment[275]. The framework for investing into energy projects can be more favourable through: predictable tariff regimes, simplified licensing procedures, standardized "technology-based" power-purchase agreements and realistic energy-planning tools[276]. Key to feasible generation projects are power-purchase or off-take agreements. Investments in transmission and distribution also require creditworthy and effectively managed power utilities that can afford to meet their obligations, and effective grids that do not waste much money through losses and breakdowns.

Financing industry: Inadequate electricity imposes crippling costs on businesses. Business leaders say power supply is the top obstacle to the region's growth. African businesses are estimated[277] to lose 5 per cent of annual sales due to power outages. Already, privately owned diesel generators supply more than 5 per cent of total electricity, mostly to businesses, and the costs of running back-up generators are equivalent to between 1 and 4 per cent of gross domestic product (GDP). For example, Nigerian manufacturers spend four to eight times as much of their manufacturing costs on power generation as their competitors in similar economies.

Instead businesses can create "captive" power-generation units[278] strategically located in areas with high demand, as outlined in Part II above. These mini-grids can improve reliability and quality of power supply – which is essential for competitive manufacturing – reduce losses on transmission and significantly cut time, planning and investment capital for new projects. Users can add or take away generation units as demand changes, and may also be able to sell excess power back into the national grid. Power-supply companies can choose customers based on their creditworthiness, instead of relying on a single buyer like a distribution company or state-owned utility. They can also provider cleaner and more efficient generation than the individually owned diesel generators on which many businesses currently depend. Making captive mini-grid power work requires a favourable policy and regulatory environment, established local industries, reliable fuel supplies (including gas), technical knowhow and business skills. It offers a scalable, bankable investment option for tackling the power deficit that is crippling businesses.

Africa's lack of power is holding back development across the continent. It hampers the businesses that already provide economic growth and jobs. Their competitors have cheaper and more reliable power, hindering their growth. The power gap also blocks development, education and health at household level.

This paper shows that many options are available to African policymakers, including reforming regulation, restructuring utilities, holistic planning and encouraging the wide range of solutions appropriate to different settings, including off-grid, mini-grid and renewable energy inputs into the national grid while expanding access. It outlines the step and reforms necessary to achieve this and discusses experience and potential in financing these projects as well as in making power systems more efficient and sustainable.

The paper highlights where success stories are already working in Africa, demonstrating solutions that can be scaled up and replicated by other countries.

PART IV: POLICY INSIGHTS

Africa's huge energy needs have sparked a greater sense of urgency and a higher level of ambition across the continent, with new initiatives since we published the 2015 Africa Progress Report, *Power People Planet: Seizing Africa's Energy and Climate Opportunities*. This new report shows how to sustain and extend that urgency and ambition, by using every available means to accelerate electrification – on and off the grid, via projects large and small. We also evoke Africa's potential to leap forward by harnessing the emerging forces that are shaking up technology and energy markets worldwide. **(See infographic: Disruptive innovation unlocks Africa's energy future)**

In this section, we gather some of the paper's key policy insights, shedding light on the necessary ingredients of Africa's energy transition, including: national and regional planning frameworks, policy and regulatory frameworks, finance, capacity-building, power-sector reforms, developing new energy systems, and special measures to support off-grid solar, other renewables and mini-grids.

Underpinning these policy insights, and indeed the entire paper, are the following key messages.

The first is that if countries are to have greater control over their energy pathways, they need to find ways to address the serious capacity deficit. This requires significant investment and a long-term strategy of building knowledge institutions that will supply the technical, managerial and policy workforce.

Second, and related to this, domestic actors need to assume a stronger and more central role in planning, financing and implementing projects.

Third, the global consensus on switching to renewables is good news all round. However, there is a risk that, as investment financing for energy tends increasingly towards renewable energy sources, African countries may find that building needed generation, transmission and distribution infrastructure lags while they make that transition. This is why we have called for countries to adopt a judicious energy policy mix that will enable them to meet their pressing short-term energy needs whilst transitioning to renewables in a phased and realistic time frame.

Finally, South-South cooperation is critical: many of the lessons and resources needed to take Africa into a new age fuelled by renewable energy will come from the Global South. As we have highlighted in this paper, innovation is already happening, fuelled by the opportunity to leapfrog. Learning from what is working in developing countries and regions of the world will be crucial to Africa's energy transformation.

DISRUPTIVE INNOVATION UNLOCKS AFRICA'S ENERGY FUTURE

Radical change that reshapes markets

GLOBAL MEGATRENDS:
Urbanization, demographics, technology and political shifts are changing the ground rules and opening markets.

AFRICA'S LEAPFROG:
Bypassing fixed lines and leaping straight to mobiles, Africa showed its capacity to adapt and innovate.

SCALE, SCOPE & COMPLEXITY:
The energy market is considerably bigger than telecoms. Expect huge and rapid transformation.

GLOBAL

Shaking up markets: The mega-disrupters

UBER | facebook | TESLA

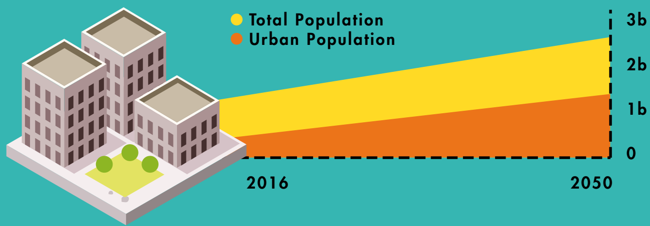
Global megatrends: Disrupting the energy sector

Innovations in energy storage could make off-grid customers self-sufficient

Energy saving technologies such as **Ecoisme, Rachio, Ecobee** and **Tado°** can track the energy consumption of any device and provide recommendations to reduce energy usage

AFRICA

Demographics: Africa's population is projected to reach 2.5 billion by 2050



Urbanization: By 2050, half the African population will live in cities compared to just over one-third today

Technology: Advances in technology are providing new possibilities for on-grid, off-grid, mini-grids and hybrid-technologies for energy provision

Shifts in Political Priorities: Energy access has become a political imperative. New policies and regulations are making room for increased investments in the energy sector

Africa's entrepreneurs leapfrogging to a low-carbon economy

M-Kopa: *(Kenya, Tanzania, Uganda)* A disruptive business model where customers access solar energy and pay off gradually

Sahelia Solar: *(Burkina Faso)* Supplies off-grid solar energy to small business using the pay-as-you-go system

Mandulis Energy: *(Uganda)* Generates reliable and affordable electricity from agri /agro-processing waste for grid and off-grid communities in emerging markets

Africa Biogas Partnership Programme: *(Ethiopia, Kenya, Tanzania, Uganda, Burkina Faso)* Could displace traditional cookstoves for half a million people by 2017

STRENGTHEN NATIONAL AND REGIONAL POLICY FRAMEWORKS

Build supportive and coherent national policy frameworks for electrification strategies that establish:

- Planning designed to encourage public-private partnership where appropriate, and to ensure a full range of solutions including off-grid and mini-grid, renewable and conventional, backed by effective transmission and distribution to customers as well as revenue collection
- A clear national planning and project evaluation system, including use of geo-spatial information system (GIS) planning tools
- Measurement tools to incorporate off-grid and mini-grid solutions, including compatibility to the grid
- The rate of expansion of electrification, aligned to electrification targets whether the system is centralized or decentralized
- A stable operating environment with clear and predictable policies, regulations, processes and standards
- Tariff-setting mechanisms specific for renewable and mini-grid projects and socio-economic conditions
- Commitment to leverage the benefits of the energy industry by developing local value chains (manufacturing and research and development) that will create jobs for both the high and low ends of the labour market and by creating linkages with other economic sectors
- Robust capability of public institutions to undertake high-quality analysis and implement policies
- Develop capacities, skills and experience
- Commitment to inclusiveness and environmental sustainability

Enhance regional policy cooperation

- Accelerate regional power integration by ensuring effective cross-border regulations and business models
- Invest massively in regional transmission infrastructure
- Harmonize grid codes at the regional level for renewable energy, quality of power supply and planning of power generation and transmission
- Set up power-trading mechanisms and foster cross-border and cross-regional power trade by developing new power-trading arrangements
- Mobilize alternative finance for regional power initiatives

OFF-GRID SOLAR – CLIMBING THE POWER LADDER

Lay the foundations for a vibrant off-grid solar industry

- Make electricity planning transparent so that families and communities can invest in off-grid generation, knowing when they might be linked to a wider grid
- Engage the utilities to explore modalities for their participation in the off-grid market
- Incorporate targets and timelines for the number of solar products to be delivered through the markets, signalling support to private players

Kick-start the off-grid solar market

- Remove tariffs and barriers such as complex importing processes in order to accelerate the introduction of off-grid solar technologies
- Consider performance-based grants as a way of attracting market entrants
- Examine models and approaches for unlocking domestic private finance
- Bridge the financing gap by relaxing regulatory barriers that limit currency exchange and by extending public finance or providing loan guarantees

Bring the off-grid solar market to scale

- Provide financial and technical support to train solar technicians and to foster entrepreneurial manufacturers and distributors of solar products and energy-efficient appliances
- Ensure consumer loans are available from microfinance institutions or through pay-as-you-go mechanisms
- Establish the regulatory environment and infrastructure for mobile money, where it is lacking
- Establish lines of credit for microfinance institutions to lend for solar solutions
- Educate people about the potential cost savings and health benefits of electric lighting
- Stimulate innovation in energy-efficient appliances customized for the off-grid market by supporting technical training programmes, strengthening intellectual property laws and investing in research and development.

MINI-GRIDS - SERVING "THE MISSING MIDDLE"

Design an adequate strategy for mini-grids

- Create policy regarding the tariffs that mini-grid operators can charge
- Link with the productive sector as a way to ensure financial sustainability of mini-grids
- Create policy for the type of mini-grid models to be used including: technologies; purpose – community, commercial, industrial; size; compatibility of mini-grid systems for integration into the national grid in terms of standards for distributed networks; and exit strategies for mini-grid investors in the event of becoming connected to the national grid

Design a coherent regulatory and policy framework for mini-grids

- Technical regulations that set engineering and construction standards, environmental regulations and quality-of-service standards
- Financial regulations governing tariffs, which are fundamental to the financial viability of mini-grid operations; fiscal regulations; public subsidies and incentives; and regulations for financing mechanisms
- Process regulations such as rules for licensing and permits (for example for electricity generation and distribution), regulation of contracts, requirements for community engagement and procedures for service connection and disconnection

MENDING AND EXTENDING THE GRID

Make energy planning more effective

- Identify and execute key projects that will produce fast returns in terms of developing and strengthening energy infrastructure (power supply, transmission and distribution, new grid networks)
- Improve electricity coverage and reduce disparities and disruptions, including using technological advances
- Adjust tariffs to ensure new grid projects can be viable, and explain to populations why this is necessary; progressive tariffs ensure electricity is affordable to the poor; competitive tariffs encourage industry and small and medium enterprises, and offer cheaper and more reliable supply than using standalone diesel and other generators

Reduce loss

- Improve maintenance and efficiency, and curb transmission and distribution losses
- Reduce electricity theft via technical/engineering methods, managerial methods and system change
- Strengthen revenue-collection systems
- The public sector, which is responsible for a significant share of unpaid energy bills, setting an example by paying power bills promptly.

Improve financing

- Provide secure off-take agreements including predictable and regulated prices and tariffs; and ensure that the power purchasers signing the agreements have the financial strength to honour these
- Identify and create robust frameworks to boost local financing of power infrastructure and projects including: the investment environment, the regulatory framework for independent power producers and other public-private partnerships, and the capital-markets framework to meet the needs of local domestic and international financing partners, including local-currency channels (such as infrastructure bonds).

Boost renewable energy supply

- Create incentives to boost the share of sustainable and renewable energy in the power mix
- Create opportunity maps and use GIS tools to identify the full range of renewable energy projects, including wind, geothermal, natural gas, biomass, methane, hydropower and solar, and incorporate all of these into the planning
- Learn from successful examples in countries such as South Africa and Morocco, where generation costs from renewable energy sources are among the lowest worldwide. South Africa's Renewable Energy Independent Power Producer Procurement Programme (REI4P) could be adapted with caution for the needs of individual countries, where possible.
- Consider the full range of policy measures to improve market access and increase supply of renewable energy, including electrification targets, feed-in tariffs, energy market auctions, tax waivers and tax reductions
- Ensure that pension funds and impact investors find it attractive to invest and help solve the long-term financing challenges of renewable energy programmes.

Make power sector reforms work for all

- Shifts to widespread private-sector participation in the power sector should not only focus on improving efficiency and creating profits, but also on bringing energy access to all and supporting the broader development agenda
- Decide for each case which are the most appropriate solutions, drawing from a full range including public-private partnerships, management contracts, corporatization, unbundling and independent power producers
- Ensure that clear legal, regulatory and licensing frameworks are in place to ensure the correct balance between: the needs of the public and development; and the incentives for investors and governments to develop projects. Set up effective mechanisms, including regulatory bodies, to enforce these frameworks. These can also include shareholders' agreements in the case of public-private partnerships
- Establish strong governance mechanisms for increased accountability and transparency of energy operators and to ensure proper channeling and utilization of funds to energy projects (minimizing corruption and mismanagement)
- Build and strengthen the institutional capacity of new and existing government entities involved in the transition to clean energy systems, so that they can develop bankable energy projects, manage and implement auction systems (one example could be South Africa's experience with REI4P), mobilize adequate external financing (including from new sources such as China and the Gulf states) and form innovative partnerships, such as public-private partnerships (PPPs) and partnerships between municipalities
- Appropriate systems (such as targeted subsidies) to support and protect consumers and to encourage consumers to produce (for instance being able to feed back into the national grid)

REFERENCES

A.T. Kearney and GOGLA (2014), Investment and Finance Study for Off-Grid Lighting, A.T. Kearney and Global Off-Grid Lighting Association (GOGLA), https://www.gogla.org/sites/www.gogla.org/files/recource_docs/investment-study-vol-2.pdf

Africa Progress Panel (2015), Power, People, Planet: Seizing Africa's Energy and Climate Opportunities, Africa Progress Panel, Geneva, http://www.africaprogresspanel.org/wp-content/uploads/2015/06/APP_REPORT_2015_FINAL_low1.pdf

Africa Renewable Energy Initiative (AREI) (2015), A framework for transforming Africa towards a renewable energy powered future with access for all, AREI, http://www.arei.org/wp-content/uploads/2016/04/AREI-Framework_ENG-1.pdf

Africa-EU Energy Partnership (AEEP) (2016), Africa-EU Energy Partnership Status Report Update: 2016, AEEP, Eschborn, Germany, https://www.africa-energy.com/sites/default/files/AEEP-2016-final-web.pdf

African Development Bank (AfDB) (2016a), African Development Bank Group Annual Report 2015, African Development Bank, Abidjan.

Alstone, Peter, Dimitry Gershenson and Daniel Kammen (2015), "Decentralized energy systems for clean energy access", Nature Climate Change, Vol. 5, published online 25 March 2015, NClimate 2512, https://rael.berkeley.edu/wp-content/uploads/2016/04/Alstone-Gershenson-Kammen-Nature-ClimateChange-2015-EnergyAccess.pdf

Asian Development Bank (ADB) (2011), Viet Nam's Success in Increasing Access to Energy through Rural Electrification, ADB, Manila, https://www.adb.org/sites/default/files/publication/28952/rural-electrification-vie.pdf

Bafana, Busani (2016), "Africa's cities of the future", Africa Renewal, April 2016, http://www.un.org/africarenewal/magazine/april-2016/africa%E2%80%99s-cities-future

Baker, Aryn (2016), "How Rwanda turned a toxic menace into a source of power", Time, 17 May 2016, http://time.com/4338310/rwanda-kivuwatt-methane-lake-kivu/

Barber, D. (2014), "Solar panel factories spark job growth across Africa", AFK Insider, http://afkinsider.com/48374/africas-solar-panel-manufacturing-creating-jobs/

Bates, Michael, and Bruce, Nigel (not dated), WHO Indoor Air Quality Guidelines: Household Fuel Combustion Review 9: Summary of systematic review of household kerosene use, World Health Organization, Geneva, http://www.who.int/indoorair/guidelines/hhfc/Review_9.pdf

Bazilian, Morgan and Roger Pielke Jr. (2013), "Making energy access meaningful", Issues in Science and Technology, Vol. 29, No. 4, http://issues.org/29-4/making-energy-access-meaningful/

Bazilian, Morgan and others (2012a), "Improving access to modern energy services: insights from case studies", The Electricity Journal, Vol, 25, No. 1, Elsevier, Amsterdam.

Bazilian, Morgan and others (2012b), "Energy access scenarios to 2030 for the power sector in sub-Saharan Africa", Utilities Policy, Vol. 20, No. 1, March 2012, Elsevier, Amsterdam.

Berenbach, Shari (2015), "What's holding back Africa's renewable energy entrepreneurs?" ONE.org, https://www.one.org/us/2015/07/23/whats-holding-back-africas-renewable-energy-entrepreneurs/

Bloomberg New Energy Finance (BNEF) (2016), "Clean energy defies fossil fuel price crash to attract record $329bn global investment in 2015", BNEF, https://about.bnef.com/press-releases/clean-energy-defies-fossil-fuel-price-crash-to-attract-record-329bn-global-investment-in-2015/

Briceño-Garmendia, Cecilia, and Maria Shkaratan (2011),"Power tariffs caught between cost recovery and affordability", Africa Region Sustainable Development Unit, World Bank, Washington DC, http://documents.worldbank.org/curated/en/234441468161963356/Power-tariffs-caught-between-cost-recovery-and-affordability

Bundock, Rose (2014), "Electricity theft on an industrial scale", The Africa Report, August 13, 2014, http://www.theafricareport.com/East-Horn-Africa/electricity-theft-on-an-industrial-scale.html

Burney, Jennifer, Rosamond Naylor and Sandra Postel (2013), "The case for distributed irrigation as a development priority in Sub-Saharan Africa", PNAS, Vol. 110, No 31, http://www.pnas.org/content/110/31/12513.full.pdf

CAFOD (2013), Thinking small 2: Big ideas from small entrepreneurs - Understanding the needs and priorities of small-scale farmers and business owners, CAFOD, London, http://cafod.org.uk/content/download/12681/98366/file/Thinking%20Small%202.pdf

Castellano, Antonio, and others (2015a), Brighter Africa: The growth potential of the Sub-Saharan electricity sector, McKinsey, http://www.mckinsey.com/~/media/McKinsey/dotcom/client_service/EPNG/PDFs/Brighter_Africa-The_growth_potential_of_the_sub-Saharan_electricity_sector.ashx

Castellano, Antonio, and others (2015b), Powering Africa, McKinsey, http://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/powering-africa

Cayten, Megan and Morgan Bazilian (2016), "Powering Africa: How captive generation can electrify the continent", Foreign Affairs, 16 September 2016, Council for Foreign Relations, New York, https://www.foreignaffairs.com/articles/africa/2016-09-16/powering-africa

Clean Energy Ministerial (2014) is the ministerial meeting on clean energy hosted in Seoul in May 2014, http://www.cleanenergyministerial.org/Events/CEM5.

Climatescope (2016), Mixed results for West Africa in Climatescope 2015, Climatescope, http://global-climatescope.org/en/blog/2016/06/02/climatescope-update-westafrica/

Coal International (2016), "Post-COP21: A mixed picture for African coal", May-June 2016, http://www.kslaw.com/imageserver/KSPublic/library/publication/2016articles/7-13-16_Coal_International.pdf

Creamer, Terence (2016), "Progress on 'Zizabona' interconnector critical to unlocking Southern African power projects", Engineering News, 16 February 2016, http://www.engineeringnews.co.za/article/progress-on-zizabona-interconnector-critical-to-unlocking-southern-african-power-projects-2016-02-16

Davis, Kurt (2016), "Top 5 opportunities for power investment in Sub-Saharan Africa", AFK Insider, http://afkinsider.com/127011/top-top-5-opportunities-for-power-investment-in-sub-saharan-africa/

Del Bello, Lou (2016), "In pictures: the energy poor of Africa's biggest slum", Climate Change News, 30 September 2016, http://www.climatechangenews.com/2016/09/30/in-pictures-the-energy-poor-of-africas-biggest-slum/

Deloitte (2013), "Using analytics to crack down on electricity theft", Deloitte/Wall Street Journal, 2 December 2013, http://deloitte.wsj.com/cio/2013/12/02/using-analytics-to-crack-down-on-electricity-theft/

Demierre and others (2014), Potential for Regional Use of East Africa's Natural Gas, Sustainable Development Solutions Network, http://unsdsn.org/wp-content/uploads/2014/05/140528_East_Africa_report_WEB.pdf

Diecker, Johanna, Susie Wheeldon and Andrew Scott (2016), Accelerating access to electricity in Africa with off-grid solar: Policies to expand the market for solar household solutions, Overseas Development Institute, London, https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/10231.pdf

Disrupt Africa (2015), "Powerhive first company to receive Kenyan utility concession", http://disrupt-africa.com/2015/07/powerhive-first-company-to-receive-kenyan-utility-concession/

Dubey, Sunita (2015), "Jamaica, Kenya take cues from India on electrifying urban slums", World Bank, 27 August 2015, http://blogs.worldbank.org/energy/jamaica-kenya-take-cues-india-electrifying-urban-slums

East African (2016), "AfDB approves $138m for Rusizi III hydro project", The East African, 2 January 2016, https://www.theeastafrican.co.ke/Rwanda/Business/AfDB-approves--138m-for-Rusizi-III-hydro-project-/1433224-3017284-v7c905/index.html

Eberhard, Anton (2016), "It's time South Africa learnt from others and overhauled its power sector", The Conversation, http://theconversation.com/its-time-south-africa-learnt-from-others-and-overhauled-its-power-sector-64379

Eberhard, Anton, and others (2008), Underpowered: The State of the Power Sector in Sub-Saharan Africa, World Bank, Washington DC, http://documents.worldbank.org/curated/en/142991468006934762/pdf/482140ESW0P11110Power0Sector0Review.pdf

Eberhard, Anton and others (2011), Africa's Power Infrastructure: Investment, Integration, Efficiency, World Bank, Washington DC, https://openknowledge.worldbank.org/bitstream/handle/10986/2290/613090PUB0Afri158344B09780821384558.pdf

Eberhard, Anton and others (2016), Private Investment Trends and Challenges in Power in Africa, Africa Utility Week, Finance and Investment Forum, 17 May 2016, Cape Town, South Africa. https://www.esi-africa.com/wp-content/uploads/2016/05/Anton-Eberhard-UCT.pdf

Economist Intelligence Unit (EIU) (2016), Power Up: Delivering Renewable Energy in Africa, Economist Intelligence Unit, London, https://www.eiuperspectives.economist.com/sites/default/files/Power%20Up.pdf

ECREEE (2012), Baseline Report for the ECOWAS Renewable Energy Policy, ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE), http://www.ecreee.org/sites/default/files/documents/basic_page/221012_baseline_report_including_annexes.pdf

ENEA (2016), Rapporto Annuale Efficienza Energetica 2016, Unità Tecnica Efficienza Energetica dell'ENEA, Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economic sostenibile, Rome, http://www.enea.it/it/pubblicazioni/edizioni-enea/2016/rapporto-annuale-efficienza-energetica-2016

Energy 4 Impact and Inensus (2016), "Green mini-grids in sub-Saharan Africa: Analysis of barriers to growth and the potential role of the African Development Bank in supporting the sector", Green Mini-Grids Market Development Programme, Document Series: No 1 Dec 2016, https://www.energy4impact.org/publications

ESI Africa (2015), ESI Africa, Issue 4, 2015, Rondebosch, South Africa

ESI Africa (2016), "West Africa Gas Pipeline puts Ghanaian power supply at risk", ESI Africa, 15 April 2016, https://www.esi-africa.com/news/west-africa-gas-pipeline-puts-ghanaian-power-supply-at-risk/

Eskom (2016), The Power is in Your Hands: Operation Khanyisa Fact Sheet, Eskom, http://www.operationkhanyisa.co.za/wp-content/uploads/2016/06/Operation-Khanyisa-Fact-Sheet.pdf

ESMAP (2015), Beyond Connections: Energy Access Redefined, ESMAP/World Bank, Washington DC, http://www.worldbank.org/en/topic/energy/publication/energy-access-redefined

EY (2016), "Power Transactions and Trends: 2015 review and 2016 outlook", EY, Brisbane, http://www.ey.com/Publication/vwLUAssets/EY-power-transactions-and-trends-q4-2015/$FILE/EY-power-transactions-and-trends-q4-2015.pdf

Ford, Neil (2016), "Gas fuels Tanzania, Mozambique growth", The Africa Report, 30 August 2016, http://www.theafricareport.com/East-Horn-Africa/gas-fuels-tanzania-mozambique-growth.html

France24 (2016), "Solar backpacks help kids do homework in the Ivory Coast", France24, 9 September 2016, http://observers.france24.com/en/20160909-solar-backpacks-kids-homework-ivory-coast

Frankfurt School (2015), Renewable Energy in Hybrid Mini-Grids and Isolated Grids: Economic Benefits and Business Cases, Frankfurt School of Finance and Management/UNEP, http://fs-unep-centre.org/sites/default/files/publications/hybridgrids-economicbenefits.pdf

GIZ (2016), Photovoltaics for Productive Use Applications: A Catalogue of DC Appliances, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), Eschborn, http://thecleannetwork.org/downloads/97-GIZ_(2016)_Catalogue_PV_Appliances_for_Micro_Enterprises.pdf

Global LEAP (2015), Off-Grid Appliance Market Survey: Global Lighting and Energy Access Partnership, Global Lighting and Energy Access Partnership (Global LEAP), http://energyaccess.org/wp-content/uploads/2015/07/GlobalLEAPOff-GridApplianceSurvey-April2015-for-publications.pdf

Global LEAP (2016), The State of the Global Off-Grid Appliance Market, Global LEAP, http://www.cleanenergyministerial.org/Portals/2/pdfs/GlobalLEAP_Market_Reserarch_Summary.pdf

GreenCape (2016), Utility Scale-Renewable Energy Sector: 2016 Market Intelligence Report, GreenCape, Cape Town, South Africa, http://greencape.co.za/assets/GreenCape-Renewable-Energy-MIR-2016.pdf

GTM Research (2014) "US Microgrid Capacity Will Exceed 1.8GW by 2018", GreenTechMedia, 2014, http://www.greentechmedia.com/articles/read/US-Microgrid-Capacity-Will-Exceed-1.8-GW-by-2018

GTM Research (2015), "Cumulative US Microgrid Investments Will Surpass $3.5 Billion From 2015-2020, GreenTechMedia, http://www.greentechmedia.com/articles/read/cumulative-us-microgrid-investments-will-surpass-3.5-billion-from-2015-thro

GTZ (2007), Successful Energy Policy Interventions in Africa, Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Eschborn, http://www.globalbioenergy.org/uploads/media/0707_GTZ_-_Successful_energy_policy_interventions_in_Africa.pdf

Guay, Justin (2016), "Who will serve the world's missing middle?", The Huffington Post, 25 May 2016, http://www.huffingtonpost.com/justin-guay/who-will-serve-the-worlds_b_10129844.html

GVEP (2011a), Phone Charging Micro-businesses in Tanzania and Uganda, GVEP International, http://www.energy4impact.org/sites/default/files/phone_charging_businesses_report_with_gsma_final_for_web_0.pdf

GVEP (2011b), The history of mini-grid development in developing countries, GVEP International, http://www.energy4impact.org/sites/default/files/policy_briefing_-_mini-grid_final.pdf

Harrison, Kat, Andrew Scott and Ryan Hogarth (2016), Accelerating access to electricity with off-grid solar: The impact of solar household solutions, Overseas Development Institute, London, https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/10229.pdf

Harsdorff, Marek and Patricia Bamanyaki (2009), Impact assessment of the solar electrification of micro enterprises, households and the development of the rural solar market, Promotion of Renewable Energy and Energy Efficiency Programme, Kampala, https://energypedia.info/images/d/d4/Impact_assessment_shs_preeep_uganda_2009.pdf

Hill, Matthew and Thomas Wilson (2016), "Congo to select phase-1 builder of $100 billion dam by August", Bloomberg News, 6 May 2016, https://www.bloomberg.com/news/articles/2016-05-06/congo-to-select-phase-1-builder-of-100-billion-dam-by-august

Hogarth, Ryan (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, Vol. 16, No. 4, Elsevier, Amsterdam

Hogarth, Ryan and Ilmi Granoff (2015), Speaking Truth to Power: Why energy distribution, more than generation, is Africa's poverty reduction challenge, Oxfam/Overseas Development Institute, London, https://policy-practice.oxfamamerica.org/static/media/files/FINAL_speakingpowertotruth_SH.pdf

Infrastructure Consortium on Africa (2013), Infrastructure Financing Trends in Africa: ICA Annual Report 2012, ICA Secretariat, African Development Bank, Tunis, https://www.crossborderinformation.com/sites/default/files/ICA%20_AnnualReport%202012.pdf

International Energy Agency (IEA) (2011), World Energy Outlook 2011, Organization for Economic Cooperation for Development/IEA, Paris, https://www.iea.org/publications/freepublications/publication/WEO2011_WEB.pdf

International Energy Agency (2014), Africa Energy Outlook, special report to World Energy Outlook 2014, Organization for Economic Cooperation for Development/IEA, Paris, https://www.iea.org/publications/freepublications/publication/WEO2014_AfricaEnergyOutlook.pdf

International Energy Agency (2016), Boosting the Power Sector in Sub-Saharan Africa: China's Involvement, Organization for Economic Cooperation for Development/IEA, Paris, https://www.iea.org/publications/freepublications/publication/Partner_Country_SeriesChinaBoosting_the_Power_Sector_in_SubSaharan_Africa_Chinas_Involvement.pdf

International Monetary Fund (2015), "Making Public Investment More Efficient", staff report, IMF, Washington DC, http://www.imf.org/external/np/pp/eng/2015/061115.pdf

IRENA (2012), Prospects for the African Power Sector, International Renewable Energy Agency (IRENA), Abu Dhabi, https://www.irena.org/DocumentDownloads/Publications/Prospects_for_the_African_PowerSector.pdf

IRENA (2013a), Africa's Renewable Future: The Path to Sustainable Growth, IRENA, Abu Dhabi, http://www.irena.org/documentdownloads/publications/africa_renewable_future.pdf

IRENA (2013b), Renewable Energy and Jobs, IRENA, Abu Dhabi, http://www.irena.org/rejobs.pdf

IRENA (2015a), Battery storage for renewables: Market status and technology outlook, IRENA, Abu Dhabi, http://www.irena.org/DocumentDownloads/Publications/IRENA_Battery_Storage_report_2015.pdf

IRENA (2015b), Off-Grid Renewable Energy Systems: Status and Methodological Issues, IRENA, Abu Dhabi, http://www.irena.org/DocumentDownloads/Publications/IRENA_Off-grid_Renewable_Systems_WP_2015.pdf

IRENA (2015c), Africa 2030: Roadmap for a Renewable Energy Future, IRENA, Abu Dhabi, http://www.irena.org/DocumentDownloads/Publications/IRENA_Africa_2030_REmap_2015_low-res.pdf

IRENA (2016), Roadmap for a Renewable Future: 2016 Edition, IRENA, Abu Dhabi, http://www.irena.org/DocumentDownloads/Publications/IRENA_REmap_2016_edition_report.pdf

Jain, Amit (2015), "Solar energy brings smiles to healthy babies and happy farmers", World Bank, 8 August 2015, http://blogs.worldbank.org/energy/solar-energy-brings-smile-to-healthy-babies-and-happy-farmers

Kojima, Masami, and others (2016), "Who uses electricity in sub-Saharan Africa? Findings from household surveys", Paper for Energy and Extractives Global Practice Group, World Bank, Washington DC

KPMG (2015), Sector Report: Power in Africa, KPMG

KPMG (2016), Sub-Saharan Africa Power Outlook 2016, KPMG, https://assets.kpmg.com/content/dam/kpmg/pdf/2016/05/kpmg-sub-saharan-africa-power-outlook.pdf

Lam, Nicholas, and others (2012a), "Kerosene: A review of household uses and their hazards in low- and middle-income countries", Journal of Toxicology and Environmental Health, Part B: Critical Reviews, 2012. 15(6):396-432, Taylor & Francis Group, London, https://www.scribd.com/document/248203937/Kerosene-Review-12

Lam, Nicholas, and others (2012b), "Household light makes global heat: high black carbon emissions from kerosene wick lamps", Environmental Science & Technology, 2012; 46 (24) pp 13,531-13,538, ACS Publications, Washington DC, http://pubs.acs.org/doi/abs/10.1021/es302697h

Latham & Watkins LLP (2016), Nigerian Power Sector: Opportunities and Challenges for Investment in 2016, Latham & Watkins, London, https://www.lw.com/thoughtLeadership/lw-nigerian-power-sector-opps-and-challenges

Ligami, Christabel (2016a), "East African countries commence trade of power from Olkaria geothermal plant", Renewable Energy World, 4 May 2016, http://www.renewableenergyworld.com/articles/2016/05/east-african-countries-commence-trade-of-power-from-olkaria-geothermal-plant.html

Ligami, Christabel (2016b), "Egypt Pulls Out of Regional Power Pool As It Protests Use of Nile Water", The East African, 6 February 2016, http://www.theeastafrican.co.ke/news/Egypt-pulls-out-of-power-pool-as-it-protests-use-of-Nile-waters/2558-3065704-x4qbu2z/index.html

Malama and others (2014), "The effects of the introduction of prepayment meters on the energy usage behaviour of different housing consumer groups in Kitwe, Zambia", published by AIMS Energy, Vol. 2, Issue 3, pp237-259, AIMS Press, Springfield, MO, United States of America, http://www.aimspress.com/fileOther/PDF/energy/20140303.pdf

Mills, Evan (2015), "Identifying and reducing the health and safety impacts of fuel-based lighting", Energy for Sustainable Development, 30 (2016) pp39-50, Elsevier, Amsterdam, http://evanmills.lbl.gov/pubs/pdf/mills-off-grid-lighting-and-health.pdf

Miret, Santiago (2015), "The rise of micro-grid start-ups", Berkeley Energy & Resources Collaborative, BERC Solar News, 18 March 2015 - http://berc.berkeley.edu/the-rise-of-micro-grid-start-ups

Montmasson-Clair, Gaylor, and Georgina Ryan (2014), "Lessons from South Africa's renewable energy regulatory and procurement experience", Journal of Economic and Financial Services, September 2014, Johannesburg, https://ssrn.com/abstract=2747885

Navigant (2015), Market Data: Remote Microgrids and Nanogrids, Navigant Research, Boulder CO, USA, https://www.navigantresearch.com/research/market-data-remote-microgrids-and-nanogrids

NERC (2015), "NERC replies Senate's Query on fixed charge and estimated billing", Nigerian Electricity Regulatory Commission (NERC), 18 August 2015, http://www.nercng.org/index.php/media-and-publicity/press-releases/298-nerc-replies-senate-s-query-on-fixed-charge-and-estimated-billing

NERC (2015), Amended Multi Year Tariff Order (MYTO) – 2.1, Order No. NERC/REG/3/2015, Nigerian Electricity Regulation Commission (NERC), Abuja, http://www.nigeriaelectricityhub.com/download/myto-2-1-multi-year-tariff-order-for-2015-2018/

Nerini, Francesco, and others (2015), "A cost comparison of technology approaches for improving access to electricity services", Energy, Available online 2015, published in Energy 95 (2016) pp255-265, Elsevier, Amsterdam

Never, Babette (2015), "Social norms, trust and control of power theft in Uganda: Does bulk metering work for MSEs?" Energy Policy, Vol. 82, Elsevier, Amsterdam.

Nyeko, Elizabeth (2016), "Power of Innovation: Sustainable Industrialization and Economic Development in Rural Africa", LinkedIn Pulse, https://www.linkedin.com/pulse/power-innovation-sustainable-industrialization-economic-nyeko

Obeng, George, and Hans-Dieter Evers (2010), "Impacts of public solar PV electrification on rural micro-enterprises", Energy for Sustainable Development, Vol. 14, No. 3, Elsevier, Amsterdam, http://www.academia.edu/5100571/Impacts_of_public_solar_PV_electrification_on_rural_micro-enterprises_The_case_of_Ghana

OCP Policy Center (2016), "Morocco's Green Energy Opportunity", Policy Paper, October 2016, OCP Policy Center, Rabat

Okafor, Chineme (2016), "MDAs, States, LGs' owe Discos N78.7bn in electricity bills", This Day, 8 May 2016, http://www.thisdaylive.com/index.php/2016/05/08/mdas-states-lgs-owe-discos-n78-7bn-in-electricity-bills/

Orlandi, Itamar, Nico Tyabji and Jenny Chase (2016), Off-Grid Solar Market Trends Report 2016, Bloomberg New Energy Finance and Lighting Global, https://data.bloomberglp.com/bnef/sites/4/2016/03/20160303_BNEF_WorldBankIFC_Off-GridSolarReport_.pdf

Pachauri, Shonali, and others (2013), Energy for All: Harnessing the Power of Energy Access for Chronic Poverty Reduction, Chronic Poverty Advisory Network, London, https://dl.orangedox.com/Energy-Policy-Guide-2013

Palit, Debajit, and Akanksha Chaurey (2011), "Off-grid electrification experiences from South Asia: Status and best practices", Energy for Sustainable Development, Vol. 15, 2011, https://www.dmu.ac.uk/documents/technology-documents/research-faculties/oasys/project-outputs/peer-reviewed-journal-articles/pj1--palit-chaurey-paper.pdf

Poggiolini, D. (2016), "Power lines binding Africa", NowHow, 4 April 2016, http://nowhow.international/power-lines-binding-africa/

Poudineh, Rahmatallah, and Alessandro Rubino (2016), Business Model for Cross-border Interconnections in the Mediterranean Basin, The Oxford Institute for Energy Studies, University of Oxford, https://www.oxfordenergy.org/wpcms/wp-content/uploads/2016/06/Business-model-for-cross-border-interconnections-in-the-Mediterranean-basin-EL-19.pdf

Practical Action (2013), Poor People's Energy Outlook 2013, Practical Action Publishing, Rugby, UK, http://infohub.practicalaction.org/oknowledge/bitstream/11283/556928/1/PPEO%202013.pdf

Practical Action (2014), Poor People's Energy Outlook 2014, Practical Action Publishing Ltd, Rugby, UK, http://infohub.practicalaction.org/oknowledge/bitstream/11283/556929/9/PPEO_English_2014_LowRes_New.pdf

PRNewswire (2014), "World Loses $89.3 Billion to electricity theft annually, $58.7 billion in emerging markets", PRNewswire, 9 December 2014, http://www.prnewswire.com/news-releases/world-loses-893-billion-to-electricity-theft-annually-587-billion-in-emerging-markets-300006515.html

PV Insider (2016), "South Africa's PV firms eye Sub-Saharan markets for growth", PV Insider, http://analysis.pv-insider.com/south-africas-pv-firms-eye-sub-saharan-markets-growth

PwC (2016), Powering Nigeria for the Future, PwC, https://www.pwc.com/gx/en/growth-markets-centre/assets/pdf/powering-nigeria-future.pdf

Quartz Africa (2015), "Kenya's M-Kopa is set to deliver solar power to a million homes", Quartz Africa, 9 December 2015, http://qz.com/569815/kenyas-m-kopa-is-set-to-deliver-solar-power-to-a-million-homes-in-east-africa/

Quitzow, Rainer, and others (2016), The Future of Africa's Energy Supply: Potentials and Development Options for Renewable Energy, Institute for Advanced Sustainability Studies, Potsdam, Germany, http://www.iass-potsdam.de/sites/default/files/files/study_march_2016_the_future_of_africas_energy_supply.pdf

RECP (2013), Mini-Grid Policy Toolkit: Policy and Business Frameworks for Successful Mini-grid Roll-outs, Africa-EU Renewable Energy Cooperation Programme (RECP), http://www.ren21.net/Portals/0/documents/Resources/MGT/MinigridPolicyToolkit_Sep2014_EN.pdf

REI4P (2016), Independent Power Producers Procurement Programme (IPPPP), An Overview at 30 September 2016, Department: Energy and National Treasury South Africa, https://www.ipp-projects.co.za/Publications

REN21 (2016), Renewables 2016 Global Status Report, REN21, Paris, http://www.ren21.net/wp-content/uploads/2016/10/REN21_GSR2016_FullReport_en_11.pdf

Rockefeller Foundation (2013), "Waste and spoilage in the food chain, Decision Intelligence Document May 2013", Rockefeller Foundation, New York, USA, https://www.rockefellerfoundation.org/app/uploads/Waste-and-Spoilage-in-the-Food-Chain.pdf

Rosen, Jonathan (2015), "Lake Kivu's great gas gamble", MIT Technology Review, 16 April 2015, Cambridge, Massachusetts, https://www.technology-review.com/s/536656/lake-kivus-great-gas-gamble/

SARDC (2016), "SADC to commission 3,000 MW of new power in 2016", Southern Africa News Features, 12 May 2016, Southern African Research and Documentation Centre (SARDC), http://www.sardc.net/en/southern-african-news-features/sadc-to-commission-3000mw-of-new-power-in-2016/

SBI (2013), Scaling up Successful Micro-Utilities for Rural Electrification: Private Sector Perspectives on Operational Approaches, Financing Instruments and Stakeholder Interaction, Sustainable Business Initiative (SBI), http://www.inensus.de/download/2013-SBI-INENSUS-Studie.pdf

Schnitzer, Dan, and others (2014), "Microgrids for rural electrification: A critical review of best practices based on seven case studies", United Nations Foundation, https://ceic.tepper.cmu.edu/-/media/files/tepper/centers/ceic/publications/reports/2014/micro-grids-rural_electrification-critical-rev-best-practices-based-seven_case_studies%20pdf

Scott, Andrew, and Charlie Miller (2016), Accelerating access to electricity in Africa with off-grid solar – The market for solar household solutions, Overseas Development Institute, London, https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/10230.pdf

Scott, Andrew, and others (2014), How does electricity insecurity affect businesses in low and middle income countries? Overseas Development Institute, London, https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/9425.pdf

SE4All (2014), High Impact Opportunity: Clean Energy Mini-grids, Sustainable Energy for All (SE4All), http://www.se4all.org/sites/default/files/l/2014/08/MinigridsHIO.pdf

Seguin, Robert (2014), "Economic feasibility of rural electrification projects", Side Event at the High-Level Meeting of the Africa-EU Energy Partnership, Addis Ababa, February 11, 2014, http://docz.io/doc/2901762/energy-systems-modelling---reiner-lemoine-institut

Senelwa, Kennedy (2015), "Regional high voltage lines expected by 2018", The East African, 12 September 2015, http://www.theeastafrican.co.ke/business/Regional-high-voltage-lines-expected-by-2018-/2560-2867884-ndn0syz/index.html

Shared Solar (not dated), "Smart microgrids for energy access", http://sharedsolar.org/

Smith, Thomas (2004), "Electricity theft: a comparative analysis", Energy Policy, Vol. 32, No. 18, Elsevier, Amsterdam, http://www.provedor.nuca.ie.ufrj.br/eletrobras/estudos/smith1.pdf

SolarServer (2016), "Powerhive completes USD 20 million financing to support development of off-grid energy access solutions in emerging markets", http://www.solarserver.com/solar-magazine/solar-news/archive-2016/2016/kw04/powerhive-completes-usd-20-million-financing-to-support-development-of-off-grid-energy-access-solutions-in-emerging-markets.html

Sovacool, Benjamin, Morgan Bazilian and Michael Toman (2016), "Paradigms and poverty in global energy policy: research needs for achieving universal energy access", Environmental Research Letters, Vol. 11, No. 6, June 2016. IOP Publishing, Bristol, UK, http://iopscience.iop.org/article/10.1088/1748-9326/11/6/064014/pdf

Standard Bank (2016), "Power trading will drive electricity landscape over the next five years", Standard Bank, Johannesburg, South Africa, http://corporateandinvestment.standardbank.com/CIB/Latest-News/Power-trading-will-drive-electricity-landscape-over-the-next-five-years

Strohmeier, Hannah (2015), Why Sustainable Energy Matters to Children: The Critical Importance of Sustainable Energy for Children and Future Generations, UNICEF, New York, https://www.unicef.org/environment/files/UNICEF_Sustainable_Energy_for_Children_2015.pdf

Sy, Amadou, and Amy Copley (2016), "Closing the financing gap for African energy infrastructure: Trends, challenges, and opportunities", Paper published by Africa Growth Initiative, The Brookings Institution, Washington DC

Szabó, Sándor, and others (2013), "Sustainable energy planning: Leapfrogging the energy poverty gap in Africa", Renewable and Sustainable Energy Reviews, Vol. 28, Elsevier, Amsterdam

Tallapragada, Prasad, and others (2009), Monitoring Performance of Electric Utilities: Indicators and Benchmarking in Sub-Saharan Africa, World Bank, Washington DC, http://hdl.handle.net/10986/13030

Tortora, Bob, and Magali Rheault (2012), "In sub-Saharan Africa, most workers are without electricity", Gallup, http://www.gallup.com/poll/151889/sub-saharan-africa-workers-without-electricity.aspx

Traoré, Amidou (2013), Independent Power Generation: The Ivorian Model, Proparco, Paris, http://www.proparco.fr/webdav/site/proparco/shared/PORTAILS/Secteur_prive_developpement/PDF/SPD18/SPD18_Amidou_traore_UK.pdf

Tsiko, Sifelani (2015), "SADC power trading volumes hit USD50m", The Southern Times, 18 December 2015 http://southernafrican.news/2015/12/18/sadc-power-trading-volumes-hit-us50m/

Tsiko, Sifelani (2016), "Boost for SADC power – First phase interconnector project nears completion", The Southern Times, 7 April 2016, https://southernafrican.news/2016/04/07/boost-for-sadc-power-first-phase-interconnector-project-nears-completion/

Tumiwa, Samuel (2014), "Energy for all, promoting mini-grids in Asia and the Pacific", presentation to ESMAP-UNF-USAID mini-grid workshop October 2014, https://www.esmap.org/sites/esmap.org/files/DocumentLibrary/Samuel%20Tumiwa%20ADB%20Mini%20Grid%20Conference%20Slides%20Oct%202014.pdf

Tungu-Kabiri (2016), The Tungu-Kabiri community hydro project, http://microhydropower.net/ke/Tungu-Kabiri/

United Nations Department of Economic and Social Affairs (UNDESA) (2016), Universal Access to Electricity: Visualizing Electrification Modelling Results, (UNDESA), New York, https://un-desa-modelling.github.io/electrification-paths-presentation/

United Nations Environment Programme (UNEP) (2014a), Light and Livelihood: A Bright Outlook for Employment in the Transition from Fuel-Based Lighting to Electrical Alternatives, United Nations Environment Programme, Nairobi, http://www.ecreee.org/sites/default/files/documents/news/light_and_livelihood_-_a_bright_outlook_for_employment_0.pdf

United Nations Environment Programme (UNEP) (2014b), "Light for life: Identifying and reducing the health and safety impacts of fuel-based lighting", United Nations Environment Programme, Nairobi, http://www.ecreee.org/sites/default/files/light_for_life_-_health_and_safety_impacts_of_fuel-based_lighting_0.pdf

United Nations Environment Programme (UNEP) (2015a), Developing Effective Off-Grid Lighting Policy: Guidance note for governments in Africa, United Nations Environment Programme, Nairobi, http://www.enlighten-initiative.org/portals/0/documents/Resources/publications/OFG-publication-may-BDef.pdf

United Nations Environment Programme (UNEP) (2015b), Increasing Private Capital Investment into Energy Access: The Case for Mini-grid Pooling Facilities, United Nations Environment Programme, Nairobi, https://wedocs.unep.org/rest/bitstreams/16808/retrieve

United Nations Economic Commission for Africa (UNECA) (2016), Greening Africa's Industrialization: Economic Report on Africa, UNECA, Addis Ababa, http://www.un.org/en/africa/osaa/pdf/pubs/2016era-uneca.pdf

United Nations Framework Convention on Climate Change (UNFCCC) (2017), website containing Intended Nationally Determined Contribution documents for the different countries, http://www4.unfccc.int/Submissions/INDC/Submission%20Pages/submissions.aspx

United Nations Industrial Development Organization (UNIDO) (2005), Sustainable Energy Regulation and Policymaking Training Manual, Module 4: The reform of the power sector in Africa, UNIDO, Vienna, http://www.unido.org/fileadmin/import/83245_Module4.pdf

USAID (2015), Power Africa Annual Report July 2015, United States Agency for International Development (USAID), Washington DC, https://www.usaid.gov/sites/default/files/documents/1860/PA_2015_Report_V16_TAGGING_508.pdf

USAID (not dated), Powering Health: Electrification options for rural health centers, United States Agency for International Development (USAID), Washington, DC, http://www.poweringhealth.org/Pubs/PNADJ557.pdf

Wilson, Thomas (2016), "World Bank stops funding world's biggest power plant plan", Bloomberg News, 16 July 2016, https://www.bloomberg.com/news/articles/2016-07-26/world-bank-halts-funding-for-inga-hydropower-project-in-congo-ir3sxliv

Winiecki, Jacob, and Kabir Kumar (2014), Access to Energy via Digital Finance: Overview of Models and Prospects for Innovation, Consultative Group to Assist the Poor, Washington, DC, https://www.cgap.org/sites/default/files/DigitallyFinancedEnergy%20_FINAL.pdf

Winther, Tanja (2012), "Electricity theft as a relational issue: a comparative look at Zanzibar, Tanzania, and the Sunderban Islands, India", Energy for Sustainable Development, Vol. 16, No. 1, Elsevier, Amsterdam

World Bank (2015a), "Bringing electricity to Kenya's slums: hard lessons lead to great gains", World Bank, 20 August 2015, http://www.worldbank.org/en/news/feature/2015/08/17/bringing-electricity-to-kenyas-slums-hard-lessons-lead-to-great-gains

World Bank (2015b), Progress towards Sustainable Energy, Global Tracking Framework 2015, International Bank for Reconstruction and Development/The World Bank and the International Energy Agency, Washington DC, http://trackingenergy4all.worldbank.org/~/media/GIAWB/GTF/Documents/GTF-2105-Full-Report.pdf

World Bank (2016a), "World Bank Group suspends financing to the Inga-3 Basse Chute technical assistance project", press release 25 July 2016, World Bank, Washington DC, http://www.worldbank.org/en/news/press-release/2016/07/25/world-bank-group-suspends-financing-to-the-inga-3-basse-chute-technical-assistance-project

World Bank (2016b), "Current activities and challenges to scaling up mini-grids in Kenya", May 2016, World Bank, Washington DC, https://www.esmap.org/sites/esmap.org/files/DocumentLibrary/ESMAP_Kenya%20Roundtable_May%202016_formatted-v4.pdf

World Future Council (2016), "What place for renewables in the INDCs?", updated version March 12, 2016

SOURCES: INFOGRAPHICS

THE SUSTAINABLE DEVELOPMENT GOALS WILL ONLY SUCCEED IF THEY SUCCEED IN AFRICA: URGENTLY POWERING AFRICA TO DELIVER THE GLOBAL GOALS

Africa Progress Panel (2015), Power, People, Planet: Seizing Africa's Energy and Climate Opportunities, Africa Progress Panel, Geneva, http://www.africaprogresspanel.org/wp-content/uploads/2015/06/APP_REPORT_2015_FINAL_low1.pdf

FAO (n.d.) "Food Loss and Food Waste", FAO, http://www.fao.org/food-loss-and-food-waste/en/

International Finance Corporation, World Bank, and GSMA (2014), Tower Power Africa: Energy Challenges and Opportunities for the Mobile Industry in Africa, GSMA, http://www.gsma.com/mobilefordevelopment/wp-content/uploads/2014/11/Africa-Market-Report-GPM-final.pdf

Lighting Africa (2015), "Pilot Project Confirms Benefits of Solar Lanterns to Maternal Care in Nigeria" (Project News), https://www.lightingafrica.org/pilot-project-confirms-benefits-of-solar-lanterns-to-maternal-care-in-nigeria/

Power for All (2016), Power for All Fact Sheet: Keeping Families Healthy and Safe, Power for All, http://www.powerforall.org/fact-sheets/

Practical Action. (2014). Poor people's energy outlook 2014. Practical Action Publishing Ltd., Rugby, UK, http://infohub.practicalaction.org/oknowledge/bitstream/11283/556929/9/PPEO_English_2014_LowRes_New.pdf

UNDESA (2014) Electricity and education: The benefits, barriers, and recommendations for achieving the electrification of primary and secondary schools, UNDESA, https://sustainabledevelopment.un.org/content/documents/1608Electricity%20and%20Education.pdf

MIND THE GAP: AFRICA'S ENERGY DEFICIT IS LARGE AND GROWING

Africa Progress Panel (2015), Power, People, Planet: Seizing Africa's Energy and Climate Opportunities, Africa Progress Panel, Geneva, http://www.africaprogresspanel.org/wp-content/uploads/2015/06/APP_REPORT_2015_FINAL_low1.pdf

AFRICA'S ENERGY TRANSFORMATION

Africa Progress Panel (2015), Power, People, Planet: Seizing Africa's Energy and Climate Opportunities, Africa Progress Panel, Geneva, http://www.africaprogresspanel.org/wp-content/uploads/2015/06/APP_REPORT_2015_FINAL_low1.pdf

AFRICA'S ENERGY LADDER: ACCELERATING ACCESS

OECD, IEA (2012), World Energy Outlook 2012, International Energy Agency, Paris, France, http://www.worldenergyoutlook.org/weo2012/

MINI-GRIDS: AFRICA VERSUS ASIA

IRENA (2015), Off-Grid Renewable Energy Systems: Status and Methodological Issues, IRENA, http://www.irena.org/DocumentDownloads/Publications/IRENA_Off-grid_Renewable_Systems_WP_2015.pdf

Manandhar, Pushkar (2016), Mini-Grid Development in Nepal: Approaches, Key Challenges and Requirements, https://d2oc0ihd6a5bt.cloudfront.net/wp-content/uploads/sites/837/2016/04/4-Pushkar-Manandhar.pdf

PwC Power & Utilities (2016), Electricity beyond the grid: Accelerating access to sustainable power for all, PwC, https://www.pwc.com/gx/en/energy-utilities-mining/pdf/electricity-beyond-grid.pdf

REN21 (2016), Renewables 2016 Global Status Report, REN21, http://www.ren21.net/wp-content/uploads/2016/10/REN21_GSR2016_FullReport_en_11.pdf

Tenenbaum, B., Greacen, C., Siyambalapitiya, T., and Knuckles, J. (2014) From the Bottom Up: How Small Power Producers and Mini-Grids Can Deliver Electrification and Renewable Energy in Africa, The World Bank, Washington DC. https://openknowledge.worldbank.org/handle/10986/16571

AFRICA'S ENERGY THEFT AND LOSSES

Dike, D.O., Uchechukwu, A.O., Nwokorie, E.C., and Dike, B.C. (2015), "Minimizing Household Electricity Theft in Nigeria Using GSM Based Prepaid Meter", American Journal of Engineering Research, Volume IV, Issue 1, http://www.ajer.org/papers/v4(01)/I0401059069.pdf

Eberhard, A., Rosnes, O., Shkaratan, M. and Vennemo, H. (2011) Africa's Power Infrastructure: Investment, Integration, Efficiency, The World Bank, Washington DC. https://openknowledge.worldbank.org/bitstream/handle/10986/2290/613090PUB0Afri158344B097808213845at58.pdf?sequence=1

ERA (2011), Study on Distribution System Losses and Collection Rates by Umeme Ltd., Electricity Regulatory Authority Uganda, http://www.era.or.ug/index.php/2013-12-14-14-58-04/sector-reports/doc_download/23-umeme-distribution-loss-study

Muneza, Stephen (2014), "Umeme seeks help to cut electricity theft", Redpepper, http://www.redpepper.co.ug/umeme-seeks-help-to-cut-electricity-theft/

New Stage (2016) "Power firm loses N238bn monthly to electricity theft", New Stage, http://newstage.com.ng/2016/07/23/power-firm-loses-n238bn-monthly-electricity-theft/

Otuki, Nevile (2016), "Electricity theft and leakages cost Kenya Power Sh10bn in six months", Business Daily, http://www.businessdailyafrica.com/Electricity-theft-and-leakages-cost-Kenya-Power-/539546-3092716-106648uz/index.html

Operation Khanyisa (n.d.) "Operation Khanyisa Fact Sheet", http://www.operationkhanyisa.co.za/2016/06/08/operation-khanyisa-fact-sheet/

Winkless, L. (2016), 'These Young Inventors are Tackling Africa's Electricity Crisis', Forbes, http://www.forbes.com/sites/lauriewinkless/2016/06/11/these-two-young-inventors-are-tackling-africas-electricity-crisis/#2ca28706451e

DISRUPTIVE INNOVATION UNLOCKS AFRICA'S ENERGY FUTURE

Arica Biogas Partnership Programme (n.d.), "Africa Biogas Partnership Programme", http://www.africabiogas.org/africa-biogas-partnership-programme/

Africa Progress Panel (2015), Power, People, Planet: Seizing Africa's Energy and Climate Opportunities, Africa Progress Panel, Geneva, http://www.africaprogresspanel.org/wp-content/uploads/2015/06/APP_REPORT_2015_FINAL_low1.pdf

M-Kopa (n.d.) "Our Impact", M-Kopa, http://solar.m-kopa.com/about/our-impact/

Mandulis Energy (n.d.), Mandulis Energy, http://www.mandulisenergy.com/

Sahelia Solar (n.d.) "La Société", Sahelia Solar, http://saheliasolar.com/la-societe/

UNDESA (2015), World Population Prospects: The 2015 Revision: Key Findings and Advance Tables, United Nations, New York, https://esa.un.org/unpd/wpp/publications/files/key_findings_wpp_2015.pdf

END NOTES

[1]France24 (2016)
[2]Quartz Africa (2015)
[3]International Energy Agency (2014)
[4]Nerini and others (2016)
[5]This report considers the full range of solar devices, using terms such as "solar household solutions" or "solar off-grid options", except where it specifically refers to solar lanterns or larger solar home systems
[6]Bazilian and Pielke (2013)
[7]Alstone, Gershenson and Kammen (2015)
[8]As developed by McKinsey and the International Energy Agency (IEA)
[9]Castellano and others (2015a, p36); IEA (2014)
[10]"Branded" pico-solar products include Lighting Global quality-verified products and other branded products
[11]Generic pico-solar products include no-names, copy-cats and counterfeits. Sales figures for these products remain highly speculative given the lack of reporting by distributors
[12]The figures for branded products are from Orlandi, Tyabji and Chase (2016). The figures for generic products are based on the estimated global sales of generic products. They were calculated with the assumption that the ratio between African and Asian sales is the same for both branded and generic products
[13]Grid-connection charges in Africa range from US$2 to US$400 (Harrison, Scott and Hogarth, 2016). In Kenya, Rwanda, Tanzania, Burkina Faso and the Central African Republic, connection fees are more than the average monthly income (Alstone, Gershenson and Kammen, 2015). As a result, the process of connecting homes after a village is electrified tends to occur slowly and regressively, with better-off families gaining access first (Pachauri and others, 2013)
[14]Electricity grids in sub-Saharan Africa typically suffer from over eight power outages per month, each lasting an average of 5.3 hours (Scott and others, 2014). Grid power is unavailable for an average of 540 hours per year (6 per cent of the time), and much longer in Nigeria, Guinea and the Central African Republic (IEA, 2014)
[15]Orlandi, Tyabji and Chase (2016)
[16]Scott and Miller (2016)
[17]ESMAP (2015)
[18]By Alstone, Gershenson and Kammen (2015)
[19]Orlandi, Tyabji and Chase (2016)
[20]Orlandi, Tyabji and Chase (2016)
[21]Orlandi, Tyabji and Chase (2016)
[22]Alstone, Gershenson and Kammen (2015)
[23]Orlandi, Tyabji and Chase (2016)
[24]Harrison, Scott and Hogarth (2016)
[25]Orlandi, Tyabji and Chase (2016)
[26]Orlandi, Tyabji and Chase (2016)
[27]SolarAid found that solar lantern users directed their savings to food (46% of respondents); education costs, including fees, uniforms, books (30%); farming inputs, such as fertilizer, seeds, equipment (8%); and other small-scale businesses (7%) (Harrison, Scott and Hogarth, 2016)
[28]Between 1998 and 2006, about 24,000 fires, resulting in 1,088 deaths, were reported in informal housing in South Africa alone. Candles were thought to have ignited one-third of them (see also UNEP, 2014b, which reports candles accounted for 40% of settlement fires). In Nigeria, kerosene-lamp explosions were responsible for nearly one-third of those admitted to the hospital with burns (Mills, 2015)
[29]The compounds emitted by devices that use kerosene – carbon monoxide (CO), nitric oxides (NOx) and sulphur dioxide (SO2) – exceed World Health Organization guidelines. They impair lung function and increase the risk of infectious illness (including tuberculosis), asthma and cancer (Lam and others, 2012a; Bates and Bruce, not dated)
[30]Replacing kerosene-fueled lighting can also significantly reduce greenhouse-gas emissions (Lam and others, 2012b). In total, kerosene lanterns produce the

equivalent of 240 million tons of CO2 per year – half the annual emissions of the United Kingdom, or 0.5% of the world's total (Orlandi, Tyabji and Chase, 2016)

[31]Kerosene poisoning is common, affecting 80,000 children per year in South Africa alone (Orlandi, Tyabji and Chase, 2016). Common complications include chemically induced pneumonia and damage to pulmonary and central nervous systems. Ingesting as little as 10ml can be fatal (Mills, 2015)

[32]Harrison, Scott and Hogarth (2016)

[33]Orlandi, Tyabji and Chase (2016)

[34]Orlandi, Tyabji and Chase (2016)

[35]Orlandi, Tyabji and Chase (2016)

[36]Hogarth (2012)

[37]Orlandi, Tyabji and Chase (2016)

[38]Orlandi, Tyabji and Chase (2016)

[39]Orlandi, Tyabji and Chase (2016)

[40]Diecker, Wheeldon, and Scott (2016)

[41]Orlandi, Tyabji and Chase (2016)

[42]Global LEAP (2015)

[43]Global LEAP (2016)

[44]In Kenya, for example, half a million households reported changes to their practices based on a popular television show focused on money management. A Tanzanian drama series highlighting high fertility rates led to wider discussions about family planning (Global LEAP, 2016)

[45]Global LEAP (2016)

[46]Customers generally pay around US$30 upfront for the system, and then regular payments ranging from US$0.20-0.50 per day for smaller systems up to US$2 per day for larger ones. Some PAYG models, including M-KOPA, use "mobile money" payments; others, such as Azuri Technologies, use scratch cards. Some businesses operate on a rent-to-own basis, where the customer eventually owns the solar home systems outright; others operate through perpetual payments (Orlandi, Tyabji and Chase, 2016; Scott and Miller, 2016)

[47]Orlandi, Tyabji and Chase (2016)

[48]IRENA (2015a)

[49]Most cost reductions will result from switching from standard AC appliances to DC ones. DC appliances currently are less common and costlier. However, they are more compatible with solar panels, which produce direct current power. Costs of DC appliances are expected to decline as they become more common (Orlandi, Tyabji and Chase, 2016)

[50]Global LEAP (2016)

[51]In the meantime, the diffusion of energy-efficient refrigerators is more likely to be driven by demand from off-grid businesses, not households

[52]Global LEAP (2016); Orlandi, Tyabji and Chase (2016)

[53]Winiecki and Kumar (2014)

[54]Clients who purchase solar home systems through lease-to-own PAYG models will also gain an asset that could be used as collateral (Orlandi, Tyabji and Chase, 2016)

[55]Orlandi, Tyabji and Chase (2016)

[56]Hogarth and Granoff, 2015

[57]USAID (not dated) calculated that the electricity needs of a larger clinic (with 60 beds) ranged from 5 to 10kWh per day. Practical Action (2013) estimated that the electricity needs for a primary school with approximately 100 students and four classrooms would be similar. Hogarth and Granoff (2015) calculated that over a 20-year period, off-grid technologies – wind, solar or hybrid diesel-solar systems – tend to be more cost-effective than the electricity grid in providing 5kWh per day to rural schools and small clinics that are currently more than 3.2 km from the electricity grid

[58]Practical Action (2014); USAID (not dated)

[59]Practical Action (2013)

[60]Africa Progress Panel (2015)

[61]Practical Action (2014)

[62]Strohmeier (2015)

[63]Scott and others (2014)

[64]CAFOD (2013)

[65]Tortora and Rheault (2012)

[66]In Ghana, for example, a study found the average income of solar-electrified enterprises to be 82% higher than non-electrified enterprises (although the causal direction of this relationship was difficult to untangle) (Obeng and Evers, 2010). In Uganda, micro-enterprises with solar were found to attract more customers per day than non-electrified ones and earn US$4.40 more per month (Harsdorff and Bamanyaki, 2009)

[67]Harrison, Scott and Hogarth (2016); Harsdorff and Bamanyaki (2009); Obeng and Evers (2010)

[68]Pachauri and others (2013)
[69]GVEP (2011a)
[70]Burney, Naylor and Postel (2013)
[71]Jain (2015)
[72]Hogarth and Granoff (2015)
[73]GIZ (2016)
[74]Global LEAP (2016)
[75]GIZ (2016)
[76]Practical Action (2014)
[77]UNEP (2015a)
[78]IRENA (2013b)
[79]Barber (2014)
[80]Global LEAP (2016)
[81]Africa Progress Panel (2015)
[82]IRENA (2015b)
[83]IEA (2014)
[84]The Economic Community of West African States (ECOWAS) has estimated a potential demand for 156,000 renewable energy mini-grids in West Africa by 2030 (ECREEE, 2012)
[85]In Sub-Saharan Africa, the estimated cost of rural grid connections is around US$2,300, compared with US$1,300 to US$1,900 for mini-grids, according to research by McKinsey (Castellano and others, 2015a)
[86]RECP (2013)
[87]IEA (2014)
[88]RECP (2013)
[89]SE4All (2014)
[90]IRENA (2015b)
[91]This categorization is also used in a status report by the Republic of Kenya (World Bank, 2016b), referring to the categories as Type 1, Type 2 and Type 3
[92]IRENA (2012)
[93]IEA (2014)
[94]IEA (2014)
[95]Based on a levelized cost of energy (LCOE) analysis, i.e. over the lifetime of the scheme
[96]Frankfurt School (2015)
[97]IEA (2011); Szabo and others (2013)
[98]UNDESA (2016)
[99]GVEP (2011b); RECP (2013); SBI (2013)
[100]RECP (2013)
[101]RECP (2013); SBI (2013)
[102]UNEP (2015b)
[103]SolarServer (2016)
[104]GVEP (2011b); RECP (2013); SBI (2013)
[105]Tungu-Kabiri (2016)
[106]RECP (2013)
[107]ESI Africa (2015)
[108]Navigant (2015)
[109]Palit and Chaurey (2011)
[110]This section draws on Tumiwa (2014)
[111]The Philippines has about 375MW of installed capacity in diesel mini-grids. Most are operated by the National Power Cooperation-Small Power Utility Group (NPC-SGUP), which operates mini-grids in 221 areas (IRENA, 2015)
[112]Following paragraphs draw on Palit and Chaurey (2011)
[113]Schnitzer and others (2014)
[114]GTM Research (2014)
[115]GTM Research (2015)
[116]The blackout that affected large swathes of the north-eastern United States in 2003 and hurricanes Katrina (2005) and Sandy (2012) highlighted the importance of resilience in the electricity supply
[117]GTM Research (2015)
[118]In 2015, New York committed US$40 million for micro-grids; Massachusetts allocated US$18 million for 13 projects; and California has allocated US$26.5 million for renewable energy micro-grids (Miret, 2015)
[119]Disrupt Africa (2015)
[120]SharedSolar (not dated)
[121]IEA (2011)
[122]IEA (2014)
[123]This section draws on Energy 4 Impact and Inensus (2016)
[124]UNEP (2015b)
[125]SBI (2013); UNEP (2015b); ENEA (2016)
[126]AREI (2015)
[127]Castellano and others (2015b)
[128]IEA (2014)
[129]IRENA (2015c)
[130]UNECA (2016)
[131]AREI (2015)
[132]KPMG (2016)
[133]KPMG (2016)
[134]AEEP (2016)

[135]ADB (2011)
[136]Bazilian and others (2012a)
[137]UNIDO (2005)
[138]Eberhard and others (2016)
[139]Eberhard and others (2016)
[140]Bazilian and others (2012b)
[141]Sovacool, Bazilian and Toman (2016)
[142]AfDB (2016)
[143]REI4P (2016)
[144]Eberhard and others (2016)
[145]Latham and Watkins (2016)
[146]UNECA (2016)
[147]Traoré (2013)
[148]Bazilian and others (2012a)
[149]Eberhard and others (2016)
[150]Eberhard (2016)
[151]Sources for this section include: Coal International (2016); UNFCCC (2017) contains the Intended Nationally Determined Contribution (INDC) documents for South Africa, Nigeria, Senegal, Egypt and Botswana; OCP Policy Center (2016); World Future Council (2016); EY (2016); IEA (2016)
[152]Statistics South Africa website, http://www.statssa.gov.za/?p=4820
[153]World Future Council (March 2016)
[154]Also known as feed-in tariffs as they are prices at which a power producer sells to the transmission grid
[155]IRENA (2016)
[156]EIU (2016)
[157]BNEF (2016)
[158]REN21 (2016)
[159]IRENA (2012)
[160]IRENA (2015c)
[161]IRENA (2016)
[162]UNECA (2016)
[163]UNECA (2016)
[164]Quitzow and others (2016)
[165]EIU (2016)
[166]Climatescope (2016)
[167]AEEP (2016)
[168]IRENA (2015b)
[169]UNECA (2016)
[170]Davis (2016)
[171]AEEP (2016)
[172]Davis (2016)
[173]AEEP (2016)
[174]AEEP (2016)
[175]GTZ (2007)
[176]Nyeko (2016)
[177]USAID (2015)
[178]Rosen (2015)
[179]Baker (2016)
[180]Quitzow and others (2016)
[181]Climatescope (2016)
[182]EIU (2016)
[183]GTZ (2007)
[184]Quitzow and others (2016)
[185]UNECA (2016)
[186]EIU (2016)
[187]GreenCape (2016)
[188]GreenCape (2016)
[189]UNECA (2016)
[190]IRENA (2015c)
[191]Climatescope (2016)
[192]EIU (2016)
[193]UNECA (2016)
[194]GreenCape (2016)
[195]Montmasson-Clair and Ryan (2014)
[196]Berenbach (2015)
[197]PV Insider (2016)
[198]IRENA (2015c)
[199]UNECA (2016); AEEP (2016)
[200]Another classification distinguishes between transmission losses and distribution losses, according to the stage in the supply chain that they occur in
[201]IEA (2014)
[202]PwC (2016)
[203]KPMG (2015)
[204]Davis (2016)
[205]KPMG (2016)
[206]UNECA(2016)
[207]Cayten and Bazilian (2016)
[208]Bafana (2016)
[209]Del Bello (2016)
[210]Guay (2016)
[211]Dubey (2015)
[212]This section draws on Tallapragada and others (2009); Eberhard and others (2008); Deloitte (2013)

[213]This does not include the theft of overhead wires, transformer components and other materials. Although this kind of theft also causes electricity losses, strictly speaking, it is not the theft of electricity. The theft of materials is a significant problem in some countries.
[214]PRNewswire (2014)
[215]Smith (2004)
[216]Tallapragada and others (2009)
[217]Eberhard and others (2011)
[218]Eberhard and others (2011)
[219]Bundock (2014)
[220]Okafor (2016)
[221]Never (2015); Winther (2012)
[222]Smith (2004)
[223]Never (2015)
[224]Malama and others (2014)
[225]NERC (2015)
[226]Malama and others (2014)
[227]Eberhard and others (2011)
[228]Eberhard and others (2011)
[229]World Bank (2015a)
[230]Eberhard and others (2011)
[231]Eskom (2016)
[232]Smith (2004)
[233]Sources for this section include International Energy Agency (IEA) (2016)
[234]Hill, Matthew and Thomas Wilson (2016)
[235]World Bank (2016a); Wilson, Thomas (2016)
[236]IEA (2014)
[237]Poggiolini (2016)
[238]AEEP (2016)
[239]IRENA (2013a)
[240]AfDB (2016)
[241]UNECA (2016)
[242]IRENA (2013a)
[243]IEA (2014)
[244]IEA (2014)
[245]IRENA (2013a)
[246]IRENA (2015c)
[247]IRENA (2013a)
[248]AEEP (2016)
[249]Poggiolini (2016)
[250]IRENA (2012)
[251]IRENA (2012)
[252]Tsiko (2016)
[253]Creamer (2016)
[254]Senelwa (2015)
[255]East African (2016)
[256]SARDC (2016)
[257]Standard Bank (2016)
[258]Tsiko (2015)
[259]Ford (2016)
[260]IEA (2014)
[261]ESI Africa (2016)
[262]Ligami (2016a)
[263]IEA (2014)
[264]Demierre and others (2014)
[265]Ligami (2016b)
[266]Demierre and others (2014)
[267]Poudineh and Rubino (2016)
[268]Nerini and others (2016)
[269]Kojima and others (2016). They cite the Global Tracking Framework report (World Bank, 2015b) that about 35% of African households lived without access to electricity in 2012, compared to 21% in the second worst region, South Asia. Access to electricity was 69% of urban residents and 15% of rural residents, compared to 70% of rural residents in South Asia
[270]Briceño-Garmendia and Shkaratan (2011)
[271]Africa Progress Panel (2015), and Sy and Copley (2016)
[272]Sy and Copley (2016)
[273]IMF (2015)
[274]Sy and Copley (2016)
[275]ICA (2013)
[276]Antony Karembu, quoted in Sy and Copley (2016)
[277]International Energy Agency (2014)
[278]Cayten and Bazilian (2016)

AFRICA PROGRESS PANEL