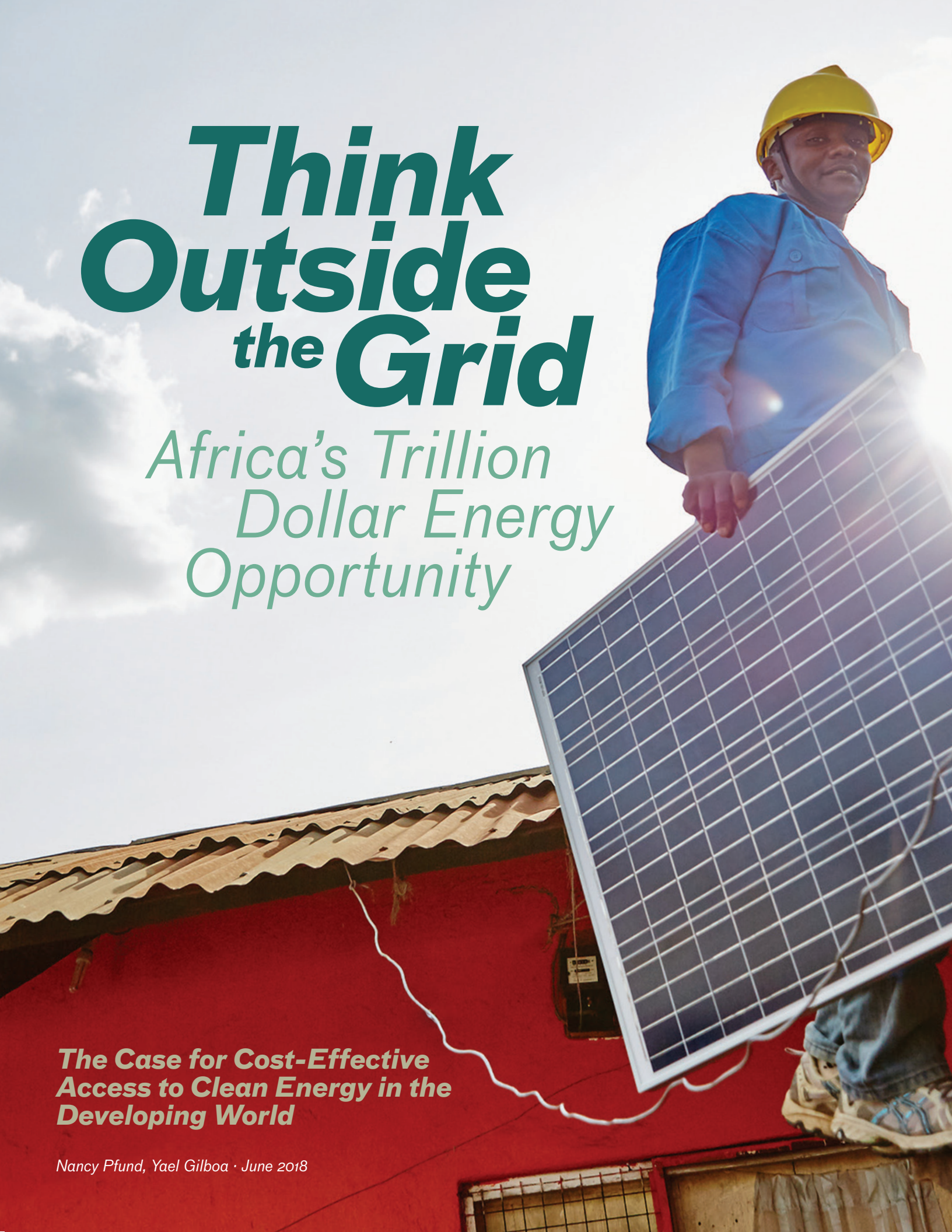

Think Outside the Grid

Africa's Trillion Dollar Energy Opportunity

The Case for Cost-Effective Access to Clean Energy in the Developing World

Nancy Pfund, Yael Gilboa · June 2018

About the Authors

Nancy Pfund
is Founder and Managing Partner of DBL Partners, a venture capital firm whose goal is to combine top-tier financial returns with meaningful social, economic and environmental returns in the regions and sectors in which it invests.

Yael Gilboa
Yael Gilboa is an Associate at DBL Partners.

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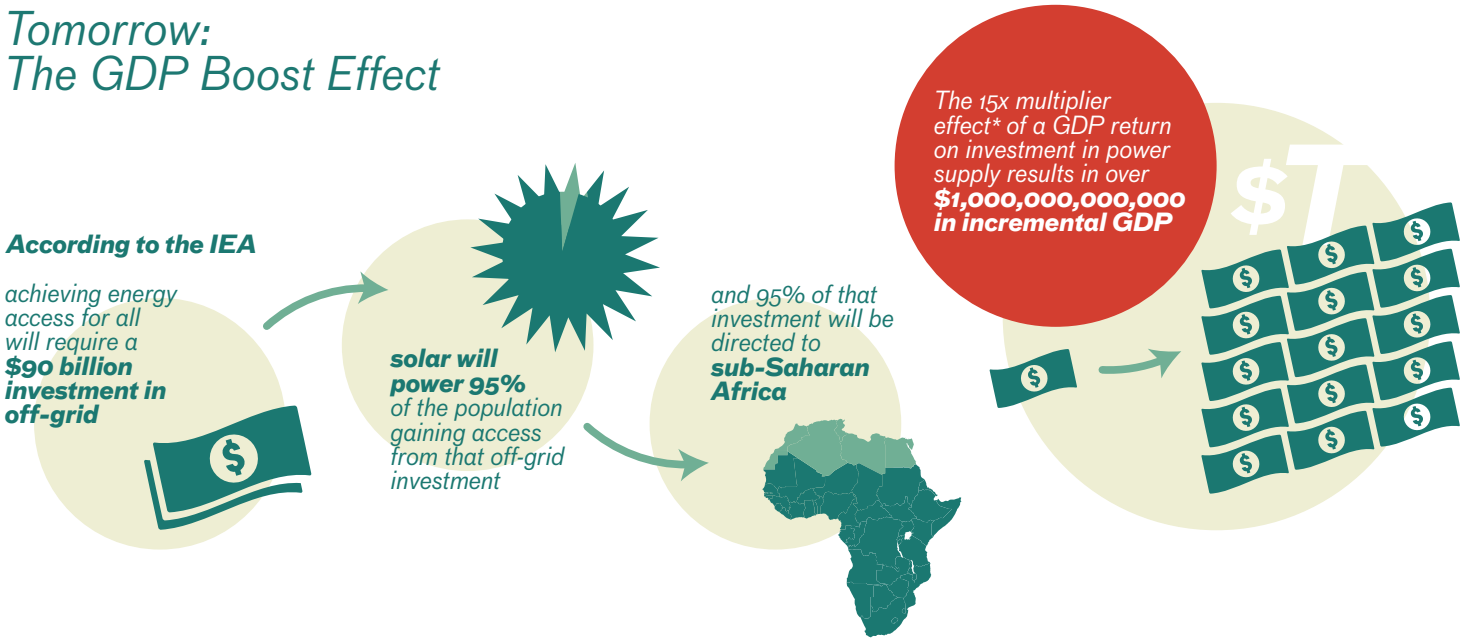
Cover photo courtesy of Zola Electric.

Executive Summary

Sub-Saharan Africa is on the cusp of a trillion dollar tomorrow. Emerging from a history of limited energy access, the region has the opportunity to unleash over $1 trillion of GDP simply by investing in off-grid solar to provide energy access to those who need it.

Exhibit 1: Investing in Solar in Sub-Saharan Africa Today For a Trillion Dollar Tomorrow: The GDP Boost Effect



Source: IEA Africa Energy Outlook and Energy Access Outlook (2017). The IEA estimates that providing electricity to all by 2030 will require a total investment of $391B, including $187B investment in mini-grid, $114B investment in grid and $90B investment in off-grid. Given that "every $1 invested in power supply generates more than $15 in incremental GDP" (IEA), and conservatively applying that 15x multiplier effect to only $90B (off-grid, excluding mini-grid) x 95% (solar) x 95% (SSA), this results in $1.2 trillion of incremental GDP from investment in off-grid solar in sub-Saharan Africa alone.

Executive Summary

The developing world, and sub-Saharan Africa in particular, is in the early stages of a dramatic energy transition. The increasingly tech-savvy and young population of Africa is embracing innovation, skipping landlines for mobile phones (2%[1] vs. 80%[2]), and increasingly choosing affordable off-grid solar in place of expensive and dangerous kerosene lamps or unreliable connections to the grid. Spurred by fundamental demographic and economic changes in the developing world, GDP growth in sub-Saharan Africa is dramatically outpacing other regions, and the supply of sustainable energy will both need to keep up and drive more growth in turn.

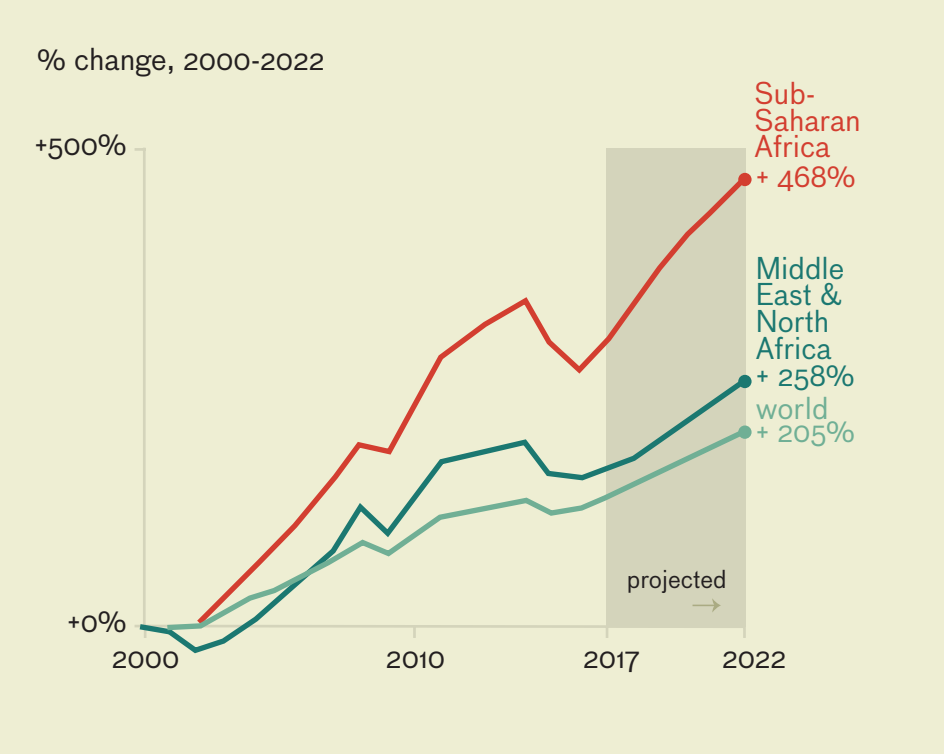


Exhibit 2: Sub-Saharan Africa Leading: GDP Growth in Africa and the World

Spurred by fundamental demographic and economic changes in the developing world, GDP growth in sub-Saharan Africa will dramatically outpace other regions over the next five years, and supply of sustainable energy will need to keep up.

Source: IMF World Economic Outlook, Jan 2018

Lack of access to reliable power presents a huge obstacle to progress, however; only 43% of the population today has access to electricity. Energy provision is not a commodity in Africa like it is in the U.S., where the grid can provide low-cost, high-quality power. For consumers across African markets who have historically lacked access and paid an exorbitant price for power, solar represents a path toward energy independence. Given that population growth is outpacing the population gaining access to electricity, the IEA estimates that the number of people on the continent without access to electricity will increase by 2030 without a commitment to invest in energy access.

While one in seven people on earth today lack access to electricity, the age of energy independence, choice and upward mobility is upon us. Africa is at the center of this transition.

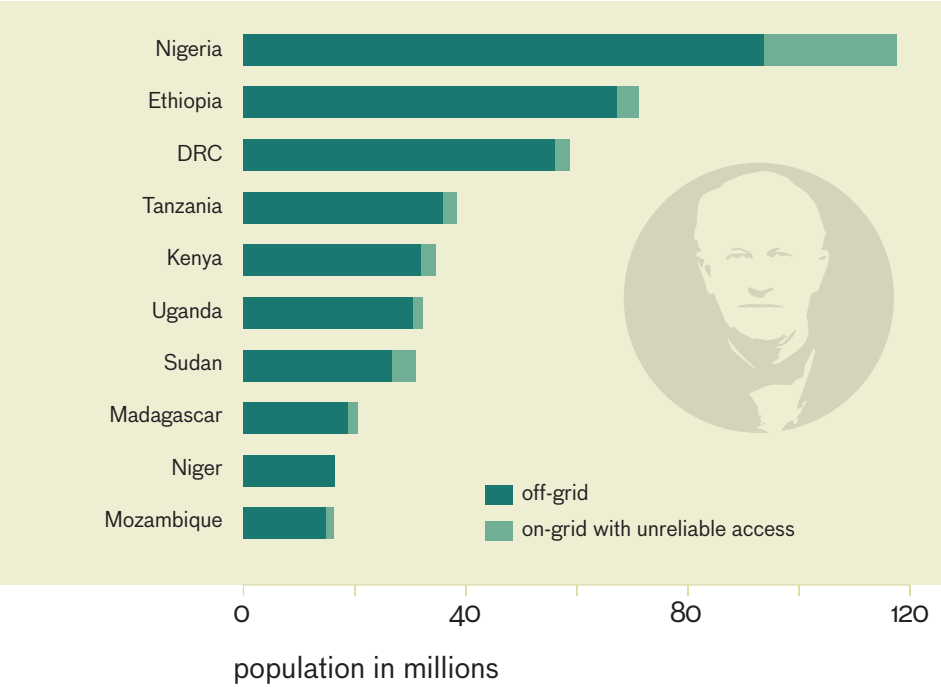


Exhibit 3: What Would Thomas Edison Do? Some 1.2 billion people today lack access to electricity – the same as when Thomas Edison invented the lightbulb in 1879 – and half of them live in Africa

Source: Africa Progress Panel, Lights Power Action: Electrifying Africa, *2016*

Exhibit 4: Carbon Crisis – Fossil Fuel Subsidies Far Outweigh Climate Finance

Source: Whitley, Shelagh and van der Burg, Laurie, Fossil Fuel Subsidy Reform in sub-Saharan Africa: From Rhetoric to Reality, *Overseas Development Institute, 2016.*

From the farm to the city, off-grid solar challenges the conventional wisdom

To address the challenges of bringing reliable access with the potential to improve quality of life dramatically across the continent, Africa needs to develop massive amounts of both on-grid and off-grid capacity. The conventional approach – and the one emphasized by most federal policies and funding in African nations – has been to construct large centralized generating stations that deliver electricity at various levels of functionality and reliability. Faced with a sub-par grid, people are not sitting still with this and often opt to add DIY systems, such as diesel generators, on their apartments, which are both costly and dirty. This paper places the spotlight on a different approach – one that is rapidly growing (and attracting investment) – off-grid solar systems and their related implementations. In addition to providing cost-effective energy access off the grid, solar home systems increasingly also provide reliable energy access in urban and peri-urban settings with dysfunctional grids.

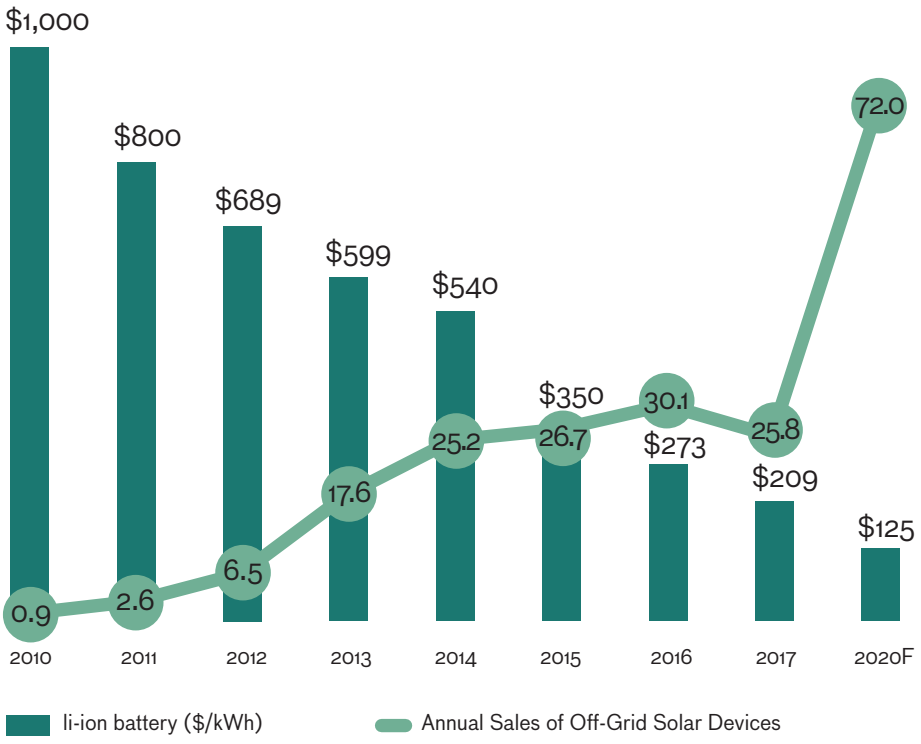
Same old fossil frenzy, solar progress in spite of subsidies for fossil fuels

Renewable energy developers and many government leaders are pursuing this tremendous opportunity in spite of the fact that fossil fuels are still heavily subsidized in Africa, and throughout the developing world. In fact, fossil fuel subsidies reached $26 billion in sub-Saharan Africa in 2015, paling in comparison to the much smaller levels of climate finance received by these countries to help combat the challenges of climate change. While fossil fuel subsidies may benefit some in developing countries – often those most wealthy – these subsidies compete with public spending on resources that would more directly address pressing needs for economic development in sub-Saharan Africa, such as health and education services, as well as extending access to clean energy for the poor and financing the development of a low-carbon infrastructure.

Thanks to falling costs, solar is on the rise, as is quality of electric life

Despite the subsidy situation, great opportunity for the continent of Africa lies in distributed energy innovations, from solar-powered lanterns to solar home systems that generate electricity to power LED lights, charge phones, and run simple appliances. These systems allow users to live their electric life the way they want to, not the way existing infrastructure has determined for them. The most essential driver of this has been economics as the cost of solar modules, lithium ion batteries and LED lights each fell 70-80% from 2010 to 2016. These cost trends translate directly to increased sales and improved energy independence.

Exhibit 5: Seeing the Light Thanks to Plummeting Costs

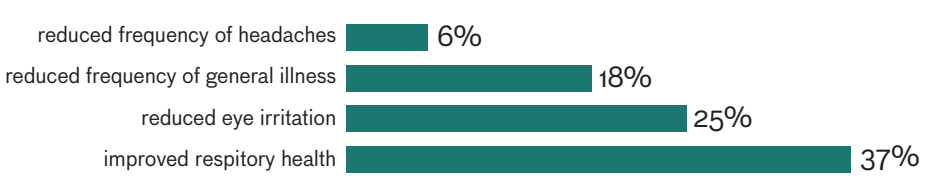


Source: GOGLA Off-Grid Solar Market Trends Report 2018

Hidden no more: the cost of health impairment from fossil energy no longer swept under the rug

Underscoring the importance of not just energy access, but clean energy access, the United Nations (U.N.) Sustainable Development Goal (SDG) #7 calls for ensuring "access to affordable, reliable, sustainable, and modern energy for all" as crucial to achieving other goals in health, education, and poverty eradication. Beyond the benefits of energy access, the U.N. has helped highlight the urgency of switching from fossil fuels not only for our planet's health, but our own. The cost of kerosene is too high, with toxic indoor air pollution from noxious gases that create health hazards, as well as increased incidence of accidents such as burns, fires and poisoning (as kerosene is routinely sold in soda bottles and people, especially children, can—and often do—ingest it accidentally).

Exhibit 6: Kicking the Kerosene Habit: improved health among households that switched from kerosene to a solar light (% of households with reductions in health issues)



Source: GOGLA Off-Grid Solar Market Trends Report 2018

Throughout this paper, we take a closer look at the energy future of the developing world and preconceived notions about so-called cheap fossil fuels vs. renewables. We note the folly of subsidizing yesterday's news (e.g. centralized coal plants) and, as a cautionary tale, take a look at other developing nations' health costs associated with coal. Glimpsing into a future already emerging, we set the stage for a continent in which an electricity system goes back and forth seamlessly between rooftop solar installations and the grid (direct current (DC) to alternating current (AC)), with an opportunity for African nations to be global leaders in energy innovation. With the proliferation of off-grid solar and microgrids (localized grids that can operate autonomously of the traditional grid, sometime also referred to as mini-grids) bypassing the conventional wisdom of large power plants using the central grid, the continent of Africa can not only transform its own energy future, but in so doing serve as a model for the rest of the world as well.

21st century solar innovation leadership in Africa

Exhibit 7: Microgrids in Africa may serve as a model for the rest of the world

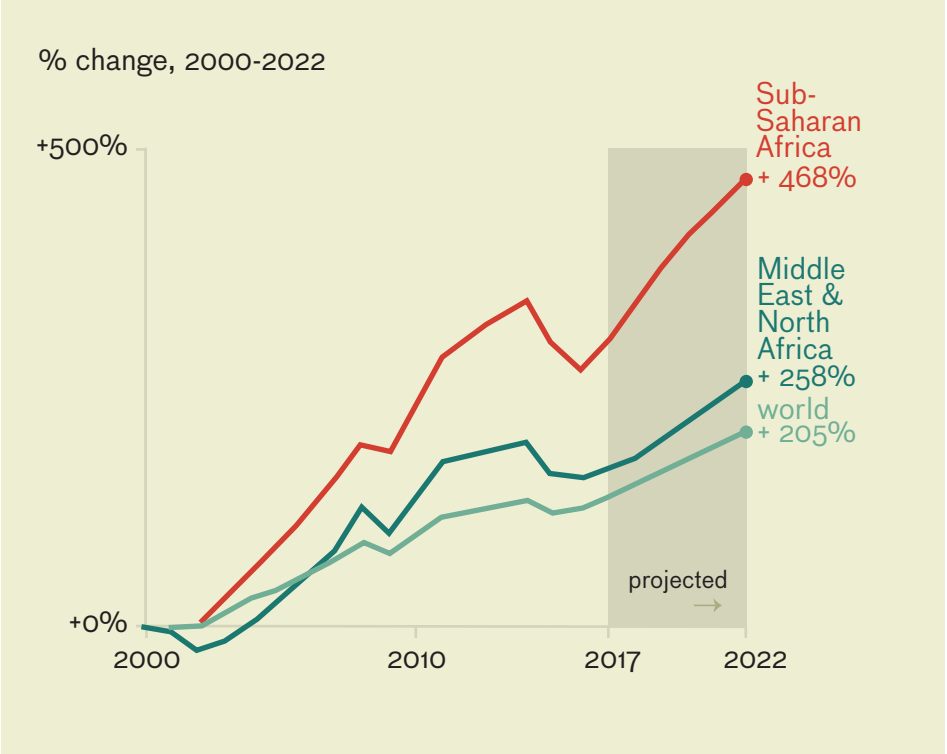
Source: EU Energy Initiative (EUEI) Mini-Grid Policy Toolkit (2014), adapted from ARE, ME SOLshare

Introduction: A World in Energy Transition as a Continent Comes of Age

Across the world, a transformation is happening. Our perceptions of the developing world will become obsolete as global GDP growth continues to shift toward Africa and Asia. Meanwhile, the increasingly young, rapidly urbanizing and tech-savvy populations in these regions are erring on the side of innovation, skipping landlines for mobile phones and mobile-based business models when traditional infrastructure has been slow to develop or is absent. Today's generation in emerging markets has the opportunity to lead the way in innovation, which will spur greater economic impact for the continent going forward and make it less dependent on importing outdated models from the developed world.

Exhibit 8: Sub-Saharan Africa Leading Global GDP Growth

Spurred by fundamental demographic and economic changes in the developing world, GDP growth in sub-Saharan Africa will dramatically out-pace other regions over the next five years, and supply of sustainable energy will need to keep up.

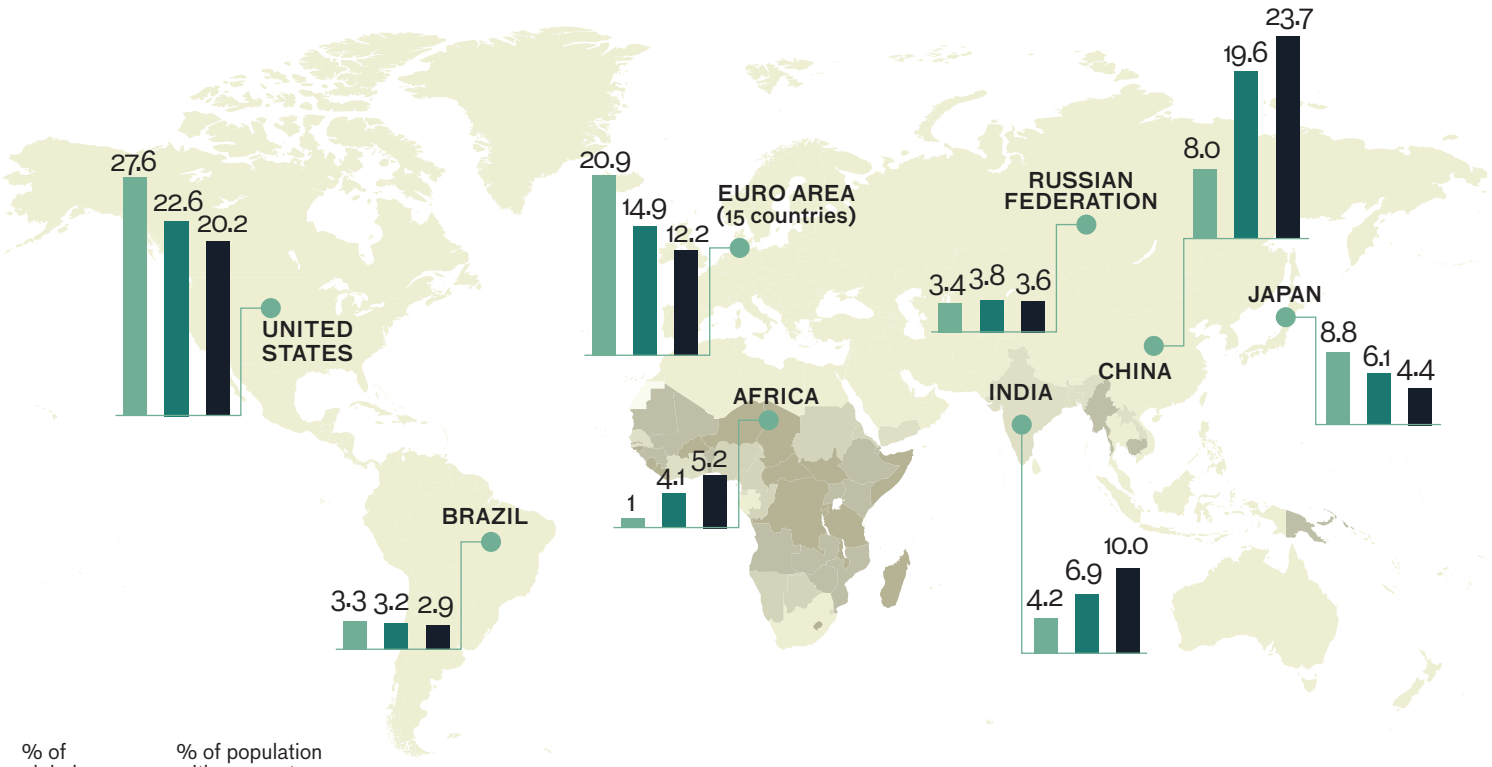


Source: IMF World Economic Outlook Database, January 2018

Fundamental demographic shifts drive this transformation that will ultimately shape our energy future: by 2100, more than 80% of the world will live in Africa or Asia,[3] Africa's population will more than double by 2050,[4] and virtually all this growth will be concentrated in urban areas, with more than 60% of Africa's population living in cities by 2050.[5] With an increasingly young population, Africa is also poised to be home to the largest pool of untapped talent in the world: 60% of the continent's population is under 35 today and the average age in Africa will be 25 by 2050 at a time when the average age in the world reaches 36. Furthermore, while the global middle class will almost double, the growth of sub-Saharan Africa's middle class (roughly 6% today, although that number varies based on how middle class is defined) will surpass growth rates in any other part of the world.[6] With such a ripe concentration of human capital, the cities of Africa and Asia are poised to become leading global leaders of innovation.

This potential is starting to take shape as companies like Andela[7] connect top African talent with global technology employment, M-KOPA contributes to the emergence of a new Kenyan workforce in distributed solar and storage, and Zola Electric (formerly known as Off Grid Electric) partners with French energy giant EDF and others to bring a clean energy ecosystem beyond its roots in Tanzania to Cote D'Ivoire, Ghana and beyond.

Exhibit 9: Fundamental Demographic and Economic Shifts Drive Global Growth to Africa and Asia

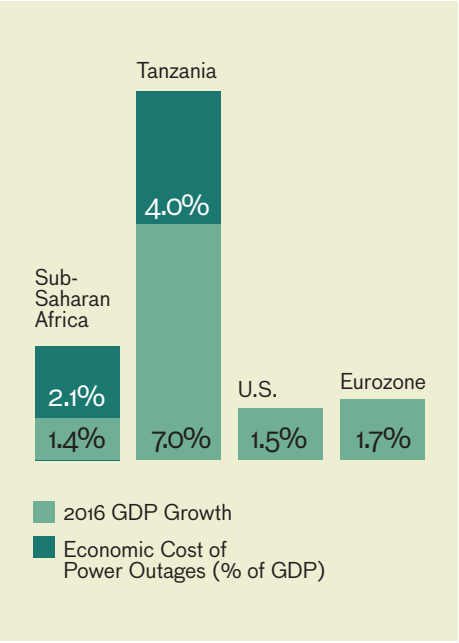


Source: OECD Science, Technology and Innovation Outlook, 2016; Statistica.com; EY's Africa Attractiveness Program, May 2017.

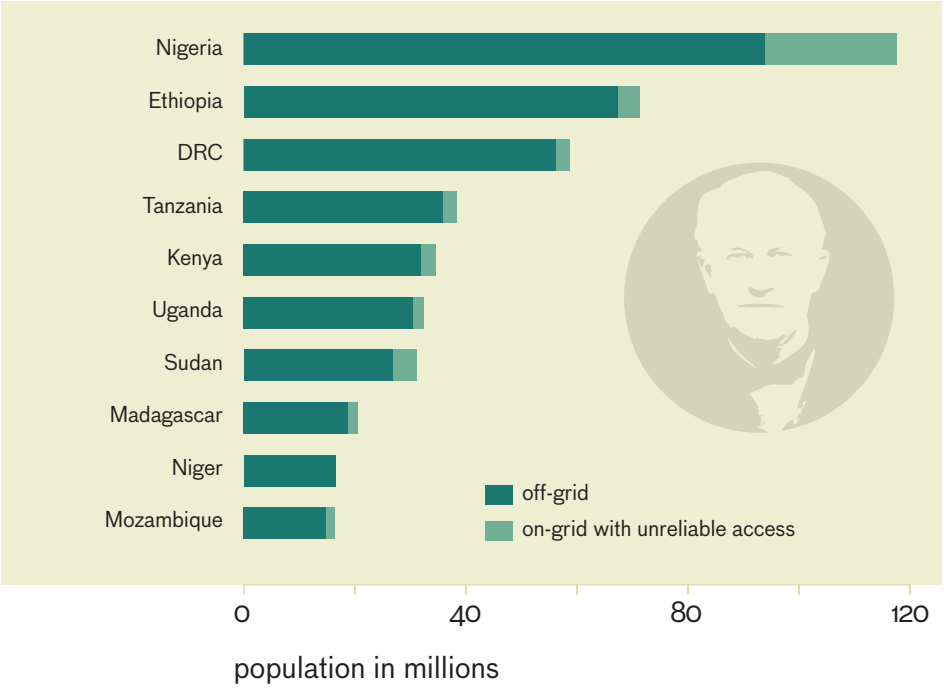
Against this backdrop, we have the opportunity to rethink the energy system that we have grown accustomed to and what should be built in the developing world. In regions around the globe, terawatts of additional capacity must come on board to support economic growth. Off-grid solar power alone is projected to be a $12 billion annual global industry by 2030.[8] The groundwork for this is underway, but still embryonic. Current lack of access to electricity, or the intermittency of unreliable grid power, along with political instability, are barriers to improved health, education, and economic advancement in the developing world. Irregularity in power limits the continent's ability to reach its full potential. In fact, the World Bank estimates that the cost of irregular power in sub-Saharan Africa equates to 2.1% of GDP, and is worse in countries like Uganda, South Africa and Malawi, where that cost is over 5% of GDP.[9] This means that fixing the problem of power outages alone would have effectively doubled the GDP growth of sub-Saharan Africa, making a tremendous impact on the region's total GDP of $1.5 trillion.[10]

To make these grid and capacity improvements happen, improved electricity services must meet the standards of quality and reliability that a rising middle class will increasingly demand. To get started, this region needs basic, affordable, distributed electricity services that can be deployed quickly to accommodate dispersed populations with limited access to power. At the current pace, however, especially in Africa, energy access will not meet U.N. SDG #7 by 2030 as access to electricity is not keeping up with population growth in sub-Saharan Africa.

Exhibit 10: Plugging Into GDP Growth: The Shadow Cost of Unreliable Electricity



Source: World Bank



One in seven people on earth today lack access to electricity

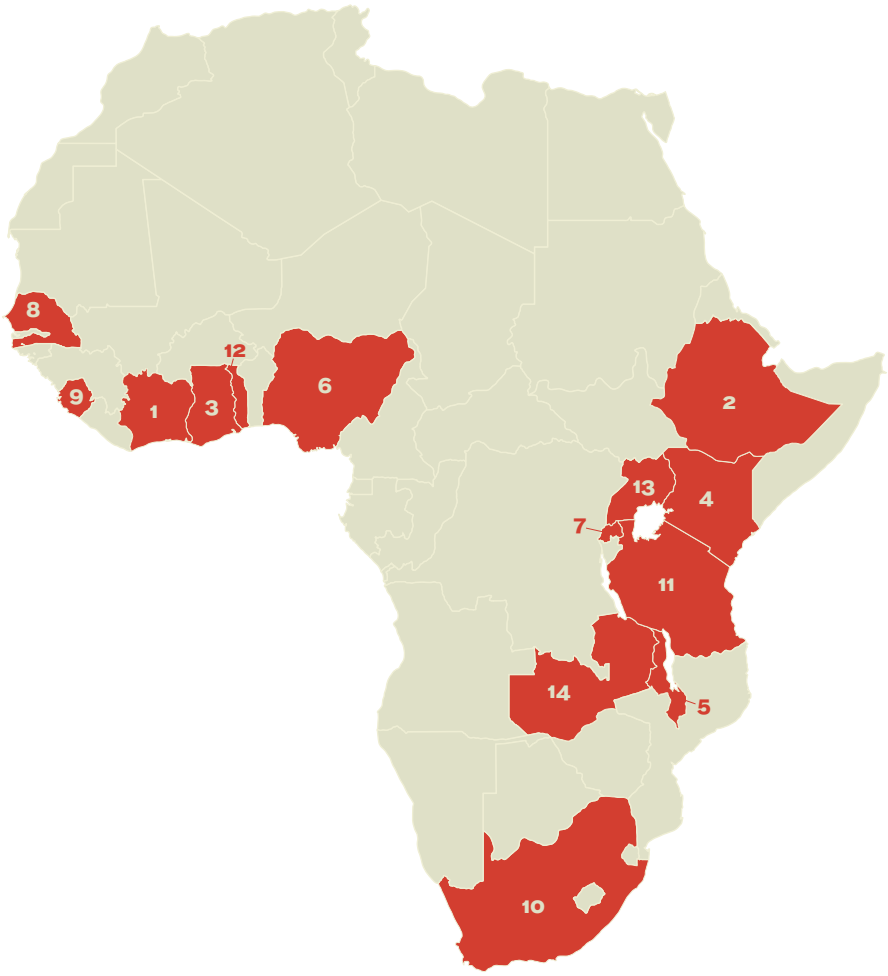
Exhibit 11: What Would Thomas Edison Do? Some 1.2 billion people today lack access to electricity—the same as when Thomas Edison invented the lightbulb in 1879—and half of them live in Africa

Source: Africa Progress Panel, Lights Power Action: Electrifying Africa, *2016*

All eyes are on off-grid solar systems to play a critical role in the energy transformation of developing nations across sub-Saharan Africa and Asia. Once a small niche dominated by non-profits subsidizing what began as an expensive energy option, off-grid solar (both stand-alone systems and those integrated into microgrids) is now a fast-growing business sector with products that are increasingly reliable, affordable, and available in remote areas. Beyond energy provision, these systems provide energy independence for consumers who have historically lacked access and paid an exorbitant price for power. Unlike the U.S., energy provision in Africa is not a commodity, and that different dynamic supports a distributed ownership model for consumers who see real value in owning the asset.

Spurred by dramatic cost reductions in solar over the last decade, entrepreneurial for-profit companies such as M-KOPA, Mobisol, BBOXX, Fenix International, Lumos Global, Azuri, d.light, Zola Electric, and others, are helping to further drive down costs, often making the clean energy option the cheapest energy option as well. Right now, many of these leading innovators, often initially funded by investors in North America and Europe, several of which are winners of the coveted Zayed Future Energy Prize, are most active in the sub-Saharan African nations of Ghana, Kenya, Rwanda, Cote d'Ivoire, and Tanzania. Expansion to other markets, including the behemoth Nigeria, is in sight for many of these players. Kenya-based M-KOPA alone has brought solar to half a million homes, and, in its first year in Cote d'Ivoire, Zola Electric went from zero to 10,000 customers. In essence, such enterprises are providing a 'double leapfrog' by both jumping over fossil fuels (powering diesel generators) and, in many instances, the need for the traditional grid itself.

Exhibit 12: Solar on Our Mind: A wide range of companies offer pay-as-you-go solar across the continent



1. COTE D'IVOIRE
Zola Electric

2. ETHIOPIA
Azuri

3. GHANA
PEG Ghana
Azuri
Zola Electric

4. KENYA
SunTransfer
BBOXX
M-KOPA
Mibawa

5. MALAWI
Azuri

6. NIGERIA
Nova Lumos

7. RWANDA
Mobisol
BBOXX
Zola Electric

8. SENEGAL
Oolu Power

9. SIERRA LEONE
Azuri

10. SOUTH AFRICA
AzuriKingo

11. TANZANIA
Mobisol
Fenix International
Zola Electric
Eternum Energy
EEG Energy

12. TOGO
Azuri

13.UGANDA
Fenix International
BBOXX
Azuri
M-KOPA
Villiage Power
Solar Now

14. ZAMBIA
Fenix Int'l

Note: This list represents a sample and does not claim to be comprehensive. Sources: GOGLA Off-Grid Solar Market Trends Report 2018, BNEF Off-Grid Solar Report 2016

Unlike the 20th Century, the Central Grid Alone is Not the Answer

Since the modern electricity system arrived on the scene over a century ago, there has been little significant disruption to the model to date. Nikola Tesla demonstrated that AC transmission lines could carry high-voltage current across long distances, and so the U.S. began building out fossil fuel-guzzling generation plants and transmission lines to bring electricity to the masses. As people needed more power, utilities built out the centralized network of plants, extended transmission lines, and grew to become regulated monopolies. Due to economies of scale, this model made sense: as more people signed on to a centralized network, the unit cost of electricity decreased as utility system costs were shared by many. Most industrializing nations followed suit, and a step-change ensued in the improvement of basic human living conditions and economic growth. Even today, such plants are increasingly being constructed across Africa and partially financed by China. Among these are Amu Power's proposed 1,050-megawatt coal plant on the Kenyan island of Lamu, the 3,050-megawatt Mambilla hydro station in Nigeria, and the 6,000-megawatt Grand Ethiopian Renaissance Dam in Ethiopia.

But this relentless pursuit has come at a cost. As a cautionary tale, Africa can look a hemisphere away to Southeast Asia to see the human and economic costs of a grid that is powered mostly by coal – which is often heavily subsidized. Air pollution from coal-fired generation directly affects human life, as well as the environment, in ways that can be particularly costly for developing nations.

According to the World Bank, air pollution has emerged as the deadliest form of pollution, the 4th leading risk factor in premature deaths worldwide, and cost the global economy more than $5 trillion in welfare losses in 2013. In East and South Asia, welfare losses represented a staggering 7.5% of the region's GDP. And it's a bigger risk than you might think: more than six times as many people die from air pollution each year than from malaria, and more than four times as many than from HIV/AIDS. Not only is the loss of life tragic, but its cost to the economy is substantial. The lost income from air pollution alone cost the global economy $225 billion in 2013. This particularly disadvantages regions with younger populations, such as sub-Saharan Africa, in which 30% of early deaths from air pollution were suffered by children under 5, relative to less than 1% in Europe and Central Asia. That lost labor income cost the equivalent of 0.61% of GDP in sub-Saharan Africa, and 0.83% of GDP in South Asia.[11]

Exhibit 13: The Deadly Cost of Coal-Related Disease

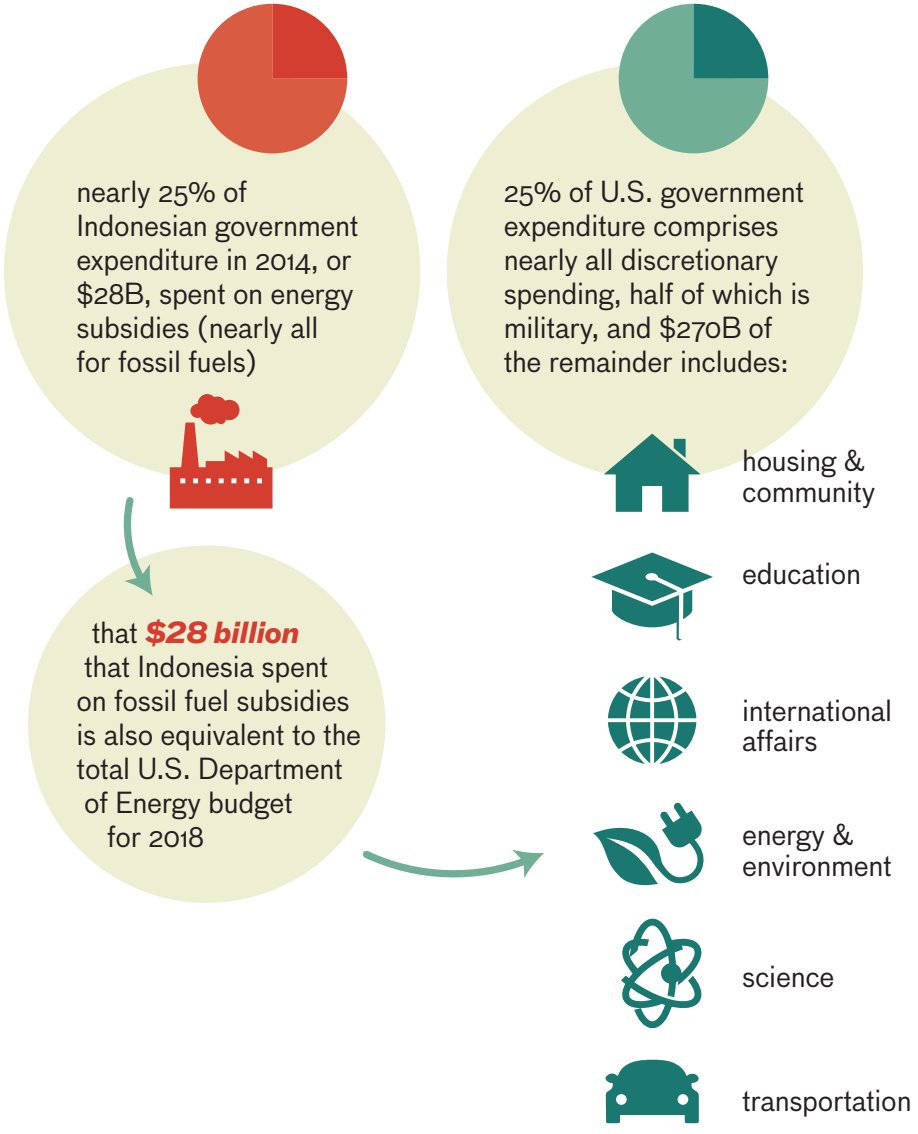
Source: World Bank

Despite this enormous human and economic toll, in Indonesia, energy subsidies (nearly all for fossil fuels) accounted for 3.1% of GDP (or $110 per capita) and close to one quarter of total government expenditure in 2014.[12] To put this into perspective, Indonesia's government expenditures on oil and electricity rate subsidies, somewhat amazingly, amounted to the entire budget of the U.S. Department of Energy, roughly $28 billion.

Indonesian citizens not only suffer the ill health effects from coal power-caused air pollution, they also pay for the privilege through these large subsidies. This adds up to a deadly double whammy and a whopping 25% of government expenditures.

Exhibit 14: Equality We Can Live Without: Indonesia's Staggering Subsidies Equal to Entire U.S. DOE Budget

Sources: 1. Global Subsidies Initiative and International Institute for Sustainable Development, Indonesia Energy Subsidy Review: A Biannual Survey of Energy Subsidy Policies, March 2014, reflects 2013 FY numbers; IEA Southeast Asia Energy Outlook 2015; OECD 2. Nationalpriorities.org 3. Department of Energy FY 2018 Budget Request Fact Sheet, May 23, 2017



Africa's Electricity Conundrum

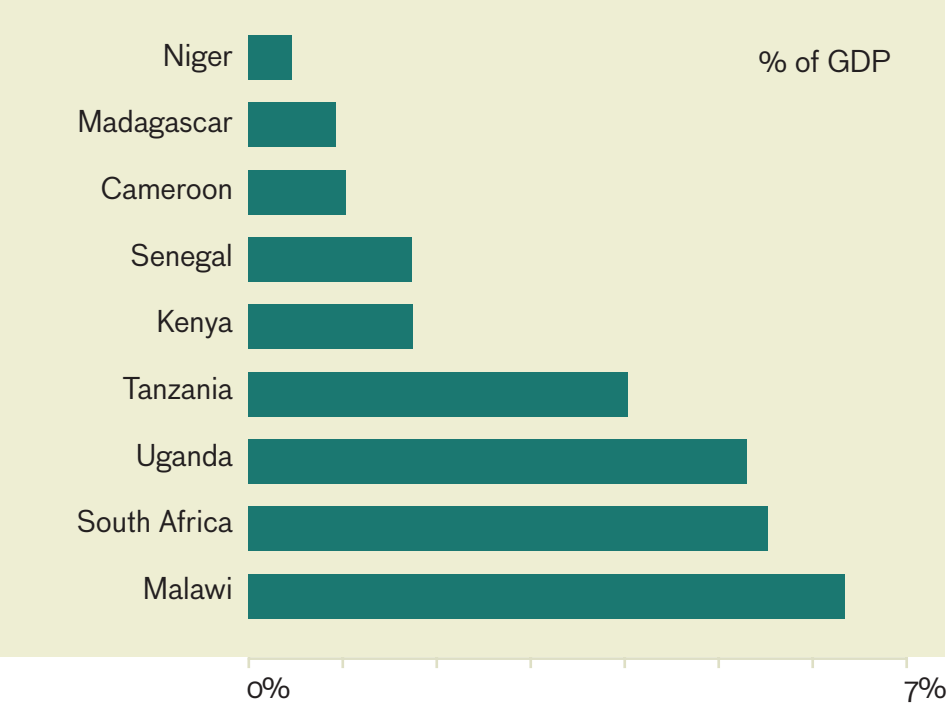
For much of the developing world today, the centralized model is broken. Approximately 1.2 billion people have no access to electricity – whether because the central grid is non-existent, inaccessible or dysfunctional – and half of them live in Africa.[13] While the U.S. had achieved 100% electrification by 1950, some of Africa's most developed countries (e.g. Egypt and South Africa) had electrification rates below 30%.[14] Today, North Africa (nations such Morocco, Tunisia, and Egypt) and South Africa have electrification rates of 99% and 85% respectively, but East and Central Africa have electrification rates of only 25%.[15] Moreover, the 500 million Africans with access to electricity consume less than 10% of an average American's electricity consumption.[16]

Part of the conundrum lies in the fact that a centralized grid requires heavy upfront capital investment, and constructing power lines is expensive (estimated at $23,000 per kilometer in sub-Saharan Africa, according to the Rocky Mountain Institute). Grid connection for customers is costly too: $400 per household in Kenya, nearly a third of average per-capita annual income in that country, and more expensive in other parts of the continent.[17] This perpetuates a stifled economy that limits the build-out of a centralized grid, which in turn limits access to electricity for basic needs and services, which in turn stunts economic development.[18]

Plugging Into GDP Growth

While there are different energy experiences across Africa for on- and off-grid users, both are in need of more power. For on-grid users, typically in urban areas with homes or businesses that are grid-connected, access to power is highly irregular. Some 30 countries in sub-Saharan Africa face daily rolling blackouts, which cause negative impacts such as clinics not being able to reliably refrigerate medicine, and businesses not being able to optimally grow as they modify their working hours to the eight to ten hours per day with reliable electricity.[19] In Tanzania, power outages were so common in 2013 that they cost businesses 15% of their annual sales.[20]

Exhibit 15: Blackouts Beware: Economic Cost of Power Outages (% of GDP)



Source: World Bank

Rolling blackouts perpetuate dysfunctionality of the grid, and reinforce the demand for energy independence

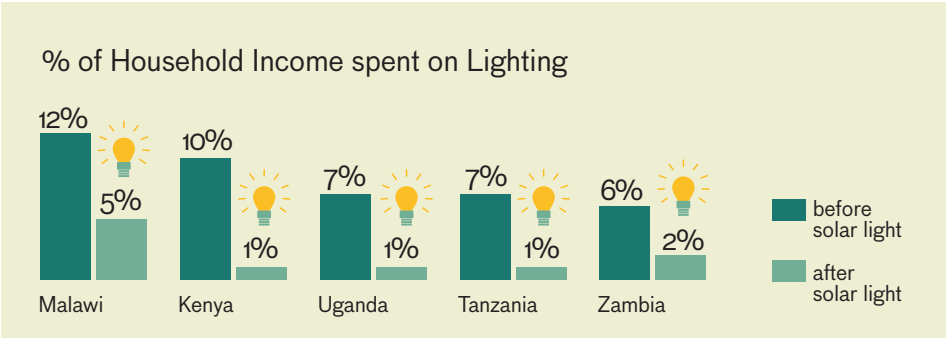
Furthermore, unreliable power has forced many to invest in backup diesel-powered generators, which produce greenhouse gases and other pollutants damaging to health. These communities need power, and are finding ways around the dysfunctionality of their grid with so-called "Frankenstein" systems of diesel generators and strewn wires to supplement the few hours of grid access they do have. In sub-Saharan Africa, private backup generation makes up 6% of total installed capacity and often costs three times more than buying power from the grid. In Nigeria, there are 60 million diesel generators,[21] which represents an astounding one per household of three people. Beyond its steep price tag, the diesel power is also dirty.[22] Solar home systems provide a clean alternative that is high quality and low cost.

Meanwhile, many off-grid users are often rural, living far from the grid or transmission lines, and have never accessed modern grid services before. As a result, rural communities have lacked access to much of the progress that the grid has enabled, with the exception of limited access to lighting, for which individuals spend up to 10% of their household income on candles and kerosene for only four hours of light at night.[23] Furthermore, due to the increasing penetration of mobile phones and mobile-based business and bill payment, they increasingly require the ability to charge their phones. Many mobile users must visit 'charging shops' in cities to charge their phones, the cost of which could add up to half of their monthly expenses between the per-charge payment and the expense of traveling to and from the charging shop. By contrast, most Americans spend only 2-3% of their annual wages on power for *all* of their electric needs.[24]

The evolving energy landscape across Africa requires a rethinking of both on and off-grid dynamics: the grid must get stronger for the on-grid user, and complemented for the off-grid user. While it is no secret that Africa has plentiful sunshine, fossil fuels (coal, oil & gas) generate most of the power in sub-Saharan Africa, which means that on-grid users will increasingly face the adverse effects of air pollution unless a material shift emerges. African utilities must scale up electricity supply to overcome rolling blackouts and meet growing demand. Off-grid technologies must also improve to support a variety of consumption needs so that rural communities can more effectively access modern comforts and commerce. Furthermore, there is a strong case for policy incentives to support, complement, and help expand the affordable pay-as-you-go (often referred to as PAYGO) models offered by off-grid solar companies given that off-grid users pay for all facets of their system, whereas on-grid customers are effectively subsidized with the shared resource of a centralized grid. One way to do this would be to provide economic incentives for individual users to feed solar power and, going forward, storage capacity back into the grid in a distributed manner, similar to other areas around the world.

Communities save by switching to solar

Exhibit 16: The Solar Advantage: Proportion of household income spent on lighting



Source: GOGLA Off-Grid Solar Market Trends Report 2018

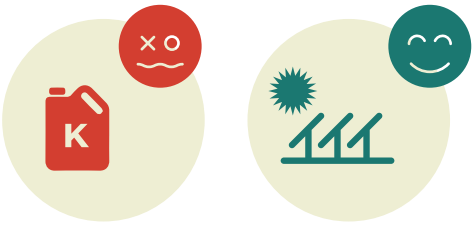
Distributed Energy's Cost Advantages Create an Opening for the Developing World

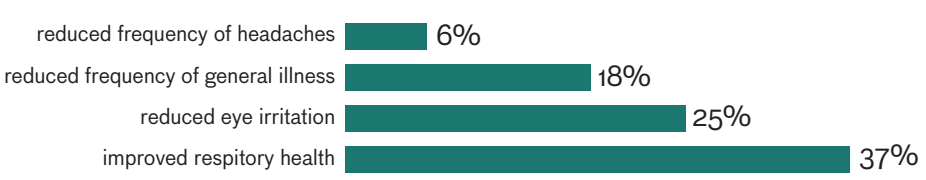
The early implementations of distributed solar in Africa are demonstrating its unique economic advantages and health benefits for the developing world. High-quality, distributed solar systems are often the best solutions for unelectrified populations because they are clean and increasingly accessible and affordable. Solar-powered lanterns are the simplest of solar products today that address the essential need of all off-grid households to have: access to lighting. Opting for solar lanterns over kerosene lamps not only saves money[25] but also avoids health and safety issues from contact with toxic fumes or fires and burns from kerosene.

Hundreds of types of solar products have come into fruition since the invention of the first solar lantern. More advanced products include solar home systems that serve a single household through solar panels installed on rooftops, small batteries to store solar panel energy for night time, and that utilize a pay-as-you-go model. Electricity generated is used to power LED lights, charge phones, and run simple appliances, such as a fan, radio, or television. More high-end applications that have a higher electricity drain (e.g. air conditioning and refrigeration) will benefit from technological advancements in appliance, solar, and battery efficiency, and the ability to tap into alternative sources of power in order to become cost-effective. Some companies are looking to address this through innovative approaches to AC/DC conversion systems, or technologies that enable tapping into microgrids or other neighboring supplies of power.

While continued innovation and entrepreneurship play essential roles in the growth of this critical sector, to date the most essential driver has been economics. The costs of small solar-powered lights plummeted 80% between 2010 and 2015, according to the Global Offgrid Lighting Association (GOGLA), a Netherlands-based nonprofit industry group, which also projects a 45% cost drop by 2020 for larger solar-powered systems that include low-powered lights, TV, and radio. Research by Lawrence Berkeley National Lab and Bloomberg New Energy Finance finds similar decreases in costs for solar-powered lanterns paired with batteries as the technology has transitioned to LED lights and lithium-ion batteries. These dramatic declines in costs track closely with the explosive growth in sales.

Exhibit 17: Kicking the Kerosene Habit: Improved health among households that switched from kerosene to a solar light (% of households with reductions in health issues)



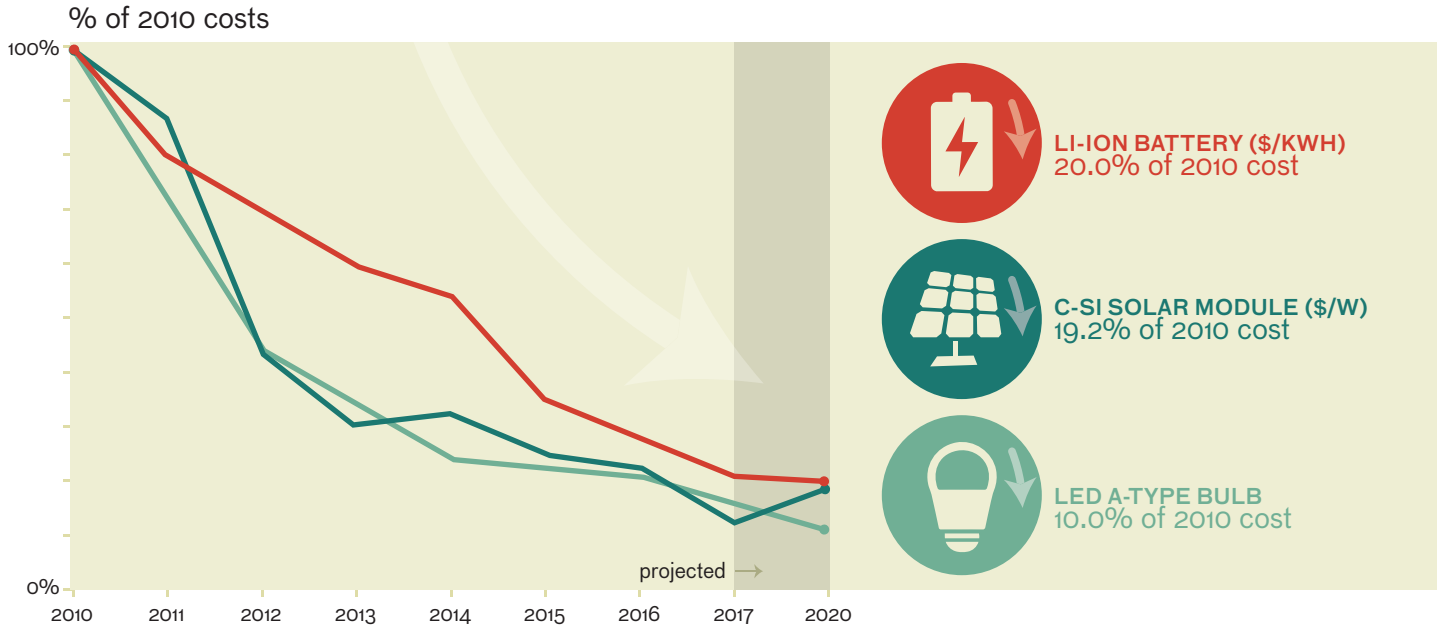


Source: GOGLA Off-Grid Solar Market Trends Report 2018

Before solar home systems came into the picture, individuals off the grid typically did not have access to conveniences such as mobile phone charging, fans, and radio. In many parts of Africa that are not on the grid, solar makes some activities possible that were previously impossible (e.g. watching television, which requires more upfront capital than lighting to pay for bigger systems). On average, off-grid households without solar products in Africa spend $84-$270 per year for lighting and phone charging, whereas a single household 20-100W home solar system can cost $56-$214 per year.[26, 27] As one example, Zola Electric's cheapest starter system (solar panel, battery, LED lights, radio, phone charger) in Tanzania requires an initial payment of about $13, then $8 per month for three years – a total of $288 – to eventually *own* the system, and all bills are paid by mobile phone.

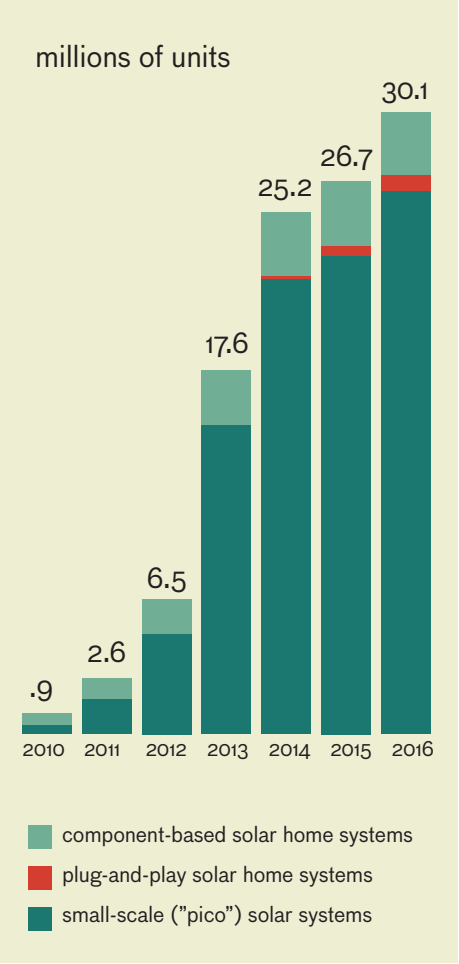
Increasingly compelling cost trends translate directly to increased sales

Exhibit 18: The Cost Curve Effect: A decade's worth of cost reduction across off-grid solar components (% of 2010 prices)



Source: GOGLA Off-Grid Solar Market Trends Report 2018

Exhibit 19: Adding It Up: Global annual sales of off-grid solar devices across categories (MM units)



Not only are costs competitive, but solar home system users get much more bang for the buck: longer-duration, higher quality lighting, charging outlets that are in the convenience of one's home, and small appliances. It is also often much simpler and more affordable for a household to pay for a small solar home system to meet basic electricity needs than to plug into the central grid (if one exists), due to grid connection costs (subsidized or unsubsidized) and the central grid's unreliability. As costs of solar home systems continue to come down, adoption should continue to accelerate. There are already sizeable markets for solar PV home systems in Tanzania and Kenya, where distributed solar PV is more the norm than utility solar PV. The demand for these systems has grown substantially in recent years throughout sub-Saharan Africa, reaching 30 million units in 2016, which is by far larger than the base of 1.6 million solar installations in the U.S., albeit with very different capacity per installation.[28] Large consulting firms like McKinsey even have this on their radar, and suggest as many as 150 million households could benefit from solar home systems by 2020.[29]

Source: GOGLA Off-Grid Solar Market Trends Report 2018

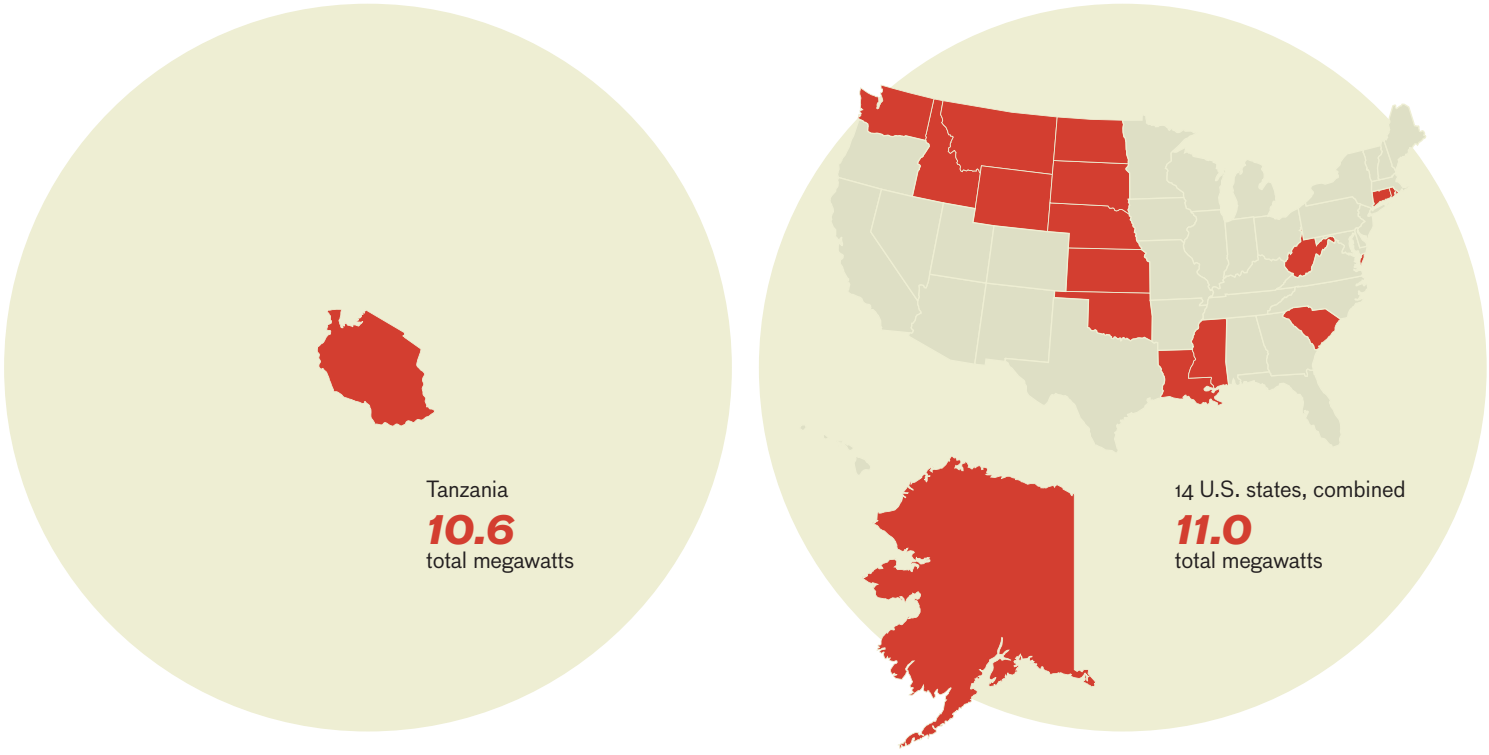
Notes:
1) Component-based systems are devices in which components (i.e. PV module, battery, lights, inverter, wiring, etc.) are compiled independently, whereas the plug-and-play SHS are sold as all-in-one packages. This enables users to purchase components a la carte on the open market to be tailored to their household's charging needs.

2) While not final, preliminary numbers for 2017 suggest 26 million units due to localized shocks in several key markets including demonetization in India (sudden removal of the INR 500 and 1,000 bills, which made up 86% of currency in circulation), a major drought in Kenya and Tanzania that limited consumer incomes in the region, and Nigeria's devaluation of the naira, which constrained consumer purchasing power.

Thanks in large part to such stand-alone home solar systems, Tanzania alone, where players like Zola Electric and Mobisol are highly active, has nearly as much total solar capacity as 14 U.S. states combined.[30] It's quite a remarkable comparison, and if current trends continue, Tanzania may soon surpass additional states.

Tanzania has as much solar capacity as 14 U.S. states combined

Exhibit 20: Tanzania has as much solar as these 14 U.S. states combined

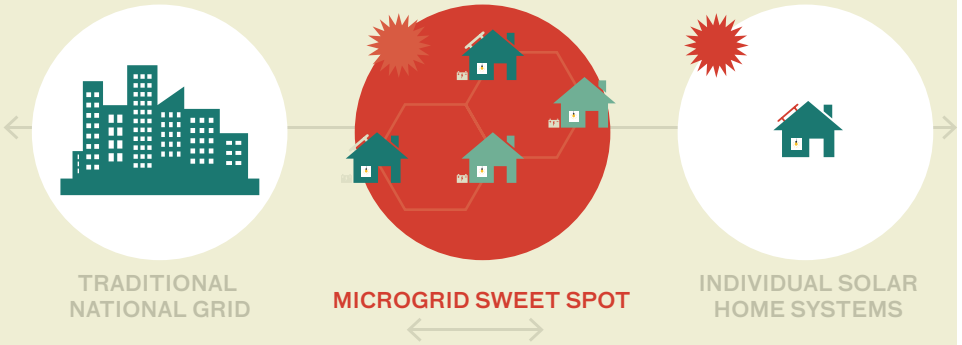


Sources: NREL Open PV Project, IRENA. States in red: LA, WA, KS, WV, ID, MS, SC, OK, MT, NE, SD, WY, AK, ND

Microgrids: The Next Frontier

While solar home systems are well suited for spatially dispersed dwellings or remote villages, microgrids can serve denser communities still too far from the grid. A microgrid can be seen as a lower cost alternative to extending the central grid. These can be independent or grid-connected and offer higher levels of energy service than solar home systems, while coexisting with those rooftop home systems as well. Solar PV microgrids are growing rapidly and are, in fact, projected to surpass diesel-powered microgrids in market share in Africa by 2040.[31] If they follow a similar growth trajectory to stand-alone systems, benefiting from falling costs of battery storage and other key components, solar-powered microgrids have enormous potential to play a significant role in Africa's clean energy future.

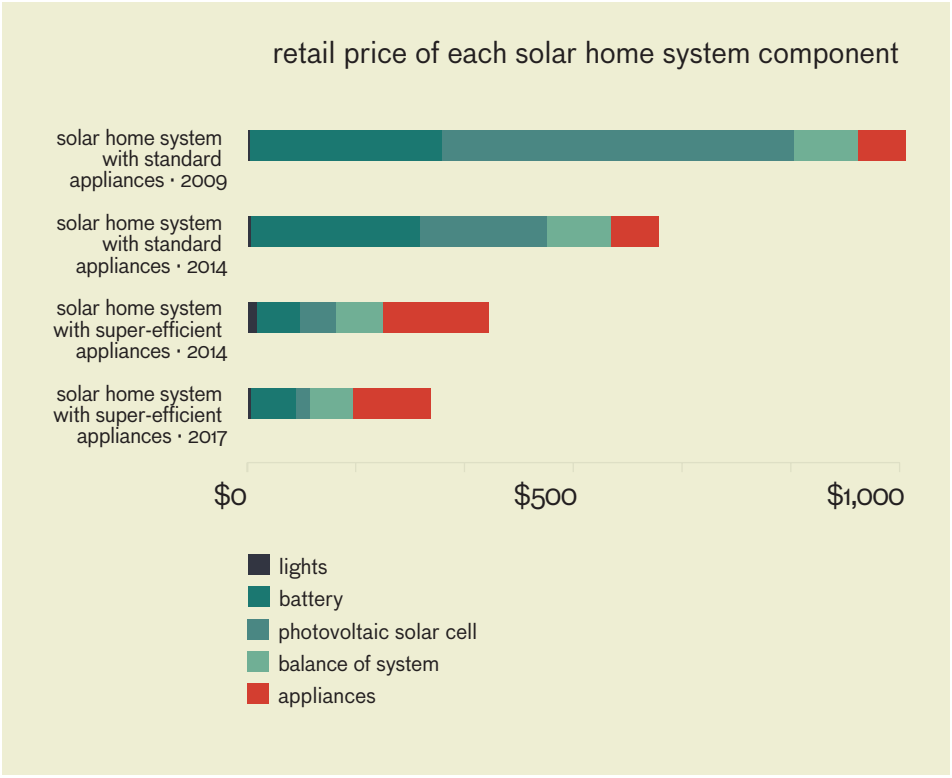
Exhibit 21: A growing role for microgrids and renewables



size of community	LARGE	SMALL
density of poplulation	HIGH	LOW
distance to national grid	CLOSE	FAR
complexity of terrain	EASY	COMPLEX
economic strength	STRONGER	WEAKER

Sources: Zola Electric, EUEI / REN21 Mini-Grid Policy Toolkit (2014)

Exhibit 22: More Costs Coming Down: Solar Home System Purchase Price Based on Appliance Type



Solar home systems equipped with super-efficient appliances use up to **78% less energy** than those equipped with normal appliances

Source: A Home Energy System in just 25 Watts: Super-Efficient Appliances Can Enable Expanded Energy Access Using Off-Grid Solar Power Systems *(usa.gov)*

Distributed energy fostering economic development

The pay-as-you-go model for solar home systems enables off-grid consumers to buy only as much as they need or can afford, and ultimately leaves the consumer with a valuable household asset. As a result, this model eliminates the customer's need to make the high up-front investment for solar, while the solar technology obviates the need for fuel costs in a diesel or diesel hybrid system. This helps spur small businesses as food shops and other entrepreneurial ventures can rely on more regular hours and stay open at night. In fact, a study in Ghana showed that average incomes of solar-electrified enterprises were 82% higher than non-electrified households.[32]

Energy-efficient appliances raise quality and affordability of distributed solar systems

Solar home systems become significantly more expensive when they must run appliances with heavier energy uses, such as microwaves, larger TVs, air conditioners, refrigerators and washing machines. Most rural households are priced out, despite a strong desire for a variety of those appliances. The strongest desire, however, is for appliances that are readily available in energy efficient forms today, such as smaller televisions and radios.

Increases in appliance energy efficiency will play a role in broadening suitability and use. New technologies that allow for dipping into the grid alternating with using household batteries and solar will also help bridge that gap. While Bloomberg New Energy Finance forecasts that solar home system costs will drop 45% by 2040, 60% of this drop will be due to cost reductions in efficient appliances.[33] The Africa Progress Panel projects that "super-efficient" appliances could reduce the average cost of a solar household system powering a 19-inch TV, radio, and two lights from $991 in 2009 to $193 in 2020. As these appliances become increasingly more efficient and affordable, they act as a considerable draw, and many customers increasingly buy the TV that comes with solar and storage, not vice versa.

The opportunity that Africa has to upend the central utility model relies on continuous experimentation with new technologies and ideas, borrowing from successes in other parts of the world. In the next section, we jump ahead and consider the future of a distributed-meets-central-grid world. Our scenarios illuminate key transitions that may underlie Africa's transformation.

The Electricity Web of the Future

An electricity web emerges and the on-grid world talks to the off-grid world

As the price of lithium-ion batteries continues to drop,[34] small-scale, solar-plus-storage systems will have the potential to provide continuous power, increase energy service tiers, or replace the need to have expensive and dirty diesel-powered generators as back-up power. As another benefit, dispatching excess power stored in the batteries of microgrids and solar home systems will help stabilize the central grid and increase grid reliability. Companies such as Advanced Microgrid Solutions (AMS)[35] in the U.S. are offering advanced versions of this functionality to commercial and industrial customers in the U.S. and elsewhere, a practice that will spread to the developing world over the next 5-10 years.

This "electricity web" of the future will also require innovations in technology converting current between AC and DC systems. Today, small-scale solar home systems and many microgrids are based on DC systems, which are highly reliable, efficient and cheap, albeit with less power. The grid transmits power (energy) in AC current, affording users greater power and reliability, albeit with greater cost. Distributed systems can receive or transmit power from the grid by converting AC to DC power and vice versa – a conversion that has historically resulted in lost power. Improvements in that AC to DC conversion technology can help further a world in which on-and-off-grid energy flow is possible, enabling solar home system customers to draw two-way power from their own solar/storage systems to the grid and back, without disrupting the grid or damaging appliances. Such bi-directional access to rooftop solar, storage, a microgrid or the grid would allow for enough electricity to power a refrigerator, for example, in places where such uses have been prohibitively difficult or expensive in the past. Due to the bias toward the status quo in places like the developed world with more established, incumbent central grids, the continent of Africa may become an early adopter in the development of such energy webs and self-assembling grids, making it a place where the grid of the future may happen sooner than in developed nations.

Perhaps the greatest power in the makings of the electricity web is in the potential for homes and small enterprises to interconnect, especially in denser off-grid environments. A self-assembled network of independent power generators can use mobile payment technology to engage in peer-to-peer energy trading. Furthermore, a blockchain-enabled transactional grid presents an increasingly distributed world with a solution that is purely market-based, rather than regulation-based, as is the case with net metering. Peer-to-peer energy trading pilot programs around the world are pushing the envelope on this thinking and conjuring new ways of socializing energy. In the developed world, companies like LO3 Energy are developing community microgrids that allow users to buy and sell electricity using a blockchain to verify energy transactions. In the developing world, companies like ME SOLshare in Dhaka, Bangladesh are installing nanogrids to facilitate peer-to-peer electricity trading between low-income solar home system users and integrating mobile money payment and grid management services. In Ghana, Zola Electric is piloting new systems in this new realm later this year.

Exhibit 23: 21st Century Solar Innovation Leadership in Africa

Microgrids in Africa may serve as a model for the rest of the world

Source: EU Energy Initiative (EUEI) Mini-Grid Policy Toolkit (2014), adapted from ARE, ME SOLshare

What Can Possibly Go Wrong? Taxes and Subsidies

Across the globe, taxes, subsidies, and incentives play a key role in determining the market success of various energy sources, and in shaping the path to addressing basic human needs. Across Africa, virtually all solar PV products are imported and are therefore potentially subject to government-imposed value-added tax (VAT). Tariffs may also extend to other import duties on key components of a system such as batteries or efficient TVs that in some places can account for up to 40% of product cost.[36] Nations such as Kenya, Tanzania, and Zambia have enacted full or partial VAT exemptions for solar products, but the subject continues to be a matter of debate throughout the continent, and can be very nuanced. Case in point: although Kenya's government lifted a 16% VAT in 2014 on solar products imported into the country, M-KOPA was engaged in a legal dispute with the Kenya Revenue Authority over a VAT on solar-powered digital TVs used by some of its customers that was only resolved in April 2018.[37]

Earlier in this paper, we noted the issues surrounding extensive subsidies of fossil fuels, pointing particularly to Southeast Asia.[1] In 2015, fossil fuel subsidies reached $26 billion in sub-Saharan Africa, and $1 billion each in Angola, Côte d'Ivoire, Mozambique, Nigeria, South Africa, Tanzania, Zambia and Zimbabwe.

For potential off-grid solar users, particularly for lighting, the key competitive fossil fuel is kerosene, which is widely used for lighting and in some countries for cooking. One study identified $4 billion in kerosene subsidies in the Economic Community of West African States (ECOWAS) alone.[38] By making kerosene artificially cheap and more generally giving fossil fuels a propped-up cost advantage, such subsidies can slow the progress toward clean energy sources like off-grid solar. As in other nations, this policy shift will come under increasing scrutiny in the coming years. In many cases we expect kerosene subsidies to be significantly altered, and possibly phased out. On the positive side, some countries like Rwanda have offered incentives for light manufacturing of solar systems that help avoid VAT and begin to create a manufacturing infrastructure. Zola Electric has utilized such incentives, opening a small solar manufacturing plant in the Rwandan capital of Kigali.

Exhibit 24: Carbon Crisis – Fossil Fuel Subsidies Far Outweigh Climate Finance

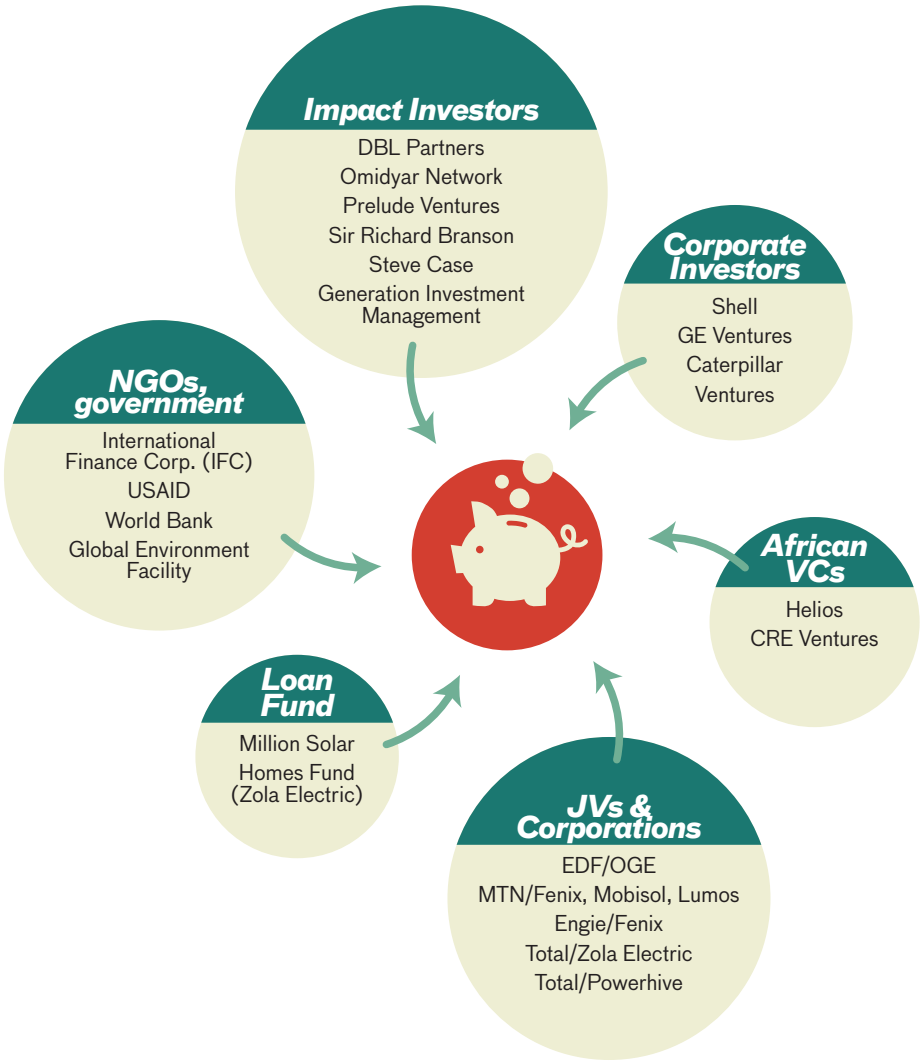
Source: Whitley, Shelagh and van der Burg, Laurie, Fossil Fuel Subsidy Reform in sub-Saharan Africa: From Rhetoric to Reality, Overseas Development Institute, 2016.

From Mission to Market: A Brief History of Solar Financing in Africa

As in other significant shifts in energy use in the U.S. and Europe, the emergence of solar as a viable option rests on decades of government policy and participation from NGOs and development banks funding both capacity building and market development. The history of financing off-grid solar in sub-Saharan Africa has also gone through several phases. Initially in the 1990s, funding came mainly in the form of loans or grants from large global NGOs like the International Finance Corp. (IFC), UNEP, USAID, and the World Bank. These were often supported by funds from the Global Environment Facility, which was established at the 1992 Earth Summit in Rio de Janeiro to address global environmental challenges. While such NGO finance streams remain active today, the financiers' playing field in Africa has recently become more diverse and grown beyond its government roots.

Early in the decade of the 2010s, high-profile investors from the U.S. and Europe came into the field as NGO grants and loans continued. The first were impact investors, those seeking both a solid investment return and a positive social impact. As the sector grew, debt financing became available to assist in the purchase of solar home systems. In December 2015, Zola Electric raised the first at-scale loan fund for hardware purchasing: the $45 million loan fund included investments from diverse players including family offices, foundations such as the Packard Foundation and Calvert Foundation, and USAID, whose key $5 million grant helped legitimize the deal for other lenders. The fund was called the "Million Solar Homes Fund" in reference to the company's goal of reaching 1 million solar homes in Tanzania. In April 2016, SunFunder closed a "beyond-the-grid" solar fund with $15 million from the

Exhibit 25: Still Changing After All These Years: Africa's Diverse Financing Sources for Solar



U.S. government's Overseas Private Investment Corporation (OPIC) to provide financing to off-grid solar companies, and plans to grow it to $50 million.[39] Beyond institutional capital, local currency banks have also increasingly entered the space and played a role in reducing the cost of a system by reducing its cost of capital, which is often the largest component of a PAYGO solar home system's cost. As these institutions bank in the local currency, they do not have to price currency risk into their offering (as non-local banks or institutions do), thereby reducing volatility and lowering the cost of capital. By way of example, in Cote d'Ivoire, local branch of French bank Societe Generale is helping Zola fund these systems and bring solar to thousands of homes.

Most recently (since roughly 2015), two other trends have emerged. One is the entry of major legacy global players in energy and tech partnering with startup companies deploying off-grid solar in Africa, and the other

is the participation of African-based venture capital in the sector. On the first trend, examples abound. Total Energy Ventures, a finance unit of French energy giant Total, secured small equity stakes in 2016 in both Zola Electric and Powerhive. Powerhive, which builds microgrids in Kenya, also counts Caterpillar Ventures among its investors. In Nigeria, Total has a deal with local solar home system provider Blackbit Energy Ltd. to sell Total-owned inverters and SunPower panels in the cities of Abuja and Lagos.

Zola Electric also has a significant partnership with global utility/energy giant EDF, including joint ventures to sell off-grid solar systems in Cote d'Ivoire and Ghana. Africa's largest telecom company, MTN, has partnerships with Fenix International in Zambia, Mobisol in Rwanda, and Lumos in Nigeria, all to enable easier pay-as-you-go customer payments via mobile phones. In October 2017, French multinational Engie announced it would acquire Fenix outright, giving the leading home solar provider in Uganda better access to commercial debt financing. And in April 2017, Facebook and Microsoft teamed with investment firm Allotrope Partners to create the Microgrid Investment Accelerator, which will put roughly $50 million towards microgrids in East Africa (as well as India and Indonesia) between 2018 and 2020. We expect such participation by global legacy players to increase as off-grid solar continues to expand.

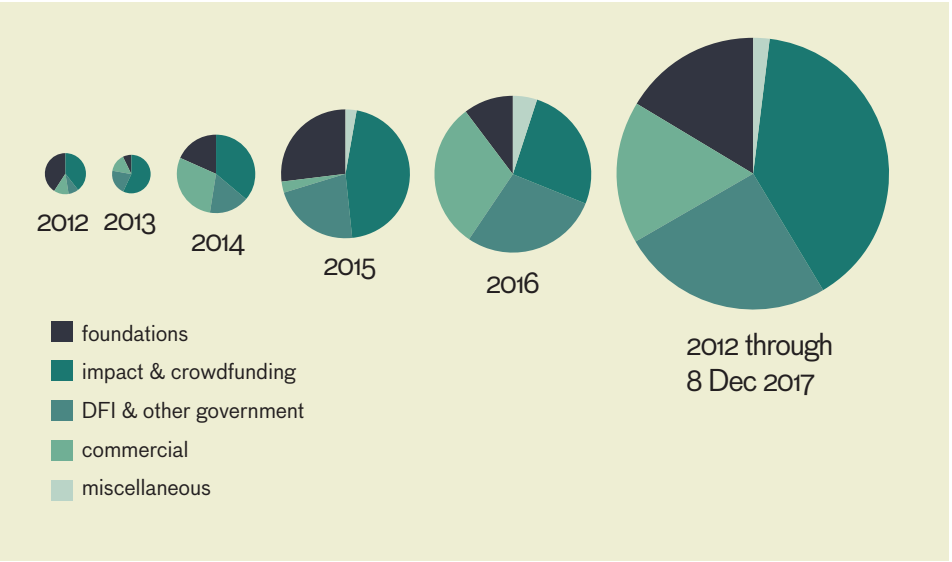
African-based investment firms are beginning to play, too. African-run firm Helios Investment Partners invested $10 million in Zola Electric in 2016, then led a $55 million Series D round in 2018 along with GE Ventures. In the tech sector, South Africa-based CRE Ventures includes notable African tech developer Andela in its portfolio. The Green Climate Fund has created Nairobi-based KawiSafi Ventures, a $100 million impact fund, to specifically target off-grid solar development in East Africa; initial investments include d.light and BBOX. Even more recently, crowdfunding has emerged as a source of funding as BBOXX raised €1 million ($1.25 million) on TRINE, a Swedish crowdfunding platform, in 2018 and is now seeking £2.5 million ($3.6 million) in debt on Lendahand Ethex, demonstrating the enormous interest of private individuals in promoting energy access.

Over the past three decades, solar financing in Africa has expanded greatly both in dollars and in the diversity of players participating.

Although traditional loans and grants from major global NGOs continue, those sources have been joined by a plethora of impact investors, venture capitalists (including Africa-based VCs), and global legacy companies. The African solar sector has gained legitimacy as a key global investment opportunity, paving the way for solar energy financing options and continued financing innovation.

Exhibit 26: Early patient and philanthropic capital has helped spur more recent interest from traditional investors

Source: GOGLA Off-Grid Solar Market Trends Report 2018



Conclusion: A Compelling Energy Transition, A Fossil Road Not Taken

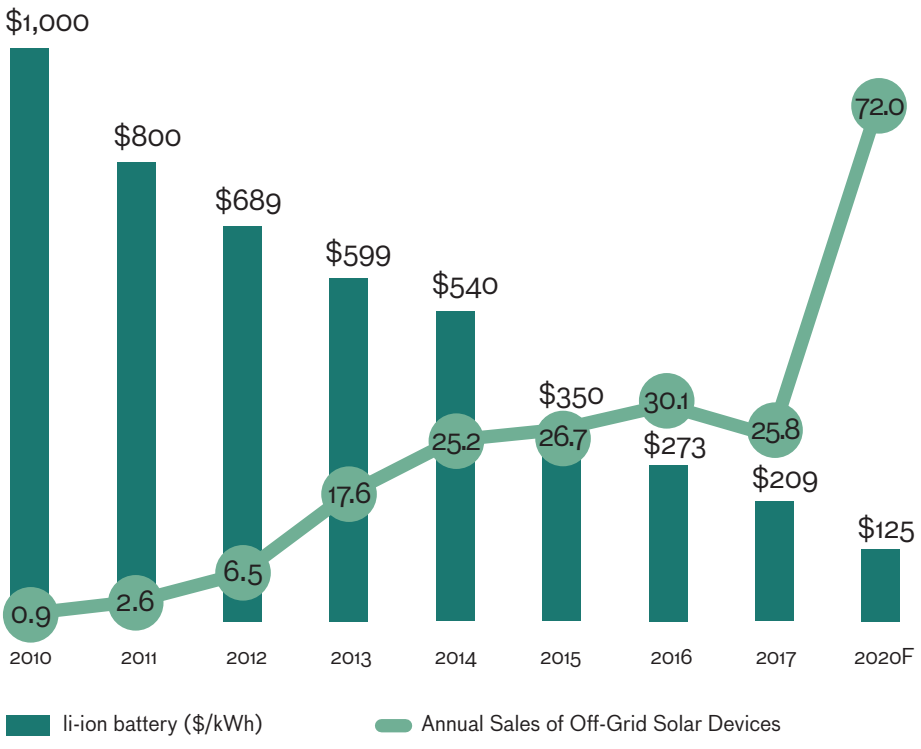
In the developing world, many compelling reasons prompt us to think outside the grid. The falling costs of solar and battery technologies, the establishment of innovative business models (e.g. pay-as-you-go), and an increasingly well-financed entrepreneurial ecosystem serving sub-Saharan Africa, particularly West Africa, has driven strong momentum for solar home systems in rural areas. The lack of strong incumbent players in many areas helps enable this trend as well; it's a bit of a land grab with lots of optionality. In many nations, these off-grid systems are outpacing connections to the (often unreliable) central grid, which can be slow and expensive. They are also expanding into more urban terrain in more robust, tech-enabled formats. Along the way, they are replacing polluting kerosene and diesel systems at an increasing rate. Off-grid solar, a sector once dominated by non-profits to subsidize what began as an expensive energy option, is now a fast-growing business sector dominated by young entrepreneurial companies with multinational teams from the U.S., Europe, and Africa.

Off-grid clean energy momentum has been impressive, with nations such as Kenya, Rwanda, and Tanzania leading the way in the past five years. The sector, however, needs much more support from government policies, which tend to favor centralized and usually higher carbon grid solutions. Both federal energy policies and funding, as well as most large-scale grants from the World Bank and other multilateral banks, focus on "mega-projects" powered by both renewable and non-renewable energy.[40] The same lack of proportional policy support is also true for microgrids, whose vast potential to power small communities cleanly in the developing world has also been hampered by a lack of investment and easily scalable business models. All these potential impediments, however, should be viewed as business variables, not insurmountable barriers. The sheer number of firms in the sector, augmented by the recent participation of large, influential global players will change both the policy and the energy landscape. These influences will pave the way for shifts in policies that reflect more 21st-century, distributed approaches to energy development in Africa's near future.

The fundamental driver of this growth sector is plummeting costs. The falling prices of solar panels and components, along with the innovative pay-as-you-go financial models have made small-scale home solar power affordable for thousands of African consumers – helping enable economic development and advancement. Super-efficient appliances and lighting are driving down costs even further. Going forward, microgrids and technology-enabled hybrid models clearly will be part of a comprehensive off-grid approach rather than today's either/or with stand-alone systems.

Exhibit 27: Seeing the Light Thanks to Plummeting Costs

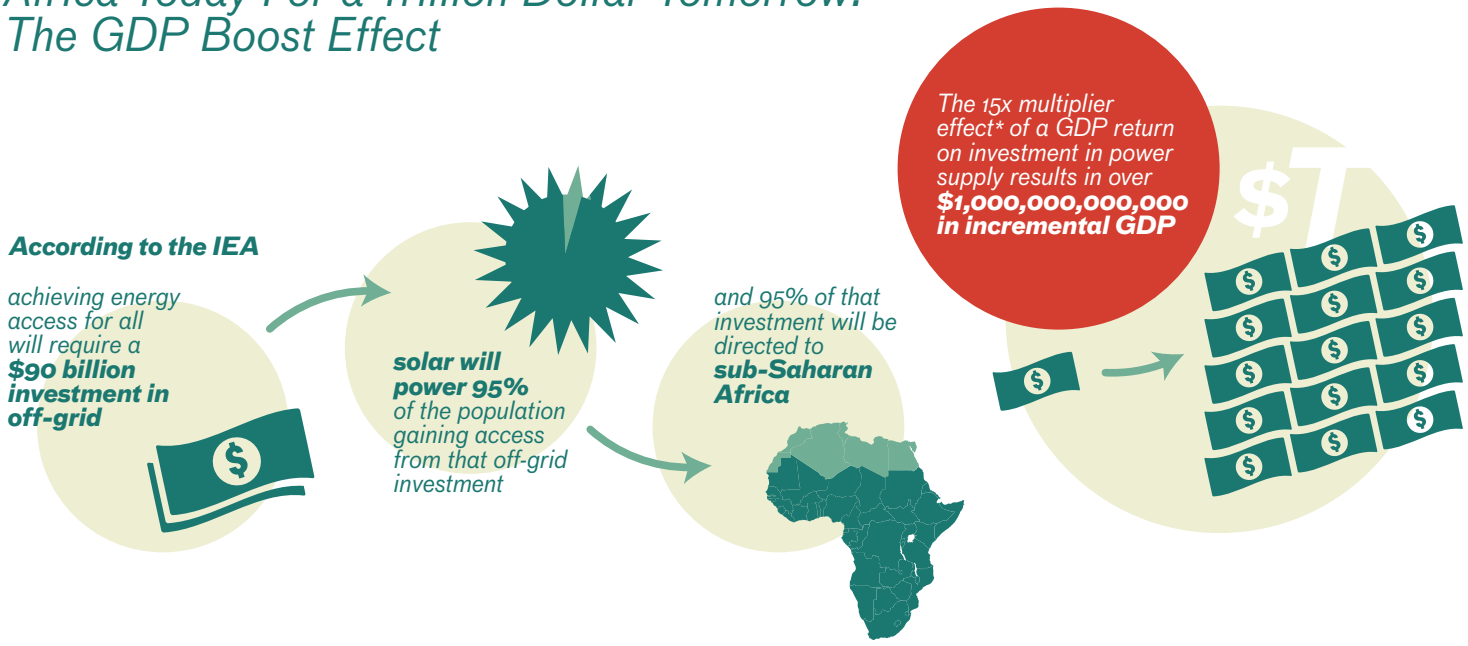
Sources: GOGLA Off-Grid Solar Market Trends Report 2018



With the developing world's energy transition to clean, distributed electricity underway, the standard of living and health of people across the continent of Africa stand to improve. As we have discussed in this paper, the case for cost-effective access to clean energy is a compelling one. Policy adds complexity to the trajectory, of course, but the increased financing, market momentum, and influence of the off-grid solar industry in Africa is leading to a fundamental shift in mentality. The era of energy independence, choice, and upward mobility is just around the corner. Policy makers, investors, business leaders, and, most importantly, customers are embracing the idea that energy access can be cleaner and cheaper by thinking outside the grid. This change in attitude will further unleash the forces of entrepreneurship and investment that have already catalyzed this dramatic—and inevitable—energy transformation.

As the sun rises, so will decentralized solar power in Africa

Exhibit 28: Investing in Solar in Sub-Saharan Africa Today For a Trillion Dollar Tomorrow: The GDP Boost Effect



Source: IEA Africa Energy Outlook and Energy Access Outlook (2017). The IEA estimates that providing electricity to all by 2030 will require a total investment of $391B, including $187B investment in mini-grid, $114B investment in grid and $90B investment in off-grid. Given that "every $1 invested in power supply generates more than $15 in incremental GDP" (IEA), and conservatively applying that 15x multiplier effect to only $90B (off-grid, excluding mini-grid) x 95% (solar) x 95% (SSA), this results in $1.2 trillion of incremental GDP from investment in off-grid solar in sub-Saharan Africa alone.

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