MALABO MONTPELLIER PANEL

ENERGIZED

Policy innovations to power the transformation of Africa's agriculture and food system

A Malabo Montpellier Panel Report

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Foreword

Energy is a key input in the food system and the basis for rural development. Clean energy is critical for people's health, the climate, and the environment. As demand for food continues to grow globally, universal access to energy, and to electricity in particular, will become an urgent necessity for the production, processing, and consumption of more nutritious and safe food. In Africa, high population growth, urbanization, and a rise in middle-class consumers together are fueling a sharp increase in food demand. Access to reliable, affordable, sustainable, and modern sources of energy to prepare land, plant, harvest, process, distribute, store and cook food, will ensure that Africa's food system can respond to this demand within the context of increasingly scarce natural resources.

Access to energy has a transformative impact on the livelihoods of the rural poor, reducing the drudgery of their work and generating higher incomes. Women in particular spend less time on collecting biomass for cooking and heating, and benefit from cleaner air in their homes, while shifting to mechanical or electrical power – such as for irrigation or milling - can greatly reduce the time and effort spent toiling. However, the overall average electrification rate in Africa south of the Sahara remains low, undermining the development of rural economies and hampering progress towards meeting the targets under the African Union Agenda 2063 and the Sustainable Development Goals.

One option is to invest in small-scale, bottom-up power generation and supply. Off-grid and mini-grid technologies for hydro, wind, and solar power are disrupting African energy landscapes and enabling Africa's consumers to leapfrog outdated and dirty technologies.

It is promising to see that several African countries have taken bold steps to better connect rural areas and food system actors to energy sources. This report – *Energized: Policy innovations to power the transformation of Africa's agriculture and food system* – provides a framework for policy innovation and design, gives an overall picture, and focuses on what six African countries – Ethiopia, Ghana, Morocco, Senegal, South Africa, and Zambia – have done successfully in terms of institutional and policy innovation for energy expansion in support of agriculture and rural people. The report recommends that integrated approaches for energy strategies and policies for agriculture also address the synergies with health, the environment and community development – such as the challenges of continued high biomass-based energy use. In addition, investments in technologies and in systems innovation to scale off-grid and mini-solutions are crucial alongside cross-border policies to ensure energy security.

The Malabo Montpellier Panel convenes 17 leading experts in agriculture, ecology, nutrition, and food security to facilitate policy choices by African governments to accelerate progress towards food security and improved nutrition in Africa. The Panel identifies areas of progress and positive change across the continent and assesses what successful countries have done differently. It then identifies the most important institutional innovations and policy and program interventions that can be replicated and scaled up by other countries. The related Malabo Montpellier Forum provides a platform to promote policy innovation by using the evidence produced by the Panel to facilitate dialogue and exchange among high-level decision-makers on African agriculture, nutrition, and food security.

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THE MALABO MONTPELLIER PANEL

The core mission of the Malabo Montpellier Panel, a group of leading African and international experts from the fields of agriculture, ecology, food security, nutrition, public policy and global development, is to support evidence-based dialogue among policy makers at the highest level. The Panel's reports seek to inform and guide policy choices to accelerate progress toward the ambitious goals of the African Union Commission's Agenda 2063, the Malabo Declaration and the global development agenda. The Panel works with African governments and civil society organizations to provide support and evidence-based research that facilitate the identification and implementation of policies that enhance agriculture, food security and nutrition.

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1. Introduction and setting the scene

Africa's energy landscape is evolving rapidly. Dedicated programs to improve access to energy over the last decade have greatly improved electricity access for millions of Africans. Across the continent the number of people gaining access to electricity doubled from 9 million a year between 2000 and 2013 to 20 million people a year between 2014 and 2018, outpacing population growth. As a result, the number of people without access to electricity, which peaked at 610 million in 2013, declined to around 595 million in 2018.[1]

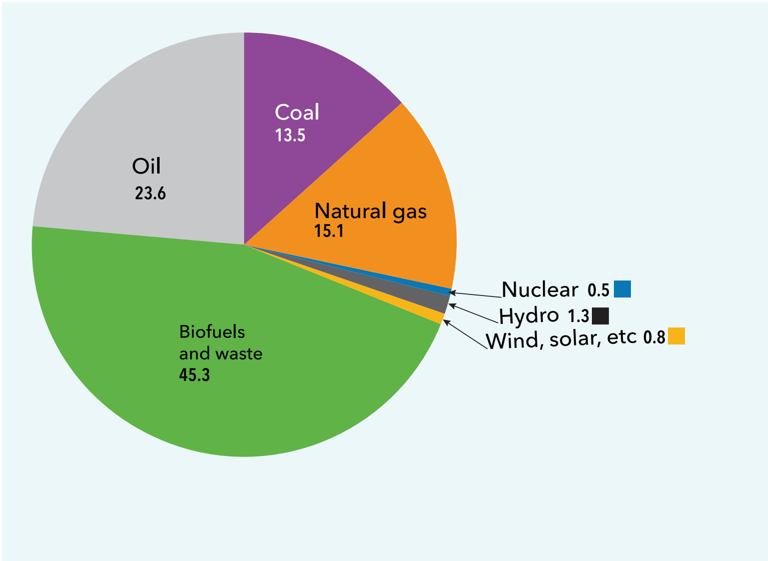
The 2019 Africa Energy Outlook predicts that, based on current and announced policies, African energy demand will grow twice as fast as the global average over the next two decades. Nevertheless, nearly 530 million people will still lack access to electricity in 2030.[2] At the same time, Sustainable Development Goal (SDG) 7.1 calls for *universal access to affordable, reliable and modern energy services by 2030*. Based on current trends, Africa is not on-track to achieve this target by 2030 or even 2040.[3]

Africa still accounts for only 6 percent of the world's energy demand, despite being home to 20 percent of the global population. Of this, North Africa, South Africa and Nigeria together account for nearly 60 percent of total demand in Africa but represent only 35 percent of the population. At 0.7 tons of oil equivalent (toe), Africa's energy consumption per person is also much lower than the global average of 2 toe. Although Africa's electricity demand is growing, it only does so at half the rate of developing Asian countries and continues to be constrained by inadequate supply.[4]

Furthermore, at 45 percent in 2018, the electrification rate in Africa south of the Sahara (SSA) remains very low compared to other regions in the world.[5] It is estimated that 80 percent of those who do not have access to electricity in SSA live in rural areas.[6] In Africa as a whole, electricity constitutes 10 percent of final energy consumption, and per capita electricity demand is around 550 kilowatt hours (kWh) (370 kWh in SSA) - compared to 920 kWh in India and 2,300 kWh in developing Asia.

Africa is the largest consumer of traditional solid biomass such as fuelwood, charcoal, and farm residues (including animal dung) in the world.[7] Cooking accounts for more than 70 percent of household energy use in Africa, in comparison with less than 10 percent globally.[8] Especially for those cooking indoors in poorly ventilated spaces, this means daily exposure to noxious fumes and the burden of collecting fuelwood, which falls heavily on women and girls. In 2017, biomass-based energy accounted for more than 45 percent of total energy use in Africa as a whole, driven largely by the traditional use of biomass for cooking. In SSA, biomass-based energy's share is estimated to be as high as 60 percent. Oil is the second largest component in Africa's energy mix at around 23 percent, while gas makes up 15 percent of the energy mix, coal 13 percent, and renewable energies about 2 percent.[9]

Figure 1 Total primary energy supply % by source, Africa 2017



Source: IEA data 2019.

Africa's continued reliance on biomass for cooking, hot water, and heating is taking a toll on the continent's forests and soils. In addition to contributing to land degradation, the typical partial combustion of fuelwood emits carbon dioxide, methane, and black carbon and is a major cause of indoor air pollution, with damaging health effects. Fuelwood scarcity, coupled with efforts to make alternative fuels more widely available, is expected to result in a switch away from wood use, especially in urban areas. Since 2015, only seven million people have gained access to clean cooking options in SSA, meaning that the number of people without access increased to over 900 million in 2018 as population growth outpaced provision efforts. Furthermore, it is estimated that, under current trends, nearly one billion people will still lack access to clean cooking options in 2030.

Box 1: Definitions

Biomass: Biomass is any organic matter, i.e. biological material, available on a renewable basis. It includes wood, charcoal, agricultural residues and animal dung, as well as organic waste from municipal and industrial sources. It can be converted with basic techniques, such as a three-stone fire, for heating and cooking.

Bioenergy: Bioenergy is the energy generated from the conversion of solid, liquid and gaseous products derived from biomass.

Biofuels: Biofuels are liquid fuels derived from biomass. They include ethanol, a liquid produced from fermenting any biomass type high in carbohydrates, and biodiesel, a diesel equivalent processed fuel made from either both vegetable oil or animal fats.

Biogas: Biogas is a mixture of methane and carbon dioxide used as fuel and produced by bacterial degradation of organic matter or through gasification of biomass.[10]

This is particularly true in rural areas. The overall average electrification rate in SSA's rural areas is a meager 23 percent, which severely limits the development of rural economies and livelihoods.[11] The main challenge to rural electrification in SSA is the limited commercial viability of expanding connections. Low population density coupled with the limited purchasing power of most rural consumers make investment in rural electricity infrastructure unprofitable in many cases.[12] While the cost of electricity supply in Africa is the highest in the world, regulated tariffs are often below cost-recovery levels, contributing to reliability challenges.

Partly as a result of this, Africa is the region with the least mechanized food system in the world.[13] Africa's agriculture sector consumes only 6 million tons of oil equivalent (Mtoe) of energy, compared to 27 Mtoe in India and 42 Mtoe in China.[14] Yet, the sector is the largest employer. Almost half of Africa's workforce is engaged in agriculture, but the sector consumes less than 10 percent of energy used for productive purposes.[15] In comparison, industry employs far fewer people and contributes less to African economic growth but consumes more than two thirds of total energy.[16] Studies in Africa have shown a positive correlation between energy consumption and agriculture such that countries which consume high energy have higher value added from agriculture.[17]

Agricultural growth between 2002 and 2010 averaged 4.6 percent per year in Africa and has increased to 5.1 percent per year during this current decade.[18] Yet, as the Malabo Montpellier Panel's 2018 report *Mechanized* noted, African agriculture still relies heavily on manual and animal draught power for production, harvest, and postharvest activities. 80 percent of the energy used to prepare land for agriculture in SSA is human manual power.[19] Across the whole agriculture value chain, manual power is equivalent to 60 percent of total energy used – often provided by women – while animal power represents an additional 25 percent of farm power.[20,21] Engine power represents a meager 10 percent, compared to developing countries in other regions where engines provide 50 percent of farm power.[22] In fact, African farmers have 10 times fewer mechanized tools per farm area than farmers in other developing regions, and access has not grown as quickly. In addition, the lack of proper storage facilities remains a major cause of postharvest losses in Africa where cold storage and other postharvest processing facilities either do not exist or are inaccessible to most smallholder farmers. In order to drive agricultural mechanization and the use of modern tools and technologies on and off the farm, one option is package solutions that bundle electricity provision with tools and technologies run on electricity or other energy sources.

> “Access to reliable, affordable, sustainable, and modern sources of energy to prepare land, plant, harvest, process, distribute and cook food will ensure that Africa's agriculture sector can to respond to growing food demand and changing nutrition requirements, both domestically and globally.”

Box 2: Smart bioenergy production

While agriculture is a primary consumer of energy in Africa, it is also an important source of energy production. Crops such as sugarcane, maize, sorghum, and jatropha can be locally grown and used to generate bioenergy where appropriate technology is available, thereby reducing reliance on fossil fuels. And although the production of heat from bioenergy can be cost-competitive with fossil fuel alternatives, lower fossil fuel prices have substantially reduced its attractiveness. Similarly, the cost-efficiency of power generation from biomass depends critically on the scale of an operation or farm as well as on the availability and quality of feedstock. However, in most cases the electrical efficiency of the steam cycle tends to be lower than that for conventional fossil fuel plants.[23]

Processing biomass for bioenergy can also provide a new source of income to smallholders. For example, in Ghana, a local women's group extracts oil from jatropha seeds and mixes it with diesel (70 percent plant oil with 30 percent diesel) both to fuel shea butter processing equipment and to replace kerosene used in lanterns.[24] More sustainable and efficient use of bioenergy can also unlock the potential of the agriculture sector by attracting new and additional investments to raise agricultural productivity. Africa's bioenergy capacity has increased steadily, reaching 1.2 GW in 2016 and accounting for 3.1 percent of renewable capacity in Africa.[25] Across Africa, bagasse, the dry, pulpy, fibrous residue that remains after crushing sugarcane or sorghum stalks, provides up to 91 percent of the bioelectricity, particularly in Sudan, South Africa, Swaziland, and Zimbabwe. Furthermore, the production of biogas-electricity is also on the rise and several biogas programs are emerging across Africa, including in Mauritius, Kenya, Morocco, Burkina Faso, Senegal, Tanzania, and Benin.[26,27]

Although bioenergy – alongside solar, hydro, and wind power – is considered a promising source of energy, production must be done carefully and be well planned. In fact, bioenergy entails risks that can compromise food security and nutrition outcomes through changes in incomes and food prices. For now, bioenergy production in Africa is likely to compete with food production for inputs, including land, labor, water, and fertilizer. The issue of competition gained much interest in the second half of the 2000s due to global food price increases and a sharp increase in the use of biofuels, which led to major investments in the large-scale production of food and biofuels across SSA.[28,29] Without appropriate regulation, however, smallholders may be overlooked in the bioenergy production value chain as larger companies or commercial farms invest in large-scale feedstock production. An increase in competition for land access may also create new pressures on land tenure arrangements and contribute to land-grabbing.

Where agricultural efficiency is optimized, the competition over inputs – such as land, water, labor, and fertilizer - decreases between food crops and feedstocks on the one hand and their use for bioenergy production on the other hand.[30] Agricultural systems must be designed in a way that creates synergies between food and energy production by improving the yields of food crops while at the same time addressing the increasingly pressing energy demands in rural and urban areas.[31] Crucially, evidence from Tanzania shows, that in order to maximize the benefits of biofuel production for poverty alleviation, smallholder farmers need to be involved in the process and their agricultural productivity be enhanced.[32]

On the other hand, as global demand for food[33] continues to grow, universal energy access is becoming an urgent necessity, both for the production and consumption of food. In Africa, high population growth rates, urbanization, and an increase in middle-class consumers are together fueling a sharp increase in food demand. Access to reliable, affordable, sustainable, and modern sources of energy to prepare land, plant, harvest, process, distribute and cook food will ensure that Africa's agriculture sector can respond to growing food demand and changing nutrition requirements, both domestically and globally. Without access to improved energy services, Africa will not be able to improve agricultural productivity, value addition, access to more nutritious foods, or employment generation.

Equally important, studies show that there is a two-way causal relationship between energy consumption and GDP growth. Access to energy is a key ingredient to raise national productivity and stimulate economic growth. At the same time, growing populations and rising incomes increase demand for energy, as households spend extra income on energy and require more energy for production. Without adequate energy services and infrastructure, economic development and poverty alleviation in SSA may be hampered. These links are especially evident for low income countries over the long-run.[34]

Importantly, universal energy access will transform the lives of the rural poor, reducing the drudgery of their daily lives and generating higher incomes.

Women and young people (particularly girls) could spend less time collecting biomass for cooking and heating and benefit from cleaner air in their homes. Shifting to mechanical or electrical power for tasks such as irrigation or milling would reduce time and effort spent on these tasks. More time would be available for education, leisure, and other income generating enterprises.[35,36] Indeed, as households improve their economic status, they also move up the energy ladder, transitioning to more efficient and cleaner sources.[37] This takes places in a context where agriculture as a sector is becoming more information intensive, knowledge-based, and data-driven. Thus, enablement for information and communications technologies (ICT), as highlighted in the Malabo Montpellier Panel's 2019 report *Byte by Byte*, is now a critical factor in the transformation of Africa's food systems. Connectivity, both on- and off-grid, is crucial.

To achieve universal access to energy by 2030 on the continent, the energy access growth rate will have to reach 8.4 percent annually, significantly higher than the current 5.4 percent.[38] According to the International Energy Agency, investments will have to increase almost fourfold to approximately US$ 120 billion per year until 2040 in order to achieve reliable electricity supply across Africa.[39] In addition to public sector finance, investments will need to be leveraged from domestic, international and private sources and innovative products be designed to enable rural communities to contribute fairly to the cost of energy services. Given the scale and investment needs, this presents a unique investment and commercial opportunity for the private sector, through the development and scalability of innovative solutions and technologies.

One option is to invest in small-scale bottom-up power generation and supply. Off-grid and mini-grid technologies for hydro, wind and solar power are already disrupting African energy landscapes and enabling Africa's consumers to leapfrog outdated and dirty technologies*. Approximately 15 million people in Africa are now connected to mini-grids and almost 5 million had solar home systems in 2018.[40] Moreover, it is estimated that by 2063 renewable energies, including wind, solar, hydro, bio, tidal, and geothermal energies, will represent more than half of the energy consumed by African households and businesses.[41] Combined with Africa's mushrooming digital market, small-scale, micro, and nano energy solutions offer tailored services for the specific needs of farmers. For instance, mini-grid and off-grid solutions now integrate additional services, such as remote monitoring, Uber-like scheduling, mobile money, and various pay-as-you-go models including rent-to-own, leasing, service for fee, and agricultural extension support to ensure that costs are covered.

At the same time, improving the efficiency of existing infrastructure will reduce losses – both energy and financial – incurred from disruptions, thus ensuring that existing services reach more people. As global food systems have become more industrialized, they have shifted away from traditional energy inputs towards fossil fuels. In most regions, the agriculture sector has also become more energy efficient, thus producing more value with less energy growth; in Europe the energy intensity of agriculture† dropped by 20 percent between 2000 and 2012. However, Africa has gone in the opposite direction with energy intensity tripling during the same period.[42,43] By leapfrogging emissions-intensive technologies and being energy-smart, African agriculture can significantly reduce its contribution to future global climate change.[44]

It is promising to see an expansion in energy generation from renewables. For example, the recently launched Lake Turkana Wind Power Project in Kenya will provide 310 megawatts (MW) of clean energy to Kenya's national grid.[45] Similarly, the Taiba Ndiaye Wind Project in Senegal will generate 158MW of additional capacity. In Ghana, the planned Nzema Solar Power Station will be the largest installation of its kind in Africa. It is expected to increase Ghana's electricity generating capacity

*- Dirty technologies are those technologies associated with (high) greenhouse gas emissions.

†- Energy intensity measures the energy efficiency of an economy or a sector of an economy. The numerical value is calculated by taking the ratio of energy use (or energy supply) to gross domestic product (GDP).

by 6 percent and allow nearly 100,000 homes to benefit from clean energy. Furthermore, Morocco seeks to deploy about 1.5 gigawatts (GW) of solar and wind capacity across the country to meet its goal of increasing the share of renewables in its energy mix to 42 percent by 2020. And South Africa signed contracts worth US$4.6 billion with 27 independent renewable energy power producers to produce 2,300 MW of electricity between 2018 and 2023.[46]

Although the use of energy – particularly renewable energies – in the African agriculture sector is rather new, important lessons can be learnt from policy innovations and successful interventions in several African countries. Their experience shows that access to energy has a transformative impact on the livelihoods of the rural poor, reducing the drudgery of their work and generating higher incomes. This report begins with an overview of the state of energy use within Africa's agriculture sector, outlining why connecting Africa's rural areas to grid and off-grid energy sources is so crucial to achieving a food system transformation and sustainable economic growth. The overview is followed by a detailed analysis of the energy needs in each segment of the agriculture value chain. The next section focuses on existing continental and global policy frameworks that support governments in their drive towards achieving universal energy access. Section 5 discusses the ingredients of an enabling environment for the smart use of energy in the transformation of rural economies and the food system. The report closes with an in-depth analysis of what six African countries at the forefront of progress in this area have done in terms of institutional and policy innovation as well as programmatic interventions. Drawing on the experience of these countries – Ghana, Ethiopia, Morocco, Senegal, South Africa, and Zambia – the report provides some key lessons and offers five recommendations for action by African governments and the private sector.

2. Action Agenda

Africa has the opportunity to leapfrog and develop smart energy systems by leveraging the potential of renewable energies and new off-grid and mini solutions. Important lessons can be learnt from those African countries at the forefront of connecting their rural areas to energy – be it on- or off-grid – to the benefit of agriculture value chain actors. By adapting these lessons to countries' specific contexts and by bringing them to scale, African governments will accelerate their progress towards the targets set under the African Union Agenda 2063 and the Sustainable Development Goals.

Drawing on the findings of the six case studies presented in this report, the Malabo Montpellier Panel recommends that African governments design integrated approaches for energy strategies that benefit rural areas, scale up investments in off-grid and mini-solutions, and address the persistent challenge of biomass-based indoor cooking and associated health risks. The Panel further stresses that innovative finance mechanisms and upgraded institutions are needed, as well as cross-border policies to ensure energy security at all times:

1. Designing integrated approaches

Energy is a key input for agriculture and agricultural transformation. Joint strategies for energy by ministries and departments that have responsibilities for energy and those responsible for food, agriculture and rural development can thus address concurrent opportunities. Integrated approaches to energy strategies and policies for agriculture will ensure that targets for energy access are achieved in good time and to the benefit of rural areas and are consistent with the overall development strategies adopted by African countries.

2. Scaling investments in off-grid and mini- grid solutions

Concessionary finance and investments at scale by governments and the private sector are needed in small-scale bottom-up power generation and supply. Off-grid and mini-grid technologies are having a disruptive impact on African energy landscapes and enable Africa's consumers to leapfrog outdated and dirty technologies. Combined with Africa's mushrooming digital market, small-scale, micro, and nano solutions offer tailored services for the specific needs of farmers. Investments in start-ups and businesses to innovate and expand are needed, as are incentives to leverage further investments, particularly in the renewable energy sector.

3. Adopting gender-responsive energy strategies

As major actors in farming, food preparation as well as processing, women are primary energy managers at the household level. They are thus affected in different ways by the lack of access to improved energy services, with considerable consequences for growth, health and the environment. The design and implementation of energy strategies as well as the choice of technologies and tools need to be adequately gender-responsive to yield maximum benefit for rural communities and the broader economy.

4. Addressing the multiple challenges of biomass-based energy use

Biomass-based energy needs to be transformed in Africa's energy mix towards clean and environmentally friendly systems. Governments, the private sector, and farmers' organizations need to ensure that biomass is produced more sustainably, and more emphasis needs to be placed on ensuring that indoor cooking is redesigned to be more environmentally friendly and not harmful to health.

5. Developing cross-border policies for energy security

A regional policy framework that governs the development and use of renewable energy sources across borders is required for an effective exploitation of Africa's substantial but unequally distributed energy resources. Renewables can help reduce the reliance on imported fuels while diversifying the power mix. They also can be deployed in a decentralized manner, which means they can be deployed faster than centralized power plants.

What works at country-level?

The experiences of six African countries that have been at the forefront of progress on connecting rural areas to energy through dedicated and effective government action offer a wealth of lessons. Their successful policies and interventions, which if replicated at scale, could enable African countries to make faster progress in the fight against poverty and hunger. The policy and institutional innovations as well as programmatic interventions by Ethiopia, Ghana, Morocco, Senegal, South Africa and Zambia are discussed in depth in section 7. The below offers a summary of the key actions.

Ethiopia	Ethiopia has placed electrification as a core element of its agricultural and rural transformation strategy. Through its Climate Resilient Green Economy strategy launched in 2011, Ethiopia has set sector-specific strategies in preparation for transitioning to a green economy. This includes expanding electricity generation from renewables and leapfrogging to energy-efficient technologies in the agriculture sector. Furthermore, through dedicated programmatic interventions, the government has integrated the electricity supply with other services to enhance productive capacity and has leveraged different energy sources to broaden energy access.
Ghana	Ghana has placed a strong emphasis on facilitating private sector engagement through regulation and on expanding local research and technical capabilities. Furthermore, the government followed a path of liberalization for leveraging private sector investment in the energy sector and to diversify its energy mix, including an increased use of renewables. Ghana's programmatic interventions are directed towards achieving universal energy access, with a focus on rural areas and the agricultural processing sector.
Morocco	A strong drive towards achieving energy efficiency and to create a private sector market for increasing the use of renewables in Morocco's energy mix is clearly visible in the government's policy design and implementation. Furthermore, the government has sent a strong signal for adopting renewable energies at scale through setting fiscal incentives, including subsidies to farmers for the use and installation of solar pumps and panels.
Senegal	Senegal passed legislation to liberalize the energy sector, incentivizing independent power producers (IPPs) to produce electricity. Since then, IPPs have been mushrooming, contributing to the achievement of the government's electrification targets. Furthermore, the government has prioritized to expand electricity access in rural areas with a target of 60 percent by 2022. Attempts have also been made under the country's Energy Policy Letters to jumpstart the domestic biofuel production and to diversify the energy mix.
South Africa	South Africa has placed a strong emphasis on bridging the energy gap for poor communities and rural areas, with an early focus on off-grid solar PV systems for rural areas. Access to electricity in remote areas was facilitated through a decentralized provision that was more cost-effective than grid connections and alternative energy sources for electricity generation. Through several programmatic interventions, South Africa also seeks to crowd in the private sector to boost and diversify its energy supply. For example, the government invited IPPs to tender for licenses to sell electricity to the Eskom grid under a 20-year purchase agreement.
Zambia	Zambia stands out for its commitment to strengthen and diversify its energy supply through fiscal incentives, including reduced import duties. Furthermore, the country has taken a cluster-based approach to agricultural electrification through "farm blocks" that are equipped with basic infrastructure and complemented by industrial cluster zones for agricultural processing. To meet increased energy demand and connect rural areas to electricity, a government strategy seeks to expand electrification using a combination of grid extension and off-grid solutions. The government also draws on different smart financing tools for power supplies and farm equipment, such as Rent to Own and funds that de-risk companies' costs of operating and expanding.

3. Energy needs in African food systems

In order to increase agricultural land and labor productivity, make rural employment more attractive, achieve future growth and poverty reduction targets, and improve overall food security and nutrition on the continent, African governments are set to increase the access to and facilitate the uptake of modern farming inputs, and improve access to markets for rural areas. This includes improved access to and use of energy, which can be achieved through a mix of traditional and renewable energy sources. As indicated in figure 2 along the agricultural value chain, energy is needed to operate farm equipment and machinery, such as for seeding, plowing, and irrigation, as well as in the later stages of food transformation, storage, and transport.[47] Mechanization, through both mechanical and electric tools and machines, can increase yields through improved irrigation, planting, weeding, and harvesting. Estimates show that a farmer using a combination of power-based mechanization and animal power can provide enough food to feed up to 50 people, compared with just 6 when using draught animal power alone.[48] In addition, energy access may reduce post-harvest losses through improved cooling, chilling, pressing, and drying technologies. Estimates indicate that over half of fresh fruits and vegetables produced in SSA are lost or wasted, and nearly half of these losses occur during post-harvest handling and processing.[49] In many cases, food losses lead not only to food insecurity but also to higher poverty levels. Evidence shows that a reduction of just 1 percent in postharvest food losses could lead to annual savings of US$40 million for the entire continent.[50] Where energy input is available, famers can adopt modern productivity-enhancing technologies for food transformation and processing, thereby facilitating their integration into high-value and export-oriented value chains. Furthermore, through storage and processing facilities, farmers can add value to their crops or sell when prices are higher, thereby increasing their income from what they grow.[51]

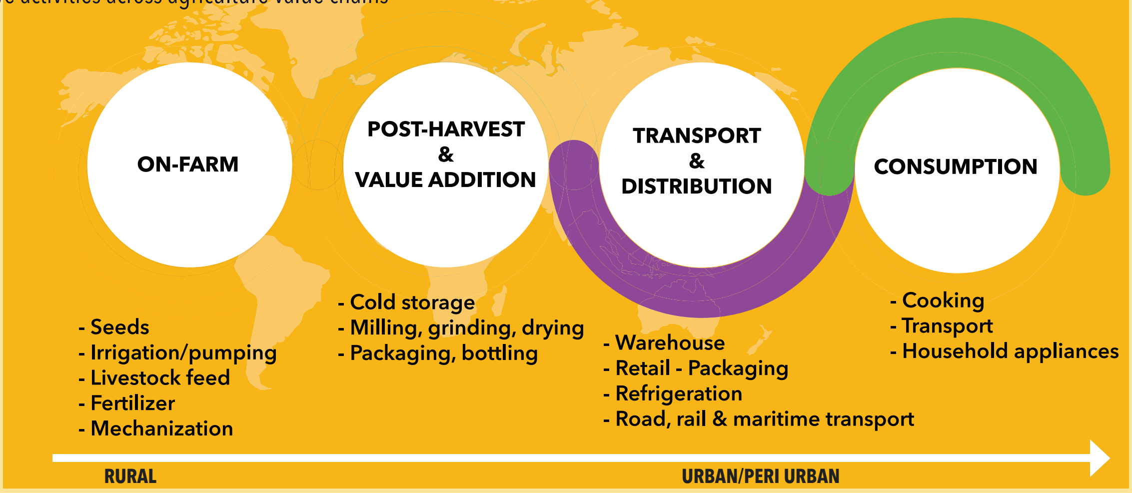
Beyond production, energy inputs are also essential to improve food safety and to preserve the nutrient content of food – in turn improving the nutrition status of both producers and consumers. Importantly, appropriate energy inputs facilitate increased consumption, and therefore commercialization of, often perishable yet nutritious crops. Furthermore, investments in energy infrastructure could significantly reduce market transaction costs and food waste across the continent.

At production level

To improve Africa's agricultural productivity, increased levels of energy input are urgently required. Until now, human muscle – manual – power has been the dominant energy source in African agriculture. Access to energy can significantly improve the capacity of farmers to deploy new technologies, tools, and machinery in tillage, plowing, and weeding. A typical farm family can cultivate up to 1.5 ha per year when relying on manual power. This increases to 4 ha per year when using draught animal power and 8 ha per year when using tractors.[52]

In addition, smallholder farmers require appropriate energy-based technologies to dig wells and lift or pump water from groundwater aquifers and other deeper water resources for irrigation.[53] As discussed in the Malabo Montpellier Panel's 2018 report *Water-Wise*, upgrading irrigation technologies to gas-, diesel-, or solar-powered water pumps can save significant save time and labor – particularly for girls and women – and lead to improved yields and incomes. Recent research estimates that the expansion of irrigation by about 30 million ha using small-scale motorized pumps in SSA could generate net revenues of US$22 billion per year and improve food security and incomes for about 185 million people, depending on fuel prices and supply reliability.[54]

Figure 2 Energy intensive activities across agriculture value chains



Box 3: Solar-powered pumps for irrigation

Solar technology in combination with pumping systems for irrigation is a more environmentally friendly alternative to diesel- or gas-powered pumps. Solar-powered drip irrigation systems require no batteries and have lower maintenance costs. The pumps are self-regulating, operating at greater capacities on sunny and hot days when evapotranspiration is higher. In northern Benin, solar-powered drip irrigation pumps were installed on plots of 0.5 ha and tested against similar plots reliant on hand-watering methods. On the solar-power irrigated plots, yields, incomes, and household consumption of vegetables were significantly higher compared with households using hand-watering methods. Overall, the standard of living for beneficiaries increased by 80 percent relative to non-beneficiaries. Although the solar-based techniques have higher up-front costs, a hypothetical comparison with motorized pumps has shown that the overall cost-effectiveness is higher when fuel prices are high and when solar technologies are used on large farms. But with high up-front costs, solar-powered technologies may only be affordable for farmer cooperatives or larger-scale government-led irrigation systems. [55]

Box 4: Smart Solar Irrigation in Senegal

In Potou, Senegal, the Earth Institute of Columbia University installed three smart solar PV irrigation pumping systems in 2014 as a part of the Powering Agriculture program. A centralized solar plant with a single PV array and monitoring and control system powers individual pumps that provide approximately 30 kWh of pumping per day. Farmers on 21 farms can control their own pumps as needed and pay for the service on a pre-paid credit basis, like a mobile phone scratch card system. To keep the costs for installation and maintenance low, the system does not include a battery, and only operates while the sun shines. Farmers receive a two-week introductory grace period, after which they are charged US$ 0.60 per hour. By the end of the project in March 2016, the Smart Solar Irrigation project led to a 29 percent average increase in production, much of which is now in high value crops, while farmers on average earn between US$1,500-2,000 per season. Moreover, this system has greatly reduced the drudgery of irrigating using wells and buckets. The solar system has also avoided 24 tons of carbon dioxide that would have been emitted by diesel pumps.[56]

Food storage and transformation

Energy access can also improve the storage of highly perishable produce. In Nigeria, 20 percent of fish, 20 to 30 percent of grain, up to 50 percent of fruits and vegetables, and 50 to 60 percent of roots and tubers are lost due to poor postharvest handling practices.[57] Poor access to energy is among the main factors contributing to this waste and loss.[58] Electricity can power cold chains, which would reduce food – and income – loss. Moreover, farmers with access to cold chains are better able to specialize in high-value perishable products such as dairy, meats, fruits, and vegetables particularly when cultivated in tropical or sub-tropical climates.[59] In addition to the preservation of quality, access to energy can allow farmers to spread delivery of agricultural products over time in order to supply markets more continuously. This can increase the bargaining power of farmers, and ultimately increase profits from what they grow.[60]

Box 5: Fruits and vegetables in Cameroon

In Cameroon's northwest and western provinces, farmers are forced to sell their produce when prices are low due to limited processing capacity. A low-cost, medium-sized ventilated gas dryer developed by Winrock International allows farmers to dry their crops, including peppers, spices, greens, fruits, and mushrooms, as well as meat and fish. The dryer produces high-quality dried fruit and vegetables that can be sold at more distant and lucrative markets. Equipped with a drying space of $5m^2$, the dryer allows users to control air circulation throughout the drying process for efficient energy consumption and production. The dryer is constructed using locally available materials. Local manufacturers are trained to construct and maintain the dryers. It is estimated that by processing one ton of fresh peppers a year, approximately US$2,000 of net income can be generated, which is more than three times the capital investment made in the dryer.[61]

Furthermore, energy can significantly improve food transformation, including cleaning, drying, milling, pressing, crushing, and pulping. Estimates indicate that approximately 1 million tons of additional milled rice could be made available in SSA by using appropriate – locally available, suitable, and adapted – milling machines, which in turn would halve postharvest losses. This translates to 17 percent of current rice imports per year, worth US$410 million. In addition, it could potentially lift almost three million people working in rice farming out of poverty.[62] However, the high costs of energy, for example in Senegal – equivalent to up to 60 percent of operational costs – severely impact the profitability of mini-dairies, which use diesel for generators or butane for pasteurizing.[63]

Box 6: Solar-powered portable cooling system

Half of the milk produced in Kenya does not reach dairy processors due to storage or transportation issues. Recognizing the need for affordable cold-chain technologies, SunDanzer in collaboration with Winrock International, has developed a small-scale portable cooling system tailored for use in the Kenyan dairy market. The system incorporates a photo-voltaic refrigerator that uses solar energy to cool a chest refrigerator. This uses phase-change materials—substances capable of storing and releasing large amounts of energy—for energy storage. SunDanzer also developed milk-can blankets to retain the cold as farmers transport milk to collection sites. The system aims to increase dairy farm productivity and income by significantly decreasing milk spoilage. Effective cold-chain storage lowers bacteria count and improves milk quality for consumers. It is estimated that these improvements can help improve the livelihoods of approximately one million smallholder dairy-farming families in Kenya. Through participation in USAID's Powering Agriculture: An Energy Grand Challenge between 2013 and 2018, SunDanzer delivered and installed 60 solar-powered milk-cooling refrigerators in Kenya, as well as two units in Rwanda.[64]

Transport and Distribution

One of the largest energy costs in the food system is associated with the transport and distribution of agricultural produce. The so-called "first mile" (the distance from farm to the collection point) often only represents only 0.4 to 10 percent of the logistics chain length, but 20 to 37 percent of the transport cost for high-value crops such as French beans, bananas, and potatoes.[65] In Kenya's Nyeri County, the cost of transporting onions over the first 2km accounts for around 10 to 20 percent of the income that farmers would derive from selling their onions.[66] Where access to cold storage and transportation is limited, food prices tend to be high, leaving nutritious food out of reach for most rural households.[67] As discussed in the Malabo Montpellier Panel's 2018 report on agricultural mechanization, improved and more cost-efficient transport systems are therefore essential to minimize the time lag between harvesting, processing and retail, and to reduce overall costs to farmers. In addition, adequate temperature control is required to preserve the quality and shelf life of perishable products as they are transported to markets.[68]

Box 7: Milk collection, processing and distribution

Nearly 90 percent of the milk consumed in Senegal is imported in the form of powder. The productivity of local cow breeds is low at an average of just 0.7 liters per day, primarily because of lack of fodder. Because of this and limited access to markets, farmers do not view milk as a source of income. In 2005, a local company, the Laiterie du Berger, started processing milk produced by local herders in northern Senegal. The company set up a milk collection system using tricycles to collect milk twice a day from about 800 herders within a radius of 50km around their factory. The exact number of herders fluctuates every season but for those who stay in the region, the company provides fodder for the cows, veterinary support, and a guaranteed price for their milk. As a result of an increased and stable income, herders gain opportunities in education, energy provision and health services. The company now employs more than 100 people across the country. Thanks to refrigerated trucks, the company's Dolima yogurt and crème fraîche are distributed in more than 8,000 points of sale in Dakar and smaller towns and villages.[69]

Food consumption

At the household level, the availability and use of energy has a direct impact on what food can be consumed, and thus on the nutritional status of household members. Limited or no access to appropriate cooking fuel means that eating and cooking habits need to be adjusted by reducing the number of meals, switching to foods that require less cooking time, undercooking food, or using some food crops as fuel instead.[70] Conversely, access to energy, particularly electricity, improves the ability of a household to store and consume more nutritious food, such as fruits, vegetables, dairy products, meat, and other nutritious crops by using a refrigerator or communal cold stations. Evidence shows that in many parts of Africa, one calorie from a chicken egg or from fruits and vegetables costs more than nine times as much as a calorie from the local staple food crop.[71] Inadequate dietary diversity in households reflects at least partially the relatively high cost of nutritive foods. Moreover, households with access to cheaper and reliable energy also have a greater share of income available to spend on more nutritious foods.

As Africa's agricultural production transforms from subsistence farming to a commercial activity, propelled by population growth, urbanization, demographic changes and new dietary habits, a positive feedback loop develops in which its food system processes become more mechanized – in turn requiring more energy.[72] Moreover, as farmers earn higher incomes, they are better able to pay for energy services, strengthening the case for investments in infrastructure. The provision of improved energy services to rural communities can transform agricultural productivity, improve nutrition outcomes, and positively impact rural development across Africa. Providing greater access to energy for Africa's rural communities, can stimulate productivity growth and associated value chain activities, and hence wider economic transformation. With these impacts, the provision of energy services enables countries to meet their commitments to continental and global agendas.

4. Continental and global policy frameworks

The importance of energy for agricultural transformation and economic growth is widely recognized, putting energy policy at the forefront of African continental and international development agendas and strategies.

Continental policies and initiatives

At the continental level, under the African Union (AU) Agenda 2063, Aspiration 1, "a prosperous Africa based on inclusive growth and sustainable development", reflects African governments' commitment to improve access to energy for economic transformation and poverty eradication by tapping into its energy sources, with a dominant role for Africa's vast renewable energy potential.[73] Under the Malabo Declaration, African governments have committed increasing the use of reliable and affordable mechanization and energy supplies.[74]

In 2015, under the mandate of the AU and endorsed by the Committee of African Heads of State and Governments on Climate Change, the Africa Renewable Energy Initiative was launched to accelerate the increased use of renewable energy sources. The Initiative seeks to add a minimum of 10 GW of new and additional renewable energy generation capacity by 2020 and to generate at least 300 GW by 2030. In addition to household access to energy, the effort uniquely targets access for productive sectors, such as small-scale farming and micro, small, and medium sized enterprises – thereby going beyond measuring success by megawatts. It also aims to support African governments in developing and transitioning to renewable energy systems, in line with their low-carbon development strategies, thereby improving the continent's energy security.[75]

Furthermore, the Clean Energy Corridors in Africa program initiated in 2014 involves 30 governments, regional organizations, development partners, and financial institutions to support efforts to meet the continent's fast-growing electricity needs through accelerated development and optimal use of the region's renewable energy resources. Clean Energy Corridors were first established within the Eastern and Southern Africa Power Pools initiative to help African countries scale up renewable power generation and cross-border electricity trade. The West Africa Clean Energy Corridor was adopted by the Council of Ministers for the Economic Community of West African States (ECOWAS) in 2016. The Corridors primarily focus on the large-scale development of renewable-based electricity sources with a cross-border trade dimension to benefit from resource efficiency and economies of scale. In 2017, the AU recommended the integration of the initiative into national renewable energy and climate change agendas.[76]

The delivery of the targets under the AU Agenda 2063 is further supported by the Africa-EU Energy Partnership (AEEP) and Power Africa. Established in 2007, the AEEP is designed to increasing investment to provide secure, affordable, and sustainable energy for both continents. The partnership aims to catalyze access to modern and sustainable energy services for at least an additional 100 million Africans, through provision of 10GW of new hydropower, 5 GW of wind power, 500MW of solar and a tripling of all other renewable sources by 2020. At the end of 2016, nearly 7 GW of hydropower, 3.8 GW of wind power, and 2.4 GW of solar had been installed. It is expected that all targets will be met comfortably. In addition, between 2008 and 2016, European commitments (including bilateral commitments from France, Germany, and the United Kingdom) to energy projects in Africa increased from US$1.9 billion to US$3.3 billion.[77]

> **"Providing greater access to energy for Africa's rural communities, can stimulate productivity growth and associated value chain activities, and hence wider economic transformation."**

In 2013, Power Africa was launched under the leadership of then US president Obama, for a period of five years. The aim of the initiative was to add 10 GW of new power generation and to expand access to power to 20 million households and businesses including agriculture, animal husbandry, and agribusiness.[78] Following the success of the first phase, during which nearly 80 percent of its original targets were achieved, a second phase of the initiative, Power Africa 2.0, was launched in 2018 by the US Agency for International Development (USAID). In a partnership model that brings together multiple US government agencies, African governments, and public and private sector actors, Power Africa 2.0 aims to develop transmission and distribution resources, improve governments' capacity to manage their power sectors, and level the playing field for competitive investment – to add a further 30 GW and 60 million connections to SSA. Power Africa facilitates private sector access to concessions for electricity production. To facilitate private sector investment the US Overseas Private Investment Corporation, US Export–Import Bank , and USAID provide loans and guarantees.[79]

Furthermore, the long-term energy sector strategy (2013-2022) of the African Development Bank (AfDB) seeks to achieve inclusive, sustainable, and increasingly green growth in Africa, promoting the use of renewable energy sources in all economic sectors. It seeks to ensure universal access to modern, affordable and reliable energy services by 2030, and to support regional economic communities in their efforts to achieve and maintain access to high-standard energy services for all.[80] AfDB launched the New Deal on Energy in Africa to inject momentum into the energy challenge, catalyze finance and improve regulation and governance of the sector. Delivered through a platform for public-private partnerships – Transformative Partnerships on Energy for Africa – this ambitious program seeks to add 160 GW on-grid capacity by 2025 and 130 million new on-grid transmission and grid connections by 2025, the equivalent of 160 percent growth. It will do so by transforming utility companies, dramatically increasing the number of bankable energy projects, particularly "bottom of the pyramid" energy access programs with a focus on women; and accelerate major regional projects to drive integration. By 2016, US$1.7 billion had been dispensed, developing 546 MW of additional capacity, 96 percent of which was from renewable energy sources and over 21,000 km of distribution lines and 641km of transmission lines. The AfDB has pledged an additional US$12 billion of its own resources and US$45-50 billion of leveraged resources to further support the delivery New Deal for Energy in Africa by 2020.[81]

Global policies and initiatives

At the global level, SDG7 commits countries to ensure access to affordable, reliable, sustainable and modern energy for all by 2030.[82] Under the goal, countries seek to achieve universal access to modern energy services, double the share of renewables in the global energy mix, and double the growth rate of energy efficiency.

Prior to the formulation of SDG7, in September 2011, then UN secretary-general Ban Ki-moon established a new initiative called Sustainable Energy for All (SE4ALL). The initiative sought to ensure universal access to modern energy services and to double the rate of improvement in energy efficiency as well as the share of renewable energy in the global energy mix by 2030. As the initiative evolved, it has sought to convene leaders in government, the private sector and civil society to accelerate action to achieving SDG7, and now provides an annual update on progress towards achieving targets.[83]

In addition, the Clean Cooking Alliance – a public-private partnership (PPP) hosted by the UN Foundation – seeks to save lives, improve livelihoods, empower women, and protect the environment by creating a thriving global market for clean and efficient household cooking solutions. The Alliance's "100 by '20 goal" calls for 100 million households to adopt clean and efficient cook stoves and fuels by 2020. Established in 2010, the Alliance seeks to drive consumer demand, mobilize investment to build a pipeline of scalable businesses, and foster an enabling environment that allows the sector to thrive.[84] Among the Alliance's seven focus countries, four are in Africa: Ghana, Kenya, Nigeria, and Uganda. Furthermore, Burkina Faso, Central African Republic, Côte d'Ivoire, Democratic Republic of the Congo, Ethiopia, and Lesotho are national partner countries that have ascribed to the principles of the Alliance.

In order to meet the ambitious targets set under continental and global policy frameworks, countries need to have in place a favorable enabling environment characterized by inclusive policy design, the active involvement of women, and adequate infrastructure and technology provision, as well as an attractive business and investment environment to catalyze and leverage private sector financing and innovative capacities.

5. Creating an enabling environment

Previous sections in this report have demonstrated the importance of improved energy services to transform African agriculture. The immediate benefits of shifting away from human- and animal-labor intensive practices in African agriculture include better health and welfare – particularly for women and young girls. More importantly, the use of improved energy services in African agriculture leads to increased productivity, higher incomes, less food waste, cleaner air, reduced environmental degradation, and better nutrition outcomes. It is thus critical that Africa's public and private sectors, and local communities work hand-in-hand to deliver an energy transition that will accelerate the transformation of Africa's agriculture and achieve wider development objectives.

However, such a transition must be managed carefully to ensure that the outcomes are environmentally and socially sustainable. While improved energy use has been shown to improve yields, "the relationship between energy inputs and productive yields is not linear."[85] Beyond a certain limit, additional energy inputs have greater negative consequences on the environment and climate and potentially on employment, than positive impacts on productivity.

Therefore, to create an inclusive, sustainable, and effective energy transition for Africa's agriculture, it is critical that appropriate institutional arrangements, regulations, infrastructure, financing, and capacity building mechanisms are put in place, ensuring the government, private sector, and local communities too have clearly defined roles.

Holistic and inclusive policymaking

Driving an energy transition for Africa's agricultural transformation requires clear vision, leadership, and commitment at the highest levels of government. The scale of the challenge and the rapidly changing landscape of solutions calls for a new – more inclusive – approach to policymaking. Several countries have developed, or are in the process of developing, national energy and electrification plans, either integrated in, or aligned with, national growth and development plans and poverty reduction strategies.[86]

It is critical that these energy and electrification plans be reinforced with a supportive policy and a regulatory environment that leverages the strengths of the private sector and includes local communities. To provide the policy *certainty* that investors and implementation partners require, the World Bank recommends that governments devise a long-term commitment to electrification (at least 15 to 20 years) to allow the formation and implementation of institutional, technical, economic, and financial systems.[87] Moreover, by sharing these plans with relevant stakeholders and potential investors, governments can coordinate interventions to ensure that they meet the objectives and are targeted and effective. For instance, the government of Rwanda shares its grid extension strategy with potential energy suppliers (including social enterprises) and provides long-term concessions with clear exit options so as to allow them to invest in appropriate capacity building.[88]

As agriculture is a significant contributor to African economic growth and poverty reduction, energy and electrification plans must define clear policies for stimulating the uptake of improved and sustainable energy services in food and agricultural systems. Often these plans simply address the supply side of energy. However, to ensure that capital investments in infrastructure can earn a return, financially sustainable plans also need to address the demand side. Investments in infrastructure must therefore be matched with programs to accelerate the uptake of agricultural machinery and technologies that rely on energy. Likewise, agricultural policies must also include substantial focus on the use and supply of energy. Furthermore, within the agricultural

ministries, necessary linkages with irrigation plans, post-harvest processing, and storage as well as food distribution will ensure that solutions address whole value chains and food systems.[89]

Equally essential is cross-government endorsement of national targets for universal energy access. Earlier sections have shown that the provision and use of improved energy services in agriculture encapsulates synergies among health, environment (including water and land use), and community development sectors. Therefore, multisectoral cooperation among these ministries and departments can create holistic and more coordinated policy formulation for smart energy systems, delivering solutions that address concurrent challenges.[90,91,92,93] By establishing an intersectoral taskforce constituting representatives from ministries, and overseen by the head of state or equivalent, governments can ensure that strategies and policies are developed in harmony with health, air pollution, climate, water, land use, food, and transport policies and targets.[94]

While coordination at the ministerial level is critical to ensure policy *coherence*, implementation will only be successful if rural communities are at the heart of policy design in the first place. As the ones living in energy poverty, rural consumers must be consulted and involved throughout the process of policy formulation,[95,96] ensuring that programs are tailored for local contexts, are sustainable and deliver real benefits to rural communities.[97,98]

An innovative approach to ensuring that voices from rural communities are heard was employed by Sierra Leone's Energy Revolution Taskforce. The Taskforce brought together 149 provincial 'paramount chiefs' during the design and implementation phases, thereby ensuring buy-in during the implementation phase. The Taskforce also comprised other key stakeholders including development partners, business, and industry associations as well as the Ministry of Finance, thus becoming a powerful collaboration tool between the Rural Electrification Agency and the National Renewable Energy Association. Finally, the Taskforce is accountable directly to the president, accelerating progress in delivery.[99,100]

Gender-responsive energy policies

As the primary energy managers in their farms, households and businesses, women are variously affected by the lack of access to improved energy services. Not only are women major consumers of poor energy services, they are also often the main supplier of energy to the households. Fuelwood, coal, and agricultural waste constitute the largest sources of primary energy in much of rural SSA and women are largely responsible for their collection and preparation (chopping wood), with substantial economic, social, health and safety costs. As deforestation and climate change make resources scarcer, women are forced to travel farther and for longer, putting additional pressure on their time, health, and security. It is estimated that more than 40 million work-years are spent annually in Africa on fuelwood gathering and slow biomass cooking.[101] Therefore, the use of efficient energy saving technologies for cooking can significantly reduce the time spent on gathering fuelwood, and increase the time that can be devoted to other economic activities.[102] The continued use of fuelwood and charcoal for cooking, warming water, and heating has significant negative impacts on the health of Africans, especially women and children. Each year nearly 600,000 people die in Africa due to chronic illnesses caused by air pollution from inefficient and dangerous traditional cooking fuels and stoves.[103]

In Mali, evidence shows that access to energy and appropriate cooking technologies can yield substantial benefits to health and welfare of households through the time saved in the lives of women and children, combined with the added socio-economic benefits to women.[104] While an evaluation of the Ugandan Energy Saving Stove Project showed stove users reported a 21 percent reduction in acute respiratory diseases compared to non-users.[105]

Box 8: The SEWA charcoal cookstove in Mali

To improve the energy efficiency of household cooking, the Household Energy and Universal Access Project (HEURA) in Mali supported the production and dissemination of 500,000 efficient cookstoves to reduce household consumption of traditional biomass. It was launched in 2004 by the government of Mali with financial support from the World Bank and the Global Environment Facility. Cookstoves are manufactured locally by a network of metal artisans in Bamako under the brand name SEWA using locally produced ceramic liners. The firms manufacturing and distributing the ceramic liners were subsidized in the first three years of operation. After the subsidy period, Katene Kadji, one of the firms under HEURA, partnered with E+Carbon, a US carbon project developer, to set up a carbon offset project selling carbon credits to private companies in Europe and the United States. The income from sales has covered the costs of carbon registration and monitoring and allowed for expanded production and subsidized sales of stoves. By 2014, around 180,000 stoves had been sold benefiting 1.6 million people. In addition to social and environmental benefits, use of the stove reduced household spending on fuel by 25 percent and reduced particulate matter pollution by 56 percent compared to a three-stone fire.[106]

At the same time, without access to improved energy services, women are forced to resort to manual power for productive activities, including weeding, irrigation, and distribution.[107] It is estimated that the average female labor share in crop production is 40 percent, but slightly above 50 percent in Malawi, Tanzania, and Uganda, and substantially lower in Nigeria, Ethiopia, and Niger at 37, 29 and 24 percent respectively.[108,109]

Therefore, making improved energy and appropriate technologies available to women, can catalyze women's wider empowerment, accelerate their economic advancement, and bring wider social and environmental benefits. In Ghana, rural electrification programs allow women to run small businesses from their homes, such as preparing and selling snacks.[110] In the Kalale district in northern Benin, introduction of solar-powered drip irrigation systems in gardens farmed by a cooperative of 45 women meant that women only had to fetch water once or twice per week, rather than every day. Women also saved up to four hours each day by using modern technologies for watering plant beds.[111] In contrast, in Mazuru, Zimbabwe, women walk nearly 4 km or more each day to bring water from a dam site to irrigate their farms.[112]

The availability or absence of modern energy affects women and men differently. A survey conducted by Practical Action in rural Togo revealed gendered differences in priorities for energy use. In addition to security and safety, women prioritized energy for pumping drinking water and processing crops, including milling, threshing, and hulling. Men prioritized mobile-phone charging and heating water for washing. It is therefore essential that women be involved during the design and implementation of energy strategies and that women lead the innovation of technologies and tools, which deliver energy services to rural areas, to ensure that end products meet their needs, and those of their families.[113]

Box 9: Diesel-powered multifunctional platforms in Mali

Between 1993 and 2012, a program by UNDP, UNIDO, and IFAD in Mali promoted the empowerment of women by supplying multifunctional diesel-powered machines to rural villages to decrease the burden of fuel collection. The women's groups covered 40 to 60 percent of initial cost of the machines. The multifunctional machines supply power for time- and labor-intensive work including milling and de-husking and electricity for approximately 200–250 small bulbs, welding, or pumping water. Between 1999 and 2004, up to 400 platforms were installed benefiting 8,000 women. Initially, women benefited from the capacity-building and institutional support and later were in charge of operating the platforms, drawing on the support of a network of private suppliers and technicians. An evaluation from 12 villages found that the platforms significantly reduced the time required for labor-intensive tasks from many hours to a few minutes per day. Women spent the time saved on other income-generating activities, leading to an average daily increase of US$0.47 in their income. Rice production and consumption also increased, an indirect benefit arising from time saved, while the ratio of girls to boys in schools and the proportion of children reaching grade 5 increased. Improvements in women's health and increases in the frequency of women's visits to local clinics for prenatal care were also reported. Due to the reported success of the program, UNDP and partners have implemented similar programs in Burkina Faso, Ghana, Guinea, Niger, Senegal, and Togo.[114]

Infrastructure and new technologies

Several factors determine the most effective way to connect communities: the terrain and natural resources, the demographics of the community (size, population density), distance to national grid, level of economic activity, and socioeconomic, cultural and political realities.[115,116] Following privatization and reform of energy supply utilities in the 1990s, African countries sought to connect more communities to a central grid. Traditional grid extension programs have successfully connected millions of citizens in countries such as Côte d'Ivoire and Tunisia as a result of sustained government commitments, effective prioritization and planning, lower construction and operation costs, sustainable financing, and maintaining a customer focus.[117] Yet grid extension programs have not kept up with population growth or increasing energy consumption. The total electricity supply in SSA, excluding South Africa, is approximately 100,000MW in a region with almost one billion people. In contrast, Spain produces the same amount of energy for a population of less than 50 million people.[118]

For other countries, grid extension programs into remote rural areas are limited and unlikely to occur at large scale for political reasons or because of poor financial viability or simply the sparseness of population. In such cases, mini-grids or individual systems fill the gap in rural electricity provision.[119] Centralized grid extensions are costly, slower to construct, capital intensive, and face high operational costs. Poor rural populations are rarely able to afford the high rates required to recover the costs of construction, further encumbering electricity companies and governments who have to heavily subsidize service provision. Finally, where grids rely on fossil fuels, they are exposed to volatile global oil prices and contribute to global climate change. Other common challenges include poor planning and the use of low-quality equipment to meet targets quickly; inadequate maintenance; loss of trust in electricity companies, which are often large national monopolies; and theft of electricity, often without construction and safety standards – all of which lead to insufficient, poor quality and expensive service provision.[120]

The impact of centralized grid extension (rural electrification) schemes on agriculture across other parts of SSA is limited, at best.[121,122] In Rwanda in 2013, about 3.5 years after electrification, electricity consumption and uptake of appliances remained low. Although electricity consumption for mobile phone charging and entertainment (radio, TV, computers) increased, there was little change in productive use, such as machinery for agriculture. Nonetheless, there was a small increase in the number of small enterprises, as well as an improvement in the productivity and profitability of existing ones. Mills benefited most from access to electricity, as they switched from expensive diesel operations to cleaner, cheaper, and faster electric machinery, making them more profitable too. But these results were only relevant among those who could afford to and were willing to pay for the connection from the low voltage electricity lines (60 percent). For the others, it was simply too costly to connect to the grid.[123] As a result, this program and similar centralized grid extension programs across the continent have been hampered with low connection rates (due to high connection fees) and weak productive use of electricity.[124] Therefore, to avoid further indebting governments, grid extension programs tend to require heavy subsidization unless they are deliberately designed to keep costs low and recover part of the investment.[125] These shortcomings of central grid extension programs have provided an impetus to identify new and innovative approaches to addressing Africa's energy challenge.

In Ghana (see also case study), the Self-Help Electrification Program took a more bottom-up approach: communities within 20km of an existing grid could apply to the Ministry of Energy to accelerate their connection on condition that they take responsibility for the construction of low voltage distribution lines. In addition, at least one-third of the households are expected to be wired and ready to connect to the grid. Once these preconditions have been assessed and approved by the Ministry of Energy, implementing agents are awarded contracts for construction and maintenance and the Ministry of Finance funds the program. Despite the arduous approval process, nearly 2,000 towns were connected through this program between 1990 and 2008.[126]

Countries are also increasingly incorporating renewable energy sources into their central supply, because they are cheaper and cost-recovery time is shorter; they diversify grid composition, providing additional energy security; and contribute towards climate change commitments. Geothermal sources constitute over 650 MW in Kenya's supply, expected to grow to 1,869 MW by 2030 – approximately 25 percent of total production.[127] In addition, the recently completed Lake Turkana Wind Power Project added over 11 MW to total production, expected to grow to 861 MW by 2030, which will represent nearly 12 percent of total production.[128] Once completed, the Gibe III dam in Ethiopia is expected to produce 6,500 GWh annually, thereby doubling the country's total current production. However, the growth in renewable energy across the continent will have to be matched with updated modeling systems to accommodate the variability of production, particularly from solar and wind sources. It will also be necessary for grid operators, planners, and renewable energy developers to cooperate closely to adapt to the constantly changing parameters and to revise the rules and regulations of their existing systems.[129]

> **Only 7.5 percent of power crosses borders within the South African Power Pool, while the Central and East African Power Pools trade less than 1 percent each**.

Increased regional co-operation

Regional power pools – aggregated markets for energy generation and demand - also have a vital role to play in the energy landscape in SSA. Unequal distribution of energy sources and the high cost of investment require the strengthening of regional cooperation.[130, 131]

Sharing power across national boundaries provides an incentive to increase diversity of primary energy sources, improve efficiency, stabilize and secure energy supply, and make systems more robust. Studies have found that by increasing regional energy integration in SSA, countries could reduce capital spending by more than US$40 billion and save nearly US$10 billion in costs for consumers per year by 2040.[132]

Despite the presence of at least four power pools in Africa, none is actively trading significant amounts of energy: only 7.5 percent of power crosses borders within the South African Power Pool, while the Central and East African Power Pools trade less than 1 percent each. Power pools can be particularly attractive options for smaller countries such as Rwanda, Ghana, or Senegal, for which connecting to imported electricity could be cheaper and faster. If designed well and with sufficient technical, financial, and political support, power pools can also be strong tools for regional economic integration, collaborative innovation, and stability.[133, 134]

Access to reliable energy

More investment in energy infrastructure is urgently needed in Africa. In addition, improving the efficiency of existing infrastructure and technology offers "low hanging fruits" to address energy gaps. Aging and inefficient power generation plants and transmission and distribution networks are leading to high losses and reducing the availability and system reliability of electricity in Africa, with frequent and lengthy blackouts and brownouts. Most businesses in SSA cite the lack of energy access as a major obstacle to their growth and development, particularly in the food sector. About 29 percent of food-sector firms considered the lack of electricity a constraint to investment, compared to just 15 percent of businesses in other economic sectors.[135] In Sierra Leone and Uganda, more than 30 percent of households that are connected to the grid reported never actually having electricity. In Liberia this figure is a staggering 50 percent. In Burundi, Ghana, Guinea, Nigeria, and Zimbabwe, among other countries, more than half of connected households reported receiving electricity less than half of the time in 2014. Yet, data shows that for every percentage point increase in the frequency of electricity outages experienced by businesses, output declines by 3.3 percent.[136]

The World Bank estimates that countries in SSA experience annual outages ranging from 50 to 4,600 hours, requiring use of expensive and polluting generators.[137] Power outages in Malawi cost the country up to 7 percent in GDP. In contrast, regular and reliable electricity would add 2 to 3 percent to countries' annual GDP. For the agricultural value chain, power outages reduce the efficiency of agricultural machines and processing plants, disrupt irrigation, and spoil refrigerated food, particularly affecting dairy and perishables within cold chains.[138] Therefore, improving the quality of existing infrastructure and ensuring its maintenance would have an immediate effect by increasing the energy available for distribution.[139, 140]

When combined with energy saving policies and improved access to efficient and high-quality end-use equipment, regular maintenance of existing infrastructure ensures smaller losses of energy produced, thus ensuring that existing infrastructure can serve more people.[141, 142]

Increase energy efficiency

In addition to increasing Africa's capacity to produce energy and the operating efficiency of its existing infrastructure, there is also a need to improve the efficiency of consumption, that is to use less energy to achieve the same level of output. In most regions the agriculture sector has become more energy efficient, thus producing more value with less energy growth. By growing energy consumption from renewable sources, farmers will be less exposed to volatile global oil prices, while improving their agricultural productivity and incomes, as well as their climate resilience.[143]

The benefits of increasing energy efficiency include a reduction in energy prices and energy demand, which may lead to an increase in renewable energy uptake by improving the financial feasibility of renewable energy investment.[144] Barriers to energy efficiency include the lack of a locally trained workforce that is needed for project design and implementation and the maintenance of energy infrastructure, a weak regulatory environment, and a lack of access to financing for energy efficiency projects. Standards institutions also play a vital role to ensure that all machinery, technologies, and appliances using electricity perform at the most efficient levels.

Following recent blackouts and brownouts in South Africa, the national energy supplier Eskom issued advice to actors in the agricultural value chain on reducing their energy consumption and improving the efficiency of their processes, systems, and technology in order to reduce their vulnerability to fluctuations and high costs. The advisories recommended simple behavioral change actions such as switching off building lights at farms and repairing irrigation system leaks to reduce overall energy consumption.[145]

In Kenya, energy auditors have been trained since 2014 to conduct energy audits in 68 tea factories, which has resulted in energy cost savings of US$13.5 million, prevented the deforestation of 1.3 million trees, and led to an emission reduction of 10,000 tons.[146] In Ghana, a program for labeling appliances with energy use and efficiency information was initiated in 2005 has reduced electricity demand by up to 120 MW. The program saved the government US$105 million in investment for electricity production while reducing emissions by more than 11,000 tons of carbon dioxide annually.[147]

Mini-grids and off-grid technologies

Even as grid extension programs are gaining renewed support, including from the New Deal for Energy in Africa, the explosion of off-grid and mini-grid technologies is disrupting African energy landscapes. A mini-grid is comprised of small-scale electricity generators, and in some cases energy storage systems, connected to a distribution network that supplies electricity to a small, local group of customers and operates independently from the national transmission grid. Off-grid technologies such as solar-powered irrigation (drip and pumping), solar-or biogas-powered cold storage and dryers, and hybrid-powered tractors operate independently of a central or mini-grid.

Advances in technologies have made mini- and off-grid solutions more practical and viable alternatives to centralized grid extensions. These decentralized technologies are smaller, faster to construct and can employ more flexible models of financing than grid extensions.[148] They often take advantage of local natural resources, and hence better accommodate rural communities. Mini- and off-grid solutions also provide the flexibility of using singular or a combination of different sources of energy. Fossil-fuel-based mini-grids offer stability in service although they are more vulnerable to fluctuations in oil prices. On the other hand, "green mini-grids" – which solely rely on renewable sources are more climate-friendly, less polluting, and cleaner. As technologies evolve, mini-grids can also combine fossil fuels and renewable energy sources to provide more reliability and resilience.

Although mini-grids generate less than 10MW of electricity and connect customers through local distribution networks, they are sufficiently large to support small agro-processing operations and stimulate economic growth. In Tanzania for example, a hydro-powered mini-grid in Ludewa District was installed in 2009 serving 1,600 customers in 10 villages. Among other benefits, the residents were able to press their own sunflower seeds rather than exporting them for processing.[149]

Well-constructed mini-grid systems are also less prone to outages and connect consumers at a much lower cost than extending national grids to rural communities.[150] In some cases, mini-grids can be connected (back) to feed into centralized grids, providing communities with an additional source of income, or reducing the cost of their energy, when more energy is produced than consumed. Because mini- and off-grid technologies are diverse in scale (individual to community), they are more conducive to bottom-up inclusive planning and to creative pro-poor financing models. They can also be replicated and scaled out, thus ensuring that solutions deliver real benefits to the users. With these advantages, it is estimated that 140 million rural Africans will be connected to mini-grids by 2040, requiring an additional 100,000 units to be built.[151]

Box 10: Tapping into Africa's renewable energy potential

Although the importance of switching away from fossil fuels is widely recognized across the continent, Africa's vast renewable energy potential remains largely untapped. The main potential sources of renewable energy are hydro, solar, wind and geothermal. With abundant perennial and nonperennial water resources, Africa's hydropower potential represents about 10 percent of global hydropower potential, yet Africa currently only exploits a meager 7 percent of its potential. The largest share of the continent's hydropower potential is concentrated in the Inga Dam in the Congo basin.[152]

This unequal distribution of energy resources within the continent highlights the importance of a regional policy framework for the development and use of renewable energy sources. Africa also has one of the highest level of solar irradiance in the world – the power per unit area received from the sun. SSA alone accounts for about 19 percent of global potential of solar electricity. In the Sahel and the Horn of Africa the solar irradiance is more than 280 W/m^2.[153] Yet the continent's share of the world's generated solar energy is less than1 percent. Africa's investment in wind energy is equally low despite its high potential benefits. Africa's global share of installed wind turbine capacity is estimated at just 0.8 percent compared to 40.4 percent in Asia and the Pacific, 34.2 percent in Europe and Eurasia, and 20.9 percent in North America. Despite the high potential, Africa's installed wind energy capacity is less than 5 percent of China's installed capacities, 6 percent of the United States', 12 percent of Germany's, and 40 percent of Brazil's.

Renewable energy could drive economic diversification and growth in Africa by facilitating rural communities' access to energy. This would require supporting quality standards for solar equipment, investment in training, removing bottlenecks for the private sector, and actively pursuing partnerships between the public and private sectors. However, there are some shortcomings to renewables that affect their potential for expanding Africa's electricity supply.[154] For instance, intermittency and variability of solar and wind power mean that these sources require storage and backup capacity, while hydropower, particularly large dams, can cause flooding, threaten livelihoods by causing the loss of agricultural land, require resettlement, and negatively impact wildlife.[155] At the same time, a careful and prudent management of water resources for energy – and agriculture – is indispensable. Renewable energy technologies also have a high upfront cost, although they tend to have a shorter cost-recovery period due to lower operation costs.

Of course, there is no "one-size-fits-all" approach for building and managing an off- or mini-grid solution, and various models are emerging across the continent. In Tanzania, a community in Urambo District partnered with TANESCO to bring electricity to their community. Residents purchased three 85kW diesel generators for a small power station while TANESCO established the distribution network. When the government failed to run the system successfully, the local community formed an "electricity cooperative" with a locally elected executive committee to take control of the management and maintenance of the mini-grid. Despite higher rates than grid electricity, the approach succeeded through strong local leadership and commitment, use of well-proven technical solutions, and training of the co-operative's staff.[156]

In Thiba, Kenya, a community partnered with a local NGO to develop a mini-hydro system. Households were expected to make an upfront contribution of US$150 each, and provide labor and two electricity poles in exchange for shares in the project, earning dividends once the project was profitable. The technology was installed by the NGO and is maintained by four local men who received formal training in Nairobi. The project is governed by an elected committee of 17, including a female member. Some 180 households within a 1.6km radius have been connected (not metered), paying a flat tariff of US$3 per month to cover repairs and the technicians' salaries.[157] The project has become a benchmark for others in the region.

Several other models exist beyond these examples, combining the expertise and skills from various stakeholders, including the government, business, and civil society, and local communities, which take on varying responsibilities. Fundamentally, ensuring the buy-in required for mini-grids to be sustainable over the long term requires significant and organized involvement of rural communities, including women.[158] In turn, this requires inclusive capacity building to allow communities to play a meaningful role in the design and development of their local energy solutions.

Africa faces an immense energy challenge that will require a multitude of solutions. While grid extension continues to play a role in rural electrification, alternative grid solutions accelerate the speed at which remote communities are connected and provides additional capacity. Energy strategies for agriculture would benefit from an integrated approach including grid, mini-grid, and off-grid solutions to ensure that energy access targets are achieved in good time.[159] Although renewable energy sources tend to be more readily available, widely dispersed throughout rural areas, reliable and affordable, their potential remains largely untapped.[160] To accelerate the uptake of renewable technologies, policies to support their commercialization and scale-up are essential. These would include more awareness raising among users, capacity building and financial incentives for producers and installers, and training for repair and maintenance. These policies should be designed to phase out once the technology matures, costs decline, and there is increased familiarity with them.[161]

Supporting the growth of mini-grids and off-grids in Africa's rural communities requires capacity building among grid developers, and other rural actors; a greater and wider understanding of these systems, ensuring that lessons learnt from their deployment, both positive and negative, are shared widely; and creating a flexible policy and regulatory (licensing and permitting) framework that can support the adoption of these systems.[162]

> **Because mini- and off-grid technologies are diverse in scale (individual to community), they are more conducive to bottom-up inclusive planning and to creative pro-poor financing models.**

Private sector

Africa's private sector, especially small and medium-sized enterprises (SMEs), are already playing a key role in providing access to energy, particularly to rural and remote communities. Through the development of innovative products and alternative business and pro-poor financing models, the private sector – including energy SMEs – has developed solutions suitable for specific contexts. Innovative businesses and social enterprises are increasingly integrating skills and knowledge from energy providers and agribusinesses to establish "one-stop-shops" offering products and services for a range of farmers' needs.[163,164,165] For instance, the Kenyan social enterprise SunCulture sells solar-powered water pumps and customized irrigation systems as well as access to finance and training – through technicians and via mobile phone – and soil analysis.[166] Supporting these initiatives to ensure that they reach scale requires a conducive economic and regulatory environment. For instance, Senegal has eased the red tape surrounding business registration, and established a government department specifically to support SMEs. In Ghana, the Rural Enterprises Programme aims to bring to scale a support system for micro- and small-scale enterprises across the country. The total budget of the program is US$125 million, funded by the AfDB, District Assemblies, the International Fund for Agricultural Development (IFAD), the government of Ghana, the beneficiaries themselves, and participating financial institutions.[167]

Arguably, it may be more economically viable for government initiatives to prioritize relatively mature technologies such as fuel efficient cookstoves, which are reliable, easy to understand, and suitable for local distribution. On the other hand, supporting less well-established solutions allows the private sector to capitalize on its capacity and skills for innovation and to drive research and development. This in turn would build on initiatives that use local resources and skills to design and manufacture low-tech solutions that would be otherwise imported. Importantly, it would also enable the development of an African industry for the production and distribution of agricultural energy solutions.

Yet, the private sector continues to be deterred by the high-risk, low-returns of providing energy solutions to smallholder farmers. Clear policy signals and a robust partnership between the private sector and governments could bolster the sector to further enhance its capacity and reach.[168] In particular, PPPs can provide vehicles through which governments can offer subsidies or other financial incentives, while the private sector would take responsibility for the development and transfer of technologies and the provision of energy services. For instance, simply creating Sierra Leone's Energy Revolution Taskforce, chaired by the President, sent a strong signal to the private sector about the seriousness of country's intentions. In addition, among the first policy actions taken by the Taskforce – and ratified in law – was the elimination of import duties on solar products meeting international quality standards. This was further supported by the creation of a fast-tracking process at customs and an elimination of sales tax for qualified products. Tying tax exemptions to the quality of products ensured that there was clear direction for importers, as well as attention to the well-being of consumers.[169]

> **At an average of US¢14 per kWh, the cost of electricity in SSA is among the highest globally and where electricity is provided by generators, this can reach US¢40 per kWh. This compares to US¢4 per kWh in Asia Pacific or US¢1per kWh in South Asia.**

Financing Africa's agricultural energy transition

The high cost of electricity is a key factor in keeping smallholder farmers disconnected from improved energy services. At an average of US¢14 per kWh, the cost of electricity in SSA is among the highest globally and where electricity is provided by generators, this can reach US¢40 per kWh. This compares to US¢4 per kWh in Asia Pacific or US¢1per kWh in South Asia.[170] There are several reasons for these high costs: low investments, poor maintenance, few cross-border interconnectors, difficult topography, and frequent droughts.[171] As a result, connecting even a single household in a small country like Rwanda can cost up to US$2,000 – well above the average annual income.[172] Similarly, rural connections in Kenya cost from US$1,400 to US$1,800, almost 70 percent of which is the cost of poles and wires.[173]

Due to a combination of innovation and the falling cost of renewable technologies, Africa's farmers now have access to solutions that are more cost-effective and affordable. Africa's private sector is leading the way in creating innovative business and payment models that bring improved energy services to smallholder farmers in remote and rural parts of Africa. For instance, mini-grid and off-grid solutions now integrate additional services such as remote monitoring, Uber-like scheduling, mobile money, and various pay-as-you-go models, including rent-to-own, leasing, service for fee, and agricultural extension support, to ensure that costs are covered and enterprises remain viable.[174]

Among the most financially sustainable energy businesses are the ones that share risk via an "ABC(D) approach": safeguarding their demand on a predictable, reliable, and creditworthy **anchor** client such as an agroprocessor, manufacturing company, or mobile phone tower operator; developing and supporting small **businesses** including irrigation systems, which can grow into anchor businesses; and connecting **community** facilities and **consumers** for **domestic** use. Although individual smallholder farmers are unlikely to form an anchor large enough to justify investment from an energy provider, by joining forces, cooperatives can form a viable anchor client. These programs can then partner with local micro-finance institutes and savings and credit cooperatives (SACCOs) to ensure that smallholder farmers can fully access the products and services provided. Alternatively, an energy service company can serve as the anchor, thus making the system self-sustaining.[175] For example, the Markala Sugar Company in Mali is both an anchor and an energy service company, as it produces biomass-based energy for its own consumption.

Although these enterprises can be financially sustainable in the long-term, they usually require co-financing in the form of grant funding, loans, donor investments or government funding during the pilot stages when capital costs are at their highest. To that end, several alternative sources of "patient" capital have become available, such as impact and angel investors and venture capital, who invest for long-term returns. For instance, AlphaMundi and Factor[e] Ventures are both impact investment companies on the Powering Agriculture Investment Alliance that seek to ease access to capital for small viable companies and to provide technical assistance to improve their capacity to handle large investments to help them grow.[176] Root Capital is another social investment fund that provides loans and equity to small and growing agribusinesses that use climate-friendly technologies. Acumen Fund has invested US$20 million as equity and debt in 20 early-stage energy companies in South Asia and Africa, providing 58 million people access to modern energy for the first time.[177] The Africa Enterprise Challenge Fund provides matched concessionary finance for start-ups and young businesses to innovate, create jobs, and leverage investments, particularly in the agribusiness and renewable energy sectors. Working in 25 countries and on 40 value chains, the Fund's interventions reached and improved the lives of 16 million people in 3.2 million households in 2017.[178] Such sources of capital allow small and medium-sized enterprises to establish themselves and develop recovery and payment models that work with local consumers, including smallholder farmers.

It is also critical that projects be bankable in order to attract the desired investment upfront and ensure long-term sustainability. As smaller private enterprises join the energy landscape to provide decentralized energy solutions, the resulting projects can be too small (and risky) for large institutional funding, even if they have significant socioeconomic benefits. Crowdfunding can play an important role in funding small projects, as can support from domestic and local financial institutions. Alternatively, bundling smaller projects can also be a solution, which requires capacity building for project preparation and development.[179]

Box 11: Beyond the Grid

In 2014, USAID and other partners, including the United Kingdom's Department for International Development (DfID) and the Shell Foundation, launched Beyond the Grid, an initiative focused exclusively on unlocking investment for expanding off-grid and small-scale energy solutions in Africa. Beyond the Grid fosters collaboration, accelerates transactions, and drives systemic reforms to facilitate investment specifically relating to off-grid and small-scale energy solutions. To date, Beyond the Grid has partnered with over 40 investors and practitioners that have committed to investing over US$1 billion in off-grid and small-scale solutions. These private sector commitments will be significant in helping Power Africa achieve its target of 60 million new connections for households and businesses.[180]

In Kenya, Uganda, Tanzania, Ethiopia, and Burkina Faso, the Africa Biogas Partnership Programme (ABPP) in partnership with the Dutch government, Hivos and SNV have been supporting national biogas programs since 2009. The program disseminates biogas plants among small-scale farms that would benefit from a cheap and clean energy source as well as organic fertilizer, which is a byproduct of biogas production. By 2016, more than 13,000 bio-digesters had been installed in Tanzania providing access to clean energy to over 70,000 people, particularly benefiting women and children. In addition, more than 18,000 biogas plants have been constructed in both Kenya and Ethiopia as of 2019.[181]

At the other end of the scale, energy infrastructure for extraction, processing and transportation, generation, networks and storage is highly capital-intensive; in 2018 approximately US$100 billion was invested in the energy sector in Africa.[182] Notwithstanding the advances made by the private sector in plugging the gaps in energy provision for smallholder farmers in Africa, private finance alone is unlikely to be sufficient to address the challenges involved. In this respect, governments can provide grants and concessional loans for capital investments, put in place laws to encourage foreign direct investment (for example, in Burundi, Kenya), and facilitate private sector investment by removing barriers to investments.[183]

On the other hand, providing electricity has significant economic, social, and environmental benefits for households and overall national GDP including: increases in higher education, improved health services, better indoor health quality, reduced spending on fuels, and greater productivity. A study done by the Overseas Development Institute for SE4ALL and Power 4 All shows that Ethiopia's aggregate savings on spending on kerosene, candles, and external sources for mobile phones could add up to US$328 million (about 0.5 percent of total GNI in 2016). Similarly, Kenya could save US$837 million over a 10-year period in spending on fuel. Furthermore, the provision of electricity in Kenya enables children to study for an additional 32.6 hours per year, equivalent to approximately 2 percent of a school year.[184] Electrification in South Africa's KwaZulu Natal province led to an increase in employment among women by nearly 10 percent.[185]

Governments will have to go beyond national budgets to raise enough capital, including from development partners and multilateral development banks and funds. Although not quite at scale, climate finance can provide an additional source of funding for agricultural energy programs. For instance, the Special Climate Change Fund and the IFAD's Adaptation for Smallholder Agricultural Programme have supported the integration of climate risk management into agricultural value chains, improved access to diversified energy sources, and scaled up efficient irrigation and sustainable land management technologies.[186]

In addition, the Scaling-Up Renewable Energy Program in Low Income Countries (SREP) is a US$8 billion trust held at the World Bank to support climate mitigation and adaptation action in developing countries. From this source, Mali has received US$40 million in grants and near-zero interest credit financing to remove barriers inhibiting the scaling-up of private sector investments and developing standardized business models for solar PV and biofuel hybrid mini-grid schemes and development of mini/micro hydroelectricity. Of this amount, nearly US$9 million is allocated to a micro and mini-hydro development, which will provide energy (and water) for irrigation in rural Mali.[187]

To achieve economies of scale, governments can join and participate in power pools. Several such power pools have already been established on the continent (East Africa Power Pool, Southern Africa Power Pool, Central Africa Power Pool, and Electricity Committee of the Maghreb [COMELEC]). The West Africa Power Pool (WAPP) (including Benin, Burkina Faso, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, and Togo) was established in 2001 to promote energy trade between member countries, and to facilitate the funding of generation and transmission lines.

In addition, Africa Power Vision and the Africa Renewable Energy Initiative are both endorsed by the AU and African heads of state to meet the continent's energy needs and provide capital through the AfDB.[188] The African Bio-Fuels and Renewable Energy Fund at the ECOWAS Bank for Investment and Development is also an alternative source for funding for large, national agricultural-energy projects.

6. Capacity strengthening and employment opportunities

To increase the uptake of the growing number of agricultural energy solutions available in Africa, there is an urgent need to couple increased investments with more awareness creation and capacity building among agricultural/rural value chain actors as well as institutions. While the success of rural electrification programs is often measured by the number of poles, meters, or MW installed, these programs cannot translate into positive effects for rural households and farming communities without a broad and robust effort to educate and build their skills in the use, repair, and maintenance of connected technology. The Barefoot College Initiative teaches women to be solar engineers and partners this with other income-generating activities such as bee-keeping and sewing. The Initiative was conceived in India, but is now replicated across rural areas in Burkina Faso, Senegal, Liberia and Madagascar, supported by India's Ministry of External Affairs as part of its South-South cooperation program. Within six months, women learn how to install solar panels and link them to batteries, handle sophisticated charge controllers and inverters, and establish a local electronic workshop for major and minor repairs.[189]

For rural communities to maximize the benefits from improved energy use and make informed choices, agricultural energy programs and extension services should include appropriate energy and financial literacy training so that users understand the various forms and combinations of technologies, products, and services available and the benefits and the risks involved.[190]

To overcome the challenges of poor workmanship in Kenya's solar installations, a lack of qualified and trained technicians, an influx of substandard products, and a lack of properly laid of quality assurance mechanisms, the Energy Regulation Commission (ERC) published solar PV and solar water-heating regulations in 2012. Solar PV installers and designers are legally required to be qualified and licensed by the ERC. In addition, manufacturers, importers, vendors, and contractors are also required to be licensed. The training and certification curriculum were developed in collaboration with the Kenya National Industrial Training Authority (NITA) in the Ministry of Education and other partners. By June 2016, there were 342 advanced registered technicians in comparison to 800 to 1,000 uncertified technicians previously. The certification program is now formally institutionalized and offered by 16 technical training institutions and universities, all of which are accredited by NITA and ERC.[191]

Finally, civil servants and ministerial staff involved in national commitments and ambitious goals to deliver improved energy services (across all the relevant sectors) must be well-versed in the options available in order to tailor solutions to the needs of their citizens.[192] These interventions will ensure that countries build a thriving sector and ecosystem around agricultural energy solutions in the short-term.

This in turn requires capacity building among farmers to make their engagement in planning more meaningful – as is being implemented in Kenya's newly devolved county-level governance arrangement.[193] Under this arrangement, specific focus must be paid to the needs of women and young girls who are more adversely affected by a lack of access to improved energy services.

Box 12: IsDB's Reverse Linkage Mechanism: Development through sharing

In 2010, the Islamic Development Bank (IsDB) introduced the Reverse Linkage mechanism, a "technical cooperation mechanism enabled by the IsDB whereby member countries and communities in non-member countries exchange their knowledge, expertise, technology and resources to develop their capacities and devise solutions for their autonomous development." During the first five years of Reverse Linkage, the cumulative amount approved reached US$123 million, covering projects involving 21 countries.

The Reverse Linkage mechanism promoting cooperation between Mali and Morocco to boost rural electrification capacity in Mali is one example of member country cooperation under Reverse Linkages. Solar irradiation in Mali is about 5 to 7 kWh/m^2/day and is well distributed across the country, offering promise for diversifying the country's energy-mix and reducing the country's energy deficit. Despite significant progress over the past decade, access to electricity in rural areas in Mali remains a challenge due to core institutional, financial, capacity and knowledge barriers. Under the country's national development plan, Mali aims to develop a sustainable business model to increase rural electrification from its current rate of less than 20 percent to 80 percent. To contribute toward achieving this target, the IsDB has matched Mali's challenge with Morocco's experience so that the two countries will cooperate to enhance Mali's capacity in rural electrification. Under the Reverse Linkage project, the Malian Agency for the Development of Domestic Energy and Rural Electrification, and the Moroccan National Office for Electricity and Potable Water collaborate. The three-year project began in 2018 and seeks to enable the introduction of utility-scale PV solar plants, use of prepayment meters, and electrification of 24 villages with more than 35,000 inhabitants.

In the long-term, however, building a thriving agriculture and agricultural energy sector will require significant investments and focused efforts in building the knowledge and skills capacity of Africa's youth to enable them to play a meaningful role in the sector. Africa has the youngest global population in the world, and an estimated 15 to 20 million young people are expected to join the workforce over the next three decades.[194] While many of these young people will be well educated (and highly connected), there is likely to be a mismatch between qualifications obtained and the skills required to contribute meaningfully to the economies of the future. As improved energy solutions take hold and Africa's agriculture sector becomes more mechanized, it will be necessary to ensure that the youth are trained to design, assemble, and repair new technologies.

On the other hand, new energy supplies and technologies have been one of the top 10 drivers of a changing employment landscape. As African countries respond to the call for more sustainable economic models, the demand for cleaner energy generation, energy efficiency, pollution control and natural resource management have the potential to create millions of "green jobs" on the continent. In South Africa alone, it is estimated that an additional 462,000 green jobs will be available by 2025.[195] In 2013, the government of Namibia identified green jobs as a strategic pillar for job creation within its development plan. Potential policies include retraining and re-skilling the existing labor force, including within the agriculture sector, as well as reforming skills authorities and extending government-funded vocational training programs.[196] Similar plans are being drawn up by Mauritius, Kenya, Senegal, Uganda, and Zambia. Furthermore, studies show that the expansion of green products, services, and infrastructure will translate into higher labor demand across many sectors of the economy, thereby leading to the creation of new employment opportunities. This includes jobs in renewable energy, energy efficiency, manufacturing, transportation, and building and construction. In addition, indirect employment is created along the agriculture supply chains, including in the building of necessary infrastructure.[197]

Access to reliable and affordable energy may drive job creation for young people particularly in the agriculture sector. According to the International Labour Organization, youth are twice as likely as adults to be unemployed, and the growing mismatch between demand and supply for certain skills remains the main driver of hight unemployment rates.[198] Agriculture, often considered as outdated, unprofitable, and hard work by many youth, may become more attractive with energy access allowing the adoption of energy-based technologies and machines. In Kenya, for instance, an irrigation development program managed through a PPP attracted 5,000 young participants. The government provided 90 percent of the financial capital as an interest-free loan, and a Kenyan company, Amiran Kenya, supplied the technical capacity and equipment, known as the Amiran Farmers Kit (AFK).

This low-cost irrigation kit is based on energy-based drip irrigation technologies that use 30 to 60 percent less water than other irrigation techniques. A government fund of US$1.6 million allowed the acquisition of 420 kits in 2014, benefitting 200 youth groups and 15,000 farm families.[199] In Ghana, the Energising Development (EnDev) Partnership Programme subsidized the grid connection or acquisition of solar irrigation systems for small-scale farmers and implemented a market-based incentive scheme for small-scale agro-processors to access and use improved cookstoves. Overall, 1,000 micro, small, and medium-sized enterprises and 3,000 employment opportunities were created between 2009 and 2015.[200]

As the next section will show, several African governments and private sector innovators have embarked on ambitious programs to provide universal energy access to their citizens. Although there are some noteworthy initiatives already in place across the continent, there is an urgent need for these to be formulated as part of a comprehensive vision and strategy at the national level, and for institutions to be adapted to ensure successful implementation. Well-designed, inclusive, and sustainable strategies in turn guide regulatory, investment, and capacity building programs toward a common goal, ensuring that citizens have access to reliable, affordable, and clean energy. Furthermore, the role of farmers' organizations will become increasingly important in order to raise farmers' awareness and understanding of the relationship between their activities and the demand and supply of energy, as well as what is required and expected of them.

7. Methodology

Several countries in Africa have demonstrated a high level of commitment to sustainable energy use in their economies, including in the agriculture sector. Their experience in terms of policy and institutional innovation and interventions on the ground provide important lessons for other African countries seeking to develop and strengthen their sustainable energy use for an agricultural transformation. To identify the best performing countries, both in terms of expanding access to modern energy in rural areas and agricultural growth, the report relied on three indicators: nighttime lights, the agricultural value added per worker growth rate, and the Regulatory Indicator for Sustainable Energy (RISE). Based on these indicators, six countries were selected for analysis.

As a first step, the logarithm of the difference of number of the areas (pixels) of nighttime lights between 1992 and 2013 —as a proxy of electricity expansion indicator—was chosen to assess countries' progress in energy access and use. The Nighttime Lights Time Series were taken from the United States National Oceanic and Atmospheric Administration's Defense Meteorological Program (DMSP) Operational Line-Scan System (OLS). DMSP-OLS identifies visible and near-infrared emission sources at night.[201] Available statistics on the extension of access to electricity in rural areas effectively capture the extension of electricity lines into these areas. However, they do not necessarily capture the availability of electricity in these same areas. Moreover, in many urban and rural areas across Africa, disruptions in electricity access are frequent, reducing the reliability of access to electricity. For this reason, the use of the stable nighttime lighting intensity data series provides a more accurate measurement of reliable access to electricity.[202] Between 1992 and 2013, most countries in Africa made considerable progress in providing a reliable access to electricity. Countries that reported an electricity expansion above the average level of 8 for the entire continent were categorized under the cluster of countries with a higher level of electricity expansion. Countries below that threshold were categorized under the cluster of countries with a lower level of electricity expansion.

In the second step, the report identified countries showing high rates of agricultural growth. Hence, the average of annual growth rates in agricultural value added per worker for the period 1992–2013 from the World Bank database was chosen as an indicator (World Development Indicator).[203] Countries showing a positive average of annual growth rates were grouped within the higher growth category. Countries showing a negative average were grouped within the lower category.

Comparing the relative performance of African countries on these two variables (Figure 3), the countries were divided into four clusters:

Cluster 1 - higher electricity expansion, lower growth of agricultural valued added per worker

Cluster 2 - higher electricity expansion, higher growth of agricultural valued added per worker

Cluster 3 - lower electricity expansion, higher growth of agricultural valued added per worker

Cluster 4 - lower electricity expansion, lower growth of agricultural valued added per worker

The resulting cluster of countries showing higher electricity expansion and higher growth of agricultural valued added per worker represent countries where progress in access and use of energy is likely to be strongly contributing to agricultural growth and transformation. In fact, modern productive agriculture requires energy input at all stages of the agriculture value chain, including for farm machinery, water management, irrigation, cultivation, harvesting, and postharvest activities such as processing and consumption.

Figure 3: Country clusters

	Lower growth of agricultural valued added per worker	Higher growth of agricultural valued added per worker	
Higher electricity expansion	**Cluster 1:**	**Cluster 2:**	
	Angola, Botswana, Congo-Brazzaville, Côte d'Ivoire, Democratic Republic of Congo, Kenya, Zimbabwe	Low RISE score	High RISE score
		Mali, Mozambique, Namibia*, Nigeria, Sudan, Uganda*	Algeria, Burkina Faso, Egypt, Ethiopia, Ghana, Morocco, Niger, Senegal, Tanzania, Tunisia, Zambia, South Africa
Lower electricity expansion	**Cluster 4:**	**Cluster 3:**	
	Burundi, Central African Republic, Chad, Equatorial Guinea, Gabon Gambia, Madagascar, Togo	Benin, Cameroon,Cape Verde, Guinea, Guinea-Bissau, Lesotho, Liberia, Malawi, Mauritania, Rwanda,Swaziland	

*No data for RISE

Finally, the selection considered the degree of sustainable energy use in the countries. Good national policy and regulatory frameworks are indispensable for sustainable energy access and use. The World Bank's 2018 Regulatory Indicator for Sustainable Energy (RISE) was chosen to assess countries' policy and regulatory support for each of the three pillars of sustainable energy—access to modern energy, energy efficiency, and renewable energy.[204] Based on RISE, countries with good national policy and regulatory frameworks for sustainable energy access and use were identified within Cluster 2. RISE scores are grounded in 27 indicators across the three pillars, underpinned by 80 sub-indicators and 158 questions. There are 8 indicators in energy access, 12 in energy efficiency, and 7 in renewable energy. RISE indicators are designed to measure policy actions to address barriers to scaling up sustainable energy across the three pillars. Ultimately, RISE scores represent the vision of governments translated into plans at the national level and their attributes for good practice, as well as policies and incentives focusing on appropriate price signals to markets and subsidy mechanisms to facilitate the development of sustainable energy. For the purpose of this report, a threshold value of 34 for RISE was chosen based on the World Bank's classification. Countries with a value above 34 are considered at least "middle" performers* in terms of good national policy and regulatory frameworks for sustainable energy—they have demonstrated a certain degree of commitment to increasing the sustainable use of energy through relevant policies and regulations.

This step resulted in a sub-cluster of 12 countries that have made progress towards sustainable use of energy for agricultural development: Tunisia, Egypt, Burkina Faso, Ethiopia, Tanzania, Zambia, Senegal, Morocco, Niger, Algeria, South Africa, Ghana. Within this cluster of 12 African countries, six were selected for case study countries—Ethiopia, Ghana, Morocco, Senegal, South Africa, and Zambia—for a balanced regional representation across the continent.

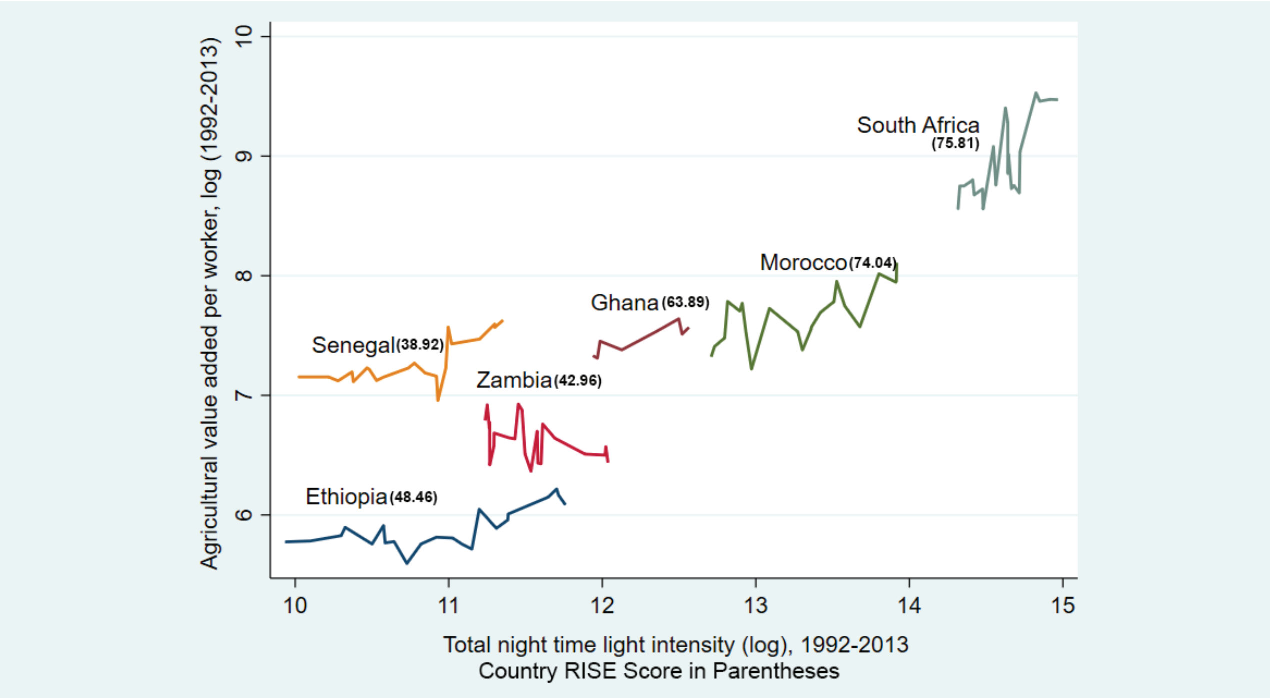
*- RISE classifies countries in three groups based on their score levels as strong performers (those having a score equal to or above 67), middle performers (those having a score equal to or above 34 and below 67), weak performers (those having a score equal to or below 33). As only four African countries are in the group of strong performers, in order to classify countries in two groups, high and low commitments groups, the threshold of 34 was selected.

Table 1: Values of the indicators for the selected countries

Country	Expansion of electrification in logarithm of the difference of number of Nighttime Lights pixels between 1993 and 2013	Averaged growth in agricultural value added per worker over 1992-2013 period	RISE score 2017
Ethiopia	9.10	2.36	48.46
Ghana	9.49	4.55	63.89
Morocco	10.98	6.53	74.04
Senegal	8.55	2.68	38.92
South Africa	11.23	5.08	75.81
Zambia	8.43	1.51	42.96

Figure 4 below displays the evolution of agricultural value added per worker per Nighttime Lights by country intensity between 1992 and 2013 for the selected countries.

Figure 4: Agricultural growth rates per Nighttime Lights intensity between 1992 and 2013



CASE STUDY

Ethiopia

Between 1992 and 2013, Ethiopia's electricity expansion indicator increased by 9.10, thereby being slightly above the average of 8 for Africa as a whole.* During the same period, agricultural value added per worker grew at an average of 2.36 percent per year. With a score of 48 out of 100 on RISE in 2017, Ethiopia rates as a middle performer in terms of policies and regulations that support the access to modern energy, energy efficiency and renewable energy.[205] Nevertheless, within SSA, Ethiopia is a leader on policy frameworks for energy access. The country has been commended for having one of the most advanced and comprehensive National Electrification Programs in Africa, which has provided a strong basis for clear policy frameworks for grid electrification, mini-grids, and stand-alone systems.

Institutional Innovations

In Ethiopia, responsibility for the production of energy and electricity is shared by the Ministry of Water, Irrigation and Electricity (MoWIE) and the Ministry of Mines and Petroleum (MoMP). MoMP was established as the Ministry of Mines, Energy and Water Resources in 1977, and has since been reconfigured several times, most recently in 2018. The key functions of MoMP include the promotion of mining, facilitating mining investment, and licensing and regulation of mining operations—including the exploitation of hydrocarbon and geothermal resources. MoMP also leads the development of new regulations to facilitate greater private sector investment in biofuel development in Ethiopia.[206]

To complement this, MoWIE directs the development and management of Ethiopia's water resources to ensure they contribute to national food security. Specifically, MoWIE promotes the expansion of electricity supply in Ethiopia from hydropower and other renewable energy sources such as solar, biogas, and micro-hydro, through the National Electrification Program (NEP), initiated in 2017.[207] Ethiopia's energy sector is regulated by the Ethiopian Energy Authority (EEA) established in 2013. EEA also manages licensing and import and export of energy to Djibouti, Sudan, and Kenya. The primary authority responsible for the generation, transmission, and wholesale of electricity is the Ethiopian Electric Power Company (EEP), also established in 2013. The EEP operates and maintains more than 12 hydropower plants and three wind power plants across Ethiopia. Although the sector has been opened to private sector investment, much of the investment in generation is still tendered by EEP. A new framework for private sector investment through independent power producers (IPPs) and their regulation is currently being developed in partnership with the USAID-run Power Africa project.[208]

The Ethiopian Electric Utility (EEU), a directorate under MoWIE, is responsible for electricity distribution across the country, including in rural areas. It manages NEP and is required to establish clear cross-sectoral linkages with the productive and social service sectors, such as health, education, and water supply.[209] The Ministry of Trade is responsible for tax reduction mechanisms for importation of off-grid solar technologies by the private sector. [210]

The formulation of rural energy policy is led by the Ethiopia Rural Energy Development and Promotion Centre, which also acts as the executive arm of the Rural Electrification Fund (REF). REF is a permanent financial source set up within the Ministry of Finance and Economic Development in 2003. The fund leverages private sector engagement (including cooperatives, municipalities/local governments, local communities, NGOs, and CBOs) in rural electrification projects that specifically use renewable energy technologies. The fund subsidizes up to 85 percent of electrification costs and up to 95 percent for renewable energy sources.

A Ministry of Environment, Forest and Climate Change (MEFCC) was established in late 2013 and in put in charge of implementation of the new Climate Resilient Green Economy (CRGE) strategy.[211] MEFCC is supported by the Ethiopian Environment and Forestry Research Commission, which was adapted from its former role in 2014 as an autonomous federal office in order to coordinate, generate, and disseminate technologies, information, and knowledge on forest development and to mitigate

*- This indicator is expressed in logarithm of the difference of number of Nighttime Lights pixels between 1992 and 2013

environmental degradation from use of forest products.[212]

Policy Innovations

Agricultural development has been at the center of Ethiopia's poverty reduction and development strategies for nearly 30 years. Each successive national development plan has also recognized and directly addressed the nation's energy challenges. Ethiopia has been following an Agriculture Development Led Industrialization (ADLI) strategy since 1991, an approach that focuses on rural development and transformation, particularly through agricultural growth, supported with an expansion of infrastructure.

Rooted in ADLI, the Sustainable Development Poverty Reduction Programme (SDPRP) 2002/3–2004/5 explicitly acknowledged the constraints that limited access to electricity place on establishing a strong agro-processing sector, commercial enterprises, and irrigation facilities in Ethiopia's rural areas. The SDPRP began the process of liberalizing the power generation sector to complement government initiatives to achieve universal access by 2025.[213]

Electrification as a core element of agricultural transformation

The subsequent five-year plans – the Plan for Accelerated and Sustained Development to End Poverty (PASDEP) 2005/06–2009/10, the Growth and Transformation Plan (GTP) I (2010–2015), and GTP II (2015–2020) reiterated the vision of modernizing and commercializing agriculture through greater use of technology.[214,215] GTP I outlined the essential role of electricity as an input for agriculture, irrigation pumping, commercial agriculture production, and processing and highlighted the importance of alternative technologies to meet the country's growing energy needs. The provision of basic services, such as electricity in rural areas, was further bolstered by capital expenditure so as to attract private investment in these areas. Specifically, the Ethiopian Agricultural Transformation Agency (ATA) was established in 2010 to deliver the agricultural transformation agenda, although there is scope for it to play a stronger role in energy provision for agriculture.[216]

Each national development plan has provided targets for electrification, generation capacity, and guidelines for agricultural development. Moreover, recognizing the detrimental environmental and health impacts of high fuelwood and charcoal use, PASDEP and GTP I also encouraged a transition to cleaner energy sources, particularly in cooking. These development plans have set a high benchmark for the current one, GTP II, which further promotes the modernization of the agriculture sector supported by a vibrant and diverse energy sector.

Preparing for the transition to a green economy

The Climate Resilient Green Economy (CRGE) strategy was launched in 2011 to underpin Ethiopia's transition to a carbon neutral and climate resilient middle-income economy by 2025. The CRGE, which includes sector specific strategies for agriculture and forestry, water and energy, and transport was mainstreamed into GTP II. The latter focuses on delivering rapid, sustainable, and broad-based growth by boosting agricultural productivity; protecting forests and reforestation; expanding electricity generation from renewable sources of energy; and leapfrogging to energy-efficient technologies.[217] In addition, MEFCC partnered with Ministry of Finance and Economic Cooperation to establish a national climate fund (CRGE Facility) to mobilize climate finance to achieve these goals.[218]

With focused, pioneering, and comprehensive development plans, electricity access in Ethiopia grew rapidly, connecting 2.3 million customers by 2015, up from 952,000 in 2004/5.[219] Agricultural value added grew at almost 6 percent annually during this time, and the national annual economic growth rate over the last decade has averaged over 9 percent –putting it amongst the highest rates globally.[220]

Programmatic Interventions

Integrating electricity supply with other services to enhance productive capacity

Ethiopia has had an active rural electrification program since the SDPRP. During the five-year timeframe of the SDPRP, the program sought to extend the central grid to 164 *woredas* (districts) out of about 710 and their environs at a cost of US$160 million to support irrigation, poultry and livestock keeping, and preservation of produce, as well as the development of small and medium industries such as oil and flour mills. The SDPRP also set targets for the power sector to improve the quality, adequacy, cost-effectiveness, and efficiency of supply to customers.[221]

Notably, GTP I also initiated the process of developing Agricultural Commercialization Clusters (ACC) and Integrated Agro-Industrial Parks (IAIPs) in Ethiopia, managed by the ATA. IAIPs identify geographies for the production and processing of nine selected agrifood value chains, based on their capacity to create jobs, linkages to the agriculture sector, export potential, and capacity to attract private sector investment. Crops include wheat, maize, sesame, malt barley and horticulture crops such as tomato, onion, banana, mango, and avocado. Each IAIP will benefit from purposeful infrastructure investments such as roads, power, water, communications, and drainage and rainwater harvesting to commercialize the production and processing of these crops.[222] By June 2018, four IAIPs were under construction in Amhara, Oromia, SNNPs, and Tigray states, aiming to process animal products, grain and oilseeds, and fruit and vegetables for local and international markets. IAIPs have also drawn interest from international investors from China and India which bring specialization in selected industries and create opportunities for South–South learning and technology transfer.[223]

In addition, Ethiopia's National Electrification Program (NEP) sets 2025 as the target year for universal access to electricity, five years earlier than the target set by the SDGs. In order to meet this target, the EEU will manage a fast-paced grid and off-grid rollout program to scale up connectivity, at a cost of about US$1.5 billion. In particular, the NEP will build cross-sectoral linkages with other productive sectors such as health, education and water ensuring that secondary schools and primary health centers are fully connected by 2022. It is expected that approximately 65 percent of the population will be connected to the grid while the remaining remote communities will benefit from individual solar and mini/micro grid solutions.[224]

Leveraging different energy sources to broaden access

This builds on the ambitions set by PASDEP, which raised the target by launching the Universal Electrification Access Program to connect 6,000 rural towns and villages—approximately 24 million people—and raise electrification to approximately 50 percent by 2010[225]. GTP I reported that 5,163 towns and rural villages had been electrified by 2010, meeting 78 percent of the PASDEP target. Three hydropower plants were also constructed between 2005 and 2010, adding more than 1,300MW in hydropower generation. In addition, 3 million improved energy-saving biomass ovens and 4.6 million energy-saving lightbulbs were distributed to customers, saving over 26,000 ha of forest from deforestation.[226]

Ethiopia

In addition, GTP I initiated processes to expand biofuel production through the Bio-fuel Development Program. The program convenes research institutes, universities, implementing agencies, and the private sector to adapt and promote sustainable development of biofuel technology. GTP I set a target for annual ethanol production from sugar at 304,000 m^3 and 607 MW of electric power by 2015.[227]

With these focused efforts, access to electricity in Ethiopia doubled between 2010 and 2016, from 21.9 percent to 42.9 percent. Rural electrification grew fourfold, from 6.6 percent in 2010 to 26.5 percent in 2016.[228] In addition, 77,380 m^3 of ethanol was produced and construction began on four blending facilities during GTP I. As recorded by GTP II, 16.6 million ha had been planted with biofuel crops such as jatropha and castor during GTP I.[229]

Beyond national programs, Ethiopia has also benefited from the Energising Development (EnDev) Partnership Programme. EnDev Ethiopia is co-funded by the German, Dutch, Norwegian, and Irish governments and implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), MoWIE, MEFCC, and other partners. EnDev Ethiopia supports a growing market for modern renewable energy technologies and energy efficiency solutions such as micro hydro (upgraded from water mills), solar PV for health centers, and improved cookstoves. The Programme provides technical assistance in the form of appropriate low-cost designs, capacity building through training of local entrepreneurs and engineers, financial support for the hardware and installation of solar systems, awareness and marketing campaigns for improved cookstoves, and incubation of stove business start-ups. By the end of its second phase in 2017, EnDev Ethiopia had provided access to electricity to 395,000 people, electrified over 100 health centers, and built four micro hydropower stations.[230]

Improving energy efficiency and reducing cost

Ethiopia has also implemented several programs to improve the efficiency of its energy use. EnDev Ethiopia sold 430,000 improved cook stoves and enabled 560 stove producers to establish themselves. Users of improved cookstoves saved up to 50 percent on fuel costs, money which was reallocated to food, education, and other costs. Similarly, stove producers spent their additional income on food and education. With these achievements, the European Union extended an additional EUR 10.35 million (approximately US$12.1 million) in 2017 to continue this work and contribute further towards the NEP.[231]

This program built upon the achievements of GTP I and the Sustainable Rural Energy Technologies for Households and Productive Uses project. During GTP I, nearly 9 million biomass stoves and more than 2 million solar technologies were also distributed and 11,618 biogas plants were constructed during GTP I. GTP II has set targets for electricity coverage at 90 percent, which would connect about 7 million additional customers by 2020.[232]

Working in tandem with the NEP, the Sustainable Rural Energy Technologies for Households and Productive Uses project aims to disseminate 200,000 solar home systems and 600,000 improved cook stoves in rural communities by 2020. Launched in 2016, the project is working to remove barriers to private sector provision of these off-grid technologies in order to extend their availability. To do so, the project has aligned the legal and regulatory framework with national standards, run an awareness campaign in rural areas about the technologies, created a financial mechanism for rural households, and supported entrepreneurs through a business incubation phase. The project is managed by MoWIE and is estimated to cost more than US$5.5 million. It is funded by the Global Environmental Fund and co-financed by the UNDP Ethiopia Country Office, the United Nations Capital Development Fund, and the Development Bank of Ethiopia.[233]

With the successes of the 2017 NEP, the Ethiopian government issued an updated plan in 2019, the National Electrification Program 2.0: Integrated Planning for Universal Access. NEP 2.0 focuses on integrated access–grid and off-grid electricity access–and provides an implementation framework through public-private partnerships. The program aims to deliver 8.2 million new grid connections to 6 million beneficiaries by 2025.[234]

Ethiopia is clearly on a pathway for rapid transformation in its energy and agriculture sectors. Importantly, there is a recognition of the links between these two sectors at the highest levels, as demonstrated in the national development plans. While the energy sector is steaming ahead in addressing the overlapping challenges simultaneously, programs at the Ministry of Agriculture and ATA would benefit from clear guidelines on enhancing access to improved energy services. Finally, although significant steps have been taken to diversify Ethiopia's energy mix, the country still relies largely on biomass and waste, which account for 88 percent of total energy supply. At the same time, hydropower is the source for 93 percent of electricity. Since both these sources are extremely vulnerable to climate change, there is an urgency to further and rapidly diversify the sector.

CASE STUDY

Ghana

Ghana has one of the highest rates of access to electricity in SSA. At 80 percent in 2017, it is considerably higher than the continental average of 43 percent. Between 1992 and 2013, the electricity expansion indicator[†] increased by 9.49 thereby being slightly above the average of 8 for Africa as a whole. The agricultural value added per worker annual growth rate averaged 4.55 percent. In addition, Ghana was among the top three performers in SSA as measured by the RISE score in 2017. With a score of 63 out of 100, Ghana rates as a middle performer in terms of policies and regulations that support the access to modern energy, energy efficiency and renewable energy.[235]

Ghana's success has been driven largely by strong political will, clear policies reflecting long-term planning with clear targets, and smart, bottom-up implementation.[236] Large hydropower and oil-fired power plants provide most of Ghana's electricity, although there is a growing supply from renewable sources, particularly solar.[237] The country's mature policy framework for clean energy access is reflected in the RISE score too.

Institutional Innovations

Regulatory capacity for private sector engagement

Rural electrification in Ghana is led and managed by the Ministry of Energy (MoE), which is responsible for the formulation, implementation, and monitoring of energy, power, and petroleum sector policies.[238] The Ministry has undergone several iterations since independence, and most recently has absorbed the Ministries of Power and Petroleum.[239] As a result, MoE oversees various generation, transmission, and distribution agencies in both the power and petroleum sectors. Although MoE has a budget of its own, it also receives financial support from the Ministry of Finance and Economic Planning.[240]

In 1994, liberalization of the energy sector opened the market to private investment, introducing Independent Power Producers (IPPs) to increase power generation and refinery capacity and to deploy technical innovation to accelerate progress towards the electrification target.[241] Therefore, to regulate an increasingly complex power sector with multiple actors, an Energy Commission was established in 1997 through the Energy Commission Act 541. Overseen by MoE, the Energy Commission provides a legal, regulatory, and supervisory framework covering development and use of Ghana's energy resources. It also advises on national energy policy; licenses public utilities, fosters competition, and promotes energy efficiency. In addition, the Energy Commission promotes the use of local and indigenous energy, including renewable sources such as solar, wind, and biomass. Public utilities in Ghana are regulated by the Public Utilities Regulatory Commission (PURC), established in October 1997. Created as an independent body and administered by the Office of the President, the PURC monitors the quality of service that consumers receive and regulates the electricity tariffs charged to consumers.[242]

In 2012, the Energy Commission initiated a process under the SE4ALL initiative to review the progress being made, and to recommend actions to ensure that Ghana fully met its targets. The process highlighted gaps in incentives to attract private sector investment and the application of productive use of electricity to accelerate agricultural development. In order to accelerate progress, the resulting Country Action Plan proposed the expansion of irrigation on river banks with electricity, wind pumps, and mini hydro-dams; agro-processing such as solar drying and multifunctional platforms for grinding and milling; clean cookstoves; and cold chain refrigeration as opportunities to enhance the use of energy in Ghana's agriculture sector.[243]

Research and technical capabilities

To complement efforts in harmonizing national institutions, significant investments are also being made in capacity building through the education sector. For instance, The Energy Centre at the Kwame Nkrumah University of Science and Technology contributes towards the replication and scaling up of successful energy technologies, policies, and management practices in partnership with other departments at the university, including

†- This indicator is expressed in logarithm of the difference of number of Nighttime Lights pixels between 1992 and 2013.

agriculture and engineering. Similarly, the University of Energy and Natural Resources, established by an Act of Parliament in 2011, provides interdisciplinary research programs to support the development of Ghana's energy sector. The university's School of Agriculture and Technology was established in 2015 to promote higher productivity, modernization, efficiency, and competitiveness of the agriculture sector through the application of science, technology, and economics.[244]

Policy Innovations

The use of improved energy in Ghana's agriculture sector is increasing gradually, driven by innovative policymaking and comprehensive implementation. The sector is evaluated independently through the Sustainable Energy for All (SE4ALL) process to ensure that it remains on track to meet its national target of providing universal access to energy services by 2020.

Liberalization for private sector investment and energy diversification

Ghana's government gradually liberalized the energy sector through the 1990s to improve efficiency and effectiveness among the state-owned generation, transmission, and distribution agencies. Recognizing the critical role that energy plays in achieving its ambition of reaching middle-income country status by 2020, Ghana's 1996–2000 development plan recommends setting specific goals to establish an efficient, dependable, and integrated energy system, which maximizes the use of renewable energy.[245]

The 2006 Strategic National Energy Plan (SNEP) provided an overview of the energy resources available to Ghana and pathways to exploit them for sustainable economic growth. To accelerate progress towards poverty alleviation, SNEP recommended increased access to modern energy services in off-grid areas, combined with a strong program to enhance productive uses of energy to ensure that electricity is used to support economic activities. In addition, to increase the use of modern energy in Ghana's agriculture sector to improve productivity and overall food security, SNEP encouraged the replacement of diesel with biodiesel in agricultural mechanization, the use of solar dryers to dry exportable farm produce, and replacement of diesel for irrigation with grid electricity and mechanical wind pumps.[246]

Although the SNEP was not formally adopted by the government, elements of its recommendations were reflected in both the Energy Sector Strategy and Development Plan 2010 and the National Energy Policy 2010.[247] The former identified off-grid renewable technologies in the agriculture sector as the focus for government funding,[248] and the latter aimed to create a conducive environment for investments to develop the energy sector's vision of an economy with universal access to energy services by 2020. To do so, the National Energy Policy proposed increasing access to electricity through: increased funding for the National Electrification Scheme and rural electrification; co-financing private sector initiatives; and promotion of productive uses of electricity. The National Energy Policy identified the high cost of renewable energy technologies as a challenge to their adoption and outlined policy direction to increase their uptake through fiscal and regulatory instruments.[249]

Initiating a transition towards renewables

Following the discovery of offshore oil and natural gas deposits in 2007, Ghana has restructured its energy and development goals in order to use this endowment to diversify the economy and catalyze the growth of other sectors, including agriculture. In line with this ambition, both the Ghana Shared Growth and Development Agenda I (2010–2013) and II (2014–2017) aspired to leverage the resources from oil and gas development to improve national infrastructure, increase agricultural productivity, and accelerate agricultural modernization through greater use of technology. These national development plans also promoted the use of renewable energy in the national energy supply mix, acknowledging the vast potential for solar, wind, and small hydro sources in the country.[250]Although specific targets for renewable energy had not been specified in the National Energy Policy, the share of renewable energy also grew exponentially, supplying nearly half of total national energy supply.

CASE STUDY

Ghana

The use of renewable energy was further bolstered through the passing of the Renewable Energy Act (Act 835) in 2011, which provides the fiscal and regulatory framework to institute a licensing regime for renewable energy producers (especially from the private sector), create a feed-in tariff scheme, and establish a renewable energy development fund. Although the fund had not yet been established at the time of writing, it would provide financial incentives, capital subsidies, production subsidies, and equity participation for renewable energy power generation. Act 835 also provides for off-grid electrification for more isolated, rural communities, the promotion of clean cookstoves, research and development, and the establishment of a Renewable Energy Authority. The Renewable Energy Master Plan 2019 refines the act into an implementation plan to increase the proportion of renewable energy from 42.5 MW in 2015 to 1363.63 MW in 2030.[251]

Programmatic Interventions

Ghana's institutional structure for its energy sector is well established, allowing the country to make significant strides in achieving its electricity access objectives. By 2011, nearly 85 percent of urban and 42 percent of rural populations had access to electricity. Rural electrification in Ghana began in the 1970s to drive rural economic activity, reduce the inequalities between urban and rural areas, and to mitigate pressures to migrate to urban centers. At the time, Akosombo Hydroelectric Power Station on the Volta River, managed by the Volta River Authority, provided the largest share of electricity. However, following severe droughts in the 1980s, thermal power plants were introduced to Ghana's energy mix and now provide 60 percent (the largest share) of electricity.[252] National development plans have since promoted the complementary efforts to provide access to electricity across the country, increase the uptake of renewable energy, and improve agricultural productivity.

Drive for universal access

The government formally instituted its commitment to universal access to electricity with the establishment of the National Electrification Scheme (NES) in 1989. Starting from a national access rate of only 15 to 20 percent, the goal of the NES is to provide universal access to electricity by 2020 by extending the interconnected transmission grid to small towns and rural areas. The NES has two main programs: the District Capitals Electrification Programme (DCEP) and the Self-Help Electrification Programme (SHEP). DCEP connected 110 district capitals and towns/villages with a population greater than 500 to the grid. For communities that did not qualify under DCEP, a grid connection was sped up through the SHEP. Under the SHEP, communities that fell within a 20 km radius of a national grid connection, and had a minimum of 30 percent households that were already wired were asked to provide electricity poles and labor to reduce the cost incurred by the government program. By 1999, just over half of the original 4,200 communities were connected to the grid, and by 2016, all district capitals had been connected.[253] NES was also the basis of electrification programs of successive governments.[254] Nevertheless, later research has shown that households opted to consume electricity mainly for domestic lighting, and hence consumed less than 50 kWh per month. Although a Productive Uses of Energy program had been designed to complement the electrification scheme, implementation was limited. For the agriculture sector, this program was expected to target activities that enhance income such as pumping for irrigation and agro-processing.[255]

A second successful project that has contributed to the high rate of electricity access in Ghana is the Ghana Energy Development and Access Project (GEDAP), initiated in 2007. Funded by the World Bank, Swiss Economic Cooperation, and the African Development Bank, GEDAP was overseen by the Rural Energy Directorate created at the Ministry of Energy. The project was designed to enhance institutional efficiency and performance, improve electricity distribution, and increase the share of electricity from renewable sources such as small hydropower, wind, and biomass below 10 MW. Solutions were implemented based on the geographical location, potential electricity demand, and distance from the existing grid. GEDAP offered finance, technical assistance, and training to intensify and extend the grid, construct mini-grids for remote and rural communities, and deploy over 7,500 solar systems for schools, hospitals, and rural households. GEDAP financing subsidized half of consumers' cost of purchasing appliances, while the remaining costs were financed over three years by Apex Bank or other Ghanaian SMEs.

Investors in electricity generation also benefited from a total import duty exemption on renewable energy technologies such as solar generators and wind turbines as well as plant, machinery, and equipment imported exclusively for the establishment of new, small private energy companies. Renewable energy products were also exempted from the value-added tax. Through GEDAP, 150,000 households were connected to national distribution networks. An additional 17,000 remote rural households, with little prospect of getting grid supply in the near term, were provided with solar PV systems through an innovative financing model involving small rural credit agencies. By upgrading the distribution system, GEDAP also reduced power losses by 11 percent by 2012. Furthermore, the GEDAP project led to the development of Ghana's Renewable Energy Act in 2011.[256]

Energy for homes, farms and processing in rural areas

Ghana's agriculture sector benefited from the Energising Development (EnDev) partnership. Arising from the 2002 World Summit on Sustainable Development in Johannesburg, EnDev is an energy access partnership currently financed by six donor countries: the Netherlands, Germany, Norway, the United Kingdom, Switzerland, and Sweden. In Ghana, the project prioritized grid extension for irrigation, solar PV irrigation systems, and improved stoves for processing cassava, designed to consume less energy (usually in the form of biomass) and

reduce emissions. From 2014, the project focused on training, technical advice, and business development services and offered subsidies to farmers for grid extension for irrigation. For smallholder farmers who preferred solar PV irrigation pumps, grants were made available to purchase equipment. At least 307 additional farmers without previous access to energy for irrigation benefited from an electric connection for irrigation. An additional 300 farmers, employing more than 1,700 people, benefited from 79 installed solar PV systems. In addition, by the end of 2018, 538 improved stoves were sold to communities, processing groups, and individuals for roasting *gari*—a storable fermented flour made from cassava. The stoves are approximately 30 to 40 percent more fuel efficient than traditional methods, which reduced the cost of production, and produce about the same amount of indoor pollution. Demand for the safer, more convenient, and more efficient Burro Gari Elephant stove surpassed supply and has since been supplemented by a hire-purchase scheme since 2017.[257]

In addition to the strong policy framework and an active international development sector, Ghana also has a very active private sector providing clean energy solutions for rural populations. The Gyapa stove is an efficient cookstove that requires 50 percent less fuel, saving families as much as US$100 per year in energy costs. The Gyapa cookstove also produces less smoke, hence reducing health impacts for users. Since the stove also reduces carbon emissions, Gyapa stoves benefit from carbon financing through Climate Care (an international NGO), which in turn enables them to be sold at a more affordable price. Gyapa stoves were developed in 2002 with initial start-up capital from USAID, Shell Foundation, and the U.S. Environmental Protection Agency. The stoves are manufactured by 350 accredited local ceramicists using a scrap metal casing with a ceramic liner inside, and are sold by approximately 500 retailers in Ghana, thus providing local employment opportunities. The Gyapa cookstove is a gold-standard fuel-efficient stove, a global standard achieving maximum positive impact in climate and development, measured in credible and efficient ways. Approximately 130,000 units are sold in Ghana per month. More than 831,000 stoves had been sold by June 2015, preventing nearly 2 million metric tons of CO2 emissions.[258]

To address food waste in the mango value chain and improve processing, Sustenance Agro Ventures (a warehousing and agribusiness service provider), Eucharia Farms Ltd (a large farm), Ujuizi Laboratories (a digital technology provider), and the Horticulture Department at Kwame Nkrumah University of Science and Technology formed an alliance in 2015 to develop a low-cost solar dryer. The dryer uses a combination of solar, gas, and electricity to dry fruits and vegetables at approximately half the cost of standard commercial fruit dryers. It is manufactured by local artisans using local materials. Although an independent review of the impacts has not yet been conducted, initial observations suggest that postharvest losses have been reduced from 40 percent of production to 5 percent, and incomes have increased by over 180 percent.[259,260,261]

In the cocoa value chain, both Cargill and Barry Callebaut (a Swiss chocolate and cocoa brand), installed solar PVs at their processing facilities in Tema, in 2017 and 2019 respectively. The Cargill site added a 764 MwH fully automated, digital solar system to its site, while Barry Callebaut added a 504 kw array.[262,263] Furthermore, the University of Nottingham, the Centre for Energy, Environment and Sustainable Development Ghana, the Ghana Cocoa Board, and Kwame Nkrumah University of Science and Technology initiated a project in late 2018 to develop a new technology to produce biofuels from discarded cocoa husks to supplement electricity in rural areas of Ghana.[264]

Ghana has clearly made great progress towards universal electrification, thanks in part to private sector friendly strategies as well as investment in local technical capacities. To ensure that the agriculture sector draws maximum benefits from this progress, it is essential that agriculture and energy policies are implemented concurrently —as identified in the SNEP. This in turn would require closer institutional cooperation between the Ministries of Agriculture and Energy.

CASE STUDY

Morocco

Morocco has made considerable progress in sustainable access to and use of energy in the agriculture sector. The pace of progress was strong between 1992 to 2013, with an increase in the electricity expansion indicator of 10.98, thereby being above the average of 8 for Africa as a whole.‡ Morocco also had an average agricultural value added per worker annual growth rate of 6.53 percent.[265] In addition, Morocco scored 74 out of 100 on the RISE index in 2017 and is therefore considered a strong performer in terms of setting good national policy and regulatory frameworks for sustainable energy access and use. Such progress is largely due to the government's institutional and programmatic commitments to enhance access to and use of energy across the country.

Institutional Innovations

The Ministry of Energy, Mining, and Environment (MEME) oversees overall energy policy design and implementation. The Ministry also ensures stable energy provision, defines the rules for energy markets, and manages the country's low-carbon transition by promoting energy efficiency and the use of renewable energy in all sectors of Morocco's economy.[266]

In addition to MEME, several agencies work towards increasing overall energy access and use. The National Office of Electricity and Drinking Water (ONEE) was created in 2012, when the National Office of Electricity and the National Office of Drinking Water were merged, to promote sustainable development of water and electricity. ONEE is a public agency that owns the country's transmission network and infrastructure for electricity generation. It is the sole authorized buyer of electricity generated by other parties, including independent power producers (IPPs). ONEE also oversees the import of electricity and its distribution either directly or through private and public distribution companies. The agency is also involved in the design and implementation of major structural projects.[267] Since the mid-1990s, ONEE aims to:

- Expand and modernize energy generation networks to improve access to electricity
- Ensure the marketing and distribution of power
- Improve the efficiency of electricity use

To promote efficient energy use, in 2016 the National Agency for Energy Efficiency (AMEE) replaced the National Agency for Renewable Energies and Energy Efficiency, which had been created in 2010, to implement Morocco's policy on energy efficiency, to reduce energy dependence, and preserve the environment. In the agriculture sector, the agency promotes the adoption of solar-powered irrigation pumps as a means to energy efficiency and sustainable development.[268]

In 2010, the Moroccan Agency for Solar Energy (MASEN) was created as a limited company with public shareholders. Initially, MASEN was responsible for managing the deployment of solar energy under Morocco's solar energy plan. In 2016, however, the agency was renamed the Moroccan Agency for *Sustainable* Energy and its responsibilities were extended to cover of the use of all renewable energy technologies. MASEN promotes R&D by developing renewable energy projects and raising funds to finance them. Through renewable energy projects, MASEN aims to stimulate industrial development and job creation. MASEN also promotes training and capacity building, local development, and industrial integration to gradually build a national renewable energy industry.[269]

In 2011, the Institute for Research into Solar and Renewable Energies (IRESEN) was established as one of the main R&D and innovation bodies for energy. IRESEN is primarily a funding agency to support the government's renewable energy and energy efficiency strategies. IRESEN identifies research priorities and projects, disseminates research findings, and promotes their effective use by businesses. It also finances and implements R&D projects. The innovation aspect has been fully operational since 2018 when IRESEN funded 20 projects under "Green INNO-PROJECT" and "Green

‡ - This indicator is expressed in logarithm of the difference of number of Nighttime Lights pixels between 1992 and 2013.

INNO-BOOST" to develop innovative products, processes, and services in renewable energy with high commercialization potential in the national and continental markets.[270] Furthermore, IRESEN seeks to develop a network of R&D facilities in collaboration with local universities and national and international research institutions. At the time of writing, IRESEN had established the first applied research center in Morocco—the Green Energy Park dedicated to solar technologies, including those for use in agriculture.[271]

In addition, the National Authority for Electricity Regulation (ANRE) was created in 2018 with a mandate to organize the open and competitive segment of the electricity sector. ANRE regulates access to networks, sets the tariffs for the use of transmission and medium-voltage grids, and ensures the efficient functioning of the market.[272]

Policy Innovations

Morocco has limited fossil fuel deposits, leaving it entirely dependent on imported fossil fuels for energy production. Consequently, the government faced the risks of rising costs for fossil fuel imports and the resulting high burden on public finances. Morocco has committed to improving energy efficiency in the National Priority Action Plan adopted for 2008–2012 and the 2009 National Energy Strategy. Morocco's National Energy Strategy foresees the development of the renewable energy sector to increase energy independence, guarantee energy access through secure and affordable energy supply, and protect the environment.[273] The strategy is based on five main objectives:[274]

• Secure energy supply by diversifying fuel types and origins

• Development of renewable energy sources, especially solar and wind, as well as fossil fuels

• Overall energy efficiency improvements

• Universal energy provision and access at affordable prices

• Promotion of regional integration of energy among the Euro-Mediterranean markets through enhanced cooperation and trade with Maghreb and EU countries.

By 2014, Morocco had increased the share of renewable energy in its electricity generation capacity mix to 32 percent. The target for 2020 is to reach 42 percent.[275]

Drive for energy efficiency

Morocco's National Energy Efficiency strategy 2014–2030 has set ambitious targets for reducing final energy consumption by 25 percent by 2030. In the agriculture sector, the strategy aims to reduce energy intensity by 0.2 percent per year until 2030. Successful implementation of this strategy would create an estimated 520,000 direct and indirect jobs and increase the purchasing power of Moroccan households by 1.2 percent by 2030.[276] Some actions planned under the energy efficiency strategy aim to:[277]

• Raise awareness among nearly 1.4 million farmers by 2030 on good practices in the use of agricultural equipment

• Train farmers and other operators on the use of renewable energy technologies and energy efficiency practices

• Promote solar irrigation use by subsidizing 1,000 solar pumps per year by up to 50 percent (with a limit of US$5,500)

• Establish national standards for solar irrigation installations

• Conduct mandatory energy audits and information sharing for farms greater than 100 ha, bringing the threshold to 50 ha in 2020, and to 20 ha in 2025.

Creating a private sector market for renewables growth

The increase in energy access in Morocco began in the 1990s with the partial liberalization of the electricity sector that allowed the involvement of IPPs and the implementation of large-scale electrification programs. In 1994, a law was passed allowing IPPs to produce up to 10 MW for their own use, but with the obligation to sell the surplus exclusively to ONEE at an agreed price. Due to the growing demand for electricity, another law was passed in 2008 that enabled IPPs to produce up to 50 MW of electricity with all excess power to be sold to ONEE through so-called Power Purchase Agreements. The aim was to improve overall electricity supply.[278] IPPs have played a great role in achieving the objectives of Morocco's rural electrification program (PERG). Under Act No. 13–09 of 2010 amended and supplemented by Act No. 58–15 in 2016, the government of Morocco allows private companies to produce electricity from renewable sources and to buy it from the market.[279] The IPP model was considered a success that significantly increased the share of the private sector in power generation.[280]

Programmatic Interventions

Morocco's rural electrification program (PERG) is one example of a large-scale program that started in 1990 and which markedly improved electricity access even in remote, rural communities that could not previously be connected to the country's main grids. PERG boosted access to electricity by providing locally adapted solutions. For each rural community, the program implemented the most viable solution among the range of off-grid options, including photovoltaic generators, small hydro turbines, wind turbines, diesel generators, and hybrid systems. Between 1995 and 2009, more than 35,000 villages were electrified, connecting nearly 1.9 million rural households to electricity. The rural electrification rate increased from 18 percent in 1996 to 97 percent by 2009.[281]

To achieve greater energy efficiency in the agriculture sector, a voluntary energy audit program for agricultural producers was carried out by Groupe Crédit Agricole du Maroc and AMEE between 2011 and 2012. The program quantified energy consumption and estimated the savings potential that would result from the use of more efficient equipment or the adoption of good energy practices including the replacement of fossil fuels with renewable energy. A *Practical Guide to Energy Efficiency in Farms* published by Groupe Crédit Agricole du Maroc allows producers to make informed decisions and to prioritize energy efficiency measures or renewable energy production to optimize consumption and reduce household expenditures. A public-private partnership between AMEE and the Groupe Crédit Agricole du Maroc was established to provide technical assistance to farms involved in the project.[282]

Fiscal incentives for renewables adoption at scale

In 2013, a National Solar Irrigation Program was launched to subsidize solar pumping over an area of 100,000 ha over three years. A subsidy of up to 50 percent of the installation cost of solar panels was provided to farmers through the Energy Development Fund. Initially, only small farms of up to 5 ha were to benefit from the subsidy, however, the government subsequently opted to make larger farms also eligible when using localized irrigation systems that would save water resources.[283,284]

There is evidence of the positive impact of solar pumping on the socioeconomic situation of Moroccan farmers. An evaluation in three zones—Marrakesh, Midelt, and Tata—found that the time required for return on investment in solar pumping was between 2.7 and 3.6 years, and the increased profit margin ranged from US$839 to US$12,500 per hectare. The increased profit is partly due to a reduction in the irrigation systems operations and capital costs as a result of switching to solar pumping systems. This represents on average an 80 percent gain for the farmer and is equivalent to US$740/ha/year for switching from an electrical pumping system, US$806/ha/year for switching from a butane pumping system, and US$950/ha/year from a diesel pumping system.[285]

Morocco's electrification program has been extremely successful because of its focused and coordinated approach, which combines both supply and demand side solutions. The involvement of the private sector through public-private partnerships increased the share of renewable energy in the energy mix, facilitating the development of locally adopted solutions. This in turn has generated a positive impact on both the rate of electrification and agricultural growth.

CASE STUDY

Senegal

Senegal has improved access to and use of energy to foster economic growth, including in the agriculture sector due to policy coherence and long-term programmatic commitment. Between 1992 and 2013, the electricity expansion indicator[§] increased by 8.55, thereby being slightly above the average of 8 for Africa as a whole. During the same time period, the agricultural value added per worker growth rate averaged 2.68 percent annually.[286] In addition, with a score of 39 out of 100 on the RISE index in 2017, Senegal is a middle performer in terms of setting good national policy and regulatory frameworks for sustainable access and use of energy.

Institutional Innovations

Several institutions in Senegal work towards the development of energy provision and use. Of these, the Ministry of Oil and Energies—formerly the Ministry of Energy and Renewable Energy Development—is the main actor and is responsible for the design and implementation of national energy policies. The Ministry develops energy supply plans and ensures their execution through coordination among stakeholders. It also leads and regulates the exploration, extraction, and production of crude oil, natural gas, and other hydrocarbons.[287]

The National Electricity Company of Senegal (SENELEC) was created in 1983, as a majority public limited company that holds a monopoly of purchase, transmission, and sale of electricity. It is the largest electricity generator, and the only provider for on-grid transmission and distribution services.[288]

In 1998, the Regulatory Commission of the Electricity Sector (CRSE) was created as an independent agency to regulate the production, transmission, distribution, and commercialization of electricity. CRSE also promotes competition and private sector participation at all stages of the electricity supply chain, and contributes significantly to securing investments by ensuring the financial viability of companies in the electricity sector. At the same time, the CRSE protects the interests and rights of consumers regarding prices, supply, and quality of electrical energy.[289]

The Senegalese Rural Electrification Agency (ASER) was created in 1999 under the auspices of the then Ministry of Energy (now the Ministry of Oil and Energies). ASER administers rural electrification policies and provides technical and financial support to businesses and individuals involved in rural electrification initiatives. ASER designs rural electrification priority programs, reviews and adapts lessons learnt in Senegal and elsewhere, develops innovative lower-cost solutions, and mobilizes funding.[290] ASER also leads the diffusion of photovoltaic solar systems across the country.[291]

The Agency for Saving and Control of Energy, created in 2011, focuses on sustainable energy consumption and implements the national policy of managing energy resources for sustainability. To do so, the Agency employs a strong integrated framework that considers the main forms of energy used, including electricity, domestic fuels, and petroleum products.[292]

Furthermore, in 2013, the National Agency for Renewable Energies was established to promote the use of renewable energies in all sectors of the economy. The agency aims to:[293]

- Contribute to the development of an attractive legislative and regulatory framework for the development of renewable energies
- Identify, evaluate, and develop potential renewable energy programs across the country
- Develop and execute national renewable energy projects and programs and ensure their coherence
- Contribute to the improvement of R&D and encourage innovation in renewable energies
- Popularize the use of equipment for the generation of electricity from renewable energy sources
- Conduct prospective and strategic studies for the development of renewable energies

§- This indicator is expressed in logarithm of the difference of number of Nighttime Lights pixels between 1992 and 2013.

CASE STUDY

Senegal

Policy Innovations

Senegal's energy policy has been formulated through "Letters of Energy Sector Development Policy." Under the first Energy Policy Letter (EPL) formulated in 1997, the government sought to reduce inefficiencies in the energy sector and increase the affordability of energy by using subsidies to reduce the cost of supply. The government had also planned to strengthen the role of Independents Power Producer (IPPs) in the energy sector, however, private sector involvement in the energy sector did not reach the level envisioned by the 1997 EPL. To fully achieve the targets set under the EPL 1997, the government signed a second EPL in 2003 which called for a greater role for the private sector in financing the development of the national energy sector and reducing the costs borne by consumers.[294]

Crowding in Independent Power Producers

In 1998, Senegal also passed legislation to liberalize the energy sector, allowing Independent Power Producers (IPPs) to produce electricity. Since then, IPPs have been mushrooming, contributing to the achievement of electrification targets. SENELEC, the national electricity company, has an electric power generation fleet and purchases electricity from IPPs, such as Tobène Power and Centrale solaire Bokhol, which are connected to its network and inject their electricity generation into the national network.[295]

To meet increasing demands for energy – particularly electricity – the government has prioritized the development of renewable energy and biofuels since 2007. Under the EPL of 2008, the government seeks to:[296]

- Develop and exploit Senegal's renewable energy potential
- Diversify energy sources, particularly for electricity, by tapping into mineral coal sector, biofuel, biomass, solar, and wind resources
- Amplify hydropower through regional cooperation, particularly within river basin organizations and the West African Power Pool

The fourth EPL, covering the period 2012 to 2017, sought to ensure the provision of sufficient, affordable, and clean energy by diversifying the country's energy mix. It aimed to increase the share of renewable energy in total supply as a means to reduce the country's vulnerability to exogenous shocks. It also sought to improve access to modern energy services across the country by ensuring a more equitable distribution of investments and by targeting some of the poorer and remote regions and vulnerable groups. An equitable distribution of energy services was also highlighted under the Plan for an Emerging Senegal 2012–2035. In addition, the Plan recommended a better articulation of energy within the strategic sectors of development–including agriculture–for an effective reduction of poverty and protection of the environment through the promotion of clean energy.[297]

Programmatic Interventions

Prioritizing access in rural areas

The electrification rate in Senegal's' urban areas increased significantly between 2000 and 2010, from just 58 percent to 90 percent. Given the low rate of rural electrification of 9 percent in 2000, the government designed and implemented several programs to significantly increase rural electrification.[298]

The Rural Electrification Action Plan for the period 2002 to 2022, which seeks a rural electrification rate of 60 percent, illustrates the government's programmatic commitment. The ambitious 20-year plan has three complementary programs. Under the Priority Rural Electrification Program (PPER), the provision of electricity is conferred to the private sector, and the country was split into 10 concession areas. To be awarded a concession area, private investors are required to finance at least 49.15 percent of the investment costs for electricity provision in that area. SENELEC is not authorized to operate in the 10 zones in order to avoid competition with private initiatives.[299] However, only 6 out of 10 concessions areas have been conferred to the private sector, largely due to limited cooperation with SENELEC and resistance among local populations due to difference in prices and levels of service from private sector entities compares to those offered by SENELEC.[300]

Senegal

Another program, the Local Rural Electrification Initiative, promotes viable local approaches to rural electrification initiated by communities or the private sector to accelerate the electrification of communities outside the PPER or SENELEC's areas of intervention. These include the promotion of mini-grids and use of alternative sources of electricity, such as wind, solar, micro hydro, and biomass. This initiative has resulted in a significant increase in the use of renewable energies, especially solar. Finally, the Multisectoral Energy Program (PREM) aims to broaden the social and economic benefits of electrification. PREM also seeks to stimulate electricity consumption in rural areas for agricultural use and livestock management.[301]

In 2015, Senegal's government approved the National Program for Rural Electrification to further accelerate rural electrification. To do so, an Emergency Plan covering the period 2015–2017 was implemented, as well as an Additional Plan for Universal Access by 2025 ("Programme Complémentaire pour l'Accés Universel à l'horizon 2025").[302]

Struggling to jumpstart biofuel production

Furthermore, a program under the EPL of 2008 promoted the production of jatropha at scale, highlighting the government's reliance on biofuels to improve Senegal's fuel supply. The program, which drew on Brazil's experience, aimed to increase jatropha cropping among smallholders for fuel production.[303] The program sought to plant jatropha on 1,000 ha to produce about 1.19 billion liters of jatropha biofuel per year beginning in 2012.[304] However, in 2012, an opportunity cost assessment of jatropha in the Kaolack and Kaffrine areas showed that jatropha production was not more profitable for famers than the production of cereals, peanuts and other annual crops, partly due to the lack of a reliable value chain for biofuels.[305]

In addition, between 2010 and 2015, Senegal's National Domestic Biogas Program aimed to provide clean cooking energy to urban and rural households. Initially, the program targeted the installation of 8,000 bio-digesters, yet only 1,000 units were effectively installed within the five years. Although the program did not reach its goal, it did improve famers' understanding about the role of agriculture and livestock in the bioenergy sector and created jobs through the training of masons and manufacturers. For the second phase (2015–2019), a target of 10,000 bio-digesters was set with a budget of US$18.2 million funded by the government of Senegal, the European Union, and other partners; this program subsidizes the bio-digesters at a rate of 80 percent.[306]

The policy coherence and the effectiveness of Senegal's rural electrification program have significantly contributed to improved access and use of energy. Yet, the potential of renewable energy remains largely untapped. By increasing the share of renewable energy in the energy mix, the government could further enhance access to and use of energy, particularly in rural areas.

CASE STUDY

South Africa

South Africa has made significant progress in improving access and use of energy to foster economic growth. From 1992 to 2013, the increase of the electricity expansion indicator* is estimated at 11.23 thereby being above the average of 8 for Africa as a whole, and the agricultural value added per worker growth rate averaged 5.08 percent annually. In addition, the score of 76 out of 100 on the RISE index in 2017 makes South Africa a strong performer and reflects the government's commitment to setting good national policy and regulatory frameworks for sustainable access to and use of energy.

Institutional Innovations

South Africa has several institutions responsible for developing its energy sector. The Department of Energy (DoE) takes the lead in the formulation and implementation of energy policy. The DoE also controls the generation, transmission and distribution of energy by Eskom, a parastatal, and Independent Power Producers (IPPs), and ensures energy is consumed efficiently. Eskom was established in 1923 as the Electricity Supply Commission under the Electricity Act of 1922. Within the DoE, a dedicated office for the Independent Power Producers Procurement Programme (IPPPP) manages public procurement for IPPs projects based on coal, gas and renewable energy. Several other state-owned agencies also contribute to the implementation of South Africa's energy policy.[307]

In 1977, the government created the Central Energy Fund, which has played a central role in ensuring South Africa's energy security. The Fund's role is to:

• Provide an affordable, reliable and diverse use of primary energy resources;

• Strategically partner with the DoE by providing insights in support of policy development and regulation.[308]

The National Energy Regulator of South Africa (NERSA) was created under the 2004 National Energy Regulatory Act to regulate the electricity, gas and petroleum pipeline industries. It is also in charge of licensing for electricity generation and for enforcing compliance. NERSA regulates all tariff increases recommended by Eskom, provides national grid codes, develops regulatory rules for relevant industries and determines the applicable standards.[309]

South Africa's energy mix includes nuclear energy since the introduction of a nuclear power program during the 1970s. Many institutions were created for the safe management of nuclear power. In 1999, the National Nuclear Regulator was established to monitor and enforce regulatory safety standards to prevent nuclear accidents and mitigate consequences of nuclear accidents.[310] During the same year, the Nuclear Energy Corporation of South Africa (NECSA), previously known as the Atomic Energy Corporation was established for the development and promotion of the use of nuclear technologies.[311] In 2009, recognizing the importance of the management of radioactive waste, the government created the National Radioactive Waste Disposal Institute (NRWDI) under the Ministry of Energy. The Institute informs the public on all aspects of radioactive waste management and provides technical assistance to power plants in the management of small quantities of nuclear waste. NRWDI has institutional control over closed repositories, including radiological monitoring and maintenance as appropriate.[312]

Furthermore in 2011, the South African National Energy Development Institute (SANEDI) was created under the National Energy Act No. 34 of 2008 as a public institute to support the DoE in the implementation of energy policies. SANEDI oversees R&D in the energy sector and leads on the development and deployment of new technologies as well as the promotion of green, low-carbon energy and energy efficiency. In addition, SANEDI oversees data and knowledge management on energy, energy efficiency, fuel technology, low-carbon energy, and transport, as well as energy end-use and infrastructure.[313]

*- This indicator is expressed in logarithm of the difference of number of Nighttime Lights pixels between 1992 and 2013.

CASE STUDY

South Africa

Policy Innovations

Significant changes were made to South Africa's energy policy during the 1990s, as access to energy was recognized as central to bridging social inequalities following the apartheid era. For example, electricity was seen as a key to generating new business opportunities and to improving health by reducing indoor air pollution. In 1998, a White Paper on Energy Policy was published by the government promoting access to affordable energy services for disadvantaged households, small businesses, small farms, and community services. The policy also sought to improve governance of the energy sector and diversify the energy mix. In addition, the policy called for more accountability and transparency with respect to the roles and functions of the various institutions involved in energy governance.[314]

For a long time, South Africa had been exploiting its coal resources and has developed an efficient, large-scale, power generation system providing comparatively low-cost electricity through a grid system that extends to rural areas. However, following the Johannesburg World Summit on Sustainable Development in 2002 and amid increasing concerns on climate change, a white paper on renewable energy was published in 2004 to complement the 1998 White Paper on Energy Policy. The 2004 policy paper envisioned an increased share of renewable energy in South Africa's energy mix and the creation of a renewable energy industry to produce a sustainable, non-subsidized alternative to fossil fuels. The government at the time aimed to increase the consumption of renewables to 10,000 GWh (0.8 Mtoe) by 2013, to be produced mainly from biomass, wind, solar, and small-scale hydropower.[315]

In January 2008, the National Response to South Africa's Electricity Shortage was released jointly by the DoE and Eskom. The policy focused on improving the electricity distribution infrastructure, and fast-tracking electricity projects by IPPs and power-generation partnerships between Eskom and private industries, such as chemical processors.[316,317]

In 2011, in its pursuit of tapping into renewable energy sources, the government adopted the Integrated Resource Plan (IRP) 2010–2030 (generally known as the IRP 2010) as the official long-term plan for building new electricity generation capacities. The IRP seeks to double South Africa's electricity generation capacity through a diversified energy mix including coal, gas, nuclear and renewables. The share of renewable energy was expected to reach 42 percent of all new capacity by 2030, equivalent of 17,800 MW. To achieve this goal, the government launched several bidding rounds to procure renewable energies under its Renewable Energy Independent Power Producer Procurement Programme (REIPPPP)[318]. The IRP is regularly updated to ensure stable electricity provision at low cost and to minimize any negative environmental impacts.[319] Yet, Eskom, which produces up to 95 percent of consumed electricity, has been struggling to meet the country's electricity demand. It is being restructured into three entities – for generation, transmission, and distribution – to improve its operational sustainability.[320]

The National Development Plan (NDP) of 2013 outlines the government's long-term plan to eradicate poverty and reduce inequality by 2030. The NDP calls for improving energy infrastructure in a sustainable way, increasing investments in energy efficiency, and reducing carbon emissions by procuring at least 20 GW of renewable energy by 2030. The NDP aims for 90 percent grid access by 2030 with the remaining 10 percent to be met through quality off-grid technologies. The NDP also recommends a greater diversity of IPPs in the energy industry and adjusting electricity pricing and access to the needs of the poor.[321]

Furthermore, in 2013 the Cabinet approved the New Household Electrification Strategy with a target of providing 300,000 rural households with off-grid electrification through installation of solar home systems and other cost-effective, non-grid renewable energy technologies including mini-grid or hybrid systems. Under the Strategy, all efforts are aligned with the goals of the United Nation's Sustainable Energy for All (SE4All) initiative to achieve universal access.[322]

CASE STUDY

South Africa

Programmatic Interventions

Bridging the access gap for poor and rural communities

In 1994, under the Reconstruction and Development Program, South Africa's government aimed to connect 450,000 households annually to electricity. Although this goal was exceeded with an average of over 500,000 households per year between 1994 and 1999, a strong rural-urban electrification divide has persisted. In 1999, the electricity access rate was just 46 percent in rural areas but reached almost 80 percent in urban areas.[323] To reduce this gap, in 2000, the Integrated National Electrification Programme run by the DoE was launched. Off-grid electrification was merged into the National Electrification program, with an early focus on off-grid solar PV systems for rural areas. Access to electricity in remote areas was facilitated through the use of alternative approaches to main grid extension, alternative energy sources for electricity generation, and decentralized provision that was more cost-effective than grid connections. As a result, remarkable progress has been made in increasing access to electricity across the country. Within just 10 years – between 1994 and 2014 – more than 6 million households were connected to the grid, and between 2002 to 2014, more than 80,000 households were supplied with off-grid energy technologies (primarily solar).[324,325] In 2011, an evaluation showed that improved access to electricity in South Africa's rural areas increased employment rates, with a notable impact on women's labor market participation.[326]

Alongside the electrification program, a range of pro-poor energy-related policies were introduced by the government. In 2000, the Free Basic Electricity Tariff of 50 KWh came into effect, funded partly by the Local Government Equitable Share Grant of the National Treasury and, in cases of shortfalls, by surpluses generated by the municipalities' sale of electricity. A household is eligible if it uses less than 450 KWh per month from the grid. In 2007, this support was extended to subsidize alternative energy services to rural households–including farmers–not connected to the national grid through the Free Basic Alternative Energy in Rural Areas Policy. However, not all municipalities have been able to implement the policy. Electricity consumption by the poor is also subsidized through an *inclining block tariff system*, introduced in 2010, whereby charges increase with consumption. This system allows users with higher consumption rates to be charged at a higher rate, thus facilitating cross-subsidization of low-income groups that are charged at the lower rates.[327]

Crowding private sector to boost and diversify supply

In 2011, the government launched REIPPPP, inviting IPPs to tender for licenses to sell electricity to Eskom under a 20-year purchase agreement. The bids were evaluated based on price and economic development potential, including job creation, participation of disadvantaged populations, local environmental protection, rural development, community ownership, and skills development.[328] REIPPP was overseen by the DoE IPP office. Specific requirements for the REIPPPP include:

• At least 40 percent of each project be owned by a South African entity

• Inclusion of shareholding by black South Africans across the value chain

• A required minimum ownership of 2.5 percent by local communities as procurement condition

• No more than 60 percent of project capital investment consisting of foreign currency; and

• Local content requirements above 40 percent.

By 2016, 6,590 MW were procured in four bidding rounds, awarding 95 onshore wind, solar, and small biomass and hydropower projects. As of October 2016, 54 power plants with the capacity of 2,800 MW were fully operational and 15 percent of the delivered energy was supplied into the grid during system peak periods, alleviating pressure on the power system. The source of electricity supply has broadened significantly with REIPPPP, with over US$19 billion in private investment and a significant drop in the price of electricity sourced from renewable energy.[329]

There is also evidence that energy production from agricultural waste is increasing in South Africa. In 2015, the Bronkhorstspruit Biogas Project was

South Africa

launched by Bio2Wat, a South African IPP. Roughly 120,000 tons of feedstock, the bulk being manure along with food waste and additional supplements from slaughterhouses, are processed annually by the plant to generate a capacity of 4.6 MW. Over its expected lifespan of 20 years, the project is expected to contribute to the diversification of the South African energy mix by reducing the use of coal.[330] It has also resulted in the creation of long-term direct and indirect employment in peri-urban South Africa. With over 14 million cattle in South Africa, owned mainly by large farms, the potential for project replication is substantial.[331]

South Africa is among the leading countries in Africa in terms of electrification. However, rising demand and the near full-capacity operation by Eskom have been causing significant shortages of electricity and repeated outages, with significant impacts on the South African economy. For example, the cost of power shortages in early 2008 was estimated to be between US$253 and US$282 million.[332] Fresh produce and meat industries are worst affected by power cuts which are also detrimental to consumers and pose a huge threat on the nation's food security.[333] The programs for energy diversification therefore require urgent scaling up to transition to a cleaner energy system and reduce the country's reliance on its deteriorating fleet of coal fired power plants.

CASE STUDY

Zambia

Electrification has been the cornerstone of Zambia's development plans over the last few decades. Between 1992 and 2013, the increase of the electricity expansion indicator[*] was estimated at 8.43 – slightly higher than the average of 8 for Africa as a whole. During the same period, Zambia's agricultural value added per worker grew at an average of 1.51 percent annually. Zambia scores 43 out of 100 on the RISE index in 2017, making it a middle performer in terms of policies and regulations that support access to modern energy, energy efficiency and renewable energy.[334]

By 2017, 75 percent of Zambia's urban population and 14 percent of the rural population had access to electricity.[335] Biofuels and waste constituted the largest share of total primary energy supply in 2017 (75 percent). Hydropower provided nearly all of Zambia's *electricity* supply until 2014, when a small amount of oil-based generation was introduced to diversify sources and counter the impacts of recurrent droughts.[336]

Institutional Innovations

Zambia has a dedicated agency for rural electrification. Established in 2003 through Parliamentary Act 20, the Zambia Rural Electrification Authority (REA) is mandated to increase access to electricity to 51 percent by 2030 by providing infrastructure and appropriate technology to all rural areas. Although this is not in line with SDGs that call for universal access to electricity by 2030, Zambia requires an exponential effort to meet this target, with an access rate of less than 15 percent in 2017.[337] The REA advises on suitable policies, designs and implements the Rural Electrification Master Plan (REMP), and administers and mobilizes the Rural Electrification Fund (REF)—also founded through Parliamentary Act 20. The REF streamlines the previous bottom-up process of selecting and funding rural electrification projects. It is funded by a 3 percent levy charged by national utilities.[338]

The establishment of the REA followed extensive changes to the energy sector between 2011 and 2016. As part of the liberalization process of the sector in the 1990s, the Zambian government created the Ministry of Energy and Water Development, later rationalized as the Ministry of Energy (MoE) in 2016. The Department of Energy (DoE) within the MoE is responsible for the development and implementation of energy policies, programs, and projects, including the promotion and facilitation of renewable energy, energy efficiency, and electrification solutions.[339]

An Energy Regulation Board (ERB) was another outcome of the liberalization process. The ERB was created in 1995, and operationalized in 1997, to monitor the reliability and quality of service provided by national and independent private providers. It is overseen by the MoE.[340] In addition, an Office for Promoting Private Power Investment (OPPPI) was established in 1999 within the MoE to facilitate the growing involvement of the private sector in power project development in Zambia.[341]

Although the energy sector was largely liberalized, Zambia Electricity Supply Corporation Limited (ZESCO) remains the key national energy supply utility, responsible for generation, transmission, and distribution of electricity across the country. Rather than privatize ZESCO in the 1990s, the government chose to corporatize and commercialize it to enhance efficiency and improve its performance. Although there were some increases in tariffs too, electrification across the country expanded rapidly.[342]

Hydropower provides 99 percent of ZESCO's electricity, and the rest is from diesel-powered generators. Almost half of the hydropower comes from the Kariba Dam on the River Zambezi; eight additional dams provide the rest. Maintenance of the Kariba Dam and development of new dam sites on the Zambezi are the responsibility of the Zambezi River Authority.[343] Copperbelt Energy Corporation Plc and the Lunsemfwa Hydro Power Company Ltd—the first independent power producer (IPP) in Zambia—provide approximately 53 MW of additional capacity.[344]

* - This indicator is expressed in logarithm of the difference of number of Nighttime Lights pixels between 1992 and 2013.

CASE STUDY

Zambia

Beyond hydropower, Zambia's energy sector is supported by TAZAMA Pipelines Limited, which transports crude oil from the coast at Dar-es-Salam in Tanzania to Indeni Petroleum Refinery Corporation in Zambia. Incorporated in 1968, the ownership of Tazama Pipelines Limited is shared between the Governments of Zambia (66.7 percent) and Tanzania (33.3 percent).[345] Petroleum is the only energy source that is wholly imported among Zambia's energy supply mix, constituting 12 percent of total primary energy supply in 2016.[346] In comparison, hydro provides between 8 and 11 percent of total energy supply and biomass and waste provide 75 percent.[347] Zambia's Vision 2030 aims to reduce the share of fuelwood in the overall energy mix to 40 percent by 2030.[348]

Policy Innovations

Fiscal incentives to boost and diversify energy supply

The Zambia Development Agency is the first point of call for private sector companies wishing to engage in the energy sector, for fiscal and non-fiscal incentives as well as coordination with the ERB, OPPPI, and other regulatory bodies. For investments of more than US$500,000 in an industrial park, rural enterprise, or a priority sector, companies benefit from favorable tax and import duty incentives. Furthermore, investors may be entitled to a zero percent tax rate on dividends for five years from the first declaration of dividends; zero percent tax on profits for five years from the first year of operation; and zero percent import duty on capital goods, machinery, and specialized motor vehicles for five years. Smaller investments of between US$250,000 and US$500,000 benefit from non-fiscal incentives.[349]

Zambia's energy policies have also aimed to diversify the energy mix, increase access to electricity and modern energy services in rural areas, and expand private sector involvement. The first Energy Policy issued in 1994 focused on increasing the supply and demand for energy and forming the institutional structures to support this growth. It aimed to increase rural electrification from 2 to 15 percent and urban electrification from 45 to 78 percent and to reduce charcoal consumption by 400,000 tons. Further, it aimed to replace fuelwood with alternative energy sources (such as liquified petroleum gas), and to promote off-grid renewable energy sources.[350] This policy was reviewed and updated in 2008, when access to electricity in rural areas had increased eightfold to 5.3 percent and urban electrification had increased to 55 percent.[351]

The 2008 National Energy Policy (NEP), still in effect, provides policy and implementation guidelines to increase access to modern energy in rural areas, including from alternative and renewable energy sources. To support this, a renewable energy feed-in-tariff (REFiT) policy was drafted in 2015 to catalyze private sector investment in renewable-energy power generation.

Through specific fiscal and regulatory measures such as smart subsidies, low interest loans, loan guarantees, tax incentives, and waivers, the NEP seeks to make biomass use more sustainable, including through a transition to biogas technologies, to reduce pressure on indigenous forest resources, and to expand the role of biofuels in the energy mix. In particular, the policy pledges to support farmers wishing to engage in biofuel crop production and support the provision of modern energy sources to small rural farmers to reduce the need for slash-and-burn agriculture. Thus, the 2008 NEP advocates for, and should result in, closer collaboration among other economic and social sectors such as agriculture, trade and industry, transport, information and communications technology, health, and education.[352]

Cluster based approach to agricultural electrification

Zambia's Vision 2030 declares the ambition to become "a prosperous middle-income nation by 2030."[353] This goal is founded on transforming Zambia's agriculture sector into a competitive, sustainable, and export-led sector by increasing productivity and growth in processing of agricultural products, particularly for export. Although rural electrification is increasing, the amount of electricity used by the agriculture and forestry sectors remained relatively stagnant between 1994 at 2013, averaging about 160 GWH per year. Among Zambia's economic sectors, the agriculture and forestry sectors are the lowest consumers of electricity, although the agriculture sector contributes on average at least 10 percent to GDP and employs about 67 percent of the labor force.[354] Currently the sector accounts for less than 1 percent of total energy consumption.[355]

Within this context, a key policy objective has been to promote increased productivity for major crops in which Zambia has a comparative advantage, such as wheat, sugar, cotton, coffee, tobacco, cashew nuts, cassava, and horticultural/floricultural crops. These crops form the basis of a core venture within "farm blocks"—large agricultural areas—in addition to other medium- and small-sized commercial farms. To date, the government has identified 11 farm blocks with a total area of 895,000 ha through land development programs. Each farm block benefits from basic infrastructure and facilities such as trunk roads, bridges, electricity, dams, schools, and health centers, provided either by the government or in partnership with private sector and development partners.[356] These complement the establishment of industrial cluster zones for processing agricultural produce and ensuring it is competitive in export markets. Several sites are currently undergoing environmental impact assessments, with pledges amounting to one billion Zambian kwacha (approximately US$100 million) received from investors from China, South Africa, Botswana, Sudan, Jordan, and India.[357] Farmers will be connected to hydroelectricity for farming and processing at 10 sites.

The National Agricultural Investment Plan (NAIP) 2014–2018 also recognizes the importance of agricultural development in reducing poverty. Targets to introduce 1,900 renewable-energy-based irrigation pumps have been proposed within the "sustainable use of the natural resource base" pillar in the NAIP. Further, the NAIP proposes to reduce charcoal and fuelwood consumption by targeting 4,000 households to adopt energy efficient stoves.[358] These objectives align with Zambia's 2019 Climate-Smart Agriculture Investment Plan, which recommends prioritizing a reduction in biomass burning and charcoal use.[359]

Programmatic Interventions

Matching demand and energy mix to accelerate rural electrification

The 2008 NEP emphasizes implementation of the Rural Electrification Master Plan (REMP). Effective from 2008 to 2030, the REMP provides a detailed strategy for expanding electrification using a combination of grid extension and off-grid solutions. Following a decentralized planning process, 1,217 "rural growth centers"—hubs of residential, social, and commercial activity such as schools, hospitals, and agricultural depots or markets—have been identified for electrification across the country. Each center is then reviewed based on potential peak demand, distance from the grid, cost of grid extension, and rates of return to select the most cost-effective solution for electrification. From the centers identified, 972 were selected for grid extension, 241 for solar home systems, and 4 for mini-hydro power development—at a total cost of US$1.1 billion, or US$50 million per year over 22 years. With this approach, REMP aims to double the number of electrified households by 2030, equating to 50 percent of total rural areas. By 2017, 152 grid extension projects had been implemented and 423 solar home systems delivered. One mini-hydro plant was completed in 2018. In addition, one solar mini-grid was constructed in 2013, and two more initiated in 2016.[360] As a result of these interventions, rural electrification nearly tripled by 2017, increasing from 5.3 percent to 14 percent.[361]

Power Africa, an initiative led by USAID, has further supported the Zambian government's electrification program. In addition to strengthening regulatory frameworks, Power Africa invested US$2 million to provide approximately 100 MW of new solar power in 2016.[362] Similarly, a collaboration between Sweden and the Netherlands provided grid extensions to 11 locations across Zambia, which led to a proliferation of enterprises and mills and to an improvement in health services and education, as children were able to study for longer hours.[363]

Smart financing for power suppliers and farm equipment

The Beyond the Grid Fund for Africa was founded to foster new private sector business models offering affordable and clean energy access across the continent. The Fund is financed by the Swedish International Development Agency, managed by the Nordic Environment Finance Corporation, and implemented by the Renewable Energy and Energy Efficiency Partnership. Initiated in 2016, Beyond the Grid for Zambia (BGFZ) "de-risks" costs of operating and expansion while companies establish themselves in the market. BGFZ operates as a fund with a tendering process, with results measured in terms of the provision of energy services for Zambians. The first round of tendering resulted in the selection of four companies to deliver clean energy services: Standard Microgrid, Fenix International, energizing cooking solutions, and Vitalite, which offer mini-grid installations, solar home systems, clean cooking products, and agricultural innovations such as solar irrigation pumps. In January 2019, at the end of the first 18 months, the companies had overshot their targets, serving 447,000 people, nearly double the target number.[364] It is expected that BGFZ will meet its goal of bringing modern energy services to one million Zambians much earlier than targeted date of 2021. Benefits include:

- Job creation: the number of sales agents (also consumers themselves) grew tenfold and the number of employees within the four companies tripled
- Income generation: customers are undertaking new income-generating activities such as mobile-phone charging and lighting of shops
- Savings: savings made on fuel and candles are being redirected to food, animal feed, and loan repayments
- Communications: more information sharing via mobile phones, radio, and television. Specifically, Vitalite produces educational shows for smallholder farmers on improving productivity and farming practices
- Education: children are studying for longer hours and attended school more
- Cleaner indoor air.

BGFZ has also formed an Off-Grid Energy Task Force, composed of stakeholders from the government, development partners, finance, and the private sector to coordinate activities, share challenges and opportunities, and define pathways to strengthen the enabling environment for the market. The Task Force is embedded in, and led by, the Ministry of Energy. It has already assisted with the drafting of a new national mini-grid policy and the initiation of discussions to improve the affordability of off-grid energy solutions.[365,366]

The Rent to Own (RTO) initiative mitigates the lack of access to affordable, available, and appropriate equipment for farming and food production. Founded in 2010, RTO loans productive assets requiring either grid or off-grid electricity, such as submersible solar irrigation pumps, freezers, oil presses, maize shellers, stoves, and hammermills to farmers. Each asset is carefully selected for clients and combined with tailored financing, delivery, and training on equipment maintenance and repair. The equipment itself also acts as collateral if needed. By December 2018, with support from Shell Foundation, Small Foundation, and others, RTO had delivered over 7,000 productive use assets and achieved an exceptional 96 percent repayment rate. The solar irrigation pumps—which deliver over 10,000 liters of water per day at 25 meters of lift—have been particularly successful for farmers and livestock producers facing climate change and increasingly frequent droughts.[367]

Although renewable energy technologies and off-grid solutions are increasingly available on the market—in response to a growing demand to counter Zambia's blackouts—there is still a perception that grid extensions are prioritized and continue to receive a large proportion of resources.[368] Moreover, continued reliance on hydropower and bioenergy have further exposed the country's energy system to climate change and contributed towards rapid deforestation. Importantly, strengthening climate-smart agriculture programs would ensure that farmers are both more efficient in their energy use and resilient to climate change impacts. More attention to off-grid, mini, and micro solutions would potentially enable Zambia to reach its electrification targets more quickly and at a lower cost. Ensuring that these solutions are based on renewable energy sources will avoid an increase in CO2 emissions.

Finally, although the energy sector has been liberalized, there is an opportunity to clarify and maximize the role of private finances in funding the Rural Electrification Authority.[369]

8. Conclusion

To spur economic growth, African countries need to create smart energy systems that are designed to benefit all actors along the food value chain, particularly those living and working in rural areas. Energy is a key input in food systems. It is required in all aspects of food production, transformation, distribution and consumption. Therefore, ensuring the availability of affordable, clean, reliable and continuous supply of energy plays a vital role in transforming agriculture, improve food security and contribute towards reducing hunger and malnutrition across the continent. Furthermore, the use of improved energy services will also support continental and global efforts on tackling poverty, employment, food loss, air pollution and environmental degradation.

Although some African countries have made significant headway in electrification through the extension of central grid infrastructure, there is now an opportunity to leapfrog this traditional approach and instead focus on bottom-up, off-grid and mini-grid solutions, tapping into the continent's vast resources for renewable energy including solar, wind and hydro power. In Africa, the combination of high population growth rates, urbanization, and a rise in middle-class consumers are fueling a sharp increase in food demand making universal access to energy an urgent necessity, both for the production and consumption of food.

The rapid increase of off-grid and mini-grid technologies for hydro, wind and solar power is already disrupting African energy landscapes and enable Africa's consumers to leapfrog outdated and dirty technologies. It is estimated that by 2063, renewable energies, including wind, solar, hydro, bio, tidal and geothermal energies will represent more than half of the energy consumed by African households and businesses. Combined with Africa's mushrooming digital market, small-scale, micro and nano solutions offer tailored services for the specific needs of farmers.

As this report and the experience from six African countries show, energy provision in rural areas can have a transformative effect on people's livelihoods and Africa's food system as a whole. One strategy is to replicate and bring to scale those policy innovations and interventions that have proven to be successful on the ground.

Ethiopia's achievements are founded on its Agriculture Development Led Industrialization Strategy, which provides a framework for concurrent improvement in the agriculture and energy sectors. For example, the Universal Electrification Access Program has driven the development of hydro sources, which support both, small scale energy provision, and irrigation for agriculture. Furthermore, through its Climate Resilient Green Economy strategy launched in 2011, Ethiopia has set sector-specific strategies in preparation for transitioning to a green economy. This includes expanding electricity generation from renewables and leapfrogging to energy-efficient technologies in the agriculture sector. Ghana has one of the highest rates of electrification in SSA. This is founded upon the success of the Self-Help Electrification Programme, which propelled grid extension to the more remote communities, and a strong emphasis on facilitating private sector engagement through regulation. Ghana has also expanded local research and technical capabilities as well as programmatic interventions directed towards achieving universal energy access, with a focus on rural areas and the agricultural processing sector. In Morocco, the government has sent a strong signal for adopting renewable energies at scale through setting fiscal incentives, including subsidies to farmers for the use and installation of solar pumps and panels, while in Senegal, the government passed legislation to liberalize the energy sector, incentivizing IPPs to produce electricity and prioritized to expand electricity access in rural areas with a target of 60 percent by 2022. Through the implementation of the Integrated National Electrification Programme, the South African government facilitated access to electricity in the most remote areas using alternative approaches to main grid extensions, including decentralized solutions which were more cost-effective and using different energy sources for electricity generation. Finally, in Zambia, the government has taken a cluster-based approach to agricultural electrification through "farm blocks" that are equipped with basic infrastructure and complemented by industrial cluster zones for agricultural processing. To meet increased energy demand and connect rural areas to electricity, a government strategy seeks to expand electrification using a combination of grid extension and off-grid solutions.

The experience of the six countries analyzed in this report can enable other African governments to develop country-specific strategies to increase the provision and use of energy in rural areas and at the benefit of food systems and rural populations. The Malabo Montpellier Panel has identified a set of policies and practices summarized below that, if brought to scale, could have a significant impact on agricultural transformation and overall economic across the continent:

RECOMMENDATIONS

1. Design integrated strategies for energy by ministries and departments that have responsibilities for energy and those responsible for food, agriculture and rural development to address concurrent challenges.
2. Scale investments in off-grid and mini-grid solutions especially via start- ups and businesses to leapfrog outdated and dirty technologies.
3. Adopt gender-responsive energy strategies for the design and implementation of energy strategies as well as the choice of technologies and tools applied.
4. Address the multiple challenges of biomass-based energy use to ensure that biomass is produced more sustainably, and that indoor cooking is redesigned to be more environmentally friendly and not harmful to human health.
5. Develop cross-border policies for energy security to help reduce countries' reliance on imported fuels while diversifying the energy mix.

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