The energy challenge in sub-Saharan Africa

Two new reports from Oxfam and the Renewable and Appropriate Energy Laboratory at the University of California, Berkeley, detail the policy challenges involved in meeting the energy challenge in sub-Saharan Africa. The first considers the potential for renewable energy technologies to generate electricity for sustainable and equitable development. The second looks at the challenge of addressing energy poverty on the region. The reports are intended as technical resources, discussion papers, and guides for action for all those concerned with a just and sustainable energy transition in the region.

The full reports can be found here: https://www.oxfamamerica.org/explore/research-publications/the-energy-challenge-in-sub-saharan-africa/

THE ENERGY CHALLENGE IN SUB-SAHARAN AFRICA

Sub-Saharan Africa's energy systems face an enormous challenge. The region currently has the lowest electricity generation capacity and experiences the most acute forms of energy poverty in the world. Approximately 630 million people live without reliable access to electricity, and 790 million people are forced to rely on solid biomass to cook their food and heat their homes. The results are deprivation, pollution, environmental damage, drudgery, and forgone economic opportunity. Compounding these challenges is Africa's vulnerability to climate change, which means that traditional pathways to increasing energy supply, based on the burning of fossil fuels, will become increasingly unviable.

Recent reductions in the cost of renewable energy are creating new opportunities for sub-Saharan Africa to address the energy challenge without increasing greenhouse gas emissions

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and exacerbating environmental damage. They also offer new opportunities for connecting households to energy sources more quickly and more cheaply.

This pair of linked reports explores the scientific, technical, economic, and policy opportunities for renewable energy technologies to address Africa's electricity generation shortfall and tackle the challenge of energy poverty. They identify issues of underinvestment in energy resources at household, national, and regional levels, and highlight the importance of state policy and institutions in meeting the energy challenge.

Decisions made on energy today in Africa will have long-term effects because they stand to lock the region into particular energy development pathways. Our aim is thus to inform the policy debates on these issues and make the technical dimensions of the challenge easily understandable so as to broaden the community of people engaging on this topic.

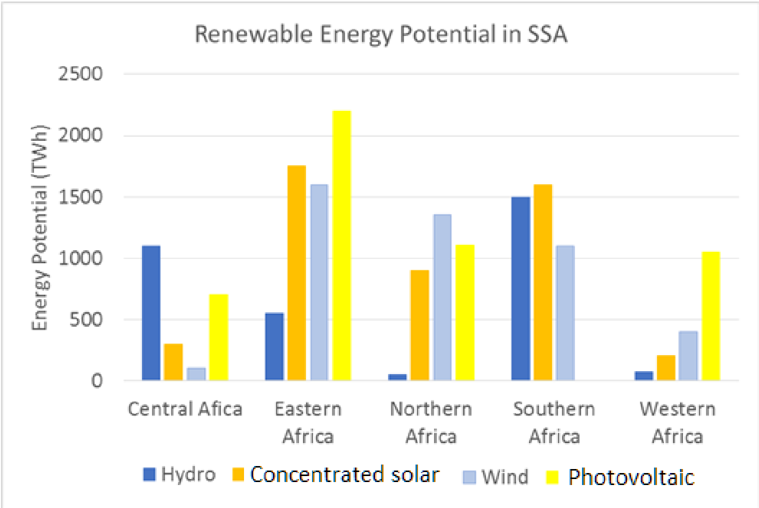
AN ABUNDANT RESOURCE BASE

Sub-Saharan Africa has abundant energy resources, including renewable and fossil sources and in this regard, the region has access to sufficient resources to meet its future demands for electricity. Overall technical generation potential is estimated at 11,000 gigawatts (GW), though these resources are not distributed evenly across the region.

Total generation potential from different sources in sub-Sharan Africa

Source	Solar	Wind	Geothermal	Hydroelectric	Natural Gas	Coal
Total Potential	10,000	109	15	350	400	300

Total energy resource potential in sub-Saharan Africa and its regional distribution



CURRENT CHALLENGES TO THE ENERGY SYSTEM

The current generation capacity in Africa is beset with challenges. Utilities have historically been poorly managed, resulting in an energy system that relies on expensive oil and gas—and thus suffers from the volatile prices associated with these sources—and experiences large losses from the electrical grid. As a consequence, tariffs are high and utilities are financially unsound. The region also relies heavily on hydropower, which is particularly vulnerable to climate change.

ENERGY FUTURES

Whether Africa pursues a path dominated by fossil fuels or one dominated by renewables, it will face challenges.

The fossil fuel path will exacerbate climate change, continue wasteful fossil fuel subsidies, and leave people vulnerable to price fluctuations.

The renewable energy path will present challenges related to capacity and intermittency. The energy system must be designed to evolve and take advantage of the many benefits of distributed clean energy. Yet renewables like solar and wind, are only available intermittently, Close attention to demand patterns is therefore crucial to ensure that supply meets demand, so that electricity is available when needed but is not wasted when demand is low. The grid must be flexible enough to respond to rapid changes in both demand and generation and keep the energy system balanced.

Toward a smart African grid

Grid flexibility refers to how effectively the grid can respond to changes in generation and demand in order to keep the overall energy system in balance. Grid flexibility can be increased in several ways:

1. **Ensure access to large amounts of dispatchable energy generation that can be turned on and off quickly.** This means using more gas and hydropower and less coal and nuclear.
2. **Shift demand to match times when the energy supplied by renewables is available**. For example, demand could be shifted to times of the day when solar energy output is high.
3. **Interconnect many variable renewable energy sources over large geographic areas.** This means that if the wind stops blowing in one place or if one area gets covered by clouds, it is possible to draw from other generating areas that are experiencing sunny or windy conditions.
4. **Invest in "smart grids" that can be integrated with information and communication technologies.** Smart grids allow for certain non-essential appliances to be switched off briefly when demand on the grid is high and for distributed generation and storage to be brought online when needed.

Taken together, these efforts at grid flexibility mean that backup power generation for wind and solar systems does not have to be built on a one-to-one basis. They also mean that only limited storage is needed. . Nonetheless, with 100% penetration of renewables—that is, if all electricity generation in sub-Saharan Africa relied on renewables—large-scale grid storage in one form or another would be required.

Opportunities for the African grid

Africa has significant opportunities to make its grid more flexible by **reducing grid losses and improving the regional integration of power pools**. Grid losses place an extra strain on the energy system, and at the same time undermine the financial viability of the utility Regarding power pools, currently only about 10 percent of electricity is sold internationally in sub-Saharan Africa. Increasing regional cooperation will reduce costs by reducing the generation capacity needed. It will also allow for greater penetration of renewable energy sources that are not evenly distributed across the region. The large-scale regional sale of power will, however, make addressing the issue of grid losses even more important.

Given the complexity of factors affecting grid flexibility, the only way to understand how much renewable penetration is possible while ensuring the cheap and reliable provision of electricity is **through models that can incorporate these factors** and compare the costs of building, running, maintaining, and decommissioning different generation plants. Our efforts to model these systems in Africa reveal the following:

- Most countries in sub-Saharan Africa **lack, or have not made available, the data needed to undertake the sort of modelling that is necessary**. This lack of data makes planning impossible, raising the risk that countries will make poor investment decisions that lock them into expensive and polluting energy pathways.
- To meet their future energy demand, some countries are **prioritizing coal for development even if it is not the most economic resource**. This calculus looks worse if the externalities of coal are internalized through a carbon price, as is increasingly taking place in other parts of the globe.

- Many African countries will likely have to make tough **trade-offs between gas and hydroelectric power investments.** Both gas and hydroelectric power will be important for achieving high penetration levels of renewables as they are able to support renewables with high levels of intermittency. Yet hydroelectric power damages watersheds and frequently impoverishes the communities living around and downstream of large dam sites. Hydroelectric power is also vulnerable to future changes in the climate. Focusing on gas will lead to ongoing carbon emissions and also require investments in gas transport infrastructure, which will be expensive and lock countries into long payback periods.

- Even when countries pursue least-cost options, the levels of renewable energy penetration will **vary substantially across countries**, as will the specific energy mix in the energy system.

Modeling innovative approaches for Kenya and Nigeria

Kenya and Nigeria have the data to model their energy systems and modeling them shows the economic potential of renewables. Under a business-as-usual scenario, the model showed several results: Kenya's load growth through 2035 could be met sustainably and cost-effectively predominantly with geothermal and wind resources. In Nigeria the least-cost expansion pathway includes natural gas, hydropower, and an aggressive new approach to distributed and centralized solar photovoltaic energy. In neither case is coal economically optimal.

Forcing the Kenya model to install 4,500 megawatts of coal by 2030 (as per Kenya's medium-term development plans) increases generation costs by $2 billion by 2035 relative to a clean, distributed energy plan. Removing wind from Nigeria's power mix increases costs by $6.5 billion.

Deploying energy efficiency does not change the mix of energy sources that produce the lowest-cost system in either case, but results in savings of $5 billion in Kenya and $10 billion in Nigeria. A carbon tax of $40 per ton in Nigeria does not change the mix of energy sources that achieve the least-cost system, but it does increase overall system costs by about $10 billion. If Kenya chooses to deploy coal, a $40 carbon tax increases costs by $6 billion.

A UNIQUE FUTURE DEMAND PROFILE

The challenge of modeling Africa's future energy pathways is made more complex by the fact that it is difficult to estimate the continent's current and future demand profiles. Current demand is obscured by large amounts of self-generation—mostly through diesel generators—and by latent demand among groups who want electricity and would be willing to pay for it but who are currently unconnected. Future **demand is obscured by the unique consumption habits that will be prominent in Africa**, and by the advent of energy-efficient appliances that will become prominent on the continent and change the relationship between generation capacity and energy services.

PROVIDING ACCESS TO ELECTRCITY

As with the specific mix of generation capacity, the specific trajectory any African country might take toward connecting its population and affording them large quantities of energy is also context specific and depends on the country's current grid extent, available resources, and demographic characteristics. Falling prices for renewable energy technologies—principally solar energy—mean that there are now novel possibilities for providing households with access to electricity and addressing energy poverty. The different technologies have different sets of advantages and disadvantages:

- **Expanding the grid** offers economies of scale and can thus provide large quantities of energy at the cheapest retail price. Because it is a well-understood technology, blueprints for institutional support are well known. However, low population densities and low levels of energy consumption in Africa limit these advantages. Grid expansion is also expensive and relies on effective regulation, which has historically been lacking in sub-Saharan Africa.

- **Mini-grids** (both grid connected and standalone) can provide electricity in quantities similar to that of the grid and can effectively serve isolated yet clustered populations. Mini-grids can often be built more quickly and more cheaply than expanding the traditional grid, but because of the limited economies of scale and the need for storage, energy from these systems may be more expensive than that provided by the central grid. Mini-grids are also relatively new technologies that suffer from a lack of established business models and supply chains (including technical capacities) and uncertainty in the policy environment. To take advantage of mini-grids for mass electrification requires new regulatory and approval strategies, greater coordination with local authorities, and support for the private sector.

- **Solar home systems and solar appliances** both provide valuable energy services in the form of lighting, power for electronics, and cooling. The value of these services means that there is an effective market for them that the private sector is able to supply. Such devices fail, however, to provide power for productive purposes and cannot effectively meet needs for thermal energy services.

- **Gender and socioeconomic equity** are key issues that the smart integration of on- and off-grid energy strategies can address across Africa. Systems such as pay-as-you-go energy systems, mobile "e-money," and other information resources have already greatly increased resource access and economic opportunity for African women and households, and represent important new areas of innovation and empowerment across the continent.

The cost of electricity and energy poverty

Electricity is expensive compared with household incomes in the region, regardless of the technology used. Based on current estimates, so long as a household is buying electricity from the grid, an average household in sub-Saharan Africa will only just be able to afford the minimum amount of electricity needed to meet the definition of energy poverty. Considering electricity from distributed sources, the average household would not be able to afford enough electricity to meet even its most basic energy needs. **Ensuring that the poorest households in the region are able to access electricity and meet their basic energy needs will likely require significant support**.

ADDRESSING ENERGY POVERTY

Providing households with electricity can significantly improve their welfare: newly connected households are generally willing to pay for electricity to supply lighting, cooling, and power for electronic devices. Only in some cases, though, do newly **connected households use electricity for cooking and heating,** even if the energy provided is capable of supplying these services. In addition, **providing electricity to households and communities appears to be necessary—but not sufficient—to drive significant economic development.** Together these findings have several implications:

- A greater focus is needed on managing households' use of solid biomass for cooking and heating, which is expected to increase through 2030. This means, for example, promoting improved cookstoves and ensuring that solid biomass is harvested sustainably. At the same time, it will be crucial to aggressively support the transition to cleaner fuels, including electricity.

- More work is needed to understand the link between electrification and economic development—and especially what concomitant policies are required to ensure that electrification results in improvements in household income. Faster progress is needed on developing technologies, market forces, and other means of providing clean, cost-effective energy options. Addressing these challenges is important not only to reduce poverty, but also to ensure the sustainability of electrification efforts.

MOVING FORWARD

In addition to increasing grid flexibility, linking electrification with economic development, and creating policy to support the sustainable use of biomass, the following will be important areas of policy concern when addressing energy access in sub-Saharan Africa:

- **Efforts to both expand the grid and deliver distributed energy must be pursued simultaneously** and include explicit allowances for how distributed energy will be incorporated into the grid when it arrives.
- While technological advances are changing the possibilities for addressing energy poverty, **institutions will be crucial** and should remain a focus for advocates: tariffs, subsidies, and quality control will all be essential to closing the energy gap and addressing energy poverty, and all of these will remain the purview of the state.
- **Public and donor financial support will be needed to leverage private investment** to ensure that Africa can meet its energy challenge. Money should support targeted pro-poor subsidies, resource evaluations, and supply chain development.

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