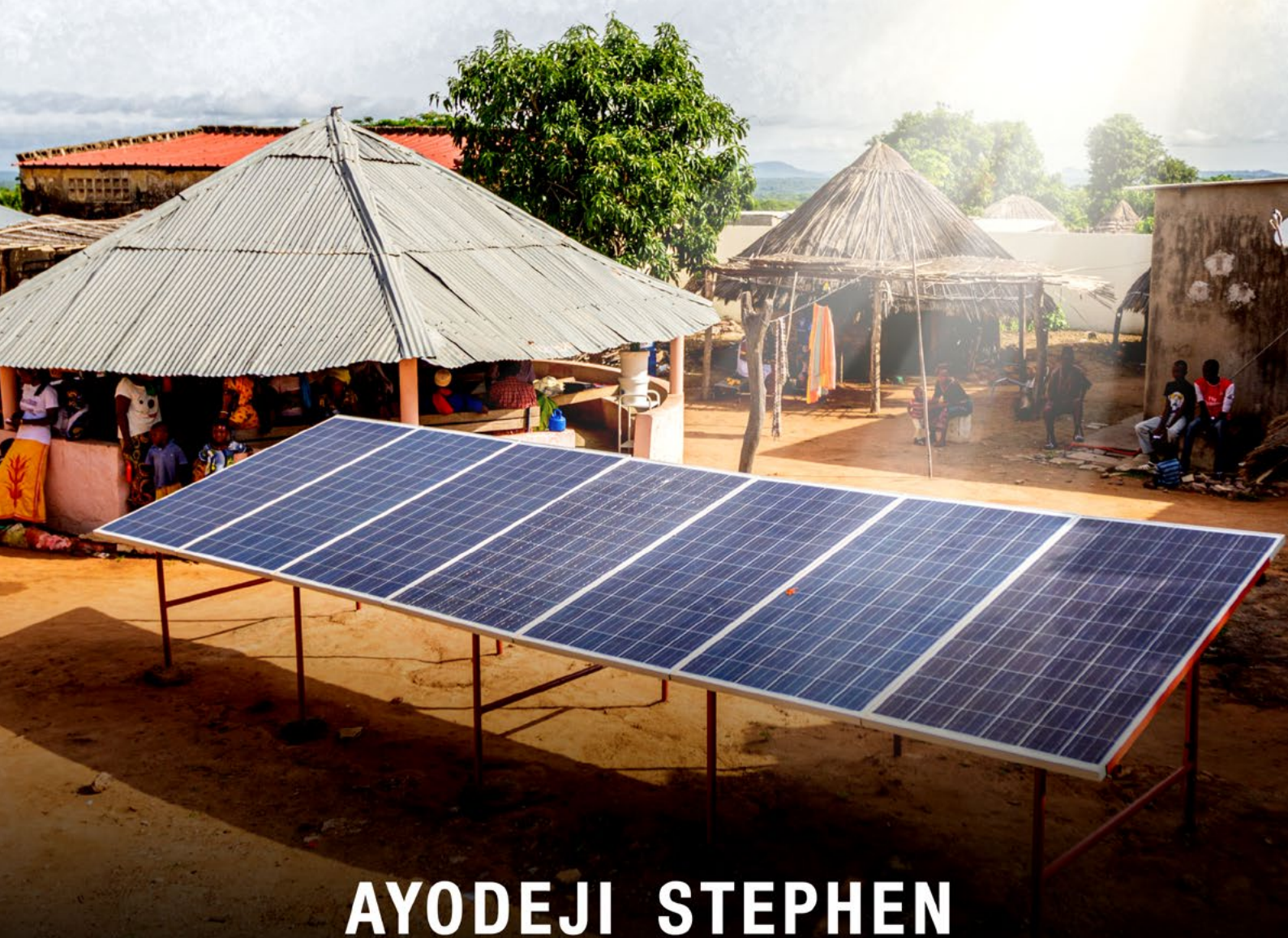


Energising Rural Africa

HARNESSING OFF-GRID AND MICROGRID
SOLUTIONS FOR SUSTAINABLE DEVELOPMENT



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Introduction

Numerous obstacles to energy availability exist in rural Africa, mostly because of poor infrastructure, scarce financial resources, and remote location. The inability of rural communities to maintain a dependable energy infrastructure and maintain grid coverage limits access to contemporary energy services, such as heating, cooking, lighting, and productive uses of power. Furthermore, traditional biomass sources like firewood and charcoal, which present health concerns and contribute to deforestation and environmental degradation, are the only sources of biomass available to rural communities in many cases due to a lack of access to clean cooking fuels. These issues provide serious obstacles to socioeconomic growth and impede the pursuit of sustainable development objectives.

Wide-ranging and pervasive, energy poverty in rural Africa affects many facets of everyday life, health, education, and economic possibilities. In rural communities, limited access to power and clean cooking fuels stifles production, stunts socioeconomic growth, and prolongs cycles of poverty. Traditional biomass fuels cause indoor air pollution, respiratory disorders, and other health problems when used for cooking, especially in women and children. Furthermore, the lack of dependable energy sources restricts access to contemporary healthcare and educational opportunities, aggravating inequality and impeding human progress.

The issues associated with energy availability in rural Africa necessitate a multimodal strategy that includes community engagement, policy reforms, and technical advancements. Clean cooking and rural electricity are two sustainable and decentralised solutions provided by renewable energy technologies, including solar, wind, and hydroelectric power. Bypassing the requirement for expensive grid extensions, mini-grids, and off-grid renewable energy technologies can increase access to electricity in isolated and underserved communities. Additionally, encouraging clean cooking options can lower health risks, improve indoor air quality, and increase cooking practices' energy efficiency. Examples of these solutions include upgraded cookstoves and biogas digesters.

Investment and policy assistance are essential for expediting rural Africa's transition to universal electricity access. Governments, development organisations, and other stakeholders must prioritise energy access programmes, fortify legal frameworks, and raise financial resources to encourage sustainable energy development in rural areas. Beyond this, community empowerment, fostering ownership, and maintaining the sustainability of energy projects depend on community engagement and capacity growth.

The obstacles to energy availability in rural Africa are numerous and intricate, but they are not insurmountable. Overcoming these obstacles and realising the potential of sustainable energy to propel socio-economic development, enhance livelihoods, and build resilience in these African communities can be accomplished by embracing a comprehensive strategy that incorporates technology advancements, policy changes, and community involvement. By working together, we can advance the sustainable development goals in rural Africa and achieve universal access to energy.

Importance of off-grid and microgrid solutions in addressing energy poverty

Off-grid and microgrid solutions are essential in combating energy poverty because they give marginalised people dependable and long-lasting access to electricity. Decentralised energy systems present a feasible substitute for conventional grid extension methods, especially in isolated and distant regions where grid connectivity is unfeasible or prohibitively expensive.

The capacity of off-grid and microgrid solutions to strengthen livelihoods, empower communities, and promote sustainable development makes them significant. In rural and off-grid locations, off-grid and microgrid systems supply clean, reasonably priced electricity to homes, businesses, schools, and healthcare institutions by utilising renewable energy sources, including solar, wind, and hydroelectric power.

Scalability and flexibility are two major benefits of off-grid and microgrid solutions. In contrast to centralised grid systems that necessitate substantial infrastructure expenditures and lengthy lead periods for deployment, off-grid and microgrid systems can be swiftly deployed and customised to fulfil the distinct energy requirements of communities. As communities grow and change, this flexibility allows for incremental growth and swift responsiveness to shifting energy demands.

In the face of climatically related catastrophes and natural calamities, off-grid and microgrid solutions also provide resilience and dependability. These systems, which decentralised energy generation and distribution, make communities less susceptible to disturbances and outages in the grid and provide constant access to electricity for critical services and emergency response operations.

Off-grid and microgrid solutions also lessen greenhouse gas emissions and our dependence on fossil fuels, which promotes environmental sustainability. These

systems limit air pollution, carbon emissions, and environmental degradation by utilising renewable energy sources. This helps to mitigate climate change and encourages environmental stewardship.

Off-grid and microgrid systems not only help rural and off-grid areas get power, but they also stimulate economic growth and reduce poverty. Economic resilience is strengthened, and job possibilities are created when income-generating activities, including small-scale agriculture, agro-processing, and microenterprises, are made possible by access to dependable energy. In addition, the electrification of schools and healthcare facilities facilitates better access to information and communication technologies (ICTs), healthcare services, and education, all of which support the development of human capital and enhance quality of life.

Achieving sustainable development goals and combating energy poverty are made possible by off-grid and microgrid solutions. Through the provision of dependable, inexpensive, and sustainable electricity to marginalised communities, the enhancement of resilience, the promotion of environmental sustainability, and the stimulation of socio-economic development, these decentralised energy systems empower communities. In addition to being a workable strategy to combat energy poverty, investing in off-grid and microgrid solutions can help create a more just, sustainable, and inclusive future for all.

The brief aims to empower African rural communities by promoting governmental support and investment in off-grid and microgrid solutions. This goal is a result of the realisation that rural inhabitants throughout the continent continue to confront obstacles to energy access and that these obstacles must be urgently addressed with decentralised and sustainable energy solutions. It seeks to draw attention to the revolutionary potential of off-grid and microgrid solutions in enhancing socioeconomic development, expanding access to energy, and promoting the SDGs in rural Africa. It highlights how crucial investment and governmental support are to fostering an atmosphere that will allow these decentralised energy systems to be implemented and scaled up.

Current Energy Landscape in Rural Africa

Lack of access to electricity: Statistics and trends

Electricity is the cornerstone of modern civilisation, powering industries, lighting homes, and driving technological progress. However, for many rural areas in Africa, this vital resource remains out of reach. The lack of access to electricity in these regions is not just an inconvenience; it is a barrier to economic development, healthcare, education, and overall quality of life.

As of 2022, close to 600 million people across Africa do

not have access to electricity, predominantly in the sub-Saharan region. This represents about 43% of the total population, a stark contrast to the global electrification rate, which stands at 90%. The situation is even more dire in rural areas, where the electrification rate can be significantly lower than the national average. The recent global energy crisis, compounded by the COVID-19 pandemic, has reversed positive trends in improving access to modern energy. Notably, there has been a 4% surge in the number of people living without electricity from 2019 to 2022. This setback has deepened the financial difficulties of utilities, increased the risk of blackouts, and contributed to a sharp rise in extreme poverty in sub-Saharan Africa.

The Sustainable Development Goal (SDG) 7.1.1 is committed to ensuring universal access to cost-effective, dependable, and modern energy services by the year 2030. To realise this ambition, the Sustainable Africa Scenario (SAS) posits that it is imperative to establish connections for 90 million individuals annually, a pace that triples that of recent years. Nonetheless, fewer than 20% of African nations have established objectives to secure universal electricity access by 2030, revealing a considerable chasm between goals and the current state of affairs.

Energy Poverty

Energy poverty stymies socio-economic growth, as electricity is a fundamental driver of economic activity. In rural Africa, the absence of reliable power sources impedes the operation of businesses, limits agricultural productivity, and restricts access to global markets. The lack of electricity also hinders the development of infrastructure, such as roads and telecommunications, further isolating rural communities from economic opportunities.

Educational attainment in rural Africa is significantly affected by energy poverty. Schools without electricity struggle to provide quality education; they cannot use digital resources, offer evening classes, or maintain a conducive learning environment. Students are forced to study under inadequate lighting, which can lead to eye strain and hamper academic performance. The digital divide also widens, as children in unelectrified areas cannot develop the necessary computer skills for the modern workforce. The healthcare sector equally suffers immensely due to energy poverty. Clinics and hospitals without a stable power supply face challenges in storing medicines, operating medical equipment, and providing emergency services. This results in compromised healthcare delivery and increased vulnerability to diseases, particularly in remote areas where healthcare facilities are the only beacon of medical assistance.

For the majority of rural Africans, daily survival is contingent on natural resources, with energy poverty dictating the rhythm of life. Tasks such as cooking

and heating are performed using traditional biomass, which is time-consuming and poses health risks due to indoor air pollution. The lack of electricity also means that women and girls, who are typically responsible for household chores, spend considerable time collecting firewood and water, limiting their opportunities for education and income-generating activities. The impact of energy poverty on rural Africa is profound and far-reaching. It not only affects immediate health and educational outcomes but also has long-term implications for the socio-economic trajectory of the continent. Addressing energy poverty is not merely an infrastructural challenge; it is a prerequisite for unlocking the potential of rural communities and paving the way for a sustainable and equitable future.

Some challenges faced by rural communities in accessing grid electricity are highlighted below:

1. **Financial challenges:** Significant investment gaps exist for setting up and sustaining electrical grid infrastructure in rural regions.
2. **Operational Inefficiencies:** Outdated technologies and lack of proper maintenance lead to unreliable electricity services and frequent disruptions.
3. **Geographical Limitations:** The logistical and financial challenges of extending electrical grids to remote areas often result in limited coverage.
4. **Data Challenges:** A lack of transparent and up-to-date data impedes strategic planning and attracting necessary investments.
5. **Policy Gaps:** Inadequate policies, insufficient capacity for implementation, and complex bureaucracies often obstruct the development of the energy sector.
6. **Lack of technical Expertise:** There is a scarcity of skilled professionals to manage and maintain sophisticated energy systems in rural settings.
7. **Environmental factors:** Climatic changes threaten the reliability and sustainability of power supply systems.

Off-Grid Solutions: Overview and Benefits

Off-grid solutions refer to decentralised energy systems that operate independently of the main electricity grid, providing reliable and sustainable electricity access to communities that are not connected to centralised power infrastructure. These solutions are essential for addressing energy poverty in remote and underserved areas where grid extension is impractical or cost-prohibitive. Off-grid solutions typically utilise renewable energy sources such as solar, wind, hydroelectric, and biomass to generate electricity, offering clean and affordable energy access to off-grid populations.

There are several types of off-grid solutions, including:

- **Solar Home Systems (SHS):** Solar home systems consist of photovoltaic (PV) panels installed on rooftops or standalone structures to capture solar energy and convert it into electricity. These systems typically include a battery storage component to store excess energy generated during the day for use at night. Solar home systems provide electricity for lighting, charging small electronic devices, and powering appliances such as fans, televisions, and refrigerators in individual households.
- **Mini-Grids:** Mini-grids are localised electricity distribution networks that serve multiple households, businesses, and institutions in a specific geographic area. These systems are designed to operate independently of the main grid, utilising a combination of renewable energy sources (e.g., solar, wind, hydro) and sometimes diesel generators to generate electricity. Mini-grids typically consist of a centralised power generation facility, distribution lines, and metering infrastructure to supply electricity to end-users within the mini-grid coverage area. They offer a reliable and scalable solution for providing electricity access to communities that are geographically dispersed or located far from the main grid.
- **Pico-Grids:** Pico-grids are small-scale decentralised energy systems that serve a limited number of households or businesses within a localised area. These systems are similar to mini-grids but are designed to meet the energy needs of smaller communities or individual customers. Pico-grids typically consist of a small power generation unit (e.g., solar panels, wind turbines) connected to a battery storage system and distribution network. They are often deployed in remote villages, rural health clinics, schools, and other community facilities to provide basic electricity services for lighting, communication, and productive uses.
- **Standalone Power Systems (SPS):** Standalone power systems, also known as remote power systems or independent power systems, are off-grid energy systems that provide electricity to isolated or remote locations where grid connection is not feasible or cost-effective. These systems can include a variety of renewable energy technologies, such as solar PV, wind turbines, micro-hydro, and diesel generators, depending on the local resource availability and energy demand. Standalone power systems are commonly used in off-grid applications such as telecommunications towers, weather stations, remote mining sites, and off-grid residences.

These off-grid solutions play a critical role in expanding energy access, improving livelihoods, and fostering sustainable development in rural and off-grid areas. By leveraging renewable energy resources and decentralised energy systems, off-grid solutions offer a viable pathway towards achieving universal energy access and empowering communities to build resilient and inclusive energy systems for the future.

Off-grid solutions offer a multitude of benefits that make them a compelling choice for addressing energy poverty and promoting sustainable development in underserved communities. Here are some key benefits of off-grid solutions:

- **Increased Energy Access:** Off-grid solutions provide electricity access to communities that are not connected to the main electricity grid, expanding energy access to remote and isolated areas. By harnessing renewable energy sources such as solar, wind, and hydroelectric power, off-grid solutions enable households, businesses, and institutions to access clean and reliable electricity for lighting, cooking, heating, communication, and productive uses.
- **Affordability:** Off-grid solutions offer a cost-effective alternative to grid extension in areas where extending the centralised grid infrastructure is prohibitively expensive. By utilising renewable energy sources and decentralised energy systems, off-grid solutions minimise upfront infrastructure costs and ongoing operational expenses, making electricity access more affordable for off-grid populations. Additionally, off-grid solutions often involve innovative financing mechanisms such as pay-as-you-go (PAYG) models and microfinance, enabling customers to access electricity services through flexible payment plans.
- **Reliability:** Off-grid solutions provide reliable and uninterrupted electricity access, even in remote and underserved areas where grid reliability may be compromised. By decentralising energy generation and distribution, off-grid systems reduce the risk of grid outages and disruptions, ensuring continuous electricity supply for essential services, emergency response activities, and economic activities. Moreover, off-grid solutions often incorporate energy storage technologies such as batteries, allowing for energy storage and backup power during periods of low renewable energy generation or high demand.
- **Environmental Sustainability:** Off-grid solutions promote environmental sustainability by reducing reliance on fossil fuels and mitigating greenhouse gas emissions. By harnessing renewable energy sources such as solar, wind, and hydroelectric power, off-grid solutions minimise air pollution, water pollution, and carbon emissions associated with traditional fossil fuel-based energy

generation. Additionally, off-grid systems are typically designed to be energy-efficient and environmentally friendly, incorporating energy-saving technologies and sustainable practices to minimise environmental impact and conserve natural resources.

Off-grid solutions offer a range of benefits that contribute to improved quality of life, economic development, and environmental stewardship in rural and off-grid areas. By providing increased energy access, affordability, reliability, and environmental sustainability, off-grid solutions play a vital role in advancing universal energy access goals and empowering communities to build resilient and sustainable energy systems for the future.

Success stories and Case studies

- **Ethiopia's NEP 2.0** is a comprehensive initiative that aims to achieve universal electricity access by 2025. The program has a dual approach: expanding the national grid and deploying off-grid technologies, particularly in areas where grid extension is not feasible. NEP 2.0 has identified potential mini-grid sites and is working towards integrating renewable energy sources to power these grids. The program has already seen success in electrifying numerous households and is expected to reduce off-grid connectivity significantly by 2030.
- **Adem Tuleman**, a remote village in Ethiopia, serves as a prime example of successful rural electrification through hybrid renewable energy-based off-grid technology. The project involved the optimal hybridisation of wind, solar, and diesel systems to meet the village's energy demands. The electrification of Adem Tuleman has led to enhanced welfare and development of the community, with a financial analysis indicating the project's viability and sustainability. The success of this case study confirms the effectiveness of hybrid systems in electrifying remote rural communities.
- **The Nigerian Electrification Project and the Rural Electrification Fund have supported Nigeria's focus on mini-grid development.** These efforts have led to the establishment of numerous mini-grids across rural communities, providing stable and reliable electricity. The success of these projects has spurred economic growth, improved healthcare and education, and is projected to continue expanding, with the potential to electrify millions more in the coming years.
- **Kenya, Ethiopia, and Rwanda** have embraced solar power to electrify their rural areas. These countries have implemented various off-grid solar

systems, providing clean and sustainable energy to communities. The impact has been profound, with improvements in local businesses, healthcare services, and educational facilities. Future projections indicate that the continued adoption of solar technology will play a significant role in achieving energy independence and sustainability.

Microgrid Solutions: Overview and Advantages

A microgrid is a localised energy system that operates autonomously or in conjunction with the main grid, comprising interconnected loads and distributed energy resources (DERs) such as renewable energy sources, energy storage systems, and controllable loads. Microgrids are designed to provide reliable, resilient, and efficient electricity supply to a specific geographic area, such as a community, campus, industrial park, or military base, while also offering the flexibility to disconnect from or connect to the main grid as needed. Key characteristics of microgrids include:

- **Decentralised Energy Generation:** Microgrids incorporate a diverse mix of distributed energy resources (DERs) for electricity generation, including solar photovoltaic (PV) panels, wind turbines, micro-hydro generators, combined heat and power (CHP) systems, and diesel or natural gas generators. By diversifying the energy generation sources, microgrids reduce reliance on centralised power plants and fossil fuels, enhance energy security, and promote environmental sustainability.
- **Energy Storage:** Microgrids often incorporate energy storage systems such as batteries, flywheels, or pumped hydro storage to store excess energy generated during periods of low demand or high renewable energy production. Energy storage enables microgrids to balance supply and demand, optimise renewable energy integration, and provide backup power during grid outages or emergencies.
- **Intelligent Control and Management:** Microgrids are equipped with sophisticated control and management systems that monitor, optimise, and coordinate the operation of DERs, loads, and energy storage devices in real-time. Advanced control algorithms, automation, and communication technologies enable microgrids to dynamically adjust energy generation, consumption, and storage based on demand forecasts, grid conditions, and economic considerations.
- **Islanding Capability:** One of the distinguishing features of microgrids is their ability to operate in island mode, disconnected from the main grid during grid disturbances, blackouts, or emergencies. Microgrids employ islanding detection and control mechanisms to seamlessly transition between grid-connected and islanded modes, ensuring

uninterrupted electricity supply to critical loads and maintaining grid stability and reliability.

- **Grid Interconnection and Integration:** While microgrids can operate independently of the main grid in island mode, they can also be interconnected with the main grid to exchange electricity, ancillary services, and financial transactions. Grid-connected microgrids participate in demand response programs, ancillary service markets, and renewable energy integration initiatives, contributing to grid stability, reliability, and efficiency.
- **Resilience and Reliability:** Microgrids enhance energy resilience and reliability by reducing vulnerability to grid outages, natural disasters, and other disruptions. With their decentralised architecture and self-sufficiency, microgrids provide a resilient energy infrastructure that can continue to supply electricity to critical loads and essential services during emergencies or grid disturbances.

Microgrids offer a flexible, resilient, and sustainable energy solution that can address a wide range of energy challenges, including energy access, grid reliability, and environmental sustainability. With their decentralised energy generation, intelligent control systems, islanding capability, and grid integration features, microgrids play a crucial role in shaping the future of energy systems towards a more decentralised, resilient, and sustainable paradigm.

Advantages of microgrid solutions

Microgrid solutions offer a range of advantages that make them an increasingly popular choice for energy management and distribution.

1. **Flexibility:** Microgrids provide a high degree of flexibility in terms of energy sources and usage. They can integrate various types of distributed energy resources, including renewables like solar and wind, as well as conventional power sources. This flexibility enables microgrids to respond to shifts in energy supply and demand, including the availability of renewable energy or energy cost variations.
2. **Scalability:** Microgrids are inherently scalable, meaning they can be expanded or reduced in size depending on the needs of the community or facility they serve. This ensures that microgrids can start small and grow as demand increases, or they can be scaled down if necessary without significant impact on the broader energy system.
3. **Resilience:** One of the key advantages of microgrids is their resilience. In the event of a larger grid failure, microgrids can disconnect from the main grid and continue to operate independently, providing uninterrupted power

to critical infrastructure and services. This capability is particularly important in areas susceptible to extreme weather events or where grid reliability is not guaranteed.

4. **Community Ownership:** Microgrids can be owned and operated by the communities they serve, which fosters local engagement and investment in energy solutions. Community ownership allows for decision-making that reflects the community's specific needs and priorities, such as sustainability goals or economic development. It also keeps the economic benefits, such as job creation and revenue generation, within the community.

Microgrids have been successfully implemented in various rural African communities, providing reliable and sustainable energy solutions. In South Africa, microgrids have been established to address the electrification challenges in remote rural areas. These microgrids often incorporate energy storage systems, distributed generators, and localised loads to ensure sustainable and consistent operation. The country has focused on creating a supportive policy framework to facilitate the development of microgrids that can provide electricity to rural communities. Uganda also has seen the socio-economic benefits of solar photovoltaic-based mini-grids in rural communities. These systems have proven to be environmentally clean, economical, and socially beneficial, providing sustainable lighting for homes and power for small businesses.

Policy Recommendations

To foster the growth of off-grid and microgrid solutions in rural Africa, a comprehensive approach involving regulatory, financial, educational, and strategic initiatives is essential.

- **Enabling Regulatory Frameworks:** Regulatory frameworks serve as the backbone for the development and operation of off-grid and microgrid systems. Streamlining licensing procedures can remove bureaucratic hurdles and accelerate project initiation. Simplifying tariff structures ensures that pricing is fair for consumers and financially viable for operators. Establishing technical standards guarantees system safety, reliability, and compatibility with existing and future energy systems.
- **Financial Incentives and Support Mechanisms:** Financial incentives such as subsidies and grants can reduce the initial investment barrier, making rural electrification projects more appealing to investors and affordable for communities. Support mechanisms like low-interest loans or risk guarantees can encourage private-sector investment by mitigating financial risks associated with rural electrification.

- **Capacity Building and Technology Transfer:** Investing in human capital through training programs and knowledge sharing is vital for the sustainable management of off-grid and microgrid systems. Partnerships with experienced organisations can facilitate technology transfer, ensuring that local technicians are equipped to handle these systems' installation, operation, and maintenance.
- **Integration with National Energy Planning:** Integrating off-grid and microgrid solutions into national energy strategies ensures that these systems are recognised as a significant component of the overall energy infrastructure. This integration helps in planning for grid expansion and determining the role of microgrids within the national energy landscape.



The Case for Investment and Partnership

- **Economic opportunities:** Off-grid and microgrid projects are more than energy solutions; they are economic catalysts. They have the potential to create jobs in the construction, maintenance, and operation of energy systems. Local entrepreneurship can thrive with reliable electricity, leading to the growth of small businesses and stimulating broader economic development. These projects can also attract new industries and improve productivity in existing sectors, contributing to the overall economic upliftment of rural communities.
- **Social impact:** Reliable electricity can lead to better healthcare services by enabling the operation of medical equipment and the preservation of medicines. Education outcomes can improve with extended study hours and access to digital resources. Energy projects can also promote gender equality by reducing the time women and girls spend collecting fuel, allowing them more time for education and economic activities.
- **Environmental benefits:** Off-grid and microgrid projects often utilise renewable energy sources, which have a lower environmental impact than traditional fossil fuels. By reducing greenhouse gas emissions, these projects contribute to global efforts against climate change. They also promote sustainable development by reducing reliance on non-renewable resources and encouraging conservation and efficient energy use.

Conclusion

The role of off-grid and microgrid solutions in empowering rural African communities cannot be overstated. These systems are crucial for providing sustainable energy access, which is foundational to the socio-economic development of these areas. They are instrumental in harnessing local renewable resources, reducing dependence on fossil fuels, and providing resilient power that can withstand disruptions. The implementation of these systems has been shown to drive economic opportunities, enhance healthcare and education, and promote gender equality. Investment in off-grid and microgrid projects is not merely a financial venture but a partnership towards sustainable development. Therefore, there is a pressing call to action for policymakers, donors, stakeholders, investors, local governments, international agencies, private investors, and community members to prioritise and support off-grid and microgrid initiatives. This support is essential for ensuring sustainable energy access in rural Africa and fostering a brighter future for all. By investing in these solutions, we can make a significant impact on the lives of millions, paving the way for a more equitable and sustainable world.



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