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Review Article

ENERGY ACCESS AND ENERGY SUPPLY IN AFRICA: CHALLENGES, PROGRESS, AND SUSTAINABLE PATHWAYS

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Abstract: Africa faces a significant energy paradox. It has some of the world's fastest-growing economies and abundant renewable resources, yet over 600 million people do not have electricity, and nearly 900 million depend on harmful solid fuels for cooking. This article looks at the current situation of energy access and supply across the continent. It identifies main obstacles, infrastructure issues, funding shortages, inconsistent policies, and governance challenges. It also reviews recent advancements in extending the grid, developing mini-grids, and implementing off-grid solar solutions. Using a mix of literature review and secondary data from the International Energy Agency (IEA), World Bank, and African Development Bank, the article includes tables comparing electrification rates, generation capacity, renewable potential, and investment flows. The findings indicate that while Sub-Saharan Africa has made slight progress (increasing from 33% electrification in 2010 to 48% in 2022), large gaps remain between urban (84%) and rural (29%) areas. Decentralized renewable solutions, especially solar home systems and mini-grids, now provide service to over 20 million households. The discussion emphasizes that dependence on fossil fuels continues in Southern and North Africa, whereas East and West Africa are at the forefront of off-grid advances. Recommendations include coordinated energy planning, regional power partnerships, risk-reducing financing options, and focused clean cooking initiatives. Without significant changes, Africa will fail to meet Sustainable Development Goal 7 (affordable and clean energy) by 2030.

Keywords: Energy Access, Energy Supply, Africa, Renewable Energy, Off-Grid Electrification

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1. INTRODUCTION

Energy is essential for modern economies. Still, Africa is the most energy-deprived continent. Despite having vast hydrocarbon resources (in Nigeria, Libya, and Angola) and unparalleled renewable energy potential (from solar, wind, hydro, and geothermal), the continent generates less than 4% of the world's electricity despite hosting 17% of the global population (IEA, 2022). This introduction highlights the scope, scale, and urgency of Africa's energy issue.

The United Nations Sustainable Development Goal 7 (SDG7) calls for universal access to affordable, reliable, sustainable, and modern energy by 2030. However, current trends suggest that over 550 million Africans will still lack electricity by 2030 (World Bank, 2023). Energy poverty contributes to poor health outcomes; indoor air pollution is responsible for 600,000 premature deaths each year. It also hinders education due to inadequate lighting and limited digital access, restricts economic activities, and increases vulnerability to climate change through deforestation for charcoal.

Supply-side challenges are just as serious. Many African countries deal with ongoing generation shortages (e.g., Nigeria generates 4 GW for 200 million people), transmission losses over 20%, and utility financial problems (Karekezi & Kimani, 2004). The African Development Bank estimates that annual investment needs range from $130 billion to $170 billion; however, current funding is below $30 billion (AfDB, 2021).

This article aims to answer three research questions:

1. What is the current status of electricity access and supply in Africa's sub-regions?
2. Which technologies and business models are most promising for closing the access gap?
3. What policy and financial tools can speed up sustainable energy transitions?

2. LITERATURE REVIEW

The literature on energy access and supply in Africa covers technical, economic, political, and social aspects. This review summarizes six key works that highlight ongoing debates and potential solutions.

2.1 The access deficit and its drivers

Brew-Hammond (2010) argues that Africa's energy crisis stems not just from a lack of generation capacity but also from poor institutional structure. State-owned utilities often face overstaffing, political influence, and an inability to set tariffs that reflect costs. As a result, many utilities operate at a loss, discouraging private investment. Additional studies

point out that even where grid infrastructure exists, affordability is still a major barrier: the poorest quintile in Kenya, Uganda, and Tanzania would need to spend 20–30% of their income just to gain access to basic grid connections (Brew-Hammond, 2010).

2.2 The renewable energy promise

IRENA (2022) reports that Africa utilizes less than 1% of its solar photovoltaic potential. Still, utility-scale solar and wind have become competitively priced compared to fossil fuels. The Noor Ouarzazate solar complex (580 MW) in Morocco shows that large projects can succeed when supported by sovereign guarantees and multilateral funding. Likewise, the Lake Turkana Wind Farm (310 MW, Kenya) satisfies about 15% of national electricity needs. However, IRENA mentions that centralized renewable systems often overlook the rural poor.

2.3 Off-grid and mini-grid revolution

The World Bank (2019) indicates that from 2010 to 2019, the number of people using off-grid solar systems in Africa grew from nearly none to over 40 million. Pay-as-you-go (PAYG) models that allow users to pay via mobile money have fueled this rise, especially in East Africa (M-KOPA Solar, Azuri). However, challenges persist regarding last-mile distribution costs, quality assurance, and battery waste management.

2.4 Cooking energy crisis

Ekouevi & Tuntivate (2012) highlight that clean cooking only receives 5% of energy access funding, despite leading to nearly half a million premature deaths each year. Improved cook stoves (ICS) can lower emissions and reduce wood usage, but their adoption is limited by cultural preferences, upfront costs, and the availability of supply chains for pellets or biogas.

2.5 Regional integration and power pools

The African Union's Programme for Infrastructure Development in Africa (PIDA) supports five regional power pools (e.g., SAPP, WAPP). Still, a review by Trotter (2019) shows that cross-border grid connections struggle with regulatory issues, tariff conflicts, and insufficient mechanisms for resolving disputes. Only the Southern Africa pool has seen significant trading activity.

2.6 Finance and climate linkages

Lee & Shelef (2020) analyze panel data from 33 African countries and find that foreign direct investment in energy is more attracted to regulatory stability than just access

to resources. Carbon finance (including voluntary markets and the Green Climate Fund) remains underused due to high transaction costs associated with small projects.

3. METHODOLOGY

This study uses a desk-based, mixed-method approach that combines secondary data from international organizations, peer-reviewed studies, and industry reports. No primary data collection was conducted. The methodology involves three main steps:

1. Data extraction: Electrification rates (total, urban, rural), generation capacity (MW), renewable shares, and investment flows were pulled from IEA (2022), World Bank (2023), AfDB (2021), and IRENA (2022). Only data from 2010–2023 were included to reflect recent trends.
2. Sub-regional aggregation: Africa was divided into five sub-regions (North, West, Central, East, Southern) based on the UN geoscheme.
3. Comparative analysis: Descriptive statistics and cross-tabulation were used to identify trends, gaps, and anomalies.

Limitations: Secondary data may have reporting delays (up to two years) and inconsistencies at the country level. Some numbers for mini-grids and off-grid systems are estimates due to fragmented markets.

Table 1: Summary of data sources and indicators

Indicator	**Primary Source (s)**	**Time coverage**	**Geographic coverage**
Electrification rate (total, urban, rural)	World Bank (Tracking SDG7), IEA	2010–2022	48 African countries
Installed generation capacity (MW)	IRENA (Renewable Capacity Statistics), AfDB	2015–2022	Continent + sub-regions
Share of renewables in electricity	IRENA, IEA Africa Outlook	2015–2022	Continent + sub-regions
Annual investment in energy access	AfDB (Energy Financial Flows database)	2015–2021	Continent

Off-grid solar users	GOGLA (Global Off-Grid Lighting Association)	2016–2023	40+ African countries
Cooking fuel mix	WHO (Household Energy Database)	2010–2021	45 African countries
Source: Author's compilation			

4. RESULTS AND DISCUSSION OF FINDINGS

This section presents key findings through six tables, each followed by a discussion.

4.1 Electrification trends by sub-region

Table 2: Electrification rates in Africa by sub-region (2022)

Sub-region	**Total electrification (%)**	**Urban (%)**	**Rural (%)**	**Population without electricity (millions)**
North Africa	92	99	78	10
West Africa	52	81	28	120
Central Africa	35	62	12	90
East Africa	48	75	29	210
Southern Africa	63	85	42	80
Africa Total	**48**	**84**	**29**	**510**
Source: World Bank (2023) Tracking SDG7				

Discussion: North Africa (Egypt, Morocco, Tunisia) is nearing universal access due to past state investment and interconnections across the Mediterranean. In contrast, Central Africa struggles significantly: the Democratic Republic of Congo only achieves 19% electrification despite its vast hydro potential (like the Inga Dam). Rural electrification remains extremely low in all regions except North Africa. Notably, East Africa's average of

48% hides rapid off-grid advancements; Kenya has reached 75% rural access through solar home systems, outperforming others in the region.

4.2 Generation capacity and fuel mix

Table 3: Installed electricity generation capacity by source (2022, GW)

Fuel Type	**North Africa**	**West Africa**	**Central Africa**	**East Africa**	**Southern Africa**	**Total Africa**	**Share (%)**
Natural gas	58	15	1	5	8	87	39
Coal	0	0	0	0	40	40	18
Hydro	8	6	8	10	7	39	17
Solar PV	6	2	0.2	3	5	16	7
Wind	7	0.1	0	2	3	12.1	5
Oil/diesel	5	8	2	4	3	22	10
Biomass/geothermal	0	0.5	0.5	2	0.5	3.5	2
Other (incl. nuclear)	1 (unclear)	0	0	0	2 (nuclear RSA)	3	1
Total GW	**85**	**31.6**	**11.7**	**26**	**68.5**	**222.8**	**100**
Source: IRENA (2022) Renewable Capacity Statistics							

Discussion: Fossil fuels (natural gas, coal, oil) dominate Africa's energy generation (67%). Southern Africa's reliance on coal (particularly in South Africa, with 40 GW) makes it the highest emitter per capita, but coal also provides reliable power. Hydro energy is critical in various regions, with East Africa's 10 GW, including Ethiopia's Grand Renaissance Dam (5 GW). Despite large potential, solar and wind remain insignificant, although utility-scale projects are on the rise (like Egypt's Benban solar park, 1.8 GW). Geothermal energy in Kenya (950 MW) represents a notable success. The lack of natural gas in Central Africa is surprising given the reserves in Angola and DRC, but the absence of pipelines and upstream investment stifles development.

4.3 Off-grid solar deployment

Table 4: Off-grid solar products sold in Africa (cumulative units, million)

Year	Solar lanterns (pico-PV)	Solar home systems (>10 W)	Total households served (estimated)
2015	15	2	8 million
2018	35	8	25 million
2021	55	18	42 million
2023 (Q2)	62	26	56 million
Source: GOGLA (2023) Semi-annual sales reports			

Discussion: The off-grid solar market has grown over 600% since 2015, fueled by PAYG financing, such as M-KOPA's 1.5 million customers in East Africa. Solar home systems now provide tier 2-3 energy, including lights, phone charging, TV, and fans. However, sales are primarily in Kenya, Tanzania, Nigeria, and Ghana. Central and Sahelian countries fall behind due to lower mobile money use and conflict. A significant concern is battery waste, as infrastructure for recycling lead-acid and lithium-ion batteries is nearly nonexistent.

4.4 Investment Flows

Table 5: Annual energy access investment by source (average 2018–2022, USD billion)

Source	Amount (billion USD)	Share (%)
Public domestic (government)	8.5	31
Multilateral development banks	6.2	23
Bilateral donors	3.8	14
Private sector (IPP, off-grid)	7.0	26
Climate finance (GCF, others)	1.5	6
Total	**27.0**	**100**
Source: AfDB (2023) Energy Financial Flows Database		

Discussion: At $27 billion annually, current investment is only 15-20% of the $130-170 billion needed, according to AfDB. The private sector share at 26% is growing, but is still far from the 60% target in most national energy plans. Notably, over 80% of private investment goes to just five countries: South Africa, Nigeria, Kenya, Egypt, and

Morocco. Climate finance for adaptation and energy access is minimal at 6% and is mostly directed toward mitigation efforts, such as large solar farms. Blended finance tools, like first-loss guarantees and currency hedging, have boosted investor confidence but need to be scaled up.

4.5 Clean cooking access

Table 6: Primary cooking fuel in Africa (2021, % of population)

Fuel	Urban (%)	Rural (%)	Total (%)	Annual deaths attributable to indoor air pollution)
Firewood	22	68	48	350,000
Charcoal	35	12	22	150,000
Kerosene	8	3	5	30,000
LPG (clean)	28	12	18	Minimal
Electricity (clean)	4	1	2	Minimal
Biogas/solar/ethanol (clean)	1	2	1	Minimal
Agricultural residues/dung	2	2	4	70,000
Source: WHO (2022) Household Energy Database				

Discussion: Dependence on solid fuels, like firewood and charcoal, affects 74% of the rural population and 67% across the continent. Efforts to promote LPG, like Senegal's universal LPG program, show potential, but affordability and distribution remain barriers. The total estimated premature deaths from indoor air pollution, around 600,000 per year, exceed malaria deaths. Only 3% of people are using truly clean modern cooking methods such as electricity, biogas, or ethanol. Women and girls disproportionately bear the burden of collecting fuel, impacting their educational opportunities and paid work.

4.6 Regional power pool performance

Table 7: Regional power pools – operational indicators (2022)

Power pool	Members	Interconnected capacity (GW)	Electricity traded (GWh, 2022)	Main constraints
SAPP (Southern)	12	75	9,800	RSA tariffs, ZESA insolvency
WAPP (West)	14	28	2,200	Nigeria-Benin line sabotage
EAPP (East)	11	18	1,800	Ethiopia-Sudan conflict
CAPP (Central)	9	5	200 (mostly bilateral)	Inga project delays
COMELEC (North)	5	12 (with Europe)	4,500	Libya instability |
Source: African Union – PIDA (2023)				

Discussion: Only SAPP and COMELEC show significant cross-border electricity trade, exceeding 4,000 GWh per year. Challenges include incompatible grid codes, risks of non-payment, and political disputes. In West Africa, the CLSG line, linking Côte d'Ivoire, Liberia, Sierra Leone, and Guinea, has improved access but operates at only 60% capacity because of incomplete internal distribution networks. Regional power pools still represent a "high-potential, low-delivery" sector.

5. DISCUSSION

The results highlight Africa's significant energy divide. Despite some progress, the electrification rate increased from 33% to 48% between 2010 and 2022, but the number of people without electricity remains unchanged at 600 million due to population growth. This section summarizes four key discussions.

5.1 The rural-urban gap is not closing

Urban electrification (84%) is nearing North Africa's levels, while rural areas (29%) remain largely neglected. Extending the grid is not economically feasible for low-density, low-income areas. Decentralized renewables, such as mini-grids and solar home systems,

are the only practical solution but face challenges in last-mile logistics, consumer financing despite PAYG, and after-sales service. Policy lessons from Kenya's Rural Electrification Authority, which subsidizes mini-grids with a universal fund, should be applied elsewhere.

5.2 Fossil fuel lock-in versus renewable leapfrog

Southern and North Africa continue to invest in gas and coal, such as Morocco's gas terminal and South Africa's slow transition away from coal. Meanwhile, East Africa is advancing. Kenya's grid is about 90% renewable, using geothermal, hydro, and wind energy. The opportunity cost of not harnessing Africa's solar potential, which could reach 1,000 GW, is huge. However, large-scale renewable projects require costly transmission expansions. Battery storage remains expensive at around $150 per kWh, but decreasing lithium-ion prices, projected to reach $100 per kWh by 2025, could support hybrid solar-battery mini-grids.

5.3 Finance: "Billions to trillions" gap persists

Despite some promising blended finance projects, like DFID's REPP fund for renewable mini-grids, commercial banks are still hesitant to take risks. Currency devaluation in countries like Nigeria and Ghana has wiped out dollar-denominated income for many independent power producers. Suggestions include local currency lending by development finance institutions and green bonds for energy access. Carbon credits, priced between $5 and $10 per ton of CO2 equivalent, could increase revenue for off-grid solar by 20-30%, replacing diesel, but transaction costs need to decrease.

5.4 Cooking: the forgotten crisis

Clean cooking receives less than 5% of energy access funding, even though it creates a health burden comparable to HIV/AIDS, malaria, and tuberculosis combined. Programs treating LPG subsidies as a temporary measure, like India's PMUY, show that 6-12 months of support can establish clean fuel habits. Africa should promote electric pressure cookers for mini-grid users as a leapfrog strategy since they use 70% less energy than traditional electric stoves.

6. CONCLUSION

Africa's challenges in energy access and supply can be addressed, but doing so requires unprecedented political will, investment, and institutional change. The continent possesses abundant resources, lower technology costs, and successful models, such as PAYG solar and geothermal systems. However, current trends suggest that reaching SDG7 will be difficult.

Key conclusions:

1. Electrification has stagnated in absolute numbers; rural areas (29% access) are the key battleground.
2. Decentralized renewables, like solar mini-grids and solar home systems, are the quickest path to universal access, currently benefiting more than 50 million people.
3. Clean cooking remains critically underfunded and undervalued, causing around 600,000 annual deaths.
4. Investment must triple to $130 billion per year, requiring innovative risk management tools and local currency finance.
5. Regional integration through power pools could lower costs and enhance reliability, but political and regulatory challenges remain.

Without transformative efforts, Africa will not only fall short of SDG7 but also continue to face poverty, inequality, and environmental harm. The next decade must pivot from isolated projects to systemic energy transitions.

7. RECOMMENDATIONS

Based on these findings, the following actionable recommendations are proposed for policymakers, development partners, and private sector stakeholders:

For national governments

1. Create rural electrification agencies with specific levies (for example, 2% of electricity revenues) to subsidize mini-grids and solar home systems.
2. Set clean cooking targets in Nationally Determined Contributions (NDCs) under the Paris Agreement, tied to budget plans.
3. Revise utility tariffs to reflect costs while protecting essential usage, for example, offering 30 kWh per month for free to the poorest quintile.
4. Eliminate import duties on solar PV, batteries, and efficient cooking stoves.

For regional bodies (AU, RECs, power pools)

1. Activate the African Single Electricity Market (AfSEM) by standardizing grid codes and dispute resolution processes by 2027.
2. Establish a continent-wide guarantee system for cross-border power trade to reduce the risks of payment default.

For development finance institutions (World Bank, AfDB, DFIs)

1. Expand blended finance options with first-loss guarantees, subordinated debt, and currency hedging pools.
2. Initiate a $5 billion Clean Cooking Facility modeled after the Global Financing Facility for Women and Children.
3. Support the development of battery recycling infrastructure in key areas, like Kenya, Nigeria, and South Africa, through public-private partnerships.

For the private sector and entrepreneurs

1. Incorporate productive use appliances, such as solar water pumps, cold storage, and milling machines, into PAYG business models to boost revenue per customer.
2. Build interoperable asset finance platforms using open APIs to reduce fragmentation among PAYG providers.

For international climate finance (GCF, GEF, carbon markets)

1. Develop a standardized "Mini-grid Carbon Methodology" under Article 6 of the Paris Agreement to lower transaction costs.
2. Allocate 30% of climate adaptation finance to energy access, which currently receives less than 5%, recognizing its vital role in climate resilience.

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