United Nations University
Vice-Rectorate in Europe

POLICYBRIEF

Transforming rural energy access in sub-Saharan Africa with digital technologies

Key insights

1.

Digitalization presents a unique opportunity to address energy access challenges in sub-Saharan Africa by leveraging frontier technologies to develop **practical** and **contextualized solutions**, supported by **enabling regulatory and institutional environments**.

2.

Knowledge and skills gaps in the workforce limit the utilization of innovative technological and financial approaches to enhance energy access in rural areas. This demands the **periodic upskilling of the workforce** in state-of-the-art technologies.

3.

Advancing rural electrification and clean cooking technologies in sub-Saharan Africa is constrained by financial, technological and governance challenges, including high investment risks for the private sector and limited end-user affordability. **Investing** in **alternative energy solutions** that leverage digital technologies while also **involving communities** and other **stakeholders (particularly the private sector and academia)** in their development and operation can help reduce such constraints.

4.

Marginalized groups, particularly rural women and girls, are disproportionately impacted by limited energy access in the region. Enhancing their **digital literacy** and **enabling** their participation in the energy transition can help not only to close the gender gap but also to achieve energy access for all.

5.

Energy systems in sub-Saharan Africa are already **witnessing climate-change-induced operational challenges**. In rural energy planning, considering the current and future impacts of climate change as well as the risks to supply and demand can help minimize negative impacts and avert losses, while increasing long-term resilience and cost-effectiveness.

Background

As of 2023, approximately 90 per cent of the world's population had access to electricity, yet nearly 666 million people remained without it (World Bank, 2025). Sub-Saharan Africa (SSA) accounts for the overwhelming majority of people without electricity – around 600 million people – and 18 of the 20 countries with the largest access deficits are in the region (World Bank, 2025). This underscores how rapid population growth has outpaced electrification gains. This gap is most evident in rural areas, where many households do not have access to electricity or clean cooking fuels and technologies.

Although recent years have witnessed a steady decline in access deficits, the challenge persists due to several factors including global disruptions such as COVID-19, which affected energy prices and electrification efforts worldwide. SSA has also been hit by climate impacts, such as increasingly frequent and severe floods and droughts. This is further compounded by rapid population growth in the region. Simultaneously, only 7 per cent of rural households in SSA have access to clean cooking fuels and technologies (WHO & University of Glasgow, 2025), making it the only region in the world where the urban–rural gap in access to clean cooking is rising (AFREC, 2026; IEA, 2024). The lack of access to clean cooking solutions contributes to greenhouse gas emissions and deforestation (Energy and Industry Transition, 2024). This disproportionally affects women and girls, who often work long hours for little or no pay while being more vulnerable to indoor air pollution-related health impacts due to exposure to biomass fuel collection and burning (ENERGIA and others, 2018).

In this context, ensuring access to clean and sustainable energy for all must be an urgent political priority at all levels. In SSA, this will require providing access to electricity to approximately 100 million additional people every year (IEA, 2024), most of whom live in remote rural areas. **This calls for innovative energy solutions supported by transformative energy policies, and will also require infrastructure development and capacity-building, and the use of supportive financial mechanisms and frontier technologies.**

Opportunities in a "digitalizing" world

Digital technologies can drive innovation and entrepreneurship across sectors, thus multiplying energy transition efforts (IRENA, 2025). Digitalization is already transforming energy access around the world (Engelmeier and others, 2020), making the energy value chain sustainable, safer and more efficient (Engelmeier and others, 2020). Fintech (financial technology) innovations, such as mobile-based finance, are also rising in SSA, driven by the widespread use of smartphones across the region (Hornuf and others, 2024).

© HisArt Photos / Unsplash

This offers a unique opportunity to leverage emerging digital technologies (called "frontier technologies") to achieve safe, sustainable and affordable rural energy access in SSA, while accelerating the low-carbon energy transition. However, leveraging this opportunity will require integrating digitalization into regional and national energy policies. Countries in SSA can also benefit from engaging in collaborations and knowledge exchanges as they work to adapt the application of frontier technologies to local contexts, and build on existing research and development to speed up and scale up implementation. Transdisciplinary efforts and cross-sectoral coordination are fundamental to such advancements.

Relevant capacity enhancement and upskilling

The current global information and communications technology (ICT) landscape is largely shaped by high-income countries, which often lead the research, develop the technologies and establish governance frameworks. However, these frameworks tend to prioritize individual and household-level needs, whereas the low- and middle-income countries require more community-based approaches to effectively address their unique challenges (OECD, 2009). In SSA, gaps in the technical skills of the workforce employed (or involved) in the energy/electricity sector limit the incorporation of digital technologies in advancing energy access. Moreover, **constrained digital capacities and capabilities** pose a barrier to widespread uptake of innovative technological approaches in the energy

sector, especially in rural communities. There is also a big gender gap in the energy sector (Idem and others, 2024), both in terms of the inclusion of women in the workforce and consideration of their needs and perspectives when making energy access investments and designing interventions (Gbolonya & Tetteh, 2025; Jodoin and others, 2024).

Enhancing the **capacity** of the energy sector workforce, particularly in related **frontier technologies** (e.g. internet of things [IoT]-based off-grid energy systems, smart system integration, remote monitoring, machine learning [ML]-based automated analytics), can address the specific needs of the region, empower local communities and create a more skilled workforce (Ayuk, 2023). Closing the gender gap by enabling greater female participation in energy-related fields is also crucial for promoting inclusive growth (IUCN, 2020). Additionally, supporting green innovations and sustainable energy solutions can drive progress, helping the region transition to a more resilient energy system (Payton, 2024).

Interlinked investments and returns in the energy sector and consumer affordability

Despite the limited public funding available for grid extension, upgradation, as well as last-mile grid connection, several SSA countries have undertaken rural electrification campaigns. However, low energy consumption – particularly due to high costs and nominal paying capacity of end users – hinders these efforts, keeping people in a vicious circle of poverty (World Bank Group, 2019a). For example, despite unreliable electricity supply across SSA, the average cost per unit is seven times higher than in the Middle East and North Africa region (World Bank Group, 2019b). At the same time, the low paying capacity of consumers disincentivizes private sector investments due to the high risks involved (IEA & AfDB, 2023). The lack of enabling energy policies and adequate guarantee mechanisms are significant barriers to private sector investment in rural electrification projects in SSA. Without governance and institutional reforms that address investment risks, including policy and regulatory uncertainties, the attractiveness of decentralized energy systems remains low, hindering progress toward universal electricity access (Falchetta and others, 2021). On the demand side, **innovative fintech solutions are driving small-scale decentralized rural energy access**, such as "pay-as-you-go" approaches in Kenya (IRENA, 2020a) and Uganda (UNCDF, 2020), enabling rural dwellers with limited financial capacities to access clean and reliable energy. This highlights the importance of innovative and context-specific technology and financial models in enhancing energy access.

Infrastructure development and enhancing resilience through digitalization

In most SSA countries, the electricity sector depends largely on public utilities (Baskaran & Coste, 2024). Limited fiscal capacity and high levels of debt hinder public investments in energy infrastructure (Baskaran & Coste, 2024), leading to multiple challenges. For instance, distribution networks are largely underdeveloped and characterized by inefficient equipment and technologies (IEA, 2024). At the same time, at the global level, the energy sector is projected to become more sustainable to address changing climatic conditions, as the proportion of energy sources that are renewable continues to increase; however, political volatility may influence this transition (IRENA, 2020b). Energy systems in SSA are already facing climate change-related operational challenges due to extreme events, such as droughts that particularly affect hydropower (Falchetta and others, 2019). The lack of spatial and technological diversity of small-scale energy systems makes them particularly vulnerable to climate variability.

Digitalization provides an opportunity to **modernize** the existing infrastructure of energy systems (IRENA, 2026), **decentralize** production (e.g. IoT-based off-grid solutions [Okafor, 2025]) and **reduce operational losses**, assist in **integrating** fluctuating and scattered renewable energy resources into the grid (FTSG, 2025), and make energy services more climate resilient, thereby improving energy efficiency and reliability.

Creating an enabling policy and regulatory environment

There are also significant limitations in current policies, particularly in ensuring that energy prices are aligned with the local economic conditions of rural populations. Additionally, the social-economic equity gap between rural and urban areas must be bridged with particular attention to the needs

© Konstantin Dyadyun / Unsplash

of the most vulnerable sections of society. Issues such as land tenure rights and energy efficiency also need to be addressed.

Through **real-time monitoring, efficient energy distribution and data-driven decision-making**, digital technologies can enhance the reliability and affordability of energy services. Energy transformation, however, also requires addressing root causes such as poverty, piecemeal regulations, limited financial resources and technical capacities, and infrastructure challenges. Finally, raising awareness and promoting the adoption of renewable energy, particularly solar power, are crucial steps to increase energy access (Sanchez Santillano and others, 2024). An enabling environment for cohesive efforts that integrates socioeconomic, political and environmental perspectives into policies, investments, digital innovations, and pursues cross-sectoral coordination, is urgently needed.

Policy options and recommendations

1. Integrating digitalization into regional and national energy policies to leverage frontier technologies for sustainable, safe and affordable rural energy access in SSA

Recommendation: To maximize the potential of digitalization for achieving energy access for all, SSA countries should adopt a multifaceted approach that integrates frontier technologies into energy policies, fosters cross-sectoral collaboration, invests in local capacity-building and promotes regional knowledge sharing. By embedding digital strategies into energy frameworks, countries can enhance grid optimization, encourage decentralized energy solutions, and promote Fintech systems. Such integration can accelerate collaboration between the government, the private sector, civil society and non-governmental organizations, and catalyse scalable and context-specific digital solutions.

2. Accelerating digital technology innovation and uptake to support rural energy access

Recommendation: To improve rural energy access, digital innovation incubators with regulatory and financial support shall be established by competent authorities across SSA. This should be complemented with robust digital infrastructure and services – especially reliable internet services – and energy supply chain digitalization.

3. Creating an enabling regulatory and institutional environment for innovation and collaboration

Recommendation: To enhance energy access in SSA through digitalization, regulations, standards and institutions that foster collaboration should be put in place. This can enable innovators, technology providers, research institutions, energy companies and other stakeholders to develop contextually relevant accessible solutions.

4. Decentralizing infrastructure for energy access

Recommendation: Network alternatives (e.g. off-grid and micro-grid energy production) and the involvement of communities in the development and operation of such alternative systems (such as through community-based organizations) should be encouraged by competent authorities to decentralize energy access infrastructure.

5. Integrating current and future climate change risks into the planning and operation of rural energy systems to minimize negative impacts and avert losses

Recommendation: To make rural energy systems future ready, it is recommended that the competent national and regional actors develop robust climate risks and impact models that leverage frontier technologies. Such models should integrate considerations of current and future climate change scenarios, including anticipated impacts on demand and supply, into energy planning and operations.

6. Nurturing investment in decentralized, modular, small-scale energy providers, particularly for low-income rural communities

Recommendation: National and regional actors should support and nurture investment in frontier technology-based energy systems that offer innovative and inclusive solutions for end users, address investment risks and can make energy more affordable. For example, building on successful financing models for energy services (e.g. pay-as-you-go) and exploring frontier digital technologies (e.g. blockchain and IoT) to support small-scale rural energy trading/markets (through peer-to-peer energy trading).

7. Developing a skilled workforce capable of driving a fair and inclusive energy-access agenda and energy transition

Recommendation: Periodic upskilling of the workforce employed (or involved) in the energy/electricity sector across the entire value-chain in necessary frontier technologies (e.g. IoT-based off-grid energy systems, smart system integration, remote monitoring, ML-based automated analytics). This shall be complemented with enhancing the understanding of potential impacts and benefits of such technologies on the rural communities. Such training should be tailored to local conditions, regulations, and the likely impacts of changing climate. Additionally, developing specialized curricula and training programmes will help to equip the next generation. Strengthening linkages between universities and industry, and promoting regional centres of excellence, can help build a skilled workforce capable of driving scalable, locally adapted energy-access solutions.

8. Enabling participation of rural communities, particularly women and youth, in energy transition processes

Recommendation: Building capacities of rural communities, particularly women and youth, and enhancing their digital skills can further improve their employability and empower them to use digital innovations and participate in the energy market. This can include establishing partnerships among various stakeholders, including local authorities, civil society and energy companies, to identify and empower local energy champions.

References

African Energy Commission (AFREC) (2026). Sustainable scaling: Meeting the clean cooking challenge in Africa. AFREC. https://au-afrec.org/sustainable-scaling-meeting-clean-cooking-challenge-africa

Ayuk, NJ (2023). The challenge: Building capacity for Africa's renewables sector. African Energy Chamber. https://energychamber.org/the-challenge-building-capacity-for-africas-renewables-sector/

Baskaran, Gracelin and Sophie Coste (2024). Achieving universal energy access in Africa amid global decarbonization. Center for Strategic & International Studies (CSIS). https://www.csis.org/analysis/achieving-universal-energy-access-africa-amid-global-decarbonization

ENERGIA, World Bank—Energy Sector Management Assistance Program (ESMAP) and UN Women (2018). Policy brief #12: Global progress of SDG7 – Energy and Gender. In Accelerating SDG 7 Achievement Policy Briefs in support of the first SDG 7 review at the UN High-Level Political Forum 2018. United Nations. https://sdgs.un.org/sites/default/files/documents/17489PB12.pdf

Energy and Industry Transition (2024). African Clean Energy: Improving access to clean cooking in sub-Saharan African and South-East Asia. World Economic Forum. https://initiatives.weforum.org/equitable-transition-initiative/case-study-details/african-clean-energy:-improving-access-to-clean-cooking-in-sub-saharan-african-and-south-east-asia/aJYTG0000000HfB4AU

Engelmeier, Tobias and others (2020). Energy access, data and digital solutions. TFE Energy. https://thefutureof.energy/wp-content/uploads/2024/05/TFE_Report-Digital_Solutions_Web_compressed.pdf

Falchetta, Giacomo and others (2019). Hydropower dependency and climate change in sub-Saharan Africa: A nexus framework and evidence-based review. Journal of Cleaner Production, vol. 231 (September), pp. 1399–1417. https://doi.org/10.1016/j.jclepro.2019.05.263

Falchetta, Giacomo and others (2021). The role of regulatory, market and governance risk for electricity access investment in sub-Saharan Africa. Energy for Sustainable Development, vol. 62 (June), pp. 136–150. https://doi.org/10.1016/j.esd.2021.04.002

Future Today Strategy Group (FTSG) (2025). 2025 Tech trends report, 18th edition: Energy & climate. FTSG. https://ftsg.com/wp-content/uploads/2025/03/Energy_Climate_FINAL_LINKED.pdf

Gbolonyo Emmanuel Y. and Bright Tetteh (2025). Energy access and gender gaps in sub-Saharan Africa: The role of institutional quality. World Development Perspectives, vol. 40 (December), art. 100722. https://doi.org/10.1016/j.wdp.2025.100722

Hornuf, Lars, Kulondwa Safari and Johannes Voshaar (2024). Mobile fintech adoption in sub-Saharan Africa: A systematic literature review and meta-analysis. SSRN. Elsevier. http://dx.doi.org/10.2139/ssrn.4680786

Idem, Rosemary, Ava Strasser and Adenike Abimbola (2024). Improving energy data to enhance gender equality. Sustainable Energy for All. https://www.seforall.org/system/files/2024-07/report-g%26y-genderdatastudy-002_compressed.pdf

International Energy Agency (IEA) (2024). Population without electricity access, 2010–2024. IEA. https://www.iea.org/data-and-statistics/charts/population-without-electricity-access-2010-2024

International Energy Agency (IEA) and the African Development Bank Group (AfDB) (2023). Financing clean energy in Africa: World Energy Outlook Special Report. IEA. https://www.iea.org/reports/financing-clean-energy-in-africa/

International Renewable Energy Agency (IRENA) (2020a). Innovation landscape brief: Pay-as-you-go models. IRENA. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jul/IRENA_Pay-as-you-go_models_2020.pdf

International Renewable Energy Agency (IRENA) (2020b). World Energy Transitions Outlook 2023, vol. 1. IRENA. https://www.irena.org/Digital-Report/World-Energy-Transitions-Outlook-2023

International Renewable Energy Agency (IRENA) (2025). Digitalisation. IRENA. https://www.irena.org/Energy-Transition/Innovation/Digitalisation

International Renewable Energy Agency (IRENA) (2026). Energy transition technologies set to open new opportunities for global energy systems. IRENA. https://www.irena.org/News/pressreleases/2026/Jan/Energy-Transition-Technologies-Set-to-Open-New-Opportunities-for-Global-Energy-Systems

International Union for Conservation of Nature (IUCN) (2020). Energizing equality in the African energy sector. IUCN. https://genderandenvironment.org/energizing-equality-in-the-african-energy-sector/

Jodoin, Laurent and others (2024). Making energy justice work for women in rural sub-Saharan Africa: A quantitative diagnostic from Benin, Senegal, and Togo. Energy Research & Social Science, vol. 118 (December), art. 103754. https://doi.org/10.1016/j.erss.2024.103754

Okafor, Joyce Odu (2025). Internet of Things (IOT)-enabled smart microgrids for off-grid electrification in sub-Saharan Africa. World Journal of Innovation and Modern Technology, vol. 9., No. 8. https://iiardjournals.org/get/WJIMT/VOL.%209%20NO.%208%202025/INTERNET%20OF%20THINGS%20(IOT)%2030-42.pdf

Organisation for Economic Co-operation and Development (OECD) (2009). The development dimension: ICTs for development: Improving policy coherence. OECD. https://www.oecd.org/content/dam/oecd/en/publications/reports/2010/01/icts-for-development_g1ghbddc/9789264077409-en.pdf

Payton, Ben (2024). How bridging the skills gap can boost Africa's green energy transition. Reuters. https://www.reuters.com/sustainability/climate-energy/how-bridging-skills-gap-can-boost-africas-green-energy-transition-2024-11-19/

Sanchez Santillano, Federico Alberto and others (2024). Water-energy-food (WEF) nexus technologies in Africa's Sahel region and SDGs 2, 6, and 7. In: SDGs in Africa and the Middle East Region. Implementing the UN Sustainable Development Goals – Regional Perspectives, Abubakar, IR and others (editors). Springer, pp. 807–829. https://doi.org/10.1007/978-3-031-17465-0_38

United Nations Capital Development Fund (UNCDF) (2020). Digital finance for energy access in Uganda. UNCDF. https://www.uncdf.org/article/5314/digital-finance-for-energy-access-in-uganda-a-big-data-analytics

World Bank Group (2019a). Electrification efforts in sub-Saharan Africa must address root causes of low access. World Bank Group. https://www.worldbank.org/en/region/afr/publication/electricity-access-sub-saharan-africa

World Bank Group (2019b). Getting electricity. Doing Business Archive. World Bank Group. https://archive.doingbusiness.org/en/data/exploretopics/getting-electricity

World Bank (2025). Chapter 1. Access to electricity. In Tracking SDG 7: The energy progress report 2025, International Energy Agency (IEA), International Renewable Energy Agency (IRENA), United Nations Statistics Division (UNSD), World Bank, World Health Organization (WHO). World Bank. https://trackingsdg7.esmap.org/sites/default/files/download-documents/chapter1_accesstoelectricity.pdf

World Health Organization (WHO) and University of Glasgow (2025). Chapter 2. Access to clean fuels and technologies for cooking. In Tracking SDG 7: The energy progress report 2025, International Energy Agency (IEA), International Renewable Energy Agency (IRENA), United Nations Statistics Division (UNSD), World Bank and WHO. World Bank. https://trackingsdg7.esmap.org/sites/default/files/download-documents/chapter2-sdg7-report2025-0804-v11.pdf

This policy brief stems from and builds upon the discussions and work done during the 15th Climate Academy ("The People's Pathways to Climate Action") held in September 2022, and also draws upon subsequent online discussions in 2024 and 2025. Stage I of the Academy, conducted from 12 to 16 September 2022, comprised eight webinars focused on identifying policy gaps and agenda-setting for energy transition and digitalization. Participants approached the topic from a multidisciplinary and cross-cultural perspective, drawing on case studies from across the globe. Recordings of these discussions are available online. Stage II was a one-week in-person gathering in Kigali, Rwanda, between 26 and 29 September 2022, during which participants worked intensively to refine research and practices focusing on specific outputs that aim to collectively inform policy gaps identified by the Academy. This Academy was organized by the United Nations University – Institute for Environment and Human Security (UNU-EHS) and the Munich Re Foundation, in coordination with the United Nations Framework Convention on Climate Change (UNFCCC), with ICLEI – Local Governments for Sustainability as a special partner.

Contributors: Himanshu Shekhar (United Nations University Vice-Rectorate in Europe [UNU-VIE]), Germany; Paul Nduhuura (Makerere University Business School), Uganda; Aboubakr Benazzouz (Green Energy Park), Morocco; Aparajita Dubey (National Institute of Urban Affairs [NIUA]), India; Carlos Cadena-Gaitan (Escuela de Administración, Finanzas e Instituto Tecnológico [EAFIT University]), Colombia; Christine Juta (University of Cape Town), South Africa; Denis Korchunov, (United Nations Development Programme [UNDP]), Indonesia; Dereje Ashenafi (The United Nations Economic Commission for Africa [UNECA]), Ethiopia; Dorcas Stella Shumba (United Nations University Institute for Environment and Human Security [UNU-EHS]), Germany; Fabio Iannone (Sant'Anna School of Advanced Studies), Italy; Fides Kirimi (International Rescue Committee), Kenya; Ghafi Kondi Akara (AIMS Research & Innovation Centre), Rwanda; Grace Nanteza (The Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH [GIZ]), Uganda; Hrishikesh Ballal (Geodesignhub), Ireland; Jilan Plecha, (University of Freiburg), Josef Noll (University of Oslo), Norway; Koko Warner (University of Pennsylvania), USA; Lisa Indah Wijayani (University of British Columbia), Canada; Marianne Zeyringer (University of Oslo), Norway; Parveen Kumar (Wageningen University & Research and Maastricht University), the Netherlands; Pietro Visetti (Green Digital Finance Alliance) Switzerland; Polina Koroleva (United Nations Environment Programme [UNEP]), Kenya; Pourya Salehi (ICLEI – Local Governments for Sustainability), Germany; Shailendra Kumar Mandal (NIT Patna), India; Federico Alberto Sanchez Santillano (UNU-VIE), Germany; Ananya Ramesh (UNU-EHS), Germany; Erick Tambo (UNU-VIE), Germany.

Recommended citation: Shekhar, Himanshu; Nduhuura, Paul; Benazzouz, Aboubakr; Dubey, Aparajita; Cadena-Gaitan, Carlos; Juta, Christine; Korchunov, Denis; Ashenafi, Dereje; Shumba, Dorcas Stella; Iannone, Fabio; Kirimi, Fides; Akara, Ghafi Kondi; Nanteza, Grace; Ballal, Hrishikesh; Plecha, Jilan; Noll, Josef; Warner, Koko; Wijanyani, Lisa Indah; Zeyringer, Marianne; Kumar, Parveen; Visetti, Pietro; Koroleva, Polina; Salehi, Pourya; Mandal, Shailendra Kumar; Sanchez Santillano, Federico Alberto; Ramesh, Ananya; Tambo, Erick (2026). Transforming rural energy access in sub-Saharan Africa with digital technologies. United Nations University Vice-Rectorate in Europe.

The Climate Academy project was co-organized by UNU-EHS and the Munich Re Foundation.

UNU VIE

Munich Re Foundation
From Knowledge to Action