Off-Grid Energy and Economic Prosperity

Evidence on the relationship between off-grid electricity access and local economic well-being in sub-Saharan Africa

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The findings and recommendations of this report do not necessarily reflect the official views of UCL and Bboxx.

Cover Photo: Off-Grid Electricity in Kigali, Rwanda
Credit: Dr Iwona Bisaga

Executive Summary

Under the 2030 Agenda for Sustainable Development, the United Nations (UN) established Sustainable Development Goal (SDG) 7 in 2015 to 'ensure access to affordable, reliable, sustainable and modern energy for all by 2030' [1]. However, **despite significant efforts before the coronavirus (COVID-19) pandemic, 789 million people still live without access to electricity, nearly 70% of which is concentrated in sub-Saharan Africa (SSA).** Compared to other regions in the world, SSA exhibits the lowest electrification rate at 47% [2] and the degree of urban-rural electrification inequality is also greater in SSA than anywhere else [3].

The COVID-19 pandemic has further challenged the resilience of the economies in SSA and is threatened to reverse the recent progress towards the UN's 2030 Agenda. The regional growth contracted by -1.9% in 2020, triggering its first recession in 25 years, and per capita output is not expected to return to 2019 levels until after 2022 [4]. Moreover, cumulative output losses from the pandemic are estimated approximately 12% of GDP over 2020-21. It was also estimated that the catastrophic effects caused by the pandemic may have pushed an additional 26.2 million to 40 million people into extreme poverty in SSA by the end of 2020 [5]. As governments and international organisations plan the COVID-19 recovery, they must look at effective interventions that have the largest impact on the resilience and prosperity of the poorest and most vulnerable communities.

Off-grid electrification plays a vital role in extending electricity access to rural communities and improving economic resilience. It can reach end-users in remote locations by using local renewable energy resources while providing cost-effective electrification options [6], [7]. More importantly, it can improve living standards and community services including education and healthcare services [8]. In terms of local economic growth, off-grid energy provides numerous benefits including better household and business financial capacity (i.e. increase income and reduce expenditure) and improvement in employment and business efficiency. For instance, access to off-grid electricity has enabled 36% of rural consumers in Kenya, Mozambique, Rwanda, Tanzania and Uganda to increase their monthly income by 35 USD a month, more than half of the average monthly GDP per capita [9].

The purpose of this discussion paper is to therefore synthesise the existing evidence in academic and grey literature on links between off-grid (e.g. pico-photovoltaic (Under 10Wp lighting systems), solar home systems (SHS) and mini-grids) energy access and economic prosperity at household and community level in SSA in light of COVID-19. Some of the evidence on this relationship are shown in Box 1:

1. Off-grid electricity access can boost household's financial capacity by improving income and reducing expenditure
• Off-grid systems improves income by allowing electrified households to start new businesses, operate with additional hours, and work with better equipment efficiency. • The systems reduce a household's energy expenditure through the transition from kerosene and fuel-based lighting to off-grid technologies. The additional income and savings can be reinvested in food, children's needs including nutrition and education, lead to time saving for women or improvement of their businesses.

2. The off-grid solutions can generate employment across the value chain, as well as for local businesses
• The off-grid solar value chain could create up to 570,000 full-time equivalent jobs in SSA by 2022 [10]. • Rural electrification boosts business start-ups and new income generation activities as an estimated 24% of customers in East African countries use their off-grid connections to directly enhance existing business or new income generating activity [11].
3. Integrating off-grid solutions into local value chain productivity can trigger local rural development and overcome the challenges of affordability of electricity
• Productive use of electricity (PUE) activities can both stimulate demand for off-grid energy systems and enhance rural livelihoods through additional income from new and improved businesses and employment opportunities. • Increasing off-grid electricity access to local social services such as health centres and schools can act as an indirect mean (improving health and immunization and literacy) to enhance local economic development. • There is immense untapped potential for domestic off-grid companies to add value in the off-grid energy ecosystem, with a total addressable market of 11.3 billion USD for SSA [12], [11].
4. Financing off-grid products can instil financial confidence through improving financial literacy and building history credit
• The majority of rural consumers in many SSA countries have limited access to bank accounts. Introducing Pay-as-You-Go (PAYG) based off-grid solutions to unbanked customers acts as an initial step towards financial inclusion and can help them manage their financial resources better and as a result establish creditworthiness.

Box 1. Evidence on Links between Off-grid Energy Access and Economic Prosperity.

Based on the literature found for this paper, the following gaps of knowledge (Box 2) emerged from this study:

1. Effects of increased financial literacy on households and businesses
Evidence shows that successfully financing off-grid energy products leads to improved financial inclusion [13], [14]. Yet, there is currently a lack of comprehensive study on how, and to which extent, improved financial literacy is translated to non-energy household and business activities. Additional research is necessary to understand the role of off-grid energy as an enabler for personal, household and business financial management.
2. The relationship between off-grid energy provision and country-level GDP
The evidence on GDP growth via off-grid energy access is still limited. A quantitative study examining the direct impact of increased off-grid energy specific provision and technologies on GDP growth per capita at national and sub-national levels is necessary to underpin the crucial link between off-grid energy and economic prosperity.

3. PUE and value chain integration
As the market is still in its infancy, there is still a lack of extensive evidence and case studies on how off-grid companies can offer their products beyond selling electricity and fully integrate themselves with the local value chain.
4. Medium- and long-term energy-sector measures
To lessen the impact of COVID-19, governments in SSA have implemented various energy-related specific policies. However, most of these are short-term interventions [15]. A detailed investigation of effective off-grid policy measures in both medium- and long-term is necessary in order to mitigate the damage, reduce harmful subsidies, and accelerate the sustainable energy transition.
5. Potential change in off-grid end-user's behaviour and financial habits
As a result of COVID-19, it is likely that off-grid end users will alter their behaviour, attitudes and financial habits towards energy accordingly. In order to ensure that these users will continue to have access to off-grid electricity, a study on these changes at a household level is required.

Box 2. Gaps of Knowledge in Off-grid Sector in SSA.

In order to drive the clean energy transition forward and strengthen the relationship between off-grid electricity access and economic well-being post COVID-19 pandemic, we recommend the following, illustrated in Box 3:

1. Prioritise off-grid electricity sector investment
As electricity is a key catalyst for economic recovery, it is critical to prioritise maintaining and increasing energy access as a key response to the COVID-19 crisis. Governments should focus on designing supportive policies and address enabling environment barriers to advance off-grid energy access and associated economic development. Policymakers should also make sure that short-term energy responses and policies do not exacerbate electrification inequalities seen across developing countries. To reach universal energy access, governments and partners must promote both supply and demand side subsidies. The former are essential to support off-grid companies scale up operations and serve more difficult market segments, including in more remote areas. The latter can help to close the affordability gap for the poorest customers [16].
2. Integrate PUE into government electrification strategies
PUE can strengthen the links between access to electricity and economic prosperity as it reinforces the creation and improvement of local value chains, and reduce vulnerability to external shocks. In order to enhance local economic growth, it is evident that energy policies and rural electrification projects should expand beyond the provision of electricity connections for meeting these basic needs, including the promotion of inter-governmental coordination (e.g. between Ministry of Energy and Ministry of Agriculture); the promotion of PUE should be made a priority in government plans for electrification.
3. Greater attention on promoting gender inclusive interventions

Gender mainstreaming is necessary to incorporate women's concerns and experiences as a critical dimension of policy and project planning. Increasing women participation as customers, workers along the energy value chain, business owners and policy makers, understanding women's energy needs and consequently designing appropriate gender-focused interventions will enable women to enhance financial literacy and access more productive and profitable activities.

Box 3. Recommendations.

Access to off-grid electricity should be seen as a key mechanism for rural development to improve economic well-being and living standards. While the potential and benefits of off-grid electrification are evident, finding the necessary investment remains a significant challenge for the sector. While the pandemic has challenged the economies in SSA, it also provides an opportunity to address structural issues in energy development for a more decentralised energy system. A transformative change in financial investment is critical for a more sustainable economic recovery. Higher levels of public and private investments in the off-grid energy sector are an urgent priority to strengthen the SDG7 commitment and rapidly connect the poorest and most vulnerable communities to affordable, reliable electricity for increased prosperity and resilience.

Photo 1. Solar home system in a local shop, improving the quality of lighting and extending shop hours. Credit: Bboxx.

Contents

1. Introduction

Under the 2030 Agenda for Sustainable Development, the UN established Sustainable SDG7 in 2015 to 'ensure access to affordable, reliable, sustainable and modern energy for all by 2030' [1]. Access to electricity is also considered a critical enabler for sustainable development and social well-being as the provision of electricity provides socioeconomic benefits for rural communities [17], [18]. However, despite significant efforts before the COVID-19 pandemic, 789 million people still live without access to electricity, nearly 70% of which is concentrated in SSA. Compared to other regions in the world, SSA exhibits the lowest electrification rate at 47% [2] and the degree of urban-rural electrification inequality is also greater in SSA than anywhere else [3].

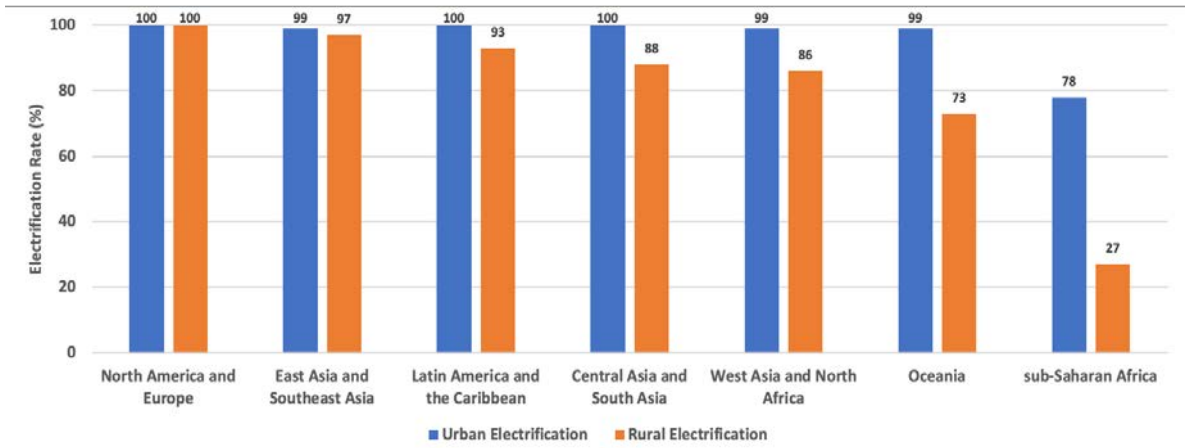

Figure 1. Rural and urban electrification rates across regions, 2018 [2].

Off-grid electrification plays a vital role in extending electricity access to rural communities. It can reach end-users in remote locations by using local renewable energy resources while providing cost-effective electrification options [6], [7]. More importantly, it is seen as a key mechanism for rural development to improve living standards and community services including education and healthcare services [8]. In terms of local economic growth, it provides numerous benefits including better household and business financial capacity (i.e. increase income and reduce expenditure) and improvement in employment and business efficiency.

While the potential and benefits of off-grid electrification are evident, finding the necessary investment remains a significant challenge for the sector. According to the International Energy Agency (IEA), an estimated 25 billion USD per year in solar PV is required to achieve universal access to electricity in SSA by 2030, with approximately half of which going towards off-grid and mini-grid energy systems [19]. However, the financial investment estimates are insignificant in relative to estimates to what is required; as the end of 2019, as the off-grid sector had only attracted approximately one billion USD (4%) in investment to connect those without electricity access in SSA [11].

In order to support the rural electrification investment for enhancing economic prosperity, it is critical to examine and connect the relationship between off-grid electricity access and economic well-being. The aim of this discussion paper therefore is to synthesise the existing

evidence on links between off-grid energy access, mainly pico-photovoltaic (e.g. solar lanterns) and SHS - Tier 1 and 2 according to the World Bank's Multi-tier Framework - and economic prosperity at household and community level in SSA [20]. This paper will also include a review of the impact of COVID-19 pandemic on the off-grid energy sector in SSA. An extensive literature review was conducted for this study. The paper reviews mostly peer-reviewed literature, but also include grey literature from organisations such as Global Off-Grid Lighting Association (GOGLA), the World Bank, and IEA.

Section 2 of this report reviews the relevant literature on the links between off-grid electricity access and household poverty alleviation. Section 3 synthesises the existing evidence related to economic growth and productive employment. Section 4 describes the current and potential impact of COVID-19 pandemic on the off-grid energy sector in SSA. Next, Section 5 outlines the current gap in the literature review. Finally, Section 6 completes the report with a conclusion and recommendations.

2. Household Poverty Alleviation

2.1 Household income

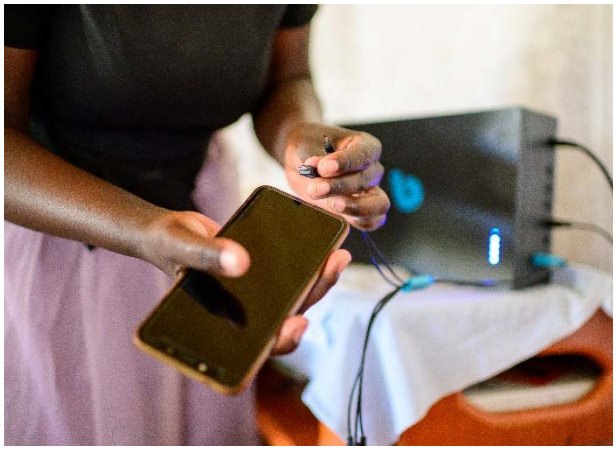

Photo 2. Solar home system providing mobile phone charging services. Credit: Bboxx.

Access to off-grid electricity can boost household's financial capacity by improving income through numerous ways. First, off-grid systems allow electrified households to start businesses in order to increase income. According to a study conducted by Opiyo [21] in Kenya, the acquisition of SHS leads to households offering home-based mobile phone charging services to neighbours, earning about additional 25 USD per month. Other households also opened barbershops and hairdressing businesses, generating net income between 25 and 50 USD per month. School teachers also formed a tutorial group, providing additional lessons to pupils on weekends, earning them between 50 and 75 USD.

Second, off-grid electricity provides additional hours of lighting for household members to undertake more economic activity in the evening, that would otherwise be unavailable. For example, up to 29% of SHS users spend more time working by shifting their tasks to the evening [11]. However, it is noted that the degree of benefit from additional hours highly depends on the type of business to operate. As SHS is a small PV system size, the increase in working hours only applies to small businesses [22].

Finally, household members are able to have more time available to work due to new and better equipment efficiency. Through the use of off-grid electricity access, the previously manually performed tasks are now mechanised. Off-grid users also no longer have to spend time travelling to purchase fuel or charge their phones [11]. The improvement in household's financial capacity can have a direct effect on boosting the local economic growth (see the following Section 3). This underlines the relationship between access to electricity and both household- and community-level economic prosperity.

2.2 Impact on expenditure

Access to off-grid electricity also impacts households' expenditure for domestic energy supply. For many households in SSA, expenditures on kerosene and fuel-based lighting technologies constitute a considerable portion of their total expenditures. The transition to off-grid technologies (e.g. solar lanterns and SHS) can reduce household expenditure and cash flow burdens, and in turn reduce energy poverty [23]. An analysis by Lemaire [22] concluded that the decrease of kerosene expenditure is estimated between 85 and 75%. On the same note, Adkins et al [24] reported that after the introduction of off-grid LED lanterns in rural Malawi, lighting expenditures fell from 1.06 USD per week to 0.15 USD per week after lantern purchase, a total reduction of 85%. As a result of reduced expenditure, household's financial

capital is increased and can be allocated to other expenditures related to food and services, supporting a positive loop on local market production and electricity consumption [25].

The significant savings from this switch to off-grid solutions can enable households to reinvest in other well-being aspects that are directly related to long-term economic growth. Based on the studies by SolarAid [26], 45% of respondents interviewed in Tanzania said that they spent their savings on food, 23% on education, and 14% on farming. Similarly, 34% of respondents in Kenya spent their savings on investing their business and farming and 32% on food. Furthermore, similar to an increase in income, this reduction on expenditure can have a long-term impact on economic growth and quality of employment. With children gain additional hours of lighting and spend more time on education (e.g. reading and completing homework), they improve their grades and develop self-confidence, which play a prominent role in their desire to continue their education and seek high-paying jobs in the future [26]. Similarly, off-grid energy relieves women from burdensome activities (e.g. travelling long distances to collect or purchase solid fuels) and enables them to pursue additional productive activities (see Section 3.1) [27].

On the other hand, some studies suggest that many households in SSA also experience an increase in expenditure after electrification. Based on Bensch et al [28], while it is true that the switch from traditional sources of energy to off-grid leads to significant savings, newly electrified households are likely to take up more intensive lighting options and new services and electrical appliances, which offsets the transition savings and increases the final energy bill. The cost of off-grid products also contributes to the increase in expenditure; households with a SHS tend to spend money on energy due to the monthly payment of the system [25]. Therefore, it is critical for off-grid businesses to ensure that their solutions are affordable for rural end-users.

2.3 Enhancing financial inclusion

In addition to the direct benefits of electrification (e.g. extended working and studying hours), successfully financing off-grid products can instil financial confidence through improving literacy and building history credit. The majority of rural consumers in many SSA countries have limited access to traditional financing; the Lighting Africa market survey revealed that 88% of surveyed households across five SSA countries do not have any bank accounts [29]. These households face numerous finance-related challenges including financial illiteracy, a lack of credit history, inability to make large down-payments, and limited cash flow [13], [30]–[32]. Introducing Pay-as-You-Go (PAYG) based off-grid solutions to unbanked customers acts as an initial step towards financial inclusion. A survey by 60 Decibels for Bboxx internal purposes showed that connecting off-grid solutions has led 55%, 73%, 81%, and 88% of its customers in Democratic Republic of the Congo, Kenya, Rwanda, and Togo, respectively to have access to credit for the first time. If regular payments are completed successfully, PAYG financing helps off-grid customers manage their financial resources better and as a result establish creditworthiness [31]. This credit history leads to greater financial literacy, which can result in customers opening bank accounts that enable them to leverage additional loans to assist their businesses [14]. Moreover, from the bank's perspective, new bank accounts establish relationships with rural households previously thought of as being unleadable [32].

While the aforementioned challenges for financing are universal for both men and women, women have additional set of obstacles preventing them from accessing credit. Niethammer and Alstone [30] discovered three gender-specific challenges for women in SSA. First, collateral requirements can be difficult to meet when the property is held by men. Second, compared to men, women are less likely to have formal jobs, which can be noted for creditworthy assessment. Finally, banks are more likely to be inaccessible to women as they tend to spend more hours on household responsibilities than men. Travelling to banks that are located faraway from rural communities also poses as safety risks.

Photo 3. Outdoor light powered by an off-grid solar system installed in front of a family's home. Credit: Iwona Bisaga.

3. Economic Growth and Productive Employment

3.1 Productive use of electricity

Photo 4. Off-grid solar system on a farmland, supporting agricultural activities. Credit: Bboxx.

In many rural areas across SSA, off-grid solutions are the cheapest and cleanest electrification option due to the abundance of solar resources and rapidly falling system costs [6], [7]. Integrating off-grid solutions into local value chain productivity can trigger local rural development and overcome the challenges of affordability of electricity [12]. Productive use of electricity (PUE) is referred to as "agricultural, commercial and industrial activities involving electricity services as a direct input to the production of goods or provision of services" [33]. PUE activities play an essential role in off-grid electrification and rural economic development in that they can both stimulate demand for off-grid energy systems, resulting in increased electricity consumption and revenue, and enhance rural livelihoods through additional income from new and improved businesses and jobs [34], [35]. De Groot et al [36] present extensive evidence underlining that access to electricity advances development and stimulates growth of enterprises. There is immense untapped potential for domestic off-grid companies to add value in the off-grid energy ecosystem; while the PUE market remains in its infancy, the rapid expansion in market participants indicates strong potential growth, with a total addressable market of 11.3 billion USD in 2018 for SSA [11], [12]. Furthermore, there is an opportunity to reskill and transfer knowledge to workers from the fossil fuel industry to ensure that the transition to clean energy is both fair and inclusive.

Particularly in SSA, productive use activities from SMEs and agriculture and local services sectors can significantly benefit from electricity access. As mentioned, a range of activities include agriculture (e.g. irrigation, grain milling and food processing), commercial (e.g. hair dressing and restaurants), and industrial (e.g. clothing and construction). PUE in the agriculture sector is the most common [12]. For example, Hirmer and Guthrie [8] investigated the benefits of productive use activities in seven off-grid projects across rural Uganda, and found that agricultural activities from electricity access like grain milling and irrigation can provide multiple benefits such as increase in productivity, time saving, and additional income generation. However, in the case of agriculture, it is noted that PUE provides a varying degree of benefits depending on whether farmers are either subsistence farmers or commercial farmers with access to markets and substantive land ownership. Land access is also becoming an issue in SSA and can potentially hamper the further improvement of livelihoods when using off-grid energy solutions.

Moreover, PUE has the flexibility to go beyond the production of input services and instead sell the actual end-product itself, including fish, ice blocks, maize flour and potable water [12]. For instance, in addition to selling electricity to rural households, an off-grid company on

Ukara Island, Northern Tanzania, also installed an ice block production unit to sell ice for local fishermen [37]. By integrating the ice production unit into the island's fish value chains, not only the ice blocks provide a new revenue stream for the company, but they also help local fishermen by avoiding fish losses and reducing dependency on fish traders. PUE can strengthen the links between access to electricity and economic prosperity as it reinforces the creation and improvement of local value chains, facilitate diversification of economic structures and livelihoods, and reduce vulnerability to multiple stresses and external shocks [33].

Despite the positive relationship between energy access and PUE, it is noted that women entrepreneurs and employees face a different set of challenges compared to men when it comes to use and derive benefits from electricity [38]. Men are more likely to be targeted by PUE interventions as men-related PUE activities cover a wide range of sectors in the community, especially in energy-intensive sectors like construction and manufacturing [38], [39]. On the other hand, PUE activities that increase more employment opportunities for women are either unskilled or self-employed positions that required less electricity consumption [40]. A number of gender-specific constraints include unequal distribution of care responsibilities, lack of access to skills and education and low access and control over resources such as land, energy and income [38]. Understanding women's energy needs and consequently designing appropriate gender-focused interventions are necessary to increase women-related PUE activities and empower women in the community.

Photo 5. Lighting from solar home system allows the user to nurse her baby with greater ease in evenings. Credit: Iwona Bisaga.

3.2 Impact on local market demand

The transition to off-grid electricity can positively influence the demand per-capita in local communities. Johnstone et al [41] noted that the switch to off-grid lighting had a positive impact on local business prosperity through reduced expenditures and increased traffic and revenue to shops due to the quality of lighting and extended hours. Similarly, Neelsen and Peters [42] reported that the improved quality of lighting from off-grid products can attract more customers from surrounding communities due to additional hours and perceived security, boosting the volume of goods sold.

Furthermore, off-grid electricity increases the quality and variety of goods and services offered in the community. For instance, retail services such as barbershops and hairdressing businesses can offer improved, more accurate services due better equipment and lighting [42]. These shops can also offer electronic repair, phone charging services, and entertainment, illustrating electrification's potential for more diverse business opportunities [43]. Hajat et al [44] examined the impact of off-grid solar containers on small-scale businesses in rural community in South Africa and discovered economic benefits including offering of business products previously not available in the area (e.g. bread and cool drinks), and additional income to the entrepreneurs. Lastly, through the diffusion of electrical devices (e.g. television, radio and telephone) and off-grid electricity access, local shops and retailers can experience higher demand and revenues from advertisement [45].

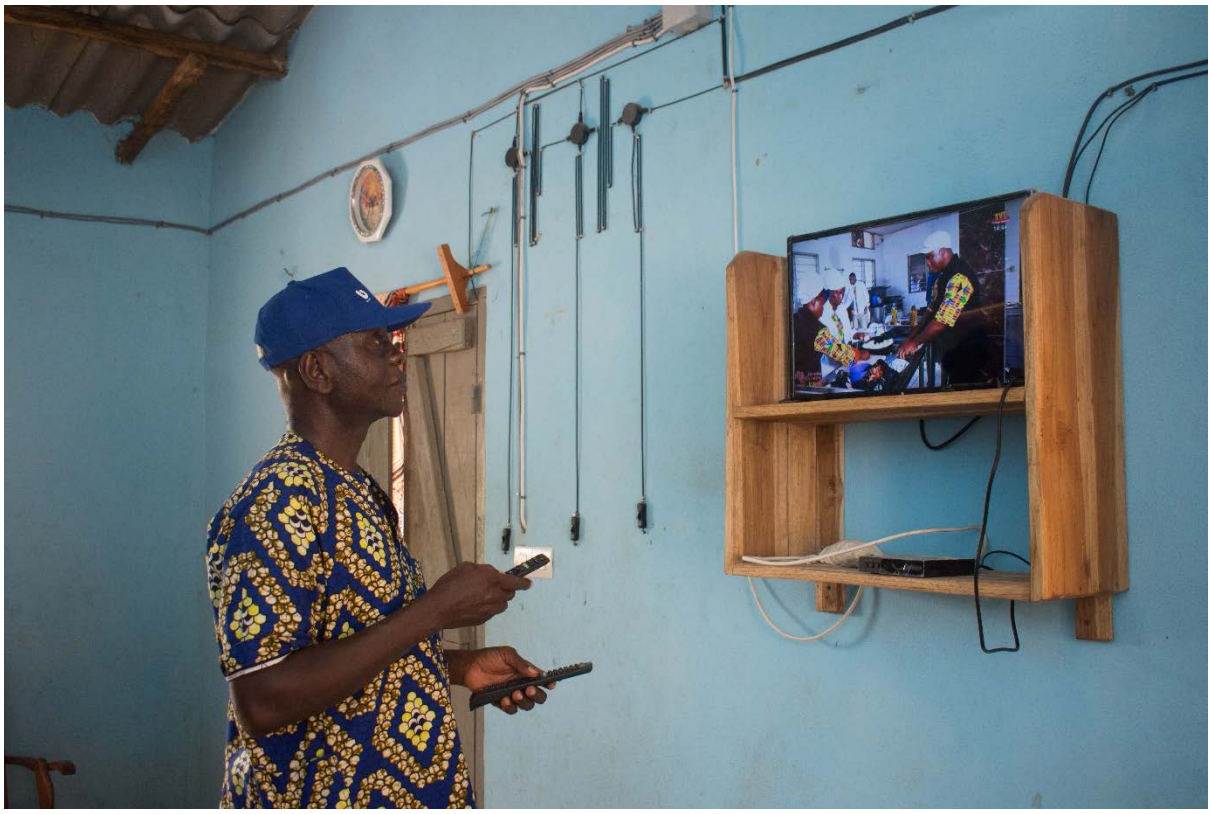

Photo 6. Solar home system in a customers' shop, powering a television. Credit: Bboxx.

Beyond businesses, increasing off-grid electricity access to local social services (e.g. health centres and schools) can act as an indirect mean to enhance local economic prosperity. For example, electricity access to health facilities enables refrigeration for vaccines, medications,

and medical equipment to be stored, resulting in higher immunisation rates in nearby communities [17]. Access to reliable electricity also provides healthcare workers with longer hours and a better working environment, instead of depending on kerosene lanterns and candles [46].

3.3 Impact on local employment

The off-grid solutions can generate employment across the value chain, as well as for local businesses. In terms of off-grid business employment, a report by GOGLA estimated that the off-grid solar value chain could create up to 570,000 full-time equivalent (FTE) jobs in SSA by 2022, excluding manufacturing [10]. Likewise, Shirley et al [47] discovered that pico-solar appliance and SHS companies currently drive employment in the off-grid sector in Kenya and Nigeria, and estimated that a total of 69,000 formal jobs and 54,000 informal jobs will be created by 2022-2023. These job opportunities range from lower-skill (e.g. customer relations and sales), medium-skill (e.g. technicians and logisticians), and high-skill (e.g. managers and engineers). Sales and distribution skills account for the largest portion of off-grid jobs, and crucial for sustaining the sector, while management skills represent a critical gap for unlocking the sector's growth [10], [47]. Specifically to off-grid lighting, the transition away from kerosene and other fuel-based lighting will create more than ten times more jobs than it displaces, while improving the availability and quality of light in homes and workplaces, and improving productivity [48].

On the demand side, investing in the off-grid sector creates additional jobs, and extends working-hours for electrified households and businesses. Rural electrification boosts business start-ups and new income generation activities. An estimated 24% of customers in East African countries use their off-grid connections to directly enhance existing business or new income generating activity; existing businesses can increase their income by up to 69% [11], [49]. Phone charging and SHS-powered television are common income streams for new business [49]. Adding solar products to the local shops also generates income for local business owners. Local shop owners in Kenya reported that through selling solar products, their income is increased by 10% [26].

The availability of off-grid systems also enables local shops to improve sales and businesses by extending working-hours into the evening [10], [25], [50]. For instance, Grimm et al [51] found that tailors with access to electricity in Burkina Faso have 51% higher revenues than those without due to longer operating hours and the use of electric sewing machines. Dinkelman [52] discovered that rural electrification increases working-hours for both men and women. Moreover, electrification significantly raises female employment as it releases women from home production and enabling microenterprises [38]. The increase of working-hours is particularly common for commercial activities located in residential areas, including retail shops, barbershops and hair salons, and restaurants, where increasing in operating hours has a direct impact on revenues [25]. In addition, electrification reduces the burden on hiring family members; a survey conducted by Energy Sector Management Assistance Program (ESMAP) found that small enterprises with access to electricity shifted from using family members to recruiting non-family full-time employees [53].

4. Impact of COVID-19 on Off-Grid Energy Sector in sub-Saharan Africa

4.1 Impact of COVID-19 on off-grid energy

The COVID-19 pandemic (see Appendix A for an overview as of November 2020) has challenged the resilience of the economies in SSA and is threatened to reverse the recent progress towards the UN's 2030 Agenda. The regional growth contracted by -1.9% in 2020, the worst outcome on record, and per capita output is not expected to return to 2019 levels until after 2022 [4]. Moreover, cumulative output losses from the pandemic are estimated approximately 12% of GDP over 2020-21. It is also estimated that the adverse impact of COVID-19 will push up to 71 million people into extreme poverty and 100 million people into poverty, the majority of which are concentrated in SSA [54], [55].

The consequences of COVID-19 also present a massive challenge for the off-grid energy sector in SSA. Lockdowns and social distancing measures are enforced by governments to mitigate the adverse effects of the pandemic. However, this results in a significant increase in residential electricity demand as most people are staying at home [15]. Moreover, the imposition of lockdowns means a cut in disposable incomes, which limits the household's ability to pay for electricity [56]. This inability to pay leads to an increase in energy insecurity which may bring many households back into the energy poverty trap.

On the supply side, many SSA countries lack the local development and manufacturing capacity of renewable energy technologies, and therefore are heavily dependent on international imports, particularly from China. For instance, between 2009 and 2013, China exported solar PV cells and modules worth 869 million USD to a large number of SSA countries including South Africa, Ethiopia, Kenya and Nigeria [57]. The emergence of COVID-19 negatively disrupts the international supply chain of renewable energy technologies because countries exporting the equipment shifted their attention to combat the pandemic [58], [59]. Balkenhol and Martínez Gutiérrez [60] interviewed key stakeholders in the off-grid sector and discovered that due to the dependency on Chinese imports, disruptions to the supply chain were experienced especially at the beginning of the crisis. This generated a backlog of equipment at Chinese factories and ports. Furthermore, the pandemic also impacts the worldwide transportation as costs significantly surged, especially air freight, delaying the timelines of import deliveries and subsequently renewable energy projects [15], [58], [60].

The pandemic also puts the renewable energy-related businesses and jobs at risk, most visibly the off-grid energy companies targeting rural communities not connected to the main grid system. A survey conducted by Sustainable Energy for All (SEforALL) discovered that, on average, off-grid companies expect to lose between 27% (SHS) and 40% (mini-grids) of their revenues in the coming months [61]. Another survey conducted by GOGLA on the impact of COVID-19 on off-grid businesses in SSA revealed that nearly 46% of respondents are very concerned regarding the financial health of their businesses due to numerous immediate challenges including ceased operations of sales agents and disrupted new sales and after-sales support [62]. Accepting that their businesses will not grow for the foreseeable future, they have shifted their attention to preserving their operations and the quality of existing portfolio of receivables [60], [61]. A survey from Bboxx also showed that the pandemic has

impacted the price of SHS components, for example because of the difficulties sourcing components in China (e.g. microchip shortage), affecting end-customer affordability.

In terms of immediate in-country responses, governments in SSA have implemented various energy-related specific policies and interventions. Akrofi and Antwi [15] reviewed energy-related interventions in 23 African countries, most of which are located in SSA, and classified them into six main categories shown in Table 1. According to this analysis, the most favoured immediate response is the full cost absorption or suspension of bill payments. These measures were found in countries including Chad, Gabon and Ghana. For instance, the Ghanaian government paid the cost of electricity for the vulnerable households, while absorbed 50% of the cost for other customers during the lockdown periods [63]. Similarly, the government in Gabon provided free electricity to the most economically disadvantaged communities [64]. Another common energy sector response is the subsidy or reduction of electricity costs. These were implemented by countries such as Burkina Faso and Equatorial Guinea. The government in Burkina Faso introduced a 50% reduction on solar kits for rural households. Likewise, the electricity bills in Equatorial Guinea were reduced for households and SMEs. Overall, these immediate energy-related responses provide needed support to vulnerable households, SMEs and energy access companies alike.

Type of energy sector response	Countries
Full cost absorption or suspension of bill payments	Chad, Cote d'Ivoire, Democratic Republic of the Congo, Eswatini, Gabon, Ghana, Guinea, Liberia, Mali, Mauritania, Niger, Nigeria, Togo
Subsidy or reduction of electricity costs	Burkina Faso, Equatorial Guinea, Eswatini, Ghana, Mauritius, Senegal, Seychelles, Uganda
Incentives for renewables	Burkina Faso, Kenya, Nigeria
Tax exemptions on energy bills	Mali
Support for oil and gas	Burundi
Cancellation of fossil fuel subsidies	Nigeria

Table 1. Immediate in-country energy sector COVID-19 responses in sub-Saharan Africa [15].

However, it is noted that these interventions are short-term, spanning between two to four months, meaning concrete medium- and long-term measures are required to sustain the recovery efforts and drive the clean energy transition forward post pandemic.

4.2 Outlook of the off-grid energy sector post COVID-19

Numerous countries in SSA will have to address a significant economic downturn as a result of high unemployment and low demand for goods and services from COVID-19. However, despite the increasing concerns regarding the impact of the pandemic on the clean energy transition, there is currently a lack of medium- and long-term energy-sector specific policy and economic measures [15]. Once the public health is safely contained, the main challenge

is to continue the sustainable energy transition under a new economic and political environment [65].

Investment in the off-grid sector has a significant impact on both post-pandemic recovery and decarbonisation. Off-grid systems are more resilient, flexible, and less-capital intensive compared to conventional systems [66]. Consequently, increasing access to electricity through off-grid renewables must remain a central priority of energy policies in the medium term [67]. It can act as a catalyst for economic recovery by regaining lost jobs, reskilling fossil fuel workers, and creating new opportunities for both skilled and unskilled workers from other industries. Moreover, off-grid systems can also supply electricity supplies for rural public infrastructure such as schools and hospitals, as well as creating a clear recovery path for economically vulnerable households. [67]. Productive use of electricity, previously discussed in Section 3.1, can be pivotal in providing an energy safety net, resilient livelihoods and long-term social security for rural communities without electricity access. Governments and international partners should encourage measures, such as inclusive financing options and adequate capacity building, to scale up the off-grid energy solutions that deliver affordable and reliable electricity for productive applications. By strengthening the links between energy supply and livelihoods through productive use of electricity, rural communities can recover quicker and become more resilient.

Policy makers and regulators also have a prominent role in designing clear, supportive post-COVID-19 energy policies and subsidies that attract investors in the off-grid sector [67]. For instance, Barbier and Burgess [68] suggested that countries should adopt a subsidy swap for fossil fuels, meaning the savings from the subsidy reform from coal, oil and gas consumption are instead allocated to fund renewable energy investments. Another example is to accelerate licensing and streamlining permitting procedures can safeguard off-grid projects that are currently facing delays. Furthermore, energy policy should take advantage of low interest rates to accelerate private investments in renewable energy [65]. As the levelised cost of electricity (LCOE) from renewables highly depend on the interest rate, low interest rates can increase the competitiveness vis-à-vis fossil fuel technologies [69].

While the medium-term measures focus on stimulating economic recovery, the long-term measures focus on ways to make the sector proof to similar shocks in the future, based on lessons learned from COVID-19. The current pandemic is exposing weaknesses in the renewable energy technologies supply chain, affecting businesses in the off-grid sector. Instead of relying on external suppliers, countries in SSA should use this opportunity to reduce future exogenous shocks by reinforcing the need for localisation of manufacturing of renewable energy technologies [58], [66]. This can be achieved by developing and implementing effective policy measures including financial incentives for research and development, renewable energy-based power generation, and manufacturing industries. Moreover, it is also important to enhance capacity and training programmes to develop local personnel and local supplies while reducing dependence on foreign expertise. Both suggested medium- and long-term responses are summarised in Table 2.

Type of energy sector response	Description	References
Medium-term		
Fossil fuel subsidy swap	Savings from subsidy reform for coal, oil and natural gas consumption are allocated to fund clean energy investments and dissemination of renewable energy in rural areas.	[68]
Streamlined licensing and permits	Licensing and permit processes are streamlined in order to support the deployment of mature renewable energy technologies.	[67]
Low interest rates for low-carbon technologies	Energy policy should focus on providing low interest rates for low-carbon technologies to increase market competitiveness and accelerate private investments.	[65]
Long-term		
Increased national expertise	Localisation of manufacturing of renewable energy technologies can improve supply and reduce dependency on imported technology.	[58]
	Capacity and training programmes should be enhanced to develop local personnel and workforce.	[66]

Table 2. Examples of suggested medium- and long-term responses in sub-Saharan Africa.

5. Current Gaps of Knowledge

Based on the literature found for this paper, the following are the current gaps of knowledge related to the impact of off-grid electricity access and household- and community-level economic prosperity:

1. Effects of increased financial literacy on households and businesses

Evidence from researchers and off-grid companies in SSA shows that successfully financing off-grid energy products leads to improved financial inclusion [13], [14]. Yet, there is currently a lack of comprehensive study on how, and to which extent, improved financial literacy is translated to non-energy household and business activities. As a result, additional research is necessary to fully understand the role of off-grid energy as an enabler for personal, household and business financial management.

2. The relationship between off-grid energy provision and country-level GDP

Illustrated throughout this report, it is clear that creating additional energy supply capacity stimulates economic growth [70]. However, while there is an extensive body of literature highlighting the effects of energy infrastructure on gross domestic product (GDP) growth per capita [71]–[74], the evidence on GDP growth via off-grid energy access is still limited. A quantitative study examining the direct impact of increased off-grid energy specific provision and technologies on GDP growth per capita at national and sub-national levels is necessary to connect the crucial link between off-grid energy and economic prosperity.

3. PUE and value chain integration

PUE activities play an essential role for both off-grid electrification and rural economic development; they can stimulate demand for off-grid energy systems and indirectly enhance rural livelihoods. However, as previously mentioned, the PUE market in SSA has an enormous untapped potential. As the market is still in its infancy, there is still a lack of extensive evidence and case studies on how off-grid companies can offer their products beyond selling electricity and fully integrate themselves with the local value chain.

4. Medium- and long-term energy-sector specific policy and economic measures

To lessen the impact of COVID-19, governments in SSA have implemented various energy-related specific policies and interventions. However, most of these responses are short-term while, as stated by Akrofi and Antwi [15], medium- and long-term measures were often broad and financial in nature. Therefore, a detailed investigation of effective off-grid policy measures in both medium- and long-term is necessary in order to mitigate the damage, reduce harmful subsidies, and accelerate the sustainable energy transition.

5. Potential change in off-grid end-user behaviour and financial habits post COVID-19 pandemic

A report by 60 Decibels and GOGLA learned that almost 40% of surveyed households were

most concerned about the ability to earn income during the pandemic [75]. Due to their financial circumstances as a result of COVID-19, it is likely that off-grid end users will alter their behaviour, attitudes and financial habits towards energy accordingly. The degree of these adjustments is currently unknown. In order to ensure that these users will continue to have access to off-grid electricity, a study on these changes and energy priority at a household level is required.

6. Recommendations

Access to off-grid electricity has the enormous potential to support local economic growth in rural communities across SSA. These economic benefits include increase income through new businesses, reduce expenditure by transitioning from fuel-based technologies, and improve demand for local businesses and PUE. In order to strengthen the relationship between off-grid electricity access and economic well-being, especially post COVID-19 pandemic, the following recommendations emerged from this study.

1. Prioritise off-grid electricity sector investment

As electricity is a key catalyst for economic recovery, it is critical to prioritise maintaining and increasing energy access as a key response to the COVID-19 crisis [46]. Prior to the pandemic, the degree of urban-rural electrification inequality is greater in SSA than anywhere else. Therefore, governments should focus on designing supportive policy environments for electricity access to make sure that short-term energy responses and policies including suspension of bill payments or reduction of electricity costs do not exacerbate the already high degree of electrification inequality. Subsidies from both supply and demand sides are essential to promote off-grid companies to scale up operations and increase access while simultaneously close the affordability gap for consumers [16]. Public funding for the off-grid sector will also drive the growth of both formal and informal jobs in rural areas, as well as creating employment in the value chain. By prioritising electrification rates, through measures such as incentives for renewables, local economic development will be stimulated as it expands the production of goods and services, regain lost jobs and creates new job opportunities.

2. Integrate PUE into government electrification strategies

PUE can strengthen the links between access to electricity and economic prosperity as it reinforces the creation and improvement of local value chains, facilitate diversification of economic structures and livelihoods, and reduce vulnerability to multiple stresses and external shocks [33]. However, PUE remains limited in rural areas of SSA, where electricity is largely used for basic needs such as lighting, radio or television [76]. In order to enhance local rural development and economic growth, it is evident that energy policies and rural electrification projects should expand beyond the provision of electricity connections for meeting these basic needs. Therefore, the promotion of PUE should be made a priority in government plans for electrification. Identifying local productive activities and developing strategies accordingly will also allow for a closer link between local economic development and energy policies. Lastly, the promotion of PUE should be complemented by capacity building, information provision, and awareness-raising in order for PUE to be sustainable [14].

3. Greater attention on promoting gender inclusive interventions

Lastly, gender-neutral energy policies and strategies tend to benefit more men than women. As a result, gender mainstreaming is necessary to incorporate women's concerns and experiences as a critical dimension of policy and project planning. Increasing women participation, understanding women's energy needs and consequently designing appropriate

gender-focused interventions will enable women to enhance financial literacy and access more productive and profitable activities.

This report has provided extensive evidence demonstrating the importance of off-grid electricity access on local economic prosperity in SSA. Substantial investment in the off-grid energy sector is essential to rapidly and effectively connect rural communities to affordable, reliable electricity for development. The UK government has recently shown leadership in supporting clean energy transition internationally by announcing a doubling of International Climate Finance to 11.6 billion GBP from 2021-2025 [77]. Successfully translating this political commitment into collective action will ensure better economic well-being for all.

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Appendix A

Overview of the COVID-19 pandemic in SSA

According to the World Health Organisation (WHO), more than 1.3 million cases have been confirmed in SSA and almost 30,000 total deaths as of November 8th, 2020 [78]. While it was predicted that the epidemic in SSA would be delayed compared to hard-hitting regions such as North America and Europe due to the lower risks of cases being imported from China [79], this number of reported cases remains relatively low, amounting to approximately 2.6% of the global total cases. South Africa reports the highest number of COVID-19 cases and deaths in the sub-region, accounting to 57% of total cases and 67% of total deaths (Table 2). The number of new cases in South Africa peaked mid-July where there were more than 86,000 reported cases weekly [78]. Ethiopia has the second-highest number of cases, followed by Nigeria, Kenya and Ghana. Top-ten countries with the highest number of COVID-19 cases in sub-Saharan Africa is shown in Table 3.

Country	Access elect. rate[1] (%)	Urban elect. rate[1] (%)	Rural elect. rate[1] (%)	Cumulative cases	Cumulative cases per 1 million	Cumulative deaths	Cumulative deaths per 1 million
South Africa	91.2	92.0	89.6	735,906	12,408	19,789	334
Ethiopia	45.0	92.0	32.7	99,204	863	1,518	13
Nigeria	56.5	81.7	31.0	63,790	309	1,156	6
Kenya	75.0	84.0	71.7	61,769	1,149	1,103	21
Ghana	82.4	94.2	67.3	48,788	1,570	320	10
Cameroon	62.7	93.3	23.0	22,342	842	429	16
Cote D'Ivoire	67.0	100.0	32.9	20,801	789	126	5
Madagascar	25.9	69.6	-	17,111	618	244	9
Zambia	39.8	77.2	11.0	16,908	920	349	19
Senegal	67.0	92.4	44.2	15,668	936	326	19
Total (Top ten)				**1,102,287**		**25,360**	
Total (SSA)				**1,305,346**		**29,756**	

Table 2. Ten countries in sub-Saharan Africa with highest total cases from COVID-19 as of November 8th, 2020 [78].

[1] World Bank data [80].