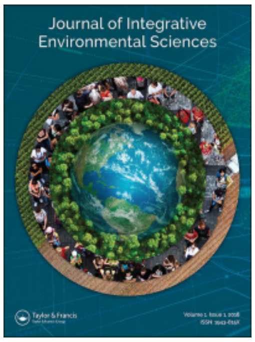

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COMMENT

Integrating household energy needs and agricultural productive uses in energy planning can enhance economic development in Sub-Saharan Africa

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ABSTRACT

Sub-Saharan Africa (SSA), with one of the fastest-growing populations in the world, is experiencing rapid urbanization and the emergence of a growing middle class. However, agricultural production falls short of meeting the projected food demand, hindered by a lack of access to modern energy. Improving the productivity of smallholder farmers and expanding local crop processing are vital strategies for addressing food security and improving the livelihoods of farmers. Supplying electricity for irrigation and crop processing can stimulate entrepreneurship, foster local wealth creation, and support the achievement of several Sustainable Development Goals, while improving the cost-effectiveness of clean energy plans in rural areas. This article argues that Africa's energy planning should prioritize clean and modern energy solutions aimed at accelerating economic growth extending beyond basic household services. The argument applies specifically to rural smallholder contexts in SSA, typically served by mini-grids or off-grid systems. Drawing on a synthesis of recent literature and illustrative projects from rural Tanzania, this manuscript shows that the benefits of productive energy use extend beyond mechanizing agriculture and crop processing. These initiatives enhance local economic development by integrating electricity into household business operations, such as milling and agro processing, which create jobs and diversify income, while acknowledging that local context, water governance and market access critically shape outcomes. They also enhance communication and provide critical market information, empowering rural communities. By prioritizing productive energy uses, these projects increase electricity consumption, improving the financial sustainability of electrification efforts.

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Universal access strategies; Sub-Saharan Africa; agricultural transformations; sustainable development; productive uses of energy; water–energy–food nexus

Introduction

Agricultural productivity gap

Bridging the agricultural productivity chasm in Sub-Saharan Africa (SSA) is essential for poverty reduction and climate adaptation. This paper presents a critical conceptual argument for a reframing of rural energy planning in SSA, i.e. for one that treats households not only as consumers of basic electricity but as productive economic units whose energy needs include irrigation, crop processing and enterprise activities alongside domestic services. To achieve these goals, there is a need for a shift in energy planning—moving beyond metrics focused solely on connection numbers and energy quantities towards metrics that capture productive uses of energy (PUE) that improve well-being and enhance productivity. This paper argues that planning energy access for rural Africa becomes significantly more effective when household electricity needs and agricultural productive uses are treated as a single, interconnected demand system. When energy systems are initially designed to include irrigation, processing and household services together, they generate higher and more stable demand, support greater agricultural productivity and incomes and enhance the financial sustainability of electrification projects. This combined effect creates a reinforcing

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Highlights

- Prioritize specific community needs for effective, sustainable energy access.
- Shifting Africa's energy focus to productive uses can enhance rural development.
- Integrate productive uses into rural electrification to boost economy and reduce costs.
- Context-specific analysis is essential for integrating productive uses of energy in Africa.

pathway through which modern energy drives economic development instead of only fulfilling basic consumption needs. Schöne et al. (2024) highlight that PUE appliances generate maximum value when their demand coincides with household load profiles, thereby avoiding the need for additional storage.

Africa is undergoing rapid demographic change, with one of the fastest-growing population globally. Between 1995 and 2020, the continent's population doubled and is projected to nearly double again by 2050 (United Nations 2022). This rapid population growth, coupled with rising income, rapid urbanization and a growing middle class, is expected to drive food demand up by 55% by 2030 compared to 2020 (Froidmont-Goertz et al. 2020). Achieving food sovereignty has become increasingly urgent, especially as global events like the war in Ukraine disrupted food supply chains and highlighted vulnerabilities (ADB 2022). Addressing this challenge requires closing the gap between the current level of production and the projected food demand through a rapid increase in output (Dagnachew and Hof 2022).

Smallholder farmers account for 80% of the agricultural production in SSA, with rainfed cropland accounting for 90% of the total crop production (AGRA 2017). In 2022, agriculture made up an average of 17% of the continent's GDP, with shares as high as 60% in Sierra Leone (World Bank 2024b). Despite its importance, African agriculture faces substantial productivity challenges, evidenced by one of the largest yield gaps globally in cereal and other food crop production (Leitner et al. 2020), as also shown in Figure 1. For instance, the annual yield for maize, Africa's most important staple crop, averages two tons per

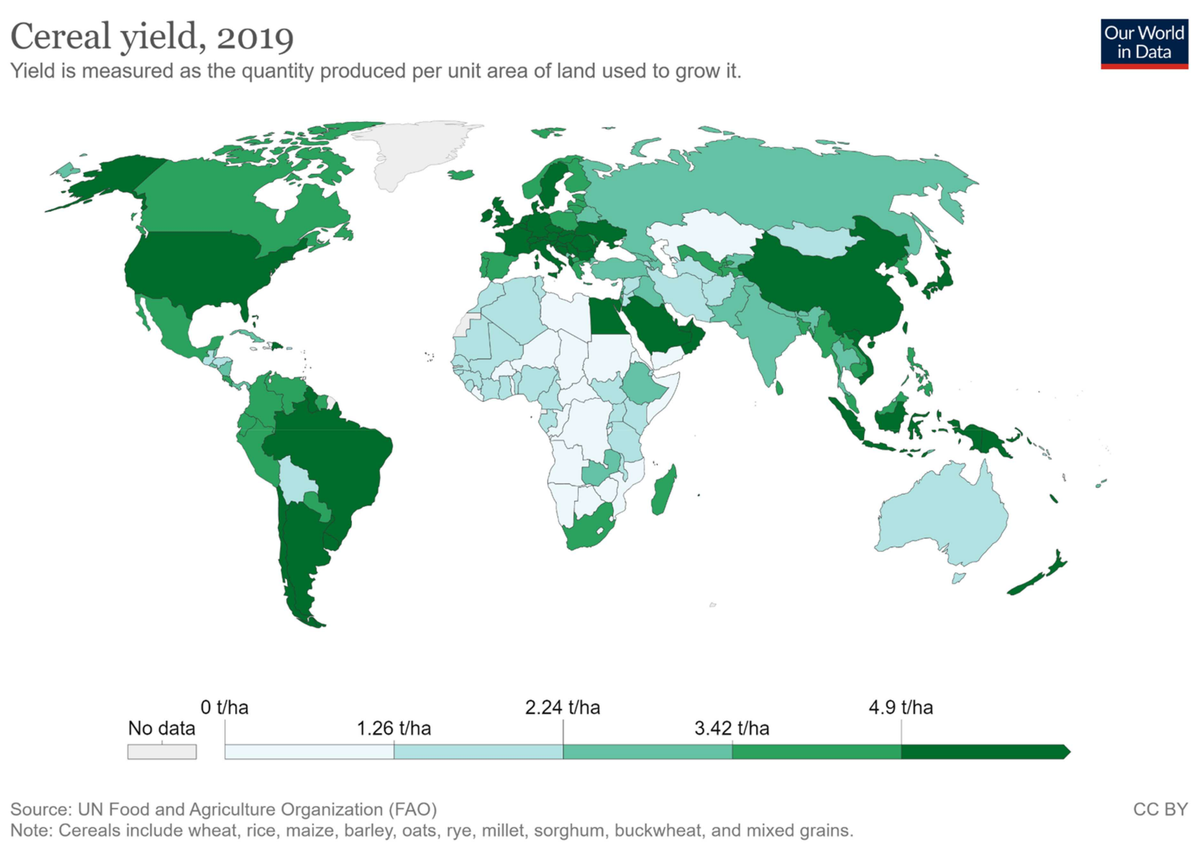

Figure 1. Cereal yield by country in 2019, Source: Ritchie and Roser, (2022). The cereal yield varied considerably across African countries as well, ranging from 0.5 ton/ha in Niger to 7 ton/ha in Egypt. However, only 5 countries in the region have a crop yield of more than 2.25 ton/ha, and only one country has a yield of more than 5 ton/ha.

hectare—less than a quarter of the yield achieved in the Americas. There also remains a sizeable amount of untapped irrigation potential and uncultivated land that is still available for farming. Further exacerbating the productivity challenge is the reliance of 75% of smallholder farmers on hand tools (AGRA 2017), reflecting a low level of mechanization in the sector. Closing the yield gap requires addressing multiple overlapping constraints, such as access to credit, availability of inputs, extension services and water management. Among these, energy has received comparatively little systematic attention in planning frameworks, despite being a cross-cutting enabler; reliable electricity simultaneously supports irrigation, mechanized processing and storage. Using national census data, Szerman and Assunção, 2022 demonstrate that the arrival of electricity represents a significant productivity shock in agriculture. They conclude that a 10% increase in electricity infrastructure in Brazil resulted in a 12% increase in crop production per hectare. Bhattacharyya (2012) also shows that, by recognizing the link between rural electrification and economic development, China's focus on agricultural advancement and local enterprises led to rapid poverty reduction and improved living conditions.

Improving agricultural productivity reduces food production costs and enhances the household income of farmers. The crucial role of agriculture in reducing poverty is highlighted by Thirtle et al. (2003), who estimated that yield increases have the highest impact in reducing the total number of people living in poverty—i.e. 73% of the impact of increases in per capita incomes would be derived from increased crop yields for SSA. Due to the greater participation of smallholder farmers in the development process of SSA, agricultural growth is typically more effective at reducing poverty than non-agricultural growth (Diao et al. 2010). Moreover, if crop yields are not substantially improved, increasing production to meet the demand would also have a massive impact on biodiversity as new agricultural land is cleared mainly at the expense of natural habitats (Williams et al. 2020).

Addressing the agricultural productivity gap in SSA requires a shift from land- or labour-intensive strategies to approaches that enhance resource efficiency and resilience of smallholder farmers. One of the most overlooked enablers in this regard is energy. Reliable access to clean and modern energy is not only a development goal but also a critical input for raising agricultural productivity by enabling irrigation, mechanization, food processing and storage. Nonetheless, despite its transformative potential, energy access remains limited and uneven across the continent.

Energy access disparities

As of 2023, over 600 million people are without electricity, and approximately 960 million lack access to clean cooking facilities (IEA 2024). The lack of access to modern energy is pervasive across both urban and rural areas, yet there are notable disparities in access levels. While nearly 80% of the urban population in SSA has access to electricity, the share with access to electricity for rural households is less than 30%. For clean cooking technologies and fuels, more than 93% of the rural population in SSA lacks access, compared with 59% of the urban population. There is also a stark difference in household end-use electricity consumption between sub-regions, ranging from 55 kWh/capita/year in Eastern Africa to 1000 kWh/capita/year in the Republic of South Africa (Dagnachew et al. 2018). This end-use also ranges from low-tier access, such as lighting and phone charging, to higher-tier demands that include space and water heating, cooling, electric cooking and other household appliances (Bhatia and Angelou 2014). This energy access gap is driven by a combination of factors, including economic growth, urbanization, gender disparities in education, innovation and population growth (Alola 2024).

Ensuring universal access to electricity therefore requires governance systems that facilitate the expansion of off-grid technologies in low-population-density settlements, in parallel with the rollout of the central grid in high-population-density and/or high-consumption settlements. It also calls for scaling up of electrification investments by more than fourfold compared to the current level of investment (IEA 2022). Similarly, universal access to clean cooking requires an unprecedented level of technology and infrastructure deployment, enough to shift over 130 million people away from dirty fuels that have major health and environmental consequences every year until 2030 (Dagnachew et al. 2020; IEA 2022).

Achieving universal access to clean and modern energy necessitates investments in scaling up innovative financing models, alongside raising awareness about the benefits of electricity and clean cooking, particularly for rural households. This can be realized by emulating successful community-managed initiatives like LUMAMA, Matembwe Village Company and JUMEME, as highlighted in Box 1. Additionally,

Figure 2. The share of the population without access to modern energy services in Sub-Saharan Africa from 2000 to 2022, Source (World Bank 2022). Although progress has been made in increasing the proportion of people with access, the absolute number of those without access to electricity and clean cooking has been increasing in all regions. There is also a stark difference between the level and pace of access to clean and modern energy between rural and urban households in Sub-Saharan Africa.

financial and technical support could be extended to innovative small and medium enterprises operating in this sector, as demonstrated by the strategic planning for agricultural transformation activities in pilot projects across rural Tanzania, also detailed in Box 1. Therefore, efforts to ensure universal access to clean and modern energy could be seamlessly integrated into broader economic development strategies.

Energy access disparities are linked to local developmental outcomes

These energy access disparities are not only an infrastructure problem; they are also a planning failure, since traditional energy access strategies have often overlooked the real needs of communities and their development priorities. A complex interaction between economic, political, technical and social factors influences the decision on the kind and level of electricity access in energy planning (Barnes 2005; Omole and Olajiga, 2024). For example, resource-constrained planners face an implicit incentive problem: extending a minimum-tier connection to the largest number of households maximizes the headline SDG7 indicator per dollar spent, whereas planning for PU loads requires larger upfront investment per connection (ESMAP 2008). As long as electrification programmes are evaluated on connection counts rather than economic outcomes, this will tend to systematically favour low-tier solutions even where higher-tier access would generate greater long-term returns (Dagnachew et al. 2018; Pachauri and Rao 2020).

Literature has examined the nexus between access to energy and socio-economic development, highlighting how focusing only on providing electricity to households might not be enough to trigger development (Riva 2020). Other complementary factors are relevant in allowing the community to use the provided electricity to take steps out of poverty (Tonini et al. 2022). Designing energy access strategies that incorporate the unique characteristics and specific needs of communities could unlock development opportunities enabled by electrification itself (Stevanato et al. 2021) and could help ensure that the intended impacts of the electrification are achieved (Terrapon-Pfaff et al. 2018). As energy access needs to leverage local development, the inclusion of income-generating activities in the set of needs of the community is a key step for effective electrification strategies (Colombo et al. 2024).

Reframing energy planning in rural SSA

Reframing in this context refers to a shift in how energy needs are conceptualized and measured, shifting from a narrow focus on meeting low-tier household demands to a more integrated view of households as both consumers and producers of goods and services. It involves identifying the full range of energy services needed for domestic well-being and for the agricultural and commercial activities that routinely take place within and around rural households in SSA and incorporating all these services directly into electrification planning, demand forecasting and system sizing. This might include evaluating the demand for PUE, incorporating this demand in system sizing, and engaging with the community to promote local value creation.

Shifting focus in energy access planning

This paper argues that energy planning for rural households could be reframed around a minimum threshold of energy services that enable both a decent standard of living and meaningful economic participation. The paper builds on existing frameworks such as the Modern Energy Minimum (Millward-Hopkins et al. 2020) and Decent Living Standards Framework (Rao and Min 2018), which redefine energy access not by the quantity of electricity consumed, but by the set of services required to support human well-being and productive activities. Explicitly linking household energy needs with agricultural productive uses could bridge the productivity gap and promote more inclusive and resilient rural development. This shift requires recognizing rural households not only as consumers of electricity but also as engines of local value creation, where farming, processing and enterprise activities take place within the same physical and economic space. By integrating productive uses into the design of energy systems from the outset, especially those tied to agriculture and food systems, planners could address multiple challenges at once: boosting agricultural productivity, improving household incomes, enhancing the financial viability of energy projects and supporting climate adaptation and resilience. The following sections unpack this argument, drawing on recent research, emerging planning frameworks, and lessons from real-world cases.

Energy planning occurs at multiple scales, from national to community levels. At the national level, it typically involves long-term planning by governments, utilities and regulatory agencies to develop strategies for generation, transmission and electrification based on projected demand and economic growth. This often focuses on expanding grid infrastructure and meeting basic energy access targets. At the community level, energy planning may involve decisions on whether to extend the national grid or to deploy off-grid solutions such as mini-grids or standalone systems (Howells and Rogner, 2017). It includes selecting appropriate technologies and optimizing system sizing to meet anticipated demand in a cost-effective and reliable manner.

In the context of rural communities in Sub-Saharan Africa, most national electrification plans prioritize the rapid expansion of access through low-tier connections. Planning models used in these contexts typically assume minimal consumption profiles and often do not account for the productive uses of electricity—such as irrigation, crop processing, or small enterprises that can significantly increase demand once electricity becomes available (Falchetta, Stevanato et al. 2021).

By 'reframing energy planning', it is meant changing the frame of reference through which energy needs are understood and quantified—specifically, recognizing the multifunctional nature of rural households, where energy needs are for meaningful economic engagement, particularly through agriculture-linked household enterprises. For instance, in Tanzania's Matembwe Village, planners designed a mini-hydro system not only to meet domestic demand but also to power poultry feed production, milling and cold storage. These loads were deliberately included in system planning, resulting in higher utilization, improved incomes and financial sustainability (Contejean and Verin 2017; see also Box 1). This case illustrates how aligning system design with productive activities can create synergies between energy access and rural development. This reframing, therefore, implies changes to the tools used in electrification planning, including the development of integrated demand profiles, scenario analysis that incorporates productive uptake of electricity, and the use of participatory methods to identify the meaningful enterprises that align with the local context. A small but growing set of modelling frameworks already points in this direction—For instance, the Global Electrification Platform and its *gep_onsset* backend (GEP 2024), which includes scenario levers for agricultural and other productive uses of electricity; multi-sectoral demand platforms such as M-LED (Falchetta, Stevanato et al. 2021) and nexus frameworks like RE4AFAGRI (Falchetta et al. 2024, RE4AFAGRI) that jointly characterize household, irrigation and agro processing loads; and recent extensions of geospatial electrification models (e.g. OnSSET) that embed electric agriculture within least-cost planning. However, these efforts remain the exception and are typically deployed as research prototypes rather than as standard practice in national planning. Such tools, if mainstreamed, would allow planners to embed agricultural and household needs within a single modelling and investment framework.

Operationalising this reframing may therefore involve: (1) incorporating productive agricultural loads into demand projections at the earliest planning stage; (2) identifying household-linked enterprises likely to emerge or expand with electricity; (3) building demand profiles that reflect irrigation, milling, cooling and cooking loads alongside basic domestic uses; (4) aligning system designs with frameworks such as Decent Living Standards to ensure energy services enable both well-being and income generation, (5) integrating these demand and system design choices into financing schemes and tariff structures and (6) coupling infrastructure roll-out with awareness-raising, SME capacity building and tailored financial mechanisms for productive investment.

Electrifying agriculture: a pathway to poverty reduction and rural development

With evidence that pro-poor approaches have not been able to solve the structural drivers of poverty, it is more widely recognized that poverty reduction will require a focus also on 'job creation and investing in the productive capacity of people' (World Bank 2024a). As argued above, this reframing requires treating rural households as productive economic units, not only welfare recipients. A key implication of this reframing is that energy planning in rural SSA could encompass agricultural activities within household energy demand. In SSA, agricultural activities are deeply intertwined with households, often functioning as household enterprises (Dagnachew and Choi, 2023). As such, household enterprises around agricultural productivity have the potential to transform local value chains, enabling wealth creation and improving market power for smallholders.

From basic access to economic empowerment

Although it is acknowledged that basic electricity access is crucial for improving living standards in the short term, it is equally important to invest in long-term development strategies that promote economic growth, create jobs and build human capital. The current focus on low-tier access objectives restricts access to services that could catalyze significant economic transformation (Stevanato et al. 2021). This need for investing in transformations of productive capacity of people is, however, increasingly recognized in the energy access discourse and practice; for example, the (IEA 2022) emphasizes the need to shift from basic

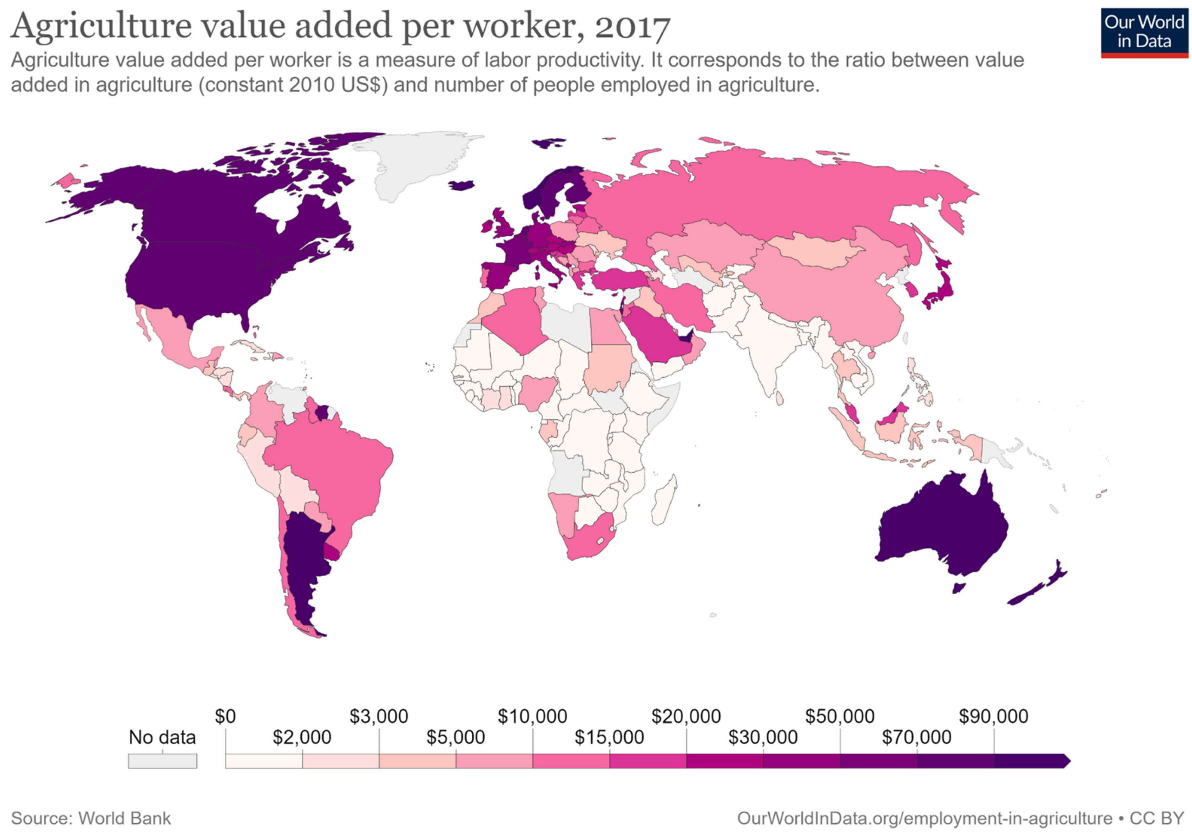

Figure 3. Agriculture value added per worker by country in 2017, Source (World Bank 2022). There is a big variation in the agriculture value added between countries in Africa. it ranges from a high 14225 USD in Algeria to a low 238 USD in Democratic Republic of Congo. Most of the countries in the region have a value added under 200USD, which is way below the world average of 3542 USD.

access to 'productive uses' of energy, such as powering small- and medium-enterprises (SMEs) and agricultural activities as a crucial step for fostering economic growth and poverty reduction. Similarly, some very recent energy access initiatives are also programming productive electricity access to marginalized and women farmers (Power Africa 2022). Successful examples of such approaches are presented in detail in Box 1.

The three areas, irrigation, processing and enterprise development, are interconnected aspects of rural economic activity and are discussed below. Electrification influences them collectively: irrigation boosts production, processing enhances value capture by farmers, and household enterprises provide diversified income. Considering them together clarifies the broader developmental impact of access to energy.

Enhancing household income through agro processing

Historically, many agricultural transitions have shown that increasing yield alone, especially of high-value crops for export, does not necessarily result in structurally transforming economic benefits and food security for the smallholder farmers or their developing countries (Meijerink and Roza 2007). Household enterprises could become more relevant to increase the overall productivity of smallholders with improvements in crop processing. Currently, food processing is done using conventional methods that are often time-consuming. For instance, grinding millet, rice, maize and cassava for gruels and porridges, are often done with mortar and pestle (Ajala and Gana 2015). This has kept the value added from agriculture in Africa, particularly in SSA, very low compared to other regions (see Figure 3). Using modern energy for these processes would not only considerably improve efficiency and product quality but also improve the productivity of these processes and free time for additional on-farm and household productive activities and leisure. Energy access and mechanization benefits women by saving time previously spent on labour-intensive tasks like milling cereals and de-husking rice. It can reduce daily grinding time for women and girls by 1.0–3.3 hours, enabling them to engage in other productive activities (Porcaro and Takada 2005). This would increase household income and help address the gendered dimensions of labour-intensive household activities.

Improving agricultural productivity

Evidence from the agricultural development literature broadly aligns in showing that electricity improves productivity through three channels: reliable water access for irrigation, time-saving mechanization of post-harvest processing, and reduced losses through improved storage conditions. Studies across SSA consistently find that these channels increase yields, reduce labour burdens—especially for women—and enhance the profitability of smallholder production.

Agriculture, despite being the largest employing sector in SSA, contributes relatively little to the region's economic output due to persistently low productivity levels both on the farm and after the farm gate. Even though the form of structural transformations that can best address developmental issues for these farmers is contested (Akram-Lodhi et al. 2010), all such pathways would need to include reducing the yield gap and increasing labour productivity to cope with climate change and variability. Raji et al. (2024) examine the role and impact of electricity in enhancing agricultural productivity in the region. Through a systematic review, the authors identified how access to electricity can improve various agricultural processes, such as irrigation, crop processing and storage, which in turn can lead to increased yields and economic benefits for farmers. Irrigation is linked to increased agricultural productivity (Giordano and Namara 2023) and higher incomes for farmers (Nyamba and Zidouemba 2025). Expanding irrigated agriculture represents a viable solution for boosting agricultural production and enhancing climate resilience, particularly when integrated with sustainable water management systems, improved access to financing for better seeds and inputs, increased public investment in research and development, and the widespread adoption of new technologies (Falchetta, Dagnachew et al. 2021).

Although significant expansion of centralized irrigation infrastructure is feasible and could be aligned with planned multi-purpose reservoirs (Xie et al. 2018), large-scale irrigation remains capital-intensive. Many SSA states have been unable to raise the required capital to provide such infrastructure fast enough. Moreover, the effectiveness of large-scale irrigation systems in achieving developmental goals has also been contested, often attributed to inadequate political and management frameworks (Higginbottom and Adhikari, 2021).

As a more viable alternative, small-scale distributed irrigation systems have been proposed. Wamalwa and Maqelepo, 2024 used seven representative food crops to assess both the cropland area and the economic feasibility of solar irrigation in SSA. The study suggests integrating irrigation energy needs into electrification planning to boost rural demand and accelerate electrification, supporting sustainable agriculture and development in SSA. Similarly, Falchetta et al. (2023) show, with the help of a spatially explicit model, that standalone solar photovoltaic irrigation systems could meet over one-third of the unmet irrigation water needs that could help stabilize crop yields, boost incomes and enhance food security for smallholder farmers. These systems, where groundwater or surface water sources are co-located with irrigated land, offer a cost-effective solution, reducing both capital investments and operational expenses for irrigation and pumping technology (Burney and Naylor, 2013).

Distributed irrigation systems are typically owned and managed by individual farmers or cooperatives. As such, these decentralized systems, when coupled with modern farmer extension services, could empower farmers and experience limited inefficiencies or political relations constraints in comparison with publicly operated large infrastructure. Such irrigation systems however, often require pumping water over a height of 10 m, making manual irrigation labour-intensive, hence making modern, energy to drive motor pumps an urgent priority in rural SSA (Burney and Naylor, 2013). Advances in household solar systems, together with PV-powered pumps and associated reductions in system costs, could make irrigation energy use at the household level ubiquitous; similarly, an expansion of micro and mini-grids can make community-scale solar-powered water pumps feasible. However, more than three-quarters of the rural population in Sub-Saharan Africa currently do not have access to modern energy, limiting the expansion of such irrigated agriculture and mechanization at the moment.

Box 1. **Lessons from Rural Tanzania: Integrating Productive Uses for Successful Rural Electrification and Development.**

Grey literature reports on energy access initiatives often highlight strategies that integrate farm and food production uses of electricity, assessing the impact of these approaches on project outcomes. The International Institute for Environment and Development (IIED) frequently publishes Working Papers that draw field evidence from implemented projects to inform global policy changes. One such report, 'Remote but Productive: Using Energy Access Investments to Catalyze Enterprises and Income in Tanzania's Rural Communities' by Best and Garside (2016), specifically examines how focusing on productive uses of electricity, especially in small-scale farming, can transform local economies. It emphasizes that simply providing electricity is not enough to achieve this transformation.

The paper documents three cases in rural Tanzania:

1. *The ACRA Case*: A 300-kW run-of-the-river system supplies power to nine villages through an isolated mini-grid. This project has facilitated productive uses of electricity in local businesses, such as milling, oilseed pressing and tailoring. Approximately 30% of the community utility's customers use electricity for business purposes, accounting for 58% of the electricity sold.
2. *The CEFA Case:* This initiative includes three mini-hydro power plants and was driven by end-use demand, specifically food security, rather than just the supply of energy. It established a holistic model where power is integrated with agro-processing businesses. For example, Matembwe Village Company (MVC) not only sells electricity but also operates a poultry farm and animal feed factory, creating jobs and income for local farmers.
3. *The JUMEME Case*: Located on an island in Lake Victoria, this pilot project features a hybrid system with a 60-kW solar PV, a 240-kWh battery pack and a 33-kVA diesel generator. Developed based on an energy needs assessment, the project prioritizes identifying and targeting productive energy uses, particularly for micro-enterprises often developed within households.

These cases demonstrate that aligning electricity provision with productive uses can significantly enhance local economic development, rather than simply making electricity available.

The success of the observed cases is evident not only in the improved quality of life and increased average income for beneficiary communities but also from the supplier's perspective. These projects have achieved increased profitability and timely recovery of investments, which is notable in a sector that often struggles to achieve financial viability (Bandi and Sahrakorpi, 2022; Maqelepo et al. 2025; Peters et al. 2019). These cases highlight the benefits of focusing on productive uses of energy (PUE), as reported by the IIED in their follow-up report, 'Making Mini-Grids Work: Productive Uses of Electricity in Tanzania' (Contejean and Verin 2017).

PUE increases electricity consumption, especially during daytime hours, which aligns with solar PV generation. This synergy reduces system downtime and boosts revenue per unit of installed capacity. Business customers, such as local enterprises, typically consume more electricity than households, generating a larger portion of total revenue despite being a smaller segment of the customer base. For instance, ACRA reported that its 21 milling business customers generated more revenue than 600 household customers combined. These micro-businesses, with their predictable and higher energy consumption, stabilize revenue streams and can cross-subsidize lower-paying household connections.

Evidence of PUE-linked profitability enhances the attractiveness of mini-grids to investors and funders, particularly in rural and remote areas. The JUMEME initiative has been widely recognized as a best-practice model in electrification projects (ADB 2022; SEforALL 2018), underscoring the value of integrating productive energy use in mini-grid systems.

The business models and ownership arrangements of the three case studies are also innovative. ACRA established the community utility LUMAMA alongside its mini grid, while CEFA founded the Matembwe Village Company. Both community utilities are driven by a social mission that extends beyond energy supply to include community development, agriculture and environmental conservation. JUMEME, on the other hand, is a joint venture between a German solar mini-grid firm, a Tanzanian university, and two Austrian renewable energy consultancy companies. JUMEME adopts a holistic approach by investing in stimulating customer demand and conducting support activities with customers, in collaboration with NGOs and consultants.

These business models demonstrate the potential of integrated approaches that align energy access with broader rural development objectives, with a particular focus on farm activities and agricultural transformation. They highlight how coordinated efforts, beyond the traditional focus on infrastructure access, can address diverse community needs and foster sustainable development outcomes.

In conclusion, these case studies clearly show that energy access initiatives that explicitly incorporate productive uses of electricity are more effective in transforming local economies and ensuring the long-term sustainability of energy systems. They underscore the importance of going beyond simply meeting household energy needs and adopting a holistic approach that prioritizes productive activities closely tied to rural households. These examples emphasize the necessity of integrating energy strategies with local economic development goals to make energy access financially viable while also catalyzing lasting social and economic impacts in communities.

Across the reviewed studies and cases in Box 1, a consistent empirical pattern emerges: productive uses account for the majority of electricity sold in well-performing rural systems, load factors increase (by 30%–60%), LCOE is reduced when irrigation loads are included (Energy Sector Management Assistance Program 2022), and PUE substantially raises user incomes through higher yields and value-added processing. These effects jointly strengthen the economic rationale for linking household and agricultural energy needs within a single planning framework.

Empowering rural households through household enterprises

Household enterprises involved in crop processing could play a pivotal role in transforming local agricultural value chains. These enterprises increase income for smallholders, enabling them to reinvest in productive technologies and improve their market power (Falchetta et al. 2024). The post-farm gate supply chain elements (processing, wholesale/transport, retail, food stalls, restaurants, etc.) account for 40%–70% of the cost of food for urban settlers in Africa (AGRA 2017). For instance, in the wheat value chain, making bread from wheat flour adds 0.53 USD in value per kilogram of flour, where the flour is sold for 0.32 USD/kg and the bread for 0.85 USD/kg (Borgstein and Mekonnen, 2020). Currently, only a fraction of this value from agriculture processing is captured by the local community with the lion's share going to large-scale industries located in urban and semi-urban areas.

Enhancing the financial viability of electrification projects

Stimulating energy demand for agriculture could increase the financial viability of energy access projects in rural areas, in addition to agricultural transformation. Maximizing value chains through different tiers of energy access for different purposes has multi-dimensional advantages for rural households. Access to energy for smallholder households has a multiplier effect for wellbeing because it can improve access to water, health, education and work opportunities. The gendered dimensions of poverty will also be addressed simultaneously.

The effectiveness of PUE interventions is highly dependent on the local context, including socio-economic factors, resource availability and community needs. There are risks and challenges of rapidly expanding PUE in rural SSA (Ngowi et al. 2019; Raji et al. 2024). These studies show that newly electrified communities often struggle to use electricity for productive activities, which undermines the anticipated economic stimulation from electrification and reduces the revenues of energy access projects. Such scenarios might lead to a raise in electricity tariffs to recover investments, which can create a vicious cycle whereby higher costs make electricity less affordable, further reducing demand and hindering the success of energy projects. Another risk is that agricultural intensification can lead to excessive water extraction that depletes water tables. Raji et al. (2024) show that the negligence of water cost in the techno-economic assessments of irrigation systems complicates the implementation of water pricing and inadvertently promotes over-exploitation of water, especially in solar-powered systems, where operating costs are low. Other risks mentioned include lack of technical knowledge for maintenance of equipment and proper agricultural practices, high initial costs of the system, market access constraints, seasonality of agricultural activities that can complicate cash flow and investment, and unreliable power supply that can impede the operational continuity of productive initiatives.

Integrating productive uses into electrification strategies

Recognizing household enterprises and enhancing energy demand

Building on the above discussions, the paper argues that a shift in how energy access planning is conceived in the first place could bring about a meaningful change in the effectiveness of the planned strategies. The acknowledgement of the household as foundational unit of rural communities in SSA and the primary target of electrification strategies, has to be complemented with the recognition of the multifaceted nature of the SSA rural household itself, and the transformative/productive uses of energy that will take place inside the boundaries of the household, aimed at meeting a set of both basic needs and developmental aspirations (Rao and Min 2018).

Including in the strategy formulation, the energy needs to drive the rural households out of poverty can be translated into 'taking into account energy needs that go beyond basics'. Households have the potential to initiate household businesses, ranging from agricultural transformation activities, including crop processing, and production of juices or jams, to manufacturing activities such as welding or carpentry workshops in the backyard of the house.

In some rural electrification projects, unexpected productive demand has led to challenges. For example, when a new mini-grid spurs entrepreneurial activities such as villagers opening barbershops, small eateries, or welding shops (Díaz et al. 2010; Kobayakawa and Kandpal 2015; Ulsrud et al. 2011), these additional loads can quickly surpass the system's design capacity if not accounted for, resulting in power shortfalls or quality issues. This common scenario highlights the limitations of traditional 'minimal' planning approaches.

Cooking is another essential part of agricultural product transformation processes, and in particular, food preservation. As depicted in Figure 2, access to clean cooking technologies is a significant challenge, especially in the poorer settlements of rural areas in SSA. The Modern Energy Cooking Services program has conducted a study on the financial sustainability benefits of integrating electric cooking into off-grid energy systems designed for electricity access (Clements and Batchelor, 2024). The report draws insights from 7 different Mini-grid developers in SSA that modelled the integration of electric cooking in the load that existing, or planned, Min-grids have to meet and studied the effect on the financial sustainability of the projects. Although the results vary by project specifics, some general considerations can be extracted from the study and are supported by the literature. Including electric cooking in a Mini grid's load directly increases the demand and load factor—especially if cooking activities are concentrated around noon—which in turn boosts the system's revenues. Higher utilization not only enhances these revenues by making the investment more appealing to developers, but also decreases the net present cost of the system (ESMAP 2019), allowing for lower tariffs for end-users.

The same logic applies to other productive uses of energy. Wamalwa and Wafula, 2025 and Wamalwa et al. (2023) argue that mini-grids face economic challenges due to low electricity demand, leading to higher tariffs than centralized utilities. By incorporating irrigation energy demand, the study shows that mini-grid LCOE can be reduced by up to 47%, with variations based on location and climate scenarios. The integration of productive uses of electricity for agriculture in off-grid system also improves the profitability of interventions, as reported also by World Bank sectorial reports (ESMAP 2022). This, in turn, could increase the attractiveness of investments, create room for innovative business models, and allow for more concrete financing opportunities. These points are illustrated through practical examples in Box 1.

In cases where multiple productive uses are anticipated and integrated from the outset—jointly by the community and developers—the outcomes could be positive. Box 1 reports prominent examples of this, including the CEFA initiative in Tanzania, where mini-hydro power was not deployed as a standalone energy intervention but rather embedded in a holistic rural development strategy. The Matembwe Village Company (MVC), for instance, paired electricity provision with direct investments in productive businesses like poultry farming and feed production, creating stable electricity demand while simultaneously generating income for the community. Similarly, the JUMEME project on Lake Victoria was developed following a detailed energy needs assessment and deliberately focused on productive uses—especially household-based micro-enterprises. Through partnerships with NGOs and consultants, JUMEME implemented entrepreneurial training and demand stimulation activities before electrification, ensuring that once electricity arrived, it could be immediately harnessed for income-generating uses. By training entrepreneurs and arranging financing for equipment in advance, this 'demand stimulation' approach ensures that once electricity is available, it is immediately used in ways that generate income, raise load factor, and potentially enable lower tariffs for basic use in poorer households. Reframing planning in this way means planning the supply and the demand (i.e. including envisaged economic activities) together as a package; this approach can also be considered as anticipating and potentially adapting to local productive demands that emerge in practice.

Conclusion and policy implications

This article has proposed reframing energy planning to incorporate productive uses within household demand. This requires fundamentally changing the frame of reference through which energy planners understand rural energy needs. Rather than viewing households merely as consumers of basic electricity services, they should be recognized as productive economic units whose energy systems could accommodate both essential needs, like lighting and phone charging, as well as the power demands of productive equipment such as mills, pumps and processing machinery from the initial planning stages. It should be emphasized that this reframing is not merely theoretical; it is gaining traction in policy circles and is backed by data. International experts are urging an increase in the ambition of SDG7 targets, such as adopting the 'modern energy minimum'.

Such reframing could enable poverty reduction through multiple concrete mechanisms. Households could generate substantial income by capturing much of the post-farmgate value through local processing. The approach could also address gender inequality by saving time—electric mills reduce daily manual grinding that falls predominantly on women. Agricultural productivity increases considerably when irrigation enables year-round cultivation, increasing yield and income per hectare. Furthermore, the financial sustainability of energy systems could improve significantly. Health outcomes also improve when electric cooking cuts deadly household air pollution and refrigeration enables proper food preservation. To operationalize this reframing, several concrete policy recommendations emerge:

- A framework that includes agricultural productive uses of energy within national and local electrification plans could be established. Planning models could take energy demand from irrigation, crop processing and household enterprises into consideration.
- Collaboration between energy, agriculture and water management sectors, developing integrated policies that comprehensively address the needs of small-holder farmers, could be facilitated.
- It is important to invest in participatory planning processes that engage communities in identifying their energy and economic needs, thus tailoring electrification projects to local priorities.
- Adapting definitions and standards for energy access to encompass productive uses beyond minimal household needs, adopting metrics that reflect energy needs for both human well-being and local economic development, is crucial.

However, as is often said, a one-size-fits-all solution does not exist. African countries need contextualized analyses on how to integrate these productive uses into household demand in energy planning, how to prioritize them and how to integrate them with water and land use planning. In the case studies, each community was initially examined from the agricultural and supply chain perspective to customize the energy intervention around the specific local economy; this also could include climate adaptation strategies for agriculture, such as decentralized solar-powered irrigation through green financing.

It is not claimed here that energy access at any level is a sufficient condition for social and economic transformation, but it is a vital enabler to jump-start the transformation. Given the diversity in resource availability, level of economic development, and the limited financial capacity of rural communities in SSA countries, this approach improves the affordability of access strategies and encourages innovative finance and local ownership and minimizes the cost of stranded assets.

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