IGC

State Fragility initiative

POLICY TOOLKIT

Driving productive use of energy in fragile contexts

Sarah Logan

Access to energy for productive purposes is essential to ensure that electricity connection translates into improved incomes and livelihoods for end-users. It is also critical for ensuring that end-users are able to pay for energy consumption, therefore improving the financial viability of solar mini grids. Stimulating uptake of productive use of energy in fragile contexts is not straightforward and complementary investments and cooperation from a range of actors is needed.

JULY 2024

DIRECTED BY

LSE UNIVERSITY OF OXFORD

FUNDED BY

The Rockefeller Foundation

Acknowledgements

The author wishes to thank Kevin Johnstone of the International Institute for Environment and Development (IIED) for his insight and invaluable review of this toolkit.

For any inquiries about this work or further engagement, contact the IGC State Fragility initiative team at **sfi@theigc.org**.

In this paper

This paper provides evidence to inform policy decisions around supporting the adoption of productive use of energy (PUE) appliances and their linkage with distributed renewable energy (DRE) projects in fragile and conflict-affected situations (FCS). It is intended to help equip policymakers in fragile settings with an understanding of the key considerations around financing, consumer awareness, appliance distribution and after-sales services, enabling regulatory environment, and integration of PUE into market systems development in low-income countries and FCS. To scale up PUE in fragile settings, collaborative efforts are required from a range of stakeholders, including appliance distributors, donors, development finance institutions (DFIs), philanthropic entities, private investors (both domestic and international), and energy project developers. Consequently, this paper outlines important lessons for other key stakeholders too. The technological scope of this toolkit focuses primarily on appliances to be run off solar mini grids or grid connections, with some coverage of standalone solar-powered appliances.

List of abbreviations

Abbreviation	Meaning
AC	Alternating current
AMDA	Africa Minigrid Developers Association
CLASP	Collaborative Labelling and Appliance Standards Programme
DC	Direct current
DSM	Demand-side management
EELA	Energy Efficient Lighting and Appliances project
ESMAP	Energy Sector Management Assistance Programme
GDC	Global Distributors Collective
GOGLA	Global Off-Grid Lighting Association
FCS	Fragile and conflict-affected settings
LEIA	Low-Energy Inclusive Appliances programme
MEPS	Minimum Energy Performance Standards
MFI	Microfinance institution
MSME	Micro, small and medium-sized enterprise
NGO	Non-governmental organisation
PAYGo	Pay-as-you-go
PUE	Productive use of energy
R&D	Research and development
RBF	Results-based financing
REDP	Rural Electrification Densification Programme
RPA	Rapid Product Assessment
SEFFA	Sustainable Energy for Smallholder Farmers
SMG	Solar mini grid
VAT	Value Added Tax

Contents

Boxes, Figures, and Tables

Driving productive use of energy in fragile contexts

Executive summary

Access to energy alone is not sufficient to change lives or lift people out of poverty – rather, productive use of energy (PUE) is vital to ensure that energy access has a transformative impact and increases people's income-generating capabilities and wellbeing. PUE is also key to enabling the financial viability of solar mini grid projects, as customers' higher incomes increases their ability to pay for electricity usage and raises their demand for energy over time.

PUE uptake is not automatic after an electricity connection has been established, however, and concerted efforts are needed to stimulate PUE uptake. This is particularly so in fragile settings (which are characterised as lacking basic security and a functioning private sector and having inadequate government capacity and divided societies[1]) and rural and remote areas with fragile economic conditions, weak market linkages, and lack of natural resources.[2] The most effective approach is to ensure that electrification efforts specifically target livelihoods and income generation to support the expansion of economic activities among connected communities.[3] It is critical that specific efforts are made to reach women and other marginalised groups for PUE awareness, financing, and continued adoption, which necessitates specific efforts along gender and other dimensions.

Most of the focus of PUE is on increased mechanisation in agriculture, value-added processing, storage, transport, and lighting, cooling and processing equipment for businesses and households. Most PUE appliances can be run off the grid or mini grids, while some of the larger PUE appliances are stand-alone products with their own solar PV cells and batteries. Some off-grid appliances are relatively well established now, such as solar lanterns and solar home systems that support lighting, phone charging, televisions, radios and a few other appliances, depending on system size. Other PUE appliances are still emerging, such as solar water pumps, solar refrigeration units, and agri-processing equipment such as grain mills and crop drying equipment.[4]

PUE has the potential to increase the socio-economic impact of electrification, magnifying the opportunities presented by energy access. It enables improved service provision, reduces manual workloads and time required to complete tasks, creates income-generating opportunities for households and small businesses, and supports greater resilience and sustainability. However, significant complementary investments are needed to realise these improved outcomes, including ensuring that teachers and health care workers are paid on time, road and communication infrastructure is sufficiently built out, and that people gain the access to markets needed to procure improved agricultural inputs and sell excess crops, for example. PUE by itself cannot raise incomes unless the

1 Logan & Sacchetto, 2021.
2 World Bank, 2023.
3 ESMAP, 2008.
4 GOGLA, 2023a.

complementary investments are in place to allow PUE users to effectively leverage PUE appliance usage.

Despite the evident socio-economic benefits of expanded PUE, a number of challenges hinder the full-scale deployment of PUE products and appliances. These challenges are particularly pronounced in settings of fragility and displacement and span both the demand side and supply side, requiring complex coordination between a range of stakeholders to overcome these constraints. On the demand side, affordability and lack of consumer awareness are among the most notable constraints. Different financing models have been developed to increase affordability for consumers, including pay-as-you-go (PAYGo) and payment in kind arrangements. Raising consumer awareness around energy access and PUE appliances requires targeted efforts, including roadshows, demonstrations and pilots, and product fairs, taking into account local dynamics and gender-based differences. Specific attention needs to be paid to how to reach different groups of potential consumers, including women and other marginalised groups, and how to ensure that they're able to participate in awareness and training activities. Business support services have been seen to be important in ensuring that customers are able to make maximum use of their PUE appliance to grow their economic activities.

The supply side is affected by the investment climate in a country, renewable energy sector dynamics (such as the design and implementation of policies and regulations that support the uptake of PUE), and the presence and reach of PUE appliance distributors, who play a key role in driving PUE uptake. Distribution is affected a number of factors, including distribution networks (including those in rural and remote areas) and the working capital constraints of distributors (which determines whether they can provide in-house consumer financing or not). Sales and after-sales support requires trained technical personnel and knowledgeable sales agents, who are needed to ensure that customers purchase the right PUE appliances. Broader regulatory issues include the need for effective regulatory frameworks that can support the uptake of PUE, including licensing regimes, quality standards, and adoption and implementation of tax and duty regimes that encourage PUE investment, among other things. Supply-side financing instruments have been developed to ensure that appliance distributors are better able to finance their activities and growth, including results-based financing and several instruments using concessional financing. Additionally, government policies that waive or lower taxes or duties on PUE appliances lower cost and therefore raise affordability for customers and financial viability of appliance distributors.

Integrating PUE promotion into market systems development can help achieve maximum impact for households, farmers, and small businesses, while also improving the financial viability of mini grid operators. In rural areas, PUE adoption should be part of an integrated rural development strategy. If consumers are not able to generate greater incomes from their adoption of PUE appliances and, for example, the greater crop yields achieved as a result, then their PUE investment will not be worthwhile. Therefore, complementary investments are needed to ensure that gains from electricity connection and PUE adoption can be attained, such as road and bridge construction and transport and logistics services that enable market access and the sale of agricultural outputs in urban areas.

Mini grid development should better integrate productive use of energy activities and be sized appropriately to cater for the level and nature of existing and future local PUE demand, in addition to estimated household usage. PUE plays a key role in ensuring that mini grids are financially viable, with PUE users contributing a notable proportion of mini

grid revenues despite normally comprising only around 15% of mini grid customers.[5] Mini grid developers need to balance how much electricity they're providing with how much consumers are using, making good use of PUE use during daylight hours (when the cost of solar energy generation is marginal). This approach balances the needs of customers and increases the capacity utilisation of mini grids.

Support is also needed for governments, particularly those that experience capacity constraints, to assist in development of PUE regulations and keeping them abreast of sector developments. Cross-sectoral and inter-ministerial collaboration is needed to cover key sectors (including energy, agriculture, health, water, vocational training, infrastructure development, and rural development) and coordinate a large number of different actors (including local governments, mini grid operators, appliance distributors, local communities, donors and development partners) and all aspects of the PUE ecosystem (including licensing, quality standards for appliances, tax and duty regimes, etc).

Although the challenges around stimulating PUE adoption in low capacity and fragile environments are considerable, mechanisms developed to overcome these challenges are being innovated and improved continuously. More public and private finance needs to be mobilised to enable these efforts to scale up. Greater recognition of the critical importance of PUE to mini grid viability and improved integration of financing of mini grids and PUE is needed to ensure that PUE distribution can be scaled up in line with efforts to scale up mini grid development as part of efforts to expand energy access.

5 Interview with EnerGrow.

1. Introduction

Access to energy alone is not sufficient to change lives or lift people out of poverty – for energy access to have a transformative impact on people's lives and enable improvements to their socio-economic wellbeing, it is critical that consumers can use energy for productive purposes. It is also vital that consumers are willing and able to pay for electricity usage – otherwise their access to electricity may be ineffectual.[6] It is not just electricity connections that matter, but what customers do with the electricity they receive.

This toolkit will focus on fragile settings (which are characterised as lacking basic security and a functioning private sector and having inadequate government capacity and divided societies[7]) and rural and remote areas with fragile economic conditions, weak market linkages, and lack of natural resources.[8] Households experiencing poverty have low energy demands, particularly in settings of fragility or displacement. Low levels of energy consumption do not cover the cost of connecting these households to electricity, which undermines the financial viability of extending electricity access. An estimated 90% of those living in emergency situations lack access to electricity to meet their basic needs and businesses, including those in refugee camps, have insufficient electricity to upgrade their services.[9] This presents a binding constraint on development in settings of fragility and displacement.

While electricity provision does not necessarily need to be profitable – indeed, the electricity sectors of most developed nations today were (and many continue to be) subsidised – the involvement of private sector actors in electricity provision in low-income countries has led to increased reliance on funding sources that require some degree of positive return on investment. Private sector involvement in electricity provision in low-income countries has emerged in large part due to the governments of these countries being too fiscally constrained to be able to extend national grids or to reliably pay independent power producers for generated electricity.

Much private sector involvement is focused on developing mini grids in areas where populations are either unserved or under-served by existing electricity services. Mini grids are a set of small electricity generators connected to a distribution network that supplies electricity to customers located close by. Solar mini grids, which utilise solar photovoltaic panels to generate electricity, have become an important energy option for unconnected populations, including those living in countries characterised as fragile, due to declining costs of equipment and the abundance of solar resources in many fragile settings. Fragile and conflict-affected situations (FCS) and displacement settings are the focus of this toolkit, being where a vast majority of those without electricity access live. Many of the constraints faced in these settings

6 Ireri & Kilonzo, 2024.
7 Logan & Sacchetto, 2021.
8 World Bank, 2023.
9 Alianza Shire, 2022; GIZ & UNHCR, 2021.

are shared by more remote and rural areas, therefore some focus is given to rural settings too.

Affordability constraints are very pronounced in these contexts, making it essential that energy access translates into an increase in income for customers. Productive use of energy (PUE) is of vital importance as it provides a route for customers to increase their income, thereby raising their ability to pay for energy usage. PUE refers to the "use of electricity to produce goods or services for the production of income or value."[10] PUE involves energy-efficient and productive use appliances for farmers, small businesses, public service facilities (such as schools and health clinics), and households. PUE increases the income-generating capabilities of households and small businesses through raising the productivity and profitability of both new and existing economic activities and reducing their time requirements. Increasingly, PUE is more than technology and greater emphasis is being placed on the socio-cultural innovations possible with how communities interact with PUE within the constraints of their environment.

This toolkit will cover both standalone PUE products and PUE appliances that can be run off solar mini grids (or the main grid) as standalone products are of notable relevance in FCS where mini grids are yet to be scaled up in a significant way. That said, more focus will be placed on PUE appliances that can be run off mini grids and their linkage to improving the financial viability of mini grids in these settings.

This toolkit will not cover cooking solutions beyond electric cookers, given its focus on PUE appliances that can be run off solar mini grids. However, clean cooking solutions remain a vital priority for low-income countries and settings affected by fragility and displacement, where women and girls are often exposed to gender-based violence while trying to source firewood for cooking, and where deforestation is causing serious environmental impacts.

Concerted effort must be made to stimulate uptake of PUE; it does not happen automatically, particularly among low-income populations. This is particularly so in rural and remote areas with poor economic conditions, weak market linkages, and lack of natural resources.[11] The most effective approach is to ensure that electrification efforts specifically target livelihoods and income generation to support the expansion of economic activities among connected communities.[12] This requires an understanding of existing economic activities as well as potential new economic activities that could be made possible by PUE and factoring this into the design and development of SMGs. Specific attention must be paid to gender differences in PUE, with differing needs, preferences, and economic activities of women and men and different communication channels for awareness raising and mechanisms for financing PUE purchases. PUE is an activity within a broader, complex system characterised by layered interactions between actors and circumstances.[13]

10 Hartvigsson et al., 2021.
11 World Bank, 2023.
12 ESMAP, 2008.
13 World Bank, 2023.

While the scope for economic activities and PUE may be constrained in some FCS and displacement settings, there is diversity in the conditions that exist in these environments, making different levels of PUE possible. As such, we will explore what PUE could look like in a range of settings and what is needed to establish supporting conditions for PUE expansion. Examples are also taken from lower-middle and middle-income countries to give a sense of what more low-income countries can work toward in coming years.

This paper will first cover key PUE appliances and the potential benefits they offer to users, provided the necessary complementary investments are made. It will then explore the range of challenges that are limiting PUE adoption in FCS, including factors on the demand side (such as affordability and consumer awareness) and on the supply side (such as distribution networks and the regulatory environment). Challenges around financing constraints will be highlighted and different mechanisms to overcome these constraints will be explored. The paper will conclude with outlining a number of recommendations for different stakeholders to consider in efforts to scale up PUE adoption in FCS.

1.1. PUE products and appliances

Most of the focus on PUE has been on increased mechanisation in agriculture, value-added processing, storage, transport, and lighting, cooling, and processing equipment for businesses and households. Some off-grid solar appliances and products are relatively well established, such as solar lanterns and solar home systems (SHSs), which can support lighting, phone charging, televisions, radios, fans, and refrigeration units, depending on their size.[14] Where these appliances are used specifically for income-generating purposes, such as televisions in cafes or bars, which increase the number of customers and sales, or refrigerator units in shops to keep perishable goods for longer, they are considered to be for productive use. These established technologies currently comprise a majority of the market share across the PUE market in general.[15]

There are also a number of near-to-market and emerging PUE appliances and products, primarily for use in agriculture, including solar water pumps, solar refrigeration units, and agri-processing equipment such as grain mills and crop drying equipment (see **Figure 1**).[16] These are standalone PUE products that use solar PV cells to directly power appliances or recharge batteries, rather than being connected to a mini grid. They tend to be more complex, require more energy to operate, and are more expensive than smaller, more established products.

14 GOGLA, 2023a.
15 Ibid.
16 Ibid.

Figure 1 Examples of PUE appliances and their applications[17]

Examples of Productive Uses of Renewable Energy (PURE) products and appliances

Product Category	Application	Level of market maturity	Visual example
Small and portable solar water pumps (SWPs)	SWPs enhance irrigation for smallholder farmers and enable production during dry seasons	Near-to- market	
Solar refrigeration units (SRUs)	SRUs preserve perishable produce and beverages, and enable MSMEs to increase their services	Near-to- market	
Solar inverter	It provides clean 24/7 energy and allows solar kits and PURE appliances and products to connect in weak-grid areas.	Near-to-market	
Walk-in cold rooms (cold storage)	Off-grid fee-for-service cold-storage solutions to enable preserve dairy, fish, meat, fruits, or vegetables.	Emerging	
Produce transportation	PAYGo service electric vehicle transportation of agricultural produce in rural areas.	Emerging	
Agri-processing	Electric milling machines to grind the grain and produce flour or electric dryers to accelerate drying of agricultural produce like mango, coffee or banana.	Horizon	

Solar water pumps and solar refrigeration units have moved from 'emerging' to 'near-to-market' in the last few years. Solar water pumps available today are more efficient and affordable than they were a few years ago and are often integrated with pay-as-you-go (PAYGo) capabilities and enabled for improved monitoring, control, and information provision for users.[18] Solar refrigeration units have great potential to reduce food waste along value chains and innovations in insulation, efficient compressors, and better controllers are enabling costs to be lowered and products to be more efficient and durable.[19]

A range of other agri-processing products also exist, including crop sprayers and floodlights, as well as agriculture-related appliances that can run off mini grids (or SHSs, depending on their capacity), such as egg incubators, sterilizers for dairy processing, and fruit juicers. Retail appliances for use by micro, small and medium-sized enterprises (MSMEs) include small-scale manufacturing equipment (such as for welding, ice making, and carpentry), as well as hair clippers, sewing machines, charging units, televisions, and refrigerators for retail use. SHSs can generally only support smaller direct current (DC) appliances, while most mini grids offer an alternating current (AC) supply for higher-power appliances.[20]

17 Ibid, page 8.
18 World Bank, 2022.
19 Ibid.
20 World Bank, 2023.

2. Significant socio-economic potential of PUE

PUE has the potential to increase the socio-economic impact of electrification, magnifying the opportunities presented by electricity access. By enabling improved service provision, creating income-generating opportunities for households and small businesses, reducing manual workloads and the time required to complete tasks, and supporting greater resilience and sustainability, PUE products and appliances hold considerable socio-economic potential for users. As many communities without electricity access live in climate-vulnerable regions, integrating renewable energy technologies into agriculture, operations of MSMEs, public infrastructure, and communication systems can be critical to building resilience and ensuring provision of vital services.[21]

Despite the significant enabling role that energy access and PUE plays in development, it is often overlooked and underfunded in humanitarian responses in conflict and displacement contexts.[22] Greater attention to and more consistent investment in PUE is vital for development in these settings.

2.1. Unequal benefits of PUE

There are considerable differences across gender when it comes to PUE and these need to be borne in mind across all aspects of PUE. Men generally benefit more from electricity access as they more frequently occupy vocations where electricity can greatly increase their productivity, such as welding and carpentry, whereas women may be less exposed to mechanised equipment. Where men and women operate in the same sector, however, their performance is similar,[23] indicating that while abilities do not necessarily vary across gender, the nature and income-earning potential of different roles does differ in the context of PUE. Preferences for PUE technologies also differ across gender, and women also tend to prefer PUE appliances that can be located close to their homes and which can be used for both productive and domestic purposes.[24]

Men frequently have greater access to the resources needed to purchase PUE appliances than women do, with women facing constraints both within and outside the home around financial decision-making, which further skews benefits towards men, especially in low-income households. Women's needs may not be prioritised in households experiencing poverty, despite their labour tending to be more dominated by time-consuming and low-productivity menial labour, such as manually preparing and grinding grain for household consumption.[25]

21 GOGLA, 2023a.
22 Mercy Corps, n.d.
23 Pueyo et al., 2018.
24 Theis et al., n.d.
25 ESMAP, 2022.

Time savings through use of PUE appliances for such household tasks can be significant – for example, while it takes two hours to grate a basin of cassava by hand, a grating machine can do the same in one minute.[26] Mills for grinding and de-husking have saved women six hours of menial manual work per day, freeing up time for other activities.[27] Yet these benefits for women may not be recognised or prioritised in many instances as their time may be less valued. The household distribution of use of PUE appliances and control over revenues they generate affects who benefits from PUE adoption and who may be incentivised to adopt a technology.[28]

While gender may be one of the more prominent dimensions of unequal benefits, this pattern can also be seen on other dimensions too, such as age and ethnicity. Where people experience marginalisation on more than one dimension, these structural barriers may severely impede PUE access and adoption.[29] Ensuring that projects are better integrated could remedy this, with skills development and empowerment training being provided together with financing for PUE appliances.

Displacement settings, such as camps for refugees and internally displaced persons (IDPs), must be given careful consideration in the context of PUE given that refugees and IDPs often face restrictions on formal employment in host countries and access to markets outside camps. This necessitates specific support to enable PUE adoption in these contexts, including efforts to promote job creation.

2.2. Improved service provision

Energy access enables PUE in improved service provision, potentially allowing health clinics to stay open for extended hours, powering refrigerators to preserve vaccinations and medications, and enabling diagnostic equipment dependent on electricity to function.[30] Solar water pumps can make potable water more accessible and cold storage lowers the risk of food contamination, reducing the prevalence of disease. PUE usage in healthcare is particularly significant since two-thirds of healthcare facilities in low-income countries lack access to reliable electricity.[31]

Similarly, energy access could improve education, with education gains having been seen to amplify other positive impacts of energy access.[32] PUE also supports improved communication services by powering mobile phone charging stations, as well as communications infrastructure, televisions, radios, and internet access. Broader benefits of communication services include facilitating the transfer of knowledge and information, which may be integral to both economic activities and social networks.

26 Ibid.
27 World Bank, 2023.
28 Theis et al., n.d.
29 Johnstone et al., 2022.
30 Efficiency for Access, n.d.
31 GOGLA, 2023a; GIZ & UNHCR, 2021.
32 Efficiency for Access, n.d.

Access to electricity to charge phones and access telecommunications services promotes digital financial inclusion, which plays a key role in reducing poverty and supporting economic growth. Digital financial inclusion enables users to better manage existing financial resources and participate in more effective risk sharing with a more diverse and geographically dispersed network, which contributes to greater financial resilience of households.[33]

PUE can also support improved government administration by enabling use of hardware and information technology systems needed to deliver key government functions, such as tax administration and e-governance services. Additionally, PUE in the form of lighting at border posts enables extended opening hours and improved safety for cross-border traders, especially women. This eases cross-border trade, which is frequently a vital mechanism for communities in fragile settings to access basic goods, and makes it safer for women, who more often experience harassment, theft, and gender-based violence around border crossings.

Lighting is also a particular issue in refugee and displacement camps, where insufficient lighting can pose a security risk and increase vulnerable persons' exposure to gender-based violence.[34] Given the increasingly lengthy lifespan of displacement camps, recent years have seen a greater focus on developing longer-term renewable energy options for camps, with ongoing efforts to transition operations of UNHCR, the United Nations Refugee Agency, from diesel generators to solar solutions.[35] Projects at the humanitarian-development-peace nexus, sometimes linked to pledges under the Global Compact for Refugees, are increasing in number. Solar streetlights have markedly improved security in a number of camps, including Bokolmanyo refugee camp in Ethiopia,[36] and in more insecure settings, such as in Ndosho in eastern Democratic Republic of Congo.[37] Mini grids in Bokolmanyo also provide electricity to a market, computer centre, communal television room, and nearby organisations and households.[38] A further example of electricity provision in refugee camps is outlined in **Box 1**.

BOX 1 ELECTRIC COMMUNAL KITCHENS IN REFUGEE CAMPS IN ETHIOPIA[39]

UNHCR has installed electric communal kitchens in a number of refugee camps in Ethiopia in order to improve access to clean cooking in refugee camps. Due to the cost and availability of infrastructure, efforts are currently limited to shared facilities rather than households. Each kitchen can meet the needs of 150-200 households, with stoves, ovens, sinks, lighting for night-time use, and kettles. The facilities also include areas for children to play while their parents cook.

33 Logan, 2017.
34 GIZ & UNHCR, 2021.
35 Ibid.
36 UNHCR, 2023.
37 3degrees, n.d.
38 UNHCR, 2023.
39 Ibid.

These cooking facilities provide an important alternative to cooking with firewood These cooking facilities provide an important alternative to cooking with firewood in contexts where collection of wood for cooking has resulted in significant deforestation, which has triggered grievances from host communities. Although people prefer cooking in their own homes, difficulties around firewood collection have made them more accepting of using shared cooking facilities.

To date, the cooking facilities have been powered by the national grid, with grid extension needed in several instances to reach the camps, posing significant upfront costs. The costs of grid connection, water supply, and waste management solutions for the cooking facilities have been covered by UNHCR, Danish Church Aid (DCA), International Commitment for the Development of Peoples (CISP), and the Ethiopian Evangelical Church Mekane Yesus Development (EECMY) and the Social Service Commission.

It is important to note that improved public service outcomes also depend on a number of factors other than electrification and, without complementary investments, such as paying the salaries of teachers and health care staff on time, making budgetary provision for repair and maintenance of PUE appliances, providing gender-awareness training for border officials, ensuring reliable electricity supply from mini grids, educating users on digital financial products, extending mobile phone reception coverage, and improving government administration processes, adoption of PUE appliances in public service facilities will not translate into improved outcomes. These complementary investments are costly for governments of FCS to make, requiring support from development partners to ensure that improved outcomes can be achieved in practice.

2.3. Improved livelihoods, increased income generation, and greater resilience

PUE both creates opportunities for new sources of income generation and offers the potential to drive increased productivity and profitability from existing economic activities, thereby raising the income of PUE users. For example, in Kenya, "solar water pumps increased crop yields for households by as much as USD 800 per year and solar-powered cooling reduced losses and improved sales, leading to a 150% improvement in key dairy performance indicators such as milk quality and production and farmer's income."[40] Solar water pumps may also enable an additional growing season each year by reducing reliance on rainfall.[41]

40 World Bank, 2023, referring to research undertaken by Crane, Zukerman & Thrift (2020) and Savanna Circuit Tech & UK Government (n.d.)
41 UOMA, 2020.

As economic activities become more productive and profitable, small firms can grow, creating more jobs which may become better paid and higher quality over time. For every 100kW deployed, it is estimated that seven permanent direct jobs are created, as well as further local economic development that generates indirect employment and income-generating opportunities for communities, thereby contributing to higher living standards.[42]

The greatest impacts of renewable energy-powered PUE will be seen in sectors that represent notable shares of national GDPs, particularly agriculture, which represents one-fifth of Africa's GDP.[43] This includes enhanced mechanisation across multiple industries, saving time and reducing manual labour, achieving higher efficiency and productivity, as well as improved worker safety.[44] For example, solar water pumps and cold-storage facilities in supply chains are critical to boosting agricultural productivity in rural areas by reducing reliance on rain-fed agriculture and increasing yields, as well as lowering post-harvest losses and preserving agricultural produce to reach urban markets.[45]

Greater agricultural productivity and reduced post-harvest food losses resulting from PUE technology usage contribute directly to improving local food security, which is especially critical in instances of instability where supply chains may be disrupted and stock outs may trigger hoarding and price hikes, which undermines food availability, affordability, and access. Improved food security, in turn, can lower malnutrition, which remains a dire challenge in many FCS and low-income countries.

Availability of energy for productive use at the local level enables greater local value addition and localisation of value chains with grain milling and crop aggregation and refrigeration, for example, taking place locally. By moving processes such as processing, packaging, and cooling closer to farmers and areas of production, profits for actors in the local agricultural supply chain increase.[46] This would create more jobs in the local area and, critically for FCS, localisation of a variety of value chains may make communities more resilient to instability in surrounding areas.

As with improved service provision, a number of complementary factors also determine whether PUE adoption translates into higher incomes, improved livelihoods, and greater resilience. Notably, PUE users must be able to access both input markets and markets for sale of their goods, including crops, produced through PUE adoption. This necessitates complementary investments in information sharing, road infrastructure, agricultural input supply chains, and agricultural extension services, for example.[47] Interventions to promote PUE must also specifically target women and other marginalised groups to ensure that their needs are reflected in complementary investments. These complementary investments can be difficult for governments of FCS to achieve and maintain, due to financial constraints as well as the damage and disruptions to infrastructure and supply chains that conflict and instability can bring.

42 AMDA, 2022.
43 IEA, 2022.
44 GOGLA, 2023b.
45 IEA, 2022.
46 Wearne et al., 2022.
47 Johnstone et al., 2022.

philou1000,
Getty Images

2.4. Financial sustainability of service

As the incomes of households and small businesses increase as a result of their more productive and profitable economic activities, their ability to pay for energy usage increases, enabling them to 'climb the energy ladder'. This involves an increasing number of households and small businesses being able to afford higher tier energy products and services, such as more or larger appliances.[48] Over time, this can create further economic opportunities and improve well-being and, critically, can lead to future increases in energy demand, as well as willingness and ability to pay for energy consumption. This PUE-driven increased demand for energy is critical for the financial viability of solar mini grids, with PUE users being critical for the financial sustainability of SMGs.[49]

There are a number of constraints that obstruct greater adoption of PUE appliances in fragile and low-income contexts, holding back these many potential improved outcomes. These challenges will be explored in the next section, with ways to address these challenges being outlined where relevant.

48 EnDev, n.d.a.
49 Ibid.

3. Challenges to expanding PUE in FCS and how these may be addressed

Although the potential socio-economic benefits of expanded PUE are vast, there are a number of challenges that hinder the full-scale deployment of PUE appliances. These challenges are heightened in FCS and low-income countries and span both demand side constraints, such as affordability and consumer awareness, as well as supply side constraints, including distribution, after-sales services, and regulatory issues.[50] Importantly, expanding PUE inherently requires complex coordination between a range of stakeholders, notably local and national government, mini grid developers, PUE appliance distributors, microfinance institutions (MFIs) or asset financing companies, and local groups (including farmers groups, savings groups, and religious groups, ensuring inclusion of groups that include women and other marginalised people as members).

3.1. Demand side factors

The demand side looks at the consumer and constraints they face in PUE adoption. Challenges around low affordability and limited consumer awareness of PUE products and appliances are the most severe demand-side challenges, and are particularly significant in low-income countries, and even more so in FCS.

3.1.1. Affordability and demand-side financing

The cost of PUE products and appliances often represent significant shares of the annual incomes of low-income consumers in FCS. While their adoption offers the potential to raise incomes, the high upfront costs of purchase (typically between USD 100 and USD 1,500) are a major obstacle to adoption and credit options to help finance purchases in these settings are limited. This is particularly so for women, who have lower access to credit due to more limited financial literacy and knowledge of how loan processes work,[51] as well as less documented credit histories.

Older (generally pre-owned) appliances may be cheaper to purchase in local markets and may be compatible with AC from SHSs and mini grids, but as they tend to not be energy efficient, they consume more energy per unit of output produced, which erodes the profitability – and, therefore, the affordability – of appliance investments. In some cases, the initial load required to start some older equipment, such as old milling machines, exceeds the capacity of solar mini grids. Access to newer, energy-efficient appliances for PUE is therefore essential to ensure that they can be run on solar mini grids and to lower the cost per unit of output produced, making energy consumption more affordable and investments in PUE more financially viable. However, these newer PUE appliances will be more expensive.

50 GOGLA, 2023a, page 2.
51 Theis et al., n.d.

Despite the promising economics of PUE appliance investments, accessing finance is a key obstacle in FCS, with low or no bank presence in rural areas and high interest rates, which makes credit unaffordable for most potential PUE users. Additionally, commercial banks may require collateral for loans, which customers are often not able to provide in FCS.[52] However, there are some demand-side financing instruments that have proven to be effective in more under-developed markets, including:

- **Pay-as-you-go (PAYGo) or lease-to-own arrangements** where appliance distributors or microfinance institutions (MFIs) provide loans for appliance purchase. The financing company would need the expertise required to accurately assess loan applications and would need to ensure that the size of instalments, frequency of instalment payments, interest rate, and loan length offered are workable for potential customers.[53] This model improves affordability of products as it allows households and small businesses to pay for the cost of solar products and systems over time, thereby removing the high upfront cost.

  Importantly, PAYGo models also allow revenues generated from using the PUE appliance during the loan period to be used toward paying off the loan, which contributes significantly to improving affordability.[54] PAYGo technology is integrated into some systems and a run-stop function cuts off functionality if a payment has not been made.[55] To date, few MFIs have been willing to take on financing of PUE appliances, particularly on terms that are affordable for customers. An example of a MFI that has managed to do this, however, is EnerGrow in Uganda, which is covered in **Box 3** and a case study accompanying this toolkit, *EnerGrow: Providing asset financing for productive use of energy products in Uganda.*

- Appliance distributors can also explore accommodation of **different payment options**. Importantly, repayment plans should align with agricultural cycles and allow for repayment over several seasons.[56] For example, SolarWorks in Mozambique allows seasonal payment plans, reflecting the reality of seasonal income of e.g., farmers, while Natfort Energy in Zimbabwe accepts non-cash payments, such as livestock or agricultural produce, which they can easily find markets for.[57] Similarly, Sumba Sustainable Solutions in Indonesia accepts payment in goods and services, most commonly in bamboo and coconut oil.[58]

52 GOGLA, 2023b.
53 USAID, 2021.
54 AfDB, 2020.
55 UOMA, 2020.
56 Theis et al., n.d.
57 Colenbrander et al., 2022.
58 GDC, n.d.; Hobgen, 2021.

- **Diaspora financing** plays an important role in financing PUE appliances through remittances and gifts.[59] If PAYGo systems allowed international payments for PUE appliance loans, this would enable the diaspora population to contribute directly to loan repayments for family members back home, likely with lower transaction costs than repayments made locally after funds have been received through remittance channels.

- Other **end-user financing** mechanisms include tailored loan products developed with MFIs to lower the interest rate through provision of a specialised de-risking fund, and guarantee programmes or funds with local banks to allow collateral-free or low interest loans for end-users.[60] Such programmes are often only possible with support from development partners.

- **On-bill financing** may be relevant in more developed energy markets and involves customers purchasing PUE appliances and products using loans from mini grid operators, which loans are paid off through the addition of a surcharge to customers' monthly electricity bill.[61] Loans from mini grid operators tend to be on better terms (leveraging their lower cost of capital) compared to local alternatives, which are often very short-term, high interest informal loans. Kenya Power and Lighting Company is one utility that has been exploring on-bill financing of PUE appliances for last-mile customers.[62] However, undertaking in-house financing for PUE appliances may significantly increase the working capital requirements for mini grid operators, making it a more unlikely option in FCS.

ESMAP has found that over 130 income-generating PUE appliances have a payback period of under 12 months in Ethiopia.[63] Longer repayment periods may be needed to increase affordability, although this would incur higher interest costs. It is thought that if MSMEs and smallholder farmers have payback periods of between one and six years for their off-grid products and appliances, the economics of these investments becomes overwhelmingly positive, particularly when the increased yields and reduced post-harvest losses enabled by these products are factored in.[64] However, climate change is making agriculture increasingly risky and consecutive bad seasons as a result of repeated rain failures, for example, have become more common, such as the five consecutive failed rainy seasons in northern Kenya between 2020 and 2023. Climate change could severely undermine PUE appliance affordability and usage in climate-vulnerable regions which will have knock-on impacts on availability of financing for PUE appliance purchases.

59 Interview on July 4, 2022.
60 Endev, n.d.b.
61 USAID, n.d.
62 World Bank, 2023.
63 ESMAP, 2022.
64 GOGLA, 2023a.

3.1.2. Consumer awareness

Increasing consumer awareness of PUE technologies and their benefits is critical to stimulating demand for PUE appliances. However, consumer awareness of PUE technologies beyond SHSs and how they work remains low, particularly in rural areas, partly as a result of PUE appliance distributors often having very limited distribution networks beyond more densely populated urban areas. These distribution networks are often even more limited in FCS. To address this gap, some PUE appliance distributors aim to reach potential rural consumers through aggregators, such as agricultural cooperatives, or dealers who supply rural communities with agricultural inputs.[65] In displacement settings, appliance distributors could work with non-governmental organisations (NGOs) and others who have a footprint in the areas they are trying to reach. Partnering with entities that have these more direct connections to potential PUE customers in rural areas should also help ensure that the PUE technologies offered are technically feasible in the specific environments in which customers operate.

The Efficiency for Access Coalition is one initiative that aims to improve consumer awareness by increasing the availability of information about high quality, efficient, and suitably designed appliances for off-grid and weak grid settings.[66] Mechanisms that can be used to improve awareness of PUE technologies and their socio-economic benefits, and to address market information gaps, include business model demonstrations, road shows, product fairs, initiative pilots, and public awareness campaigns. Giving potential customers the opportunity to see and touch PUE appliances is key to raising interest and demand, but this can be costly for appliance distributors and challenging to implement in practice, particularly in fragile contexts.

What works to raise consumer awareness varies across contexts and it is necessary for appliance distributors and other actors to understand the relevant context enough to design appropriate consumer awareness approaches. It is also vital that gender-based differences and barriers to PUE adoption are taken into consideration in consumer awareness efforts to ensure equitable interventions in communities. This requires reaching out to women and men separately to invite them to participate in awareness activities, including through different channels depending on how women and men hear about marketing information. For example, women tend to not have access to mobile phones as much as men do, so invitations communicated by phone calls only may fail to adequately reach women, necessitating specific outreach to women through other channels,[67] such as religious or savings groups, for example. It also requires an understanding of gender dynamics around participation in training activities, including whether women are more comfortable attending workshops with their husbands or in single sex groups, and ensuring that meetings are held at safe and convenient times and locations.[68] Providing childcare may also be essential to secure participation of women in PUE training activities.[69]

65 Ibid.
66 Efficiency for Access, n.d.
67 Theis et al., n.d.
68 Ibid.
69 Ibid.

Looking at Ethiopia specifically, the Sustainable Energy for Smallholder Farmers (SEFFA) project identified efforts needed to increase PUE technology uptake in the country, as shown in **Box 2**.

BOX 2 INCREASING UPTAKE OF PUE TECHNOLOGIES IN ETHIOPIA[70]

The SEFFA project aims to support scalable business cases by providing practical and affordable renewable energy services and technologies for agricultural value chains (for irrigation, cooling, and drying) to improve livelihoods in Uganda, Kenya, and Ethiopia.[71] In addition to improved production and livelihoods, SEFFA aims to increase nutrition status, strengthen resilience to climate change, and reduce greenhouse gas emissions. The project's baseline study identified that increased uptake of PUE technologies among dairy and horticulture farmers and processors would require:[72]

- Creating awareness, focusing on demonstration centres, and including training.
- Technical pilots.
- Designing customised financial products for farmers.
- Policy advocacy to reduce import barriers for PUE technologies.

To be effective, consumer awareness efforts require coordination and contributions from a range of actors, including current and potential PUE users, mini grid developers, appliance distributors (including entities that can provide consumer finance), community leaders, and local government.[73]

Simultaneously, improving **awareness of available financing sources** will be essential to enable communities, particularly in rural areas, to explore options to finance PUE technology adoption. The Rural Electrification Densification Programme (REDP) run by the Tanzanian Rural Energy Agency demonstrates the effectiveness of combining interventions to address affordability and consumer awareness constraints to drive PUE adoption (see **Box 3**).

70 EnDev, 2021.
71 Ibid.
72 EnDev, 2022.
73 ESMAP, 2022.

BOX 3 RURAL ELECTRIFICATION DENSIFICATION PROGRAMME (REDP), TANZANIA[74]

Interventions that seek to simultaneously address affordability and consumer awareness of PUE products and appliances have demonstrated notable results. REDP Tanzania provided entrepreneurs with technical training, business mentorship, and support to access finance for small-scale PUE appliances, achieving the following results:[75]

- Increased profitability of entrepreneurs by 87%.
- Increased awareness and knowledge of PUE.
- Increased electricity consumption by 80%.
- More market linkages with equipment suppliers and financial institutions.
- 121 loans for financing PUE appliances secured from local financial institutions.
- 214 permanent jobs created, 40% of which were for women.

3.1.3. Business support services

In addition to raising consumer awareness of PUE technologies and helping to unlock access to finance, it has become evident that **broader business support services** for local entrepreneurs and MSMEs are often needed to ensure that PUE users are able to make maximum use of PUE products to grow their economic activities. This may include business and management training, such as bookkeeping, inventory management, marketing, and customer service training, as well as services such as climate information, agricultural support, financial management guidance, and facilitation of market linkages.[76] Follow-up mentorship that allows people to apply their new skills and experiment with new business activities is a necessary complement to this initial training. Agronomy support has also been seen to be particularly important, involving providing information to farmers on inputs, planting and harvesting times, and route to market to enable farmers to gain maximum value from their PUE investments.[77]

Business support services may be provided by NGOs and local associations, as well as appliance distributors in some instances.[78] Some appliance distributors see strengthening MSME customers' business operations as critical to ensuring that they're able to pay off their asset loans on time, which is in the interests of the appliance distributors as well as the customers. For example, Mwezi is an appliance distributor in Kenya that helps to facilitate market linkages for their solar egg incubator customers by connecting them with other actors along the poultry supply chain, such as input suppliers and

74 USAID, n.d.
75 AfDB, 2020.
76 GOGLA, 2023a.
77 OUMA, 2020, page 26.
78 Lecoque & Weimann, 2015.

buyers of chicks.[79] Other appliance distributors play a role in helping their customers to find new markets for their products. The experience of EnerGrow, an asset financing company in Uganda, is found in **Box 4**.

BOX 4 ENERGROW IN UGANDA

In addition to providing asset financing for PUE products, EnerGrow provides basic business training to its customers, including training on basic bookkeeping, micro marketing, customer service, and inventory management. EnerGrow has found that this business training is critical to building trust with customers, who often fear taking on debt, and that the business training strengthens the management of small businesses and raises entrepreneurs' confidence around taking on debt for PUE appliance purchases. By helping customers to gain maximum value from their PUE appliances, EnerGrow also raises the likelihood of their loans being repaid on time. EnerGrow has seen that thriving customers are good for their business too.

Providing these business support services is not a straightforward exercise, however, as it requires technical assistance to be tailored based on sector, type of business, and size and maturity of business.[80] It also requires dedicated capacity and specific skills, with cost implications for appliance distributors.[81]

3.2. Supply side factors

The supply side looks at the perspective of appliance distributors primarily, and is shaped by a myriad of factors, including the business environment and investment climate in a country, as well as renewable energy sector specific dynamics, such as design and implementation of policies and regulations that support the uptake of PUE. Additionally, the presence and reach of appliance distributors plays a key role in PUE uptake in a country. While appliance distributors are growing in number, including in FCS and low-income countries, they often struggle to scale up their businesses in these contexts, needing support with raising capital, increasing their distribution networks, and optimising their product offering.[82]

3.2.1. Distribution

Distribution is affected by distribution networks and a distributor's working capital constraints. Additionally, it can be difficult for appliance distributors to compete in the presence of donor programmes that subsidise PUE appliances, with subsidies being essential given the low purchasing power of most households in FCS.

79 Colenbrander et al., 2022.
80 Endev, n.d.b.
81 GDC, n.d.
82 GOGLA, 2023a.

Distribution networks. As noted above, appliance distributors often have limited distribution networks beyond more densely populated urban areas. The result is that businesses and households in rural areas with electrification challenges frequently have limited access to PUE appliances and after-sales support services.[83] This issue arises in part from government entities and NGOs being key purchasers of PUE appliances in many FCS, and distributors having few direct commercial customers due to affordability constraints within local populations. The result is that distribution channels are short, with suppliers sometimes procuring, importing, and distributing appliances themselves (without the involvement of retailers and wholesalers) and focusing primarily on distribution to urban areas.[84]

Working capital constraints. Appliance distributors face financing challenges that constrain their own growth. Many of them use lease-to-own models, where they provide consumer financing in-house, with the result that they face significant working capital constraints.[85] Appliance distributors may have difficulties raising investment to enable their growth, particularly younger firms and those in more challenging environments such as FCS, where operating costs are higher and achieving scale is more difficult. It is also challenging to build out supply chains before sufficient market demand exists, but the lack of distribution networks, sample products, and locally available inventory dampens demand and constrains distributors' ability to gauge market demand and viability.[86]

Relationships with PUE suppliers and manufacturers. Appliance distributors looking to expand their product offering may struggle to find suppliers/manufacturers willing to provide distributors with samples for testing. Similarly, distributors cannot easily give potential customers the opportunity to try out PUE products themselves in order to inform purchase decisions as this can be logistically complex and also risky with high-value assets, especially at scale.[87] This is additionally challenging in FCS or more remote rural areas. Manufacturers' minimum order requirements are often higher than what appliance distributors can meet, resulting in difficulties with sourcing products at best prices.[88] As a result, appliance distributors in more under-developed markets are likely to source products from local retailers, which may come at higher cost but allows for smaller order volumes.

PUE appliance subsidisation by donor programmes. In many FCS and displacement settings, target populations are unable to afford unsubsidised appliances and NGO and donor programmes play a vital role in making PUE appliances available. Appliance distributors cannot compete with subsidised products and would need to cooperate rather than compete with donor programmes in these contexts until markets become more mature.

83 Wearne et al., 2022.
84 GOGLA, 2023b.
85 GDC, n.d.
86 Ibid.
87 Ibid.
88 Ibid.

3.2.2. Sales and after-sales support

Skilled labour is critical for PUE market development and there's a need for PUE appliance distributors to invest in upskilling technical staff and sales agents to provide effective sales and after-sales support.[89] It is important for appliance distributors to understand customer needs and expectations to ensure alignment between expectations and ability to pay.

Trained technical personnel. Technical assistance and support is needed for installation, maintenance, and repair of PUE systems – where this is lacking, it erodes customers' confidence in the PUE market as it creates concerns that it will be difficult for customers to access support services if their products fail.[90] If PUE products require repair but distributors have no reliable supplier or manufacturer to repair products and they are unable to repair products themselves, customers will stop paying instalments and distributors can be financially compromised as a result.[91] Therefore, it is in distributors' interests to ensure that trained technical personnel are available promptly for any necessary repairs.

Knowledgeable sales agents. It is vital that sales agents understand the available range of PUE appliances and their functionality, uses, and constraints, as well as have knowledge of the key sectors that their products are intended to serve, the activities within these sectors that consumers wish to use PUE appliances for, and how best to engage with potential consumers of different genders. This requires development of specialist knowledge on the part of PUE appliance distributors. For example, sales agents must be able to convey sufficiently detailed information to consumers to enable them to make informed PUE appliance purchases. This has led to SolarWorks in Mozambique, for example, developing specialist refrigeration and irrigation teams to handle sales and after-sales services for these products.[92] Having both male and female sales agents who can engage with male and female customers in culturally and gender appropriate ways is also necessary.

If the appliance distributor is handling consumer financing in-house, it will also be necessary that sales agents are able to share full information on financing options and payment plans with potential customers. Alternatively, if consumer finance is being handled by a third-party finance provider, such as a MFI, sales agents must be able to connect potential customers with them in order to receive this information. It is vital that potential customers fully understand the financial implications of taking on debt and that they are protected against aggressive sales of PUE appliances if they do not have the ability to pay.

After-sales services. Appliance distributors report that after sales support for PUE products is more complex and intensive than with other products and that it takes time for staff to build up the expertise needed to be comfortable with providing after-sales support for new products.[93] In some cases, it can also be logistically difficult to replace products

89 GOGLA, 2023a.
90 GOGLA, 2023b.
91 GDC, n.d.
92 Colenbrander et al., 2022.
93 GDC, n.d.

or transport them to the nearest city for repair in a timely manner. As a result, it could be more cost effective for appliance distributors to train local technicians to undertake repairs in more remote areas.

Expanding agent networks. In an effort to broaden their reach into underserved areas, some appliance distributors are using agent-based distribution channels to drive sales and provide after-sales support.[94] This could be done through establishing their own dedicated network of agents, but this approach would be prohibitively expensive for rural and remote areas.[95] Alternatively, appliance distributors can have local energy entrepreneurs, agricultural cooperative members or representatives of agricultural input vendors act as their agents and train these actors, supply them with inventory, and pay them on a commission basis for products sold.[96] Experience has shown that group training of agents is more effective than one-on-one training as it enables agents to meet other agents in nearby areas and to learn from one another.[97]

3.3. Regulatory environment factors

Both formal regulations and policies and informal norms and market practices (including illegal aspects) shape investment attractiveness and PUE adoption.[98] Informal dynamics tend to be a stronger influence in FCS than in more developed markets and vested interests, for example fuel traders' interests in consumers' continued reliance on diesel generators, need to be factored in when designing PUE adoption efforts. To develop policies and regulations that encourage PUE adoption, it is necessary to engage with the range of stakeholders active in both the supply and demand sides of the PUE sector to sufficiently understand the political economy of energy access and usage to ensure that policy and regulatory reforms are suited to and workable in local contexts.[99]

3.3.1. PUE regulation

PUE regulation should cover all aspects of ecosystem development, including business registration, licensing, taxes and duties, connection costs, standards for appliances, quality of service provided by energy providers, etc. Regulators and line ministries (e.g., energy, water, agriculture, rural development) play key roles in developing regulations and, therefore, in shaping the business environment for investors in renewable energy technologies. PUE regulation and policies are often undeveloped in more fragile contexts, giving rise to challenges. For example, there may be a lack of specific business licenses for PUE suppliers and distributors, with the licensing regime for PUE appliance distribution not having developed sufficiently.

The nature of PUE also makes government regulatory and oversight responsibility complex, as PUE appliances span across different sectors (such as health, agriculture, and water), as well as numerous government ministries (including national energy utility companies and

94 GOGLA, 2023b.
95 Wearne et al., 2022.
96 USAID, 2021.
97 GDC, n.d.
98 World Bank, 2023.
99 Ibid.

rural electrification agencies) and there are continual innovations and developments in PUE technologies that regulation must keep pace with. Establishing a cross-ministerial working group to coordinate inputs and regulatory responsibilities of different government entities may be useful in overcoming some of this complexity.

3.3.2. Taxes and duties

Taxes and duties may be determining factors in whether investments in PUE are commercially viable or not, and the nature of these policies and regulations and how they are applied in practice can either promote or hinder investment in PUE technologies. A lack of clarity in policy or regulation or their inconsistent application in practice can cause delays at the point of import or result in overcharging of import tariffs, which drive up the cost of PUE appliances for customers. For example, while a number of governments have introduced tax waivers for imported renewable energy technologies to encourage uptake of these technologies and to lower their cost for customers, these waivers are often inconsistently applied by customs authorities in low-income countries. This may be due to a lack of coordination between government entities or incorrect valuation by customs authorities using outdated pricing lists, rendering import tariffs higher than they should be.[100]

Lengthy customs clearance processes can pose a big challenge for importers, with valuable inventory tied up in customs for extended periods of time, which is particularly problematic for products with shorter shelf lives, such as batteries. Delays can sometimes also be used as a frustration tactic by customs officers to induce bribes from importers. These obstacles contribute to increased product cost for customers and discourages market actors from investing in PUE technologies.

The importance of developing clear and well-informed policies and regulations and ensuring that customs officials and other government officials receive the necessary training to understand how different PUE appliances are to be approached is essential for consistent application of policies and regulations. This also brings greater certainty and predictability for PUE suppliers and distributors and others investing in imported PUE technologies.

3.3.3. Quality assurance

PUE appliances are of varying quality and durability, with some failing to perform adequately on safety, durability, and performance measures, with quality assurance becoming a larger issue as more complex PUE appliances are developed.[101] The standards agencies of most low-income and FCS governments have not yet developed specific quality assurance standards for PUE products beyond more established solar lanterns and SHSs. As PUE products tend to be imported, it becomes a specific challenge for customs authorities who frequently lack the capabilities needed to identify substandard products and prevent them from reaching markets.[102]

100 GOGLA, 2023b.
101 Lighting Global, n.d.
102 GOGLA, 2023b.

Appliance distributors face greater difficulties in serving settings of fragility and displacement and remote rural areas, with the result that certified energy products may not be available in these areas, leaving consumers to resort to products of low quality or without after-sales support, often also at higher cost.[103] Low-quality goods spoil the market and hinder the adoption of more efficient, cleaner technologies,[104] highlighting the importance of appropriate standards being adopted and enforced to maintain product quality and consumer confidence, particularly for emerging technologies that are rapidly evolving. Where cheaper products still perform well, this is a win for customers. However, when customers have been persuaded to purchase poor quality solar pumps and refrigeration units due to their lower prices and these poor quality goods break quickly, it leaves a negative experience for customers and spoils the market for PUE products.[105] Enforcing quality standards is not a straightforward task for standards agencies, however, as they must stay abreast of sector developments and determine the most appropriate approach to regulation of that product or service.[106]

To assist in efforts to guard against poor-quality products and adopt harmonised policies, Lighting Global has developed a set of quality standards and testing methods for small off-grid solar systems up to 350 Wp (Watts peak), which quality standards were adopted by the International Electrotechnical Commission to serve as a quality assurance reference point for off-grid solar products.[107] In 2020, Lighting Global, the Collaborative Labelling and Appliance Standards Programme (CLASP), and Schatz Energy Research Center together launched VeraSol, an independent quality-assurance programme. VeraSol provides quality assurance services including testing off-grid equipment and PUE appliances, issuing certificates for stand-alone PUE appliances under 350 Wp, and publishing consistent and comparable performance data that enables market actors to "identify good-quality products, de-risk investment and purchasing decisions, support healthy market growth, avoid market spoilage, and protect consumers."[108] VeraSol has since developed a Rapid Product Assessment (RPA) approach to evaluate the quality of emerging PUE appliances in a quicker and more flexible and affordable way, as outlined in **Box 5**.[109]

103 Mercy Corps, n.d.
104 GOGLA, 2023a.
105 UOMA, 2020.
106 GOGLA, 2023a.
107 Lighting Global, n.d.
108 Atieno et al., 2022, page 5.
109 CLASP, 2022.

BOX 5 VERASOL'S RAPID PRODUCT ASSESSMENT[110]

The Rapid Product Assessment (RPA) can be adapted to various PUE appliances, which is valuable as many emerging appliances do not yet have existing testing methods. The consistent approach to evaluating product quality and performance enables data to be generated that can be used to inform product design. The RPA includes the following elements:

- **Flexible product sampling** – Companies that request product testing must ship at least one (although ideally two) sample product(s) for testing.
- **A network of local testing facilities** – Local testing partners undertake testing in environments similar to those in which the product will be used (rather than under controlled conditions).
- **Focused testing on essential parameters** – Testing evaluates the most essential aspects of the product's functionality, safety, usability, and performance.
- **Product data sharing** – Test data is published on VeraSol's Product Database for transparency and to enable use by other market actors.

For effective enforcement of quality standards and to provide reliable PUE appliance performance data for public use, national governments and standards agencies should:[111]

- Draw on quality assurance standards developed by Lighting Global, VeraSol, and others to develop quality standards and a quality assurance framework (to date, more than 20 governments have adopted standards based on those developed by Lighting Global).[112]
- Adopt national policies and plans that include PUE, including making quality-verified products eligible for specific financing options, as Liberia has done with bulk procurement under their Rural Renewable Energy Agency, or the financing facility offered by Ethiopia's Development Bank.[113]
- Build laboratory capacity to test products, drawing on VeraSol's RPA and other guidance, and develop field and laboratory test protocols to ensure consistency in testing and comparability across products.

These activities require capacity and resources that are frequently in short supply in more fragile and low-income countries. Therefore, support from initiatives such as the Energy Efficient Lighting and Appliances (EELA) project outlined in **Box 6** can be of vital importance for governments of these countries.

110 Atieno et al., 2022.
111 Efficiency for Access, n.d.; GOGLA, 2023a.
112 Lighting Global, n.d.
113 Lighting Global, n.d.

BOX 6 THE ENERGY EFFICIENT LIGHTING AND APPLIANCES (EELA) PROJECT[114]

The EELA project is supporting the 21 member states of the Southern African Development Community (SADC) and the East African Community (EAC) on a range of activities that enable uptake of energy-efficient lighting and appliances. Notably, this includes:

- Building the capacity of governments to improve the capabilities of standards setting and accreditation bodies, as well as supporting testing facilities with equipment and capacity building. These efforts include establishing a network for knowledge sharing.
- Working with governments to improve their policies and regulations for energy efficient lighting and appliances, with an eye to ensuring that these policies and regulations are gender and climate responsive. This will involve "developing a regional framework for lighting and harmonising Minimum Energy Performance Standards (MEPS) for various product groups."[115] It would also cover safe 'end of life' disposal of lighting and other PUE appliances and disassembling and recycling of these products.
- EELA's efforts will also include provision of market incentives to stimulate the uptake of energy-efficient lighting and appliances and offering "supply chain actors technical assistance and financial incentives to deliver efficient and high-quality energy services."[116]

In addition to strengthening the capacity of governments to adopt and enforce appropriate standards and quality assurance processes, it is important that PUE appliance performance and market data is also available for supply chain actors and consumers to enable more informed business decisions. In this regard, the Low-Energy Inclusive Appliances (LEIA) programme collects and publishes a range of performance and market data on an interactive, digital platform.

3.4. Financing the supply side

Getting financing for PUE to work well is a critical priority for mini grid operators as, while PUE customers often represent a minority of a mini grid's customers in terms of number, they tend to provide a sizeable portion of the mini grid operator's income and are critical for the overall economic viability of mini grids.[117]

Macroeconomic instability, currency volatility, and low purchasing power among the local population are more common in FCS than in other countries, and this poses specific challenges to actors in the PUE supply chain. High inflation and depreciation of the local currency vis-à-

114 Efficiency for Access, n.d.
115 Ibid.
116 Ibid.
117 Hartvigsson et al., 2021.

vis USD or other hard currencies makes appliances comparatively more expensive for importers and distributors and, therefore, for customers too.

Additionally, shortage of foreign currency in many FCS is a key challenge for PUE appliance importers as, without access to the foreign currency needed to pay for imports, procurement and importation of PUE appliances is not possible. Where necessary, foreign currency facilities may need to be developed, generally in partnership with governments, to enable importers to access the foreign currency needed to finance imports. More facilities that enable local currency financing for PUE initiatives would also protect PUE importers, distributors, and customers from appliance costs rising due to depreciating local currency, with grant or concessional funding generally being needed to cover the high costs of currency hedging.

When appliance distributors enter a new market, a comprehensive understanding of the financing context for PUE is needed, including assessments on the availability and accessibility of financial services for MSMEs, communities, energy developers, and appliance distributors or asset finance companies, as well as any constraints that may exist on access to finance, looking at disaggregated data on women, young people, and vulnerable populations such as refugees and internally displaced persons.[118]

In most FCS, liquidity is low and risk perception is high, and capital investment in the PUE sector remains limited, constraining the growth of appliance distributors. As the PUE market is still relatively nascent in these countries, incentives and de-risking mechanisms will be needed to bring down perceived risks, and other approaches are needed to open up financing sources for PUE appliances in these settings. De-risking mechanisms are needed for PUE in fragile settings, including guarantees and subsidies, particularly for expanding distribution networks, including into areas that are hard to reach.[119] Some of the financing or de-risking options that can be used include:

- **Grant funding and highly concessional financing** is needed in instances where affordability constraints are significant, with appliance distributors in undeveloped markets and FCS frequently being unable to sell PUE products without subsidies.[120] Grants and subsidies will be essential to enabling appliance distributors to reach low-income populations.

- **Results-based financing** has shown notable promise with incentivising investment in PUE expansion. However, it does not assist appliance distributors with the upfront capital required to finance PUE appliances, thereby often excluding local companies who lack the resources required for large upfront costs. As a result, RBF primarily benefits larger, more established companies who can pre-finance investments, thereby undermining competition, unless these incentives are specifically designed in a hybrid manner to provide some degree of upfront funding too.

118 World Bank, 2023.
119 GOGLA, 2023a.
120 GDC, n.d.

- Governments may also consider providing **import tariff exemptions for purely PUE appliances** (i.e., those which can only be used for productive purposes, such as mills or welding equipment) or other incentives to support innovative financing interventions where their fiscal capacity allows. Where waivers or incentives are given, market surveys should be undertaken to check whether appliance distributors that benefitted from these policies are in fact passing on cost savings to consumers. If they are failing to do so, then these policies should be revised.

- The potential for **carbon markets and climate financing** to be leveraged to support PUE financing could be significant. Some predictions estimate that voluntary carbon markets could be worth more than USD 50 billion by 2030, which could offer appliance distributors and governments new sources of income to scale up PUE.[121] However, certification of carbon financing in energy access may take years and is not yet commonly done.

The pros and cons of the above financing options covered in the demand and supply sides are summarised in **Table 1**.

Table 1 The pros and cons of both demand- and supply- side financing options

Financing option	Pros	Cons
PAYGo / lease-to-own	Removes upfront cost, spreads cost for customer over time, customer takes upfront possession of asset, which increases affordability	Increases working capital requirements for appliance distributors, requires mobile payment functionality to work well
Different payment option flexibility	Increases affordability for customers by using value they produce and tailoring to seasonality of revenues, flexibility reduces risk of loan defaults	Lender would need to have ready markets for goods accepted for loan repayment
Diaspora financing	Can tap into greater financial resources in diaspora, overcomes affordability constraints	Done on a direct relational basis so far, aggregation would be complex but could potentially reduce costs through greater economies of scale
Outsourcing consumer financing to MFI	Reduces working capital requirements for appliance distributors, leverages greater lending expertise of MFI	Requires alignment of interests and terms and close coordination between appliance distributor and MFI
On-bill financing	Spreads cost for customer over time, loans are often on better terms than from other lenders, customer takes upfront possession of asset, which increases affordability for customers	Increases working capital requirements of mini grid operators
Subsidies / grants	Increase affordability for end-user or viability of appliance distributor to e.g., expand distribution networks	Can hamper longer-term market development

121 GOGLA, 2023a.

Results-based financing	Increase viability of appliance distributor, can lower cost for end-users	Favours companies that can cover upfront costs, which often excludes local companies, start-ups, and companies aiming to enter more challenging (and costly) environments, entrenches established companies and undermines competition
Tariff exemptions	Lowers cost of purely PUE appliances, thereby increasing affordability for customers	Government must forego customs revenue

Box 7 outlines a good example of a financing facility aimed at supporting appliance distributors to provide consumer financing and enabling cost reduction of PUE appliances through bulk procurement.

BOX 7 CLASP AND NITHIO FINANCING FACILITY FOR PUE APPLIANCES[122]

CLASP and Nithio have developed a new financing facility that aims to make PUE appliances more affordable and accessible by leveraging scale to offer procurement subsidies, consumer financing, and advisory support to enable development of credit systems for PUE appliance distributors. It will achieve "lower appliance costs for end-users by discounting the price of bulk solar appliance procurements and providing financing for distributors to enable them to sell their products on credit."[123] PUE consumer financing is key for sustainable, long-term development of the market for PUE appliances and products.

The facility will initially operate in Democratic Republic of Congo, Nigeria, Sierra Leone, Kenya, and Uganda and cover six appliance technologies that are sufficiently mature and offer notable growth potential, namely fans, mills, electric cookers, solar water pumps, refrigerators, and walk-in cold rooms.[124]

In contexts where PUE appliances remain largely unaffordable commercially, the PUE market is dominated by grant-based approaches and government agencies and NGOs are the main PUE appliance purchasers.[125] Similarly, in refugee camps or displacement settings, grant funding is generally needed to overcome the higher costs that companies face operating in these environments (due to limited distribution channels, for example), as well as the very low purchasing power of displaced populations.[126] Unfortunately, the dominance of grant-based distribution limits the potential scale up of these initiatives due to fiscal constraints of governments, NGOs, and donors.

122 Migono & Schneider, 2022.
123 Ibid.
124 Ibid.
125 GOGLA, 2023b.
126 World Bank, 2023.

4. Developing the PUE appliance market

Mini grid operators and appliance distributors can encourage PUE adoption through a number of complementary routes, including providing financing for PUE appliances and products, adopting a tariff structure that encourages PUE and, importantly, by integrating PUE promotion into local economic development efforts.[127] As roll out of mini grids scales up, targeting hundreds rather than tens of villages, PUE promotion efforts must be designed for implementation at the same scale.[128]

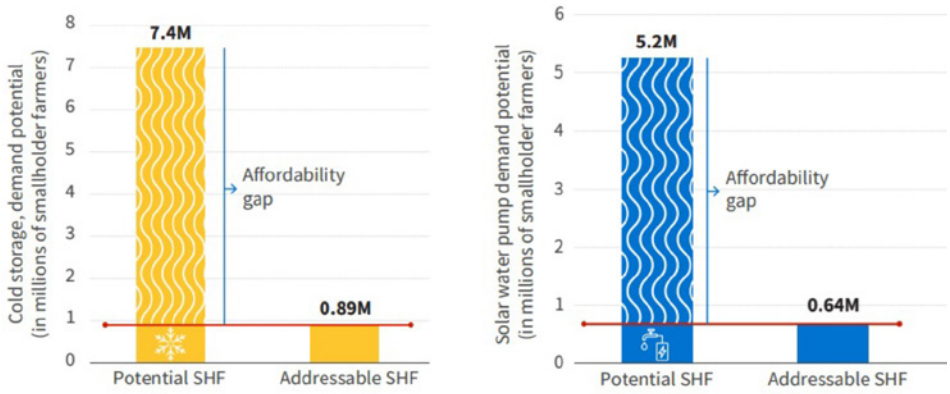
4.1. Market potential

As Africa's commercial, industrial, and agricultural activities expand, the continent's demand for PUE grows – for example, it is estimated that sub-Saharan Africa's energy demand in the agriculture, industry, and freight sectors will grow by almost 40% by 2030.[129] There is substantial potential for PUE appliances in the agricultural sector, with IFC estimating the potential market for agricultural PUE products could be as high as USD 734 million (if affordability and ability to pay constraints are factored in), and up to USD 11.3 billion if these constraints are not considered.[130]

Given the high reliance on agriculture of populations in low-income countries and FCS, access to PUE appliances for the agricultural sector could offer significant benefits in terms of increasing farmers' incomes. This is conditional on other factors needed to support improved outcomes for farmers being present, including access to quality inputs, ability to sell excess crops at market, and that farmers do not experience climate-related disasters, among other things. Cold storage technologies have the potential to reduce post-harvest losses by up to 30% and could benefit some 890,000 small-holder farmers in sub-Saharan Africa.[131] Similarly, solar water pumps have a potential market size of 5.2 million small-holder farmers in sub-Saharan Africa alone. **Figure 2** demonstrates the market potential of cold storage facilities and solar water pumps, as well as the significant affordability gap each market faces.

127 USAID, n.d.
128 Wearne et al., 2022.
129 IEA, 2022.
130 Endev, n.d.b.
131 World Bank, 2022.

Figure 2 Estimated total potential and addressable market for cold storage (left) and solar water pumps (right) (millions of small-holder farmers in sub-Saharan Africa)[132]



Affordability constraints, lack of access to finance, and low consumer awareness are key obstacles holding back uptake of cold storage technologies and solar water pumps, as they are larger and more costly products.[133] Affordability of PUE appliances is further constrained in instances where products are over-engineered to include additional features that average consumers do not need, with these features pushing up product costs. Matching product technicalities with market demand is essential but this matching is still underdeveloped – for example, solar mills are currently not able to produce the right type of end product or with sufficient capacity to match market demand in Uganda.[134]

- Questions that are valuable to explore when assessing what market potential exists in a specific context include:[135]
- What productive uses are likely to be pursued if electricity were to become available, including whether switching to higher value-added products may take place?
- How do economic activities and PUE appliance preferences differ for men and women? What other data disaggregation is possible, e.g., age, ethnicity?
- How much do households or small businesses spend per month on services for existing activities, such as milling? How much of this could be saved by localising these services and powering them off a local mini grid?
- What power output capacity may be possible and/or affordable? Can capacity be incrementally added to enable increases in PUE in the future? If so, at what cost?
- What is the likely timing of PUE? What PUE could be shifted to off-peak times or be made to operate under dispatchable load tariffs in order to manage demand and increase capacity?

132 Migono & Schneider, 2022.
133 World Bank, 2022.
134 UOMA, 2020.
135 USAID, n.d.

- What is the kVA requirement of motors operating on the mini grid when they start and while they operate? Can starting of appliances be staggered to avoid demand surging at the same time?
- What is the expected population growth and likely growth in economic activities in the area?

More broadly, it is necessary to also consider the following:

- Are there any existing infrastructural limitations or constraints that may impact the deployment of PUE solutions?
- What are the cultural and/or behavioural factors that may influence the adoption of new energy technologies and practices?
- What are the existing local regulatory and policy frameworks governing energy production and distribution?

Some analytical tools have been developed to facilitate this energy planning, including that of VIDA, outlined in **Box 8**.

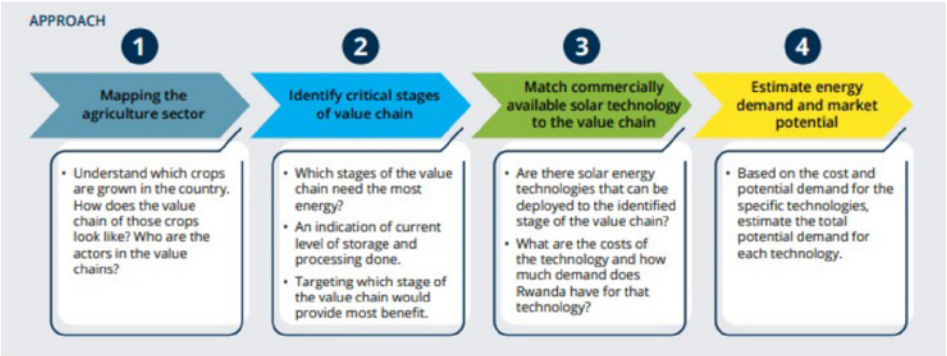
BOX 8 VIDA'S USE OF DATA TO GUIDE PUE AWARENESS EFFORTS[136]

Vida Data Analytics (VIDA), in partnership with the World Bank, is "conducting several pilots to identify the potential of using geographic information system data to encourage co-investments in productive use case appliances and mini grids in villages."[137] They analyse mini grid sites and layer in productive use related factors (such as public facilities, irrigation availability and requirements, crop growth, and road infrastructure) to identify villages that have notable demand for both productive use and residential consumption of electricity. This data then informs awareness efforts, such as roadshows, on electrification and productive use appliances.

Considering the above for different value chains is key for generating estimates of energy demand and market potential for different productive sectors – for example, **Figure 3** outlines how energy demand and market potential for the agriculture sector in Rwanda can be estimated.

136 World Bank, 2023.
137 Ibid, page 8.

Figure 3 Estimating demand and market potential of PUE in Rwanda's agriculture sector[138]



4.2. Integrating PUE promotion into market systems development

To achieve maximum impact for households, farmers, and MSMEs, and to improve the financial viability of SHSs and mini grids more broadly, it is essential that PUE expansion efforts tie PUE adoption to market systems development.[139] In rural areas, PUE adoption should be part of an integrated rural development strategy. PUE forms a crucial part of rural development and rural job creation – in addition to supporting economic growth in rural areas in an environmentally sustainable manner (thereby mitigating climate change), it may also slow rural to urban migration.[140] Building a narrative around PUE promotion that emphasises its role in industrialisation, trade expansion, and connecting rural electrification to national economic strategies has been seen to be important.[141] In turn, rural development raises incomes and energy demand, making SMGs more financially viable in these settings.

Electricity access is a necessary but insufficient condition for PUE adoption and, more broadly, economic growth and poverty reduction. In addition, transportation, training, communication, and market development are also needed.[142] For example, if farmers cannot transport the greater agricultural yields they attain through use of solar water pumps to markets for sale, then their investment in solar water pumps will generate no additional income for them and therefore not be financially worthwhile.[143] Inducing PUE therefore requires an ecosystem approach and complementary initiatives to, for example, construct roads, support transport and logistics services to develop, and otherwise enable farmers to get their produce to markets, including supporting them to enter markets for milled or processed foods, as this would differ from their existing market access.

138 World Bank, 2023.
139 Endev, n.d.b.
140 Efficiency for Access, n.d.
141 Wearne et al., 2022.
142 USAID, n.d.
143 Wearne et al., 2022.

Effectively integrating PUE promotion into rural development efforts in this way requires significant coordination and information sharing across a number of different actors – mini grid developers, appliance distributors, local and national government authorities, donor agencies, and private sector actors (farmers, MSMEs, aggregators, transporters, etc.). As PUE is an inherently multi-sectoral issue, touching on energy, agriculture, finance, regulation, development cooperation, industrial policy, and rural development, coordination is additionally complex.[144] Further specific consideration is needed of displacement settings, such as refugee camps, and how electricity access and PUE must be integrated into humanitarian and development responses. This coordination may take the form of inter-ministerial and cross-sectoral donor coordination, as well as specific dialogue platforms and multi-actor task forces.[145]

There are currently two complementary rural electrification approaches that aim to raise the benefits of electrification for communities through PUE, with both being premised on the recognition that active steps are needed to drive positive impacts of electrification.[146] These approaches are summarised in **Table 2**.

Table 2 The systematic and pragmatic approaches to rural electrification

Approach	Description	Pros	Cons
Systematic approach	This comprehensive approach assesses all existing economic activities in a specific area and the technologies used in production processes in order to strategically direct energy investments to most effectively support rural development.[147] "Every stage of the existing and potential value chains – from inputs and processing to outputs and end uses – is screened to capture actors, market dynamics, cycles, and seasonality."[148]	Very comprehensive, enables thorough understanding and more targeted efforts	Requires strong understanding of local context and multi-sectoral expertise, which may be costly or difficult to access
Pragmatic approach	This approach is opportunistic and does not look at all possible productive uses. Rather, it takes advantage of other existing or planned projects and looks for quick wins where an energy component can be tacked onto the larger project and where there are opportunities for rapid and large sectoral gains as a result of electricity access.[149]	Assessment is quicker and cheaper and builds on cross-sectoral linkages, enables faster project implementation	Not all productive use activities are assessed, less comprehensive, doesn't support very targeted efforts

Better quality data may be needed to inform these approaches, with quality data being particularly scarce in settings of fragility and displacement. It is vital that data is collected on energy use and energy expenditures in refugee camps and among nearby host communities to be able to inform solutions.[150] It is also important that vulnerable groups, such as women and girls, are central to these intervention designs.

144 Ibid.
145 GOGLA, 2023a.
146 ESMAP, 2008.
147 Ibid.
148 ESMAP, 2022, page 120.
149 ESMAP, 2008.
150 Johnstone et al., 2023.

4.3. Sizing mini grids and demand side management

Mini grids should be designed to support existing and potential new economic activities, as assessed above, however, it is not necessary that the mini grid supports *all* productive use activities to be conducted at the same time. If this was to be done, the mini grid would need to have greater capacity (much of which would go unused at times), more battery storage, or the mini grid would need to be boosted with diesel generation at peak demand times. These approaches are more costly than if a mini grid is correctly sized and demand side management (DSM) is employed to strategically balance demand from different customers throughout the day.

Correctly sizing a mini grid is essential for its economic viability. If made too small, revenues will be too low and customers that are not properly served will seek out alternative sources of energy, whereas oversizing a mini grid increases its capital and operational expenditures, making it more costly and requiring a longer payback period for financing.[151] More on mini grid sizing and DSM can be found in the accompanying toolkit: *Demand-side factors: Tools to measure, incentivise, and sustain demand for solar mini grids in fragile contexts*.

Adding PUE customers to a mini grid's customer base is not always straightforward for mini grid developers – it makes project design more complex as developers have to work out "how to connect these loads, which differ in terms of time of use, magnitude of power and energy demand, and seasonality."[152] Developers need certain information as early on in project design as possible, and CrossBoundary has worked with developers to identify a set of questions that elicit this necessary information:

- "How much additional generating capacity is needed to support the load demand?
- What inverter size and distribution system will allow multiple productive use machines to operate simultaneously?
- How low can the tariff be while still proving to be sustainable?
- What time of consumption will allow least-cost generation?
- How should the tariff structure be adjusted to account for seasonality?"[153]

DSM refers to the "planning, implementation, and monitoring of activities to encourage (and sometimes force) customers to alter their electricity consumption habits, in respect to time of use, peak consumption levels, and overall energy consumption."[154] DSM enables more efficient mini grid load management without requiring the expansion of energy generation assets (such as solar panels) or increased reliance on diesel.[155] It places specific importance on encouraging PUE appliance usage during the

151 ESMAP, 2022.
152 Ibid, page 123.
153 Ibid, page 123.
154 AfDB, 2020.
155 Ibid.

day, when electricity is produced at marginal cost. Key strategies used by mini grid developers, in coordination with appliance distributors, include:

- Encouraging commercial PUE (such as use of grinders, mills, carpentry, and welding equipment) during the day, aligning with energy generation hours when energy is more plentiful and mini grid systems have spare capacity due to low household demand during the day. This reduces the need to store significant amounts of energy for PUE activities outside of energy generation hours and, since battery storage is costly, this helps to keep storage capacity requirements and capital expenditure costs down. PUE during times of high supply and low demand can be encouraged through time-of-use tariffs, which are differentiated by time of day and have lower tariffs applicable during the daytime (or middle of the night) when the system has spare capacity, thereby encouraging commercial PUE at times when household demand is low.[156]

- Managing household demand (which peaks in the early morning and evening, i.e., outside of generation hours) by encouraging the adoption of energy-efficient appliances and shifting household PUE activities that are not time-dependent to the daytime, i.e., generation hours. An example of the impact of doing this can be seen in **Box 9**.

- Limiting power consumption of individual customers outside of generation hours where large appliances may drain too much power and negatively affect all customers, in order to accommodate requirements of households and commercial PUE active in the evening, e.g., restaurants and bars.[157] This can be done by using load limiters, which reduce the flow of electricity to specific customers, or curtailable-load tariffs, which involve providing lower tariffs for customers or loads where curtailing by the mini grid operator may be necessary in order to meet demand of other customers.[158]

BOX 9 RAFIKI POWER, TANZANIA[159]

An example of managing household demand by encouraging the adoption of energy-efficient appliances and shifting non-time dependent household activities to during generation hours can be seen with Rafiki Power in Tanzania. Rafiki Power implemented a combination of DSM approaches in an initiative that reached 1,000 customers. They distributed and helped finance appliances for both household and commercial use, provided customer education, and integrated smart meters into a mobile money platform to enable data collection.

156 USAID, n.d.
157 AfDB, 2020.
158 USAID, n.d.
159 AfDB, 2020.

Rafiki Power found that educating customers and selling energy-efficient appliances increased overall energy demand by 20-30% and spread demand over a greater number of connections without significantly raising peak demand. Further, PUE appliances increased energy consumption during the daytime when energy generation is cheaper. The data that Rafiki Power accessed from the smart meters provided insight into consumption patterns and informed the design of tailored DSM solutions.

When managed well, mixing household and PUE customers offers both technical and economic benefits for mini grid operators as mini grids are well suited to accommodate different peak demand times and can be sized to handle diverse customers with a high load factor.[160] On the technical side, higher demand for electricity as a result of PUE appliance usage increases the capacity utilisation of mini grids, which lowers the unit cost of electricity.[161] It also allows for more optimal system usage, especially during the daytime when residential energy usage is low and the system would otherwise be underutilised.[162] Economically, the addition of PUE users to a mini grid is key to achieving economic viability and profitability. ESMAP research from Cambodia, Myanmar, and Nepal has shown that every 1% increase in non-household customers on a solar mini grid adds 20% to the mini grid's average kWh consumption, clearly demonstrating that the addition of commercial customers to a mini grid is key to driving greater monthly consumption and, therefore, mini grid profitability.[163]

Additionally, clustering productive users close to mini grids through developing multifunction platforms or solar kiosks can be effective in limiting distribution costs and ensuring a high-quality supply of electricity, while also facilitating greater linkages between different productive users, which could increase knowledge sharing and innovation within local communities.[164]

4.4. Research and development

More funding is needed for research and development (R&D) to accelerate the development, testing, and deployment of PUE appliances and services beyond solar water pumps and cooling technologies, such as for agri-processing solutions including milling, heating, and drying.[165] R&D is needed to improve technology and design and research needs to better link product design with customers, both male and female, to adjust design based on feedback from customers, and to ensure that viable solutions with the potential to scale are identified.[166] Funding is also needed for experimentation by appliance distributors and asset financing companies to determine optimal loan terms and mechanisms for providing effective after sales services, such as repair of appliances.

160 Hartvigsson et al., 2021.
161 ESMAP, 2022.
162 Ibid.
163 Ibid. Note: this effect holds up until 15 percent of a SMG's customers are non-households, after which the effect begins to dissipate.
164 Ibid.
165 GOGLA, 2023a.
166 Endev, n.d.b.

Collaboration between different actors, including energy organisations, research institutions, government entities, donors, and the private sector is needed to develop innovative technologies and business models, as well as to provide complementary capacity building.[167]

Access to finance is critical to cover R&D costs. Some market stimulation and incentives that have been adopted to promote R&D efforts include prizes and awards for innovative new technologies and best market actors, including the Global Leap Awards and Efficiency for Access Design Challenge, as noted in **Box 10**.[168]

BOX 10 THE LOW-ENERGY INCLUSIVE APPLIANCES (LEIA) PROGRAMME[169]

The Low-Energy Inclusive Appliances (LEIA) Programme is a research and innovation programme funded by the UK's Foreign, Commonwealth, and Development Office (FCDO) and the IKEA Foundation. It seeks to "double the efficiency and halve the cost of a range of electrical appliances suited for off- and weak-grid household, small business, and industrial consumers."[170] It aims to achieve this through addressing key market barriers in the following ways:

- Supporting market stimulation through incentives to catalyse innovation in early market development and rewards for innovative early market movers. Examples include the Global LEAP Awards and the Efficiency for Access Design Challenge.
- Developing market intelligence through a research agenda focused on markets, consumers, impacts, and technologies that aims to address gaps in market intelligence in off-grid appliance markets and to measure the socio-economic impact of appliance adoption.
- Establishing technology roadmaps that identify and prioritise R&D efforts for opportunities with the greatest potential to accelerate development and commercialisation of emerging PUE technologies.
- Enabling R&D co-investments by building partnerships between private sector entities and research institutions to attract new market entrants and unlock private financing.

Much work is still needed around developing standardised monitoring and evaluation frameworks that better measure productive use, and contributions from research institutions, universities, and workgroups would be valuable in this regard.[171]

167 GOGLA, 2023b.
168 Efficiency for Access, n.d.
169 Ibid.
170 Ibid.
171 Endev, n.d.b.

5. Conclusion

PUE has tangible impacts on increasing the socio-economic impact of electrification, magnifying the income-generating opportunities presented by electricity access. PUE can enable improved service provision, create income-generating opportunities for households and small businesses, reduce manual workloads and the time required to complete tasks, and support greater resilience and sustainability. However, complementary investments are also needed to ensure that these improved outcomes are achieved, such as ensuring agricultural extension services and reliable road infrastructure are in place, including electricity supply from mini grids and roads to access markets to purchase improved agricultural inputs and to sell excess crops. Uptake of PUE after electrification – and PUE adoption translating into socio-economic benefits – are not automatic; rather, deliberate efforts must be made to enable this.

There are considerable differences across gender when it comes to PUE and these need to be borne in mind across all aspects of PUE, as it affects everything from how to reach women and men through awareness efforts to what PUE appliances best meet their varied needs and preferences through to supporting continued use of PUE appliances. Without specific efforts to reach women and more marginalised groups, men will continue to benefit the most from electricity access, given their greater access to the resources needed to purchase PUE appliances and their holding of vocations that can easily benefit from electricity access, such as welding and carpentry. These gender differences are often more pronounced in households experiencing poverty and where the time of women is less valued. More broadly, socio-cultural innovations around how communities interact with PUE technologies within the constraints of their environment is gaining prominence.

There is no standard business model for expanding PUE in the context of solar mini grids, but targeting livelihoods and income generation is critical and expanding renewable energy-powered PUE is much easier when economic activities are already taking place in an area. In these instances, focus can be put on tailoring PUE solutions to the existing needs of small businesses and households in local communities, rather than it being necessary to stimulate PUE from a low base of economic activity. This makes a significant difference to the financial viability of mini grid projects and the PUE demand potential of existing economic activities can be factored into the economic models of mini grids from the project design stage. Additionally, it is often easier to obtain financing for rural energy infrastructure from banks or microfinance institutions if there is demonstrated economic activity and revenue generation already taking place.[172]

172 EnDev, n.d.a.

A number of challenges remain to expanding PUE in fragile contexts, on both the demand and the supply side, but lessons from a range of contexts are building up the evidence base on how these challenges can be addressed effectively in these contexts. On the demand side, efforts are needed to facilitate consumer financing and increase affordability of PUE appliances for customers, including through the use of PAYGo and lease-to-own models. Improving consumer awareness of PUE products is necessary, but how this is best done varies across contexts, products, and different categories of consumers and appropriate channels must be used to reach women and other marginalised groups. PUE customers also benefit significantly from receiving basic business training as part of their PUE appliance loan package as it empowers them to attain maximum advantage from their PUE appliance investment.

On the supply side, appliance distributors and asset financing companies need funding themselves to enable them to offer consumer financing, scale up their own activities, and better serve their customers. De-risking mechanisms are needed for them to enter and scale up in fragile contexts, including guarantees for investors and subsidies that can support expansion of distribution networks, including into hard-to-reach areas. Sales and after-sales support can be complex, particularly for remote and rural areas and fragile settings, and distributors need trained technical personnel and knowledgeable sales staff, as well as the distribution networks to deliver products and associated services. More funding is needed for R&D, on the consumer financing business model aspect as well as technology, and feedback from distributors and customers should inform improved technology and design, ensuring that products better cater to the needs of customers.

Finally, effectively regulating the PUE sector is very challenging for governments, particularly those that experience capacity constraints. Developing PUE regulations and keeping them updated and abreast of sector developments will require cross-sectoral and inter-ministerial collaboration, covering key sectors (including energy, agriculture, health, water, vocational training, infrastructure development, and rural development), a myriad of actors, and all aspects of the PUE ecosystem (including licensing, quality standards for appliances, taxes and duties, etc.). Fortunately, a number of international initiatives have developed resources that can be used to inform development of standards and testing methods for PUE products, or that provide publicly available product and performance data, for example. It is likely that further support will also become available for governments as focus on scaling up PUE in low-income contexts is increasingly prioritised.

6. Recommendations

It is first necessary to establish increasing PUE as a mission critical element of energy access, as it is only through PUE that the socio-economic benefits of energy access can be attained.[173] An ecosystem perspective is needed to focus on both the needs and productive potential of PUE users, including farmers, MSMEs, and income-earning households, with a multidisciplinary design team and partnerships being necessary to effectively achieve this.[174] Specific attention must be given to women and other marginalised groups, ensuring that they are reached by PUE adoption efforts and have the opportunity to benefit from the gains that PUE offers.

6.1. Appliance distributors and asset financing companies

- **Start small and assess market needs and demand** – pilot PUE products, learn about agricultural market systems, consumer financing needs, and existing and potential economic activities in local communities,[175] paying attention to how this varies across gender and other dimensions. Pilots can be valuable to help identify the right products, suppliers, pricing model, repayment terms, and sales and after sales strategies.[176] Where possible, promote learnings around successful PUE adoption approaches.[177]

- **Offer flexible payment plans** to accommodate repayment capabilities of different customers as well as the seasonal income of smallholder farmers.[178] Using a lease-to-own model and allowing non-cash payments and longer or seasonal repayment plans can help overcome affordability barriers.

- **Develop the expertise of sales and technical personnel** to provide effective sales and after-sales support for customers, thereby enabling customers to make informed decisions regarding PUE appliance purchases, receive training on how to properly use PUE appliances, and access repair and replacement support when needed. This will necessitate staff having a deep understanding of the capabilities of PUE appliances, the economic activities that they will be used for, and the environments in which they will be used.

- **Raise consumer awareness** of the benefits of electricity and PUE adoption, as this is key for stimulating demand for PUE appliances. This may include demonstrations, pilots, roadshows, product fairs, marketing materials, and trainings, giving potential customers the opportunity to experience products before purchasing wherever

173 World Bank, 2023.
174 Ibid.
175 Colenbrander et al., 2022.
176 GDC, n.d.
177 Endev, n.d.b.
178 OUMA, 2020, page 26.

possible.[179] These efforts will require disaggregation by customer group, notably men and women, and may be done most effectively in partnership with cooperatives, agricultural input providers, or mini grid operators, which entities have existing distribution networks in rural areas.

- **Provide basic business training** to customers where possible, including basic bookkeeping and inventory management. This has been seen to have an impact on strengthening customers' business management. In turn, thriving customers are good for distributors and asset financing companies as they are more able to repay loans on time.

6.2. Appliance manufacturers

- **Match technicalities of products with market needs** and work closely with appliance distributors to gain insight into market needs.[180] Do not over-engineer products, as inclusion of additional features reduce affordability and are often not needed by customers. Think about marketing, sales, and after-sales services for products, not just product development, as products must be both technically correct and meet the needs and ability to pay of potential customers.[181]

- **Build strong relationships with appliance distributors**, as they are key partners in testing and refining products and ensuring they are fit for different markets. Make sure it is clear who is responsible for after-sales support and that appliance distributors have the information needed to fulfil their responsibilities to customers.[182]

- **Develop platforms to share information** with appliance distributors and other actors about products, pricing, quality standards, order volume requirements, geographies served, etc.[183]

6.3. Development partners

- **Better integrate PUE initiatives with mini grid project development**, especially where donor or development partner financing is involved, as both elements are needed to achieve optimal outcomes.

- **Scale up R&D funding** for emerging and horizon technologies to enable the testing, prototyping, and piloting of innovative products, services, and business models.[184]

- **Support appliance distributors and asset financing companies** to serve customers, especially in hard-to-reach areas, providing grant funding, guarantees, technical assistance, or business development support as needed, including to enable them to conduct pilots to

179 GDC, n.d.
180 Ibid.
181 Ibid.
182 Ibid.
183 Ibid.
184 GOGLA, 2023a.

ensure PUE products and consumer financing models are aligned with market needs.

- **Enable financing packages** that enable PUE consumers to also secure financing for high-quality agricultural inputs and farm labour, as this is frequently needed to incentivise PUE adoption among consumers, paying attention to different priorities and risk tolerance of women and other marginalised groups.[185]

- **Contribute to publicly accessible tools and information**, including sharing reliable third-party information about products and suppliers and funding the development of standardised frameworks (e.g., on quality standards and testing methods) that can be used by governments and other actors.

6.4. Governments

- **Integrate PUE into rural economic development** and invest in the complementary infrastructure needed for PUE users to be able to achieve maximum benefit from electricity connection and PUE adoption, including road infrastructure, transport and logistics services, and connecting farmers to input and output markets. Specific planning is needed for refugee camps and other displacement settings and these must be factored in, including in data collection efforts.

- **Mainstream gender-transformative policies into PUE sector** by integrating gender policies into local government departments and local economic development plans and appointing gender and equity champions across departments to represent the interests of women and other marginalised groups.[186] Government also has a role to play in strengthening groups whose membership includes women and other marginalised people, to ensure that they can actively participate in PUE activities and adoption.

- **Provide incentives to promote renewable energy technologies**, including structuring subsidies, tariffs, and tax exemptions to encourage renewable energy uptake where this is fiscally possible. Where this is done, governments should undertake market surveys to ensure that appliance distributors are passing on these cost savings to consumers in practice.

- **Lower perceived risks** on the regulatory, political, and market development level to promote private sector investment in mini grid projects and PUE appliance distribution.[187]

- **Strengthen consumer protection** by adopting and enforcing quality standards that improve the quality of PUE appliances in the market and root out counterfeit products which risk spoiling the market.

185 Johnstone et al., 2022.
186 Ibid.
187 Lecoque & Weimann, 2015.

- **Enable PUE market development** by strengthening cross-sectoral and inter-ministerial coordination on PUE by establishing dedicated platforms and facilitating multi-stakeholder engagement across all key sectors (including agriculture, health, water, education) and between all actors (including government, development partners, private sector actors, financial institutions, non-governmental organisations, and academia).
- **Raise the technical capabilities of the labour force** by working with technical education and vocational training organisations to design and implement certification programmes on technical servicing and installations, to increase availability of the skills needed for installation, repair, and maintenance of PUE appliances.[188]

188 GOGLA, 2023a.

References

3degrees (n.d.). Solar grid in DRC generates first-ever Peace Renewable Energy Credits (P-RECS). Accessed at https://3degreesinc.com/resources/nuru-solar-energy-project/

AfDB (2020). Green mini-grid help desk: Mini-grid productive use and demand management. African Development Bank, Energy4Impact, INENSUS & Sustainable Energy Fund for Africa. Accessed at https://greenminigrid.afdb.org/sites/default/files/3_pu_and_dsm_web.pdf

Alianza Shire (2023). Gender gap on productive uses of energy in refugee camps and its impacts in livelihood opportunities. S-@ccess Conference, Mallorca, Spain, April 2023. Accessed at https://alianzashire.org/wp-content/uploads/230419_Session-8.-Ramos-Galdo-Sonia-v2.pdf

AMDA (2022). Benchmarking Africa's minigrids report. African Minigrid Developers Association.

Atieno, C., Kimathi, K., Lai, E. & Macdonald, R. (2022). Rapid Product Assessment: A new approach to testing productive use appliances. VeraSol.

CLASP (2022). Rapid Product Assessment: A new approach to testing productive use appliances. CLASP. February 20, 2022. Accessed at https://www.clasp.ngo/research/all/rapid-product-assessment-a-new-approach-to-testing-productive-use-appliances/

Colenbrander, E., Erboy Ruff, Y. & Beland, C. (2022). Five hurdles to getting productive use of energy products to the last mile. SEforALL. August 18, 2022. Accessed at https://www.seforall.org/news/five-hurdles-to-getting-productive-use-of-energy-products-to-the-last-mile

Efficiency for Access (n.d.). Accessed at https://efficiencyforaccess.org

Endev (n.d.a). Productive use of energy. *EnDev*. Accessed at https://endev.info/approach/productive-use-of-energy/

Endev (n.d.b.) Productive use of energy: Moving to scalable business cases. Endev Learning & Innovation. Accessed at https://endev.info/wp-content/uploads/2021/03/EnDev_Learning_Innovation_PUE.pdf

Endev (2021). Sustainable Energy for Smallholder Farmers (SEFFA) in Ethiopia, Kenya, and Uganda: Baseline study and market assessment. *EnDev*. Accessed at https://endev.info/wp-content/uploads/2022/01/SEFFA_Baseline_Study_2021.pdf

Endev (2022). EnDev with support from the IKEA Foundation reveal details about the PUE sector in Ethiopia, Kenya, and Uganda. *EnDev.* January 26, 2022. Accessed at https://endev.info/endev-and-the-ikea-foundation-reveal-details-about-the-pue-sector-in-ethiopia-kenya-and-uganda/

ESMAP (2008). Maximising the productive uses of energy to increase the impact of rural electrification programs. Energy Sector Management Assistance Program Formal Report 332/08.

ESMAP (2022). Mini grids for half a billion people: Market outlook and handbook for decision makers. Energy Sector Management Assistance Program & World Bank.

Theis, S., Lefore, N., Bryan, E., Ringler, C. & Meinzen-Dick, R. (n.d.). Feed the Future Innovation Laboratory for Small Scale Irrigation (FTF-ILSSI) Project Notes.

GDC (n.d.). Selling productive use of energy products to last mile consumers: Lessons learned. Global Distributors Collective.

GIZ & UNHCR (2021). Energy solutions for displacement settings (ESDS): Improving the sustainable energy supply for refugees and host communities in Uganda, Kenya, and Ethiopia. GIZ & UNHCR.

GOGLA (2023a). Powering lives and livelihoods: Scaling Productive Uses of Renewable Energy (PURE). Handbook for governments and development partners. GOGLA, ESMAP, World Bank Group, Efficiency for Access, SNV, Water and Energy for Food & Lighting Global.

GOGLA (2023b). Productive Use of Renewable Energy in Ethiopia: Market assessment for technologies scale-up. GOGLA, PRECISE, Water and Energy for Food & Ethiopian Solar Energy Development Association.

Hunt, S. (2023). 12 lessons from the Distributed Renewable Energy (DRE) experience in Africa. Medium. February 15, 2023. Accessed at https://medium.com/@stevenahunt/12-lessons-from-the-distributed-renewable-energy-dre-experience-in-africa-5bae058a406

Hartvigsson, E., Ehnberg, J., Ahlgren, E.O. & Molander, S. (2021). Linking household and productive use of electricity with mini-grid dimensioning and operation. *Energy for Sustainable Development,* Vol. 60: 82-89.

Hobgen, S. (2021). How a Pay-As-You-Go solar project reaches the poorest households. Development Asia. February 1, 2021. Accessed at https://development.asia/explainer/how-pay-you-go-solar-project-reaches-poorest-households

IEA (2022). Africa Energy Outlook 2022: Key findings. International Energy Association.

IEA, IRENA, UNSD, The World Bank & WHO (2024). Tracking SDG 7: The energy progress report 2024.

Ireri, B. & Kilonzo, M. (2024). A new solution to power Africa: Productive use of renewable energy. World Resources Institute. February 2, 2024. Accessed at https://rb.gy/1d9ig2.

Johnstone, K., Perera, N. & Garside, B. (2023). Calibrating cooking for refugee camps and surrounding host communities in Kigoma, Tanzania. International Institute for Environment and Development.

Johnstone, K., Kajumba, T. & Wong-Perez, K. (2022). Better farmer benefits from renewable energy: Improving inclusion and uptake in Kenya. International Institute for Environment and Development, Loughborough University & Caritas Kitui. Briefing.

Johnstone, K. & Perera, N. (2020). Can cooking solutions for refugees better serve gender dynamics? International Institute for Environment and Development. Briefing.

Lecoque, D. & Weimann, M. (2015). The productive use of renewable energy in Africa. Africa-EU Energy Partnership & Alliance for Rural Electrification.

Lighting Global (n.d.). Quality assurance. Lighting Global. Accessed at https://www.lightingglobal.org/how-we-work/quality-assurance/

Logan, S. (2017). Regulating mobile money to support scale-up. International Growth Centre.

Logan, S. & Sacchetto, C. (2021). Scaling energy investments in fragile states. Council on State Fragility & International Growth Centre.

Mercy Corps (n.d.). Closing the energy access gap: De-risking private sector entry into Bidibidi refugee settlement. Mercy Corps.

Migono, D. & Schneider, C. (2022). Press release: CLASP & Nithio launch financing facility for productive use appliances. CLASP. October 19, 2022. Accessed at https://www.clasp.ngo/updates/press-release-clasp-nithio-with-support-from-the-global-energy-alliance-for-people-and-planet-launch-financing-facility-for-productive-use-appliances/

Pueyo, A., Maestre, M. Carreras, M. Bawakyillenuo, S. & Ngoo, G. (2018). Unlocking the benefits of productive use of energy for women in Ghana, Tanzania, and Myanmar. Energia.

UNHCR (2023). Access to clean energy in displacement settings. Case study: Ethiopia. Accessed at https://www.unhcr.org/sites/default/files/2023-07/clean_energy_case_studies_ethiopia.pdf

UOMA (2020). Productive use of energy in Uganda: Learnings from the Uganda Off-grid Energy Market Accelerator (UOMA). USAID, Power Africa, and UOMA.

USAID (n.d.). What productive uses can mini-grids power? Accessed at https://www.usaid.gov/energy/mini-grids/economics/productive-use

USAID (2021). Microfinance loans for increasing access to off-grid solar products. USAID & Power Africa.

Wearne, A., van der Linden, J. & Bloomfield, Z. (2022). Energy for rural industrialisation: Productive use of energy 2.0. New scaling opportunities and innovations in the sector. GET.transform.

World Bank (2022). Off-grid solar market trends report 2022: State of the sector. World Bank Group Lighting Global, ESMAP, GOGLA, Efficiency for Access & Open Capital.

World Bank (2023). Accelerating the productive use of energy: Enabling energy access to power rural economic growth. ESMAP & World Bank.

State Fragility initiative

The **State Fragility initiative** (SFi) is an International Growth Centre (IGC) initiative that aims to work with national, regional, and international actors to catalyse new thinking, develop more effective approaches to addressing state fragility, and support collaborative efforts to take emerging consensus into practice. SFi brings together robust evidence and practical insight to produce and promote actionable, policy-focused guidance in the following areas: state legitimacy, state effectiveness, private sector development, and conflict and security. SFi also serves as the Secretariat for the Council on State Fragility.

theigc.org/statefragilityinitiative