IGC

State Fragility initiative

POLICY TOOLKIT

Demand-side factors: Tools to measure, incentivise and sustain demand for solar mini grids in fragile contexts

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Scaling up solar mini grids in fragile contexts requires a customer-centric approach that focuses on understanding the specific circumstances of a target population and how their demand for energy can be stimulated. This toolkit outlines methods to measure energy demand and strategies that can help grow and sustain energy demand, as well as metering and payment technologies that can enable customers to better manage and pay for their energy consumption.

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In this paper

This paper is intended to help equip policymakers in fragile settings with an understanding of the key considerations affecting the demand-side of solar mini grids, including customers' willingness and ability to pay for energy from mini grids, the need to increase uptake of productive use of energy appliances to raise energy demand and improve the viability of mini grids, and the role that consumer awareness and knowledge exchange plays in encouraging use of mini grids. It also covers billing and payment technologies that can enable consumers to have greater control over their energy consumption and spending, while also facilitating improved bill collection for mini grid developers. To scale up investment in off-grid systems in fragile settings, collaborative efforts are required from a range of stakeholders, including 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 on solar mini grids. However, these are only part of a necessary wider, integrated energy strategy that should include additional off-grid and grid-based technologies. Where relevant, we draw lessons from other technologies, such as solar home systems, and endeavour to ensure that this toolkit has lessons that can also be applicable for other technologies beyond the core focus of mini grids.

List of abbreviations

Abbreviation	Meaning
DRE	Distributed renewable energy
EEA	Energy-efficient appliances
ESMAP	Energy Sector Management Assistance Programme
FCS	Fragile and conflict-affected settings
IBT	Inclined block tariff
INR	Indian rupee
MTF	Multi-Tier Framework
O&M	Operations and maintenance
PAYGo	Pay-as-you-go
PPP	Public-private partnership
PUE	Productive use of energy
R&D	Research and development
RBF	Results-based financing
RTM	Route-to-market
SHS	Solar home system
SME	Small- and medium-sized enterprise
USD	United States dollar
WTP	Willingness to Pay

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Executive summary

Achieving sustainable energy access in fragile and conflict-affected settings (FCS) requires a customer-centric approach that focuses on understanding and stimulating energy demand. This policy toolkit provides policymakers, developers, and stakeholders with actionable strategies to measure, incentivise, and sustain energy demand for distributed renewable energy (DRE) systems, such as solar mini grids, to help ensure long-term economic viability and scalability in challenging environments.

FCS present unique obstacles to scaling energy access. Energy demand is often suppressed due to weak governance, poor infrastructure, low appliance ownership, and limited financial capacity. These factors, combined with volatile economic and political conditions, create significant barriers for mini grid providers aiming to achieve financial viability. Some of the critical challenges include:

- **Low willingness and ability to pay** – Household and small business incomes in fragile settings are often depressed, leading to reduced ability and willingness to pay for energy services provided by solar mini grids. Consumers are often credit-constrained, lack access to financial products, and are wary of spending due to the uncertainty of their environments.
- **Market and infrastructure gaps** – Poor infrastructure, such as weak transportation networks, unreliable supply chains, and limited market development, complicate the deployment and maintenance of solar mini grids. These gaps can also increase operational costs and make energy services less affordable for low-income populations.
- **Knowledge and awareness deficits** – Communities in fragile settings often lack awareness of the benefits of energy access, which can limit demand for energy. In many cases, consumers are not fully informed about how electricity can improve livelihoods.

Having relatively accurate measurements of energy demand is critical for ensuring that mini grids can be made to be economically viable. This toolkit outlines various tools to estimate and analyse energy demand, thereby helping developers design systems that match customer needs. These tools include:

- **Willingness to Pay (WTP) surveys** – These surveys capture data on how much customers are willing and able to spend on energy services, offering insights into potential demand and allowing developers to tailor their projects accordingly.
- **Geospatial analysis** – These leverage satellite imagery and machine-learning algorithms in order to assess market potential and identify suitable locations for mini grid deployment, particularly in underserved areas.

- **Multi-Tier Framework (MTF)** – This comprehensive framework measures different levels of energy access and identifies the barriers limiting electricity usage, enabling stakeholders to implement solutions that directly address the needs of specific communities.

The toolkit provides several strategies that can help sustain energy demand in fragile contexts by targeting households and small businesses, as well as broader market systems, including:

- **Financial support and products** – End-user subsidies (e.g., cash transfers, vouchers) and innovative financial products (e.g., mobile money, micro-loans) can help bridge the affordability gap for low-income households, thereby increasing uptake of energy services.
- **Promoting the productive use of energy (PUE)** – Encouraging the use of electricity for income-generating activities (such as agriculture, small-scale manufacturing, and commercial services) can improve livelihoods, raise incomes, and increase energy consumption.
- **Raising awareness** – Effective community engagement and communication are essential to change perceptions and encourage the adoption of mini grid systems. Public awareness campaigns and education initiatives can inform communities about the long-term socio-economic benefits of electrification.

Ensuring financial sustainability in fragile contexts requires innovative approaches to billing, metering, and payment collection. Key solutions highlighted in the toolkit include:

- **Smart metering technologies** – Smart meters provide real-time data on energy consumption, enabling users to monitor and manage their electricity usage effectively. These technologies also help mini grid operators optimise systems and reduce operational costs.
- **Pay-as-you-go (PAYGo) models** – PAYGo systems offer flexible payment plans, allowing consumers to pay for energy in smaller, more manageable instalments. This reduces the risk of default and makes energy services more accessible to lower-income households. Mobile money integration further enhances the accessibility of these models in remote and conflict-affected settings.

Scaling DRE systems in FCS requires a holistic approach that prioritises customer needs, promotes productive energy use, and provides financial and technological innovations. This toolkit equips stakeholders with practical tools to measure demand, deploy effective financial products, and raise awareness, while offering strategies for overcoming the unique challenges faced in these environments. By fostering collaboration among governments, developers, donors, and local communities, sustainable and scalable DRE markets can emerge, supporting long-term energy access and socio-economic development even in challenging environments.

1. Introduction

Scaling up investments in distributed renewable energy (DRE) technologies, such as solar mini grids, in fragile and conflict-affected settings (FCS) is only feasible if the projects can be made economically viable. In the case of mini grids, economic viability depends on several factors, including meeting target usage/consumption levels, setting appropriate tariffs, and implementing effective billing and payment collection processes.

Sufficient energy demand and consumption is critical to ensure investors and mini grid operators can achieve profitability and be able to carry out operations and maintenance (O&M) needed for their systems to function and potentially expand in the long-term. This raises the need to be able to measure customers' demand for electricity and effectively incentivise and sustain greater energy usage. Achieving this requires a customer-centric approach[1] to mini grid project development: mini grid project planners and implementers must understand their customers – their lived realities, the constraints they face, the scope that exists to incentivise greater energy consumption, and approaches to ensure effective billing and payment.

This policy toolkit explores these demand-side dynamics of solar mini grid projects and aims to inform policymakers, mini grid project developers, and others on how to:

- **Measure energy demand** of a target population through estimating willingness and ability to pay,
- **Set appropriate tariff levels**, bearing in mind available financial support such as subsidies,
- **Incentivise and sustain greater demand** for energy in fragile settings, especially through unlocking productive uses of energy that can contribute to raising household income and purchasing power over time, and
- **Implement effective billing and payment collection** for energy consumed, including leveraging technology to do this more cost effectively.

These elements are essential for achieving project profitability and the long-term sustainability of the mini grid market.

Although this toolkit is intended primarily for policymakers of countries impacted by conflict and fragility, the challenge of low energy demand and consumption in these challenging settings is a systemic problem that will require collaboration among all stakeholders, including mini grid companies, the donor community, and national governments.[2] It is also important to recognise that developing a mini grid in a context of deep uncertainty necessitates factoring in not only demand estimates, but also the expected development and construction constraints, costs of capital, risk of violence, security concerns, and logistical complexities that are inherent in settings of fragility and conflict.

Demand for energy consumption is influenced by numerous factors, including level of income, socioeconomic background, educational attainment, environmental awareness, proximity to key infrastructure (such as markets, roads, and urban areas), and economic stability of the country. The affordability gap remains a key impediment to scaling energy access, as the cost of energy services and appliances is still much higher than what households and individuals are willing to pay for and able to afford.[3] This is particularly true in fragile contexts where households and businesses tend

1 Power for All, 2019.
2 AMDA, 2020.
3 Mitra and Buluswar, 2015.

to have depressed incomes and poor state regulation results in weak consumer protection, creates scope for corruption, and triggers an environment of uncertainty, making consumers less willing to make investments. Customers in fragile contexts often have low purchasing power, no access to formal credit, face high transaction costs, and may struggle to make informed decisions due to insufficient knowledge and awareness about the benefits of electrification.

Even when consumers do have some knowledge, they may not fully grasp the magnitude of its impact. Additionally, the expectation of volatility and uncertainty in these contexts can further dampen their willingness to spend on energy investments. Consumers' inability and unwillingness to pay for energy in the face of conflict and uncertainty makes it even more difficult for potential energy suppliers to recoup their investments in fragile settings.[4]

Recent consumption data from East Africa suggests that off-grid systems may not be commercially viable in many instances due to a persistently low demand for electricity once connected. This is because despite having access to electricity, newly connected customers may not be consuming sufficient electricity to make the system economically viable and connected households may be failing to take full advantage of their energy access.[5]

Since customers who can and do pay their electricity bills are critical to scaling energy access, policymakers must identify measures to ensure that newly connected households and businesses are able to afford energy (through subsidies, financing, and other schemes) and experience the benefits of electrification (by unlocking productive uses, using energy-efficient appliances, and powering small businesses). Although affordability is highly contextual and market dependent, the appropriate combination of financing and awareness can stimulate demand for energy and raise affordability for customers.

4 EEG, 2017.
5 Lukuyu et al., 2021.

2. Demand-side challenges in the fragile contexts

The impact of fragility and conflict on the energy sector implies that both energy needs and opportunities differ compared to more stable situations.[6] To understand how to spur and sustain demand for energy, it is first important to identify the key drivers of low energy demand in fragile contexts. Key demand-side challenges in fragile settings include:

- **Characteristics of fragile markets** – The nature and volatility of fragile economies may supress demand for DRE systems. This includes the following challenges:
  - *Low appliance ownership* – If households do not own many appliances or do not rely heavily on them, they may have insufficient demand for energy services, such as those provided by solar mini grids.
  - *Weak governance and low state penetration* – Weak governance can lead to an unreliable and inefficient energy system, can create scope for corruption, and discourages households and businesses from investing in DRE systems. Weak governance may result in frequent power outages, high energy prices, and limited access to energy services. Additionally, low state penetration – where the central state's governance and policies do not effectively reach all regions – can further exacerbate these issues. Even with appropriate governance frameworks, if a state's reach is insufficient, some regions may experience unreliable energy services and lack the benefits of well-designed policies.
  - *Conflict and security issues* – Conflict and security issues can lead to disruption of energy infrastructure, limited access to energy resources, and reduced potential for economic activity. This can supress demand for energy, particularly in regions where energy infrastructure is unreliable or unavailable.
  - *Poor transport infrastructure* – This can make it difficult or expensive to transport solar mini grid equipment and materials to remote or rural communities. This can lead to limited availability of mini grid systems and higher costs for those that are available.
  - *Lack of public financial capacity* – The high upfront costs of developing solar mini grids is a barrier to adoption in lower-income populations. If public financial capacity is limited, it may be difficult to provide the financing and subsidies that are needed to make these systems affordable. When this happens, energy costs will be beyond the affordability of households and businesses, therefore decreasing their demand.

6 EEG, 2017.

- **Lower ability and willingness to pay** – Fragility and conflict often undercut the purchasing power of energy consumers, who tend to be credit constrained and may be dependent on episodic income (e.g., seasonal income for predominantly agricultural economies). Additionally, fragile environments are characterised by uncertainty, risk, poor state regulation (e.g., corruption, weak consumer protection, fragmented judicial systems, etc.), and weak physical and digital financial infrastructure, all of which undermine consumer confidence and dampen their willingness to invest in DRE systems.

- **Lack of knowledge and awareness** – Limited knowledge and awareness about solar mini grid systems and the benefits of electrification may also hinder demand for these projects. This includes limited awareness of livelihood opportunities that could be unlocked through increased energy access and energy-related businesses. In fragile contexts, communities may also be hesitant to deviate from more traditional sources of energy which have been the norm for many years, a dynamic which is known as 'inertia bias'. Thus, there is a need for consumer awareness campaigns and education to induce a behavioural change towards increasing demand for energy provided by solar mini grids.

- **Poor quality of supply** – It is important to recognise the interconnected nature of demand and supply. If rising demand is not met by an increase in supply and improvements in electricity infrastructure and services, it will damage consumer confidence and decrease demand. For a more detailed discussion on supply side constraints, refer to the accompanying toolkit on *Improving the supply side for solar mini grids in fragile contexts*.

- **Limited/early-stage market development** – The solar mini grid market is a nascent sector which is inherently subject to investment risks and uncertainties related to limited or non-existent market data and knowledge. These risks are amplified in fragile settings, making it even more difficult for developers to access early-stage financing. This, in turn, holds back market development and the creation of market data and knowledge.

These challenges highlight how uncertainty around demand remains a key area of risk for both developers and investors in fragile settings. Developers use demand estimates as key inputs to not only inform the design of their mini grids, but to also secure financing.[7] Mitigating the risks of low demand requires concerted efforts to increase customers' productive use of income-generating appliances and equipment and enable financing mechanisms that help de-risk some of the demand uncertainty.

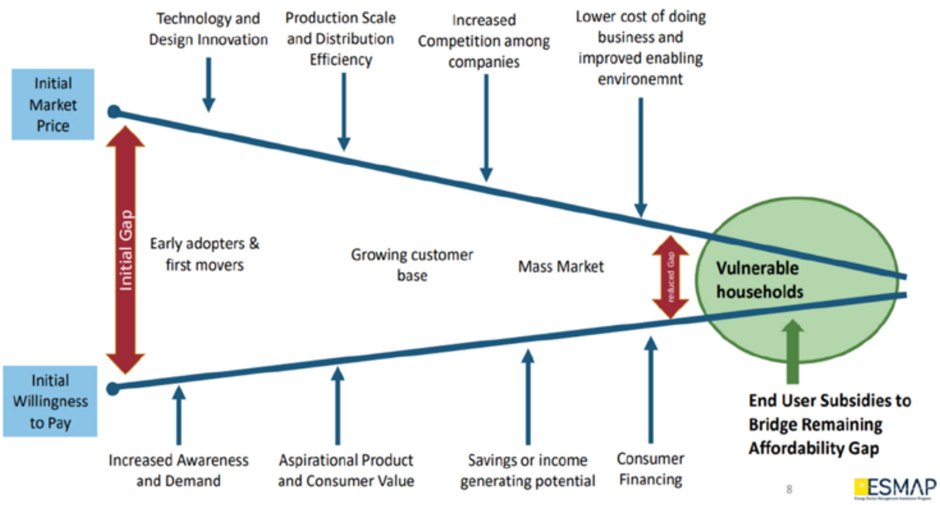
The key interventions needed to bridge the affordability gap, which is the greatest demand-side challenge in fragile contexts, are illustrated in Figure 1. As can be seen, the initial gap is represented by the difference between the initial market price and willingness to pay, with the market mainly dominated by early adopters and first movers at this stage. To bridge this gap, interventions are needed on both:

7 ESMAP, 2022a.

- **Supply-side** – technology and design intervention, production scale and distribution efficiency, increased competition, lower costs, and enabling environment
- **Demand-side** – increased awareness and demand, aspirational product and consumer value, savings/income generating potential, and consumer financing.

Together, these interventions will gradually reduce the affordability gap and foster a growing customer base which could then lead to the development of a mass market. However, end-user subsidies (discussed in section 5) may still be needed to bridge the remaining gap and reach vulnerable households. The focus of this toolkit will be on interventions on the demand-side. For a discussion on supply-side interventions, please refer to the *Improving the supply side for solar mini grids in fragile contexts* policy toolkit.

Figure 1 Interventions to bridge the affordability gap[8]



8 Ibid.

3. Tools to measure energy demand

The financial feasibility of mini grid projects is largely dependent on the ability of customers to pay a tariff that generates sufficient revenue to cover the costs of supply, including project development, operation, maintenance, and repairs. Setting an appropriate tariff requires understanding the energy needs of customers and the use of tools that enable customer profiling. This information would feed into the design, size, and cost structure of mini grid projects, determining not only the price of the energy produced but also its quality.[9] This information is needed during both the planning and operation and maintenance (O&M) stages of mini grid projects.

However, it is difficult to accurately estimate energy demand in fragile countries due to data scarcity, uncertainty and risks, and constrained socio-economic situations.[10] These factors collectively make data collection notoriously difficult and innovation around data collection is needed to develop suitable solutions that are viable in and tailored to local contexts. Lack of knowledge about energy demand, usage patterns (including when and how much is used), and future demand trajectories when deciding project size could result in:

- **Oversized mini grid systems** – Oversizing a mini grid occurs when the mini grid capacity exceeds demand, i.e., the system is bigger than it needed to be. A bigger system means higher capital expenditure on equipment and increased operating costs for the lifetime of the project. It creates longer payback times due to increased investment and inefficient use of excess energy, which is not effectively utilised and goes to waste. This reduces the overall efficiency of the system and drives up costs to the customer.

- **Undersized mini grid systems** – Undersizing the mini-grid system occurs when demand exceeds the mini grid capacity. It can lead to insufficient power supply, resulting in blackouts and reduced service quality. This, in turn, could lead to consumer dissatisfaction and negatively impact future demand.

Thus, it is important to develop and use tools that can enable data collection on energy demand in order to support effective design by helping developers understand the sector's market potential, develop appropriately sized mini grid systems, and engage relevant stakeholders. Below, we explore three key mechanisms for data collection:

9 GIZ, 2016.
10 Sayani et al., 2022.

I. **willingness to pay surveys**, which gather data on energy demand through surveys,

II. **geospatial analysis**, which is dependent on algorithmic methods and remote sensing techniques

III. **the multi-tier framework**, which is a robust conceptual framework for measuring energy access.

It is important to note that tools for demand assessment should always be adjusted and adapted to national and local conditions.[11]

3.1. Willingness to pay surveys

A common approach to gather data on energy demand that is employed by both researchers and developers is to carry out surveys to determine the willingness to pay (WTP) of different customer groups in a target community, with a focus on early adopters. WTP is defined as "the maximum amount that an individual indicates that he or she is willing to pay for a good or service."[12] Since WTP varies across customers, it can only be assessed through direct surveys which are typically carried out in one of two ways:

1. A survey of **expressed WTP,** which is the maximum amount that a person says he or she is willing to pay for electricity.

2. A survey of **revealed WTP** (also known as **ability to pay**), which is the actual amount people already pay for kerosene lamps, candles, flashlights, or other substitutes for energy from mini grids.

Data from these surveys are compiled into a database to determine an **average WTP** along with a distribution profile of survey respondents' WTP, ranked from highest to lowest.[13] **Box 1** illustrates an example of consumer surveys that have been conducted for solar home systems (SHS) in Mozambique. Surveys in some African countries have also shown that consumers are willing to pay higher tariffs for better quality of service as long as the higher tariffs are below the costs of self-generation in electricity.[14] It is important to note that WTP is not a fixed value, but rather is strongly dependent on the quality of service provided and the alternatives available.

11 Energypedia, 2016.
12 NRECA, 2009.
13 USAID, n.d.
14 Ibid.

BOX 1 POWER AFRICA'S CONSUMER AFFORDABILITY SURVEY IN MOZAMBIQUE[15]

Power Africa's Southern African Energy Program (SAEP) has developed comprehensive surveys to provide SHS companies and other sector stakeholders (e.g., donors planning subsidy programmes) with detailed information on the ability and willingness of unelectrified communities to pay for basic electrification services. These surveys also evaluate familiarity with and perceptions of small-scale solar products and access to mobile money networks to enable the use of PAYGo models (which are discussed in greater detail in **section 7**).[16]

SAEP designed the survey to be representative of target markets of SHS companies and identified three key focus areas:

- Household expenditure and WTP
- SHS awareness, ownership, and perceptions
- Mobile phones and usage of mobile money

The ability and WTP for SHS was estimated in two ways:

i. Through data collected on weekly spend/consumption of candles, kerosene, mobile phone charging, and transport, and

ii. self-reported WTP.

A sense check of these two findings was then conducted against reliable external sources, including World Bank data, Mozambique national statistics, and previous affordability surveys conducted in Mozambique. Approximately 2,700 households participated in the face-to-face interviews across nine provinces in Mozambique. The composition of these households included 67% from rural areas, 91% without access to grid power, and 61% of respondents were women.

The results from these surveys were used to inform the plans and strategies of key players in Mozambique's electrification programme, including the government, SHS companies, and development partners on scaling off-grid solutions. The survey gathered critical information to help inform SHS companies on strategies and decision-making around scale-up, marketing, and the viability of using PAYGo models. The survey also provided development partners with an estimate of funding requirements for the following five years to bridge the consumer affordability gap, and government received valuable insights on potential market interventions needed to facilitate universal energy access in Mozambique. A similar survey-based approach could be employed for the mini grid market.

15 USAID, 2020.
16 USAID & Power Africa, 2022.

Moreover, in the case of mini grids, the Detailed Electricity Survey (DES) tool is a comprehensive on-the-ground survey used to capture required information (e.g., energy usage profiles) needed for estimating the economic viability of mini grid systems.[17] This includes using the tool to facilitate mini grid site selection and evaluate existing as well as future demand potential, time of day usage, and the seasonality of demand.

Estimates of WTP can also be determined using **unbinding take-or-pay contracts** – once customers are requested to sign a take-or-pay contract for a specific amount of electricity at a specific price, they often rethink their initially stated demand and available budget. Thus, if customers sign the contract, they are essentially indicating that they can afford the stated price, which is an effective technique to get accurate WTP.[18]

Undertaking consumer surveys in FCS is more complex and expensive than in non-fragile settings. Some practical recommendations on implementing consumer demand surveys in fragile contexts include:[19]

- **Feasibility and risk assessment** – Conduct a thorough assessment of the situation on the ground to determine survey feasibility, implement strict security protocols for enumerators, and consider delaying or cancelling surveys if risks such as active conflict or social tensions are too high. Avoid aggravating social tensions during sensitive times, such as in the run-up to elections, where survey implementation could be misconstrued as house-to-house campaigning activities.

- **Time and resource allocation** – Allocate extra time and resources to account for unpredictable conditions, access challenges, and the need for contingencies like alternative transport methods or additional local enumerators who can safely navigate the area. Survey implementation is a costly and time-consuming process, even more so in challenging and uncertain settings.

- **Enumerator training** – Provide robust training to ensure that enumerators are familiar with the data collection procedures that take into consideration cultural sensitivity, conflict dynamics, and trauma-informed interviewing techniques to ensure safe and effective engagement with communities in fragile contexts. Ideally, a pilot survey can be conducted to test enumerators' capabilities and robustness of the survey instrument so that remedial action can be taken before implementing the survey.

- **Community engagement and trust-building** – Engage with local leaders and community groups to build trust, ensure transparency about the survey's purpose and scope, and address any concerns, while being mindful of conflict dynamics that could influence perceptions.

17 Smart Power India, 2020.
18 The RECP, 2014.
19 GIZ, 2016.

- **Supervision and data verification** – Implement real-time monitoring of enumerator activities, consider third-party verification, and establish a robust review process to ensure data accuracy and correct estimation of energy demand, particularly in areas where local power dynamics or security incidents may impact data integrity.

It is important to recognise that WTP is highly context-specific and influenced by local factors, with significant variation seen both across and within countries. In fragile contexts, risks and uncertainties may distort WTP. For example, security concerns can lead to limited access to certain areas while the presence of armed groups or social tensions may bias responses or lead to data falsification. Additionally, the capacity to implement and analyse complex on-the-ground surveys is often constrained due to scarce resources for data collection, limited revenue generating capacity, and competition for funding with other pressing needs and government priorities, such as humanitarian aid or infrastructure rebuilding. These constraints often prompt developers to seek more practical and context-specific ways to build an understanding of energy demand in these settings. Geospatial tools, for example, may be more effective for information gathering where traditional survey methods are either too risky or impractical, as will be discussed in the next section.

3.2. Geospatial tools

In recent years, geospatial analysis has been gaining traction and emerging as an effective tool to gather information on market size and potential energy demand.[20] Machine-learning algorithms and remote sensing techniques can analyse geospatial datasets and produce maps that identify suitable, high-impact locations for project implementation. This technology-enabled and data-driven approach to market assessment collects a range of geotagged data, including:

- Locations of buildings and markets
- Road and electricity networks
- Location of existing mini grids
- Nightlight imagery
- Socio-economic and demographic data (e.g., gender composition, household income, areas under crop cultivation)
- Mobile network coverage, cell-phone ownership, etc.

In contexts of conflict or extreme fragility, such innovative approaches to data collection may be more suitable than complex and costly on-the-ground surveys. Some notable companies and organisation that provide remote sensing services include:

20 ESMAP, 2022a.

- **WAYA Energy** (MIT Energy Initiative) – Offers a geospatial planning tool that gathers national or regional data to generate least-cost electrification plans. The software allows for a scalable effort to design multiple off-grid sites quickly, which can be used to guide a large-scale mini grid programme. The software has been employed in a number of countries to date, including India, Uganda, Kenya, Peru, Nigeria, Cambodia, and Indonesia.

- **Energy Access Explorer** (World Resources Institute) – This an online, open-source, and interactive platform that employs mapping to visualise the state of energy access in unserved and underserved areas. The Energy Access Explorer tool analyses credible and public data to draw connections between the demand for and supply of energy. The interactive nature of the tool also enables individuals to create custom analyses to identify and prioritise areas where energy markets can be expanded.

- **Route-to-Market (RTM) Tool** (Power Africa) – This is a free geospatial modelling tool that employs geospatial data and techniques to map data such as population, electrification, telecommunications, roads, infrastructure, etc. to support mini grid companies with off-grid access planning. The RTM tool enables companies to identify and prioritise geographic markets with the highest potential for expansion or deeper market penetration and has been employed in southern African countries such as Zambia, Malawi, and Mozambique.[21]

- **Village Data Analytics (VIDA)** – This is an AI-powered, data-enabled tool that employs satellite imagery, publicly available geospatial data, on-ground survey data, and modelling to extract valuable information on remote areas and assess their suitability for off-grid electrification, including mini grids. VIDA serves as a decision-making tool that provides map visualisations, analysis, and reports tailored to individual users. PowerGen has partnered with VIDA to assess mini grid site selection in West Africa.[22]

- **GridFinder** – Offers an open-source tool that maps the location of existing power lines based on nightlight satellite imagery and road data. This can serve as an effective tool to measure the likelihood of a village being connected to the grid in the near future.

The data and information obtained from these geospatial tools can be valuable for a range of stakeholders, including:

- Mini-grid developers, who can utilise these tools to identify market opportunities.

- Development partners and impact investors, who can use these tools to identify regions with the greatest energy access gaps.

- Electrification planning agencies, who can explore the potential for off-grid systems and clean energy access in their countries.

21 USAID & Power Africa, 2022.
22 VIDA, PowerGen, and TFE Energy, n.d.

While geospatial tools offer innovative solutions for assessing energy demand, they are not without limitations. For instance, nightlight data may not reflect actual grid connectivity in rural areas lacking streetlights or may misrepresent grid access in areas with intense nightlight from generators, such as artisanal mining sites. Additionally, these tools might not capture detailed socio-economic and cultural factors influencing local energy needs. Combining geospatial analysis with targeted on-the-ground research and community engagement is therefore needed for a more accurate and comprehensive understanding of energy demands in fragile contexts. For a more detailed discussion on data collection in fragile countries, refer to the policy toolkit on *Data and technology: Challenges and opportunities for solar mini grids in fragile contexts.*

3.3. The Multi-Tier Framework (MTF)

The Multi-Tier Framework (MTF) initiative launched by the Energy Sector Management Assistance Programme (ESMAP) in 2015 provides a standardised approach to measuring energy access across different countries and regions. The MTF is a comprehensive data collection tool which gathers data at the country level and analyses it to identify energy access gaps and develop potential solutions to improve energy access.[23] The framework categorises energy access into five tiers, each representing a different level of access to energy services, with Tier 0 representing no access to energy services and Tier 5 representing access to reliable and high-quality energy services.

The MTF uses data to identify the primary reasons why households are not using electricity or why usage is limited (e.g., due to capacity, reliability, or affordability constraints) and develops recommended solutions to address these constraints. The MTF has been widely adopted by governments, development organisations, and researchers and could be a particularly valuable tool to deploy in fragile contexts where such a targeted and nuanced approach to tracking energy access is needed.

23 ESMAP, 2022b.

4. Raising awareness and knowledge exchange

In fragile contexts, addressing knowledge and information gaps to facilitate the uptake of mini-grid systems requires a two-pronged approach of **raising consumer awareness** and encouraging **knowledge exchange** among key stakeholders at the policy and practice level. Firstly, consumers in these settings often face critical knowledge gaps regarding mini grids, the productive use of energy, and the benefits of electrification more broadly, which may suppress their demand for mini grid systems.[24] Secondly, knowledge exchange among key stakeholders can help disseminate successful ideas and establish communities of practice to support solar mini grid market development in more challenging environments. Each of these will be discussed in greater detail ahead.

Tools for raising awareness and platforms for knowledge exchange include:

- **Public awareness campaigns** – These are targeted efforts to inform and engage the public on issues related to energy access and electrification and can include community meetings, radio and television broadcasts, and social media outreach.
- **Knowledge hubs** – These are platforms for sharing information and best practices related to scaling energy access. Knowledge hubs can be physical or virtual spaces that bring together a variety of stakeholders to exchange ideas and collaborate on solutions (discussed further in section 4.2).
- **End-user education** – Involves providing training and education to end-users (i.e., consumers) of energy services to help them understand how best to use energy services to meet their needs and share information on the multiple socio-economic advantages of electrification for a cleaner, healthier, and better quality of life.
- **Vocational training** – Involves providing skills training and education to those working in the energy sector (e.g., technicians, installers, maintenance workers etc.) to ensure that they have the necessary skillset and knowledge needed to install and maintain energy systems efficiently. Vocational training can take the form of classroom instruction, hands-on practice, or apprenticeships.

24 IIED, 2017.

4.1. Raising consumer awareness

In fragile settings, a key explanation for suppressed demand and limited adoption of mini grids is that communities have adapted to life without electricity (or unreliable electricity) and may be unaware of the full potential benefits of electricity services (or requirements to achieve this). Low consumer awareness poses a major obstacle for mini grid developers and operators because:

- There is limited awareness of product benefits and financing options.
- There is a general perception that technology is unaffordable.
- There are high perceptions of risk, raising the need to address negative perceptions or perceived barriers in the adoption of off-grid products. This can arise from fear of investing in a new technology, uncertainty about the reliability and quality of the product, lack of knowledge about product specifications, etc. Additionally, there may be cultural or social factors that influence consumer perceptions of off-grid products, such as the perceived social status of using a certain type of technology.
- There is limited understanding of how increased access can positively affect consumer incomes.
- Products designed without consumer feedback may also fail to meet consumer needs and expectations.[25] For example, the adoption of solar cookers has been unsuccessful in several contexts due to the lack of fit-for-purpose designs tailored to the intended communities.[26] The success of such products is dependent on numerous factors including socio-economic, environmental, and cultural aspects. Therefore, it is necessary to conduct robust assessments of local cooking situations (e.g., equipment used, food characteristics, cooking habits, etc.) and identify cultural preferences, energy needs and other relevant factors which should then be integrated into the design of such products.[27]

Raising awareness about the benefits of electrification requires changing community mindsets. This involves understanding the **behavioural elements** that drive consumer decision-making, including socio-economic, environmental, and cultural drivers, such as the influence of personal preferences and social norms on energy consumption. The complexity of understanding decision-making is intensified in fragile contexts where limited resources, conflicting priorities, mistrust of new technologies, and entrenched behaviours may make consumers hesitant to use alternative energy sources, even if they are cleaner and cheaper.

25 CLASP, 2020.
26 Otte, 2013.
27 Ibid.

Energy consumption at home is often shaped by ingrained habits that are hard to change due to factors like inertia or a preference for the status quo, magnifying the perceived effort associated with making alternative choices.[28] Therefore, it is important to **integrate behavioural levers into policymaking** to nudge consumers to make decisions that can facilitate mini grid demand and adoption of productive uses (discussed in greater detail in section 6).

Community engagement plays a key role in raising awareness, shaping behaviour, and sustaining demand, particularly in fragile settings where mistrust of external entities and reluctance to deviate from established norms are common. In such contexts, the involvement of local leaders or community heads is vital. These individuals often hold more influence within their communities than formal governments and can serve as trusted voices that help build acceptance and shape a positive attitude towards new projects, such as mini-grid systems. Local leaders also have intimate knowledge of the community's social dynamics and structure and are familiar with both how the community operates and who are the key individuals whose support is crucial for the success of the project. By identifying and working with those who can influence the wider community, these leaders can help overcome resistance and encourage collective buy-in. Thus, local leadership is a key driver of a successful solar mini grid project, as their endorsement can significantly enhance community support and long-term project sustainability. Getting them involved requires understanding which leaders to approach and how to work through existing power structures to ensure that the project aligns with the community's values and needs.

As communities gain awareness around energy usage and electricity consumption and household incomes improve over time, mini grid usage and energy demand can be further optimised. Smart Power India has developed an approach called the Community Engagement, Load Acquisition, and Micro-enterprise Development (CELAMeD) which has "enabled the development of communication and marketing strategies to inform consumers about the benefits of renewable energy and catalyse the growth of rural businesses."[29] Building trust with communities and other partners from the early stages of the project is key for its success. A key component for achieving this requires the design of **effective communication strategies**.

4.1.1. Designing an effective communication strategy

Communication plays a critical role in facilitating knowledge creation and awareness and, ultimately, shaping energy demand. This is particularly true in fragile contexts where communication can help build trust in communities where individuals may be sceptical of new initiatives or wary of external actors. An effective communication strategy for mini grid developers and operators involves gaining consumer trust, addressing key barriers and concerns, promoting the benefits of electrification, and aligning messages with local cultural and traditional values.

28 IEA, 2021.
29 ESMAP, 2022a.

Any geographic setting has different customer segments, each with unique demand characteristics that need to be carefully assessed to design a communication strategy that is tailored to the local country context.[30] For example, in areas with recent or ongoing conflict, messaging should emphasise the stability and reliability of electricity to improve daily life, enhance safety through public lighting, offer flexible payment options, and empower communities by supporting local businesses (e.g., more efficient agricultural processes), job creation, and education. These messages can be effectively communicated through a variety of interventions including advertisements, campaigns, awareness programmes, and knowledge exchange hubs.

Moreover, consumer awareness campaigns should focus on a few key messages tested by focus groups and should be designed to reach various audiences including the public, residential, and industrial sectors.[31] For example, in Uganda, consumer awareness campaigns using radio, community events, and cooking demonstrations were successful in stimulating demand for fuel-efficient cookstoves among refugees and rural communities by highlighting benefits such as fuel savings, affordability, and smoke reduction.[32] Similarly, in Tanzania, JUMEME set up a Village Power Committee and launched door-to-door communication campaigns to improve understanding of electricity's potential and financing options for their mini grid project.[33] Ultimately, effective communication and community engagement requires a **flexible approach** and a **clear understanding of the local socio-economic and cultural characteristics** that shape a country.
A successful example of a customer awareness campaign for mini grids in Bangladesh is presented in **Box 2.**

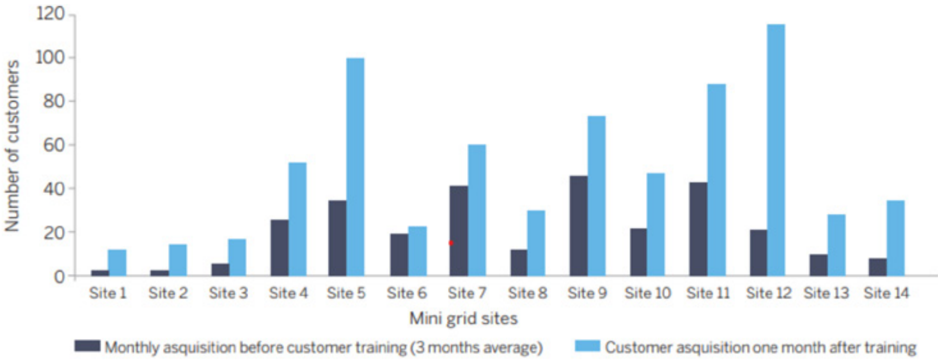
BOX 2 CUSTOMER AWARENESS CAMPAIGN IN BANGLADESH[34]

In 2017, the Bangladesh Infrastructure Development Company Limited (IDLOC) launched an extensive three-day customer awareness campaign to stimulate demand and increase the uptake of 20 solar mini grids. The campaigns were conducted by international experts and trainers from major equipment manufacturers and included customer training programmes along with public events to shed light on the benefits of electrification.

These campaigns combined customer training with public shows featuring folk singing and street theatre, increasing productive use customers and total customer acquisition by nearly 500% as can be seen in **Figure 2** below. The success of the campaign has prompted IDLOC to develop further training content targeting women and drawing attention to the benefits of social facilities, street lighting, schools, clinics, etc. to enable local entrepreneurs to see community benefits and the sustainability of their own businesses.

30 Smart Power India, 2020.
31 World Bank, 2020.
32 EnDev, 2021.
33 IIED, 2017.
34 ESMAP, 2022a.

Figure 2 Monthly acquisition before and after introduction of customer awareness campaigns[35]



However, it is important to recognise that in the fragile country context, engaging consumers through behavioural change campaigns or encouraging widespread adoption of new and more efficient technologies may be harder to achieve because levels of social cohesion may be weakened and the potential to disseminate new technologies may be disrupted by violence.[36] To address these obstacles, developers can leverage trusted community networks, start with targeted small-scale pilot projects, and use face-to-face communication methods. Collaborating with humanitarian organisations and adapting strategies to local conditions could also help mitigate these challenges.

4.2. Knowledge exchange: Communities of practice

To support the solar mini grid market to develop in fragile contexts, it is also essential to establish a large and rapidly expanding knowledge network among key stakeholders, including policymakers from FCS countries who can shed light on the unique set of challenges faced in their countries and key country priorities for mini grid deployment. Such a network can help identify and disseminate successful ideas, share best practices, and establish communities of practice.[37] Thus, in addition to raising consumer awareness, peer-to-peer learning networks and knowledge hubs can generate mutual benefits and facilitate effective policy implementation and practice.

By connecting key players within the mini grid space, knowledge exchange networks can reduce information asymmetries, build trust, and enable the co-creation of solutions. This, in turn, can generate increased demand through the integration of **advocacy at the policy level**,[38] ensuring that mini grid projects are sustainable and deliver long-term benefits to communities.

35 Ibid.
36 EEG, 2017.
37 ESMAP, 2019
38 Smart Power India, 2020.

Examples of initiatives active in this include:

- **Africa Mini-Grids Community of Practice (AMG-CoP)** – A peer-to-peer working group for African state and non-state actors committed to improving mini grid policies and scaling mini grid systems in their respective countries.

- **GOGLA Community of Champions** – A platform for ongoing knowledge exchange primarily between governments, the private sector, and development partners to work collaboratively to scale off-grid energy access in sub-Saharan Africa. The platform aims to facilitate peer-to-peer learning, highlight best practices, and create an open learning and sharing environment for key stakeholders.

- **The Clean Energy Mini-Grids High Impact Opportunity Group** – Developed within the UN's SE4ALL programme, this effort has managed to aggregate many mini grid partners to facilitate regulations, develop and share knowledge, advise on business models and increase visibility.

- **The Green Mini-Grid Help Desk** – This was designed by Inensus and Energy4Impact as an information portal for mini grid developers and stakeholders. The portal provides an exhaustive list of mini grid resources including market reports, links to industry stakeholders, instruction guides, business forms and templates, financial models etc.

- **Platform for Energy Access Knowledge (PEAK)[39]** – This is an interactive knowledge exchange platform developed by Power for All and Renewable and Appropriate Energy Laboratory (RAEL) and was designed to help aggregate and synthesise large, growing bodies of data into easily accessible and useable knowledge.

39 Power for All, n.d.

5. Financial support and financial products and services

The adoption and financial sustainability of mini grid systems in fragile contexts can be significantly enhanced through mechanisms and tools that **boost consumer finance capabilities.** Rural communities in fragile countries often have low purchasing power, no access to formal credit, and few financial products and services available to ensure timely payments. As a result, many customers may default on their payments, request disconnection, or trade down on their service packages.
To address these challenges, two key issues need to be considered:

- **Financial support** such as cash transfers and subsidies can help facilitate financial inclusion and de-risk demand uncertainty that is prevalent in fragile contexts. Such cost-smoothing tools are particularly necessary in the initial adoption period. However, it is important to recognise that this financial support would be time-bound with the ultimate objective being to switch to a commercially viable system in the long term.

- **Financial products and services** such as mobile money, micro loans on mobile money platforms, and smart meters can allow better control of energy usage can and provide customers with tools that enable timely payments for energy usage. These products and services must be designed keeping in mind the specific needs and constrains of fragile contexts (e.g., low levels of financial literacy and constrained access to technology).

Each of these will be discussed in greater detail below.

5.1. Financial support: Subsidies

5.1.1. End-user subsidies

Public actors aiming to scale energy access through the provision of DRE have typically focused on supply-side support, which indirectly brings down costs for end-users. Supply-side subsidies are provided to the producers (or developers) of a product or service, such as mini grid developers, and can take various forms, such as results-based financing (RBF). This is discussed in greater detail in the *Financing and de-risking tools and approaches for solar mini grid projects in fragile contexts* policy toolkit. By lowering the costs of electricity generation, mini grid developers can sell their electricity at a lower price, indirectly lowering costs for customers by partially absorbing the cost of business.[40]

40 GOGLA Off-Grid Solar Forum & EXPO, 18-20 October 2022, Kigali, Rwanda.

However, in low-income settings, end-user subsidies (i.e., demand-side subsidies) are necessary to fully bridge the affordability gap and increase energy access for households and small businesses. These subsidies aim to increase the purchasing power of low-income consumers and **directly** reduce the price they pay, regardless of market dynamics. **Box 3** highlights the case for end-user subsidies, which are particularly important in FCS and hard-to-reach-communities.

Examples of end-user subsidies include:

- **Cash transfers** – This involves direct transfer of cash from the government or an organisation to individuals or households to improve their access to off-grid solutions. For example, the Energy Cash Plus/Mwangaza Mashinani Programme (MMP)[41] in Kenya employs conditional cash transfers to help bridge the affordability gap of eligible households by partially covering their payments to off-grid solar companies. Impact surveys found this intervention to have a positive socio-economic impact, including increasing study hours for children, enhancing community safety, and generating additional household income (e.g., by helping neighbours charge their phones for a small fee).
- **Vouchers** – These are prepaid certificates or coupons that customers can use to access off-grid services at a reduced cost or to provide direct cash discounts on energy bills. For example, Smart Power India has introduced a Customer Voucher Scheme that provided customers with a direct cash discount of up to 75% in their electricity bills over a three-month period.[42]
- **Freely distributed products** – This is provision of products or services free of charge to individuals or households (e.g., solar lanterns, clean cookstoves, and other off-grid solutions)
- **Interest subsidies for end-user loans** – These cover the interest costs on loans, such as loans for the purchase of productive use appliances. They improve affordability by reducing the cost of borrowing.
- **End-price/capital subsidies** – These help to reduce the upfront cost of purchasing or installing off-grid solutions.

41 GOGLA, n.d.
42 Smart Power India, 2020.

BOX 3 THE CASE FOR END-USER SUBSIDIES IN FRAGILE MARKETS

The case for end-user subsidies is particularly strong in hard-to-reach and vulnerable communities, especially in FCS where households face a range of financial challenges, including limited access to financial services and credit constraints. These factors make it difficult for low-income households to afford the energy provided by solar mini grids, which is critical to achieving last-mile rural electrification. By directly reducing the price paid by customers, end-user subsidies can make electricity more affordable and accessible, particularly for those who may not be able to afford it otherwise. Mini grid projects are more viable when end-user subsidies have been deployed and this links to the concept of financial additionality, whereby the use of subsidies enables investments and generates positive impacts which would not have been possible otherwise.[43].

While subsidies may not be a sustainable solution in the long-term, they can play an important role in supporting the initial adoption of mini grid systems and kickstarting energy usage in fragile countries. This is particularly important during the initial adoption period when consumers may be hesitant to use new technologies, helping to overcome 'inertia bias'. Ideally, over time, consumers' purchasing power would increase due to greater productive use of energy and the need for subsidies may decline.

While they can be very impactful, end-user subsidies are complex in their design, they rely on significant data and information about the beneficiary population, and they risk market distortion if not implemented carefully.[44] Market distortions are most evident when subsidies are not sufficiently targeted, have unclear priorities, and lack transparency. Untargeted subsidies tend to be extremely costly and wasteful as they extend support to *all* consumers, including those who can afford unsubsidised electricity. The price difference between the market price and the subsidised price is usually absorbed by government (thereby burdening the national budget), by the electricity utility (thereby undermining its financial sustainability) or mini grid developers through foregone revenues (thereby threatening the viability of electricity provision).

Where untargeted end-user subsidies are applied to moveable commodities, such as petrol or diesel, they also create scope for arbitrage and encourage smuggling of fuel from low-price areas to areas where the commodity can be resold for a higher market price. An example of distortive end-user subsidies is included in **Box 4**. While the risk of end-user subsidies with mini grid projects is far lower, and the case for end-user subsidies in achieving last-mile electrification is clear, these programmes need to be carefully designed to minimise distortions that could undermine the long-term commercial viability of the mini grid market. Whether end-user subsidy programmes for alternative energy sources, notably fossil fuel products, are present in a country also affects demand for energy

43 Collier, et al., 2021.
44 Smart Power India, 2020.

from solar mini grids – if fossil fuels are subsidised, stimulating demand for solar mini grids (which may have higher tariffs than what households pay for subsidised fossil fuels) will be more difficult.

BOX 4 FUEL SUBSIDIES IN SUDAN

Fuel subsidies have been implemented in many developing countries with the intention of providing short-term protection to consumers, but they often generate distorted benefits, crowd out public spending on social services, create scope for widespread corruption, and lead to unaffordable economic burdens on government.[45]

Such inefficiencies were evident in Sudan, where the government had historically provided subsidies on fuel with the aim to keep prices low for consumers. However, fuel subsidies mainly benefit those segments of the population that use the most fuel, being the middle and upper class. The wealthiest benefitted the most while the poor received both minimal benefit and bore the brunt of fuel subsidies crowding out public spending on social services.[46] There was also widespread smuggling of subsidised fuel out of Sudan to be re-sold in neighbouring countries for higher market prices.[47]

This untargeted end-user subsidy programme drained the country's foreign currency reserves and pushed the government budget into a perpetual deficit. This caused inflation and currency depreciation which, in turn, further raised the financial burden of fuel subsidies on government. By 2020, the cost of the fuel subsidy policy reached a staggering USD 3.5 billion per year.[48]

In response to this spiralling fiscal crisis, the transitional government of Sudan gradually lifted the fuel subsidy in 2020 with the objective of achieving macroeconomic stability, better targeting protection measures to the most needy and vulnerable households, and creating the market conditions needed to support economic growth.

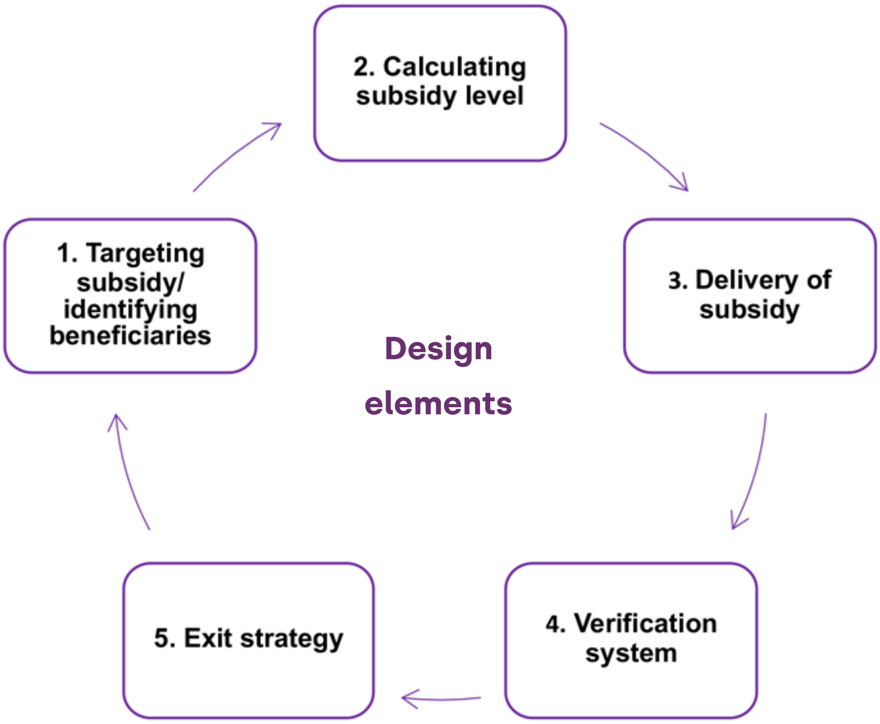
Once in place, removing subsidies is politically difficult and can incite public discontent and even civil unrest, as was the case in Sudan. This is particularly so when fuel subsidies are seen to be the only service that government provides to a population. The Sudanese governments' decision to remove fuel subsidies was met with large public backlash and rioting in the streets.[49] Despite the political difficulty of lifting fuel subsidies, this reform was implemented successfully by the transitional government of Sudan.

This example demonstrates the importance of accompanying subsidy reforms with an effective and far-reaching communication strategy to educate the population on why subsidy removal is necessary (highlighting how benefits are captured by the middle and upper classes and fuel smugglers) and how government intends to use the revenues saved from the subsidy's removal to better target assistance to the poorest in society.

45 Asare and Reguant, 2020.
46 World Bank, 2019.
47 Logan, 2021.
48 Ibid.
49 IISD, 2014.

The case study in **Box 4** highlights that a successful subsidy programme should be designed with a focus on **sustainability and scalability** from the start. Additionally, there is no one-size-fits-all formula for setting demand-side subsidies: understanding the local context is key for a successful end-user subsidy programme. Once the need for a subsidy is identified, there are many interrelated design decisions to make, and it is important that the subsidy is tailored towards the specific market failure that it intends to address and, consequently, is well targeted to the intended beneficiary population. **Figure 3** identifies key elements of an effective end-user subsidy design framework and **Table 1** delves deeper into the components of the design elements.

Figure 3 Key elements of the end-user subsidy design framework[50]



50 Adapted from GOGLA Off-Grid Solar Forum & EXPO, 18-20 October 2022, Kigali, Rwanda, session on end-user subsidy.

Chris McGrath, Getty Images

Table 1 Design elements of an effective end-user subsidy programme[51]

Design element	Key aspects to consider
Level of targeting	Subsidies could be implemented widely across a population or instead target specific subsets of a populations. Forms of targeting include geographic, demographic, or economic targeting. Targeted approaches require a lot more information on intended beneficiaries and take longer to construct, but they do ensure support is given only to intended beneficiaries (lowering wastage and overall costs).
Subsidy level	Subsidies could be applied in fixed amounts based on a percentage of a product cost or they could vary across subsets of targeted groups to match the varying affordability gaps more closely across different users.
Delivery channel	It's necessary to identify the most appropriate delivery channel for subsidies, which could include direct provision via cash transfers or vouchers or transfer through private companies/third parties who must reduce prices for end-users.
Verification system	A verification mechanism is needed to ensure that the subsidy reaches the intended beneficiary, that subsidies are not duplicated, and that products are not resold for profit. Verification programmes could either be manual (e.g., beneficiary booklet that records receipt of subsidy) or technology based (e.g., biometric cards have been used in various cash transfer schemes in South Africa and Mexico on the basis that they minimise fraud).[52]
Exit strategy	The commercial viability of a mini-grid system is dependent on a clearly defined exit strategy for subsidy programmes that is pegged to a specific date or milestone. This facilitates a smooth transition to a commercial market in which customers and companies are not dependent on permanent subsidies.

An example of a successful end-user subsidy programme that addressed the affordability gap in Togo is illustrated in **Box 5** below. The challenging conditions that prevail in Togo imply that practical lessons can be extrapolated and applied to fragile contexts.

51 Adapted from Africa Clean Energy, 2020.
52 CGAP, 2012.

BOX 5 TOGO CIZO CHEQUE PROGRAMME: PROVIDING END-USER SUBSIDIES

In 2019, the Togolese government launched an end-user subsidy to help bridge the affordability gap of eligible households. The CIZO cheque is a monthly subsidy that complements household payments for SHSs for a period of three months. According to data provided by participating companies, the subsidy **increased SHSs uptake by 125%** in the first three months after launch and roll-out.[53] The success of the programme can be attributed to a robust and well-designed framework, which addressed key features, and design principles that included the use of digital tools to **verify eligibility of subsidy recipients,** a **clear exit strategy** to facilitate a progressive phasing out of the subsidy, and strong partnerships with a range of stakeholders.

Approximately 71,600 household benefitted from the CIZO cheque subsidy and the level of SHS uptake has been growing steadily. The CIZO cheque has also generated favourable impacts on key performance indicators of off-grid solar companies by doubling customer adoption, significantly increasing energy consumption, and decreasing the probability of defaults from 24% in the pre-subsidy period to 8% after.[54] The CIZO cheque programme is a successful example of an effective and well-designed end-user subsidy that succeeded in promoting the rapid uptake of SHSs in off-grid and remote areas in Togo despite the challenging market conditions that prevail in the country.

Key takeaways for policymakers in designing an effective end-user subsidy programme include:[55]

- Governments should exploit demand-side subsidies to **reach the poorest and most marginalised households** in fragile countries.
- These subsidies must be **targeted** and defined with a better contextual understanding of local needs and factors that influence the uptake of DRE in fragile contexts.
- A **comprehensive analysis** of multi-dimensional factors is needed, taking into consideration the financial availability and needs of end-users.
- Effective demand-side subsidies require significant data to be able to identify intended beneficiaries and it is important to **address data gaps** with more systemic engagement at the local level.
- End-user subsidies must have a **clear exit strategy** to ensure that the mini grid system is commercially viable in the long-term.

53 GOGLA, 2022.
54 Ibid.
55 IIED, 2020.

5.1.2. Inclined block tariffs

Inclined block tariffs (IBTs) have a step structure that charges customers different rates depending on their electricity consumption. The transition from one block to the next is automatic, determined by the amount of energy consumed by the customer, which can be monitored via smart metering technologies (discussed in section 7). While smart meters can enhance the ability of customers to monitor their electricity usage and keep it within blocks governed by lower tariffs, they are not strictly necessary for applying IBTs. As long as a meter records the total amount of energy used in the billing period, the bill can be accurately calculated according to the tariff structure.

Such a block structure may also include a 'lifeline' or social tariff (represented by the green line in **Figure 4**) with a lower cost for consumption of an initial amount of electricity in a specified timeframe. For the poorest consumers, who tend to consume small amounts of electricity, this social tariff can keep their electricity costs down, thereby helping to address the affordability issue. Additionally, the system enables small purchases of energy, which benefits low-income households that are financially constrained, as they tend to make frequent, small purchases of electricity. To illustrate how IBTs work, **Box 6** looks at hypothetical examples of different households at various levels of consumption and **Figure 4** depicts a typical IBT billing structure.

BOX 6 ILLUSTRATING IBTS COST STRUCTURE USING HYPOTHETICAL EXAMPLES

The examples below illustrate how the IBT cost structure would look like for different consumers at different levels of consumption:

Example 1 – Low-income household within the lifeline block

Assuming that the initial lifeline block allows for the first 50 kWh of electricity consumption at a discounted rate of USD 0.10 per kWh, and subsequent blocks charge higher rates, a low-income household that consumes 30 kWh of electricity in a month would pay:

- 30 kWh x USD 0.10/kWh = USD 3.00 (within the lifeline block)

Example 2 – Middle-income household in a higher block

Assuming that the subsequent block charges USD 0.15 per kWh for consumption between 50 kWh and 200 kWh, a middle-income household that consumes 80 kWh of electricity in a month would pay:

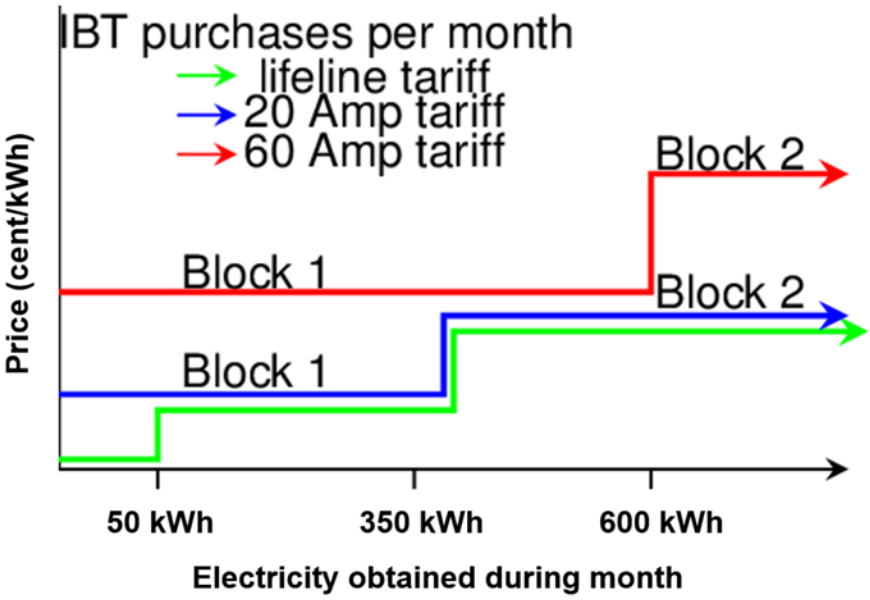
- The first 50 kWh x USD 0.10/kWh = USD 5.00 (within the lifeline block)
- The remaining 30 kWh x USD 0.15/kWh = USD 4.50 (within the second block)
- Total bill: USD 5.00 + USD 4.50 = USD 9.50

Example 3 – High-income household in the highest block

Assuming that the highest block charges USD 0.25 per kWh for consumption above 200 kWh, a high-income household that consumes 300 kWh of electricity in a month would pay:

- The first 50 kWh x USD 0.10/kWh = USD 5.00 (within the lifeline block)
- The next 150 kWh x USD 0.15/kWh = USD 22.50 (within the second block)
- The remaining 100 kWh x USD 0.25/kWh = USD 25.00 (within the highest block)
- Total bill: USD 5.00 + USD 22.50 + USD 25.00 = USD 52.50

Figure 4 Typical inclined block tariff billing structure[56]



In fragile contexts, IBTs can make electricity more affordable and accessible for low-income households. By applying a lower lifeline tariff block below cost to all low-income households, IBTs can effectively reduce the financial burden on economically vulnerable populations. This structure also ensures that large consumers, who essentially pay prices above cost, effectively subsidise smaller consumers, creating a cross-subsidy that supports the lifeline tariff. This model has been adopted in South Africa, with the National Energy Regulator of South Africa (NERSA) approving its use in 2010.[57]

56 Extracted from Prinsloo, 2018.
57 BVM, 2020.

Importantly, IBTs can be one of the simplest tariff structures when designed with clarity, reducing the complexity that might otherwise challenge consumers in areas with low levels of education or limited access to information. However, effective communication strategies and awareness raising remains essential to ensure that consumers understand how the tariff works. Additionally, the success of IBTs depends heavily on accurate data regarding energy consumption across different tariff blocks. Without careful design and reliable consumption data, there is a risk of unintended consequences such as discouraging customers from increasing their energy usage even if it would be beneficial for them to do so. Overall, the effectiveness of IBTs in fragile contexts hinges on thoughtful design, implementation, and communication, as well as a deep understanding of the specific needs and preferences of the customers they serve.

5.2. Financial products and services

In fragile contexts, financial products and services such as mobile money, micro loans on mobile money, and smart meters can play a critical role in enhancing affordability and facilitating timely and remote payment of bills, which is particularly valuable in FCS where travel can be time-consuming and dangerous. These financial products and services can collectively increase the demand and uptake for energy services provided by minigrids. The benefits of mobile money are discussed ahead, with a more detailed discussion on the role of smart meters provided in section 7.

Mobile money has emerged as a powerful tool for promoting financial inclusion and improving access to energy services, especially in FCS where security risks and travel restrictions can make it challenging for households to access traditional financial institutions or make in-person payments. By enabling remote transactions and making it easier for households and businesses to pay for electricity services and for mini grid operators to collect payments, mobile money can help increase the demand for mini grid systems.

The benefits of mobile money include:

- **Facilitating payments for energy services** – Mobile money enables customers to make and receive payments through their mobile phones, without the need of a bank account. This is particularly useful in FCS, where traditional banking infrastructure tends to be limited or disrupted. Mobile money provides a safe, secure, and convenient way for households to manage their payments, while also reducing the risk of theft.

- **Enabling remote transactions** – Mobile money facilitates remote transactions which is particularly valuable in settings where travel may be difficult, time-consuming, or dangerous.

- **Supporting small firms** – Mobile money enables small firms to collect payments from customers and manage their finances more efficiently.

Nattrass,
Getty Images

- **Increasing financial inclusion** – Mobile money provides access to financial services in areas where the state is not physically present or where mainstream financial institutions have a limited footprint. In FCS, mobile money strengthens the financial resilience of households and communities by allowing them to effectively manage and monitor their expenditures. This is particularly important in contexts where traditional banking services are scarce or unreliable.

It is important that these products and services are designed with the specific needs and constraints of fragile contexts in mind. For example, low levels of financial literacy and limited access to technology could hinder adoption. Thus, the design of these products and service should prioritise simplicity and ease of use and be accompanied by education and awareness raising so that customers are better able to use these tools effectively.

6. Demand stimulation through productive use

The productive use of energy (PUE) refers to the use of energy services to **enable income-generating activities** and **increase productivity** of economic activities. While the exact definition of PUE may vary depending on local contexts and circumstances, it is generally understood as the use of electricity for business and commercial purposes, rather than solely for household consumption or lighting. Governments, investors, and development partners are increasingly realising the potential of off-grid solutions to power PUE appliances and positively impact customers' economic productivity through income and employment generation. In fact, in 2021, USD 7.7 million of a total of USD 10.2 million grant capital invested in the off-grid solar sector was directed towards PUE.[58]

ESMAP categorises a host of productive use leveraging solar energy (PULSE) technologies to provide livelihoods and income-enhancing opportunities for households and small businesses across the agricultural, industrial, commercial, and public sectors.[59] When **anchor loads** from large, consistent electricity consumers are integrated into mini grid systems, they play a critical role in strengthening demand for energy services, thereby improving the economic viability and sustainability of these projects. Anchor loads are often tied to economic activities, which not only generate revenue for users but also help energy developers ensure a stable and predictable customer base. In many cases, anchor loads are driven by entrepreneurial activities. Thus, productive use activities serve a dual purpose: supporting local economies while ensuring the financial viability of the energy system.

Ultimately, this can strengthen demand for energy services and increase the viability of mini grid systems. A comprehensive list of productive uses relevant to the off-grid sector can be seen in **Figure 5** and can be summarised as:

- Agricultural loads (e.g., irrigation pumps, milling, cold storage, etc.)
- Industrial loads (e.g., clothing, carpentry, construction, etc.)
- Commercial loads (e.g., hairdressers, restaurants, phone charging, etc.)
- Social/public loads (e.g., education, health centres, ICT etc.)

58 ESMAP, 2022c.
59 ESMAP, 2019.

Figure 5 Universe of productive uses relevant for off-grid markets in SSA(PULSE)[60]

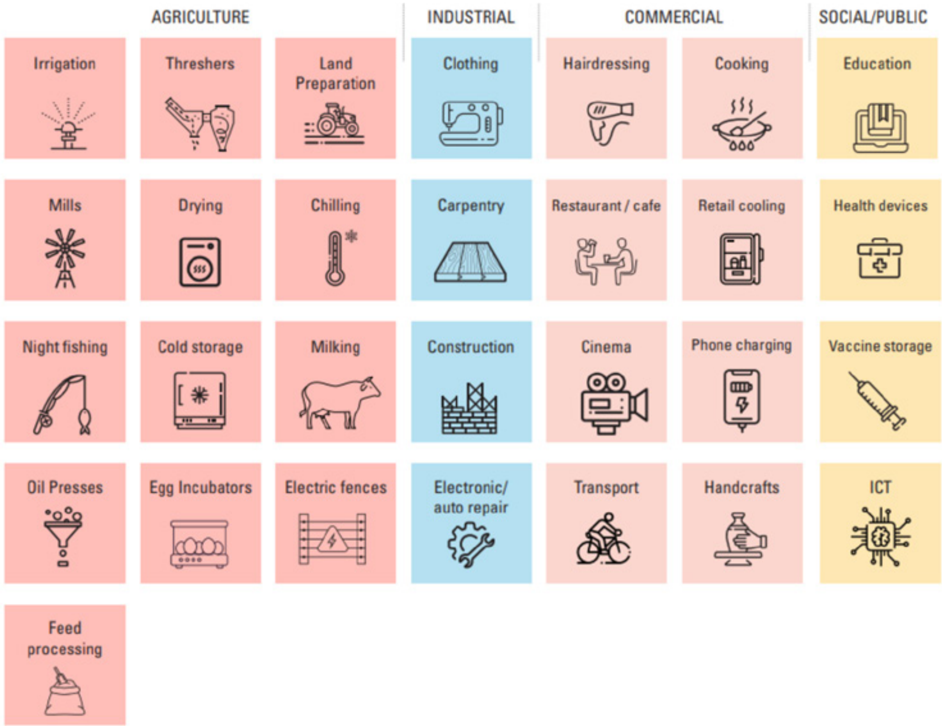


Figure 5 illustrates the diverse range of applications for PUE across multiple sectors. PUE is a critical tool for stimulating demand and promoting broader socio-economic development, as it encourages the use of energy to unlock income-generating opportunities and improve education, health, and overall welfare.[61] Additionally, PUE can benefit stakeholders across the value chain by enabling mini grid developers to increase their revenues (through greater energy consumption) and lower costs (through improved efficiency, reduced losses, and strengthened project sustainability in the long term). PUE can also support local communities through employment generation, enhanced economic activity, and improved welfare, and even benefit national utilities from the economic expansion of rural and fragile economies.[62] Encouraging PUE is important, as enabling customers to consume more is the single most effective strategy that governments and other stakeholders can employ to ensure the commercial viability of mini grids.

In fragile contexts, the creation of jobs and improved livelihoods can also serve as a key **peace dividend.**[63] For example, job creation can reduce disenfranchisement and vulnerability to radicalisation among young people and dissuade them from recruitment into armed groups.[64] Policymakers aiming to harness PUE towards conflict prevention should "integrate conflict analysis into their energy sector planning to ensure productivity gains accrue to sectors where conflict drivers can be most effectively addressed."[65] PUE can therefore not only improve socio-economic outcomes but also has potential to contribute to the peace and stability of FCS.

60 Lighting Global, 2019.
61 GOGLA Off-Grid Solar Forum & EXPO, 18-20 October 2022, Kigali, Rwanda, session on PUE.
62 ESMAP, 2022a.
63 Council on State Fragility, 2021.
64 EEG, 2017.
65 EEG, 2017.

However, it is important to recognise that markets in fragile contexts may be more susceptible to bottlenecks in local value chains, which prevent the translation of energy access into productive use. Thus, more targeted interventions may be required to scale the uptake of PUE in these contexts. **Box 7** below presents a case study on productive use in Zimbabwe.

BOX 7 MASHABA SOLAR MINI GRID IN GWANDA, ZIMBABWE[66]

The Mashaba solar mini grid project is Zimbabwe's first inclusive solar-powered 99kw mini grid commissioned in 2019 in the rural district of Gwanda. The project is a public-private partnership (PPP), being implemented under the Sustainable Energy for Rural Communities (SE4RC) initiative and is jointly funded by the European Union, OPEC Fund for International Development, and the Global Environmental Facility.

The project is now benefitting more than 10,000 people across 2800 households and demonstrates the ability of DRE to empower local communities to engage in productive use. It also offers greater stability, reliability, and independence compared to traditional off-site power stations, giving local communities greater control over their energy needs and use. The project involved building **energy kiosks** and designing and installing mini grids that have **service delivery** as their primary aim. The mini grid powers three irrigation schemes, five business centres, a clinic, a primary school, and a study centre.[67] Key achievements of the Mashabo solar mini-grid project include:

- **Energy centre** that supports economic activities such as cold rooms, agro-processing, welding, and similar activities that utilise significant energy.
- **Resource/study centre** which will enable ICT provision, e-learning, internet and television access, and additional hours for study.
- **Energy kiosks** that meet household energy requirements such a lighting, mobile phone charging, entertainment (televisions and radios), battery charging, and other low energy uses. These energy kiosks help stimulate demand for electricity services and increases household access to clean energy in the Mashaba community and beyond through the sale of solar products.

Collectively, the project is supporting local communities to survive droughts, enhance food security, improve livelihoods by boosting economic activities, and strengthen overall resilience to external shocks. The Mashaba solar mini grid project has not only facilitated the productive use of energy but also demonstrated the ability for DRE to support socio-economic development as well as environmental stability and increased resilience.

66 The Herald, 2019.
67 SNV, 2022.

6.1. Key obstacles for scaling PUE

While the potential for PUE in the solar mini grid market is growing, its adoption remains relatively low due to a number of factors, including underdeveloped supply chains, affordability challenges, distributors' lack of reliable data and sectoral and gender expertise, and customers' need for business services. Addressing these obstacles is critical to ensuring that PUE products can reach the last mile and be implemented in challenging contexts. Five key obstacles for PUE adoption are:

- **Affordability gap** remains a key issue in the widespread adoption and scaling up of PUE products and highlights the need for greater end-user financing.
- **Underdeveloped supply chains** in many product categories makes it difficult for distributors to procure appropriate, affordable products. Distributors are also required to provide after-sales services to customers, including maintenance and repair, which can be challenging in fragile contexts.
- **Distributors' lack of reliable data and sectoral and gender expertise** to understand consumer needs and WTP, as well as effectively service different sectors (e.g., agriculture) and navigate the social and gender dynamics related to PUE products and the differing preferences, marketing, distribution, and support needs of female customers as well as men. This shortage of data and sectoral and gender expertise can hinder the development of effective market strategies and fail to meet the needs of specific consumer groups.
- **Customers' need for business services**, such as business advisory support and market linkages, makes it challenging for customers to maximise the productivity gains from their investments in PUE products. Some appliance distributors provide different types of business services – for example, Mwezi in Kenya is helping customers that have purchased solar egg incubators to connect with other actors along the poultry value chain.[68]

For more detailed coverage of PUE in the mini grid market, refer to the *Driving productive use of energy in fragile contexts* policy toolkit.

68 SEforAll, 2022.

6.2. Energy efficient appliances

Energy efficient appliances (EEAs) can play a key role in increasing energy demand in an affordable manner and promoting sustainable energy use. EEAs are appliances that require considerably less energy to perform their intended task, allowing consumers to use more appliances with the same amount of energy and without an increase in their energy bills.[69] They comprise a range of household appliances such as lighting, refrigerators, cooking appliances (e.g., electric cookers), fans, solar water heaters, and more. For example, if a household replaces its old incandescent light bulbs with energy-efficient LED bulbs, they can use more lights without a significant increase in energy consumption or cost, as is illustrated by the calculations shown in **Table 2** below. According to these calculations, such a replacement results in payback within the first month and generates continuous savings due to enhanced bulb lifespan. Additionally, energy-efficient refrigerators can use up to 40% less than traditional models and energy-efficient cookstoves can reduce cooking time and energy use by up to 50%. Thus, the use of EEAs is particularly attractive for low-income households where affordability challenges pose a significant barrier to energy access.

Table 2 Illustration of cost savings using EEAs (in Indian rupees, INR)[70]

Parameter	60 W incandescent bulb	7 W LED bulb
Electricity consumed/day assuming 6 hours/day usage	40 x 6 = 240Kh or 0.24 units	7 x 6 = 42Wh or 0.042 units
Electricity cost @ INR 20/unit	0.24 x 20 = INR 4.80	0.0042 x 20 = INR 0.84
Monthly expense assuming 6 hours/day usage for 30 days	4.80 x 30 = INR 144	INR 0.84 x 30 = INR 25.20
Cost of bulb	INR 10	INR 60
Savings after replacement/ month	144 – 25.2 = INR 119.8	
Payback for replacement	Less than one month	

The use of EEAs can reduce energy consumption while maintaining or increasing productivity, making economic activities more profitable. For example, an energy-efficient irrigation pump can reduce the amount of electricity needed to irrigate farmland, allowing farmers to increase their crop yields and overall profitability while saving money on electricity costs. The adoption of EEAs by mini grid consumers can generate the following benefits:

69 Smart Power India, 2020.
70 Extracted from Smart Power India, 2020.

- **Efficient usage** – With the same amount of energy consumption, a household or small business can derive more benefits from the electricity that it consumes.

- **Generating savings (reduced costs)** – Households and small businesses can lower their electricity bills by replacing energy-inefficient appliances with efficient ones.

- **Increasing demand** – Once the benefits above are realised, households and small businesses are likely to move up the energy ladder and discover new ways to use electricity. This may involve using additional appliances, ultimately leading to improvements in the quality of life, increasing in household income, and increasing demand.

Some notable organisations focused on promoting EEAs include:

- **CLASP** – An organisation that conducts research and provides technical assistance to help improve the energy efficiency of appliances and other equipment.

- **The Alliance to Save Energy** – A non-profit organisation consisting of business, government, environmental, and consumer groups that advocates for high-impact energy efficient policies that minimise costs to society and individuals.

- **Efficiency for Access** – A global coalition working to promote affordable, high performing, and inclusive appliances.

6.3. Policy recommendations to promote PUE

In order to effectively promote and scale the PUE in mini-grids, targeted intervention is needed to address the key challenges identified above. This includes:[71]

- **Identifying local cooperation partners for the promotion of PUE** (e.g., utilities, technology providers, financing institutions, non-governmental organisations, and development partners): these partners can provide valuable support in terms of technical expertise, financing, and outreach to ensure the success of PUE initiatives. Additionally, investing in development of local supply chains for PUE products is needed to improve product quality and availability.

- **Identifying cost effective approaches** – Given the limited resources in fragile contexts, governments need to identify cost-effective approaches for promoting PUE in sectors with the highest potential to spur economic development (e.g., agriculture, services, and trade).

- **Increasing access to end-user finance** – This is key for accelerating the adoption of PUE as affordability remains a key impediment. This can include tax breaks, grants, or subsidies (discussed in section 5) which can help to offset the initial costs of adopting PUE technologies and make them more accessible to households and small businesses.

71 Energypedia, 2021.

- **Employing suitable technology solutions** – Governments should choose technology solutions that use electricity in the most productive way and can be operated by either consumers, entrepreneurs, or mini grid operators. In some cases, it may be necessary to develop or adapt technology solutions to suit the local context and needs of the target population.

- **Providing technical training and support** to equip local entrepreneurs, technicians, and installers with the necessary skills needed to ensure proper installation and maintenance of PUE products. This includes investing in end-user education and after-sales services to improve customer satisfaction and retention.

- **Engaging with local communities** – Governments should involve local communities in the planning and implementation of PUE initiatives to ensure that they are aligned with local needs and priorities and strengthen local buy-in. This can include consultations with local stakeholders, engaging with community-based organisations, and involving local entrepreneurs in the design, development, and implementation of PUE initiatives. Governments should also plan awareness-raising activities to promote PUE. For example, in 2021, the Efficiency for Access Coalition ran a solar water pump consumer awareness campaign in Kenya which generated over 100 leads.[72]

- **Monitoring and evaluating PUE activities** – To ensure the effectiveness of PUE initiatives in fragile contexts, governments should put in place monitoring and evaluation mechanisms to track progress and identify areas for improvement. This can include regular data collection, impact assessments and stakeholder consultations.

72 SEforAll, 2022.

7. Billing and payment technologies

There are significant advantages that enhanced billing and payment technologies can bring to increasing the viability and demand for mini grids. Often, high transaction costs, such as time and travel costs associated with large distances and security concerns can lead to consumers not being able to make electricity payments. This is particularly relevant in fragile contexts where instability may make it unsafe to travel distances to make payments.

These risks and concerns can be minimised by streamlining billing and payments services and employing devices that provide customers with timely information on their consumption, planned power outages, and IT platform improvements. Ultimately, improved service leads to increased demand and strengthens the viability of mini grid systems. Significant progress has been made on the development of real-time monitoring, billing, and payment devices throughout the world. However, there is still need for greater information on the variety of monitoring and billing technologies that would be most useful in fragile contexts given poorer infrastructural environments and evidence on how they can benefit both end-users and solar mini grid developers. Advancements in digitalisation have enabled the remote payment of bills, which is particularly valuable in FCS. Different types of metering and payment technologies are discussed in greater detail ahead.

7.1. Metering technologies

The purpose of meters is to measure energy consumption and track electricity usage for billing purposes. Conventional meter technologies include post-paid or pre-paid meters. However, smart meters are becoming increasingly popular due to reduced prices and improvements in communication technology.[73] The different types of meter technologies include:

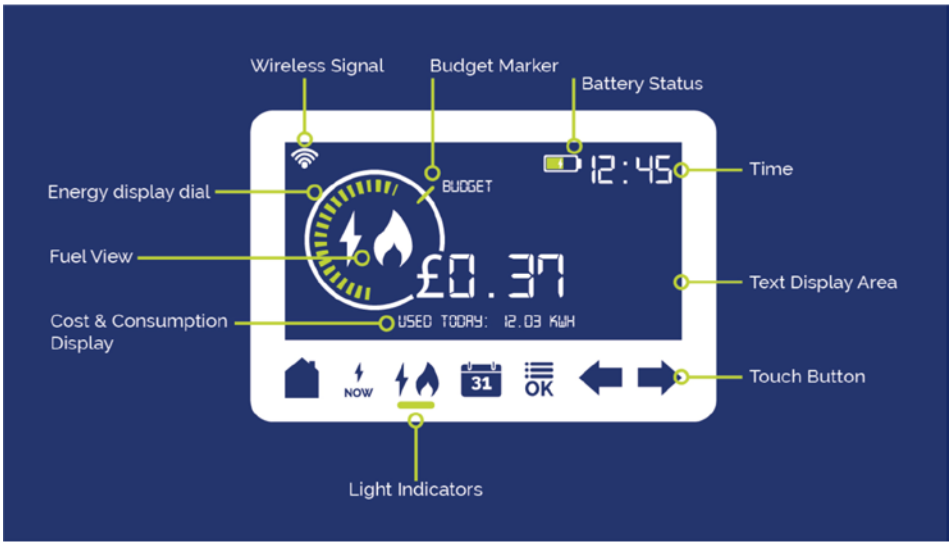
- **Post-paid meters** measure the monetary balance owing and energy consumed. Payments by households and small businesses are made periodically *after* electricity has already been consumed and there is no real-time feedback to customers about their energy usage and spending patterns. This can make it difficult for customers to manage their energy usage, leading to higher bills and wasteful energy consumption, which is particularly problematic for low-income households.

73 Energy4Impact & Insensus, 2019.

- **Pre-paid meters** require tokens or codes for recharging energy balance *before* electricity is consumed and they measure the amount of energy consumed. The electricity cuts off when the pre-loaded value has depleted. This allows customers to have greater flexibility over their energy usage while avoiding unexpected bills and service disconnections. Pre-paid meters are popular in many developing countries as they can help utilities reduce losses associated with unpaid bills and electricity theft. A study conducted in Cape Town found that low-income households take advantage of the flexibility offered by pre-paid meters by purchasing electricity often and in small amounts.[74]

- **Smart meters** measure and communicate payment and consumption data without manual intervention, allowing remote monitoring by mini grid operators. They increase transparency on consumption patterns, allowing consumers to maintain their consumption within the bounds of what they can afford. Additionally, they can provide valuable information on usage patterns for mini grid developers, thereby enabling improved forecasting that can transform the long-term sustainability and profitability of mini grid systems by automating operations and reducing operating costs.[75] A typical smart meter device and the information it conveys to customers can be seen in **Figure 6**. Smart metering is gaining popularity in multiple countries including South Africa and India.

Figure 6 Typical smart meter device[76]



Mini grid operators have adopted a different business model around meters depending on the local context and no standardised model has emerged yet. For example, some install meters from a single supplier, while others install meters from multiple suppliers. Some manufactures, such as Devergy, choose to assemble their own meters to allow for customisation.

74 Jack & Smith, 2015.
75 Smart Power India, 2019.
76 Smarter Business, 2019.

Regardless of approach, a robust metering system can provide valuable information that can inform efforts to increase deployment of solar mini grids. A summary of the advantages and disadvantages of different meter technologies can be found in **Table 3** and a case study on the use of smart meters in Uganda and Mali is presented in **Box 8**.

Table 3 Advantages and disadvantages of metering technologies[77]

Meter technology	Advantages	Disadvantages
Post-paid meter	• Cheapest of the three options • Robust and locally available • Does not require user training • Does not require local mobile network	• No real-time monitoring possible • Lack of immediate feedback on energy usage and spending patterns, so no insight into controlling energy usage • Manual meter recordings, which is difficult in contexts of conflict where travel is unsafe • Susceptible to electricity theft • Risk of low payment collection rate as customers can consume more electricity than they can afford
Pre-paid meter	• Not dependent on local mobile network, although can be integrated • Inexpensive in comparison to smart meters • Flexible payment options, including purchase of small amounts of electricity • Avoids unexpected bills and service disconnections	• No real time monitoring possible • User training required • Distribution of scratch cards and tokens can be costly and time-intensive and subject to dangers of travel in contexts of conflict • Requires manual recharging of tokens and codes • Installation is complex to ensure ease of access for users
Smart meter	• Provides real time monitoring and feedback on energy usage and spending • Enables remote management of energy consumption, which is particularly valuable in fragile contexts • Allows predictive load analysis and demand growth forecasting • Availability of ancillary services (e.g., demand management) • Theft detection • Automated tariff moderation	• Dependent on mobile network • Expensive compared to conventional pre-paid meters • May require technical expertise to manage • Ongoing transaction fees to use proprietary software services • Vulnerable to privacy breaches or data mishandling due to external data storage

BOX 8 SHAREDSOLAR SMART METERS IN MALI AND UGANDA[78]

SharedSolar has successfully extended micro-grids to approximately 20 poor and remote villages in Mali and Uganda, deploying smart metering to support their operations. The smart meter enables real time measurement and control and facilitates demand and supply management. SharedSolar allows customers to pre-pay for the service at any time, in quantities of their choosing, and there are no requirements of monthly fees. The smart metering technology provides all stakeholders with access to real-time, contextual information that can facilitate informed decision-making. Customers can monitor their use and balance data and make payments, and operators have greater situational awareness and control, allowing them to develop real-time demand and supply management strategies. Additionally, donors and agencies can oversee performance using the same platforms. Ultimately, the key success of Shared Solar is attributable to the PAYGo model, which provides customers with flexibility in purchases, and the metering technology, which has increased access to critical information and helped keep costs low.

As can be seen in the case study in **Box 8**, smart metering can serve as an effective tool to provide stakeholders with access to real-time, contextual information that can facilitate informed decision-making. Headquartered in Nigeria, SparkMeter is another company that is increasingly gaining prominence for it's smart metering solutions that have been used in rural and underserved communities in over 30 countries. Their smart meters communicate wirelessly through radio frequency, and the data is transmitted to a central hub or base station, which can then be accessed remotely for monitoring and analysis.

7.2. Payment technologies

Pay-as-you-go (PAYGo) models are an innovative and flexible approach developed to support the uptake of DRE technologies and provide affordable energy access for consumers. These models utilise available technologies and smart meters to facilitate payment in instalments.[79] Unlike traditional payment models, PAYGo enables customers to first pay directly for the service they use (i.e., they do not receive any service for which they have not first paid). As a result, payments can be made in smaller amounts and customers are given greater control over their consumption and spending on energy. PAYGo companies employ a variety of combinations of payment systems including:[80]

78 EarthSky, 2012.
79 IRENA, 2020.
80 Energypedia, 2022.

- mobile money
- scratch cards or tokens (e.g., used by providers in Rwanda to launch their PAYGo solar operations)
- door-to-door to collectors.

In fragile contexts, the flexibility of PAYGo payment plans can support lower-income customers who face financial constraints and are more vulnerable to economic shocks and disruptions.[81] Mobile technologies underpin the PAYGo model in three ways:

- **Facilitating payment collection** through mobile money or other forms of mobile payment, making it more convenient and accessible for customers to pay for their solar products. This increases the likelihood of successful repayments, reducing the risk of default and improving profitability.
- **Enabling communication** between service providers, customers, and local agents through mobile devices and services (e.g., SMS or mobile apps) can help build trust and strengthen relationships, which can be especially important in fragile contexts where social networks and community ties may be disrupted. This communication facilitates customer support, after-sale services, and marketing activities.
- **Machine-to-machine technology** enables the remote updating and controlling of PAYGo-enabled assets or services, allowing companies to monitor and optimise their systems for better performance.

The PAYGo model offers several benefits to both consumers and mini grid developers and operators, especially in fragile contexts. For consumers, PAYGo provides flexible payment plans, making energy services more accessible to those who may be unable to afford them otherwise. Additionally, the after-sale services and customer support that is often accompanied with PAYGo models generates additional value and appeal. For mini grid developers and operators, the PAYGo model reduces the risk of default and improves profitability by enabling payments to be made in smaller and more manageable amounts. The use of smart meters and mobile money also enables mini grid developers and operators to monitor and optimise their systems to strengthen performance and provide more efficient customer support.

There a numerous examples of PAYGo applications for SHSs, including M-KOPA, which is the largest company in terms of scale, and D.light, which serves customers in Kenya. Off-grid companies that employ the PAYGo model for mini- and micro-grids include Devergy, EarthSpark International, SharedSolar, and Powerhive. The degree of payment flexibility offered by these companies vary and reflect their circumstances. While some off-grid companies offer complete flexibility on when and how much customers can pay, most impose varying restrictions on the timing and size of the payments.[82] Bboxx enables financing over long-term PAYGo plans and are active in numerous countries across Africa. **Box 9** presents a case study on the PAYGo model that Bboxx uses in the Democratic Republic of Congo (DRC).

81 World Bank, 2015.
82 World Bank, 2015.

BOX 9 BBOXX'S PAYGO MODEL IN THE DRC

Bboxx employs PAYGo models to increase energy access in several challenging contexts, including the DRC and Togo. In 2018, Bboxx collaborated with Victron Energy to deploy large solar energy solutions on a PAYGo model, which has helped enhance productivity and power growth for small- and medium-sized enterprises (SMEs) such as grocery stores, restaurants, and micro-processors. This has increased access to reliable, clean, and affordable power in areas with limited electricity access and frequent blackouts.

In 2022, Bboxx also partnered with Orange Energie to combine their technologies, integrating Orange's Smart Metering platform with Bboxx Pulse, Bboxx's proprietary operating system. This merger aims to connect 150,000 people in the DRC to an innovative mini grid model and enable close monitoring of mini grid performance and remote management of customers (including collection and payments) through PAYGo solutions.

8. Conclusion

This toolkit aims to understand and address key demand-side dynamics, including challenges and opportunities to ensure the economic viability of mini-grid projects in FCS. By focusing on the critical elements of measuring, incentivising, and sustaining energy demand, this toolkit serves as a resource for policymakers, mini-grid project developers, and other stakeholders involved in the electrification of these complex environments.

The toolkit underscored the importance of accurately estimating energy demand through tools like Willingness to Pay surveys, geospatial analysis, and the Multi-Tier Framework. These methodologies are essential for designing appropriately sized systems and setting realistic tariffs that reflect customers' willingness and ability to pay.

The toolkit also emphasises the necessity of raising consumer awareness and facilitating knowledge exchange. These are vital to educate consumers about the benefits of electrification and to foster a supportive environment for DRE initiatives. Financial support mechanisms, such as subsidies and innovative financial products, play a crucial role in bridging the affordability gap, enabling greater access to energy for underserved populations.

Moreover, stimulating demand through PUE is highlighted as a key strategy to enhance the economic impact of mini grids. By promoting energy-efficient appliances and supporting income-generating activities, stakeholders can help increase household incomes and purchasing power, thereby driving sustained demand for electricity.

Effective billing and payment technologies are also critical components of facilitating the demand-side of solar mini grids. Implementing advanced metering and payment systems can improve revenue collection, reduce operational costs, and enhance the overall customer experience. These technologies are especially important in fragile contexts where traditional methods may be less reliable or feasible.

The toolkit acknowledges the inherent challenges and uncertainties in fragile settings, such as weak governance, poor infrastructure, and security concerns. It calls for a collaborative approach involving contributions from various stakeholders to overcome these obstacles and create an enabling environment for mini grid development.
Key responsibilities of stakeholders include:

- **Policymakers**
    - Develop and implement supportive policies and regulatory frameworks that facilitate mini grid deployment.
    - Contribute to making subsidies and financial incentives available to bridge the affordability gap and support low-income households.

- **Mini grid developers**
    - Conduct thorough demand assessments and engage with communities to understand their needs and constraints.
    - Implement innovative technologies for metering and payment to ensure that customers are able to effectively manage their energy consumption and spending and to support efficient operations and revenue collection.
- **Donor community**
    - Provide financial support and technical assistance to solar mini grid projects in fragile settings.
    - Fund awareness campaigns and capacity-building initiatives to enhance consumer knowledge and acceptance of solar mini grid systems more broadly.
- **Financial institutions**
    - Develop and offer tailored financial products that can support both consumers and developers in the DRE sector. This includes microloans, PAYGo models, and other innovative financing solutions.
- **Communities and consumers**
    - Engage actively with project developers and policymakers to communicate needs and provide feedback on service provision.
    - Participate in awareness and educational programs to maximise the benefits of electrification.

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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.

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