IGC

State Fragility initiative

POLICY TOOLKIT

Improving the supply side for solar mini grids in fragile contexts

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The supply side of mini grid development comprises factors that encourage or hinder investments and decisions of mini grid developers and investors to enter a market. A range of factors affect the supply side, including economic dynamics of a market, costs of key components, the state of supply chains and labour capabilities, availability of reliable data and geospatial planning tools, and enabling and complementary sectors, such as financial inclusion. Understanding how these factors affect mini grid deployment can inform efforts to improve them.

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In this paper

This paper provides evidence to inform policy decisions around improving the supply side for deploying solar mini grids, including on lowering real and perceived risks associated with fragile and conflict-affected situations (FCS), improving the business environment, regulatory framework, financing, and supply chains for solar mini grids. It also explores the enabling and complementary sectors where investments need to be made for electrification to have a transformative impact on people's lives and how to build local capacity to support development of a solar mini grid sector. It also covers the various costs of solar mini grid deployment and what elements are driving cost reductions in the sector.

Improving factors that affect the supply side of mini grid deployment requires efforts from a range of stakeholders, including donors, philanthropic entities, private manufacturers and energy project developers. Consequently, this paper outlines important lessons for other key stakeholders too.

List of abbreviations

Abbreviation	Meaning
AML/CFT	Anti-money laundering and combatting the financing of terrorism
CapEx	Capital Expenditure
CGAP	Consultative Group to Assist the Poor
DART	Demand Aggregation for Renewable Technologies
ESMAP	Energy Sector Management Assistance Program
EU	European Union
e-waste	Electronic waste
FCS	Fragile and Conflict-affected Settings
GEAPP	Global Energy Alliance for People and Planet
GIS	Geographic Information System
GOGLA	Global Off-Grid Lighting Association
IMF	International Monetary Fund
kWh	Kilowatt Hour
kWp	Kilowatt Peak
LCOE	Levelized Cost of Energy
MDB	Multilateral Development Banks
MW	Megawatt
O&M	Operation and Maintenance
OpEx	Operating Expenditures
PAYGo	Pay-as-you-go
PPP	Public-private Partnerships
PV	Photovoltaics
R&D	Research and Development
RISE	Regulatory Indicators for Sustainable Energy
TVET	Technical and Vocational Education and Training
UNDP	United Nations Development Programme
UNHCR	United Nations High Commissioner for Refugees

Contents

Boxes

Figures

Improving the supply side for solar mini grids in fragile contexts

Executive summary

The supply side of solar mini grid is concerned primarily with factors that encourage or hinder investments and decisions of mini grid developers and investors to enter a market. Ensuring more conducive investment environments is critical for scaling up the deployment of solar mini grids in fragile and conflict-affected settings (FCS).

More than a billion people reside in FCS globally and it is expected that FCS will account for around two-thirds of the world's poor by 2030.[1] According to the most recent estimates available, only 58% of the population in FCS have access to electricity, with 36% of rural populations and 86% of urban populations having access to electricity.[2] However, these figures hide significant variations across FCS, with some countries having far lower electrification rates. Fragility and conflict exacerbate challenging macro dynamics in FCS. Real and perceived risks, economic dynamics, ease of doing business, regulations, and financing all deeply impact developers' decisions around whether to enter a market.

While all the FCS for which data was available allow the private sector to own or operate solar mini grids, the business environment in these countries is less than conducive, with a majority of FCS ranking in the bottom quarter of the World Bank Doing Business index 2020.[3] Domestic financing is not easy to access as local banks often lack sufficient liquidity, international banks may be reluctant establish relationships with local banks where they are not sufficiently reassured that local banks are able to adhere to anti-money laundering and combatting the financing of terrorism (AML/CFT) requirements or where economic sanctions or targeted sanctions against named individuals and entities may be in place.

Additionally, FCS were disproportionately affected by the economic impact of Covid-19 pandemic, with per capita incomes not expected to recover to their 2019 levels even by 2024, and with the share of the population living in extreme poverty in these countries increasing to 38% during this period. These negative macro dynamics lower consumers' ability to pay for electricity and can reduce energy demand, thereby extending the period needed for developers and investors to recoup their initial investments.

Solar mini grids depend on well-functioning supply chains for their equipment and end-user appliances (household and productive use), as well as for maintenance, repair, and replacement of equipment and appliances. In turn, these supply chains are dependent on raw materials (especially critical minerals), key semi-finished components (such as semi conductors), and finished products (including solar photovoltaics (PV)), the value chains of which have become highly concentrated in a few countries, notably China. Establishing and maintaining functioning supply chains is a significant

1 The list of FCS referred to in this policy toolkit is based on the list of countries classified by the World Bank as facing situations of fragility and conflict. The World Banks updates this list annually, and the latest version is attached in the Annex.
2 World Development Indicators, 2022.
3 The most recent Doing Business index is for 2020.

challenge in FCS: during times of unrest, there may be site access problems, labour shortages, and unavailability of equipment and spare parts, which tend to increase construction and repair times.

A promising development for FCS is that the costs of deploying solar mini grids have been declining. According to the Energy Sector Management Assistance Program (ESMAP), the Levelized Cost of Energy (LCOE), which captures capital and operating costs per kilo-watt hour (kWh) decreased by 31% between 2018 and 2021. This reduction in LCOE has been driven by many factors: the declining costs of key components (such as solar PV), technological innovations (including in batteries and adoption of smart meters), increased usage of geospatial planning tools, and greater economies of scale in manufacturing. Unfortunately, FCS may not fully benefit from these cost reductions unless persisting structural issues are effectively addressed.

There are several important complementary sectors that are key to enabling the deployment of solar mini grids. Availability of transport infrastructure such as roads, railways, bridges, and ports are crucial for transporting solar mini grid equipment and replacement parts to electrification sites, as well as energy efficient products and appliances needed to support productive use of energy. Financial inclusion of end-users is key to improving their access to finance. Digital technologies that assist in sensing and data collection and provide communication, digital platforms, and analytics, have proven to be transformative in reducing the cost and increasing the reliability of electricity provision.

In many instances, FCS governments experience weak institutional capacity and the inability to provide quality education and skills development opportunities for their citizens, resulting in a gap between existing skills and capabilities of the population and the needs and opportunities of labour market. It is necessary that detailed capacity needs assessments are undertaken in these contexts to understand existing capacity and the capacity gaps. Capacity gaps can be present at the policy, project, and community levels and targeted interventions will be needed to enable the capacity building required to successfully implement solar mini grid projects that offer quality electricity services.

This policy toolkit is targeted towards policymakers in FCS with the objective of improving understanding of supply side considerations and identifying interventions that can address supply-side challenges to support deployment of solar mini grids in FCS. The information contained in this policy toolkit may also be useful for policymakers in countries that are transitioning out of fragility and conflict and in the process of building, or rebuilding, energy infrastructure. In addition, this policy toolkit is also relevant for private developers of solar mini grids (local and international), public financing entities (multilateral development banks, development financial institutions, and bilateral donors), as well as philanthropies, impact investors, and others involved in expanding energy access who are interested in understanding the supply-side challenges that the solar mini grid sector is facing, so they can build the business case for entering these markets accordingly.

This policy toolkit presents policy recommendations for governments of FCS, development partners, and mini grid developers operating in FCS. These recommendations include:

- Governments should establish relevant policies and regulations that enhance the ease of doing business and provide clear guidance for developers to navigate the process of setting up mini grid projects. This will also require proactively building the capacity of policymakers to effectively design and implement policies and regulations relevant to the solar mini grid sector, including integrating solar mini grids into national electrification plans and setting fair, cost-reflective tariffs.

- Governments should work with development partners to invest in enabling and complementary sectors that will ensure that electrification with have a transformative impact on people's lives. These sectors include transport infrastructure, financial inclusion, and digital technologies.
- Governments should work with development partners and mini grid developers to undertake a capacity needs assessment for the solar mini grid sector and to develop capacity building initiatives that respond to local needs and are sensitive to the local context.
- Both mini grid developers and government technical staff need to proactively build their expertise on emerging technologies in the solar mini grid sector, particularly those that can help with cost reduction, such as geospatial planning tools.
- Development partners should support the establishment and scaling-up of initiatives that can lower CapEx or OpEx costs of mini grid developers operating in FCS, such as providing concessional or grant funding to enable them to enter more hard-to-reach areas and enabling bulk procurement like that achieved by the DART programme.

It is important to note that FCS are a heterogenous group of low- and middle-income countries and the underlying causes of fragility and conflict can differ greatly from one context to another. Hence, careful consideration must be given to country-specific political, governance and social contexts when assessing reforms and policy action.

1. Introduction

The supply side of solar mini grid is concerned primarily with factors that encourage or hinder investments and decisions of mini grid developers and investors to enter a market. Solar mini grids are infrastructure projects that provide a public utility (i.e., electricity), require upfront investments and generate returns over their lifespan (typically up to 20 plus years).[4] For solar mini grids to play a transformative role in expanding energy access in FCS by 2030, investors need to be confident about investing in these settings and be willing to invest at scale, both in terms of number and size of mini grids.

A number of factors affect investors' confidence. An effective enabling environment is needed to ensure that developers and investors are able to deliver quality, cost-efficient, and reliable energy services to end-users. To operate a financially sustainable solar mini grid model, they must also have dependable access to finance for up-front investments and for everyday cashflow management, assurance of sustained and increasing energy demand, confidence that they will recover payments from end-users, and reasonable expectations that economic conditions will remain sufficiently favourable to continue operations.

In fragile and conflict-affected settings (FCS), factors that support mini grid development are often constrained. Investors face real and perceived risks, including around governments' ability to consistently and uniformly enforce regulations and policies, whether economic instability will undermine consumers' ability to pay for energy, and if declining political commitment could lead to expropriation. Developers often have to navigate volatile economic conditions, regressive business environments, uncertain financing streams, high risk exposures, and damaged or non-existent physical infrastructure, all of which increases costs and disrupts supply chains. Operators may be unable to recruit skilled labour to support construction, maintenance, and repair functions. Beyond these challenges, there is an overarching security concern – solar mini grid developers have no guarantee that their operations will be protected if an armed conflict breaks out or compensated if their equipment is damaged or destroyed.

While significant, these challenges do not diminish the importance of expanding energy access in FCS. Electricity access remains a key driver of economic and social development. It increases productivity, supports new kinds of income-generating activities, and eases household chores, thereby freeing up time for paid work.[5] Expanding energy access is critical for lifting hundreds of millions of people out of poverty worldwide.

4 CrossBoundary, 2020.
5 Pueyo & Maestre, 2019.

This policy toolkit aims to document the supply-side challenges that solar mini grid developers face when operating in FCS and presents recommendations to enable policymakers in FCS to develop and implement policies and initiatives that strengthen the enabling environment and support solar mini grid deployment as an effective instrument for expanding energy access in their countries. In the process, the policy toolkit also presents useful insights to other key stakeholders that are involved in furthering the Sustainable Development Goal (SDG) 7 on universal access to affordable, reliable, sustainable, and modern energy, including private developers of solar mini grids (local and international), public financing entities (multilateral development banks, development financial institutions, and bilateral donors), as well as philanthropies, impact investors, and others. Supply-side interventions to improve access to affordable, reliable, and sustainable energy through deployment of solar mini grids should factor in existing and future energy demand. This is covered in detail in the accompanying toolkits on *Demand-side factors: Tools to measure, incentivise, and sustain demand for solar mini grids in fragile contexts* and *Driving productive use of energy in fragile contexts.*

This policy toolkit draws on information gathered from existing literature on mini grids, electricity access, and supply-side considerations that include broader macroeconomic and policy environment factors in FCS, cost considerations, auxiliary sectors, and capacity. This evidence has been complemented with a series of consultations with researchers, experts, and practitioners involved in the development of the mini grid sector and expansion of electricity access. Effort has been made to contextualise findings to FCS to the extent possible.

The policy toolkit is structured as follows: section 2 presents the macro-level challenges that FCS face that deter investment in all sectors, including the nascent solar mini grid sector; section 3 discusses the costs associated with solar mini grid deployment and their downward trend over recent years that has improved the financial viability of solar mini grids; section 4 discusses the importance of complementary sectors that are essential for enabling the establishment and scale-up of the domestic solar mini grid sector; section 5 discusses the skills and capabilities required for a functioning solar mini grid sector; section 6 concludes; and the final section provides policy recommendations for different stakeholders active in the mini grid sector.

2. Macro factors in fragile settings

The presence of fragility and conflict undermines macroeconomic stability and hinders sustained growth prospects. The macro-level challenges manifest in fiscal vulnerabilities, low revenue mobilisation, disruption of financial flows, debt and inflationary pressures, higher incidence of extreme poverty, and an under-developed private sector. Governments of FCS face multiple constraints when trying to address these challenges, including weak administrative capacity, inability to enforce the rule of law, lack of state legitimacy in some instances, and elite capture or corruption.[6] They typically lack the ability to effectively manage risks, including those arising from social, economic, political, governance, security, and environmental factors.[7] Limited options for policy manoeuvring increases the trade-offs that policymakers face when trying to deliver on public goods – for instance, public expenditures are frequently diverted from social benefits and infrastructure towards salaries and security.[8] Moreover, when progress is made, it remains susceptible to high risk and repeated setbacks.[9]

More than a billion people reside in FCS[10] and, it is expected that, by 2030 they will account for around two-thirds of the world's poor.[11] According to the most recent estimates available, only 58% of the population in FCS have access to electricity, with rural areas faring far worse (only 36% of rural populations have access to electricity) compared to urban centres (86% of the urban population has access to electricity).[12]

This section discusses how the macro-level implications of fragility and conflict affect the electricity sector in FCS and discusses real and perceived risks, economic dynamics, business environment, regulations, and financing challenges that solar mini grid developers and investors experience when entering these markets. The section also discusses solar mini grid supply chains. Importantly, FCS are a heterogenous group of low- and middle-income countries, and careful consideration must be given to country-specific political, governance, and social contexts when assessing reforms and policy action.

6 IMF, 2022
7 OECD, n.d.
8 IMF, 2022
9 Ibid.
10 World Development Indicators, 2023.
11 Corral et al., 2020.
12 World Development Indicators, 2022.

2.1. Real and perceived risks

FCS are characterised by a number of real and perceived risks. In 2018, United Nations Development Programme (UNDP) developed a comprehensive framework for de-risking renewable energy investments in developing countries.[13] The risks identified and proposed policy actions to limit/mitigate these risks are summarised below and have been adapted here to focus on solar mini grids. These risks can be expected to be even more pronounced in FCS and include:

- **Energy market risk** – this arises from a bleak market outlook as a result of an absence of political commitment to expanding energy access; a lack of integration of mini grids into national electrification strategies and regulations that obstruct developers' access to the electrification market; lack of clarity around grid expansion, potential future competition, tariff regulations, technical standards (such as quality of service and grid integration); and competition from fossil fuel subsidies that make solar mini grid tariffs comparatively more expensive for customers. Possible policy de-risking actions to address these risks include building political will, developing achievable electrification targets, and reforming subsidies for fossil fuel.

- **Social acceptance risk** – this arises when communities are not familiar with renewable energy technologies and there can be misinformation and poor perceptions about solar mini grid operations. There may also be opposition from existing energy businesses threatened by the entry of solar mini grids in the market (such as from diesel genset operators and solar home system distributors). Mitigating actions can involve undertaking consumer awareness and community engagement.

- **Hardware risk** – this arises from a lack of clarity on government's technical standards for solar mini grid components, the absence of a competitive market for buying hardware, unavailability of warranties for components, and high customs tariffs and lengthy clearance processes for imported mini grid equipment. Policymakers can help reduce frictions through developing hardware certification and standards, ensuring a competitive market for buying hardware, and developing clear and consistent customs processes and tariffs.

- **Labour risk** – this arises from the absence of local educated, skilled, and qualified labour, resulting in increased training costs for local staff or hiring non-local staff. Policymakers should consider skills development through targeted apprenticeships and certification and university programmes. This is covered in more detail in section 5 below.

13 Waissbein et al., 2018.

- **Developer risk** – this arises from a developer's inexperience or limited capacity for effective management (such as in business planning, financial structuring, plant design, installation, operations and maintenance), and inability to borrow at a low-cost (arising from lack of creditworthiness or inadequate cash flows to meet investors' return conditions). Government initiatives that support setting up industry associations, creating customised academic studies, and establishing networking and collaboration platform(s) can help build developer capacity.

- **End-user risk** – this arises when developers do not have reliable data to be able to assess end-users' willingness and ability to pay for electricity (including connection fees, regular electricity bills, and household- and productive-use equipment such as lights and appliances). The experience of practitioners suggests that the demand risk (from over- or under-estimating energy demand) is by far the largest risk.[14] End-user risk can also arise from delayed or defaulted payments, electricity theft, and the absence of mobile money or domestic microfinance facilities. Potential policy instruments that work to improve end-user credit data and end-user's ability to pay (such as through improved access to consumer finance and promoting productive uses of electricity) can reduce end-user risk.

- **Financing risk** – this arises from scarcity of domestic capital for developers (as a result of low liquidity and limited number of mature financial institutions) and local banks' lack of familiarity with solar mini grids, which affects availability of relevant financing structures. Policymakers can intervene by introducing incentives for financial institutions to lend to solar mini grid projects where it would be financially viable and enhancing local investors' familiarity regarding solar mini grids.

- **Currency risk** – this arises from exchange rate volatility and the local currency depreciating against foreign (hard) currencies, which is common in instances of macroeconomic instability. Currency risk is a particular challenge when financing is provided by foreign investors in hard currency, but where projects generate revenues (and have their cash flows) in local currency, as is generally the case with solar mini grids. Local currency depreciation can result in foreign currency loans becoming substantially more expensive (in local currency terms), which can imperil the financial viability of investments in mini grids.[15] Policymakers can provide support through maintaining macroeconomic stability to guard against local currency depreciation and encouraging lending in local currency where possible, including by strengthening the domestic banking system.

- **Sovereign risk** – this arises from a range of cross-cutting political, economic, institutional and social dynamics caused by conflict, political instability, economic performance, weather events and natural disasters, legal governance, ease of doing business, corruption, crime and law enforcement, land tenure and infrastructure in a particular country.

14 Contributed by Nico Peterschmidt.
15 ESMAP, 2022a.

2.2. Economic dynamics

The economic trajectory of a country has a substantial impact on investment attractiveness. In FCS, years of conflict, civil war, or natural disasters have often damaged or limited access to essential infrastructure, including electricity. Governments of FCS are often not able to maintain and rehabilitate public electricity services due to lack of funding or because it is unsafe for maintenance personnel to access sites regularly. Furthermore, the absence of functioning basic infrastructure impedes public and private investments in all sectors, including electricity, which contributes to stalling of overall economic growth.[16]

At the same time, economic recessions or regional or global shocks tend to reduce end-users' capacity to pay for electricity, and uncertainty around future prospects reduces their willingness to make investments – this both lowers the financial viability of solar mini grids and reduces incentives to invest in them.[17] For instance, the disproportionate economic impact of the COVID-19 pandemic on per capita incomes and inflation in FCS has significantly reduced purchasing capacity of end-users. Per capita incomes in FCS are not expected to return to their pre-COVID levels even by 2024, with the share of the population living in extreme poverty in FCS projected to increase from 30 to 38%.[18] This translates into reduced ability of consumers to pay for electricity, lower electricity demand, and a longer period for investors and developers to recoup their initial investments – with the longer recovery period exposing them further to the likelihood of additional shocks during that time.

Governments of FCS are struggling to finance energy access expansion due to their limited fiscal capacity and competing priorities with other humanitarian and development objectives. This increases the importance of the private sector playing a key role in bridging the electricity access gap in these settings. However, private investments are drawn towards markets reputed for good governance and conducive business climates, and where sanctions or high risk premia do not inhibit financing options. Attracting this private investment is more difficult for FCS, where the enabling environment is often weak.

16 PPPLRC, n.d.
17 ESMAP, 2022a.
18 IMF, 2022.

2.3. Doing business environment

Environments that are conducive to doing business enhance investor confidence and benefit from higher levels of entrepreneurial activities, better employment opportunities, higher government tax revenues, and improved personal incomes.[19] The World Bank Doing Business project provides objective measures of business regulations and their enforcement in economies worldwide.[20] According to their 2020 study, the majority of FCS rank in the bottom quarter of countries. In these contexts, it takes on average six times longer to start a business, around 12 times longer to transfer property, and almost twice the time to resolve commercial disputes when compared to the 20 countries classified as having the best business environments.[21]

Additional challenges include the lack of competition and transparency in the procurement process, absence of legal protection for private investments (for example, against expropriation, removal of concession rights, dispute redressal), difficulties accessing land and skilled labour, challenges associated with working with bad actors that may exist within government, and not involving the private sector in policy dialogues that aim at enhancing the investment climate. These obstacles increase the time and cost requirements of doing business and can be serious impediments to investors' willingness to do business in fragile settings.

2.4. Regulatory framework

The quality and enforcement of policies and regulations matter for investors when making decisions on where and whether to invest. According to the Regulatory Indicators for Sustainable Energy (RISE) developed by the World Bank's Energy Sector Management Assistance Program (ESMAP), all FCS for which data was available allow private companies to own and/ or operate solar mini grids. This indicates that governments acknowledge that achieving universal energy access is beyond the abilities and capacity of the state alone and that the private sector has a critical role to play as a stakeholder and partner in reducing the energy access gap. Additionally, most FCS have programmes to develop and support solar mini grids, with many reflecting an understanding that financially viable tariff pricing is important to attract mini grid developers, and that legally allowing them to charge a cost-reflective tariff (which may be different from the national tariff) is essential for mini grid development.

There has also been significant progress made in a majority of FCS to align their broad renewable energy targets with international or regional commitments (for example, Nationally Determined Contributions) on mitigation of greenhouse gases.[22] For example, Mozambique has introduced significant reforms that address renewable energy targets, including monitoring greenhouse gases and introducing financial

19 World Bank Doing Business Index 2020.
20 Ibid.
21 Ibid.
22 Ritchie et al., n.d.

incentives for producers, with a focus on off-grid energy resources such as solar mini grids.

For most FCS, however, commitments have not yet translated into policies and, for all, implementation of policies remains challenging.[23] A lack of debt financing, bureaucratic red tape, and uncertainty around policies regarding what will happen to solar mini grid operations if the national grid arrives at that location are issues that remain unresolved and constitute disincentives for investors, although the latter point is of low relevance in FCS where national grid extension is unlikely.[24] A quarter of the countries for which data is available have debt financing facilities to support mini grid developers, and even fewer have established e-government or other initiatives (such as online processes for tariff submission, review and approval) to help reduce bureaucracy and directly facilitate mini grid developers. The importance of a sufficiently developed and conducive policy and regulatory framework for attracting private investment in solar mini grids cannot be understated.

2.5. Availability of financing

For solar mini grid developers operating in FCS, accessing funding is not straightforward for several reasons:

- **Lack of domestic public finance** – Governments of FCS are characterised by high levels of debt and domestic public funds are not readily available – a situation significantly worsened by the COVID-19 pandemic and the growing debt crisis. According to International Monetary Fund (IMF) estimates, public debt in FCS rose by 17 percentage points to 78% of GDP in 2021 compared to pre-COVID projections.[25]

- **Insufficient liquidity in local banks** – Borrowing from local commercial banks by fiscally-constrained governments crowds out credit available for the private sector, resulting in local banking systems lacking the capital needed to expand lending.[26]

- **AML/CFT concerns** – International banks may opt to avoid financial relationships with banks in FCS due to heightened concerns around their ability to comply with anti-money laundering and combatting the financing of terrorism (AML/CFT) requirements and the associated financial and reputational concerns this poses.

- **Sanctions** – Sanctions may have been imposed, for various reasons, on the government or named individuals or companies. Various instruments are used to impose sanctions, such as restricting a sanctioned country's access to credit (including from MDBs) and increasing scrutiny on financial transactions made with the sanctioned country's banks (including Central Banks).[27] In the case of sanctioned individuals or entities, access to funds or economic

23 ESMAP, 2022c.
24 Ibid.
25 IMF, 2022.
26 Collier et al., 2019.
27 Rodriguez, F.R., 2003.

resources can be blocked either directly or indirectly.[28] Many FCS have been subject to economic sanctions in the form of restrictions to trade, finance, travel, arms, and military assistance in recent decades and many countries remain sanctioned to date. Evidence from existing literature shows that sanctions can have significant negative impacts on the sanctioned entity (individuals, firms, sectors), as well as negatively affect the broader economic parameters (such as foreign investment, trade, economic development) in targeted states. Moreover, it has been observed that these sanctions continued to have adverse impacts even after they were removed.[29]

As a result of the above, solar mini grid developers in FCS have more limited access to financing, pay higher interest rates or risk premiums, and have shorter loan repayment periods for financing that is available. They may also struggle to secure payment for energy services from customers, who may have a low ability to pay. If FCS are to reach the goal of universal energy access by 2030, and solar mini grids are to play a role in reaching this target, the cost of finance will need to be brought down and much financing will have to be concessional and from grants. More information on financing challenges and financing and de-risking mechanisms that may work in FCS can be found in the accompanying toolkit *Financing and de-risking tools and approaches for solar mini grid projects in fragile contexts.*

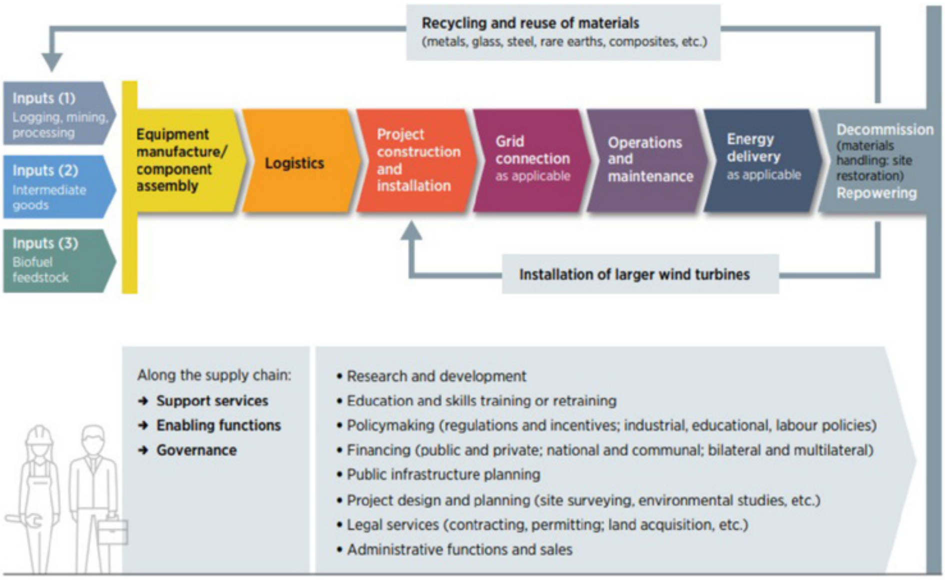
2.6. Solar mini grid supply chains

Solar mini grids depend on well-functioning supply chains for their equipment and end-user appliances (for both household and productive use), as well as for maintenance, repair, and replacement of equipment and appliances.[30] Solar equipment supply chains are dependent on the supply chains of raw materials (especially critical minerals), key semi-finished components (such as semi conductors), and finished products (including solar photovoltaic (PV) panels), the manufacture of which are highly concentrated in a few countries, notably China.

Figure 1 shows the solar mini grid supply chain across the project lifecycle. Establishing and maintaining functioning supply chains is a challenge in FCS. During periods of unrest, issues with accessing site(s), shortages of labour, and lack of availability of equipment and spare parts delay construction and repair times.[31]

28 Central Bank of Ireland, n.d.
29 Clifton Morgan et al., 2023.
30 Ibid.
31 Bazilian & Chattopadhyay, 2015.

Figure 1 Solar mini grid supply chain[32]



The key components of the solar mini grid supply chain, along with the challenges that persist in FCS while maintaining them, are discussed below.

2.6.1. Inputs, equipment manufacture, and international logistics

Critical minerals are an essential raw material for manufacturing solar PV panels and batteries. Although critical mineral deposits are widely distributed, their mining is highly concentrated in specific geographical locations and their processing is even more geographically concentrated, with China dominating the processing of most critical minerals as well as manufacture of semi-finished and finished components, including solar PV products (wafers, cells and modules) and batteries (both lead-acid and lithium-ion).

The geographical concentration of critical mineral processing and manufacturing of solar mini grid equipment makes these supply chains vulnerable to global shocks and supply chain disruptions can deeply affect mini grid investors and developers. Increasing geopolitical rivalries, trade barriers, and obstructions to key trade routes are impacting global supply chains and increasing the time and cost requirements of shipping.

To diversify and de-risk their supply chains and boost their energy security, a number of more developed countries, such as the United States and European Union member states, are hoping to increase their domestic processing and manufacturing capabilities.[33] While this will reshape global manufacturing and trade dynamics, low-income countries and FCS will remain as importers of finished products given the cost and complexity of building out these value chains and the need for significant economies of scale to make domestic processing and manufacturing competitive. As importers, FCS will continue to be

32 IRENA, 2022.
33 IRENA, 2023.

dependent on global supply chains and be impacted by any disruption or volatility that may occur. However, it may be possible for FCS to explore strengthening regional and sub-regional supply chains to reduce their vulnerabilities.[34]

2.6.2. Construction, installation, and domestic logistics

The construction, installation, and grid connection phases must be done domestically. These phases enable job creation, especially for tasks that require low- to medium-skilled labour. In fragile contexts where there are pre-existing ethnic, religious, or social tensions, it will be important for developers to make hiring decisions based on a clear understanding of local sensitivities to ensure fair distribution of opportunities and to guard against feelings of marginalisation and bias that can arise, for example, when workers from outside the local area are preferred over local workers. For instance, Nuru, a solar mini grid company based in the Democratic Republic of Congo (DRC), made a conscious effort to ensure their hiring decisions did not exacerbate existing grievances between the dominant Hema and Lendu communities when they were recruiting locally for their 8 MW site in Bunia city,

In situations of greater unrest or conflict, labour may be difficult to find and retain, and existing staff may relocate (either to more safe areas within the country or they may leave the country altogether). Conflict may also create problems with importing equipment and accessing site(s) and may also increase the likelihood of sabotage attempts and delays in financing.[35] Poor road transport infrastructure may also delay the delivery of panels, batteries, and other equipment to the site. All of these factors affect construction and installation timelines.

2.6.3. Operations and maintenance

The expected lifespan of a solar PV plant is more than 20 years, with operations and maintenance (O&M) activities continuing throughout this period. Maintenance is, fortunately, relatively straightforward with solar mini grids, but inconsistent equipment maintenance during times of conflict can increase malfunction rates.[36] Failing parts should also be promptly repaired or replaced.[37] Where replacement equipment and parts are not easily available, or where technical skill and expertise to provide repair services is lacking, component failure or damage can result in extended periods of system downtime.[38] Additionally, during conflict, electricity system assets may be attacked because of their strategic value, although this risk is lower for mini grids, which tend to serve more confined areas.

34 Ibid.
35 Bazilian & Chattopadhyay, 2015.
36 Bazilian & Chattopadhyay, 2015.
37 IRENA, 2022.
38 Harvey et al., 2016.

As some mini grid sites may be more remote or difficult to reach, developers may decide to train local technicians to promptly undertake routine maintenance activities, such as cleaning solar panels, as well as undertake initial assessments of repair needs in instances of malfunction. Recently deployed solar mini grids may come equipped with Supervisory Control and Data Acquisition (SCADA) systems that allow for remote monitoring of operations, which can be used in conjunction with local technicians to reduce the need for the developer to send staff out to remote grids except in instances of more complex repair being needed.

Some solar mini grids use diesel gensets for back-up, which makes them reliant on functioning fuel supply chains for continued operations. Fuel shortages are common in conflict zones and may result from deliberate attacks on fuel supply lines, disruption of imports and transportation infrastructure, and shortages of labour.[39] The risk of disrupted fuel supply chains will need to be built into mini grid planning and operations.

2.6.4. Energy end-uses

Beyond supplying electricity, solar mini grid developers need to increase the electricity usage of existing customers to stimulate future electricity demand, which is critical for the financial viability of solar mini grids. Productive use appliances, such as refrigerators, welding and carpentry equipment, electric cookers, and solar water pumps, play a key role in increasing both energy consumption and users' ability to pay for this increased energy consumption. To stimulate the adoption of productive use of energy appliances, developers need to collaborate closely with appliance distributors, who have the knowledge about the functionality of these appliances and are able to source (and, often, finance) these appliances.[40]

2.6.5. Decommissioning

The mini grid's lifespan can be extended through regular maintenance and repair, but at its end-of-life, the mini grid must be decommissioned. Equipment must be properly disposed of, particularly batteries, which have very harmful health and environmental impacts, and as much of it recycled as possible to reduce electronic waste (e-waste) volumes. Almost all of the materials that are used to make lithium-ion batteries and solar PV can be recycled.[41]

The solar mini grid sector is fairly nascent, with most assets not yet being old enough to have required decommissioning. Many countries, including most FCS, however, lack the infrastructure to manage the e-waste expected to be generated by decommissioning solar mini grids in the coming years.[42] In FCS, where governments may not be able to undertake e-waste management themselves, it will likely fall on developers to ensure that equipment and materials are recycled. More information on e-waste management can be found in the accompanying toolkit *E-waste management: Strategies and policies in fragile contexts.*

39 Bazilian & Chattopadhyay, 2015.
40 ESMAP, 2022a.
41 IRENA, 2022.
42 Ibid.

3. Cost of solar mini grid deployment

The cost of deploying solar mini grids comprises capital expenditure (CapEx), associated with physically constructing the solar mini grid and associated distribution network, and operating expenditure (OpEx), associated with ongoing operations. Together, CapEx and OpEx represent the Levelised Cost of Energy (LCOE), which captures the cost per kilowatt hour (kWh) supplied to end-users over the mini grid's lifespan.

ESMAP estimates that the global best-in-class solar mini grid produced electricity with a LCOE of USD 0.38 per kWh in 2021, which was a 31% decrease from the LCOE of USD 0.55 per kWh calculated for the global best-in-class solar mini grid in 2018.[43] The 2021 estimate represents an average from three high performing solar mini grids in Ethiopia, Myanmar, and Nigeria, which are all classified at FCS (see Annex I).[44]

This reduction in LCOE has been driven by many factors: the declining costs of key components, introduction of geospatial tools for planning and digitalisation for management, economies of scale achieved in associated industries and from portfolio investments, and through incentivising income-generating consumption, especially during daytime hours. Despite these encouraging developments, FCS may not fully benefit from cost reductions unless key structural issues are addressed.

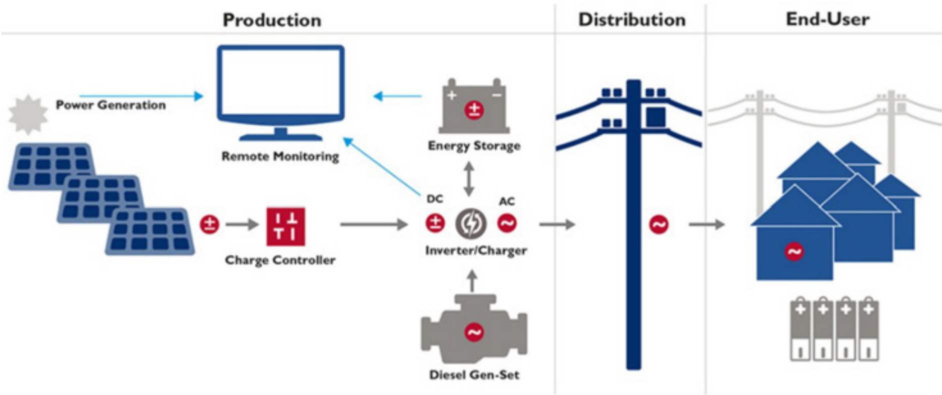
This section looks at the different cost components of solar mini grids, key factors driving costs, the available opportunities for cost reductions, and the role different stakeholders can play to support these cost savings.

3.1. Cost structure

A classic solar mini grid system is shown in **Figure 2**, with a solar mini grid connected to an energy storage system (batteries) and a back-up diesel genset. Developers may choose to employ diesel gensets (often for less than 10% of total energy generation) where seasonal variation in solar energy, extended periods of cloud cover, or increased night-time loads are common.[45] More complex solar mini grid architecture also exists, for example, when the developer provides in-house financing for productive use appliances like grain mills, welding and carpentry equipment, etc., which add to CapEx. However, for the sake of simplicity, we consider the model represented here.

43 ESMAP, 2022a.
44 Ibid.
45 Ibid. According to ESMAP calculations, the LCOE of an optimally-sized 100% solar mini grid with battery storage only is 24-39% higher than an optimally-sized solar mini grid with battery and diesel back-up (producing 6-9% non-renewable energy.

Figure 2 Technical components of a solar mini grid[46]



The typical costs associated with such a set up are detailed below.[47]

CapEx hard costs are directly related to the tangible construction of the project and include:

- *Generation*: PV modules (including spare parts), structure for the PV modules, solar inverters, and protection equipment.
- *Storage and powerhouse*: lead-acid or lithium-ion batteries (including cells, cabling and protection, monitoring and control systems, powerhouse (building, cabinet, container, fences).
- *Conversion*: battery inverter (including cabling); energy management system, back-up diesel genset.
- *Distribution*: low-voltage (and sometimes medium-voltage)[48] grid and distribution poles, smart meters, and service connections.
- *Customer systems*: end-user indoor wiring (cabling, sockets and protection); end-user appliances (if applicable).

CapEx soft costs are intangible and are associated with the planning and management of the project. These typically involve:

- *Project development*: site selection (including energy needs assessment, permits, approvals, and licenses), management and engineering, community engagement, capacity building and training.
- *Logistics*: international shipping costs (maritime) including customs, local transportation costs (road), storage of equipment, insurance.

OpEx costs generally consist of staff costs, equipment maintenance, repair and replacement, payment collection, fuel costs, security, complaints redressal and mobile money fee (where the developer uses this mode for bill collection).

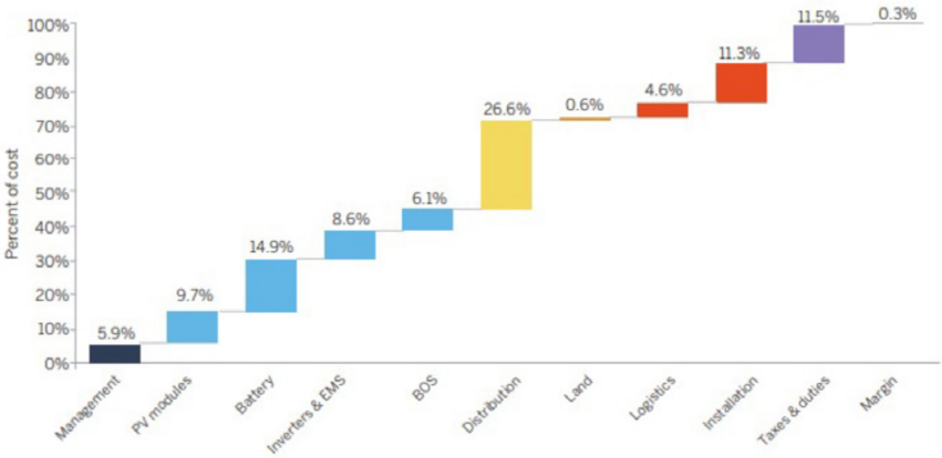
46 USAID, n.d.a.
47 Arranz-Piera, 2017.
48 ESMAP, 2022a. Mini grids serving more than 500 customers require transformers and medium voltage lines to distribute power.

3.2. Share of different costs

Generally, solar mini grids have high CapEx and low OpEx, compared to diesel mini grids that have low CapEx and high OpEx. However, credible OpEx data for solar mini grids is hard to obtain, and available calculations range from approximately 30-40% of the overall costs.[49]

The average share of CapEx costs associated with different solar mini grid components is shown in **Figure 3**. Distribution (~27%), battery (~15%), taxes and duties (~12%), installation (~11%), and PV modules (~10%) were the main contributors to the total CapEx. These estimates have been calculated by ESMAP based on data collected from almost 300 solar mini grids in 2021.

Figure 3 Average share of components in CapEx[50]



Average figures mask variation, however, and large differences in costs exist within the same component category. For FCS especially, costs can multiply significantly during the construction period. These variations can be country specific, with costs increasing as a result of the following:

- If supply chains are not sufficiently developed or if a country is landlocked[51] or is not well connected to international markets through efficient ports.[52]
- If there are high insurance costs for equipment in transit (if an insurance option indeed exists).[53]
- If waivers on imported renewable technology equipment are not honoured by customs officials or if imports face extended delays in customs (including with storage costs).

49 Presentation by Chris Greacen at 7th Mini Grid Action Learning Event in Nairobi, Kenya 27 February-3 March 2023.
50 ESMAP, 2022a.
51 Nine countries on the World Bank FCS FY23 list are landlocked: Afghanistan, Burkina Faso, Burundi, Chad, Ethiopia, Kosovo, Mali, South Sudan and Zimbabwe
52 In 2021, China dominated 75% of the global solar photovoltaic (PV) panel manufacturing and processing (Niccolo, 2022), and 79% of global lithium-ion battery production (Statista, n.d.)).
53 Interview with Nuru SASU on December 16, 2022.

- If criminal outfits control ports and extort rents in return for allowing imports to pass.[54]

These variations can also be site specific, with costs increasing when:

- The process for fulfilling the mandatory assessments and acquiring necessary approvals, permits, and licenses or concessions is inefficient and laborious.[55]
- Equipment has to be transported through regions of unrest or, alternatively, has to bypass regions of unrest increasing transit distance and time.
- Road quality is poor or road density is low, and the project sites are remote and in hard-to-reach areas.
- Required skills are not available locally and labour has to be extensively trained.
- New distribution lines have to be built or existing ones upgraded.
- There are incidences of theft of assets.

Policymakers in FCS will have to assess and determine what elements are contributing the highest costs in their specific country and take measures to lower those costs.

3.3. Key drivers of cost reductions

Costs facing solar mini grid developers have declined due to innovations in key solar mini grid equipment components, advancements in geospatial technologies used for electrification planning, and economies of scale.

3.3.1. Technological innovations

Solar PV modules/panels – A study investigating the cost reductions in solar PV modules found improvements in module efficiency, reduction in input prices and usage (both for silicon and non-silicon materials), public and private research and development (R&D), economies of scale enabled by increased plant sizes, and learning-by-doing as the main contributors behind declining solar PV costs.[56] Solar mini grids have been a beneficiary of this decrease in global solar PV costs, and have experienced reduction in their solar PV panel costs of USD 32 per kilowatt peak (kWp) per year on average between 2012 and 2021.[57]

54 Interview with Chris Greacen on December 8, 2022.
55 Interview with Nuru SASU on December 16, 2022.
56 Kavlak et al, 2018.
57 ESMAP, 2022a. Kilowatt peak is the maximum performance obtainable from a solar panel/module when operating under perfect conditions. For example, a 2 kWp system will produce 2 kW of electrical power in bright sunshine.

The solar PV industry has been innovating to develop technologies with higher efficiency to improve performance. Improved efficiency also helps with lowering costs through reducing the number of modules that need to be transported to the site, the required land area for installation, and the length of wires and cables needed.[58] Silicon cells currently dominate 95% of the global PV production.[59] Innovations include development of non-silicon based solar cells that have the potential to achieve high efficiency levels using perovskite, copper indium gallium selenide, and cadmium telluride that are in R&D phase, market entry, and market penetration stages, respectively.[60] In 2021, China dominated 75% of the global solar PV panel manufacturing and processing.[61]

An area that requires attention is the increased frequency and severity of extreme weather events that are becoming the biggest threat to failure of solar PV installations. Eighteen countries experiencing fragility or conflict rank in the top 25 countries globally for highest vulnerability and least coping capacity for climate change.[62] The solar PV panels deployed in these settings need to be designed to be resilient to climate change through continued improvement in technology, application of standards, and learning from field experience.[63]

Batteries – Lead-acid batteries were the dominant choice for solar mini grid developers until the introduction of lithium-ion batteries in 2016.[64] Although lithium-ion batteries are more expensive (costing 3 to 4 times more)[65] than lead-acid batteries, their costs have been declining by an average of 19% with every doubling of capacity.[66] These reductions have been driven primarily by improved cell charge density (enhancing battery performance), reduction in material and non-material prices, public- and private-funded R&D, and economies of scale (especially in electric vehicle and utility-scale energy storage industries).[67] Due to lithium-ion batteries' superior lifetimes (lasting 2 to 3 times longer than lead-acid batteries) and higher performance, they lower solar mini grid LCOE.[68] However, solar mini grids with lead-acid batteries remain competitive, especially in countries like Nigeria where strong supply chains allow discounts on bulk purchases.[69]

Beyond lithium-ion batteries, other emerging battery technologies are being researched and piloted for commercial use in solar mini grids. The aim is to improve:

- battery life (to have deeper discharge and last longer);
- sensitivity to temperature (lead-acid and lithium-ion batteries both degrade quickly in hot climates, but lithium-ion batteries have a higher threshold);

58 IRENA, 2019.
59 Philipps & Warmuth, 2024.
60 IRENA, 2019.
61 Niccolo, 2022.
62 Alcayna & Cao, 2022.
63 IRENA, 2019.
64 ESMAP, 2022a.
65 Radiance Tek, 2022.
66 Ritchie. 2021.
67 ESMAP, 2022a; Ziegler et al., 2021.
68 ESMAP, 2022a.
69 Ibid.

- round-trip efficiency (so electricity can be provided to larger communities more cost-effectively); and
- energy density (higher density batteries lower transportation costs and reduce powerhouse size).

When setting quality standards for batteries, FCS policymakers should consider the attributes of different batteries, as well as the transportation and construction costs (large batteries increase both) especially when batteries have to be imported, which will be the case for FCS. China dominated 79% of global lithium-ion battery production in 2021.[70]

Smart meters – The global market for smart meters has been driven by strong policy support from China and Europe. Smart meters enable remote real-time collection, monitoring and control of electricity data. This allows end-users to manage their electricity usage more effectively and developers to better understand and manage demand on mini grids.[71] Smart meters also incorporate pay-as-you-go (PAYGo) features, with consumers pre-paying for electricity. They can help to substantially lower costs and improve revenues by detecting electricity theft, removing the labour costs of meter reading and post-pay billing and collection, and alerting technicians to problems when parameters exceed programmable thresholds so they can be resolved timely. For FCS, where mobility may at times be restricted, smart meters are an important innovation that facilitates time and cost savings for both the end-users and solar mini grid developers.

Powerhouses – A powerhouse structure houses batteries, inverters, control panels, the main distribution box, monitoring system power electronics, and safety equipment.[72] Various structures for powerhouses have been developed: i) traditional masonry powerhouses; ii) shipping containers; and iii) weatherproof cabinets sheltered under the solar panel array. Solar mini grid developers will need to decide which powerhouse structure is most cost-effective (subject to fulfilling quality standards) based on site-specific attributes. Conventional powerhouses built by local masons are most cost-efficient where road density and quality is poor and there are high shipping and transportation costs. Container powerhouses come pre-assembled with equipment and are ready to operate when they arrive at the site, but transportation infrastructure must allow for their safe delivery. Additional costs can be saved when the container is also used to transport solar PV panels and other materials to the site. Weatherproof cabinets can save transportation costs (as they are lighter) and installation costs.[73]

70 Statista, n.d.
71 Future Electronics, 2023.
72 AEPC, 2022.
73 ESMAP, 2022a.

Solar mini grid developers in FCS will have to assess the threat of conflict breaking out in close proximity to the site and the agility with which they may be able to relocate their assets if an adverse event occurs. This will also be a consideration in case of extreme weather events (such as hurricanes). Shipping containers and weatherproof cabinets should be easier to move from an area under threat (although repurposing them for reuse will be subject to the condition there are in). These structures may also be deployed swiftly in humanitarian settings.

3.3.2. Geospatial planning

The availability of open-source and affordable satellite data and the development of sophisticated web-based platforms that allow least-cost electrification analysis has substantially brought down the preparation and planning costs that solar mini grid developers must incur. Previously, assessing a site for mini grid deployment required detailed socio-economic surveys, energy audits (looking at energy demand and willingness and ability of consumers to pay) and high-level on-site analysis that cost about USD 30,000 per site. Geospatial technology applications can now be used to prepare a mini grid development portfolio (including bills of quantities, bid documents, and purchase orders) so that they are ready for full feasibility assessments and community engagement at a cost of USD 2,300 per site, based on World Bank's experience in Nigeria.[74]

This is great news for policymakers and developers in FCS, especially in settings where conducting surveys would be too expensive, respondents may be reluctant to freely share information, and the field teams surveying the site may face security threats. However, there are some challenges that exist that electrification planning platforms should address as they become more sophisticated, notably concerning the frequency with which reliable and verified socio-economic data is updated at the backend. Additionally, accurately assessing existing and potential productive uses of energy is an area that cannot yet be fully addressed through geospatial planning tools, although efforts are being made in this regard. These aspects are covered in greater detail in the accompanying toolkits *Driving productive use of energy in fragile contexts* and *Data and technology: Challenges and opportunities for solar mini grids in fragile contexts.*

74 Ibid.

3.3.3. Economies of scale

Financial benefits accrue to solar mini grid developers when they increase their portfolio sizes, both in terms of the number of sites and investment value of each site. Data from an ESMAP study suggests that for each additional 100 customers that the mini grid serves, the per customer cost of supplying electricity reduces by about USD 9. The study also finds that deploying solar mini grids as a portfolio saved USD 81,000 in soft costs compared to one-off projects.[75] These savings arise from discounts that can be negotiated on bulk procurement of equipment (resulting in lower per unit costs) and shipping and instalment of bulk purchases, bundling the processing of requisite permits and approvals, and savings on administration and management costs (as they are spread over more units of production). Examples where cost savings have been achieved in these ways are outlined in **Box 1** and **Box 2**.

BOX 1 DEMAND AGGREGATION FOR RENEWABLE TECHNOLOGIES (DART) PROGRAMME

DART was piloted in Nigeria in 2021, with the USD 10 million project being supported by All On, Odyssey Energy Solutions, and Global Energy Alliance for People and Planet (GEAPP).[76] The aim of the programme is to support small and medium-sized clean energy enterprises, especially those focused on solar energy (including mini grids), reduce the barriers they face due to their dependence on international supply chains and foreign manufacturers, and relative small purchase orders that increases the cost of procurement for each energy enterprise.[77] The DART programme pools the demand of different developers and enables bulk procurement and logistics aggregation of solar equipment in order to drive down costs and bring utility-scale pricing to projects.[78] During the COP28 in Dubai, All On and GEAPP announced an additional USD 15 million in investments to expand the DART programme.[79]

75 Ibid.
76 Takouleu, 2021.
77 Boyls Engineering Services Limited, 2023.
78 GEAPP, 2021.
79 GEAPP, 2023.

BOX 2 NAYO TECH, NIGERIA

Nayo Tech, a solar mini grid developer in Nigeria, developed their first mini grid in Tungan Jika. When neighbouring communities saw the benefits of affordable, reliable power in Tungan Jika, they approached Nayo Tech to bring electricity to their communities as well.

When assessing scaling up to ten new solar mini grids clustered around their original site in the Tungan Jika community, Nayo Tech estimated that they could reduce average costs of supplying electricity by 40% compared to the first site. Nayo Tech expects these cost savings to be achieved through the following:

- developing the solar mini grids in close clusters,
- procuring solar equipment in bulk,
- spreading out construction expenses across the sites (for example, Nayo Tech had to build a bridge to connect to Tungan Jika to install the original mini grid, which bridge can now provide access to the new sites), and
- cost sharing of soft costs (in-person site visits, connecting customers, payment collection and overall operations and maintenance).[80]

As policymakers and developers work to reduce costs, it is important to also assess the potential trade-offs that may arise. For example, do technological innovations replace employment opportunities for the local community, leading to a feeling of marginalisation and discrimination? Policymakers and developers operating in FCS need to identify and be cognisant of local sensitivities.

80 Agenboard et al., 2018.

4. Enabling and complementary sectors

There are a number of other sectors that are key enablers for expanding energy access and which are needed to complement the sustainable scale-up of the solar mini grid sector. Notable ones include:

- **Transport infrastructure** – availability of transport infrastructure such as road, railways, bridges, and ports are crucial for transporting solar mini grid equipment and replacement parts to electrification sites. Solar equipment is rarely moved by air given their weight and the higher cost of air transport.

- **Productive use appliances** – energy efficient products and appliances are needed to support consumers' productive use of energy, to ensure that electricity access leads to improved socio-economic outcomes for consumers.

- **Telecommunications services** – these allow for mobile or other digital payments of electricity costs and are particularly vital when project sites are remote and travel of either bill collectors or consumers for in-person bill payments may be time-consuming or dangerous.

- **Financial inclusion** – and end-users' improved ability to access credit is important for enabling business and livelihood activities, which can lead to increasing electricity demand.

- **Digital technologies** – these assist in sensing and data collection, communication and control, digital platforms and analytics tools which provide transformative solutions, reduced cost of maintenance and repair (through remote monitoring and problem solving), and increased reliability of electricity supply.

In FCS, these enabling and complementary sectors may be damaged or underdeveloped. This section provides details of how these enabling and complementary sectors help build an ecosystem that allows solar mini grid developers to build viable business models. It also highlights the challenges that FCS face when these enablers have limited coverage or are absent, possible remedial actions that can be undertaken to make the most of these difficult situations, potential fallout that may result as a consequence of these actions, and mitigation strategies that should be inbuilt in policies and implementation plans.

4.1. Transport infrastructure

A functioning transport infrastructure, including roads, railways, bridges, ports, and airports, reduces the cost of transporting goods from one place to another and can determine where energy investments are made. The cost of building electricity grid infrastructure is lower where roads already exist.[81] Essential solar mini grid equipment such as solar PV panels and batteries are generally manufactured outside FCS (primarily in China), and therefore ports, roads, and railways are needed to import and transfer essential equipment to mini grid sites. Roads are also vital for facilitating the movement of locally manufactured equipment used in grid construction, as well as enabling the mobility of skilled labour. Findings from research studies on the impacts of complementary investments can be found in **Box 3**.

BOX 3 EVIDENCE ON THE IMPACTS OF COMPLEMENTARY INVESTMENTS

A recent study in Ethiopia looking at districts that received road expansion or electricity network extension, or both, found that, although there were instances of districts with road connections having no electricity, there was never a case of districts getting electrified in the absence of a road connection, i.e., the availably of roads was a necessary prior condition for electrifying a district.[82] The study also found that, while isolated electrification and road investments increased welfare by 0.7% and 2%, respectively, the welfare effect resulting from combined electrification and road infrastructure was significantly higher, at around 11%.[83]

The World Bank found similar results in the Horn of Africa and the Lake Chad region when they studied the extent to which bundling road investments with access to electricity led to greater structural transformation of the economy from low-productivity agriculture towards higher productivity manufacturing and services. Simulations on future infrastructure investments predicted annual real income in Somalia and Chad to increase by 1.4% and 0.7%, respectively, from transport investments, and 6.2% and 6%, respectively, when combined with major electricity investments. These findings highlight the complementarity of the road and electricity infrastructure.[84]

As a result of this evidence, governments of FCS should consider focusing energy access efforts on areas with existing roads. At the same time, they should build roads to unconnected areas for later roll-out of energy access in those areas, recognising that areas without roads are likely to be historically marginalised or be inhabited by historically marginalised communities. Therefore, it is necessary to take deliberate steps to connect these areas to roads (and, later, electricity), otherwise

81 Jack, 2022.
82 Moneke, 2022.
83 Vagliasindi, 2022.
84 Dappe & Lebrand, 2021; Lebrand, 2022.

it will worsen inequalities. This can be particularly problematic in FCS where further entrenching historical inequalities can lead to increase in social tensions and conflict.

Quality of transport infrastructure matters significantly as poor-quality roads and railways can damage equipment and untarred roads may be impassable for extended periods during rainy seasons. Airlifting thousands of tonnes of equipment into areas unreachable by road or rail is not financially viable for most projects. Comprehensive A-rated insurance to cover goods in transit to remote sites in FCS is frequently difficult to obtain, with developers having to accept cover from lower-rated local insurance providers or having to bear the risk of damage to equipment themselves.[85] Transporting goods through unstable, complex environments adds to project costs, with or without insurance.

Road or rail connections to project sites are also needed to transport replacement parts over time, as well as energy efficient products and appliances to enable consumers' productive use of energy. In turn, these transport networks are essential to convey goods produced (including as a direct result of communities being connected to electricity) to markets for sale.[86]

Border-crossing can be a tiresome process and add significantly to the time and cost of shipping goods due to both official border taxes as well as a myriad of non-tariff barriers that may be particularly acute in FCS. Although some countries have waived certain taxes and tariffs on renewable energy equipment, these waivers are often not consistently applied in practice, giving rise to issues at border posts. The non-tariff barriers that those conveying solar equipment across borders may experience include extensive delays and inefficiencies, as well as demands for bribes and harassment. A study looking at the Dakar-Lagos corridor (or the Trans-West African highway) that crosses 12 countries (and 11 international borders), including several FCS, found that truckers often spent more time waiting at border crossings than driving to their destination.[87]

Critical transport infrastructure may also become the target of attack because they are considered symbols of state power or because they facilitate the movement of government soldiers and military equipment or militant groups. In 2016, an audit of the American-built Afghan roads discovered that 30% had insurgent activities along them, with the Taliban strategically making use of the roads built by the coalition forces.[88] Therefore, the security situation along road infrastructure should also be factored into decision-making.

85 Interview with Nuru SASU on December 16, 2022.
86 Pueyo & DeMartino, 2018.
87 Lebrand, 2021.
88 SIGAR, 2016.

4.2. Financial inclusion

The typical end-users of solar mini grids in FCS can be expected to live in rural areas, be dependent on agriculture and livestock, have low and periodic incomes (primarily due to seasonality of weather, or vulnerability to climate change), and have low demand for electricity.[89] Electricity consumption is limited both by their low ability to pay as well as limited options to make productive use of their electricity (with low ownership of electric appliances for household and productive use).[90] This is challenging for developers because when served communities do not sufficiently optimise the grid's capacity, revenues generated are insufficient to sustainably operate the grids. It is also a lost opportunity for the community as they do not benefit fully from access to electricity.

Solar mini grid developers can deliberately stimulate energy demand and raise consumers' ability to pay in order to improve profitability of the mini grid. Increasing access to productive use appliances is key, as is ensuring that these appliances are energy efficient, thereby enabling end-users to produce more output per unit of energy consumed. Given affordability constraints in these contexts, it will be necessary for appliance distributors, mini grid developers, or local microfinance institutions to provide consumer financing to enable consumers to purchase appliances under lease-to-own financing models, where they can pay off appliance costs over time (including by using revenue generated from using their appliances). This is an effective way to increase energy demand and ability to pay, with evidence showing that providing 12-month loan terms to finance productive use appliances almost doubled electricity consumption and increased mini grid revenues by 18% after 11 months.[91]

However, providing in-house consumer finance raises developers' working capital requirements and requires them to build out supply chains for appliances and establish a system for managing loans. This often diverts focus from their core business and expertise, and it is significantly better if this is left to appliance distributors or microfinance institutions instead. Additionally, these entities may have existing financial products, credit mechanisms, and distribution networks.

The financial sector in FCS, however, often remains underdeveloped, with a large share of populations underserved with no or limited access to financial services. The number of formal financial service providers (such as commercial banks, microfinance institutions, and mobile money agents) in FCS are substantially lower than in non-FCS.[92] Consultative Group to Assist the Poor (CGAP) analysed the Global Findex 2017 data and found that formal account ownership of adults in FCS was half that of non-FCS (36% versus 71%, respectively).[93] Additionally, women in FCS were 11% less likely to have a formal account compared to men in FCS,

89 World Bank Indicators, 2021. More than 56% of the population in FCS was residing in rural areas in 2021, and only one-third was electrified.
90 Lovin et al., 2019.
91 Agenboard et al., 2018.
92 Chehade et al., 2021.
93 Ibid. Formal account ownership in a financial institution can include a bank, credit union, microfinance institution, or post office that falls under prudential regulation by a government body. Adults are classified as aged year 15+ under World Development Indicators.

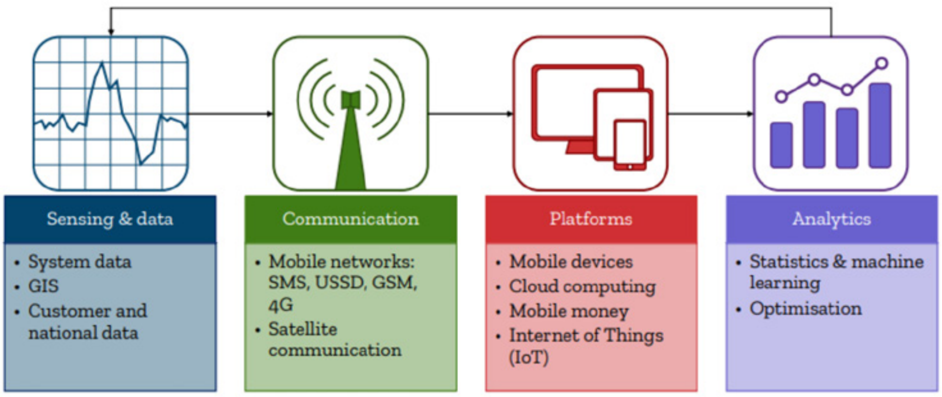
and 38% less likely to have a formal account than women in non-FCS.[94] Lack of financial inclusion deprives individuals from important financial services such as savings accounts or microloans , making it unsurprising that adults in FCS have limited access to credit, with only 8% having borrowed from a financial institution compared to 14% in non-FCS.[95]

Digital financial inclusion is far more important in FCS than access to formal bank accounts, however. Mobile money account ownership is 8% higher in FCS compared to non-FCS, although the number of mobile money agents per 100,000 adults was more than six times lower in FCS, indicating that greater investments, particularly in deepening distribution networks, are required to increase penetration of digital financial services in these contexts.[96] Greater use of mobile money would also enable users to build up credit histories that may improve their access to mobile loans, as has been done by Safaricom in Kenya. Specific actions are needed to improve digital financial inclusion of refugees as they may lack the documentary requirements needed to open mobile money accounts.

4.3. Digital technologies

Digital technologies can play a critical role in improving the supply-side of solar mini grids. They can help with reducing costs (such as using satellite imagery for initial site analysis or providing remote support for on-site technicians to reduce the number of physical visits), accessing equipment on distant project sites remotely, and assessing project risk. Figure 4 shows the different technologies that are driving digital innovation in electricity and influencing how solar mini grid developers design their investments.[97]

Figure 4 Digital technologies enabling electricity access[98]



94 Chehade et al., 2021.
95 Ibid.
96 Ibid.
97 Energy Catalyst, 2021.
98 Ibid.

More on these technologies can be found in the accompanying toolkit *Data and technology: Challenges and opportunities for solar mini grids in fragile contexts*. In brief:[99]

Sensing and data – This includes (i) onsite sensor hardware that measures key energy system parameters; (ii) geographic information systems (GIS) that use satellite data to take high resolution images of the earth, identifying key structures and distribution of electricity services; and (iii) customer and national data, including socio-economic and energy consumption data. These tools help developers reduce costs by identifying issues before failure occurs, reducing the need for on-site assessments and maintenance visits in more remote locations, and ensuring better site selection and system design.

Communication – This includes (i) mobile networks, which enable the use of mobile money and facilitate customer engagement, remote monitoring, and smart metering, as well as (ii) satellite communication that allows for monitoring energy systems where mobile network is not available.

Digital platforms – This includes (i) mobile devices, which are used by developers to maintain community engagement and to provide support to on-site technicians; (ii) cloud computing, which allows developers to store data and access technology services, including data analytics;[100] (iii) mobile money, which facilitates customers' paying for electricity services; and (iv) the internet of things, which enables devices to record and exchange data via the internet to support optimal operations.

Analytics – This includes (i) statistics and machine learning, which are used to develop models based on the large amount of data generated by energy systems, consumer behaviour, and GIS in order to predict the characteristics of new data, and (ii) optimisation, which determines the best possible hardware configuration and operation mode for a system. This reduces costs for developers and, therefore, for customers too.

Digital technologies hold great promise for scaling up electricity access through solutions that provide transparency and support more targeted investments, leading to improved impact measurement and knowledge generation.[101] As these technologies become cheaper, and regulation around them is formalised to improve compatibility with energy equipment, their penetration in energy access applications is expected to increase in the future.

99 Ibid. This section draws heavily from cited resource.
100 AWS, n.d.
101 Duren et al., 2021.

Punit Paranjpeafp, Getty Images

However, there are a number of challenges associated with deploying digital solutions in FCS, including low mobile network penetration, low internet coverage (with only 38% of people in FCS using internet compared to the global average of 63% in 2021).[102] As the internet is critical to enable other digital technologies, it presents a key limitation where it does not exist. There is also a lack of available funding in FCS to invest in deploying digital solutions and often a lack of awareness of the benefits and insights that digital technologies can generate in terms of optimising costs and efficiency of solar mini grids. Given the huge amount of data created as a result of applying digital technologies, there may be privacy concerns around data acquisition, data storage and retention, use and presentation. Failure to protect privacy can result in dire security implications for individuals and communities in situations of conflict and unrest.[103]

In order to address these challenges, policymakers in FCS should work towards developing regulations that facilitate the expansion of digital technologies by lowering entry barriers and risks for companies providing these services, while at the same time ensuring adequate rules are in place for data protection and privacy.[104]

102 World Development Indicators, 2021.
103 Idris, 2019.
104 Fritzsche et al., 2019.

5. Labour market capabilities and capacity building

In many instances, governments of FCS experience weak institutional capacity and the inability to provide quality education and skills development opportunities for their citizens, resulting in a gap between existing skills and capabilities of the population and the needs and opportunities of the labour market. To support the scale-up of solar mini grids, policymakers need to (i) undertake a capacity needs assessments, to identify the skills and capabilities required by the solar mini grid sector and to assess existing capacity and capacity gaps, and (ii) implement capacity building efforts that address the capacity gaps that may exist at the policy, project, and community level.

This section outlines the different kind of skills needed at different design and implementation levels (policy, project and community) and at different stages of the solar mini grid deployment (planning, construction, and operations and maintenance). It outlines how capacity needs assessments can be approached, presents challenges of conducting capacity building in FCS, and provides recommendations around how capacity building efforts can address capacity gaps, enabling employability and livelihoods that may result in broader socio-economic and peace dividends beyond electricity provision.

5.1. Assessing capacity needs

A capacity needs assessment should be conducted to: (i) understand the skills and expertise needed to successfully deliver sustainable and scalable solar mini grid projects; and (ii) identify existing capacity and capacity gaps. A capacity needs assessment involves:[105]

1. **Identifying key stakeholders**, including who will build, own, operate and maintain the solar mini grid (private sector, community, public sector, or hybrid), the end-users (residential, commercial, public institutions, etc.), and other actors that may facilitate the development of the solar mini grid ecosystem (financiers, suppliers of energy-efficient appliances for household and productive use and those able to source replacement parts, logistics, and transport providers etc.).

2. **Determining capacity required across the project lifecycle**, including policy, technical, financial and management skills that stakeholders need to successfully implement and operate the solar mini grid.

3. **Assessing existing capacity** by gathering information through conducting self-assessments, key informant interviews, focus group discussions, and surveys of the key stakeholders already identified, and analysing this information.[106]

105 USAID, n.d.b.
106 UNDP, 2008.

4. **Identifying capacity gaps** to understand what skills and expertise are lacking in different stakeholder groups and at different management levels (e.g., leadership and field staff).

5.2. Capacity building

The capacity gaps identified during the needs assessments exercise should inform targeted capacity building interventions at the policy, project and community levels:

- **Policy level** – Government energy and electrification ministries, regulators, rural electrification agencies, and other government bodies that have a stake in renewable distributed energy systems (such as climate change agencies) may need to be trained to strengthen their expertise in designing polices and regulations on integrating solar mini grids into national electrification plans, creating an enabling business environment, developing appropriate licensing and procurement processes, and setting tariffs and technical standards, for example. Capacity building on how to use rapidly evolving technology and processes that are cost-effective and time-efficient (such as geospatial planning), as well as how to undertake resource assessments and best utilise financial planning tools would also be valuable. Skills training that would enable government to better monitor and respond to stakeholder complaints and enforce compliance with regulations could also be undertaken.[107]

- **Project level** – Necessary skills and expertise required include:[108]

  - *Planning and development:* site selection, demand assessment, technical system design and system sizing, distribution network mapping, business models, financial modelling, feasibility studies, capital raising, and project management.

  - *Construction:* contracting, procurement, installation, commissioning, capital raising and financing, and project management.

  - *Operation and maintenance (O&M):* O&M process management and software, marketing and sales, tariff setting, customer service, metering, demand side management, demand stimulation including for productive uses, performance monitoring and evaluation, and enterprise management.

Solar mini grid developers, technical experts (system designers and engineers, financial experts, field staff (local technicians and installers) and suppliers across the value chain may need to be trained depending on the skills and expertise gaps that exist.

107 ESMAP, 2022a.
108 Green Mini-Grid Help Desk, 2018.

- **Community level** – Capacity building should focus on raising awareness on the benefits of electricity and how to safely use electricity for household and income-generating activities. Training targeted at household customers can assist them in understanding their electricity usage and moving towards higher tiers of energy consumption. Training targeted at productive use customers can help them in identifying energy-efficient appliances, securing asset financing, increasing revenues, and expanding their businesses.[109]

In FCS and low-income countries, particularly in rural areas, local staff and communities may also lack basic numeracy and literacy skills. When conducting feasibility assessments for site identification, developers often check for the availability of educational institutes in the area because they understand that educational fundamentals are essential for further capacity building at the local level.[110]

Capacity building can be provided by the government (especially when the solar mini grid sector is top-down and government driven), mini grid developers (initiated by private sector or local community and, hence, bottom-up), development partners, technical professional organisations (such as the Institute of Electrical and Electronics Engineers),[111] polytechnic schools or training institutes, and appliance distributors (when promoting their appliances to potential customers). These actors may either deliver the training themselves or can be facilitators that provide financial and non-financial support (such as designing training material or providing free equipment for hands-on training) for those delivering training.[112]

There are four main types of training programmes:

- *Vocational training,* which is based on developing practical skills and is targeted to entry level individuals;
- *Professional development*, which caters for specialised training of skilled professionals;
- *In-house training* provided by mini grid developers for their field staff; and
- *Academic training* that focuses on theoretical content in a specific field of study rather than practical experience.

Trainings can run for weeks or months (in the case of vocational, professional and in-house training) or years (for academic training). They can be informal or more formal certification from accredited training institutions.[113] Training can be delivered through in-person sessions (classroom training, seminars, roundtables, group exercises, workshops, assessments, field visits, etc.) or through distance learning (virtual meetings, webinars and e-learning).[114] In FCS, especially in cases where mobility may be restricted for safety reasons, online training appears to be an attractive option where there is internet

109 ESMAP, 2022a.
110 Interview with Nuru SASU on December 16, 2022.
111 IEEE, n.d.
112 Green Mini-Grid Help Desk, 2018.
113 Ibid.
114 Ibid.

access. Attention should be paid to ensuring fair distribution of training opportunities across different groups of people on ethnic, religious, gender, and age, in order to ensure that training opportunities do not aggravate existing social divides in FCS.

In order to be effective, capacity building trainings should be adapted to the level of experience the individuals or organisations have in deploying and implementing solar mini grids, and the level of seniority and responsibility of the staff to be trained. In all instances, training content should incorporate security modules and the actions that need to be taken during different types of emergencies in order to mitigate against risks in FCS. Additionally, with the rapidly changing technology and innovation in the solar mini grid sector, capacity building interventions should be planned to be a continuous exercise rather than a one-off activity.

At the **policy level**, the training required will depend on the country's existing experience with deploying solar mini grids or even wind or hydropower mini grids at any scale of renewable energy project (utility level or stand-alone systems). Institutional knowledge can help facilitate knowledge building on solar mini grids. A few FCS are experienced in electricity service delivery through mini grids (for example, Afghanistan and Myanmar have more than 4,000 mini grids each, with a total installed capacity of around 100 MW), which experience can be further built upon.[115] However, the majority of FCS are in early stages of developing their solar mini grids sectors and will require more comprehensive training that covers all relevant aspects of solar mini grids. Training should also be customised to the role that staff play within government, from policy decision-making to technical positions, although some general training would also help mitigate disruptions arising from high turnover, which is more common in FCS. Training should also be directed to the relevant administrative level responsible for electricity service delivery.

At the **project level**, training requirements will vary depending on size and experience of the mini grid developer, whether the developer is international or local, and between management roles and field staff. Larger, more experienced developers may focus efforts on building knowledge on country-specific laws around taxation and customs procedures. These developers can also be great source of learning for new developers entering the market.[116] Local developers will have greater understanding of country-specific factors but may need training on technical aspects of technologies and engineering, and financial skills. Lastly, training needs will differ across the management level (where the focus is on business modelling, financing, human resource management, and regulations) and field staff level (where the emphasis is on mini grid operations including customer management and bill collection).[117]

115 ESMAP, 2022a.
116 Contributed by Nico Peterschmidt.
117 Ibid.

At the **community level**, training should be adapted to whether the community is being newly powered or has been using electricity for a while, and could focus on safe usage of electricity, stimulating income-generating activities, and using energy-efficient appliances. In all instances, it is critical to ensure that local customs and traditions are respected. Effort should be made to have the training material translated and the training conducted in local languages. Where educational levels are low, training providers may explore innovative ways of engaging the community, such as through incorporating graphical illustrations in manuals or through developing explanatory videos. For example, Quicksand is a video-based digital platform that was envisioned by the Word Bank to promote mini grids and solar energy by showcasing user experiences.[118]

5.3. Challenges and lessons learned when developing capacity

Most policy level training initiatives are funded by development partners and international financial institutions.[119] Although not focused on capacity building within the solar mini grid sector specifically, research findings on internationally funded initiatives that aim to build state capacity and improve service delivery in FCS have identified a set of challenges and lessons for these initiatives, including:[120]

- Substituting for government's responsibilities and hiring skilled staff out of government positions can undermine (rather than enhance) local capacity.
- Capacity building should engage with all levels of (sometimes hybrid) political orders, in order to mitigate against competing power dynamics.
- Training programmes should be flexible and be able to adapt to the rapidly changing and unpredictable conditions in FCS.
- Bottom-up engagement is important in instances where fragility is caused by divisions between the centre and periphery or between the state and society.

Energy4Impact and Inensus have conducted the only detailed capacity gap analysis on existing mini grid training programmes, looking at mini grids using all energy sources, not just solar. They analysed information from interviews with mini grid developers and training providers and found that:[121]

- Developers were unable to find skilled staff in remote areas and, when skilled staff from urban areas were recruited to remote areas, it was expensive and there was high turnover. In some countries, like Mali and Niger, qualified engineers were not available even in urban areas.

118 Quicksand, n.d.
119 ESMAP, 2022a.
120 Mallet et al., 2014.
121 Green Mini-Grid Help Desk, 2018.

- Developers preferred shorter, practical or field based trainings implemented by local training institutions to save costs and accredited by local authorities to ensure high quality. They were interested in more opportunities for peer-to-peer learning and for the training content to be closely linked and relevant to ongoing developments in the sector.

- Training providers emphasised the organisational and logistical issues with scaling up mini grid training and challenges around translating training into local languages and building in cultural context. They stressed the importance of training all relevant stakeholders in the mini grid ecosystem to improve collaboration.

5.4. Societal benefits of capacity building

In FCS, capacity building can also serve as a means for empowering local stakeholders, especially young people, through improving their employability and providing them with an opportunity to engage in gainful employment, thereby contributing to building a more peaceful and resilient community.[122] Young people between the ages of 15 and 29 years old are estimated to comprise of more than one-third of the population residing in FCS. They are most adversely affected by unrest and fragility as they have limited options to establish decent livelihoods, which deteriorates their socio-economic standing and having few economic opportunities may make them susceptible to recruitment into armed gangs and militias.[123] An example of capacity building undertaken in two FCS is found in **Box 4**.

BOX 4 TVET PROGRAMMES IN SOUTH SUDAN AND LIBERIA[124]

A study of technical and vocational education and training (TVET) programmes in South Sudan and Liberia targeting ex-combatants, refugees, and other vulnerable groups found that the programmes created the feeling of 'becoming someone in the eyes of the community', led participants to opportunities for employment and earning money, and resulted in them becoming less aggressive. Consequently and, as consequently, reduced violence in the community.

At times of unrest and conflict, women often find themselves in unconventional roles as income-providers and heads of households because male relatives are away or engaged in fighting. This period can serve as an opportunity to improve gender equality.[125] UNDP Yemen has supported women with capacity building to successfully develop their businesses, recognised the critical role women can play in determining

122 ILO, 2016.
123 ILO, 2021.
124 Pompa, 2014.
125 ILO, 2021.

community priorities because of their unique understanding of local challenges.[126] In 2020, women in three frontline communities of Yemen's conflict in Hajjah and Lahj were trained by UNDP on establishing, managing, and promoting their solar micro-grid businesses. Women who participated in the training were able to earn a respectable livelihood and provide for their families for the first time, which also altered community perceptions on the roles women can play in society.[127]

Gender disaggregated employment data for solar mini grids in FCS is not currently available. However, a Global Off-Grid Lighting Association (GOGLA) survey found female employment in off-grid solar to be 27% - while this may not be representative (as the focus of the survey was on solar products), it is still promising. [128] Reducing barriers (such as gender and social norms, discriminatory laws restricting women's ownership of assets, etc.), encouraging market entry for women (through mentorship opportunities, easing access to financial services, etc.), and providing business and technical training can make the solar mini grid sector more inclusive to women.[129]

Refugees and internally displaced persons fleeing their homes to escape from conflict and harassment are often discriminated against by host communities, who may fear increased resource scarcity. Language constraints and administrative and logistical issues make it difficult for displaced persons to establish livelihoods.[130] Refugees may suffer even more in instances where they do not have the right to work in host countries and, therefore, cannot enter the labour market. Where refugees are able to work, they can be valuable participants in the host country's labour market, as example initiatives show in **Box 5**.

BOX 5 REFUGEES IN HOST COUNTRY LABOUR MARKETS

A trade agreement between the European Union (EU) and Jordan allows for simplified rules of origin and tariff-free access to the EU market for Jordanian products made in part by refugee workers. This provision has created jobs for refugee women and benefitted the Jordanian economy by increasing textiles and garments exports, a sector where women predominate.[131]

In 2017, United Nations High Commissioner for Refugees (UNHCR) trained refugees in the Mahama camp in Rwanda and employed them in the construction and installation of two solar mini grids and solar streetlights and, later, also as technicians to provide maintenance service for the solar lighting systems.[132]

126 Zena Ali Ahmad, 2023.
127 UNDP, 2020.
128 GOGLA, 2023.
129 ESMAP, 2022b.
130 ILO, 2021.
131 Al Nawas, 2020.
132 UNHCR, 2020.

6. Conclusion

FCS are characterised by conflict, weak institutions, risky business environments, and fragmented societies. In turn, fragility and conflict adversely affect development, including progress in energy access, and the absence of development perpetuates fragility.[133] Electricity access is critical because it acts as an enabler for other development goals: it allows children to study for longer in the evenings, health care centres to have refrigeration facilities to store medicines and vaccines, and can save women time from time-consuming daily household chores such as grinding flour. Where electricity is available in FCS, low consumer ability to pay for electricity and poor quality of electricity services hinder sustainable livelihoods and firm growth, keeping energy demand and energy consumption low.

Cost reductions and technological advancements in solar mini grid solutions have presented an opportunity to expand energy access in FCS in situations where expansion of the national grid would be prohibitively expensive or susceptible to damage. These developments require investment, however, which necessitates improvements in supply-side factors, such as economic growth, ease of doing business, effective regulations, and lower risks – considerations which determine whether developers and investors of solar mini grids will decide to enter FCS markets. Solar mini grids depend on well-functioning supply chains for movement of equipment and end-user appliances (household and productive use), as well as for maintenance, repair, and replacement of equipment and appliances. Developing a solar mini grid sector also requires having labour with the requisite skills and expertise, as well as investments in complementary sectors that enable scale-up of the solar mini grid sector, including transport infrastructure, financial inclusion, and digital technologies.

This policy toolkit is targeted towards policymakers in FCS with the objective of providing guidance on understanding and improving supply-side factors needed to support investments in solar mini grid deployment in FCS. The information contained in this policy toolkit may also be useful for policymakers in countries that are transitioning out of fragility and conflict and in the process of building, or rebuilding, energy infrastructure. It highlights the challenges that FCS face when these supply-side factors are limited or are absent, and possible interventions that should be included in policies and implementation plans to address these gaps.

The policy recommendations presented in the next section have been determined through focus on the best-case scenario which, in this case, involves policymakers being able to develop and implement policy with some degree of confidence. In all instances, political economy considerations should be factored in and the policy recommendations should be adapted to the unique circumstances prevalent in the relevant FCS.

133 Council on State Fragility, 2021.

7. Policy recommendations

7.1. Governments

- Establish relevant policies and regulations that enhance the ease of doing business and provide clear guidance for developers to navigate the process of setting up mini grid projects. For instance, the administrative processes for reviewing and approving proposals should be streamlined so timelines are reduced, communication across various government departments involved in electricity provision should be improved, and the roles and responsibilities of the different government departments should be clearly defined.
- Consider building flexibility into relevant policies and regulations by reflecting a range of potential scenarios. For example, it may be feasible to attract private sector actors into more stable parts of a FCS, therefore, polices and regulations should govern this possibility. Where monitoring and enforcement capabilities may be limited, government can consider allowing a more bottom-up approach to electricity service provision (including by encouraging and facilitating activities of local energy providers).[134]
- Government should enable mini grid developers to develop a portfolio of solar mini grid projects, rather than single projects, to enable them to achieve lower costs of electricity provision through economies of scale. Government can support this through establishing procurement processes that enable bundling of sites and streamlining the licensing and permitting that this requires.
- Expanding energy access and ensuring that electricity can have a transformative impact on people's lives requires investment in enabling and complementary sectors such as transport infrastructure, financial inclusion, and digital technologies. This requires governments to make simultaneous investments across a number of sectors, with careful assessment and selection of projects. Governments may draw on financing and technical expertise of development partners where this is available.
- Government should work with development partners and mini grid developers to conduct a capacity needs assessment at the policy, project, and community level, and facilitate capacity building efforts of various actors, including mini grid developers.
- Government should proactively build the capacity of policymakers to effectively design and implement policies and regulations relevant to the solar mini grid sector, including integrating solar mini grids into national electrification plans and setting fair, cost-reflective tariffs.

134 Contributed by Nico Peterschmidt.

- Government technical staff should also proactively build their expertise on emerging technologies in the solar mini grid sector, particularly those that can help with cost reduction, such as geospatial planning tools.

7.2. Development partners

- Development partners should support the establishment and scaling-up of initiatives that can lower CapEx or OpEx costs of mini grid developers operating in FCS, such as providing concessional or grant funding to enable them to enter more hard-to-reach areas and enabling bulk procurement like that achieved by the DART programme.
- FCS generally have constrained financial and human resources and will require financial and technical assistance support from development partners if they are to sufficiently invest in enabling and complementary sectors.
- Development partners can finance capacity needs assessments and capacity building initiatives, ensuring that international experience can be coupled with understanding of country-specific dynamics.

7.3. Mini grid developers

- Based on the findings from a capacity needs assessment, developers can work with government and development partners to develop capacity building training programmes that respond to local needs and are sensitive to the local context, as well as realistic in terms of what can be achieved during a specified period of time. It will be important for the needs of women, young people, displaced people, and other marginalised groups to be specifically taken into consideration with capacity building initiatives.
- Mini grid developers will need to proactively build their expertise on emerging technologies in the solar mini grid sector, particularly those that can help with cost reduction, such as geospatial planning tools.

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Annex: World Bank list of fragile and conflict-affected situations, FY24[135]

Conflict	Institutional and social fragility
Afghanistan	Burundi
Burkina Faso	Chad
Cameroon	Comoros
Central African Republic	Congo, Republic of
Congo, Democratic Republic of	Eritrea
Ethiopia	Guinea-Bissau
Haiti	Kiribati
Iraq	Kosovo
Lebanon	Libya
Mali	Marshall Islands
Mozambique	Micronesia, Federated States of
Myanmar	Papua New Guinea
Niger	Sao Tome and Principe
Nigeria	Solomon Islands
Somalia	Timor-Leste
South Sudan	Tuvalu
Sudan	Venezuela, RB
Syrian Arab Republic	Zimbabwe
Ukraine	
West Bank and Gaza	
Yemen, Republic of	

The above list distinguishes between countries based on the nature of issues faced, using these categories:

- "Countries with high levels of institutional and social fragility, identified based on indicators that measure the quality of policy and institutions, and manifestations of fragility.
- Countries affected by violent conflict, identified based on a threshold number of conflict-related deaths relative to the population."[136]

135 World Bank, 2024.
136 World Bank, 2024.

State Fragility initiative

IGC

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

theigc.org/statefragilityinitiative