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SOLAR
ALLIANCE

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Report on

Roadmap of Solar Energy for Universal Energy Access

Consultation Draft

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वसुधैव कुटुम्बकम्

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PREFACE

As the irreversible effects of climate change become evident for all to see, the world is transitioning towards low carbon energy sources while ensuring that the growing global energy demand needs are met. However, it is important to note that although energy consumption is rising, not everyone is getting access to reliable and affordable energy supply. Access to energy remains a major challenge, particularly in Least developed countries (LDC's). The importance of universal energy access to development and economic goals has been recognised, and energy access is included as one of the UN's Sustainable Development Goals (SDGs), SDG 7. However, despite efforts made thus far, SDG 7's ambitious target to achieve universal energy access by 2030 may not be on track. Progress has been hampered by several challenges, including the complexities of providing last mile access, the mismatch between consumer affordability and supplier financial viability, the unstable socio-political environment in some the countries, the impact of the Covid-19 pandemic, and the effect of recent geopolitical tensions.

The Group of Twenty (G20) comprises of 19 countries (Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Republic of Korea, Mexico, Russia, Saudi Arabia, South Africa, Türkiye, United Kingdom and United States) and the European Union. The G20 members represent around 85% of the global GDP, over 75% of the global trade, and about two-thirds of the world population.

India's G20 Presidency for 2023 has identified various key global issues and priority areas for deliberations. These issues would be taken up through various working groups. Energy Transition Working Group (ETWG) is one such working group deliberating on Energy related issues. "Universal Access to Clean Energy and Just, Affordable, and Inclusive Energy Transition Pathways" is one of the 6 priority areas identified under ETWG. Ministry of Power (MoP) and Ministry of New and Renewable Energy (MNRE), Government of India, are spearheading the deliberations with G20 Countries and the other invited Countries on this priority area.

International Solar Alliance (ISA), as an Inter-Governmental organization headquartered in India, with 115 Countries on board, has been supporting the countries to scale up solar applications. The key focus areas of ISA are to facilitate Energy access, Energy security and Energy transition. The key interventions of ISA include Analytics & Advocacy, Programmatic & Projects implementation support and capacity building. ISA believes in working with partner organizations will have a multiplier effect in scaling solar energy.

ISA is a partner organization to India's G20 Presidency for 2023. This Report has been prepared by ISA in association with MNRE. The objective of this report is look into the current state of Universal Energy Access, a sustainable development Goal (SDG-7), set by UN in 2015. Since solar, it's derivatives and battery storage will play a crucial role in accelerating energy access, this Report analyses the issues and bottlenecks and suggested solar roadmap to accelerate the Universal Energy Access. Looking at the current issues, ISA has been taking various actions. However, these efforts require support from G20 Countries and other partner organization.

International Solar Alliance (ISA) and G20 are uniquely positioned to tackle the energy access challenge. A combination of ISA's technical capabilities and multi-stakeholder platform, and G20's resources and knowledge, can be harnessed to deploy customised interventions that seek to tackle the key issues hampering energy access efforts. These tailormade solutions, deployed appropriately, can help bridge the energy access gap and allow the world to meet the universal energy access target.

The report comprises of 9 main chapters. **Chapter 1** highlights the current status of energy access around the world, the challenges to achieving universal energy access, the technology options for expanding access (including grid extension, mini grids, and Distributed Renewable Energy (DRE) systems), and the potential of using solar technologies as an enabler. **Chapter 2** showcases the evolving market for clean cooking solutions, the various emerging business models, and the challenges preventing scale up. The chapter also highlights how solar based solutions can be leveraged to provide clean cooking access. **Chapter 3** provides an overview of grid expansion, including the components required for grid expansion, investments made in electricity networks, and factors affecting the grid extension decision. **Chapter 4** showcases the common business models used to deploy mini grids and DRE systems for electricity access and presents select case studies highlighting successful deployments. **Chapter 5** provides detailed techno-commercial analysis of mini-grid deployment and comparison of cost economics with grid extension, identifies key drivers for improving viability and assesses the potential positive impact of mini-grids on the entire ecosystem, especially for the communities. **Chapter 6** identifies the key gaps in the current approaches used to provide energy access while providing an assessment of the current ecosystem across important parameters (policy and regulatory, financial viability, quality and standards and capacity building etc.). Based on the identified gaps, Chapter 6 also includes a country assessment framework to identify common groups of countries having similar needs, in terms of ecosystem development for facilitating mini-grid deployment. **Chapter 7** showcases the key initiatives taken by India to provide electricity access and identifies relevant learnings that can be leveraged by energy access deficit nations. **Chapter 8** highlights the existing initiatives undertaken by ISA, and their relevance to helping address the energy access situation. **Chapter 9** concludes the findings by providing specific and tailormade interventions that can be deployed by ISA and G20 to help mitigate the identified gaps and improve the energy access situation.

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EXECUTIVE SUMMARY

As a major intergovernmental forum, the G20 drives international cooperation on economic issues. The G20's focus areas also include key global issues including trade, sustainable development, energy, environment, climate change, and more. In recent years, the irreversible effects of climate change have necessitated a green energy transition using low-carbon energy technologies and energy efficiency to meet increasing energy demand. The ETWG under India's G20 presidency in 2023 is working on a number of priority areas related to the energy transition. Of these, access to energy is essential to address as it sits at the intersection of energy transition and economic development. The ETWG is chaired by the Ministry of Power in collaboration with the Ministry of New and Renewable Energy. These ministries are working with intergovernmental organisations like ISA to drive energy access improvements.

Access to energy remains a major challenge, particularly in developing and conflict-affected regions. The global share of the population without access to electricity was 9% in 2020 i.e., 733 million. **At the current growth rate of energy access, 670 million people may still not have access to electricity by 2030**, i.e., about 8% of the global population. Additionally, only 69% of the world's population in 2020 had clean cooking access, and current progress rates will leave over 500 million people without access by 2030. The energy access challenge is more acute in developing countries and regions, particularly Sub-Saharan Africa and in rural areas. **As it stands, the target of universal energy access by 2030 developed under SDG 7 will not be met.** The green energy transition will remain incomplete if SDG 7's goal to "ensure access to affordable, reliable, sustainable and modern energy for all" is not achieved.

The current inability to provide universal energy access also has ramifications for global socio-economic development. Energy access is closely linked with job creation, increased income, reduced air pollution, and access to educational and health institutions. Additionally, access to clean energy, and particularly clean cooking, has a marked gender specific benefit, reducing time spent by women on household chores and increasing productive hours available for other activities. **The socio-economic and gender specific impact of not achieving universal energy access will be felt by the most vulnerable populations around the globe.**

The typical approach to electrification has been to extend the grid to all regions, regardless of regional characteristics. However, since such projects are often time-consuming and expensive, many countries have been developing stopgap solutions for electrification. However, a sustainable option is now available. **Solar combined with battery storage is emerging as the best energy choice** for electrification due to its technical maturity, affordable cost, modularity and flexibility, localized generation, bankability, and climate and social benefits. Different solar options can be deployed to address energy access challenges in different situations. Electricity access in grid connected urban/semi-urban areas can be improved through ground mounted solar and rooftop solar deployment. However, **electricity access in rural and remote regions are best addressed through small, localized off-grid solutions, such as mini-grids, Solar Home Lighting systems, and other DRE systems.** Additionally, integrating solar PV clean cooking with solar electrification solutions can help accelerate efforts to achieve clean cooking access.

Although the technology solutions needed to achieve energy access are available, there are a number of challenges that need to be addressed in order to sustainably scale up their deployment. These can be categorised under three main areas:

- **Policies and Regulations:** The development of energy access initiatives is built on the bedrock of having a robust policy and regulatory environment in place, which is conducive for the growth of this sector. Although countries are recognizing the need for enabling policies for energy access, the overall progress remains low. As a result, the private sector participants and local entrepreneurs are not motivated for participating in energy access projects. **Adequate policy provisions can help create an enabling environment for energy access initiatives and promote private sector participation.**

- **Access to affordable finance:** A significant share of the energy access deficit population is located in remote and underdeveloped regions and struggle to afford electricity even if the access is provided. As a result, governments and utilities in energy-deficit countries bear the financial burden of subsidies to provide its access. The high financial risks in such countries also increase project costs for developers. **Matching consumer affordability with supplier viability through a combination of risk mitigation measures and targeted concessional financing is crucial to improve the energy access situation.**
- **Training and Capacity Building:** Key stakeholders in energy access deficit countries, including government bodies, policy makers, financial institutions, banks, and project developers, often lack the technical and financial expertise to drive electrification initiatives. The rural and remote nature of most access deficit populations requires on ground skill development activities, sharing of global best practices, and initiatives to support local entrepreneurs in developing, operating, and maintaining energy access projects. **Thus, there is a strong need for training, capacity building, entrepreneurial support, and awareness creation measures in energy access deficit countries.**

Current energy access measures are not sustainable and are heavily dependent on grant support by governments and international development agencies. Additionally, financing needs to be provided at scale. Current annual clean cooking finance committed is a fraction of the forecasted annual cost of achieving universal clean cooking access by 2030. **Suitably addressing these challenges can drive the development of sustainable business models for energy access, which in turn can attract private sector investment.** Private sector involvement will be a key enabler to sustainably scale up energy access measures, while ensuring the socio-economic development of energy deficit populations and countries.

India has made remarkable progress towards providing its population with access to electricity, with access rates growing from around 50% in the early 1990s to ~100% currently. This growth has been achieved through targeted interventions developed under a robust policy and regulatory framework. India's flexible approach and utilisation of technology for electricity access has been supplemented by private sector business models. Several electricity access initiatives have been spearheaded by solar energy, providing sustainable electricity in remote and rural regions. The learnings from such interventions can help design tailored initiatives for access deficit countries. The Indian ministries' experience of supporting access initiatives combined with the sustainable business models deployed by the private sector can be leveraged to support access deficit countries.

With its significant technical and financial capabilities, the G20 is well positioned to help create a supportive ecosystem for global energy access initiatives, particularly in the worst affected countries. The G20 support can be directed through related intergovernmental development organisations, including ISA. ISA has been supporting their member countries through various programmes covering entire gamut of solar solutions. Support can be targeted for activities in LDCs and other regions that are worst affected by lack of energy access. **G20's policy and regulatory implementation experience, technical knowledge, and financial support can be channelled through existing initiatives such as ISA's Global Solar Facility, ISA SolarX Startup Challenge for entrepreneurial support, and Solar Technology Application Resource Centre (STAR-C) for capacity building** to catapult the unelectrified population towards achieving universal energy access by 2030.

1. Universal Energy Access and Solar

The irreversible effects of climate change have been evident for all to see in recent years, with natural disasters including floods, storms, droughts, and heat waves striking all around the world. The 2021 Intergovernmental Panel on Climate Change (IPCC) Report found that average global temperature is expected to reach or exceed 1.5 degrees Celsius of warming from a 1850-1900 temperature baseline over the next 20 years. Anthropogenic global warming is a reality, and urgently needs to be addressed to prevent deleterious impact on the global ecosystem. The world is responding by driving a transition to low carbon sources of energy.

Curtailing emissions remains the foremost target as countries adopt measures to meet their respective Nationally Determined Contributions (NDCs) commitments. Global peaking, and subsequent reduction, of emissions in the coming years will be crucial for achieving the temperature targets of the Paris Agreement, but the scale and pace of current mitigation action remains insufficient. As per IRENA estimates, approximately two-thirds of global greenhouse gas emissions (GHG) originate from energy production and use, and thus any efforts to mitigate climate change impacts must include the energy sector. It is estimated that, in a Business-as-usual scenario, CO_2 emissions from energy use will fall by only around 10% by 2050.[1]

As this energy transition takes place, it is important to note that global energy demand and consumption have continued to rise. Global primary energy consumption has grown by ~14% since 2011 to reach 595.15 Exajoules (EJ) in 2021.[2] This energy consumption is not expected to peak in the coming years, as continued economic growth drives demand for energy.

However, it is important to note that although energy consumption is rising, not everyone is getting proper access to reliable and affordable energy supply. Access to energy remains a major challenge, particularly in developing and conflict affected regions. It is difficult to imagine life without a reliable energy supply, but for hundreds of millions of people around the world, this remains a harsh reality to this day.

Access to a clean and reliable energy supply can allow a community to reduce human labor requirements, improve comfort, and provide access to previously unavailable amenities such as telecommunications, education, and healthcare. Lighting systems can extend useful working hours in a day. Access to energy and clean cooking also has a marked gender specific benefit, supporting women and girls who would otherwise spend time gathering cooking fuel and exposing themselves to smoke from cookstoves. Energy access also improves productivity and can promote economic activity through powering income generating or enhancing machines, resulting in job creation and income supplementation.

From job creation to economic development, from security concerns to the full empowerment of women, energy lies at the heart of the Sustainable Development Goals (SDGs) - agreed to by the world's leaders in September 2015 as part of the 2030 Agenda. The United Nations (UN) SDGs include SDG 7 to cover energy access. SDG 7 aims to ensure access to affordable, reliable, sustainable, and modern energy for all. SDG has several targets and indicators, including:

- Improving access to energy services
- Increasing the share of renewables in the global energy mix
- Doubling the global rate of improvement in energy efficiency

[1] BP Energy Outlook 2022
[2] BP Statistical Review of World Energy 2022

- Enhancing international cooperation to facilitate relevant research and technology development
- Expanding infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries

Table 1: Targets and Indicators under SDG 7

S. No.	Target	Indicator (s)
7.1	By 2030, ensure universal access to affordable, reliable, and modern energy services	7.1.1: Proportion of population with access to electricity 7.1.2: Proportion of population with primary reliance on clean fuels and technology
7.2	By 2030, increase substantially the share of renewable energy in the global energy mix	7.2.1: Renewable energy share in the total final energy consumption
7.3	By 2030, double the global rate of improvement in energy efficiency	7.3.1: Energy intensity measured in terms of primary energy and GDP
7.a	By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology	7.a.1: International financial flows to developing countries in support of clean energy research and development and renewable energy production, including in hybrid systems
7.b	By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support	7.b.1: Installed renewable energy-generating capacity in developing countries (in watts per capita)

Source: United Nations Department of Economic and Social Affairs: Sustainable Development

There is no single internationally adopted definition of energy access, but most definitions typically involve some common aspects: household access to a minimum level of electricity, household access to safer and more sustainable cooking fuels and stoves, access to modern energy for productive economic activities, and access to modern energy for public services.[3] While there are many different sources of energy, energy access is typically focused on two major elements: access to electricity and access to clean cooking sources. Electricity is a key aspect of modern energy supply and can serve as a proxy for the level of development and wealth in a country. Additionally, electricity is also the key enabler to allow populations to

[3] https://www.iea.org/articles/defining-energy-access-2020-methodology

access the amenities mentioned above. Thus, measuring the degree of electrification of a region can allow us to gauge its level of modern energy access. Similarly, access to safer and more sustainable sources of energy for cooking are also an important way to measure access to clean and modern energy.

While its benefits to a population are clear, it can be complicated to gauge access to energy, and it cannot be easily simplified into a binary question of whether a particular population does or does not have access to energy. Simply measuring whether someone has access to energy does not provide a complete view of the quality of the access. There are several additional facets to consider for a holistic view, including adequacy of supply, availability, reliability, convenience, affordability, safety, and more. By taking all these factors into account, we can get a more nuanced view on the level of energy access a particular population enjoys.

To address this challenge, The Energy Sector Management Assistance Program (ESMAP) launched the Multi-Tier Framework (MTF) initiative in 2015 to redefine the way energy access is measured. Under this initiative, several frameworks were devised to measure access to electricity and clean cooking solutions, access to space heating, access to productive applications of energy, and access to street lighting. A separate matrix was also developed to measure access levels in community infrastructure.

Under the MTF initiative, electricity access is measured based on the combination of seven key parameters. These key parameters are used to define six tiers of access by defining the minimum requirements to achieve each tier. The lowest access tier, Tier 1, refers to limited electricity quantity available for a few hours per day. Higher tiers have subsequently higher capacity and greater duration of supply, allowing for the operation of appliances and machineries with higher loads. The multi-tier framework for measuring access to electricity is shown below:

Figure 1: Multi-Tier Framework for measuring access to electricity and description of various tiers of electricity access

Attributes		Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Capacity	**Power Capacity Ratings (W or daily Wh)**	Less than 3 W Less than 12 Wh	Atleast 3 W Atleast 12 Wh	Atleast 50 W Atleast 200 Wh	Atleast 200 W Atleast 1 kWh	Atleast 800 W Atleast 3.4 kWh	Atleast 2 kW Atleast 8.2 kWh
	Services		Lighting of 1000 lmhr per day	Electrical lighting, air circulation, television, and phone charging are possible			
Availability	**Daily Availability**	Less than 4 hours	Atleast 4 hours		Atleast 8 hours	Atleast 16 hours	Atleast 23 hours
	Evening Availability	Less than 1 hour	Atleast 1 hour	Atleast 2 hours	Atleast 3 hours	Atleast 4 hours	
Reliability		More than 14 disruptions per week			At most 14 disruptions per week or at most 3 disruptions per week with total duration of more than 2 hours	>3 - 14 disruptions per week or >=3 disruptions per week with >2 hours of outage	At most 3 disruptions per week with total duration of less than 2 hours
Quality		Household experiences voltage problems that damage appliances				Voltage problems do not affect the use of desired appliances	
Affordability		Cost of a standard consumption package of 365 kWh per year is more than 5% of household income			Cost of a standard consumption package of 365 kWh per year is less than 5% of household income		
Formality		No bill payments made for the use of electricity				Bill is paid to the utility, prepaid card seller, or authorised representative	
Health and Safety		Serious or fatal accidents due to electricity connection				Absence of past accidents	

Tier 0	Tier 1	Tier 2
Electricity is not available or is available for less than 4 hours per day (or less than 1 hour per evening). Households cope with the situation by using candles, kerosene lamps, or dry-cell-battery-powered devices (flashlight or radio).	At least 4 hours of electricity per day is available (including at least 1 hour per evening), and capacity is sufficient to power task lighting and phone charging or a radio. Sources that can be used to meet these requirements include a SLS, a solar home system (SHS), a minigrid (a small-scale and isolated distribution network that provides electricity to local communities or a group of households), and the national grid.	At least 4 hours of electricity per day is available (including at least 2 hours per evening), and capacity is sufficient to power low-load appliances—such as multiple lights, a television, or a fan (see table 1)—as needed during that time. Sources that can be used to meet these requirements include rechargeable batteries, an SHS, a mini-grid, and the national grid.

Tier 3	Tier 4	Tier 5
At least 8 hours of electricity per day is available (including at least 3 hours per evening), and capacity is sufficient to power medium-load appliances—such as a refrigerator, freezer, food processor, water pump, rice cooker, or air cooler (see table 1)—as needed during that time. In addition, the household can afford a basic consumption package of 365 kWh per year. Sources that can be used to meet these requirements include an SHS, a generator, a mini-grid, and the national grid.	At least 16 hours of electricity per day is available (including 4 hours per evening), and capacity is sufficient to power high-load appliances—such as a washing machine, iron, hair dryer, toaster, and microwave (see table 1)—as needed during that time. There are no frequent or long unscheduled interruptions, and the supply is safe. The grid connection is legal, and there are no voltage issues. Sources that can be used to meet these requirements include diesel-based mini-grids and the national grid.	At least 23 hours of electricity per day is available (including 4 hours per evening), and capacity is sufficient to power very high– load appliances—such as an air conditioner, space heater, vacuum cleaner, or electric cooker (see table 1)—as needed during that time. The most likely source

Source: Bhatia and Angelou (2015)

A Multi-Tier Framework for measuring access to cooking solutions has also been proposed in a similar fashion. The design of MTF consist of two technical attributes, cooking exposure and cookstove efficiency, and four contextual attributes, convenience, fuel availability, safety and affordability, which capture the user's cooking experience. The multi-tier framework for measuring access to clean cooking is shown below:

Table 2: Multi-tier framework for clean cooking

Attributes	Measuring Indicators	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Cooking Exposure	ISO's voluntary performance targets (Default Ventilation) PM2.5 (mg/MJd) CO (g/MJd)	>1030 >18.3	£1030 £18.3	£481 £11.5	£218 £7.2	£62 £4.4	£5 £3
	High Ventilation PM2.5 (mg/MJd) CO (g/MJd)	>1489 >26.9	£1489 £26.9	£733 £16.0	£321 £10.3	£92 £6.2	£7 £4.4
	Low Ventilation PM2.5 (mg/MJd) CO (g/MJd)	>550 >9.9	£550 £9.9	£252 £5.5	£115 £3.7	£32 £2.2	£2 £1.4

Attributes	Measuring Indicators	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Cookstove Efficiency	ISO's voluntary performance targets	£10%	>10	>20%	>30%	>40%	>50%
Convenience	Fuel acquisition and preparation time (hours/ week)	≥7		<7	<3	<1.5	<0.5
	Stove preparation time (minutes per meal)	≥10			<10	<5	<2
Safety	Severity of accidents caused by the stove over the past year	Serious			Minor	None	
Affordability	Fuel cost as a share of household expenditure (%)	≥10			<10	<10	
Fuel availability	Ready availability of primary fuel when needed (% of the year)	£80			>80	>90	100

Source: World Bank

The clean cooking MTF assists in identifying and analyzing the main reasons why households do not use modern clean cooking fuels and technologies, such as capacity, reliability, or affordability difficulties. However, the impact of constraints, such as reliability and affordability of fuels, vary according to region. MTF also act as a tool to suggest a set of solutions to eliminate these constraints.

The six attributes of the MTF are used to define six tiers of access by defining the minimum requirements for each tier The lowest access tier, Tier 0, refers to households having no access to modern cooking or heating technologies, and which rely on traditional biomass fuels such as firewood, charcoal, or agricultural waste. A household meeting Tier 2 or 3 cooking practices is considered as being in transition towards using improved cooking services. **A household can be considered to have gained access to modern energy cooking services if it scores on Tier 4 or above on all six attributes of the MTF for cooking.**

Providing access to affordable, reliable, sustainable, and modern energy to all is a key developmental goal since energy access has a knock-on impact on other important developmental indicators, including health, education, and gender equality.

High Level Dialogue on Energy (HLDE) and Global Energy Compact Network

The importance of achieving SDG 7 has been recognized at the highest level. In 2021, the UN held a High Level Dialogue on Energy (HLDE), which was the first UN General Assembly summit-level event on energy in 40 years. The event resulted in the development of a Global Roadmap for Accelerated SDG 7 Action, containing two sets of SDG 7 related milestones for 2025 and 2030. The event also resulted in USD 400 billion in pledges, known as 'Energy Compacts'. A subsequent event in May 2022 revealed that there are now over 200 Energy Compacts with over USD 600 billion in funding and investment. These Energy Compacts are aligned with the SDG 7 aim to ensure clean and affordable energy for all by 2030 and the Paris Agreement's goal to reach net zero emissions by 2050.

1.1 Current Global Energy Access Scenario

Significant progress has been made across the various energy access related targets under SDG 7. The various targets under SDG 7 track a wide range of relevant indicators, allowing for a holistic overview of the global scenario with respect to energy access. The governments across the globe have recognized the significant importance of expanding energy access. This is reflected in their respective NDC commitments. 11% of energy supply measures committed under the NDCs were identified to be contributing to achieving SDG 7. This has also resulted in significant gains in energy access in the last decade or so. Several hundred million more people have gained access to electricity and clean cooking sources. Primary energy intensity has reduced whereas the share of renewables in global final energy consumption has also increased. Despite some progress, the world is still not on track to achieve universal energy access by 2030. The ramifications of this can be far ranging as without universal energy coverage, countries as well as communities will not enjoy equal economic opportunities thereby impacting the global economic growth and hindering the sustainable development agenda. The table/graphic below showcases the progress made for various targets enshrined under SDG 7:

Table 3: Key Targets and indicators for Energy Access

Target	Indicator	Value in 2010	Value as of latest year	Progress
By 2030, ensure universal access to affordable, reliable, and modern energy services	Proportion of population with access to electricity	**1.2 billion** people without access to electricity	**733 million** people without access to electricity (2020)	Not on Track
	Proportion of population with primary reliance on clean fuels and technology for cooking	**3 billion** people without access to clean cooking	**2.4 billion** people without access to clean cooking (2020)	Not on Track
By 2030, increase substantially the share of renewable energy in the global energy mix	Renewable energy share in total final energy consumption	**16.1%** share of total final energy consumption from renewables	**17.7%** share of total final energy consumption from renewables (2019)	Not on Track
By 2030, double the global rate of improvement in energy efficiency	Energy intensity measured as a ratio of primary	**5.6 MJ/USD** primary energy intensity	**4.7 MJ/USD** primary energy intensity (2019)	Not on Track
By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel	International financial flows to developing countries in support of clean energy research and development and renewable energy	**11.2 USD billion** international financial flows to developing countries in support of clean energy	**10.9 USD billion** international financial flows to developing countries in support of clean energy (2019)	Not on Track

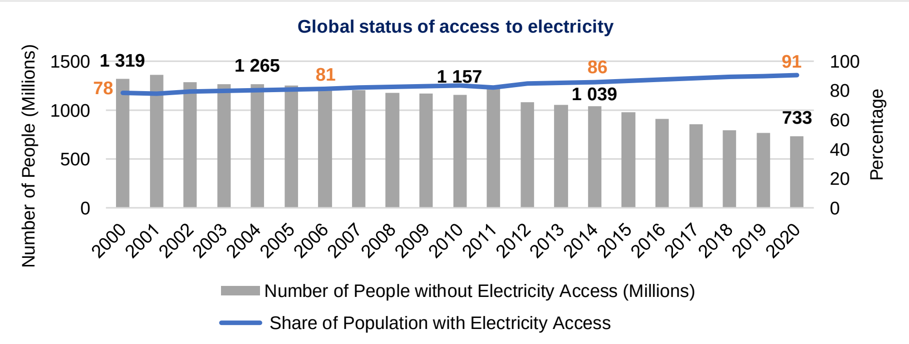
Target	Indicator	Value in 2010	Value as of latest year	Progress
technology, and promote investment in energy infrastructure and clean energy technology				

Source: Tracking SDG7: The Energy Progress Report 2022, IEA

1.1.1 Access to electricity

Although there is a long way to go to achieve universal electricity access, the world has made significant progress on this metric. **The global share of population with access to electricity has grown from 78% in 2000 to 91% in 2020**. This corresponds to around 585 million people receiving electricity access over this period of time.

Figure 2: World Status of access to electricity

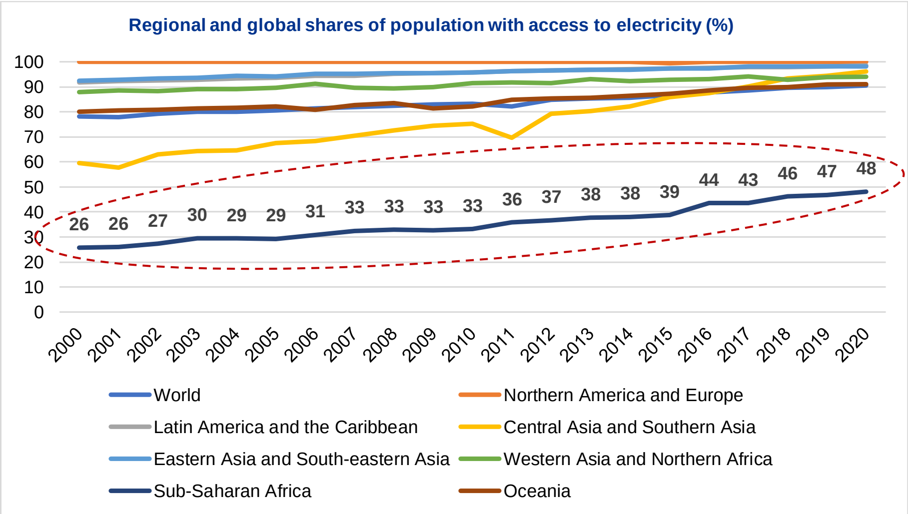


Source: World Bank: ESMAP

Global access to electricity is still not uniform. As seen in the chart below, almost all regions around the world have seen a steady improvement in access to electricity over the last 2 decades. However, Sub-Saharan Africa lags significantly behind the rest of the world. **Less than 50% of the Sub-Saharan population had access to electricity in 2020, up from 33% in 2010, and just 26% in 2000**. Among people without access to electricity, 77 percent—about 568 million people—lived in Sub-Saharan Africa in 2020.[4]

[4] Tracking SDG7: The Energy Progress Report 2022, IEA

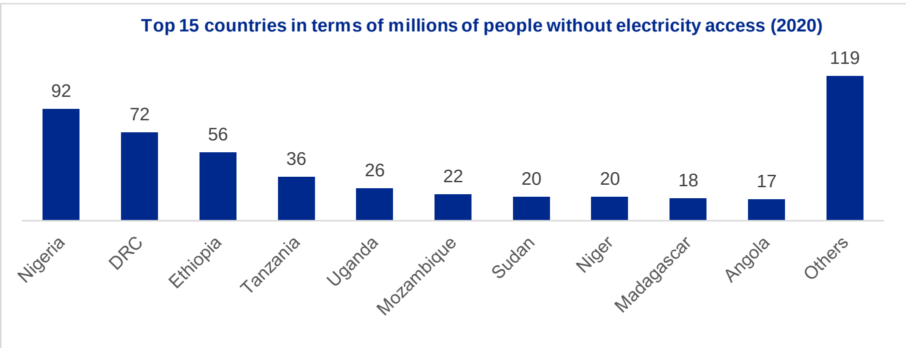
Figure 3: Regional and global shares of population with access to electricity (%)



Source: World Bank: ESMAP

The 15 countries with the largest access deficits were home to around 68% of the entire global population living without access to electricity in 2020. Closing the access gap by 2030 hangs on electrification efforts in these countries. 15 out of the top 20 were in Sub-Saharan Africa. The largest unserved populations are in Nigeria (92 million people), the Democratic Republic of Congo (72 million), and Ethiopia (56 million). 12 out of the top 15 access deficit countries are Least Developed Countries (LDCs), 8 are classified as fragile or conflict affected, and 7 are classified as both.

Figure 4: Top 15 countries with electricity access deficit



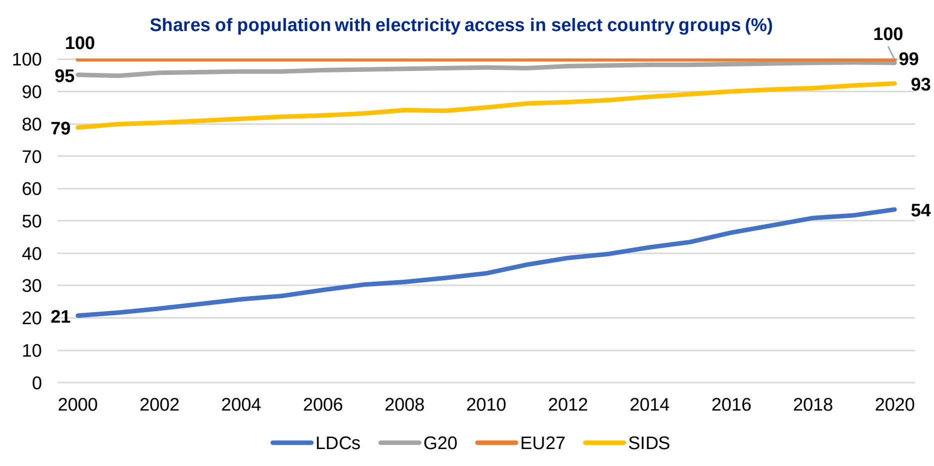
Source: Tracking SDG7: The Energy Progress Report 2022, IEA[5]

It is apparent that there are significant regional disparities in electricity access, usually due to lack of economic development and troubled geopolitical situations. The correlation with lack of development becomes clearer when studying access to electricity in countries that have been identified as Least Developed Countries (LDCs). These LDCs are defined by the UN as

[5] Top 15 countries include Nigeria, Democratic Republic of Congo, Ethiopia, Pakistan, United Republic of Tanzania, Uganda, Mozambique, Sudan, Niger, Madagascar, Angola, Burkina Faso, Malawi, Myanmar, Kenya

low-income countries confronting severe structural impediments to sustainable development. Although LDCs have seen progress in their electricity access statistics, with access rising from just **21% in 2000 to 54% in 2020**, there is a still a long way to go before universal electricity access is achieved. Small Island Developing States (SIDS) have high access to electricity, but this does not provide a comprehensive view of their energy situation. Electricity demands in SIDS countries are often met through fossil fuel-based sources, which impacts their sustainability and affordability. Thus, there is work to be done for SIDS countries to meet SDG 7 targets. **The G20 and EU27 countries, with high access to electricity and an increasing share of renewables entering their generation mix, are well placed to handhold and provide support to LDCs and SIDS countries as they seek to expand their electricity access situation.**

Figure 5: Shares of population with electricity access in select country groups (%)



Source: World Bank: ESMAP

Indonesia's Energy Access Progress

Indonesia has unique energy access challenges to tackle. The country has an estimated population of over 270 million people. However, the country consists of a large archipelago comprising of more than 17,000 islands. The country's population and economic activity are concentrated on the island of Java, and the country's geography makes economic and infrastructure development in remote provinces particularly challenging. In 1995, Indonesia had an electricity access rate of around 67%.

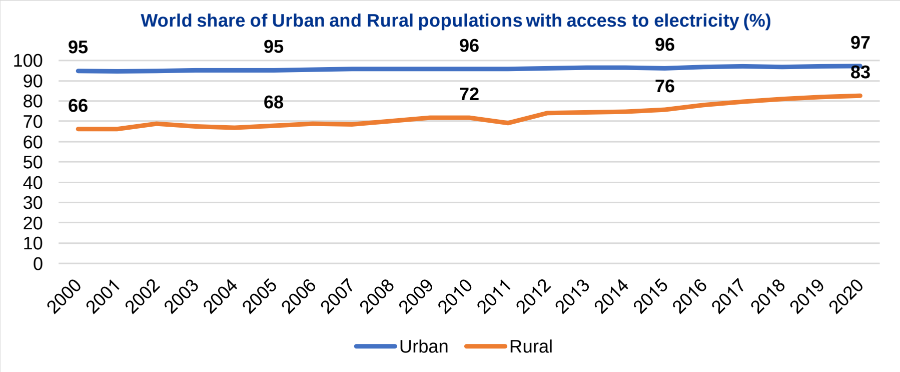
Indonesia has since made rapid progress in electricity access, reaching ~96% by 2020. This improvement in access has been driven by a strong policy focus and commitment from the government. The national electric utility, for example, connected nearly 4 million consumers in 2013 alone. The country's 2014 National Energy Policy targeted approaching 100% electrification by 2020 and is supported by a robust policy framework. Law 30/2009 on Electricity states that electricity supply is the responsibility of the central and regional governments. They are obliged to provide funding for electricity supply to disadvantaged communities, development of electricity infrastructure in remote, undeveloped, and border regions, and for rural electrification.

Although initial electrification progress was achieved through grid expansion, future electrification efforts in remote regions may require a different approach for last mile access. Micro grids and individual solar home systems are being deployed to meet access needs. In 2021, the country recruited 23 "Energy Patriots" along with UNDP in order to install solar panels on certain remote islands. The country has already installed over 1000 mini grids supported by central government and donor agencies, with over 650 more installed by regional governments. Thus, the country is well placed to understand the access challenges faced by LDCs and provide guidance to help them improve their energy access situation.

Source: ADB, UNDP, Minigrids.org

The trend of disparate levels of energy access is also observed when comparing urban and rural populations around the world. Rural populations have consistently lower access to electricity than urban centres. **Although the world's share of rural population with electricity access has grown from 72% in 2010 to 83% in 2020, it is significantly behind urban population (96%-97%) over the last decade**. The lack of electricity access for rural populations limits their ability to access healthcare, education, and equipment to improve their livelihoods.

Figure 6: World Share of Urban and Rural populations with access to electricity (%)

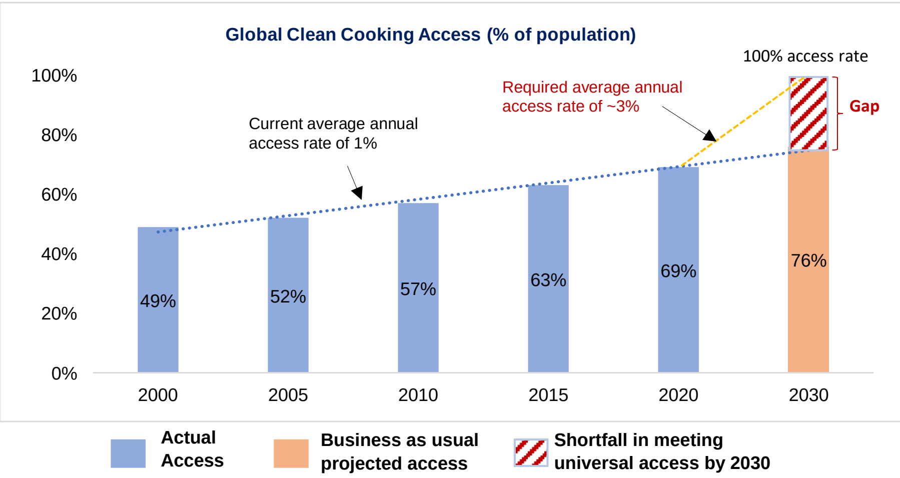


Source: World Bank: ESMAP

1.1.2 Access to clean cooking

Globally, the number of people with access to clean cooking has increased significantly but is still a long way off from achieving the universal clean cooking access scenario. **The share of global population with access to clean cooking has increased, at an average annual rate of 1%, from 49% in 2000 to 69% in 2020.**

Figure 7: Percentage of global population with access to clean cooking



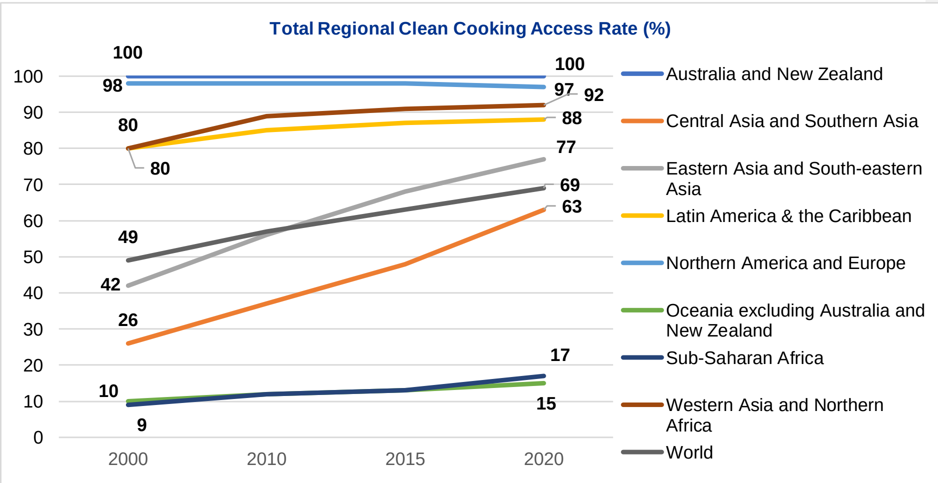
Source: SDG7 tracking report 2022

Despite these advances, only about 76% of the population is expected to have access to clean cooking fuels and technologies by 2030. **To meet the 2030 goal of 100% access to clean cooking fuel and technology, it is essential to boost the access rate by 3% annually,**

assuming 2020 as base year, otherwise over half a billion people would be left without access to clean cooking solutions.

During the past decade, the increase in percentage of people with access to clean cooking fuels and technologies was driven almost entirely by growth in the most populous and significant countries in Asia, such as India and China.[6]

Figure 8: Total Regional Clean Cooking Access Rate (%)



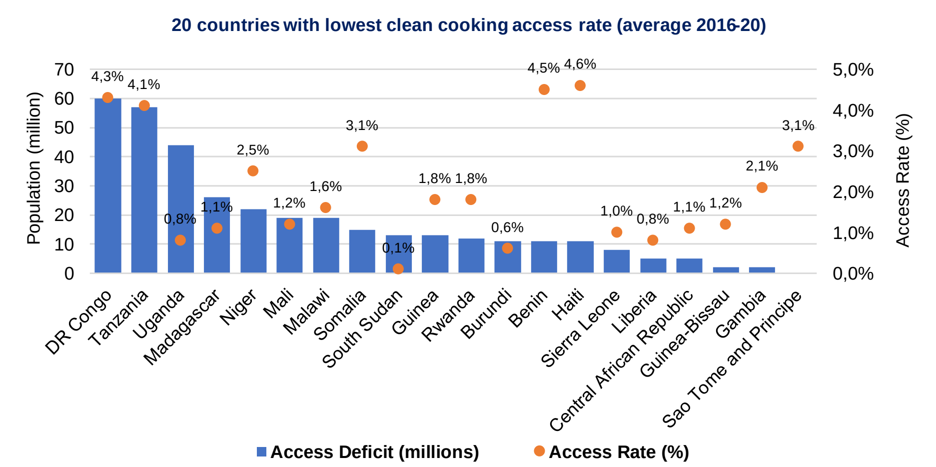
Source: World Bank: ESMAP

Clean cooking access improvements have occurred in Eastern Asia and South-eastern Asia since 2000 and in Central Asia and Southern Asia since 2010. In contrast, Sub-Sharan Africa and Oceania, excluding Australia and New Zealand, are the regions with lowest access rate. There have been significant gains made in improving access to clean cooking sources. particularly in the Sub-Saharan Africa, but these gains have been overshadowed by population growth. **The access deficit in Sub-Saharan Africa has nearly doubled since 1990. It rose by more than 50 percent since 2000, reaching a total of 923 million people in 2020[7]. As a result, only 2 out of every 10 people in Sub-Saharan Africa had access to clean cooking fuels and technologies.[8]**

Nineteen of the world's twenty nations with the lowest access rates to clean cooking are located in Africa, with Haiti being the only exception. With only 0.1% of population having access to clean cooking fuels and technologies, South Sudan has the world's lowest access rate. In none of the 20 countries, the number of people with access to clean cooking fuels and technologies grew by 0.4% between 2016 and 2020.

Figure 9: 20 countries with lowest clean cooking access rates

[6] https://trackingsdg7.esmap.org/data/files/download-documents/sdg7-report2022-full_report.pdf
[7] https://www.iea.org/news/covid-19-slows-progress-toward-universal-energy-access
[8]https://trackingsdg7.esmap.org/data/files/download-documents/sdg7-report2022-ch2-access_to_clean_cooking.pdf

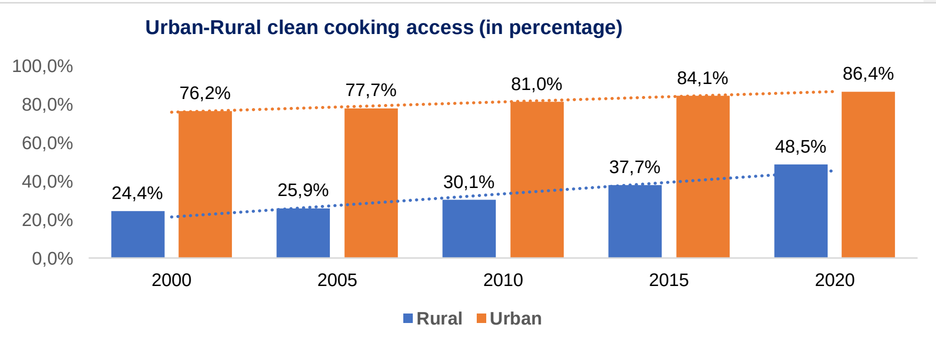


Source: World Health Organisation

With around 355 million people living without access to clean cooking solutions, these 20 countries represent 15% of the worldwide access deficit population. 97% of this population lies in Africa region. Moreover, some countries like Benin, DR Congo, Gambia, Malawi, and Uganda have witnessed negative annualized access rate from 2016 to 2020.

In addition to that there is huge disparity in the access to clean cooking solutions among the urban and rural areas worldwide. The people living in rural areas have significantly lower access to clean cooking fuels and technologies than the people living in urban areas, but the gap has been reducing over the past two decades.

Figure 10: Urban-Rural access to clean cooking



Source: World Bank

In the past decade, the rural areas have shown greater progress than the urban areas, particularly the Central and Southern Asian region with an annual increase of around 3%. However, **in the year 2020, only 48.5% of people living in rural areas had access to clean cooking[9], which means that around 1.7 billion people from the rural areas representing ~73% of total population without access to clean cooking solutions. While having ~86% of urban population with access to clean cooking, the recent decades trends indicates**

[9] https://trackingsdg7.esmap.org/data/files/download-documents/sdg7-report2022-full_report.pdf

that the yearly rise in access rate is dropping and if the trends to follow the urban population with access to clean cooking is anticipated to decline in future.

Key Insights

- Although progress has been made, the world is not on track to meet the ambitious energy access targets set under SDG 7
- With the current growth rate, it is expected that by 2030 about 8% of world population will be left without access to electricity whereas around one-fourth of population would be left without access to clean cooking
- Progress under SDG 7 has not been uniform across various regions, with Sub-Saharan Africa facing severe electricity as well as clean cooking access challenges
- LDCs lag significantly in terms of electricity access, with the average LDC electricity access rate in 2020 standing at 54%
- Around 73% of 2.4 billion people without access to clean cooking resides in rural areas
- Even though urban areas are having 86% of clean cooking access rates, the past trends indicates that the annualized access rate is declining, with probable future projection of decline in access rate

There is still a long way to go before global access to energy is achieved. The annual rate of growth in access has slowed in recent years due to several challenges and complicating factors:

- The challenge of providing energy access to the most remote communities is a complex one that is yet to be comprehensively tackled. The pace of both electrification and clean cooking expansion is limited by the gap between the costs of reliable, quality service delivery, and affordability levels. To close this gap, costs need to decline and consumer willingness to pay (closely linked to affordability) needs to increase.
- Several technology options are available for deployment to provide energy access. However, it is challenging for low-income consumers to pay for these solutions. There is an associated lack of access to finance for the consumers. Aligning consumer affordability with supplier financial viability with respect to energy access in these situations is complex.
- The Covid-19 pandemic reversed years of steady progress in improving energy access.[10]
- The recent geopolitical unrest and the associated increase in fuel, and thus energy, prices around the world have had major ramifications for energy access. Additionally, rising food and commodity prices have also disproportionally impacted vulnerable lower income groups and regions. Around 75 million people who recently gained access to electricity are likely to be unable to pay for it, and 100 million people may revert to traditional biomass for cooking.[11]
- The presence of an unstable political environment in a number of countries with low energy access levels further exacerbates the challenge of providing reliable energy access. Unstable environments increase the risks for private players to enter the market, lead to a policy and regulatory gap, and hamper the energy access efforts of non-state development agencies such as the UN.

[10] https://www.iea.org/commentaries/the-pandemic-continues-to-slow-progress-towards-universal-energy-access
[11] https://www.iea.org/topics/energy-access#energy-access-in-the-world

SDG 7 for ISA and G20

Both the ISA and the G20 have recognized the importance of achieving universal energy access. In 2015, the G20 prepared an Energy Access Action Plan to strengthen collaboration of G20 members on energy access, considering existing initiatives, and adding value through knowledge, experience, and best practice sharing. ISA's goals and vision are fundamentally aligned with SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action), including its focus area of accelerating deployment and reducing costs of solar in developing countries. The focus on these SDGs is also enshrined in ISA's Theory of Change. In 2017, ISA launched its third programme, Scaling Solar Mini Grid, which aimed to cater to the energy needs of ISA member states in identified areas with unreliable or no grids, and in island member states. ISA also conducts capacity building and institutional strengthening to support the deployment of energy access solutions such as solar mini grids and other Solar DRE solutions. ISA also aims to support LDCs and SIDS with technical and financial assistance in setting up solar pilot projects.

1.2 Technologies for expanding energy access

1.2.1 Technologies for electricity access

A number of electrification options are available to ensure universal access to electricity. Typically, electrification has been achieved through grid expansion and the use of standalone diesel generators. However, in the search to provide clean and modern energy, renewable sources have become increasingly attractive for providing electricity access. The various available options for electrification are showcased below:

Grid densification and expansion: This includes reinforcement and upgrading of ageing infrastructure to minimize transmission and distribution losses. This has been the typical approach to electrification and can still be effective when deployed in the right circumstances. The grid connection route is estimated to be the least-cost option for serving 42–57% of the unelectrified population by 2030[12], but does not necessarily guarantee reliable electricity (especially where distribution utilities are weak) or sustainable electricity (especially if power is fossil fuel–based). Nor does it guarantee power system resilience. For instance, Ethiopia, Lesotho, Malawi, and Zambia have energy mixes that are reliant on hydro and are already affected by seasonality and lower water levels (due to climate change). The overreliance on a single power source lowers the national power system's resilience and sustainability. Approaches that incorporate a diverse energy mix, centralized renewable generation, and distributed energy resources, can augment resilience and sustainability.

Standalone Diesel Generators: In places that cannot be reached by grid extensions or are unable to get a steady supply of electricity, standalone diesel generators are generally utilized to generate electricity for use. This generator uses a well-established technology for generation and comes in a variety of sizes depending on output, allowing a degree of customization depending on the size of the load that is to be serviced.

Standalone diesel generators have been a common solution deployed for electrification. However, there are several downsides associated with them. Operating a large generator regularly can require large amounts of diesel, which may be a challenge in remote locations where supply is irregular. Additionally, the fluctuating price of fossil fuels, which has been made especially apparent due to recent global conflicts, can also threaten security of supply. Additionally, combustion of diesel leads to air pollution, which in turn adversely impacts the local environment as well as the health of the local population.

Wind Energy: Wind energy has become an important source of renewable energy, and smaller wind turbines can be deployed to generate electricity at remote locations with sufficient

[12] United Nations Theme Report on Energy Access, 2021

wind speed. Wind energy typically has a greater capacity utilization factor than solar energy. However, it is heavily dependent on location and the available wind speed. Thus, suitable wind speed data is required prior to deployment, and conducting a site assessment becomes crucial before a project can be deployed.

Micro/Pico Hydro: Micro/Pico hydroelectricity plants can be suitable for providing electricity to local communities or industries. Such hydro projects typically require relatively less construction work as compared to large scale hydro power and have little to no reservoir capacity. Such run-of-the-river hydro projects can be suitable for providing electricity access in locations with suitable water supply, and are well suited for deployment in remote, hilly terrain where there is presence of fast flowing rivers.

Biomass/Biogas: Biomass systems utilize organic matter, typically wood and crop residue, to generate electricity. Similarly, biogas systems convert such organic residue in an anaerobic or aerobic process to produce methane that can in turn be burnt as a fuel. Biomass and biogas systems are suitable for rural regions where there may be an abundance of excess organic matter, particularly in farming communities. However, larger scale biomass/biogas systems require development of infrastructure for collection and storage of the organic matter. Additionally, the system may be affected by seasonality of crop residue, and the organic matter to be used as fuel is susceptible to damage if stored improperly.

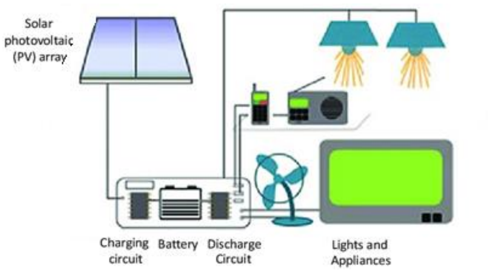
Solar Energy: Solar has become a key technology for generation. The clean electricity generated from solar will be crucial for a successful energy transition. Solar can be deployed in a variety of configurations:

- **Utility Scale and Rooftop Solar:** Solar deployments can be carried out at large scale for utility level deployments but are also suitable for smaller scale deployment on rooftops in urban and semi urban areas. Such solar deployments have seen significant cost reduction over the last few decades due to technology developments and improved access to finance. However, these larger scale deployments may not be ideal for electricity access initiatives that aim to provide electricity to consumers that lack grid access or sufficient access to finance.
- **Decentralized Renewable Energy (DRE) systems:** Distributed Renewable Energy systems can generate energy for the purposes of power, cooking, and operate independently of the central grid. They can operate in isolation or in conjunction to the central grid in both rural and urban areas. They are also responsible for improving the services and operations across all sectors ranging from agriculture to health care.[13] Other DRE systems can be focused on specific applications such as agricultural post-processing, cold storage, irrigation, textile manufacturing, etc. and are usually the DRE-based versions of traditional machinery used in these sectors. Solar Home Systems (SHS) and mini grids are two important forms of DRE utilised for electricity access:

[13] Distributed Renewable Energy for Energy Access, REN21

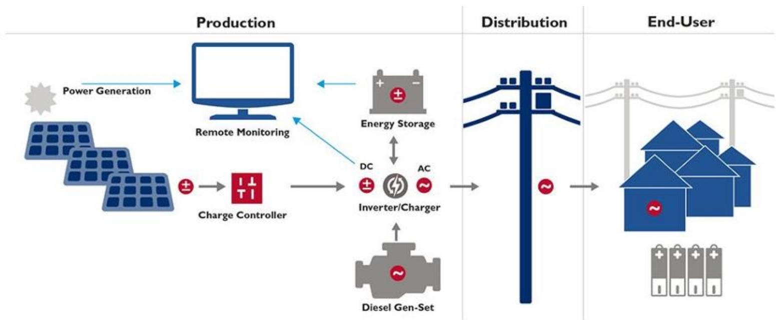
- **Solar Home Systems (SHS):** Solar Home Systems consist of solar panels which charge a battery utilizing the available sunlight and subsequently help power household devices such as LED lamps, phone chargers, small TVs, electric cookers, etc. for three to five hours during the day. The solar power feeds directly into the electric circuit of that household and the energy generated is typically for self-consumption. Stand-alone PV systems have also been used to provide electricity for primary health centers for their lighting needs along with the refrigeration for vaccines and medicines.[14]

Figure 11: Schematic of a Solar Home System



- **Mini grids:** Mini grids typically comprise of three components – (a) decentralized RE-based electricity generator (with capacity of 10KW and above) (b) public distribution network, and (c) target set of consumers (residential, commercial, productive, industrial, and institutional setups, etc.).[15] If the system has a total load of less than 100 kVA and is supplied by micropower systems or stations, it is typically referred to as a microgrid. These microgrids may be powered either by fossil fuels or renewable energy.[16] Mini grids can be designed to operate on either Alternating Current or Direct Current (AC or DC). The design influences the project cost, type of suitable appliances, and type of interconnection. DC mini grids are usually used for smaller geographical areas and low power applications like lighting, charging, fans, TVs etc. and are typically not suitable for interconnection with the main grid. AC mini grids can support high power applications (by using single or three phase) and can interconnect with the grid.[17]

Figure 12: Schematic of a Mini Grid



Source: Mini grids and Access to Electricity in SAARC Report

Mini grids can be designed to operate on either Alternating Current or Direct Current (AC or DC). The design influences the project cost, type of suitable appliances, and type of interconnection. DC mini grids are usually used for smaller geographical areas

[14] Solar Home Systems, Energypedia
[15] Mini grids and Access to Electricity in SAARC Report (2021)
[16] IEC TS 61836 Edition 3.0 2016-12
[17] Draft Mini grid Policy (2016), MNRE-India

and low power applications like lighting, charging, fans, TVs etc. and are typically not suitable for interconnection with the main grid. AC mini grids can support high power applications (by using single or three phase) and can interconnect with the grid.[18]

Based on the complexity of the mini grid operation, the World Bank's Energy Assistance Management Program (ESMAP) has created three categories for mini grid classification.[19] The first generation consists of Primitive, isolated, and scattered mini grids built more than a 100 years ago which have since been integrated into the main grid, the second consists of community-built-and-operated, small and isolated systems in rural areas (typically powered by SHP and diesel. The third generation has technically complex systems running on new energy sources, i.e., PV, wind, batteries, etc. and utilising diverse business models. Due to the increased reliability of the third-generation mini grids, communities have begun implementing revenue-generating activities using the electricity from the mini grids to operate productive end-use appliances. This brings down costs of electricity and improves the sustainability of the system, which in turn improves the financial viability for the project developer operating the grid.

DRE can play a vital role in expanding access, especially in rural areas. Distributed renewable energy solutions are playing a growing role in expanding electricity access in off-grid areas and strengthening supply in already connected areas, especially in developing regions. In the off-grid context, renewables-based stand-alone systems (e.g., solar lights, home systems) and mini-grids have spread recently due to technology improvements, cost reductions, and certain improvements in policy and regulatory environments. At the same time, grid-interactive distributed renewables are also increasingly being considered to raise the quality and reliability of supply in connected areas, particularly for commercial and industrial consumers.

1.2.2 Technologies for clean cooking access

Access to cooking facilities comprises both fuel and technology as necessary components. Fuels are the sources of heat or energy necessary for cooking food. Firewood, kerosene, charcoal, pellets, biogas, Liquified Petroleum Gas (LPG), natural gas, ethanol, electricity, and solar power are some of the commonly used fuels to cook. Cooking technologies are effectively cook stove technologies that are used to burn the fuels for cooking. There are many different kinds of cook stoves, and each one has its own features. The table below highlights the combination of various cooking fuels and technologies that used are commonly used worldwide.

Table 4: Cooking fuels and technology mix

Fuel	Cooking Technology
Firewood	— Openfire — Three stone stove — Traditional mud-stoves — Improved cook stoves
Kerosene	— Kerosene Burner
Charcoal	— Traditional charcoal stoves — Improved cook stoves
Pellets	— Improved cook stoves

[18] Draft Mini grid Policy (2016), MNRE-India
[19] State of the Global Mini grids Market Report (2020), BNEF

	— Gasification stoves
Ethanol	— Ethanol Burner
Biogas	— Biogas burner
LPG	— Gas burner
Electricity	— Hot Plate cook stove — Induction cook stove
Solar Power	— Solar-Thermal cooking (box type, parabolic, etc.) — Solar PV cooking (induction, hot plate, etc.)

Formerly, rural-centered efforts to promote clean fuels and technology consisted mostly of distributing improved cook stoves (ICS). The primary objective of the ICS is to burn the fuels more efficiently, which in turn reduces fuel consumption and air pollution. The ICS can be used with a variety of solid biofuels, including firewood, charcoal mass, and pellets, etc. The following table provides an overview of various cooking fuels and technologies as per MTF framework:

Table 5: Clean cooking fuels and technologies

Cooking Fuel and Technology	MTF	Category	Impact
Open fire, three stone stove, or traditional stove with traditional solid fuel (e.g., firewood, charcoal, dung, agriculture residue)	**TIER 0-1**	No Access	Significant negative health, climate, and gender impacts
ICS (e.g., rocket stove, natural draft gasifier with traditional solid fuel, pellets/ briquettes, or kerosene)	**TIER 2-3**	Improved	Good climate and gender equality improvements due to reduced fuel usage. Limited health improvements as indoor air can remain polluted
Modern cooking appliances with clean cooking fuel (e.g., biogas, LPG, ethanol, electricity, solar and natural gas)	**TIER 4-5**	Modern	Negative health, climate and gender impacts are significantly mitigated.

Source: World Bank

1.3 Case for using Solar Energy for achieving Universal Energy Access

While the challenges associated with energy access and the urgent need to tackle them are apparent, it is less straightforward to determine the best way to address the universal energy access challenge. A wide variety of conventional and renewable energy sources are available as options, each with their own unique benefits. However, due to a number of advantages, solar energy is emerging as the most suitable choice to meet energy access needs:

- **Technical maturity:** Solar has seen rapid deployment at scale over the last two decades and is now a mature technology. Global solar capacity crossed the 1 TW mark in 2022 and looks set to continue increasing.[20] With significant efforts being put into research and

[20] https://www.solarpowereurope.org/insights/market-outlooks/global-market-outlook-for-solar-power-2022

development, solar modules continue to achieve high efficiencies and power outputs. The technical maturity of solar also extends to the availability of universally accepted international standards and codes of practices, including from the International Electrotechnical Commission (IEC). The IEC's Technical Committee for Solar Photovoltaic energy systems covers 61 work programmes and 196 publications, while a separate Technical Committee for Solar thermal electric plants has also been created.[21] Additionally, this technical maturity also ensures that there is availability of trained technicians, project planners, and Operations and Maintenance (O&M) personnel to construct, commission, and operate a solar installation. The presence of robust training and capacity building material also allows for the upskilling of local communities to operate distributed solar installations.

- **Cost considerations:** With the large scale of solar installations achieved around the world, solar energy has seen significant reductions in cost. The average LCOE for solar PV plants has seen a steady decrease over the last decade or so, falling 88% between 2010 and 2021.[22] Additionally, the development of a large supply chain for solar components has further reduced costs while also improving operational lifespans. Solar electricity is now able to compete with traditional fuels in terms of cost per unit of electricity. Solar also benefits from its ease of installation as well as the possibility of carrying out operations and maintenance through locally available manpower, further bringing down costs. The static and noise free nature of solar generation, without the need for moving components, helps to reduce wear and tear and further brings down maintenance costs.
- **Modularity:** Solar energy installations are modular in nature and can be sized according to the load requirement. Thus, solar installations can range from a few kW all the way up to MW and even GW scale as required. This modularity allows for development of customized solar solutions for different locations and helps optimize project development requirements. Additionally, small appliances, solar cooking systems, and solar lighting systems can provide standalone energy access without the need for the development of a solar power plant. The modular nature of solar energy also allows for future augmentation of power plants as and when required. This opens additional options for developers to ensure that the solar project remains viable in the long term.
- **Flexibility:** The wide variety of solar solutions and applications available in the market can allow a diverse range of situations to be addressed. Solar can be deployed on the ground, on rooftops, integrated into buildings, and even on agricultural land and water reservoirs. Additionally, the characteristics of a solar installation can be tuned to best take advantage of local conditions. Solar's flexibility is also demonstrated through its capability to be combined with other technologies, such as energy storage and/or other forms of renewable generation to achieve electricity supply beyond daylight hours. This capability to provide Round the Clock (RTC) power can allow for solar (alongside other generation technologies and/or energy storage) to replace grid expansion.
- **Localized generation:** The modularity and flexibility of solar energy allow for generation to be located close to the load center. This minimizes the need for expensive grid infrastructure and avoids the losses associated with supplying electricity over long distances, while bringing direct and reliable access to clean energy to locations that may otherwise be remote and inaccessible. Localized generation also allows for community ownership of solar projects and can result in job creation for the local communities where the system is deployed. Solar, due to its emission, noise, and movement free generation,

[21] https://iec.ch/technical-committees-and-subcommittees#tclist
[22] IRENA Renewable Power Generation Costs in 2021

is also well suited for local generation and has minimal negative externalities associated with it.

- **Innovative financing tools and business models:** Several technologies for renewable energy generation, including solar energy, have become well established and accepted. Thus, solar projects are now well demonstrated and understood by financiers, and solar projects are considered bankable. Additionally, several innovative financing tools and business models for solar have been developed and deployed in the past. Access to finance at reasonable rates and innovative business models to ensure revenue generation can be a crucial factor for energy access, where the worst affected populations are often not able to pay for energy or its associated infrastructure.
- **Climate and societal benefits:** Solar energy can directly support in mitigating climate change. Solar energy deployment can either replace or prevent the use of fossil fuel powered generation. This reduces local air pollution that is caused by combustion of fossil fuels. Additionally, the deployment of distributed solar systems and even standalone solar appliances have significant socio-economic benefits for local communities, including improvements to quality of life, health and safety, education, and empowerment of women and children. Distributed solar can also power economic machinery, resulting in job creation and increase in income for local communities.

Solar energy can also be integrated with other renewable energy systems, whether wind, micro/pico hydro, or biomass/biogas. This integration creates hybrid systems that can have distinct advantages compared to deploying just a single renewable energy source. The hybrid system can be designed in a manner to offset the concerns related with using each of the renewable technologies alone and can improve system reliability and generation. The hybrid system provides firmer power for a longer period of time, thus improving duration of electricity access. As a result, the end electricity consumer benefits from the use of hybrid renewable energy systems.

Solar has even more clear advantages when compared to conventional generation technologies. Replacing conventional generation systems with solar allows communities to save on the cost of fuel, avoid fuel supply irregularity, and mitigate local air pollution as well as the associated impact on community health due to emissions. Localized solar generation can also minimize the need for costly grid extensions in remote regions where it is difficult to develop the requisite infrastructure.

DRE applications and mini grids powered by solar energy can thus be the key to providing last mile access to energy in the remote locations currently not being serviced by the grid.

2. Achieving Universal Access to Clean Cooking

Over 2.4 billion people cook with fuels that are harmful and pollute the air. Even though the deployment of renewable energy capacity and energy efficiency measures has increased, the continued use of open fires or inefficient cooking technologies powered by kerosene, biomass, coal, etc. is hampering progress towards SDG 7 targets. This is especially true in the least developed and developing countries, where lack of clean cooking is causing serious health problems as a result of severe Household Air Pollution (HAP). HAP claims the lives of ~3.2 million people each year due to illnesses caused by indoor air pollution, with the greatest impact felt by women. Inhaling particulate matter (soot) from HAP is responsible for nearly half of all deaths in children under the age of 5 caused by lower respiratory infections.

According to a World Bank study, the cost of inaction, driven by negative health, gender, and environmental externalities, is estimated at USD 2.4 trillion per year if the clean cooking target is not met. Women pay a disproportionate amount of the cost of inaction, which is estimated to be USD 0.8 trillion per year and comes in the form of poor health and safety as well as lost productivity. Also, it is estimated that cooking with high-emission stoves and fuels made from non-renewable biomass costs USD 0.2 trillion per year as environmental damages and effects on the climate.

2.1 Evolution of clean cooking market

The diversity of global household, cultural, and environmental situations, makes it unlikely that a single cooking fuel and technology can be accepted worldwide to replace harmful and polluting fuels, such as charcoal, coal, crop waste, manure, kerosene, and wood.

When it comes to assessing how widespread the use of clean cooking technologies will be, one of the most prominent issues is affordability. This includes not only the price of the equipment and fuel, but also the cost of maintaining the innovative technology and obtaining funding for it. In addition, the retail prices of various clean cooking appliances vary greatly from country to country, ranging from as little as USD 5 for an inefficient unbranded upgraded biomass stove, USD 100 for a multifunctional electric cooker, to over USD 1,000 for a battery backed e-cooking system.

Historically the financing in the clean cooking sector is dominated by grants supported by various country governments, NGOs, and multilateral development banks. However, in the past few years, the financing instruments for the clean cooking sector have evolved, with the overall capital share of grants shrinking, accounting for more than 50%[23], with the increase in equity of corporate sector.

Government of India Initiative to Promote Clean Cooking: Pradhan Mantri Ujjwala Yojana (PMUY)

To promote clean cooking, the Ministry of Petroleum and Natural Gas (MOPNG) launched the PMUY as a flagship scheme, in May 2016. The aim of the scheme was to make clean cooking fuels such as Liquified Petroleum Gas (LPG) accessible to rural and disadvantaged households who had traditionally relied on traditional cooking fuels such as firewood, coal, and cow dung cakes, among others.

Over a three-year period, 80 million women from Below Poverty Line (BPL) families provided LPG connections through the PMUY scheme. All of the recipients were found on the Socio-Economic and Caste Census (SECC) 2011 list. On September 7, 2019, the Honorable Prime Minister of India gave away the 80 millionth LPG connection. With Ujjwala 2.0, an extra 16 million LPG connections were made available to migrant households as part of the PMUY.

[23] SEforAll Finance for Clean Cooking

By providing credit-linked subsidized connections, PMUY removed a key barrier to poor household's access to LPG connection. It includes financial assistance from the central government amounting to USD 20/- for the new LPG connection, as well as additional loan facility to balance the cost of the stove followed by the first refill which was to be recovered from the subsidy provided to the beneficiaries on LPG refills under Direct Benefit Transfer for LPG (DBTL).

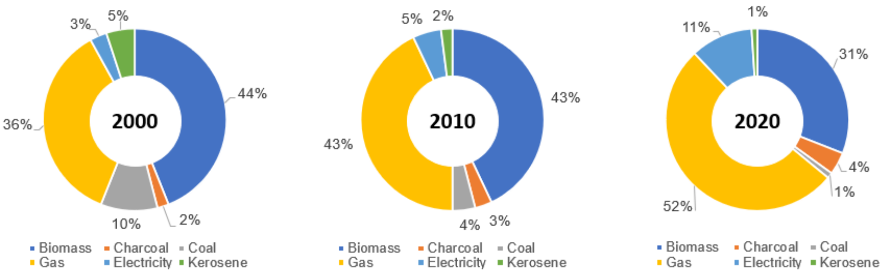
The key achievements under the PMUY scheme are as follows:

- As on 30th January 2023, around 95.8 million total LPG connections are released under the PMUY scheme
- Increasing the LPG coverage from 62% on 1st May 2016 to 99.8% as on 1st April 2021
- The domestic LPG sales increased by 59% from the financial year 2014-15 to 2021-22
- About 158% growth in distributor network in the rural areas, generating several jobs in rural areas

Sources: pmuy.gov.in, CEEW, IMPRI, LONGDOM, exchange rates (1USD = 80 INR)

Clean cooking trends over the past 20 years show that primary cooking with gaseous fuels increased steadily around the world, particularly in low- and middle-income countries, with a 52 percent share in 2020, passing biomass as the most common cooking fuel in 2010. With an 11% of market share in 2020, electricity is also emerging as the preferred source of clean cooking.[24]

Figure 13: Main cooking fuel used in low and middle-income countries



Source: World Bank ESMAP

Gaseous fuels, particularly liquified petroleum gas (LPG), have emerged as a promising clean cooking alternative to polluting fuel combustion. With moderate pressure, LPG readily liquefies, facilitating simple storage and transport in cylinders. These characteristics make LPG advantageous in terms of efficient distribution in low- and middle-income countries. It is also widely used around the world and with policy and regulatory support from various countries, it is often the first clean fuel to reach rural populations.

2.2 Emerging clean cooking business models

Globally, the majority of clean cooking appliances are sold for cash, customers pay 100% of the cost of the appliance upfront. However, the poor households in rural setups, which are most impacted by HAP, cannot afford the upfront costs. Because of this, the size of the target market has shrunk significantly. As a result, there has not been much progress towards the 2030 targets of achieving universal clean cooking.

Considering the advanced technologies, high costs, and aspirational character of clean cooking appliances, new end-user financing-based business models are emerging as a means to rapidly expand the reach of these products. These primarily include PAYGO energy as service model, Utility-led financing, and Razor blades model.

[24] https://trackingsdg7.esmap.org/data/files/download-documents/sdg7-report2022-full_report.pdf

1. PAYGO energy as service model

PAYGO energy as service model is an innovation that emerged to address the energy access challenge and to provide electricity generated from renewable energy sources, especially for solar home lighting systems, at affordable prices on consumption basis. In the clean cooking context, PAYGO technology removes the upfront price barrier of the cooking kit, by allowing end users to pay a small deposit, or none, followed by payments made on a daily, weekly, or monthly basis, often using mobile money. With the elimination of paying upfront cost of the product, this payment model is very well received in the rural setup. The cooking kit can be remotely enabled or disabled if a customer tops up or falls behind on the payments.

Most leading clean cooking companies have developed PAYGO solutions for electric cookers, LPG cooking kits, induction, hotplates, biomass gasifiers, and solar-biomass hybrid energy systems, either directly for end users or through intermediaries.

2. Razor blades model

The razor blade business model is a pricing strategy in which a product such as clean cooking appliance is sold with a low or even no profit margin and investment is recouped by making profits through selling of other products such as fuels for cookstoves. This model is named after the razor and blades analogy, which argues that once a consumer has invested in a razor handle, they are likely to continue purchasing replacement blades for the life of the handle, providing the company with a consistent stream of revenue.

The razor blade business model has not yet proven to be suitable for large-scale adoption of clean cooking, although it has been adopted by a number of biomass gasifier companies with mixed results. The success of the model depends on fuel sales. Prices need to be high enough to make up for the low profits from stove sales, but cheap enough to get people to switch from burning charcoal or other polluting fuels.

3. Utility-led finance model

Electric cooking utility-led finance is a type of financing where a utility provider offers financing for the purchase and installation of electric cooking appliances. Financing can be offered at low interest rates or with flexible payback terms to encourage customers to switch from more traditional cooking techniques (such as gas or charcoal) to electric cooking. This business model allows for the upfront equipment costs to be recovered through:

- On-bill financing (OBF), in which the devices are funded on the balance sheet of the utility and the repayments are collected through the utility bill.
- On-bill repayment (OBR), in which the devices are financed by a third party (such as an asset financier or a distributor of clean cooking equipment), and the repayments are collected through the customer's energy bill.
- Co-marketing and data-sharing, in which a third company handles the financing and invoicing for the devices, while the utility contributes data and other support relating to their consumers for the purposes of credit scoring and marketing.

Overall, the provision of utility-led finance for electric cooking is an essential instrument for the promotion of sustainable energy practices and the improvement of the health and well-being of communities all over the world. Except for a few pilot programmes in Sierra Leone and Uganda, the vast majority of utilities in the low- and middle-income countries with the least clean cooking access rates are cash-strapped and are already having difficulty collecting payments. As a result, the utilities do not prefer to add to the customer's financial burdens by providing on-bill payment choices for appliances.25

2.3 Challenges in adopting clean cooking solutions

The transition from polluting fuels to clean cooking fuels and technologies not only contributes to SDG 7, but also has a profound impact on 10 out of the 17 SDGs. Thus, it contributes to an enabling environment for achieving widespread socio-economic progress. However, despite its great potential, there remain various challenges hampering widespread adoption of clean cooking solutions, particularly for clean cooking access deficit countries. The key challenges include:

- **Policy and regulatory ecosystem:** The governance framework for clean cooking interventions is not always clear, with different ministries and agencies working on the sector, which often leads to bureaucratic and administrative hurdles. While majority of low- and middle-income countries have made clean cooking a priority in national policies, there is absence of dedicated agencies to standardize the clean cooking technologies and track the progress made in adopting the clean cooking solutions. Moreover, majority of countries lacks clean cooking specific financing facility, duty exemptions, tax benefits, and/or subsidies for the private sector developers and end-users to promote clean cooking solutions. Weak institutional capacity and limited availability of data related to clean cooking access rates, household cooking patterns, and standards of cooking solutions utilized are significant barriers towards implementing a good policy and regulatory framework to attain universal clean cooking access targets.
- **Limited access to finance:** Absence of clean cooking specific financing facilities, funding modalities, tax and subsidy incentives for the private sector are the key reasons for the limited private sector capital investments. To encourage the adoption of clean cooking solutions and to mobilize private investments in the clean cooking industry, innovative financing mechanisms, along with subsidies and/or grant support from governments and development organizations, are essential requirements. Limited access to capital is one of the greatest challenges to enable universal access to clean fuels and technology for cooking.
- **Complex infrastructure and supply chains:** Worldwide implementation of clean cooking solutions, especially in low- and middle-income countries, faces complex infrastructure and supply chain barriers that can be challenging to overcome. Liquefied petroleum gas (LPG) and electricity are two clean cooking solutions that have been used successfully in most countries around the world. However, low- and middle-income countries lack the infrastructure, such as gas pipelines/ gas transportation network and electricity distribution grids, which are necessary for accessing these resources. In the absence of a reliable supply chain, people are forced to rely on environmentally hazardous and expensive alternatives such as kerosene, charcoal, and wood.
- **Affordability of clean cooking solutions:** Most rural households have grown accustomed to using traditional stoves, which are inexpensive to purchase and maintain. Aside from the infrastructure and supply chain constrains, the existing clean cooking solutions are often out of reach for low-income households because of their high initial costs, recurring fuel expenditures, or both. As a result, despite providing subsidized clean cookstoves, the rural households embrace inefficient cook stoves and polluting fuel stacking, a phenomenon to concurrently use multiple stove-and-fuel cooking within the same household.

[25] https://mecs.org.uk/wp-content/uploads/2021/07/Clean-Cooking-Financing-Appliances-for-End-Users.pdf

- **Technological barriers:** Most of the low- and middle-income countries lack the inhouse capabilities to develop such solutions and are often reliant on imported products. The majority of manufacturing companies are focused on improving cook stove technology and the large-scale manufacturing process to cut costs per unit and increase profits. However, end-user inputs are rarely considered during design, resulting in products that are poorly suited for actual cooking needs and frequently rejected by end-users. Moreover, clean cooking technologies, such as advanced wood stoves and biogas digesters, often use relatively complex fuel production and combustion technologies that may be challenging to maintain for end-users due to unfamiliar technology and lack of access to skilled technicians. As a result, it is difficult to achieve sustainable deployment and operations of clean cooking technologies.
- **Social and cultural barriers:** Typically, the social and cultural values of a society influence the choice of cooking system used by consumers. Ignoring the social and cultural background of targeted consumers is one of the primary causes of the failure of many clean cooking projects worldwide. In many communities, especially in rural areas, cooking is seen as a woman's responsibility and the cook stove preparation time spend by the women is undervalued. In addition, women do not have the authority or financial means to use clean cooking solutions, especially if they are more expensive than traditional cooking methods. In addition, clean cooking solutions that do not work with traditional cooking methods are often turned down by users, even if they are cheap. The lack of knowledge and understanding about the use and benefits of clean cooking solutions exacerbates resistance to their adoption.

The multifaceted challenges to access and adoption of clean cooking solutions do not exist in isolation. Rather, they are deeply interconnected. The sustainable adoption of clean cooking solutions requires a thorough understanding of local socio-economic and livelihood conditions, which creates a unique set of challenges. To be successful in overcoming these challenges, a multi-pronged strategy is required, one that incorporates policies and regulations enacted by the government, investments made by the private sector, educational and awareness campaigns, and participation from the community. To accomplish this goal, substantial effort is required on the part of governments, international organizations, non-governmental organizations, and the business sector to establish an environment that is conducive to the implementation of clean cooking solutions.

2.4 Role of solar energy for clean cooking transition

Solar energy based solutions can be deployed to meet clean cooking needs. Solar thermal has mostly been explored for cooking, which employs solar cookers that operate on the principle that sunlight warms the pot used for cooking the food. In general, there are two types of solar thermal cooking systems that have existed, direct and indirect cooking systems.

Direct cooking systems use the sun rays to directly heat the food utensils. This type of cooking technique is often used for residential cooking purposes. Commercially successful direct type cookers are box type (utilising the black-body principle) and concentrating (parabolic) type cookers. These types of solar cookers have proven to be quite effective in reducing up to one-third of firewood or other biomass fuel in rural setups. However, these cooking methods are only suitable for outdoor installations in addition to their sporadic availability.

Indirect cooking systems utilizes the thermic fluids which in turn warm up the utensils to cook the food. Solar cooker with concentrating type collector are commercially available cookers under this category. These type of cooking systems are generally used for community/ commercial scale cooking purposes.

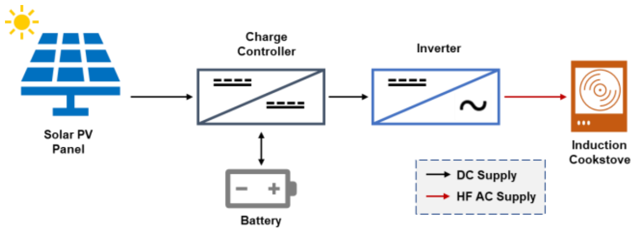
While solar thermal cookers have many positive attributes (no pollution, no fuel costs, free energy from the sun, low management costs, etc.), their widespread adoption has been hampered by various limitations. These include limited window of opportunity for use throughout the day, inability to be utilized at night or during cloudy/unfavorable weather conditions, and a longer cooking time compared to conventional cooking stoves.

Solar PV cooking has emerged as a cutting-edge technology with the potential to transform the way we cook and use energy due to the remarkable fall in the prices of PV technologies and the substantial rise in the efficiency of electric cooking stoves over the past decade. During the day, solar photovoltaic (PV) panels collect sunlight and convert it into electricity that can be directly used to power electric stoves or cookers; this electricity can then be stored and used at night or during inclement weather. The Solar PV cookstoves are generally formed through integrating with induction cookstoves or efficient heating cookstove systems with additional energy storage systems.

A. Solar PV powered induction cookstoves

With induction cooking being widely used nowadays due to its high efficiency and safety, it has become the most preferred choice for being powered through solar PV. The key components for the solar PV powered induction cooking are mentioned in the figure below.

Figure 14: Typical solar PV induction cooking stove



In the marketplace, the available induction stoves work on standard household electricity supply. The induction stove works on high frequency alternating current (HF AC). The induction of eddy currents in the vessel, which generates heat, requires high frequency alternating current power. Since power generation and storage in solar PV cookstoves take place in the form of DC, solar PV cookstoves with DC power control circuits are more appropriate and effective than induction stoves with grid-supplied electricity. With PV modules and batteries, induction cookstoves can provide enough power to cook a wide range of meals around the clock, matching the efficiency of cooking with liquid petroleum gas.

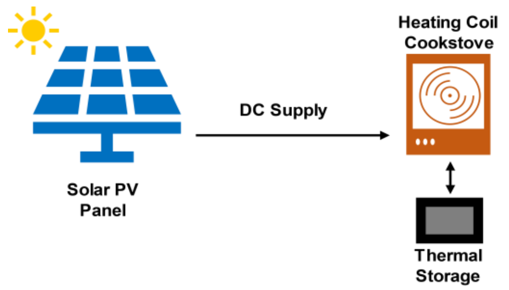
The commercially available induction cookstoves are of capacity of around 1 kW_p which means required size of solar PV would also be around 1 kW_p and higher. Additionally, capacity may be required as per household needs. The cost of a typical solar PV induction cookstove would be around USD 925 comprising of 1 kW_p solar PV with 7 kWh of battery storage, capable of supplying 3 kWh of energy sufficient to cook 3 meals per day for a 5-person family.[26]

[26] Solar PV Cook-stove | Engineering for Change

B. Solar PV Heating Cookstove

Solar PV heating cookstove is basically a combination of a PV module, directly coupled with DC resistive coil designed to match the impedance of coil and panel for maximum power transfer. In this simple arrangement, the heating coil (generally made up of Nichrome or Constantan) is embedded with the vessel and PV module, directly supplying power to the coil during daytime.

Figure 15: Typical solar PV heating cooking stove



In addition to the basic configuration, it also enables the use of different type of energy storage devices such as battery banks as well as thermal storage via phase change material (PCM) that can store the additional heat generated by the heating coil and can be used later at night or during inclement weather.

Example of Solar PV Heating Cookstove with Thermal Storage

An Indian Public Sector Undertaking (PSU) has recently launched PCM based thermal storage as a more cost-effective replacement for battery storage in their Solar PV cooking system Surya Nutan.

Surya Nutan, a solar PV based cooking system developed by IOC R&D Centre, is a stationary, rechargeable, and always kitchen connected indoor cooking solution for collecting energy from Sun, converting the Sun's energy into heat through a specially designed heating element, storing thermal energy in a PCM based thermal battery and recovering the thermal energy for use in indoor cooking as and when required.

The product gets charged and discharged simultaneously while performing its function of indoor cooking. During use, the stored solar energy is recovered in a controlled manner for indoor cooking of a variety of food items involving boiling, steaming, frying and "roti" making.

Salient Features

- Provides simultaneous cooking mode while charging through the sun thereby maximizing system efficiency utilization
- Detachable heat control assembly for cooking energy release on demand
- Operates in a Hybrid Mode (can use both solar and auxiliary energy sources at the same time), making it a dependable cooking solution

Figure 16: Surya Nutan – Solar cooking system

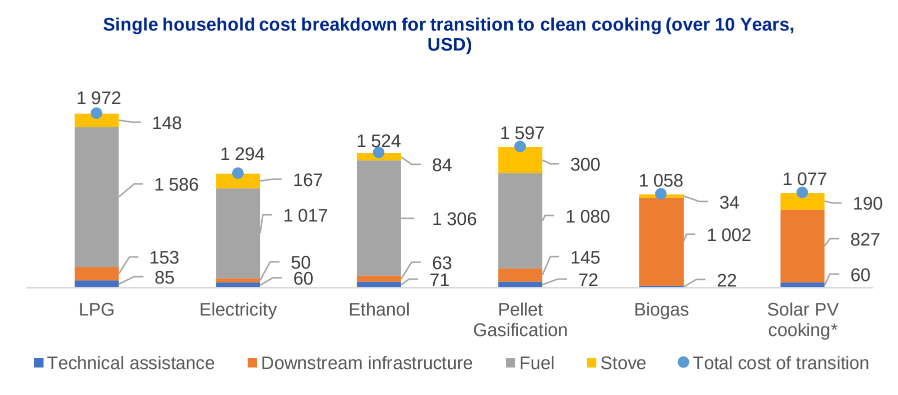
- System is suitable for family of four persons and can be modular in size as per requirement
- The cooking time is comparable to the time necessary when cooking with LPG.

Source: IOCL

2.5 Cost comparison between solar PV and other clean cooking solutions

The transition cost of clean cooking solutions incorporates multiple elements including of downstream infrastructure cost of the technology, cost of technical assistance, cost of cook stove, as well as the recurring cost of fuels. In addition to the onetime upfront costs, the recurring cost of fuel is an adverse factor for the for the households to embrace clean cooking fuel and technology

Figure 17: Transition costs for various clean cooking solution



*Source: World Bank, *ISA Analysis*

In order to estimate the total transition cost of clean cooking solutions, the recurring cost of fuel and cook stove replacements over time also needs to be considered. Cost estimates for one household's transition to various clean cooking solutions over a period of 10 years are shown in the figure below. These solutions include LPG, electricity, ethanol, pellet gasification, biogas, and solar PV. To estimate the downstream cost of solar PV cooking systems, a typical 1 kWp solar PV system with a battery bank capable of supplying at least 3 kWh of energy per day is considered, to cook three meals a day for a household of five members. The cost breakdown for one household's solar PV system is USD 827 in downstream costs, zero expenditure in fuel costs, USD 60 in technical assistance, and USD 190 for an induction cook stove.

The downstream cost for fuels like LPG, electricity, ethanol, and pellet gasification is quite low ranging between USD 50 to USD 150 in comparison to solar PV and biogas. However, over the period of 10 years, these fuels cause additional transition costs due to recurring fuel expenditure. The proportion of fuel recurring cost to total cost of transition for 10 years stands at 80% for LPG, 79% for electricity, 86% for ethanol and 68% for pellet gasification.

This comparative analysis shows that, despite of high upfront cost of solar PV cooking compared to other clean cooking solutions, the total transition of solar PV cooking is more cost-effective in long run because it does not require any recurring fuel costs.

The ESMAP forecasts that the cost of transitioning to universal access to modern energy cooking services (MECS) by 2030 will be between USD 148 billion to USD 156 billion a year based on present policies.[27] Comparatively, on a country-by-country basis, public and private, international, and local financing commitments for clean cooking in the 27 high-impact countries[28] — which together are home to more than 80% of people without clean cooking access — averaged approximately USD 130 million per year between 2015 and 2019. The limited availability of capital is one of the main barriers to universal access to clean fuels and cooking technologies. If the current trend to continue, around one-fourth of the global

[27] sdg7-report2022-ch2-access_to_clean_cooking.pdf (esmap.org)
[28] High Impact countries: Afghanistan, Angola, Bangladesh, Burkina Faso, Chad, China, DR Congo, Ethiopia, Ghana, India, Indonesia, Kenya, Korea (DPR), Madagascar, Malawi, Mozambique, Myanmar, Nepal, Niger, Nigeria, Pakistan, Philippines, South Sudan, Sudan, Uganda, Tanzania, and Vietnam

population is expected to remain without access to clean cooking fuels and technologies by 2030.

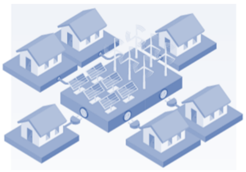
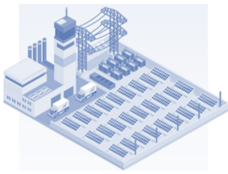
Considering the limited financial flow in the clean cooking sector, integration of solar PV based cooking solutions with the various ongoing and planned electrification initiatives across the globe can fast-track the efforts to achieve universal clean cooking access. Solar PV based cooking offers a sustainable cooking solution that can supplement existing or upcoming energy infrastructure, including the existing grid, grid extension, mini grids, or standalone systems, and help achieve all the targets of SDG 7.

3. Achieving Electricity Access through Grid Extension- the typical approach

Typically, the only way to electrify a household was to connect it to the local distribution network which in turn connects to a transmission network through which centrally produced power is supplied to the end consumers. Conventional power sources (such as coal, natural gas, hydro, etc.) typically only operate at larger scales, resulting in this centralised generation approach. The relationship between the power producer and the consumer was strictly unidirectional with regards to the flow of electricity.

With the overall economic development in low income and developing countries, the demand of energy, primarily in the form of electricity, has grown significantly in remote and rural areas. The typical approach to provide electricity access in such remote areas and improve access in the already-connected areas is through grid expansion and densification. Additionally, energy transition has become an important global agenda and is bringing out new challenges for the electricity grid. According to a World Bank study, grid extension costs as much as USD 2,500 per connection and it would require more than USD 600 billion to achieve universal energy access through grid expansion approach.

Figure 18: Factors to assess the feasibility of various solutions to achieve energy access

Solar Home Systems (SHS)	Mini Grids	Grid Extension
		
	Size	
10-100 W	< 10 MW	>= 10 MW
	Viability based on distance from the existing Grid	
-	> 20-50 kms	< 10 kms
	Population Density	
Sparsely populated areas	Clustered populations not connected to the grid	Densely populated areas very close to the grid

Source: Achieving clean energy access in sub-Saharan Africa report (OECD-World Bank) and CrossBoundary analysis

The extension of the existing grid infrastructure can provide electricity to a significantly large number of people as compared to other decentralized solutions. But this solution comes with its own set of challenges as the investment costs for the state-owned utilities to improve upon the existing grid infrastructure are high and the financial health of these utilities typically in the least developed countries is extremely poor. Apart from this, there are several other factors that affect the decision to expand the grid infrastructure.

Typically, SHS are smaller in size and are used in sparsely populated areas due to their ability to operate as standalone systems. The viability for solar home systems also does not depend on the distance from the grid as they can be installed anywhere and are typically similarly priced in almost all regions. Mini grid on the other hand become viable when the system size is lesser than 10 MW and the distance from the existing grid connection is more than 20 kms. These number may vary in different geographies based on a variety of factors ranging from the grid extension costs to the import costs of the various components that constitute the mini grid. In some cases, mini grids may also be viable for grid connection distances lesser than 20 kms if the population densities are too low for grid extension to be viable. Mini grids typically work best in situations where the majority of the population is located close by, like a cluster of 3-4 villages, situated at a long distance form the existing grid connection.

Grid extension presents the least cost solution for situations where the population is located very close to the existing grid. The cost of connection can be significantly lowered if the grid connects a large population to the existing system as these additional infrastructure costs get distributed among a much larger set of end consumers. While mini grid tariffs can be higher than grid tariffs, they can be effectively used for providing access in previously unconnected areas, enhancing reliability of power supply, and for replacement of expensive diesel generation.

Grid expansion projects are expensive and take a long time to develop

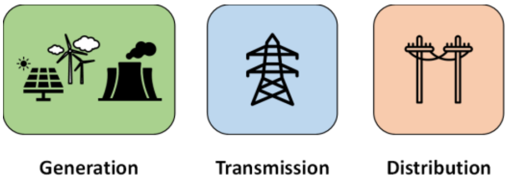
Expanding the grid is a significant undertaking and takes a large amount of time and resources. Based on an analysis of grid extension projects in Sub-Saharan Africa carried out by GTM Research and Power for All, grid expansion projects in the region took an average of 5-6 years to carry out. These expansion projects were carried out at an average cost of nearly USD 100 million. The long development time of such projects only increases the time that people without energy access must wait for electrification, and thus has an impact on the region's development and socio-economic status.

This chapter outlines the typical elements of the grid, the current status of investments made in the grid expansion in the low-income countries of the world and elaborates on the factors affecting the decision to expand the grid infrastructure to new areas.

3.1 Components of the main grid and requirements for extension

The main grid typically consists of 3 main components – namely generation, transmission, and distribution. These assets are typically state-owned with a very few countries allowing private participation.

Figure 19: Main Grid Components



Generation: Electricity is generated in power plants either through conventional sources, like coal, natural gas, hydropower, or nuclear fuel, or through non-conventional sources such as wind, solar, biomass, biogas, small hydropower, geothermal, etc. Centralised power generation typically happens at MW or GW scale and are usually placed away from the demand centres.

Transmission: The generated electricity is transported towards the demand centres at high voltages. The power lines that are used for the transmission of this electricity and a 'step-up' transformer is used at the generation end to increase the voltage level of the electricity for it to be transferred over long distances with minimal losses.

Distribution: The high-voltage electricity is then stepped-down to lower voltages at the distribution sub-stations. A distribution grid then connects the substations to the end consumers, including industrial, commercial, and residential consumers, at different voltages according to the usage and safety levels. Industrial consumers require relatively higher voltages whereas additional smaller transformers are required within the network to further step down the voltage to make if safe to use for the residential and commercial consumers.

Main components of the electricity grid

- Large-scale generators based on coal, natural gas, hydropower, nuclear fuel, or wind and solar
- High Voltage (HV) transmission line
- Bulk substations that tap into the High Voltage transmission line and feed the Medium Voltage (MV) distribution lines
- Medium Voltage distribution line
- Medium Voltage/Low Voltage (LV) distribution lines and the Low Voltage distribution lines to supply load at a limited distance of the distribution substation
- Service drop line that links the distribution Low Voltage line and the meter of the consumer
- Service entrance system including the distribution board with protection and the in-house wiring that connects the appliances

Grid extension to remote, unconnected regions may require augmentation of all three components of the main grid. While transmission infrastructure typically forms the largest component of the investments required for augmentation, significant investments are also required to establish the distribution network to connect all the end consumers. Additionally, some amount of generation capacity may also have to be added to the grid network to account for the estimated demand from the new connections. Grid densification, on the other hand, may only require augmentation of the distribution network infrastructure in the demand centres.

Grid extension costs are typically quoted as "per-kilometre" cost for extending medium-voltage (MV) or low-voltage (LV) lines to the village and "per-connection" cost to connect new customers. If required, these costs may account for a step-down transformer to convert from medium to low voltage. Additionally, these costs might vary for a three-phase and single-phase connection depending on the load requirements. End consumers will need to pay the initial connection cost (one-time) and meter charge (monthly, if applicable), after which consumers only pay for their consumption based on the tariff set by the utility.[29] The table below shows the average cost of transmission and distribution lines, as seen in underdeveloped and developing countries:

Table 6: Average Cost of Transmission and Distribution lines in Underdeveloped and Developing countries

	HV Line (69-132 kV)	MV Line (11-33 kV)	LV Line (0.2-0.4 kV)
Average Cost in Underdeveloped and Developing Countries	~53,000 USD/Km	~7,000 USD/Km	~4,250 USD/Km

Source: World Bank: ESMAP Global Electrification Platform (GEP)

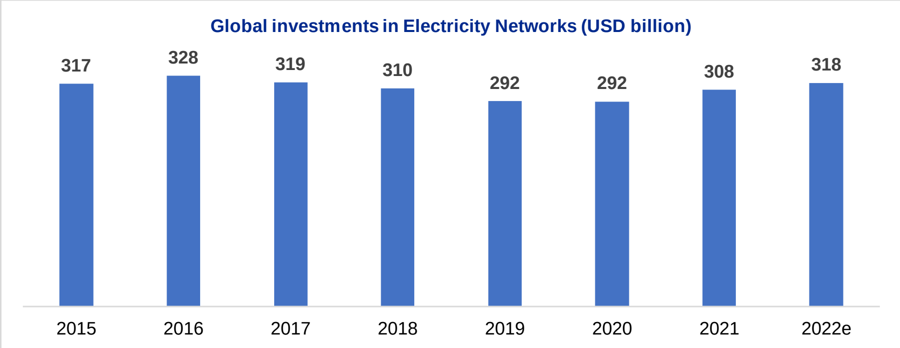
3.2 Status of investments in electricity networks

Investments in electricity networks touched USD 308 billion in 2021 and are estimated to have reached USD 318 billion in 2022. This includes investment in transmission and distribution infrastructure. Investment in various digital technologies that can enable greater

[29] Cost-effectiveness of mini grids, USAID

efficiency in grid management or operation, or integrate new solutions such as electric vehicles, are also seeing an increasing share of investment. In recent years. global investment in the electricity grid is also driven by the need to integrate a greater share of renewables in countries around the world. The figure below showcases the global investments in electricity networks from 2015-2022:

Figure 20: Global investment in Electricity Networks



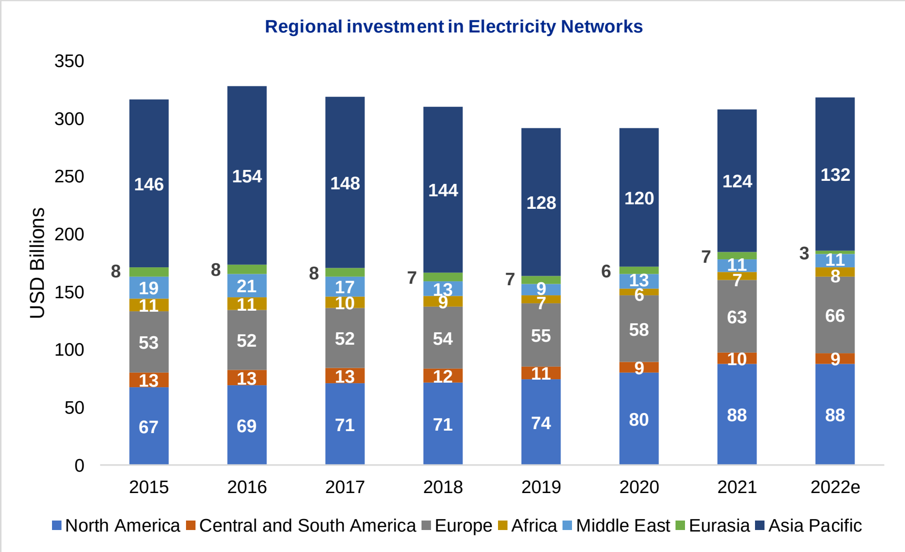
Source: IEA World Energy Investment 2022

Overall, investments in electricity networks have been stagnant over the past eight years, peaking in 2016 at USD 328 billion. Subsequent years saw a fall in investments, including three years of consecutive reductions in electricity network spending between 2017 and 2019. This reduction was primarily driven by a reduction in transmission investment in China. However, there has been a rebound in investments in 2021 and 2022, driven by large expansion plans in China and Europe.

As a result of this stagnation corresponding with increased investments in renewable energy capacity, the share of electricity network investments in overall power sector investments has come down from a peak of nearly 40% in 2016 to around 33.3% in 2021, with a further drop to 32.5% estimated for 2022. It is essential that investments in the network keep pace with renewable energy capacity, as variable renewable energy generation must be suitably integrated into the grid and distributed to a wider range of consumers.

The dominant share of investments in electricity networks can be attributed to Asia-Pacific, North America, and Europe. **These three regions have accounted for 85% - 90% of total investments in the grid over the last 8 years.** Investments remain low in the Middle East, Central and South America, Africa, and Eurasia. Investments in these regions have also shown a steady decline since 2015, a worrying trend considering the pressing need to improve electricity access and integrate renewable generation. Additionally, the low investment in regions such as Africa, which typically has countries with lower electricity access rates, highlights the challenges of meeting the large levels of capital expenditure and operational expertise required for grid expansion.

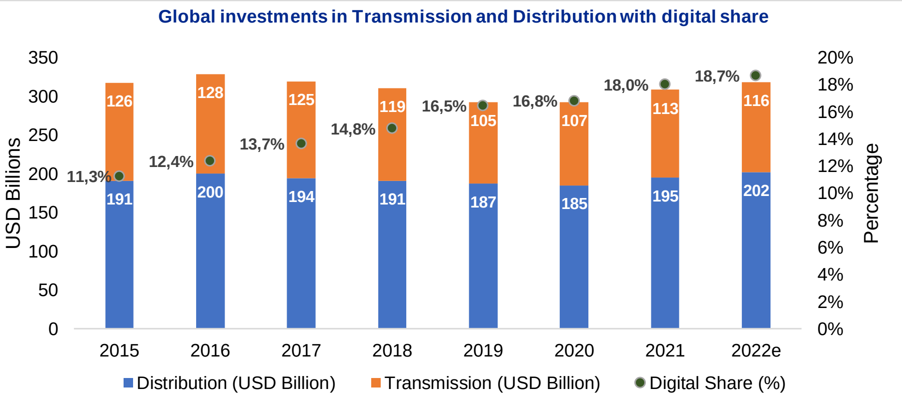
Figure 21: Regional Investment in Electricity Networks



Source: IEA World Energy Investment 2022

While exploring further subcategorization under electricity network investments, it becomes clear that the distribution sector dominates investment expenditure when compared to the transmission sector. **Annual distribution sector investments have been in the range of USD 185 billion – USD 205 billion over the last 8 years, while annual transmission sector investments have ranged from USD 105 billion – USD 130 billion over the same time period.** An important trend in the investments made over the last 8 years has been the steadily increasing share of investments in digital technologies, including public electric vehicle charging infrastructure, transmission and distribution automation, networking and communications, analytics, smart metering, distribution and energy management systems, sensors, and other digitalisation activities. **The share of such digital investments has increased from around 11% of total electricity network investments in 2015 to 18% in 2021, with a further increase to over 18.5% estimated in 2022.** These systems serve to improve grid performance and reliability, while also adding automation, remote monitoring, and control capabilities. Greater investment in such digital technologies may be seen in the future as digitalisation and upgradation of grids continues to be an important focus area for several geographies. The distribution sector has accounted for ~75% of all investment in digital technologies.

Figure 22: Global Investments in Transmission and Distribution with digital Share



Source: IEA World Energy Investment 2022

3.3 Factors affecting the grid extension decision

The utilities' decision to invest in grid extension depends on a wide variety of factors ranging from the population size to be catered at the distribution end to the utility's financial health and marginal cost of excess generation required. Investments in improving the grid infrastructure are more cost effective when the new infrastructure is utilized by a large number of end consumers with reasonably high demands. It is also beneficial to have households near each other to reduce the distribution infrastructure costs. Grid extension is typically the least cost option for improving electricity access in areas where the option of connection is feasible.[30]

The following factors affect the decision of extending the main grid to previously unconnected areas:

- **Population density –** A kilometre of an electricity distribution line costs approximately the same across any system design.[31] Assuming a similar household consumption across various least developed countries, the feasibility of investment in new distribution infrastructure will primarily depend on the number of end consumers that the infrastructure is proposed to serve. The infrastructure costs will eventually be divided among the new consumers as initial connection costs and result in better financial returns for the utility. Therefore, greater the population density, the more cost-effective it is to extend the grid to new areas.
- **Distance from the grid –** The costs of extending the distribution network to unconnected areas is a direct product of the distance between the current point of connection of the main grid and the unconnected area with the 'cost per kilometre' of the distribution line. These costs need to be within reasonable limits and should be weighed against other decentralised options of electrification, along with other factors like installation and O&M costs that become prohibitively expensive in remote locations.
- **Consumer category and load profiles –** The type of consumers in these unconnected regions also needs to be assessed prior to making the decision of extending the grid. For residential consumers with extremely low demands for electricity, it may not be feasible to invest in the capital-intensive grid extension option. Grid densification, on the other hand, could be required as a result of the rapid urbanization rates in the major cities of these

[30] Defining Energy Access Methodology, IEA (2020)
[31] Electricity Access in Sub-Saharan Africa, AFD-World Bank (2019)

underdeveloped countries. Electricity demand has significantly increased with the increase in income and the desire for improved standard of living in such cities. This continuous need for upgrading and expansion of the supply, T&D infrastructure requires heavy capital investments, which further strains the financial health of the already over-burdened utilities in these regions.

- **Installation, operation, and maintenance costs –** As a significant portion of people without electricity access resides in remote rural areas, the grid extension may become drastically expensive for the utilities. Sparsely located households and difficult terrain (such as hills, valleys, water bodies, etc.) add on to the initial installation costs and the operation and maintenance costs of grid extensions in case of failures.
- **Additional cost of excess generation required to be procured –** As additional demand is added to the system, the utilities will also need to assess the readiness of the grid to fulfil the electricity demand. In most cases, the demand may be small and only some ramp-up of generation or small-scale augmentation of the existing power plants may be needed to address reliability concerns. But, planning for the grid extension across major unelectrified parts of a country could require significant investments in the generation-side infrastructure as well.

Additionally, the utilities in the least developed countries in the world are typically seen to be struggling in terms of finances, with billing and collection and theft of electricity being a few of the most prominent issues. If the utility is deep in debts and is already struggling to cover operational expenses, it is unlikely to invest in the capital-intensive grid extension networks despite understanding the need for it. Moreover, the existing grid infrastructure will also require strengthening, which is also a capital-intensive activity, to support the new demand being added to the system.

Other avenues of financing, including multilateral financing, to fund the grid expansion are also difficult to arrange due to the geopolitical risks in these countries and the extremely low propensity of the end consumers to pay for the electricity connection. Policy support and government interventions in this area can be critical in improving the utilities' financial health and thereby mitigating the issue of electricity access through the grid expansion.

With the innovations in renewable energy, the potential to decentralise the production of power has been established. RE sources, specifically solar energy, are abundantly available in most locations and enable consumers to generate electricity at source, typically for self-consumption. Based on the above outlined factors affecting the investment decisions for grid extension, it may be the least-cost option to improve electricity access for a large-population, high-demand area located reasonably close to the grid. But off-grid DRE technologies and mini grids may prove to be more effective solutions to provide last mile electricity access in remote locations and their costs decrease with increase in population density. Further, grid extension may take 2-3 years for installation and commissioning, whereas DRE solutions and mini grids can be operational in a relatively less time.

Mini grids offer a versatile solution. They can be sized according to the end consumer demand in the area and can be rapidly scaled up at relatively lower costs. Further, mini grids can operate in isolation and can also be operated as grid-connected systems, 'islanding' themselves where the main grid fails to protect their own operations. Accurate demand assessment and optimal system sizing can help reduce the overall investment in the mini grid and result in reduced tariffs for the end consumers which are much closer to the grid tariffs. Therefore, mini grids could be proposed as viable solutions in places where the grid is foreseen to be developed soon as they are capable of grid interconnection thereby complementing the existing grid infrastructure.

Chapter 3 describes ways of achieving electricity access through mini grids and DRE systems. Apart from discussing various aspects of both these alternatives, it also elaborates on the various business models that the developers use in implementing mini grids and DRE systems. The chapter also outlines a few key case studies, which help further explain the business models and elaborates on the key drivers for the successful implementation of such DRE solutions.

Mini grids coexisting with the main grid

It is not necessary that mini grids need to be abandoned or pushed out of business once the main grid reaches a remote location. There are several business options that an isolated mini grid can undertake to continue operations if a main grid arrives at its location:

- **Small Power Producer (SPP):** The mini grid converts to a grid connected SPP and does not sell at retail prices to consumers.
- **Small Power Distributor (SPD):** The mini grid converts to an SPD, purchases wholesale electricity from the main grid, and sells this at retail prices to consumers. The mini grid may or may not offer backup generation.
- **SPP + SPD:** The mini grid continues to sell at retail prices to consumers from either its own generation or from wholesale purchases from the main grid. Surplus generation, if any, is sold to the main grid.
- **Side-by-side without interconnection:** The mini grid continues to serve consumers alongside the main grid without any interconnection.

Ensuring suitable regulations to allow mini grids to plan for the arrival of the main grid can also alleviate mini grid investor concerns and make access to finance more affordable for them.

Case

The main grid could not reach the rural villages in Cambodia till the early 1990s due to the situation of unrest within the country. As a result, hundreds of diesel-powered mini grids were built and operated by local entrepreneurs who put in their own money, without any government support.

In early 2000s, when the national utility, Electricité du Cambodge (EdC), began expanding the main grid to the rural areas, the electricity landscape changed drastically. Cambodia established the Electricity Authority of Cambodia (EAC) which called for mini grid operators to procure 'distribution licenses' and in exchange allowed them to operate at higher tariffs. The EAC also allowed isolated mini grids to become 'small-power distributors (SPDs)' who were allowed to purchase electricity from the EdC or any neighboring countries at prices lower than the diesel generation. The EAC also provided on-ground technical assistance on the installation and operation of mini grids and helped improve the quality of the distribution network to ease future grid connectivity.

Currently, more than 250 formerly isolated mini grid have been connected to the national grid as SPDs, helping serve more than 1 million consumers. In 2016, the government also intervened to create uniform tariffs for all SPDs across the countries and introduced subsidies to close the gap between the set retail tariff and the higher operational costs of the SPDs.

Source: Mini Grids and the Arrival of the Main Grid: Lessons from Cambodia, Sri Lanka, and Indonesia, ESMAP

4. Mini grids and DRE solutions can ensure last mile Electricity Access

Access to electricity is major driver for the economic and human development and it becomes even more critical for rural socio-economic development. Improving electricity access in countries with low-income population often proves to be challenging and expensive.

According to IRENA and ESMAP, 91% of the world's population has access to electricity as of 2020. The remaining 9% of the global population has no access to the grid and the reliability and quality of electricity supply remains a rising concern for the rural population. Extension of the main electricity grid to remote areas for the most vulnerable populations is operationally difficult and commercially inviable, and thus remains a key challenge in achieving universal electricity access.[32] Even in case that such grid infrastructure is established, the high equipment, construction and operation costs are borne by only a few stakeholders. This results in exorbitantly high cost of electricity to the consumers creating the issue of affordability for the low-income population.

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Small, localized off-grid solutions, such as Mini grids, Solar Home Lighting systems, and other DRE systems, have thus emerged to tackle these issues and their importance has significantly increased in the recent years. These predominantly use location specific renewable energy sources like solar, biomass/biogas, wind, solar-wind hybrids, small hydro or geothermal energy to provide self-reliant, flexible and cost-effective electricity supply and have become critical in enhancing the service to last-mile users while also delivering grid ancillary services (if grid-connected).[32]

Generally, these systems operate in isolation from the main grid but can also interconnect with the grid to exchange power and operate as grid-connected systems. To deal with the intermittency of RE-based energy, some of these systems may also use a diesel generator as backup or resort to fuelwood-based heating. Such solutions result in higher on-site emissions and therefore, system-integrated energy storage is being used to mitigate these intermittency issues.[33] In some cases, solar water pumps are also used to pump out extra water in the sunshine hours so that this stored water can be used at other times.

The above-mentioned DRE solutions also provide significant socio-economic benefits such as[34]:

- **Improved convenience of electricity availability and lighting** – Houses can sustain longer duration of lighting thus improving the quality of life and facilitating activities like studying, cleaning, etc. even in the evenings. Dependence on kerosene lamps has also decreased significantly resulting in a cleaner indoor environment. Lighting has also positively impacted women allowing them to participate in other income-generating activities apart from managing their households. Additionally, small power packs can be charged using the solar energy to be used during the night for small household appliances like lights, fans, laptops, phone chargers, small TVs, etc.
- **Enhanced public services** – Improved electricity supply has allowed public services such as schools, community centers, religious places, healthcare centers, small commercial stores, and dispensaries to continue functioning efficiently. There is reduced wastage of essential drugs/medicines as they can be securely stored in refrigerators. Installation of streetlights in public areas have reduced crimes against women and have also created social spaces for villagers to gather in the evenings. Uninterrupted power supply and

[32] Socio-economic impacts and challenges associated with the electrification of a remote area in rural Tanzania through a mini grid system (2021). https://doi.org/10.1007/s40974-021-00216-3
[33] State of the Global Mini grids Market Report (2020), BNEF
[34] Assessing the co-benefits of decarbonizing the power sector report (2019)

improved lighting has extended the working hours thereby allowing children to study during evening hours resulting in improved quality of education.

- **Employment creation** – Productive end-use appliances sustained by RE sources, as isolated DRE appliances or as a part of mini grids, have led to direct employment creation for the local population. Rural self-help groups and entrepreneurs have also benefitted from the use of appliances due to increased availability of semi-skilled technicians to operate machinery. Villagers can also get involved in the construction, operation, and maintenance of these DRE systems.
- **Improved resilience** – In case of natural disasters like floods, storms and earthquakes, these DRE systems can operate in isolated mode thus providing electricity supply even when the main grid is down, thereby significantly reducing the impact of the disaster on the locals.
- **Improved access to information and opportunities** – Earlier, the remote population had a very limited access to electricity which resulted them being disconnected from the world due to the inability to access information and other opportunities. Off-grid solutions have improved the access to information about the outside world for these remote communities, thus improving their quality of life. Phones can be charged locally leading to improved connectivity resulting in timely updates on weather alerts, welfare schemes and other vital government facilities. Solar powered cyber kiosks have also been set up in some places resulting in an improved access to information for the rural population.

The following section outlines the various business models involved in the implementation of most of the DRE and mini grid projects.

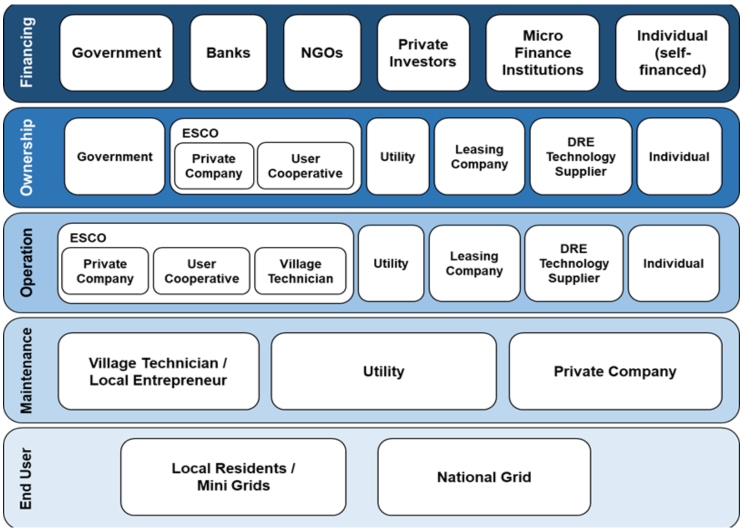
4.1 Business Models

A business model defines the investments, ownership, operations, and end-of-life for a project. An appropriate business model choice predominantly depends on the local conditions, availability of finance, policy & regulatory support for the project, along with other project-related factors like the project size and end consumers. A business model should also clearly outline the various stakeholders involved at every stage of the project and clearly map out their roles to prevent conflicts.

The following figure outlines the relevant stakeholders according to their roles in the installation, operation, and maintenance of a DRE system.[35] Any combination of stakeholders in the figure below can work together to create a successful project outcome.

[35] Business Models to Realize the Potential of Renewable Energy and Energy Efficiency in The Greater Mekong Subregion, ADB

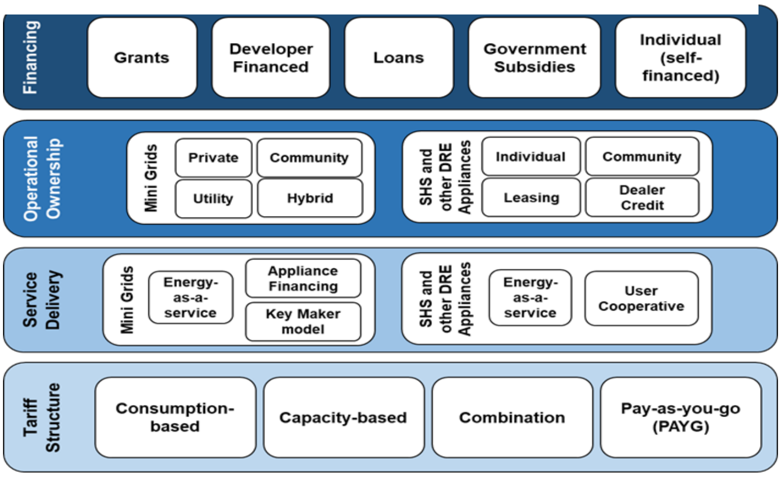
Figure 23: Stakeholders at various levels in a typical DRE project



Source: Business Models to Realize the Potential of Renewable Energy and Energy Efficiency in The Greater Mekong Subregion, ADB

Business models for DRE technologies can broadly be classified based on (1) operational ownership, (2) technology used, (3) type of consumers, (4) service delivery, and (5) type of tariff/billing method.[36] While the technology used and the type of consumers will be location specific for every project, the following chart shows the sub-categories of business models based on the sources of finance, operational ownership, service delivery and tariff type:

Figure 24: Options for financing, ownership, service delivery and tariff structure for DRE projects



[36] State of the Global Mini grids Market Report (2020), BNEF

A. **Based on operational ownership**[37]: Operator models define the ownership of the generation and distribution assets along with the operation of the DRE systems. Regional policies and regulations determine what type of ownership and operation model is implemented in that region.

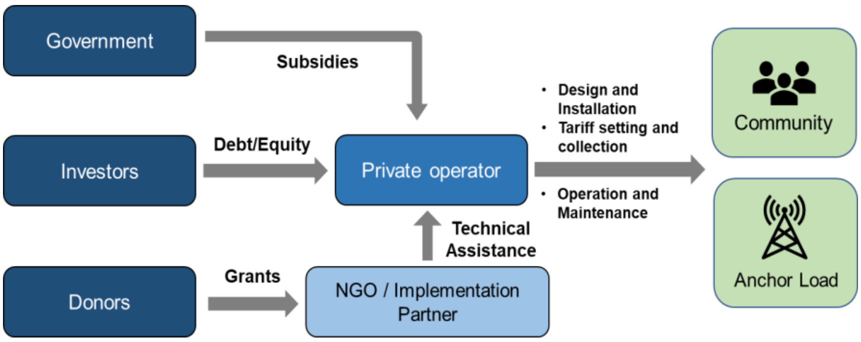
- **Utility operator model**: This model is typically seen in case of mini grids as the utility views these remote mini grids as future expansion targets. The utility operates the mini grid in the same way that it does the main grid. The utility is responsible for power generation and distribution to the consumers usually at the main grid tariffs but may choose to cross-subsidize the mini grid tariffs. Such remote investments are considered risky by the utilities due to the procurement issues and political interference beyond their typical area of operation.

Figure 25: Business model flow for Utility-owned DRE projects

Source: Minigrids and Access to Electricity in SAARC Report (2021)

- **Private operator models:** These models are often simpler with one entity responsible for planning, building, maintenance, and operation of the DRE system. The private entity may opt for external funding, loans, or invest equity, and may also require some level of government support. A significant number of NGOs and other rural development organizations operate under this model, securing foreign funds for the development of the area.

Figure 26: Business model flow for Private-owned DRE projects



Source: Minigrids and Access to Electricity in SAARC Report (2021)

The private operator models can be further classified into (a) franchisee approach, (b) clustering approach, (c) local entrepreneur approach, and (d) anchor load approach.

The **franchisee approach** distributes the management costs of the system at a franchisee level which minimizes the financial burden for the franchisee. This in turn reduces the risk and improves profitability for the private entity through economies of scale. Under the

[37] Mini grid Policy Toolkit (2014), EUEI-PDF(GIZ) & REN21

clustering approach, multiple non-interconnected mini grids across a small geographic area can be clustered together under a single management to reduce operational costs. In the **local entrepreneur approach**, the private entity can offload the management tasks to a designated local entrepreneur, who is constantly present on-site. The entrepreneur in turn benefits from the operation and part ownership of the system. The **anchor load approach** is built around a few key anchor consumers, such as telecom towers, small factories, etc., who have critical, high value loads and require high reliability and availability. Since these consumers are willing to pay higher tariffs for their requirements, it provides a steady cashflow for the system. The presence of the mini grid further benefits local businesses and other consumers resulting in additional revenue.

- **Community-owned model[38]:** The community owns, operates, and manages the DRE system for self-benefit under the **community-owned models.** The funds for establishing the system need to majorly come from grants, donations or from CSR funds with a minor contribution from the community (in cash or kind). A third-party developer handles the planning, design, procurement, and construction of the systems. The community thereafter takes over the management of the system co-operatively.

Expansion of microgrid for a rural community in Haiti using the Anchor-Business-Community (ABC) model to improve climate resilience

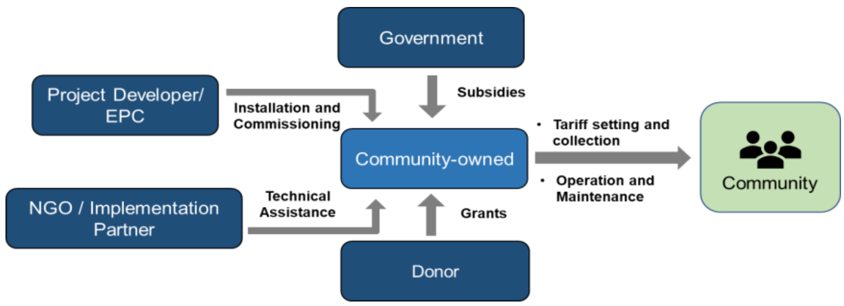
After the 2010 earthquake in Haiti, microgrids were proposed as solutions to electrify remote villages using some 'anchor load'. In 2012, EarthSpark installed a microgrid in the village of Les Anglais based on an anchor load of a telecom tower. By 2013, this microgrid was serving 54 residents, a school and other small local business from the excess capacity of the telecom tower.

In 2014, ZeroBase began expanding the existing microgrid through a 100 kW hybrid mini grid (solar-battery-diesel generator). The existing mini grids now serves 430 households, the local market, small agricultural processing units and other such small businesses.

The customers prepay for their electricity consumption and have access to clean, affordable, and reliable electricity. The mini grid also serves as a pilot to allow Haitian students and technicians to improve their skills for rural electrification and microgrid maintenance.

Source: Microgrid for rural communities in Haiti, USAID-EarthSpark-ZeroBase

Figure 27: Business model flow for a community-owned DRE project



Source: Minigrids and Access to Electricity in SAARC Report (2021)

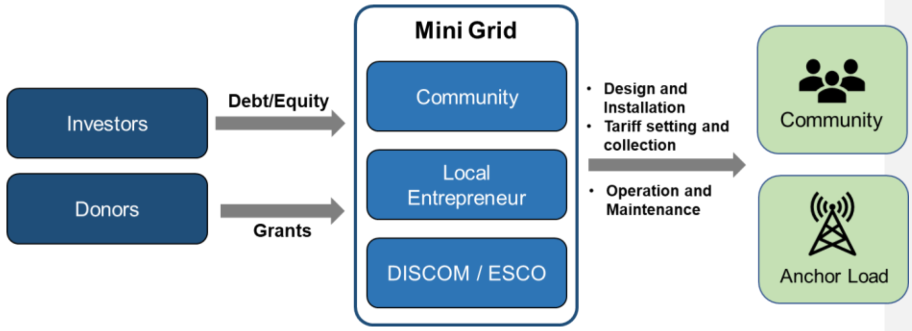
- **Hybrid models:** These models are a combination of the private entity, utility and the community playing different roles in the operation and management of the DRE systems. The utility and the private players may jointly own the generation and distribution assets deriving their own benefits from the joint venture. The private entity and the community

[38] Minigrids and Access to Electricity in SAARC Report (2021)

may be well suited to handling the day-to-day operation and management of the system respectively. Hybrid models are also typically better suited for mini grids due to the scale of the project and the size of the operations that requires multiple parties to be involved.

The hybrid models are governed by different types of contractual agreements between the relevant stakeholders. The **public private partnership (PPP) approach** may be a contract between the utility and the private entity for the ownership and operation of the mini grid respectively. The PPP contracts define the scope of all concerned entities and are typically executed as (a) build–own–operate–transfer (BOOT); (b) build–own–operate (BOO); or (c) build–own–transfer (BOT).

Figure 28: Business model flow for DRE projects with hybrid ownership



Source: Minigrids and Access to Electricity in SAARC Report (2021)

Another hybrid ownership model is the **renewable energy service company (RESCO) approach** which offloads the operation and maintenance of the system to a RESCO in return for collecting fees from the consumers, while the asset ownership remains with the utility. Entities may also choose to undertake a **power purchase agreement (PPA)** for the electricity consumption without having to own and operate the generation and distribution assets.

- **Leasing or Rental model[39]:** This model enables users to purchase DRE appliances in installments. The equipment supplier (lessor) is responsible for providing the appliances to the end users for a specified contract period receiving regular monthly/weekly payments in return.

Figure 29: Business model flow for leasing DRE appliances

Source: Business Models to Realize the Potential of Renewable Energy and Energy Efficiency in The Greater Mekong Subregion, ADB

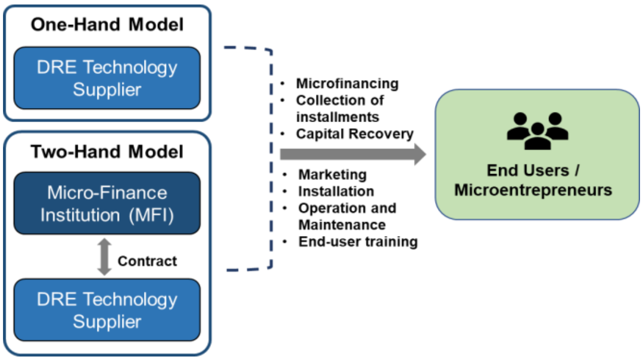
The responsibility of sourcing, financing, installing, and maintaining the equipment during the contract period falls with the supplier (lessor). At the end of the contract period, the equipment is either returned to the supplier or retained by the end user. NGOs typically

[39] Business Models to Realize the Potential of Renewable Energy and Energy Efficiency in The Greater Mekong Subregion, ADB

operate under this business model due to their access to finance which enables them to purchase these DRE appliances in bulk and disburse them in remote regions.

- **Dealer Credit model[40]:** In this model, the technology supplier can provide loans for the purchase of DRE appliances. In some cases, a micro-finance institution (MFI) and a technology provider work together, with the MFI being responsible for the loans, collection of payments and installments and capital recovery in case of default, and the technology provider handles the marketing, installation, after sales services and end user training. There is also the possibility of government intervention in this model where the government can provide a soft loan which in turn reduces the interest rates at which the MFI finances the appliances. The ownership is always transferred to the end user at the end of the loan period.

Figure 30: Business model flow for Dealer Credit



Source: Business Models to Realize the Potential of Renewable Energy and Energy Efficiency in The Greater Mekong Subregion, ADB

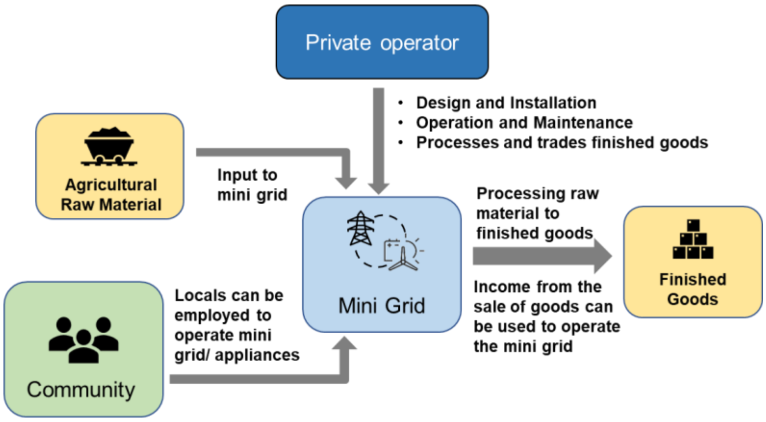
B. Based on Service Delivery[41]: Business models need to provide some product/service to the end consumer. In case of mini grids, the output is electricity which can be used by residential or commercial consumers, depending on the system design, either for domestic or productive end-use. Solar Home Systems and other DRE appliances are used at a consumer level, unlike the mini grids which have community-level benefits. Since the investment required is relatively low as compared to the mini grids, the business models for DRE appliances are slightly different.

- **Energy-as-a-service model**: A mini grid developer handles the complete installation, operation and maintenance of the mini grid and sells the energy produced in return for all the operation and management for a pre-agreed tariff. The consumers only have to pay for the energy service without any capital investment upfront.
- **Appliance financing model:** This business model allows the developer to provide the consumers with productive end-use appliances, such as solar water pumps, SHS, solar chillers, solar dryers, etc., on lease or for ownership through monthly installments. The developer may have to educate the consumers on the benefits and usage of the appliances, but this improves the livelihood generation of the involved communities and therefore increases the overall economic activity on the region.

[40] Business Models to Realize the Potential of Renewable Energy and Energy Efficiency in The Greater Mekong Subregion, ADB
[41] State of the Global Mini grids Market Report (2020), BNEF

- **Key maker model:** Involves productive end-use appliances but the developer purchases raw material/products from the rural consumers, processes these products using the electricity from the mini grid and sells them into the urban market. The mini grid provides the additional benefit of managing the electricity needs of the rural consumers.

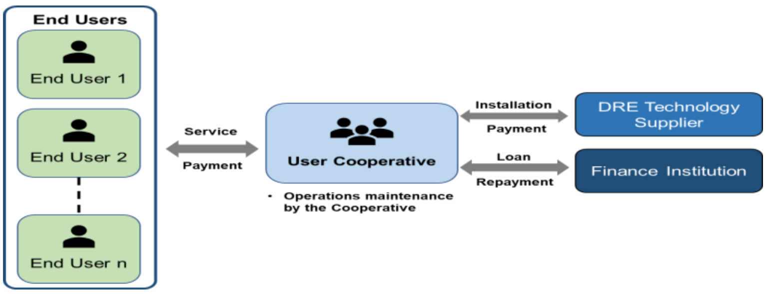
Figure 31: Business model flow for key maker model



Source: Mini-grid business models, Green mini-grid help desk (2020)

- **User Cooperative model:** In this model, a non-profit community organization is established which is owned and managed by its members. Member contributions, along with public/private financial support, are used to fund projects which are installed, owned, operated, managed, and maintained by the cooperative. NGOs and governments typically favor investing in such cooperatives through grants or loans. User cooperatives operate on the principles of voluntary membership, democratic control, economic participation, independence, and concern for the community. These cooperatives are usually set up for a larger scale of operations (community level) and sells energy as a service.

Figure 32: Business model flow for User Cooperative model



Source: Business Models to Realize the Potential of Renewable Energy and Energy Efficiency in The Greater Mekong Subregion, ADB

C. Based on the type of tariff[42]: Models can also be segregated based on the type of tariff and the billing method. Mini grid developers can charge the consumers for the electricity

[42] State of the Global Mini grids Market Report (2020), BNEF

consumption or the maximum power demand depending on the generation technology in the mini grid.

- **Consumption-based tariff structure:** Charges consumers based on the per unit electricity consumption. This type of a tariff structure is used by the national utilities and mini grid developers with solar and wind energy-based generation since the revenue aligns with the power consumption. Such tariffs can have flat rates, electricity block-wise rates, time-of-day rates or seasonal rates.
- **Capacity-based tariffs:** Charged based on the maximum demand allocation to the consumer. Typically, hydropower based mini grids implement such tariffs as the marginal cost of electricity is negligible. Such tariffs can be implemented as a fixed bill or can vary with the number of devices in a household.
- **Combination tariffs:** A combination of the consumption- and capacity-based tariffs can also be implemented which allows developers to apply demand side management strategies due to the variable consumptions charge. A time-bound tariff allows consumption within a specific block of time whereas energy-as-a-service requires consumers to pay for the devices that they use within a certain period.
- **Pay-as-you-go (PAYG) models:** Allow consumers to pay only based on their use of the service rather than a periodic fixed charge. PAYG is further facilitated by smart meters and prepaid meters but can also be implemented through a local collection agent, mobile payments, or scratch cards. Such models are often integrated with appliance financing models to stimulate demand.

PAYGO: Solar distribution through pay as you go business models in East Africa

As per the World Bank report, 77% of the total unelectrified population in the world resides in Africa. Affordability has been a key concern in the adoption of DRE technologies in the continent. After multiple failed business models to implement such technologies, a mobile payments-based "pay-as-you-go" (PAYGO) model has been put into practice in the recent years to improve the adoption of Solar Home Systems (SHS).

Many companies have adopted the PAYGO model for a varied range of system sizes with prices ranging from USD 150-1000. These systems include basic lighting and mobile charging options but can also be sized up to include TVs and small fridges. The payments are to be made in small installments spaced over 12-36 months based on the size and cost of the system. The PAYGO model has optimized the distribution costs and the mobile-based payments facility has improved payment recovery rates significantly. Using an efficient management information system (MIS) system, further improves the operational and financial efficiencies. The model has reduced the financial threshold of owing such SHS systems for poor households, which has allowed them access to cheaper and useful form of energy in the household. Along with a positive impact on family finances, it has simultaneously improved the school grades of children, helped avoid the health risks linked to kerosene lamps, and created a secure environment for the families.

Source: PAYGO: Solar distribution through pay as you go business models in East Africa, KPMG Thought Leadership

The section below outlines a few case studies where some of these business models have been successfully implemented in various geographies over the world. It also describes the impact on the communities due to the various electricity access options and the learnings from each case.

4.2 Case Studies

1. Adaptive Solar PV Mini grids in Tanzania provide reliable low-cost electricity to create widespread socio-economic benefits[43]

Need

Figure 33: Solar PV mini grid in Tanzania

Approximately 32% Tanzanians had electricity access in 2017, an improvement from the mere 9% with electricity access in 2000, but far from achieving universal access. In 2017, this corresponded to over 37 million people lacking electricity access. With a low national generation and distribution capacity, grid-connected households have intermittent access to electricity. Connectivity to the grid in rural areas was available for only 7% of the consumers. Kerosene was a predominant mode of lighting, increasing household costs due to fuel purchase requirements and having a negative impact on the environment and community health.

This widespread lack of electricity resulted in a lack of access to various modern amenities. Cell phone usage was nonexistent as there were no affordable means to charge them. There was also no potential for the use of electrified machinery for productive uses that could improve income and generate employment for the local population. The slow rate of grid expansion in the country also implied that many rural areas would not receive electricity access for over a decade. Additionally, a connection to the grid would cost an unaffordable USD 200 or more, and supply would not be reliable. Thus, there was a need for an alternative solution that could provide affordable electricity access to rural communities and assist with development.

Solution and Impact

Keeping the local requirements in mind, Devergy, a social energy services company, used an adaptive mini-grid system to electrify remote villages. Deploying a distributed solar PV network combined with battery storage across various villages, Devergy were able to provide up to 250 W of DC electricity to between 60 and 400 households at a system reliability of 99%. The various micro-grids deployed were linked with a wireless communications system to share data with each other and allow for remote monitoring and control. The mini-grid customers were able to purchase efficient DC compatible appliances from local kiosks. Thus, customers were able to access devices such as cold storages, rechargeable carpentry machinery, and chargers for cell phones.

An innovative flexible payment system was deployed, allowing consumers to pay in daily, weekly, or monthly packages at a local kiosk. Electricity credits were added to home meters through mobile money. The installation costs are covered by Devergy, apart from a small connection fee covering metering, wiring, installation, and two bulbs. Remaining costs are covered through per-use energy charges. This system benefits both consumers and operators and is far more affordable for providing electricity access to rural Tanzanians when compared to grid connection costs. Devergy's solution costs only USD 6-12 for initial

[43] USAID Mini grid Support Toolkit - Case Studies

installation/connection, with the remaining costs being recovered through the energy charges, whereas the grid connection costs USD 250.

Key Parameters

Established	2017 (operational)
Beneficiaries	1266 households and businesses across 20 villages
Technology	Solar PV with battery storage, and wireless control and monitoring
Type of Loads	Small household appliances (such as lighting, mobile-phone charging, televisions, and fans) and small businesses
Ownership	Devergy (Private ownership)
Business Model	Build-Own-Operate-Maintain along with Appliance Financing
Project Cost and Financing	Capital costs financed through grants and private equity. Distribution and interconnection network subsidized by the Rural Energy Agency
Policies and Regulations	Incentive program under the Tanzanian Rural Energy Agency

Learnings

- Innovative and technologically sophisticated systems allow easy operation, monitoring, and maintenance. Community involvement is equally important to generate employment and system planning.
- Modular battery systems allow for incremental increase in system capacity based on increasing demand.
- Private ownership is the key to success as the locals lack the skills to operate and maintain the system. But private entities should be able to make long term commitments for the continued operation of the system.
- Initially the systems installed by Devergy were not eligible for the government subsidy of USD 2.50 per W under the Rural Electrification Scheme as such subsidies only applied to solar home systems and not mini grids. The Tanzanian Rural Energy Agency later modified the subsidy program to include mini grids.

2. Anchor load based solar PV mini grid in India attracts smalls businesses to the area[44]

Need

Though the state of Uttar Pradesh (UP) is 100% electrified, reliable supply of electricity in rural areas is a significant concern for residents and small businesses. According to the Prayas Energy Group (PEG), consumers in rural UP observe an average daily power cut of more than 4 hours. Some instances also document power outages lasting almost 14 hours. Residential consumers in rural areas still rely on kerosene lamps for lighting and off-site charging solutions for mobiles. Telecom towers and small business, such as the garment factory in Kamlapur, rely on diesel generators which are expensive and polluting. Cleaner, local solutions are needed to provide access to clean electricity and improve consumer convenience at affordable costs. Thus, mini grids were proposed as a solution to provide guaranteed, reliable power across various consumer segments.

[44] Solar Mini grids Case Study (2019), ISA-NEDO

The solar hybrid mini-grid system installed under the ABC model in Bilgram, a small town in Hardoi district in the state of Uttar Pradesh, India, is illustrated in the figure. The project was an outcome of multiple private investments and debts.

Solution and Impact

These days, more and more developers are investigating ways to serve C&I customers or other commercial customers with significant predictable demands (such as for irrigation pumps and cold storage) while using the extra capacity to provide electricity to small residential consumers. This improves the mini grids' utilization rate and lowers risks, which lowers power costs and boosts developer profits. These steady loads are referred to as 'anchor loads' which form the basis for the ABC model. In OMC's case, the long-term power purchase agreements with the telecom tower company (Anchor load) helps ensure positive and stable cash flows to the solar mini grid.

As a result, telecom towers and small businesses shift from diesel to clean electricity for their electricity requirements. Telecom towers can achieve 20-30% cost savings from reduction in diesel consumption and significant emissions reduction with increased reliability of supply. Further, new businesses are attracted to the area due to the reliability and affordability of power supply.

Also, rural households shift from kerosene lamps to electricity for their lighting and charging needs. Use of electricity also improves the indoor environment and allows indoor activities like studying, cooking, cleaning even after sunset. A gradual increase in residential consumption is also observed with improvements in quality of life.

Key Parameters

Established	2019 (operational)
Beneficiaries	14 kW project serves 2 telecom towers (6 kW), 5-10 small businesses and 200-500 households
Technology	Solar PV with batteries (Diesel generator as backup)
Type of Loads	Telecom towers, small businesses, and residential consumers
Ownership	OMC Power (Private ownership)
Business Model	Build-Own-Operate-Maintain model and Anchor Load, Businesses and Consumers (ABC) model
Project Cost and Financing	Combination of private equity and debt financing with an IRR of 25-35% and a payback period of 5-7 years
Policies and Regulations	Rural Electrification Policy, Mini grid Policy Uttar Pradesh, Draft National Policy for RE based Micro and Mini grids, Sahaj Bijli Har Ghar Yojana for last-mile connectivity

Learnings

- Anchor loads provide long-term revenue certainty for project developers.
- Such projects positively affect women's empowerment, safety, employment generation, and the economic development of the community by enabling business and entrepreneurship.
- Community consumes clean, reliable, and affordable power compared to conventional sources.
- Reduction in diesel and kerosene consumption leading to reduce expenses and local emissions.

- Inclusion of the local community in the strategic planning and provision of services beyond electricity creates a positive narrative within the community thus helping technology acceptance and increasing uptake.

3. CIZO Programme in Togo to increase electricity access rapidly and effectively through the uptake of off-grid energy services[45]

Need

Togo is a country in West Africa on the Gulf of Guinea. The primary source of electricity in the country is through fossil fuel generation. However, the country is also heavily dependent on imported electricity to fulfil its electricity demands.[46]

Despite importing electricity, the country continues to face electricity access challenges. Approximately 48% of the population in Togo had access to electricity as per World Bank data from 2017. Additionally, there is significant electricity access deficit in rural regions, with only 19.5% of the rural population having access to electricity. Thus, there is a need for innovative methods of electrification that can service rural and remote communities in a clean and sustainable manner.

Solution and Impact

Figure 34: SHS in Togo, CIZO Program

In 2018, the Togolese government implemented the National Electrification Strategy (NES) with the aim of attaining universal energy access by the year 2030. A strategy has been devised under the NES to enhance private sector investments in the power sector and achieve the electrification target. The strategy involves a blend of grid and off-grid technologies, including the implementation of 555,000 solar home systems (SHS), 300 mini-grids (which will facilitate electricity access for 55,000 households), and 670,000 on-grid connections between 2018 and 2030.

Recognizing the challenges associated in securing last-mile connection, the government established a public-private partnership strategy for deploying SHS, and in 2018 launched the CIZO program ("Cizo" means "turn on the light" in the local dialect).[47] The CIZO program is operated by the Togolese Agency of Rural Electrification and Renewable Energy (AT2ER) and seeks to provide electricity access to 1,970 of the NES-identified localities having no access to electricity, thereby creating a market to electrify more than 555,000 households with SHS.

The AT2ER has implemented the program in collaboration with various authorized PAYG solar companies, which includes: BBOXX, Soleva, Engie Energy Access, Solergie and Moon. The companies that were granted licenses are required to meet following conditions:

- Service and after-sales service quality over the long term
- Preference for the energy as a service model, rather than a loan to ownership model
- Minimum 20W with the option to upgrade for all operators
- Minimum product quality (min. Lighting Global certification), and

[45] togo_country_brief.pdf (gogla.org)
[46] Power Africa in Togo | Power Africa | U.S. Agency for International Development (usaid.gov)
[47] PowerPoint Presentation (gogla.org)

- Machine to machine connectivity (M2M) with the option to connect to a national platform.

In the context of the program's public-private partnership framework, the private partners bear the responsibility of overseeing the various operations throughout the value chain, encompassing the procurement of solar PV equipment, distribution logistics, payment collection, and system maintenance. While the public sector offers subsidized access to pre-existing infrastructure, consumer awareness campaigns, and exemptions from value-added tax. With the provision of market enabling activities by the government, the private operator costs are reduced by 20% through preferential tariffs when state logistics are used (the national postal agency LaPoste provides transport and storage services), state-sponsored marketing campaigns, and the training of local agents in maintenance through solar academies, as well as customers in SHS usage. The program has facilitated the training of 3,000 local technicians in the installation, maintenance, and repair of SHS, as well as trained 3,000 agents in the domain of mobile banking.

The government has implemented measures to manage the demand side by addressing the issue of affordability for end-users. This has been achieved through the provision of access to finance for consumers via Pay-As-You-Go (PAYG) platforms offered by SHS companies, as well as through end-user subsidy known as CIZO cheque. The CIZO Cheque program offers a monthly subsidy of USD 3.30 for a duration of 36 months, thereby rendering SHS economically feasible for nearly 50% of the off-grid population in Togo.

The CIZO initiative is a notable example of a government utilizing digital technologies such as PAYG platforms, mobile money services, and a national database to ascertain the eligibility of subsidy beneficiaries, with the aim of enhancing energy access through the adoption of off-grid energy services. Nearly 80,000 households were electrified from the CIZO program, with 91% of these households having benefited from the subsidy.

Key Parameters

Established	2018 (operational)
Beneficiaries	555,00 households and across 1,970 localities
Technology	Solar Home Lighting System (SHS) with real time remote monitoring
Type of Loads	Basic household appliances and productive use
Ownership	Private ownership
Business Model	Pay-As-You-Go (PAYG)
Project Cost and Financing	Mix of Equity and Subsidy
Policies and Regulations	Licenses and Incentives provided under the CIZO program

Learnings

- Clearly defining the role and responsibility of each stakeholder provides clarity to the market and makes it easier for companies to provide SHS to consumers at affordable prices
- The use of targeted subsidies can help provide an initial push to underserved rural markets and drive growth, and can be gradually scaled back as the market achieves maturity

- Use of digital tools for program monitoring and payments makes it faster and easier to manage funds and keep track of progress and impact
- PAYG mechanism combined with capital subsidy can effectively address the affordability issues of poor households in the off-grid areas

4. Hub and spoke model based solar powered mesh-grid in Haiti[48]

Need

Haiti is a Caribbean country on the island of Hispaniola. The country suffered a devastating earthquake in 2010 that severely impacted local infrastructure. To further compound the challenges faced by the country, electricity access rates have not improved much in the past 40 years. According to the World Bank, only 46.9% of Haitians had access to power in 2020.

One of the main reasons for this lack of electricity access is the country's limited and unreliable power grid. As a result, many small towns have to rely on localized generation, often using fossil fuels, to power homes, schools, and various commercial activities.

Solution and Impact

Figure 35: Solar mini grid in Haiti

Alina Enèji, a Haitian project developer, used Okra's (an Australian mini grid technology provider) Hub and Spoke mesh-grid technology to bring solar electricity to 30 homes in Dulagon, a remote rural town. The success of this pilot drove the company to expand the network to 300 more households in Dulagon and the surrounding villages.

Site studies showed that most homes didn't need more than 200Wh per day, but there were also a lot of homes that needed medium to high amounts of electricity. Prior to the mini grid's arrival, kerosene, gasoline, and other fossil fuels were used to meet domestic demand.

Alina Enèji deployed their mini grid as a "hub-and-spoke" system, which allowed an average daily load of 440 Wh/day and 1.5 days of battery power. The "hub" is a consumer with significant electricity demand who receives prioritized electricity supply from the mini grid. This "hub" consumer is linked to multiple smaller "spoke" consumers who consume the excess electricity remaining after the "hub" consumer's demand is met. The clusters of linked homes are equipped with the "Pod" from Okra, which is a system controller that sends extra electricity from one home to another.

By installing their mini grid solution, Alina Enèji was able to provide the same electricity service for 52% of the cost of standard solutions. Additionally, Alina Enèji was able to develop the project much faster than the average time it takes for a mini-grid project to be approved and built. The deployment of solar capacity with battery storage also allowed for round the clock availability of solar electricity. As a result, the community's reliance on fossil fuel powered generators was reduced, and their usual fossil fuel costs for electricity were reduced by 50%.

So far, the beneficiary Haitian families use the access to electricity to run household appliances such as fans, freezers, and fridges. Consumers are also setting up small businesses powered by the mini grid electricity, such as restaurants and shops serving cold water and drinks.

[48] https://www.ruralelec.org/project-case-studies/alina-eneji-scaling-mesh-grids-rural-haiti,

With 330 households energized, Alina Enèji is further electrifying another 700 households. The company plans to expand its electricity access portfolio with the aim of providing electricity access to additional potential 10,000 households in Haiti.[49]

Key Parameters

Established	2022
Beneficiaries	300 households from Dulagon and surrounding villages in Haiti
Technology	Solar-powered mesh-grids with a total capacity of 63 kWp and 178 kWh of battery storage, plus remote monitoring
Type of Loads	Residential and commercial
Ownership	Alina Enèji (Private)
Business Model	Hub and Spoke based RESCO model
Project Cost and Financing	USD 156,782 Combination of equity, debt, and grant funding
Policy and Regulation	Regulatory and technical support provided by the Haitian body Autorite Nationale de Regulation du Secteur de l'Energie (ANARSE) for utilisation of hub and spoke model and associated technology for grid connected households

Learnings

- Close coordination and site surveys with the local community, along with the use of digital simulations, lead to the selection and identification of spoke and hub consumers, as well as the right sizing of the solar PV system
- Instead of a centralized mini grid, a cluster of small mini grids makes it possible for consumers to get low-cost electricity services
- The use of Pay-As-You-Go mechanism ensured quick and transparent revenue collection from the consumers
- The modular design of the system lets the service provider give Tier 3-4 level electricity access to customers, which opens long-term possibilities for social and economic growth.

5. Private-community hybrid ownership mini grid on Koh Jik Island, Thailand[50]

Need

Thailand has a number of small islands that are not connected to the main grid. These islands depend on off-grid solutions, including mini grids, to provide electricity to the community. The community of Koh Jik Island had been operating a community owned mini grid since 2004, that had been upgraded in 2012. However, by 2018, critical system components reached end-of-life, and the mini grid could no longer reliably meet community demand.

Solution and Impact

The Koh Jik ReCharge team, consisting of the project team from InnoEnergy Master's school, identified investors, conducted a techno-economic analysis for mini grid optimization, and facilitated negotiations between the community, investors, and the government. Two private sector developers, Blue Solar and Symbior Solar, provided the funding for the project.

[49] https://okrasolar.com/case-study/alina-eneji-scaling-up-in-mesh-grids-in-rural-haiti/
[50] Alliance for Rural Electrification, Energy For All, REEEP: Private Sector Driven Business Models for Clean Energy Mini-Grids: Lessons learnt from South and South-East-Asia

Figure 36: Koh Jik Island Mini Grid in Thailand

A 60 kWp Solar PV mini grid with 255 kWh batteries was planned, with diesel generator as emergency backup. The system technical design and hardware selection was carried out based on load analysis and scenario development for different configurations. Additionally, community consultations were held to ensure buy in and benchmark the new tariff with the existing tariff to assess sensitivity to price change. The presence of trained community members, along with existing knowledge of mini grids increased the likelihood of project success. Additionally, agreements were made within the community (such as limiting the usage of high demand appliances) to keep community demand within mini grid capacity.

The community energy company owns the existing assets on the island before the recent upgrade. It was responsible for maintenance, billing and collecting the electricity revenue, which has now been transferred to the investors. The investors agreed to invest in equipment upgrade under the conditions of the PPA with the community energy company. The PPA is for a duration of 10 years with an option for extension to 5 more years under the provision of a battery upgrade included in year 11. This means that during the PPA duration, all the generation is handled by the investors.

Total project cost of the mini grid was ~USD 172,000, provided by the two developers as a mix of debt and equity. A grant for ~USD 19,400 was provided by the Australian Embassy Direct Aid Program (DAP) to install and commission 100 smart meters with pre-payment functionality. The tariff for the mini grid is higher than the national tariff, but consumers are willing to pay as they are provided relatively affordable and reliable electricity access in a location with no possibility for grid connections.

Key Parameters

Established	Operating since 2004 (upgraded in 2012), but in 2018, critical system components reached end-of-life and were re-funded
Beneficiaries	A community of 400 inhabitants in the Koh Jik Island, Thailand
Technology	60 kWp Solar PV with 255 kWh batteries (Diesel generator as emergency backup)
Type of Loads	Commercial and residential loads
Ownership	Blue Solar and Symbior Solar (Private); Koh Jik Island Community
Business Model	At first, community-owned, now operates as Private-Community Social Enterprise Model under Build-Operate-Transfer modality
Project Cost and Financing	Private equity (~USD 172,000) and Australian grant (~USD 19,400) for smart meters with pre-payment functionalities
Policies and Regulations	Tariffs for off grid projects on islands can be negotiated between developer and community

Learnings

- Close coordination with the local community, including step by step consultations from design phase to tariff setting, allows for local participation in the project and clear buy in from community members

- Pre-payment billing and metering system utilised in order to ensure revenue collection and support the overall management of the mini grid
- Installation of a System Monitoring Unit (SMU) allows for data monitoring with remote access, allowing for scenario analysis and suitable sizing and design of the PV and battery storage system
- High reliability solar powered mini grid allowed minimal need for diesel generation and allowed community access to productive end use tools such as power tools and high-pressure water pumps

6. Key Maker mini grid model by JUMEME on Maisome Island, Tanzania[51]

Need

Lake Victoria is Africa's largest lake by area, and around half of its area lies in Tanzania. The lake has a number of islands, including Maisome island. Fishing is a key economic activity for the local populace, with Tilapia fish being a key produce considering the high demand for the fish in Tanzania. This demand is primarily met through imports. Despite the availability of captive demand for Tilapia, local fishermen have been unable to take advantage of this and supply the fish to larger cities due to the lack of suitable cold storages and supply chain infrastructure

Figure 37: Maisome Island Mini Grid in Tanzania

Solution and Impact

JUMEME, a rural PV mini grid power supplier, was established in 2016 as a joint venture between INENSUS and Terraprojects, as well as Tanzania's Saint Augustine University. The company received funding from an EU grant but also raised debt and equity. The company began operations in 2018 with a 200 customer pilot in Bwisya village, Ukara Island. Subsequently, company raised significant equity and began an expansion process for their mini grids. After experimentation with a number of business models for their mini grids, the company settled on the Key Maker model for deployment on Maisome island in Tanzania based on its success on Ukara island.

Under the Key Maker model, the company developed a fish trading business alongside its mini grid project. This business would purchase Tilapia fish caught by local fisherman, freeze the same on site using electric freezers, and deliver them to large cities, including the capital, Dar es Salaam. This was accomplished without breaking the cold storage chain.

The mini grid consists of 60 kWp of solar capacity, a 12 kWp back-up diesel generator, 57 kW of batteries, and 57 kW of inverters. Additionally, around 22 km of distribution lines were also set up for the mini grid. The project earns revenue through both the fish trading business, as well as the electricity supplied by the mini grid. Additionally, the mini grid capacity utilization is improved through the development of the business in the community.

As a result of both providing electricity access and establishing a local supply chain, the Key Maker model was able to improve the economic position of the local fishermen. Additionally, JUMEME purchased the Tilapia from local fishermen at fixed rates, improving their overall income and driving local employment. 16 permanent and 20 seasonal fishermen earn revenue

[51] IDS_Research_Report_89.pdf

from the model, and 170 people across 36 families enjoy the increased income. Over USD 32, 000 of additional cash is injected into the village economy annually as a result of these operations.

Key Parameters

Established	2018
Beneficiaries	600 customers, mainly residential with 21 intensive productive users and ~50 commercial users
Technology	60 kW Solar-battery-diesel hybrid power systems
Type of Loads	Irrigation, Food Processing, Cooling, Commercial
Ownership	Privately owned
Business Model	Pay-As-You-Go model
Project Cost and Financing	Total project cost of USD 230,000, mainly financed through an EU grant but also includes some debt and equity, including equity through RP Global, INENSUS, and Terraprojects
Policies and Regulations	Tanzania's Energy and Water Utilities Regulatory Authority (EWURA) sets the guidelines and provide approvals for the mini grid tariff structure

Learnings

- The diversified revenue streams under the Key Maker model, namely the fish trading business as well as mini grid operations, help diversify project risk and improve project revenue
- Employment of locals for operation and maintenance of the PV systems along with the processing of the raw material (Tilapia fish) into semi-finished goods improves income and creates jobs for the community
- Real time remote monitoring of electricity consumption helped improve overall system reliability
- PAYGO mechanism utilised for sale of electricity, with differentiated tariff depending on consumer types such as households, commercial units (shops) or industrial customers (miller), and the time of day that electricity is used

DRE solutions, and mini grids in particular, can support in bridging the electricity access gap in developing countries. However, it is important to understand and quantify how mini grids compares with other electricity access solutions. The subsequent chapter will aim to highlight the key techno-commercial factors to be considered for mini grid deployment and evaluate mini grids relative to grid extension to find situations where their deployment is preferable.

5. Techno-commercial analysis of mini-grids

Techno-commercial analysis involves the estimation of the technical and economic performance of a system throughout its lifetime based on the various technical and financial parameters. Conducting a techno-commercial analysis can allow us to determine the viability of mini grids as compared to other electrification approaches such as grid extensions or DRE in various scenarios. The major technical and cost parameters that feed into a techno-commercial analysis for a mini grid are highlighted below.

5.1 Technical and Cost Considerations

5.1.1 Technical design, sizing, and service level

For a solar mini grid, proper selection of the various components will include PV modules, PV inverters, batteries for electricity storage, distribution infrastructure, and metering components. Additionally, a diesel generator for backup and its associated fuel cost must also be accounted for.

In addition to the technology selection considerations, PV module and inverter capacity, as well as battery bank capacity must be properly sized to meet the estimated demand for the target population. Incorrect project sizing can have implications for the Levelized Cost of Energy (LCOE) from the project, as well as its overall quality of operations:

- Oversized mini grids require increased capital investment and result in higher operational costs. As a result, oversizing will result in an increased payback time for the developer and will reduce project efficiency due to likelihood of wastage of generated solar electricity and underutilization of assets.
- Undersized mini grids result in unreliable supply to the target population and can also result in blackouts. This will result in a dissatisfied and untrusting consumer base that may be unwilling to pay for electricity from the mini grid in the future. Additionally, the project developer will miss out on potential revenue from the underserved consumer base.

In addition to sizing, it is important to consider the detailed standards for system design and selection of components to be used. Additionally, details for design of technical components, such as solar PV capacity and battery bank design, are crucial to ensure optimum usage and to protect their usable life. The sizing and demand considerations must be informed by a demand assessment activity that identifies a demand profile for the target population and assesses peak demand hours and load profile characteristics.

The availability of the mini grid, its overall reliability, and its degree of flexibility for the consumer must be considered when evaluating a mini grid. These factors improve the level of service that a mini grid can provide but may also lead to increased capital expenditure. Striking the right balance between these two outcomes has a significant impact on the techno-economic feasibility of a mini grid. The targeted level of service for a particular community is also determined by the estimated demand and propensity to pay for the consumers.

5.1.2 Costs

A major determinant of the cost of mini grid electricity is the capital expenditure required for its various components. A wide range of figures are seen for the various components of mini grids as shown in the table below:

Table 7: Cost of Mini Grid Components

Component		Costs	
		Median	Range
Solar Panels (Including PV Inverter)		USD 441/kWp	388 - 599 USD/kWp
Battery	Lead Acid	USD 193/kWh	154 - 224 USD /kWh

Component		Costs	
		Median	Range
	Lithium Ion	USD 314/kWh	271 - 414 USD/kWh
Inverter and EMS		USD 415/kW	325 - 716 USD/kW
Distribution and Meters		USD 250/Cust.	163 - 331 USD/Cust.
Customers		USD 836/Cust.	480 - 1290 USD/Cust.

Source: World Bank ESMAP Analysis

Note: Range considers 25th Percentile and 75th Percentile values as lower and upper bounds respectively

The cost of each of these components have come down significantly in recent years, making mini grids increasingly viable for project developers. This significant cost reduction has been driven by a variety of reasons across components, including technology improvements, increased manufacturing scale of components, bulk procurement, supply chain development, and economies of scale due to deployment of larger mini grids.

Table 8: Cost Change per year for Mini Grid components

Component	Period	Cost Change per Year
Solar Panels (Including Racking and PV Inverters)	2012 - 2021	Reduction: ~USD 32 /kWp
Lithium-Ion Batteries	2016 - 2021	Reduction: ~USD 37 /kWh
Lead Acid Batteries	2012 - 2021	Increase: ~USD 2 /kWh
Battery Inverters, EMS, and Monitoring	2014 - 2021	Reduction: ~USD 97 /kW
Balance of System	2014- 2021	Reduction: ~ USD 89 /kW
Distribution	2012 - 2021	Reduction: ~ USD 24 /Customer

Source: World Bank ESMAP Analysis

Although average costs per component have reduced significantly, they continue to vary widely across various geographies. These variations are dependent on country specific supply chains as well as taxes and duties as applicable.

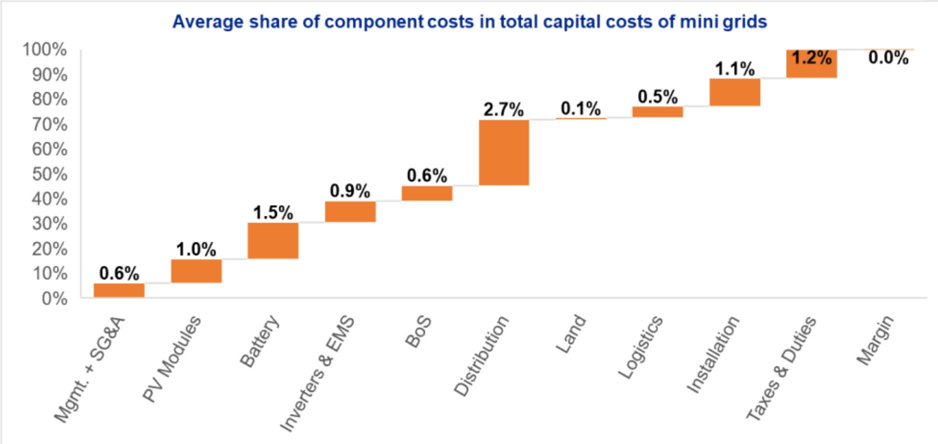
Table 9: Mini Grid component costs in select countries

	Solar Panels ($/kWp)	Lead-acid battery ($/kWh)	Lithium-ion battery ($/kWh)	Battery inverter ($/kW)	Distribution ($/customer)
Nigeria	477	180	331	-	206
Ethiopia	504	-	285	-	385
Tanzania	585	159	614	1431	496
Myanmar	497	231	422	467	321
Kenya	834	142	-	928	307

Source: World Bank ESMAP Analysis

In addition to the costs for the various technical components, additional costs such as selling and administrative costs, land costs, land costs, taxes, and duties also determine the landed cost of electricity for solar mini grids. The figure below showcases the cost distribution of capital expenditure across various components:

Figure 38: Average share of component costs in total capital costs of mini grids



Source: World Bank ESMAP Analysis

SG&A: selling, general and administrative, BoS: Balance of System

5.1.3 Landed Cost of Electricity (LCOE) considerations

Based on a World Bank report that analyzed seven mini grids with varying load factors[52], a decline in the LCOEs has been seen over the years. For a mini grid with the most optimal sizing and performance, the LCOE went down from **USD 0.55/kWh to USD 0.38/kWh** for 22% load factor and **USD 0.42/kWh to USD 0.28/kWh** for 40% load factor operation. **It is projected to further decrease to USD 0.29/kWh and USD 0.20/kWh for 22% and 40% load factors respectively**. The declines in LCOE are observed and projected on the basis of:

- **Declining component costs leading to lower upfront investments** - The upfront investment costs fell down from **~USD 8000/kW in 2010 to USD 3900/kW in 2018** and further down to less than **USD 3700/kW in 2021**. The projections estimate these costs to fall to USD **2500/kW by 2030**.
- **Reduction in operating expenditure** due to remote monitoring, smart meters and other digitalization measures.
- **Introduction of productive, income-generation appliances in the system** – These loads improve the load factor (utilization) of the mini grids and a load factor increase from 22% to 40% is expected to reduce LCOE by 25%. An even further increase in the load factor to 80%, through water pumps and anchor loads, is expected to reduce the LCOE by 37%.

The mechanism of delivery of a mini grid is also an important consideration and will have a bearing on the overall cost of the project. If a project is part of a large-scale deployment plan, it can benefit from bulk procurement and system standardization. The operations of a mini grid will also vary depending on whether they are standalone or part of a larger group of projects. The ownership model followed also changes its characteristics, and can be public, private, or community owned. Mini grids stand to benefit if the delivery mechanism promote economies of scale to lower costs or is aligned with global standards and best practices to ensure quality of project development and operations.

[52] World Bank ESMAP Mini Grids for Half a Billion People: Market Outlook and Handbook for Decision Makers

5.2 Commercial Viability Analysis

We conducted a techno-commercial analysis for a typical mini grid with various scenarios based on the number of households ranging from 100 to 1000. This analysis was conducted to allow us to compare mini grids with grid electrification and standalone solar systems. The following assumptions were taken for the analysis:

5.2.1 Technical Assumptions

- The analysis is not specific to any particular site or country. It was assumed that the location for the analysis has adequate load demand and 6 hours of sunlight.
- The analysis was done for a Tier 2 level of household electrification along with some common community loads such as streetlights and productive loads. The details are shown below:

Table 10: Load assumptions considered for commercial viability analysis

Appliance	Load (W)	Quantity	Daily Usage (Hrs)
(a) Domestic Demand per household			
LED Lamp	9	4	6
Fan	25	1	15
Mobile charger	8	2	4
TV	20	1	4
Sub-total per Household	**97**		
(b) Community and Productive End-Use			
Streetlights	40	10	10
Productive End-use Machine 1	2000	1	6
Sub-total for community loads	**2400**		

- The mini grid system is sized on the above load, with a load factor of ~30%, for the respective number of households in every scenario.
- The distribution infrastructure for the mini grid is assumed to have a loss of 18%.
- The inverter and battery efficiency are both assumed to be 85% with the battery system having a depth of discharge of 80%. The DC side of the system is sized on a stepped up voltage of 250 V for higher efficiencies.
- The peak solar capacity and the battery system capacity are sized on the input energy required at the inverter end and the battery end respectively.

Cost and Financial Assumptions

- For component costs, data was obtained from the Rockefeller Foundation's '*Electrifying Economies Datasheet*'. A comparable cost dataset was also obtained from an industry source.
- Annual O&M costs were assumed to be 5% of the total CAPEX.
- The following component life spans were assumed:
  - PV panels – 25 years
  - Battery Energy Storage System (BESS) – 5 years
  - Inverter – 7 years
  - Diesel generator – 8 years
- PV panels were assumed to degrade to 80% of generation capacity with linear degradation over the lifetime of the panels.

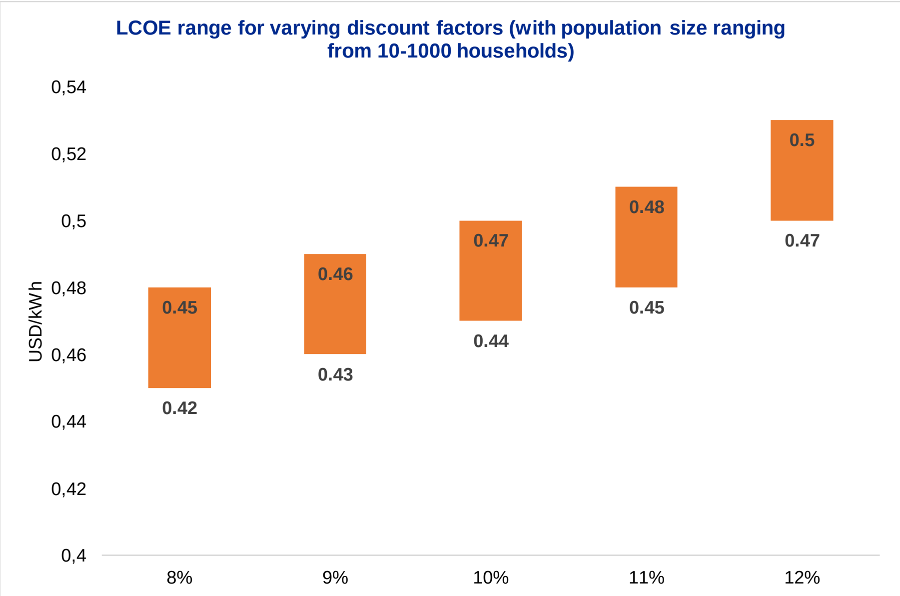
LCOE Calculation Assumptions

- Cost of components is assumed to be the same throughout the project life of 25 years.
- Calculations do not account for the diesel fuel costs for the generator and the taxes and duties on various components.
- Project costs are built without any developer profits and 100% equity is assumed.
- Discount rates of 8% - 12% were used to conduct a sensitivity analysis.

5.2.2 Outcomes from the techno-commercial analysis – Mini grids vs Grid Extension vs Off Grid

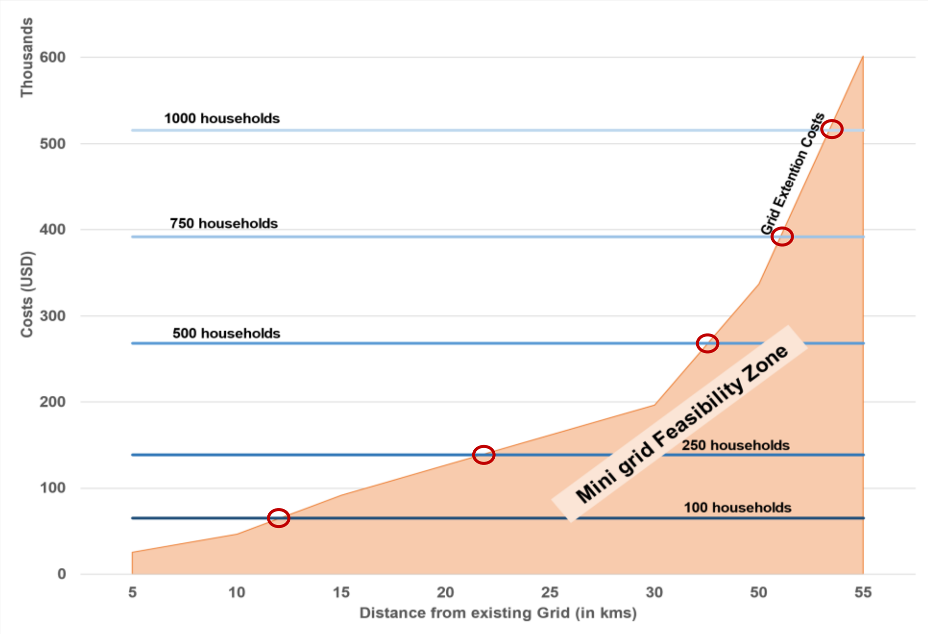
Based on the analysis, the LCOE values for the system **range between USD 0.42 – 0.50 per kWh**. The range of LCOE values for varying level of discount range for households ranging from 100 to 1000 in number is shown in the figure below:

Figure 39: LCOE ranges for varying discount factors



Further, we use the mini grid costs to make a viability comparison between grid extension and mini grids for varying distances from the existing grid. The graph below shows the mini grid capital costs for different number of households along with the grid extension costs per kilometer. The points of intersection of the 'grid extension cost' line with the mini grid cost lines shows the distances at which that particular mini grid scenario becomes feasible compared to grid extension. Grid extension presents the more feasible scenario below the respective points of intersection.

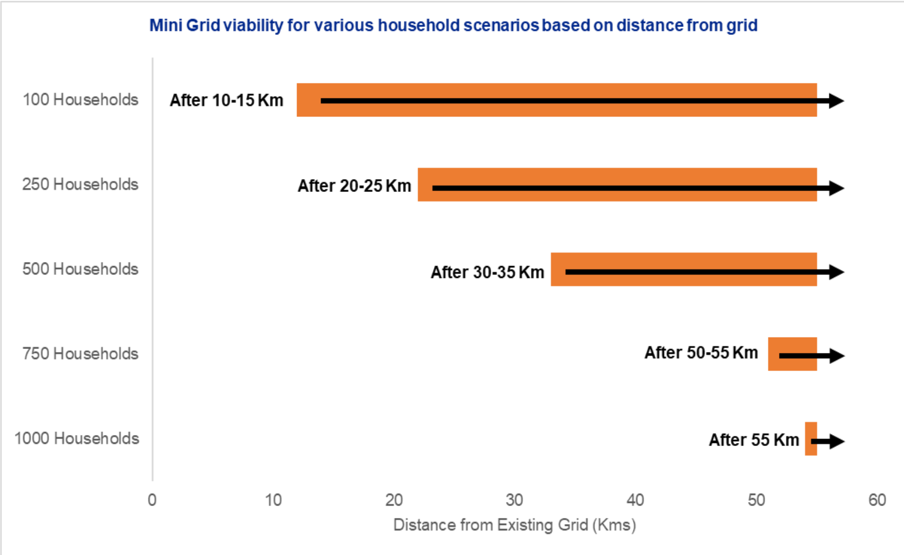
Figure 40: Cost comparison between mini grid and grid extension



As observed from the graph, mini grid capital costs are not affected by distance from the grid, and instead vary based on the number of households to be electrified. In contrast, grid extension costs vary based on the distance from the existing grid as new distribution lines need to be set up to connect with the existing grid and reach the unelectrified regions. Additionally, as the distance for grid extension increases and costlier higher voltage infrastructure is required, grid extension costs increase rapidly.

Thus, mini grids are a better alternative to grid extension for communities with a reasonable number of households that are a significant distance away from the existing grid. This makes mini grids an especially attractive option for small villages of a few hundred households that are unelectrified and located in rural regions. However, grid extension remains cost effective to electrify populations that are relatively close to the existing grid, such as those living on the outskirts of cities. The mini grid viability at various distances from the grid for different household scenarios are shown below:

Figure 41:Mini grid viability in comparison to grid extension based on distance from the grid



Key Insights from the Commercial Viability analysis

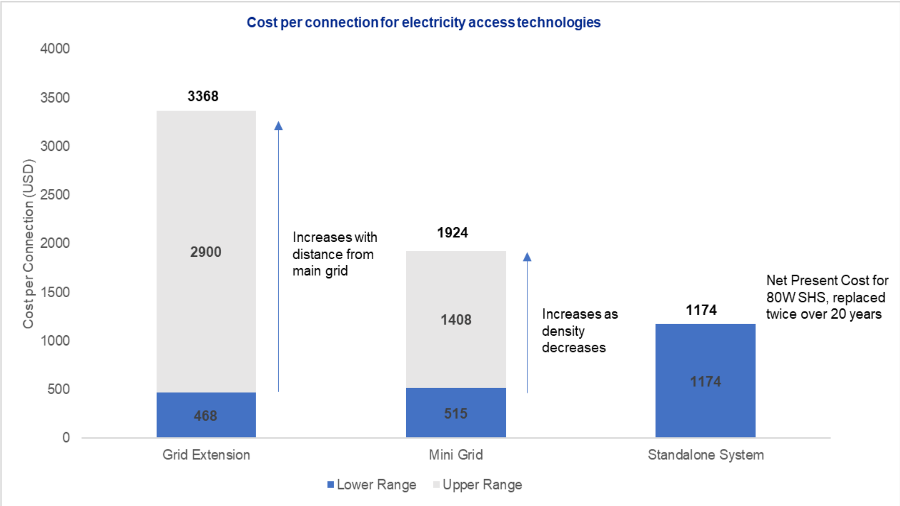
- At distances under 10 - 15 Km from the existing grid, grid extension can prove more cost effective than mini grids
- This minimum distance at which grid extension is more cost effective than mini grids increases as the number of households increase
- Grid extension costs increase sharply after 30 Km and 50 Km due to the use of higher voltage lines

The above analysis establishes a clear case for techno-commercial viability of minigrids vs grid extensions. However, standalone solar home systems must also be considered as a potential electrification option in remote rural regions. In order to obtain a clear comparision between the three main electrification options available, cost of connection per household is considered as a common metric.

Based on Crossboundary analysis for 'like-for-like' connections averaging 100 W per household, Net Present Cost for an 80 W standalone system (considering 2 replacements in 20 years) is obtained to compare alongside grid extension and mini grid costs per connection.[53] For grid extension, the range of costs to electrify a community of 100 households lying between 10 and 50 Km from the existing grid is considered. For mini grids, the range of costs to electrify a community of between 10 and 1000 households was considered. The area of the region to be electrified is considered constant.

[53] Greentech Media and Crossboundary

Figure 42: Cost per connection analysis of different electricity access technologies



Source: ISA Analysis, Crossboundary

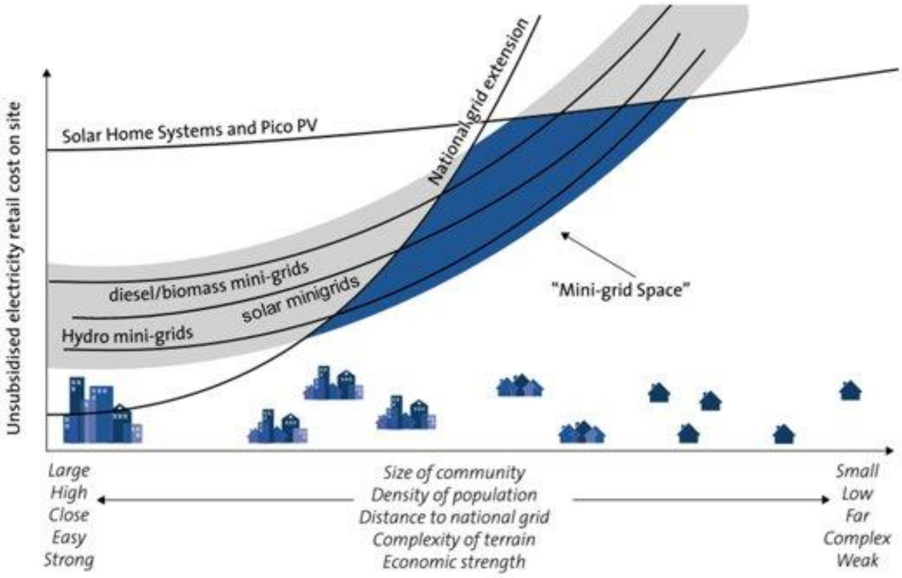
As observed from the chart, grid extension has a higher range of costs per connection, as the capital expenditure for grid extension increases significantly as distance from the existing grid increases. Grid extensions will also benefit from an increase in population density, as the cost per connection would reduce commensurately. Mini grids, due to their limited region of operation, are dependent on an increase in number of households and subsequently an increase in population density to keep cost per connection low. Standalone systems have a fixed cost that is higher than the lower range of grid extension or mini grid cost per connection due to absence of economies of scale as the households to be serviced increase. Standalone systems also provide lower tier of service and cannot be effectively scaled, making them unsuited for electrifying high population density regions. However, they can prove cost effective in low density populations in remote regions with complex terrain that would discourage the development of mini grids and grid extensions.

Key Insights from the Cost of Connection analysis

- Grid extension costs per connection for the specified parameter ranges between USD 468 per connection to USD 3368 per connection
- Mini grid costs per connection range from USD 515 per connection to USD 1924 per connection
- Standalone Systems have an estimated net present cost of USD 1174, accounting for 2 replacements over 20 years
- Grid extension costs are directly proportional to the distance from the grid, while mini grid costs are inversely proportional to the population density of the target community
- Standalone systems do not scale cost effectively but are well suited for sparse and distributed populations

Through these analyses based on population size, density, and costs, we can determine the specific scenarios in which each of the three main electrification options, namely grid extensions, mini grids, and standalone systems, will be the most suitable option for deployment. However, additional factors such as terrain complexity and economic capabilities of the target population must also be considered in order to get a holistic overview of the situation and select the relevant electrification method, as shown in the diagram below:

Figure 43: Cost Effectiveness of various electrification options



Source: USAID, ISA analysis

The cases in which grid extension, mini grids, and standalone systems will be the appropriate electrification approach are highlighted below:

Suitability for grid extension: Grid extension is a cost-effective approach to electrify populations that are within 10 – 15 kms of the existing grid. They are also well suited to electrifying very high-density populations that are within reasonable distance of the mini grids. The main electricity grid (if reliable) is also able to meet high service levels for households as well as commercial and industrial demand, if required.

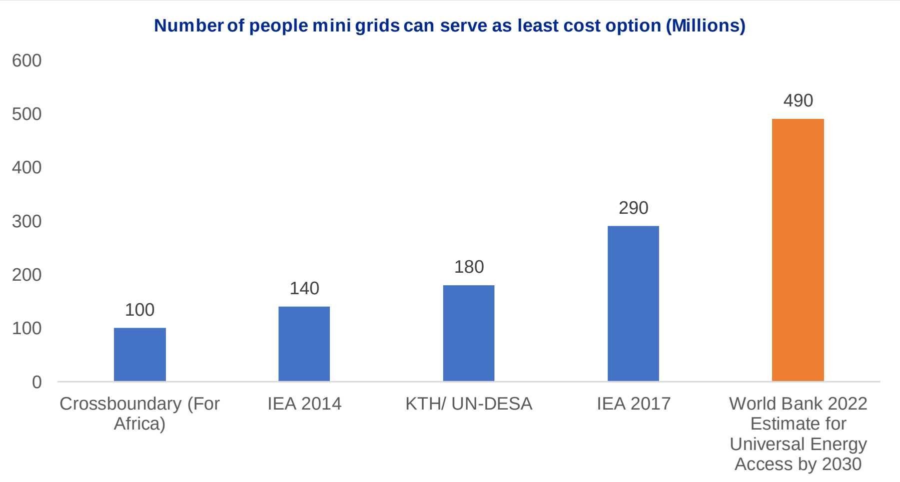
Suitable for mini grid deployment: Mini grids can be deployed in the most cost-effective manner for distances more than 10 – 15 kms from the existing grid, depending on the size and density of the target population. As seen in the component-wise costs for the mini grids, the distribution forms the highest cost head but can be significantly optimized through a clustered approach of connecting multiple small villages to the same mini grid.

Suitable for standalone systems: Standalone systems can technically be deployed in any electrification solution. However, they are typically only capable to meet a low household service level instead of any productive end use applications. As a result, standalone systems are best used to meet initial electricity access needs in remote, sparsely populated regions where mini grid and grid extension development is not viable. Additionally, standalone systems can also be distributed to low-income populations with developmental support.

Mini grid electrification lies between grid extension and standalone systems, providing a higher level of service to smaller communities than standalone systems, and at a lower cost than extending the grid to distant locations. Mini grid capacity can be scaled to meet changing needs of the target community and are also able to support community loads and drive increased demand from consumers for productive end use appliances. The potential of mini grids has been clearly recognized, with estimates for electrification of the existing population through mini grids lying in the range of a few hundred million people.

However as shown below, the World Bank estimates that the number of people that can be electrified at least cost to meet universal electricity access by 2030 is far higher than current potential estimates.

Figure 44: Number of people mini grids can serve as least cost option (Millions)



Source: Greentech Media and Crossboundary

Thus, it is clear that there is significant potential to scale up mini grid deployment for electricity access. This scale up can be enabled through a number of drivers that will be crucial to mini grid adoption in a cost-effective manner.

5.3 Drivers for improving mini grid adoption

The following drivers have been identified to aid the penetration of mini grids to improve electricity access:

- **Policy and regulatory support along with on-ground technical assistance:** Favorable policy and regulatory environment for the promotion of decentralized technologies, like SHS, mini grids, electricity efficient appliances, biogas cookstoves and other solar-based DRE appliances, is critical to alleviate the issue of electricity access. Stable policy environment creates confidence among investors and private players about the viability and feasibility of the project, which in turn reduces risk-premiums and financing costs and helps bring down the LCOE.
- **Quality of equipment and establishment of standards:** Different DRE systems are implemented in different geographies based on the need and affordability in the area. Less developed countries are usually dependent on imports of DRE technologies and other system components. Sub-standard equipment leads to failures and premature shut down of operations leading to economic losses for the project developer. It also affects the end users' trust in the technology making them hesitant to adopt any such future projects. Therefore, standardized equipment can improve project reliability and consumer confidence, increasing system uptime and consumer demand to bring down the project LCOE.
- **Innovative financing mechanisms:** Areas with low electricity access are economically weak and therefore have extremely low affordability. The relatively higher upfront costs of DRE solutions are seen to be barriers to adoption in most cases worldwide. To mitigate

this issue, innovative financing mechanisms such as the PAYG, dealer credit, subsidized loans, etc. need to be introduced on the backs of micro-finance organizations (MFIs), non-banking financial institutions (NBFCs) and NGOs operating in the area. Technology suppliers are also seen to offer DRE systems on credit and accept payments as monthly installments. These innovative financing mechanisms and tariff designs increase the demand for electricity from mini grids by increasing consumer affordability, thus improving overall project viability.

- **Local participation and employment:** Co-ordination with the local SHGs, communities, and NGOs is vital for the on-ground implementation of any remote project. Locals are often trained by the technology suppliers for the operation and maintenance of the project. Therefore, community participation also helps create employment and income for the locals, simultaneously creating a sense of ownership among the locals. Engagement with the local community also prevents any social resistance to the project implementation and operation, thereby ensuring sustainability of the project.

  The implementation of productive end use appliances as a part of the mini grids is also seen to improve local participation and their sense of ownership. These appliances either provide a regular source of income or supplement the existing sources for the end users. In most cases, agricultural products can be processed and sold as semi-finished/finished goods at a better price in the markets leading to higher incomes for the end users. Productive end use appliances also increase the demand for electricity from the mini grid project, thus improving the project LCOE and overall viability.

- **Efficient after-sales service:** Since the DRE projects are in remote locations, the technology supplier needs to commit to an efficient after sales service for a significant period after the installation to gain the trust of the end users. Without proper service arrangements, the equipment soon becomes defunct, and the community resists future technological development due to the bitter first experience. These issues can also be mitigated through training of locals on basic maintenance and repair practices so that the technology supplier can focus on major issues.
- **Pilot and demonstration projects are critical:** Small-scale pilots are necessary to demonstrate the technology, its impacts, and benefits to end users to improve uptake of DRE technologies. Demonstration of results on ground, through knowledge dissemination workshops and awareness programs, helps create confidence among investors and other concerned stakeholders regarding these decentralized technologies. This increased investor confidence helps improve access to affordable finance for project developers, thus bringing down their costs and improving project viability. Additionally, pilot projects can also help develop an understanding of the community load characteristics, which in turn can inform system sizing and demand side management measures required during operation of a full scale project.
- **Definite ownership structure:** A concrete business model with a predefined ownership structure is key to the success of the project. It is found that projects fully funded by grants are often left stranded after a short period of operations. Without technology/equipment ownership, the supplier is reluctant to conduct periodic maintenance in these remote project locations. The end users are also seen to value the electricity received as a product or a service in exchange of money more than they value freebies. Private ownership structures are typically more successful because the private entities have the incentive to keep the project operational. Community ownership is also pivotal in bringing the end users together and requiring them to work for the benefit of the whole community/village. The

deployment of innovative business models can also help improve overall project viability through various payment mechanisms and measures to increase consumer demand.

- **Capacity building and training of locals:** Preliminary checks and basic maintenance of the DRE systems can be conducted at the local community level. Hand-on trainings and capacity building workshops help create a skilled labor force to service and operate decentralized generation, storage, and distribution systems. Training of locals helps mitigate the challenge of O&M for projects in remote locations, reducing system downtime and thus improving the techno-commercial viability of the project.
- **Digitized monitoring and reporting mechanisms:** Periodic monitoring and reporting mechanisms need to be incorporated at the project implementation stage. Digitalization of infrastructure, wherever possible, reduces the need for on-ground labor for repair and maintenance of systems. Remote monitoring and control of these decentralized systems enables project developers to operate over a larger area with ease. These technological measures help improve system reliability and uptime and can also help streamline O&M activities, thus bringing down the LCOE for the project.

Despite the potential impact of mini grids and standalone systems, their deployment at scale for electricity access is hampered by a number of key gaps and barriers. These gaps represent significant and complex challenges that are as much linked to the technical aspects of the sector as they are to the socio-economic context of the access deficit countries. The upcoming chapter will aim to assess these gaps and use them to evaluate the electricity access scenario in most access deficit countries.

6. Gap analysis and Country Assessment Framework

The adoption of mini grids has the potential to revolutionize electricity access in many parts of the world. As outlined in the above chapter, there are a wide variety of business models that have been used in the implementation of these mini grid and DRE systems. Based on the various business models, case studies and learnings, and the current trajectory of mini grid adoption, we see that despite their great promise, there remain significant gaps in their implementation that need to be addressed if they are to reach their full potential.

In this chapter we outline the six broad gap areas that prevent mini grids from achieving a large-scale adoption in the LDCs with the lowest levels of electricity access.

6.1 Gaps in the Policy and Regulatory Ecosystem

An enabling policy and regulatory environment is an essential prerequisite for deployment of any electricity access intervention

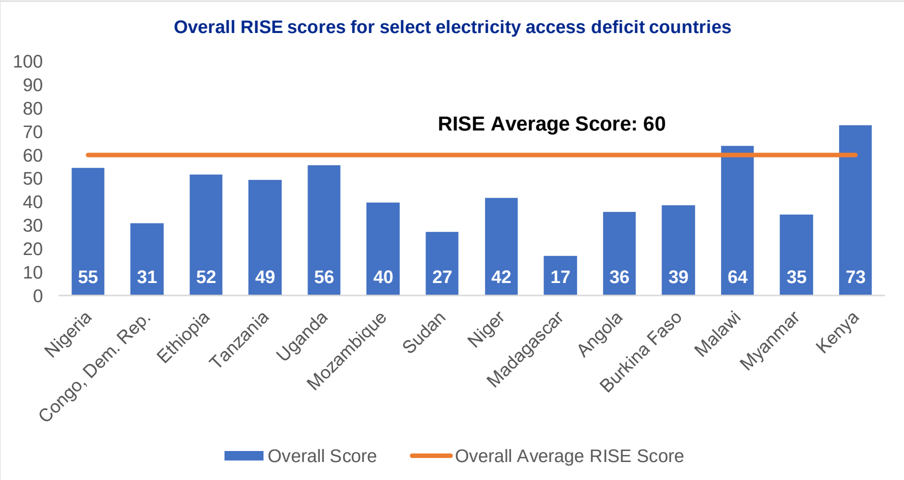
The development of electricity access initiatives is built on the bedrock of having a suitable policy and regulatory environment in place. Policy and regulatory support are often the first and prerequisite steps for electricity access planning. Additionally, the success of any business models or the quantum of financing country can attract is often interlinked with the existing policy ecosystem. The policy regime provides clarity to the investors and implementing agencies regarding the readiness of the country, which is then fed into the pricing of the project. This is especially important for mitigating electricity access challenge since the worst affected are typically least able to pay for electricity. Additionally, the long-term correlation between electricity access and socio-economic development of a country provides further incentive to a government to develop a suitable policy and regulatory ecosystem. This ecosystem and associated schemes can then serve as a signal to various development agencies and private entities to drive electricity access initiatives, with the comfort of knowing that this is a priority area for the government as well, and that they can expect support as stipulated by the government.

Baselining of the policy and regulatory system in place in different countries is challenging due the shifting nature of policies and provisions. Additionally, policies are extremely dependent on local needs, which are complex and difficult to gauge out of context. As a result, it can be difficult to compare policies and regulations across countries in a standardized and fair manner. In order to tackle the issue of fair comparison and benchmarking of policy and regulatory systems around the world, the World Bank funded and supported ESMAP Organization has developed the Regulatory Indicators for Sustainable Energy (RISE) Database. This database monitors and scores the policy and regulatory environment with respect to SDG 7 targets in countries across the world and covers a number of indicators. Each of these has a number of sub indicators grouped into various relevant buckets. Each of these buckets has several questions to determine the degree of policy and regulatory readiness in each area. These questions are assigned a scoring to add up to 100 for each bucket. Thus, a score is developed for each sub indicator, and compiling these scores provides us with an overview of the policy and regulatory situation in a particular country. The RISE Database has over 30 indicators covering 140 countries and representing around 98% of the global population, thus providing a comprehensive overview of the global policy and regulatory ecosystem around SDG 7. However, 54 countries are scored for electricity access in order to only account for access deficit countries and obtain more accurate analysis.

The overall policy and regulatory readiness in the top 15 access deficit countries fall well below required levels

Only 2 out of the top 15 electricity access deficit countries rank higher than the global overall average RISE score, while some lag significantly in terms of their policy and regulatory ecosystem. The scoring for 2021 has a standard deviation of 14.9, highlighting the disparities in the policy and regulatory systems even within a country group that could be expected to have a similar policy environment due to their electricity access deficits.

Figure 45: Overall RISE Scores for select electricity access deficit countries

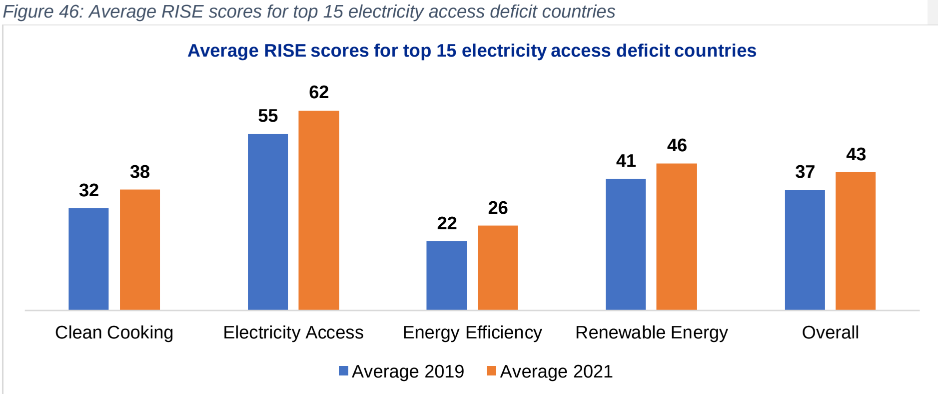


Source: World Bank ESMAP RISE

While the overall policy and regulatory ecosystem needs more work, there has been some improvement in the past few years

The average RISE scores for the top 15 electricity deficit countries grew across all parameters between 2019 and 2021. At an individual country level, 13 out of the 15 countries have shown growth in their overall RISE score between 2019 and 2021. Electricity access has seen the highest increase in scores, rising by 7 points, followed by clean cooking (6 points), renewable energy (5 points), and energy efficiency (4 points).

Figure 46: Average RISE scores for top 15 electricity access deficit countries

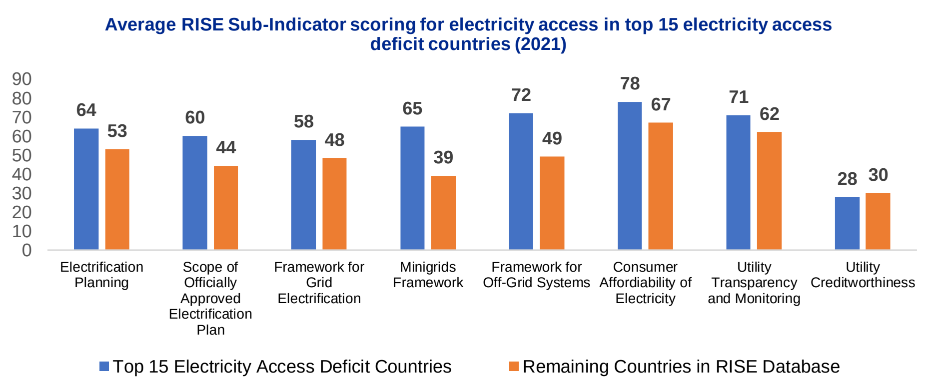


Source: World Bank ESMAP RISE

Countries have formulated policies to improve electricity access, but visible gaps remain

Within electricity access, the top 15 electricity access deficit countries rank higher than the RISE database average of the remaining access deficit countries. The top 15 electricity access deficit countries also rank significantly higher in policy and regulatory frameworks for mini grids and off grid systems and rank higher on the scope of their electrification plans. **This indicates that the worst affected countries are recognizing the importance of a robust policy and regulatory ecosystem to solving the challenge of Universal Electricity Access.** Additionally, by including mini grids and off grid systems in their electrification frameworks, these countries have also showcased their willingness to support the development of the same alongside typical electrification measures.

Figure 47: Average RISE Sub-Indicator scoring for electricity access in top 15 electricity access deficit countries (2021)



Source: World Bank ESMAP RISE

Access deficit countries have developed national electrification plans, but there is lack of clarity on the level of electricity access to be targeted

Out of these 15 countries, 12 have an officially approved national electrification plan, with 11 of these countries including an electricity access target in the plan as well. All 12 countries with official approved electrification plans include off grid solutions such as mini grids and standalone solutions, highlighting the recognition of the benefits such solutions bring to last mile electrification. **However, only 7 countries of these 15 target a specific service level for electrification in terms of metrics such as power availability or guaranteed hours of supply etc.** Providing this specificity would allow for greater clarity on what level of service counts towards electrification and what consumer needs must be met. 10 of these 15 countries encourage the leveraging of private sector financing for electrification, a welcome step considering the importance of private capital to electricity access efforts.

Grid electrification funding is focused on supply side development but not on demand side support involving consumer subsidies

Under their framework for grid electrification, all 15 countries have a dedicated funding line or budget for electrification (which encompasses grid expansion measures). **However, only 4 of the countries provide consumer financing mechanisms to support the payment of connection fees by consumers.** Grid connection fees in access deficit countries can run into hundreds of US dollars, well out of the affordability range for the typically low-income consumers that currently lack access. Thus, unelectrified populations may not be able to take advantage of the arrival of the main grid at their locations.

Poor utility creditworthiness impacts the development of electricity access projects

The 15 countries fall below the already low global average score for utility creditworthiness, and 2 countries score 0 on the parameter. This parameter is calculated based on current ratio, EBITDA margin, debt service coverage ratio, and days payable outstanding ratio. [54] These financial metrics highlight the impact that a financially stressed electricity distribution company can have on the electricity access situation in a country, and may also explain how countries, despite having frameworks for grid extension in place, can struggle to provide suitable electricity access due to lack of utility financial capabilities. Utilities in these countries are not able to implement electricity access projects by themselves, whether these projects take the form of grid extensions, mini grids, or DRE deployment.

Mini grids and DRE are recognized as potential solutions for the electricity access challenge, but are yet to see widespread deployment

The policy and regulatory scenario for mini grids and DRE is more robust. All but one of the countries have programs in place to develop or support development of solar hybrid mini grids, further underlining the growing role of solar mini grids in electrification efforts. 11 of the 15 countries also have national/large scale programs to increase productive use of energy by mini grid customers. Increasing consumer demand allows mini grids to achieve financial viability, while also providing significant economic and social benefits to the local population. Off grid systems in 12 countries benefit from duty or tax exemptions, improving system affordability for end consumers.

The trend of electricity access policy development for the top 15 electricity deficit countries has been promising, but the electricity access situation in these countries continues to remain dire. This implies that the top 15 electricity access deficit countries have developed policy and regulatory frameworks to achieve electricity access, but there have been gaps in the implementation of these frameworks. As a result, a fully fleshed out ecosystem for electricity access is not in place, and countries are unable to make the optimal use of their enabling policies and regulations. In a similar manner, there are several provisions in place to provide electricity access, but the need for financial assistance is not being met due to non-comprehensive policies and regulations, or lack of financial strength of the utilities in these countries. Having a policy and regulatory framework that includes financing aspects is key, as it helps attract private sector investment, which in turn drives development. When the appropriate market signals are not being sent, electricity access projects will struggle to source suitable finance from public or private sources, resulting in an electricity access gap.

Such gaps highlight the complex interlinked nature of the electricity access problem, where policy and regulatory aspects dovetail with economic and financial aspects, capacity building requirements, and techno-commercial viability, which complicate the challenge of achieving universal electricity access.

[54] A financial ratio that indicates the average time (in days) that a company takes to pay its bills and invoices to its trade creditors, which may include suppliers, vendors, or financiers

Key Policy and Regulatory Gaps

- Although countries are recognizing the need for enabling policies for electricity access, reflective of their improvement in RISE Database policy and regulatory scores, the overall development remains low compared to what is required
- Frameworks and provisions for electricity access are in place, which is reflected from the high RISE scores, but are not getting implemented properly
- Policy provisions have not been linked with adequate financing provisions, which means developers and funding agencies are not able to optimally utilize the presence of a mechanism
- Policy and regulatory developments have been unable to address consumer affordability of electricity
- Utilities in electricity access deficit countries are not able to implement projects of the required scale considering their poor financial health

6.2 Gaps in the economic and financial conditions

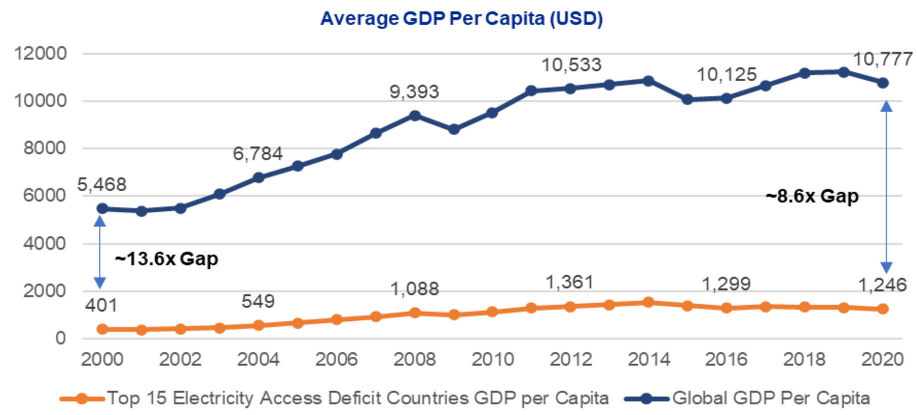
Economic and financial considerations have a significant impact on electricity access

It is important to view the universal electricity access challenge from the lens of various stakeholders. For consumers, paying for electricity access can be a challenge due to low levels of income in the typically remote and underdeveloped regions lacking access. The poor financial capabilities of potential end users disincentivizes project developers from setting up electricity access projects in such regions, due to the uncertain returns either making self-investment unattractive or leading to high cost of capital for debt funding. Unfortunately, this process acts as a vicious cycle, where the lack of electricity access impacts a populations capability to improve its income, which further disincentivizes project developers from attempting to provide access. Countries with a significant electricity access gap are also often fragile and conflict affected, which further increase project risks and reduces the capability of potential consumers of having reliable incomes or a profitable business. Thus, the economic and financial gaps between project developer requirements and consumer capabilities are a major reason that electricity access is challenging to achieve.

Electricity access deficit countries struggle to ensure consumer electricity affordability as well as supplier financial viability

Low-income consumers are unable to afford or consume significant amounts of electricity. The top 15 countries lacking electricity access are characterized by their challenging economic and financial situations**. In terms of GDP per capita, these countries lag the global average significantly.** Although, this gap has reduced in relative terms over the last 20 years, but a vast gulf in income still remains. This income gap is a significant contributor to lack of electricity access as consumers are simply unable to afford electricity.

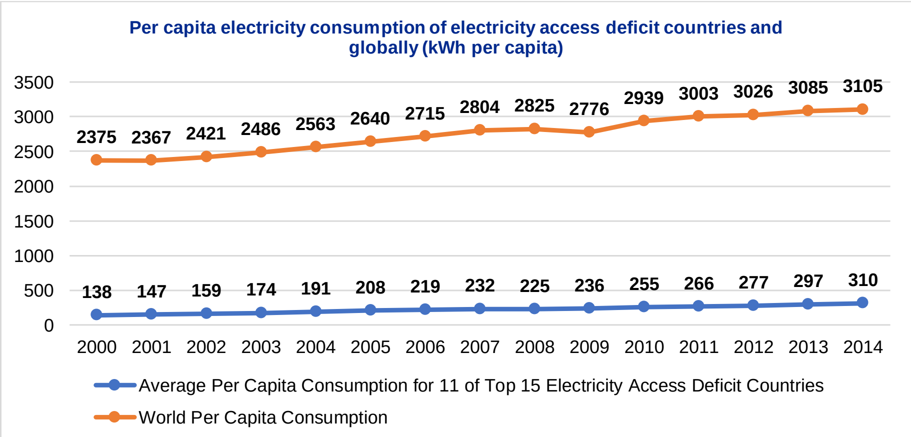
Figure 48: Average GDP per capita (USD)



Source: World Bank Database

Low-income consumers are unable to pay reliably for electricity consumption, purchase DRE solutions on their own, and may even struggle to afford the significant connection costs that are the hallmark of grid connection in some developing countries. Even once an electricity connection is put in place, low-income consumers would not be able to provide significant electricity consumption demand. **Per capita consumption of electricity in 11 out of the top 15 electricity access deficit countries (for which data is available) is roughly a tenth of the global average per capita consumption.** This low demand in turn affects the viability of electricity access initiatives, as utilities and mini grid developers would be unwilling to provide electricity access to a population that would be unable to provide sufficient demand to justify project costs without subsidies.

Figure 49: Per capita electricity consumption of electricity access deficit countries and globally (kWh per capita)



Source: World Bank Database

Poverty related challenges extend beyond lack of income, which combine to take a toll on electricity access

Low household incomes and lack of development in these countries are also reflected in the Multidimensional Poverty Measure prepared by the World Bank. This index seeks to understand the poverty status of a country beyond monetary aspects and considers access to basic infrastructure and education as well. This is expressed as the percentage of a country's population that lacks access to the relevant indicator (Consumption or income, educational attainment, educational enrollment, electricity, sanitation, and drinking water). The Multidimensional Poverty Headcount Ratio provides the share of the population considered multidimensionally deprived if they fall below the specified threshold in any one dimension or in a combination of indicators that add up to the weight of one indicator (one-third).[55]

Table 11: Multidimensional Poverty Measure indicators and weights

Dimension	Parameter	Weight
Monetary	Daily consumption or income less that USD 2.15 per person	1/3
Education	At least one school-age child up to the age of grade 8 is not enrolled in school	1/6
	No adult in the household (age of grade 9 or above) has completed primary education	1/6
Access to basic infrastructure	The household lacks access to limited-standard drinking water	1/9
	The household lacks access to limited-standard sanitation	1/9
	The household has no access to electricity	1/9

Source: World Bank Multidimensional Poverty Measure

This allows for a more holistic view of the poverty status of a particular country. As shown in the table below, the challenges faced by the top 15 electricity access deficit countries go far beyond monetary parameters, with access to sanitation, drinking water, and education also being problem areas. The overall developmental challenges faced by electricity access deficit populations can thus stretch household income and earning capabilities and make it harder for them to afford access.

Table 12: Multidimensional Poverty Measure Scores for select electricity access deficit countries

Country	Year	Monetary (%)	Educational attainment (%)	Educational enrollment (%)	Electricity (%)	Sanitation (%)	Drinking water (%)	Multidimensional poverty headcount ratio (%)
Nigeria	2018	30.9	17.6	20.3	39.4	44.9	27.5	41.8
Congo, Democratic Republic of	2012	69.7	22.5	8.0	83.0	80.0	47.9	78.3
Ethiopia	2015	27.0	66.7	31.2	64.1	95.9	42.7	72.7
Tanzania	2018	44.9	13.2	19.5	44.3	71.5	29.2	54.6
Uganda	2019	42.2	31.4	11.8	41.3	71.1	23.7	52.3
Mozambique	2014	64.6	54.9	33.3	14.6	71.3	41.1	73.7
Sudan	2014	15.3	40.2	22.7	48.5	92.9	44.9	52.5
Niger	2018	50.6	79.7	28.0	78.7	85.2	37.5	80.0
Madagascar	2012	80.7	49.0	34.7	13.0	76.9	59.9	82.9
Angola	2018	31.1	29.8	27.4	52.6	53.6	32.1	47.2
Burkina Faso	2018	30.5	56.4	50.9	47.2	69.6	19.7	60.4
Malawi	2019	70.1	54.3	3.7	88.8	75.1	11.4	78.3
Myanmar	2017	2.0	28.0	6.8	50.9	9.7	20.6	15.4
Kenya	2015	29.4	22.5	6.1	56.9	69.0	32.2	45.4

Source: World Bank

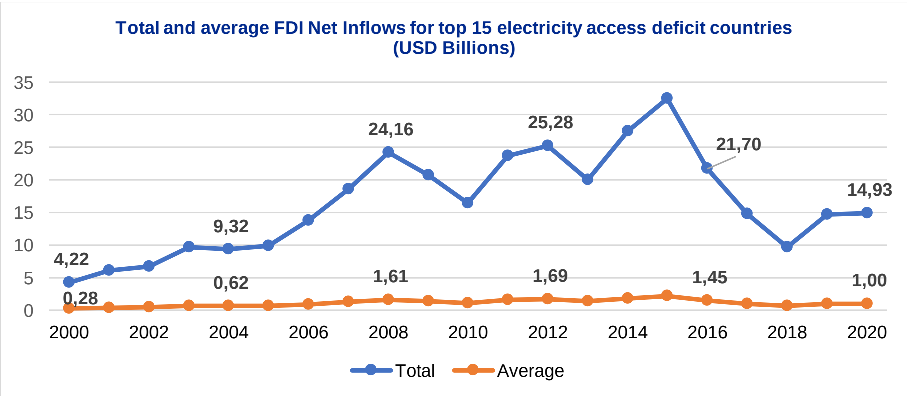
[55] https://openknowledge.worldbank.org/bitstream/handle/10986/30418/9781464813306_Ch04.pdf

The end effect of monetary and other forms of poverty on electricity access is the inability of consumers to afford electricity. This is highlighted by the RISE Database's policy and regulatory analysis. The World Bank considers electricity affordability for the first 30 kWh consumed per month by residential consumers. **As per the RISE Database, none of the top 15 electricity access deficit countries had achieved this electricity cost affordability**, underlining the challenges faced by low-income consumers. **Additionally, the electricity connection fee for residential consumers in all 15 countries could also not be considered affordable.** Thus, even when electricity access projects are developed and available, consumers may simply not be able to connect and consume the same.

Low FDI inflows highlight the economic stagnation and lack of investor trust in the electricity access deficit countries

The challenging economic environment in these countries is also reflected by the reluctance of global investors to carry out Foreign Direct Investment (FDI). **The total FDI net inflows in these countries have been erratic, showing sharp dips and rises on a year-to-year basis, and even steadily declining between 2015 and 2018.** The FDI net inflows in 2020 have now returned to the level seen in 2006, highlighting the stagnant growth and lack of trust shown by foreign investors in these regions. Average FDI net inflows across these 15 countries have stayed relatively flat in the last 20 years, unable to cross USD 2.5 billion. Some countries have even seen negative FDI net inflows, implying disinvestment and outflow of capital from the country.

Figure 50: Total and average FDI Net Inflows for top 15 electricity access deficit countries (USD Billions)



Source: World Bank Database

The poor level of FDI in these countries can be attributed to various factors, including poorly implemented policy and regulations, lack of sufficient economic value creation, lack of stability of government and institutions, unrest, conflict, and fragility. As a result, these countries have been unable to benefit from the significant amounts of investment being made by developed countries into other developing nations over the last few decades. This has meant that already struggling economies have been unable to receive a financial boost, and have continued to stagnate, further affecting local income and development levels, and subsequently having an indirect impact on the electricity access situation of the countries.

Poor country risk ratings lead to expensive finance and hamper project development

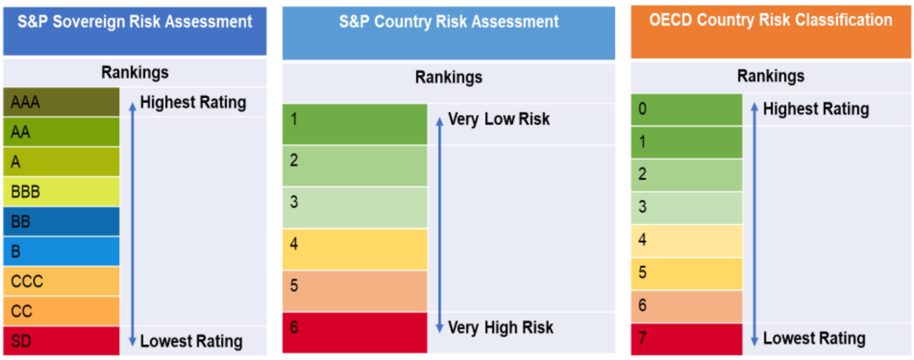
Highlighting the inability of consumers to pay for electricity access does not provide a full picture of the challenges to achieving universal electricity access. The top 15 countries lacking electricity access also struggle with a lack of affordable finance for projects. Access to affordable finance is affected by the uncertainty prevalent in these countries, as they are often fragile and affected by conflicts or unrest. This political and security-based uncertainty leads to these countries being deemed as high risk for investments by ratings agencies such as S&P, and intergovernmental organizations such as Organization for Economic Cooperation and Development (OECD). Based on these ratings, financers are driven to increase the interest rates at which they make the finance available. **Since most electricity access projects are financed through a combination of debt and equity (alongside grant support), high interest rates discourage developers from setting up electricity access projects.**

Table 13: Country Risk Assessments for select electricity access deficit countries

Country Name	S&P Sovereign Risk Assessment (Dec 2022)	S&P Country Risk Assessment (Feb 2022)	OECD Country Risk Classification (Jan 2023)
Nigeria	B-	6	6
Congo, Dem. Rep.	B-	6	7
Ethiopia	CCC	6	7
Tanzania	NA	6	6
Uganda	B	6	6
Mozambique	CCC+	6	7
Sudan	NA	NA	7
Niger	NA	NA	7
Madagascar	B-	6	7
Angola	B-	6	6
Burkina Faso	CCC+	6	7
Malawi	NA	NA	7
Myanmar	NA	NA	7
Kenya	B	5	7

Source: S&P, OECD

Key for Various Country Risk Assessment Scores



Source: S&P, OECD

Several countries are not rated by S&P and have thus been labelled as 'NA'. The lack of ratings in these countries may also be sufficient to erode the confidence of potential investors and prevent the inflow of FDI into the country due to a lack of insight into the potential risks of investing in a particular country.

Overall, for electricity access deficit countries, low consumer incomes and inability to pay on the demand side coupled with high investment risk on the supply side make it challenging for electricity access projects to reach the neediest sections of the population. The challenge is exacerbated due to the cyclical nature of the problem- both supply side and demand side issues need to be tackled simultaneously to make projects viable and consumers able to pay for electricity. Identifying measures to do so through efficient deployment of interventions and finance will be crucial to achieving universal electricity access.

Key Economic and Financial Gaps

- Electricity deprived populations are typically low-income and cannot afford to pay for electricity
- In many access deficit countries, poverty extends beyond monetary parameters and includes energy, water, sanitation, and education. Multiple priority areas for development can lead to underfunding or lack of focus on energy access, as it becomes just one of many problems to solve
- Low FDI net inflows in access deficit countries, including negative inflows in some years, imply weak economies and lack of global trust. This leads to the reluctance of wealthy foreign investors to bring capital into high-risk access deficit countries
- Poor country risk assessments due to unstable socio-political situation also affect interest rates and drive-up cost of projects for developers
- Matching consumer affordability with supplier viability is crucial. A mismatch between the two leads to a vicious cycle preventing successful energy access initiatives, and both need to be addressed simultaneously

6.3 Gaps in the Equipment Quality and Global Standards for mini grids and DRE technologies

Reliability of mini grids and DRE systems helps build trust amongst consumers

DRE systems, including mini grids, must implement strict equipment quality standards to become a reliable source of clean energy. Complex systems, such as mini grids, involve several components for the generation, distribution, and consumption of electricity. Quality standards for all the components involved in such systems are particularly important to ensure the overall safety, reliability, and performance of these systems. In the LDCs, where affordability and monthly income are a key metric in making the shift towards DRE systems, low quality products do more harm to the communities and the DRE market. Consumers typically save up for the purchase of such DRE systems. If the appliances become defunct, it not only leads to a loss of trust in such technologies but also creates unnecessary e-waste. Also, in the future, companies and vendors operating in the DRE space may find it difficult to expand the market and sell their products due to prior bad experiences in the community relating to similar DRE technologies.

Some actions have been taken to ensure quality and implementation of standards, but they are limited in scope and impact

Meeting quality requirements creates trust towards the technology among the users but requires companies operating in this space to make significant investments into research & development. **International Electrotechnical Commission (IEC)** have **recently incorporated standards for off-grid DRE appliances, microgrids, solar kits etc., are widely adopted and easily acceptable to the governments of the LDCs**. Currently, a few

African countries like Ethiopia, Zambia, Uganda, Senegal have adopted the IEC standards with Nigeria implementing its own national standards based on the IEC standards.

IEC's adoption of the Lighting Global Quality Standards under the VeraSol Quality Assurance Program

VeraSol quality standards are minimum requirements for off-grid lighting product quality, durability, truth-in-advertising, warranty, and lumen maintenance. VeraSol is the evolution of combined verification program of IFC-World Bank-Lighting Global launched in 2020. It provides quality standards for both solar lanterns and solar home systems (SHS) up to 350 W, and mandates participation in its own support programs.

The International Electrotechnical Commission (IEC) has adopted the VeraSol testing methods under the technical specification IEC 62257-9-5. IEC 62257-9-8 is applicable to both pico-photovoltaic products, which include small, portable devices such as lanterns and flashlights, as well as solar home systems (SHS). Products must include- a) a battery or other storage device, b) a power generating device such as a solar panel that can charge the battery, and c) wiring and connectors required to connect the battery and electricity generating device together.

Under the Quality Assurance Program, the quality standards are just one component and VeraSol also engages in demand side implementation of the IEC standards, supporting governments, upstream manufacturers, and other standards authorities, and looks to expand to productive end use appliances. They also maintain a central database of all VeraSol certified products and vendors.

A few other countries are also in the process of implementing these standards for applications beyond lighting and solar home systems, specifically for off-grid solar appliances and other productive end use technologies including solar water pumps, refrigerators, TVs, electric cookers, etc. **A total of 11 out of the 15 countries with the lowest electricity access rates have adopted some international quality standards** for off grid systems, ensuring that reliable systems are distributed in their markets.

Widespread implementation of these standards will help develop confidence among consumers and simultaneously expand technology adoption. Additionally, implementation of standards builds investor confidence and helps attract the necessary investment for the growth of the DRE sector. In mature markets, standardization can go a step further and help enforce modularity and interoperability in these small DRE appliances. On the software side, a uniform software and user interface could help create familiarity among consumers. Uniformity in the hardware and electrical connections will improve interoperability of appliances from different vendors, thus democratizing the market and facilitating easier adoption.

Broad coverage of quality and standardization is required for large-scale impact

While there are few standards covering some off-grid DRE systems, there are also some issues that hinder the effective implementation of these standards. Some countries introduce their own standards which results in added costs of compliance from the manufacturers which are eventually passed on to the consumers. Additionally, even where standards are present, they rarely cover the full range of technologies under the DRE ambit. For example, the IEC 62257-9-8 covers stand-alone RE hybrid products but only with power ratings less than 350W. This leads to some products being left out. Therefore, the enforcement and uniformity of standards is also crucial to the adoption of DRE technologies.

IEC Standards pertaining to DRE products

IEC 62548: Photovoltaic (PV) Arrays-Design Requirements

IEC 62257-9: Recommendations for small renewable energy and hybrid systems for rural electrification (includes 8 sub-standards for various components of such energy systems)

But there has been some progress in the development of supplemental measures to enforce quality standards compliance. For example, a **joint initiative by the International Finance Corporation (IFC), VeraSol and ACE TAF (2020-22)** improved the capacities of market surveillance solar test laboratories by **conducting trainings and upgrading lab equipment in a few countries like Zambia, Nigeria, Kenya, and Ethiopia**. However, capacity building and surveillance infrastructure in the remaining countries still requires improvement to ensure that quality products are reaching the end consumers to provide reliable electricity access.

Use of International Standards in a mini grid in Tanzania's Mpale village for interoperability and future expansion

In the village of Mpale, in Tanzania's Korogwe district, kerosene and diesel generators were the main source of lighting and electricity for the 760 households inhabited by 3000 villagers. A local developer, Ensol Tanzania, implemented a centralized solar hybrid mini grid in the village using demand side measures to match the deferrable demand with solar generation.

The project was executed in coordination with international partners, TTA and Studer, who helped bring in international standards and interoperability to the project. The main equipment selection was according to international standards and the design, procurement, and implementation of the project followed strict European regulations. The developers also built-in standard communication protocols into the system thus ensuring component interoperability. This allowed setting up of a smart tariff scheme which changes the tariff according to the available electricity in the system. A remote monitoring system was also set up, in accordance with standardized O&M protocols, to ensure optimal mini grid performance and resolve any operational issues at the site.

With the solar hybrid mini grid, these villagers now have access to sustainable, reliable, and clean electricity. The smart tariff scheme helps implement the demand side measures and defer demand to high solar generation hours. The high-quality equipment and strict protocols in the design and operation of the system ensure a safe and reliable O&M during the project life.

Source: Quality Infrastructure for Smart Mini grids, IRENA

Efficient supply chain network is also vital for accessibility and affordability

Without a reliable supply chain infrastructure, it is difficult for consumers to access the necessary materials and components needed to effectively use alternatives such as solar or wind power. Furthermore, efficient transport of the equipment to remote project locations on time is vital to maintaining the affordability and availability of these technologies. An inefficient supply chain results in added cost overheads from added inventory costs, poor customer service satisfaction ratings due to product unavailability, and lower market penetration due to smaller distribution networks. As a solution, some governments are looking to increase local manufacturing and assembly capacities, but the underlying conditions are not sufficiently developed to support local supply chains in most high electricity access deficit countries.

Key Equipment Quality and Global Standards Gaps

- Lack of explicit standards covering off-grid technologies and mini grids across different specifications
- Lack of adequate capacity and infrastructure to implement and enforce existing standards
- Lack of financial incentives for developers to use quality equipment and standardized protocols
- Complicated compliance procedures due to clashes between local and international standards
- Inadequacy of reliable supply chains for all imported equipment and components
- Absence of local manufacturing or assembly capacities

6.4 Gaps in technical competence, capacity building and awareness creation

Capacity building and awareness are vital to the successful adoption of mini grids, but may not be available

Being a technology-dominant sector, the widespread adoption and successful scale-up of mini grids requires inputs from various stakeholders throughout the project lifecycle. The stakeholders, therefore, need to be well versed with the technological, financial, and regulatory aspects of mini grids. At the implementation stage, specific skills and technology knowledge is required at the local level to create a sustainably operable project. Moreover, in the LDCs, training institutions focused on mini grids are either absent or are unable to equip decision-makers and practitioners with the necessary skills to develop and evaluate policies, understand technologies and users' needs. This has resulted in numerous failed demonstration projects across many countries due to improper sizing, unsafe operations, and under-maintenance. Therefore, capacity building, both at the institutional and individual level, is essential to the progress of the mini grids sector.

Lack of Institutional capacity building leads to large-scale systemic issues in the adoption of mini grids

Rural electrification has been one of the most significant agendas in the LDCs where the countries' low economic growth can be corelated to the lack of electricity access. Institutional stakeholders require substantial technical and financial expertise to drive the electrification agenda forward and this is largely absent in the decision-makers and financing institutions within these countries.

Government bodies and policy makers work towards the overall electrification of the countries but may not be able to focus on remote and rural electrification issues. Focused departments within the government are vital to the progress and monitoring of the mini grid projects being implemented on ground along with the disbursement of any government subsidy. Moreover, policy makers are not aware of the various technological, standardization and digitalization advancements in the recent mini grid project implemented across various geographies.

Additionally, government-owned utilities lack the data and resources to efficiently plan mini grids, engage with the communities and monitor payment collection in remote areas. The utilities also lack the skills to manage and plan the eventual grid interconnection of the mini grids.

Figure 51: Training needs and relevant stakeholders for institutional capacity building

Source: Mini Grids for Half a Billion People, ESMAP (2022)

Financing Institutions and Banks consider DRE and mini grid projects to be unviable due to the reasonably higher tariffs discovered in existing projects and the failure of past projects.

Additionally, banks and other financial institutions may not be aware of the investment opportunities in mini grids. Even in cases where a credit facility is created, these institutions lack the technical knowledge to conduct due diligence for such non-conventional projects thereby creating a funding bottleneck. The problem largely lies in assessing such applications for financing. Because of an absence of a standardized framework for consumer or developer loan, the documentation and collateral requirements are stringent, thus creating significant hurdles for the borrowers. Further, lack of awareness of the asset creates doubts related to the applicability and revenue generation capability in the minds of financers, ultimately leading to stalling of local financing enablement.

Project Developers may lack of technical knowledge, leading to oversizing of the project which further results in unnecessary costs passed on through tariffs. **Local developers** often lack the skills in standardized implementation, project management, and O&M processes. This is evident when these developers simultaneously operate multiple projects across a large area. Local developers may also lack the documentation and reporting aspect of running the project which further hampers their funding opportunities. **International developers**, on the other hand, are seen to largely lack the local experience and context for such remote implementations. Although, they have access to large amount of funds and possess the technical capacity to execute projects, they may not understand the culture, community dynamics, policies and regulations at the project location which hinders implementation and day-to-day operations.

Academic and vocational training institutions may not possess relevant training material and curriculum to facilitate local skill creation. Even with significant training content of renewable energy, the mini grid sector sees gaps in the training content across a wide variety of aspects such as business models, project finance, tariff setting, billing, metering, demand estimating, project sizing, licensing and other regulations, operational safety, data analysis, project management and risk assessment. Courses and certifications tailored to installing and operating mini grids in the local context can prove to be extremely valuable towards the sustainability of the project and in creating a skilled workforce but, such programs are absent in the local institutions. Entrepreneurship programs and incubation centers for the locals are also largely absent in the LDCs.

Capacity building and awareness initiatives for individuals and communities is also equally important

Apart from institutional capacity building, trainings and hands-on workshops for the communities are also equally important in the success of a mini grid project. Population in remote, unelectrified areas is often unaware of the technological advancements and its related benefits. Communities **lack awareness of mini grid and DRE technologies and their impacts on health and quality of life**. **Productive end use applications**, such as solar pumps, rice hullers, oil expellers, etc., are also often **overlooked by developers or utilities** but can be crucial to increasing the adoption and the electricity demand from the mini grid. Awareness and hand-on workshops on such technologies is missing from most project implementation plans.

Moreover, **promotion of trainings for solar technician, mini grid operator, local entrepreneurship courses is absent** from the messaging related to mini grids and DRE appliances. This skill building not only solves the issues in the day-to-day operation and maintenance of the mini grids but also reduces developer costs of remote travel for maintenance, billing, and collection. Transfer of technology to the community is often the most neglected issue for the project developer but leads to eventual failure of the mini grid once the developer leaves due to inadequate knowledge transfer and skill development.

Figure 52: Training needs and relevant stakeholders across the mini grid project lifecycle

Source: Mini Grids for Half a Billion People, ESMAP (2022)

Stakeholder Engagement is key to the successful development of mini grids– Nigeria Case Study

Mini grids are cost-effective solution for improving rural electricity access for many African countries but, low electricity consumption and inadequate buy-in from the local community results in increased tariffs and investment risks. Community engagement can significantly help mitigate these risks.

The Rural Electrification Agency (REA) leads the mini grids development in Nigeria. The REA, with the support of the African Development Bank (AfDB), conducted a community outreach program along with the designing a quality assurance framework for mini-grid development. The objective was to develop community engagement capacities of private mini grid developers for the optimal usage of the mini grid infrastructure across 12 communities.

With adequate engagement, the communities could be nudged into improving their electricity usage from the mini grid and providing feedback on technical and other issues. The developers, supported by the REA team, engaged with local representatives to build relationships based on the methodology and training material created for the developer training program. This method was largely successful due to the continuous support of the government for creating the quality assurance framework and participation of private developers in the training and engagement program.

Multi-stakeholder partnerships are often seen to be crucial to programs that require continuous engagement. This model can be replicated in other countries through public-private partnerships or a completely private-sector led business model in coordination with local representatives and NGOs functioning on the ground.

Source: LEDS Global Partnership Case Study: Community engagement as key component of successful mini-grid development - Experiences from Nigeria and Sierra Leone

Key Capacity Building and Awareness Gaps

- Lack of focused departments within the local governments to promote and monitor the progress in the mini grid and DRE sector
- Lack of technological awareness among policy makers, financing institutions, and banks regarding the advancements in the mini grid implementation, standardization procedures and use of digitalization
- Lack of data and resources for efficient planning, community engagement and monitoring of mini grids in remote areas
- Perceived risk and financial unviability from financing institutions, banks, and developers alike
- Lack of skills related to the standardized implementation, efficient O&M and proper documentation of mini grid projects among local project developers. Lack of understanding of the local culture and context among international developers
- Inadequate training material and certified courses specific to mini grids and DRE appliances. Absence of local entrepreneurship programs and incubation support to promote local revenue generation
- Lack of awareness programs and hand-on workshops tailored to local communities and inadequate training of locals for the O&M of the system and the eventual technology transfer

6.5 Gaps in data availability and information sharing

Reliable and accurate data is required to develop effective interventions

In order to develop effective measures to tackle the electricity access deficit, the collection and dissemination of reliable and accurate data is crucial. Achieving electricity access through any solution, whether grid extension, mini grids, or DRE, requires accurate and granular information to develop projects effectively and efficiently. Important points of information required to develop a comprehensive electricity access project include demand assessment, economic parameters, population density and dispersion, local topography, social parameters and more. These parameters are relevant to all stakeholders that are trying to achieve universal electricity access.

A number of factors hamper data collection in LDCs and access deficit countries

Obtaining data for relevant parameters is a challenge in LDCs and other such countries that typically have a large electricity access deficit. Populations lacking electricity access are typically located in remote rural locations, with limited infrastructure and connectivity. They may also be in regions of unrest or conflict, or in locations where government institutions are unable to reach them on a regular basis. As a result, availability of accurate and up to date data for such regions can be challenging.

Collection of data for electricity access initiatives have also been hampered by recent unforeseen events such as the Covid-19 Pandemic and geopolitical tensions, which have served to interrupt data collection measures and caused a series of knock-on effects that served to shift the electricity access situations significantly in a short period of time. Data also serves as a critical input for improving the policy and regulatory landscape of an access deficit country. Without data driven insights, learnings from policy implementation and identification of gaps in the same can be difficult to accomplish.

This information gap increases the challenges to providing electricity access for all relevant stakeholders:

- **Developmental organizations** are unable to track status and progress in a country, preventing them from preparing targeted initiatives and interventions

- **Project developers** are unable to understand the needs and challenges of a particular location, leading to issues with appropriate project sizing to efficiently meet consumer needs
- **Financiers** are likelier to increase interest rates for potential projects due to lack of information leading to increased project risks
- **Governments** are unable to develop suitable policy and regulatory measures if they are unaware of the on-ground realities of the electricity access challenge

Thus, data availability is a cross cutting gap that affects all stakeholders attempting to mitigate the electricity access gap. The data availability challenge involves not only ensuring a suitable monitoring framework is in place, but it also involves ensuring that the data is made available to stakeholders around the globe to ensure that all possible stakeholders that can support electricity access initiatives are aware of the on-ground realities and can plan their interventions accordingly.

Key Data Availability Gaps

- Obtaining reliable, accurate and up to date data can be challenging in LDCs and access deficit countries that have limited infrastructure, institutional capability and reach, and remote and scattered populations
- It is difficult to obtain reliable data from fragile and conflict affected countries that may also suffer from electricity access deficits
- The information gap affects all stakeholders attempting to tackle the electricity access gap, and can hamper any initiatives they might be planning

6.6 Gaps in the Techno-Commercial viability

Techno-commercial viability is a key decision factor for mini grid implementation

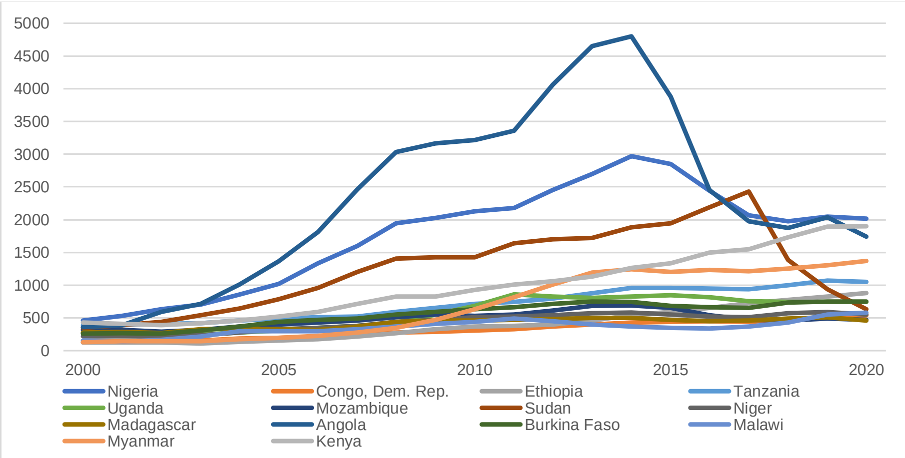
The techno-commercial viability of any mini grid project is one of the key decision factors in assessing the success of a mini grid. Viability is seen to be largely determined by two dominant factors – project developers' costs and end consumers' affordability. The population in the LDCs with the lowest levels of electricity access have extremely low incomes. The remote locations of the mini grids and the geo-political issue in these countries further builds up the cost to serve for the developers thereby widening the viability gap.

Consumer affordability significantly varies across geographies

In the countries with the lowest levels of electricity access, the GNI per capita has most often stayed below USD 2000 till date, with Nigeria and Angola being the exceptions. For the year 2020, the average annual income per person is calculated to be ~ USD 1000 (as calculated from the GNI data). Assuming four people in a household, the **average annual household income is calculated to be USD 4000**.

The consumption levels vary significantly across different countries. For a Tier 2 level of electrification, **a typical household consumes between 0.2–1 kWh of electricity daily, i.e., 6–30 kWh consumed monthly**. An African Mini Grid Developers Association (AMDA) benchmarking study calculated the national average electricity consumption for Nigeria, Mauritania, and Madagascar to be in the range of 9.5-30 kWh per month, with other African countries showing even lower consumption values between 2.5-5 kWh per month.

Figure 53: GNI per capita (USD) trend from 2000-2020

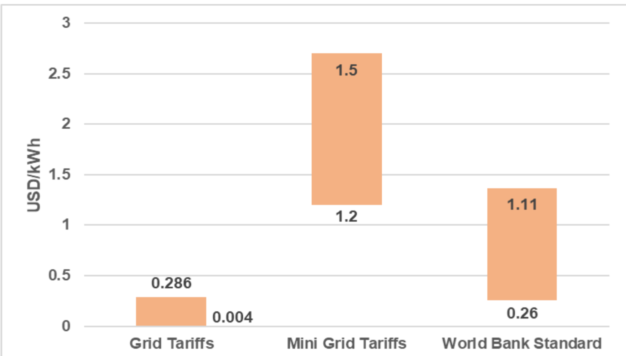


Source: World Bank Indicators Data

According to a BNEF-SE4All report on the state of the mini grid markets published in 2020, the LCOE for 6 standalone solar PV hybrid mini grids across 6 different countries ranged between USD 0.49-0.68 /kWh. Based on our analysis, the **mini grid LCOE falls within the USD 0.44-0.48 /kWh range**, without accounting for the cost-reflective technological advancements and fuel costs for the backup diesel generator over 25 years. **In contrast, the grid electricity tariffs in these LDCs range between USD 0.004-0.286 /kWh** (Tanzania and Madagascar with the lowest and highest tariffs respectively). This majorly affects the consumers' perception about the electricity tariffs as the end consumers tend to compare grid tariffs to mini grid tariffs.

The LCOE values are lower for mini grids with productive end use appliances as their demand coincides with the solar hours thus improving the utilization rate of the mini grids. Also, **the tariffs for the mini grids could be significantly higher than the LCOE values**, since the LCOE is number is projected over 25 years and the developer would ideally want a payback in a much shorter time.

Figure 54: Range of grid tariffs, mini grid LCOE and World Bank energy expenditure benchmark



Based on our analysis, the mini grid tariffs could range between USD 0.98-1.5 /kWh (USD 1.5 /kWh tariff found in a CrossBoundary study). Therefore, for the above estimated annual electricity consumption of 70-360 kWh (Tier 2), the **annual expenditure on energy for a household can vary between 2-14% of the annual household income**. This is a significantly large portion of the income based on the bare minimum Tier 2 level electrification. **The World Bank determines 5 percent of the monthly income as the affordability criteria for the first 30 kWh of energy expenditure** thus, these tariff levels create a significant viability gap from the consumer affordability angle.

Additionally, the GNI per capita assumes a uniform level of income across the country, but the remote mini grids will often target people living on annual incomes much below the national averages. **Based on Devergy's reports** from their mini grid sites, the **household income of this low income, unelectrified population is around USD 2.5 per day, i.e., an annual income of ~USD 915**, 4 times lower than the incomes calculated based on the GNI data. Based on these numbers and assuming the same level of electricity consumption, the expenditure on electricity forms ~9%-51% of the annual income, which is even more unaffordable.

Developer profitability may be highly volatile in access deficit countries due to a range of external factors

The developer costs are calculated as the least cost to serve electricity at the project site and is typically calculated in the LCOE terms. Project costs can be significantly different based on the location, resource availability and the sizing of the project. **Inefficient project sizing** is one of the most significant factors affecting the techno-commercial viability of the project due to the additional CAPEX and reduced utilization of the installed system.

Developers also build in some level default risk to account for the economic conditions of the community and the geo-political issues in the country, along with their own profitability into the project's costs. Banks and financing institutions also consider mini grids to be risky investments and therefore lend capital at a higher rate, largely due to the payment default risk from the end consumers along with the remote locations of the projects. All these factors significantly drive up the tariffs for the consumers, thereby creating challenges for the adoption of the mini grid itself.

Tariff setting is an important determinant in the developer's profitability. Ideally, developers would also build in a return rate such that the project payback period is with 7-10 years. In most cases, the tariffs required to fully recover the investments in a rural mini grid are substantially higher than subsidized retail electricity tariffs of the main grid and reasonably higher than the LCOE values for the project. **The developers are unable to set cost-reflective tariffs** taking into consideration the consumer affordability. **Subsidies are therefore required to recoup some portion of the capital and operating costs**

Tariff subsidy to improve the commercial viability of mini grids in Tanzania

Although mini grids are seen as the cheapest way to deliver electricity to the millions of unelectrified population in Africa, their unusually high electricity tariffs and low consumption can reduce the adoption of mini grids. The price of electricity affects the amount of electricity that end users consume and therefore, the operators' revenue.

CrossBoundary Labs aimed to test the impact of tariff reductions on the electricity consumption. They provided subsidy to two mini grid developers to reduce their tariffs by 50% and 75%. They made the following observations:

1. Reducing tariffs resulted in the consumers spending the savings to consume extra electricity. The consumers spend USD 0.93 on increasing their consumption for every dollar they saved.
2. The developers observed no additional revenue despite reducing tariffs. This also pointed out that the developer may be able to operate the mini grid at reduced tariffs without affecting their revenues significantly.
3. To reduce the tariffs to levels lower than the LCOE of the mini grid would require subsidies to help the developers maintain the same level of revenue.

4. The effect of increased consumption is more pronounced in the low-usage consumers than in the higher-usage consumers. Low-usage consumers are more likely to increase their demand weather in terms of 'hours of use' or the 'no. of appliances' or both.

Source: Innovation Insight: The Price Elasticity of Power, CrossBoundary (2019)

Results from a research initiative by CrossBoundary show that **rural mini-grid customers are typically budget-constrained but quite price elastic**. If the tariffs were lowered, the mini grid operators observed increases in the total consumption almost equivalent to the savings achieved from tariff reduction.

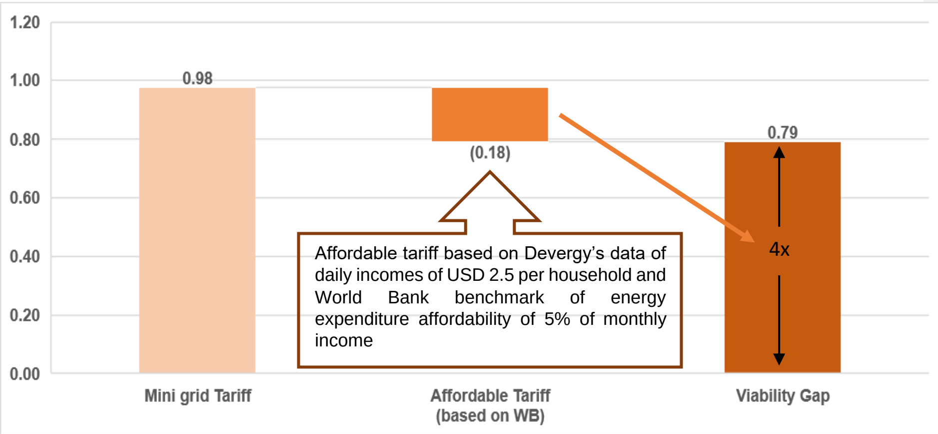
Both demand- and supply-side measures are necessary to reduce the viability gap

It is vital to bridge the techno-commercial viability gap between consumer affordability and developer profitability. Both, demand-side and supply-side measures will be necessary to reduce this viability gaps through different actions implemented for different stakeholders. Based on our analysis, we estimate the tariffs to range between USD 0.98-1.5 /kWh, which results in a **viability gap of USD 0.79-1 for every unit of electricity, which is almost 6x the affordable tariff level** (based on World Bank benchmark).

On the supply side,

- **Governments in these LDCs have many issues** on their ranging from poverty and education to sanitation and water availability. The local governments are therefore unlikely to implement focused actions and divert funds into improving electricity access.
- The geo-political issues in these LDCs along with the socio-cultural barriers result in **reluctance from most international financiers** to invest in the sector that needs a large, on-ground presence especially in the remote areas.
- Lastly, the **developers are unwilling to take the huge financial risks** and upfront capital investments due to the unavailability of low-cost financing and unaffordability among the end consumers.

Figure 55: Estimating the existing viability gap between the tariff and consumer affordability



On the demand side, lower consumption due to low household electricity demands and inadequate incorporation of additional services and productive end use appliances in the mini grid systems result in high, unsubsidized tariffs and further increase the techno-commercial viability gap in the mini grid projects.

Therefore, a substantial amount of support is required to spur the mini grid and DRE sector into action and as a result create large-scale impact on the unelectrified population by providing them access to clean, affordable, and sustainable source of electricity.

Key Techno-Commercial Viability Gaps

- Perception of end consumers on electricity tariffs and comparison of the higher LCOE of mini grids to concurrent grid tariffs
- Lack of affordability due to low household income leading to lower demand from mini grids and therefore higher cost of operation for the developers
- Higher tariffs for end consumers due to low/no government subsidies, higher lending rates and perceived risk of default
- Inefficient project sizing leading to large unused system capacities and unnecessarily higher tariffs
- Larger dependence on subsidies to reduce consumer tariffs leading to lack of ownership and unsustainable long-term operations of the mini grids

Despite the above-mentioned gap areas identified in the adoption of mini grids and other DRE technologies, these solutions can prove to be vital for the electrification of remote, rural areas. Mini grids and DRE can reach the locations and consumers that the main electricity grid cannot.

Innovative business models that suit local needs can therefore overcome the gaps mentioned above and emerge as a successful and sustainable cases of mini grid deployment as a solution for the electricity access challenge. However, despite their innovative use of technology and successful deployment record, these mini grid solutions still need to achieve scalability through widespread deployment, as well as financial sustainability through reduced grant dependence. Achieving this will require targeted interventions that will vary depending on geography and the socioeconomic characteristics that are prevalent in that location. The assessment framework below helps to group countries with similar characteristics that may be well suited to the deployment of a particular pool of interventions.

6.7 Country Assessment Framework

While the gaps identified above are common across most access deficit countries, the severity and impact of these gaps vary significantly based on the local ecosystem factors. In some cases, a country may be well placed to mitigate one particular gap despite being lacking in other gap areas. This leads to a wide variety of electricity access scenarios in different countries, including in countries that belong to the same region or have a similar level of electricity access deficit. This complexity further increases the challenge of approaching the electricity access problem.

In this context, we have undertaken an in-depth assessment of 12 access deficit ISA member countries based on 16 factors covering areas related to each gap viz. policy and regulation implementation, economic and financial conditions, equipment quality and application of global standards, data availability and techno-commercial viability. The main objective of the country assessment exercise is to identify countries where the gap areas and severity are common, analyze where each country stands in terms of electricity access factors and accordingly arrive at country groups where a common or similar approach can be adopted for achieving universal electricity access.

6.7.1 Methodology

Factors considered for assessment

For the country assessment, we have taken into consideration the factors that directly or indirectly will have an impact on the electricity access scenarios in various countries. The factors cover robustness of policy and regulatory ecosystem, ranking in terms of electricity access, economic and financial condition in the country, ease of doing business, investment climate, quality and standards mechanisms, strength of data and progress in terms of commercial scale and off-grid solar technologies. While most of the factors represent the socio-economic and geopolitical conditions in the countries, they are important to set the context for the potential development and the larger investment climate in the country.

The various factors considered under each thematic area is shown in the figure below:

Figure 56: Factors for Country Assessment based on the identified gap areas

Factors for country assessment based on identified gap areas					
Policy and Regulatory ecosystem	**Economic and Financial Conditions**	**Equipment Quality and Global Standards**	**Capacity Building and Awareness**	**Data Availability**	**Techno-commercial Viability**
• Mini grid and Off grid framework scores • RISE Electricity Access score	• GDP per capita • S&P Sovereign Risk rating • Ease of doing business rank • Political Stability rank • Lending Interest rate • Net FDI Inflows	• Adoption of international or similar standards in the mini grid and DRE sector	• Human Capital Index (0-1)	• Statistical Performance Indicator score	• Commercial Solar Capacity • Off-grid Solar Capacity
Factors to assess impact		• Unelectrified population • Rural population • National Income Share for Bottom 50% Population			

Each of the above factors dictate either the potential for impact or the country readiness or both. Accordingly, we have further classified the factors into impact factors or country readiness factors. Each country is then scored on both impact and readiness factors to identify visible country groupings amongst 12 access deficit ISA member countries. The details of the classification and the factors considered within each is explained in detail in the section below.

Impact factors

The impact score aims to quantify the scale of the possible positive effects that could be achieved if electricity access interventions were deployed in a particular country. It takes into consideration the absolute number of people these interventions could help and its effect on the income of the affected population.

The following factors are taken into consideration to assess the impact:

1. **Unelectrified Population (Millions, 2020):** Electricity access is a key area of focus within SDG 7 and is strongly linked to overall development of a country. Thus, a greater unelectrified population in a country would increase the potential impact that a mini grid or DRE based intervention would have.
2. **Rural Population (Number of People):** A country's unelectrified population is generally located in rural areas due to lack of grid access at remote locations and lack of technical personnel for operations and maintenance. Thus, countries with a larger rural population will see greater benefits from access related interventions, particularly decentralised interventions such as mini grids and/or DRE.
3. **National Income Share for Bottom 50% Population (%):** Income inequality in a country is exacerbated by a lack of access to electricity for both quality of life and productive applications. Thus, countries with greater income inequality will benefit more from electricity access initiatives that can open new avenues for economic growth and development. This indicator shows the proportion of the national income that the bottom

50% of the population earns, therefore, a lower percentage score on this indicator signals higher inequality in that country.

Country Readiness factors

Country readiness signifies the potential for deployment of mini grid and DRE solutions based on the current economic, financial, political, and social status of the country. We have identified at least one indicator against each gap area, such that the country readiness score provides a clear picture for every country's potential to adopt these technologies. The factors considered for assessing country readiness are explained below:

1. **GDP Per Capita (USD):** The level of income of a country is a major contributing factor to lack of electricity access from both a demand and supply side perspective. Low-income consumers are unable to pay for electricity, and developers are unwilling to set up projects for such consumers.
2. **S&P Sovereign Risk:** Based on the existing governance mechanism in place and the geopolitical scenario, each country differs based on their risk in the eyes of investors. This risk is quantified through risk ratings of countries, where riskier countries receive lower ratings. Financing costs across countries depend heavily on this risk rating, which can have a significant impact on the project costs for a developer.
3. **Ease of Doing Business (Rank):** Access deficit countries may not have a supportive environment for private businesses, which are often responsible for mini grid and DRE deployment. Thus, countries with better business regulations and suitable protection measures are more conducive to private sector investment in the sector. The ease of doing business index developed by the World Bank is considered to represent this factor.
4. **Political Stability (Percentile Rank):** Countries lacking electricity access are often fragile, conflict affected, and may be undergoing political turmoil. Such situations are not conducive for the development of electricity access projects, as project development and operations may be hampered. Additionally, low political stability would also influence the decision for investment.
5. **Commercial Solar Capacity (MW):** Solar energy has emerged as a leading choice of technology to provide electricity access, either through solar mini grids or standalone solar solutions. Countries with sizeable existing solar capacity can be considered to have a suitable ecosystem for development of solar powered electricity access interventions, as these countries will generally tend to have more mature markets for solar products compared to others.
6. **Off-grid solar capacity (MW)**: The capacity of off-grid solar installations provides information about the potential for adoption of solar-based mini grids and DRE applications. In countries with larger installed capacities, off-grid market will generally be more mature compared to other countries.
7. **Mini grid and Off-grid framework scores**: The RISE-ESMAP scores for mini grid and off-grid frameworks in a particular country provide a comprehensive idea about the presence of supportive programs, industry associations, funding avenues, well-defined regulations and a viable business environment for the mini grid and DRE projects.
8. **RISE Electricity Access Score**: The RISE-ESMAP score for the electricity access of a particular country provides an overall state of the electricity access in that country. The score considers the national electrification planning, frameworks for grid electrification along with mini grid and off grid solutions, financial health and performance of the national utility and the affordability of electricity for the consumers, thus providing a detailed overview of the status and plan for electricity access in the country.

9. **Human Capital Index (scale 0-1):** The human capital index takes into consideration multiple parameters such as the health and education of the population. It provides an estimate of the overall productivity of the next generation of the working population. This factor signifies the readiness of the population and the need of capacity building interventions.
10. **Lending Interest Rate (%):** The financial viability of a project is also dependent on the rates at which the developer can access funds in the form of debt. The lending interest rates in a country provide a significant basis for how cheap or expensive it could be for the developer to establish a project. The cost of debt also affects the tariffs at which end consumers get the electricity.
11. **Net FDI Inflows (USD Billions):** Foreign investments into a country is a testament of investors' confidence in that country's stability and growth. Higher FDI values also serve as a precedent for the incoming foreign investments into the country.
12. **Adoption of international or similar standards in the mini grid and/or DRE space:** This factor assesses the presence of any international or similar standard pertaining to implementation of mini grids and DRE technologies. Some countries have adopted the international standards, such as the IEC, directly whereas some others have modified the international standards to create their own national standards.
13. **Statistical Performance Indicator Score:** The statistical performance indicator measures the capability of the national statistical body in terms of data collection, availability, accuracy, etc. It can be reasonably assumed that the higher the score, the lesser is the need for mitigating data availability gap.

Scoring

The above mentioned 16 factors were given equal weightage and a 3-point scoring was given to each of the country's data points. The range of values for each factor was divided into quartiles based on the statistical distribution. The values below the 1st quartile of the range were marked as low (0), above the 3rd quartile were marked as high (2), and the rest were marked as medium (1). The factors were summed to access the country based on the impact and the readiness as mentioned above and the final scores across the two bases were plotted on the X and Y axes respectively. The resulting scatter plot provides a prominent distribution among the countries based on the impact of interventions and the country's readiness for interventions in the mini grid and DRE sector.

It is to be noted that the factors such as the ease of doing business ranks, lending interest rates, and political stability ranks were marked inversely, as lower values in these categories signify better country readiness. Additionally, the 'S&P sovereign risk' and the 'adoption of international quality standards in the mini grid and DRE space' indicators are qualitative in nature and were therefore marked accordingly.

6.7.2 Results

The scoring and resultant groupings of each of the top 15 access deficit countries is shown in the figure below:

Figure 57: Country grouping based on assessment framework

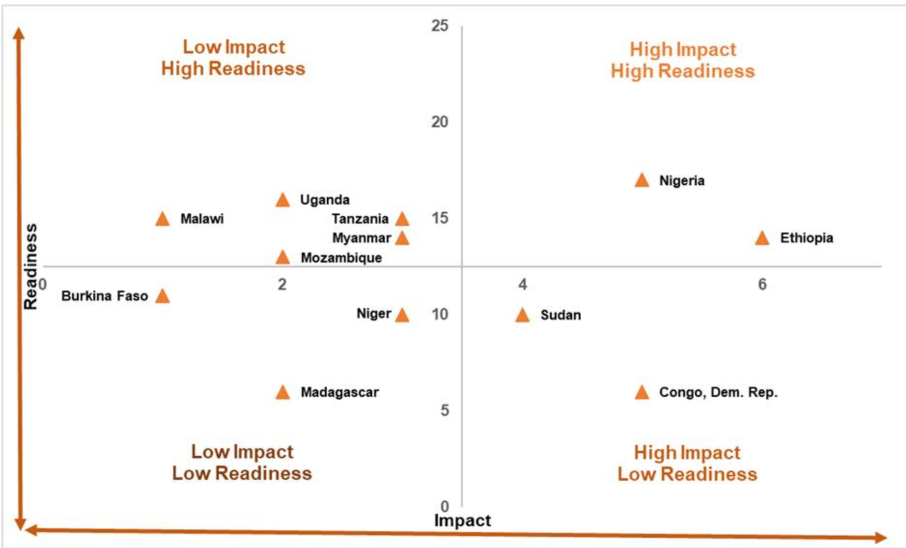
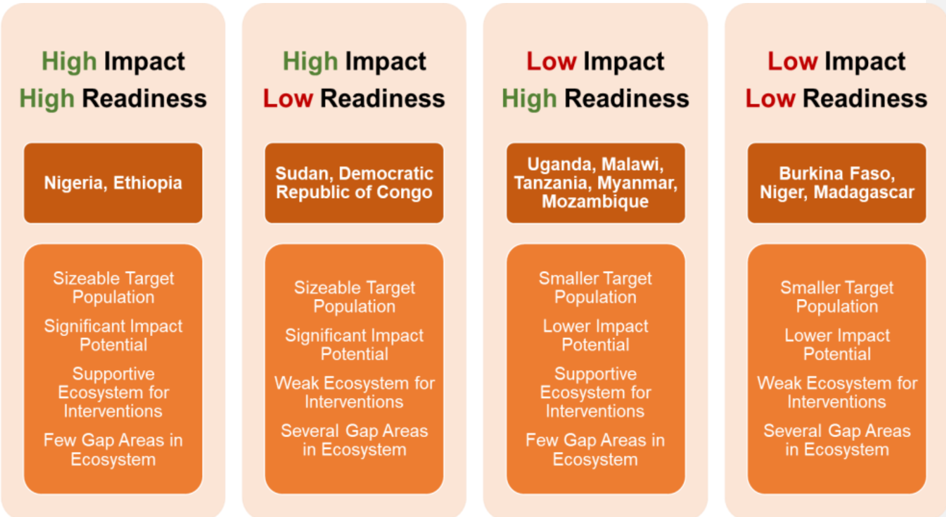


Figure 58: Country grouping based on assessment framework



6.7.3 Insights

A number of observations emerged from the country assessment data and the grouping of countries developed from it:

- The 12 countries have low national income shares for the bottom 50% of the population. All the countries have a share less than 16% which shows that the national income has a disproportionate distribution.
- All countries identified for this analysis have significantly lower 'GDP per capita' values. All of the countries lie below USD 2100 per capita and the average of all these countries is around USD 1150 per capita.
- Based on the S&P's sovereign risk rating, only 4 of the 12 countries have a rating of B/B- and all the remaining countries either have lower ratings or are unrated.
- Lending interest rates for the 'high impact, high readiness' group are better than all the remaining countries, except Niger and Burkina Faso. Lower interest rates could prove incentivizing for local developers and end consumers, and therefore critical to signal a country's readiness.
- FDI inflows for the 'high impact, high readiness' group are the highest (above 2 billion USD) among all the countries. Higher investment can catalyse faster progress in these sectors as most projects require some level of initial support either for the upfront capital or to lower consumer tariffs. Mozambique is an exception to this insight as its FDI inflow is the highest among all the countries.
- Although all of the 12 chosen countries are ranked below 100 for 'Ease of Doing Business', lower ranks typically see lower readiness. The countries with 'low readiness' have the lowest ranks among the 12 countries.

The country grouping highlights the need for different interventions and initiatives across the different groups based on the countries' readiness for adopting mini grid and DRE technologies and the impact that these interventions can bring about. Even within the groups, some countries may have widely different gaps than the others. Thus, country specific analysis is required to obtain a clear picture of their overall electricity access situation.

In addition to interventions to support electricity access, there is also a need for sustainable business models for mini grid and DRE adoption to help mitigate the gaps that are hampering electricity access measures.

6.8 Pathway towards a sustainable business model for mini grids

With analysis of the various mini grid deployment case studies in conjunction with the techno-commercial and the gap analysis, it is clear that there are ways in which a mini grid developer can reduce costs and thereby achieve a lower LCOE. Costs can be reduced through reduced costs of components, effective management of loads, higher consumer engagement, and reduced costs of construction, operation, and maintenance.

Reducing costs of technologies due to economies of scale and standardisation: various components related to solar energy, such as the panels, inverters, batteries, etc. have seen cost reductions which can be leveraged to achieve large-scale implementations. BNEF reports that the LCOE of solar PV will drop 66% by 2040. This could significantly affect the mini grid implementation over the years. With large-scale implementation, developers could undertake **bulk purchase** of the equipment which would further drive down the costs. Further, using standardized equipment and protocols could **facilitate modularity** in the system which makes it easy to implement and scale. Additionally, solar modules can be deployed alongside other renewable energy technologies to develop hybrid systems that improve the overall system generation and reliability.

Load management to effectively utilize the variable generation from solar is another way to optimally use the mini grid system. Flexible loads, such as pumps, water purifiers, or even cold storages can be switched on or off based on the solar generation profile. System utilization can also be improved through the **introduction of productive end use appliances** in the mini grids. The consumers could also be encouraged to **gradually increase their household demand** by facilitating appliance financing and leasing of household devices.

Demand Side Management (DSM) and creation

Demand side initiatives for mini grids can be conducted at both project and country level and can involve both promoting additional mini grid demand to improve project viability, or demand management measures to better manage the variable generation of solar. Tanzania's national utility, TANESCO, charges a uniform tariff throughout the country in order to subsidize mini grid operations. Tanzania also has a large scale program to increase productive uses of electricity for mini grid consumers. AfDB's Nigeria Electrification Project (NEP), implemented by Nigeria's Rural Electrification Agency, has dedicated a program component to support productive appliances and equipment for off-grid communities, and has developed a subsidy program to fund procurement of such appliances at established rural mini grid locations.

Developers, such as Rafiki Power in Tanzania, are also utilising demand management and creation measures. The company serves ~1000 customers with a solar PV mini grid and distributes and finances high efficiency household and business appliances to drive demand growth. Additionally, the company installs smart meters for data collection and analysis to design DSM measures and conducts customer education workshops and distributes information to consumers to improve awareness.

Source: AfDB Green Mini Grid Help Desk, RISE ESMAP, USAID

Involvement of the community in the design, planning, implementation, and operation of the mini grids is vital to create and stimulate demand. Community engagement also provides a better understanding of the productive loads that can be implemented in the mini grid along with the end consumers' willingness and ability to pay. **Working with ESCOs with a strong local presence** and network could ease the implementation process even more. Additionally, **locals could be trained** to conduct the daily operations and basic maintenance of the mini grid thereby saving on operational costs and providing faster solutions.

Interventions are required across multiple stakeholders to enforce these cost reduction mechanisms and create a **sustainable business model**. The local government is keen to reduce its expenditure on fuel costs and imports along with the empowerment of communities to be self-reliant in terms of their electricity and other needs. The consumers require affordable and reliable access to electricity, whereas the developers look for their financial viability, higher returns on investment and some level of payment security. Innovative and sustainable business model will need to address all these concerns to be successful and profitable, and private sector investment will play a key role in scaling of these business models to tackle the electricity access challenge.

The business models that make these mini grid deployments successful are usually some variations of the standard models tweaked to suit the local situation. After analyzing a wide variety of case studies across different geographies, the following key factors have been identified that led to the success of those cases:

- The **'ABC' model and the 'Keymaker' model are the most prominent** among the successful cases of mini grids. Their success can be attributed to the fact that both these models **include a significant portion of strategic loads** that **provide a sizeable demand** for the mini grid and are also capable of **paying higher tariffs**. This leads to the most optimal usage of the mini grid system with a **larger day-time demand** and helps **subsidize the low-demand residential consumers**, thereby improving the operational viability of the model. Additionally, the presence of a single large consumer leads to predictability in cash flow generation, as compared to the relatively uncertain cash flow from smaller domestic consumers. This predictability further improves the likelihood that the model can be successfully deployed.

- **Additional services** that augment the electricity consumption such as productive end-use appliances, charging stations, electric transportation, or other home appliances such as electric/solar cookers **can be promoted to increase the electricity demand thereby improving viability of the mini grid.**
- **Digitalization of the operations** of mini grid is vital to its success. Solutions such as smart meters, cloud-based monitoring platforms, mobile payments and data collection can be deployed to **achieve low operational costs and faster incident resolution.**
- **Low-cost financing** options such as concessional loans, dealer credit, leasing, etc. go a long way towards **improving the adoption of the mini grid and its associated appliances**. **Subsidies and grants** could be deployed as **tariff reductions or performance incentives** for the developer to maintain skin in the game for the developer.

ISA has been working with countries to design solutions customized to their needs. The next chapter outlines the interventions that ISA is already undertaking, across its different capabilities, to mitigate the issue of electricity access. The last chapter consequently brings together the findings from gap analysis and country assessment framework to identify and recommend specific interventions required for the different countries.

7. Learnings from India's electricity access and solar sector development journey

As of April 2023, India had an installed electricity generation capacity of around 416.6 GW[56] and had become the third-largest producer and consumer of electricity worldwide. Moreover, the country currently enjoys an electricity access rate of ~100%. The country has made significant strides in integrating renewable energy sources into its installed capacity in order to accelerate its energy transition plans, with 169 GW of installed RE capacity, constituting ~40% of the current total installed capacity. At present, the country stands fourth globally in terms of installed capacity of solar energy, wind energy as well as overall renewable energy sectors.

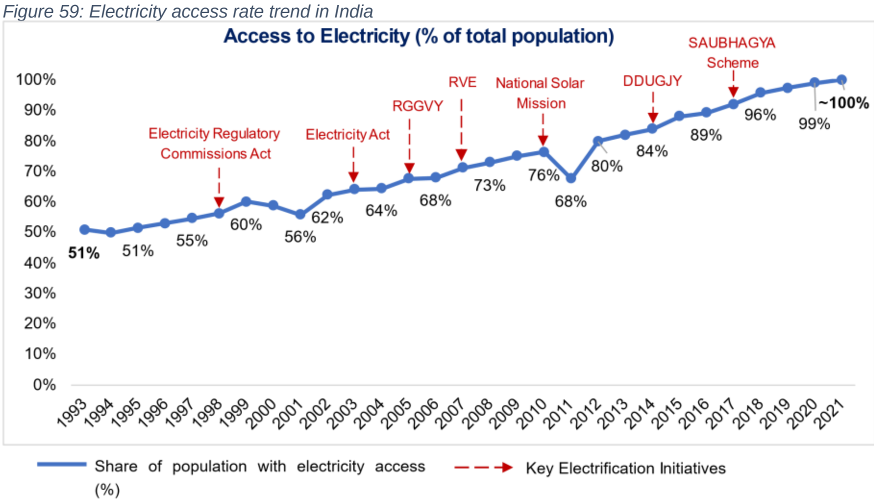
The inception of the electricity sector in the country involved the implementation of modest, self-contained power grids that were primarily installed in urban regions. The first Five-Year Plan instituted in 1951 placed significant emphasis on the enlargement of the electricity infrastructure as a crucial element of its economic growth plan and focused on prioritizing the electrification of rural regions. Historically, India has been heavily dependent on coal as its principal fuel source to fulfil its electricity requirements. However, the country has demonstrated an unwavering dedication to exploring alternative sources of energy with the aim of promoting sustainable development. However, hydroelectric power emerged as the preeminent means of generating electricity, in conjunction with coal, until the 1990s. Subsequently, clear progress towards steadily deploying Renewable Energy Sources (RES) has been made. The solar energy sector, in particular, occupies a pivotal role in the nation's strategic plan for transitioning towards cleaner sources of energy.

7.1 India's progress towards providing electricity access

India has made remarkable progress towards providing its growing population with access to electricity. In the early 1990s, India's electricity access rate stood at slightly above 50%. Consequently, various power sector reforms were launched in the following years. This included the **Electricity Regulatory Commissions Act of 1998**, which was established to develop independent regulatory bodies in the sector, such as the Central and State Electricity Regulatory Commission (CERC and SERC).

[56] National Power Portal (npp.gov.in), May 2023

Figure 59: Electricity access rate trend in India



Source: World Bank and ISA Analysis

Note: RGGVY: Rajiv Gandhi Grameen Vidyutikaran Yojana; DDUGJY: Deen Dayal Upadhyaya Gram Jyoti Yojana; SAUBHAGYA: Pradhan Mantri Sahaj Bijli Har Ghar Yojana; RVE: Remote Village Electrification

Given that the majority of the population resided in rural areas with limited access to electricity, the **Electricity Act of 2003** was enacted with the primary objective of promoting the expansion of the electricity sector and ensuring access to electricity across all regions. The act outlined a bifurcated approach aimed at augmenting the accessibility of electricity in rural areas. The initial segment of the plan entailed a countrywide strategy for the electrification of rural areas by means of the expansion of power grids. The subsequent segment focused on encouraging the installation of additional capacity through stand-alone systems including renewable energy sources at locations where grid extension would not be feasible.

The government recognized that rural electrification would be the key to providing electricity access. To this end, the **Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY)** was launched in 2005 with the aim of accelerating rural electrification by offering electricity connections to households that were categorized as impoverished. The initiative emphasized the utilization of renewable energy sources and advocated for community participation in endeavors aimed at providing electricity.

In 2007, the Remote Village Electrification (RVE) programme was launched to provide basic electricity facility to 3,254 villages/ hamlets. The programme was implemented by the Ministry of New and Renewable Energy through various DRE sources like Small Hydro Power (SHP), biomass gasification-based electricity generation systems, Solar Power Packs, etc. depending upon local availability.[57]

In 2014, the RGGVY program was replaced by the **Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY)** with the aim of enhancing rural electricity infrastructure, improving power distribution, and ensuring uninterrupted power supply to rural households, agricultural consumers, and other rural institutions, thereby further augmenting the quality of life in rural areas.

[57]https://cag.gov.in/uploads/download_audit_report/2015/Union_Civil_Performance_Renewable_Energy_Report_34_2015_chap_9.pdf

As the grid infrastructure in India improved, achieving last mile access through grid extensions become feasible in several regions. Thus, in line with the DDUGJY initiative, the Government of India introduced the **Pradhan Mantri Sahaj Bijli Har Ghar Yojana, commonly referred to as the SAUBHAGYA Scheme**, in 2017. The scheme prioritized the provision of electricity connections to both rural and urban households that previously lacked access, with a particular emphasis on improving last mile connectivity. The scheme played a pivotal role in substantially enhancing the availability of electricity in remote areas, either by extending the grid or putting up off-grid solar PV systems where the grid cannot be reached and achieving ~100% electricity access.[58]

India has also made significant efforts to expand and interconnect its various regional grids. Once grid infrastructure reached sufficient scale, organized power market operations were approved by CERC in 2008. This enabled market-based procurement of electricity and provided a marketplace for generators and distribution companies to trade in their surplus and deficits across a large, interconnected grid[59].

As a result of these initiatives, India has been able to achieve near 100% electrification currently. However, it's approach has not been limited to grid extensions. India has been an early adopter of solar energy, and the solar sector has played a key role both in providing electricity access to remote regions and in providing clean electricity access across the country.

7.2 India's solar sector

Following two oil shocks in the 1970s, India recognized the importance of energy self-reliance and made it a priority to develop the new and renewable energy sector. Hydro, wind, and solar power were the primary sources of renewable energy that the government aimed to deploy to support its plans for widespread energy access and security. The Ministry of New and Renewable Energy (MNRE) is the nodal ministry responsible for creating a favorable environment for the development of various renewable energy technologies in line with the national targets of achieving energy security and climate change action.

The Ministry of New and Renewable Energy (MNRE)

The sudden increase in the price of oil, uncertainties associated with its supply and the adverse impact on the balance of payments position led to the establishment of the Commission for Additional Sources of Energy (CASE) in the Department of Science & Technology in March 1981. The Commission was charged with the responsibility of formulating policies and their implementation, programmes for development of new and renewable energy apart from coordinating and intensifying R&D in the sector. In 1982, a new department under Ministry of Science and Technology, the Department of Non-conventional Energy Sources (DNES), that subsumed CASE, was created in the then Ministry of Energy. In 1992, DNES became the Ministry of Non-conventional Energy Sources (MNES). In October 2006, the Ministry was re-launched as the Ministry of New and Renewable Energy (MNRE).

The functions of the MNRE include the facilitation of research, design, development, manufacture, and deployment of new and renewable energy systems/devices for transportation, portable and stationary applications in various sectors.

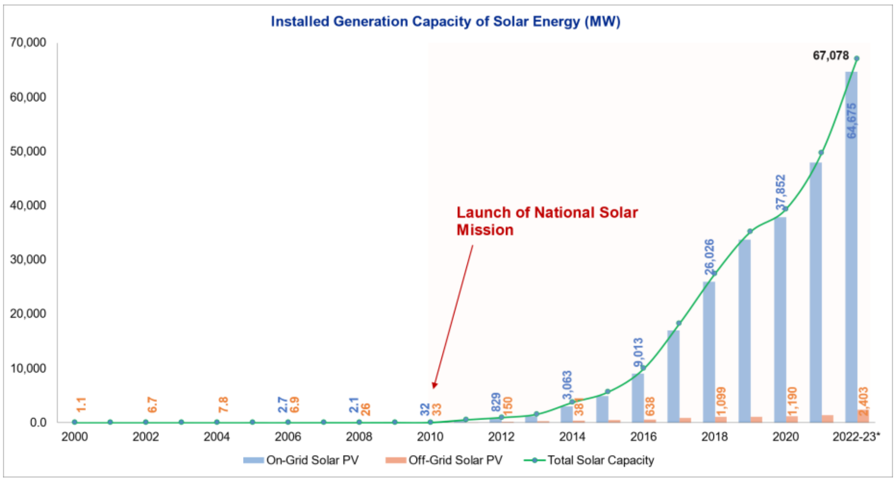
Source: MNRE

The Ministry's off-grid solar PV applications programme began in 1992. It was one of its oldest programmes and aims to provide decentralized solar PV lighting and productive use applications to areas where grid electricity is not available or is unreliable. The solutions available under the program included solar lanterns, solar home lighting systems, solar street

[58] Saubhagya | Government of India | Ministry of Power (powermin.gov.in)
[59] Ministry of Power, Report of the Group on Development of Electricity Markets in India

lighting, solar pumps, and small solar power packs including solar mini-grids. Prior to 2004, solar PV technology was mainly utilized for off-grid applications with battery backup, with a total installed capacity of 7.8 MW[60]. Advancements in technology have led to the installation of on-grid solar PV systems across the country since 2005.

Figure 60: Installed generation capacity of solar energy (on-grid and off-grid)



Source: MNRE & IRENA

Another major development for solar energy in India came in 2010, when the Government of India launched the National Solar Mission (NSM). The NSM's aim was to promote sustainable growth that is ecologically friendly, while also addressing the energy security challenges by swiftly establishing the policy conditions for the diffusion of solar technology throughout the country. The NSM required the participation of states in coordination with the central government and was deployed in comprehensive mission mode for rapid development of multi MW solar capacity. The NSM also had a focus on off-grid solar deployment and holistic solar ecosystem development, including development of solar manufacturing and solar technology R&D. Upgradation and development of grid infrastructure was also covered under the programme to allow for improved grid integration of renewable energy.

As India recognized the potential of solar energy in the country, the development of the solar energy sector has taken a central place in India's National Action Plan on Climate Change with NSM as one of the key missions. Both the central and state governments have implemented various policies and regulations centered on solar applications to encourage the use of solar energy. These measures include the Renewable Energy Certificate (REC) structure, solar tariffs, guidelines, and incentives for grid connectivity of solar projects, and improved forecasting, among others. In 2011, the **National Tariff Policy was amended to include Renewable Purchase Obligations (RPO) specific to solar energy**, with the aim of securing off-takers for the generated solar PV power. The amended policy stated that the minimum percentage of solar RPO must increase from 0.25% in 2012 to 3% by 2022.[61] Many states have even targeted to achieve solar RPOs up to 10.5%.[62] In addition to RPOs, the introduction of RECs provided an additional aspect to the renewable energy power market, enabling states with inadequate resources to meet their RPO targets by purchasing RECs.

[60] IRENA
[61] Solar RPO and REC Framework | Ministry of New and Renewable Energy, Government of India (mnre.gov.in)
[62] Target - National Portal for Renewable Purchase Obligation (rpo.gov.in)

Solar Energy Corporation of India (SECI), a public sector enterprise, was incorporated in 2011, under the administrative control of MNRE, to facilitate the implementation of NSM and achieve the set renewable energy targets. SECI was originally incorporated as a not-for-profit company but was converted into a self-sustaining and self-generating organization in 2015. SECI facilitated the establishment of a transparent and competitive tendering procedure for the development of utility-scale solar parks. Subsequently, in order to promote solar deployment through shared infrastructure and economies of scale, MNRE launched the **Development of Solar Parks and Ultra-Mega Solar Power Projects (UMSPP)** program with the objective of establishing 40 GW of utility-scale solar parks throughout India.[63] The UMSPP initiative has contributed significantly towards reducing the cost of solar electricity in India. A SECI auction for 1,070 MW of solar projects in Rajasthan set a tariff of ~USD 0.024.[64] As of 2022, the UMSPP initiative has approved 57 solar parks with a combined capacity of 39,285 MW.[65]

India also recognized the importance of suitable grid evacuation infrastructure to ensure continued growth of solar deployments. In 2015, the Indian government initiated the **Green Energy Corridor Project** with the aim of enhancing evacuation infrastructure, including an inter-state facility, for large-scale projects.

Alongside support for large scale solar projects, India also focused on developing distributed solar applications, both on-grid and off-grid, MNRE launched **the Grid Connected Solar Rooftop (SRT) Programme (Phase-I in 2015 and Phase-II in 2019)** with the goal of achieving a cumulative installed capacity of 40 GW from Grid Connected Solar Rooftop projects.[66]

Policy initiatives have not been driven by the central government alone. A few states, such as Bihar and Uttar Pradesh, have formulated their own policies to promote the development of renewable energy mini grids.

Table 14: Salient features of Bihar and Uttar Pradesh state level mini grid policies

States	Salient features of mini grid policies
Bihar (Bihar Policy for Promotion of Bihar New and Renewable Energy Sources, 2017)[67]	• Placing mini grids as a mean to supply reliable round the clock electricity supply • Mini grids can be developed in the areas with no electricity access (unserved) as well as low electricity access (underserved) areas • The policy allows mini grid developers to operate under Built Own Operate & Maintain (BOOM) with three implementation options: - **First:** Tendering model under the existing central government scheme such as DDUGJY - **Second:** State subsidy model where the developer can charge a tariff as prescribed by the extant of mini grid policy or framework - **Third:** Without subsidy model, developers can self-identify the projects and charge a mutually agreed tariff from consumers • Provides suitable exit options on arrival of main grid: - Continue standalone operations i.e., parallel to grid - Sell excess or all power to DISCOM at regulator determined tariffs - Transfer the project to the DISCOM

[63] Schemes | Ministry of New and Renewable Energy, Government of India (mnre.gov.in)
[64] India's New Record for Lowest Solar Tariff is ₹2/kWh (mercomindia.com)
[65] Press Information Bureau (pib.gov.in)
[66] Schemes | Ministry of New and Renewable Energy, Government of India (mnre.gov.in)
[67] RENEWABE_ENERGY_POLICY_2017.pdf (bih.nic.in)

Uttar Pradesh (Mini grid Policy, 2016)[68]	• To ensure minimum Tier 3 level electricity supply to 20 million households of the state • The policy allows mini grid developers to operate under two models: - **First:** State provides 30% capital subsidy to the private developers in exchange for state authority specified project location, tariffs, and technical specifications. The projects shall be established on Built Own Operate & Maintain (BOOM) basis and 10 years of operation and maintenance (O&M) services - **Second:** Developer sets up mini grids without the state subsidy and is allowed to charge mutually agreed tariff from consumers • UPNEDA acts as the Nodal Agency for single window clearance for all mini grid projects

Over 100 mini grids have been developed in Uttar Pradesh under the state mini grid policy[69]. Additionally, a number of mini grids in the state are operated and owned by private developers who have developed self-sustaining business models such as the ABC model. Likewise, in Bihar, around 90 RE mini grids had been developed as of 2019[70]. Private mini grid developers in India have underlined their confidence in the conducive environment for mini grid deployment by announcing expansion plans for the deployment of thousands of mini grids in the country.

As electricity access and solar deployments continued to grow, the Government of India began identifying focus areas for improved access and decarbonization. Focusing on energy security for farmers, the **Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM KUSUM) Scheme** was launched in 2019. The PM KUSUM scheme encompasses three distinct components: the establishment of 10 GW capacity of decentralized ground or stilt-mounted grid-connected solar PV with a maximum capacity of 2 MW (Component A), the installation of two million stand-alone solar agriculture pumps (Component B), and the solarization of 1.5 million grid-connected agriculture pumps through individual pumps and feeder-level solarization (Component C).

The steady support provided to the solar sector has resulted in rapid growth. Overall, India has achieved 67 GW of solar installations as of April 2023, including 2.4 GW of off grid solar capacity.[71] As of March 31, 2021, the country had established a capacity of 216 MW for solar mini grids. Furthermore, the country boasts a total of 10 million solar-powered lighting systems, encompassing streetlights, home lights, and solar lanterns, as well as 286,830 solar water pumps.[72]

India's plans to grow its solar sector have only expanded with its successes. The country is now targeting the development of a domestic solar manufacturing supply chain to improve its energy security as it moves towards its likely capacity of ~290 GW of solar by 2030.[73] Strong central support has been provided for the same, including the development of a Production Linked Incentive (PLI) scheme for domestic solar manufacturing, manufacturing linked solar tenders, and imposition of import restrictions to support domestic manufacturing. As a result, solar is set to play a key role in India's ambitions to achieve Net Zero by 2070.

[68] Untitled-1 (upneda.org.in)
[69] Programmes Under Off Grid Solar - Uttar Pradesh New and Renewable Energy Development Agency (upneda.org.in)
[70] India_Case_Study.pdf (minigrids.org)
[71] MNRE Physical Progress, as on 30/04/2023
[72] VOL 1: Mini-Grids a Just and Clean Energy Transition (cseindia.org)
[73] CEA Report on Optimal Generation Mix 2030, Version 2.0, April 2023

7.3 Key learnings

The learnings and experience of India's successful electricity access journey can be leveraged to support developing nations in meeting their own electricity access targets. Additionally, India's solar expertise can also help ensure that electricity access initiatives in such countries utilize a clean energy source rather than one powered by fossil fuels.

The following learnings can be taken from India's electricity access journey:

- **Robust policy and regulatory framework:** India's progress towards electricity access has been driven by strong policy pushes, backed by regulatory developments to provide further clarity. Policies and programs have regularly been introduced to support various electricity access measures and solar segments, including off grid solar, solar mini grids, rooftop solar, and utility scale solar. Thus, all relevant stakeholders are provided clarity on the government's viewpoint and objectives for each solar technology, improving the market environment. Additionally, a number of states have introduced specific solar policies as well, charting out their targets and incentives with respect to solar capacity. As a result, incentives and support are often available from two sources, and can be tailored to state specific ecosystems for maximum impact.
- **Flexible approach to electrification:** India has recognized that no single approach to electrification is capable of providing last mile access to electricity in the country. An electrification strategy is heavily dependent on a number of site-specific considerations, including community size, population density and socio-economic status, distance from existing grid infrastructure, and terrain complexity. These parameters vary significantly across different access deficit regions in India considering its diversity, and the government recognized that it is not practical to deploy a single solution to meet the country's electricity access needs. Initially, India focused on a combination of developing its electricity grid along with the development of off grid solar lighting and productive use appliances for remote and rural regions. Subsequently, recognizing the importance of a robust grid, India introduced the Electricity Act and the RGGVY and DDUGJY initiative to drive rural electrification. As renewable energy sources such as solar become more widely available, additional schemes to support renewable energy driven electrification were introduced, achieving its peak with the launch of the National Solar Mission in 2010. As grid infrastructure continued to improve, India recognized that last mile electrification through the grid had become a possibility and responded with the SAUBHAGYA scheme for last mile electrification through the grid. Once significant electrification was achieved through the grid, the focus shifted towards promoting decentralized solar systems to improve reliability of electricity access and decarbonize existing devices. Thus, countries embarking on their electricity access journey can learn from India's approach and ensure that they are able to pivot their strategy depending on their current circumstances.
- **Leveraging new technologies to improve capabilities:** In keeping with their flexible approach to electrification, India has ensured the use of new technologies as they become available. The country become an early adopter of solar for decentralized access by deploying off grid devices in 1992. The country has also taken steps to provide early support to other applications of solar energy, including utility scale solar projects, rooftop solar plants, and mini grids. India has also taken steps to digitalize its grid to better serve the populace, with smart metering initiatives and improved Transmission and Distribution (T&D) infrastructure. This grid upgradation has helped reduce power losses in the country and allowed for improved integration of solar generation. Additionally, digitalization of O&M of solar plants have improved the operations and grid integration for solar projects.
- **Targeted programs with specific objectives:** Although policies are a key enabler to drive electricity access plans, they typically outline high level targets and approaches

without providing specifics. India has ensured that its efforts have not been restricted to broad policy commitments. Instead, the government has worked to develop targeted initiatives such as PM-KUSUM, SAUBHAGYA, DDUGJY, UMSPP, etc., with specific thrust areas and targets to be achieved. The development of such focused initiatives has provided clarity to both institutions and the private sector, allowing for rapid growth in electricity access. Well defined initiatives also allow for improved institutional coordination at both state and central level, minimizing inefficiencies and ensuring that all relevant stakeholders are aligned towards the target to be met.

- **Committed political leadership, institutional capacity, and strong mandate:** Electricity access has been a key agenda item for the Indian government and has been given a high priority. The commitment to provide last mile electricity access has been driven from the top at central level, thus galvanizing efforts to meet targets. Access to electricity can take a number of years to achieve, and strong long-term support from the top can ensure that the implementing agencies have a strong mandate to drive change. Additionally, adequate institutional capacity and know how has been developed to ensure that the relevant ministries are well placed to support electricity access initiatives. This political leadership and institutional capacity ensured timely and stringent implementation of electricity access initiatives, ensuring that key targets were achieved in a reasonable timeframe. Additionally, in order to improve coordination between the key Ministries of Power, New and Renewable Energy, and Coal, a single Minister of State for the three ministries was appointed in 2014.
- **Transparent monitoring and tracking:** Insufficient data availability can hamper electricity access initiatives. However, India placed a strong emphasis on data collection to ensure proper monitoring of electricity access and solar related initiatives. This data collection allowed stakeholders to make informed decisions within scheme frameworks. Additionally, the country developed online portals for the power sector as a whole, as well as online portals for various specific schemes. These portals were easily accessible to the public and were regularly updated. As a result, non-government stakeholders have easy access to up-to-date information regarding scheme progress, allowing for improved analysis and decision making. The collected data was also provided at state level, providing greater granularity in analysis while also encouraging internal competition across states to further speed up progress.

India has recognized that it's experience in the solar sector can be leveraged to support developing countries meet their energy needs in a sustainable manner. As a result, India and France established the International Solar Alliance (ISA) in 2015. As a treaty based international intergovernmental organization, ISA supports deployment of solar technologies for energy access for its member countries. ISA's membership includes a large share of LDC and SIDS countries, and their broad-ranging initiatives provide a platform for India and other nations to share their learnings and expertise in the solar sector.

8. ISA's interventions

The International Solar Alliance (ISA) is an international institution which acts as a 'platform-of-platforms' that seeks to create effective and sustainable markets and political commitments for deployment of solar energy systems globally, with a strong focus on sunshine rich Least Developed Countries (LDCs) and Small Island Developing States (SIDS). Currently, 115 countries have signed the ISA Framework Agreement, 92 of which have ratified the agreement to become member countries. The current membership includes 62 LDCs and SIDS member countries where the need for energy access and energy security is acute. By leveraging a unique political opportunity to empower developing and emerging economies, the ISA also promotes a transition to clean energy that is truly global, while simultaneously advancing principles of economic development and social equity.

With its vision "Let us together make the sun brighter," and mission "Every home, no matter how far away, will have a light at home," the ISA is guided by its 'Towards 1000' strategy which aims for:

Enabling: Energy Transition of 1,000 GW of Solar Capacity

Reducing: Carbon Emissions by 1,000 million Ton

Ensuring: Energy Access for 1,000 million people using clean energy Solutions

Mobilizing: USD 1,000 Billion in Solar Investments

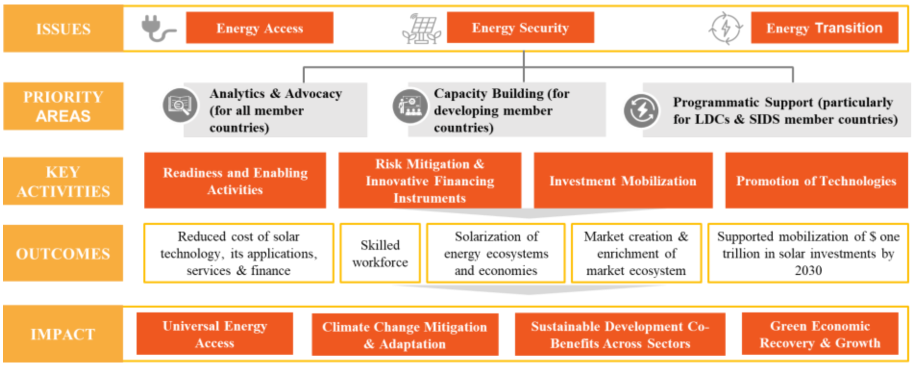
This would help in establishing solar as a shared solution for climate, energy and economic priorities across geographies and achieve three different but interlinked objectives:

— Promoting Global Energy Transition
— Enabling National Energy Security
— Delivering Local Energy Access

One of the most critical challenges that the member countries face is a lack of investments due to a lack of a pipeline of bankable projects and high perceived financial and non-financial risks. To facilitate the development of a pipeline of bankable projects in LDCs and SIDS Member countries, the ISA offers programmatic support for both off-grid and grid-based solar applications and Technical Assistance. This programmatic support covers a) readiness and enabling activities; b) risk mitigation mechanisms; c) investment mobilization. ISA helps drive implementation of early enabling activities by governments and financial and educational institutions to foster low-risk, accessible and sustainable markets for solar energy in all member countries across the globe, with support focused in developing countries and small island nations.

The ISA's Theory of Change aims to significantly contribute towards accomplishment SDGs 7 (Affordable and Clean Energy) and 13 (Climate Action) by concentrating on three critical energy concerns - Energy Access, Energy Security and Energy Transition. ISA provides upstream and downstream support for solar deployment through the following mechanisms for change.

Figure 61: Theory of Change – ISA's Strategic Framework for Global Solarization



ISA's purpose is to make solar energy the preferred energy choice of policy makers by providing analytics and advisory services, capacity building, and programmatic support for a range of solar solutions and applications.

- **Analytics and Advocacy:** ISA provides direct support to national governments to identify and implement enabling policies and government programs, such as investment friendly policy framework, solarization roadmap for clean energy goals, net-zero campaigns, enabling manufacturing and PV supply chain. At the individual country level, ISA also helps design and advocate for enactment of specific pro-solar policies.
- **Capacity Building:** ISA aims to grow the solar ecosystem in LDCs and SIDS by providing capacity building to stakeholders at all nodes of the solar value chain, from policymakers and bankers to technical workforce and master trainers through fellowships, degree programs, and trainings across the solar ecosystem.
- **Programmatic Support:** ISA works at the project and program level to provide technical assistance for solar project implementation, mitigate business and financial risks and mobilize investments.

The ISA currently has 9 active programmes that offer a variety of solar solutions ranging from a few kilowatts off-grid projects to utility scale on-grid projects, based on the needs of the member countries and their current positioning in the energy transition paradigm. These programmes include Solar Pumps, Solar Rooftop, Solar Mini-Grids, Solar Parks, Affordable Finance, Solar E-mobility and Solar Heating and Cooling, Green Hydrogen, Solar PV Battery, and Waste Management. Within each of the priority areas, ISA undertakes the following key activities:

— **Readiness and Enabling Activities:** To facilitate an enabling ecosystem for deploying and scaling up solar projects, the ISA provides technical assistance to member countries. This is done by carrying out, feasibility studies and market assessments and preparing pre-feasibility reports, solar roadmaps, bankable project proposals, integrated business models, showcasing innovative solar applications, technology, and projects through demonstration projects with the aim of replicability in future, etc.

— **Risk Mitigation & Innovative Financing Instruments:** To effectively mitigate financial and non-financial barriers and facilitate affordable finance for solar projects in member countries at the required scale, the ISA is developing blended finance facilities and related financing instruments to reduce investor risks.

— **Investment Mobilization:** The ISA aims to bring together key stakeholders, including Multilateral and Bilateral Development Banks, DFIs, local banks, corporates, and investors on a common platform to identify investing roadblocks and solutions for boosting the pace and scale of solar investments as well as for attracting finance for structured and investment ready solar projects in ISA member countries.

With equal emphasis and focus on the above thematic areas and activities, ISA is in the process of creating a conducive ecosystem for promotion of self-sustainable business models for Solar Mini Grids and other solar based DRE applications in member countries. ISA's current activities are already aligned with the needs of member countries and are addressing some key gaps as highlighted in the section above. The table below shows the primary activities of ISA and the gaps bridged by various interventions.:

Table 15: ISA interventions for developing self-sustainable business models

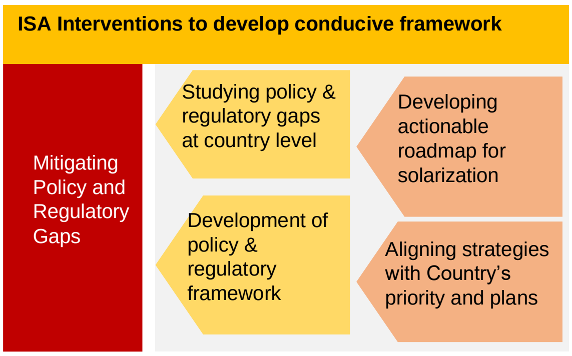
<table>
<tr><th rowspan="2">Gaps</th><th colspan="3">ISA's Interventions</th></tr>
<tr><th>Analytics and Advocacy</th><th>Capacity Building</th><th>Programmatic Support</th></tr>
<tr><td>Gaps in the Policy and Regulatory Ecosystem</td><td>Assisting countries by identifying gaps in policy and regulatory framework
Private sector engagement in developing policy frameworks</td><td></td><td></td></tr>
<tr><td rowspan="2">Gaps in the Techno-commercial viability</td><td></td><td colspan="2">Bringing economies of scale by means of demand aggregation of solar technologies in member countries</td></tr>
<tr><td colspan="2"></td><td>Developing pipeline of bankable projects
Catalyzing investments through Global Solar Facility</td></tr>
<tr><td rowspan="2">Gaps in Equipment Quality and implementation of Global Standards</td><td></td><td colspan="2">Knowledge building through E-Handbooks on solar technologies and sharing best practices
Deploying solar demonstration projects with ISA grant support, following international standards
Assist in preparing detailed project reports, standard bidding documents, and power purchase agreements (PPAs), etc.</td></tr>
<tr><td colspan="2">ISA Solar Technology Application Resource Centres (STAR-C) to act as a hub for quality assurance and for enforcement of global standards and specifications, develop human capacity and skills within member countries</td><td></td></tr>
<tr><td rowspan="2">Gaps in Technical Competence, Capacity Building and Awareness Creation</td><td></td><td>Virtual trainings to diverse stakeholders
Fellowships to mid-career professionals</td><td></td></tr>
<tr><td></td><td colspan="2">Technical webinars for the dissemination of best practices to ISA member countries</td></tr>
</table>

Gaps	ISA's Interventions: Analytics and Advocacy	ISA's Interventions: Capacity Building	ISA's Interventions: Programmatic Support
		SolarX Startup Challenge to promote innovation, discover local solutions, and enable entrepreneurs with the over-arching objective of building human and institutional capacity to sustain and grow solar businesses	
Gaps in Data Availability and Information Sharing	**Country level analysis** to assess the readiness of respective countries		
	Solar Compass, an open-access Journal, which focusses on innovation, information, data, and analytics.		
	Country specific Solar Sector Diagnostics		
	'Ease of Doing Solar' reports		
	Global solar reports covering the technology, market, and investment aspects		

ISA is the first inter-governmental organization of its kind established by and for LDCs and Middle-Income Countries and therefore represents a major contribution to geo-political equity in climate diplomacy. The ISA offers a pathway for empowering lesser-developed nations to design and drive clean energy and climate solutions, along with sustainable development goals.

8.1 Mitigating policy and regulatory gaps through technical assistance to develop conducive framework

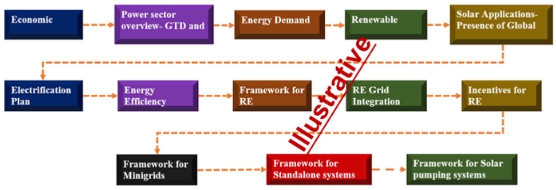
It is often challenging and poorly understood how policy and regulation can promote increased clean energy supply and demand while ensuring that everyone has access to energy. ISA's Analytics and Advocacy approach enables the adoption of policies and practices that encourage solarization in member countries. To mitigate policy and regulatory gaps, some of the ISA's key interventions are as follows:



Country level assessments and gap studies: The ISA conducts assessments at the country level to analyze the potential and state of solar applications in the respective member countries. These assessments are carried out across 13 categories consisting of 160 factors.

Currently, ISA has undertaken country-level assessments for 90 countries to identify gaps, particularly in the policy and regulatory environment, and to assist the respective countries in mitigating the concerns to develop a supporting eco-system for at-scale solar deployment. The ISA has also conducted in-depth country level solar energy sector diagnostics for Cambodia, Fiji, Indonesia, Kiribati, Maldives, Mauritius, Seychelles, and Tuvalu to understand the prevailing ecosystem within the country, identify barriers, and assist the countries with solutions to enable sustainable solar ecosystems.

Figure 62: Illustration of ISA Country Level Assessment



Development of country roadmaps for solarization: The ISA is assisting the member countries to develop an actionable roadmap for solarization in its member countries through its Joint Working Groups (JWG). The JWG is comprised of various stakeholders such as the concerned Ministry/Department of Government, the ISA Secretariat, various donor agencies, and Financing Institutions active in the country, among others, who are either nominated or invited to develop and suggest a roadmap for the consideration of the respective governments. The JWG's overarching goal is to create and implement a strategy for promoting and supporting the implementation of solar applications.

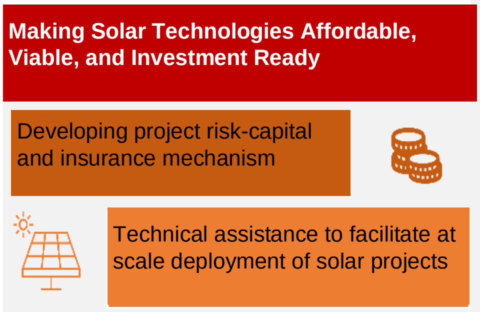
In 2022, ISA Secretariat formed two JWGs with Ethiopia; first to develop a roadmap for promoting and supporting deployment of solar water pumping technologies for irrigation and drinking water supply and second to develop a roadmap for developing solar parks and floating solar projects.

ISA and Government of Ethiopia ink agreements to scale-up solar interventions

Country Partnership Strategy: The Country Partnership Framework of ISA is a stepwise guide to developing a Country Partnership Strategy (CPS), which is a two-year agreement between ISA and a member country with clearly defined actions, funding, roles, and responsibilities to achieve tangible results. The Country Partnership Framework provides a systematic, evidence-based, adaptable approach to ISA's engagement with member countries that is aligned with their national priorities and plans. It is designed in such a way that it helps identify critical areas where ISA can make an impact and develop plans to address these gaps systematically.

ISA's Private Sector Engagement Strategy: The private sector engagement strategy seeks to accelerate the growth and development of the private sector in keeping with SDG 7 (Affordable and Clean Energy) and the 2050 Net-Zero targets. ISA's efforts to achieve this vision are anchored on two key thematic pillars: enabling the development of policy frameworks to grow private sector participation and catalyzing investment in industry actors and increasing access to finance for projects at critical junctures.

8.2 Making technologies more affordable for consumers, viable for developers and investment ready for financiers



ISA's strategy focusses on developing a vibrant solar energy eco-system, which includes developing risk mitigation & innovative financing instruments, investment mobilization, and promotion of innovative technologies. The ISA Secretariat conducted consultations with over 100+ relevant stakeholders in Africa and concluded that the existing facilities in the majority of LDCs and SIDS countries are not equipped to cater to the solar sector for various reasons, including the lack of concessional or risk-appropriate returns as well as lack of regional innovation and recognition of local innovators, lack of cost reflective tariffs and delays in approval/licensing makes financing and operations of solar companies challenging, especially for mini-grid players. To cater to these challenges, some of ISA's key interventions are as follows:

- **ISA's Global Solar Facility:** The Global Solar Facility of ISA aims to catalyze solar investments in Africa's underserved segments and geographies, thereby unlocking commercial capital in the solar energy space. The facility consists of three components to stimulate solar investment: Solar Payment Guarantee Fund, Solar Insurance Fund, and Solar Investment Fund. The Global Solar facility is intended to promote high-potential solar technologies by attracting private capital into underserved African markets while providing a payment and insurance mechanism as a first-loss guarantee.

  Solar Payment Guarantee Fund: The solar payment guarantee fund will support projects at the time of default and reduce risk of early closures/bankruptcy of solar energy projects. Projects will pay a premium to be covered by this guarantee fund. It will reduce lenders' apprehensions and enable financing for projects that otherwise might not have received financing. The payment guarantee fund will only provide a partial guarantee to projects. With minimal default, the guarantee fund would enable short-term investment in geographies that do not receive investments, and in the longer term, enable investors to invest without recourse to guarantee fund.

  Solar Insurance Fund: One of the key factors that affects the bankability of solar projects is the non-availability of affordable insurance products (specifically designed for the solar sector). It is primarily because the insurance provider has limited historical data to determine the project viability for 25 years (lifetime of solar projects). Additionally, the understanding of insurance companies about solar PV systems/ projects in specific geographies remains limited. It results in costly insurance premium since they are considered as high-risk markets. These high insurance premiums not only impact the overall project returns, but also impact the cash flow for projects especially

ISA meeting with Multilateral Investment Guarantee Agency (MIGA) to discuss the creation of feasible projects with credit guarantee mechanisms in high potential markets during the initial stages (i.e., construction or the pre-revenue stage). The impact on cash flows often makes the projects unviable for debt financiers. The Solar Insurance Fund will reduce the burden of insurance premium for solar developers in the pre-revenue phase of the project. It will offset the cost of insurance for a specified period (e.g., only for the construction phase of the project or pre-revenue phase).

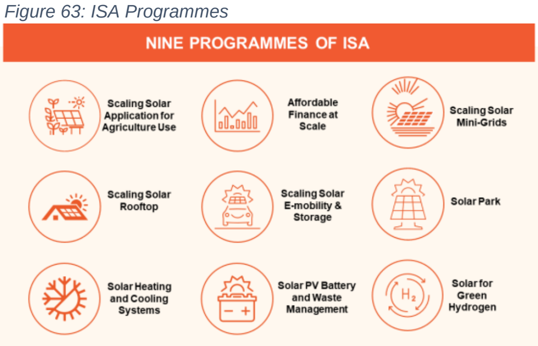
The insurance would be provided by organization that are in the business of project insurance. The projects could recoup the insurance premium covered by the fund during the pre-revenue phase of the project by charging an additional tariff during the revenue phase.

Solar Investment Fund: The investment fund would provide the core investment up to 10% of project costs in projects that are participating in the Solar Payment Guarantee Fund and/or Solar Insurance Fund. The core investment would provide the comfort of due diligence to other investors, and thus crowd-in other investors into these projects. It would help to:

- Stimulate demand through TA facility (10% of the fund)– focused on creating a pipeline of bankable projects by supporting project development and building capacities of enterprises/ sponsors as well as local governments
- Attract commercial capital providers– the facility will bring risk capital on less-than commercial terms to make the risk-return profile of solar investments more favorable

- **ISA Programmatic Support:** As part of ISA's aim to develop a sustainable eco-system for solar technologies, the ISA is also providing technical assistance services to member countries, through global project management consultants (PMC), for facilitating the development and deployment of solar projects. Currently, the ISA has 9 comprehensive programmes, each focusing on a distinct application that could help scale deployment of solar energy solutions. The programmes are developed and implemented in collaboration with member countries and global stakeholders. While each of these programmes take a distinct strategy, they all contribute to the larger goal of global solarisation and the promotion of renewable energy. The brief description for the ISA programmes is as below:

Figure 63: ISA Programmes



- **Scaling Solar Applications for Agriculture Use (SSAAU):** The programme objective is to adopt common methodologies and procedures for need assessment of decentralized solar applications for agriculture and rural use and assist in the development of bankable projects. The key focus applications include solar powered water pumping systems, solar cold storage, solar home lighting etc. 28 ISA member countries have joined the programme with the aim of developing bankable projects for 276,277 cumulative number of solar water pumping systems. The ISA is also supporting the member countries in developing pilot solar water pumping as well as solar cold storage projects.

- **Affordable Finance at Scale:** The programme objective is to strive for mobilizing low-cost capital for developing large scale solar projects and developing a common credit enhancement mechanism for de-risking investments in solar projects. In this regard:
  - Developed the Roadmap for mobilization of USD 1 trillion by 2030
  - The ISA is in process of finalizing the design and governance framework of the Multi-Donor Trust Fund (MDTF), which will channelize capital from a network of donors to a curated bouquet of projects to support its Member Countries
  - Announced the Global Solar Facility which aims to catalyze solar investments in Africa's underserved segments and geographies, thereby unlocking commercial capital in the solar energy space
  - Implementing the SolarX Startup Challenge aims to accelerate investments in solar by creating a pool of entrepreneurs and start-ups in the solar energy sector of ISA member countries.
- **Scaling Solar Mini-Grids:** The programme objective is to cater to the energy needs of ISA member countries in identified areas with unreliable or no grid(s) to promote universal energy access. 18 ISA member countries have joined the programme with the aim of developing bankable Solar Mini-Grid projects for a cumulative capacity of 786 MW.
- **Scaling Solar Rooftop:** The programme objective is to promote rapid market development and penetration of Solar Rooftops in government, commercial and residential buildings. The programme has been joined by 20 ISA member countries with the aim of building bankable Solar Rooftop projects with a total capacity of 1,059 MW.
- **Scaling Solar E-mobility and Storage:** The programme objective is to support creation of enabling ecosystem for large scale deployment of energy storage systems and to scale up uptake of solar energy in E-mobility sector. Under the programme, ISA focuses broadly on the 3 key solutions – Vehicle Integrated Photovoltaic (VIPV), solar power enabled vehicle charging stations and different energy storage technologies such as various types of batteries, compressed air energy storage, gravity energy storage, pumped hydro energy storage etc.
- **Solar Park:** The programme objective is to facilitate the development of affordable and reliable Large-Scale Solar Power Projects. 19 ISA member countries have joined the programme with the aim of developing bankable utility scale solar park projects for a cumulative capacity of 7,657 MW.
- **Solarizing Heating and Cooling System:** The programme objective is to solarize the growing thermal demand from commercial, industrial, and residential sectors. The key focus area of the programme is to scale up of proven technologies and of development innovative business mechanism to make sustainable cooling and heating infrastructure available at a low cost for all.
- **Solar PV Battery and Waste Management:** The programme objective is to reduce the amount of solar and battery waste, to re-use components whenever possible and to recycle the solar and battery waste. Key focus is on helping Member countries in creating supportive policy & regulatory framework, identifying right business models, proposing possible solutions and providing recommendations on Solar PV Battery waste Management.
- **Solar For Green Hydrogen:** The programme objective is to accelerate Green Hydrogen production and utilization in ISA Member Countries. The ISA is developing

the Centre of Excellence portal which will act as a knowledge hub for member countries in green hydrogen sector.

Each of these programmes is crucial to furthering ISA's commitment to individual member countries as well as for achieving the overall goal of enabling universal energy access. These programmes, currently at various levels of development and implementation, are customized to fit the capacity and potential of various countries. The box below presents the key developments under the ISA's Scaling Solar Mini-Grid Programme.

ISA Programme 3: Scaling Solar Mini-Grids

The ISA's third programme, Scaling Solar Mini Grid, was launched on May 24, 2017, during 52nd meeting of the African Development bank group at Gandhinagar, Gujarat, India. The objective of the program is to cater to the energy needs of ISA member countries in identified areas with unreliable or no grid(s), having abundant potential to tap solar energy. The following are the key highlights of the programme.

- **Analytics and Advocacy**: ISA has developed an E-Handbook for Solar Mini-Grids covering the technical aspects including the advantages of Solar Mini-Grids, as well as best practices for ensuring sustainable systems operation and maintenance. In addition, ISA has also analyzed and disseminated the learnings and best practices from Anchor Load Business Community Model Solar Mini-Grid, operational in Uttar Pradesh, India with support from New Energy and Industrial Technology Development Organization (NEDO).
- **Capacity Building**: ISA has trained 348 technicians across 27 member countries in collaboration with RENAC AG with funding support from GIZ, Germany.
- **Programmatic Support**: In 2022, the ISA partnered with Ethiopia Electric Utilities (EEU) to identify viable sites out of the proposed 2,231 locations for the development of bankable solar mini-grid projects. 10 more countries have also submitted the Expressions of Interest (EoIs) to join the programme with a cumulative capacity of 660 MW. Given the earlier EoIs submitted by various countries, the total cumulative stands at 786 MW from 19 member countries, of which 10 countries are from African Region.

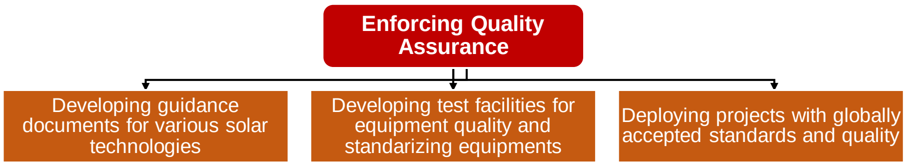
- **Grant support for demonstration projects:** ISA extends technical and financial support to LDCs and SIDS by providing grants in setting up solar pilot projects. Presently, 27 countries are availing grants of up to USD 50,000 for implementing projects in the areas of Solarization of Health Care Centers, Solar Pumps, Solar Cold Storage, and others. To enable long-term operation of the projects, special provisions are made for procuring project equipment with globally acceptable standards and quality. Through these demonstration projects, the ISA has assisted the beneficiary member countries in refining the institutional ability to design the project as well as helped in inter-departmental/ ministerial co-ordination to manage the grant, tax exemptions, project implementation and operations and maintenance, etc.

Togo: Solar Powered Water Pumping systems at three localities in the Savanes administrative region (Kpadjenta, Kpong Mossi and Kotoure)

Guyana: Solarization of Orealla Health Center (9 kWp/37 kWh)

Jamaica: 30kWp Solar PV System at Little Park F3 Pump Station

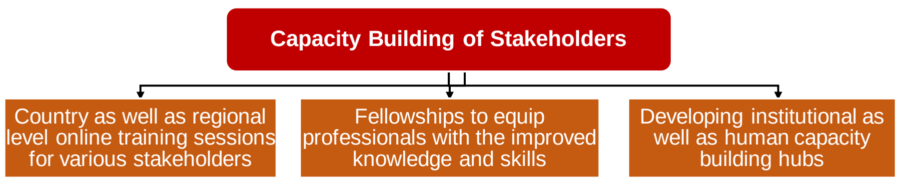
8.3 Enforcing quality assurance through setting up of global standards and specifications



The use of low-quality and substandard equipment has several negative consequences, including project operating at low efficiency leading to lower output and decrease in overall performance, shorter lifespan with high chance of breakdown requiring frequent maintenance and replacements, high risk of accidents, fire, and other hazards, putting workers, equipment, and the surrounding environment at risk, etc. All these elements have a detrimental impact on investment profitability and returns. The ISA is taking the following measures to enforce quality assurance for longer lifespan and high returns on solar projects:

- **E-handbooks as a guidance document:** As a guide for its member countries, the ISA has developed E-handbooks on various solar applications. It includes different system configurations based on solar applications such as solar pumps, solar rooftop, and solar mini grids, among others, as well as equipment specifications and international standards. The E-handbooks have already been shared with ISA member countries as knowledge documents, and they are being invited to provide suggestions for future versions of the E-handbooks.
- **ISA STAR Centers to standardize product and services:** Recognizing the urgent capacity building need in the member countries with high potential for solar technology deployment, the ISA is establishing an international network of STAR Centers. The aim of these centers is to build the necessary human capacity and skills within member countries to undertake energy transition on their own while also boosting economic growth and job creation. One of the primary functions of the STAR Centers is to develop standard quality and testing facility for solar components and technologies based on national and international standards. The ISA aims to develop 50 STAR Centers by 2030.

8.4 Making stakeholders better equipped for handling solar energy transition



One of ISA's primary goals is to enable global, large-scale solar deployment with a special focus on LDCs and SIDS. ISA recognizes that for successful deployment at this scale, the sector requires increased institutional capacity and skilled human resources. Some of ISA's key initiatives for enhancing capacities of institutions as well as individual stakeholders are as follows:

- **Large scale solar training programs for various stakeholders:** ISA has collaborated with global training institutes to forge a partnership to establish regular training sessions for on-ground actors as well as key decision-makers. These training programmes are thus crucial platforms that enable the consistent upskilling of all stakeholders involved in the solar energy ecosystem. ISA has thus far trained close to 3000 stakeholders spanning diverse geographical regions and technical areas as shown in the figure below:

Figure 64: ISA's capacity building initiatives for various stakeholders

- **ISA's Fellowship for mid-career professionals:** The ISA Fellowship for mid-career professionals is an initiative for professionals working in public institutions involved in the environment and renewable energy. The initiative is jointly implemented by ISA and the National Institute of Solar Energy (NISE), an autonomous institution of the Ministry of New and Renewable Energy (MNRE), Government of India. This Fellowship aims to equip professionals in the sector with improved knowledge and skills to facilitate the promotion of solar energy generation within their countries. The fellowship is offered to 20 professionals every year to pursue a two-year Master of Technology programme in Renewable Energy and Management (with a specialization in Solar Energy Technology and Economics) through the Department of Energy Science and Engineering (DESE), Indian Institute of Technology (IIT), Delhi.
- **ISA's STAR Centre as a hub of capacity building:** The ISA's STAR Centres are intended to meet the capacity building needs of countries by developing capable solar workforces, sensitizing policymakers and financial institutions, incubating enterprises, standardizing products, and services, and creating a knowledge repository on solar energy information. The STAR Centres are intended to serve as a capacity-building, testing, innovation, and knowledge-management hub for member countries at the regional and national levels. It will act as a knowledge management centre providing solar energy data, guidelines, analytical tools, relevant policies, and technical assistance to solar developers, decision-makers, and local institutions.
- **SolarX Startup Challenge:** The SolarX Startup Challenge aims to accelerate investments in solar by creating a pool of entrepreneurs and start-ups in the solar energy sector of ISA member countries. The first edition is focused on the African region, aiming to promote innovation, discover local solutions, and enable entrepreneurs with the overarching objective of building human and institutional capacity to sustain and grow solar businesses. The SolarX Startup Challenge will enable four-fold benefits in technology, finance, innovation, and the business startup ecosystem of the solar energy sector in the region. The SolarX Startup Challenge is intended to be a driving force in enabling the world's transformation to a renewable energy economy by encouraging innovation in the solar energy space and accelerating a responsible energy transition. The challenge is expected

to bring together more than 100+ start-ups from across the African solar segments in the first year. Up to 20 new and innovative startups would be shortlisted and given technical and financial assistance under this initiative. Women entrepreneurs from the African region have been encouraged to apply through various outreach activities in order to ensure suitable gender representation in the contest.

8.5 Providing analytics and data to support decision making

Bridging the Analytics and Data Availability Gaps

- Publishing journals covering innovation, knowledge, data, and analytics for solar
- Track and support the progress of solar ecosystem on member countries
- Analyzing the technology, market and investment aspects of solar energy sector

Through its priority area of Analytics & Advocacy, ISA enables the adoption of policies and practices that encourage solarization in member countries. This is done primarily through the publication of research and reports on the global solar energy sector spanning technology, investments, and markets. Some key interventions are:

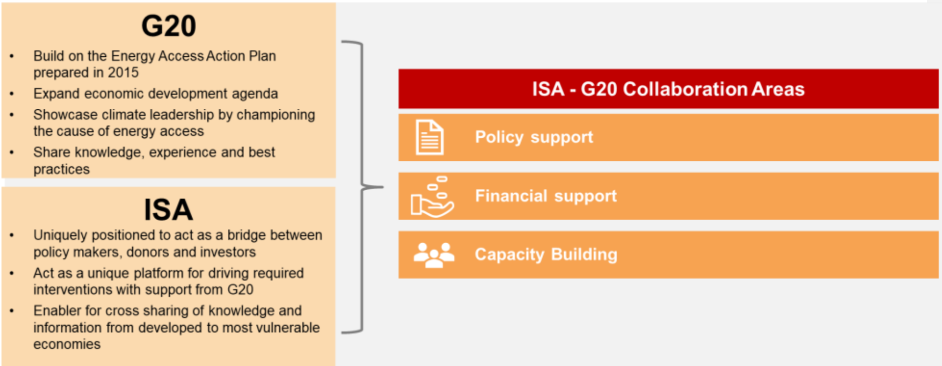
- **ISA Solar Compass:** ISA's Solar Compass is an open access quarterly journal which is part of ISA's repository and initiatives to increase the use of solar energy globally. The journal is an important initiative to increase understanding and research on the use of solar power. It covers new technology, policy, and economic developments to improve global access to clean energy and feature successful case studies for wide-scale replication. The journal is designed to deliver value: innovation, information, data, and analytics to lay the foundation for better decision-making and action.
- **Ease of Doing Solar (EoDS):** EoDS is a dedicated annual publication platform for the global community including governments, bilateral and multilateral organizations, corporates, industry, and other stakeholders. The report provides an opportunity to leverage their efforts to help achieve the common goal of promoting the use and improving the quality of solar energy to meet energy needs in a safe, convenient, affordable, equitable and sustainable manner. The objective of 'Ease of Doing Solar' is to track, recognize and support the progress of the solar ecosystem in ISA's Member Countries. Starting in 2019, with a pilot version of the EoDS report comprising only 4 countries, a full-scale edition was launched in 2020 with 80 countries. In 2021, 18 new members joined the ISA family taking the report coverage to 98 countries.
- **ISA's Global Reports:** To further bolster ISA's position as a thought leader, the ISA has launched three flagship solar reports namely World Solar Technology Report, World Solar Markets Report and World Solar Investment Report. The technology report covers vital global technology-related advancements, the markets report covers market trends of different technologies whereas the investment report assesses the transition needed for the financial sector for fulfilling the investment requirements of the solar industry in the near future. The three reports provide relevant data, insights, and analytics as well as highlights gaps to support policy makers in their decision making.

Through the above efforts, ISA aims to promote self-sustainable business models in member countries. The combination of various ISA initiatives performed under the priority areas of advocacy and analytics, capacity building, and programmatic support results in the establishment of interventions that cater to the interests of various stakeholders, including:

- **Consumers:** seeking affordable and reliable access to electricity
- **Developers:** securing financial viability of the projects with high return on investment and payment guarantee mechanism
- **Government:** reducing expenditure on imported fuel costs and empowering local community.

The ISA interventions are intended to assist member countries develop the most suited self-sustaining business models for their specific scenarios, thereby facilitating the widespread deployment of solar technologies, notably solar mini grids, to achieve universal energy access targets.

With G20's support, ISA can provide scale to the above initiatives thereby enabling achievement of Universal Energy Access by 2030. The ISA has initiated various steps to carry out its mission of providing electricity to every home, no matter how far away. Reaching the last mile is a challenging endeavor that necessitates larger international collaborations for scaling up the ongoing ISA's initiatives and designing new initiatives basis the changing requirements. The G20 is a forum of the world's largest economies that is committed towards the global energy access cause and thus the ISA-G20 collaboration can provide a perfect platform for driving interventions for mitigating the energy access gap. The G20 can support ISA in expanding affordable finance mechanisms across all developing geographies, deploying viable projects, policy and regulatory knowledge transfer, stakeholder training, and other areas.



9. Recommendations

Electricity access and economic growth are strongly intertwined, and electricity access fosters development and progress in various ways. For example, electricity is a crucial enabler for productive use applications and small businesses. Additionally, the poor substitutability of electricity means that its absence could limit economic output. Electricity is also integral part of delivering essential services like health and education that have a significant impact on overall quality of life. Electricity also provides access to household devices such as lights, chargers, and cooking systems, leading to improvements in time taken for household chores, increase in the useful hours in a day, and access to communication devices.

Over the past five years, the world has made significant progress by working through multiple forums. However, despite this growth, these initiatives are not sufficient to bridge the electricity access gap in the required time to achieve the SDG 7 target of universal electricity access by 2030. Additionally, current studies and literature on the topic exhibit a lack of clarity on how the SDG 7 target can be achieved in the short time that is left.

Recognizing the significance of access to energy towards the sustainable development, under the 2014 Principles on Energy Collaboration, G20 Leaders committed to work to "ensure access to affordable and reliable energy for all." This supports the agenda 2030 which includes an SDG on ensuring access to affordable, reliable, sustainable, and modern energy for all.[74]

Within this context, ISA and G20 are uniquely positioned to tackle the energy access challenge. A combination of ISA's technical capabilities and multi-stakeholder platform along with G20's widespread stakeholder network, financial resources and knowledge can be harnessed to deploy customized interventions that seek to tackle the key issues hampering energy access efforts. These tailormade solutions, if deployed effectively, can help bridge the energy access gap and allow the world to meet the universal energy access target.

9.1 Recommendations for ISA-G20 collaborative interventions

It is important to note that energy access solutions need to be tailored to the specific needs and conditions of each country and community. The suggested interventions, for ISA-G20 collaboration, are grouped under three main areas – policy and regulatory framework assistance, affordable finance, and capacity building and supply chain development.

9.1.1 Policy and regulatory framework assistance

The analysis conducted in the previous chapter highlights that most of the top 15 electricity access deficit countries already have a supportive policy and regulatory framework in place to some degree. While a few countries within this group have a more effective framework than the worldwide average, some of them lag significantly behind the global average. Although there have been notable improvements in recent years, the overall policy and regulatory ecosystem requires strengthening.

Implementing electricity access initiatives in different countries often presents unique challenges and it is important to consider the local ecosystem and circumstances in each country when designing and implementing these projects. In this context, to promote large-scale adoption of solar mini grids, country-specific interventions are necessary to **analyse the existing ecosystem, recommend relevant changes and additions, and create implementation strategies to mitigate the challenges within the current policy and regulatory framework**. Based on the gap analysis, some of the key interventions recommended are:

[74] G20 And Low Income Developing Countries Framework

Intervention Area 1: Guidance on drafting national energy access policies, roadmap for national solar targets and other energy transition action plans

Countries, especially the 'low readiness' countries, may not have the necessary policies and regulations for the smooth deployment of mini grids and DRE technologies. Under this intervention, these countries may benefit from guidance in drafting energy access policies and linking them to the country's just energy transition, development plans and actions for net-zero energy systems.

Further, the intervention would extend to developing solar targets for the specific country's and create a roadmap for the adoption of solar and associated technologies to reach the target. Supporting policies and regulations to create a conducive environment for solar technologies will also be required wherever inadequate.

ISA's Existing Interventions

ISA is well-versed with helping countries design and advocate specific pro-solar policies. It has also worked in conjunction with the country's governments by establishing Joint Working Groups to promote and support the deployment of solar-based technologies (solar pumps, floating solar projects, etc.).

Intervention Area 2: Improve existing regulatory frameworks to aid the deployment of mini grids and DRE technologies

Policies pertaining to the deployment of mini grid and DRE technologies to alleviate the issue of electricity access may exist in some countries, but there are gaps and challenges in implementation due to the absence of a robust regulatory framework. In such cases, the existing regulatory frameworks need to be assessed to understand shortcomings and propose modifications to help the proper execution of policies.

Improvements would also be required in the regulatory framework for inter-departmental/ ministerial coordination for ease of deployment of solar mini grids. Processes for licensing and commissioning of mini grids and other DRE solutions will need to be simplified and streamlined to reduce the obstacles in the development of electricity access projects. These supportive frameworks can be targeted to help drive the development of sustainable business models for mini grid and DRE deployment.

ISA's Existing Interventions

ISA has substantial experience of conducting gap assessment of countries' policies and regulatory frameworks. It has conducted a thorough country-level assessment of about 90 countries across 13 categories and +150 parameters.

Intervention Area 3: Assist in developing policies and regulations for the adoption of standardized products and processes

Standardization of products and processes is critical to the efficient implementation and successful adoption of mini grids and other DRE technologies. Most projects in the least-access countries fail due to sub-standard products and implementation processes. Interventions would be needed to guide these countries towards globally adopted measures for streamlining project execution, transparent empanelment of suppliers.

Tariff regulation and finalization also requires significant interventions in terms of regular submissions of petitions from the utilities, periodic approvals from the concerned regulators and stringent enforcement of timelines and processes. Additionally, monitoring the quality of equipment and enforcement of testing and standards for the various components of the DRE systems will go a long way towards ensuring the sustainable success of mini grids in the country.

ISA's Existing Interventions

ISA could help with technical assistance during the project development and implementation phases to ensure adequate implementation of standards and use of quality equipment. ISA's e-handbooks on various subject matters and the STAR-C centers to test and standardize products could also prove vital in this aspect.

Intervention Area 4: Guidance on assessing and diverting fossil fuel subsidies towards sustainable development initiatives

Fossil fuels typically attract the highest subsidies in the power sector in all the countries around the world. The quantum and relevance of these subsidies needs to be assessed from time to time to understand whether they are being disbursed in the most optimal way to create the largest impact. Interventions are needed to assess the scale and distribution of the subsidies going towards fossil fuels and assist in developing a reorientation strategy to divert some subsidies to promote energy equity and sustainable development. Advocacy support to governments can also be provided to ensure that the redirected subsidies are be better utilised to support the development of sustainable business models for mini grids and DRE solutions for electricity access.

ISA's Existing Interventions

ISA's expertise with country partnerships, advocacy support, and stakeholder engagement could help the countries to assess the impacts of the subsidies over the course of a long-term country engagement. With a proven track record of supporting both large and small scale solar deployment, ISA is also well placed to guide countries on how to redirect fossil fuel subsidies to impactful electricity access solutions like DRE and mini grids

G20's Role

With assistance from G20, ISA can help replicate some of the learnings and best practices for mitigating energy access issues for the access deficit countries. The ISA-G20 collaboration could greatly help the access deficit countries to mitigate issues related to electrification plans, optimal approach towards complete electrification and other issues related to electricity access. G20 could also help ISA in nudging these countries towards a sustainable energy transition agenda by advocating for the diversion of subsidies to the RE sector. Further, with support from G20 resources, country assessments could be conducted to comprehensively cover polices and regulations pertaining to mitigating electricity and energy access issues and include a larger number of parameters/data points to gain vital insights across all identified least-access countries. Additionally, G20 could also contribute their expertise in terms of product quality metrics and standardized processes and help develop customized solutions as per local needs.

9.1.2 Affordable finance to support at scale deployment of Solar Mini-Grids and DRE

The amount of international funding for energy access services in the top 15 electricity access deficit countries falls far short of what is needed to ensure universal access to electricity. Given the scale of the investment needs, and the potential for energy investments to drive economic development, private finance will have a central role to play if the 2030 target for universal electricity access is to be met. Public capital providers will also have to be involved through the dual role of providing public finance as well as enabling private financers to deploy investments. These enabling activities will allow limited public finance to mobilize far larger sums of private finance to help meet the required investment volume.

The gap between supply side project financial viability and consumer electricity affordability is a major reason that electricity access is challenging to achieve in a sustainable manner. In this context, country need as well as readiness specific interventions are required in **developing financing partnerships and integrated business models to provide affordable financing for the electricity access deficit countries**. The possible interventions to provide affordable finance to enable at-scale deployment of solar mini grids are follows:

Intervention Area 1: Conduct country specific market research to understand the needs and preferences of the target consumers and assess the financing required to support the mini grid ecosystem

Country finance needs for electricity access vary widely based on local requirements. This intervention would initially involve the development of a standardised framework to determine the degree of financial support required to develop a scalable solar mini grid market in the country. The country specific data that is available through secondary research should be complemented with on ground data collection. This on-ground research would involve site visits and consultations with stakeholders including mini grid developers, DRE suppliers, operations and maintenance personnel, and local officials. The secondary data collected, and market research inputs received would then be fed into the developed framework to assess the country's financing needs and determine the degree of financial support required to develop a scalable and sustainable solar mini grid market i.e., full project grants, partial grants, or only technical assistance.

ISA's Existing Interventions

ISA's activities such as the development of solar specific country level assessments and gap studies alongside Ease of Doing Solar reports have resulted in the development of a significant database of country level information. This pool of knowledge can support in market research activities across countries. ISA may also be able to facilitate site visits and consultations with member country stakeholders.

Intervention Area 2: Mobilize potential investors interested in supporting the electricity access projects

Scaling up of electricity access will require the involvement of significant amounts of finance, including from the private sector. This intervention would aim to support finance sourcing through identification and mobilization of potential investors. A longlist of investors may be broadly developed through secondary research but will be further detailed through identification of points of contact within organizations with similar development agendas. G20 can act as a perfect platform to mobilize private investors especially for developed countries by highlighting the scale of the problem, impact of finance and benefits to various stakeholders. Potential investors could include impact investors, socially responsible investors, and development finance institutions.

ISA's Existing Interventions

In a continued effort to support climate action, ISA is playing a catalysing role in creating the requisite environment for an equitable revival, working in tandem with public and private sector including banks, companies, regulators, and other key stakeholders. To energize finance and accelerate solar investments, ISA is organizing "Investment Series" of virtual forums/talks/fireside chats with CEOs of financial institutions as well as with key decision makers in ISA member countries to facilitate investment in supply chain gap with structured, smart, and sustainable solutions. This Investment Series in line with ISA's Coalition for Sustainable Climate Action (CSCA) initiative, which is aimed at building strategic partnerships between investors and policy makers to promote the role of private sector finance in developing clean energy projects in ISA member countries.

Intervention Area 3: Develop financing partnerships or facilities to de-risk private investment

A number of electricity access deficit countries are affected by political and financial instability, resulting in them being considered high risk for investments, and thus attracting high interest rates for project finance. This intervention would aim to support the development of financially viable electricity access projects through de-risking activities. These activities could involve the development of financing partnerships and facilities involving a number of multilateral organisations and country specific government entities where relevant.

A financing facility may be developed in order to leverage the resources of these varied stakeholders. This financing facility would be able to pool the available resources and channel them to various electricity access initiatives that have been evaluated to ensure suitable likelihood of success and on ground impact. This evaluation framework can consider the characteristics of the proposed country and region for the initiative, the site-specific details available, as well as the track record of the project developer, amongst other factors. The framework can also take into account gender and social inclusion considerations to ensure that women and disadvantaged communities see benefits from the electricity access project, including through job creation and access to appliances for productive uses of energy. Once the initiatives to be supported have been evaluated, financial support through low-cost financing and payment security guarantees can be provided to improve project viability and consumer affordability.

ISA's Existing Interventions

ISA is developing a Global Solar Facility to stimulate solar investments, particularly in underserved segments and geographies. This facility will consist of a payment guarantee fund, an insurance fund, and an investment fund. Once operational, this existing facility mechanism can be leveraged to direct electricity access funds to deserving projects that will create significant impact and bring about socio-economic benefits for the target population.

Intervention Area 4: Assist in developing integrated business models that can address the gap between supplier financial viability and consumer affordability

Although several promising business models for electricity access exist, they require further refinement based on ground characteristics, along with support to drive their scale up. This intervention would aim to identify and refine suitable business models for mini grids and DRE to support their deployment at scale. The intervention would begin with the identification of a pool of suitable business models for deployment, as well as the key characteristics that are allowing them to be successful. This study would involve consultations with the developers, national institutions and the local businesses, and communities benefitting from the deployment of these projects. Their suggestions and feedback can be incorporated to improve the model depending on the location of deployment.

Once sufficient depth of information on the business models has been collected, a guiding document on each model can be developed to inform interested stakeholders and support the uptake of these models. This dissemination can also be accompanied with support from financing facilities to help provide an integrated solution with access to low-cost finance for deployment at scale. Sensitization on the models can also be extended to other national and international stakeholders for further awareness creation and improved acceptability of the models. The progress of projects deployed with these models and with the support of these interventions will be monitored to create a feedback loop for further study and improvements as required. Advocacy and handholding support to governments can also be provided to underline the importance of government support in ensuring the deployment and scaling of successful business models. The end objective would be to develop sustainable business models that can ensure financial viability for project developers along with affordability to those at the bottom of the economic pyramid, while providing a suitable risk-return profile for potential investors.

ISA's Existing Interventions

ISA is carrying out a number of activities to support the solar mini grid and DRE ecosystem. This includes policy and regulatory support, development of a pipeline of bankable projects, capacity building and training, awareness creation, and technical knowledge development. These activities all contribute to the development of a suitable ecosystem for deployment of self-sustainable business models, and these activities can be leveraged to support this intervention.

G20's Role

G20 countries have the resources and know how to drive affordable finance initiatives for electricity access. G20 countries can support investor identification and financing partnerships by facilitating contacts with relevant entities. The G20 countries can also provide expert inputs to the design of the market research activities and the final assessment framework developed. Due to their high degree of technological expertise, these countries can bring in experience with smart meters, hybrid inverters and other advanced electronics for deployment in the mini grid systems through standardized products, efficient supply chains and bulk procurement to reduce the costs of these products. G20 can also help in expanding the scale of ISA's existing Global Solar Facility, by promoting mobilization of funds from development agencies, governments of G20 countries and other sources. The funds so mobilized can then provide concessional finance, developmental aid, and micro-finance (at consumer level) for sustainable mini grid and DRE projects. G20's involvement can also help lower risk premiums for investments in electricity access deficit countries.

9.1.3 Capacity Building and supply chain development

Capacity building at the institutional and individual level is vital to the adoption of any technology in a country. Without institutional awareness about the mini grid and DRE technologies, the country will lack in the supportive environment required for the successful implementation of these technologies. Further, limited access to skilled local workforce and inadequate supply of affordable, quality components in reasonable time leads to increase in operator costs and system downtime. Programs such as awareness workshops and hands-on trainings, along with certification programs for skilling the workforce are also crucial.

Capacity building and supply chain development for solar mini-grids would include interventions to **create the skills and knowledge required to design, install, operate, and maintain solar mini-grids with improved local supply chain capabilities**. The proposed interventions required for ensuring the long-term sustainability and success of solar mini-grid projects are as follows:

Intervention Area 1: Develop institutional capacities related to mini grids and DRE technologies

Capacity building at the institutional level is critical for the proliferation of any technology as it leads to the highest impact in terms of the population affected. Interventions are therefore needed to develop institutional strengthening programmes for government ministries, regulators, utilities, rural electrification agencies, and other agencies that influence the mini grid sector at the national level. Key national agencies need to be made aware of the technology, its working, along with the costs, benefits, and impacts on the overall electricity access issue. In some countries, such actors may be absent, in which case, the local governments need to be made aware of the scale and impact that sector focussed agencies can bring. Interventions are also required in setting up of such focussed institutions within the country.

Further, it is vital to sensitize policymakers and financial institutions regarding the latest advancement in the sector in collaboration with international experts. Such interventions could help the policymakers understand the issue better and consequently frame supportive policies. For the finance institutions, sensitization interventions could make them more receptive towards funding projects in the mini grid and DRE space.

ISA's Existing Interventions

ISA's STAR Centres are already serving as capacity-building and knowledge-management hubs for member countries at the regional and national levels by providing guidelines, analytical tools, relevant policies, and technical assistance to developers, decision-makers, and local institutions. Additionally, ISA also directly engages with local government stakeholders and policymakers from time to time on matters of policy and technology advocacy, and capacity building workshops could easily be included in the agenda for these interactions. Through its capacity building interventions, ISA has already trained 2,861 stakeholders including master trainers, professionals, bankers, and technicians.

Intervention Area 2: Knowledge transfer and community awareness related to mini grids and DRE technologies

Knowledge transfer forms a critical element of the capacity building initiative related to any technology in a country. Interventions in this aspect would include process and operation training to local project developers for ensuring more efficient project operations. International developers could be assisted with the cultural and local context through sensitization workshops and community engagement programmes. Interventions are also required to disseminate relevant knowledge and create technological awareness through a combination of education and training programs, outreach and awareness campaigns, online resources, and demonstration projects, and community engagement.

Community participation and awareness on the benefits and impacts of mini grids and DRE technologies in the remote settlements in the LDCs is critical to the uptake of these solutions for electricity access. Buy-in and acceptance from the users of the technology will drive the success of any project, and therefore, these end users need to be exposed to technology through awareness campaigns and hands-on workshops.

Intervention Area 3: Hands-on training, technical capacity building and incubation support

The deployment of mini grid and DRE solutions on a country level would require a significant skilled workforce and local entrepreneurship initiatives. For the technical capacity building, interventions would be required to develop research and development centres to promote local R&D solutions and standardize products and processes. Capacity building and training centres needs to be established to focus on developing a skilled workforce of technicians and engineers for implementation support. Additionally, incubation support needs to be provided to entrepreneurs through incubation centres, accelerator programs, start-up programs, entrepreneurial competitions, angel networks, and mentorship programs. Additional support may also be provided to women entrepreneurs to further increase the social impact of the initiative and improve gender equality in the sector.

In the long term, interventions can also support in developing mechanisms for knowledge and technology transfer between global manufacturers and local entrepreneurial hubs to increase national/regional manufacturing, assembly, and supply chain capabilities.

ISA's Existing Interventions

ISA is currently conducting the SolarX Startup challenge to support local innovation and entrepreneurship by providing technical and financial assistance, and has conducted outreach activities in order to encourage women entrepreneurs to apply for the initiative. The STAR centres also help develop a capable solar workforce, incubate local enterprises, and create a local knowledge repository on solar energy. ISA also offers fellowships and degree courses in the field of renewable energy management in India and similar interventions could be replicated in the LDCs. Further, global solar reports, e-handbooks on various topics and journals such as the Solar Compass, published by ISA and its member countries provides access to a wide knowledge base.

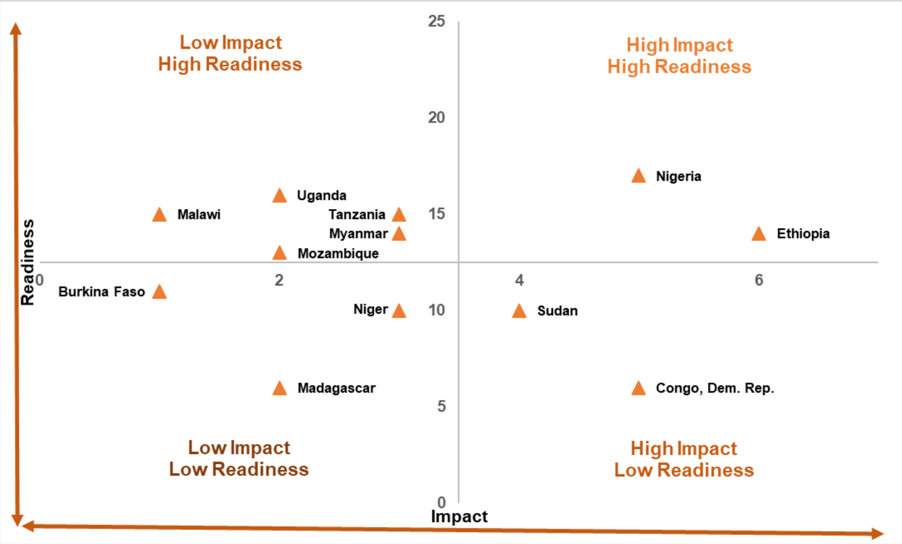
G20's Role

G20 can leverage its knowledge and technological expertise to scale ISA's existing interventions. G20 platform can help identify best practices and success stories from its member countries regarding business models, operational and technological standards, which could then be transferred, customized, and replicated to the access deficit countries through knowledge exchange forums. G20 can also provide support for creating a network of internationally accredited trainers for various capacity building interventions. Further, ISA and G20 can collaborate for creating an international programme for incubation of entrepreneurs, similar to the lines of ISA SolarX Startup Challenge. ISA and G20 can also collaborate for mapping of existing manufacturing ecosystem in access deficit countries and thereafter in handholding countries for developing a strategy for scaling up local manufacturing through international partnerships and business level agreements.

9.2 Mapping of interventions

A wide range of possible interventions are available to support electrification in countries around the world. However, as highlighted earlier, each country has a unique ecosystem that brings its own benefits and challenges. In this context, mapping interventions to the country groups identified earlier will be beneficial for efficient and effective implementation of the identified interventions. Interventions across the three main areas detailed above will be required across all the identified country groups. However, the required focus of each intervention will vary depending on the status of the country. The country groups identified in earlier chapter is showcased in the figure below:

Figure 65: Country grouping based on assessment framework



There are two major approaches available to carry out the mapping of interventions:

One approach involves the maximization of development benefits, which would focus on deployment of interventions without consideration of a country's readiness or potential for benefits through electrification. Although ideal, such an approach may not be feasible due to the significant requirement of financial and technical resources. Additionally, this approach may not be as attractive for mobilizing private finance, as there would be limited consideration of return on investment and other financial metrics.

The second approach involves the deployment of initiatives based on the potential impact and current state of readiness of the country. This approach calls for the deployment of interventions in countries that require them the most and would see the greatest benefits from these interventions. Such selective deployment of interventions may prove more attractive to private finance providers as well.

The heat maps below show the country groups that require a specific intervention the most, i.e., darker color signifies the largest need for that intervention in that specific country group/

Key for Intervention Mapping

HI/HR – High Impact, High Readiness; LI/HR – Low Impact, High Readiness; HI/LR – High Impact, Low Readiness; LI/LR – Low Impact, Low Readiness	Intervention Requirement		
	High	Medium	Low

Table 16: Mapping of Interventions

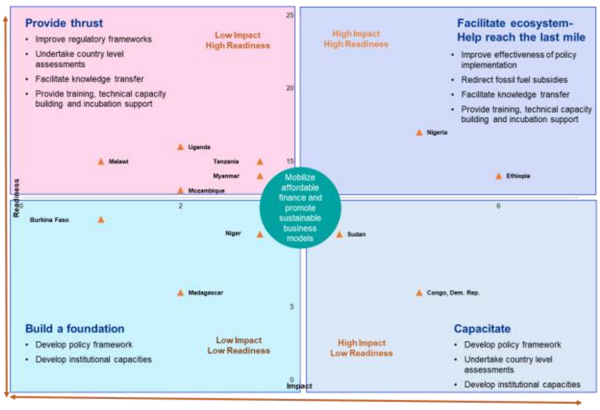
Intervention Areas	Requirement			
Policy and Regulatory Interventions	HI HR	LI HR	HI LR	LI LR
Intervention Area 1: Guidanceg on drafting national energy access policies, roadmap for national solar targets and other energy transition action plans				
Intervention Area 2: Improve existing regulatory frameworks to aid the deployment of mini grids and DRE technologies				

Intervention Areas	Requirement			
Intervention Area 3: Assist in the developing the policies and regulations for the adoption of standardized products and processes				
Intervention Area 4: Guidance on assessing and diverting fossil fuel subsidies towards sustainable development initiatives				
Financial Interventions				
Intervention Area 1: Conduct country specific market research to understand the needs and preferences of the target consumers and assess the financing required to support the mini grid ecosystem				
Intervention Area 2: Identify and mobilize potential investors interested in supporting the electricity access projects				
Intervention Area 3: Develop financing partnerships or facilities to de-risk private investment				
Intervention Area 4: Assist in developing integrated business models that can address the gap between supplier financial viability and consumer affordability				
Capacity Building Interventions				
Intervention Area 1: Develop institutional capacities related to mini grids and DRE technologies				
Intervention Area 2: Knowledge transfer and community awareness related to mini grids and DRE technologies				
Intervention Area 3: Hands-on training, technical capacity building and incubation support				

The primary level interventions have mainly been mapped to countries with lower readiness and impact to ensure a solid platform for future electricity access activities, whereas more specialized interventions that are further along the value chain have been mapped to countries with higher readiness and impact. No intervention is completely absent from a country group to ensure that small gaps in an otherwise developed country are not missed, and to ensure the holistic development of the electricity access ecosystem.

The below figure represents the mapping of various intervention areas for different country groups:

Figure 66: Strategy for implementation of various identified interventions



Our mapping aims to ensure that the limited resources available for electricity access measures are deployed in a manner to generate maximum impact for all stakeholders, while helping build foundational ecosystem in those countries that are not well placed to support the deployment of such interventions currently. At the same time, mobilizing affordable finance and promotion of sustainable business models will be required in all access deficit countries at some level irrespective of their level of readiness and potential for impact creation.

9.3 Conclusion

As an international organization with a widespread development agenda, ISA is well placed to create on-ground impact in the energy access space. ISA also has a large network of local stakeholders in the LDCs and SIDS, which are the primary target countries to achieve complete electricity access, which can be leveraged to galvanize growth of the mini grids and DRE sector in the target countries through large-scale interventions. ISA is also well placed to provide support across countries facing varying electricity as well as clean cooking access challenges. ISA's expertise ranges from small scale solar deployment through mini grids and DRE to larger scale solar deployment through utility scale plants and rooftop solar projects and can be leveraged to improve access to energy. ISA's presence and expertise can ensure no country is left behind in the effort to achieve universal energy access. G20, on the other hand, can help create a conducive investment climate in these countries by mobilizing foreign investors and developers to establish projects at scale in access deficit countries. With focused interventions and optimal use of resources across the identified country groups, G20 and ISA can catapult the unelectrified population into a fast-paced development scenario to achieve universal energy access by 2030.