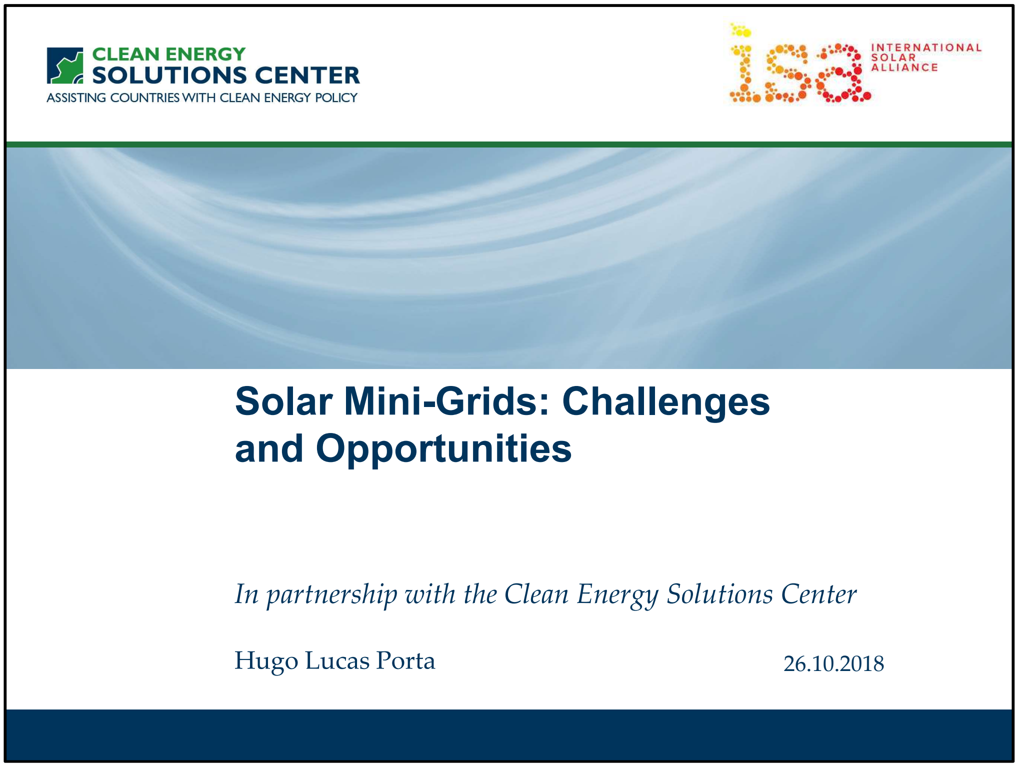


Hello Ladies and Gentlemen, I am very happy to welcome you to todays session on Solar Mini Grids: Challenges and Opportunities.

I would like to thank the International Solar Alliance and the Clean Energy Solutions Center who facilitate this webinar series.

Overview of the expert

Factor is an international group, specialized in providing global, innovative and sustainable solutions in areas such as climate change, energy, sustainability, trading and innovation.

Our key value is our people. We have offices in six countries, where our interdisciplinary team works for public and private stakeholders, international organizations and non-profit entities.

Our own history and experiences are based on constant innovation. This helps us target our services, by combining academic knowledge, technology and practical experience.

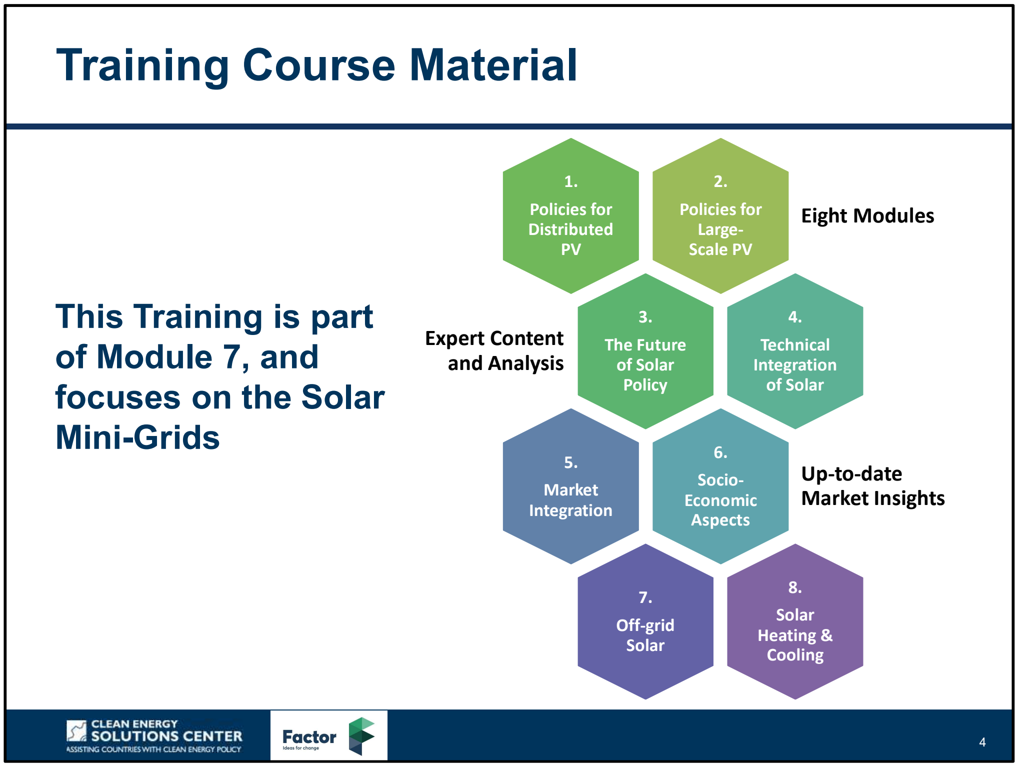
Factor
Ideas for change

Hugo Lucas Porta
Head of Energy Dept, Factor
20 years in RE Sector
- Worked for governments and private sector on energy transition strategies

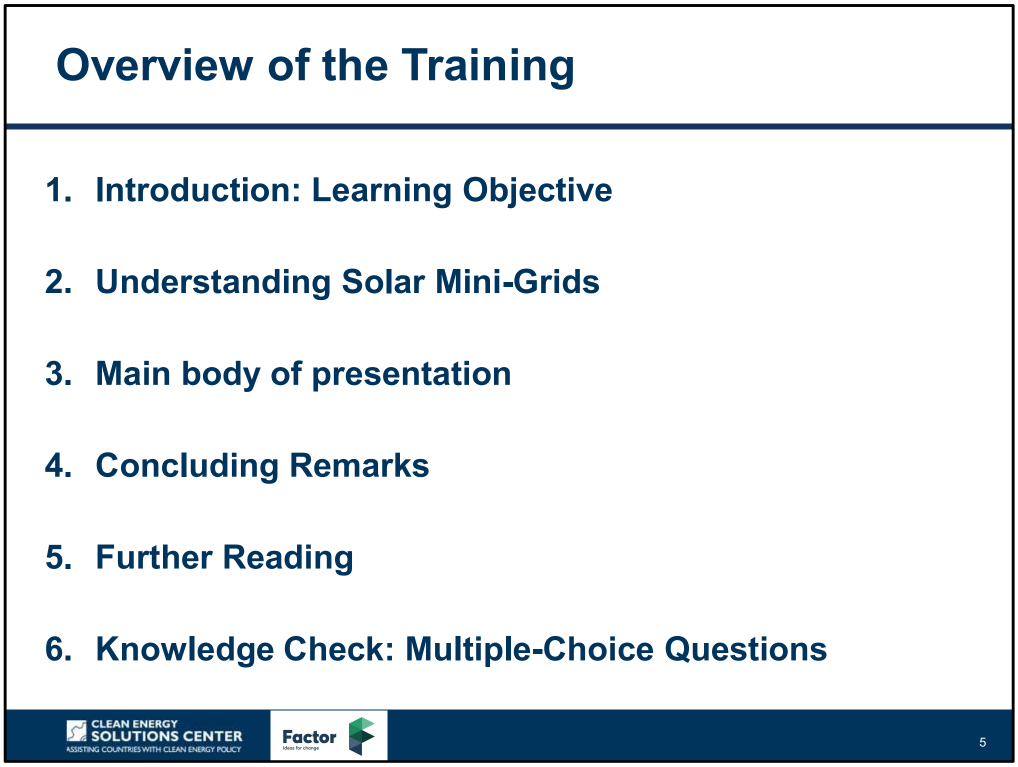
CLEAN ENERGY SOLUTIONS CENTER
ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY

3

I am head of the energy department at Factor. Factor is an international consulting firm advising public and private actors on climate change and sustainable energy transition strategies.
Before I joined Factor in 2010 I have been director for knowledge, policies and finance at the International Renewable Energy Agency - IRENA. I was responsible for the design of the access to energy work programme in the Agency. Previously as Spanish civil servant I have been involved in many national and European Regulations for the promotion of renewable energies and energy efficiency.



This lecture on the challenges and opportunitites of mini-grids is part of the Module 7 on off-grid solar.



In this module, we will start with a brief description and definition of what Solar Mini Grids are, and afterwards jump into the main body of the presentation. Don't forget, at the end of the presentation, you will be given the chance to test your knowledge with a little quiz.

1. Introduction: Learning Objective

CLEAN ENERGY SOLUTIONS CENTER
ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY

Factor
Ideas for change

Learning Objective

This module provides:

1. An overview over the basic functioning and the technical components of Solar Mini-Grids

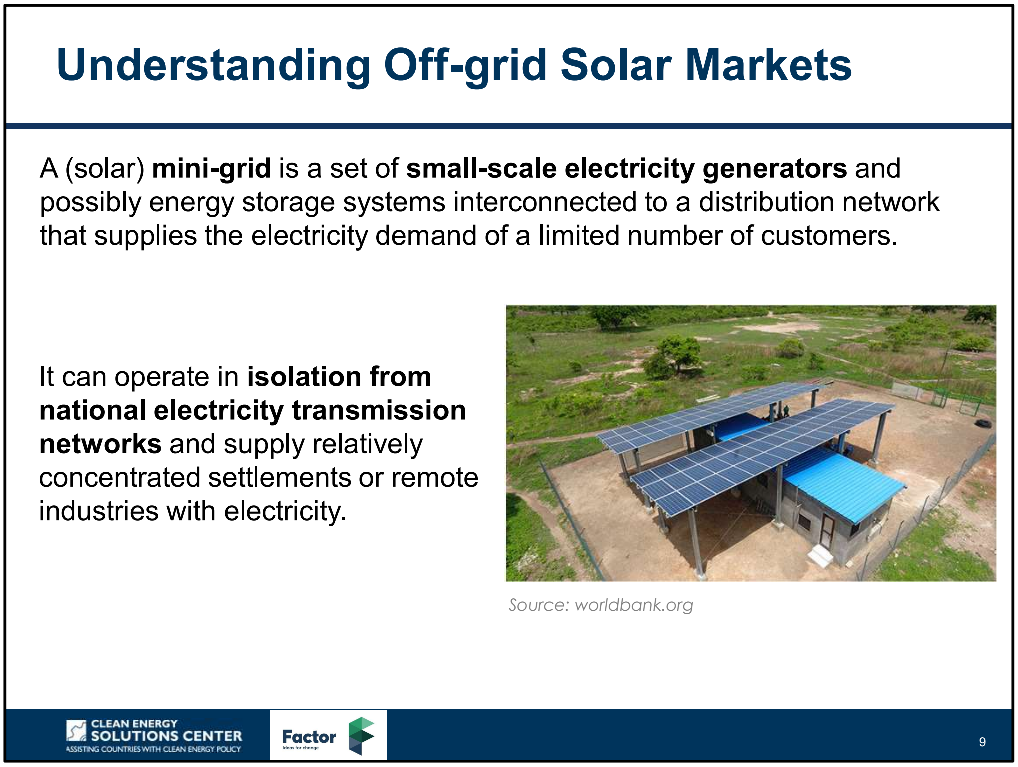
2. A discussion of the major challenges and opportunities

3. A case study analysis of a promising support programme from India

The learning objectives which this module, on solar mini grids, aims to provide can be divided into three parts:

First of, we will learn about the technical aspects of solar mini grids, followed by a discussion of the major challenges and opportunities solar minigrids are facing. We will see all of this in practice once we turn to the case study analysis of a support programme for solar mini grids in India.

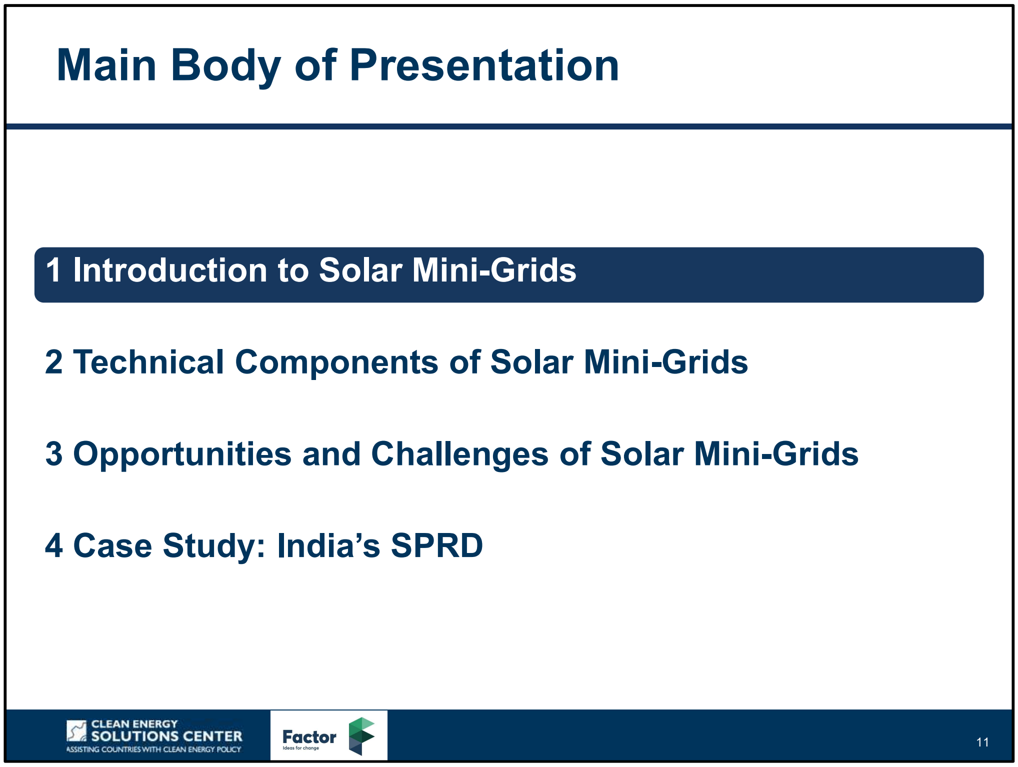
2. Understanding Off-grid Solar Markets



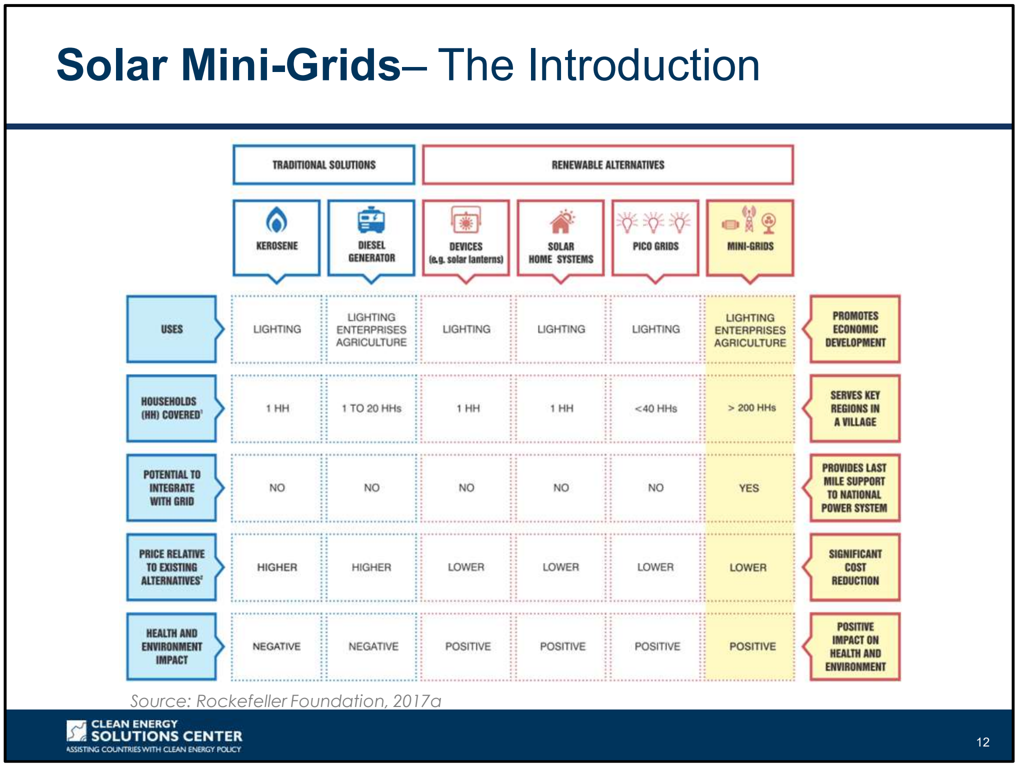
A **mini grid**, also sometimes referred to as a "**micro grid or isolated grid**", can be defined as a set of electricity generators and possibly energy storage systems interconnected to a distribution network that supplies electricity to a localized group of customers.

Mini grids offer **an alternative that entirely avoids many of the challenges that new and expensive grid infrastructure investments require**. Mini grid systems are becoming increasingly competitive compared to the cost of traditional grid extension programmes, and are a key component in achieving universal access to electricity for all. The reasons for this are, their availability to supply higher access tiers, the rapidly decreasing costs of the technology, increasing reliability and a solid deployment track record, all of which have strengthened the case for the accelerated adoption mini grid solar solutions across the the world.

3. Main Body of Presentation



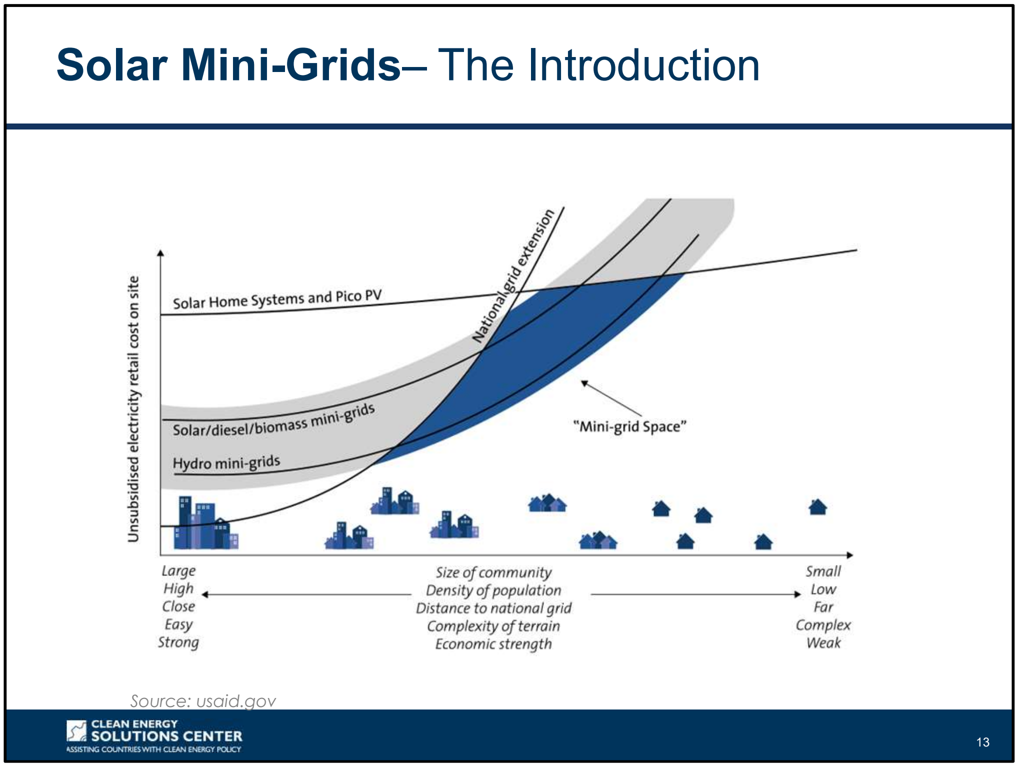
The main body of this lecture is divided into 3 parts and a case study, which will exemplify some of the aspects covered. Following the introduction we will look at the technical components that make up a mini grid system. After that we will discuss opportunities and challenges for the technology, and finally, we will evaluate these aspects as part of a case study.



Before we dig into the topic, I want to present you this chart.

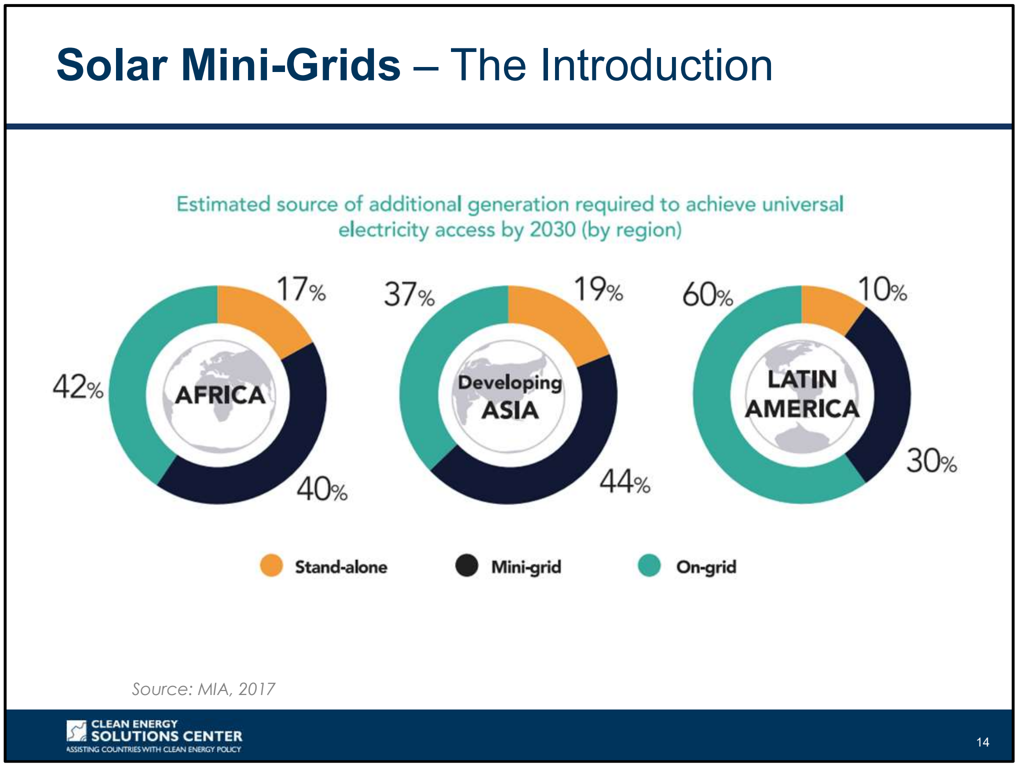
While multiple off grid renewable energy solutions are available to meet rural energy needs, each has specific applications and limitations. We have already spoken about solar home systems to some extent in previous lectures. This table compares the traditional and renewable energy solutions one would commonly find in implementation across the world. Today however, we will focus on renewable energy mini grids, and especially solar mini grids. These systems have the ability to serve both lighting and productive needs and to provide high-quality reliable electricity at lower or equivalent cost when compared to existing alternatives.

Compared to pico lights and solar home systems, which we have talked about in previous modules, the main difference is that mini grids use one or multiple central power generation sources to electrify multiple households, in fact, more than 200 in order to be economically viable, as this table suggests.



Those who have followed previous lectures know this figure already. The x axis of this graph displays the factors that determine the suitability and feasibility of different electrification approaches. The y axis portrays the electricity retail costs on site. The mini grid space, herein shaded in blue, is defined for those instances where the community to be electrified is characterized by medium size, a medium population density, a medium distance to the grid, normal terrain, and average economic strength. Extending the national grid, by contrast, is more cost-effective in large or dense communities that are close to the national grid, where electricity costs are low and/or where large quantities of electricity are required. Stand-alone solar home systems are best for dispersed homes that are far from the grid and require small amounts of electricity.

What we learn from this graph and the table before is that the instances in which mini grids find application are very different to that of SHS.



Mini grids and solar home system solutions together already provide electricity to about 90 million people. To achieve universal electricity access by 2030, the current pace of expansion will have to double. It is estimated that off-grid solutions will supply 50-60% of the additional generation needed to achieve universal electricity access by 2030. Mini grid energy service companies in the sector appear to be confident that they can provide a compelling value proposition to customers and investors that boils down to providing energy at a rate that is affordable, lower cost, and less polluting than alternatives, such as kerosene and diesel fuel. Tentatively, it is estimated that up to 45% of the needed generation capacity should come from mini grids in order to achieve universal electricity access by 2030.

But before we jump too deep into the numbers, lets talk about what mini grids actually are.

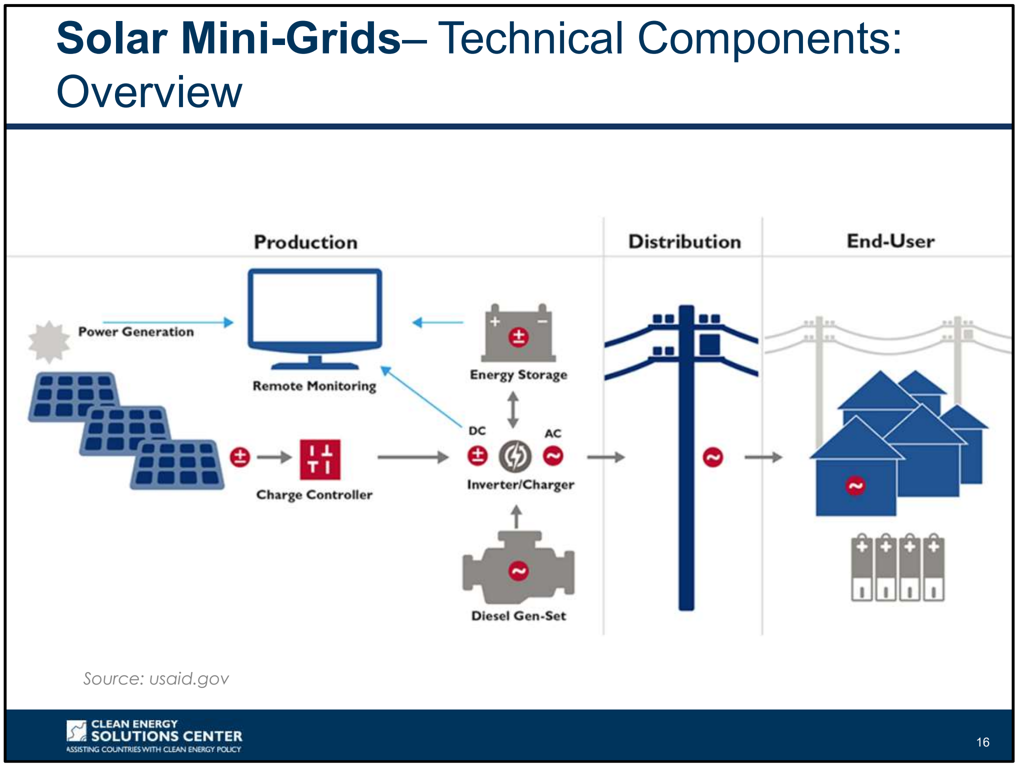
Main Body of Presentation

1 Introduction to Solar Mini-Grids

2 Technical Components of Solar Mini-Grids

3 Opportunities and Challenges of Solar Mini-Grids

4 Case Study: India's SPRD



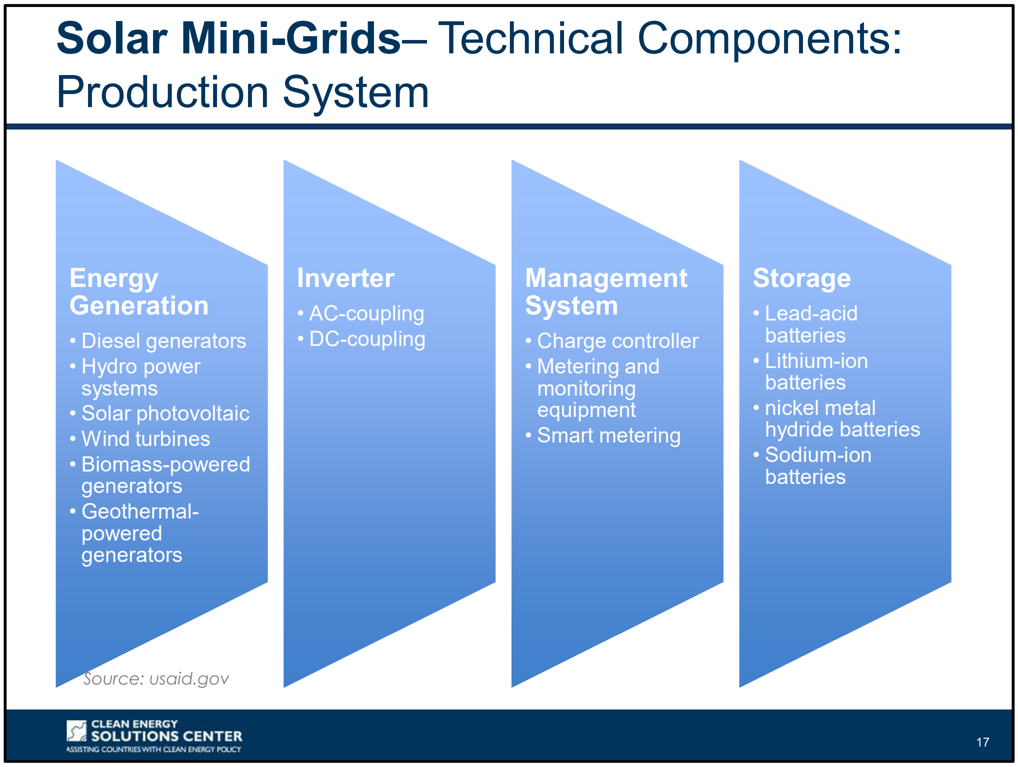
A *mini-grid's* basic technical components are grouped into three systems:

The production system generates electricity from either a single energy source or a mix of sources. In this module we are talking about solar mini grids but other renewable energies sources and fossil fuels could also be used to generate the power. Most often however, solar photovoltaic is used in combination with a diesel generator setup. We will go, in the coming slides, a bit deeper in the kind of ways these generators and power sources are usually combined.

Next, a distribution system moves electricity from the generation site to end users.

And finally, the end user is provided with connections that allow customers to use electricity.

This represents the basic setup of a solar mini grid, however individual specifications greatly depend on the combination and choice of components that we will now look into.



A *mini-grid's* production system consists of energy generation technologies, *inverters*, a *management system* and sometimes *storage* (batteries). The production system determines the mini-grid's overall capacity to provide electricity to end users. Mini-grid energy generation technologies can include *diesel* generators, *hydropower* systems, solar *photovoltaic (PV)* modules, *wind turbines*, *biomass*-powered generators and *geothermal*-powered generators. A mini-grid may use a single energy source or mix of sources (*hybrid*) that are either renewable or non-renewable.

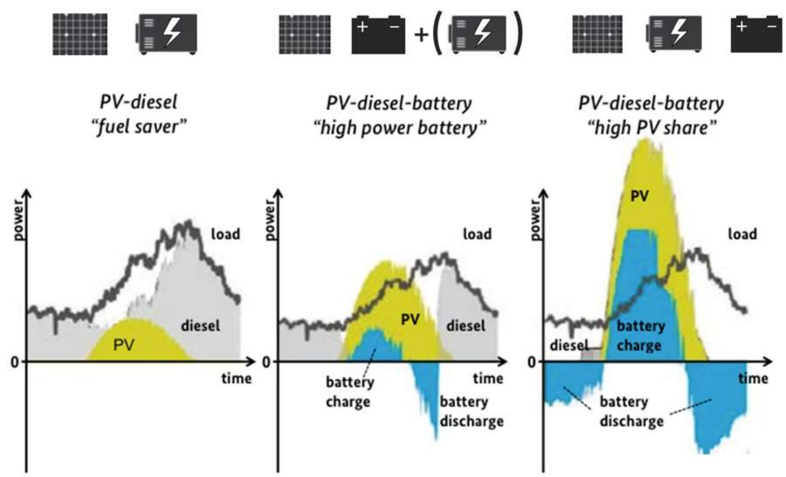
Mini-grid production systems use power *inverters* when end users need a different type of electrical *current* than what the energy production technology generates. Some energy generation technologies produce *direct current (DC)* while others produce *alternating current (AC)*. Solar power, for example, generates DC, whereas nearly all mainstream appliances require AC. So a solar-powered mini-grid serving households would need an inverter as part of its production system. Battery charging, on the other hand, requires DC power. An inverter would convert electrical current from AC to DC if the current were coming from a grid-tied (utility) system or from a diesel generator. In an AC-coupled configuration with *storage* (a battery), the energy generation and storage systems each have their own inverter. These separate inverters connect to one another on the AC side of the system. Operators can use the battery inverter to control charging and discharging.
In a DC-coupled *PV* configuration, the energy generation and energy storage systems share an inverter. DC coupling can provide better performance; battery charging is more efficient when there are fewer power conversion steps.

Mini-grid production systems include *management systems*, which measure, monitor and control electrical *loads*. A charge controller, for example, connects between the solar panel and the battery or inverter/charger to prevent over-charging of the battery. Likewise, metering and monitoring equipment allow mini-grid managers to gather data about energy use across end users, which informs operational decisions. Management systems often couple computerized energy management tools with *smart metering* to optimize performance. Some management systems allow operators to control the system remotely, including shedding loads as needed.

Some mini-grid production systems require energy storage (such as batteries). Solar and wind resources, for example, are non-dispatchable. This means they only produce power when the renewable resource is available, not according to user demand. If end users require power on demand, the mini-grid must be able to store energy and supply it when resources are not available. Energy storage adds stability to the system by storing energy for peak consumption. Large mini-grid systems that run diesel generators continuously do not require batteries, but nearly all other mini-grid systems require some type of energy storage.

The way in which solar PV, diesel generators and batteries are to be combined efficiently represents a science on its own, and we will do a quick detour into it.

Solar Mini-Grids– Technical Components: Production System



Source: GIZ, 2016

CLEAN ENERGY SOLUTIONS CENTER
ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY

18

Typically, there are three options of how to operate Solar mini grids:

PV-battery with diesel back-up: In this setting, the battery is the central element for the cost of electricity over the lifetime of the system. Large shares of PV-power combined with the battery can make the system almost independent. Usual system designs consider three days of autonomy of the system. The diesel generator is used as back-up to ensure quality of service when solar power generation and the state of charge of the battery are low or when demand is especially high.

PV-diesel: This is the lowest cost option in terms of initial investment. Quality of service (voltage and frequency provision) is ensured through the permanent operation of the diesel generator at all times of existing demand. The solar power contributes during daytime while ensuring that the operation criteria of the diesel generator are not violated.

PV-diesel-battery systems: This setting includes the battery to increase the efficiency of the overall system. In periods of low loads (i.e. during nights) the battery can cover the demand. During daytime the PV-system and the diesel generator contribute to power generation. Excess energy due to overproduction of the PV-system and constraints of the operational limits of diesel gensets, like minimum load requirements of the diesel generator and stability criteria, is used to charge the battery.

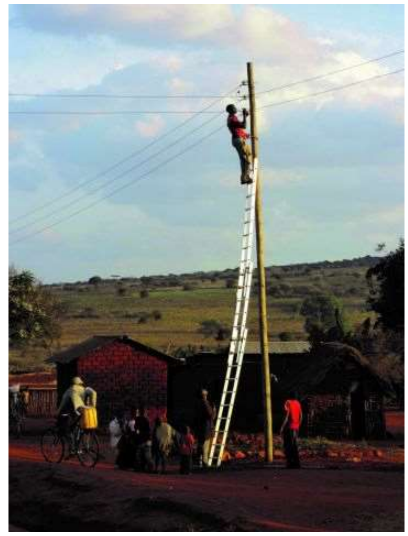
Solar Mini-Grids – Technical Components: Distribution System

The electricity distribution system moves power from the **energy production system** to **end users**

Can be **overhead** or **underground**

Variety of **voltages**, either **AC or DC** and either **single-** or **three-phase power**

Cost usually dictates which option project developers choose

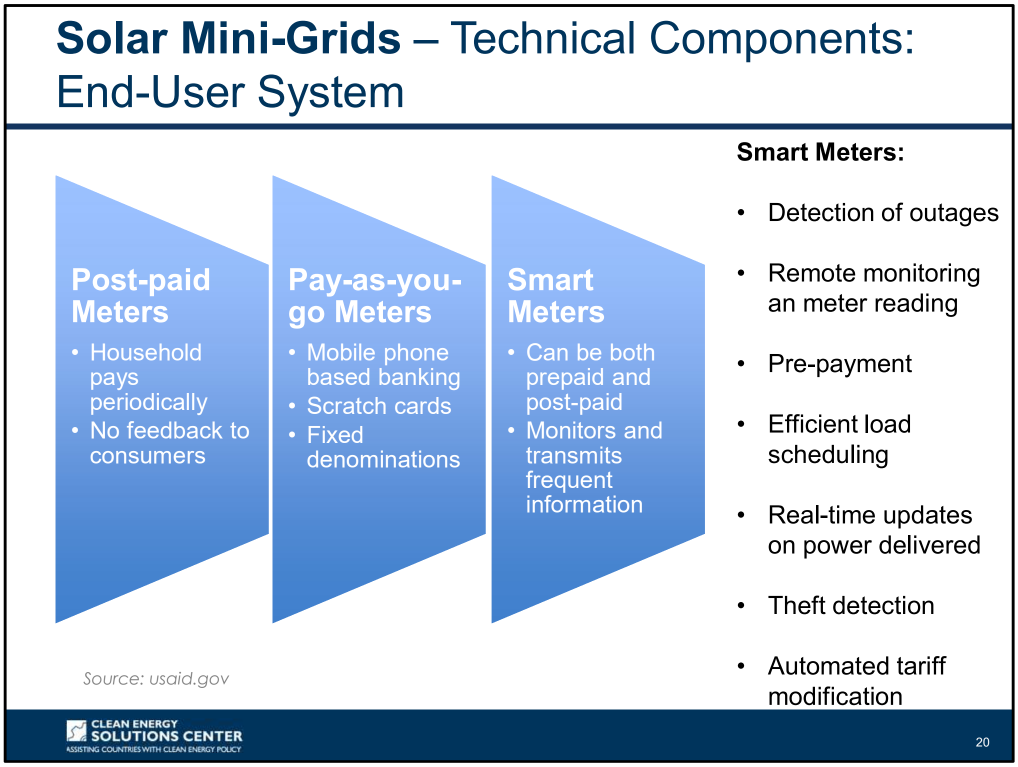


Source: wri.org

The electricity *distribution system* moves power from the energy production system to end users. The distribution system consists of distribution and/or transmission lines, *transformers* and the infrastructure to support the lines, such as poles.

The distribution system can use a variety of *voltages*, either *AC* or *DC* and either *single-* or *three-phase power*. Transformers change the AC voltage levels in a mini-grid network covering a large area. *Step-up transformers* increase the AC output voltage to transmit electricity more efficiently over a distance. Step-down transformers decrease the voltage from high- or medium-voltage transmission lines to 120 V or 220 V for residential use.

Different components have different efficiencies, so the choice of voltage, current and transformers impacts energy losses. Cost usually dictates which option project developers choose.



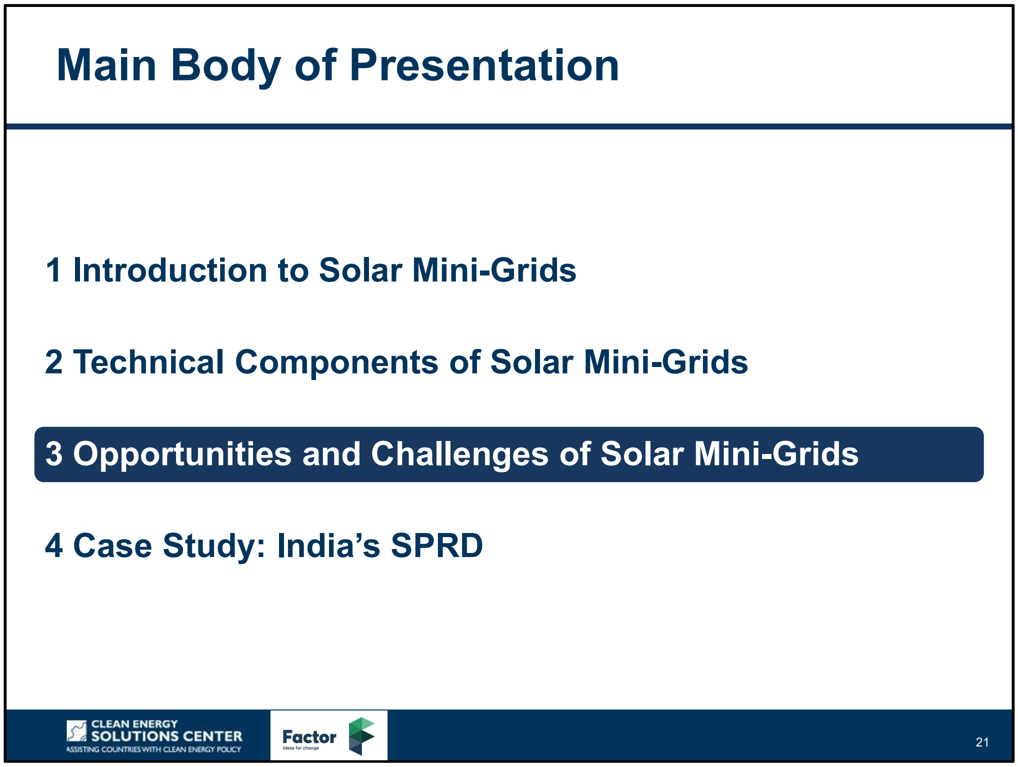
End-user systems provide an interface for end users to access, use and monitor electricity from the mini-grid. The end-user system consists of connections to and from the mini-grid, systems to prevent electrical shocks and harm to both equipment and users and power consumption metering. Mini-grid enterprises rely on frequent, small payments from their customers, making metering, billing and collection time consuming. Innovative metering and payment systems automate these otherwise complex tasks. Individual meters (one per end user) provide the greatest degree of control over energy use. Meters can be pre- or post-paid; pre-paid meters typically are called *pay-as-you-go (PAYG)* metering.

Newer generation meters are typically considered "*smart meters*." Although older, traditional meters are still in use, both have advantages and disadvantages.

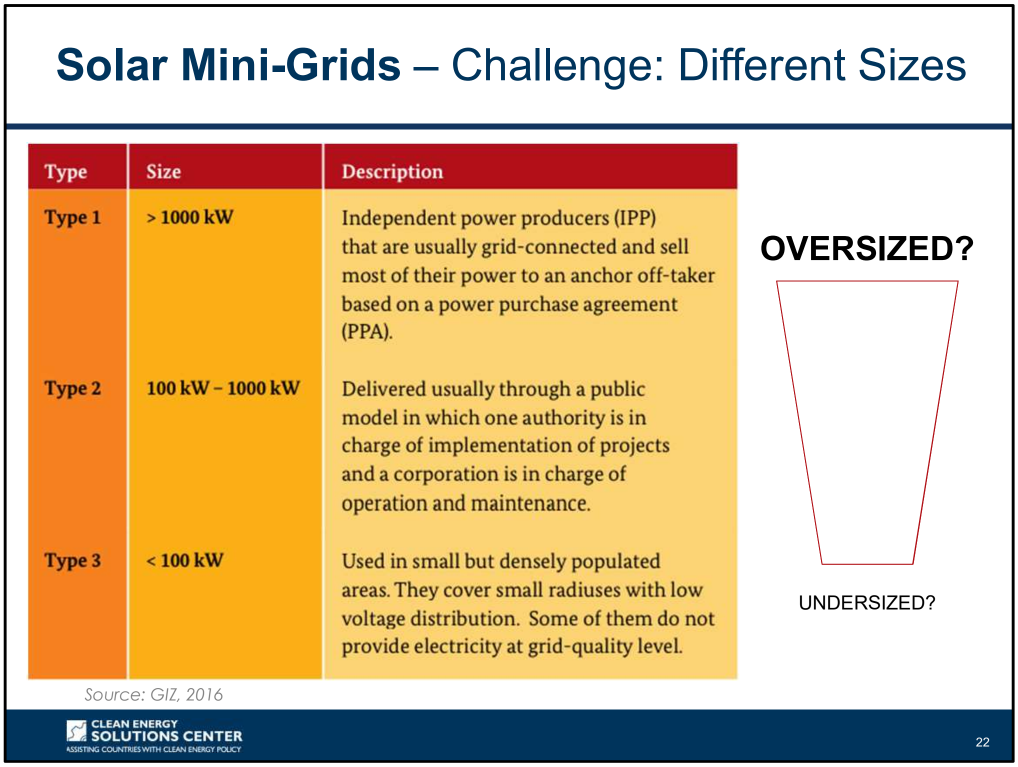
Post-paid meters were the standard technology in most countries until the 21st century. With post-paid meters, the utility company sends a meter-reader by each household monthly (or periodically) to determine how much energy is consumed. Then the utility sends the household a bill accordingly. Households using post-paid meters tend to consume electricity beyond their means as these meters provide little feedback at all. Post-paid meters work poorly in places where consumers are not used to managing their consumption.

PAYG meters benefit end users and utilities. Consumers with no credit history can gain access to energy. By showing expenditures in real time rather than in a single bill at the end of the month, PAYG meters allow users to budget for electricity more effectively. Customers often use electricity more efficiently when they can see the cost in real-time.

Both pre-paid and post-paid meters can be "*smart meters*." Smart meters offer advantages over traditional technology for both the consumer and the utility. By monitoring and transmitting frequent information, a smart meter allows the utility to better monitor consumption across the whole system, and provides the user information on their ongoing usage and estimated expense. Smart meters gather data on energy consumption and facilitate two-way communication between the energy provider and end user, usually using cell phone technology.



We have seen and talked about the technical components of solar mini grids to some extent now. We will now look at the opportunities and challenges that are to be associated with solar mini grids.



The first question one should ask when one considers to implement a solar mini grid is the sizing, as this is a question that influences both the service provision and the profitability, as well as aspects of regulation, ownership, funding and impact.

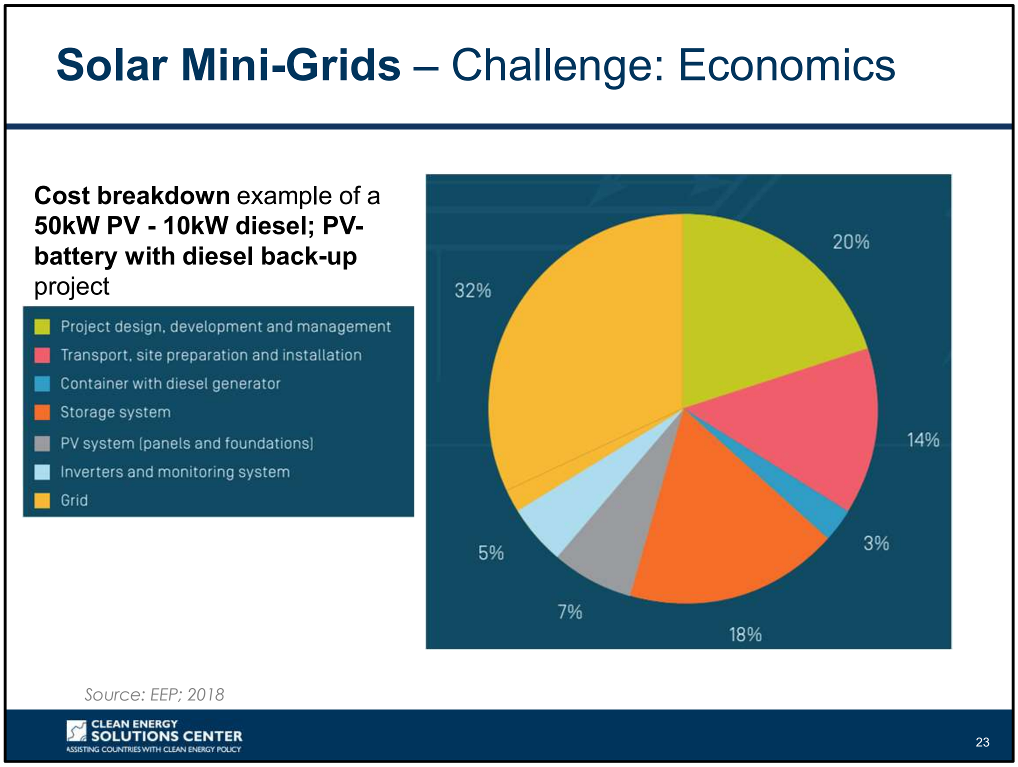
Also other aspects of project planning and goal definition come into play at this point: For example, the quality of electricity provided by the mini-grid can be equivalent to that of the national electricity network. Nevertheless, for initial rural electrification, lower service levels (e.g. 4-8 hours of supply per day) can be considered in order to reach the first tiers of electricity supply as defined by World Bank. Considering lower service levels or hours can reduce the cost of mini-grids significantly.

The design of a mini-grid directly affects the cost structure of the project and determines not only the cost of the energy produced, but also its quality. Lack of knowledge about the load conditions, electrical demand and future load growth during the sizing process can result in oversized or undersized grids.

Oversizing a mini-grid results in increased investment and thus higher payback times, as well as higher operational costs and lower overall efficiency. Over-sizing the diesel generator often leads to an operation below the recommended load factor and a low efficiency range.

Since both cases lead to an incorrect operation of mini-grids and lower quality of electricity supply at higher costs, a detailed electricity demand assessment and accurate system sizing are crucial. Demand assessment has a direct impact on the size of the components and thus the investment costs.

Undersizing the mini-grid system results in an unreliable supply, leading to blackouts and reduced service quality. Unreliable supply will negatively affect customers and lead to a high dissatisfaction. Moreover, the technical components will suffer from the incorrect sizing, potentially leading to higher operation and maintenance costs of the system.



We are staying with costs and looking more deeply at the economics of PV-battery with diesel back-up mini grids.

The commercial viability of mini-grids strongly depends on three key factors:

1) the share of electricity used for income-generating purposes,
2) the share of electricity consumed versus electricity generated, and
3) the electricity price negotiated and/or fixed by regulation.

The cost of building distribution grids to low-consumption customers remains a challenge for all rural mini-grid projects. These costs can account for more than 30% of total project costs. Larger consumers such as business customers allow higher sales with a smaller grid.

One of the most visible parts of a solar mini-grid is the PV array generating the power, although these only form around 7% of the overall cost of the system. With a relatively minor investment it is possible to scale up the installed capacity in line with demand growth. However, increasing storage capacity remains a technical challenge and increases investment costs significantly if night-time demand for power is high.

Solar Mini-Grids – Challenge: Household Connection Costs

Mini-Grid/ Country	Power Characteristics	Cost of Interconnection ($)	Price of Interconnection ($)	Notes
Devergy, Tanzania	Direct current (DC) solar mini-grid, Max 200 W per household	Undisclosed (much higher than interconnection price if generation included)	$25 (200 W connection)	24-V DC connection, pre-paid meter
Inensus, Senegal	Solar powered alternating current (AC) mini-grid with diesel backup	$78–$235 (depends on wire length and connection type, does not include generation)	$16–$64 (depends on max W capacity)	Pre-paid meter, cable to house and circuit breaker
Undisclosed (Africa)	Multi-MW AC mini-grid	$400–$1,500. Average: $920 (including 33 kV network, transformers, distribution lines)	$88 (first 2,600 AC single-phase connections) $231 (after 2,600 connections)	First 2,600 connections subsidized by grants; includes meter and up to 30 meters of line

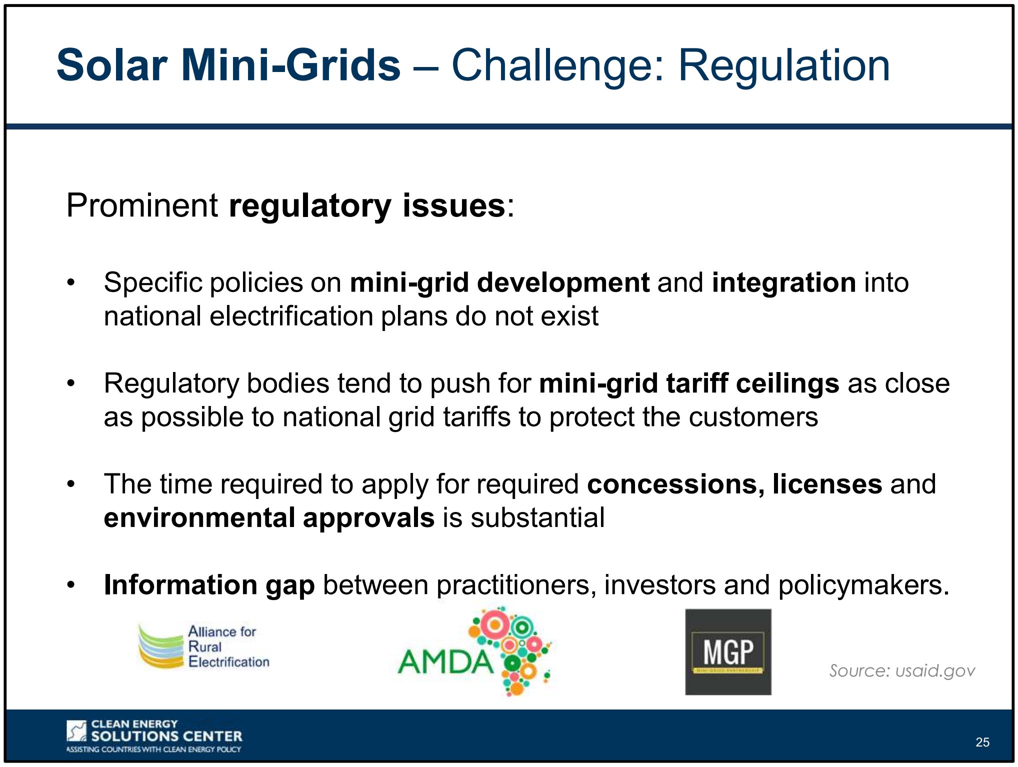
Source: usaid.gov

CLEAN ENERGY SOLUTIONS CENTER
ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY

24

Here we see some connection cost examples from Africa.

Typical household connection costs, which are not including generation costs, vary from several hundred dollars to more than $1,000 per connection. These costs depend on the type of connection, the *mini-grid* technology and whether the connection cost includes simply the cost of the *service drop* and meter or includes *deep connection costs*, such as for the transmission and *distribution system*. In many cases, prices paid by consumers are lower, as you can see in this table, reflecting subsidies or business models that seek to recover the cost of connections over time through electricity sales.



The regulatory environment can be quite different depending on the country. A growing number of developers are joining national and regional associations to lobby for regulatory and policy frameworks that are favourable to private sector mini-grid investments. We will talk about one of these associations in a minute.

For the moment however, lets look at some prominent regulatory issues:

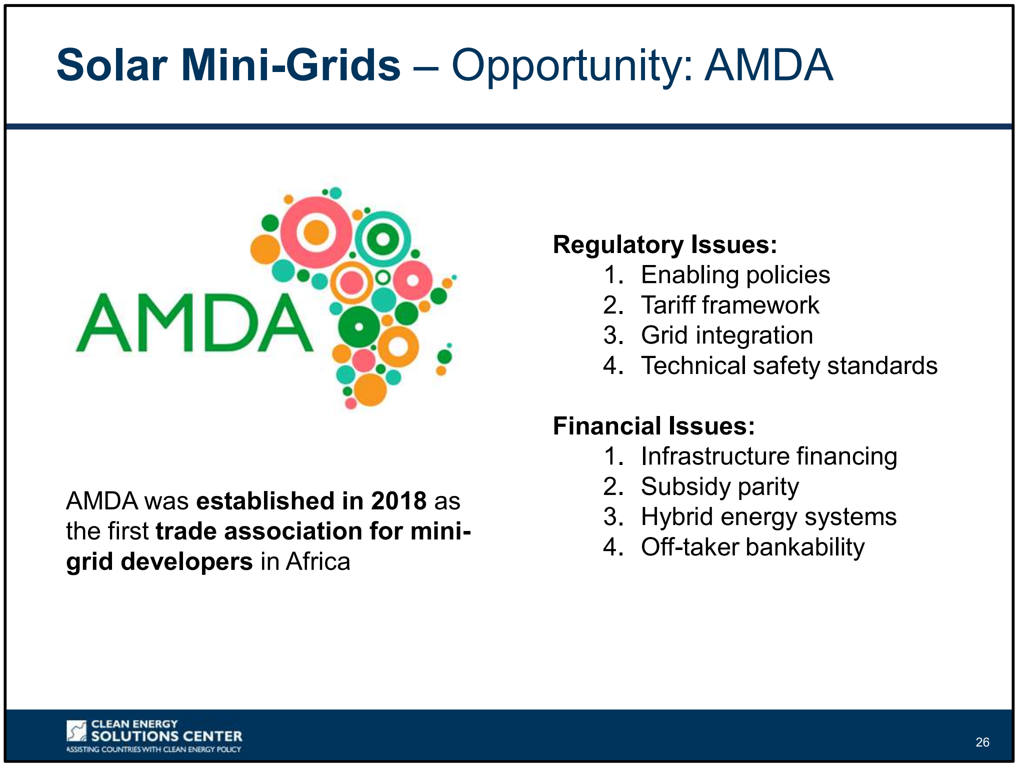
First of all, specific policies on mini-grid development and integration into national electrification plans do not exist or are still under development in many countries. This impacts site selection, licensing and permitting procedures, and future grid integration. It also restricts the access of developers to national subsidy schemes for rural electrification activities or cross-subsidies for grid extension.

Also, regulatory bodies tend to push for mini-grid tariff ceilings as close as possible to national grid tariffs to protect the customers. However, national tariffs are often not cost-reflective due to cross-subsidisation. This results in the need for mini-grid developers to secure grants or subsidies for their capital expenditures, and in some cases also their operating expenses.

One should also not forget the time required to apply for required concessions, licenses and environmental approvals is substantial and has often delayed project development. Although most mini-grids are exempt from generation and distribution licenses, they may still need to go through a process to secure this exemption. Regulatory requirements can also be very expensive.

Lastly, Regional associations have an important role to play in improving coordination and closing the information gap between practitioners, investors and policymakers. Groups such as the Alliance for Rural Electrification (ARE), African Mini-grids Developers Association (AMDA), and SEforALL Mini-Grids Partnership (MGP) offer valuable platforms for private and public-sector stakeholders to consult and collaborate on building enabling regulatory and financial frameworks for the sector.

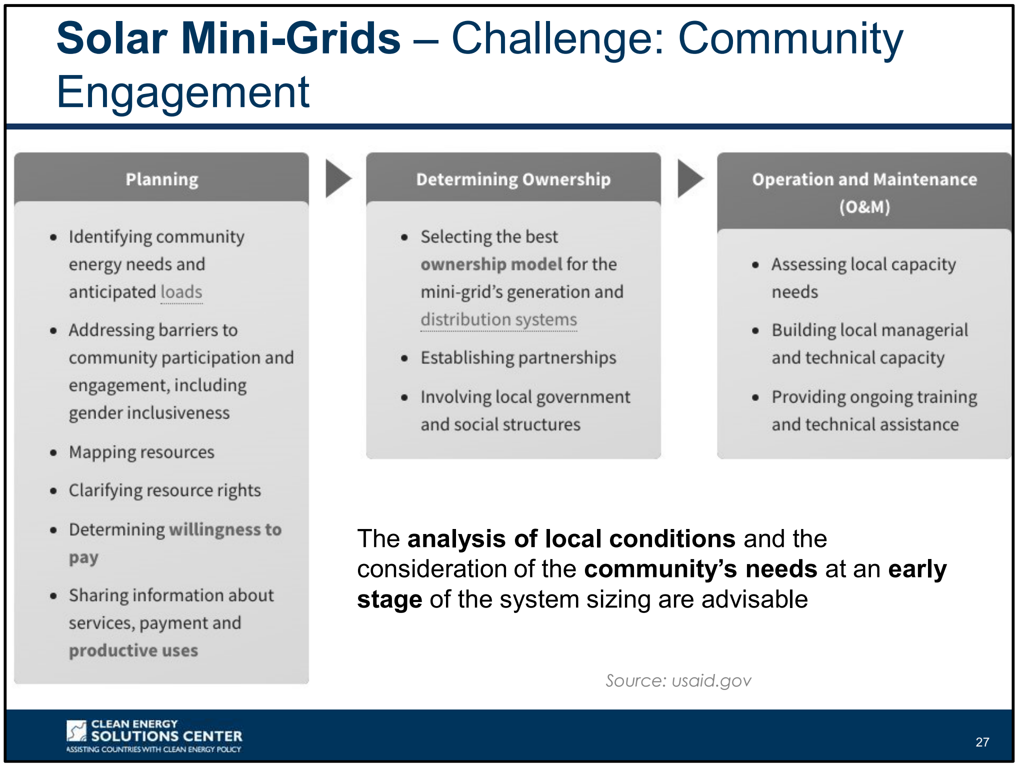
This is why we will now briefly look at the African Mini-grids Developers Association AMDA.



AMDA was established in 2018 as the first trade association for mini-grid developers in Africa. It has country-level chapters in Kenya and Tanzania, with plans to add chapters in Nigeria, Ethiopia and Uganda. The association's purpose is to facilitate business environments that support the acceleration of a sustainable private sector for mini-grid systems in African markets. AMDA aims to achieve this through activities focused on advocacy, promotion and coordination.

AMDA has identified eight core issues divided into two categories, displayed here on the right side of the slide.

AMDA's near-term objectives include to mobilise finance for mini-grids, equalise public-private incentives, establish national grid integration frameworks that are inclusive of mini-grids, better inform market support activities, and to unify and expand the voice of the sector across Africa.



Besides the regulatory issues and the costs involved, its is important to not underestimate the value of proper community involvement. Before planning a mini-grid project, developers need to understand the local context. A project that works in one community might fail in another. Involving the community helps projects meet local energy needs and can create new opportunities for improving livelihoods. Projects without local support may not be financially sustainable and may cause conflict among community members.

Early in the planning stage, project developers need to conduct a community needs assessment. A community needs assessment is a process that helps the *mini-grid* project developer understand local energy needs, technical expertise and capacity, for both the planning and the operation and maintenance stage. Further, a mini-grid is more likely to be financially viable if it can provide a superior level of for a tariff that is similar and ideally lower than a household's current energy expenditures. Willingness-to-pay surveys can help calibrate system design to sustainably provide tiers of service within the budget defined by revenue collections.

The choice of ownership also a very interesting topic, which we will cover over the next slides.

Solar Mini-Grids – Challenge: Ownership Models I

Community-based Model:

- Local communities own, manage, operate and maintain mini-grids
- External help with financing, design and installation
- Public entity or donor provides grants or other financial assistance
- Community-based ownership models are common in developing countries

Private Sector Model:

- Private investor pays to construct, operate and maintain the mini-grid
- Funding often comes from private equity and commercial loans
- Typically in countries where the government supports mini-grid energy development
- Anchor Load Approach and Community Clustering Approach

Source: usaid.gov

CLEAN ENERGY SOLUTIONS CENTER
ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY

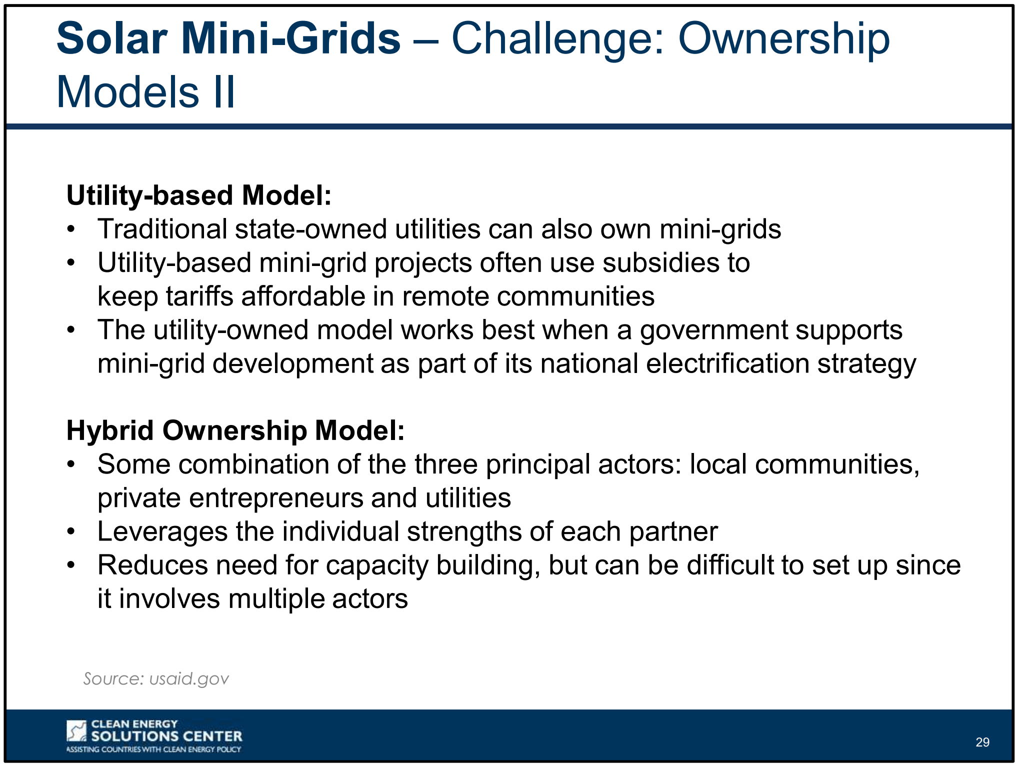
28

Identifying who will own and operate a mini-grid is crucial. Possible owners include governments, public utilities, communities, private businesses or some combination of these actors. Project developers can choose from among many ownership models, each with different benefits and drawbacks. The project's operating environment often determines which model is best. Generally speaking, there are 4 ownership models.

Under community-based models, local communities own, manage, operate and maintain mini-grids. These communities usually receive external help with financing, design and installation. Once the mini-grid is installed, the community assumes responsibility for *tariff* collection and *operations and maintenance*. Community electricity *cooperatives* and other local organizations often play this role. Community-based ownership models are common in developing countries where private companies and utilities lack the capacity or incentive to electrify remote communities. In remote rural areas, where tariffs won't cover investment costs, community-based ownership may be the only option.

In the private-sector model, a private investor pays to construct, operate and maintain the mini-grid. Funding often comes from private equity and commercial loans.
Private entrepreneurs typically get involved in countries where the government supports mini-grid energy development. Private-sector models are most common in countries with supportive policies and simple licensing procedures where investors can access credit, financing and subsidies and where bilateral donors and/or non-governmental agencies provide technical assistance. Commonly, projects are implemented using the Anchor load approach and the community clustering approach.

As a side note: In the *anchor load* approach, the developer secures a commercial client with predictable, guaranteed energy demand to supplement demand in the beneficiary community. The community clustering approach groups villages with similar needs for a shared *mini-grid* project. Later on in the case study, we will talk about the anchor approach once more.

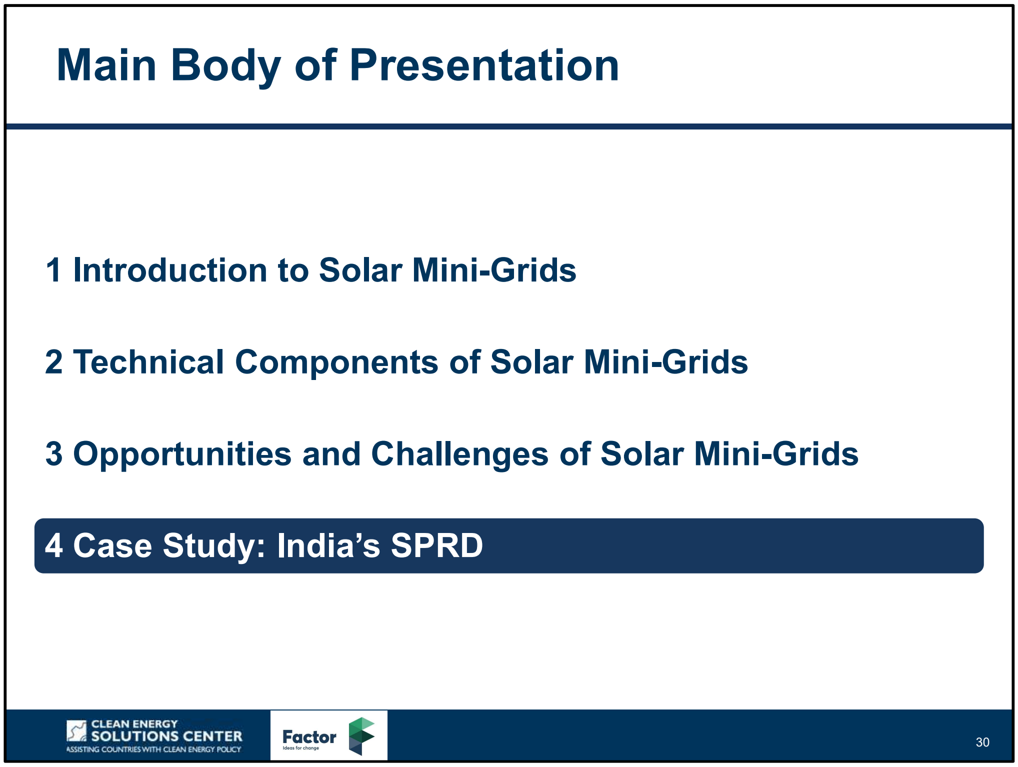


Further, traditional state-owned utilities can also own *mini-grids*. Utilities, in this case, operate mini-grids in much the same way as the national grid, but on a smaller scale. In some utility-based models, the utility contracts with local energy service companies to manage parts of the project.

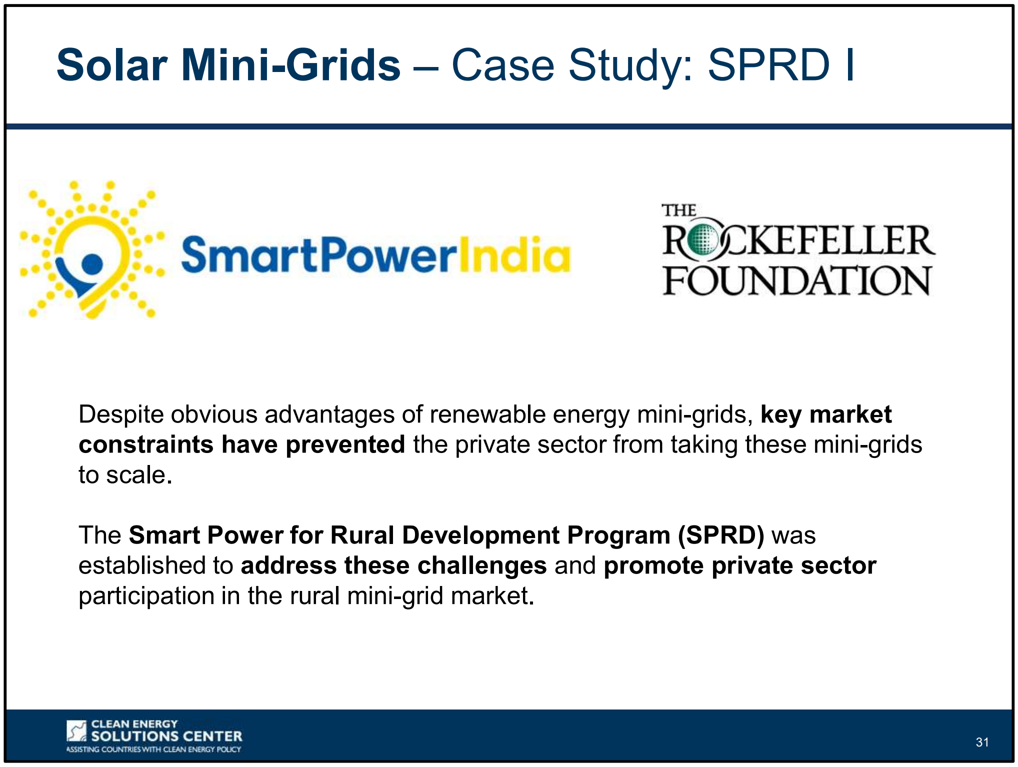
Utility-based mini-grid projects often use subsidies to keep *tariffs* affordable in remote communities. The utility charges mini-grid consumers a tariff equal to that paid by customers serviced through the national grid, even though costs are higher for rural mini-grid customers. In this system of cross-subsidization, national grid customers subsidize the cost of electricity for mini-grid customers.

Last but not least, In a *hybrid* ownership model, some combination of the three principal actors—local communities, private entrepreneurs and utilities—collaborate to implement and manage *mini-grid* projects. The organizations form *joint ventures* and/or use contracts to share ownership.

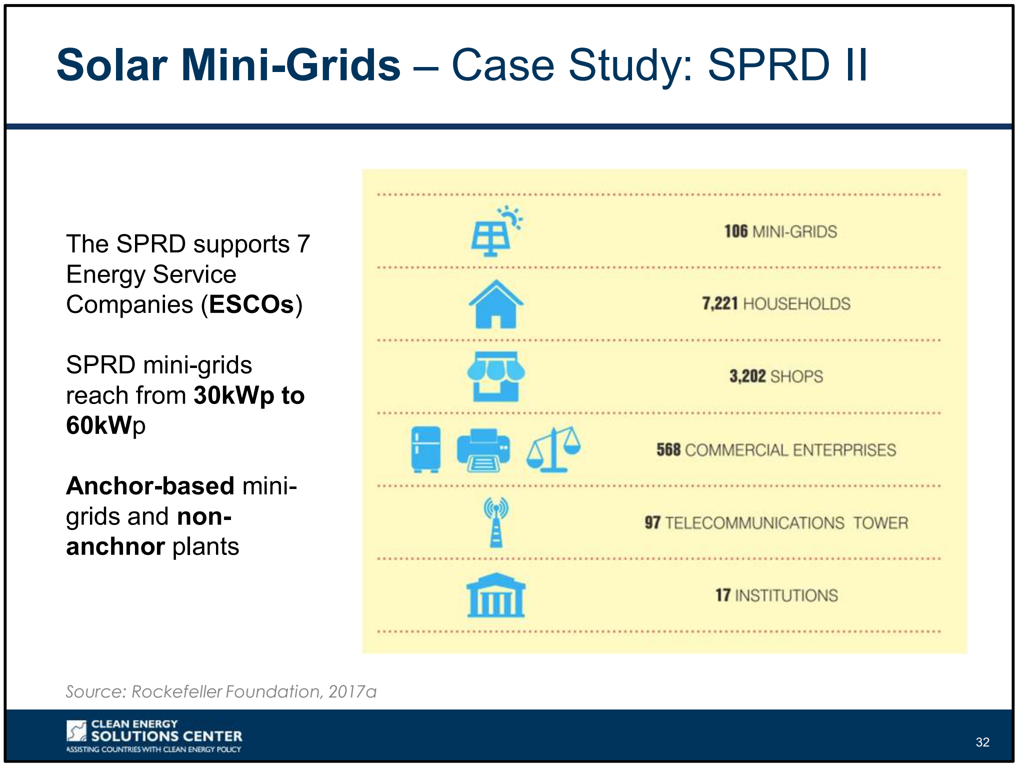
Involving multiple actors leverages the individual strengths of each partner. Project developers often use hybrid approaches when one stakeholder lacks specific capacity or expertise. In this way, hybrid models reduce the need for capacity building. However, a hybrid model can be difficult to set up since it involves multiple actors. In appropriate contexts, though, hybrid ownership can be an effective approach. One common hybrid model is for a utility to build and own a mini-grid that is then managed by a community-based organization, with technical maintenance provided by a private company.



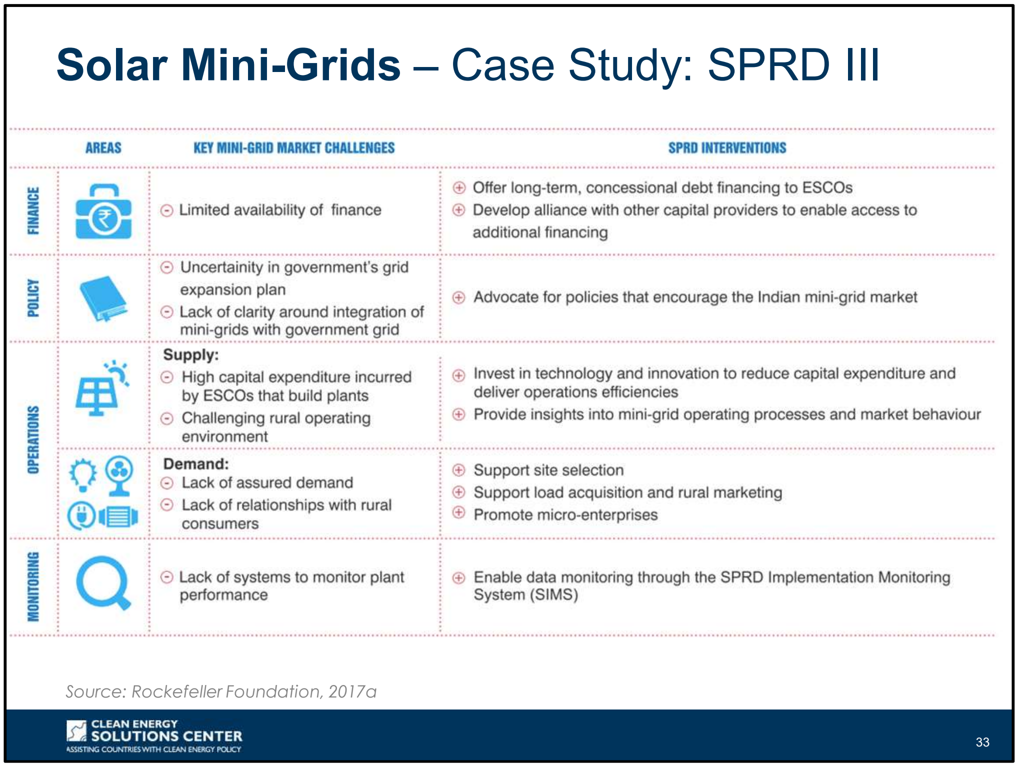
Now, we are turning to a case study of an Indian mini grid development support programme. Given that mini grids are often very different from each other, it is difficult to provide generalized figures on issues such as social impact or profitability. Hence, this case study from india should be understood as an example, both for the solar mini grids in their functioning, as well as for a potential viable support programme to be duplicated elsewhere.



Rockefeller's Smart Power for Rural Development Initiative provides affordable financing to renewable energy providers and links them to an ecosystem of Rockefeller grant-funded partners, which provide project and business development support as well as policy and regulatory recommendations. Rockefeller's partners are coordinated by Smart Power India, a Rockefeller-incubated entity and wholly-owned subsidiary. The Foundation set an ambitious target to reach one thousand villages within the first three years of the initiative, with a goal of building a viable market quickly and spurring interest, action, and innovation among key players in the ecosystem.



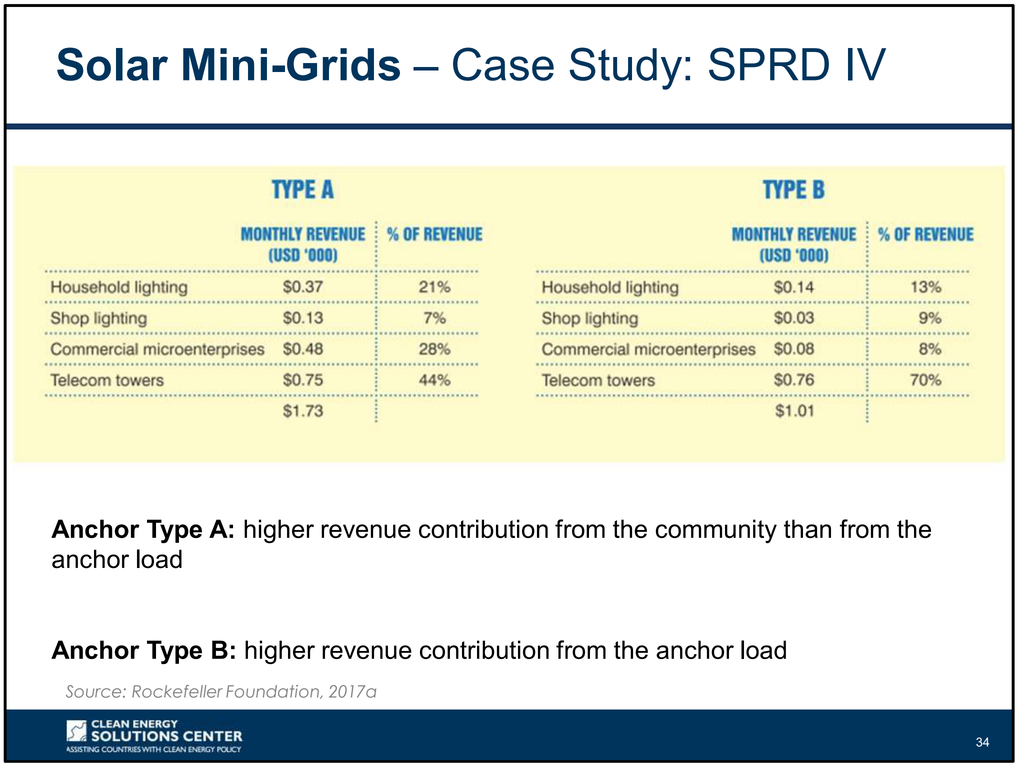
SPRD currently supports seven partner energy service companies. These businesses operate a total of 106 renewable energy based minigrids, impacting more than 40 000 people across India. The SPRD mini-grids currently range in capacity from 30 kWp to 60 kWp, and they consist of either an anchor based model or a non-anchor based model. The anchor is a main commercial energy off-taker, is predominately a telecommunication tower in the SPRD grids. However, these mini grids also hugely impact on commercial enterprises in the areas where they are active.



	AREAS	KEY MINI-GRID MARKET CHALLENGES	SPRD INTERVENTIONS
FINANCE		⊝ Limited availability of finance	⊕ Offer long-term, concessional debt financing to ESCOs ⊕ Develop alliance with other capital providers to enable access to additional financing
POLICY		⊝ Uncertainity in government's grid expansion plan ⊝ Lack of clarity around integration of mini-grids with government grid	⊕ Advocate for policies that encourage the Indian mini-grid market
OPERATIONS		**Supply:** ⊝ High capital expenditure incurred by ESCOs that build plants ⊝ Challenging rural operating environment	⊕ Invest in technology and innovation to reduce capital expenditure and deliver operations efficiencies ⊕ Provide insights into mini-grid operating processes and market behaviour
		Demand: ⊝ Lack of assured demand ⊝ Lack of relationships with rural consumers	⊕ Support site selection ⊕ Support load acquisition and rural marketing ⊕ Promote micro-enterprises
MONITORING		⊝ Lack of systems to monitor plant performance	⊕ Enable data monitoring through the SPRD Implementation Monitoring System (SIMS)

We have already defined the need for finance, policy- and grid-expansion-plan-related uncertainties already. The problems of designing and sizing solar mini grids has also been touched on. In addition the solar mini grids in this case study also add the lack of systems to monitor plant performance as a further challenge to mini grid system implementation. This is where the SPRD Interventions come in, whereby the private sector environment is meant to be supported and enabling ecosystems are created. Most importantly, the financing can be secured, but also advocacy for encouraging policies is provided.

The initiative also provides technical assistance for the operation management, especially with respect to site selection, load acquisition and rural marketing. And, to top it of, with their Implementation monitoring system, the SPRD Initiative can also facilitate the data collection and monitoring of the mini grids.



TYPE A

	MONTHLY REVENUE (USD '000)	% OF REVENUE
Household lighting	$0.37	21%
Shop lighting	$0.13	7%
Commercial microenterprises	$0.48	28%
Telecom towers	$0.75	44%
	$1.73	

TYPE B

	MONTHLY REVENUE (USD '000)	% OF REVENUE
Household lighting	$0.14	13%
Shop lighting	$0.03	9%
Commercial microenterprises	$0.08	8%
Telecom towers	$0.76	70%
	$1.01	

Scenarios were then developed to estimate the performance of an SPRD renewable energy mini-grid plant at villages with different numbers and types of customers. A sample of 23 top cohort plants run by four companies and distributed across the states of Uttar Pradesh and Bihar were analysed for the following data insights, using 6 months of operations data from each of the sample plants. Eighteen plants were anchor-based and five were non-anchor plants; age of the plants varied from 8 to 19 months; and plant capacity ranged from 27 to 60 kWp for anchor-based plants, at an average capacity use of more than 95%. and from 30 to 37 kWp for non-anchor plants, at an average capacity use of approximately 64%.

In this analysis, it was found that the typical customer mix in the investigated sample of solar mini grids was either following Type A or Type B, whereby Type A represents those mini grids for which the contribution from the community was higher than from the anchor load. For type b it is vice versa.

The tables show the monthly average revenues of both types of anchor plants from different type of energy usage within the mini grid.

Solar Mini-Grids – Case Study: SPRD VI

Source: Rockefeller Foundation, 2017a

KEY SCENARIO PARAMETERS AND ASSUMPTIONS						ESTIMATED UNIT-LEVEL PARAMETERS			
VILLAGE TYPE	PLANT MODEL	ESTIMATED POTENTIAL CUSTOMERS	COMMUNITY CUSTOMER CONVERSION	ESTIMATED CONNECTED CONSUMERS	RECOMMENDED PLANT CAPACITY	MONTHLY REVENUE	MONTHLY OPERATING MARGIN	PAYBACK PERIOD	
Small Village	Non-Anchor	280 community customers	60%	170 community customers	10kWp	$500	($510)	(Negative operating margin)	Only an Anchor-based model may be viable in a small potential village
	Anchor-based	280 community customers + 3 BTS telecom tower		170 community customers + 3 BTS telecom tower	51kWp	$1,793	$861	9 years	
Medium Village	Non-Anchor	530 community customers		320 community customers	18kWp	$831	$357	13 years	Only an Anchor-based model may be viable in a medium potential village; unless the ESCO is willing to accept a longer payback of 13 years
	Anchor-based	530 community customers + 3 BTS telecom tower		320 community customers + 3 BTS telecom tower	58kWp	$2,104	$1,157	8 years	
Large Village	Non-Anchor	830 community customers		500 community customers	50kWp	$1,580	$964	9 years	Both a Non-Anchor and an Anchor-based models may be viable in a large potential village
	Anchor-based	830 community customers + 3 BTS telecom tower		500 community customers + 3 BTS telecom tower	80kWp	$2,851	$1,796	7 years	

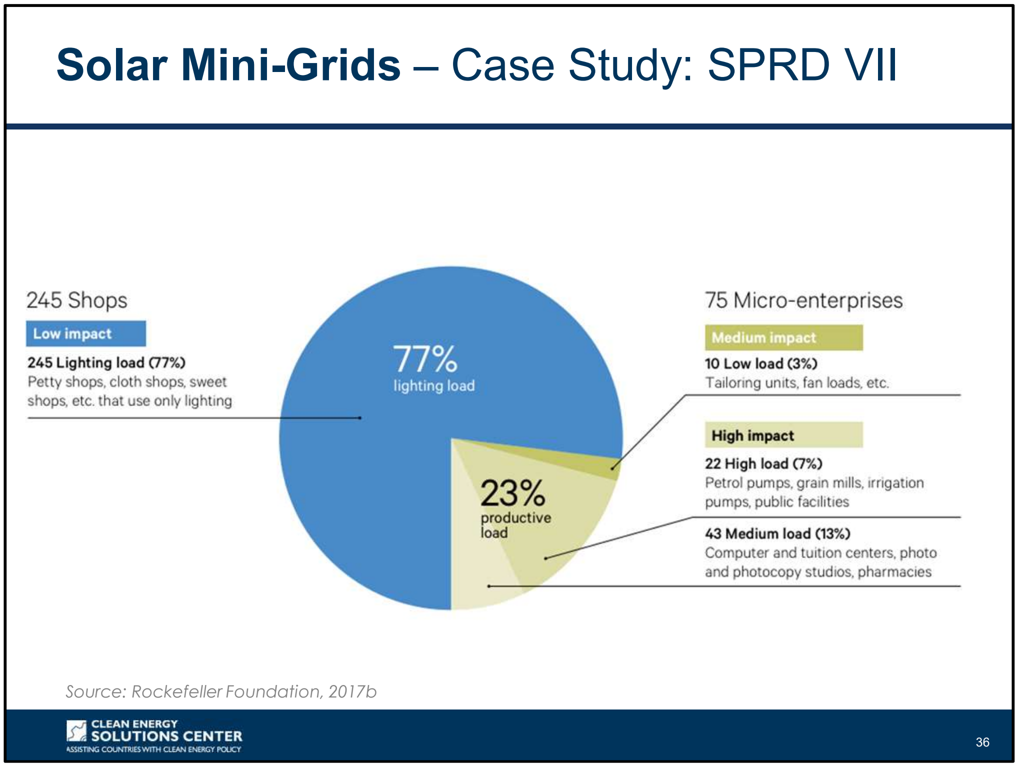
CLEAN ENERGY SOLUTIONS CENTER
ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY

35

Renewable energy based mini-grid are expected to display varying levels of performance. The level of performance and commercial viability depend on the operating model of the plant and the potential customers of the village. To better understand the different possibilities for financial performance, the SPRD program has modelled various performance scenarios for varying viIlage potentials and plant operating models, as portrayed in this table.

A small, medium and large potential village is defined based on the range of village population size currently served by the SPRD
Program company. A mini-grid in a small village is likely to have 170 connected community customers, a medium village 320 connected community customers and a large village 500 or more connected customers. The capital expenditure necessary for a typical 30 kWp mini-grid is estimated at approximately US$86,000 and is considered for payback calculations.

The table highlights that only anchor-based mini-grid plants in small and medium villages are likely to be commercially viable, meaning a
financial payback of under 10 years at the unit-level. This is because the revenue generated from the community customer is not sufficient to offset operating expenses. In such villages, a sizeable revenue from the anchor customer allows the mini-grid to function viably. In large villages, the revenue from community customers allows both non-anchor and anchor-based mini grid models to be
commercially viable. In essence, mini-grids can be commercially viable only above a certain threshold of power demand. This threshold is estimated to be 40kWp. Villages lacking in this threshold
community load can be served in a commercially viably manner by a mini-grid if an anchor load such as a telecom tower subscribes to the mini-grid electricity.



Over time, the initiative has placed a greater emphasis on the importance of engaging productive load customers – those that use energy to increase productivity, expand their business, or establish a new business. SPRD has continued to engage a wide variety of productive load businesses such as fuel stations, grain mills, and irrigation pumps, which constitute the typical high-load micro-enterprise customers. These types of units, which account for 7 percent of all micro-enterprises connected to SPRD, have the potential for positive socio-economic impact by creating new employment opportunities within villages. Computer centers, photo-copy units, photo studios, and pharmacies, which are typical medium-load customers and account for close to 13 percent of the customer base, also have high potential for positive socio-economic impact.

Solar Mini-Grids – Case Study: SPRD VII

Aspect	Indicator	Difference attributable to SPRD	Difference attributable to SPRD (monetized)	% Contribution to GDP+
Economic	GDP per capita ($)	3.0	$3.00	16%
Environmental	Carbon footprint per capita (tons CO_2e)	0.08	$0.50	3%
Social	Increase in time for leisure/ productive activities per capita (hrs)	0.5	$15.00	81%
	Reduction in domestic chores per capita (hrs)	0.0		
Net change in GDP+			**$18.50**	

Source: Rockefeller Foundation, 2017b

CLEAN ENERGY SOLUTIONS CENTER
ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY

37

In order to gain deeper insights also into the socioeconomic and environmental impact of the initiative, the GDP+ too has been created, to capture and quantify the key social, economic, and environmental changes generated through rural electrification. Recognizing the limitations of measuring only the monetary value of GDP to reflect the true value of SPRD to communities, the GDP+ tool includes measures of gross domestic product (GDP) as well as social change.

In this case, social change is monetized by analyzing the change in time allocation across economically productive or leisure activities with respect to the existing wage rates, and environmental change is monetized by measuring the reduced carbon footprint with the existing carbon credit prices in the global market. By using this method in eight intervention villages on a bi-annual basis, SPRD was able to illustrate that it created a positive change in economic welfare in its intervention villages by a per capita amount of $18.50. It is interesting to note, as shown in this table, that more than 80 percent of this change was due to social benefits, thus underscoring the importance of social and human capital in achieving impact.

Solar Mini-Grids – Case Study: SPRD VII

Energy source	Carbon dioxide equivalent1 (tons CO_2 equivalent)	March 2016		October 2016		Change (ton CO_2 e/unit)
		Average annual consumption per capita	Total CO_2 emissions (tons CO_2 e/unit)	Average annual consumption per capita	Total CO_2 emissions (tons CO_2 e/unit)	
Firewood (kg)	0.10	213	0.021	162	0.016	-0.005
Kerosene (liter)	2.50	6	0.015	6	0.015	0.000
LPG (liter)	1.70	10	0.018	11	0.019	0.001
Petrol (liter)	2.40	7	0.017	6	0.014	-0.003
Diesel (liter)	2.60	68	0.176	33	0.085	-0.091
Govt. grid electricity (kWh)	0.53	2	0.001	27	0.014	0.013
Total	**0.248**		**0.163**		**-0.085**	

Source: Rockefeller Foundation, 2017b

CLEAN ENERGY SOLUTIONS CENTER
ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY

38

Nevertheless, also the environmental impact is of importance. SPRD has been able to replace or reduce use of kerosene and diesel in households and in micro-enterprises. While replacing fossil fuel has positive effects on the indoor ambience, it also has a significant bearing on environmental stress. The GDP+ measurement factors in this environmental contribution by measuring the reduction in fossil fuel usage, which can then be monetized using the carbon dioxide equivalent factor and the existing global carbon exchange rates. The per capita environmental footprint of SPRD villages was reduced by 0.085 tons of CO2 equivalent. This translates into a contribution of $0.50 to the overall change in GDP+. Reduction in diesel and kerosene usage contributes the most towards reducing the environmental footprint.

4. Concluding Remarks

Concluding Remarks

1. Solar Mini-Grids can come in all shapes and sizes, but generally they find application in situations where neither grid extension nor SHSs are economically viable.

2. The economic viability of Solar Mini-Grids depends on an array of factors which have to be considered during the planning of the project

3. Successfully implemented Solar Mini-Grids can be profitable, and have positive economic and social impact on customers

CLEAN ENERGY SOLUTIONS CENTER
ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY
Factor

40

As always, a single technology can never be regarded as the one-off solution for everything. Solar mini grids are a solution that finds its own application, which is in environments that are not as remote and small and distributed than it has been the topic in the previous lectures on solar home systems. However, the environments in which solar mini grids are implemented remain challenging, and only with sufficient energy demand can these systems gain profitability. In order to ensure this, as we have seen, diligent planning is needed. In the end however, mini grids can be a profitable solution to advance electrification, one that can have positive economic and social impact on its customers and communities.

At this point we come to the end of the module on min girds. I would like to thank you for your attention. As before, you are invited to test your understanding of the concepts in the following small quiz.

Thank you for your time!

E3 ANALYTICS

INTERNATIONAL SOLAR ALLIANCE

IET International Energy Transition

Factor
Ideas for change

CLEAN ENERGY SOLUTIONS CENTER
ASSISTING COUNTRIES WITH CLEAN ENERGY POLICY

5. Further Reading

EEP, 2018, Opportunities And Challenges In The Mini-grid Sector In Africa. https://eepafrica.org/wp-content/uploads/EEP_MiniGrids_Study_DigitalVersion.pdf

GIZ, 2016, What Size Shall It Be? https://reiner-lemoine-institut.de/wp-content/uploads/2016/09/Mini_Grid_Sizing_Guide.pdf

MIA, 2017, Microgrid Market Analysis & Investment Opportunities. https://sun-connect-news.org/fileadmin/DATEIEN/Dateien/New/MIA_Market_Report_2017.pdf

Rockefeller Foundation, 2017a, Expanding opportunities for Renewable Energy Based Mini-Grids in Rural India. https://assets.rockefellerfoundation.org/app/uploads/20170516121444/Expanding-Opportunities-for-Renewable-Energy-Based-Mini-Grids-in-Rural-India.pdf

Rockefeller Foundation, 2017b, Understanding the Impact of Rural Electrification in Uttar Pradesh and Bihar, India: Evidence from The Rockefeller Foundation's Smart Power for Rural Development Initiative. https://assets.rockefellerfoundation.org/app/uploads/20170517145311/SPRD-Impact-Report-Final-May-2017.pdf

Usaid.gov, Mini-Grid Support Toolkit. https://www.usaid.gov/energy/mini-grids

6. Knowledge Checkpoint: Multiple Choice Questions