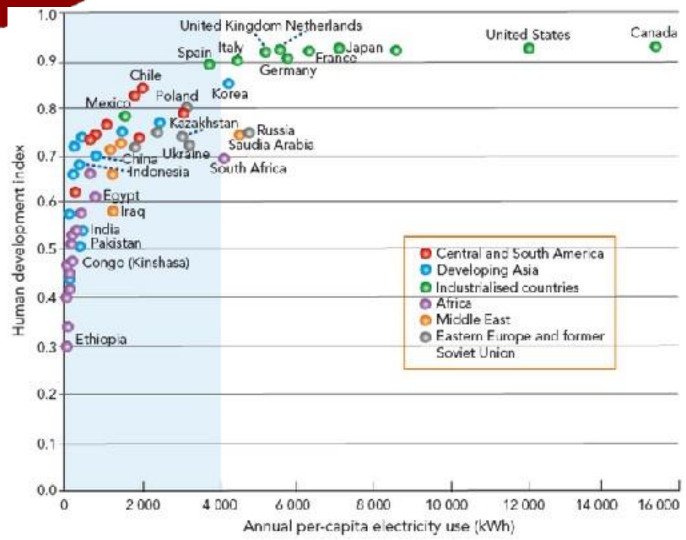
Case Studies Hybrid Mini Grids as Model of Rural Electrification and it's Financing

Energy is the principal link between **human** and **planetary** wellbeing.

100% of human development is dependent on energy services.



72% of global greenhouse gas emissions come from the energy sector.

Are we moving in the right direction?

	2010	2017
Electricity access	**1.2 billion** people without electricity access	**840 million** people without electricity access
Clean cooking	**2.96 billion** people without clean cooking	**2.90 billion** people without clean cooking
Renewables	**16.6%** total final energy consumption from renewables	**17.5%** total final energy consumption from renewables (2016)
Energy intensity	**5.9 MJ/USD** primary energy intensity	**5.1 MJ/USD** primary energy intensity (2016)

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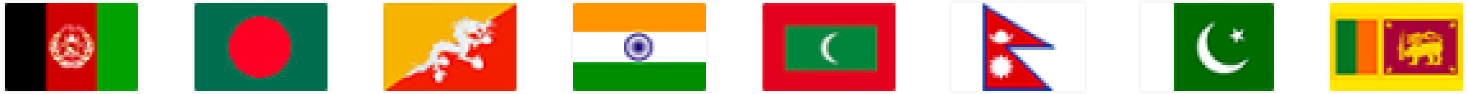
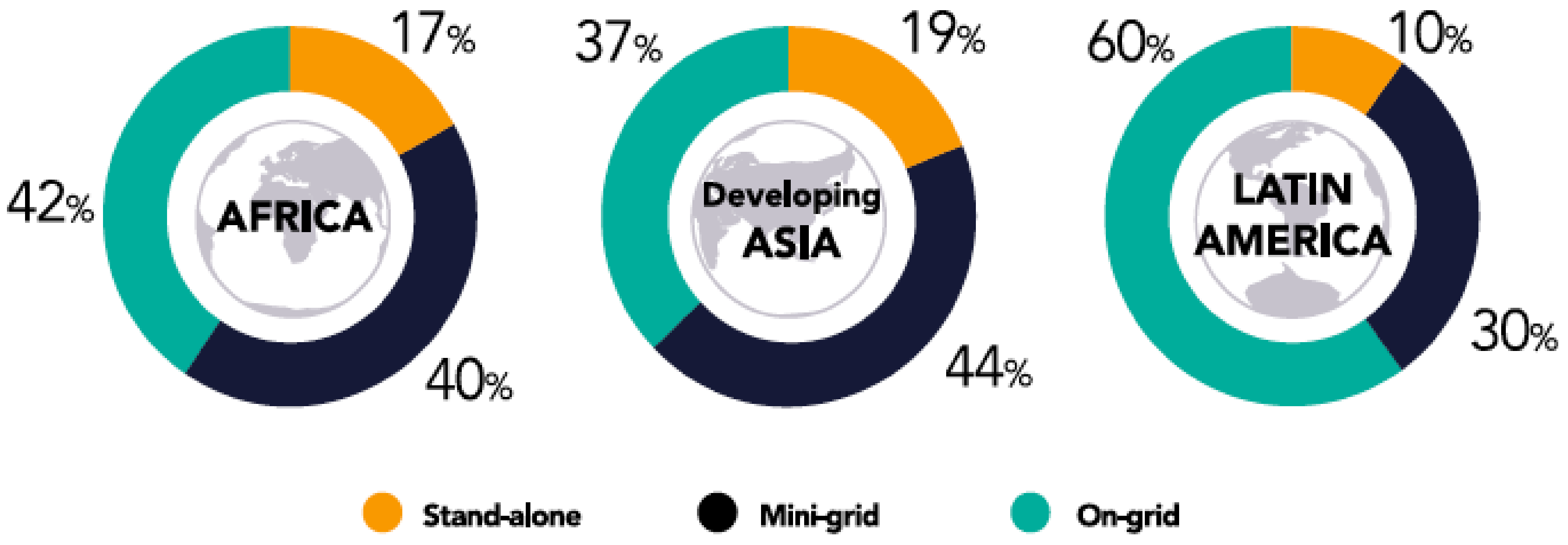


Estimated Source of Additional Generation Required for Universal Electricity Access by 2030



Where does hybrid minigrid fits in?

- Compared with the main grid and solar home systems, mini grids are a more viable solution for off-grid areas with high population density and demand.
- Extending the main grid to serve remote communities that consume a limited number of kilowatt-hours (kWh) per month is prohibitively costly in most cases.
- solar home systems are ideal for areas with low population density and low demand.
- Mini grids are generally the most economically viable option for servicing areas that are too expensive for the main grid to reach in a timely manner but have high enough demand and population density to support commercial viability.

Role of Miniogrids Now and in Future

- 47 million people connected to 19,000 mini grids, mostly hydro and diesel-powered, at an investment cost of **$28 billion**
  - Most of these mini grids are diesel-fueled, followed by hydro-powered and solar-hybrid systems

- By 2030, 490 million people will be served by 210,000 mini grids, requiring an investment of **$220 billion**.
  - Most of these grids will be solar-hybrids

Environmental Impact by 2030

10–15 GW Solar PV installed by 2030

50–110 GWh Batteries mostly lithium-ion

60% Energy Savings from energy efficient appliances

1.5 billion Tons of CO_2 emissions avoided

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Regional Trends of Microgrids

INSTALLED (Mostly 1st and 2nd generation mini grids)		PLANNED (Mostly 3rd generation mini grids)	
1,500	Africa	4,000	Africa
6,900	East Asia & Pacific	900	East Asia & Pacific
1,100	OECD & Central Asia	200	OECD & Central Asia
9,300	South Asia	2,200	South Asia
300	Other	200	Other

Top 5 Countries . . .

INSTALLED (Mostly 1st and 2nd generation mini grids)		PLANNED (Mostly 3rd generation mini grids)	
4,980	Afghanistan	1,905	India
3,988	Myanmar	1,217	Senegal
2,800	India	879	Nigeria
1,519	Nepal	506	Indonesia
1,184	China	301	Tanzania

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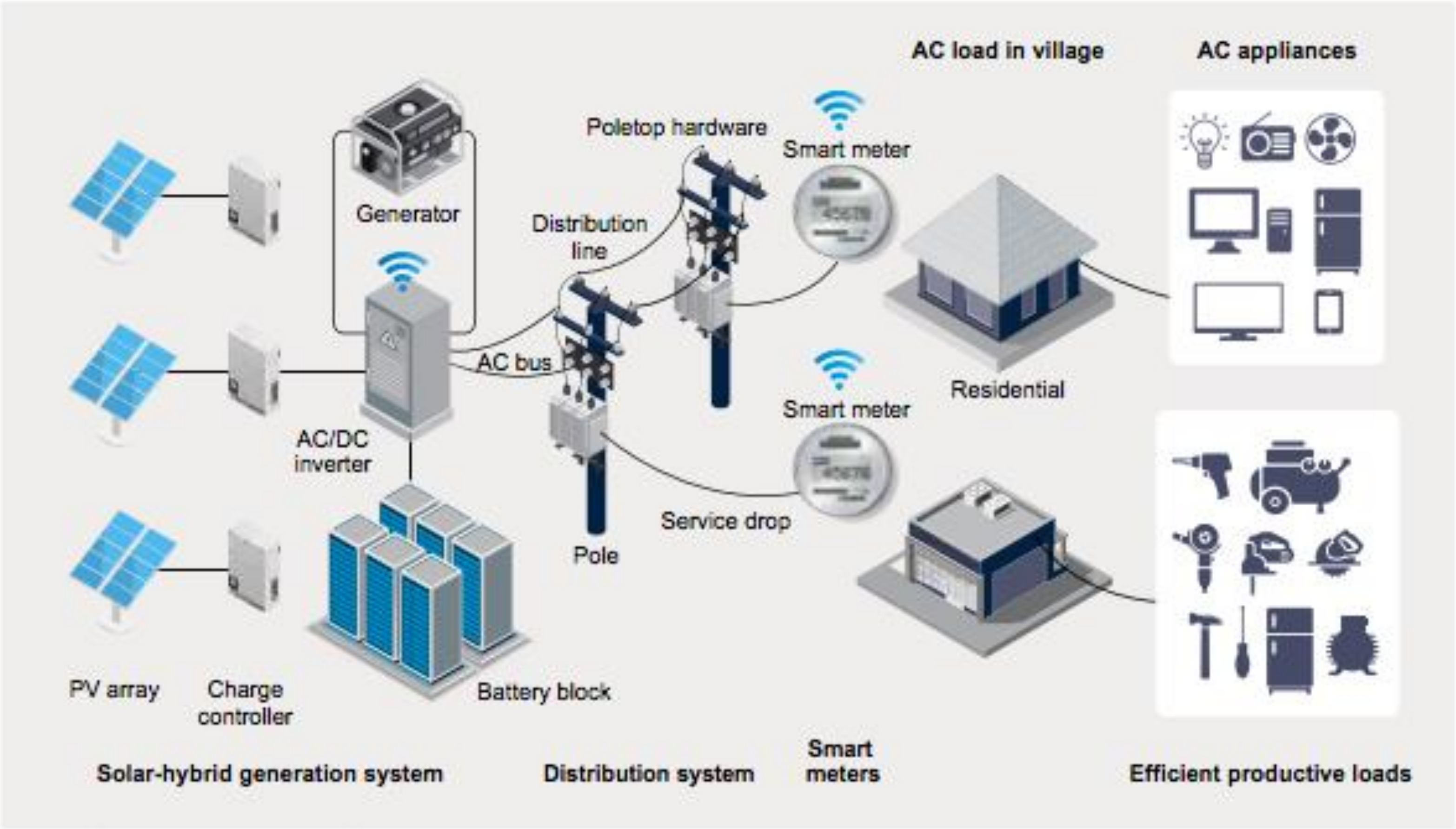
How does this Solar hybrid microgrid look like?



The 'third generation' of mini-grids can provide 24x7 reliable, locally managed power with local ubiquitously available resources such solar (combined with storage, diesel backup or both), as well as with biomass, hydro and wind.

Typical 3rd Generation Mini Grid

0.5–1.0 million US$ investment

200–800 Clients connected

800–4,000 People receiving electricity for the first time

50–100 kWp Solar PV installed

200–500 kWh Batteries installed

Characteristics of 3rd Generation Minigrid

- Use the latest mini grid component technologies, which are declining in cost
- Introduce and encourage the use of energy-efficient appliances, which can reduce the required installed capacity of a mini grid by 60 percent or more
- Enable productive uses of electricity, which reduces kWh unit costs, increases profitability, and promotes local economic development
- Provide superior-quality service, often above 97 percent uptime, to satisfy customer demands and build credibility for the product and industry
- Use remote-controlled energy management systems, Web-based data platforms, and prepay smart meters to reduce operating costs and increase revenue collection
- Use innovative solutions, such as video-exchange hubs, to engage communities that are geographically dispersed early in the sensitization processes to accelerate early uptake of electricity consumption and have the communities' buy-in of the electricity pricing strategy
- Follow standardized designs for components and processes to lower manufacturing, installation, and operating costs
- Are typically designed to interconnect with the main grid, to mitigate investment risk when the main grid arrives
- Are built as part of a developer's portfolio instead of as a one-off project, aided by geospatial analysis, to achieve economies of scale and attract investment

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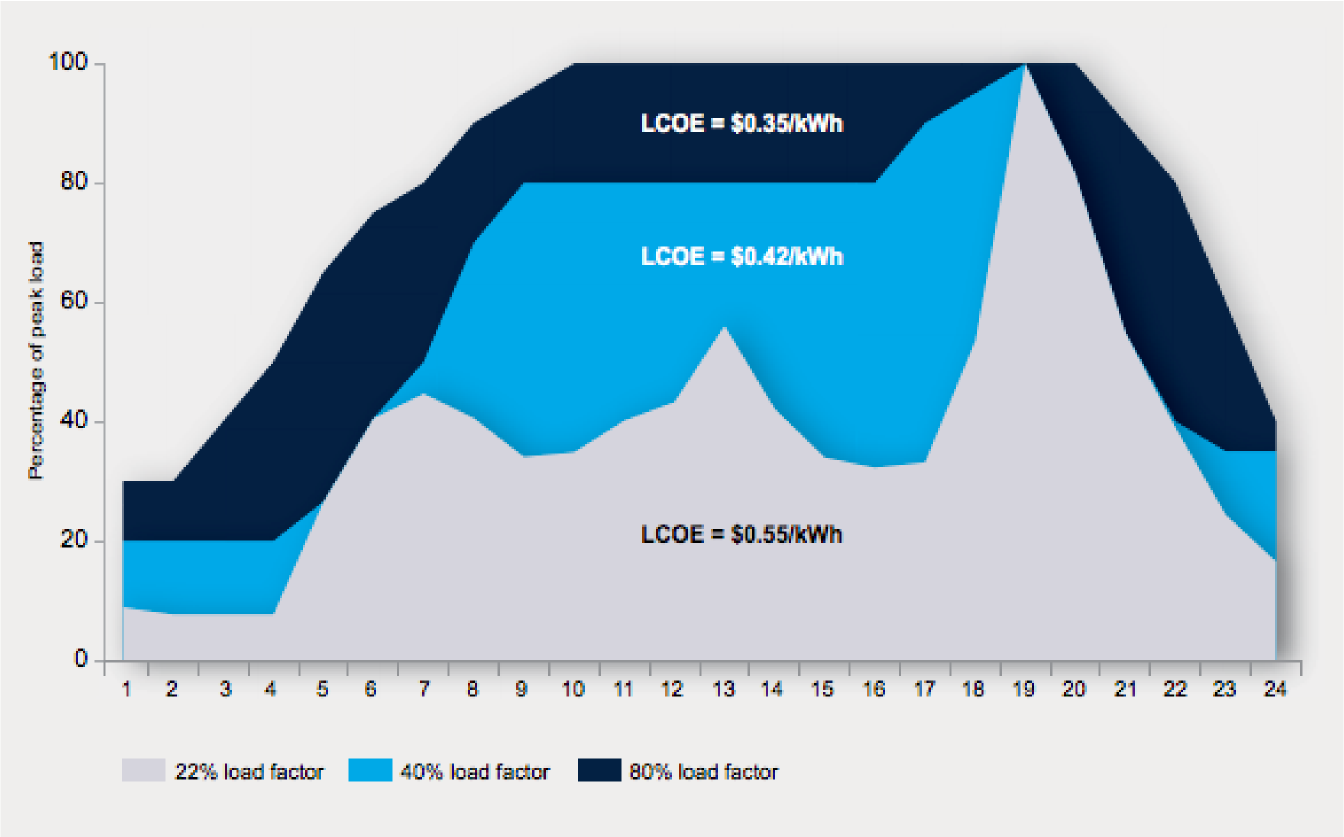
Cost Trends of Minigrids

- Capital costs have come down from more than $8,000 per kilowatt of firm power output (kWf) in 2010 to $3,900/kWf in 2018.
- The upfront investment cost of solar and solar-hybrid mini grids are expected to drop below $3,000/kWfirm by 2030.
- A well-designed solar-battery-diesel hybrid mini grid serving more than 1,500 people has a levelized cost of energy (LCOE) of about $0.55/kWh when it serves household customers, giving it a load factor of about 22 percent
- The LCOE of these mini grids can be reduced by up to 25 percent ($0.41/kWh) by 2020.
- If component costs also decline as expected, the LCOE could fall by 60–70 percent to around $0.20/kWh by 2030

What if we can't wait till 2030?: Increase Load Factor



Load factor (percent)	Levelized cost of electricity ($/kWh)	
	2018	2030
22%	0.55	0.33
40%	0.42	0.22
80%	0.35	0.23[7]

Where a 40 percent load factor was achieved through significant daytime consumption by local businesses and commercial clients, the LCOE fell by 25 percent compared with the base case. For an 80 percent load factor—achieved by inclusion of a water pump with storage tank and an anchor load, such as a telecom tower, for example—LCOE reduction was 37 percent.

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How to Improve Load Factor: Productive Use of Renewable Energy

Sector	Activities / Appliances	Power required (kW)	Cost from supplier ($)	Payback period (months)
Primary industries (agriculture, fishing)	Egg incubator	80 to 160W	$50 to $100	1 to 3
	Grinder for pulses and beans	5.2 kW	$1,500 to $4,000	6 to 12
	Water irrigation pump	3.7 to 22.4 kW	$200 to $1,000	3 to 6
	Sterilizer (for dairy processing)	3 to 6kW	$600 to $2,000	1 to 3
	Packager	250W to 3kW	$500 to $1,000	6 to 12
Light manufacturing	Electronic welding machine	3 to 7.5 kW	$200 to $300	6 to 12
	Jigsaw	400W	$100	3 to 6
	Electric drilling machine	400W	$20 to $50	3 to 6
	Popcorn maker	1.5 to 2.1 kW	$50	1 to 3
Commercial and retail activities	Computer	15 to 100W	$250 to $800	3 to 6
	Printer/scanner for stationery	0.5 to 2kW	$150 to $250	3 to 6
	Sewing machine	200W	$30 to $100	3 to 6
	Television for local cinemas and bars (including decoder)	50 to 200W	$100 to $200	1 to 3

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De-risking mini grid for Private Sector Investment

- Compared to large utility investments, higher risk profiles of mini-grids come with investor expectations for considerably shorter payback periods and higher returns and internal rates of investment (IRR).
- For the time being, the return of mini-grids is typically in the range of 10 to 15% IRR, significantly lower than the 20% and above a typical investor would expect for a comparable on-grid project.
- To resolve this challenge of a mismatch between return on investment to actual and perceived risks, two main options are available for private developers:
  - Improve the IRR to compensate for the higher risk (by increasing tariffs charged to end-users);
  - Reduce the risk of the project, so that the lower risk profile of the business model corresponds to the low IRR the projects generate.
- The other option is to reduce risks in the project in order to lower the risk profile. To do so, developers will need to mitigate risks along the phases of mini-grid projects

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Project Phase	Potential Risks to mitigate						
Site identification and Selection	Payment (off-taker) risks	Political and financial risks	Land rights risk	Theft or vandalism risk	Environmental and force majeure risks	Demand risk	Social acceptance risk
Technical design and selection of hardware	Technology risk	Resource price variability risk	Construction competition risk	Environmental and force majeure risks			
Operations and maintenance	Operational risk	Theft or vandalism risk	Payment (off-taker) risk				
Revenue and financing sources	Social acceptance risk	Payment (off-taker) risk	Foreign exchange risk	Political risks			
Billing and metering	Payment (off-taker) risk	Demand risk	Operational risks				

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Case Studies of Minigrids

#	Private Developer	Location	Size & Technology
1	Rahimafrooz Renewable Energy	Ghorjan Island, Bangladesh	80 kWp solar PV Hybrid
2	Mlinda Founation	Sahitoli, India	22.4 kWp solar PV hybrid
3	Tara Urja	Derni, India	31.2 kWp solar PV hybrid
4	Yoma Micro Power	Thit Seint Gyi Village, Myanmar	31.2 kWp solar PV hybrid
5	Gham Power	Khotang, Nepal	52 kWp solar PV hybrid
6	Subas and Sujan Electric Service Center	Simli Khola, Nepal	29 kWp hydro

#	Private Developer(s)	Project	Main criteria for Site Selection
1	Rahimafrooz Renewable Energy	Ghorjan Island, Bangladesh	Economic development potential, distance from national grid
2	Mlinda Foundation	Sahitoli, India	Economic development potential
3	Tara Urja	Derni, India	Economic development potential
4	Yoma Micro Power	Thit Seint Gyi Village	Economic development potential (anchor client), distance from national grid
5	Gham Power	Khotang, Nepal	Economic development potential, distance from national grid, proximity to company HQ (ease of transport)
6	Subas and Sujan Electric Service Center	Simli Khola, Nepal	Distance from national grid, community demand

Technical Design and Selection of Hardware

Private Developer(s)	Energy Storage	Distribution System
Rahimafrooz Renewable Energy	Flooded Lead- acid (538.56 kWh)	AC three phase LT 230 V
Mlinda Foundation	Lead-acid VRLA (71.28 kWh)	AC single phase 230 V and three phase 415 V
Tara Urja	Lead-acid VLRA x(96 kWh)	AC single phase 230 V
Yoma Micro Power	Lead-acid VLRA (192 kWh)	AC single phase 230 V and three phase 415 V
Gham Power	Lead-acid Exide (336 kWh)	AC single phase 230 V
Subas and Sujan Electric Service Center	n/a	AC single phase 230V and three phase 400 V

Operations and Maintenance

Private Developer(s)	Operations and Maintenance Measures
Rahimafrooz Renewable Energy	Remote monitoring, training of supervisor
Mlinda Foundation	Remote monitoring, clustering (engineer shared between several grids), training of local community
Tara Urja	Remote monitoring through real-time Data Management System, integrated mobile application for field agents and customer service application (Smart Connect), two local operators including technician and field agent for mini-grid.
Gham Power	Local operators hired from among the communities and trained, Remote monitoring
Subas and Sujan Electric Service Center	Maintenance fund established, local private company has taken over O&M of community-run mini-grid
Yoma Micro Power	Remote monitoring, clustering (cluster of 4-5 grids has one O&M engineer)

Revenue and Financing Sources

Private Developer	IRR	Financing sources	Revenue model
Rahimafrooz Renewable Energy	10% over 10 years	40% grant, 40% Load, 20% Debt	Micro-utility
Mlinda Foundation	15 IRR% (7 years payback)	55% grant, 20% equity, 25% debt	Micro-utility
Tara Urja	IRR not calculated (6 years payback time)	100% grant	Micro-utility (ABC model)
Yoma Micro	IRR not calculated (7 years payback time)	100% equity	Micro-utility (ABC model), service packages for households, price per kWh for productive uses, PPA with telecom towers
Gham Power	IRR 10% over 10 years	Mix of grant, equity and debt (% not disclosed	Service Packages (ABC model)
Subas and Sujan Electric Service Center	n/a	75% Grant and 25% equity	PPA (O&M with local community)

Billing and Metering

Private Developer(s)	Billing solution	Metering solution
Rahimafrooz Renewable Energy	Voucher model (smart card from vending station)	Pre-paid smart meter
Mlinda Foundation	Cash Collection	Pre-paid smart meters
Tara Urja	Cash collection	Pre-paid smart meters
Yoma Micro Power	Mobile money	Pre-paid smart meters
Gham Power	Mobile money	Pre-paid smart meters
Subas and Sujan Electric Service Centre	Cash collection	Post-paid meters

Key Recommendations

- Map out the potential of different productive uses of RE including productive and energy efficient appliances (both AC and DC), as well as income generation from coupling energy access with other sectors, such as agriculture, fishery, refrigeration and digital services.
- Start the community engagement process from the earliest stage of the project to understand what productive uses can be connected. Conduct additional studies on which types of financing and capacity building are effective at the end-user level to increase the uptake of productive appliances (e.g. micro-loans, entrepreneurial training to local community groups).
- With partnerships between the mini-grid sector and the telecom sector focusing on the wider spread use of mobile money, as well as mapping of demand via mobile phone coverage maps, further gains in terms of better quality and cost reductions can be made.
- Explore the potential of the newest digital technologies and their role in optimising mini-grid site selection, system design processes, O&M and payment models.
- Public-private partnerships can be leveraged to increase the financial sustainability and to lower the risk of projects, while securing utility or government buy-in in projects.

Thank You

Major Sources

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