EXECUTIVE SUMMARY

Mini Grids for Half a Billion People

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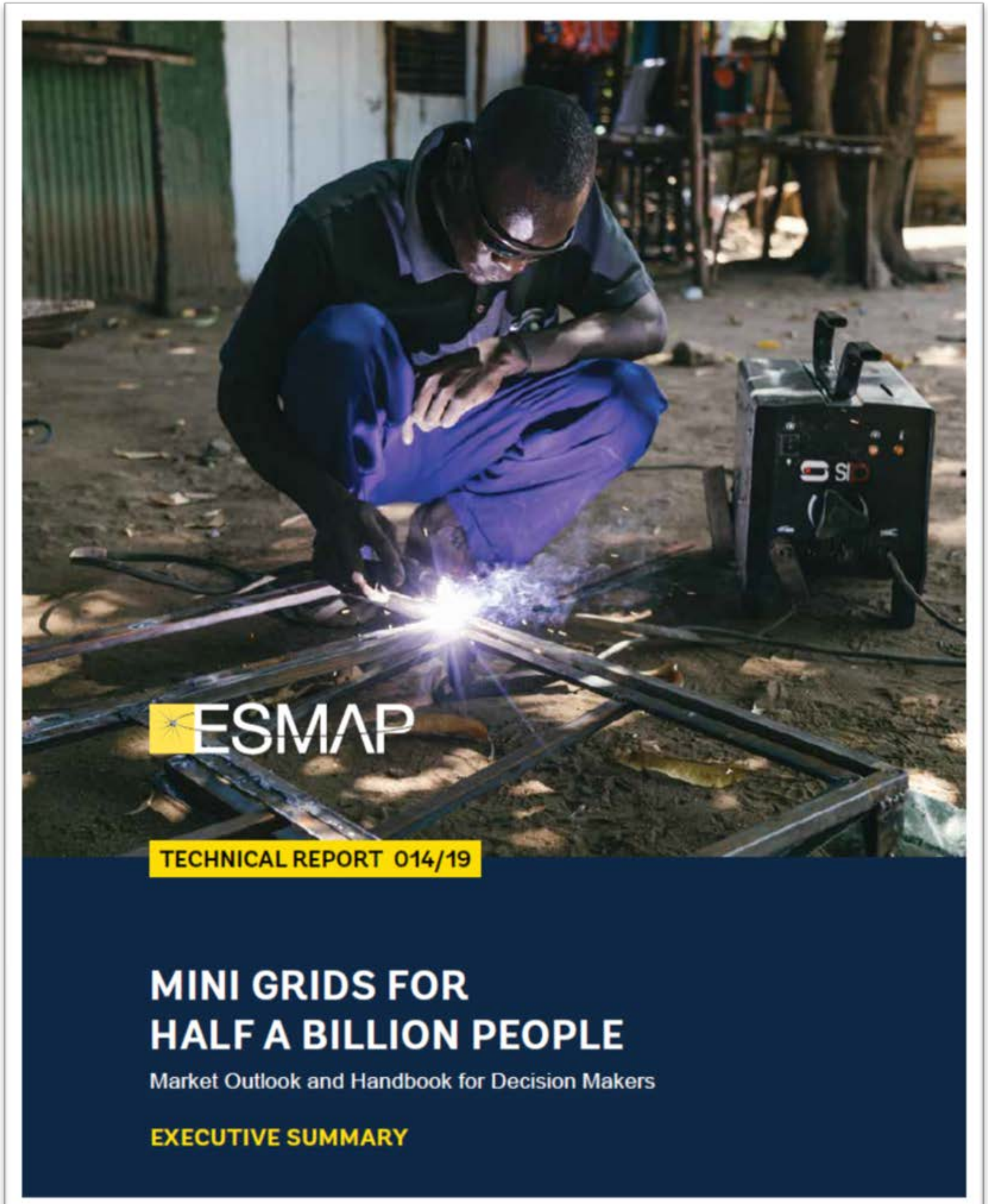
Energy & Extractives

HOMER Webinar

July 25, 2019



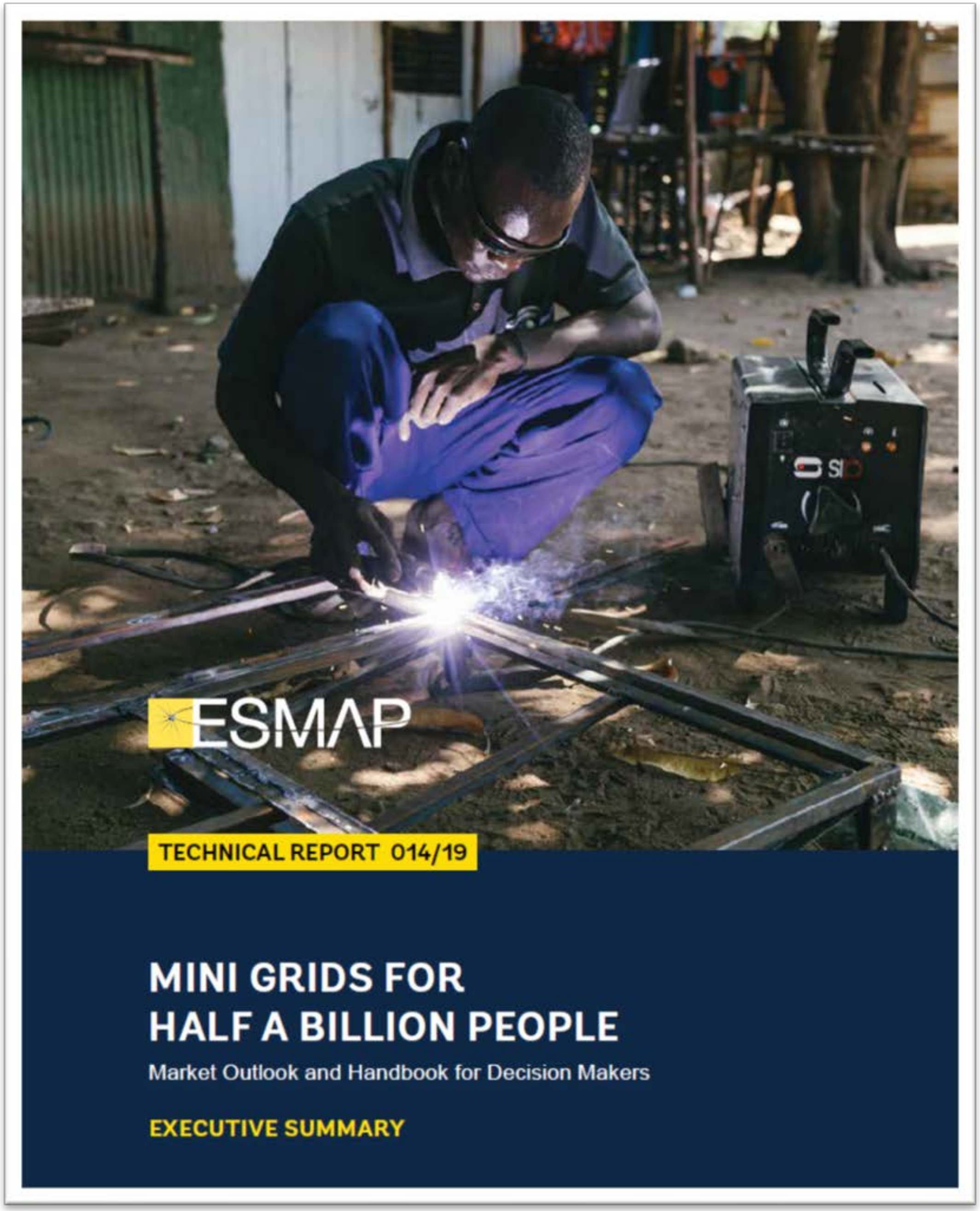
5 Action Learning Events with about 2,000 participants in total

10 knowledge frontiers researched in detail

Learning by doing through 37 World Bank mini grid operations for example Bangladesh, Myanmar, Kenya, Nigeria, Haiti possibly Ethiopia and Ghana

Roster of outstanding experts and magnificent team

Partnerships for example with:
industry: AMDA, companies
civil society: RMI, SNV
development partners: DFID, CIF, AfDB, GIZ
service providers: HOMER, Odyssey, Castalia, TTA, Inensus
research: NREL, MIT
host and client governments



Databases with:

- **26,000 mini grid projects**
- **53 solar (hybrid) mini grids with detailed CAPEX costing**
- **1,000+ operator surveys in 3 countries**
- **37 World Bank mini grid investments in 33 countries**

Executive report part of knowledge package with focus on implementation:

- **500 page main report, answering the 'how' question**
- **Volume with supporting annexes**
- **Volume with country and case studies**
- **Videos, animations, infographics**
- **More than dozen presentations**

A **mini grid** is

anything else than the main grid.

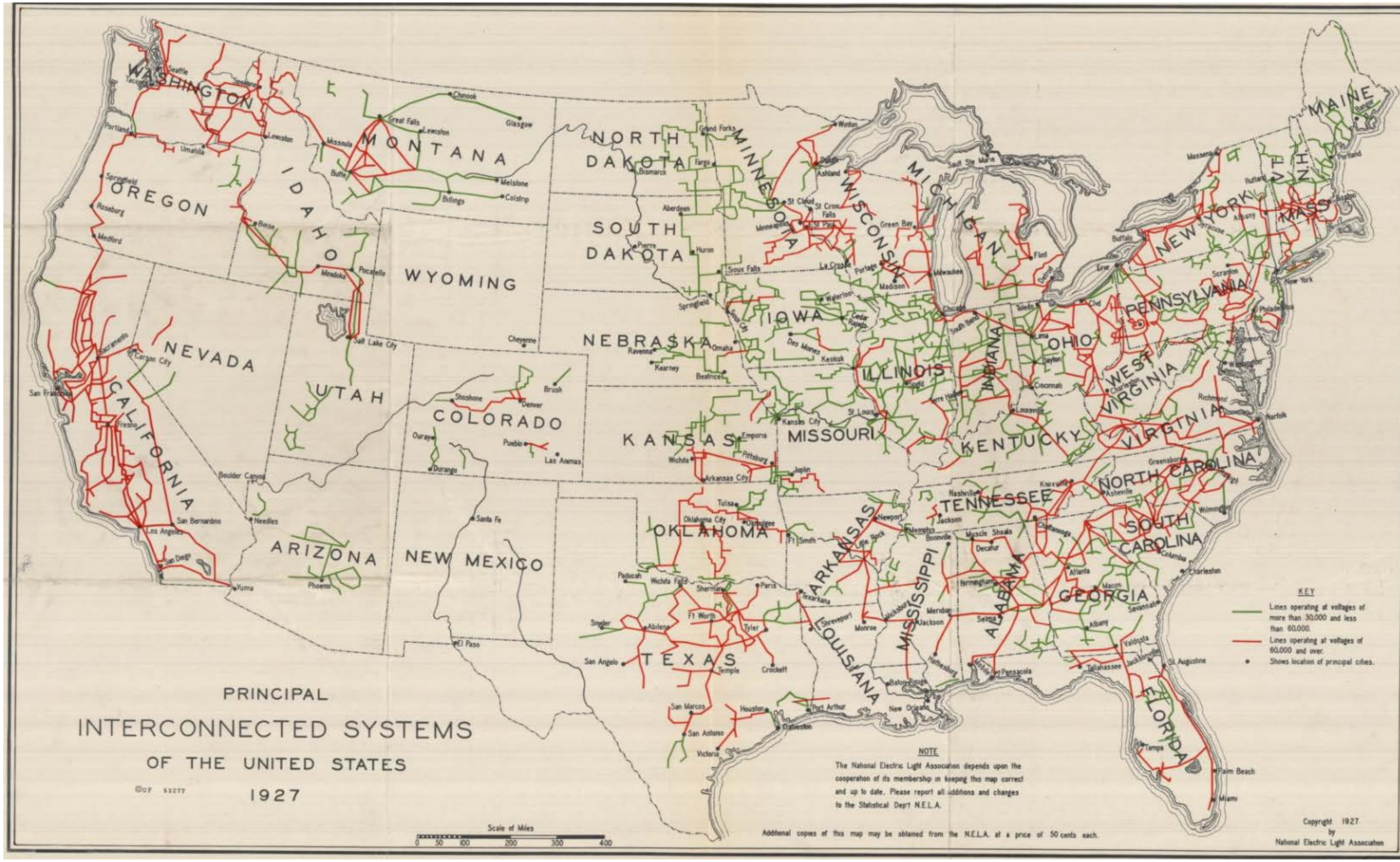
A **mini grid** is an electricity generation and distribution network that supplies electricity to a localized group of customers.

Mini grids can be isolated from and/or connected to the main grid.

Definition of a Mini Grid

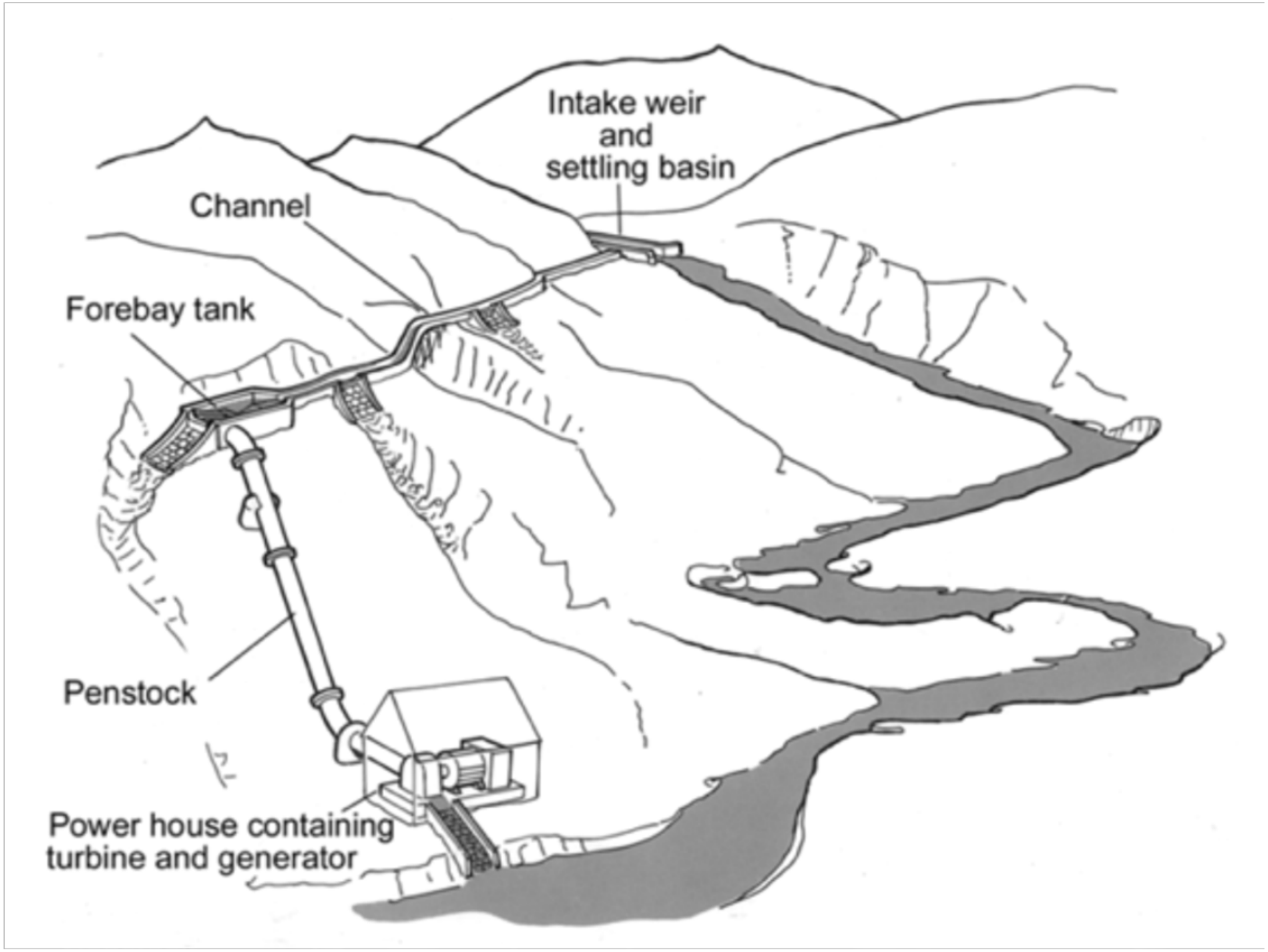
Mini grids are electric power generation and distribution systems that provide electricity to just a few customers in a remote settlement or bring power to hundreds of thousands of customers in a town or city. They can be fully isolated from the main grid or connected to it but able to intentionally isolate ("island") themselves from the grid. Mini grids supply power to households, businesses, public institutions, and anchor clients, such as telecom towers and large agricultural processing facilities. They are designed to provide high-quality, reliable electricity. A new, third generation"of mini grids has recently emerged, which are solar hybrids, incorporate the latest technologies such as smart meters and remote monitoring systems, and are typically designed to interconnect with the main grid. The "Where Mini Grids Fit in the Electricity Sector" section provides a detailed description of 3rd generation mini grids.

1st Generation of Mini Grids

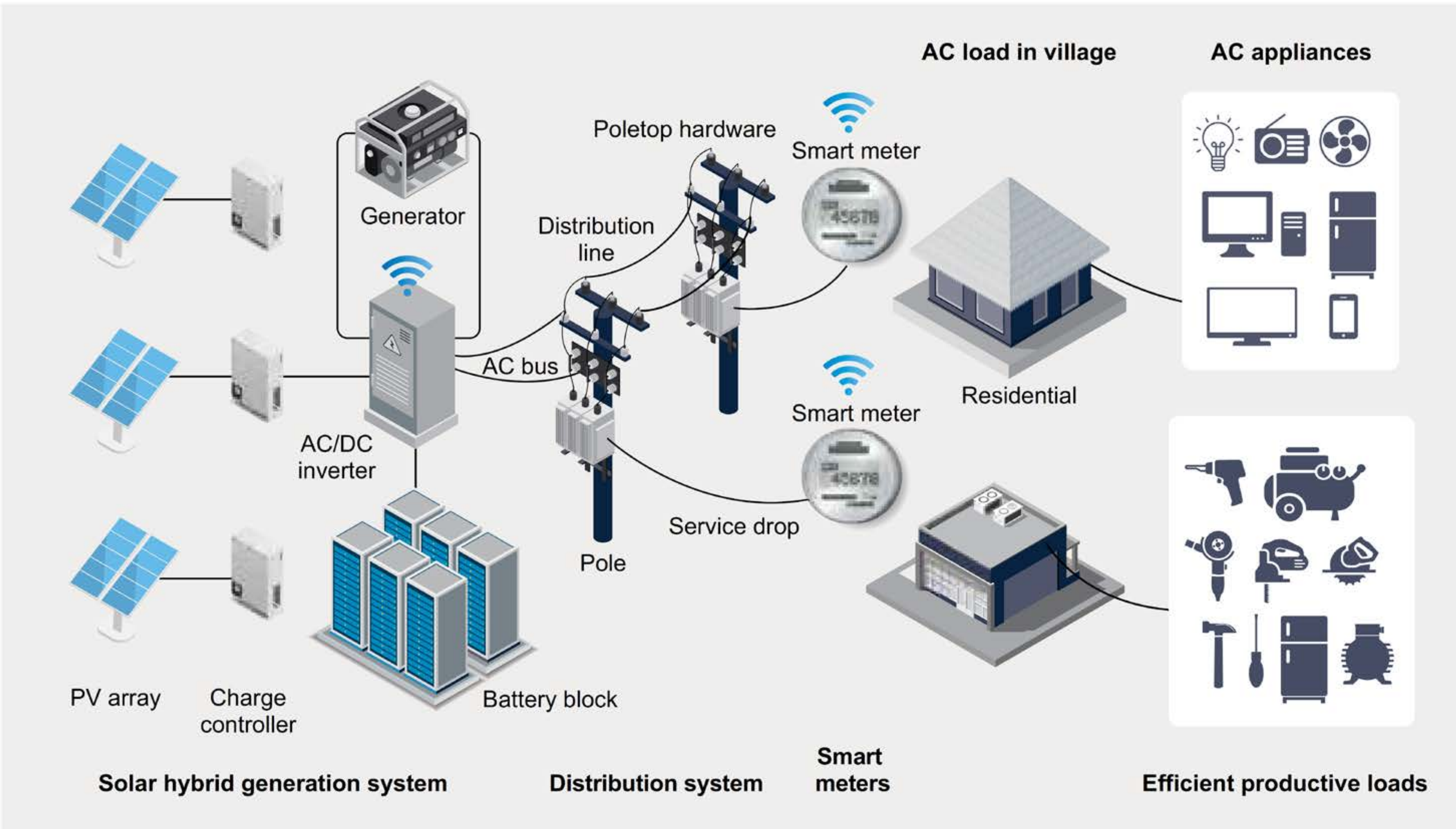


U.S. power system network in 1927

2^{nd} Generation of Mini Grids



3RD GENERATION OF MINI GRIDS



Note: AC = alternating current; DC = direct current; PV = photovoltaic.

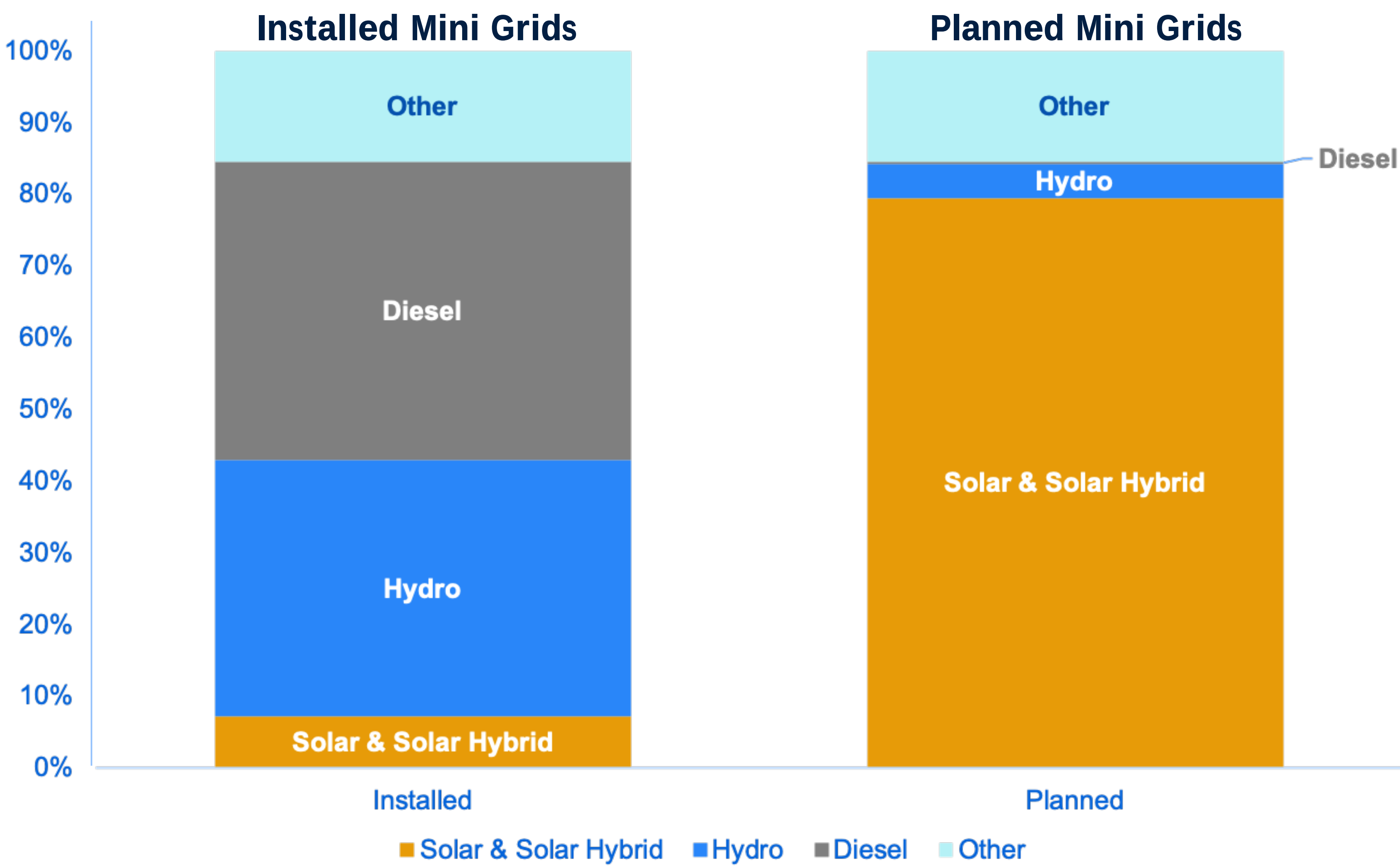
10 BUILDING BLOCKS AND FRONTIERS

- Innovative Technology
- Income-generating use of electricity
- Training and Skill Development
- Geospatial & Portfolio Planning
- Community Engagement
- Private Sector Participation
- Workable Regulations
- Enabling Business Environment
- Access to Finance

Institutional Arrangements

From diesel and hydro to solar hybrid systems

Innovative Technology



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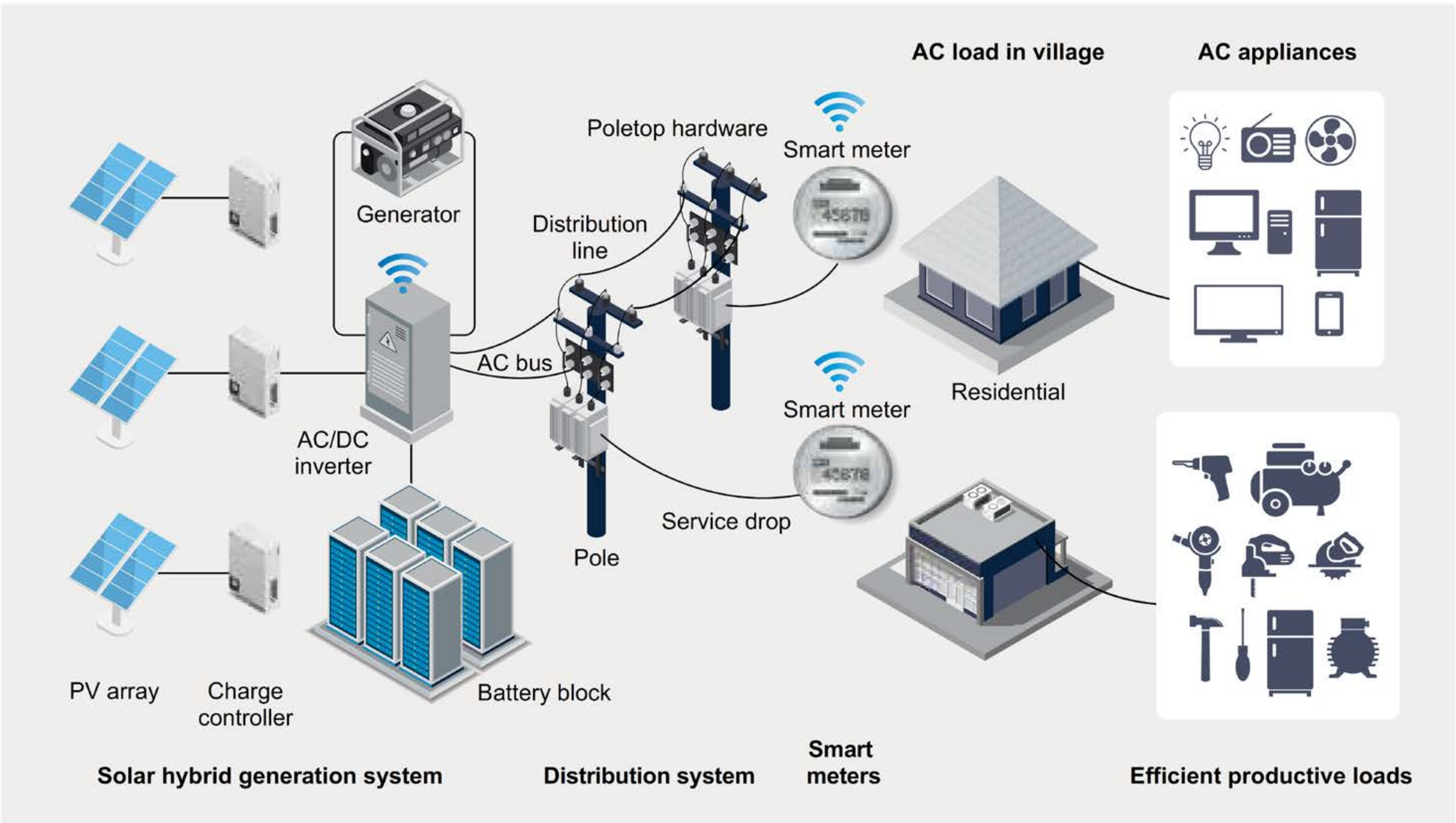
REMOTE CONTROLLED | SMART METER ENERGY EFFICIENT APPLIANCES | GRID INTERCONNECTION READY

Innovative Technology

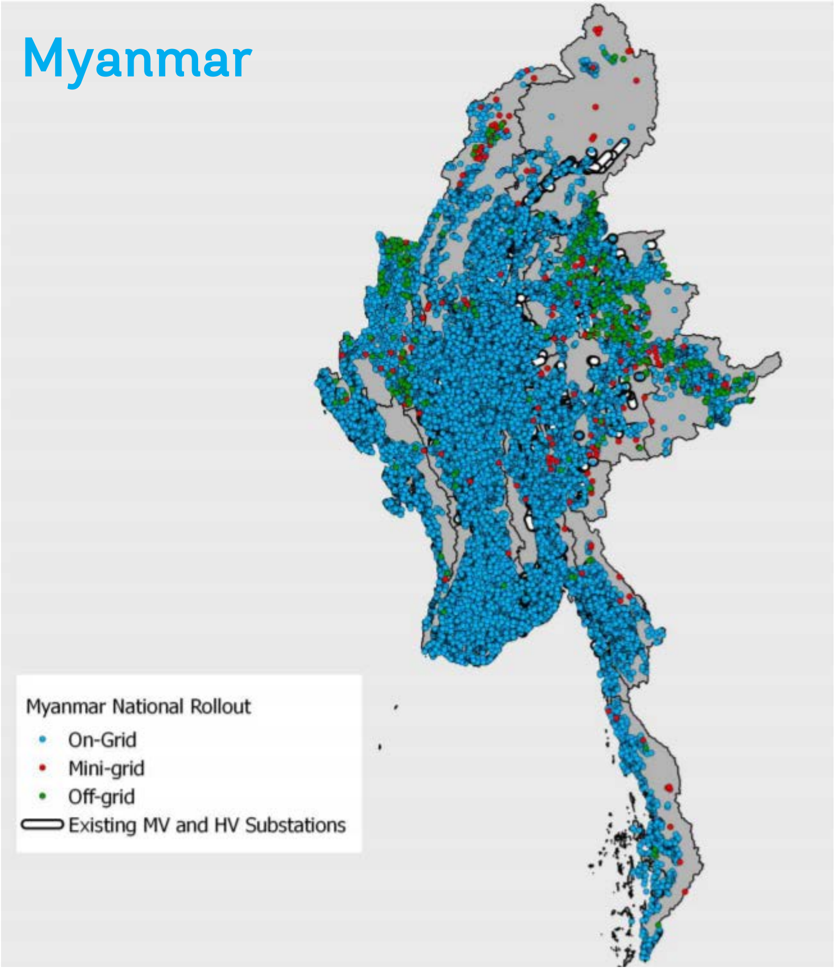


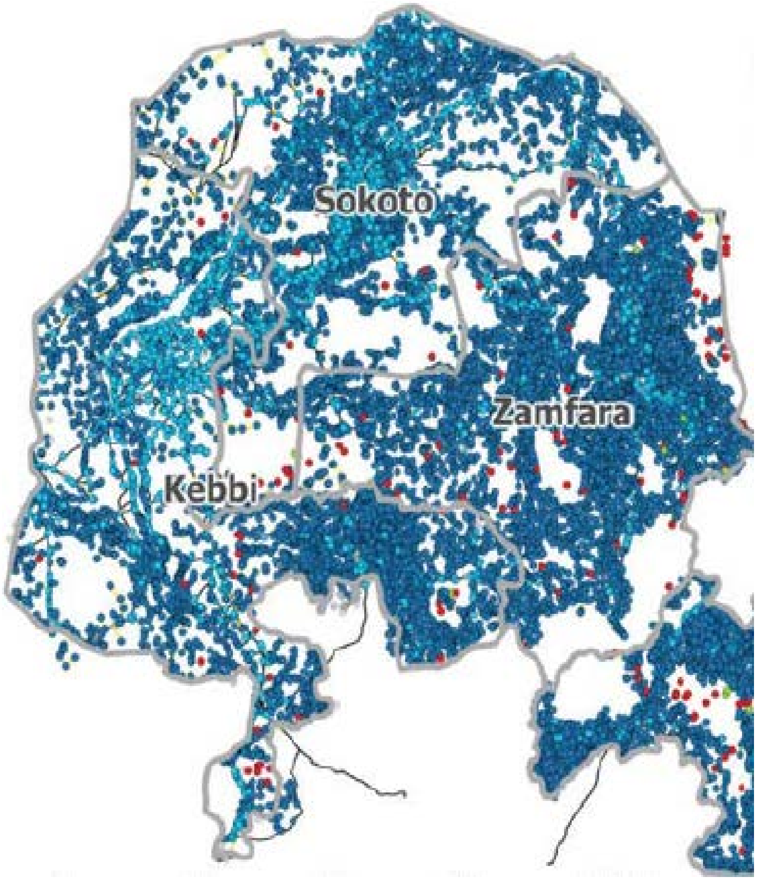
Note: AC = alternating current; DC = direct current; PV = photovoltaic.

National Least-Cost Electrification Planning

Grid Extension | Mini Grid | Off-grid

Geospatial & Portfolio Planning





Source: Myanmar National Electrification Program (NEP) Roadmap and Investment Prospectus, Castalia, 2014; Achieving Universal Access in the Kaduna Electric service area, World Bank, 2015

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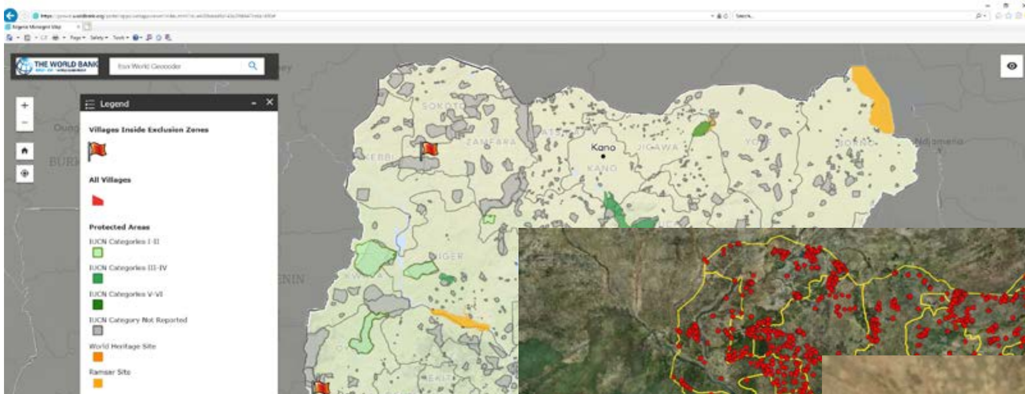
Mini Grid Portfolio Planning

Magnitude Change in Costing | $3,200 per site

Geospatial & Portfolio Planning



	No diesel constraint		Diesel limited to 20%	
	Size	Capital (USD $)	Size	Capital (USD $)
Solar PV + installation	535 kW	374,150	914 kW	639,450
Battery + installation	-	-	9,174 kWh	1,994,400
Diesel Generator	350 kW	126,000	100 kW	36,000
Inverter	403 kW	84,304	404 kW	84,304
MPPT Charge controller	-	-		96,634
Distribution network	17.3 km	284,386	17.33 km	284,386
Total		868,840		3,135,174
Network Design	Length (km)	Capital (USD $)		
Weasel	13.4	160,735		
Ferret	0.5	6,305		
Rabbit	0.9	12,019		
Horse	0.2	2,930		
Dog	1.0	19,280		
Dingo	0.4	10,233		
Panther	0.5	12,454		
Zebra	0.3	23,637		
Other	0.2	36,793		
Sub Total	17.3	284,386		

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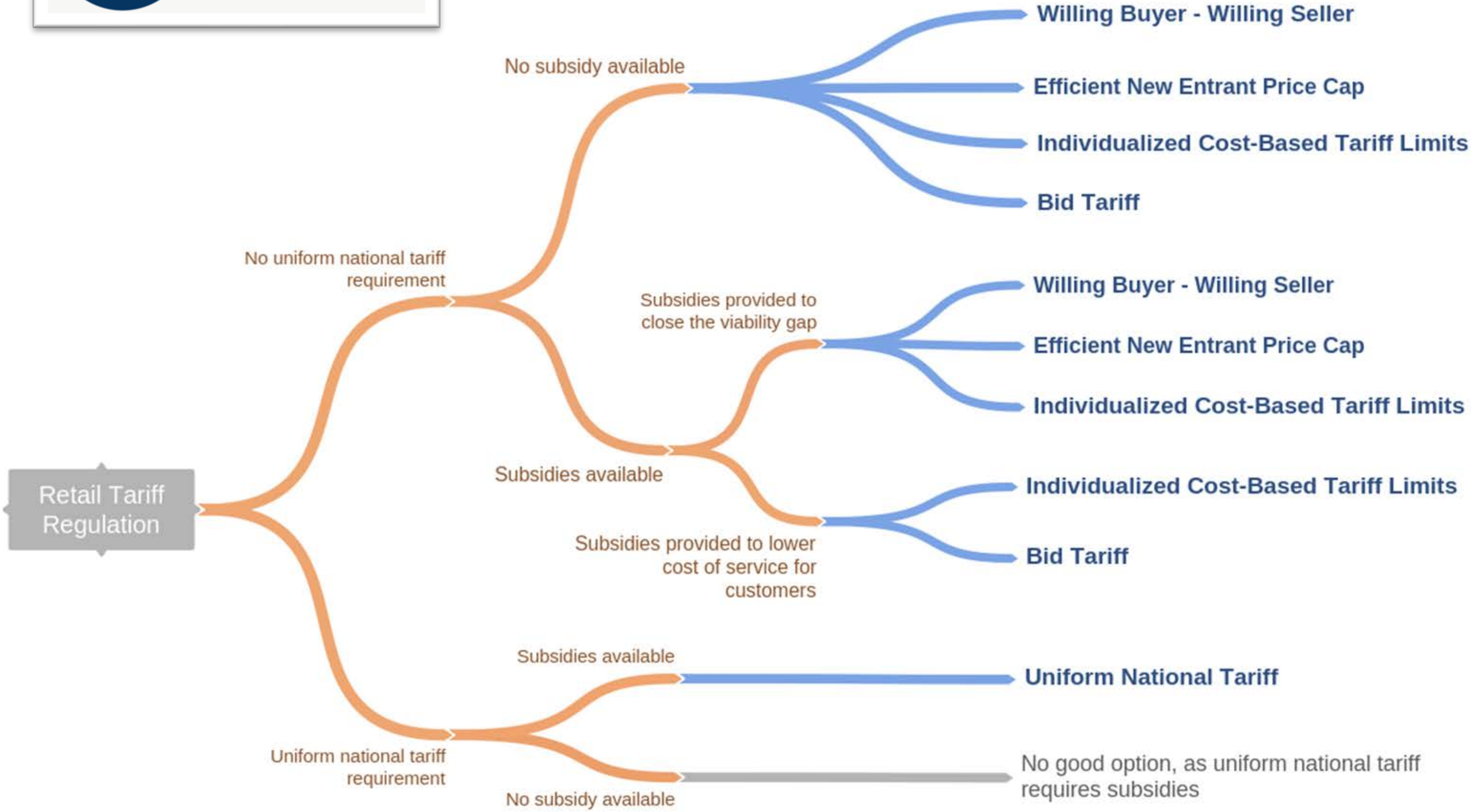
Adoption of Mini Grid Regulations

Key topics in mini grid regulation include:

- **Entry** to the market
- **Retail tariff**—tariff charged to customers
- **Service standards**—quality of power, quality of supply, quality of commercial services
- **Technical standards**—safety, equipment or construction quality, connection with the main grid, environmental sustainability
- **Relationship with the main grid**—commercial options available for the mini grid developer when the main grid arrives

Non-prescriptive
Decision trees



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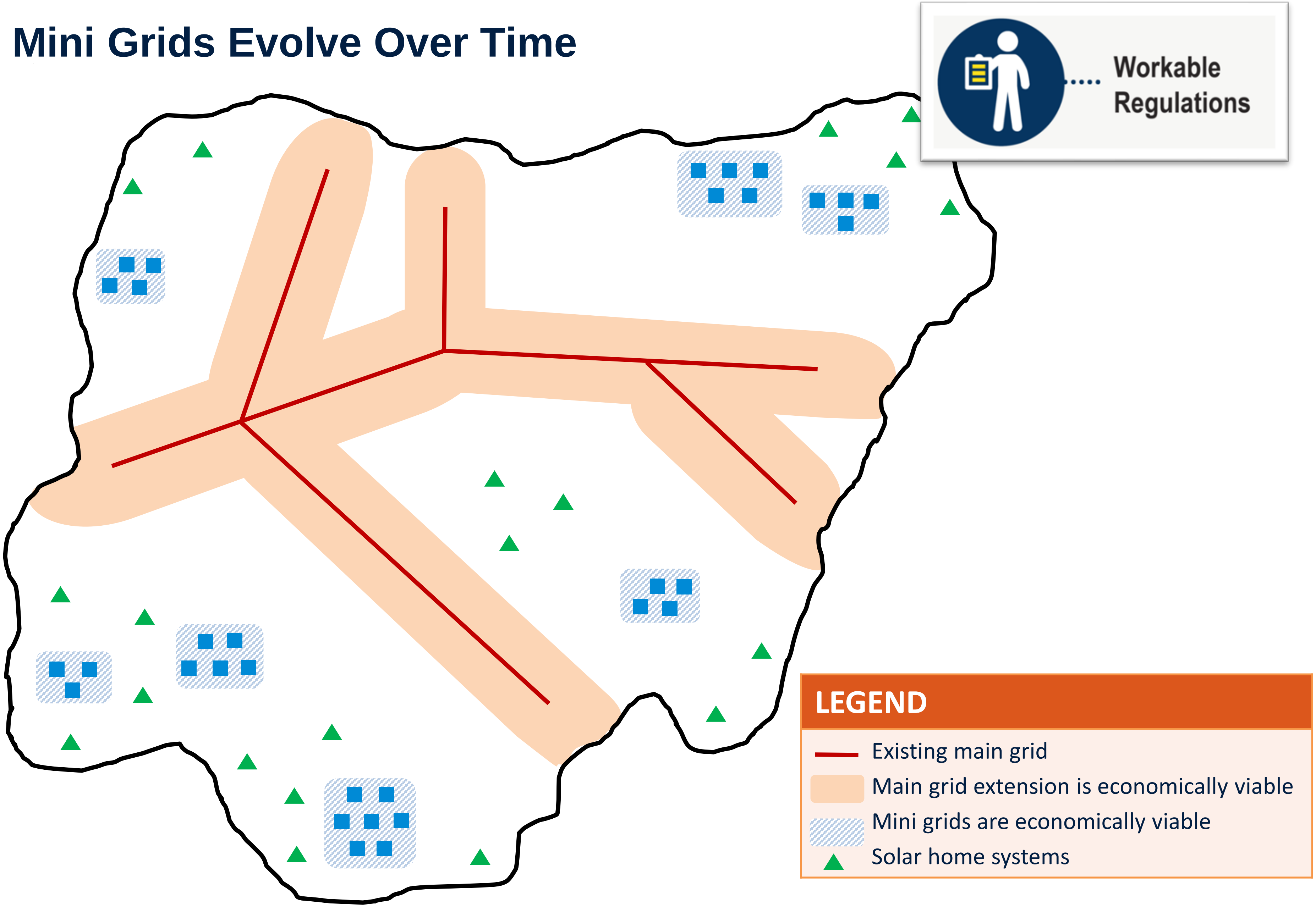
Mini Grids Evolve Over Time



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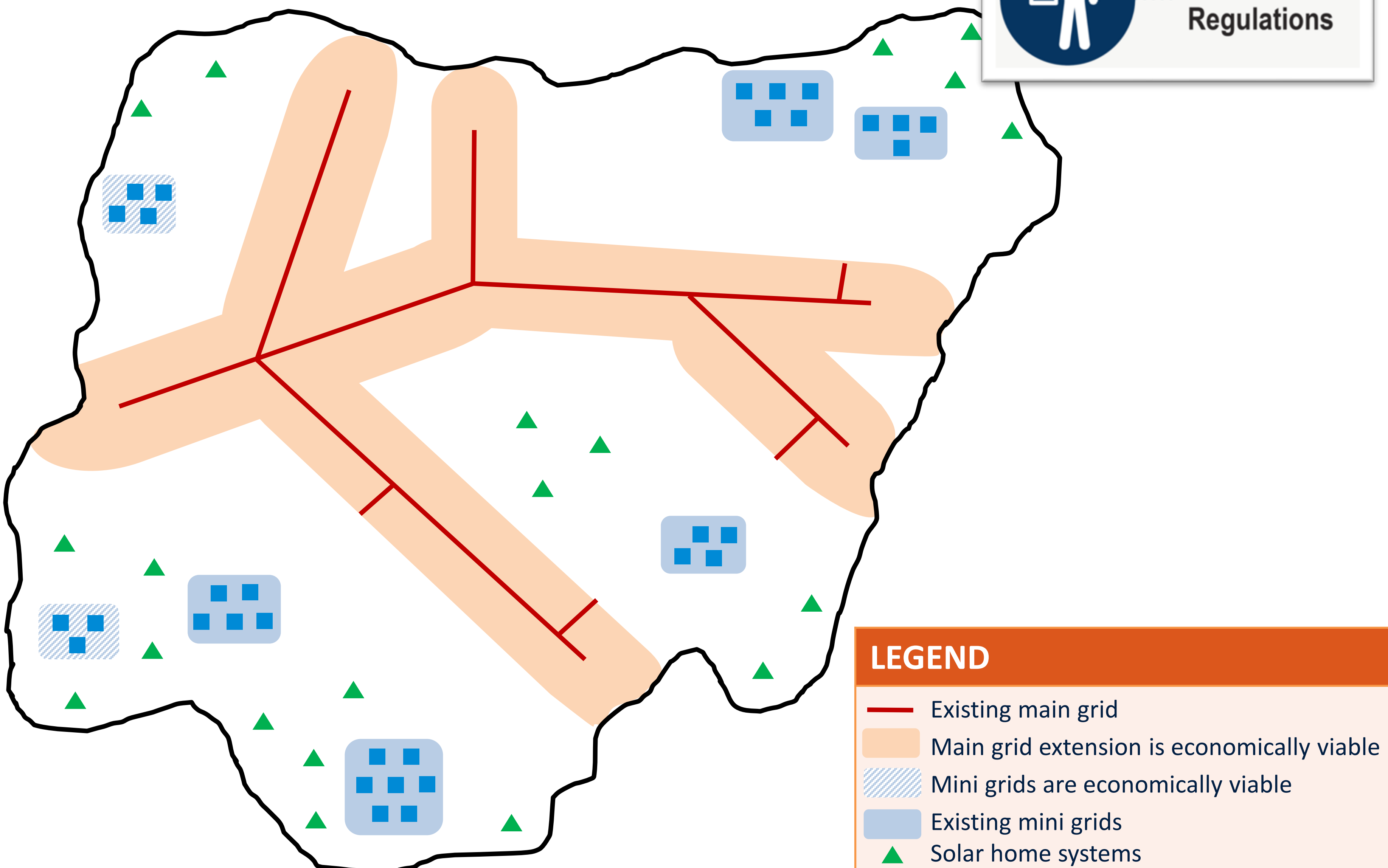

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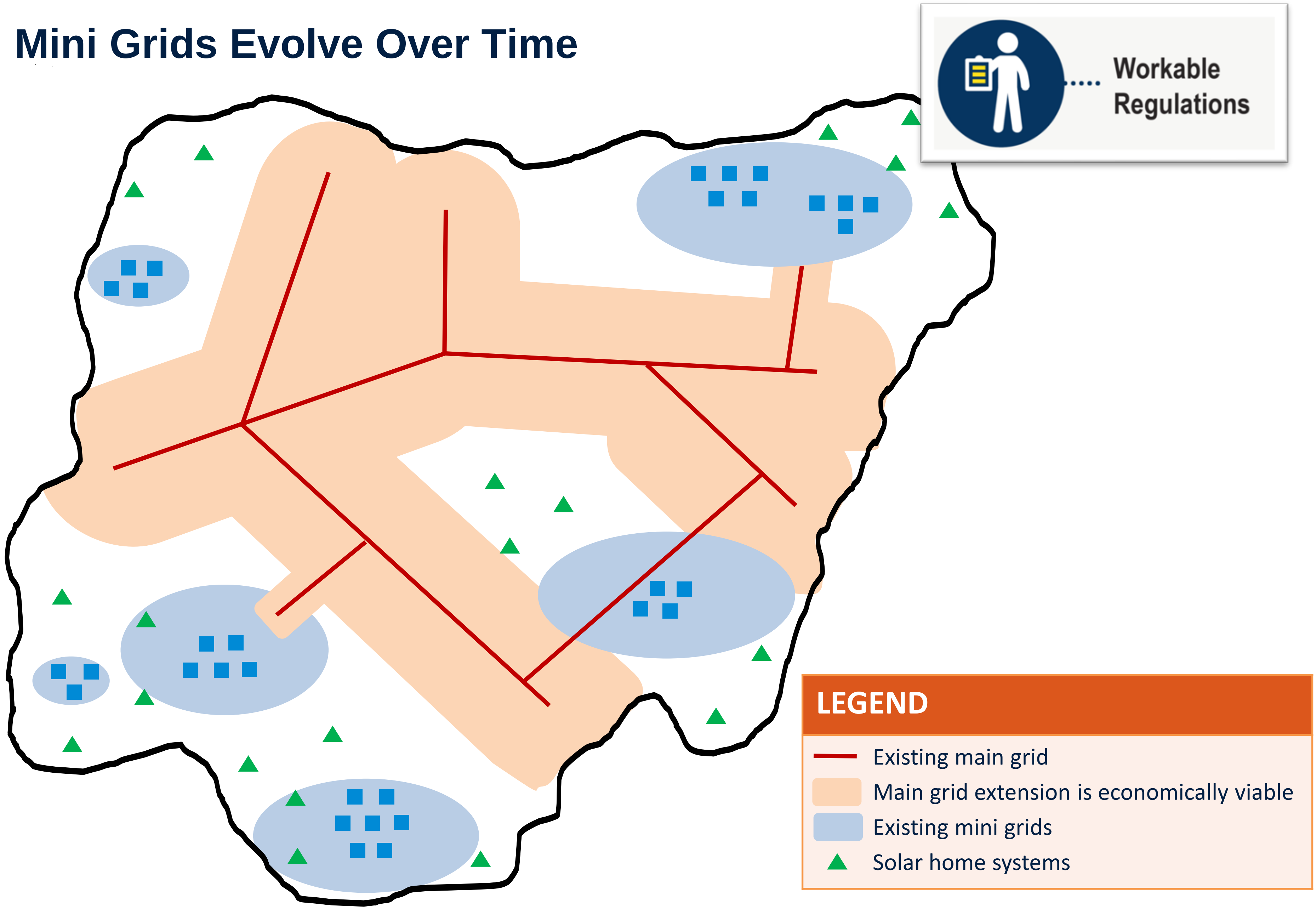
Mini Grids Evolve Over Time



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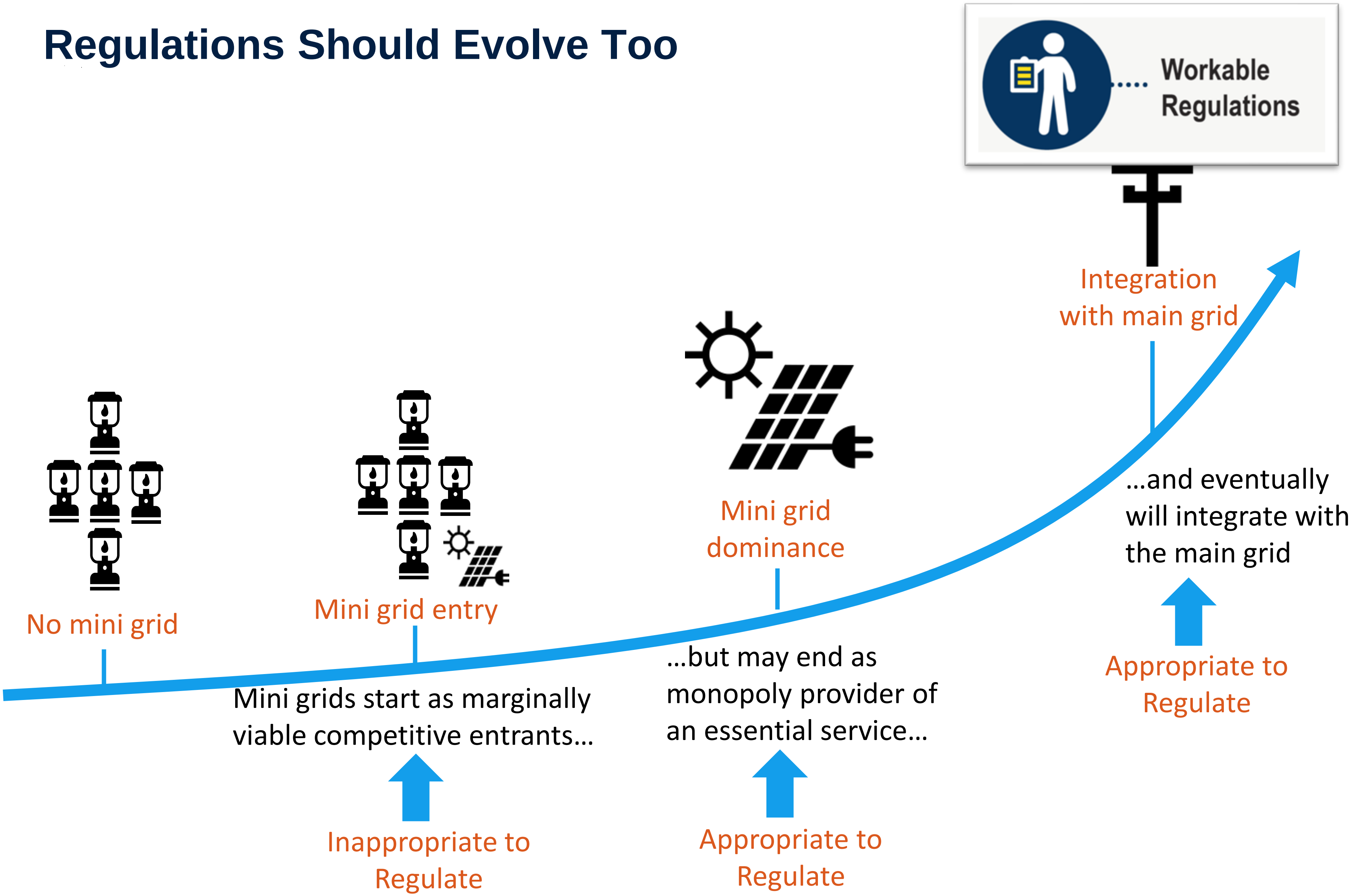
Regulations Should Evolve Too



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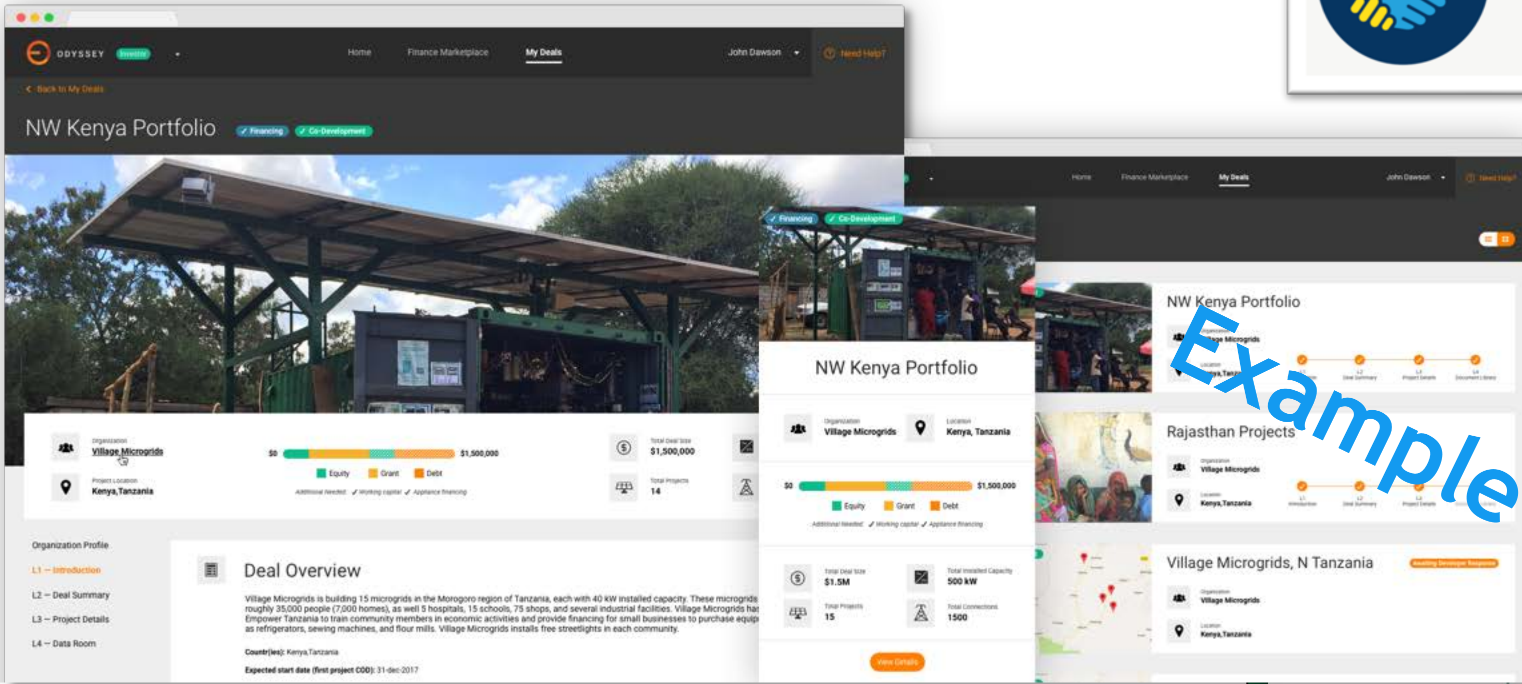
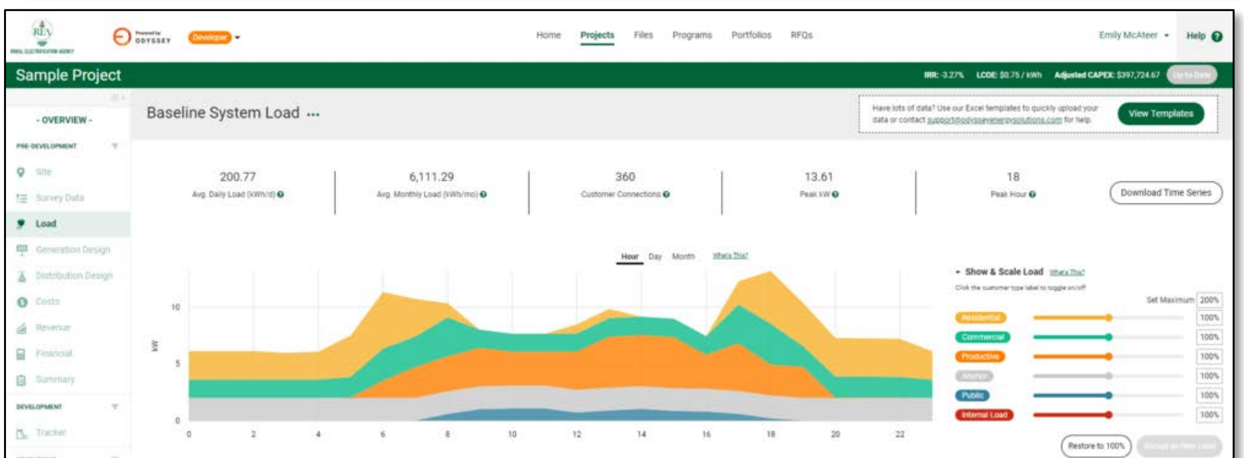
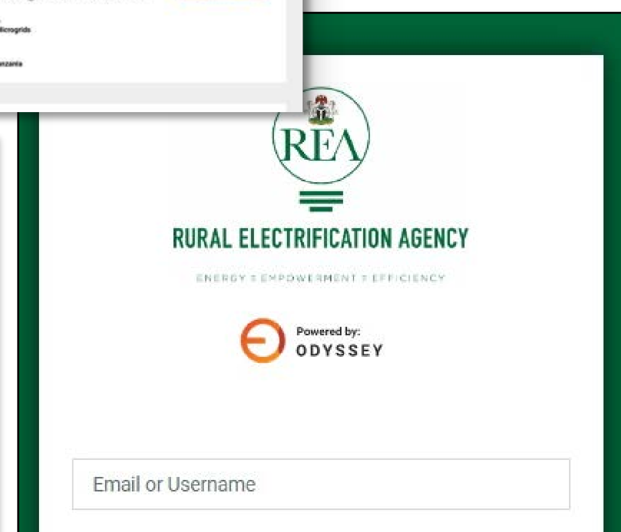
Data-based, Technology Platforms

Enabling Business Environment







Odyssey Energy Solutions:
https://www.odysseyenergysolutions.com/

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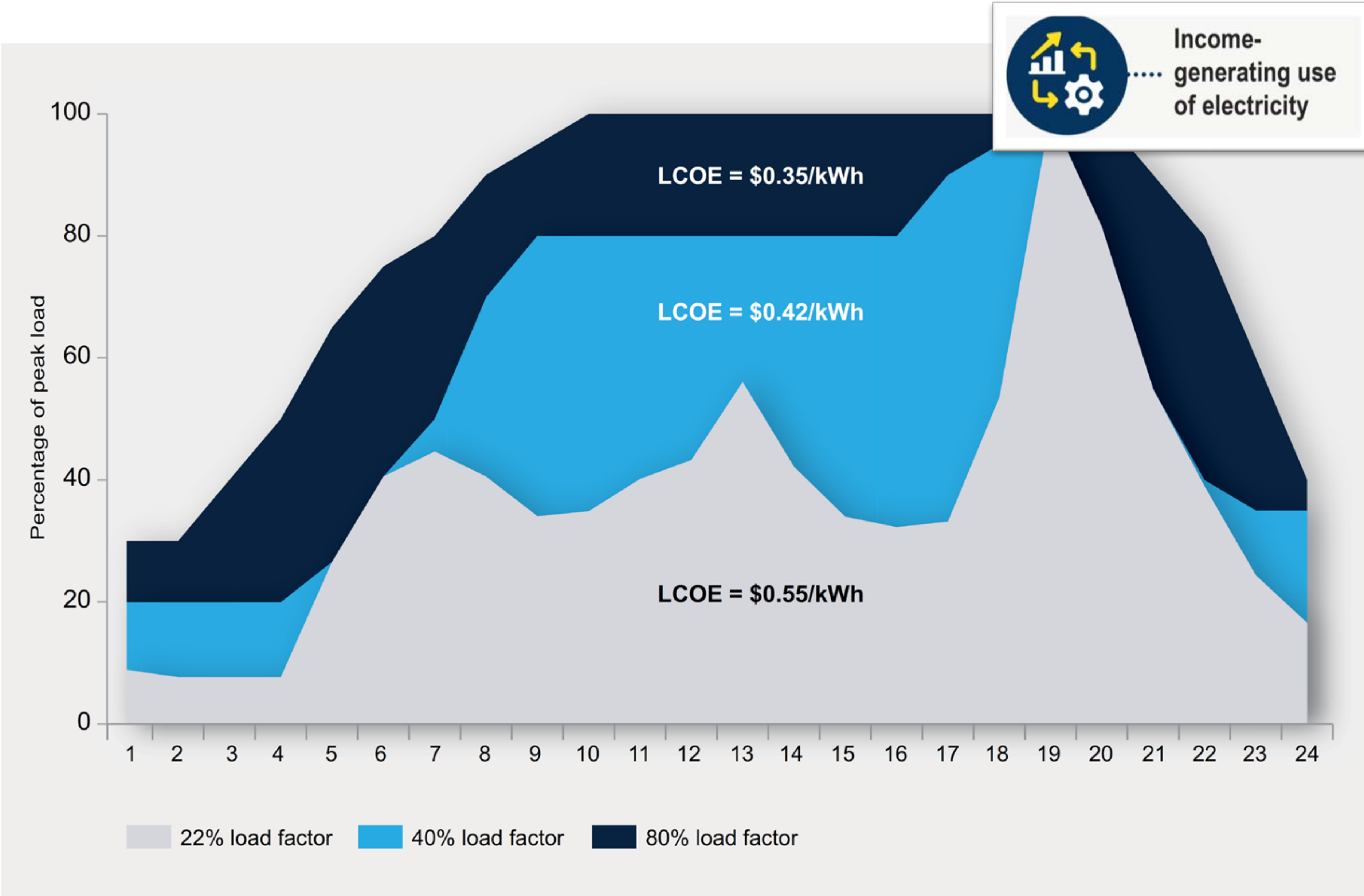


Source: ESMAP analysis.

Note: kWh = kilowatt-hour.

APPLIANCES WITH PAYBACK < 1 YEAR

NEED SUPPLIERS AND MICRO-FINANCE

Income-generating use of electricity

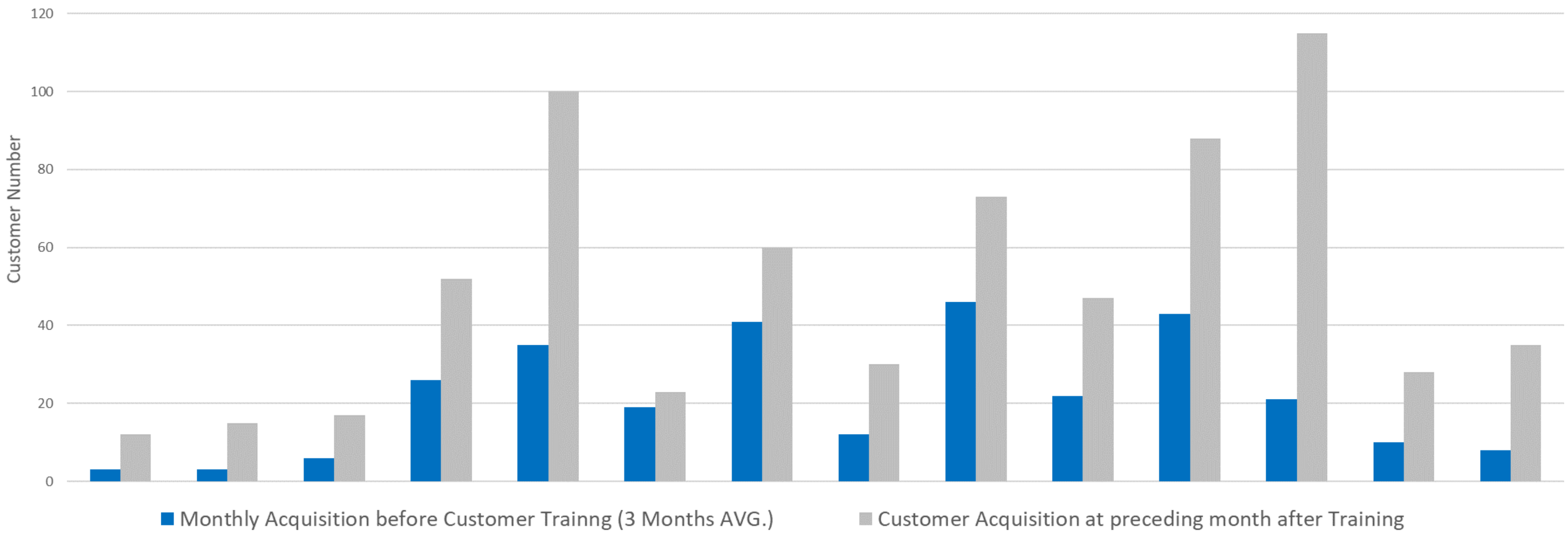
Sector	Activities / Appliances	Power required (kW)	Cost from supplier ($)	Payback period (months)
Primary industries (agriculture, fishing)	Egg incubator	80 to 160W	$50 to $100	1 to 3
	Grinder for pulses and beans	5.2 kW	$1,500 to $4,000	6 to 12
	Water irrigation pump	3.7 to 22.4 kW	$200 to $1,000	3 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

Source: ESMAP, Alibaba, Inensus.

Note: Chapter 5 of the main report provides the full table of 37 income-generating machines and other equipment. kW = kilowatt; W = watt.

Awareness campaigns can lead to 2 to 3 times improvements in rate of customer acquisition

Effect of extensive customer awareness campaigns on load uptake in Bangladesh



Source: IDCOL

There is 50 times more financing available to generate electricity than for promoting its consumption in Africa (RMI)

Private Sector Participation

Assessing profitability of operators

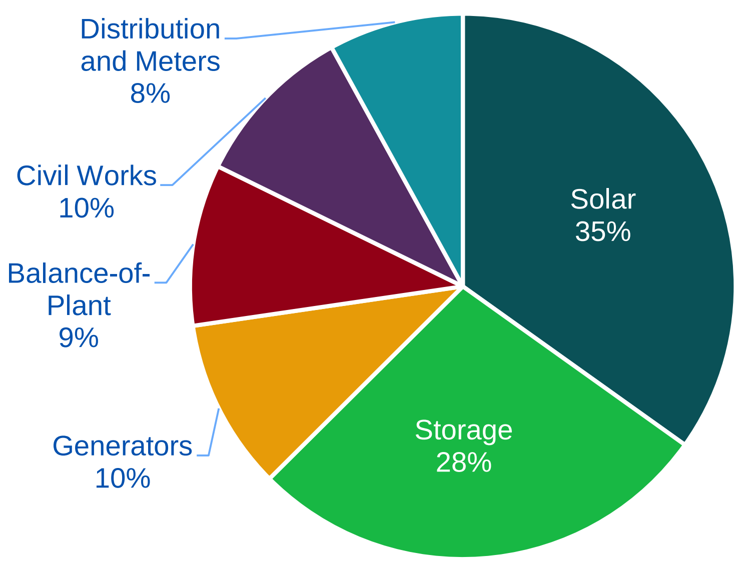
	ESCO 1	ESCO 2	ESCO 3	ESCO 4	ESCO 5	IPP		
Revenue	$46	$85,050	$1,564	$40	$145	$73.9 M	$43.7 M	$10.5 M
Gross Profit	-$251	$63,168	$985	$4	-$36	$32.1 M	$9.9 M	$2.5 M
Net Income	-$2,600	-$33,448	$672	-$11,100	-$148	$2.2 M	$4.8 M	-$148,000
Net Profit (% of Revenue)	-5454%	-39%	43%	-2744%	-102%	2%	10%	-11%
SG&A (% of Revenue)	2,700%	15%	16%	370%	88%	16%	8%	2%
Asset turnover	0.01	0.15	0.12	0.01	1.88	0.43	0.69	0.32
Return on Assets	-65%	-6%	5%	-32%	-191%	1%	7%	-4%
Current Ratio	7.14	0.81	1.82	0.32	0.04	1.06	1.12	1.06

- **Profitability remains challenged:** high personnel expense, other revenue (e.g. grants) key to offset more loss, need to incur CAPEX, should target 1-10% net profit
- **Cost containment:** SG&A high relative to comps … focus on hiring local resources, using digital tools to drive productivity
- **Low asset turnover / ROA:** driven by high investment needed over low revenue base; identify other monetization opportunities

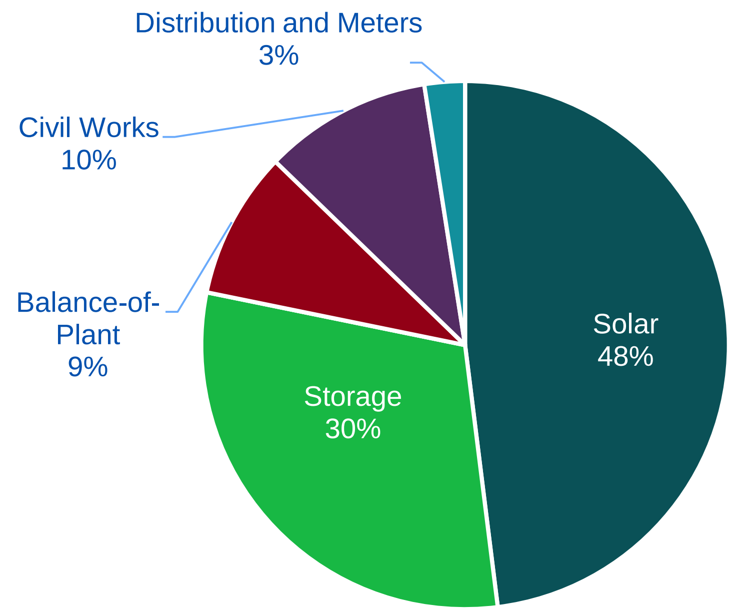
Equipment value chain profit potential

Private Sector Participation

2019 Equipment profit



2030 Equipment profit

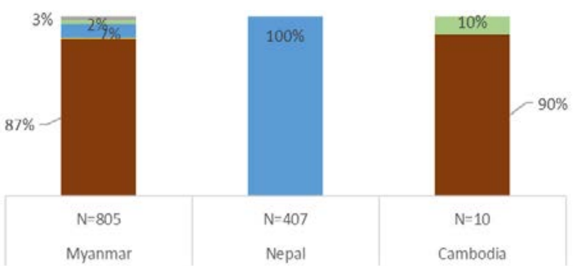


Partnership among local and international industry

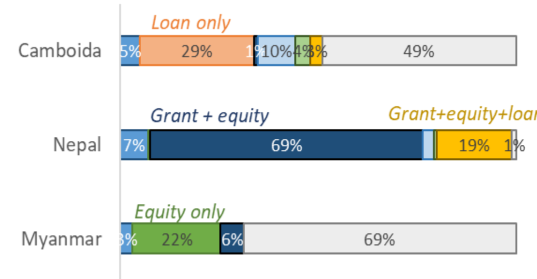
Results from first ever survey of operators

Select findings

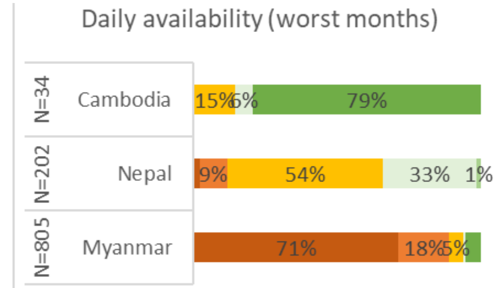
Majority of mini grids diesel-powered; all hydro powered in Nepal



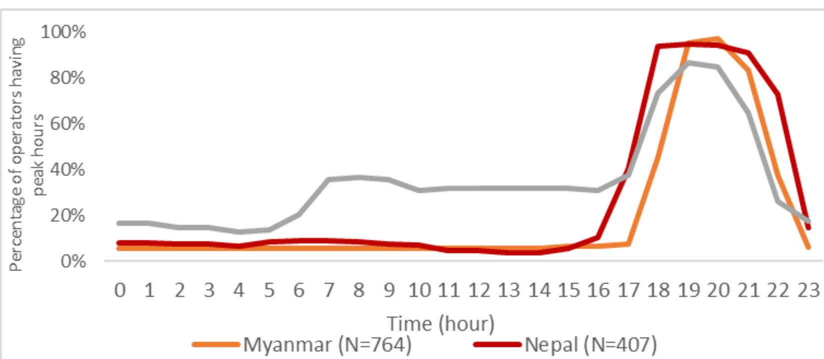
Most capitalized w/ grant & debt; use grant & equity in Nepal



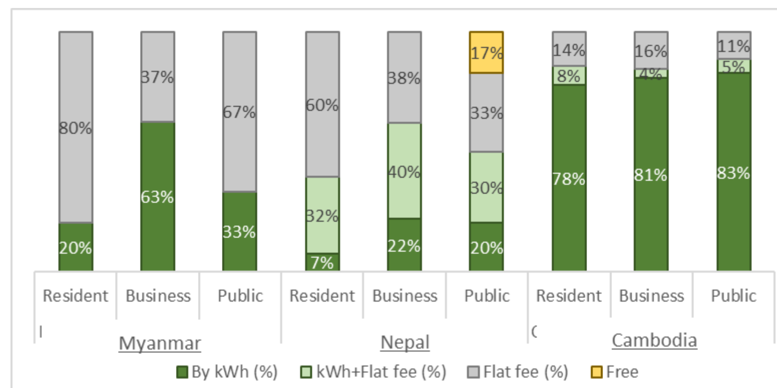
Cambodia: 24 hrs; Myanmar: 0-4 hrs., Nepal: <12 hrs.



Large evening peak, with some productive uses driving day load in Cambodia



Large portion of developers use flat fee in Myanmar & Nepal; volumetric in Cambodia



Full results available in "Mini grids for half a billion people" report

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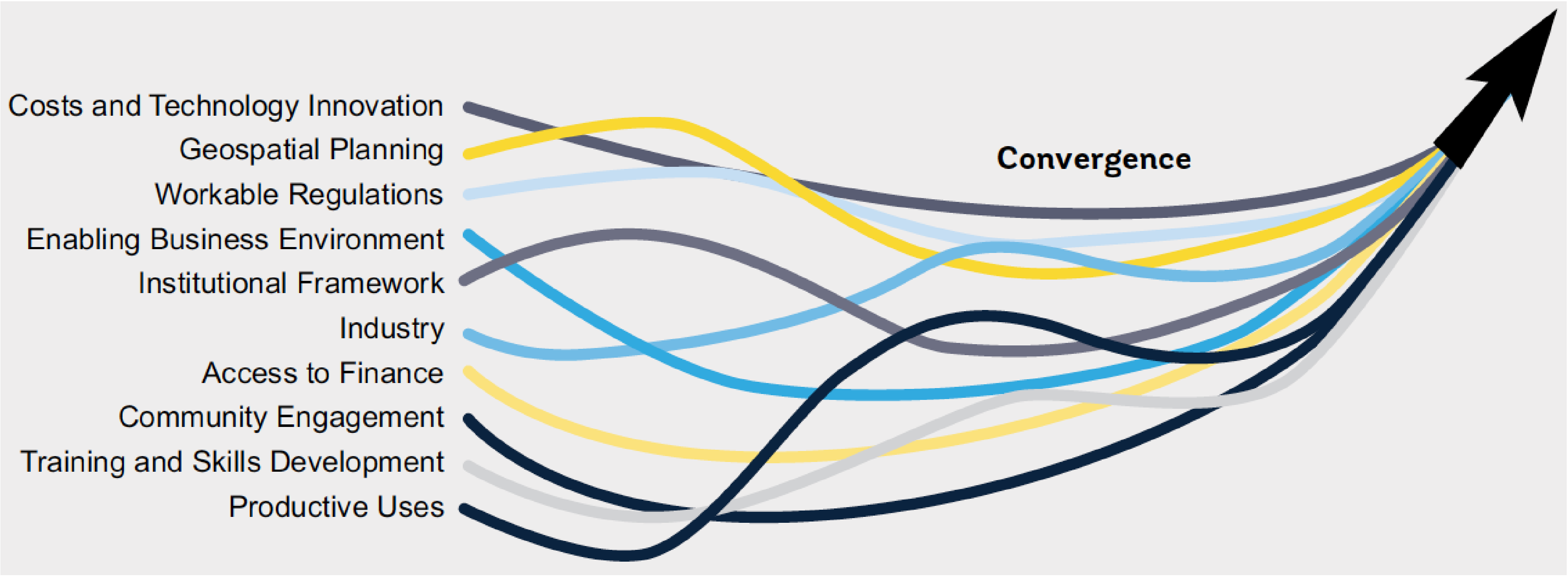
CONVERGENCE OF THESE BUILDING BLOCKS CAN RESULT IN TAKE-OFF



KEY DRIVER FOR TAKE-OFF: COSTS

Cost of Solar-Hybrid Mini Grid Today . . .

$3,908/kW
Total Capital Expense

$690/kWp
Solar PV Module

$598/kWh
Lithium-ion Batteries

$264/kW
PV Inverter

. . . and by 2030

<$3,000/kW

$140/kWp

$62/kWh

$58/KW

Cost of Unsubsidized Solar Hybrid Mini Grid Electricity (LCOE) . . .

$0.55/kWh baseline today

$0.42/kWh with income-generating machines to achieve 40% load factor

$0.22/kWh with income-generating machines & expected 2030 costs

. . . Compared with Utilities in Africa

$0.27/kWh average across 39 utilities

2 of 39 utilities with cost-recovery tariffs

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]

Source: ESMAP analysis.
Note: LCOE data are for a well-designed $294kW_{firm}$ solar-hybrid mini grid in Bangladesh serving more than 1,000 customers (more than 5,000 people). A detailed description of the underlying analysis is provided in chapter 3 of the main book. kWh = kilowatt-hour.

IMPACT OF PERFORMANCE BASED GRANTS ON LEVERLIZED COST OF ELECTRICITY

Load factor (percent)	Share of performance-based grants of CAPEX (percent)	2018 ($/kWh)	2030 ($/kWh)
22	0	0.55	0.33
22	40	0.43	0.23
22	60	0.37	0.19
40	0	0.42	0.22
40	40	0.34	0.15
40	60	0.31	0.12
80	0	0.35	0.23
80	40	0.31	0.19
80	60	0.29	0.17

Source: ESMAP analysis.

Note: Levelized cost of electricity data are for a well-designed solar-hybrid mini grid with 294 kilowatts of firm power output serving more than 5,000 people. A detailed discussion of the underlying analysis is presented in chapter 8 of the main book. CAPEX = capital expenses; kWh = kilowatt-hour.

40 – 60% of CAPEX Performance Based Grants is about $300 to $800 per connection

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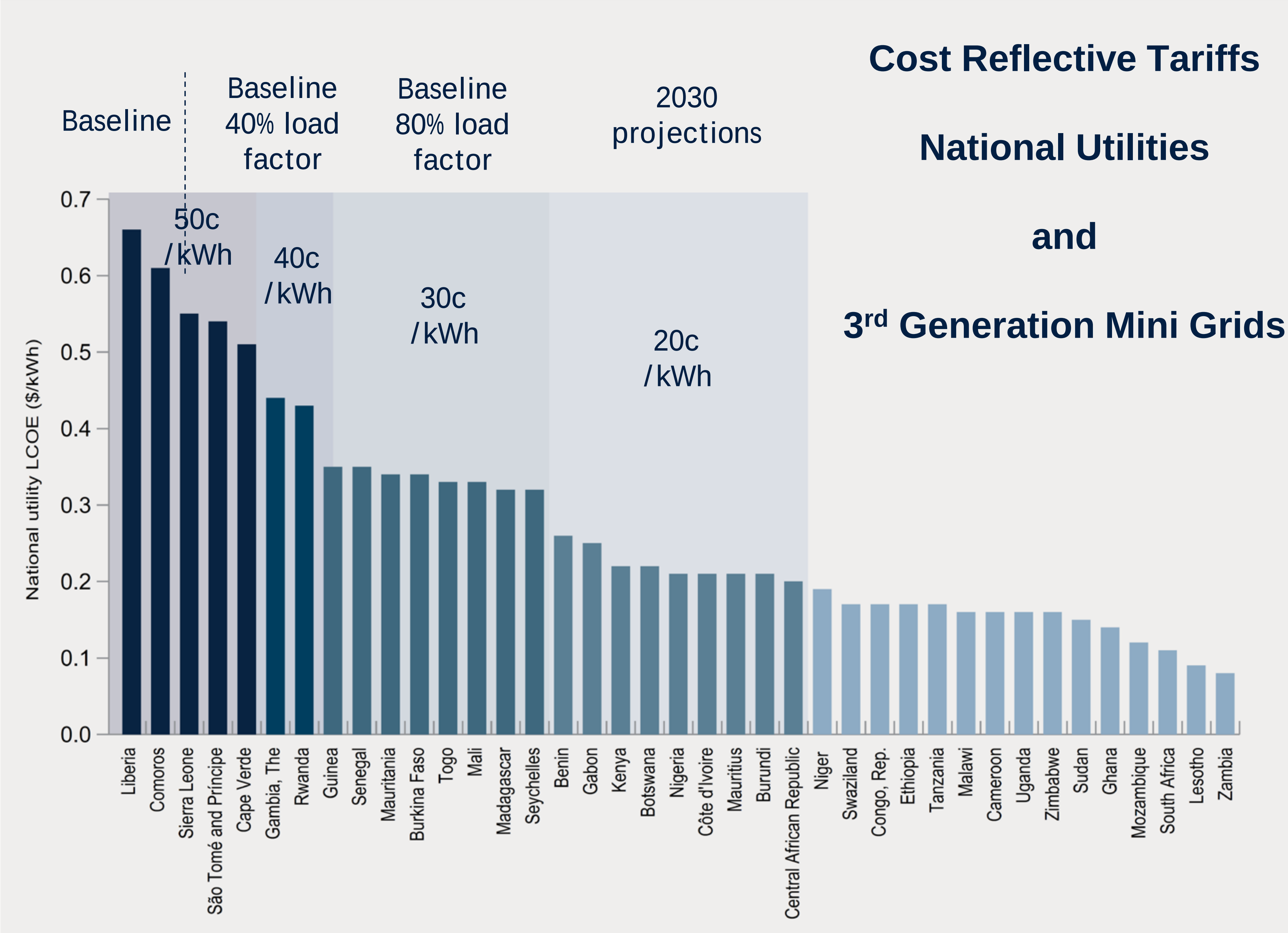
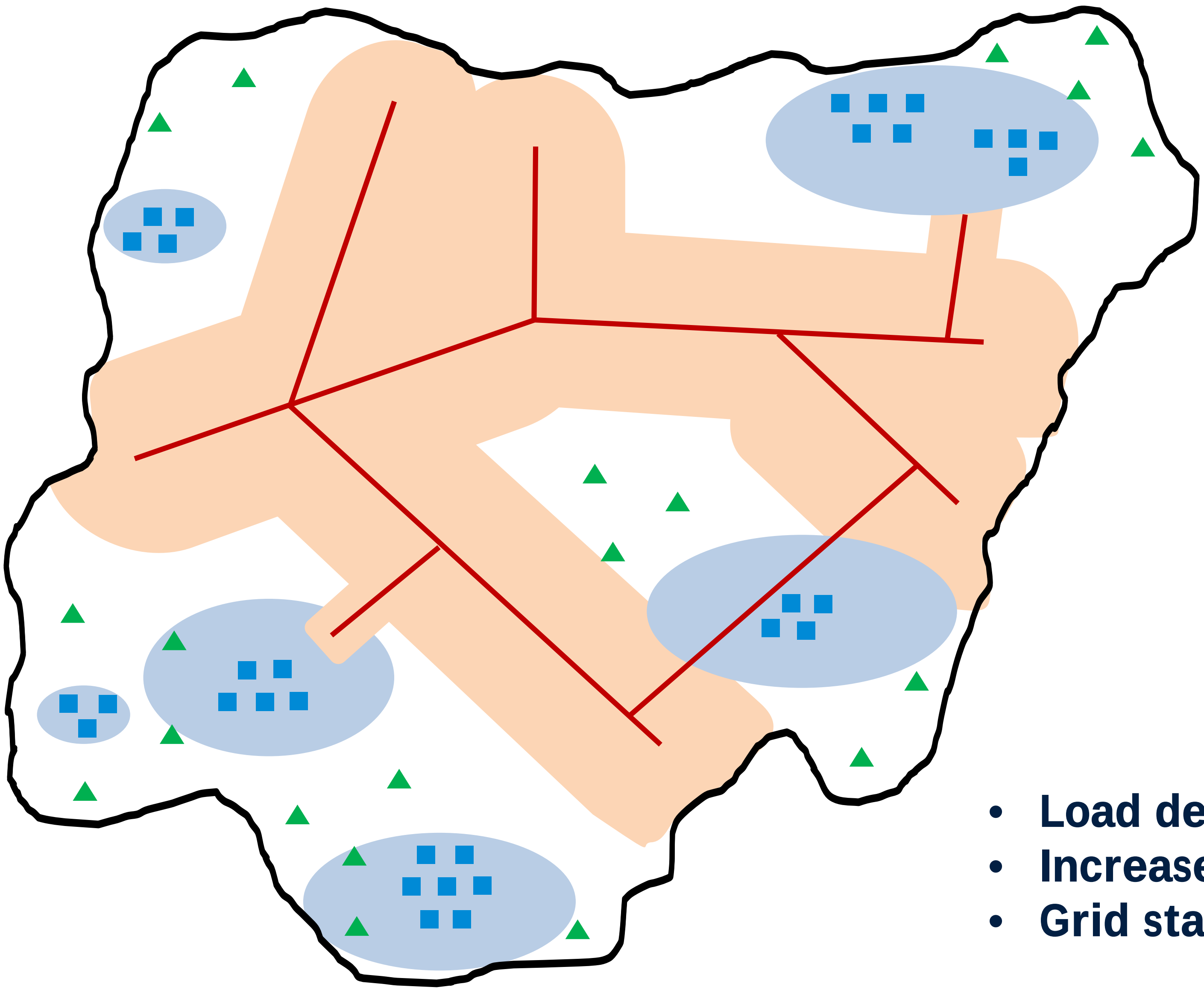


Source: Based on Kojima & Trimble 2016.

Note: kWh = kilowatt-hour; LCOE = Levelized cost of energy.

Win-Win for Utility and Mini Grid Developer



- **Load development**
- **Increase in affordability**
- **Grid stabilization**

MAKING IT HAPPEN

1. PACE

portfolio approach to around 1,500 projects per key access-deficit country per year by 2030.

2. QUALITY

keep quality of service at current 97% of up time, as well as increasing the industrywide average load factor to 45 percent

3. BUSINESS ENVIRONMENT

establishing enabling mini grid business environments to average RISE (Regulatory Indicators for Sustainable Energy) score in the top-20 access-deficit countries to 80 out of 100

4. FINANCE

Leveraging development partner funding to crowd in almost $220 billion of investment from private sector, donors, AND governments between 2019 and 2030

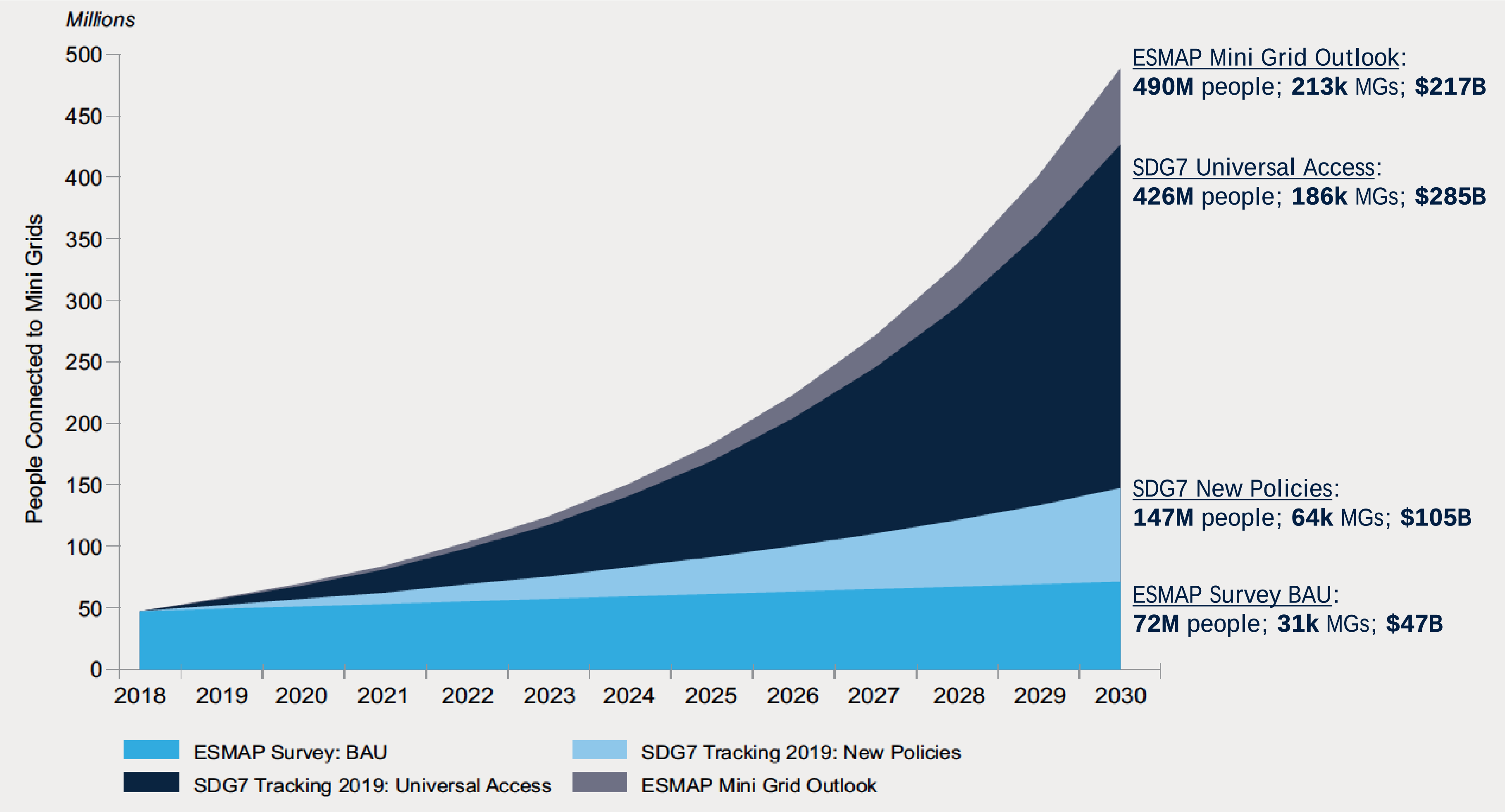
5. COST

Reducing the cost of solar-hybrid mini grids - which the other four market drivers will also support - to $0.20/kWh by 2030

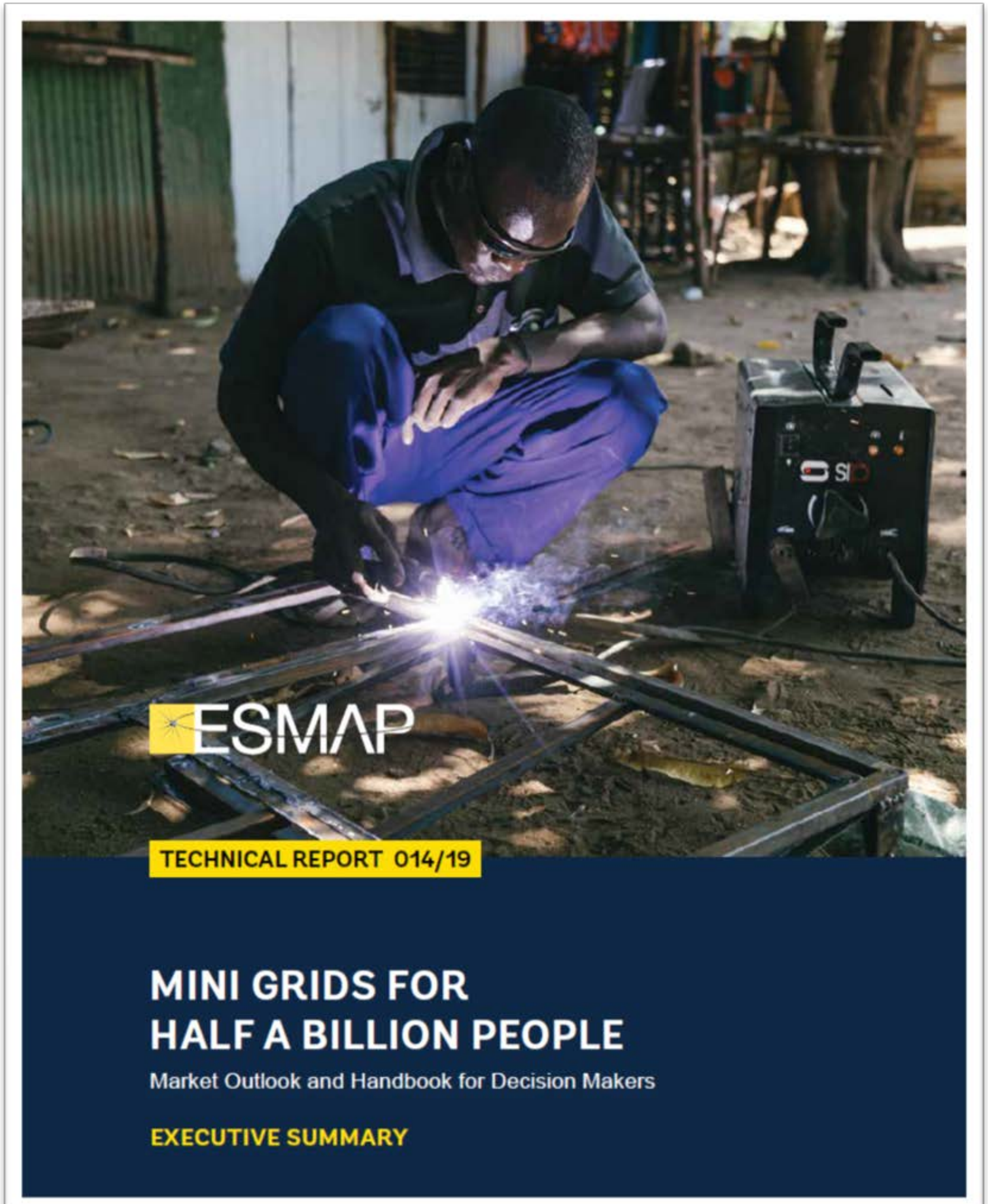
			Target		
Objective/indicator	**What is measured**	**2018 Baseline**	**2020**	**2025**	**2030**
1. Increase pace of mini grid development					
Time from purchase order to commissioning (weeks)	Cohort of leading private sector developers	6–12	7	6	5
Time from goods arriving on site to commissioning (weeks)	Cohort of leading private sector developers	6–12	5	4	3
Mini grids per portfolio per year	Portfolios from rural electrification agencies, utilities, private developers, or industry associations	10–50	> 100	> 250	> 750
2. Provide superior-quality service					
Industry-wide standard for minimum technical specifications	Industry associations	Under preparation	Developed for solar hybrid mini grids	Developed for solar hybrid and hydro mini grids	Developed for all renewable energy mini grids
Industry-wide standard for reliability of electricity supply	Representative sample of mini grid developers	90–97 percent uptime	97 percent uptime during promised availability times	97 percent uptime for 24/7 electricity	99 percent uptime for 24/7 electricity
Customer satisfaction (percent)	Representative sample of mini grid customers	82–84	85	88	90
Average load factor across the industry (percent)	Representative sample of mini grid developers	22	25	35	45
3. Establish enabling mini grid business environment in key access deficit countries					
Average RISE score for mini grids framework in top 20 electricity access deficit countries	Top 20 electricity access deficit countries	59	60	70	80
Average Doing Business Score in top 20 electricity access deficit countries	Top 20 electricity access deficit countries	52	55	65	75
4. Crowd in government and private-sector funding					
Ratio of government and private funding to donor funding	Cohort of leading development partners	1.7: 1	2: 1	5: 1	10: 1
Ratio of developer investment to donor funding	Cohort of leading private sector developers	7: 1	8: 1	9: 1	10:1
Billions of dollars Invested	Sum of all funding for mini grids in a country	28	40	93	217
5. Reduce cost of solar hybrid energy					
Levelized cost of energy ($/kWh)	Average across a cohort of leading mini grid developers	0.55	0.30	0.25	0.20

lote: A detailed discussion of the underlying analysis for each target is presented in the Introduction to Part II of the main book. kWh = kilowatt-hour; RISE = Regulatory Indicators for Sustainable Energy

Market Outlook to 2030



ESMAP Mini Grid Outlook: $444 investment per person; mini grids provide 40% of all new connections to achieve SDG7.
SDG7 Universal Access: $669 investment per person; mini grids provide 35% of all new connections to achieve SDG7 (IEA 2017).
SDG7 New Policies: $713 investment per person; mini grids provide 26% of all new connections to achieve 92% global electrification.
ESMAP BAU: Number of mini grids, investment, and people connected grow linearly following 2007-2017 trajectory.



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Or to download at:

https://openknowledge.worldbank.org/handle/10986/31926

For questions, please don't hesitate to send an email to:

Jon Exel
jexel@worldbank.org

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ANNEXES

ACCESS TO FINANCE

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

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

ACCESS TO FINANCE

Current Financing

$28 billion—Cumulative global investment in mini grids to date

$5 billion—Cumulative global investment in Africa and South Asia in mini grids to date

$1.3 billion—Development Partners committed including AFD, AfDB, DfiD, Islamic Development Bank, GIZ and WB.

$660 million—World Bank commitment to mini grids in 33 countries through 2025

$259 million—Private-sector investment in mini grid developers in low-income countries since 2013

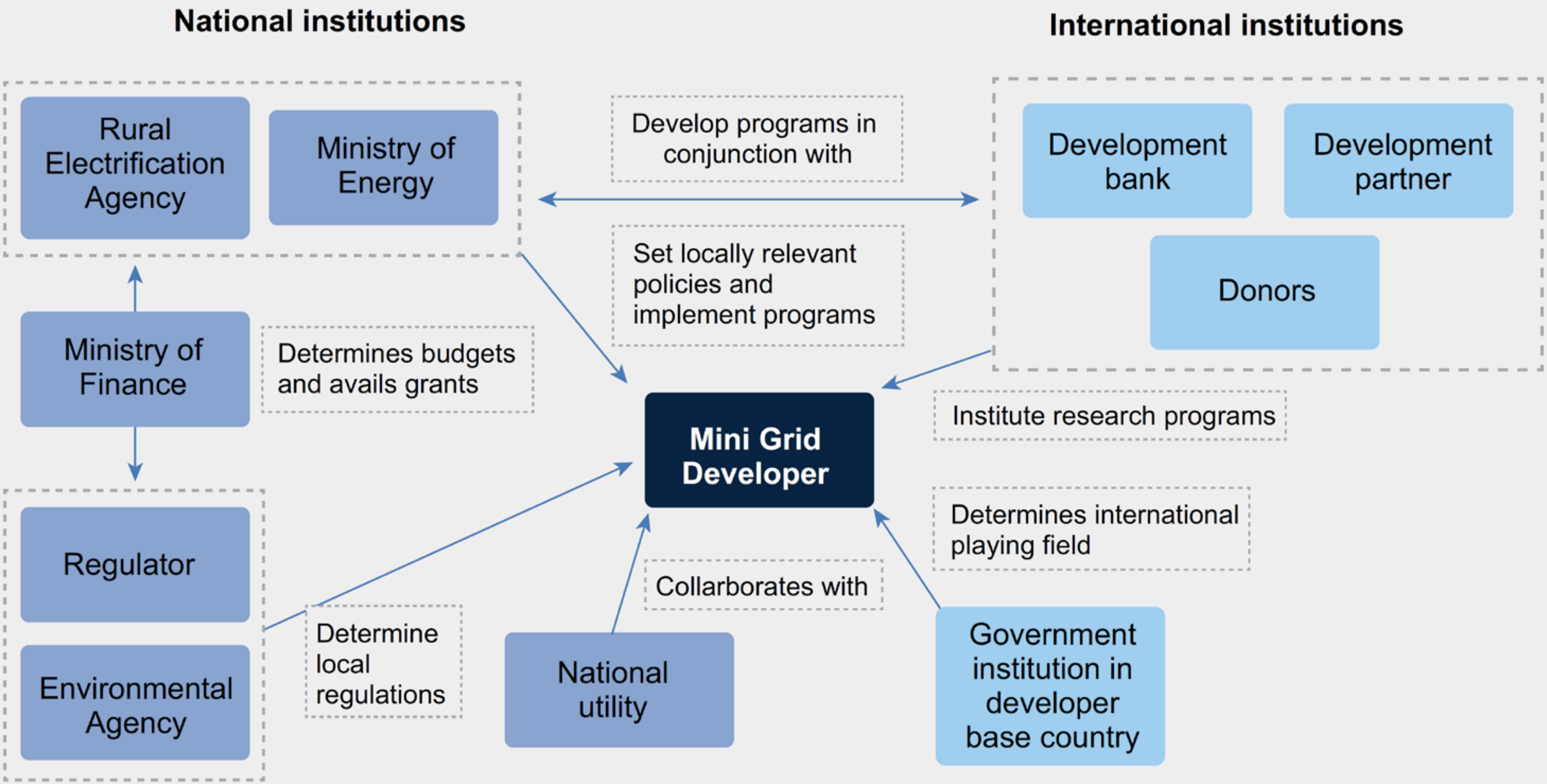
25%—Average World Bank share of total mini grid investment (government, development partners, and private sector) in client countries

REGULATIONS – NON PRESCRIPTIVE - DECISION TREES

Decision Tree Topic	Overview
Arrival of the main grid (see figure ES.6)	This decision tree provides options for what happens when the main grid arrives in the service area of a mini grid, including operating as a small power distributor (SPD) or small power producer (SPP).
Market entry	This decision tree provides options for regulating entry of mini grid developers into the market and indicates the conditions under which one of the four entry regulation options (registration, permitting, licensing, or no regulation of entry) would be most appropriate. The first branches of the tree are determined by what is legally required to operate as a mini grid business and how much control the regulator wishes to exert on who enters the market.
Retail tariffs	The options presented in this decision tree depend on the availability and type of subsidies and whether or not a uniform national tariff is required. The five options include willing buyer-willing seller tariff-setting schemes, efficient new entrant price caps, individualized cost-based tariff limits, bid tariffs, to uniform national tariffs.
Service standards	The first branches of this decision tree are determined by the maturity of the mini grid market (less stringent service standards may be more acceptable in more nascent markets) and the availability of subsidies. The options for regulating service standards orange from no service standards, to reporting standards, to differentiated standards, to uniform mini grid-specific standards, to grid-level standards.
Technical standards	This decision tree presents the options for regulating technical standards, and the first branches of the tree are determined by whether future integration of mini grids with the country's main grid is expected. The options for technical standards range from safety standards only, to mini grid-specific, to optional grid-compatible standards, to mandatory grid-compatible or main-grid standards.

FROM A WEB OF INSTITUTIONS

Institutional Arrangements

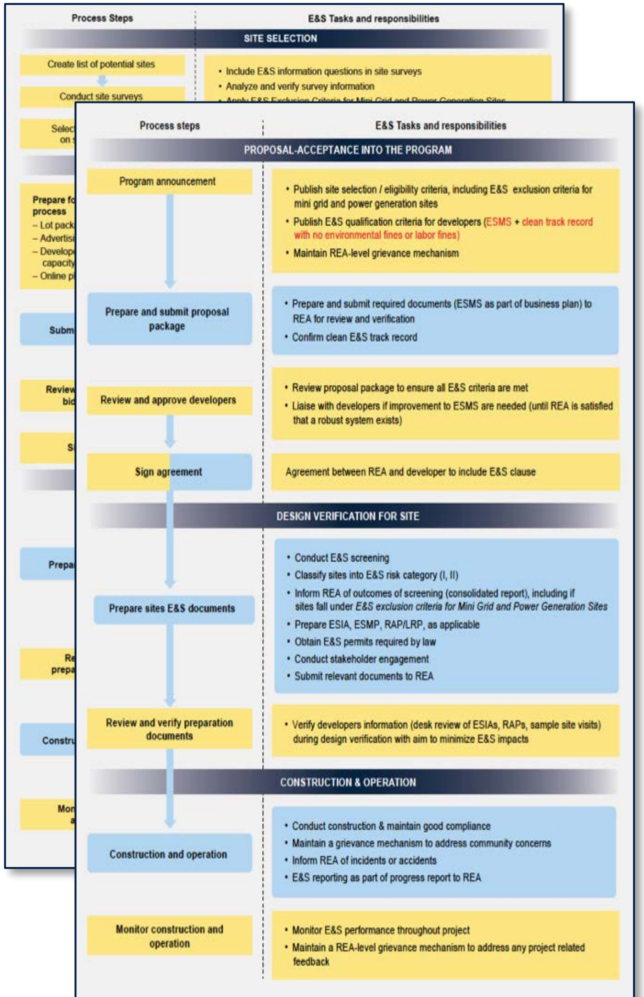


Delegating oversight to a single entity

Option	Advantages	Disadvantages	
Local government	• More accessible to developers and customers • Enforcement of regulation may be easier given the physical presence of the regulator in the community	• Potential lack of resources to be an effective regulator • Potential for different rules in different jurisdictions impedes large portfolios	Community agreements used in Haiti, Nigeria, and Myanmar
REA or grant-giving agency	Complex interfaces between agencies can be avoided if the subsidizing agency also acts as regulator (caveat: other gov. entities still may have authority over certain aspects)	• Potential lack of resources to be an effective regulator • May lead to conflict of interests	Bangladesh (IDCOL), Mali (AMADER)

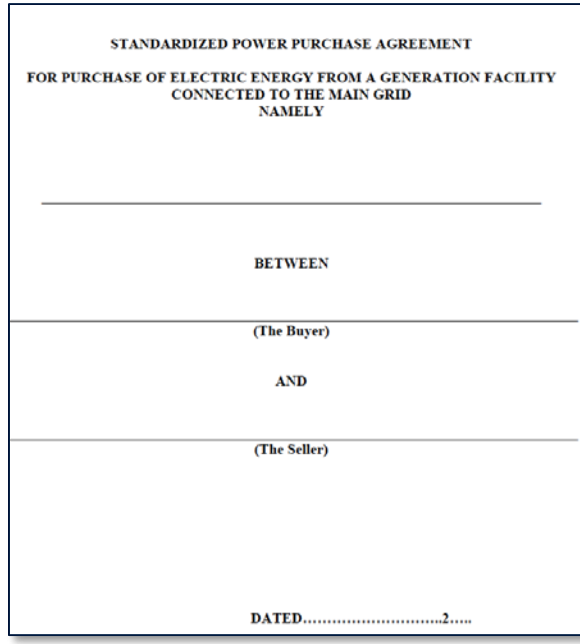
Standardized, pre-approved templates

Enabling Business Environment



Process steps	E&S Tasks and responsibilities
PROPOSAL-ACCEPTANCE INTO THE PROGRAM	
Program announcement	• Publish site selection / eligibility criteria, including E&S exclusion criteria for mini grid and power generation sites • Publish E&S qualification criteria for developers (ESMS + clean track record with no environmental fines or labor fines) • Maintain REA-level grievance mechanism
Prepare and submit proposal package	• Prepare and submit required documents (ESMS as part of business plan) to REA for review and verification • Confirm clean E&S track record
Review and approve developers	• Review proposal package to ensure all E&S criteria are met • Liaise with developers if improvement to ESMS are needed (until REA is satisfied that a robust system exists)
Sign agreement	Agreement between REA and developer to include E&S clause
DESIGN VERIFICATION FOR SITE	
Prepare sites E&S documents	• Conduct E&S screening • Classify sites into E&S risk category (I, II) • Inform REA of outcomes of screening (consolidated report), including if sites fall under *E&S exclusion criteria for Mini Grid and Power Generation Sites* • Prepare ESIA, ESMP, RAP/LRP, as applicable • Obtain E&S permits required by law • Conduct stakeholder engagement • Submit relevant documents to REA
Review and verify preparation documents	• Verify developers information (desk review of ESIAs, RAPs, sample site visits) during design verification with aim to minimize E&S impacts
CONSTRUCTION & OPERATION	
Construction and operation	• Conduct construction & maintain good compliance • Maintain a grievance mechanism to address community concerns • Inform REA of incidents or accidents • E&S reporting as part of progress report to REA
Monitor construction and operation	• Monitor E&S performance throughout project • Maintain a REA-level grievance mechanism to address any project related feedback

Nigeria ESMS



STANDARDIZED POWER PURCHASE AGREEMENT

FOR PURCHASE OF ELECTRIC ENERGY FROM A GENERATION FACILITY CONNECTED TO THE MAIN GRID NAMELY

BETWEEN

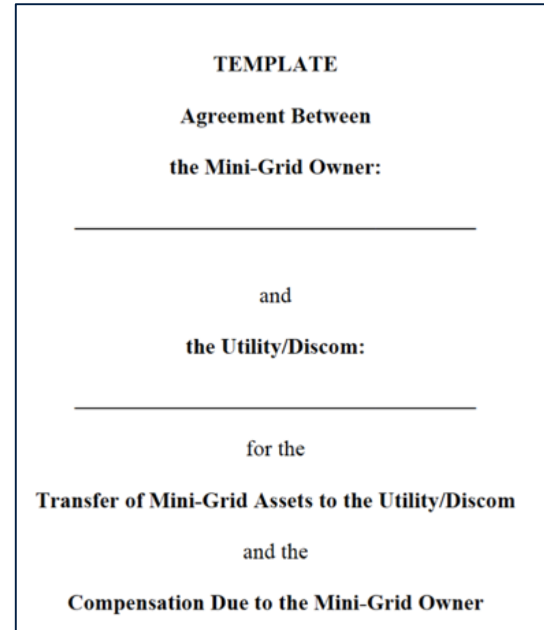
(The Buyer)

AND

(The Seller)

DATED.............................2.....

Tanzania PPA



TEMPLATE

Agreement Between

the Mini-Grid Owner:

and

the Utility/Discom:

for the

Transfer of Mini-Grid Assets to the Utility/Discom

and the

Compensation Due to the Mini-Grid Owner

Asset Transfer Template (Under preparation by ESMAP)

Examples

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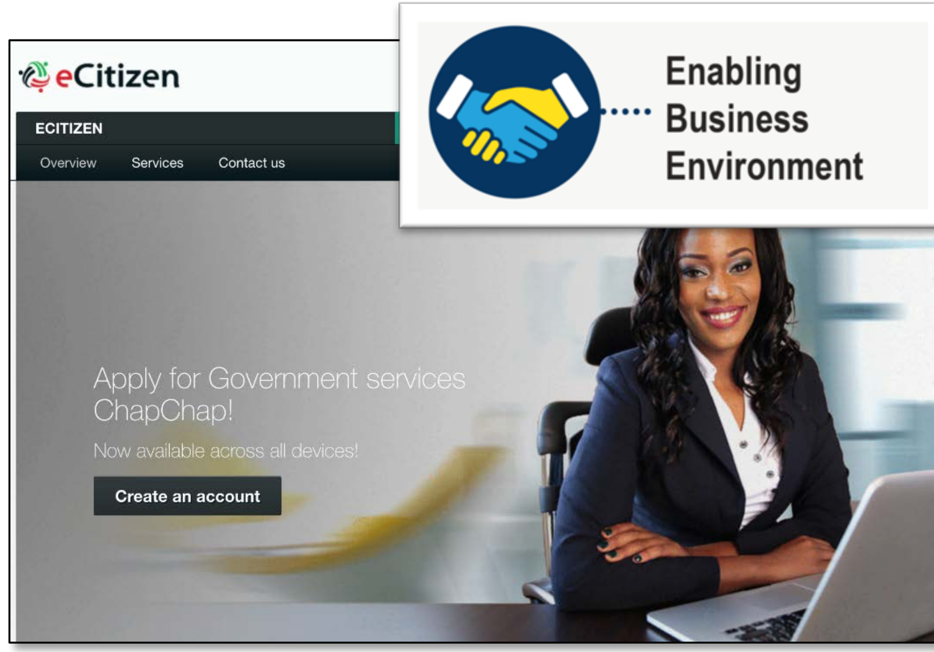
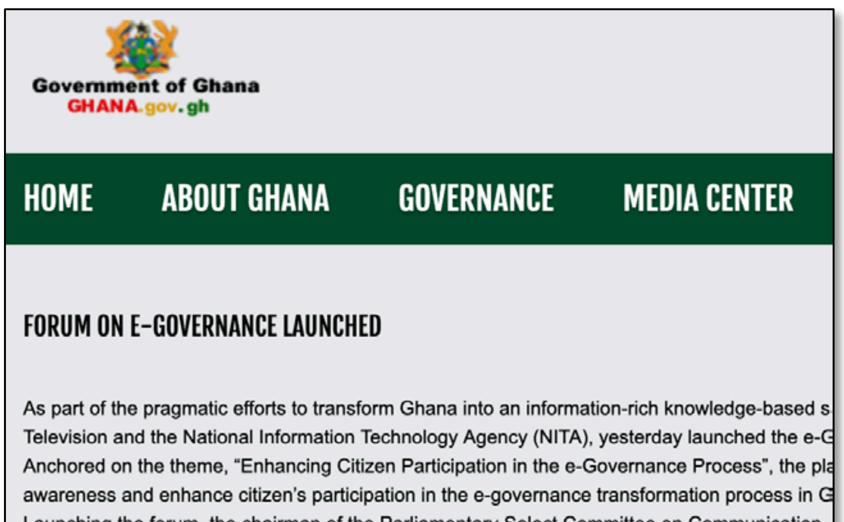
e-Government Initiatives

Nigeria

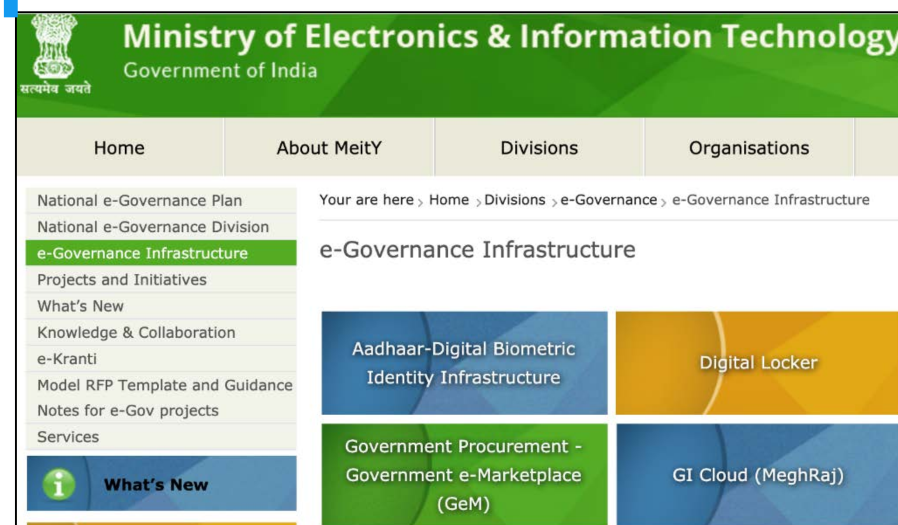


Kenya

Examples



Ghana



India

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