



INTERNATIONAL DEVELOPMENT IN FOCUS

## Mini Grid Solutions for Underserved Customers

New Insights from Nigeria and India

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and Ashish Shrestha



 WORLD BANK GROUP

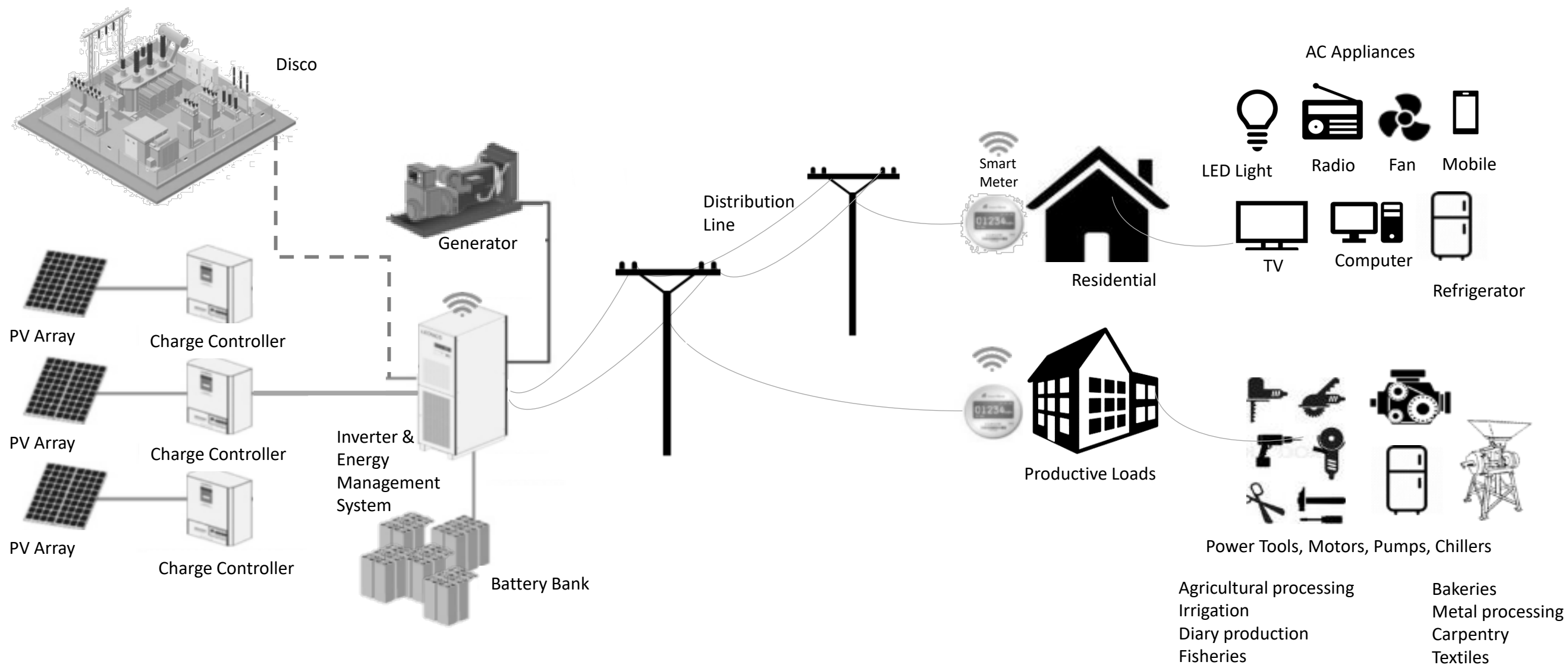
# Mini Grid Solutions for Underserved Customers

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# What is a mini 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.



Solar Hybrid Generation System

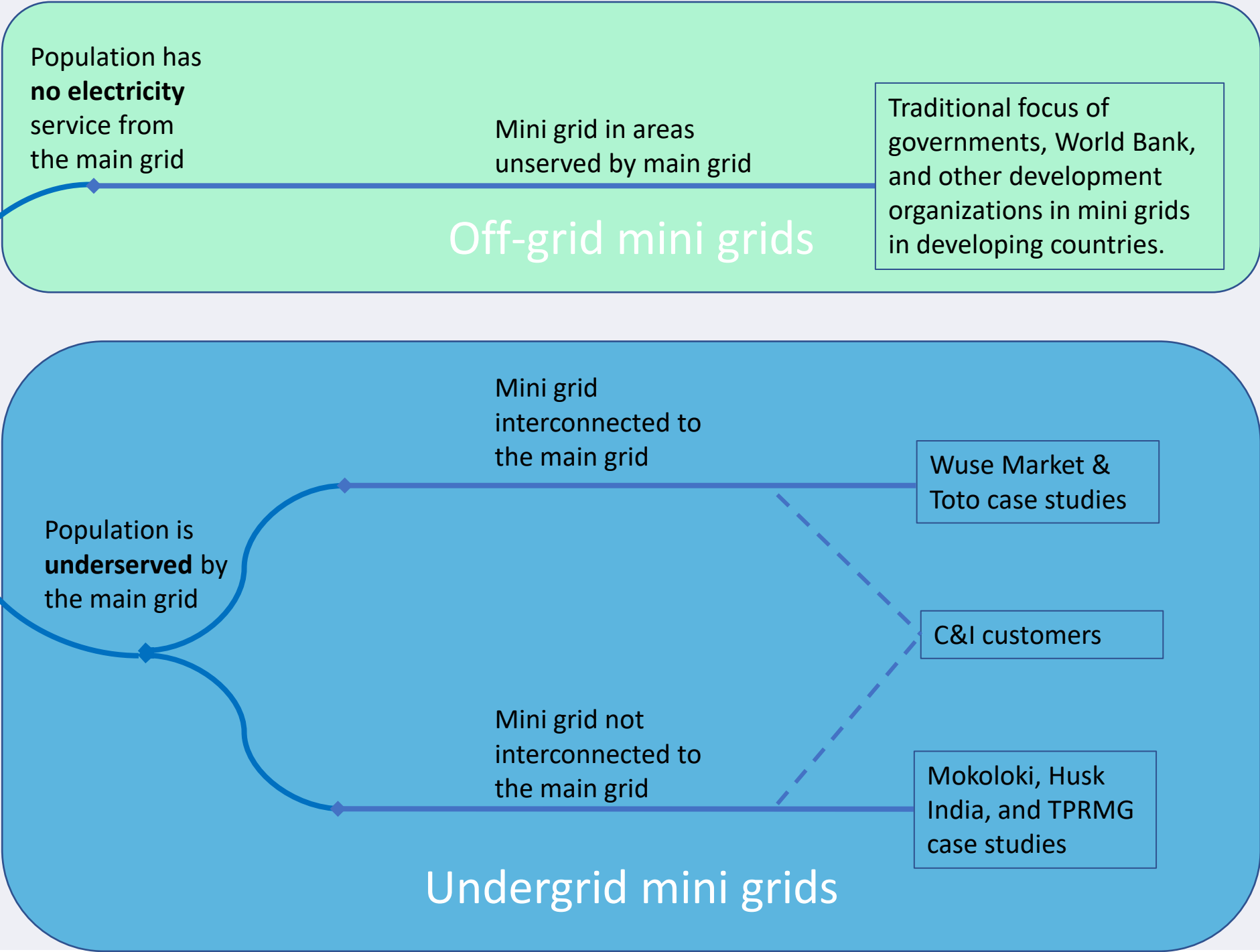
Distribution System

Smart Meters

Efficient Productive Loads

# Off-grid and undergrid mini grids

Types of mini grids





# CASE STUDIES

	<b>Nigeria</b>	<b>India</b>
Not interconnected	<b>Mokoloki</b>	<b>TPRMG</b>
		<b>Husk Power</b>
Interconnected	<b>Toto</b> <b>Wuse Market</b>	

# Mokoloki Mini Grid, Ogun, Nigeria

## Prior to mini grid:

- IBEDC provided 5 hours/day to ~90 customers
- Residents used backup generators

**10-year tri-partite agreement** between developer (Nayo Tech), local disco (IBEDC) and the Mokoloki community:

- Fixed annual fee for service territory
- Nayo had to replace 95% of poles & wires

## Initially:

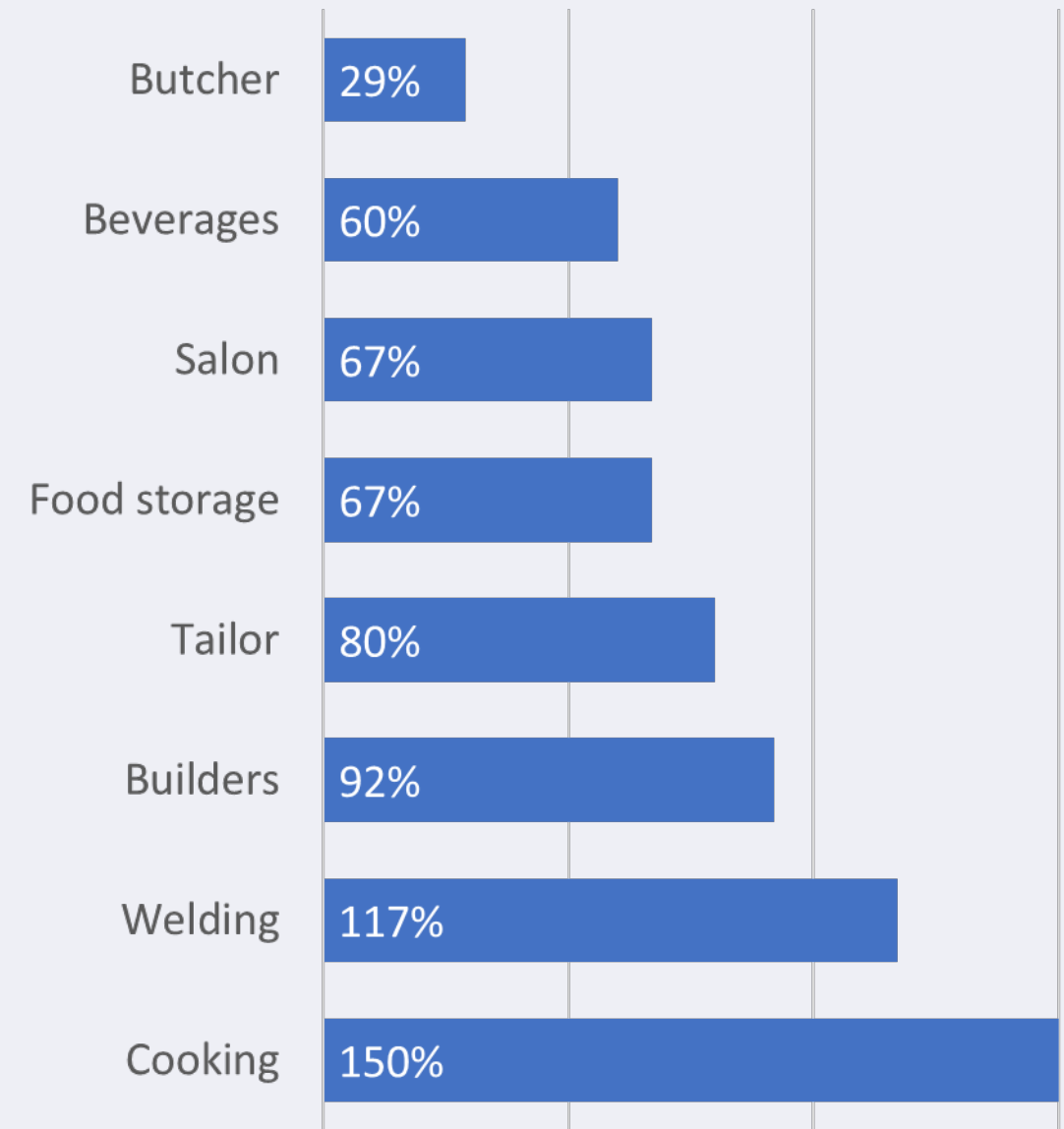
- 200 customers
- \$420k (100% developer equity)



100 kWp solar PV, 192 kWh lead-acid battery, 88 kW diesel backup

# Mokoloki: reliable electricity catalyzes growth

- **Demand:**
  - CrossBoundary daytime productive use program
  - Town grew from 250 households to 400
  - Substantial business growth
- **Diesel price:**
  - \$0.25/L (March 2020) → \$1.18/L (Oct 2023)
- **No grid connection** (As of April 2024)
- “Sharing the Power” project
  - RMI/Dutch Postcode Lottery
  - Upgraded battery from 192 to 317 kWh
  - 11% community ownership with voting rights
  - Community invests profits into community development projects
  - Power outages now less than 1 hour/day
- **Nayo’s portfolio:**
  - 12 mini grids operational, 6 in pipeline.



*Business growth after mini grid deployment*  
*Source: RMI*

# Toto Interconnected Mini Grid, Nigeria

- Peri-urban area in Nasawara State.
- Provides 24/7 power
  - ~~2,000~~ 1,600 turned on
  - 2,800 expected.
- Expanding to 2 MWp by Q4
  - Load 4X expected
  - AEDC so far unable to deliver contracted wholesale power
- Capex \$2 M including \$0.5M to refurbish distribution network
- PowerGen pipeline



351 → 2,000 kWp solar PV, 972 kWh li-ion battery, 500 kVA diesel backup

# Husk Power, Nigeria and India

- **India (>200): Bihar & Uttar Pradesh**
  - Electricity supplied over separate distribution networks (not interconnected with national grid)
  - 65% of electricity consumed by commercial customers
  - LCOE now \$0.25 per kWh thanks to economies of scale and optimization of design & operations
- **Nigeria (>30): Nasarawa state**
  - Building one mini grid every 6 days. ~60 by end of 2024.
  - All non-connected so far, but planning 2 or 3 interconnected this year.



**Husk's mini grid in Idadu, Nasarawa state**  
**Typical system: 30 kWp PV, biomass generator**



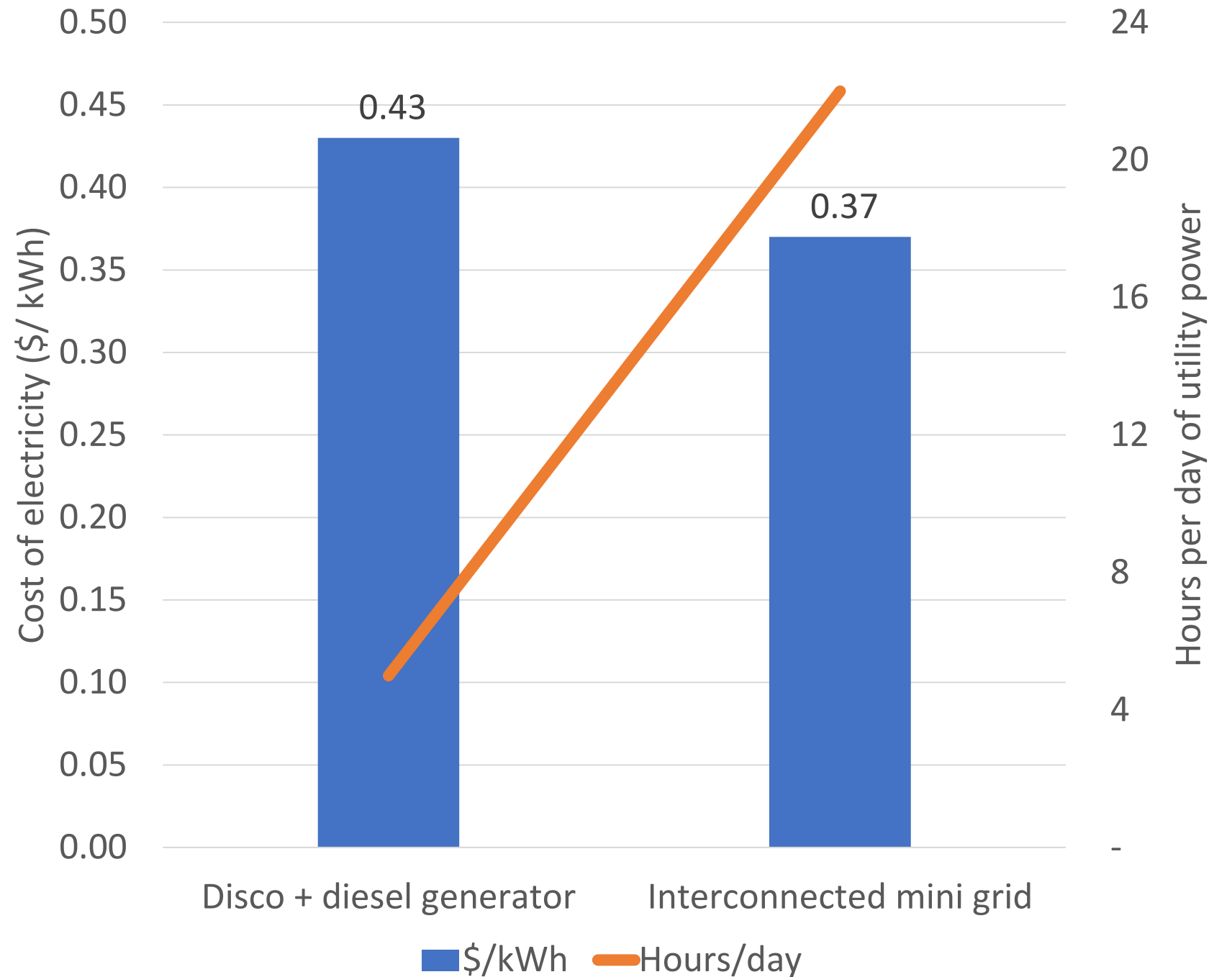
Ms. Boluwasope  
Ogboye on a  
Husk Power EV  
motorcycle  
charged by a  
solar mini grid

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# Benefits of connected mini grids: **customers**

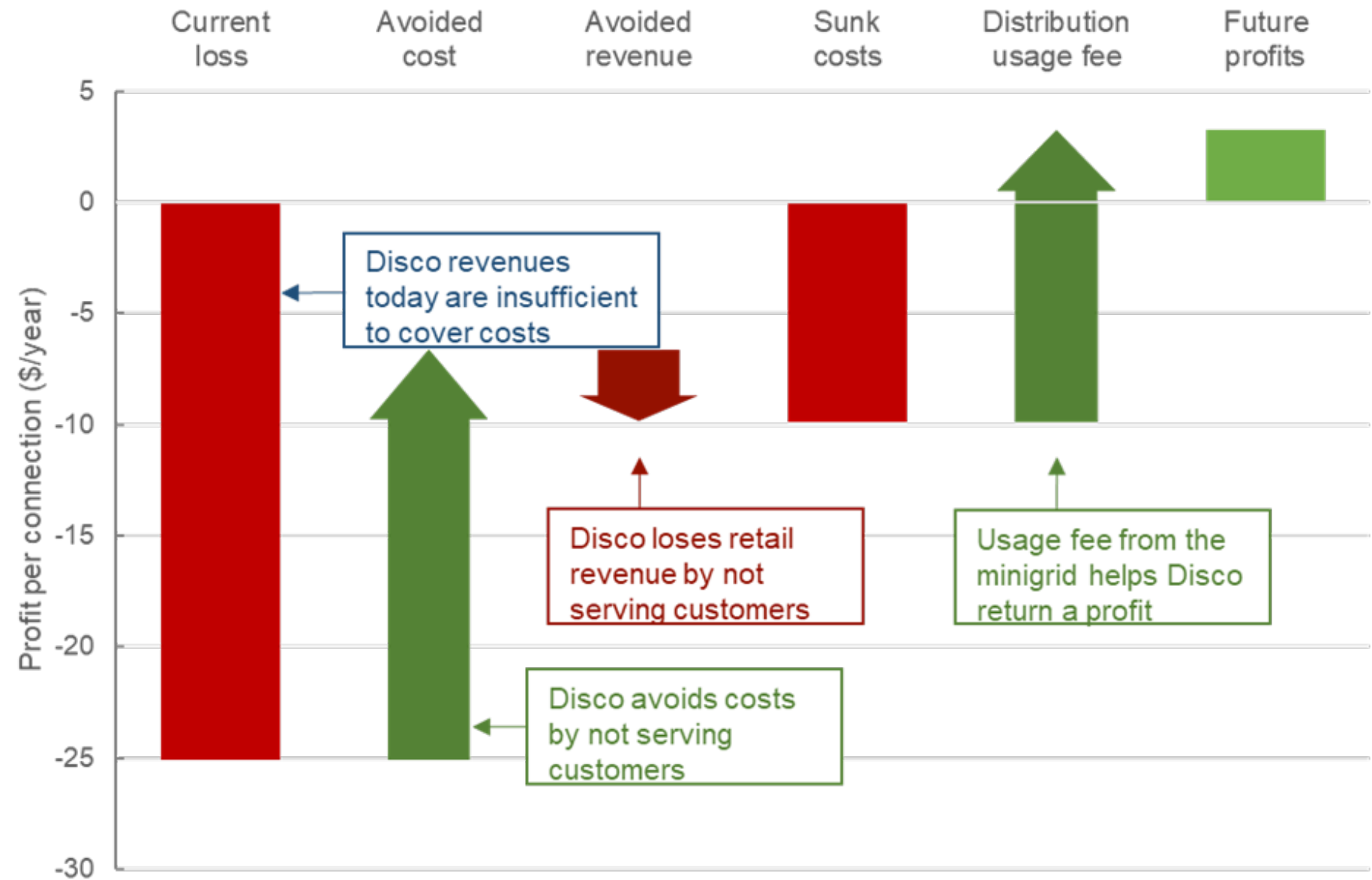
- **Increased reliability**
- **Cost savings**



*Savings in electricity cost and increase in reliability compared to pre-mini grid at Mokoloki.*

# Benefits of connected mini grids: **Discos**

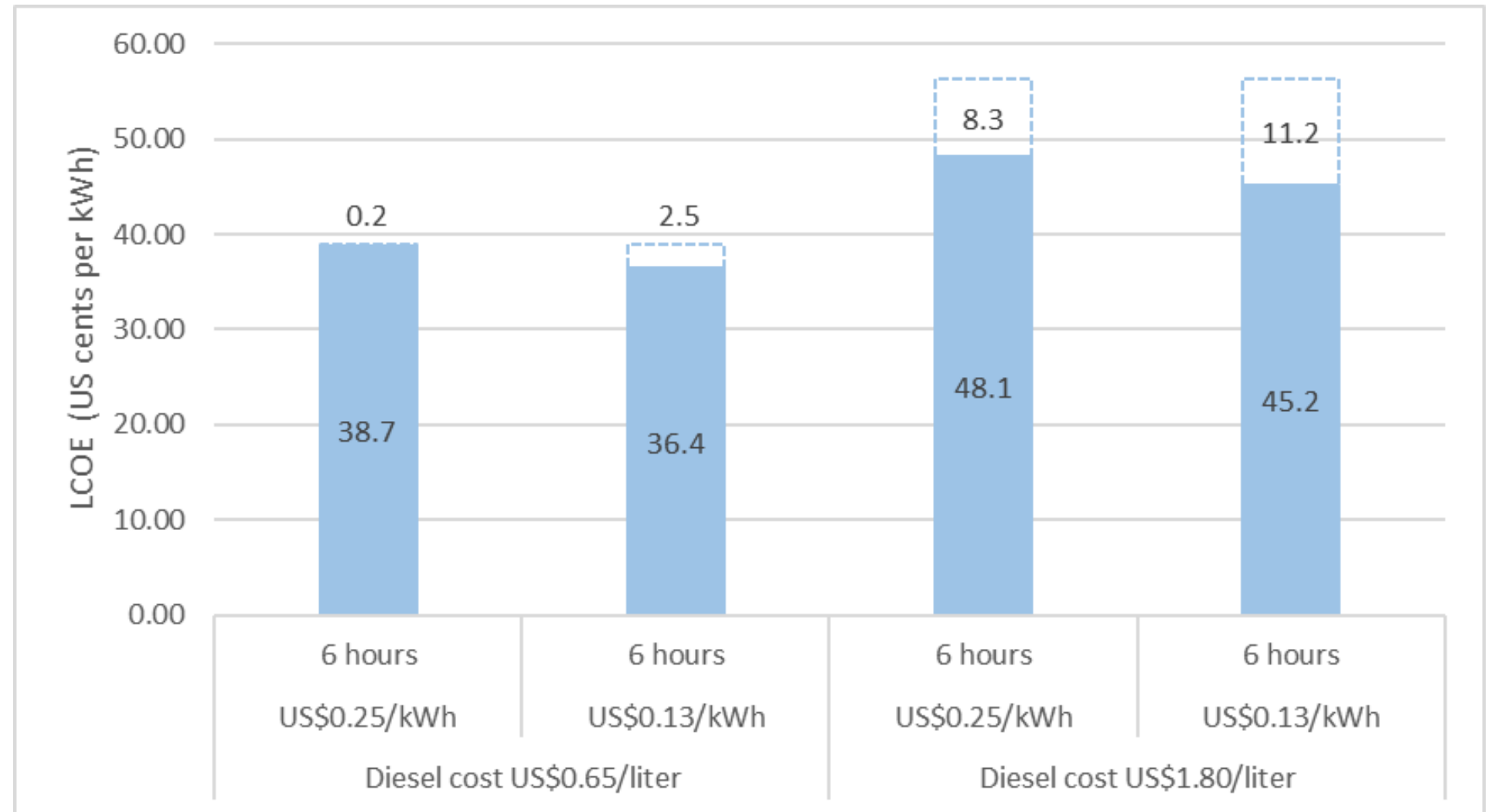
- Offloading unprofitable customers
- Leasing distribution networks
- Wholesale electricity sales to mini grids.



Effect on Disco profitability of contracting with an undergrid mini grid. Source: RMI.

# Benefits of connected mini grids: Mini grid operators

- **Reduced operational expenses.**
  - Electricity purchased at rates lower than the cost of self-generation.
- **Reduced capital expenditures**
  - Lower investment in batteries
- Savings roughly 2X with firm power, compared to non-firm



*Cost savings in a hypothetical IMAS mini grid connecting to 6 hours of firm supply from a Disco*

**Four Observations  
or  
What We Think We Have Learned**

# #1--Most least cost planning models do not see any role for undergrid mini grids.

- “Undergrid mini grids (interconnected or non-interconnected) should not exist. The existing Discos should serve these close-in customers!”
- But traditional least cost planning models assume:
  - Existing Discos will be motivated, efficient and successful operators.
  - An adequate upstream supply of electricity is available and Discos have the money to pay for this electricity.
  - The upstream transmission grid that delivers electricity to downstream Discos is working well.
  - Discos are allowed to charge cost recovering retail tariffs.
- But these assumptions are often not satisfied in many countries. That’s one reason why undergrid mini grids are being developed.

## **#2--Interconnection can create a “win-win-win” outcome for developers, Discos and final customer.**

- **Customers**
  - Household customers—higher prices for higher reliability but lower prices than non-interconnected mini grids
  - C&I customers—lower overall electricity costs with higher reliability than “going it alone”
- **Discos**
  - Earn money by leasing existing poles and wires
  - Hand-off money-losing customers (RMI-typical Nigerian disco was losing US\$0.21 per kWh)
  - Receives revenues from bulk electricity sales to interconnected mini grids
- **Interconnected mini grids**
  - Lower OPEX if mini grid can purchase electricity from the Disco during non-peak production (evening and early morning) solar hours when backup diesel generator would be used
  - Lower CAPEX (e.g., smaller battery capacity). Is the Disco supplied electricity firm or non-firm?

***Interconnection must produce a win-win-win outcome or interconnection will not happen.***

## **#3--Privately-owned and operated undergrid mini grids perform several key functions better than gov't and some privately-owned Discos.**

Mini grids generally seem to be better at:

- *Accurately metering usage*, billing and collecting payments from customers through prepaid metering and billing systems
- *Providing a more reliable supply of electricity* with fewer harmful variations in voltage and frequency
- *Increasing growth in customer demand* through financing options for appliances and machinery

*Why? Different incentives!*



## #4—Mini grids, whether interconnected or isolated, are not a “silver bullet”.

- Unrealistic to believe that a single supply option (PV panels, batteries and diesel generators) for mini grid operators will be the best solution for all potential customers in a community.
- Mini grids are a good “point of entry” but not necessarily the “end point” for scaling up and improving access.
- Regulator/grant giver: Should allow a developer to offer different combinations of supply options (mini grids, SHS, meshed grids, battery swapping and ???)
- Regulatory system should allow successful mini grids to evolve to other business models. Examples: Evolve to Discos or larger DERs through joint ventures, sub-franchising or other commercial arrangements.

# **Three Recommendations**

## **#1--Discos need incentives to interconnect.**

- If Discos are currently regulated on a cost of service (COS) basis (profits tied to the size of capital investment), the regulator should introduce performance-based elements to incentivize Disco connections to mini grids and other forms of DERs.
- This approach now being tested in the US and the United Kingdom.
- Recently recommended by RMI in Nigeria.
- Goal: encourage Discos to collaborate rather than oppose DERs.

## #2—Avoid micro-regulation for interconnected mini grids.

**TABLE 3.1** Commercial elements of interconnected and non-interconnected mini grids that could potentially be regulated

	INTERCONNECTED	NON-INTERCONNECTED
Licensing/permitting	✓	✓
Tariffs for retail sales	✓	✓
Recovery of costs to promote productive uses and household uses of electricity	✓	✓
Compensation when the main grid arrives	n.a.	✓
Length of the agreement	✓	✓
<b>Tariffs for bulk purchases by the mini grid</b>	✓	n.a.
<b>Tariffs for bulk sales by the mini grid</b>	✓	n.a.
<b>Rental rate for an existing distribution system</b>	✓	Sometimes
<b>Compensation for energy not supplied by the Disco</b>	✓	n.a.
<b>Compensation if the Disco takes back a subconcession</b>	✓	n.a.

Source: Original table compiled for this publication.

Note: Elements unique to interconnected mini grids are shown in bold. Disco = distribution company; n.a = not applicable.

- Bolded text—commercial elements specific to interconnected mini grids. Does each element need to be reviewed and approved by the regulator? Time consuming and counterproductive. Danger—the regulator could upset the balance of a complex agreement.
- A different regulatory approach. *Will the interconnection lead to lower end-use tariffs for household customers (if any)? Will technical and safety standards be met?*

## **#3--Donor/gov't technical assistance for interconnected mini grids should be given to both developers and Discos.**

- To date, most donor funded technical assistance has gone to developers of isolated and non-interconnected mini grids
- Interconnected mini grids: many Discos lack experience in negotiating with non-affiliated suppliers seeking interconnections
- Donors should fund technical assistance to both Discos and developers of interconnected mini grids
- Neutral facilitation by consultants to achieve balanced agreements.
  - Operating protocols for interconnection
  - How to finance equipment upgrades
  - Likely financial impacts



*The TPRMG microgrid in Sunheri Chauraha village (Uttar Pradesh, India) just before and just after the microgrid went live.*

# QUESTIONS?



# Wuse market Mini Grid, Nigeria

- Largest urban market in Abuja (Nigeria's capital city):
  - 2,155 shops & stalls
  - 40 cold rooms
- Provides 24/7 power
- Capex \$2.1 M
- 20-year tri-partite agreement between developer (GVE), local disco (AEDC) and the Wuse Market Traders Association:
  - GVE leases distribution poles and wires from AEDC
  - GVE to purchase 7 hours of grid electricity during priority hours: 7am to 10a and 4p to 8p.



1 MWp solar PV, 1.2 MWh li-ion battery, 1 MW diesel backup



# Wuse market Mini Grid, Nigeria

ESMAP

- The Wuse mini grid will allow shop and stall owners to stop using more than 3,000 small petroleum and diesel generators
  - Small on-site generators supplied half shop owner's electricity
  - Noisy, dirty, and costly to run
- Extend market closing from 6pm to 9pm
- Retail tariff: \$0.133 per kWh (under renegotiation)
  - Compare with \$0.38/kWh per for mix of AEDC & self-generation

