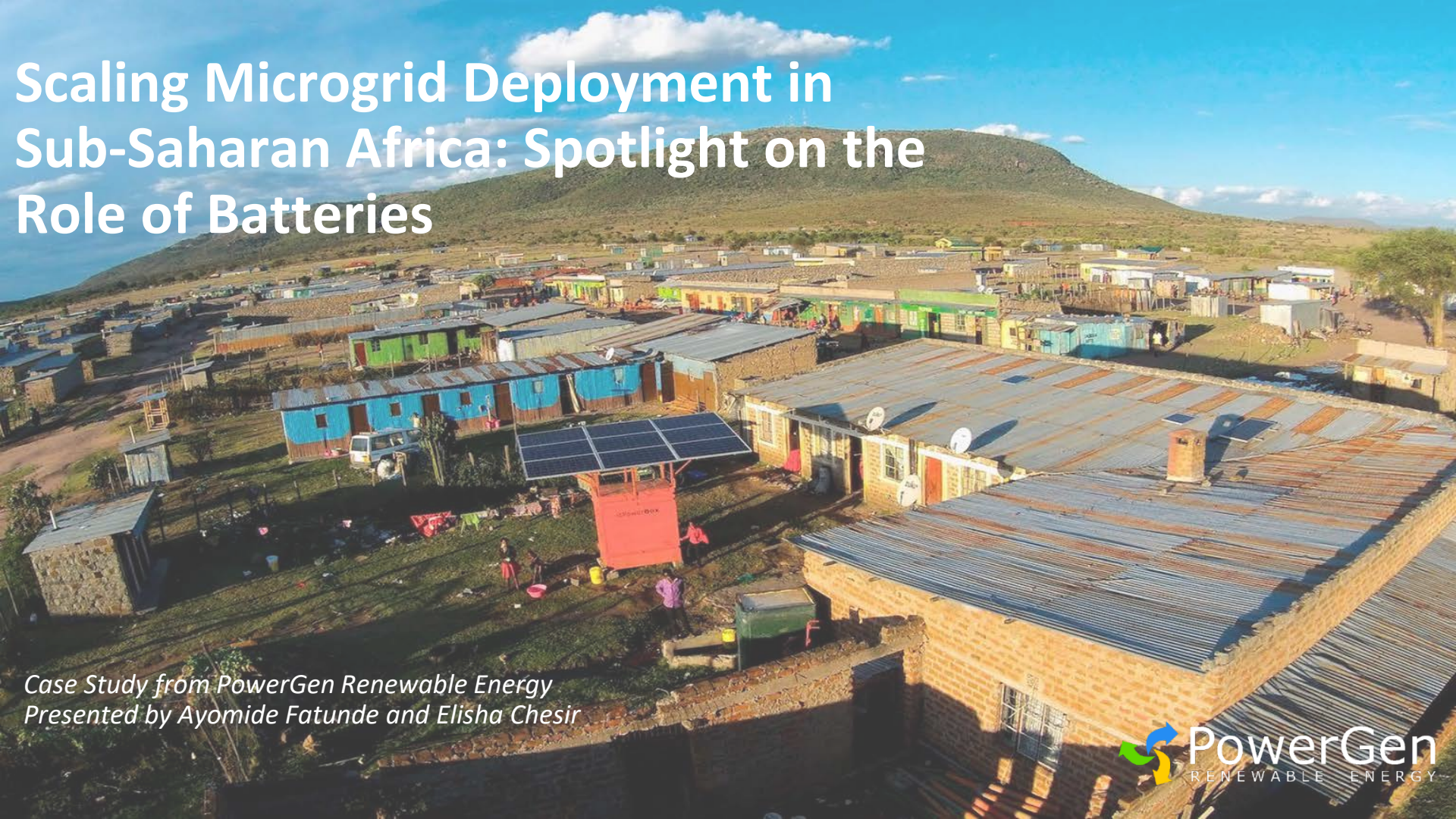
Scaling Microgrid Deployment in Sub-Saharan Africa: Spotlight on the Role of Batteries

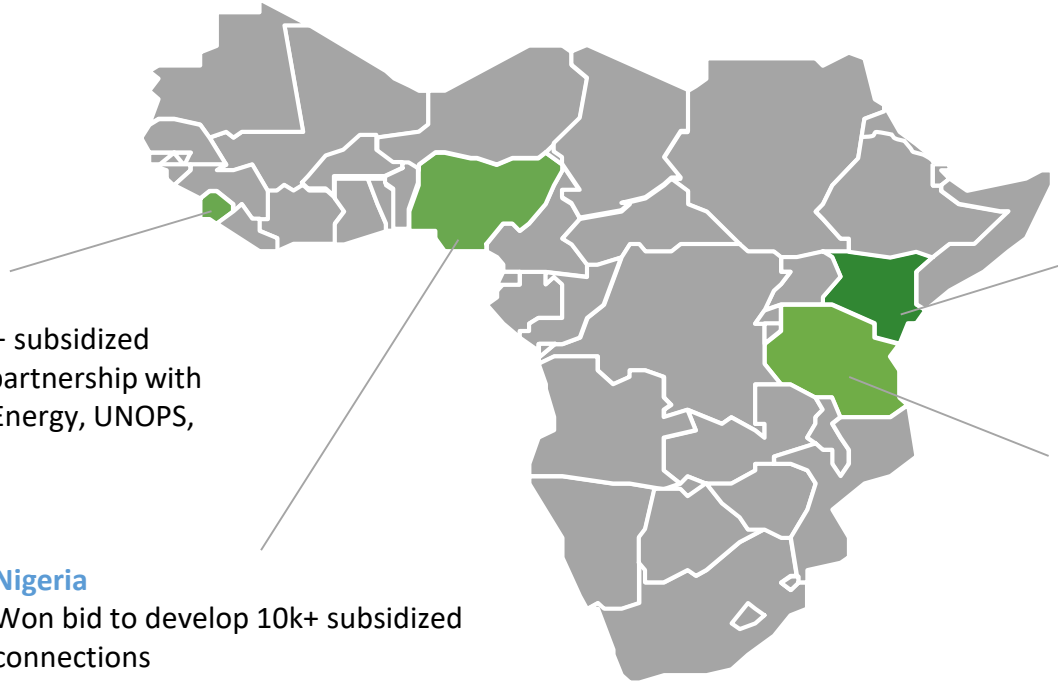


Case Study from PowerGen Renewable Energy
Presented by Ayomide Fatunde and Elisha Chesir

PowerGen
RENEWABLE ENERGY

Quick Intro to PowerGen

We are a leading mini-grid developer and off-grid power EPC. Over the past 8 years, we've installed more than 200 solar power systems in seven countries throughout the region, from Somaliland to Mozambique. Currently, our work is primarily focused on 4 markets.



Sierra Leone
Developing 10k+ subsidized connections in partnership with the Ministry of Energy, UNOPS, and DFID.

Nigeria
Won bid to develop 10k+ subsidized connections

Kenya
7k+ connections profitably implemented with a tea farm partner and another 8k connections under development for a different agricultural partner

Tanzania
Location of first PG-owned sites. 2k+ connections currently being managed

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We're highly vertically integrated so all our technical decisions influence our commercial decisions, and vice versa

Micro-grid Development

- Site surveys
- Local government engagement and permitting
- Community engagement
- Project financing
- Customer sign-ups and contracts
- Tariff setting

Engineering, Procurement, Construction

- Engineering
- Supply Chain
- Project Management
- Driving down capex
- Integrating new technologies

Customer & Asset Management

- Customer energy sales
- Customer call center
- Technical support and O&M
- Driving down opex
- Promotions
- Appliance financing
- Demand stimulation

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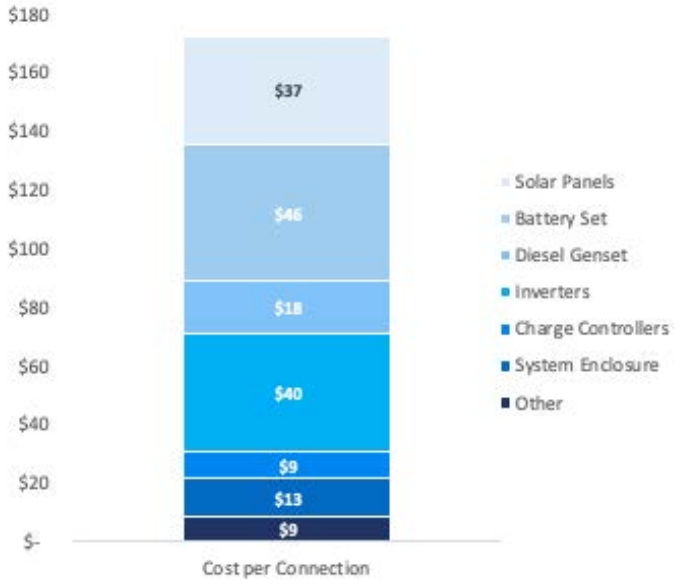
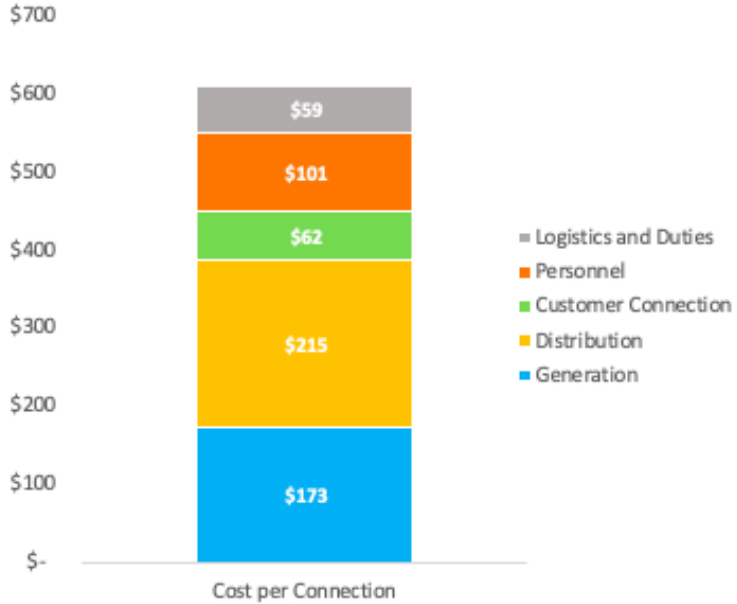
Guaranteeing 24/7 AC power to our customers requires that we invest heavily in storage





Batteries represent about 25% of our CAPEX on generation assets and roughly 8% of our total expenditures for each customer.

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Key Storage Related Challenges We Face

1. Wide Variance in Site Conditions
2. Financial Constraints
3. Wide Variety of Vendor Offerings

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Conditions at each site are so different that it is hard to develop a one-size-fits-all approach to storage solutions

Lagos, Nigeria

COMMERCIAL LOADS

COOLING SETPOINT: 30C

	HVAC	Deg.	Life	LCC ($)
Lead Acid	No System	5.42%	3.69	$88,500
	Two Fans	3.13%	6.39	$78,990
	Existing	3.13%	6.40	$79,179
	Four Fans	3.12%	6.40	$79,443
	Dantherm10kDC	3.12%	6.41	$84,592
Li-ion	No System	1.98%	10.10	$71,134
	Existing Fans	1.43%	14.00	$69,930
	Eight Fans	1.43%	14.00	$71,113
	Set Lifetime A	*2.86%*	*7*	*$73,608*
	Set Lifetime B	*2%*	*10*	*$69,067*

COOLING SETPOINT: 25C

HVAC	Deg.	Life	LCC ($)
No System	5.42%	3.69	$88,500
Two Fans	2.81%	7.11	$79,950
Existing	2.80%	7.14	$80,650
Four Fans	2.79%	7.17	$81,563
Dantherm10kDC	2.22%	9.00	$83,343
No System	1.98%	10.10	$71,134
Existing Fans	1.43%	14.00	$72,759
Eight Fans	1.43%	14.00	$75,812
Set Lifetime A	*2.86%*	*7*	*$73,608*
Set Lifetime B	*2%*	*10*	*$69,067*

RESIDENTIAL LOADS

COOLING SETPOINT: 30C

	HVAC	Deg.	Life	LCC ($)
Lead Acid	No System	10.88%	1.84	$157,547
	Two Fans	4.18%	4.78	$112,560
	Existing	4.17%	4.79	$112,762
	Four Fans	4.17%	4.80	$113,057
	Dantherm10kDC	4.14%	4.84	$120,461
Li-ion	No System	6.47%	3.09	$125,833
	Existing Fans	1.57%	12.71	$91,314
	Eight Fans	1.57%	12.76	$92,843
	Set Lifetime A	*2.86%*	*7*	*$96,317*
	Set Lifetime B	*2%*	*10*	*$89,506*

COOLING SETPOINT: 25C

HVAC	Deg.	Life	LCC ($)
No System	10.88%	1.84	$157,547
Two Fans	3.74%	5.34	$111,829
Existing	3.72%	5.38	$112,490
Four Fans	3.69%	5.42	$113,461
Dantherm10kDC	2.88%	6.94	$114,416
No System	6.47%	3.09	$125,833
Existing Fans	1.43%	14.00	$93,285
Eight Fans	1.43%	14.00	$96,826
Set Lifetime A	*2.86%*	*7*	*$96,317*
Set Lifetime B	*2%*	*10*	*$89,506*

The mean temperature of our hottest site is 35C (Soitsambu), while it is 18C at our coolest (Kericho)

It is most ideal for the batteries to be maintained at a setpoint of 25C. This can be achieved via fans, insulation, passive cooling, shading, and/or air conditioning

Some of our sites require only 18 kWh of usable storage capacity while others require 300 kWh

The results to the left show just how much the load pattern at a site can influence battery degradation

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Closing the gap in the tradeoff between battery lifetime and lifetime expenditures

When PowerGen first entered the industry, lead acid was widely held as the most economical storage solution. However, the price of lithium ion has dropped drastically since then and lithium can now be seen as an investment that pays for itself in the long run.

- ★ Double the cycle life means we replace a lithium ion bank once in the lifetime of the grid, compared to three replacements for lead acid
- ★ Financiers more willing to give one time asset capital than recurring working capital
- ★ Lithium ion cells weigh less than lead acid cells so we can see savings even in shipping and logistics costs

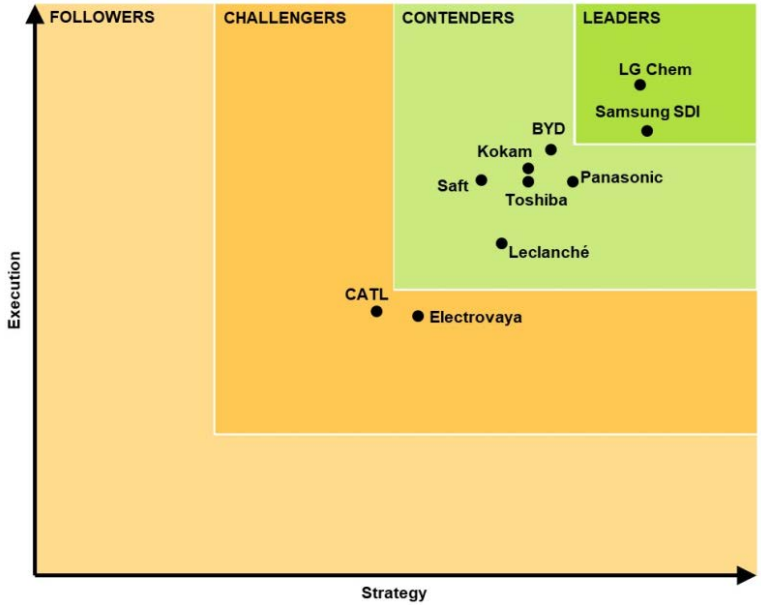
Wading Through Vendor Offerings

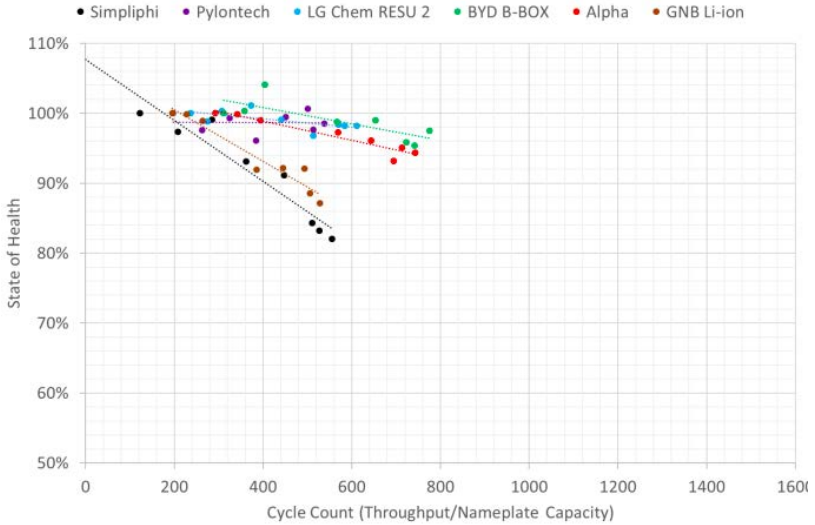
Finding the best solution is very resource intensive, requiring that both our Supply Chain and Engineering teams collaborate heavily. We structure our conversations with battery vendors around the criteria listed below.

Criteria	Questions Being Asked
Suitability to Our Business	• Does the vendor already have operating units in SSA? • What is the highest operating temperature for which their warranty is still valid? • Are the units sensitive to high discharge rates? • How deeply can the units be discharged?
Accuracy of Claimed Cycle Life	• What is their longest running operating unit? • What were the conditions (C-rate, especially) and extrapolation techniques used to reach the final cycle life number? • Are the battery cells manufactured by the vendor? If no, who is their OEM?
Cell Monitoring	• Which inverter brands are their units compatible with? • What are the key features of their BMS and is it easy to operate? • Is their API documentation available and robust enough for us to work with?

Additional Industry Research

In 2015, Navigant Research put together a Leaderboard for the Grid-Storage Lithium Ion market. Vendors were evaluated based on product performance/quality, as well as commercial characteristics such as staying power and geographic reach.





In 2018, the Australian Renewable Energy Agency's Battery Test Center published a comprehensive report on the lithium ion market leaders. Papers like this save us from having to conduct intense technical evaluations of each and every vendor.

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We're putting together a set of best practices based on the results from NREL's analysis

Temperature Sensitivity

The cycle life of most batteries is halved for every 10° increase in operational temperature above 35C. We mitigate this by insulating our PowerBoxes and installing **thermostat controlled fans** or active cooling devices that maintain at 28 C setpoint.

Cycling Sensitivity

The lifetime is also heavily influenced by the depth of discharge and the discharge rate. PowerGen sizes and configures all it's systems such that a **C/24 rate** is used for discharging and manufacturer recommended depths of discharge are never exceeded.

Storage Sensitivity

Lead acid batteries experience roughly 4-5% self-discharge/month, which usually equates to a shelf life of less than 6 months. Lithium ion batteries experience 2-3%. PowerGen accommodates this by procuring based on immediate needs and **periodically charging** units in storage.

Additional Best Practices Used to Prolong Battery Life

Enclosures

In some regions, we have started building **brick-and-mortar** PowerHouses as opposed to steel PowerBoxes to take advantage of the natural cooling properties of brick.

The tradeoff here is that our technicians have to spend more days out on site constructing the house and that testing of the final wiring cannot be done in a controlled workshop setting.

Passive Cooling

Ventilation ducts are a central component of all our power systems. We also make sure that the first 20kWp worth of PV panels are mounted above the power system to provide **shading**.

This is the cheapest form of cooling and extremely effective at our sites in Kericho, Kenya. The next step for us would be to start analyzing wind strength and direction at sites and locationally optimize our systems.

Thank You!