The Future of Power in Africa:
How Africa can Lead the Next Generation of Global Power Infrastructure
Quick PowerGen intro

**Pioneering the micro-grid model in East Africa**

- One of the leading micro-grid installers in Africa (35+ micro-grids installed over the past 3 years, mostly in Kenya and Tanzania)

- Over 60 full-time employees in offices in 2 countries (Kenya and Tanzania)

- Hundreds of kW-scale off-grid power systems installed throughout seven countries across East Africa since 2011

1. What is a “grid” and why do we need them?

2. Do autonomous systems make sense for the African consumer?

3. The global future of power

4. Re-framing the discussion: energy access and renewable energy (not “on-grid” vs. “off-grid”)

5. PowerGen’s approach

6. Challenges for the micro-grid sector to overcome
What is a “grid”— and do we still need them?
What grids are NOT...

Addressing some biases

1) An endorsement of fossil fuels
   *Grids don’t know and don’t care where their passing electrons come from*

2) An endorsement for centralized generation
   *Electric cables are OK with electrons moving either direction*

3) Going away
   *Our energy system is evolving, but in a way that makes grids more important, not less*
What grids are: the biggest, cheapest batteries we have

Grids are about storage, not generation

1) Costs to go “off-grid” are extremely high, even if batteries get much cheaper.

Average costs to go off-grid – for storage only, excluding generation costs – for average homes in a selection of countries, based on current and future costs for battery storage:

- **USA (30kWh/day):** Current: $350/kWh, > $40,000
- **Germany (10kWh/day):** Current: $350/kWh, > $10,000
- **India (2.5kWh/day):** Current: $350/kWh, > $3,000

Grids are networks, and well-managed networks drive resource utilization efficiency
What grids are: the best chance we have at controlling carbon long-term through renewable energy

*We can’t deliver cost-effective kilowatt-hours, megawatt-hours and gigawatt-hours without a grid*

- Demand for power in emerging markets will grow dramatically in the coming decades (despite great progress with energy efficiency).

- Installing large-scale renewables requires a large, smart, robust grid.

- Common misconception: because solar has “worked” in the US and Europe, and solar can be scaled down to be distributed, Africa can ‘leapfrog’ using solar.

  - This is wrong:

    - Solar may be down-scalable, but storage is not! (and ‘big storage’ = grid)

    - The only reason solar has “worked” in the US and Europe is because of the big, free battery they get to feed into called the grid (*and billions of dollars in subsidies*)
Scaling renewable energy – a visual of the limitations of the non-grid approach

- **Installed Capacity of M-Kopa Systems (~4MW)**
- **Installed Capacity of Kenyan Grid (~2,000 MW)**
- **Installed Capacity of Kenyan Grid in 5 years (~5,000 MW)**

If M-Kopa Scales **10x** in Kenya (~40MW)
Grids are big batteries, and they are critical for scaling up renewables.
So commercial and industrial applications need grid, but what about consumers. Isn’t this about energy access?
The huge positive impact of solar home systems

*SHS has been extremely effective at delivering watt-hour scale energy*

**Why have they been so effective?**

Because they sell **value reflective** energy, and consumers' initial appliances have extremely high implied energy values:

\[
\text{Value of Energy} \left( \frac{\$}{kWh} \right) = \frac{\text{Social Utility of Appliance} \left( \frac{\$}{h} \right)}{\text{Energy Consumption of Appliance} \left( kW \right)}
\]

The implication of this equation is that SHS companies can sell energy for

> $5/kWh
SHS provide high value energy in a closed system

**SHS operating regime**
But what happens when consumers want more than a few dozen watt-hours per day?

**Bad Thing 1**

*Power system cost scales exponentially, because demand grows exponentially*

**Bad Thing 2**

*Consumer willingness to pay drops quickly as their consumption grows (on per WH basis)*

\[
\text{Bad Thing 1} \times \text{Bad Thing 2} = \text{Really hard to scale up}
\]
But what about appliance energy efficiency?

*Efficiency improvements will absolutely lower the necessary consumption to live a well-powered life, but probably not to levels where it will be affordable without a grid.*

“How much energy do African consumers need” is a challenging and somewhat subjective question to answer, but if you value using any electric appliances in your home that create heat (showers, toasters, kettles, microwaves) you need the capacity for kilowatt-hours.
Some actual numbers that illustrate the challenge of scaling up SHS

Assume that PV generation costs per electron are at true grid parity (a generous assumption to solar), then frame the problem based on battery storage costs versus grid connection...

American Household (30 kWh/day)
European Household (10 kWh / day)
Future Global Household? (4 kWh / day)
Indian Household (2.5 kWh / day)
Solar Home System (0.05 kWh / day)

Storage cost values are based on Lithium Ion batteries at $0.35/WH installed, assuming 90% DOD, and 2 day autonomy factor. Battery replacement costs not included.

These battery costs will come down, but even at $100-150/kWh the cost/benefit versus a grid connection is challenging.
Autonomous systems (SHS) are excellent for initial energy access, but do not scale up well.
The evolution of the global energy system
The global future of power

The future power grid will resemble a mesh of distributed storage, generation, and consumption nodes – rather than its current mono-directional architecture.

**Old Model**

- Fossil fuel Extraction
- Centralised Generation
- Transmission & Distribution
- Retail/Supply
- Customers

**New Model**

- Fossil fuel Generation
- Transmission & Distribution
- Retail/Supply
- Customers
- Customers engage actively with the market
- Customers generate and store locally
- Smart Meters
- Interconnection
- Distributed Storage
- Distributed Generation

Intermittent generation
Another visual of the same concept

From IEEE

Fig. 1. The IEEE’s version of the Smart Grid involves distributed generation, information networks, and system coordination, a drastic change from the existing utility configurations.
Critical for Africa’s power systems to converge on the **future** of the global grid, not the old/current model.

**Existing Grid Architecture in the West**

- Smart Metering
- Distributed Generation
- Distributed Storage
- More Renewables
- Deregulation

**Future State of Global Power System**

**Africa’s Power System**

**Parallel African System, Unique from the Rest of the World**

**Good!**

**Bad!**

(gov’t, donor, DFI risk)

**Bad!**

(SHS sector risk)
A case study in convergence: telecoms

What has worked:

Same telecom architecture globally

What we need to be careful of:

AC smart grids everywhere in the world, except Africa where we have small, autonomous, DC systems?
Africa’s convergence with a global energy system is critical
How do we converge? – first, we need to better frame the problem
“On-grid” vs. “off-grid” should be re-framed

We’re all trying to solve the same problems, and those are:
1) Energy access
2) Renewable energy

Not “on-grid” versus “off-grid”

Splitting the conversation between “off-grid” and “on-grid” is causing fragmented, uncoordinated, and sometime contradictory thinking about optimal solutions.

“Team Off-Grid”

- Value Reflective Tariffs ($5/kWh)
- Service is what matters, not commodity electrons
- Energy provision = gateway for other services
- Pre-pay / smart metering technologies, paired with financing

“Team Grid”

- Grid networking = lower pricing and larger scale consumption (productive loads)
- Infrastructure for the long term
- Long term project financing
- Grids are the best way to enable more renewables!
The current landscape, re-framed along more useful dimensions

Renewable energy axis

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Where different players sit

**Renewable energy axis**

- **Only fossil fuel generation**
  - C&I fossil fuel developers
  - Oil / Gas Companies

- **No Grid (autonomous, discrete energy)**
  - Solar Lanterns
  - Solar Home Systems

- **Multi-directional grid (distributed energy)**
  - "Most Likely Future" zone
  - Solar-only micro-Grids
  - Rooftop solar

- **Centralized grid (mono-directional, large generation only)**
  - Hybrid AC grid-integrable micro-grids
  - Progressive utility companies
  - C&I RE developers
  - Utility-scale RE developers
  - Most African governments, donors, DFIs
  - Conservative utility companies

**Energy access axis**
Energy access and renewable energy are two related but distinct problems, and should not be too closely conflated.
PowerGen’s approach
The power sector in Africa

Significantly less existing grid architecture offers an opportunity for Africa to leapfrog the old utility architecture.

- Developed Country Grid
  - Existing infrastructure and entrenched incumbents makes transition to future grid more challenging

- Less-Developed Country Grid
  - Opportunity to build the power system architecture of the future from near scratch

= population center
Building Africa’s future smart grid from the “outside in”

*Autonomous and grid-connected smart micro-grids*

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**Legend:**
- **Green circles:** Population centers
- **Autonomous Smart Micro-Grids (SMGs):**
  - Circular grid with a yellow square
- **Grid-Connected Smart Micro-Grids (SMGs):**
  - Linear grid with a yellow square
- **Less-Developed Country Grid:**
  - Circular grid with a red outline
  - Population centers within the grid

**Generation:**
- **Power station, wind turbine, solar panel:**
  - Depicted in the bottom right corner

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*PowerGen RENEWABLE ENERGY*
Incorporating the elements of the future smart grid

Smart metering. Distributed storage. Distributed generation.
A closer look at the systems

**Step 1:**
Autonomous Solar Micro-Grid

- Solar energy distribution network

**Step 2:**
Grid-Connected Solar Micro-Grid

- Mobile money payments from the customer, and system communication to the customer
- Usage data helps quality customer service

**Smart metering** manages payment processing and usage data tracking

Cloud Software System

- Home
- Business

Transformers

Substations

Generation
Micro-grids solve Africa’s near-term and long-term power challenges at the same time

And in doing so also bring electricity access to millions of people more quickly than they otherwise could get it from central grid extensions

Near Term Solutions

- Finance last-mile grid connections for consumers who do not currently have access to power
- Offer improved power reliability versus the main grid

Long-Term Solutions

- Bi-directional storage improves grid quality both upstream and downstream
- Distributed architecture of the system enables for easy integration of renewable generation
- Ubiquitous smart metering throughout the grid allows improved operations, maintenance, and efficiency of the network
- Reduced grid throughputs due to distributed storage and generation can enable lower cost “thin grid” transmission and distribution
Building the future grid in Africa is in everyone’s interest

All stakeholders win

Good for:

- **Governments**: Achieve electrification targets and prepare their countries for future power investment
- **National Utilities & Regulators**: Sell more power (because more people are connected) and better manage overall grid performance
- **Consumers**: Obtain access to electricity faster, and enjoy better reliability and service from that power supply
- **Environment**: Improves due to ability to utilize more renewable energy sources on the “mesh” grid of the future
- **Donors & Lenders**: Leverage their investments further by bringing private capital into the utility sector in Africa
Challenges to overcome
Eight core principles for Smart Micro-Grids (SMGs) to succeed

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- Grid integration frameworks
- Tariff frameworks
- Programmatic permitting
- Pragmatic technical standards

Financing:
- Symmetrical subsidies
- Consolidation of funding
- Standardization of asset and bankability of off-takers
- Decoupling from “green” mandate
Thank You