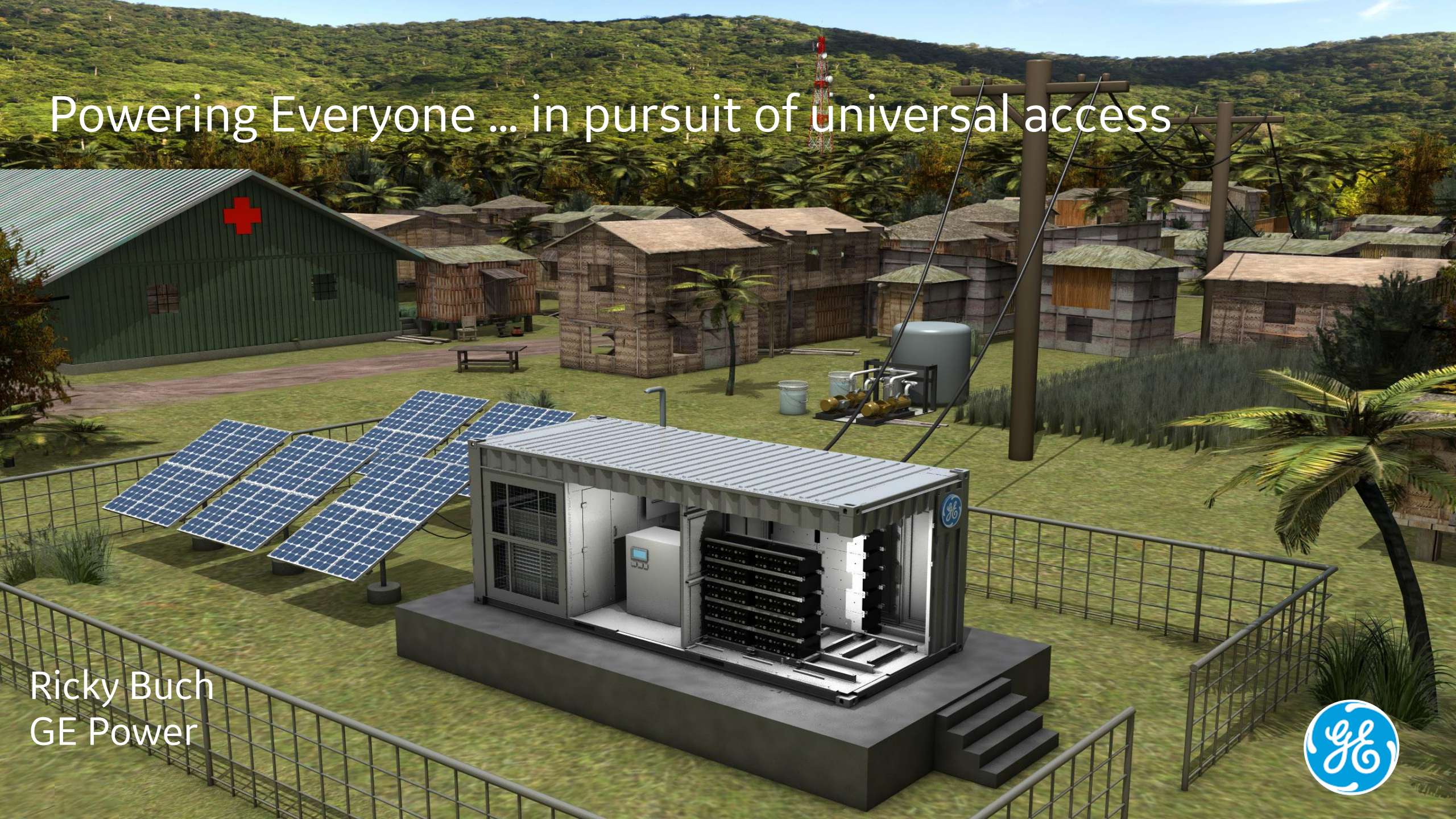


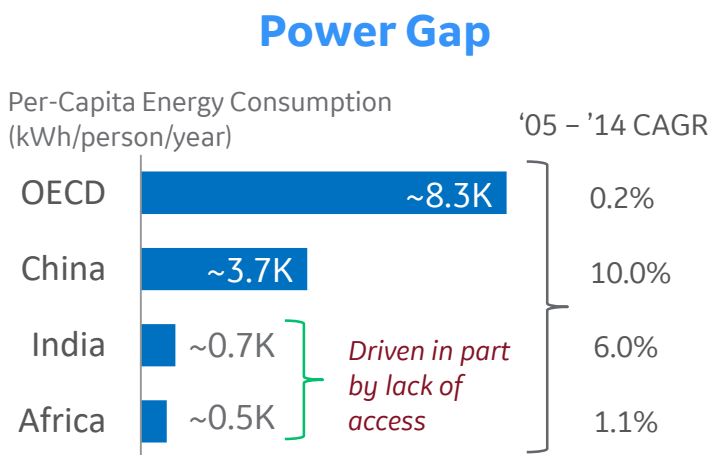
Powering Everyone ... in pursuit of universal access



Ricky Buch
GE Power



Hybrid Distributed Power: New solutions needed to provide access



Firm the Grid


1

Build the Grid

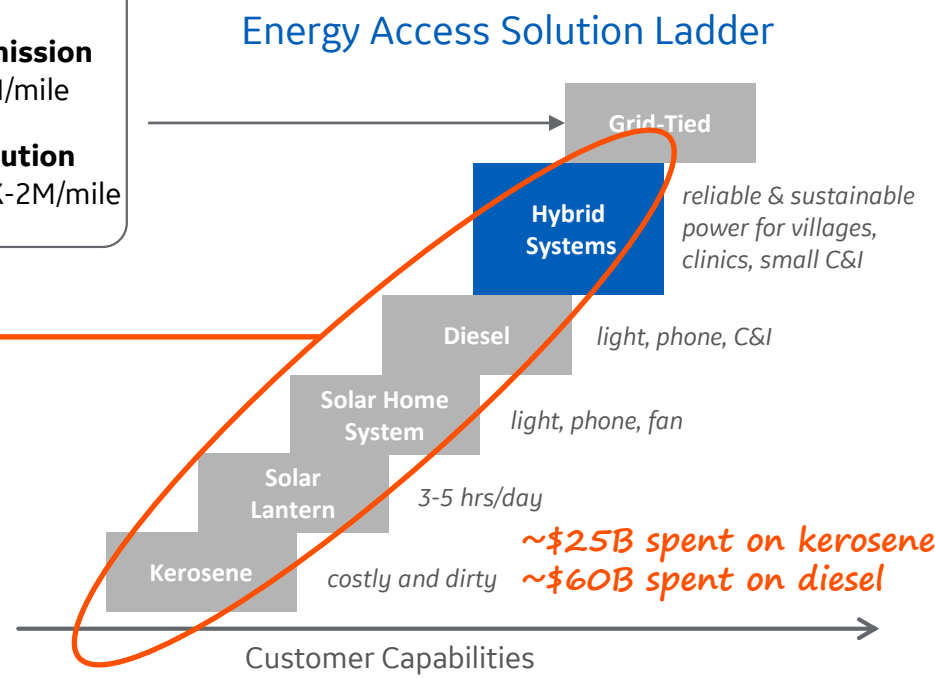
2

**Transmission**
~\$1-3M/mile

**Distribution**
~\$200K-2M/mile

Skip the Grid

3

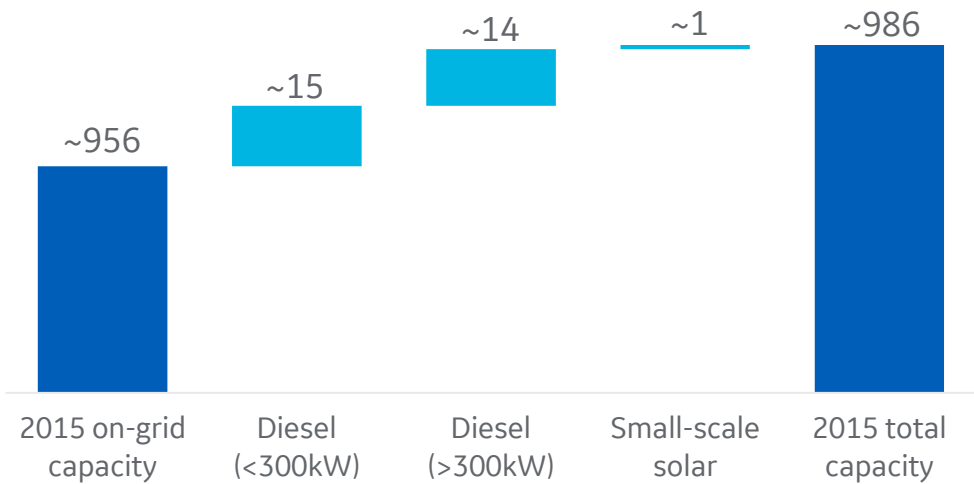
IEA: >40% of new energy connections from microgrids



Investment in hybrid power provides unique growth opportunity

Significant opportunity in developing country behind-the-meter market

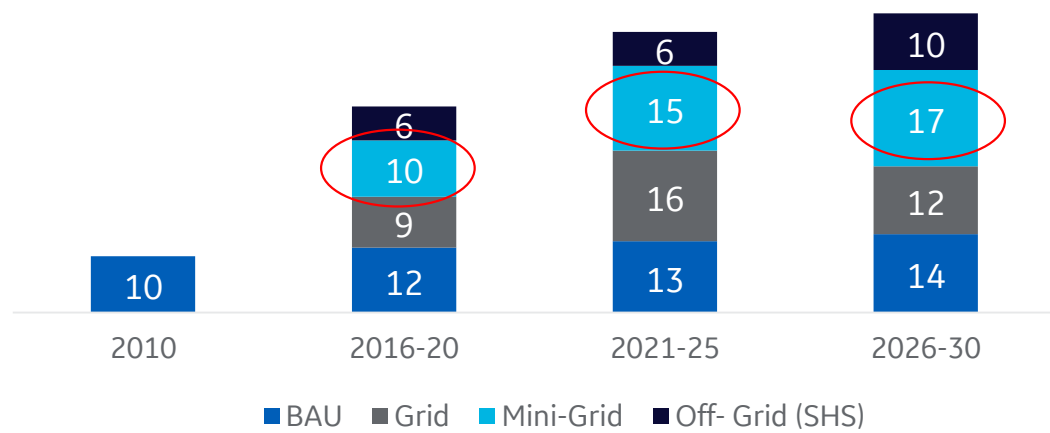
Village or captive installations of diesel in emerging markets



- ~30GW market for behind-the-meter diesel, used to operate when no grid present or poor reliability (>20% CF)
- Opportunity to replace virtual pipeline / gas engines to replace >300kW in hybrid configuration

Addressable market for off-grid electrification

\$10-15B/yr. minigrid opt'y thru 2025

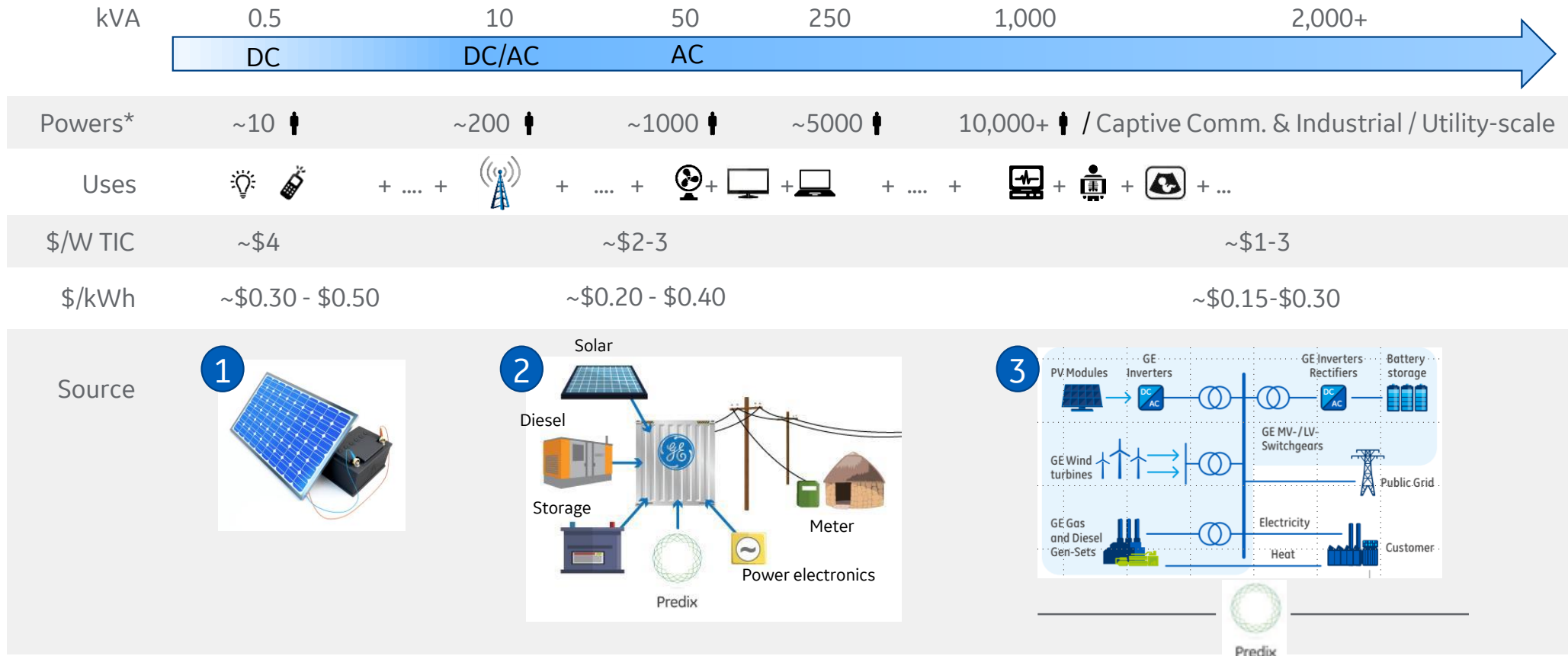


- \$10B/yr. potential spend on mini-grids for electricity access
- SHS growing w/ lower PV costs, pay-as-you-go mobile payment, but cannot drive productive uses
- Mini-grids will need to interact with the grid to firm power / export

\$10-15B market opt'y to address with renewable-based hybrid minigrids targeted at off-grid areas in growth markets



GE's comprehensive portfolio of energy access technologies



GE off-grid electrification portfolio spans different access levels:

1. DC [solar/battery system](#) provides basic access levels for residential loads
2. The [containerized renewable hybrid](#) solution can provide 24x7 power to a large village
3. GE's [utility-scale microgrid](#) technology can power village clusters & integrate seamlessly with a utility system



Renewable Hybrid Power Solution

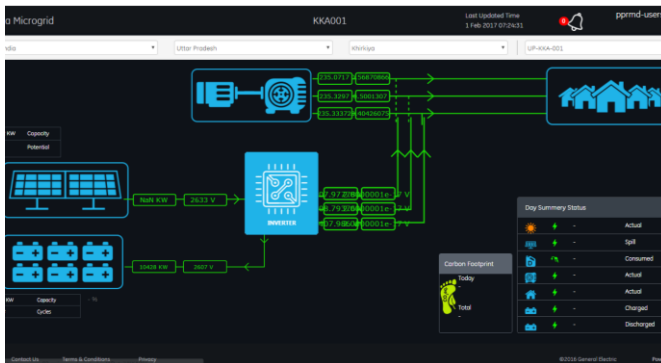
Modular, containerized, digitally-connected power solution for off-grid electrification

Features

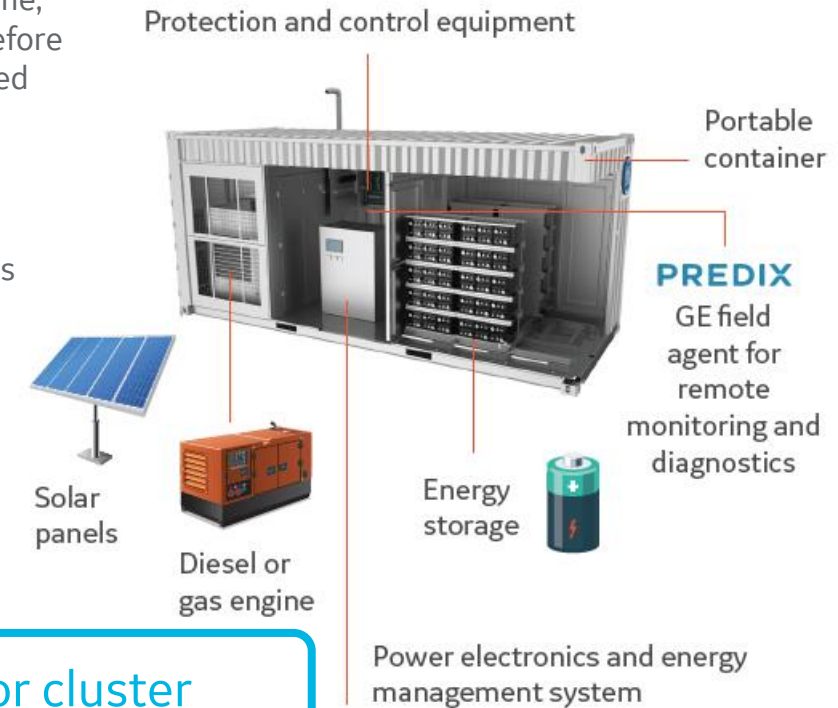
- Pre-configured and pre-fabricated with recip, storage, protection & control + power electronics—simply connect distribution lines to begin exporting power
- Easy external connection point for solar arrays
- Hybrid controller prioritizes renewable power to lower operating cost
- Cloud-enabled monitoring and diagnostics using Predix™ allows for remote supervision across multiple installations
- Quickly increase capacity either by paralleling multiple systems or adding incremental solar and energy storage

Benefits

- Lower installation and commissioning time and expenditures
- Reduced operating cost and emissions versus diesel-only systems
- Quickly scale output to capture growing demand
- Achieve higher uptime, identifying issues before they cause unplanned downtime
- Enhanced ability to monitor and control multiple installations
- Operate reliably through a variety of environmental conditions



Predix-based remote monitoring platform allows for real-time monitoring and diagnostics

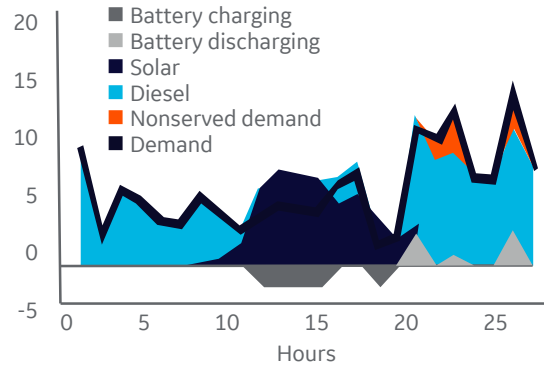


Ideally suited to provide reliable power to a single village or cluster



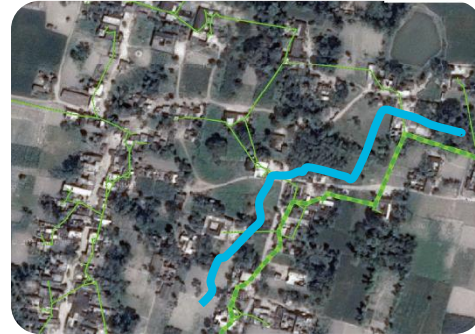
Using digital technologies to facilitate energy access

Control operation: Automate with software + Predix



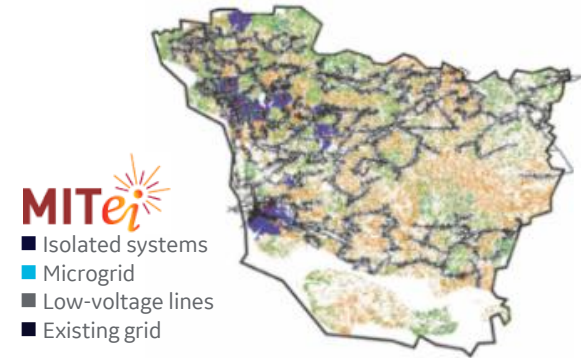
- Local controller coordinate energy sources to minimize LCOE
- Digital twin: proactively identify issues, ↑ uptime, service revenue
- Integrate w/ demand response, customer notification, billing to optimize microgrid operations

Configuration modeling: Optimize generation & layout



- Rooftop tagging, mobile surveys to estimate demand
- Modelling to identify optimal microgrid configuration (i.e. amount of solar vs. energy storage)
- Satellite data and GPS coordinates to layout distribution grid

Learning customizer: Electrification expansion



- Analytics determine whether most economic to build, or “skip” grid
- Clustering analysis: determine most economic group of sites
- Refine as deployments provide data; integrate w/ grid analytics

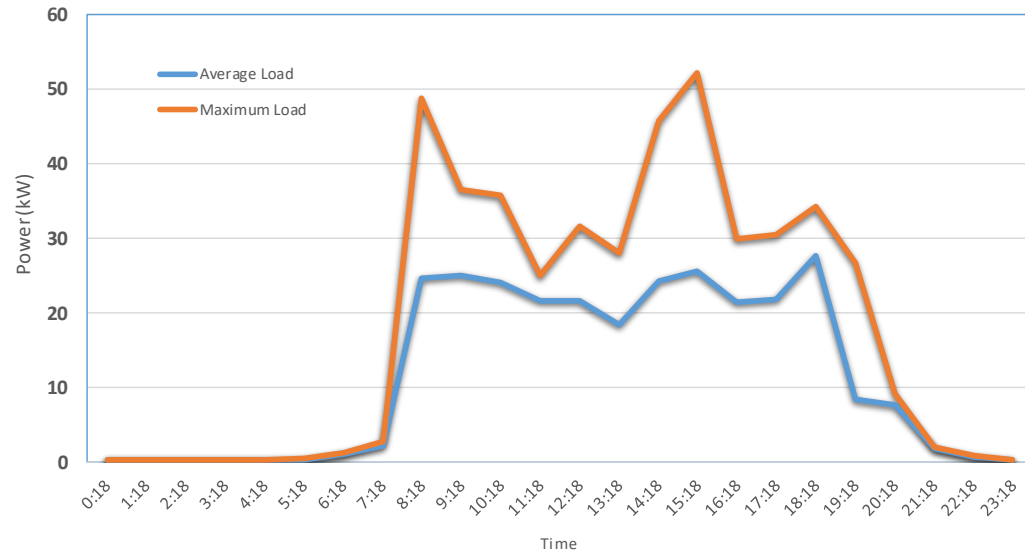
Digital tools critical to expanding access economically

- **Speed and cost to operation:** identify right tech and layout, lower upfront cost
- **Scalability:** flexible strategy to address growing demand
- **Streamline operations:** control supply and demand, customer mgmt. and mobile payment

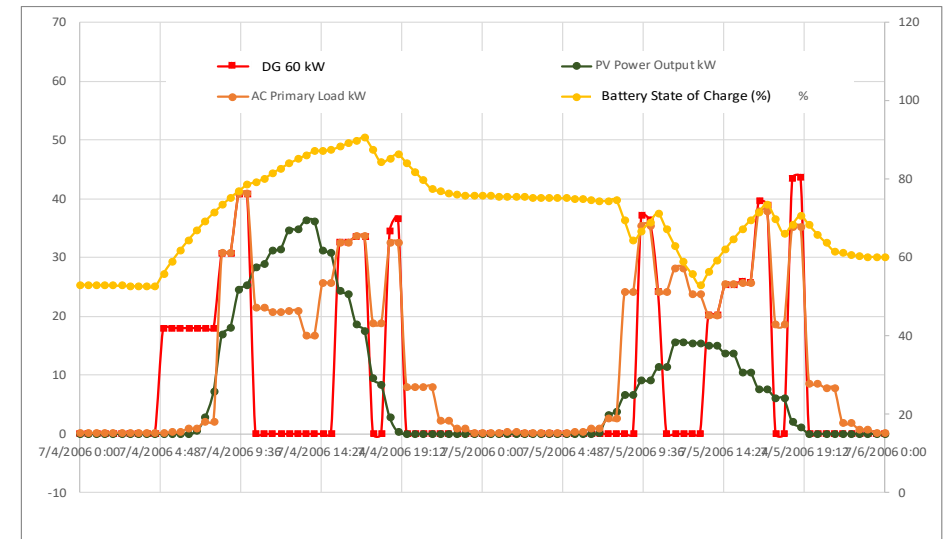


Renewable hybrid can deliver better customer outcomes

1 Assess the demand profile



2 Run hybrid dispatch model



3 Compare the hybrid financial results w/ diesel-only alternative – actual customer in Lagos, Nigeria

Case	Solar (kW)	Battery (kWh)	Budgetary Capex (\$)	Generating LCOE (\$/kWh)	Diesel operation (hours/year)	Diesel Consumption (lit/year)	Payback (years)
Diesel only	0	0	15,000	\$0.65	8,760	70,241	Base
Medium renewable hybrid	50	144	78,006	\$0.36	2,000	18,894	1.50
Large renewable hybrid	100	144	99,606	\$0.32	959	8,697	1.68

Typical projects reduce tariffs by 50%+ compared to diesel-only; developer payback IRRs of 15-20%



Partnering with GHE on DC microgrids



Hybrid Distributed Power – Case Studies

Tata Power – Bihar, India



- Provide 24x7 power to Tayyabpur village
- MIT geospatial analysis to configure grid
- Productive use development key to driving demand, project economics
- **Key lesson:** Demand estimation key weakness in project analysis; design systems for scalability / modularity

Ministry of Health - Ethiopia



- Captive power for maternal health center
- Integrated design: PV attached to container
- Identified local partner for installation / commissioning & ongoing maintenance
- **Key lesson:** Flexibility in packaging to address poor road conditions, value in GE store

Gumatj Corp. – NT, Australia



- Captive power for Aboriginal training camp
- Developed training manuals and other material to ensure ongoing equipment support
- Powered during Garma festival; inspected by NT Chief Minister & mentioned by Australia PM
- **Key lesson:** Validate applicability in OECD countries for areas that rely on diesel

Select thoughts on the off-grid journey so far...

- Electrification will be an “All of the Above” ... solar home systems, DC/AC microgrids, grid extension
- Countries with off-grid populations can “right size” grid investment by utilizing hybrid DER microgrids
- Engage with policymakers ... expand the electrification conversation to integrate microgrids
- Embrace the demand profile uncertainty ... focus on a microgrid design that is scalable and extensible
- Focus on enabling the end uses of electricity ... not just the delivery of electricity
- Need to explore alternative financing vehicles ... blended capital, equipment lease structures, guarantees, etc..
- Design tariffs and incent productive uses to utilize PV ... build the afternoon peak
- Invest in the “FEED” stage ... use tools to expedite site evaluation

Opportunity to change the electrification paradigm for 2B+ people



