



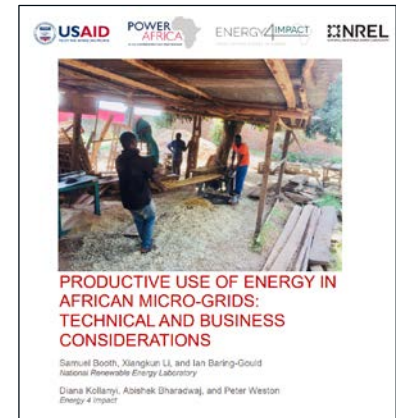
Microgrids for Access and Resiliency in the Pacific: Key Issues and Lessons

Samuel Booth
National Renewable Energy Laboratory

*Clean Energy Solutions Center Webinar
July 2019*

Introduction

- Pacific Islands present a unique opportunity for energy access and energy resiliency, but projects face unique challenges
- NREL has been supporting access and resiliency projects globally and is pleased to share some information and lessons



General Energy Planning Considerations for Islands

- Large opportunity for isolated microgrids e.g. 600 islands in Papua New Guinea
- Remote, dispersed, and hard to access locations increase costs for shipping, installation, and O&M.
- Small-medium sized power systems with unique considerations for high levels of renewables but limited existing deployment
- Need projects designed for natural disasters e.g. typhoon winds and folding turbines or special PV fasteners
- Marine environment and increased corrosion can require special materials
- Opportunity to demonstrate solutions on small systems but at a scale that matters for learning



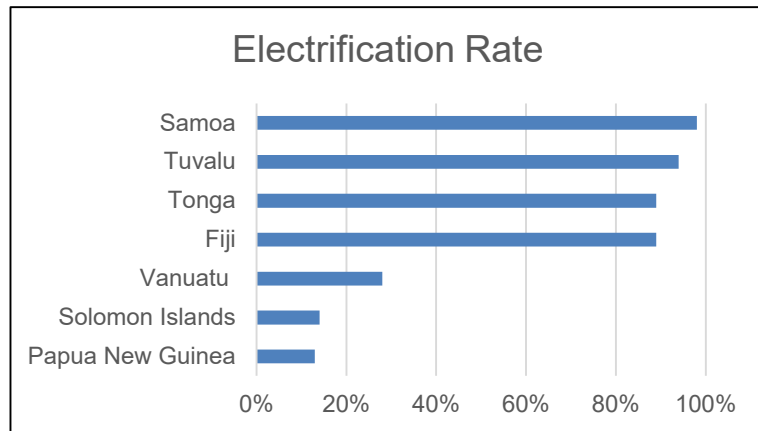
Microgrids for Energy Access

Need: About 1 billion people globally without access to electricity, 350 million in Asia, and about 80% in rural areas

Investment requirements: ~\$52 B annually needed to meet universal access targets by 2030, with ~ 50% in mini-grids.

Current: Less than half required investment. Need private capital to close the gap.

Goal: Drive private capital investment by improving the speed, scale, and standardization of projects by implementing NREL's Quality Assurance Framework and providing technical support to key issues



Sources: IEA World Energy Outlook 2018, IEA Energy Access Outlook 2017, and Prasad R, A review of Fiji's Energy Situation: Challenges and strategies as a small island developing state, Renewable and Sustainable Energy Reviews, 2017.

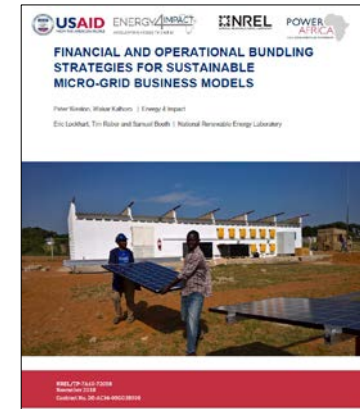
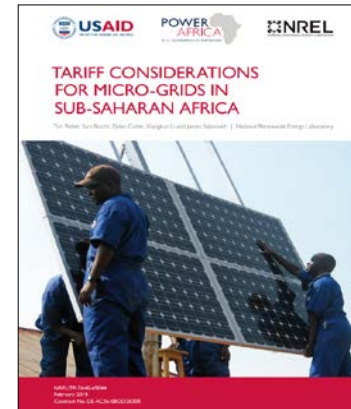
NREL's Quality Assurance Framework

- **Purpose:** Provide structure and transparency for mini/micro-grid sector, based on successful utility models.
- **Challenge:** Utility model breaks down in the case of rural electrification as a result of high costs of providing power, high risk perception, and lack of proven business models
- **Importance:** Help lay the foundation for successful business models in the mini/micro-grid space



Key Energy Access Challenges

- **Cost of power**
 - Costs are increased by isolated communities, low population density, and low power demands
 - Revenues impacted by limited ability to pay and inconsistent cash flows
- **Supportive Regulatory Environment**
 - Cost reflective versus national tariffs
 - Mitigating risk of grid arrival
 - Technical standards
- **Access to Finance**
 - Limited capital availability and high cost of financing
- **Uncertainty**
 - Lack of proven business models
 - Poor information on performance of existing systems



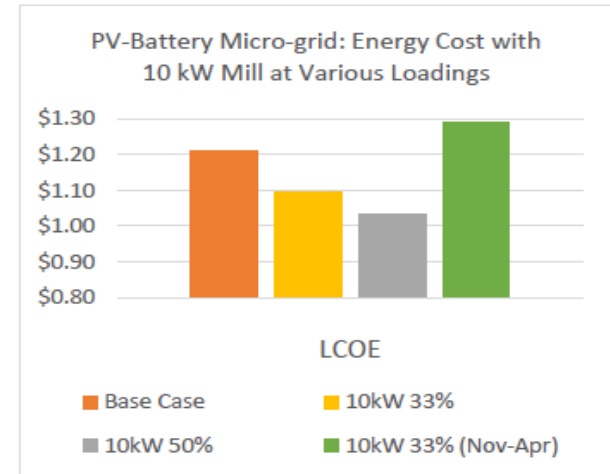
Example: Grid Arrival

NREL is supporting the development of new isolated power system regulations in Uganda. Draft regulations propose several models to reduce investment risk of grid arrival

- **Model 1:** Buy out with compensation for assets and lost profit.
Challenge: Who pays (utility, electrification agency, etc.), certainty of payment, and how to value assets and future profit?
- **Model 2:** Micro-grid generation is converted to small power producer selling power to utility.
Challenge: Likely not enough revenue to recoup microgrid investment costs e.g. energy storage and technical upgrades for interconnection (e.g. protective relays) are likely required.
- **Model 3:** Micro grid operator becomes a mini-utility and supplies a mix of utility company and self generated power.
Challenge: Can mini-utility charge more than national tariff to recoup costs?

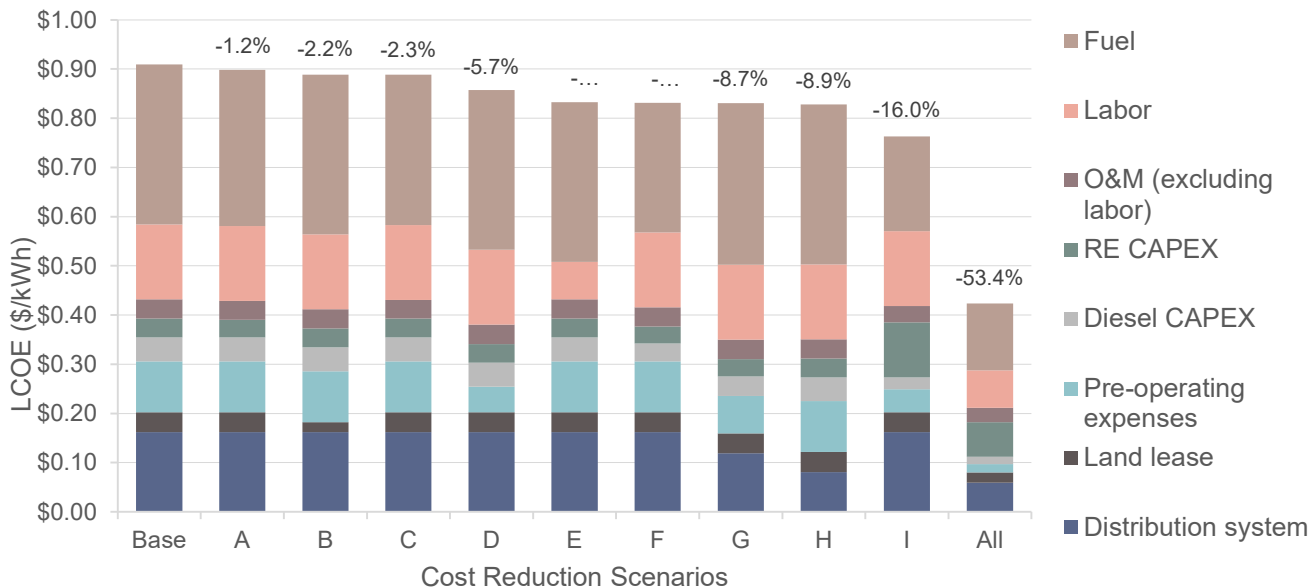
Productive Use

- Mini-grids provide enough energy for productive uses that most smaller systems cannot
- Productive needs support and stimulation
 - Training, financing, etc.
- Requires careful consideration from developer and entrepreneur
 - Load characteristics, risk, seasonality, alternatives, etc.



Link to Publication: <https://www.nrel.gov/docs/fy18osti/71663.pdf>. Image credit: Sam Booth, NREL

Costs and Levers for Reduction



Scenario Description

A	Low RE costs
B	50% reduction in land lease costs
C	95% load met
D	50% reduction in pre-operating expenses
E	50% reduction in labor costs
F	Low diesel capital costs
G	10% discount rate
H	50% reduction in distribution system costs
I	Commercial heavy load

Base case: residential-heavy load, 100% load met, 15% discount rate, medium RE costs, medium diesel capital costs.

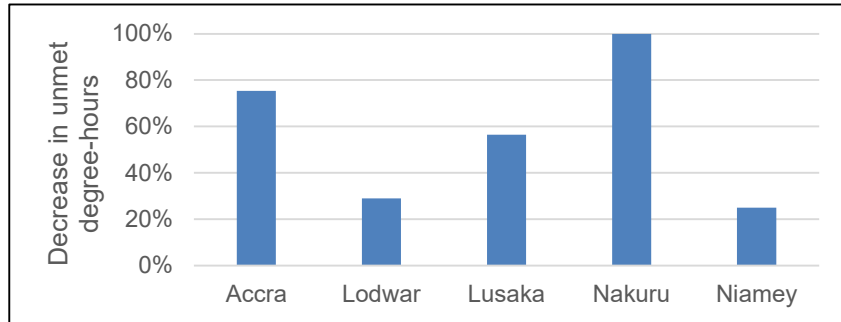
Source: Based on Tariff Considerations for Micro-grids in Sub-Saharan Africa (NREL)

Link to Publication : <https://www.nrel.gov/docs/fy18osti/69044.pdf>

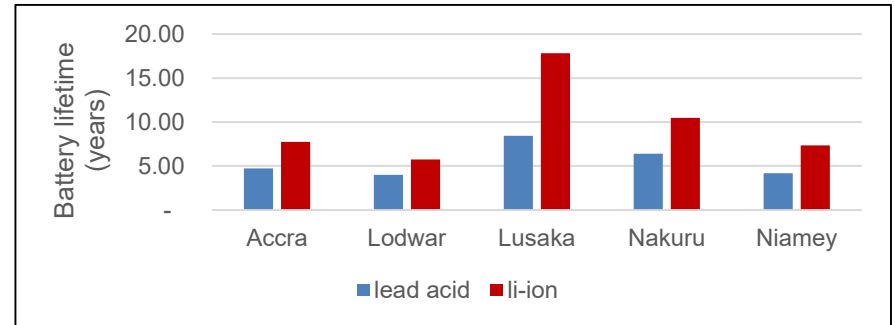
Large potential for systematic cost reduction

Battery Selection and Economics

Decrease in unmet degree-hours resulting from adding four fans to systems with lead-acid batteries in an insulated wood structure serving a commercially oriented community load profile.



Comparison of battery lifetimes between lead-acid and Li-ion batteries for different locations (commercial load profile, insulated wood enclosure, four fans)



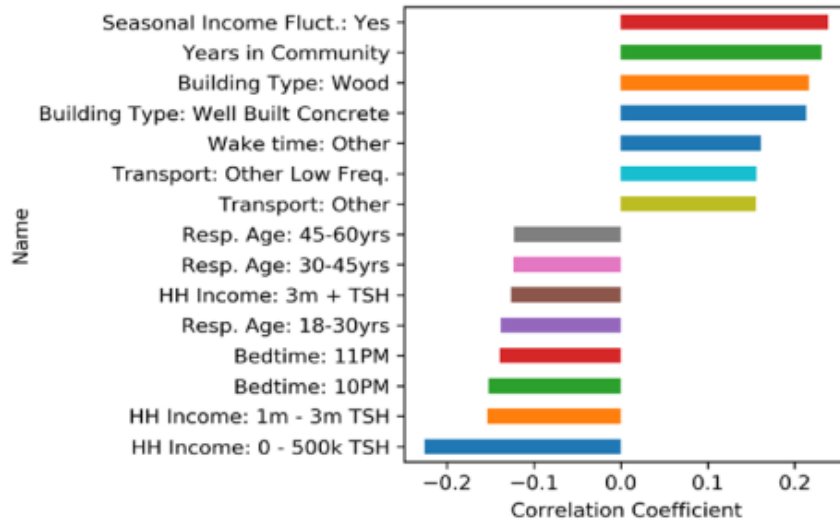
Images: Erik Lockhart, Xiangkun Li, Samuel Booth, et al. (forthcoming). *Comparative Study of Techno-economics of Lithium-ion and Lead-acid batteries in Micro-grids in Sub-Saharan Africa.*

Optimal Construction, Insulation, and HVAC Combination to Minimize Life Cycle Costs for Each Combination of Battery, Load Profile, and Location

Accra	Load Profile	Final LCC	Construction	Insulation	HVAC Type
Lead-acid	Commercial	\$119,172	Wood structure	Insulated	No system
Li-ion	Commercial	\$110,806	Wood structure	Insulated	No system
Lead-acid	Residential	\$150,129	Wood structure	Insulated	No system
Li-ion	Residential	\$143,939	Wood structure	Insulated	Air conditioner

Analysis indicates that switching to lithium ion will lower lifetime costs but decisions are impacted by location, enclosure type, loads, and capital costs.

Load Prediction from Surveys



Many existing systems are oversized (up to 4X) based on inaccurate demand estimation. Analysis of actual consumption vs survey responses (for microgrids in Tanzania) can help better predict loads, reducing risk, and cost

Source: <https://www.nrel.gov/docs/fy19osti/72339.pdf>

Proposed Survey Questions for Electrical Load Estimation

Blue indicates correlation with high consumption, while **red** indicates correlation with low consumption.

What is the nature of this connection?

Home, **Business**, **Home/Business**, Public Premises

If this is a business, what business activities are you involved in?

Restaurant, **Bar**, Guest House/Hotel, Shop, Phone Charging, Other (could specify further options or leave for free entry)

If this is a home, what is the employment of the primary income earner in the home?

Self-Employed Non-Agriculture, **Self-Employed Agriculture**, Employee, Unemployed, Other

What are your current sources of energy?

Firewood, Battery, **Diesel**, Petrol, Kerosene, Propane, SHS

What modes of transportation do you own?

Bicycle, Motorcycle, **Car**, **Boat**, **Other**

What electrical appliances do you already own?

Lights, Phone Charger, Radio, **Television**, Sound System, CD/DVD Player, **Other**

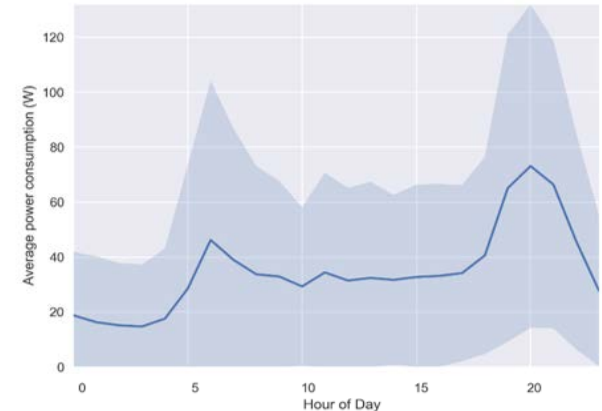
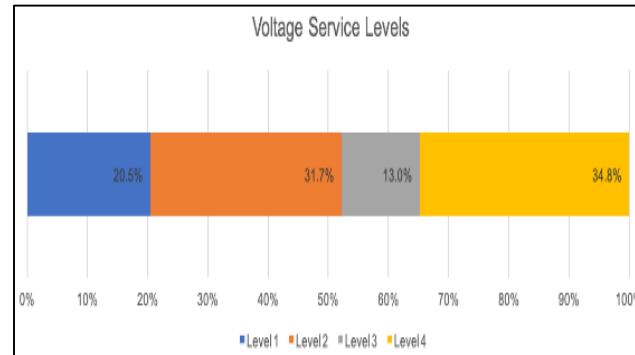
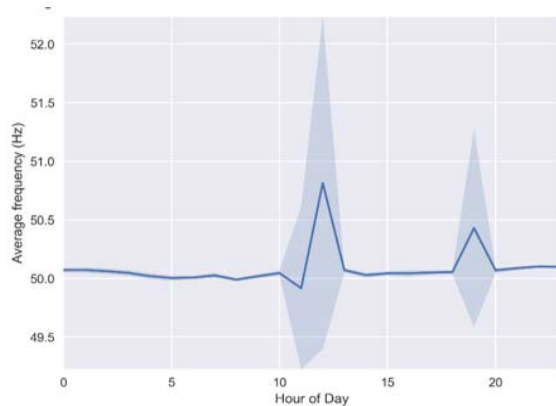
What material is the house or structure where you are seeking a connection made from? (could be observed rather than asked)

Brick, Crumbling Concrete, **Well-Built Concrete**, **Wood**, Other

In a typical week, how much money do you spend on mobile phone airtime?

Smart Systems and Metering

- **Provides:** Monitoring, management, and insight capability
- **Uses:** Remote diagnostics, system/portfolio assessment, forecasting, design improvement, distribution level visibility
- **Stakeholders:** Developers, financiers, regulators, utilities, etc.



Microgrids for Resiliency

Benefits

- Redundant power supply for grid outages, natural disasters, etc.
- Economic savings from grid connected services e.g. demand response
- Smart customer energy management e.g. peak shaving and efficiency opportunities

Trends

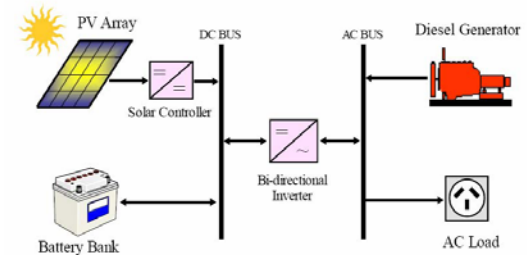
- Increasing weather related outages
- Dramatic reductions in RE and storage costs improves business model
- Existing distributed RE development lowers costs
- Control and inverter technology advances e.g. controllability, ride through, improve functionality

Picture image: credit Sam Booth, NREL

Diagram image: credit T. Markvart (editor). *Solar Electricity*, 2nd ed. England, John Wiley and Sons, 2000, p. 124.



Hybrid
Systems



Resiliency Planning

- Process
 - Identify hazards and threats
 - Assess vulnerabilities
 - Determine potential impacts
 - Identify technical solutions
 - Rank solutions
- Example Benefits
 - Reduced impacts
 - Faster recovery
 - Continuity of operations
- NREL is developing resiliency planning tools

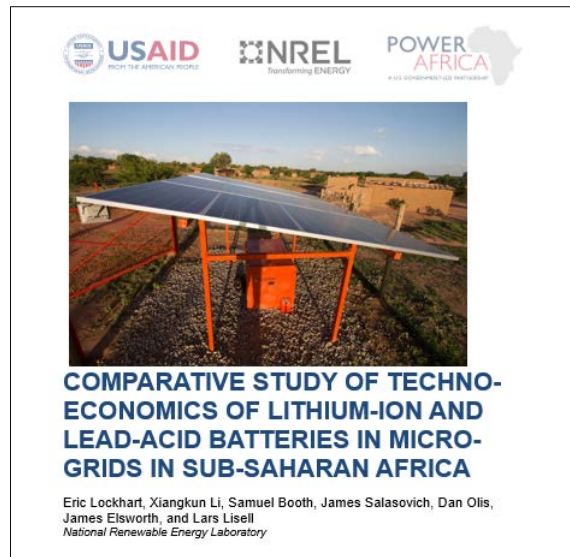
4.2 MW PV Array USVI
Pre And Post Hurricane



Source: U.S. DOE and Eliza Hotchkiss, <https://www.nrel.gov/state-local-tribal/blog/posts/pv-survivability-from-hurricanes-lessons-learned.html>

Resource List

- **Quality Assurance Framework (multiple documents)**
 - <https://www.cleanenergysolutions.org/qaf>
- **Productive Use**
 - <https://www.nrel.gov/docs/fy18osti/71663.pdf>
- **Tariff Considerations**
 - <https://www.nrel.gov/docs/fy18osti/69044.pdf>
- **Financial and Operational Bundling**
 - <https://www.nrel.gov/docs/fy19osti/72088.pdf>
- **Customer Agreements**
 - <https://www.nrel.gov/docs/fy18osti/70777.pdf>
- **Surveys for Load Prediction**
 - <https://www.nrel.gov/docs/fy19osti/72339.pdf>
- **Battery Selection and Economics**
 - <https://www.nrel.gov/docs/fy19osti/73238.pdf>
- **Coming soon:**
 - Performance monitoring



Thank you!

For more information or collaboration contact:

Sam Booth: samuel.booth@nrel.gov