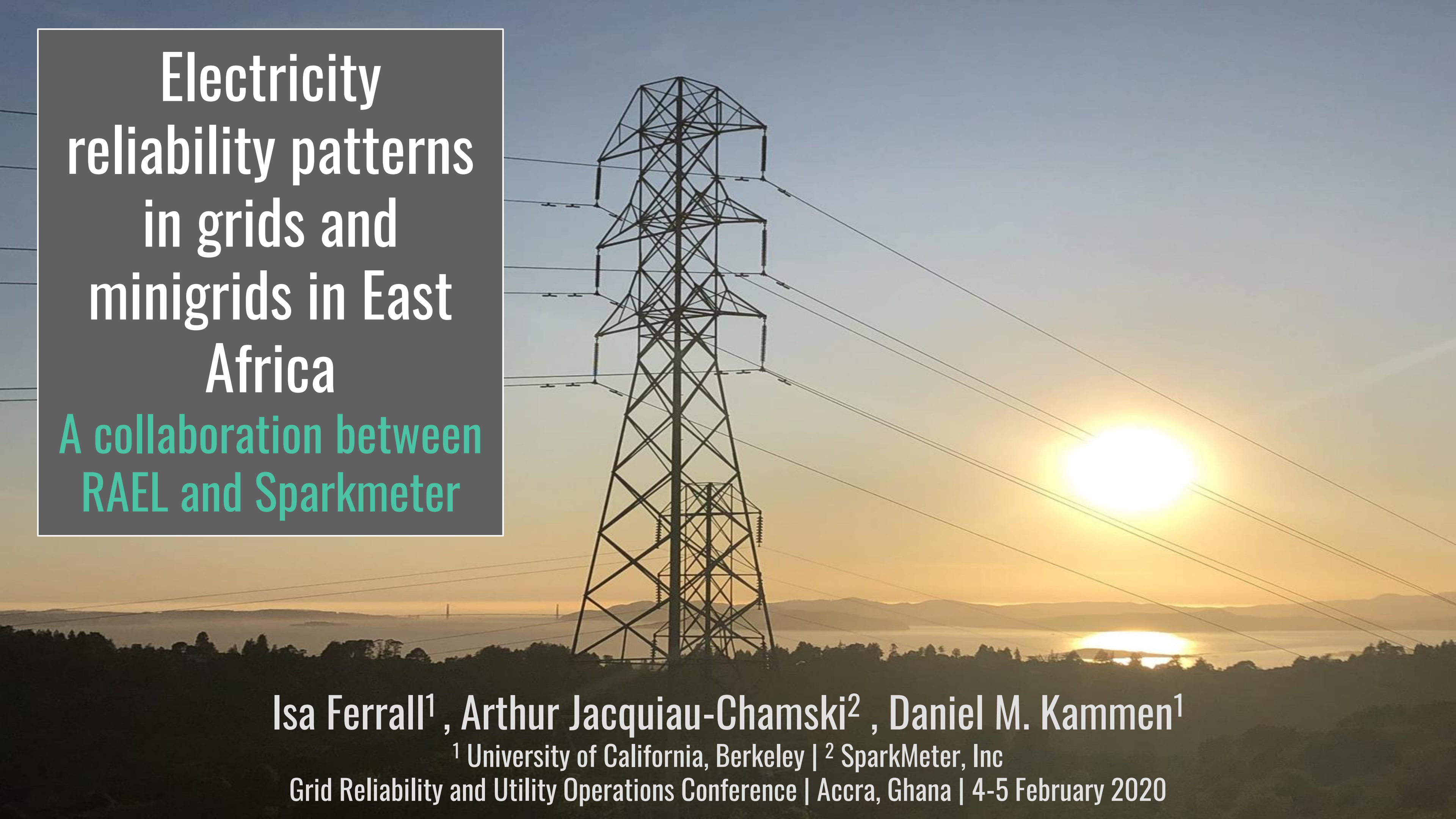


Electricity reliability patterns in grids and minigrids in East Africa

A collaboration between RAEL and Sparkmeter

Isa Ferrall[1] , Arthur Jacquiau-Chamski[2] , Daniel M. Kammen[1]

[1] University of California, Berkeley | [2] SparkMeter, Inc

Grid Reliability and Utility Operations Conference | Accra, Ghana | 4-5 February 2020

A Minigrid focus in California and in Energy Access

Microgrids could help California improve grid resilience in face of wildfire threat

Peter Asmus
Thursday, October 17, 2019 - 12:15am

The Montgomery Country microgrid in Maryland was funded through an energy as a service contract.

PACIFIC GAS AND ELECTRIC COMPANY

MICROGRIDS PURSUANT TO SENATE BILL 1339 AND RESILIENCY STRATEGIES

PREPARED TESTIMONY

INVITED PAPER

Distributed Resources Shift Paradigms on Power System Design, Planning, and Operation: An Application of the GAP Model

This article describes and demonstrates a capacity expansion model to assess the sequencing and pacing of centralized, distributed, and off-grid electrification strategies.

By Juan-Pablo Carvallo, Jay Taneja, Duncan Callaway, *Member IEEE*, and Daniel M. Kammen

Carvallo *et al.*: Distributed Resources Shift Paradigms on Power System Design, Planning, and Operation

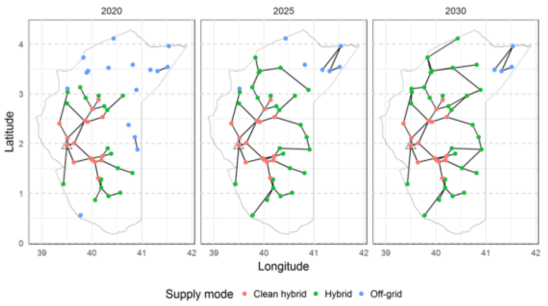
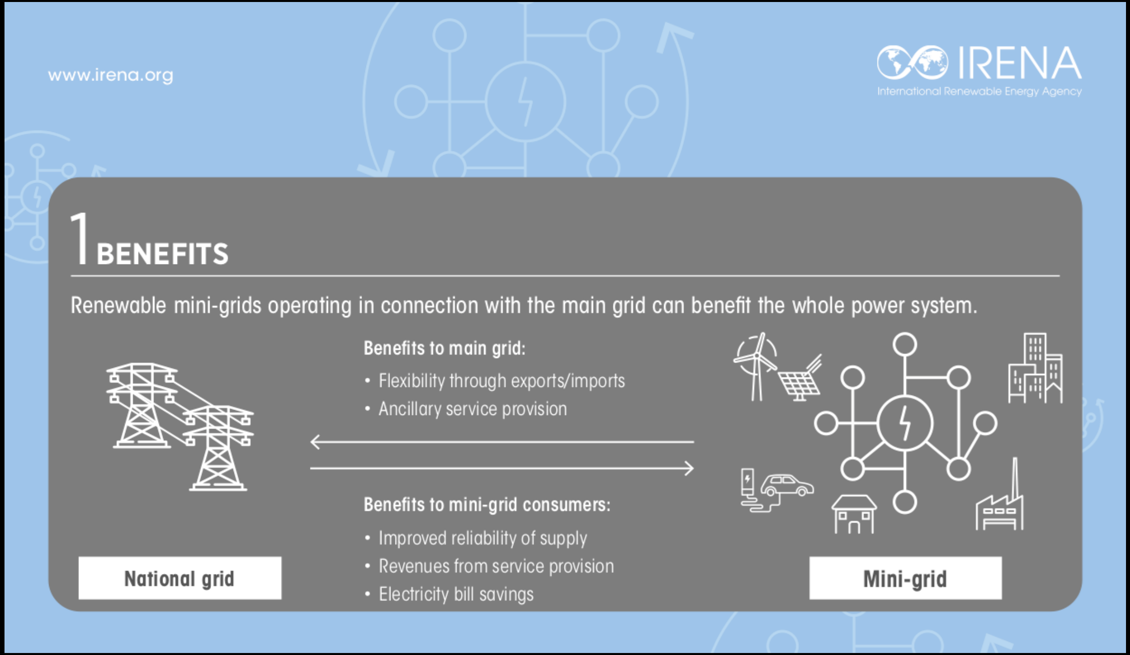


Fig. 4. *Electrification sequencing decisions for a low-density load zone in northeast Kenya.*

Minigrid integration and impacts on reliability



1. One system serving peak load from the other reducing load shedding
2. Avoidance of transmission constraints and failures
3. Improving inline power-quality which can increase component life

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Renewable Mini-grids (2019) IRENA

Problem statement:

The ways in which minigrids and decentralized energy solutions can contribute to grid reliability are shaped by factors beyond our standard reliability metrics.

Fully appreciating the causes and patterns of outages - in space, time, and their predictability - is necessary for both grid and minigrids to achieve better service provision for all.

High resolution data and collaborations

- Minigrids
  - Sparkmeter, Inc
    - a company providing plug-and-play smart metering solutions for rural and central utilities in developing markets
    - 2000 anonymized household meters covering 10 minigrids
- Grids
  - Electricity Supply Monitoring Initiative (ESMI)
    - The ESMI Kenya Initiative in Nairobi, Kenya [59 hh sensors]
    - The Energy Change Lab in Dar es Salaam, Tanzania [25 hh sensors]
    - The Prayas Energy Group across India [437+ hh sensors]
  - Kenya Power and Lighting Company (KPLC)
    - Reliability on seven 11 kV feeders in Nairobi serving 32,000 customers, outage incidents on 323 feeders across greater Nairobi
  - World Bank Surveys
    - Doing Business - SAIDI/SAIFI reported by utility across entire territory
    - Enterprise - Survey of businesses about experience

SAIDI / SAIFI: Household-Level Meters

Preliminary Findings:

Comparing data from household meters, rural minigrids have better reliability levels than urban grids in East Africa.

Average different from median.

mean *(median, standard deviation)*	SAIDI (hours / year / household)		SAIFI (count / year / household)	
	Tanzania	**Kenya**	**Tanzania**	**Kenya**
Sparkmeter sensors on Minigrids - Household Meters - 2000 customers across 10 minigrids in rural East Africa	379 *(184, ± 5612)*		65.7 *(44.5, ± 53.79)*	
ESMI sensors on Grids - Household Sensors - 25 sensors in urban Dar es Salaam TZ - 59 sensors in urban Nairobi, KE	1154 *(813, ± 1168)*	419 *(294, ± 352)*	300 *(280, ± 165)*	81.5 *(72.1, ± 44.6)*

*Both datasets use minute-resolution over 1 year.

SAIDI / SAIFI: Grids covering different geographic scales

Preliminary Findings:

Grid reliability estimates vary widely depending on the data resolution, provenance, sensor location, and assumptions.

Business survey metrics closer to household meters than utility metrics.

	SAIDI (hours / year / household)		**SAIFI (count / year / household)**	
	Tanzania *[Dar es Salaam]*	**Kenya** *[Nairobi]*	**Tanzania** *[Dar es Salaam]*	**Kenya** *[Nairobi]*
ESMI Household Meters	*[1154]*	*[419]*	*[300]*	*[81.5]*
Kenya Utility feeder SCADA		*[29.9]*		*[42.4]*
WB Enterprise Surveys *(survey of businesses)*	673 *[824]*	264 *[227]*	107 *[125]*	46 *[38]*
WB Doing Business Surveys *(reported by utilities)* *(2015-2016)*	60.4	162.6	61.9	16
(2016-2017)	24.9	80.9	10.8	16.9

*Values from specific cities in brackets and italicized, the other metrics represent the whole country.

Factors left out

1. Reason for the outage
   - Why the outage occurred
   - Planned vs Unplanned
2. Time of the interruption
   - Consistency / predictability
   - Value of the time of day
   - Restoration time
3. Distribution throughout the community
   - Equity in reliable access

Outage Categorization

Findings:

These types of outages are common on all constrained grids.

Different categories of outages occur through different mechanisms, therefore should be addressed separately in efforts to improve service reliability.

Outage categorization

Examples across scale of systems		**Resource (generation)** generally avoidable or shift-able through planning	**Technical (transmission, distribution)**
	Solar-home-system - *off-grid solar + batteries*	Battery capacity runs out for night, able to recharge via solar the following day	Fault, broken electrical component
	Mini-grid system - *Community minigrid powered by renewables and/or diesel. Islanded*	Battery capacity runs out for the night, Diesel fuel unavailable because of budgeting constraints or transport difficulties.	Fault, broken electrical component
	Grid - *Powered by hydro or fossil fuels*	Hydropower curtailed because of drought. Natural gas or heavy fuel oil unavailable because of transport difficulties. Planned outages for regular maintenance. Load shedding due to inadequate generation capacity	Fault, broken electrical component at the level of transmission or distribution

Timing patterns of outages

Depictions

1. Probability of being in an outage state at each hour of the day
2. Range of outage durations (or restoration times) for outages starting in each hour of the day.

Datasets

1. Sparkmeter Minigrid households
2. ESMI Kenya household meters
3. KPLC feeder SCADA

Sparkmeter Minigrid Timing

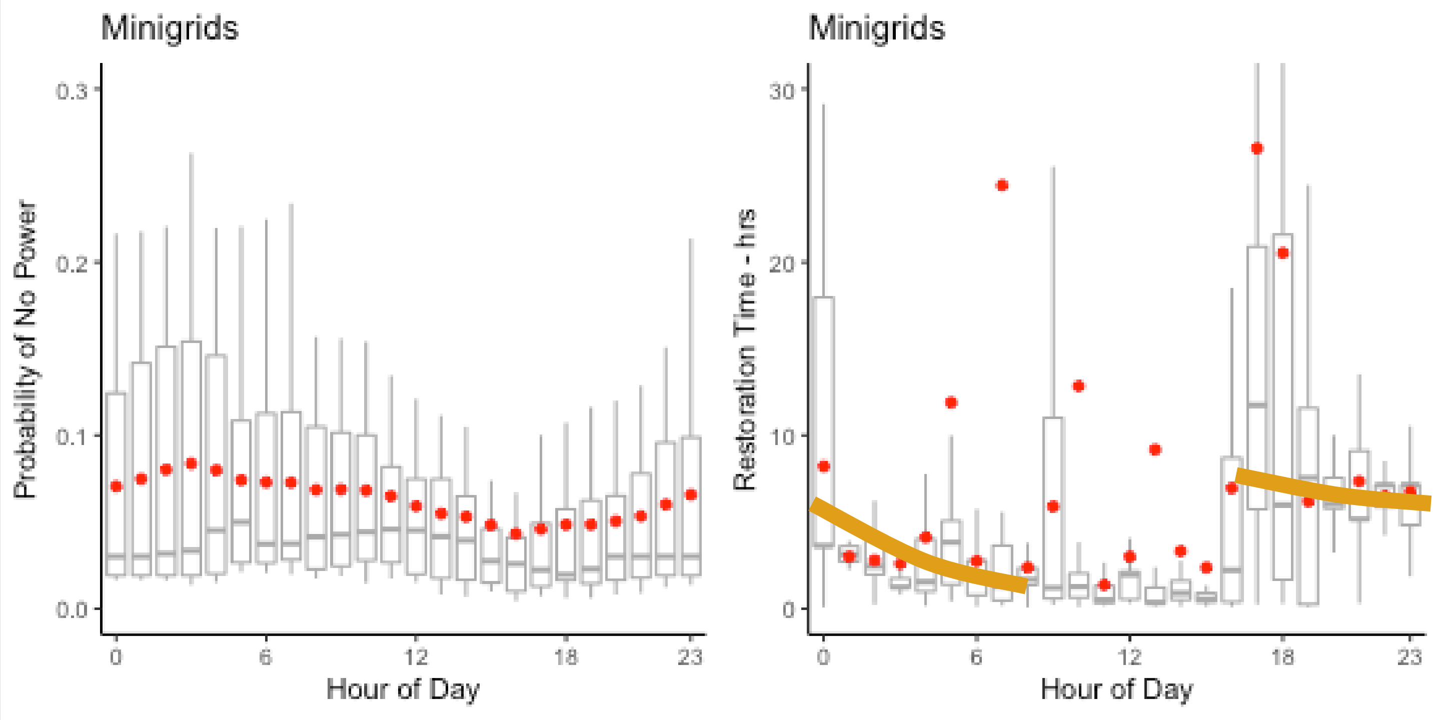
Resource constrained

Findings:

Minigrids clearly show resource constraints during the night.

Otherwise low restoration times.

Average restoration time different from median.



*Box charts show distribution of meters, red circles show mean

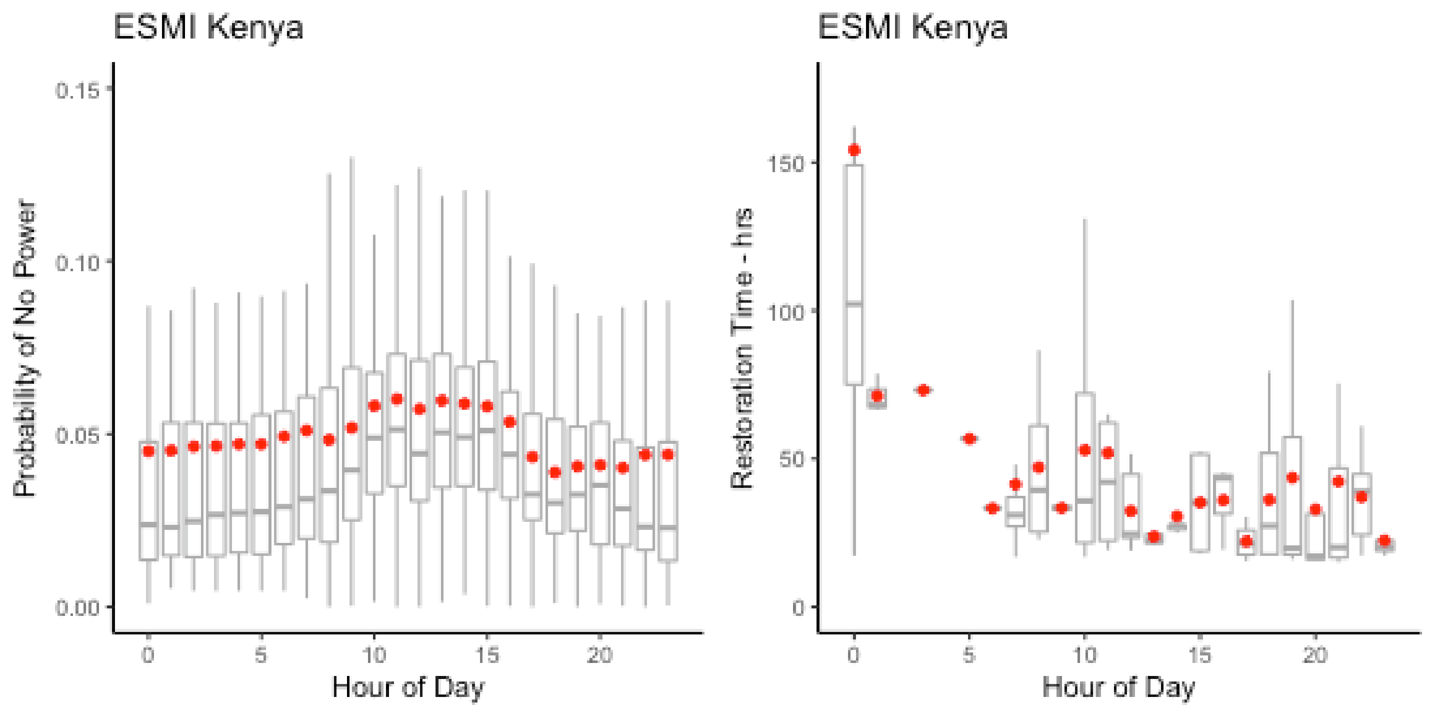
ESMI Kenya Timing

***Note different scales**

Findings:

Grid household data show random distribution consistent with technical outages.

Mostly technical outages with several large events.



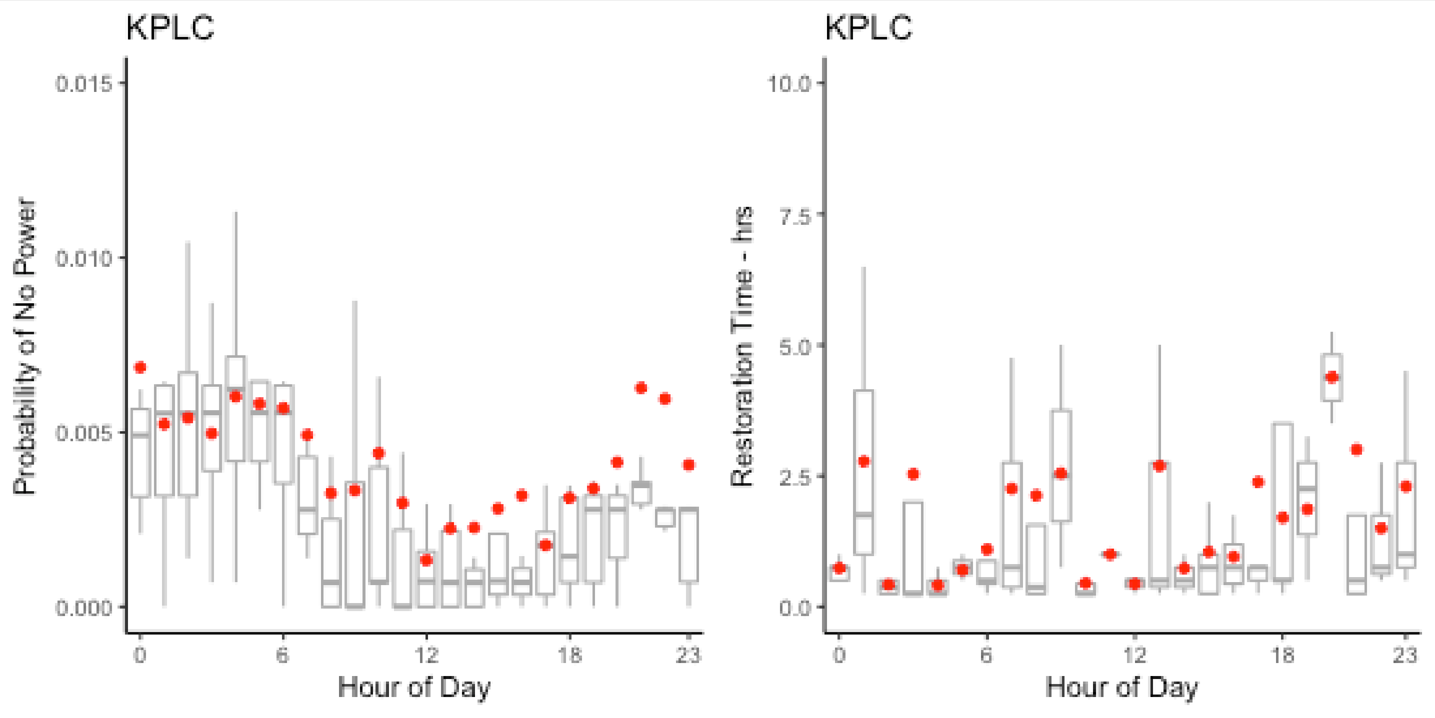
*Box charts show distribution of sensors, red circles show mean

KPLC Feeder Timing

*Note different scales

Findings:

Data on feeders, representing the same locations as ESMI Kenya households, showed very different patterns which may not represent the household experience.



*Box charts show distribution of feeder sensors, red circles show mean

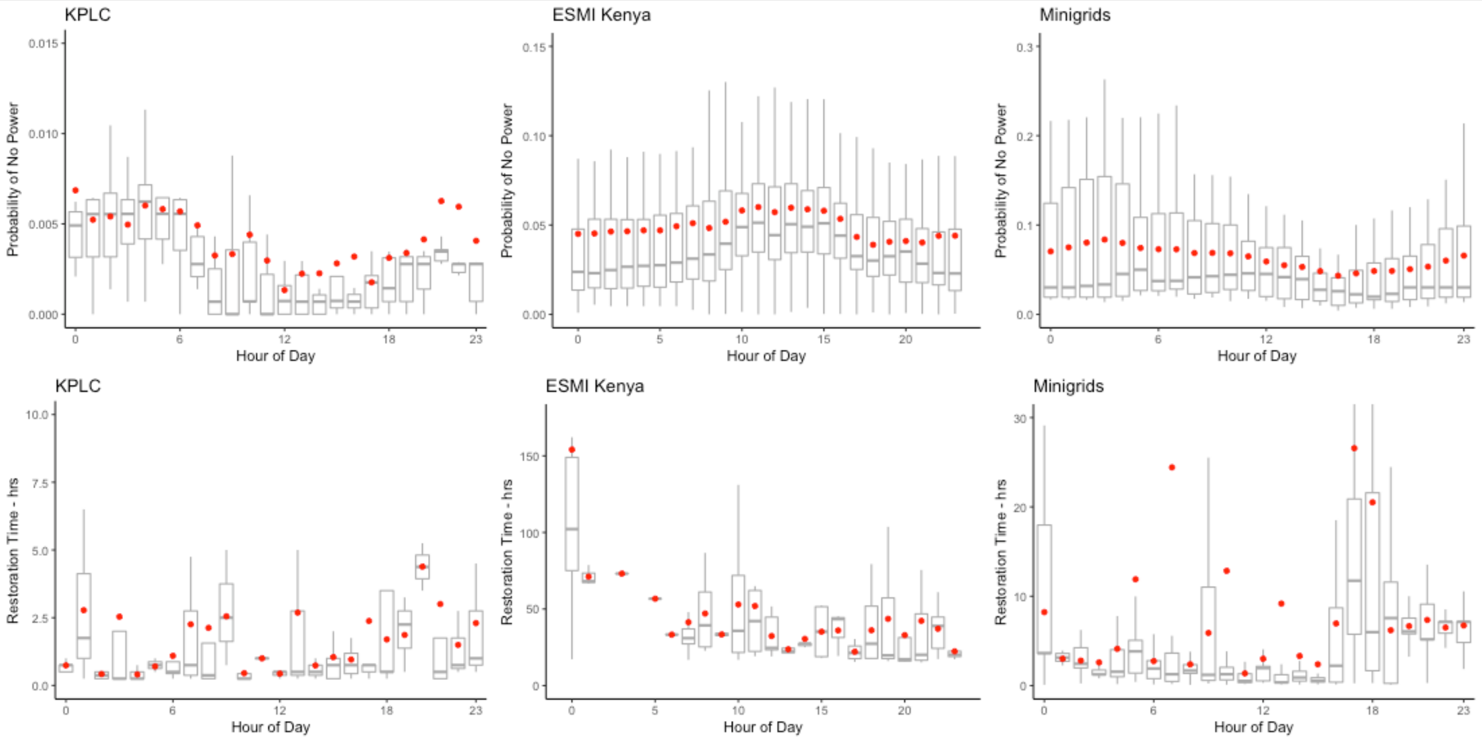
Timing Summary

*Note different scales

Findings:

Outage timing patterns can help identify outage causes and evaluate potential for minigrid and grid integration.

Data resolution and provenance are important to consider.



Distribution of outages

Method

Lorenz Curve methodology

a. Normally: cumulative share of population on the X-axis against cumulative share of income on Y-axis
b. A perfectly equal share of income across a population results in a line with a slope of one.
c. The greater the inequality in the sample, the more the curve bows down to the X-axis.

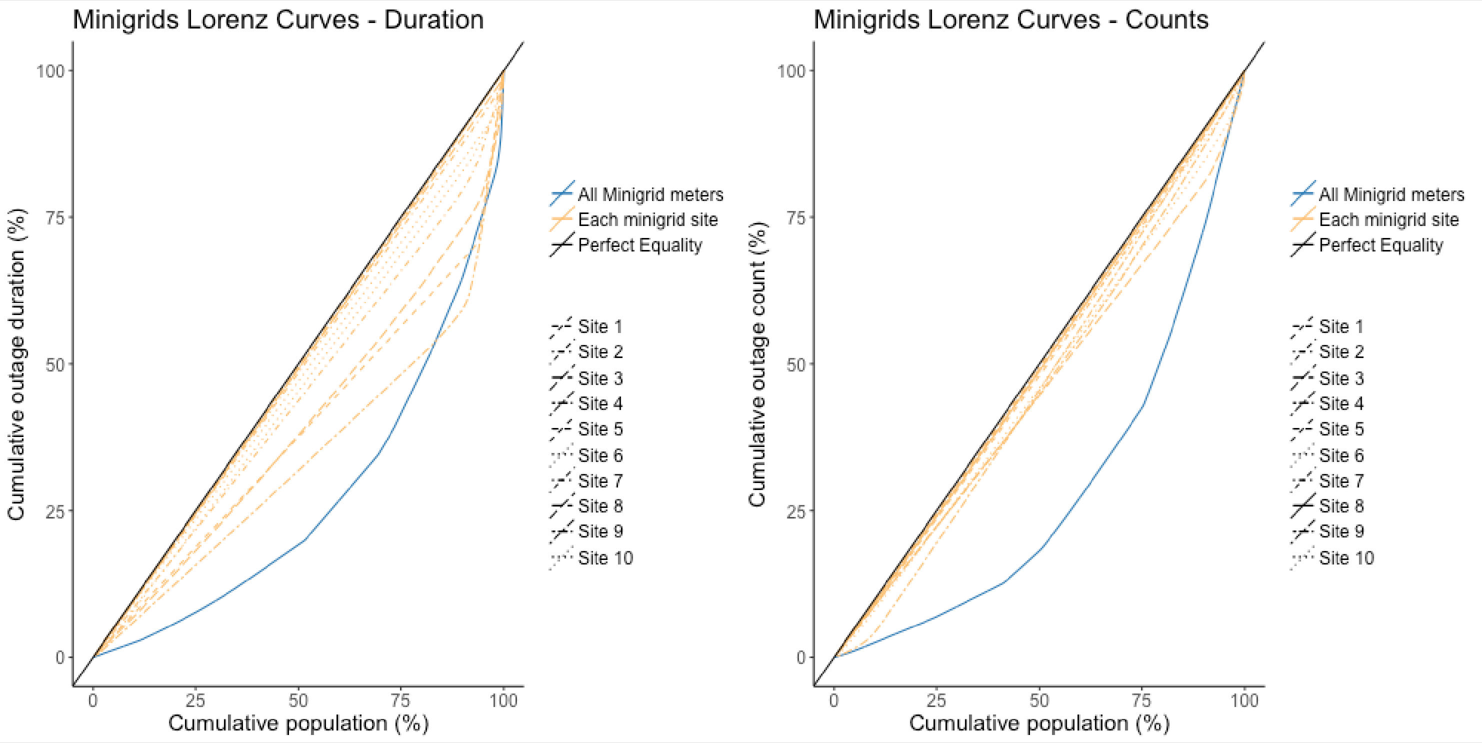
Datasets

Sparkmeter Minigrid households, ESMI Kenya household sensors, ESMI Tanzania household sensors, ESMI India sensors, KPLC feeder data, Dumsor data from Aidoo and Briggs (2018)

Minigrid Distribution

Findings:

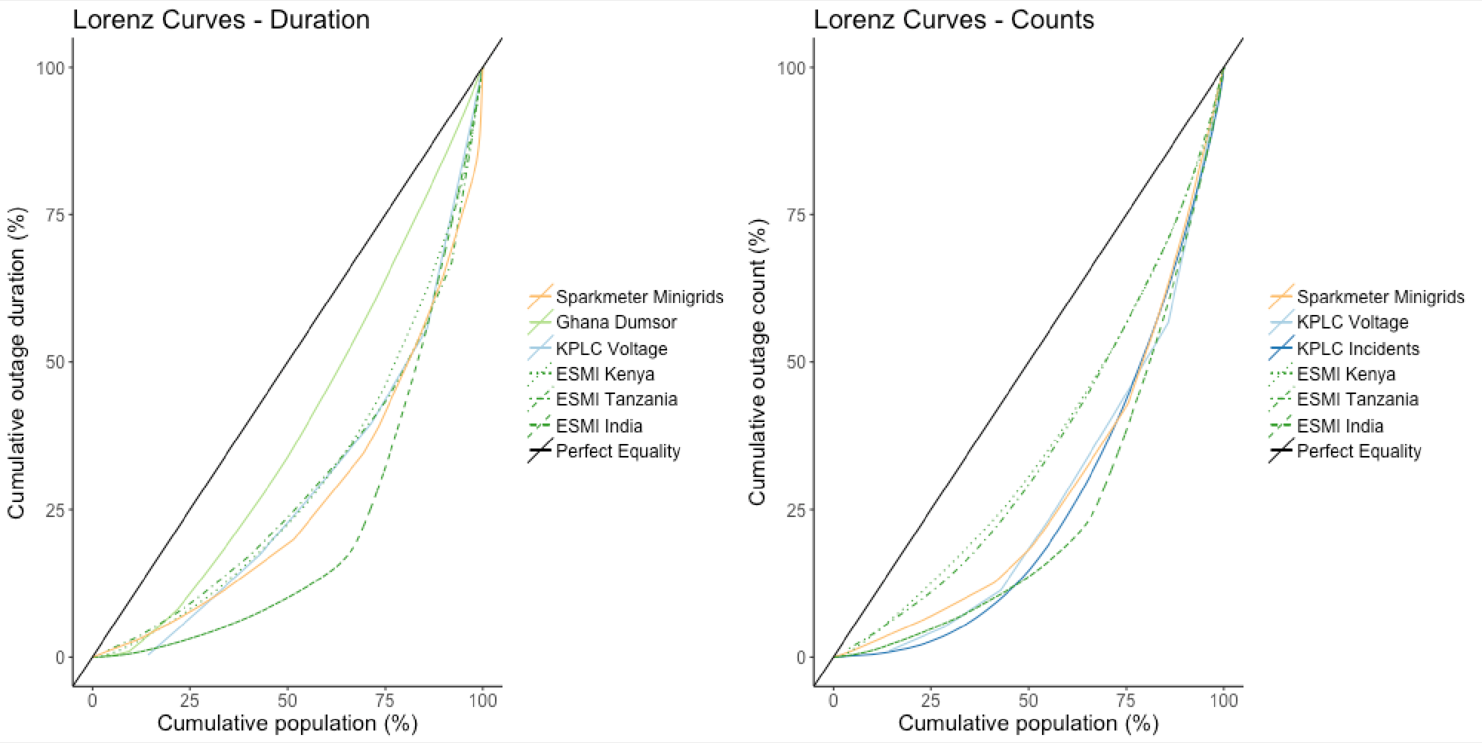
Equal distributions of outage durations and counts within each minigrid, but larger differences across minigrids.



Distribution Summary

Findings:

Examining equity of outage distributions is an important aspect of evaluating electricity reliability.



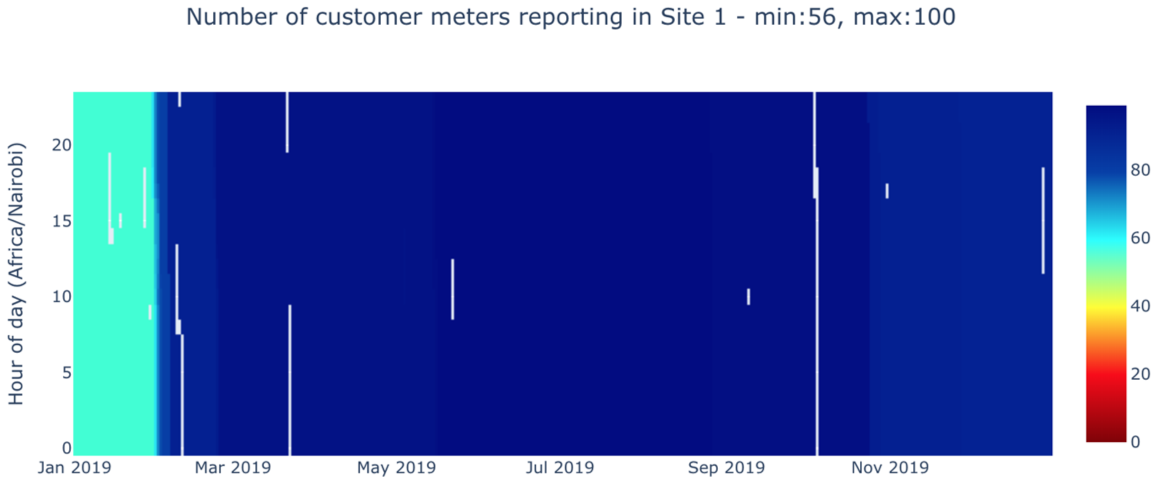
Sparkmeter Uptime Analytics Reporting

Findings:

Heatmaps can display large amounts of information allowing microgrid operators to respond efficiently to issues.

Question for Audience:

What do you consider the best ways to communicate reliability to enable action?



Site	Period start (local)	Period end (local)	# customer meters	SAIDI & SAIFI	Downtime & Uptime
Site 1	2019-01-01 00:00	2020-01-01 00:00	101	SAIDI: 98.2h SAIFI: 15.8	DT: 1.1% UT: 90.7%

Conclusion

1. **These case studies can inform broader ideas and understandings, but do not hold definitive conclusions or universal truths.**
2. **We should think critically about our metrics, including what they include and what they don't.**
3. **This type of analysis is only available with smart-meter functionality, standardization, and transparency of reporting.***
4. **There are opportunities for two-way sharing and adoption of best practices between grids and minigrids for managing constrained systems for improved reliability for all.**

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*Lee et al. (2019) Data Sharing and Privacy in Expanding Electricity Access

Thank you

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SPARKMETER

sparkmeter.io

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