



Carnegie Mellon University

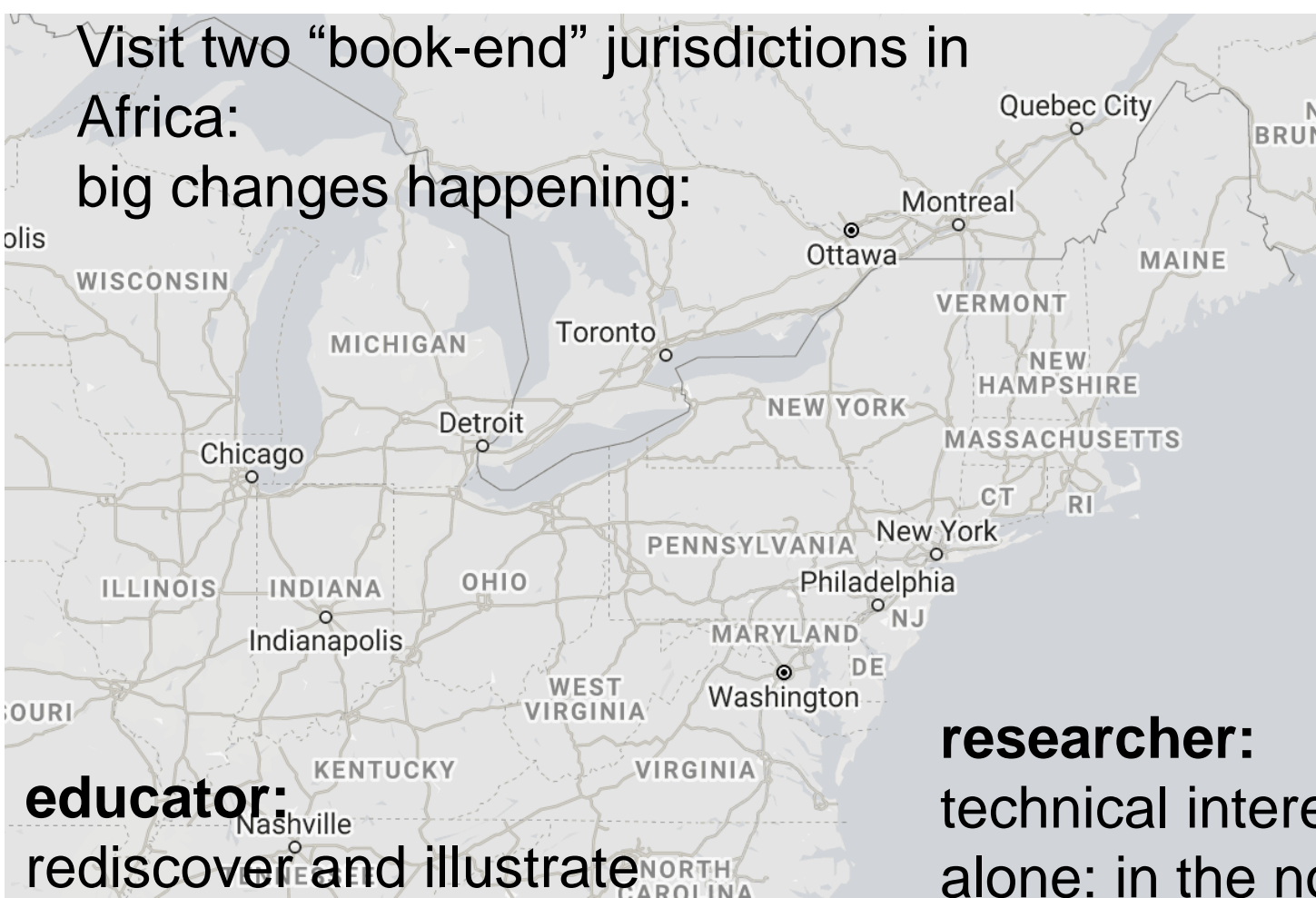
**Death and Rebirth in the
Power Sector: Why Africa
Should Fascinate the Energy
Educator and Researcher**

Carnegie Mellon Electricity Industry Center Series:
Jan 29th, 2020, Baker Hall 129

Dr Barry Rawn

Associate Teaching Professor, CMU Africa

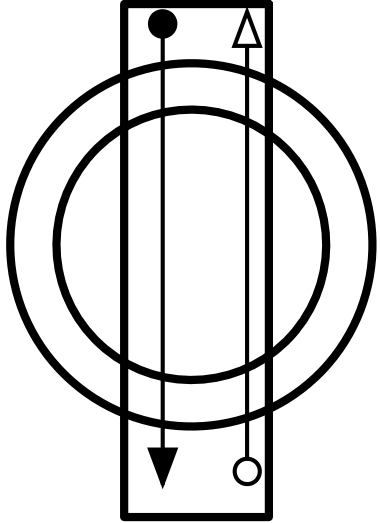
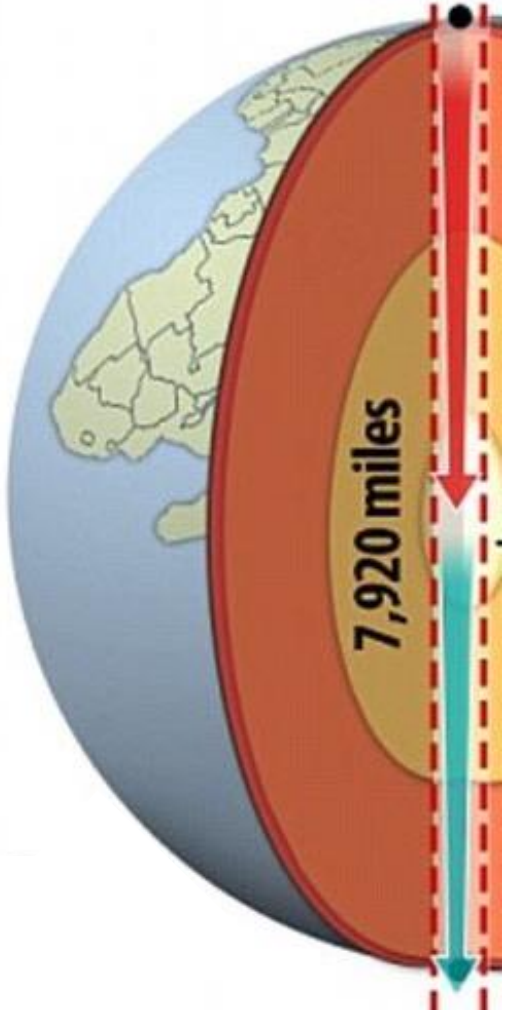
Visit two “book-end” jurisdictions in Africa:
big changes happening:

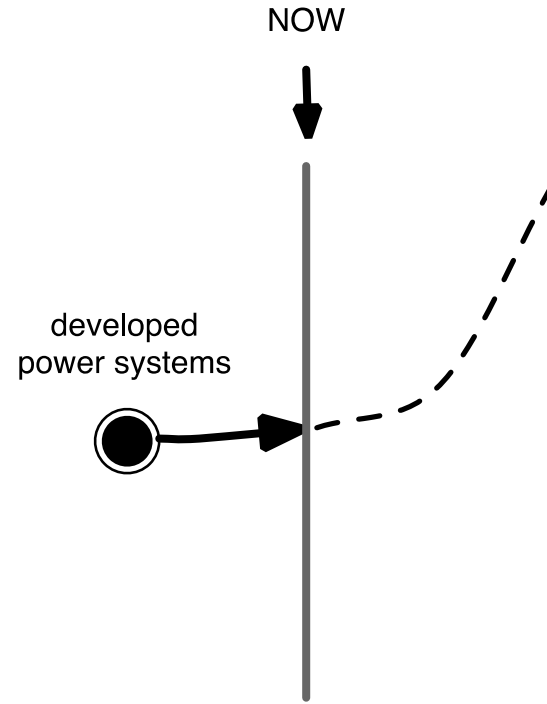


educator:
rediscover and illustrate
fundamentals

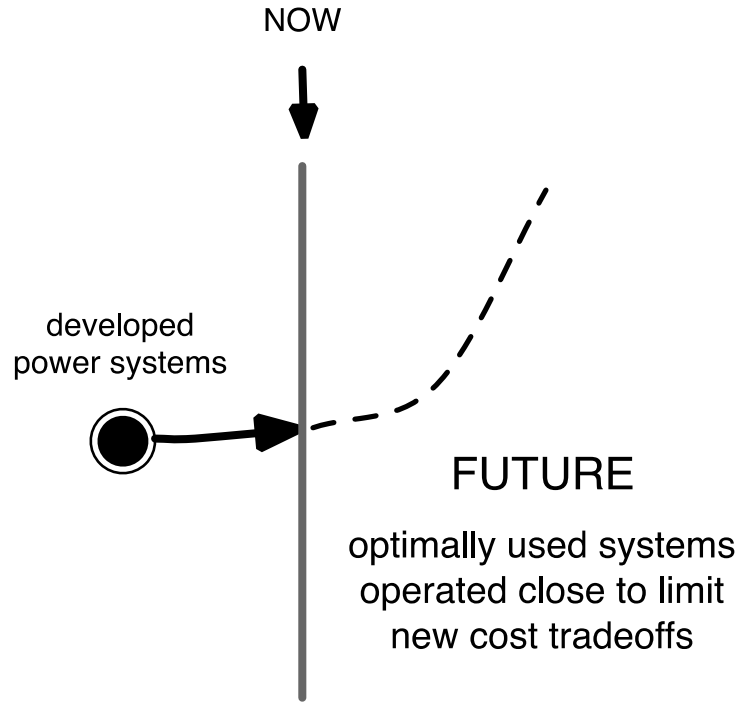
researcher:
technical interest
alone: in the now,
not the future.

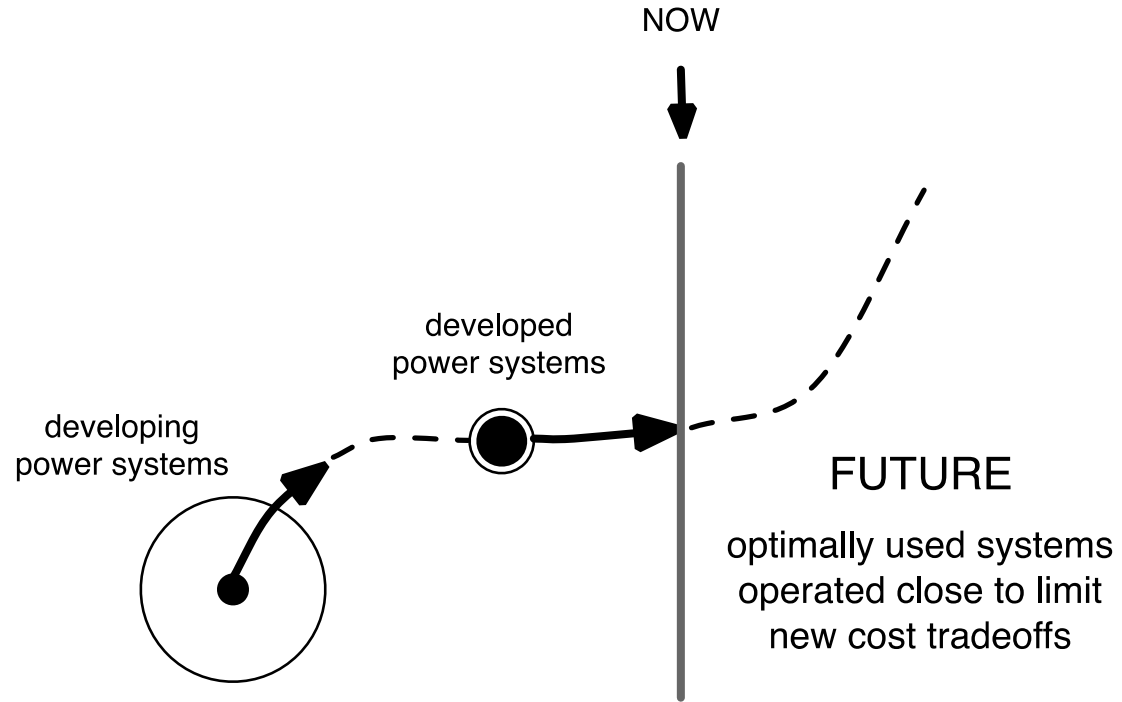


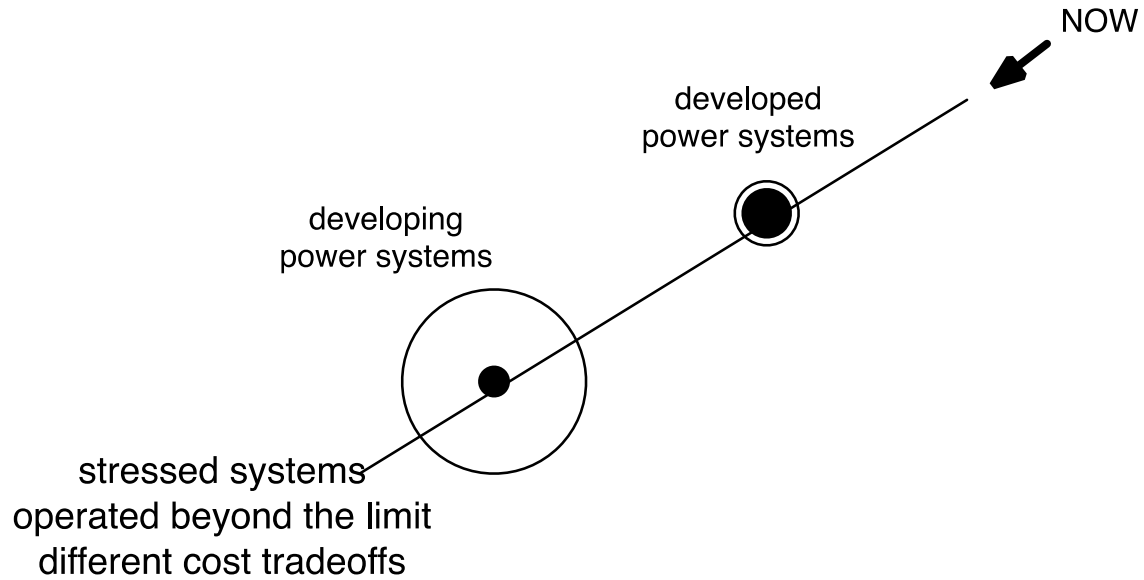


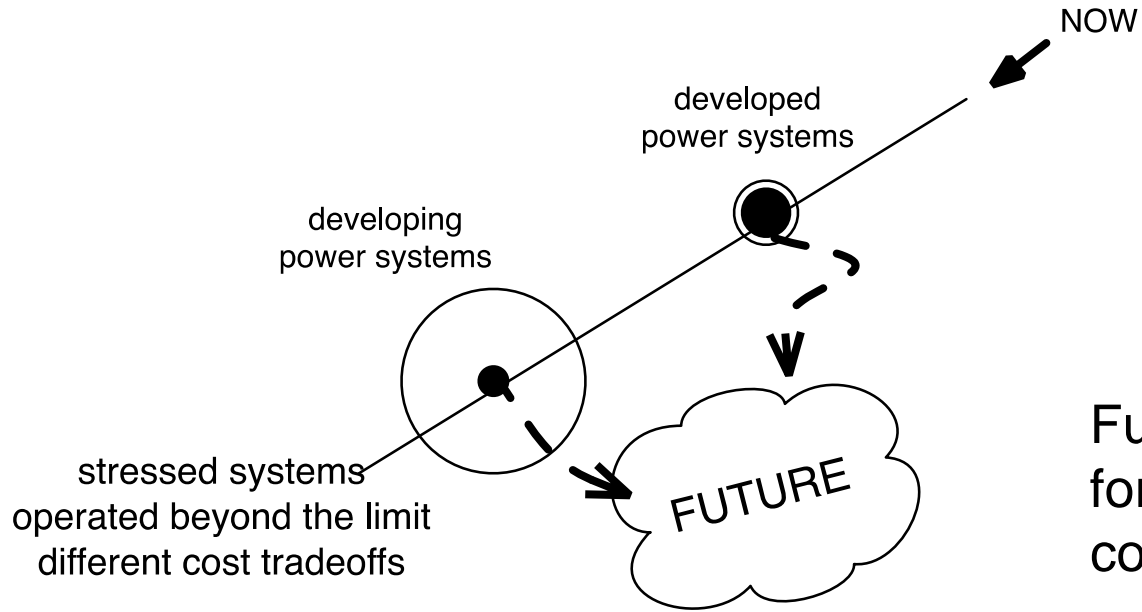


- Demand response shapes load to match renewables
- “Prosumers” and the utility death spiral
- Self-healing resilient grids from distributed resources

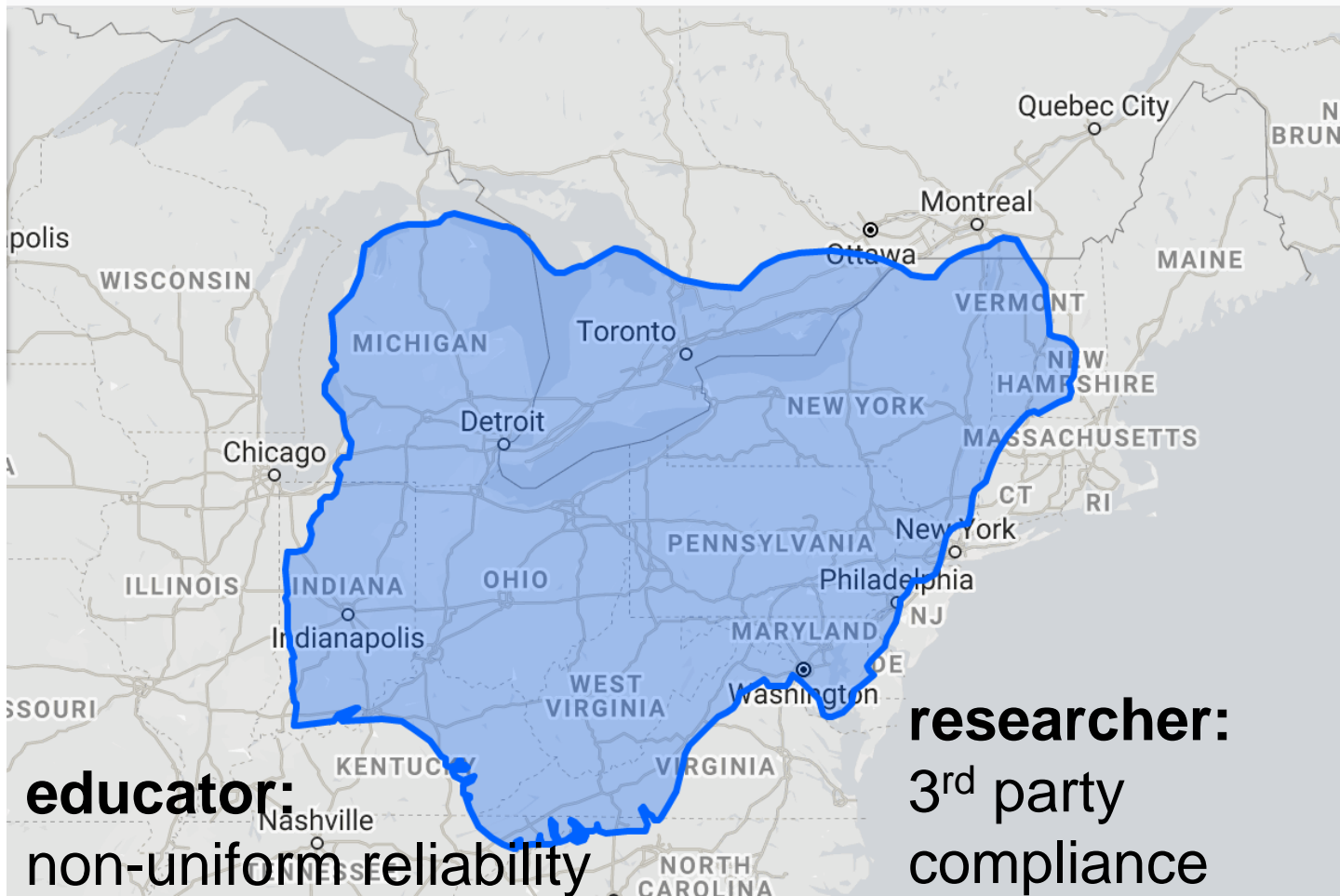








Future arrives early
for energy storage,
coupled microgrids.

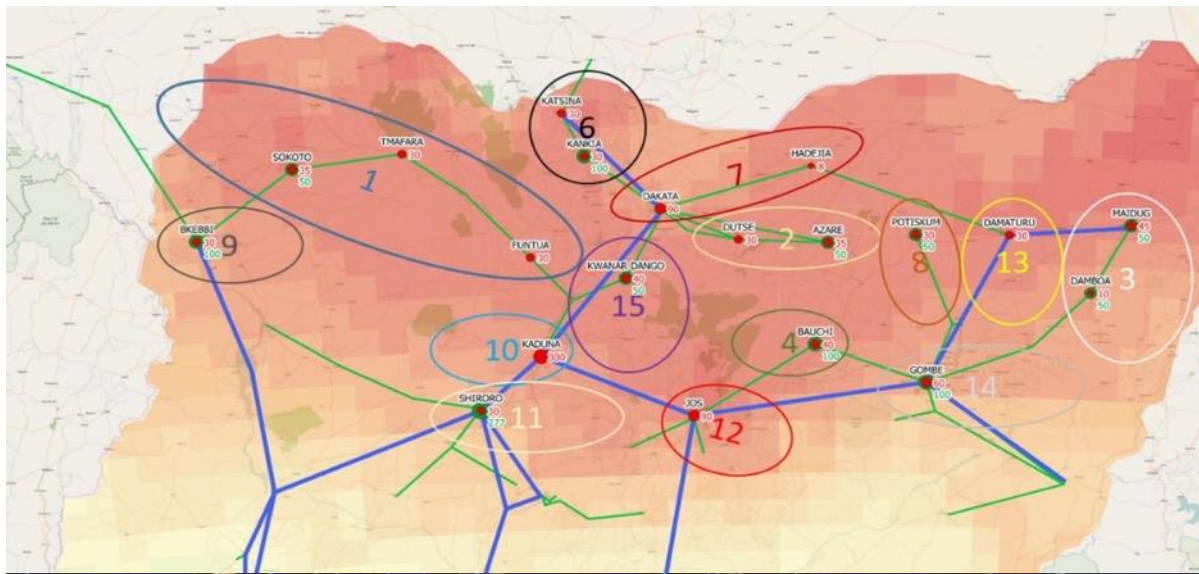


NIGERIA:
big change
due to
scale

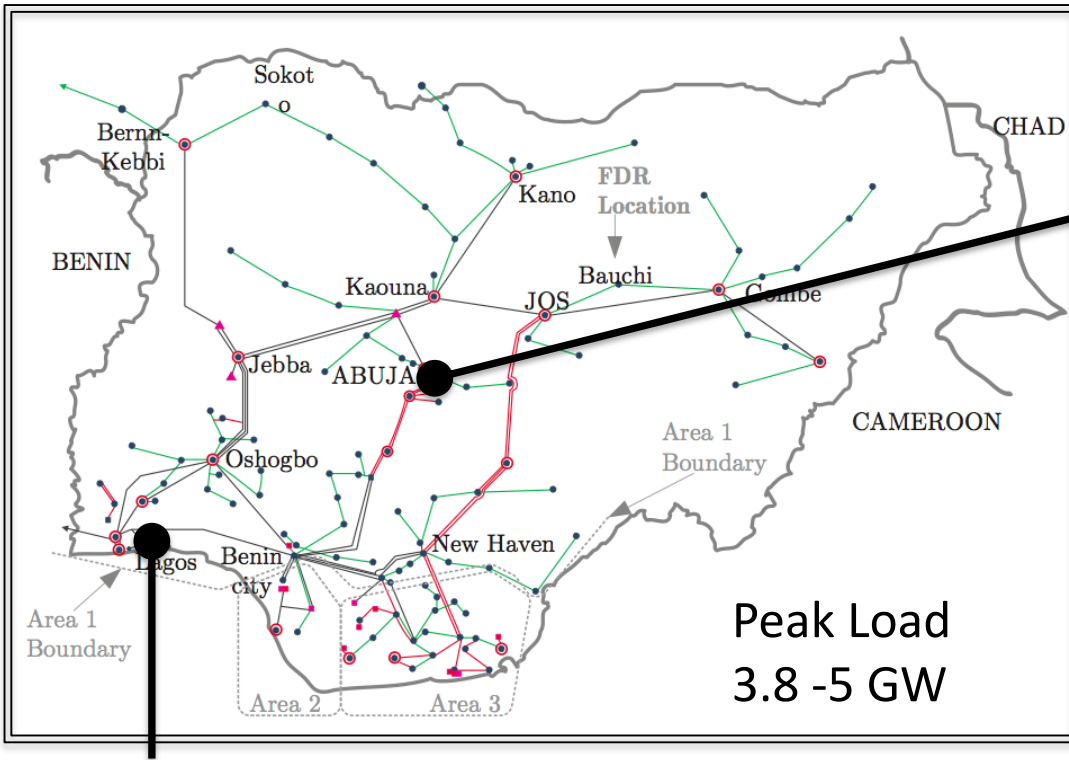
*Where the
utility death
spiral already
happened..*

educator:
non-uniform reliability
tariff design

researcher:
3rd party
compliance
monitoring



>10 GW of off-grid demand met by diesel gensets in banks, hotels, businesses, homes: **turning solar.**



Abuja:

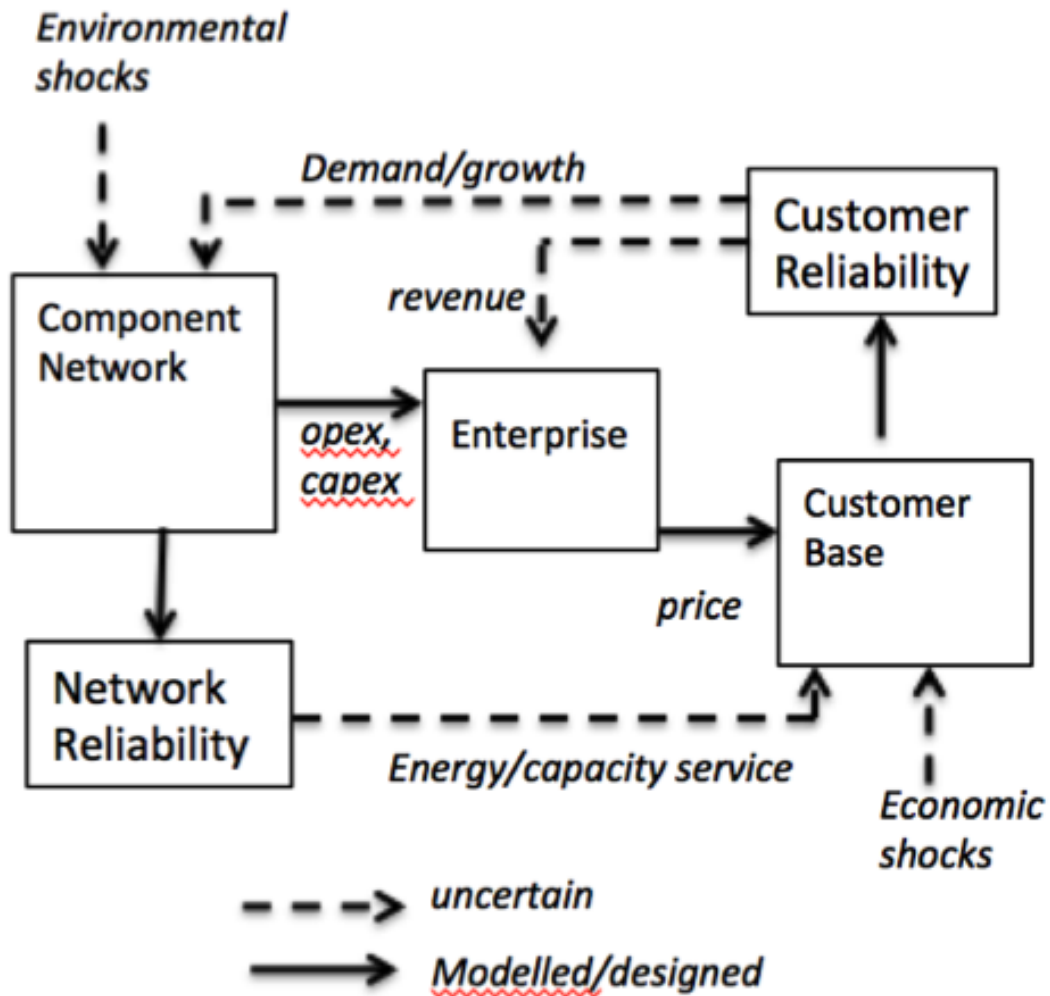
Housing development with tri-source battery charging: solar, grid, diesel;

storage batteries, stabilisers common in many homes

Lagos:

Distribution companies perform continual load shedding to follow supply

Context sets feasibility of technology solutions



Distribution investments, some of them from before 1951, had started to decay. The population and areas served by the ECN had grown enormously, but the radial distribution systems lacked the design necessary to cope with load growth. Apart from the introduction of 'Ring Main Units' the ECN had added no new feature to its distribution techniques. Substandard assets had started to creep into the system. A quick example is the wood pole to support conductors.

The Corporation had no 'Customer Service Policy' except for scanty statutory provisions at the back of 'Application Form ECN 74'. After operating for more than two decades, several issues for which operatives needed the same answers throughout the country had arisen, but the ECN had left operatives on their own to provide whatever answers they wanted and the ECN customers did not have the benefit of uniform treatment. Some of these issues had to do with revenue and I hasten to say that the Corporation's best years of revenue performance were 1961 and 1965 when it achieved 6.4% and 7.3% rate of return, which were still lower than the 8% expected return.

Adequacy in a 1208MW system already a problem.

NIGERIA:
1886-1972

***political
grid over-
extension,
civil war***

YEAR	IN NAIRA	IN US DOLLARS	ADDITIONAL CAPACITY (MW)	PEAK CAPACITY (MW)
1973	1,392,552	0	-	398.10
1974	25,350,000	15,796,360.92	-	398.10
1975	115,013,000	71,083,436.34	120	518.10
1976	160,000,000	100,496,199.99	335.60	853.70
1977	207,079,989	134,223,482.63	-	853.70
1978	509,210,000	324,193,034.95	1,190	2,043.70
1979	540,000,000	326,173,621.01	-	2,043.70
1980	370,000,000	203,341,393.71	-	2,043.70
1981	222,481,000	136,726,278.27	300	2,343.70
1982	112,370,280	75,843,871.49	312	2,655.70
1983	111,530,000	8,356,706.68	-	2,655.70
1984	167,571,370	128,436,705.76	-	2,655.70
1985	110,189,433	98,931,076.46	440	3,095.70
1986	17,666,660	10,640,002.41	980	4,075.70
1987	282,303,446	69,142,875.63	440	4,515.70
1988	143,596,149	31,818,335.70	-	4,515.70
1989	14,922,058	2,005,464.27	150	4,665.70
1990	15,000,000	1,853,591.02	1,050	5,715.70
1991	26,625,513	2,678,407.47	-	5,715.70
1992	23,750,000	1,359,971.60	-	5,715.70
1993	152,203,000	6,921,873.51	-	5,715.70
1994	142,425,639	6,475,069.97	-	5,715.70
1995	1,426,276,710	18,603,698.24	-	5,715.70
1996	1,179,199,250	14,440,158.78	-	5,715.70
1997	1,000,000,000	12,191,880.70	-	5,715.70
1998	2,700,000,000	32,060,378.00	-	5,715.70
1999	2,481,000,000	26,748,576.32	-	5,715.70
2000	22,962,834,721	224,893,881.22	-	5,715.70
2001	51,045,300,000	446,981,611.21	546	6,261.70

NIGERIA:

1972-1990

Military dictatorship

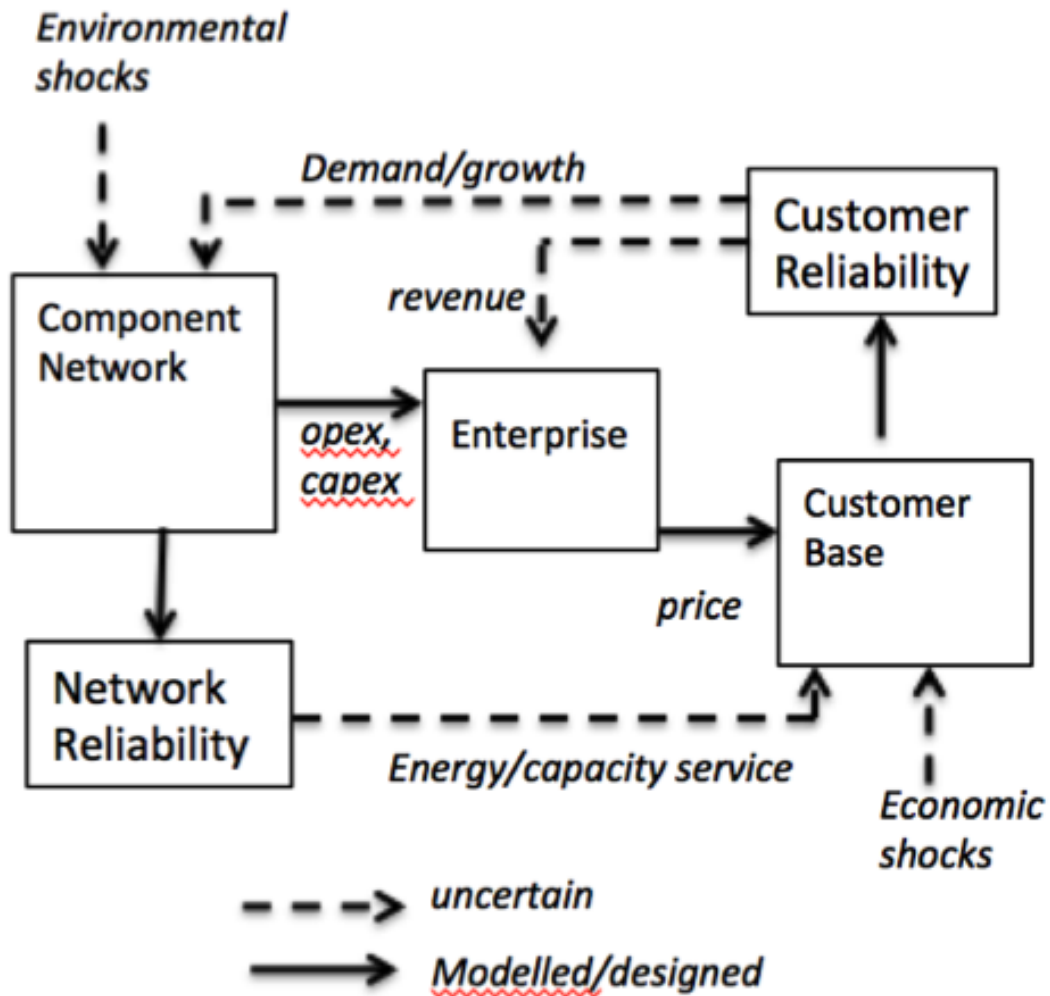
Investment continues,
capacity does not go up

“Developments in the Electric Power Sector,” Paper presented at the 2002 Media Summit on Power. serialised in The Punch. 12 August 2002

CONSUMERS	1970	1978	1987
Residential	62,212	175,858	318,808
Commercial	12,969	26,772	44,846
Industrial	347	541	1,805
Total	75,528	203,171	365,459
CONSUMPTION	MKWH	MKWH	MKWH
Residential	281.1	680.9	3247.9
Commercial	124.3	385.5	240.3
Industrial	192.2	532.4	725.8
Total	597.6	1598.8	4214

Tariff design punished large consumers, customers charged for meters

Adapted from Margaret Peil, Lagos: The City is the People, London: Belhaven Press, 1991, p. 185, Table 8.3

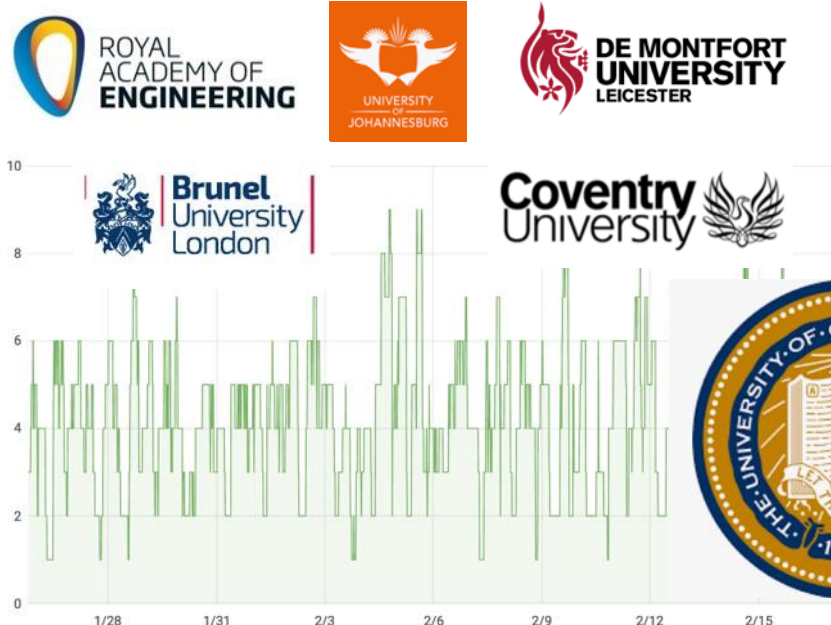


Customer Attitudes and House to House Reliability



*Reaction to outages,
preferences for
power allocation*

- Survey Responses**
1036 responses
- Survey Workers**
20 survey workers
- Survey Questions**
58 survey questions
- Total Answers**
45305 answers



YEAR	IN NAIRA	IN US DOLLARS	ADDITIONAL CAPACITY (MW)	PEAK CAPACITY (MW)
1973	1,392,552	0	-	398.10
1974	25,350,000	15,796,360.92	-	398.10
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NIGERIA:

1972-1990

Military dictatorship

Investment continues, capacity does not go up



2005

Privatization

2015

Energy Market

“Developments in the Electric Power Sector,” Paper presented at the 2002 Media Summit on Power. serialised in The Punch. 12 August 2002

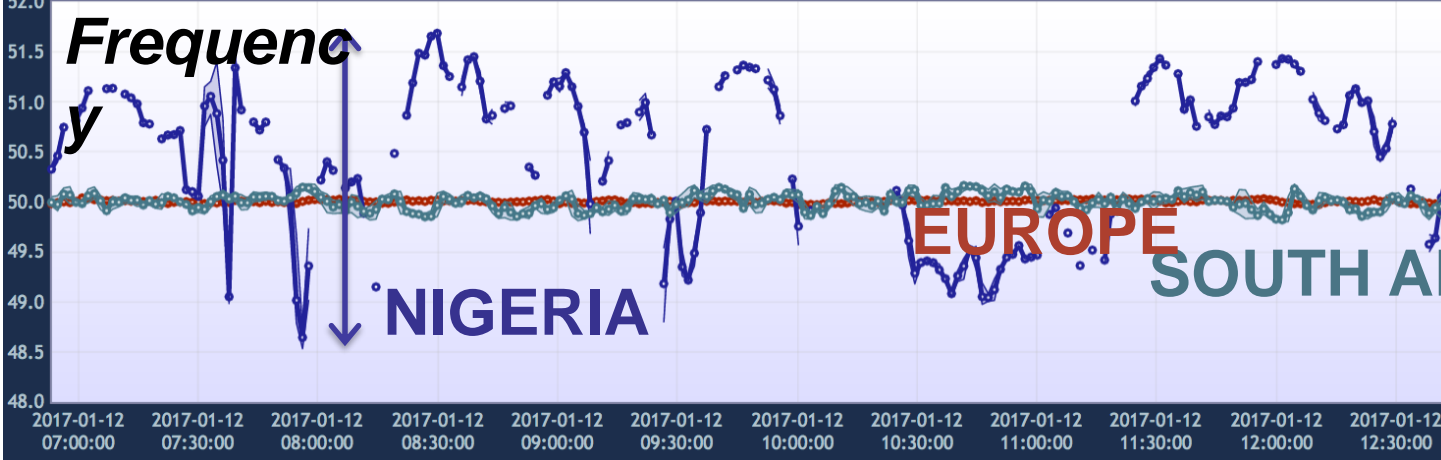
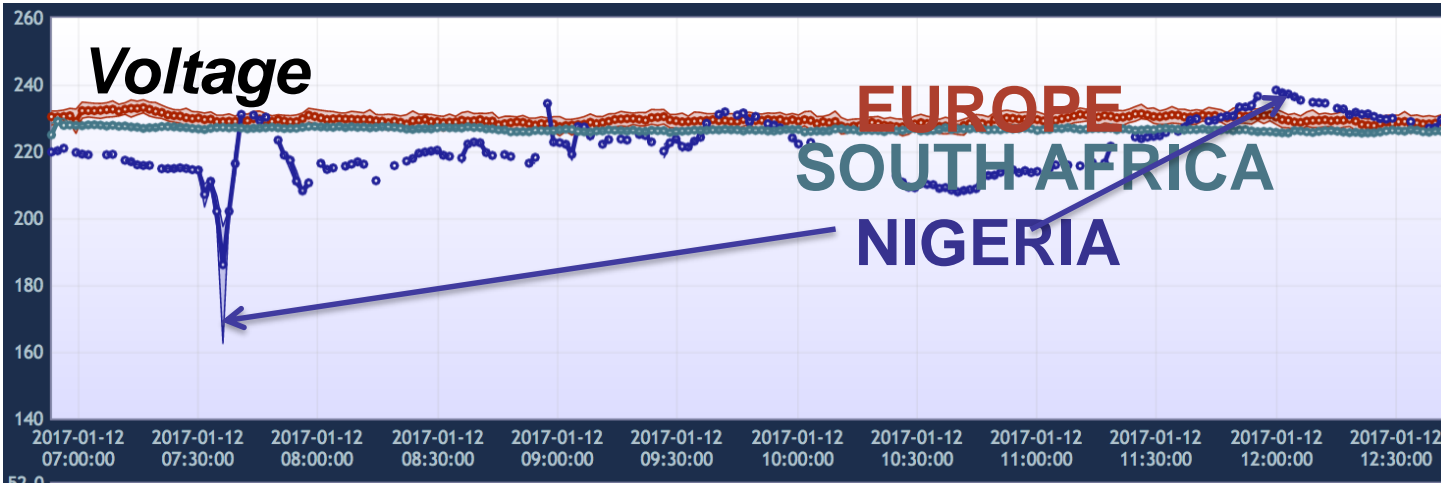
“This had grave social and economic consequences. Many artisanal or small scale enterprises depend on a regular power supply. A large number of these have been forced to fold up. In this category are the barbing/hairdressing, tailoring or fashion designing, welding, panel-beating, electrical and electronics repair enterprises. Not only were the proprietors, employees and apprentices engaged in these enterprises thrown into the labour market, some have taken to crime in desperation. The spate of violent robberies in the late 1990s derived from the high rate of unemployment generated by power shortages.”

*Infrastructure Development and Urban Facilities in Lagos, 1861-2000 —
Ayodeji Olukoju*



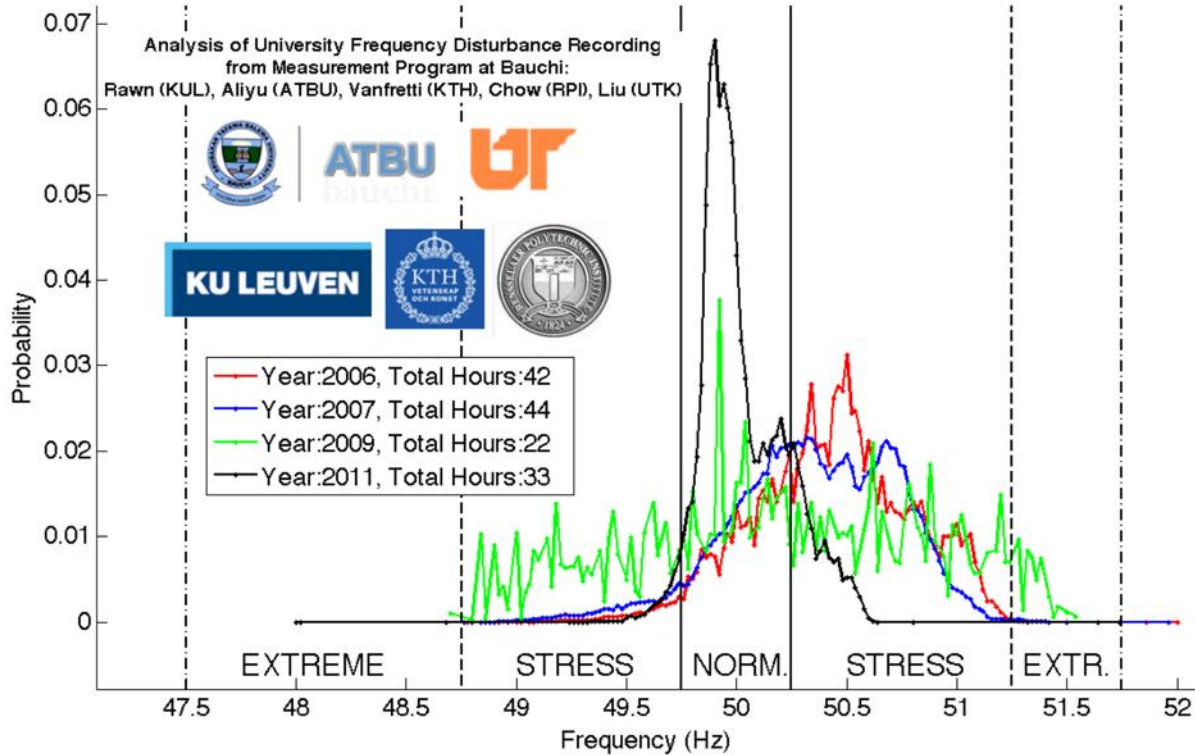
NIGERIA:
rebirth from
enterprises
that already
left the grid
(e.g. banks,
factories)?

NIGERIA: in the meantime..



**Supply
demand
balance
short term
challenge**

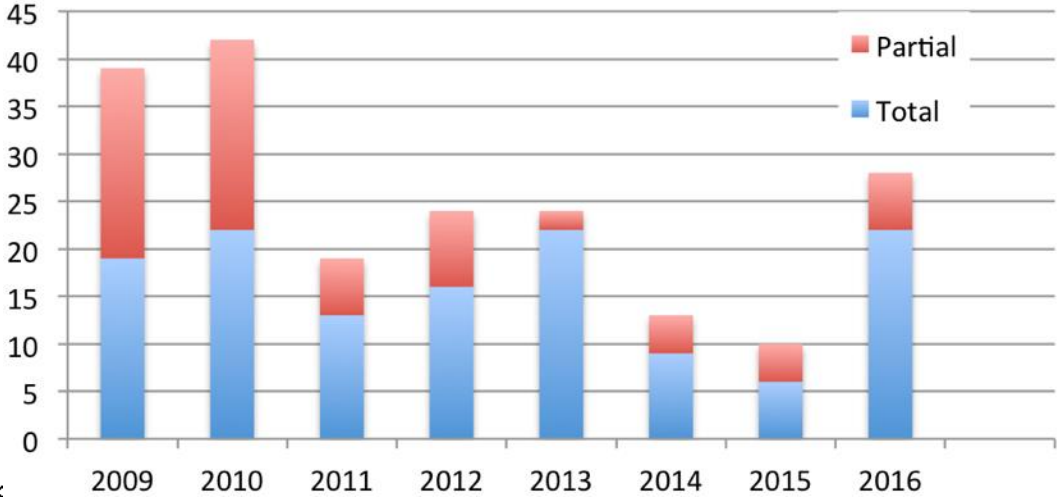
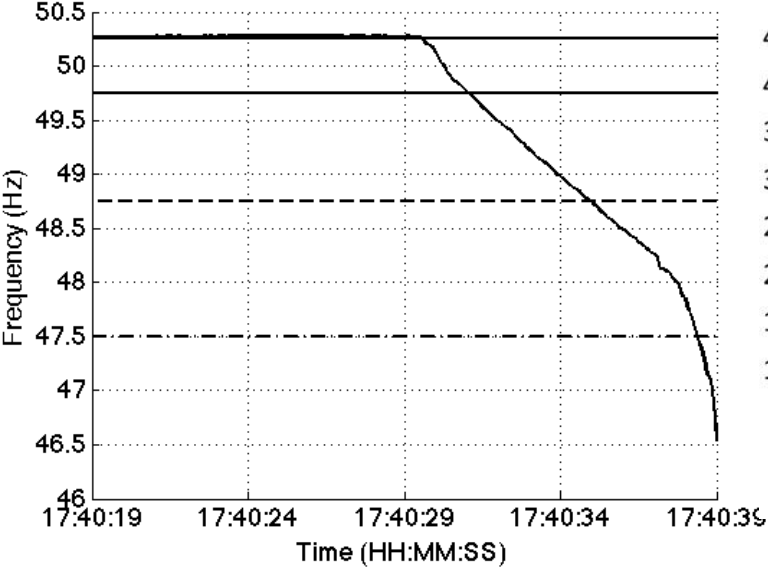
NIGERIA: in the meantime..



..due to non compliance.

NIGERIA: in the meantime..

System Collapse: June 27th, 2017



NIGERIA: in the meantime..

Circular Debt:

- Continuing privatization process
- Generators don't always comply to provide ancillary services
- **Not currently monitored or regularly verified**

Killer App #1

Online monitoring of generator compliance

Frequent System Collapses:

- **Limited situational awareness**
- **Monthly restoration from complete blackout**

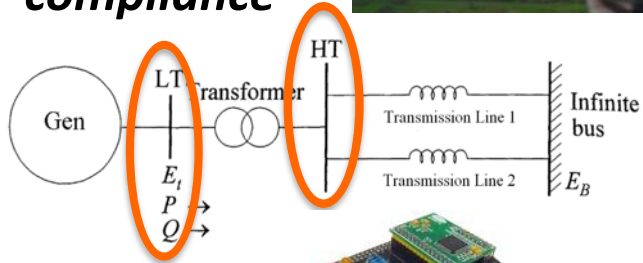
Killer App #2

Automatic Islanding and resynchronisation

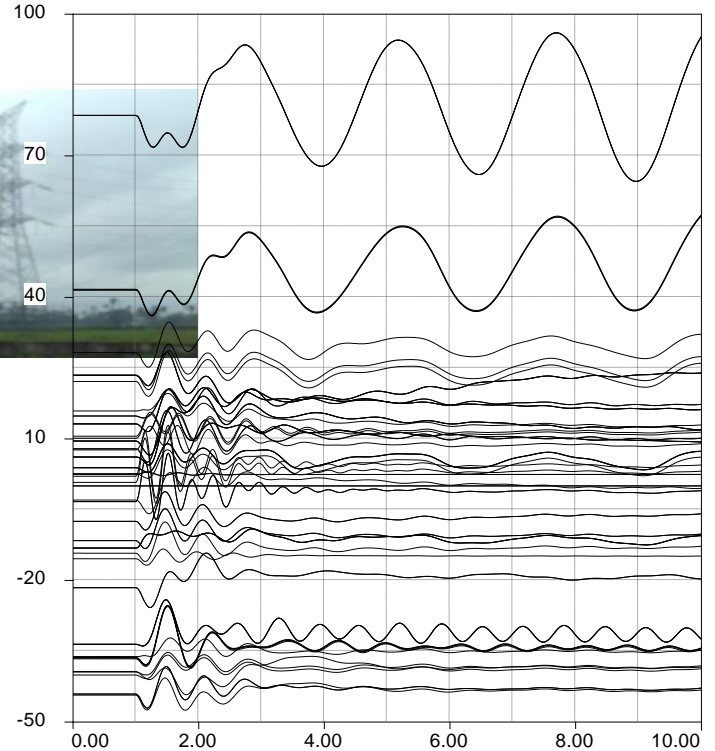
Non-compliance common and consequential in Nigeria; as is need for restoration

NIGERIA: in the meantime..

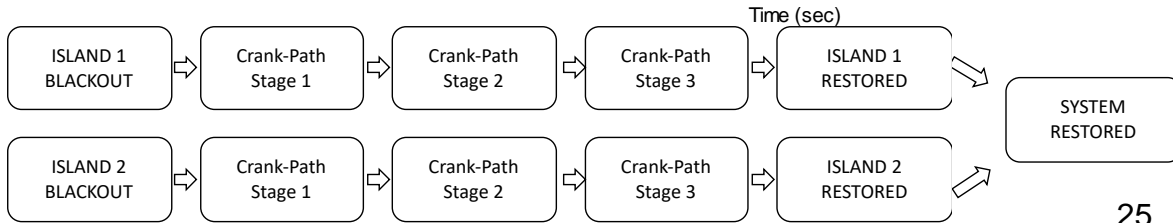
Killer App #1
Online
monitoring of
generator
compliance



Generator relative angle (deg) : Reference Generator = 16001 [EGBIN ST 2 16.0] ' 1'



Killer App #2
Automatic
Islanding and
resynchronisation



Improving the Operation and Restoration of the Nigerian HV Grid



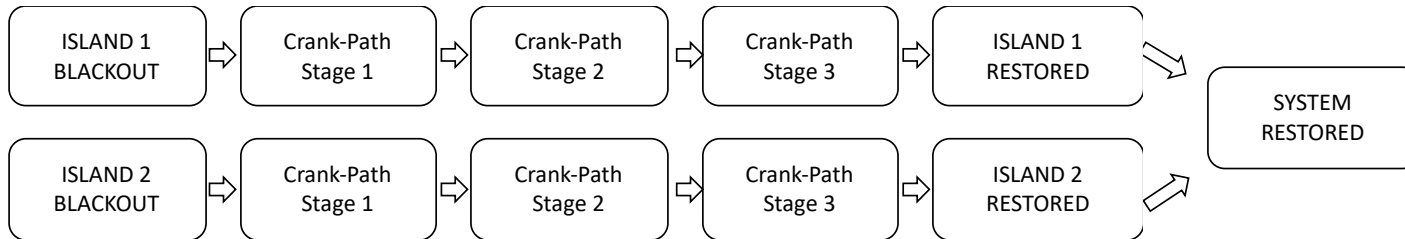
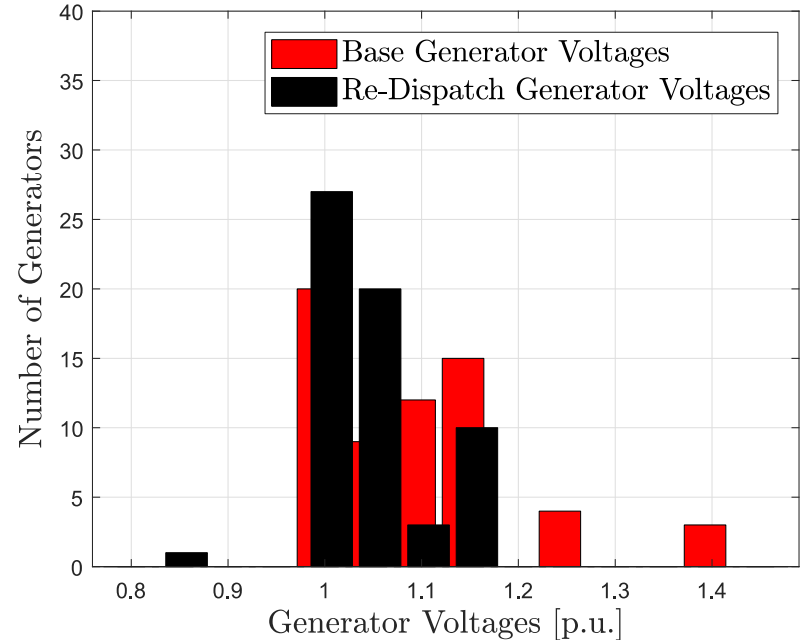
Prof Larry Pileggi
ECE

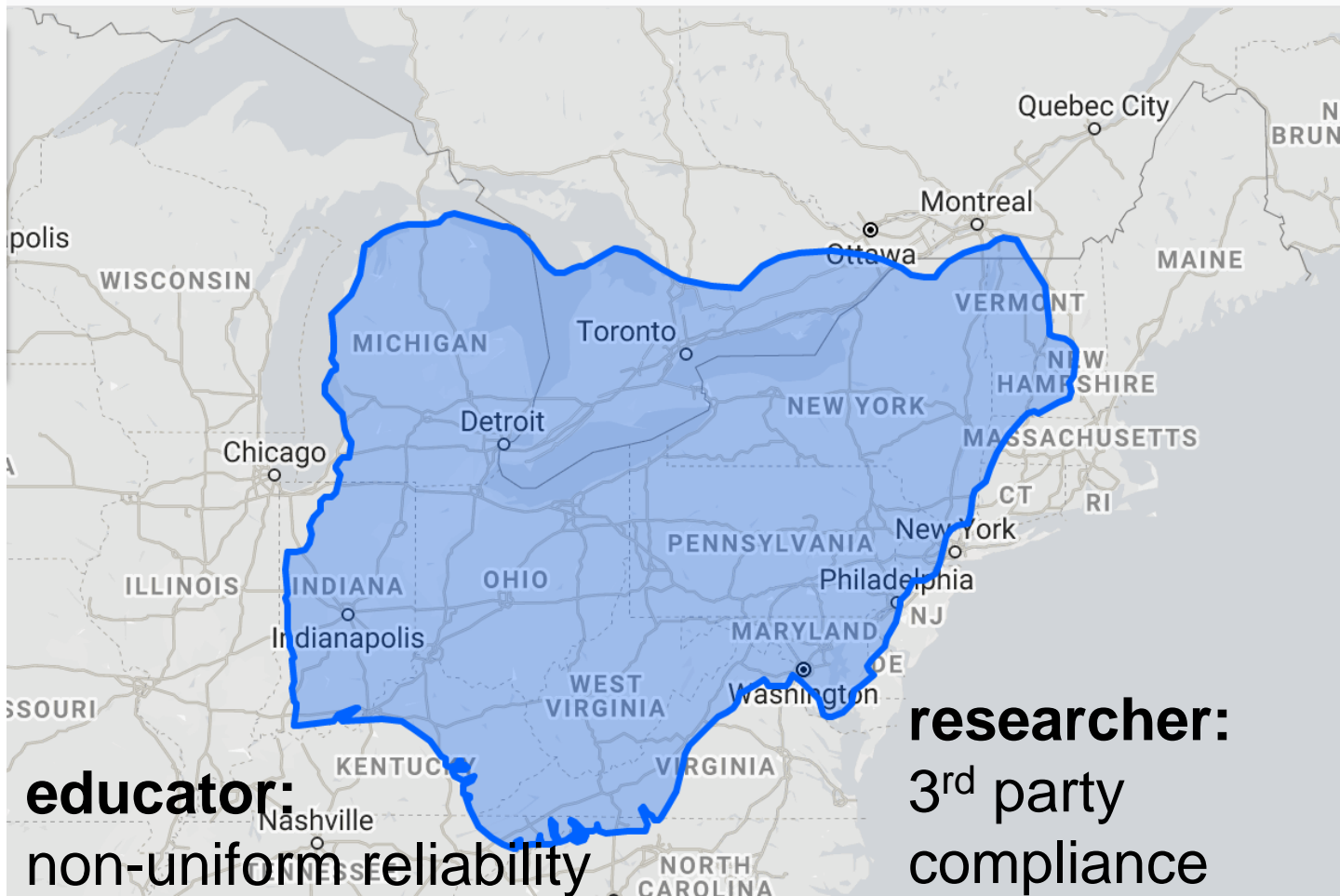


Aayushya Agrawal
PhD Candidate, ECE

Research questions

- Can acceptable operating points be found, even for large cross-country flow, ambitious delivery?
- How feasible are alternate restoration pathways after system collapse and blackout?





NIGERIA:
big change
due to
scale

*Slow change
means
contributions
needed to
manage
system as is..*

educator:
non-uniform reliability
tariff design

researcher:
3rd party
compliance
monitoring



educator:
cross-subsidies

researcher:
energy-water
nexus

RWANDA:
big change
due to pace..

100%
motorcycle
fleet
electrification
mandated,
100% access
forecast, in
next five
years.

RWANDA:
rapid pace due to size,
social organization

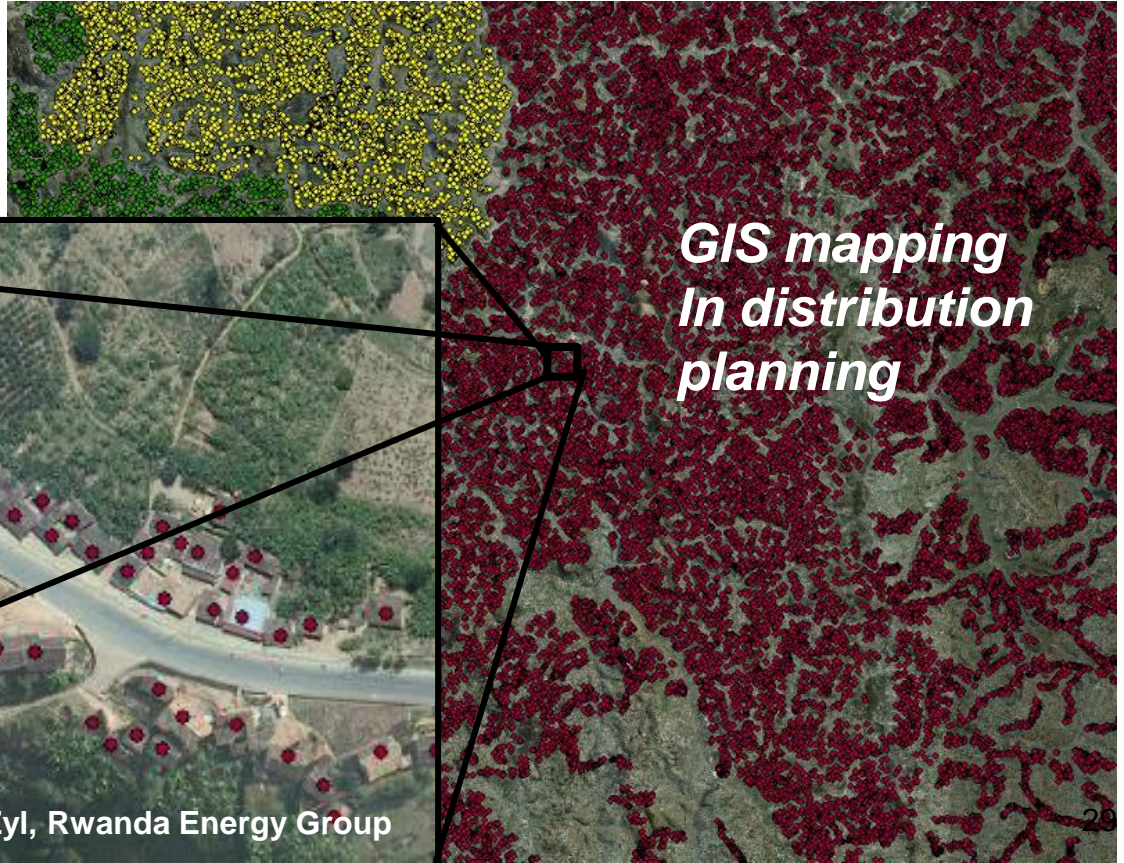


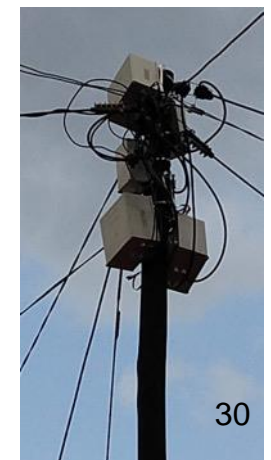
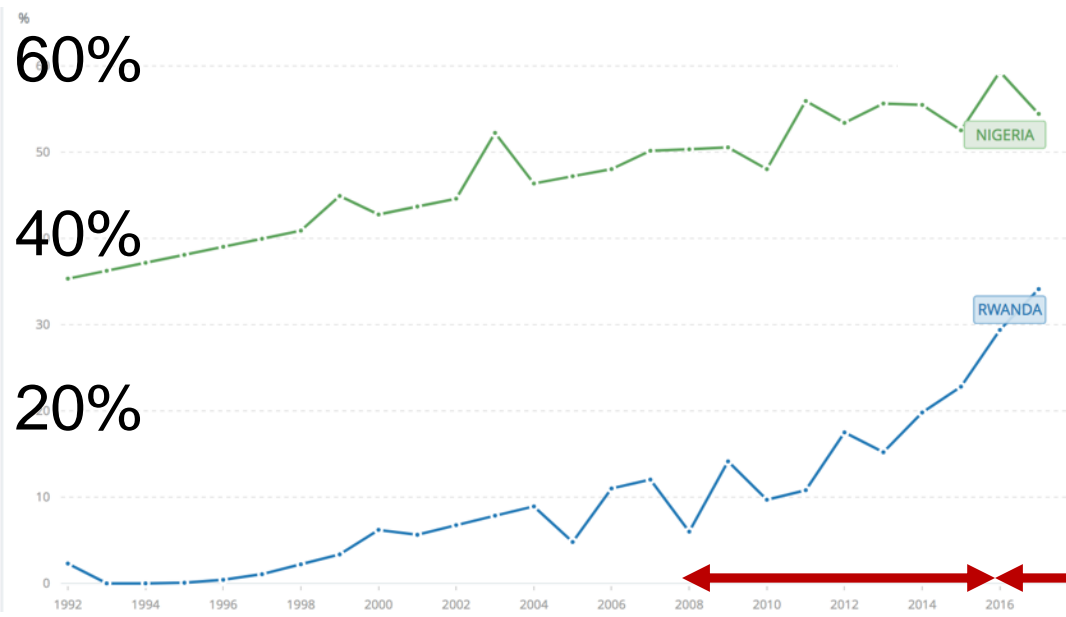
Image credit: Kobus Van Zyl, Rwanda Energy Group

RWANDA:

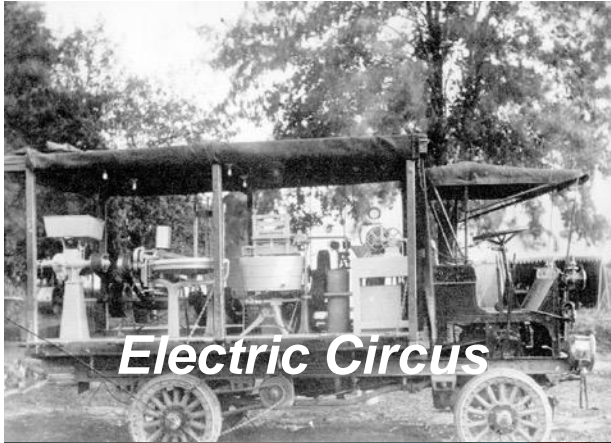
Off-grid zones open to developers, grid encroachment rules already drafted.

48% by solar decentralized (productized service)

52% by centralized (subsidized grid extension)



What can we learn about stimulation of electricity demand, and energy transport?



*Rockefeller funded
Electricity Growth and
Use in Developing
Countries*



How to work with CMU Africa in Rwanda?

..engage directly with on-going or upcoming research

Economic improvement through electrification

- How can sustainable irrigation and cold-store capacity be co-planned?
- What new models for energy distribution and mobility are possible through electric vehicles?
- What are the barriers and possible incentives?

Regulatory questions:

- How to balance commercial and industrial self-generation using solar against utility viability?
- What should goals for cross subsidies be?



Leveraging electricity infrastructure to improve agricultural productivity in East Africa

Jorge Izar,
Nathan Williams,
Paulina Jaramillo



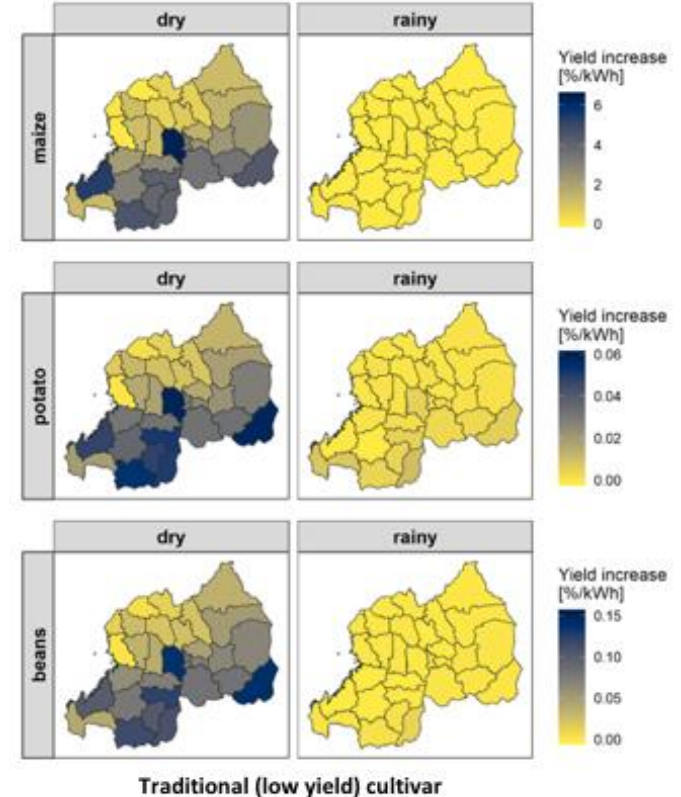
Paulina
Jaramillo
CMU,EP
P



Nathan
Williams
RIT

Research questions

- Where are there opportunities for co-investment in electrical and small-scale irrigation infrastructure in Rwanda?
- What is the potential for electricity consumption and yield increases from small scale irrigation in Rwanda?
- What other factors limit returns on electricity-irrigation investment?



Tapping Solar E-Waste Streams for Second-Use Battery Storage

B. Rawn, D. Ross, Katrina Ramirez-Meyers, S. Tennakoon, J. Whitacre



Jay Whitacre
Professor, MSE
Director, Scott Institute



Katrina Ramirez-Meyers
PhD Candidate,
EPP/MSE



David Ross
Professor of
Practice



Sarath Tennakoon
Visiting Professor



Research questions

- What is the statistical distribution of remaining capacity found in LiFePo cells in solar home system battery modules?
- What might be easily measureable and useful predictors of cell quality?
- What barriers may exist to more local manufacture and supply of energy storage services?

How to work with CMU Africa:

Visit CMU-Africa

- Give a distinguished lecture
- Meet with local stakeholders

Spend a semester in Kigali

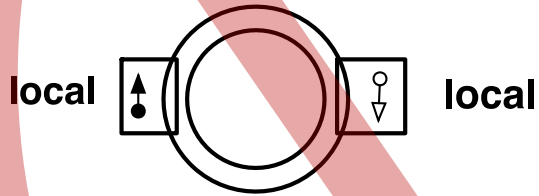
- Teach 1-2 **courses**
- Co-advise **independent studies** by CMU-Africa students
- **Meet** your CMU-Africa colleagues

Develop a research proposal in collaboration with the **KCRC**

Take a trip on the pathway to impact.

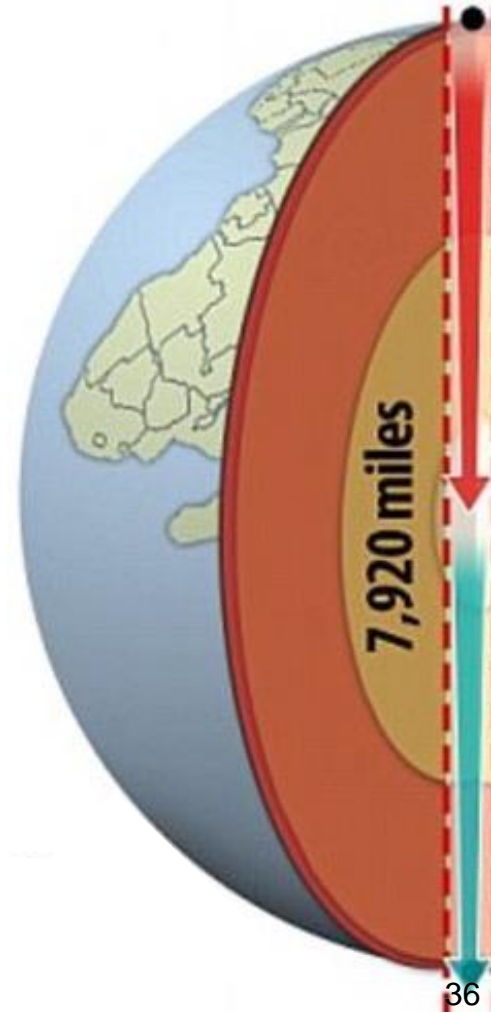


*Isolated
specialty
work:*



*Understand
just one limit
of technology*

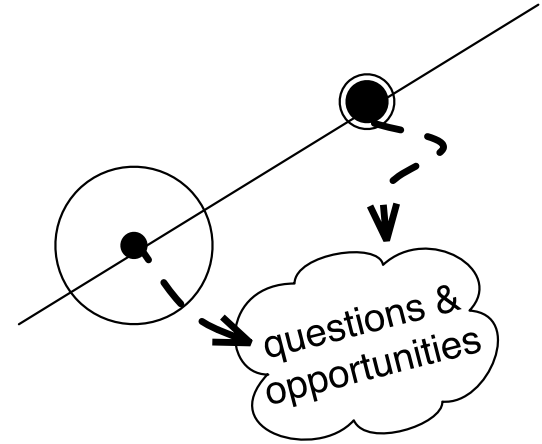
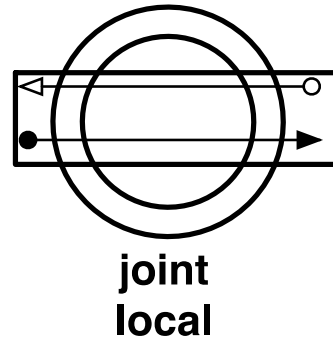
**Join us in
broad,
fundamental
applied, urgent
work:**



..to compare and exchange, to re-discovering fundamentals:



Joint work from two or more contexts:



Those who understand fundamentals and context: engineers ready to re-write