

## Session 2 – Africa talks

**Prof. Modi** (Professor in the Department of Mechanical Engineering, Columbia University)

# Can innovation be an enabler to power Africa?

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Earth Institute/Engineering

Columbia University,

RES4MED May 22, 2017

# What is different now & what implications

- Internet, cell phones, smart phones, data
- Payment systems, mobile money
- Low cost of sensing/control when done at scale
- Exponential decline in PV costs, need to lower emissions
- High variable renewables will value grid “flexibility”
- For grid operators, new opportunities in integration
- New options for energy access
- Innovation: combining these to create new business models
- How can Africa leverage/internalize/export innovations?

High willingness to pay for the first kWh/month  
+ scalability of solar PV and battery  
+ Pay As You Go and new payment systems  
have lead to new business models for solar  
home systems and solar lanterns



Energy Policy, 2010

Field testing and survey  
evaluation of household  
biomass cookstoves in rural  
sub-Saharan Africa  
ESD, Vol, 14, 2010

**Can off-grid provide grid-like service**

**What do I mean by grid-like?**

**What have we learnt so far?**

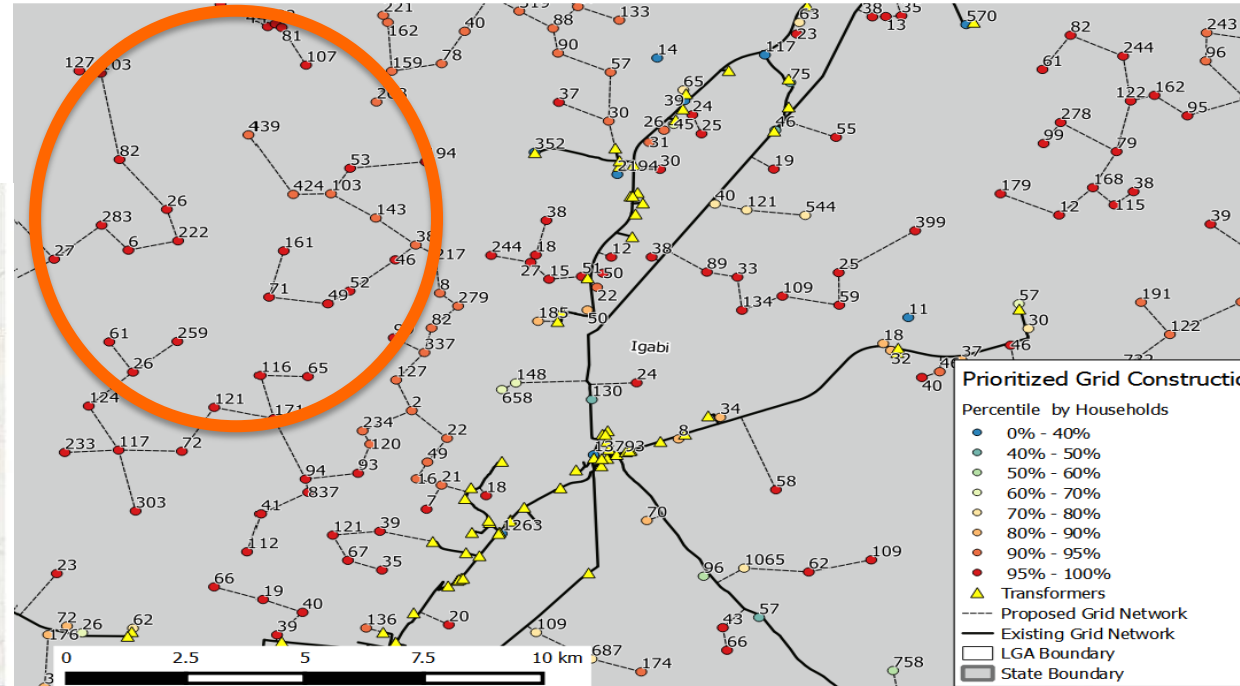
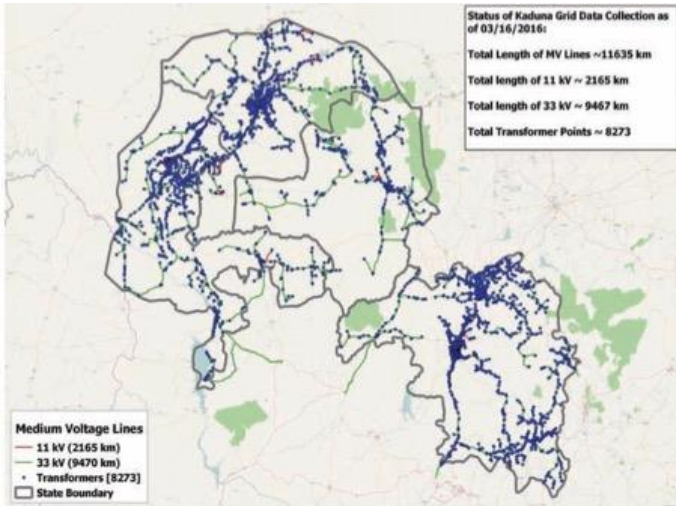
**Consumer preference**

**Successful businesses need to grow**

## Zoomed in view: Kano and Kaduna Utility

Igabi LGA, Kaduna State

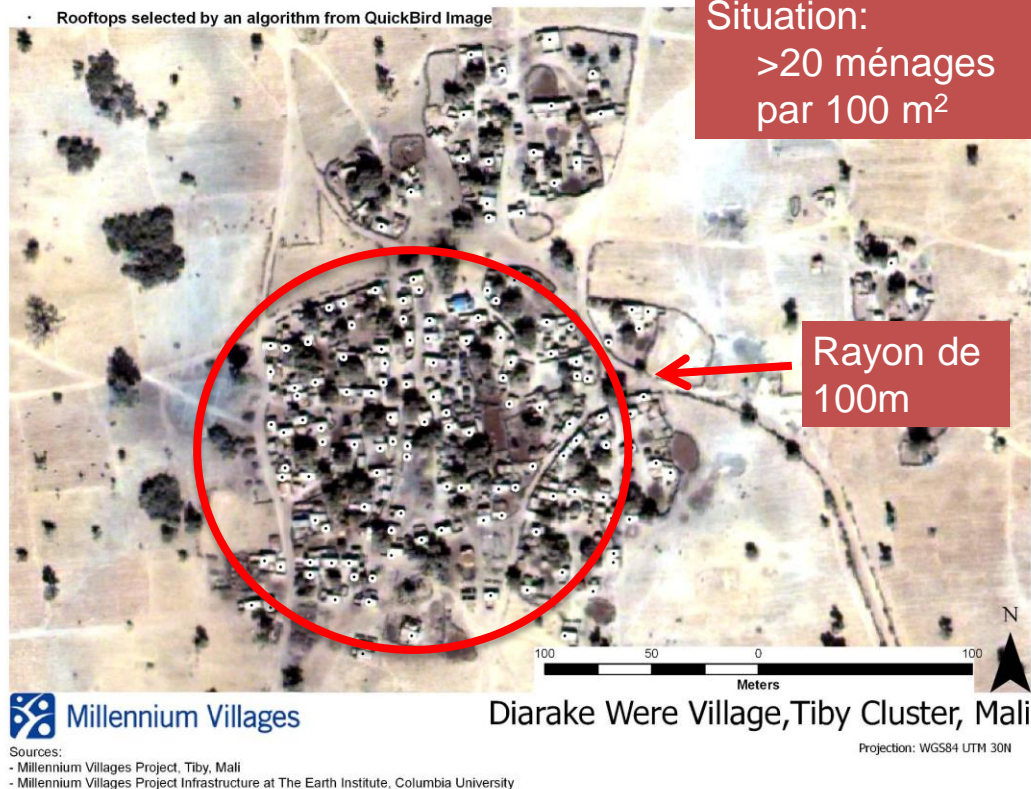
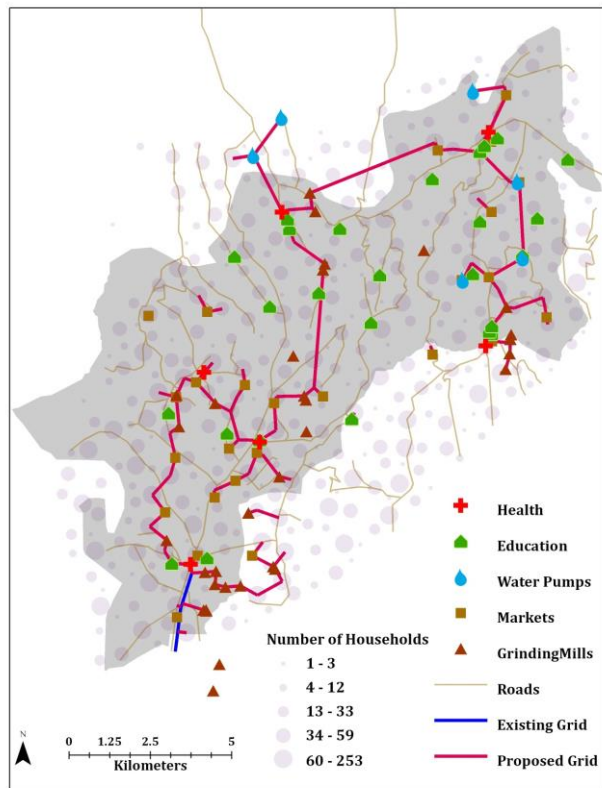
Utility teams mapped MV lines,  
transformers, substations





# Pilot learning from Uganda and Mali

## 16 systems installed in 2011





**GENERATION  
PRIVATE  
INVESTMENT**

**DISTRIBUTION  
PUBLIC/CUSTOMER  
FINANCED**

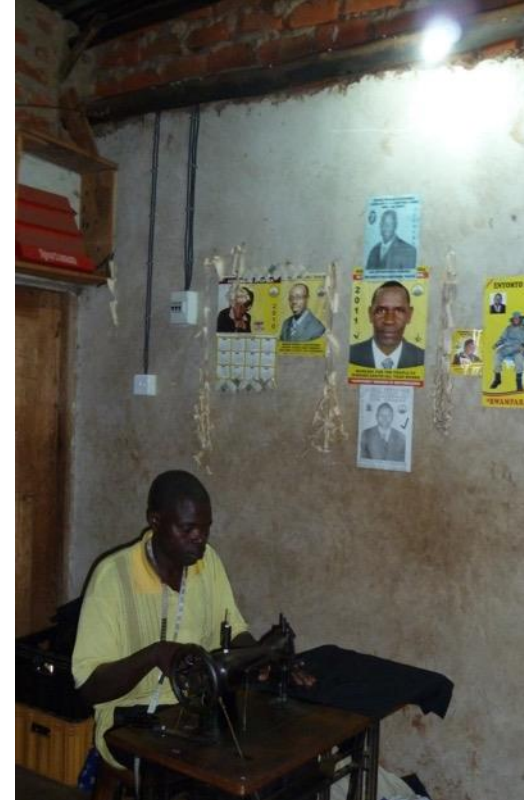
**INSIDE WIRE/APP  
TARIFF  
FINANCED**



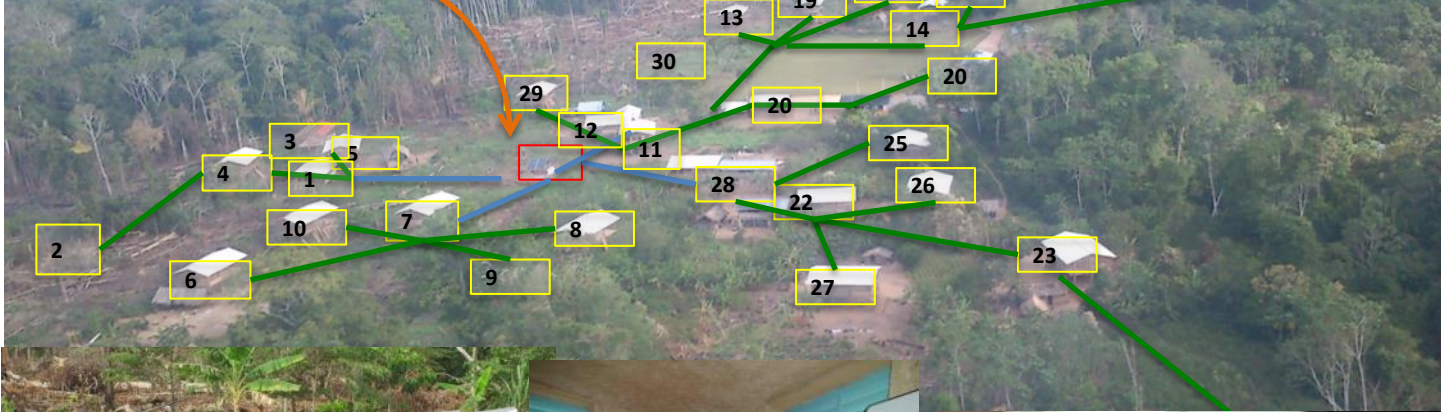
**ANY SOURCE  
eg HYBRID**



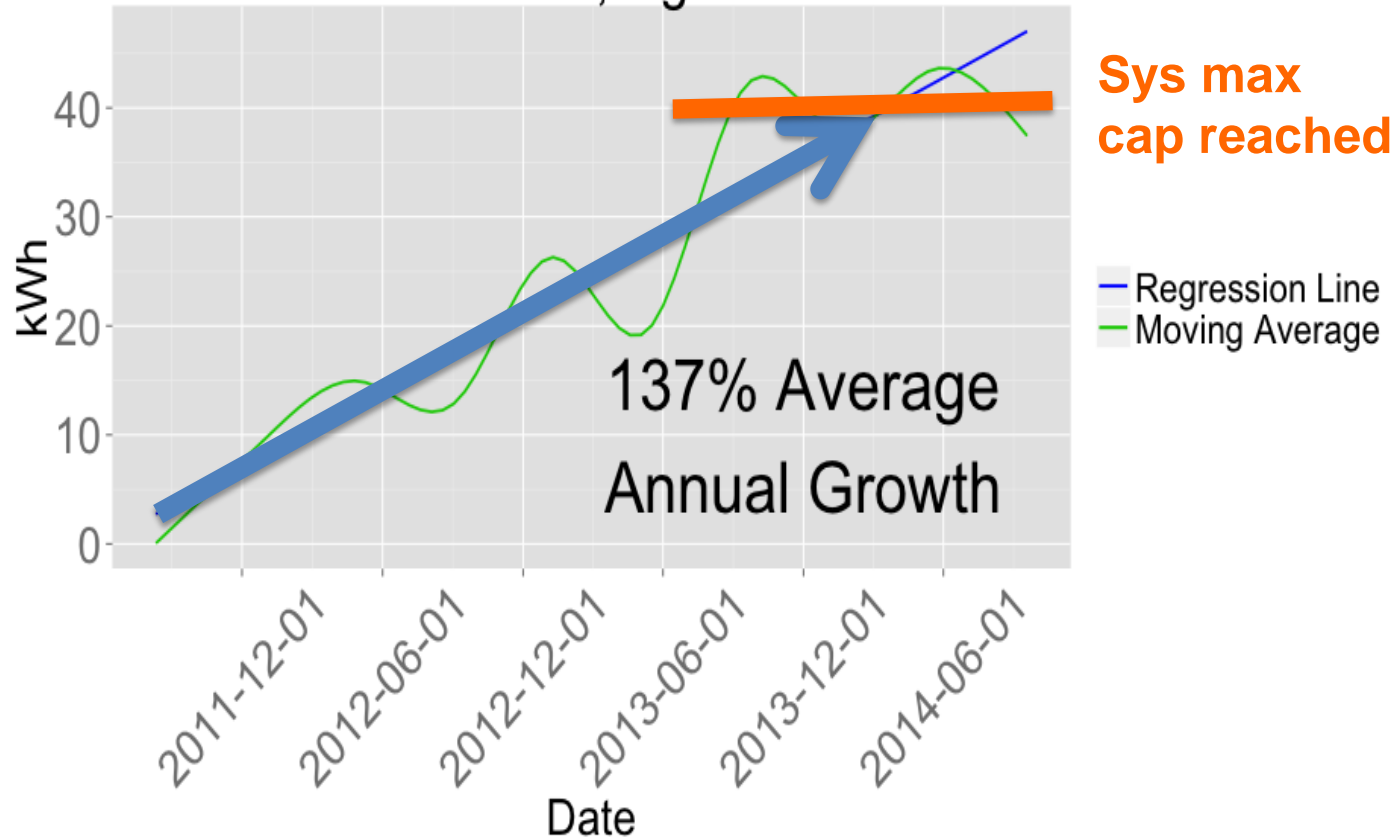
**220V AC**



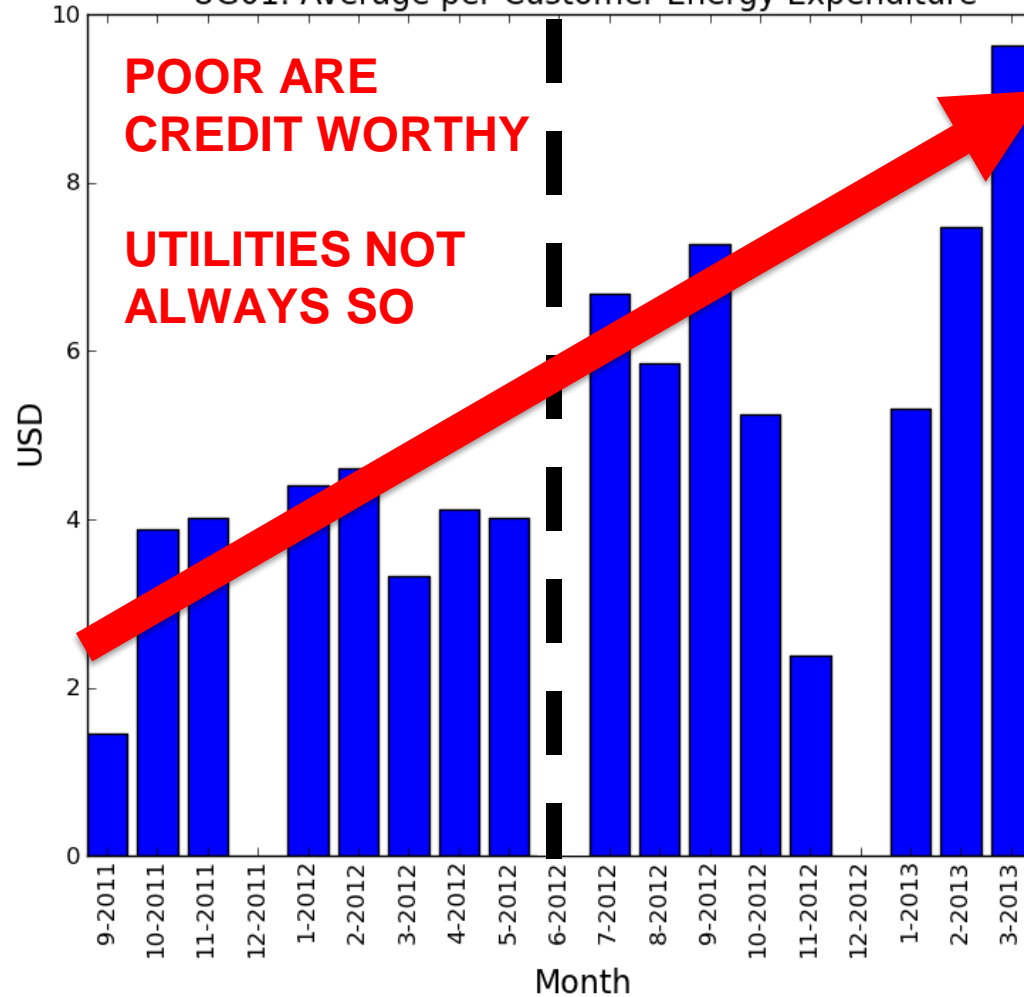
# Grid like service



# Moving Average with Regression line for Monthly Energy Usage for Systems in Ruhiira, Uganda



UG01: Average per Customer Energy Expenditure



\$9/hh pm

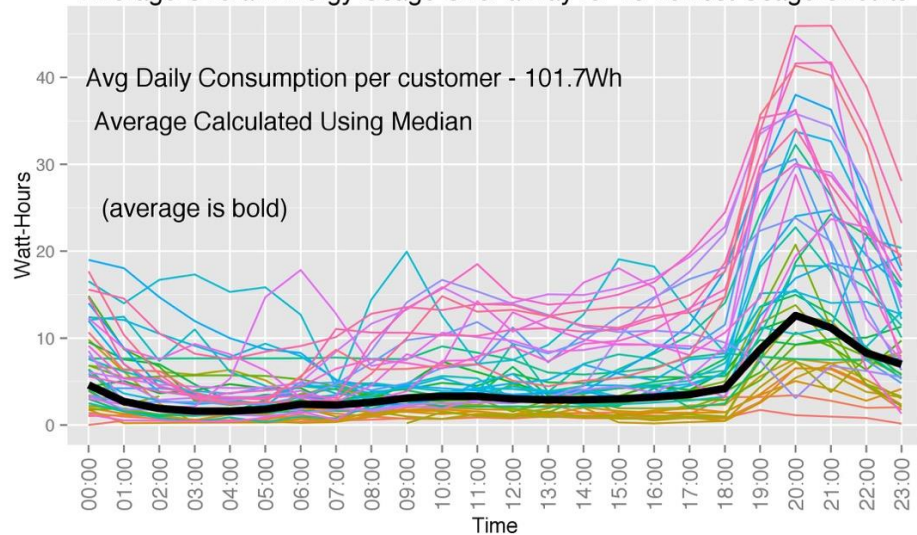
\$2.50/hh pm

**POOR ARE  
CREDIT WORTHY**

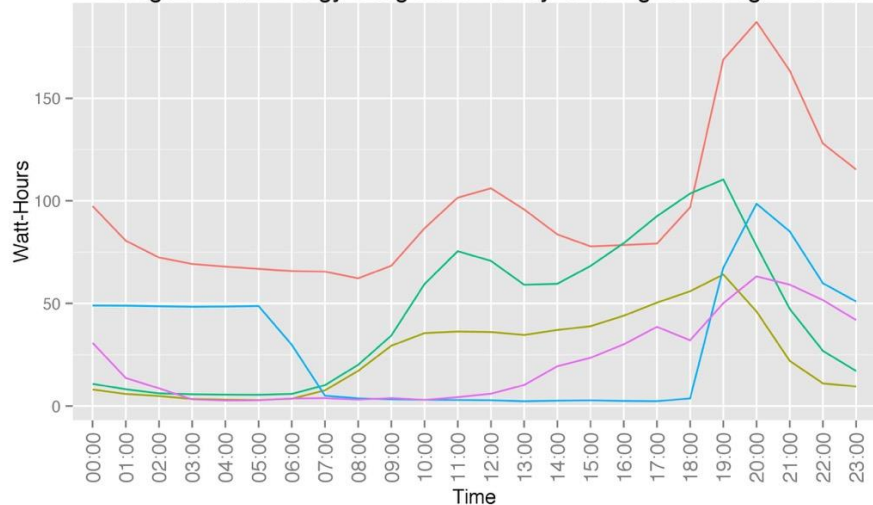
**UTILITIES NOT  
ALWAYS SO**



Average Overall Energy Usage Over a Day for 45 Lowest Usage Circuits



Average Overall Energy Usage Over a Day for 5 Highest Usage Circuits



Incremental & Modular as demand grows  
Keeps initial investments low  
Allows dynamic choice of where to grow

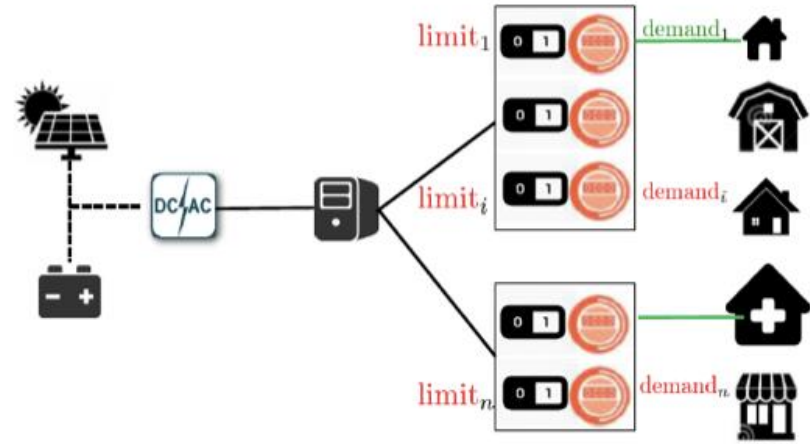




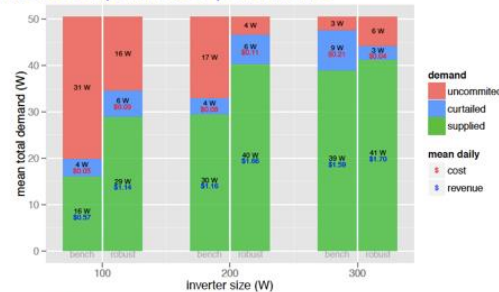
# New area of research for us

Dynamic allocation of power and energy limits to ensure high utilization and yet low disruption

Controllers learn from past usage data to ensure that service is not completely shut down

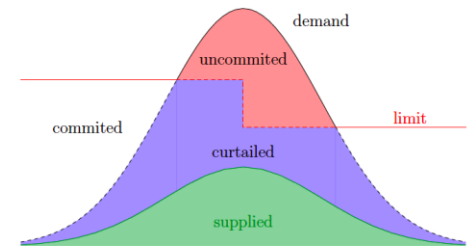


Numerical experiments: performance



- ▶ 37% decrease in uncommitted and curtailed demand
- ▶ 200% increase in revenue
- ▶ Robust control avoids extra 100 W capacity investment

Reliability: utility's commitment and curtailment



- ▶  $committed_{it} = \min\{demand_{it}, limit_{it}\}$
- ▶ Utility possibly **loses revenue** by setting **limits** too low
- ▶  $curtailed_{it} = committed_{it} - supplied_{it}$
- ▶ Utility pays **curtailment cost** by setting **limits** too high
  - ▶ Curtailment penalties  $\eta_{it} \propto predictability$

Larger demands that need lower price points



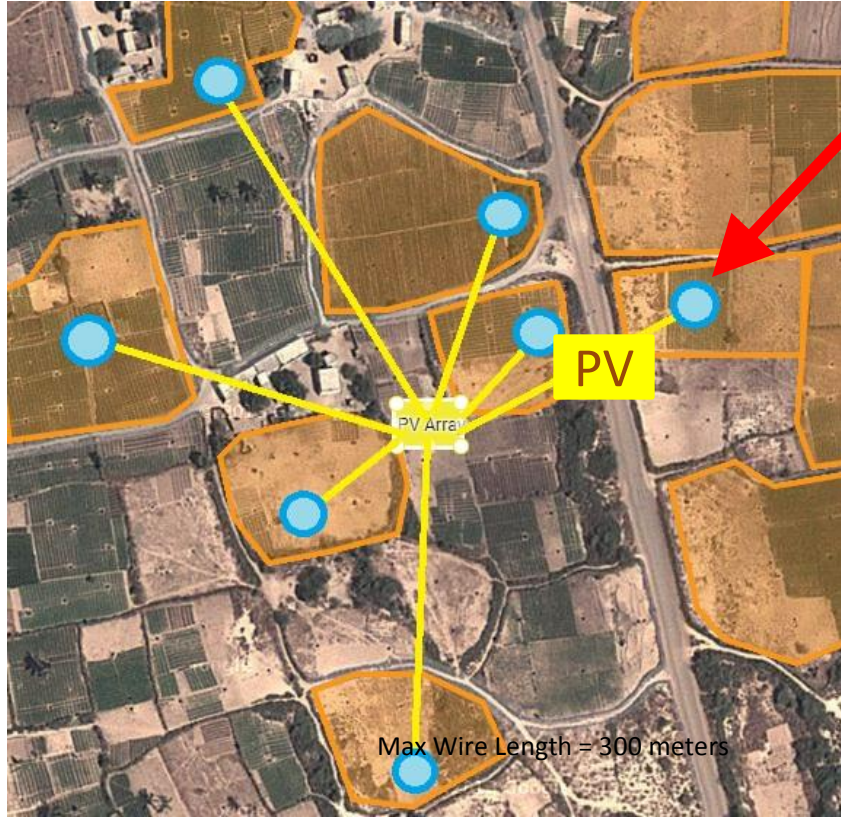
## Innovation: example from Senegal

- Understand need, context, constraints of user **and constraints of operator, finance**
- Constraints: upfront cost, small land holdings, crop & water use varies, no grid power
- How to bring benefits enjoyed by large farms to groups of small farmers?





# Innovate: Cost/O&M/biz model/local/scale in mind



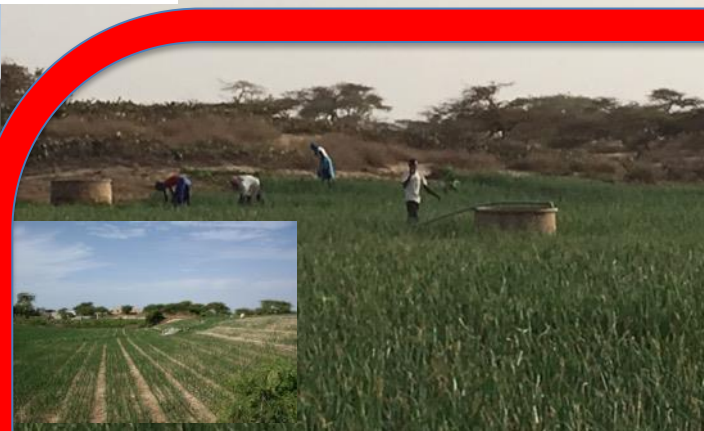
Wells &  
Pumps



**Famers own innovations**



**Biz Model**



**Roads + transport**



**Innovation**



**Co-op+Finance**

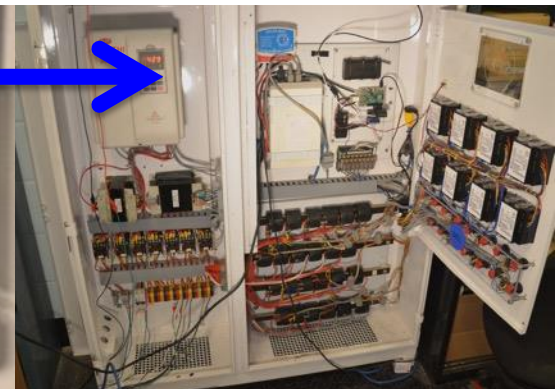


**Market**



# Logic/Power Elect/Control/Payment/Pump

- Scheduling logic
- Inverter/VFD
- 415V, 3ph, 50 Hz
- **Microprocessor**
- **Payment app**



Pump and Solar Data

