Electricity Access in Emerging and Developing Countries

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Cost/Benefit dynamics of different technologies for electrification

- Differences arise out of many factors
- Geography- settlement patterns, land-locked
- Target energy demand and power levels
- Material cost: transport/customs, scale, imports
- Standards for reticulation
- Costs of transition to smart/prepaid metering.
- First cost to connect: how to spread that
- Benefits of grid-like service
- Can Infrastructure be incremental?

Cost/Benefit dynamics of different technologies for electrification

- Cost differences that arise out of different factors
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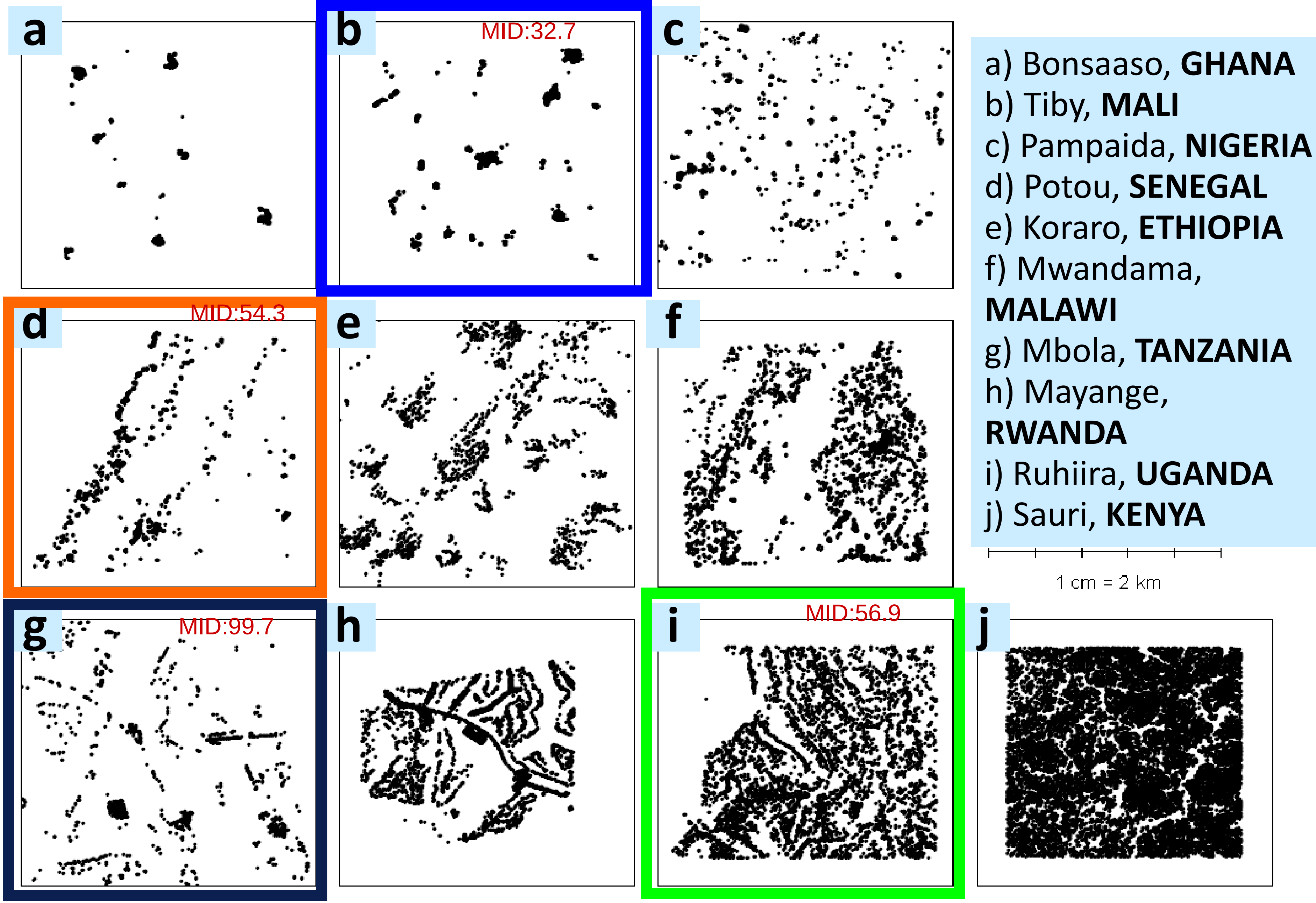
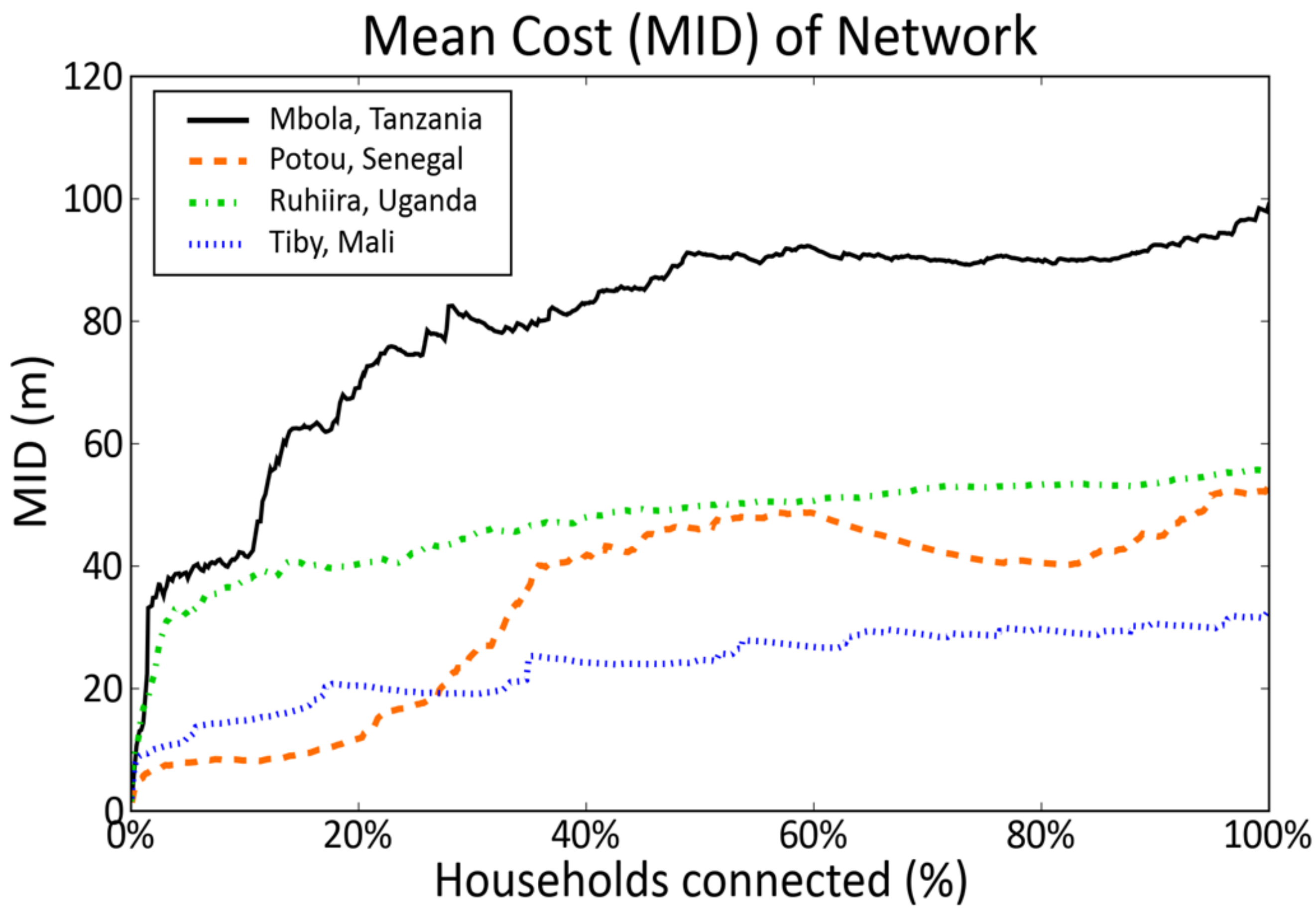
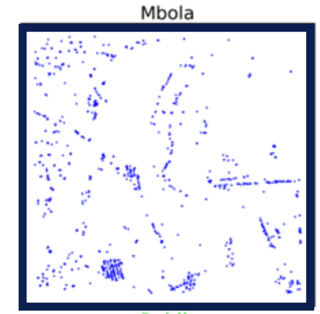
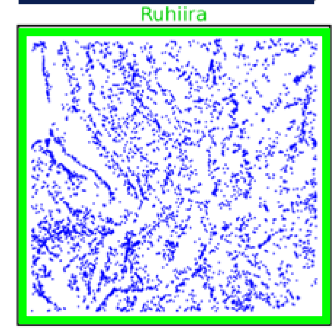
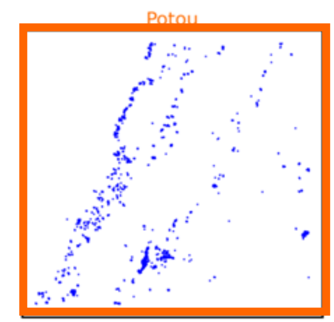
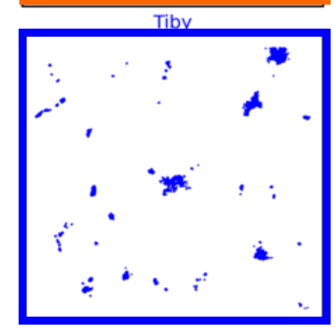

a
b
MID:32.7
c
d
MID:54.3
e
f
g
MID:99.7
h
i
MID:56.9
j
a) Bonsaaso, **GHANA**
b) Tiby, **MALI**
c) Pampaida, **NIGERIA**
d) Potou, **SENEGAL**
e) Koraro, **ETHIOPIA**
f) Mwandama, **MALAWI**
g) Mbola, **TANZANIA**
h) Mayange, **RWANDA**
i) Ruhiira, **UGANDA**
j) Sauri, **KENYA**
1 cm = 2 km











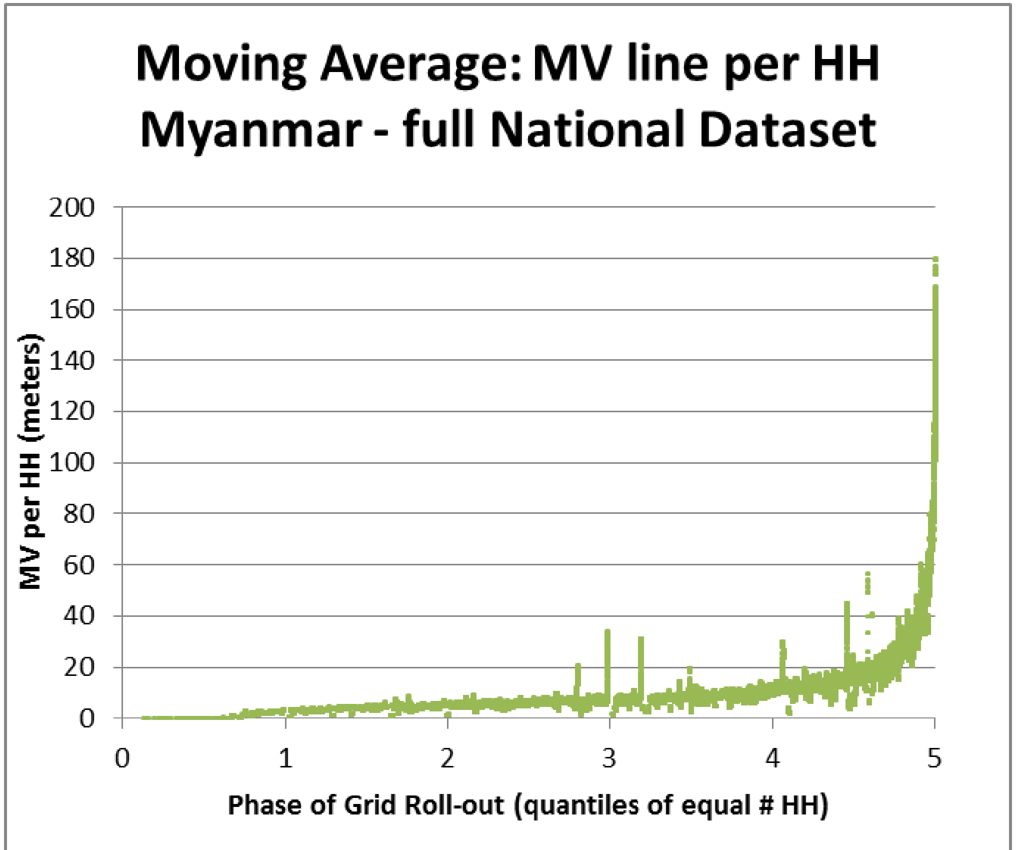
The impact of geography on energy infrastructure costs

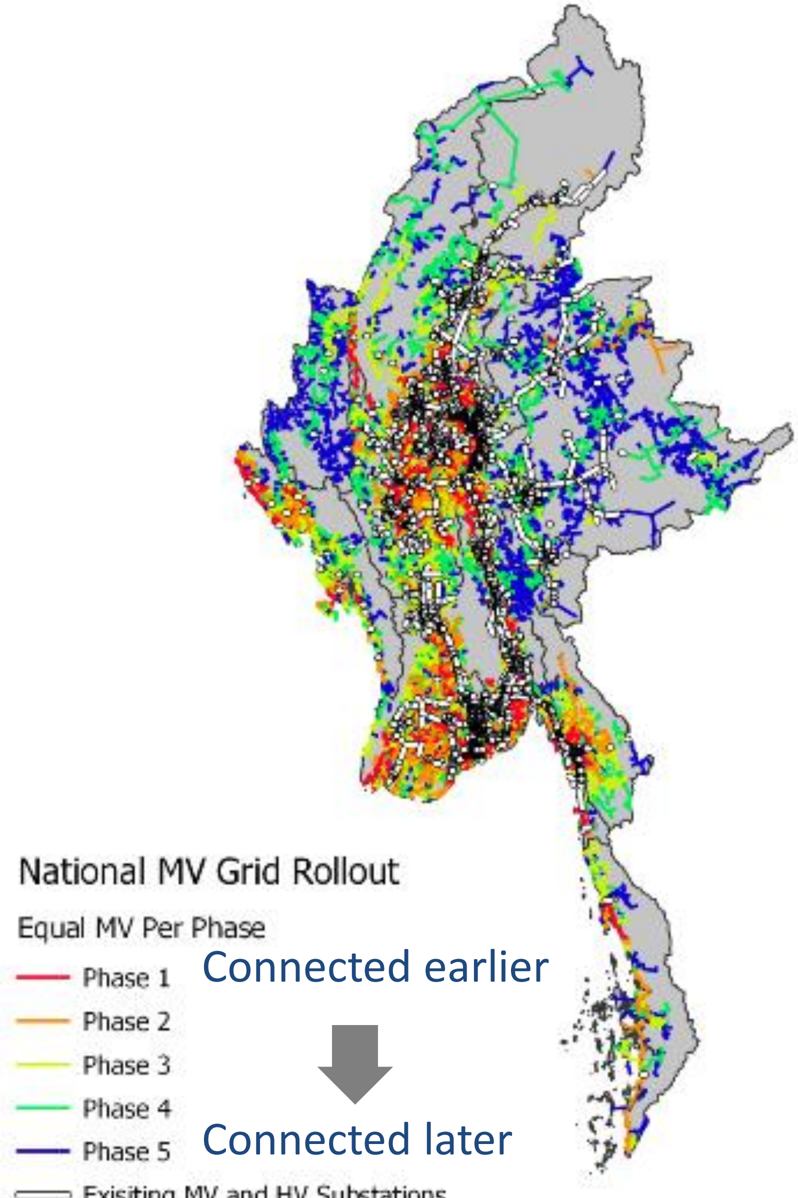
Alex Zvoleff[a], Ayse Selin Kocaman[b], Woonghee Tim Huh[b], Vijay Modi[c]

Energy Policy

Volume 37, Issue 10, October 2009, Pages 4066–4078

Myanmar:
National Electrification Plan





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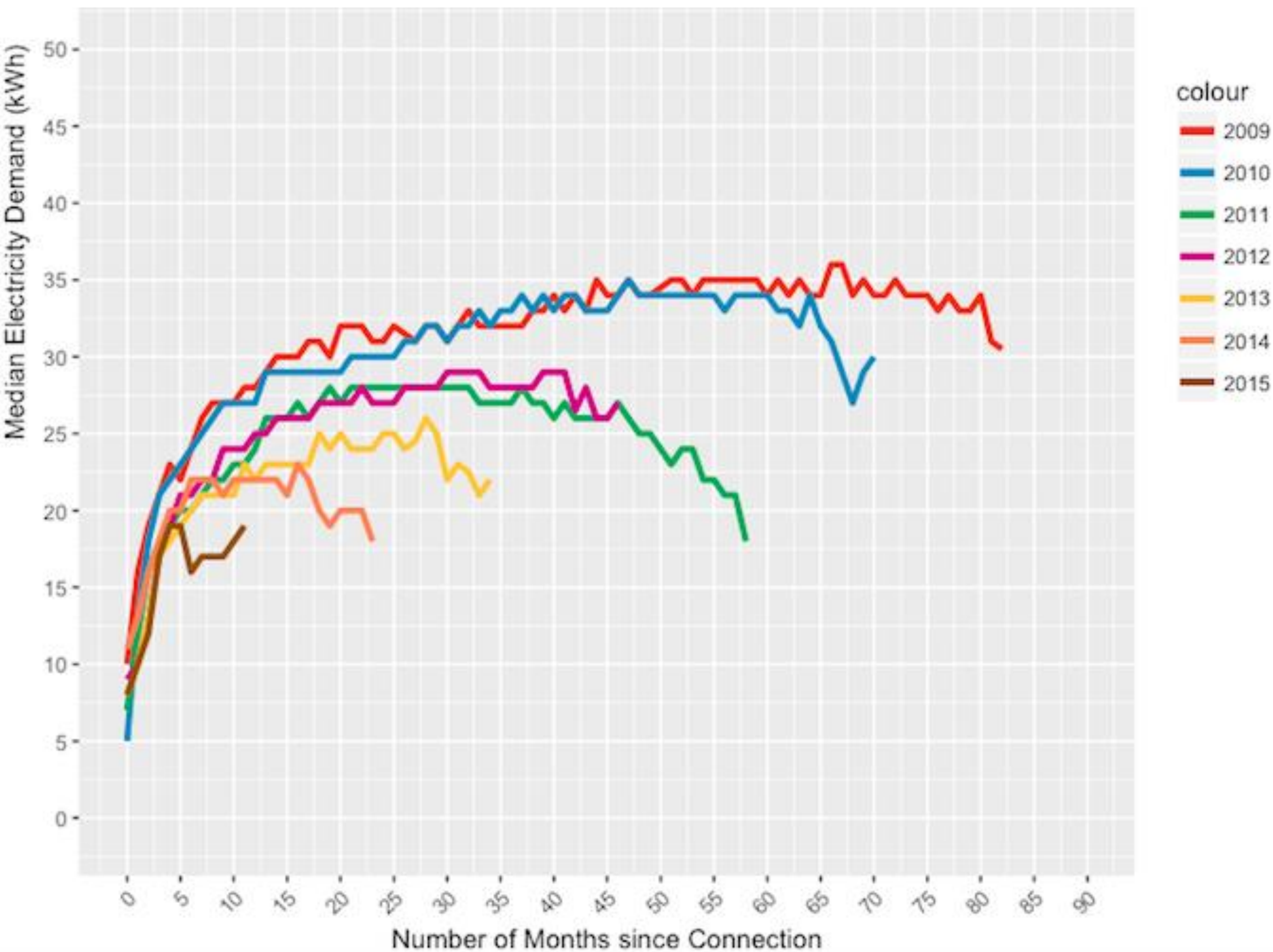
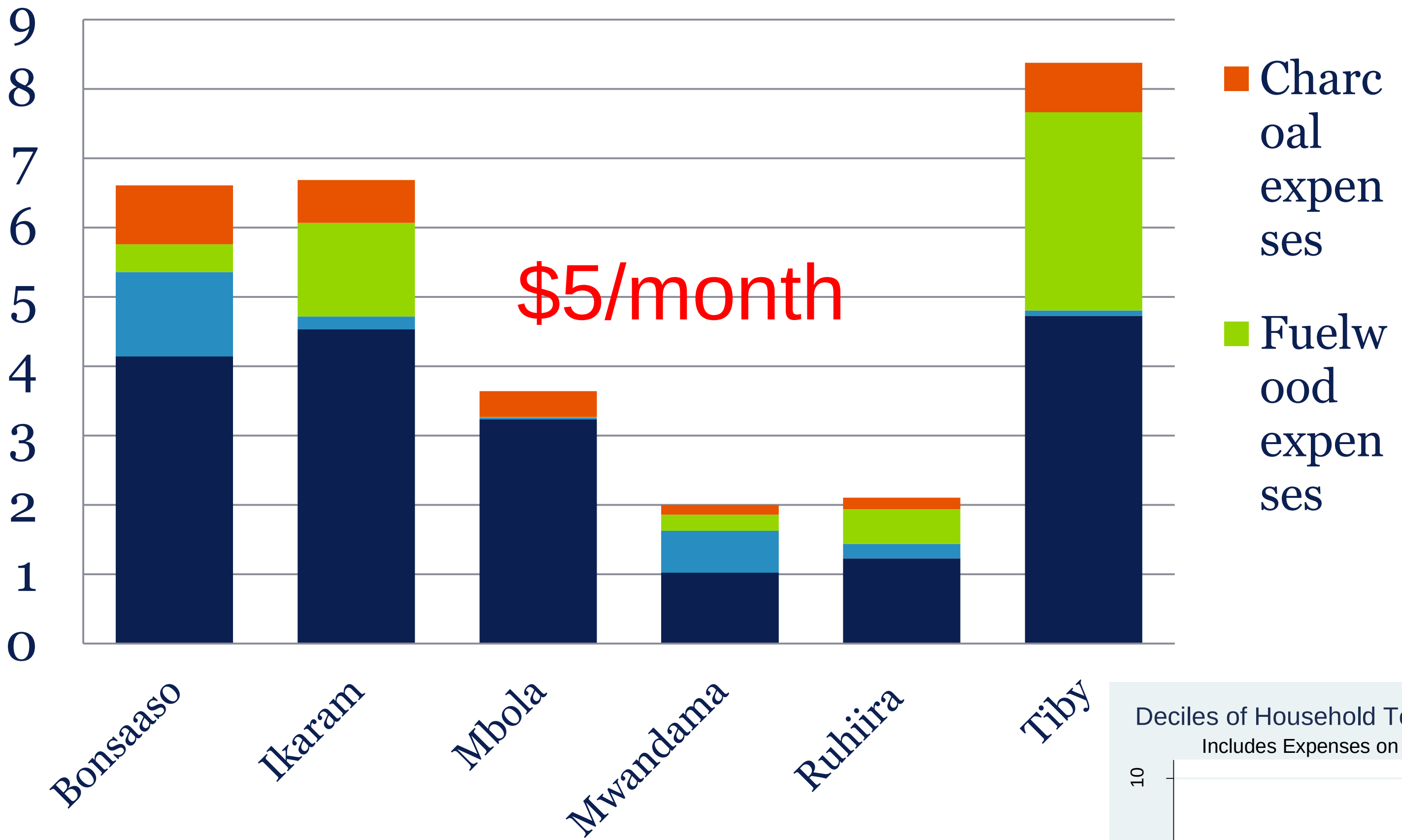
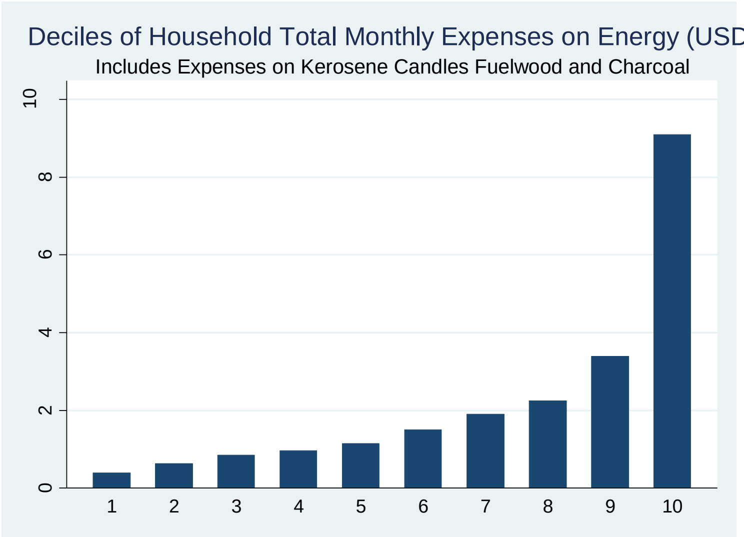

Median Electricity Demand (kWh)
Number of Months since Connection
colour
2009
2010
2011
2012
2013
2014
2015
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90

Mean Monthly Energy Expenses per Household in USD



n: Bonsaaso 290, Ikaram 258, Mbola 278, Mwandama 300, Ruhiira 300, Tiby 295



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STANDARDS and LEVERAGING LOCAL LABOR

Ready Boards

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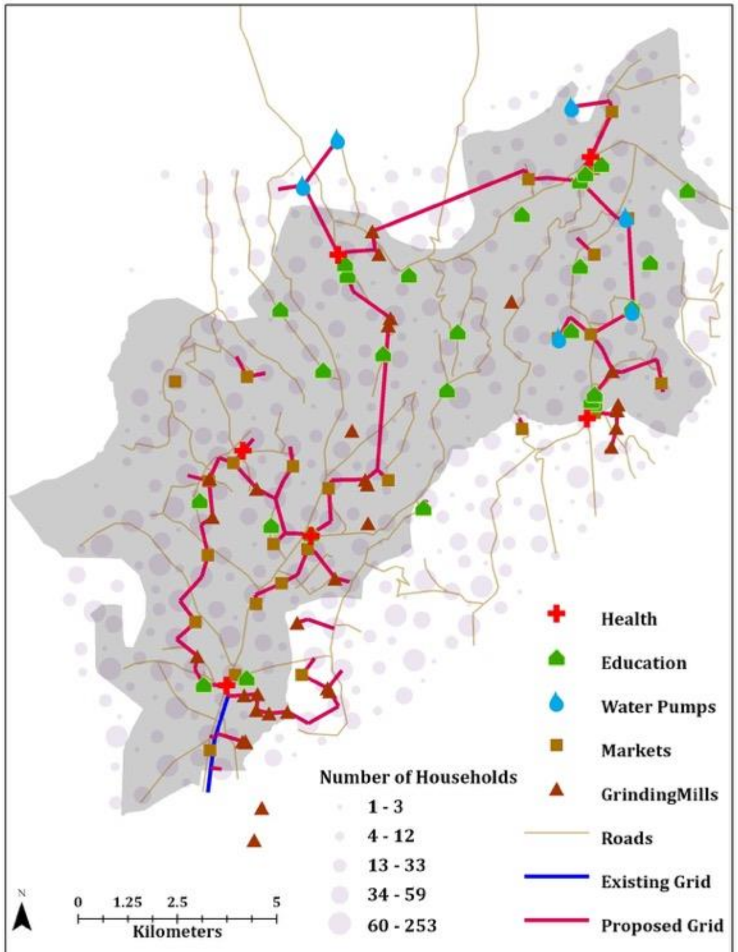
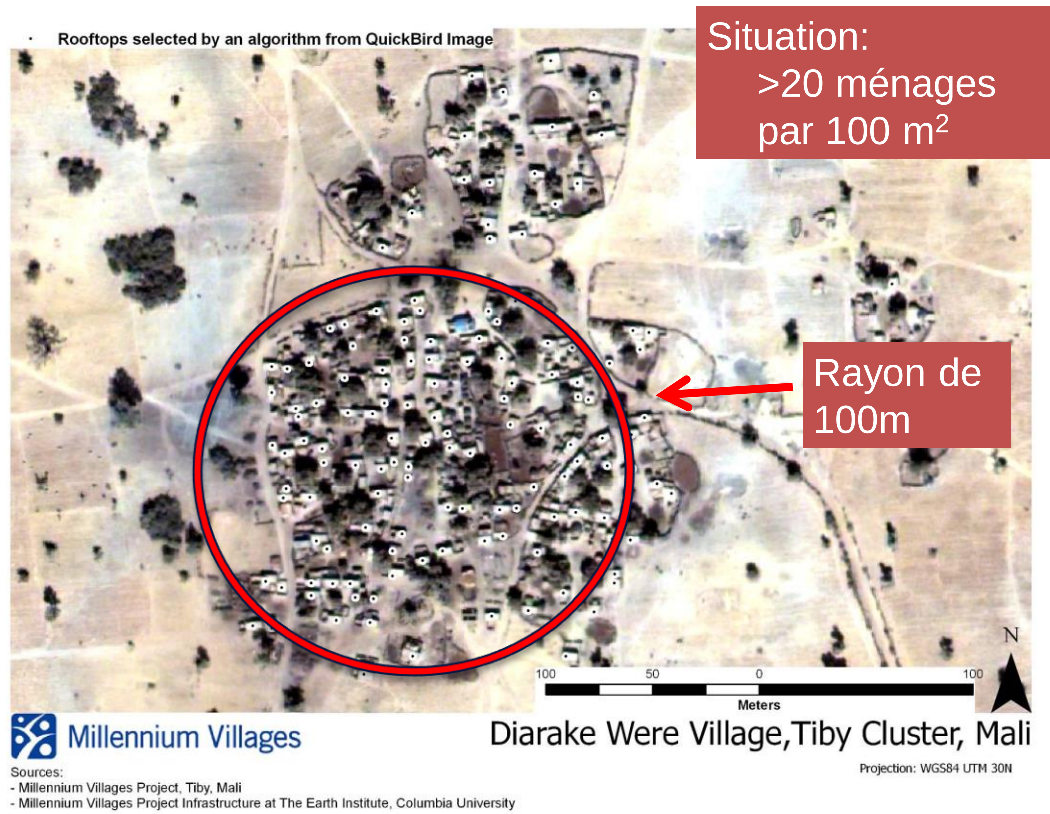
Grid-like service?
First costs: for connection + efficient appliances

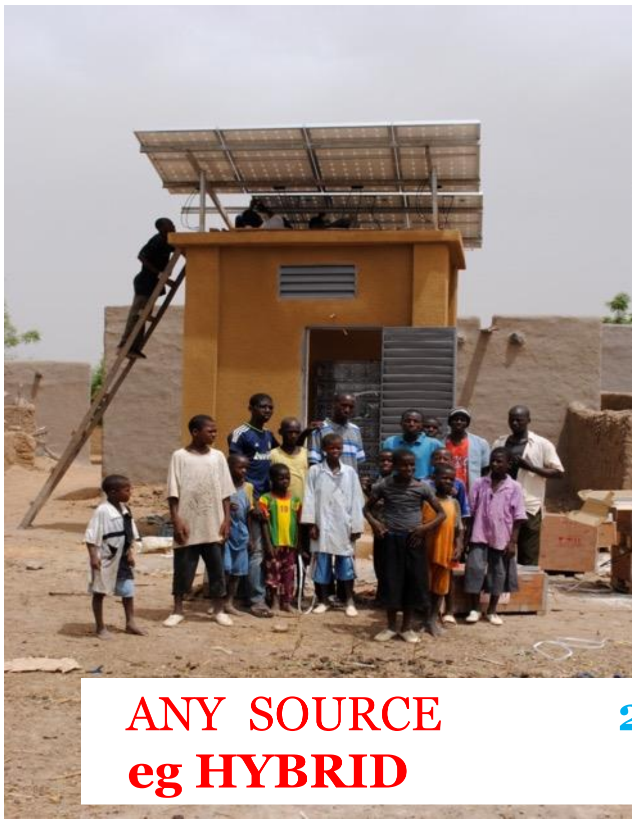


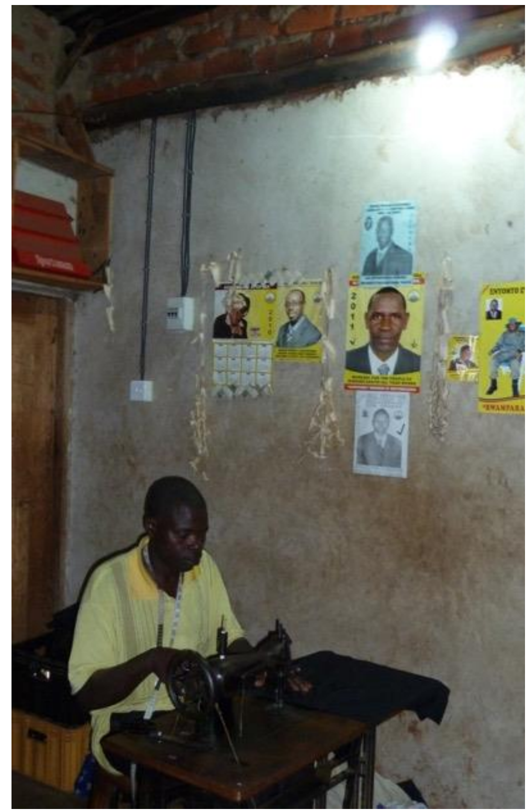


GENERATION
PRIVATE INVESTMENT

DISTRIBUTION
PUBLIC/CUSTOMER FINANCED

INSIDE WIRE/APP
TARIFF FINANCED

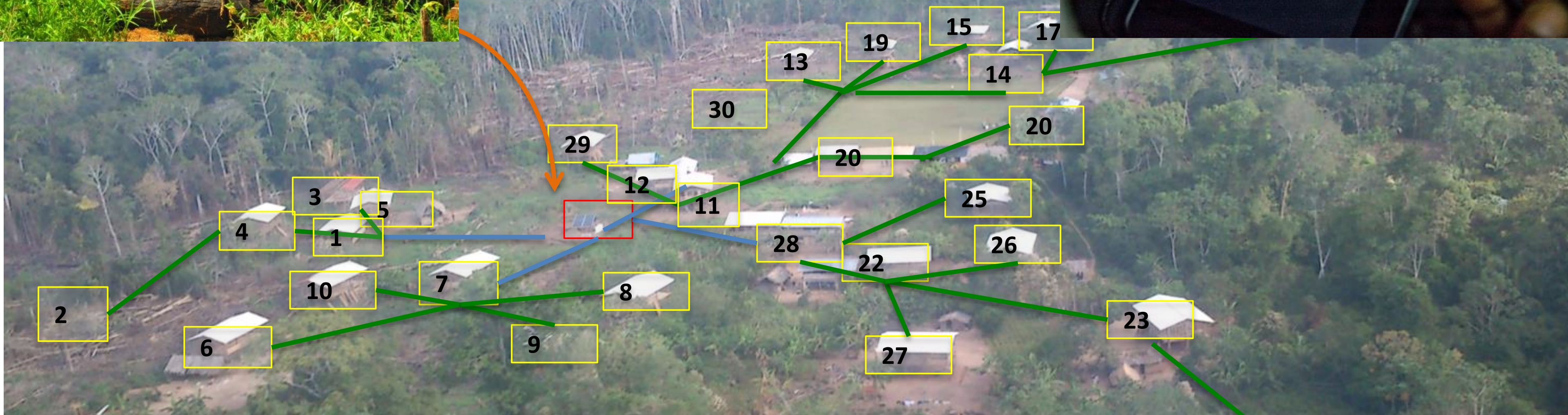


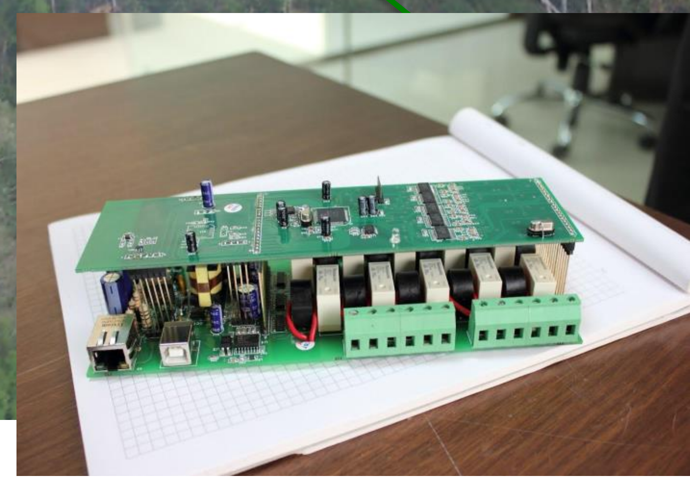


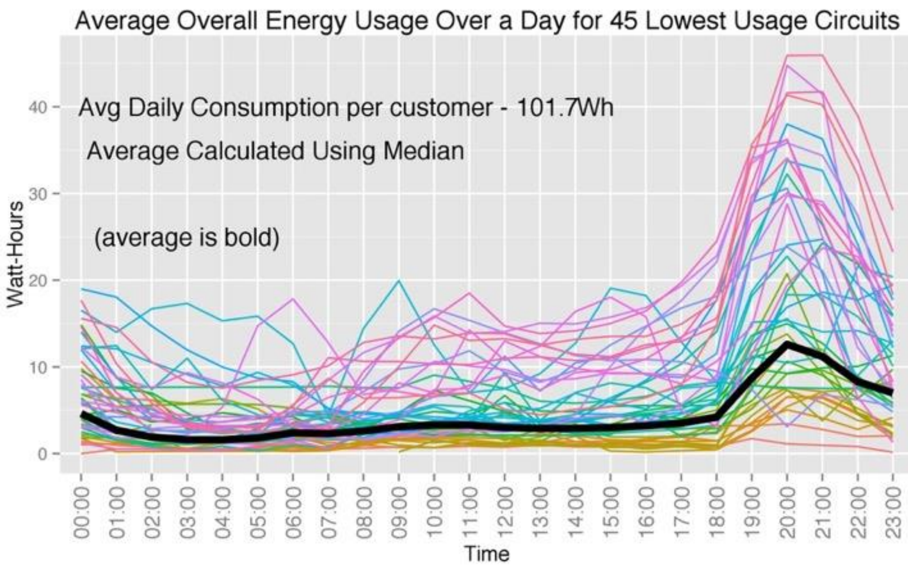
ANY SOURCE
eg HYBRID

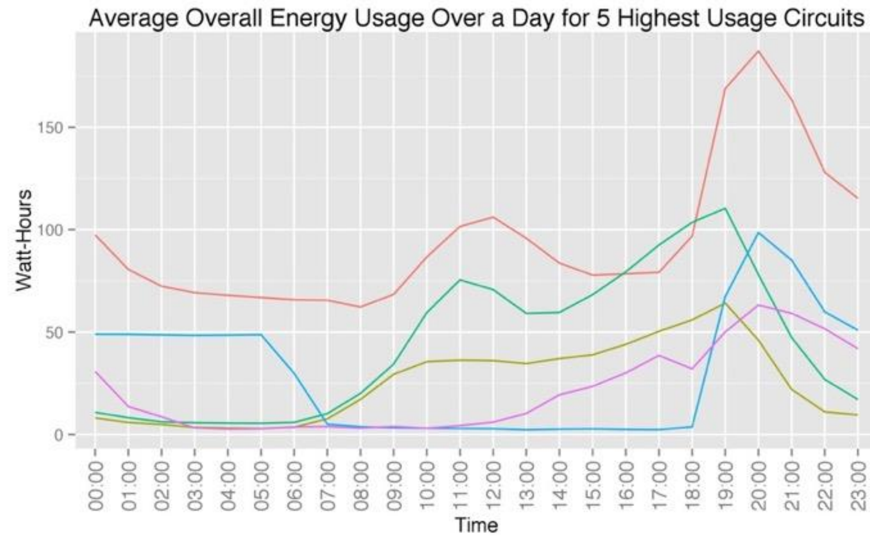
220V AC

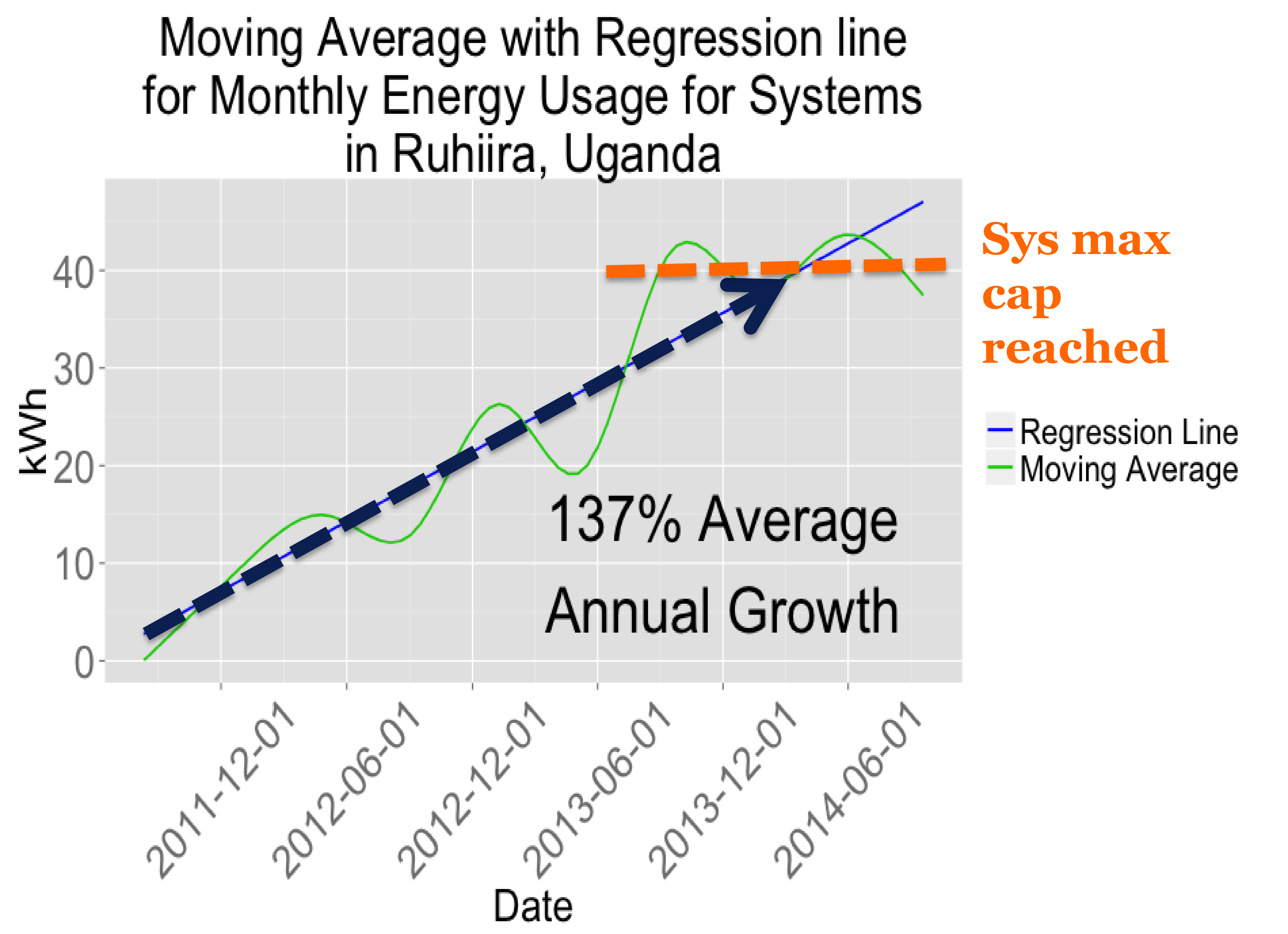
Grid like service

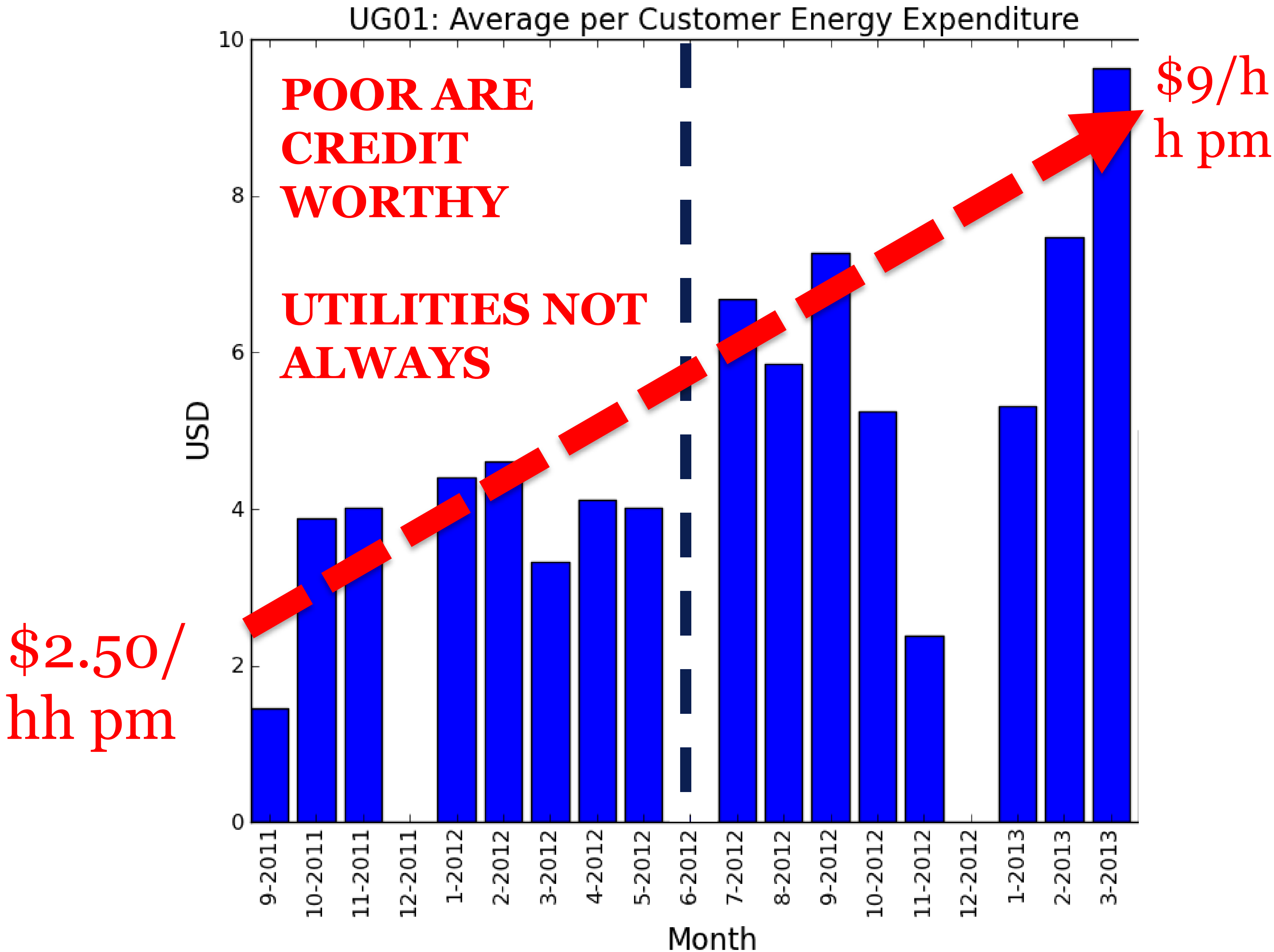




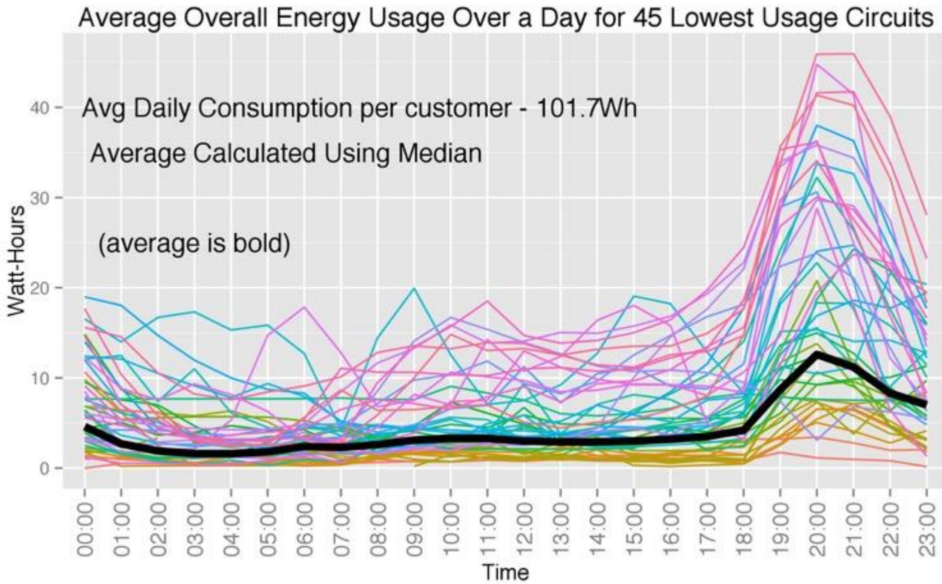

Average Overall Energy Usage Over a Day for 45 Lowest Usage Circuits
Avg Daily Consumption per customer - 101.7Wh
Average Calculated Using Median
(average is bold)
Watt-Hours
0
10
20
30
40
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time

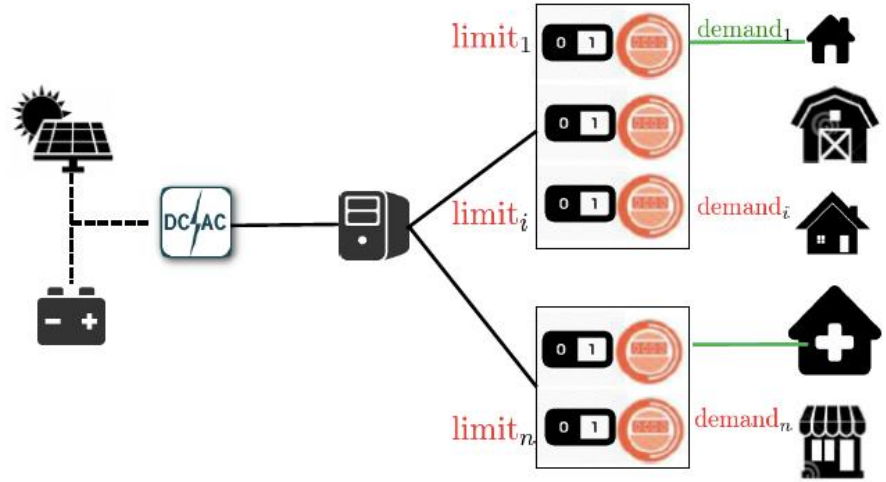

Average Overall Energy Usage Over a Day for 5 Highest Usage Circuits
Watt-Hours
0
50
100
150
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time


Moving Average with Regression line
for Monthly Energy Usage for Systems
in Ruhiira, Uganda
Sys max
cap
reached
Regression Line
Moving Average
137% Average
Annual Growth
kWh
0
10
20
30
40
2011-12-01
2012-06-01
2012-12-01
2013-06-01
2013-12-01
2014-06-01
Date

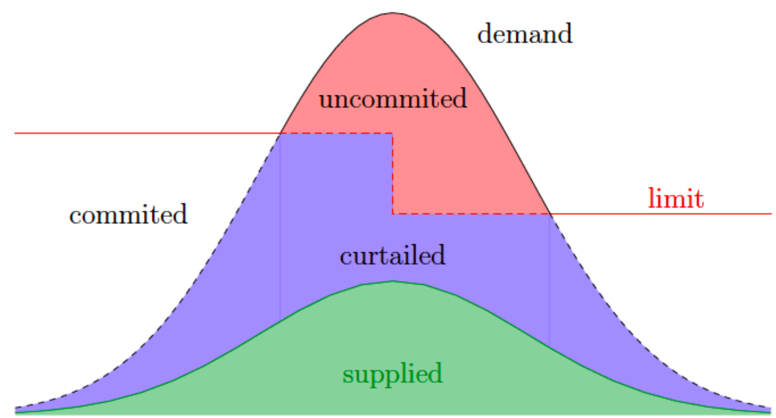

UG01: Average per Customer Energy Expenditure
POOR ARE CREDIT WORTHY
UTILITIES NOT ALWAYS
$9/hh pm
$2.50/hh pm
USD
Month
0
2
4
6
8
10
9-2011
10-2011
11-2011
12-2011
1-2012
2-2012
3-2012
4-2012
5-2012
6-2012
7-2012
8-2012
9-2012
10-2012
11-2012
12-2012
1-2013
2-2013
3-2013

Modular, incremental with growth. Can lessons apply to grid?



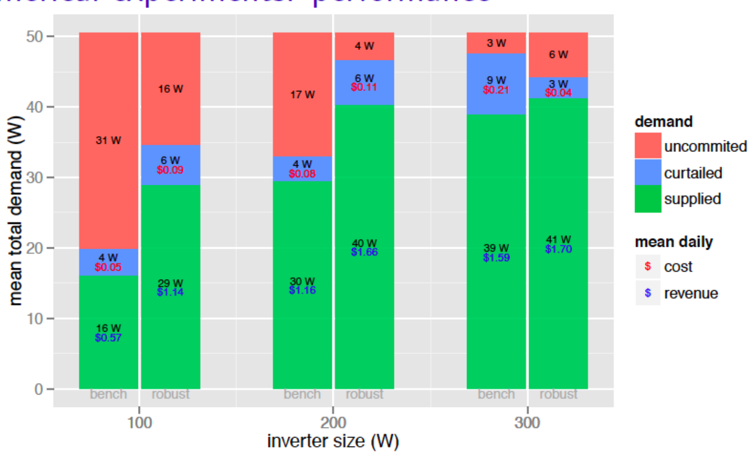


Reliability: utility's commitment and curtailment



- commited$_{it}$ $= \min\{$demand$_{it}$, limit$_{it}\}$
- Utility possibly loses revenue by setting limits too low
- curtailed$_{it}$ $=$ commited$_{it}$ $-$ supplied$_{it}$
- Utility pays curtailment cost by setting limits too high
  - Curtailment penalties $\eta_{it} \propto$ predictability

Numerical experiments: performance



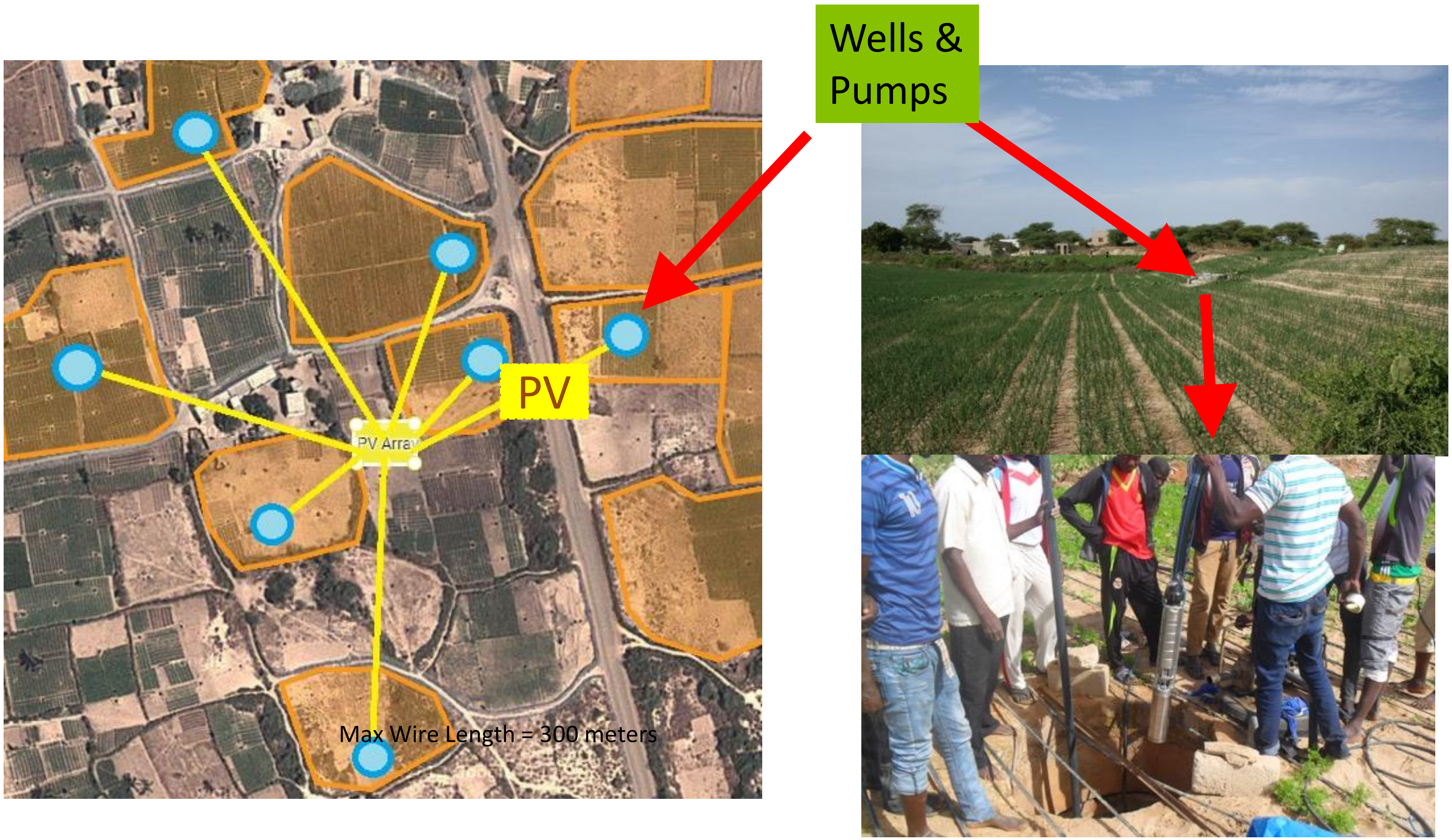
- 37% decrease in uncommited and curtailed demand
- 200% increase in revenue
- Robust control avoids extra 100 W capacity investment

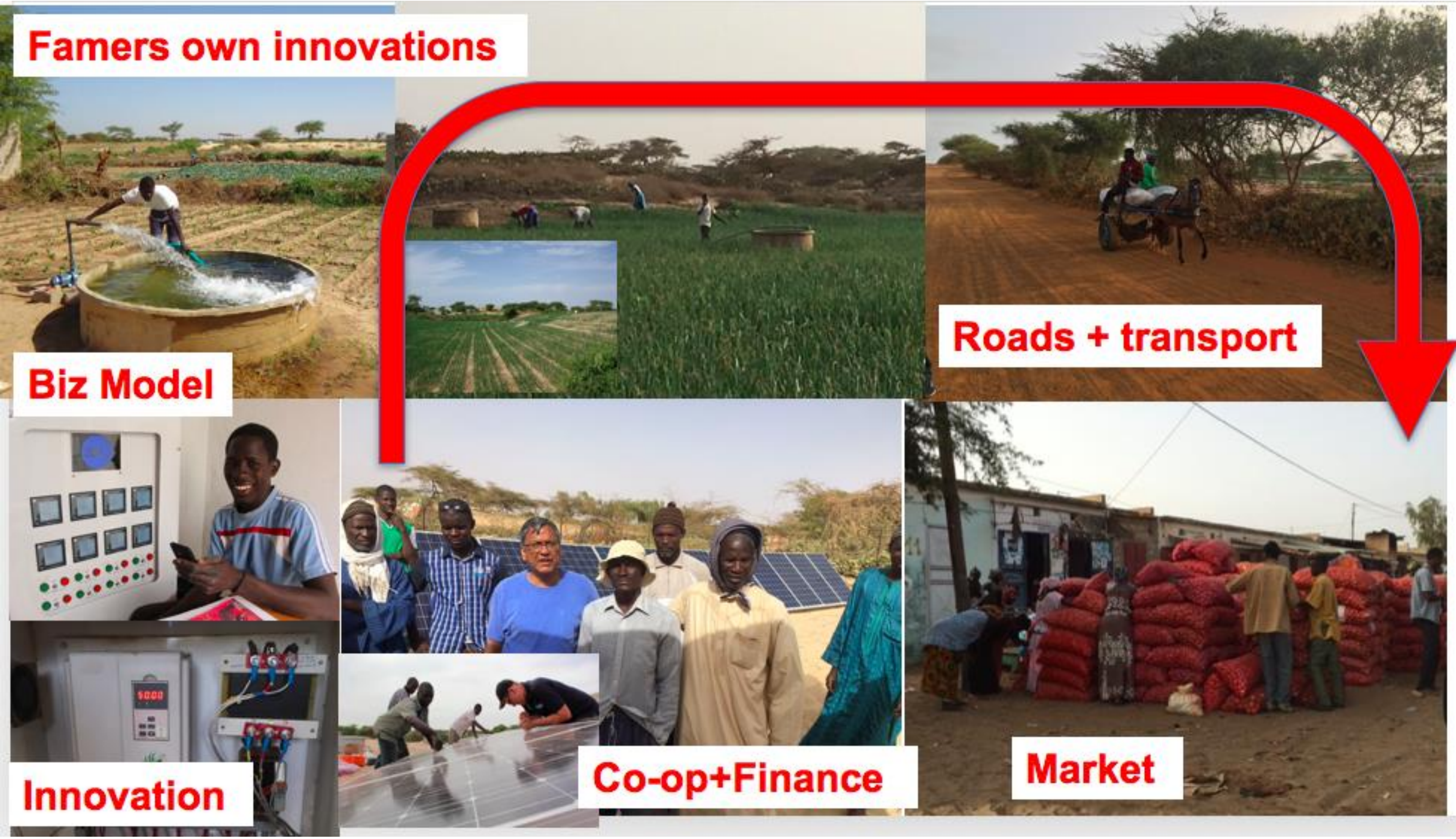
Energy and Agriculture (USAID support)

- 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?



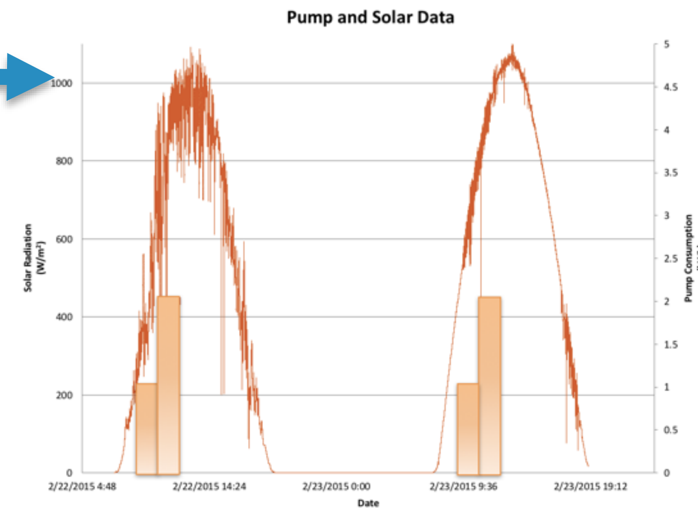

Cost/O&M/biz model/local/scale in mind

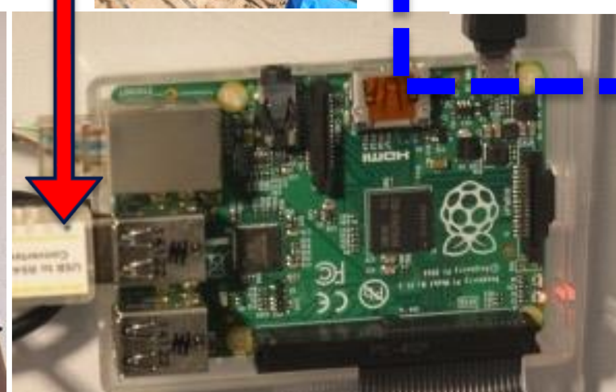


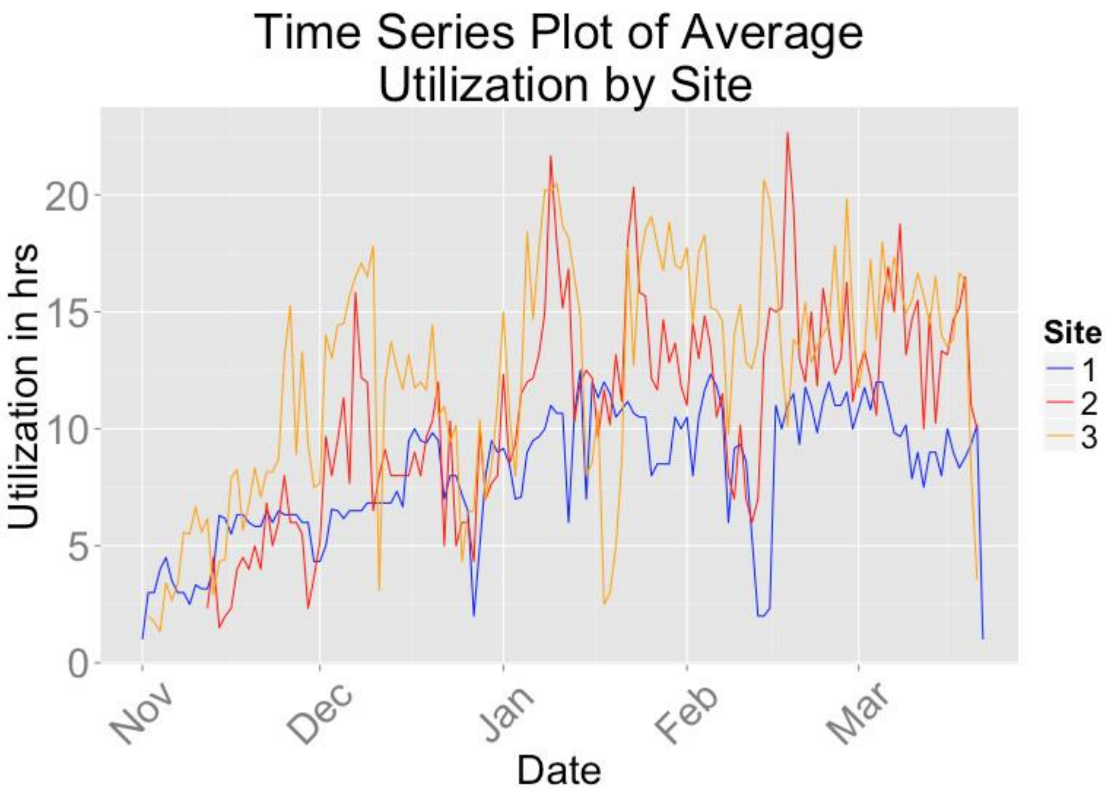

Famers own innovations
Roads + transport
Biz Model
Innovation
Co-op+Finance
Market

Logic/Power Elect/Control/Payment/Pump

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







Innovation
Low maintenance +
payment system

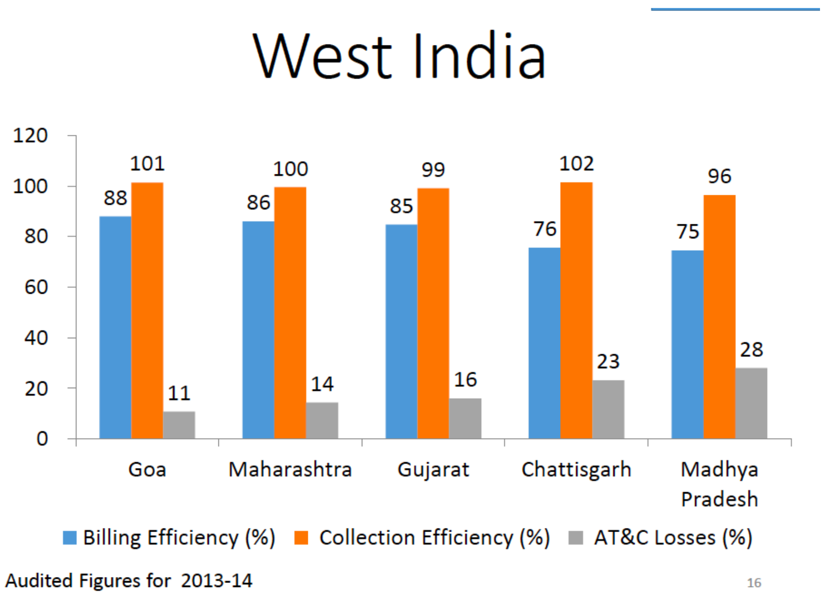
Local insight
high utilization
efficient water use

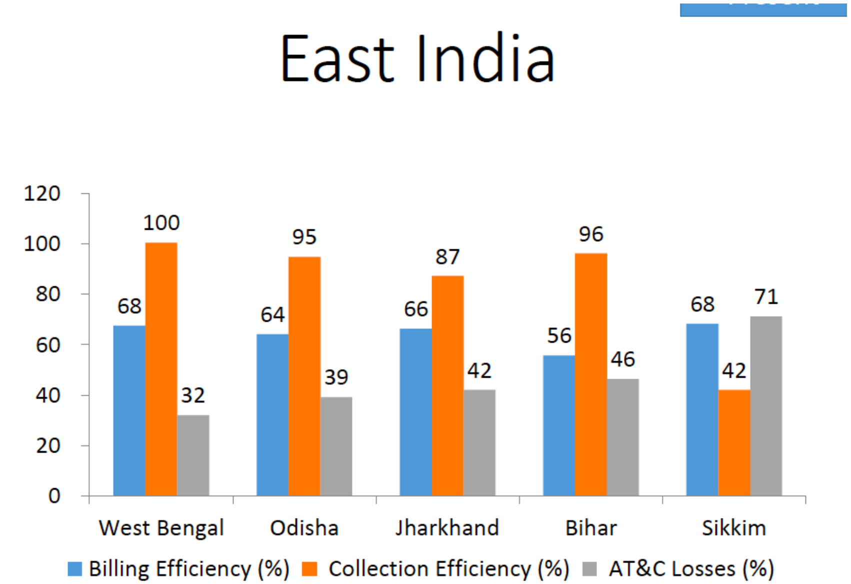
Government/Private
Scale, import duty,
low-cost finance

Summary: Demand + Prioritization

- Can norms for future demand projections that are generalizable be developed? To what extent dictated by
- Income and/or per kWh tariff
- Tariff structure, any flat monthly fees, and/or tariff stage
- Additional productive demands and other social infrastructure (present or expected).
- Productive demands and when/how/what conditions they emerge?
- Country policies for industry/agriculture
- settlement size, promotion of appliances, scarcity of biomass, thermal comfort needs and electricity subsidy delivery mechanism.

Grid: costs, losses, subsidies, tariffs, transparent transactions, payment sys





Example: Rajasthan

4.20 + 0.90 + 1.44 = Rs 6.64 = 10 c/kWh

Loss→ Rs 6.64 - 3.90 = 2.60= 4c/kWh

Revenue includes Ag subsidy!

Rs 3.90 is not the tariff but realization

transparent transactions, payment sys