# An Energy Market for Rural, Islanded Micro-grids

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# Overview

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- Proposed Solution
- Methods
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- Discussion
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# Context

- Renewable energy micro-grids are increasingly seen as an important tool in electrifying rural areas while meeting low-carbon goals
- In general, micro-grids fit above lanterns and SHS in terms of the energy access “ladder”. They are not appropriate for all situations.
- There is a desire for private-sector investment

# Problem Statement

- Little data exist to repeatably estimate rural energy use in a variety of contexts (geography, culture, income sources, etc)
- Uncertainties in estimating user demand lead to great investor risk in providing funding for capital expenditures
- Difficult to acquire private-sector investment
- Once built, grid is inflexible to changing conditions
- Link between electrification and income-generating activities is weak

# Proposed Market Framework

- Goals:
  - Maximize revenue for grid operator (within constraints)
  - Optimize user experience
  - Provide revenue source for local entrepreneurs
- Implementation:
  - Adapt pricing to expressed user demand
  - Allow local entrepreneurs to participate in the buying and selling of electricity

# Method

- Comparison of proposed market to a fixed-price scenario
- Computer simulation – HOMER + custom modeling in Python
- Sensitivity analysis of unknown variables (price elasticity, demand)

HOMER
The Micropower Optimization Model

+

python™

# Method


100
90
80
70
60
50
40
30
20
10
0
Battery State of Charge (%)
Custom Model
HOMER
Time (1 May - 7 May)

# Method

| **Households (avg. 220Whr per HH per day)** | | | | | | |
|---|---|---|---|---|---|---|
| Quantity | 17 | 17 | 17 | 17 | 16 | 16 |
| % of total load | 20% | 10% | 8% | 22% | 27% | 13% |
| Max. price willing to pay | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |

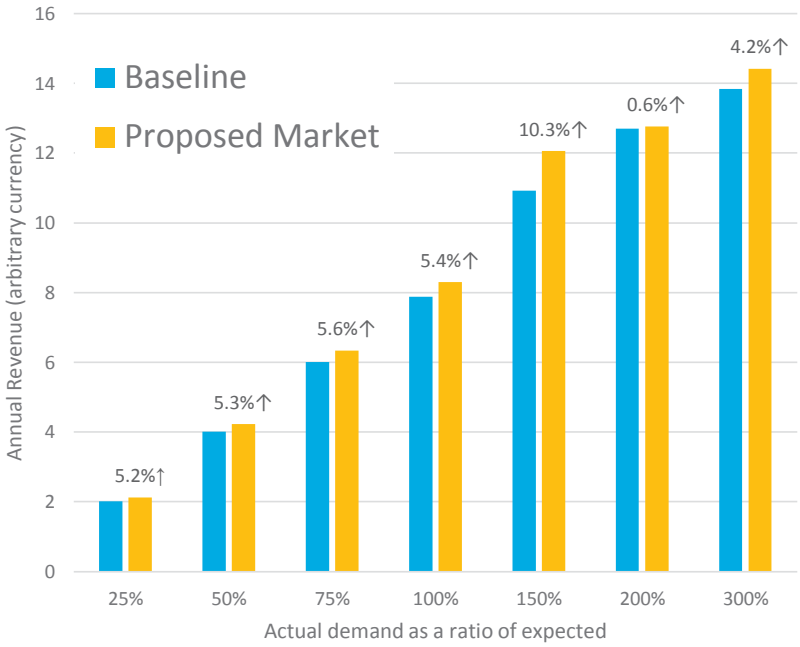
| **Entrepreneurs** | | **Operator** | |
|---|---|---|---|
| Quantity | 4 | PV Peak Output | 8kW |
| Battery Size (ea.) | 7kWh | Battery Size | 32kWh |
| Electricity sale price | 1.5 | Max hourly change in price | +/-0.5% |

# Method

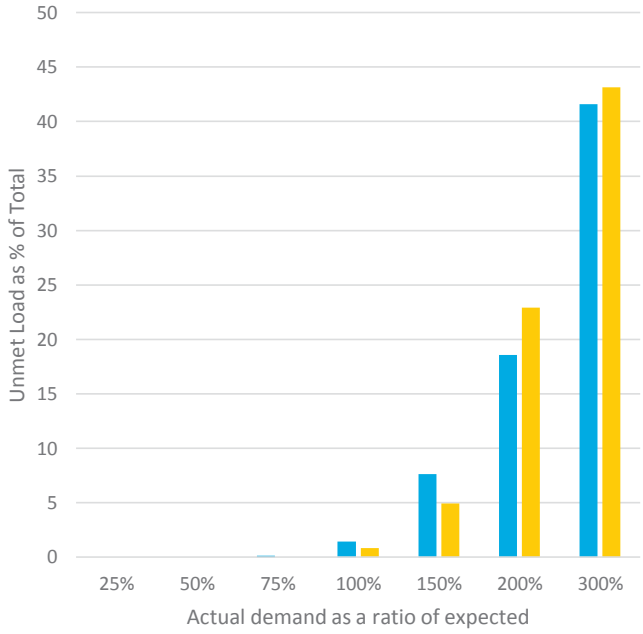
- Change prices based on load-shedding frequency (scarcity):

| | |
|---|---|
| 0% of the expected load was shed in the previous period | Lower the price to induce demand |
| More than 0% of the expected load was shed in the previous period | Raise the price to reduce demand |

# Results

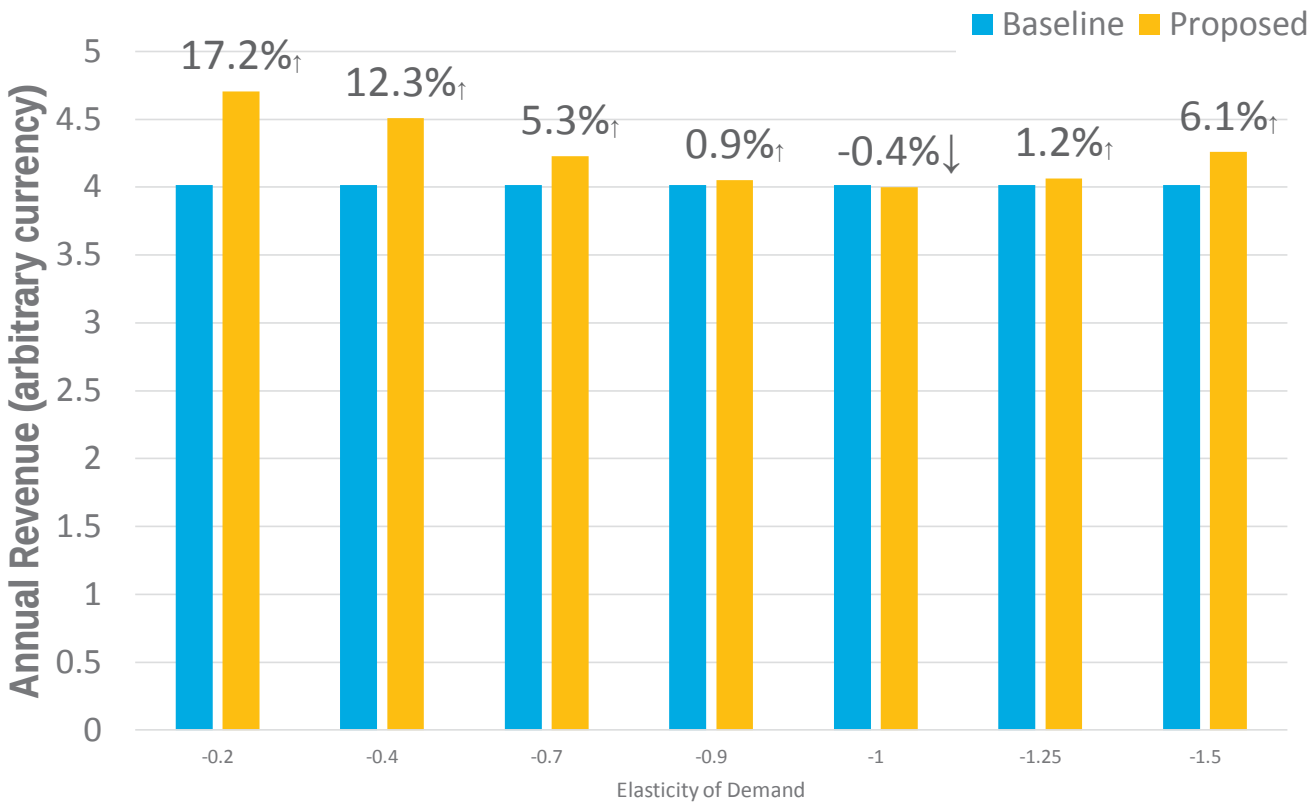



Revenue



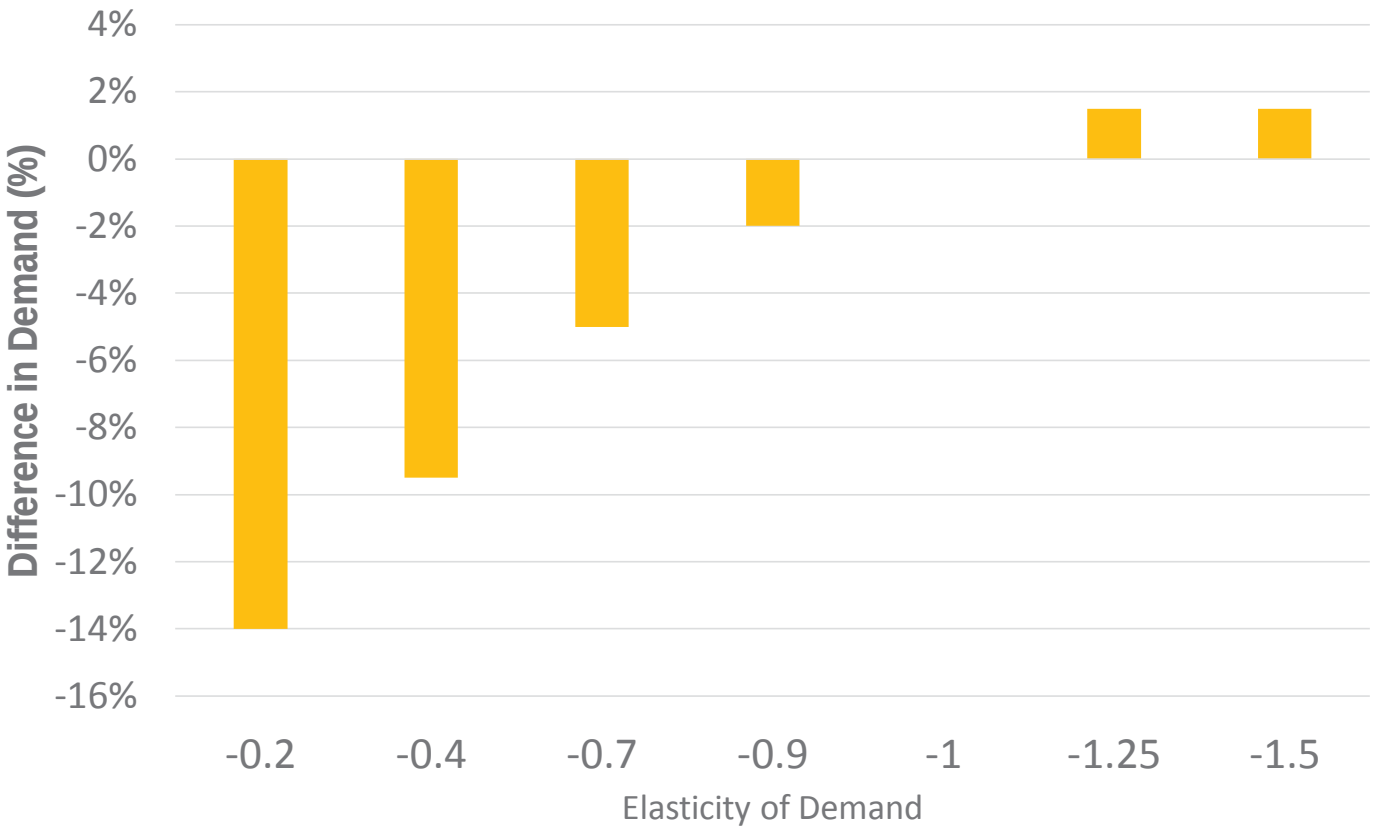

Unmet Load

Change in revenue and unmet load with proposed market, considering several demand scenarios (-0.7 elasticity of demand)




Change in revenue when considering elasticity of demand (50% demand scenario)

Resiliency to low demand




For example: demand can be 5% less than expected (in the -0.7 elasticity case), yet actual revenue will match initial projections

# Discussion

- Entrepreneurs
- System aging
- Communicating price signals & billing
- Trust

# Future Work

- Case Studies
  - Benchmark with real-world data
  - Add financial indicators (Payback, NPV, etc)
- Pilot implementation
  - Demonstrate feasibility of market
  - User and investor acceptability
  - Demonstrate ICTs

# Questions