Data-Driven Micro-Grid Design

Matt Orosz
PhD, President/Director
www.stginternational.org
info@stginternational.org
STG Vision

Delivering energy services to the un-empowered 1 Billion

Energy access for households, institutions and businesses means standard (mains power) available 24/7

Optimized systems can improve affordability and maximize use of renewable resources

Localized and energized businesses drive economic growth
Market Context

The Energy Access Ladder

Products & Distribution

Traditional fuels & systems
- Wood & Kerosene
  - Higher price per unit
  - Higher health issues
- Cook Stoves & Solar Lanterns
  - Cheaper
  - More efficient
  - Cleaner

Service & infrastructure

- Household Solar system
- Community, Off-grid systems,
- Community, Off-grid systems,
- Grid connection, LPG

Cost to customer
- $2/kWh
- >40¢/kWh
- 20-40¢/kWh
- 10¢/kWh
1.5 Billion
550M in Africa
300M in India

Lack of energy impacts:
- Health (quality of indoor air, health services)
- Education (access to modern technologies, ability to make use of evening hours)
- Economic productivity (lighting, machines for business activities)

High social impact energy services provide:

**Electricity:** area lighting, EMR, X-rays, diagnostics, communications, computer labs, lights for dorms/evenings

**Cogen-Energy:** hot water for hand washing, dorm showers, kitchens; building heating/cooling
**Current Approaches & Shortfalls**

**Communities**

Solar home systems (SHS):  
- **power limited** (<kW)  
- **expensive** ($2-5 per kWh)

Microgrids (PV or diesel):  
- **power limited and/or scheduled** (not 24/7),  
- **expensive** (per kWh >$0.50),  
- no sustainable model

**Institutions**

Stand alone “Own & operate”:  
- lack of energy expertise -  
- systems poorly sized (**cost inefficient**), **poor maintenance record**, tendency toward lowest capital cost (fossil fuels) rather than levelized cost
Microgrids Built, Owned and Operated as a Micro Utility Business

- **Local Independent Power Producer (IPP)** secures finance for generation equipment and is responsible for maintenance.
- **Power Purchase Agreement (PPA)** with institutional customers (*high ability to pay*) provides steady energy demand (revenues) -> path to bankability.
- **Smart Meter PAYG** (pay-as-you-go) connections for households and businesses lowers repayment risk and transaction costs.

Households and Businesses purchase credits (kWhs) using their mobile devices when they need them, as they need them.

A central database interfaces with the wireless service provider and updates the smart meter.

Transactions are automated and usage data strengthens the infrastructure design process and informs maintenance schedule.
Market Identification

Use Utility Planning and GIS tools to identify target geographies and learn where the grid is headed:

populations within 15km of the grid are likely candidates for grid extension in the next 5-10 years

Microgrids are suitable for communities beyond this grid buffer zone

Solar home systems (SHS) should be deployed when settlement density is too low for microgrids (<200 people/km² = high reticulation costs)

Case Study: Lesotho
Pop.: 2M
Unelectrified: 80%
Rapid, Semi-automated System Design

**STEP 1:** Use satellite imagery + image processing to identify village buildings by type (size, shape, distribution)

**STEP 2:** Use data for average demand profiles (homes, clinics, schools, etc.) to estimate total community need
STEP 3: Combine with weather and solar data (e.g., NASA datasets)

STEP 4: Allocate generation infrastructure and derive control strategy dynamically to achieve minimum tariff for positive project cash flows
STG IPP Micro-Grid: Hybrid Strategies

Energy Sources
- Solar: 85%
- LPG: 15%

Micro-Utility
- CSP
- PV
- LP Genset
- Heat Recovery

Micro-Grid
- Communities

Services
- Schools
- Clinics

Customer Segments
- M-Pesa Pay as you Go
- Anchor Tenants - PPA

Business Model
Cost of Meeting 100% of Demand

8%

$0.25/kWh

$0.80/kWh

$0.75/kWh

$0.70/kWh

$0.13/kWh

CSP

PV

CSP
STG local Joint Venture secures license to operate microgrids. Decision tools identify candidate communities and map household, SME, and institutional loads.

Cogen PPAs concluded with anchor tenants (schools, clinics, etc.). Hybrid PV-CSP-LP gas power plant is sited, near an institution if cogen loads are contracted for. Medium voltage (MV) trunk lines and transformers are sited, and low voltage (LV) distribution wiring is reticulated to individual connections.

Solar Home Systems (SHS) are supplied to distant customers if service is purely commercial (no-subsidy, debt financed). Micro grid network can be designed for high coverage factor and universal tariff if subsidy or grant program is available for extension to remote connections (households, businesses or high impact service providers).

A unified mobile payment platform serves both microgrid and SHS customers with “mains” quality power, but SHS is load limited and the service has a higher per unit tariff for cost recovery.
Cost of capital is main driver of cost recovery tariff – affordability depends primarily on loan tenure, not rate

Renewable fraction is also determined by cost of capital – short payback period = low solar fraction and high fossil fuel usage
## Microgrid Cashflow (15 yr 5% loan)

### Tariff:
- $0.40/kWh

### Yearly Expenses:

<table>
<thead>
<tr>
<th>Year</th>
<th>Cash</th>
<th>Costs</th>
<th>Loan Principal</th>
<th>Maintenance</th>
<th>Operations</th>
<th>Revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td>7650</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>308.2</td>
<td>2080</td>
<td>5880</td>
<td>135.5</td>
<td>608.2</td>
<td>2050</td>
</tr>
<tr>
<td>10</td>
<td>2116</td>
<td>3190</td>
<td>3190</td>
<td>232.4</td>
<td>608.2</td>
<td>2050</td>
</tr>
<tr>
<td>15</td>
<td>937.4</td>
<td>4874</td>
<td>4874</td>
<td>329.2</td>
<td>608.2</td>
<td>2050</td>
</tr>
</tbody>
</table>
Leverage Technology and Cloud Computing

Hybrid Generation Infrastructure
- Load following and high availability (meet 100% of unconstrained demand)
- Minimize tariff to residential consumers
- Maximize use of solar resources and minimize battery storage, fuel costs and CO$_2$ emissions

Optimized Design Tools
- Near-automated system design for any village (reduces project design overhead)
- Cost-optimize system based on solar resource availability and expected demand
Commit to Technology Transfer & Training

• Localize energy system manufacturing
• Localize system integration and installation
• Train local operations and maintenance team
• Catalyze local IPPs (Independent Power Producer)

How we support these goals
• Classroom & hands-on trainings with partners
• Internships & skilled labor pipeline
• Building enterprise systems, upgraded factories
STG Management Teams

Lesotho Field Team Management

Kopano Ts’enoli, President (STG-Lesotho)
Lengeta Mabea, Supervising Engineer
Matt Orosz, PhD, Director, System engineering
Amy Mueller, PhD, Automation/Finances

Boston USA STG Management

Bryan Urban, Business Development/Fundraising
Matthew Osborne-Smith, MBA, Strategy
STG Background

• 8 Years of experience in solar energy, R&D, and technology training in Lesotho, including:
• 3 Prototype micro-CSP plants, 1 PV-diesel microgrid integration
• Currently expanding partnerships to India (R&D) and scoping partnerships in Tanzania (implementation)
• 2 active field demonstration sites (Eckerd College and Lesotho)
• Manufacturing capacity established in Lesotho, first commercial sale in 2014
Partners & Sponsors

Government of Lesotho
Ministry of Science and Technology
Ministry of Health

MIT: Massachusetts Institute of Technology
Eckerd College
Indian Institute of Science
National Collegiate Inventors & Innovators Alliance
SOPGY

GEA P³: People Prosperity Planet
Echoing Green
Global Environment Facility
World Bank
Ignite Clean Energy
MIT e+i
MIT IDEAS Competition
Installing Manufacturing Equipment
Solar Manufacturing in Lesotho
STG brought the first CNC Mill to Lesotho
- trained 25 people on rapid prototyping methods in 2014
STG Training University Partners
STG Solar Collector Design: Built in Lesotho for use in University Courses
Hybridization leverages strengths within a generation portfolio

<table>
<thead>
<tr>
<th></th>
<th>PV</th>
<th>CSP</th>
<th>Generator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital cost</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Storage cost</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Fuel cost</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Availability</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>CO₂ emissions</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>