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A micro-grid case study: lessons learned from a rural electrification project in India

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Premier Solar & SolarVision Co

SolarVision Co & Premier Solar

- Partnership between SVC and Premier Solar
- Team of EPC and technologists
- The full matrix provides a comprehensive organization
  - Installation and execution (boots on the ground)
  - Market and business development (foot on the pedal)
  - Analysis of developing PV opportunities (eye in the sky)

Outline

- Context: A growth market for PV – Microgrid in developing countries
- Case Study in Visakhapatnam (Vizag), India
- Results and Lessons Learned
- Implications for growth
- Conclusions

Micro-grid considerations

- Goal: bring electric power to regions beyond grid access in an effective mode
  - Economic development
  - Strategic resource use
  - Limitation: cost constraints & no PPA's or FIT's here

- Key questions:
  - What is the best configuration (& cost) for limited funding?
  - How can it best be achieved?

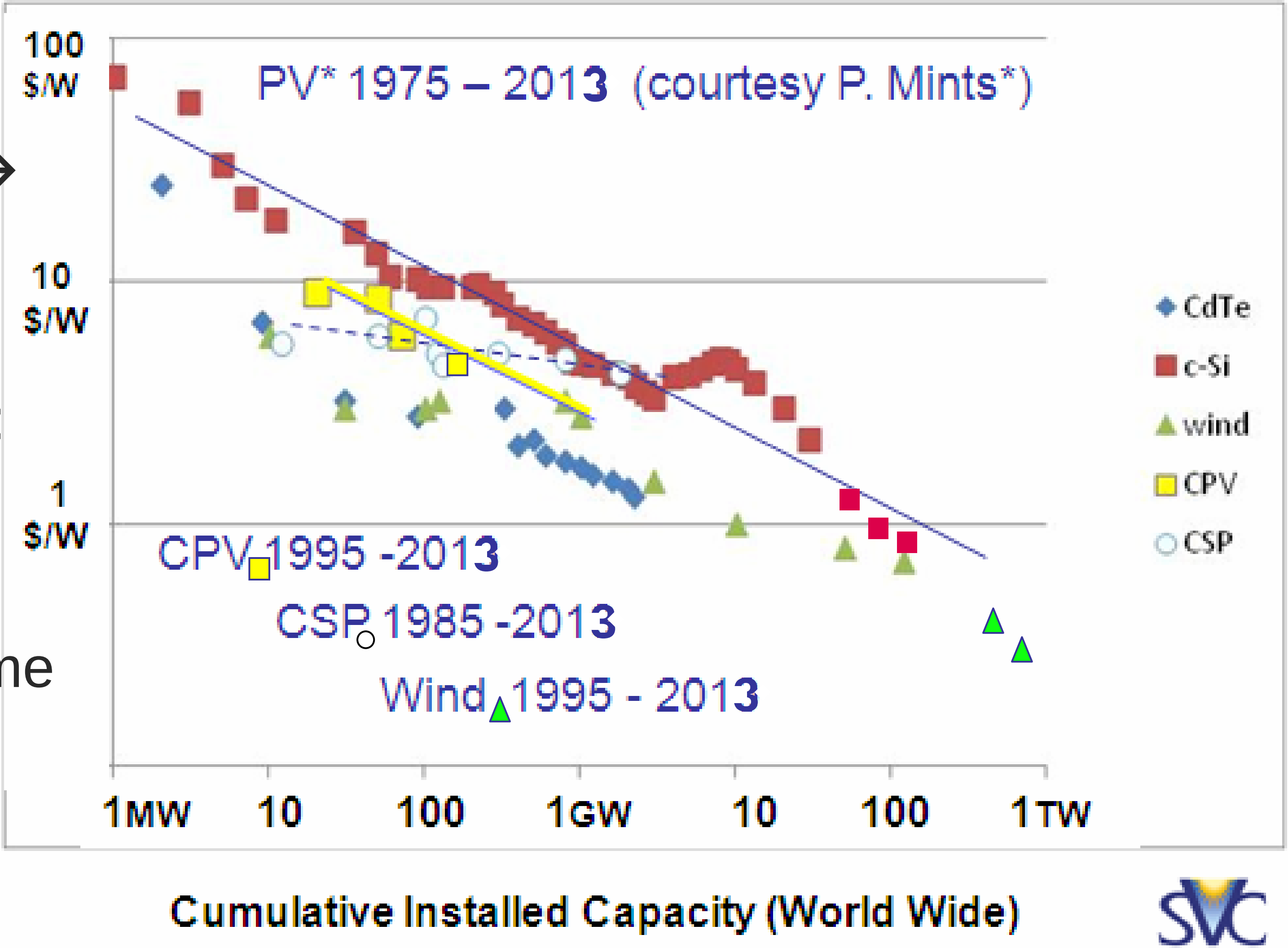
  - Need: hard data to provide policy guidance
    - Costs, benefits, issues, lessons learned

  - Market development: What will grow this segment?

Context: $/W Cost Learning Curve

Key metric: →
$/W

Other metrics:
- LCOE
- Bankability
- Payback time
- Footprint



Microgrid in Developing Countries – A Global Concern

- This project is representative of opportunities for PV in microgrid
- Global Policy Indicator - UN Foundation favors microgrid over large-scale grid as a solution to ending energy poverty
  - UN Foundation Microgrid Working Group one of several working groups assisting the UN with meeting its Energy Access for All initiatives.
- Field Indicator - Solar Electric Light Fund (SELF)
  - A nonprofit installing PV in over 20 developing countries for 20+ years.
  - Now view microgrid as a legitimate rural electrification strategy that is more sustainable than one-off PV systems

Project Methodology

- Project implementation:
  - Cost optimization
  - Successful execution: functional as well as social

- Modeling:
  - Develop quantitative measure of comparative value
  - Use to identify optimal cost and performance options

- Develop key metrics & hard data for policy planning
  - Confirmation of value of micro-grid
  - Use the project as a benchmark for others

PV Microgrid in India

- Remote PV hybrid microgrid project in Vizag, Andhra Pradesh State, India involving 57 tribal villages each with ~80 homes
  - India Govt funded
- Base level centralized 2 to 13 kW PV/battery remote microgrid configuration for basic <u>lighting</u> and <u>mobile phone charging</u>
- The project included deliberate quantification for learning capture

Results

- Successful electrification of 57 villages
  - PV/Battery backup: 6hrs + street lights + charging station
  - PV: 365kW total w/range: 2kW to 13kW
- Costs and metrics
  - Overall at **$8.40/W** (PV/batteries, install, insurance, 5 yrs Q&M)
  - Extended costs **11%** (remoteness, adversities, etc.)
  - 100% funded by Indian Govt
- Modeling of micro-grid provides LCOE, Payback, and expansion
- Specific lessons learned
  - Provides concrete & quantified support for Social Policy of Indian Govt

Challenges In Execution

- Every village is >30mi from road
- Remoteness of location
- Hardships in navigating mountainous terrain
- Manual transportation of materials
- Harsh weather: hot summer and freezing winters
- No pre-existing electricity
- Pre-fabricated control rooms to reduce construction time




Post-Execution of Project

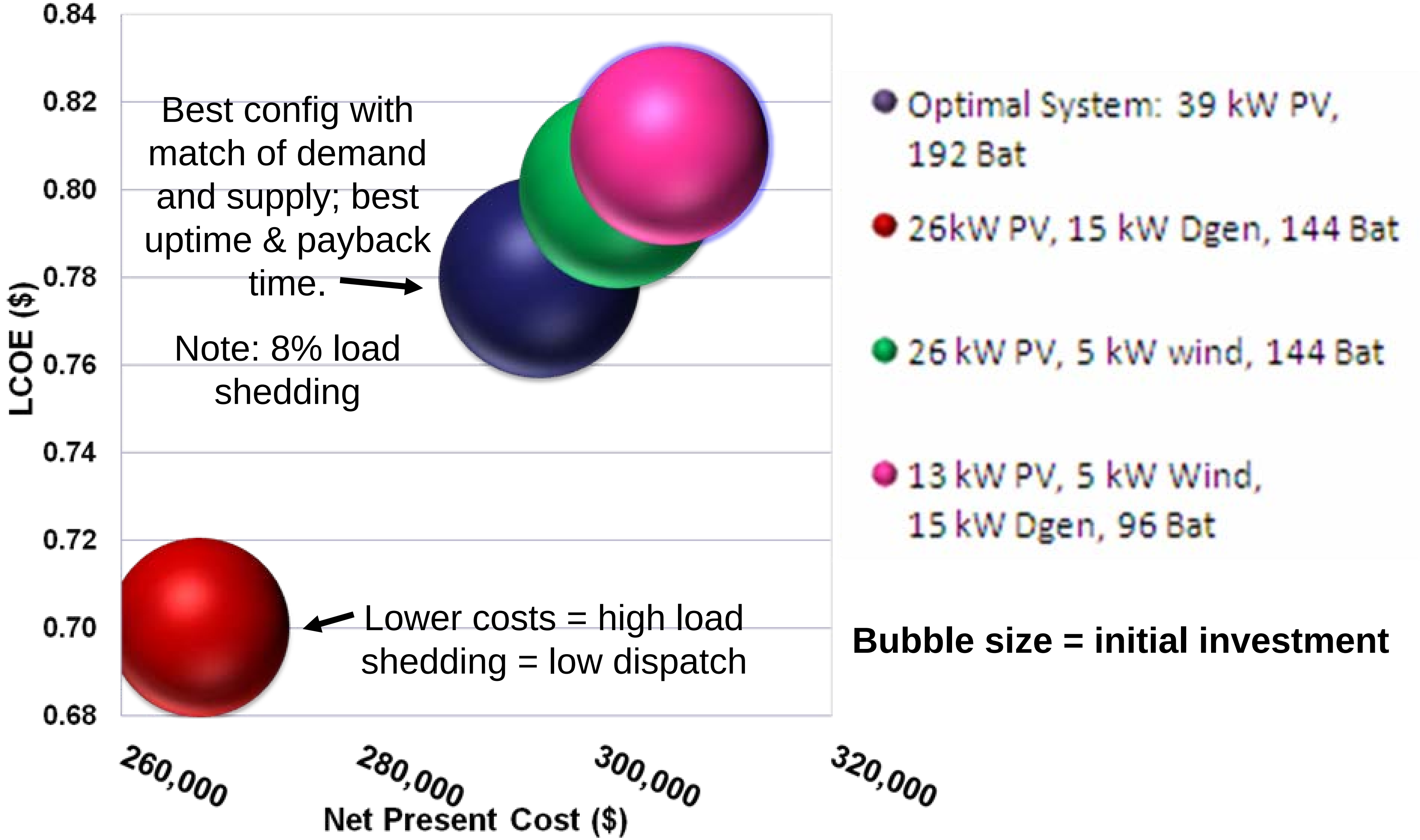
- Successfully installed 365 kWp for 57 villages with a total of 2225 homes.
- Improvements:
  - Better basic amenities: lighting water management, health care, education, sanitation
  - New social activities, e.g. televisions
  - New comfort, e.g. fans for cooling
  - New commerce by using lights at night

Accomplished goal.
- Consequently developing need for increased capacity!

Modeling results

- Developed simulations using HOMER model
  - Key metrics: LCOE, payback, Net Present Value, etc.
  - Sensitivity analysis on PV/wind/battery/diesel config's
    - Key parameters: cost of PV, diesel, local resources (sun, wind), and capacity shortage tolerance
    - Load shedding is included (system not at 100% dispatch)
- Initial configuration: developed
  - Matched model to the installed configuration
  - LCOE = **$0.62/kWh** vs $1.35/kWh for diesel generator
  - Build Costs: Simple payback compared to diesel < 4 years
- Expansion 2x configuration: best options developed
  - Remain cost effective
  - Best is: 3x PV and 4x batteries with 8% shedding
  - Gives LCOE of additional $0.15

Microgrid 2x Expansion Options



Bubble size = initial investment

Lessons Learned

- Decentralized PV/battery micro-grids can be a viable and cost-effective solution for coverage in non-grid areas
  - Utilize a central power source (not house-by-house)
- Simplicity and modularity ensure lower cost
  - Use pre-fab, and central staging
- Incorporate a mix of PV and battery storage, but also allow for hybridization w/ diesel
- Provide initial basic services at reduced capacity
  - Allow for future demand growth
- O&M is a mix of local villagers and regional staff
- Establish payment system: villagers are able to support a “pay-as-you-go” mode

Market growth

- Visionary forecast: 10GW in micro-grids in a decade
- Assumptions:
  1. Government allocate significant finances
  2. Development of business models for self-sustaining
  3. Increase in partnerships with increased learning
- Tops down view for 10GW
  - World wide; 2.5billion people need electricity
  - With 1% getting 400W, then have 10GW
  - Cost at $80B
- Support for assumptions:
  - Subsidies for diesel: $80B for 2012 by 10 top candidate countries
  - UN’s Clean Development proposing $4B/yr for energy sources
  - New business models: cell phone payment plans “pay-as-you-go”
  - This project is an example of successful partnerships

Conclusions

- Successful implementation of cost-effective, PV based micro-gird for Rural Electrification
  - Provides confirmation of the financial and functional viability of RenEnergy micro-grids
- Methodology combines project planning & modeling
- Lessons provide guidance for follow-on projects
- Major market opportunity
  - For the PV industry
  - Provides economic and cultural benefits
  - Allows for better global resource utilization

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Back-up

Optimization: Modeling Details

- HOMER software
- Base level system 13 kW PV (79 homes) and battery storage

SITE CONDITIONS

Average Solar Insolation	5.12 kWh/m^2/day
Average Wind Speed	6.45 m/s
Annual Average Energy Demand	33.2 kWh/day
Annual Average Temperature	28.4 °C

TECHNOLOGY AND FUEL COSTS

1 kW Solar PV	$1,000-$5,500
Diesel Fuel	$1.25 - $2.50 /liter
1 kW Wind Turbine	$10,000
120V 1530 Ah Battery	$950
10 kW Generator	$8,000
5 kW Inverter	$4,000

Summary Points

In much of the developing world grid extension and reliability are not possible, making it necessary to develop strategies to allow off-grid modes of power generation and storage.

A simple remote PV hybrid microgrid that creates and stores electricity from local, renewable sources of energy like solar and wind for limited distribution within a village can provide social improvements and subsequent economic growth.

Tolerance of as little as 10% annual maximum capacity shortage by village inhabitants enables microgrid design flexibility, higher penetration of renewables, slightly lower LCOE, and considerably lower NPC.

The most economical microgrid design that meets 100% electricity demand must incorporate a greater variety of renewable sources and add conventional sources into the mix.

Computer simulation is an effective tool for quantitatively assessing actual microgrid technology performance and economic metrics, as well as performing broader expansion analysis to accommodate load growth.