SPATIOTEMPORAL PV

Emily Nathan
Emily Wallace
Jeffrey Nash
Jerald Han
Robert Spragg
Existing Problem

The solar industry is growing rapidly:

California Solar Capacity

- Capacity [MW]
- Year

- 2015: 0 MW
- 2020: +136% to 40,000 MW

Costs are falling rapidly
Down 66% since 2010

Cost Graph: $
“Clouds have the strongest impact on solar energy production”
(Chow, Belongie, Kleissl, 2015)
I'm at my start-up in the Mission and it's super cloudy!

My kids and I are at the park and BOY is it windy in El Cerrito

It's raining in Marin. Again.
Location Selection

Figure 1: Clouds streaming through the Golden Gate

Figure 2: Typical prevailing winds following a winter storm

Figure 3: Schematic of the deployed sensors

LOCATION
Locations account for a variety of weather patterns
Considered microclimates (foggy, colder areas)

HARDWARE
Temperature Sensor
Light to Frequency Sensor
Light Filter
Micro-SD Card (data storage)
Location Selection
“An advantage of using ground-based sensors is that PV power output can be inferred directly... without independent estimates of the height, density, reflectivity, or spectral properties of clouds.”

(Lonij, et. al, 2013)
Our Solution Network

- **solar edge**
  - Actual PV Generation Data from THIMBY

- **Dark Sky**
  - Wind Vectors

- **MongoDB**
  - Collects data, posts to server

- **Heroku Scheduler**
  - Sends Arduino data to webserver

- **Raspberry Pi**
  - Sends Arduino data to webserver

- **Arduino Uno**

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**Introduction**

**Network**

**Model**

**Results**

**Future Goals**
Git version control allows for portable solution
Scheduler periodically runs script, stores data from external API
Data Analysis

FROM DARK SKY API

\( \vec{v}_{\text{cloud}} \)

Wind Speed

FROM SENSOR DATA, HISTORICAL SOLAR INFORMATION

\( K_i(t) \)

Sensor Coordinates

FROM DATABASE

Least Squares Analysis

Future PV generation at THIMBY

Introduction   Network   Model   Results   Future Goals
Data Analysis

\[ \hat{P}_{Thimby} = \hat{P}_{API} + \sum_{n=1}^{3} \sum_{i=1}^{3} B_{ni} \cdot K_i(t)e^{-|\Delta x_i - \bar{v}_c \Delta t_n|} \]

\[ \text{error}(t) = P_{Thimby}(t) - \hat{P}_{Thimby} \]

Perform least squares analysis to solve for prediction coefficients:

\[ B = (X^T X)^{-1} X^T Y \]

Smart algorithm recalculates coefficients every 15 minutes.
Results

![Graphs showing power output vs. time step for different models and actual data.](image)

- **Model**
- **Actual**
- **RENES**
NREL study showed that energy security at Belvoir military base is valued at $2.2-3.9M.
The research at the University of Texas is worth an estimated $500M.
Value of our model grows with solar implementation.
Useful for essential systems (hospitals), military bases, universities, microclimate research, any region.

Energy security optimization
Grid Energy purchase optimization
Stabilizing small / island energy grids
Predictions for all locations within network

Low cost ~ $75
Independent
Does not rely on data from multiple homes, which may be unreliable
Future Improvements

**Hardware**
- Improved waterproofing and sensor reliability
- Fine-tune sensor calibration
- Decrease deployment costs

**Networking**
- Avoid Raspberry Pi by leveraging affordable data logging systems
- Update all sensors to include live updates
- Google Project Fi SIM card shield

**Expanding**
- More sensor locations throughout the bay.
- Continued iterations of regression models
- Integration with other existing models

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**SPATIOTEMPORAL PV**

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Google Project Fi + SIM card shield

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Future Improvements

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