

City-wide simulations of distributed photovoltaic power production

ANU Energy Change Institute

"Energy Conversations: Smart Grids"

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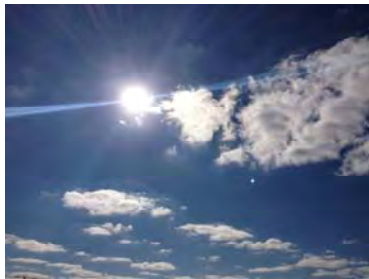
The Australian National University

NICTA, Machine Learning Research Group

Let's Ask A Question...

How much electricity is being generated by distributed PV systems in a given region in Australia right now?

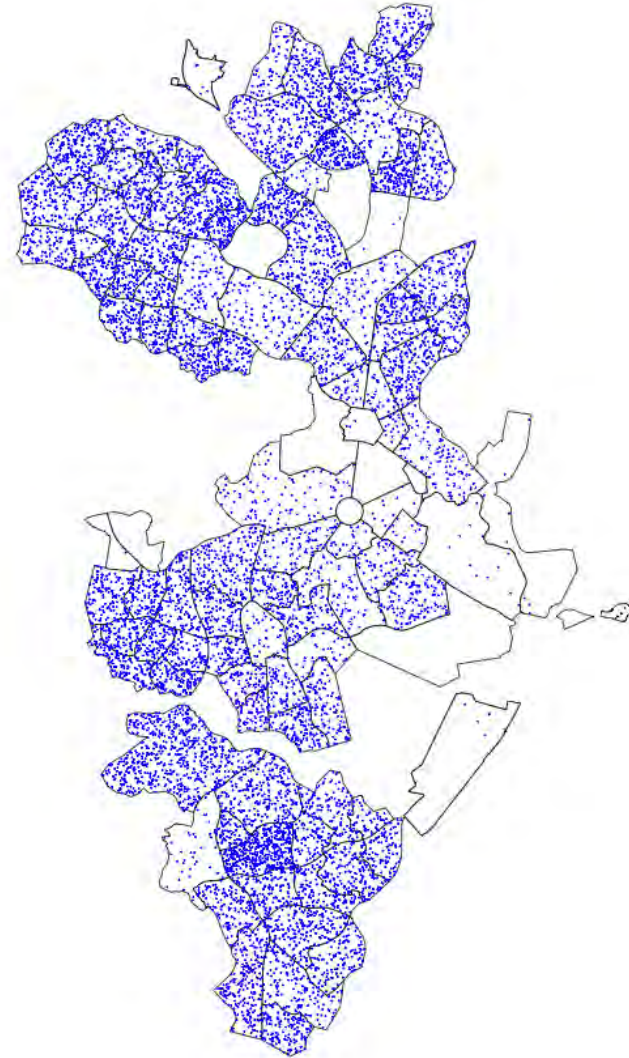
PV = photovoltaic, the electricity producing solar energy system



Distributed = spread out, behind the meter (on the order of 1-100s of kW's)

Let's get more
specific...

How much electricity
is being generated by
rooftop PV systems
in **Canberra,**
Australia right now?



This is not an easy question to answer!

- Distributed PV systems are (mostly) not actively monitored
- They are highly nuanced
- Their exact locations are hard to access
- Clouds have widely varying characteristics
- Solar radiation – a rapidly changing variable

But is an important one!

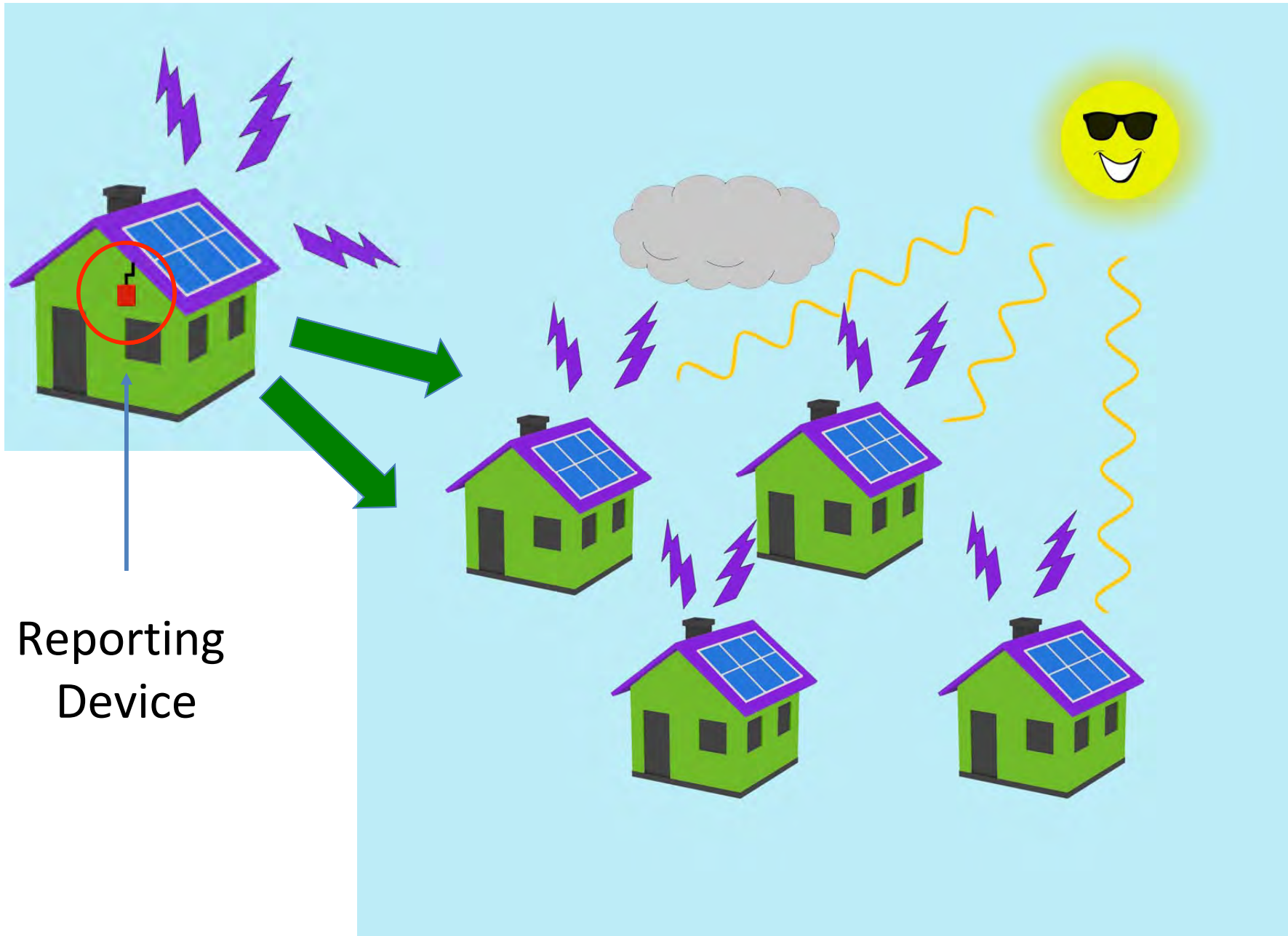
- Many areas of Australia have or will soon reach “high penetration” scenarios where more than 20% of their electricity demand is met by locally generated solar energy
- The vast majority of this is small-scale, distributed solar PV systems

High-penetrations and Intermittency

- Solar PV electricity production is **intermittent**
 - Not available at night, intensity changing throughout the day
 - And of course - **variability** from clouds
- This can be problematic, as this electricity can be 'unreliable'
- But this will be solved with the combination of **accurate forecasting** and **energy storage** (e.g. batteries)

Step 1: Distributed PV Forecasting

- Before we can forecast it, we need to **build a model** capable of **estimating the total contributions to the electricity grid from distributed PV**
- I've developed a way of doing this by **using a subset of monitored PV systems to estimate the surrounding unmonitored PV systems**



Reporting
Device

Primary Data Source: PVOutput.org

Nearly 300 sites in total
160+ Currently Reporting

Locations of Reporting Sites Dec 2014



Using one PV site to estimate the power output at second site

- Basis of city-wide distributed PV simulations:
the clear-sky index for photovoltaics: K_{PV}

Read More:

N.A. Engerer, F.P. Mills, KPV: A clear-sky index for photovoltaics, Solar Energy, Volume 105, July 2014, Pages 679-693

The K_{PV} Method

- A method for normalising a PV power output time series

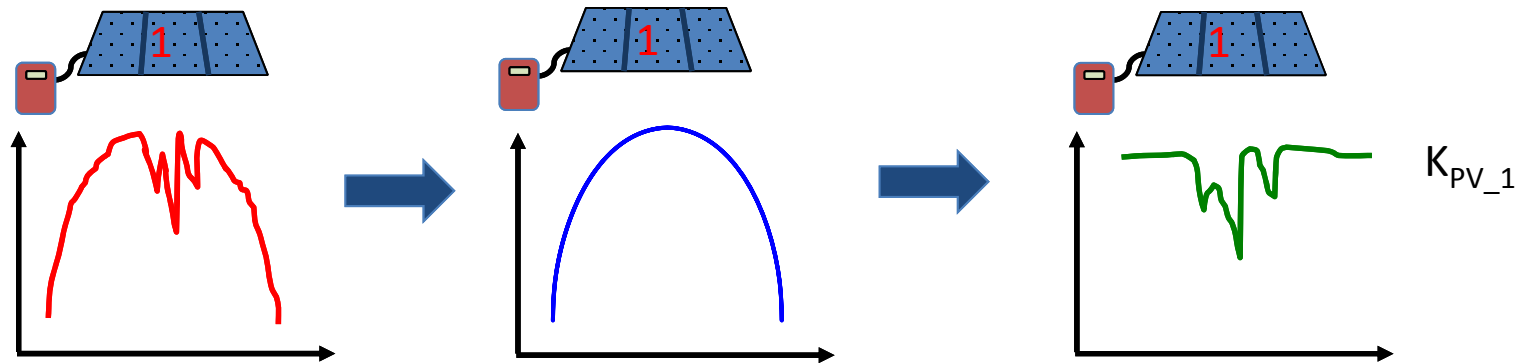
$$K_{PV} = \frac{PV_{MEAS}}{PV_{CLR}}$$

K_{PV} : A method for normalising a PV power output time series

- Removes individual tilt and orientation
- Assists in the detection and removal of shading
- Can be used to make an estimate of another PV system's power output

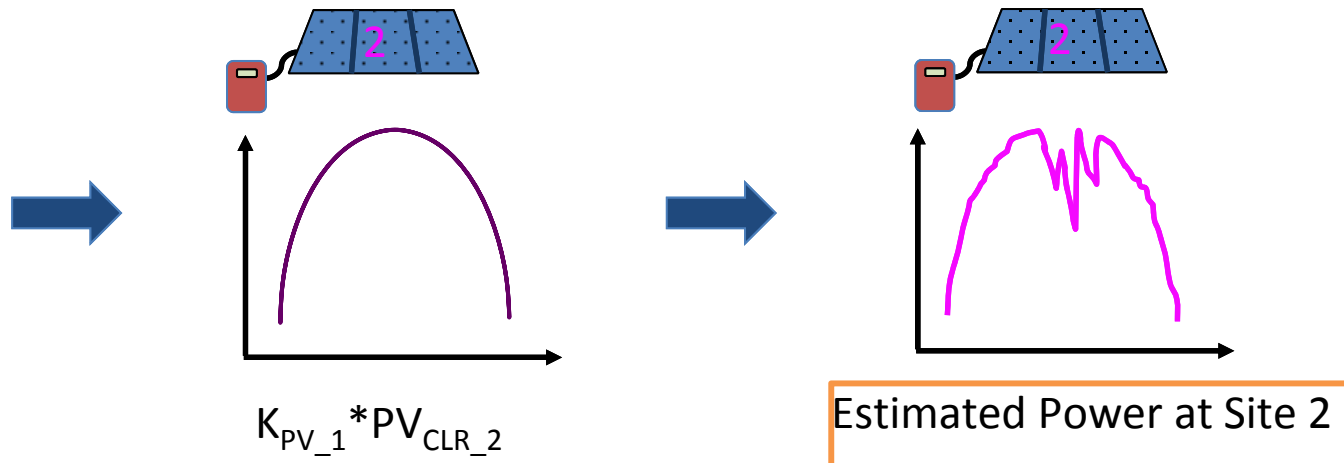
$$K_{PV} = \frac{PV_{MEAS}}{PV_{CLR}}$$

The K_{PV} Method



- Esra Clear-Sky
- Reindl Transposition
- Sandia Performance Models

K_{PV} Calculation

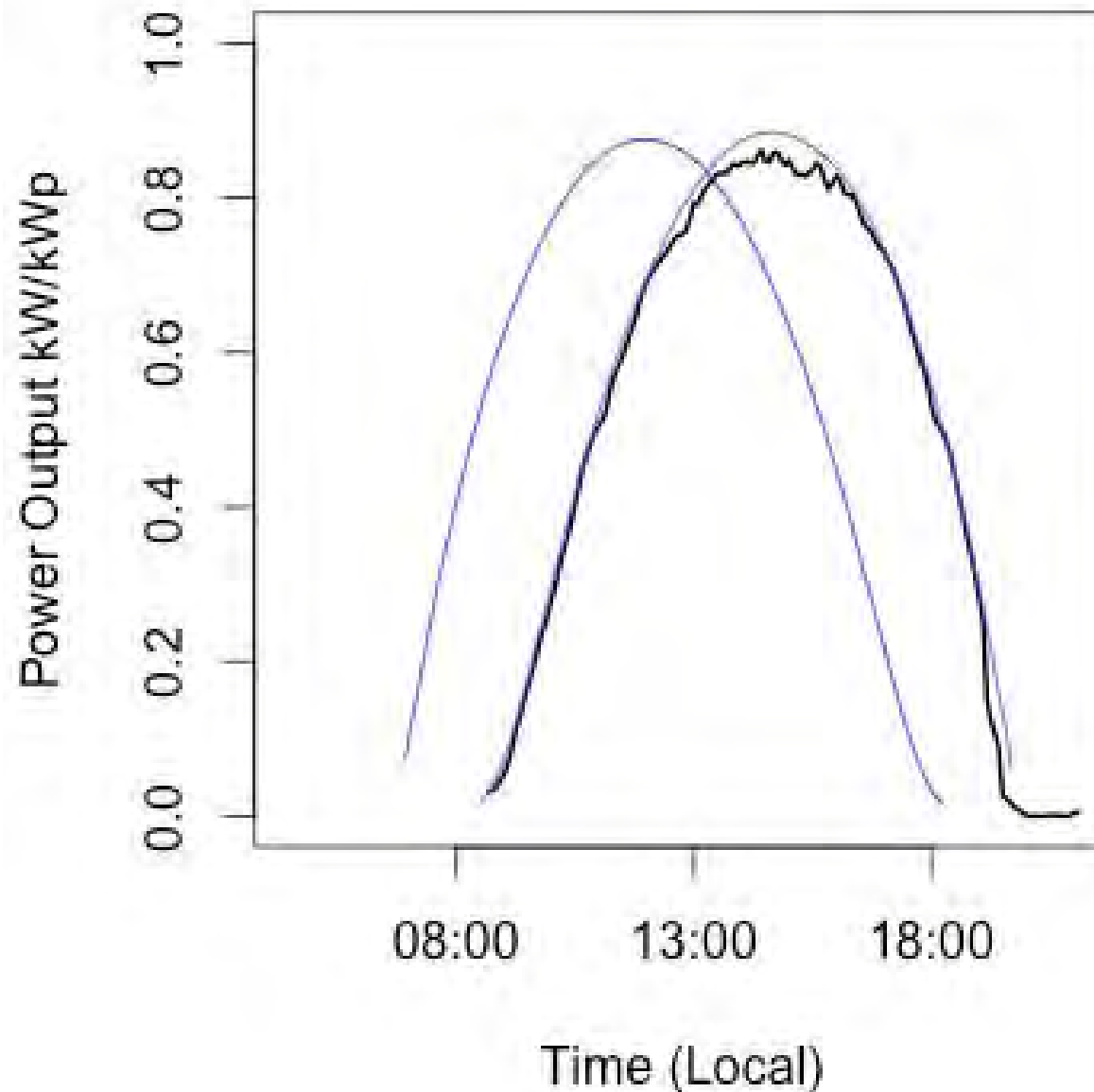


PV Data Quality Control

State of the art QC algorithm addressing two classes of problems:

1. Errors in the power output reported
2. Errors or uncertainty in the metadata

Example: Incorrect Metadata w/ QC



Black line -
measured power
output on a clear
day

Blue line - simulated
power output for a
clear day based on
reported metadata

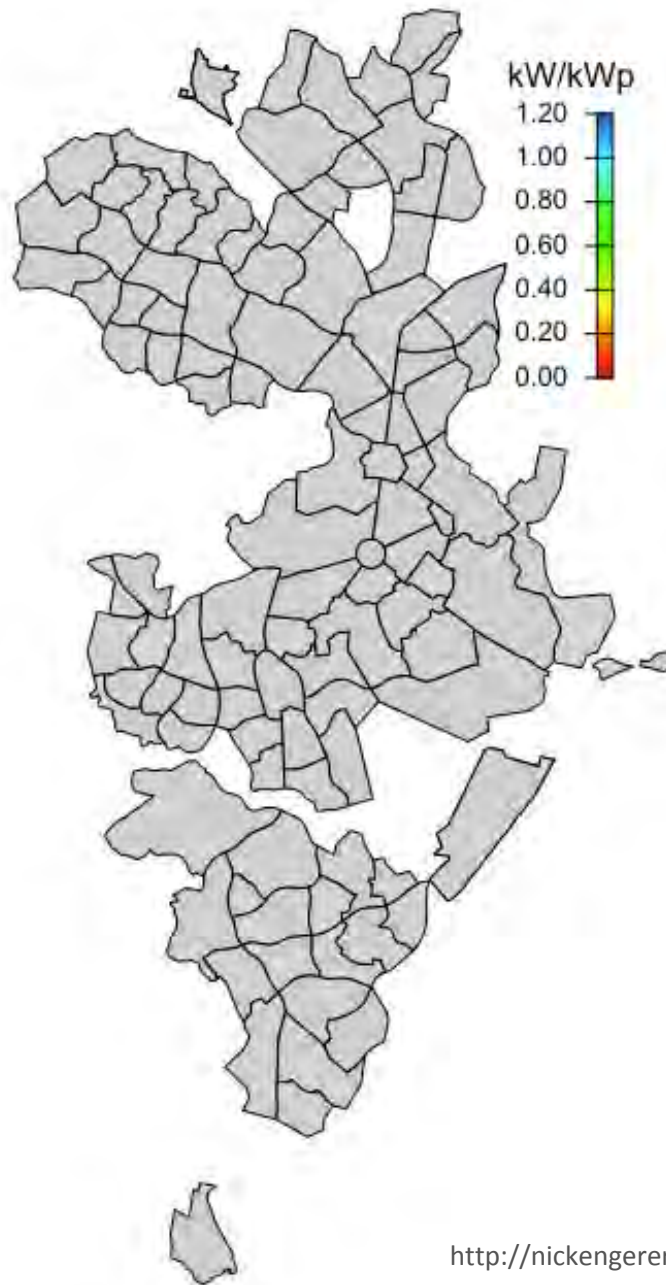
Purple line -
simulated power
output for a clear
day after QC
processing

Simulations

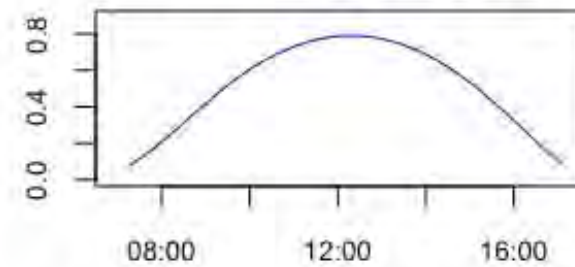
- What to simulate?
- PV system locations and ratings provided by ActewAGL (December 2012)
- Location provided at suburb-level
- Randomly distribute and assign virtual arrays

Let's take a look at a simulation for
a clear sky day

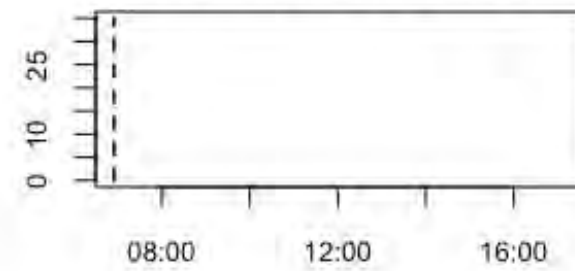
2013-08-10 06:55:00



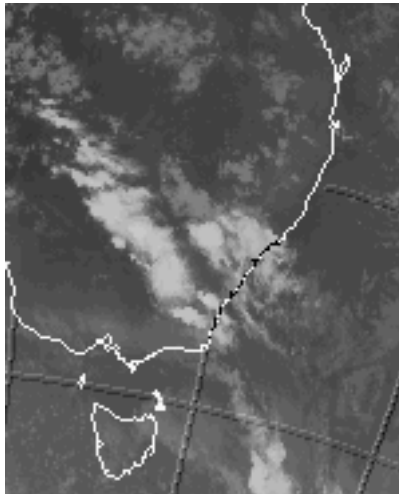
kW/kWp for all sites



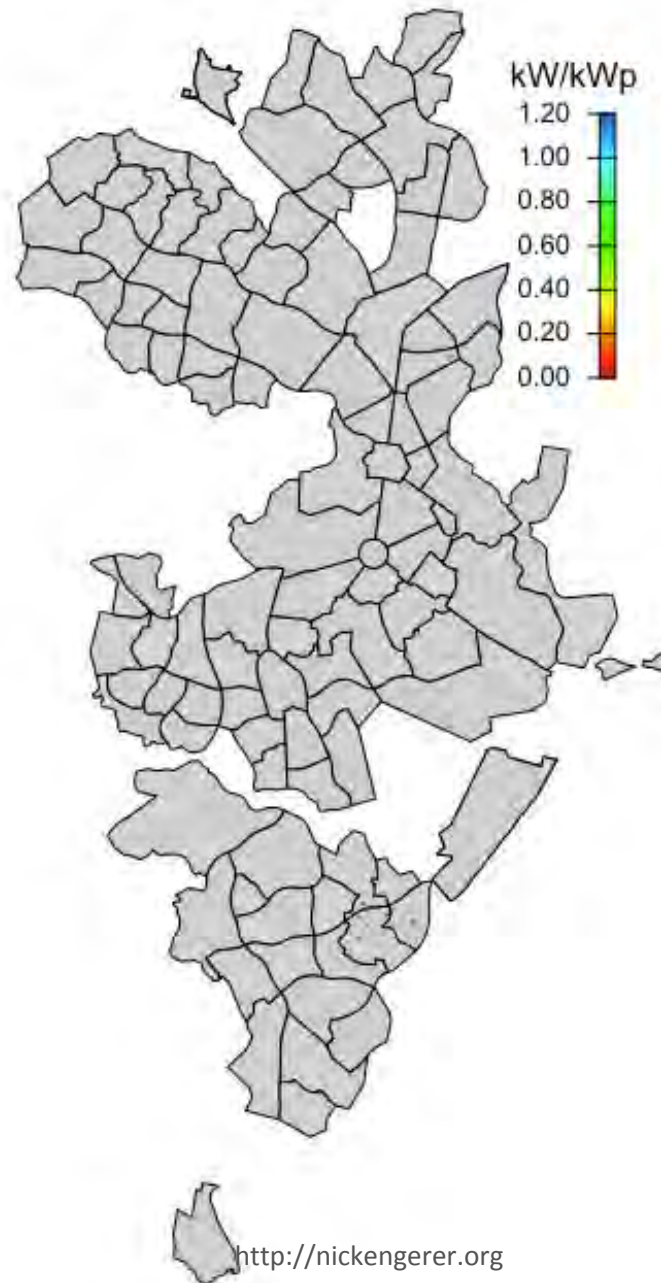
Total Simulated Power (MW)



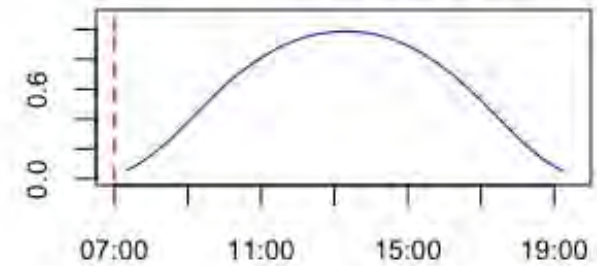
What about a high variability day?



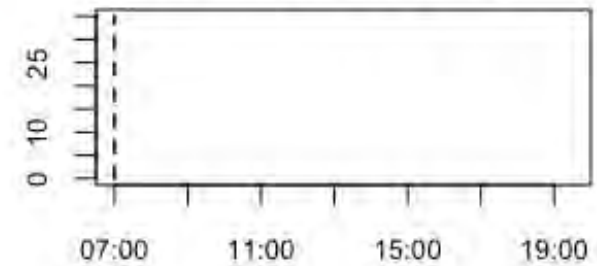
2014-03-05 07:00:00



kW/kWp for all sites



Total Simulated Power (MW)



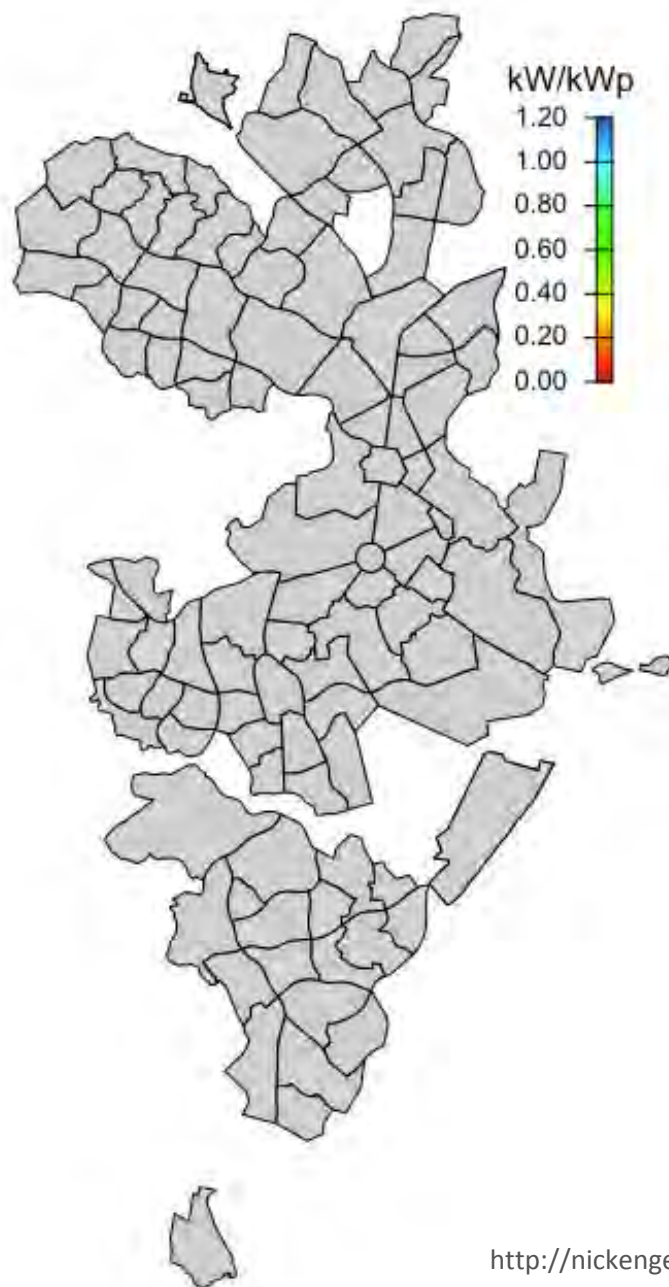
What should we simulate? Critical collective ramp events

- We've got this cool toy to play with - what should we focus on?
- Collective ramp events
- **Critical Events**: those w/ 60% change in 60 min

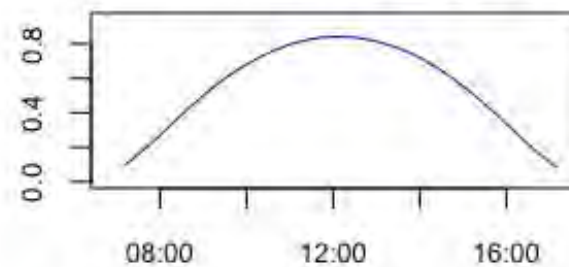
Let's look at a positive critical collective
ramp event:

fog dissipation

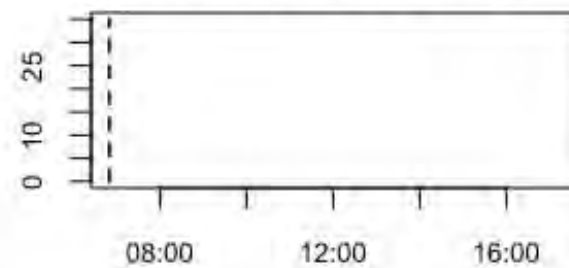
2013-08-16 06:50:00



kW/kWp for all sites

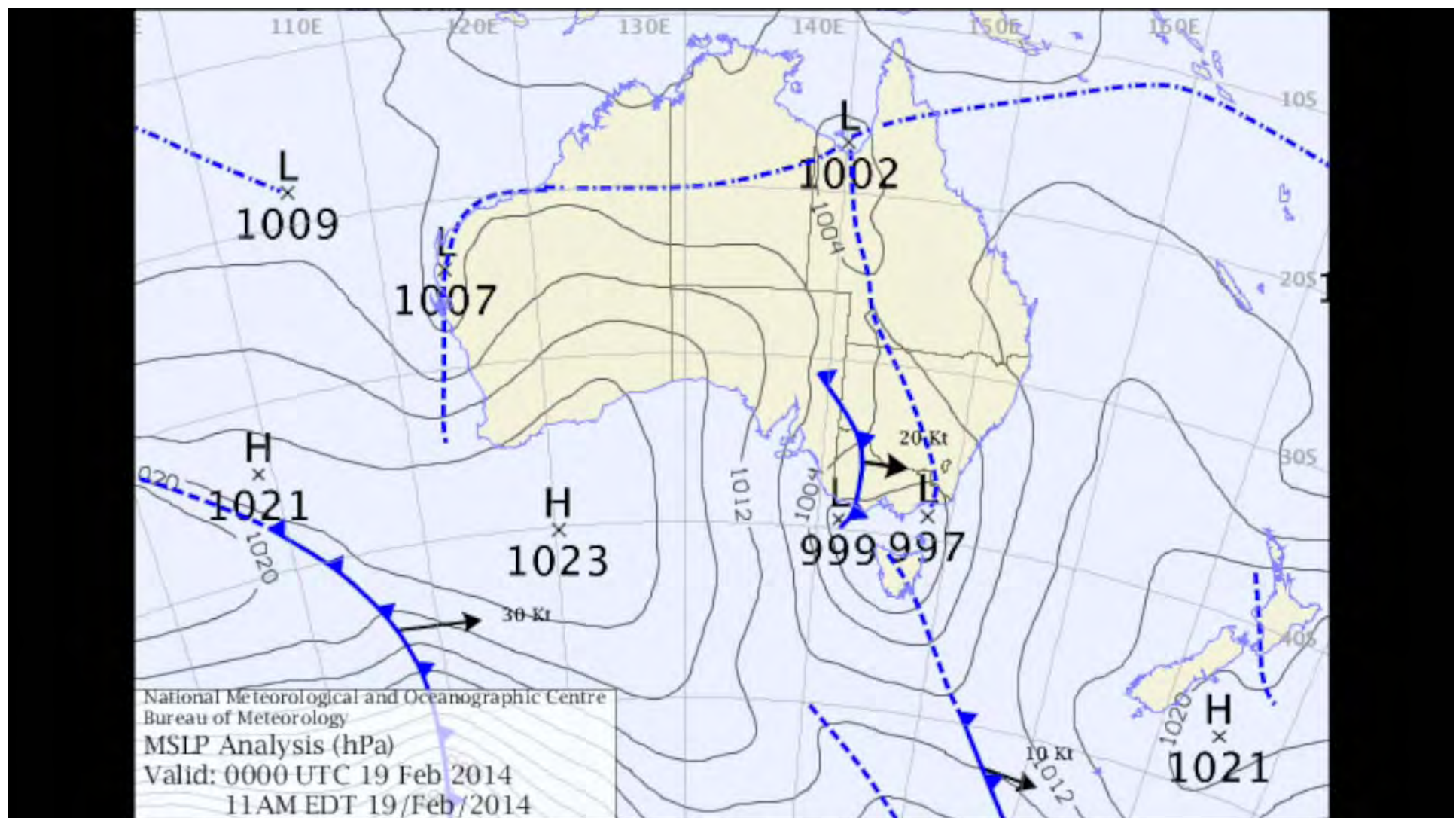


Total Simulated Power (MW)

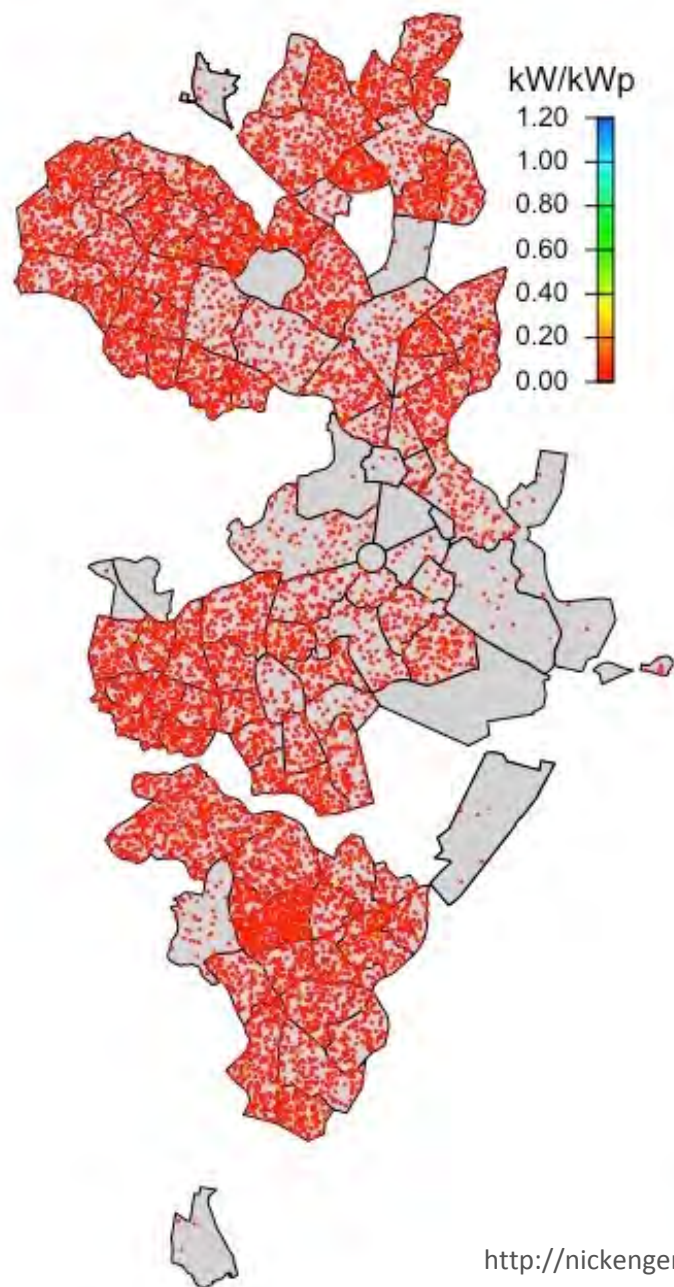


Now for a negative critical collective ramp event:

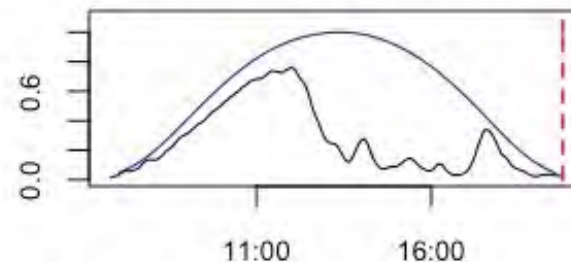
thunderstorms w/ associated
coastal trough



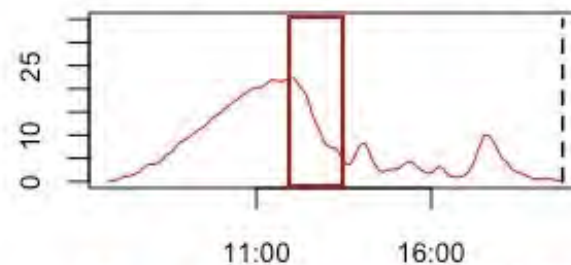
2014-02-19 19:45:00



kW/kWp for all sites



Total Simulated Power (MW)



Over 60 minutes, 19MW
of generation lost (63%)

Simulation based on
Dec 2012 installs
w/ 29.9 MW capacity

With Sept 2014 capacity
of 65.8 MWp, 41 MW lost

By 2016, another 25MWp
capacity, 67 MW lost

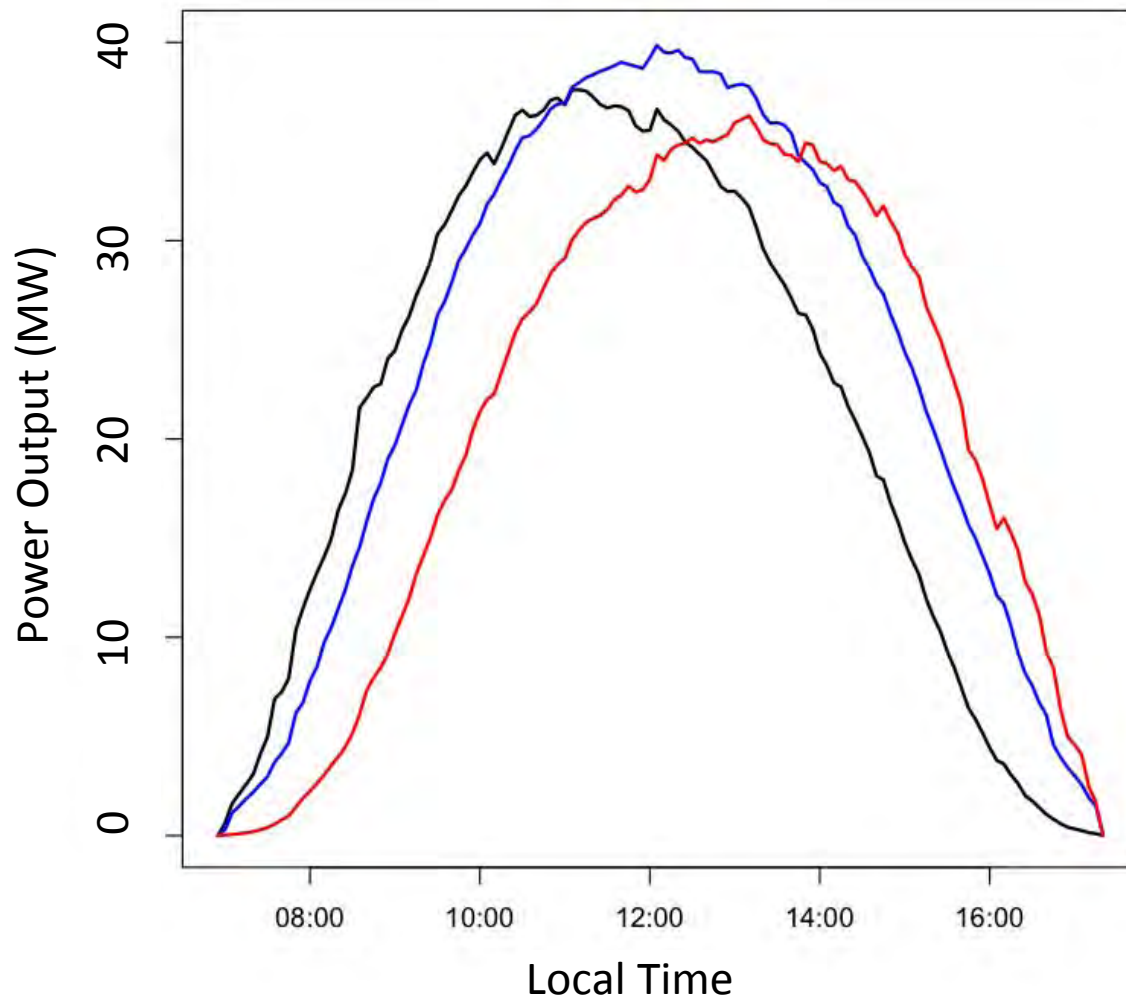
What Next?

- Expand to other cities with cooperation of local distributors
- Operate in real-time for Canberra
- Use model to generate solar forecasts
- Improved site estimations through 'on-the-fly' adaptations to cloud cover
- Integrate with Himawari 8/9 imagery

Questions, Comments, Critiques

Special thanks to ARENA, ActewAGL, SolarHub

Sensitivity Testing



Black line - full city simulation where mean azimuth is -45 degrees (NE)

Blue line - full city simulation where mean azimuth is 0 degrees (N)

Red line - full city simulation where mean azimuth is 45 degrees (NW)