Needs and methods of accurate measurements and forecasts for PV power output

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Why are accurate measurements and forecasts needed for PV power output ?

- Control of renewable energy sources such as PV and wind is much more difficult than control of conventional power sources such as nuclear, thermal and hydro because renewable energy sources change power output rapidly depending on climate conditions.
- Therefore, accurate measurements and forecasts for PV power output are needed to secure a balanced control between supply and demand (i.e. frequency control).
- In addition, when inverter power sources such as PV connected to power systems via inverters increase, synchronous generators utilized in conventional power sources decrease. And inertia and synchronizing power of power systems also decrease. This may lead to 1) increased frequency fluctuations, 2) power system instability and 3) increased voltage fluctuations and harmonic distortions.
- To solve these three potential problems, more synchronous generators are needed to connect to power systems. Therefore, accurate measurements and forecasts for PV power output are also needed to precisely understand how many synchronous generators should be connected to power systems.

Two primary methods to achieve accurate measurements and forecasts for PV power output

- There are two primary methods to achieve accurate measurements and forecasts for PV power output.
- These two primary methods are
  a) accurate measurements and forecasts for irradiance
  b) accurate measurements and forecasts for installed capacity and operational status of PV facilities
- When these two primary methods can be achieved, accurate measurements and forecasts for PV power output can also be achieved because PV power output is proportional to irradiance times installed capacity considering operational status of PV facilities.

(PV power output) ∝ (irradiance) × (installed PV capacity considering operational status of PV facilities)

Example methods for accurate measurements and forecasts (the U.S.)

Installed capacity by power source in CAISO

(As of Jun 3, 2016)

Power Source	Installed capacity (MW)	Percentage (%)
PV（>=10kW）	8,601 (approx. 2,000 in 2012)	8.9
Wind	7,343	7.6
Nuclear	2,300	2.4
Thermal (Incl. Gas)	58,739 (53,849)	60.8 (55.7)
Hydro	14,998	15.5
Biomass	1,347	1.4
Geothermal	2,435	2.5
Others (Incl. Storage)	842 (40)	0.9 (0.04)
Total	96,605	100.0

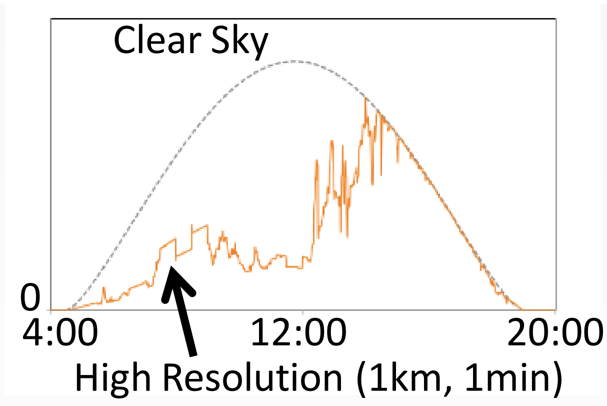
Source : CAISO

Ratio of installed capacity to peak demand (CAISO, PJM)

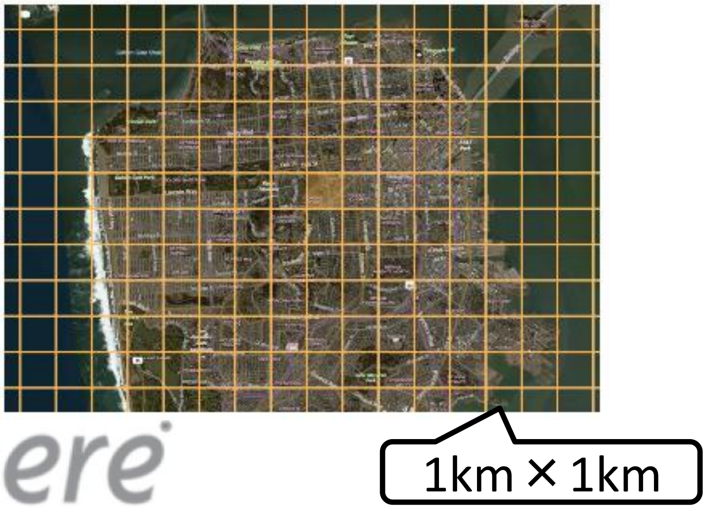
ISO/RTO	Peak Demand (MW)	Installed Capacity (MW)	Ratio of installed capacity to peak demand (%)
CAISO (Year)	47,358 (2015)	96,605 (2016)	204.0
PJM (Year)	165,490 (2013)	180,950 (2013)	109.3

Source : CAISO et al

Procedure of PV power measurements and forecasts in CAISO



High Resolution
1km gridded tile
1-minute data



SOLAR*anywhere*

Measurement ***Forecast***

PV Specifications From *power*CLERK and Other Sources

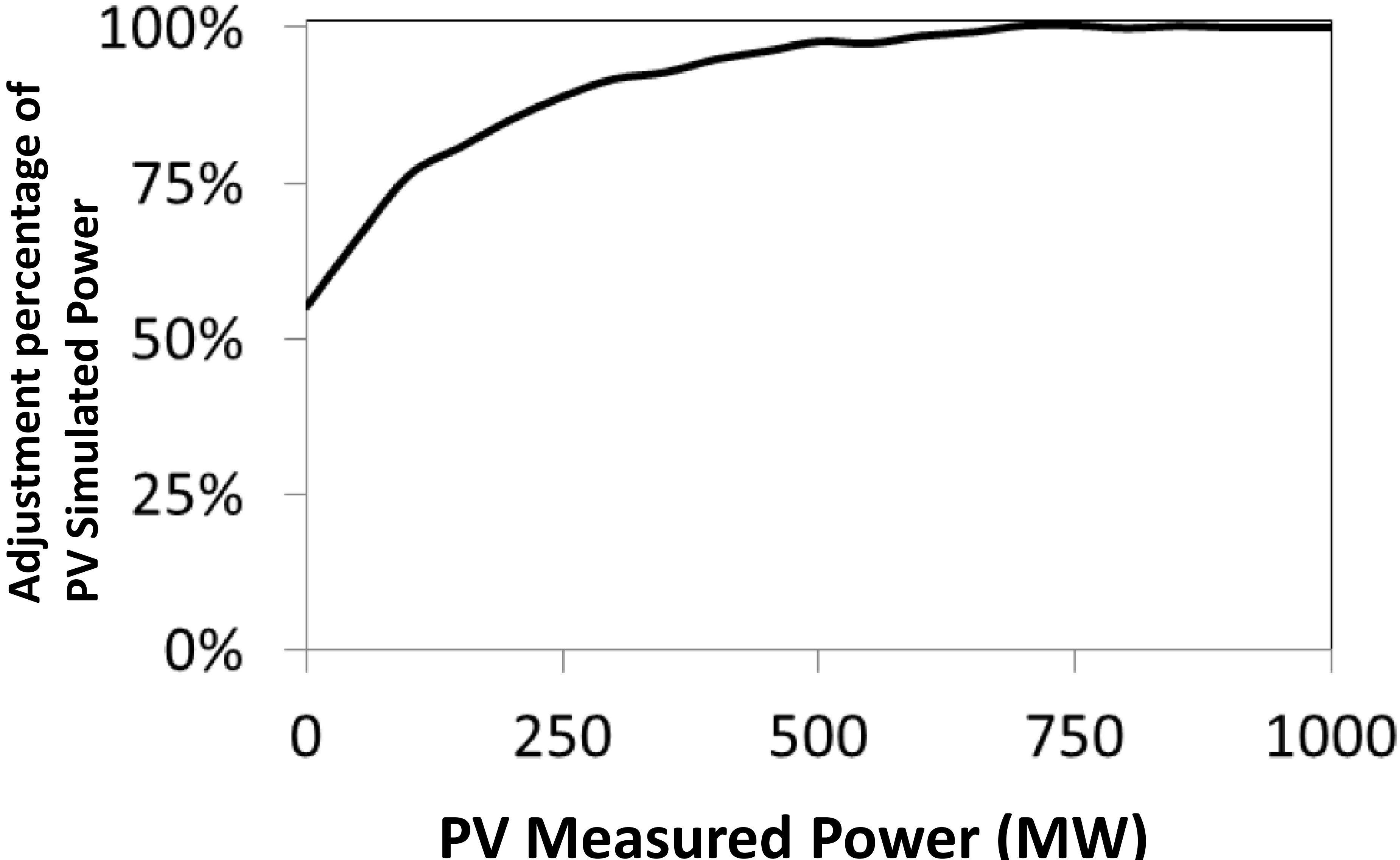
FleetView Simulation Methods

PV facilities’ planning

PV facilities’ operations

Source : Clean Power Research et al

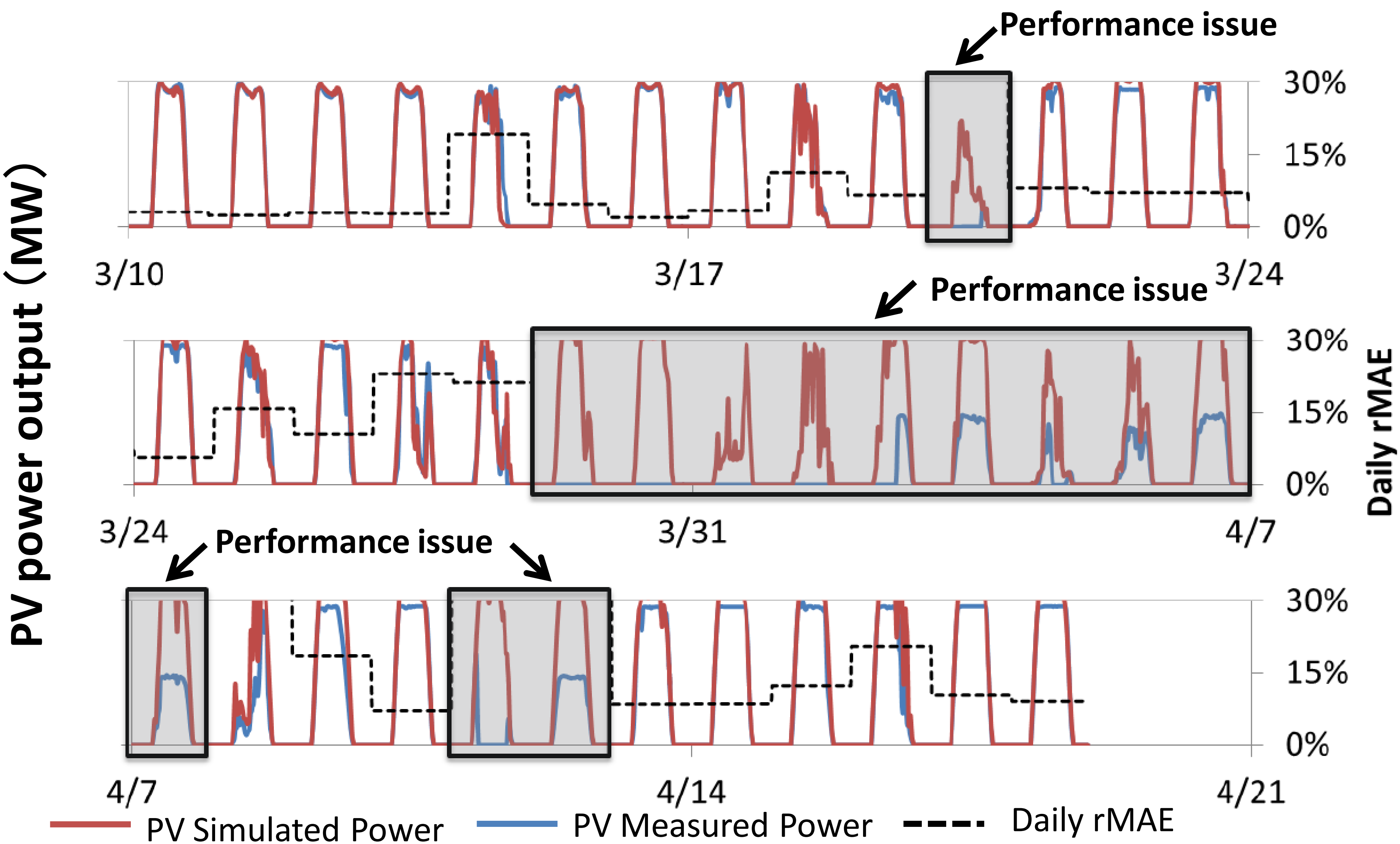
Methods for more accurate forecasts
1) Tuning PV Simulated Power



Source : Clean Power Research et al

Methods for more accurate forecasts
2) Filtering PV facilities with performance issues

Example of PV facilities with possible performance issues



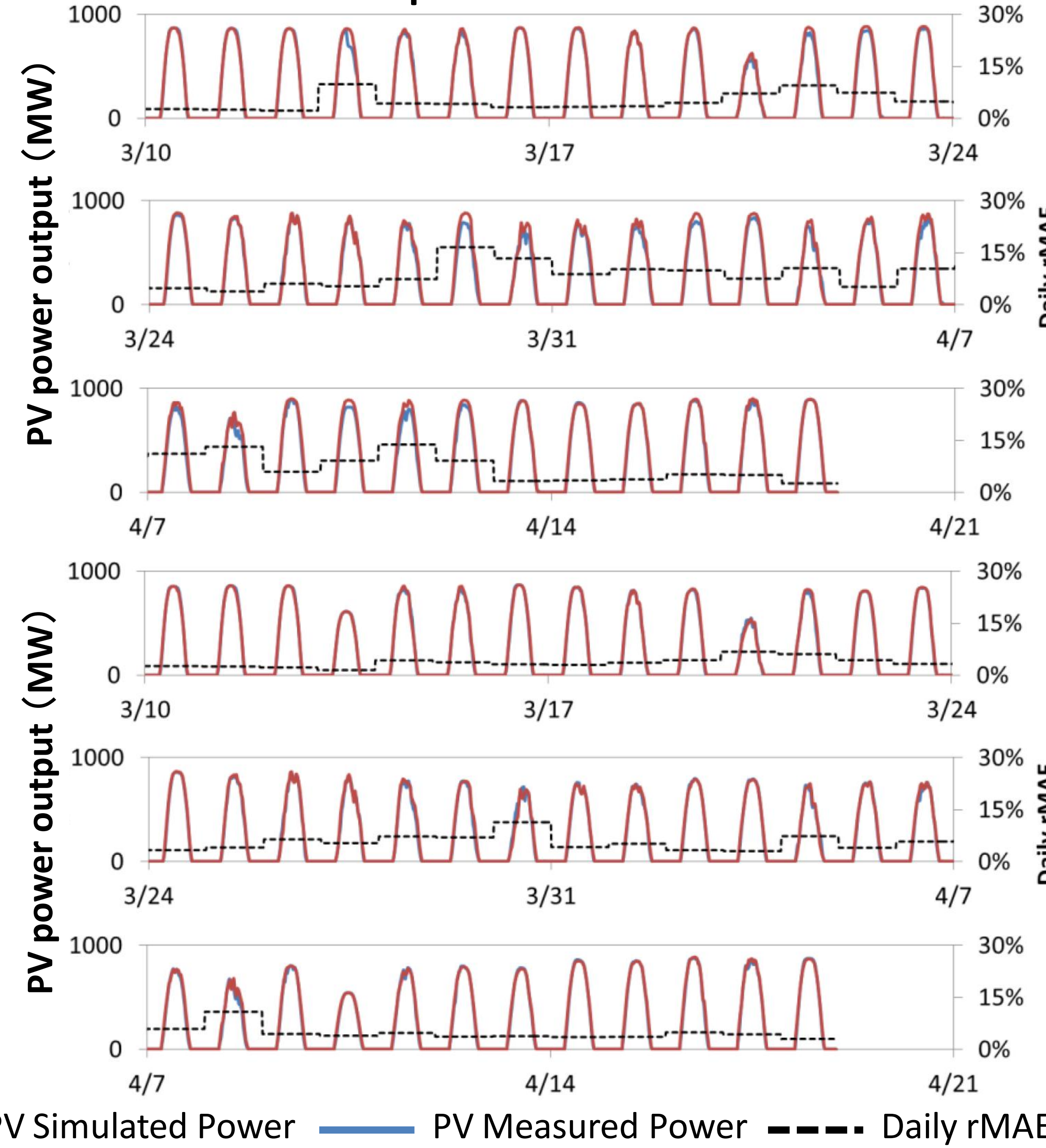
Source : Clean Power Research et al

rMAE : relative Mean Absolute Error

Methods for more accurate forecasts
2) Filtering PV facilities with performance issues

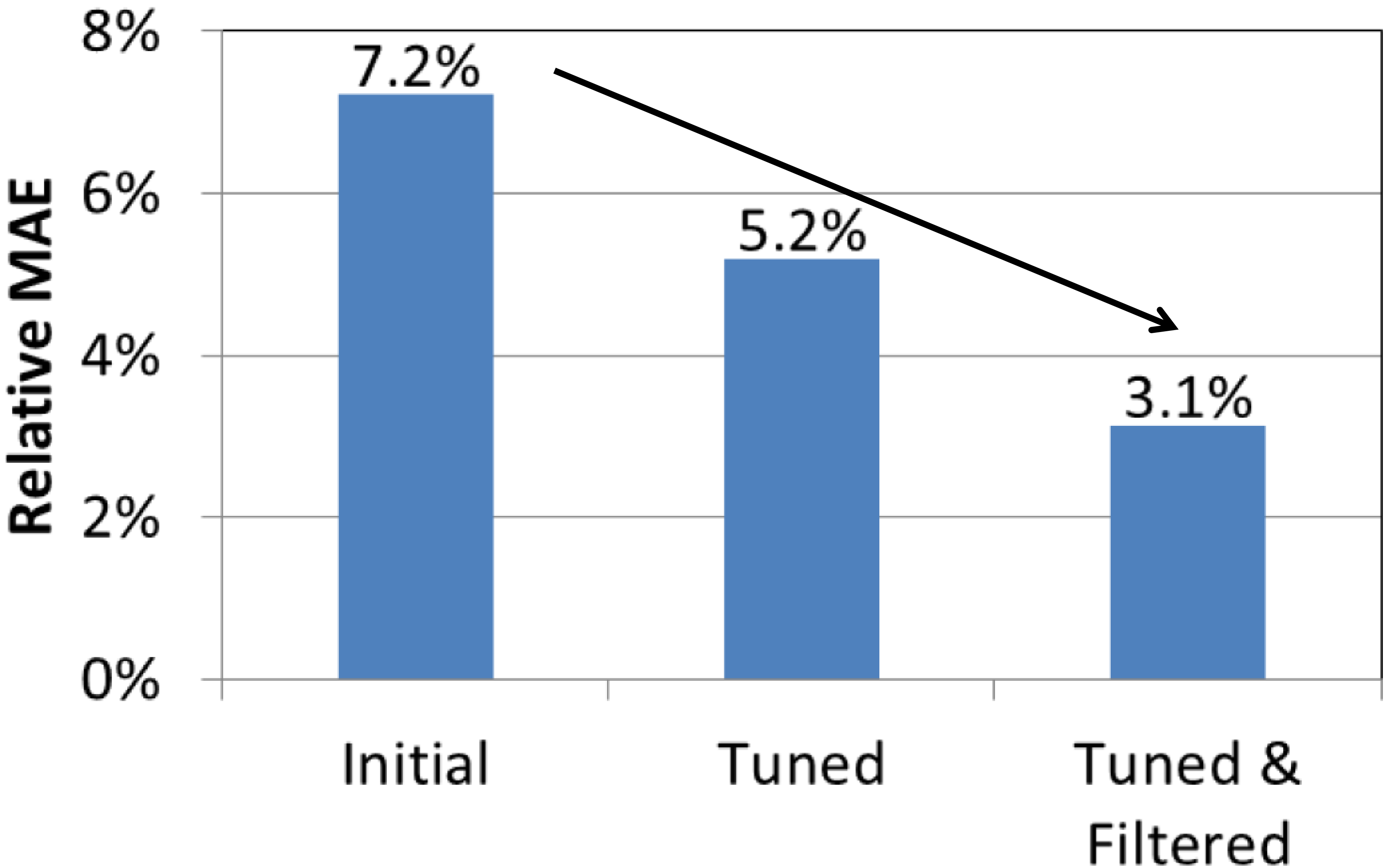
Before filtering PV facilities with possible performance issues

After filtering PV facilities with possible performance issues



Source : Clean Power Research et al

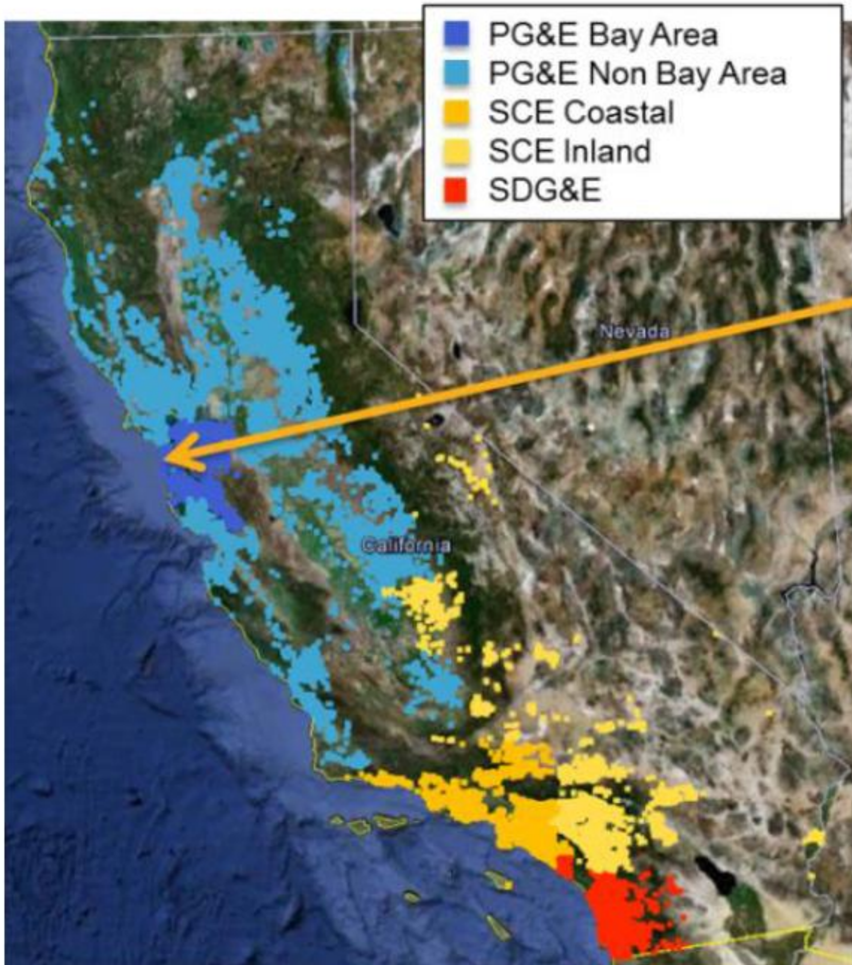
Total Relative Mean Absolute Error (Total rMAE)

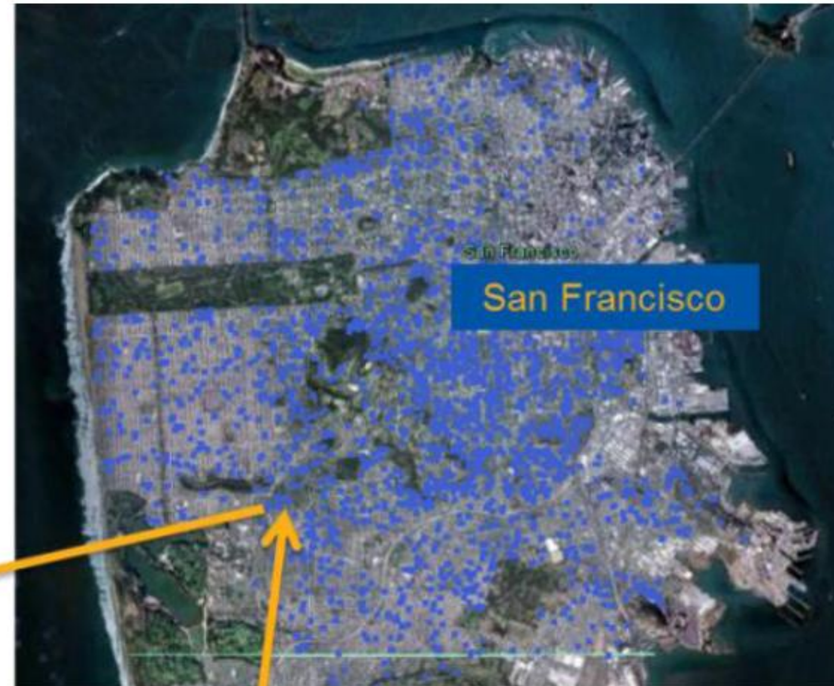


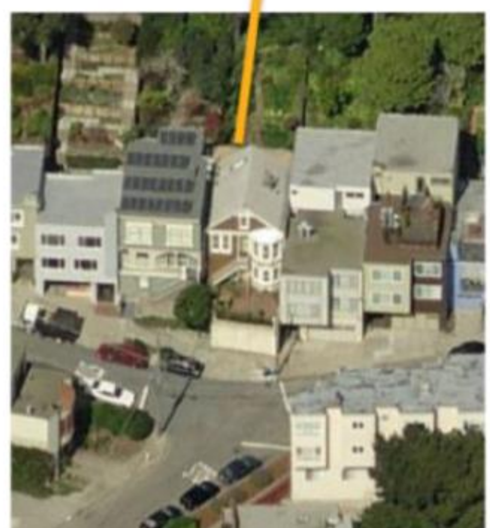
Source : Clean Power Research et al

PV facilities map in San Francisco, California

PG&E : Pacific Gas & Electric
SCE : Southern California Edison
SDG&E : San Diego Gas & Electric



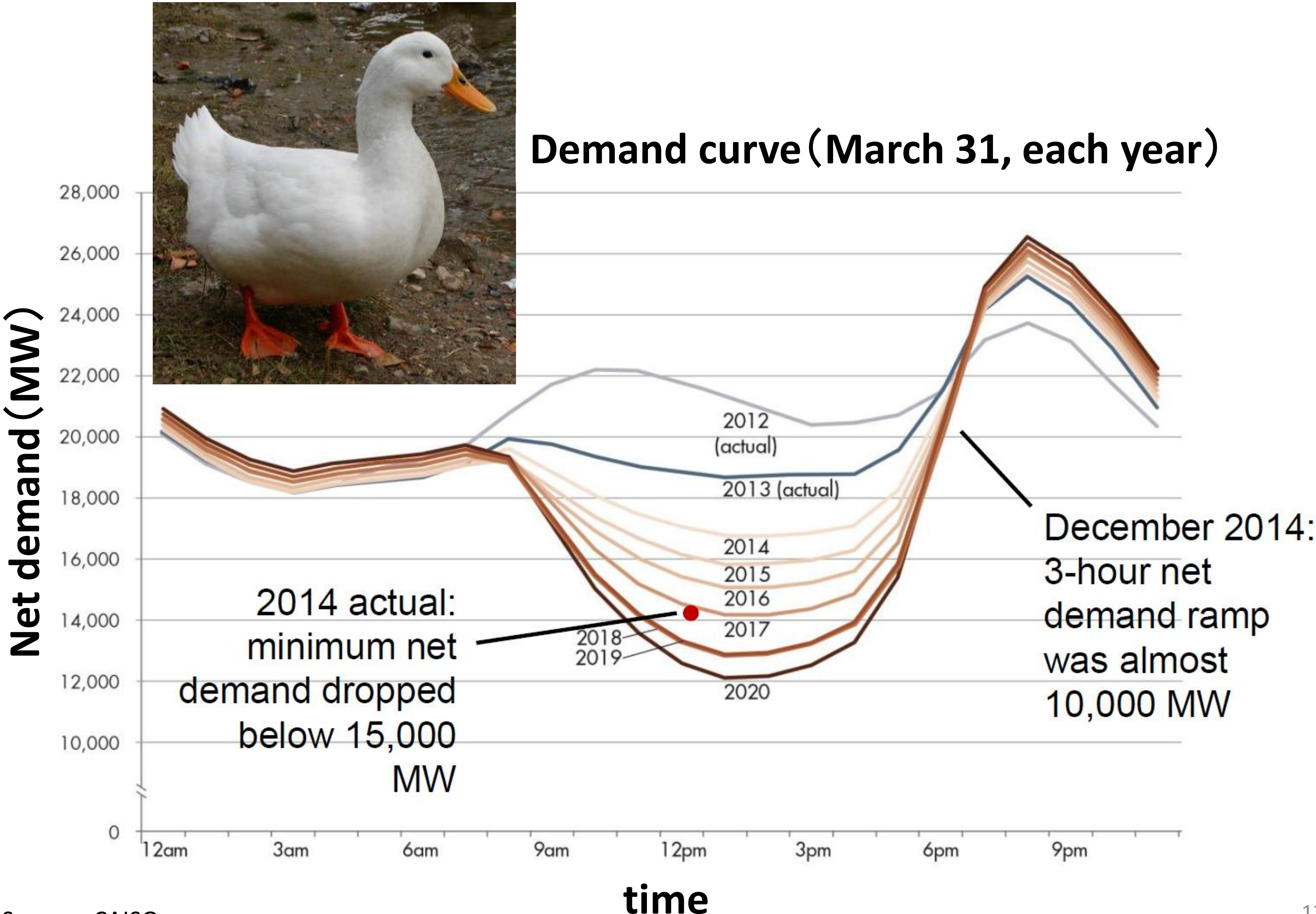




- 4.49 kW-AC
- SunPower Inverter (SPR-5000X, 240V)
- 27 Modules (SunPower 210 W, SPR-210-WHT)
- 37.76281° N, 122.44313° W
- Commissioned April 2008

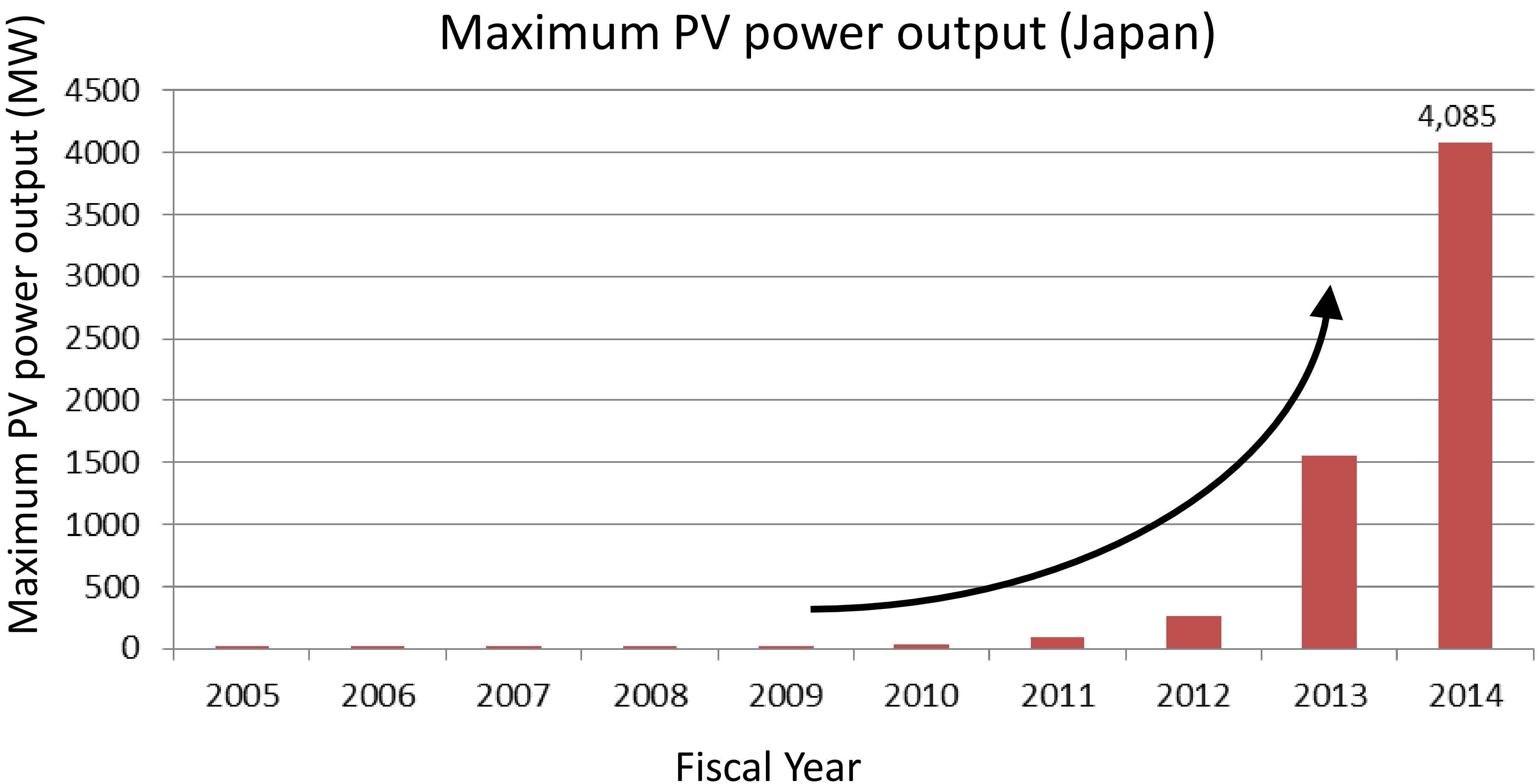
Source : Clean Power Research

Demand curve in CAISO is named "duck curve"



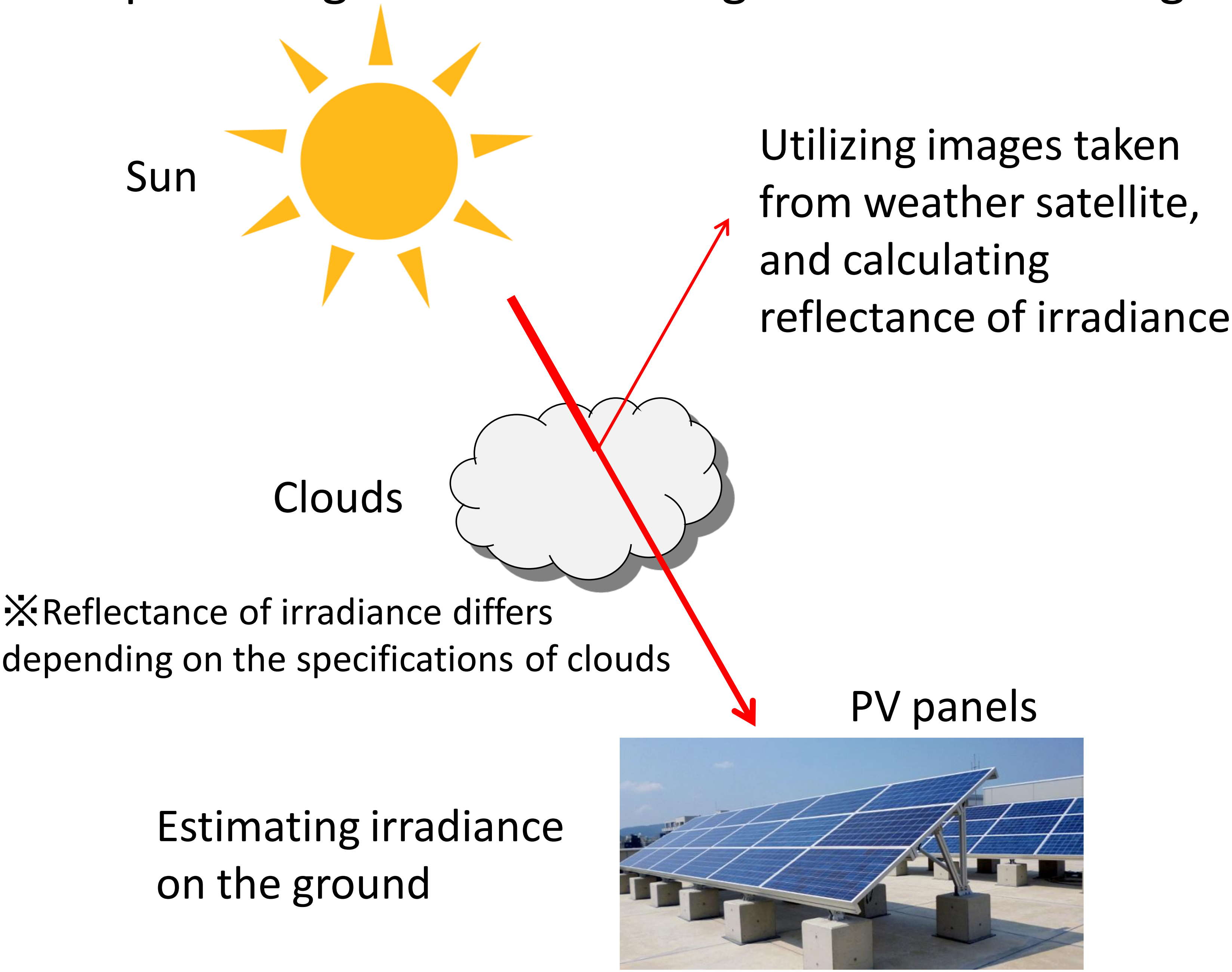
Source : CAISO

Example methods for accurate measurements and forecasts (Japan)



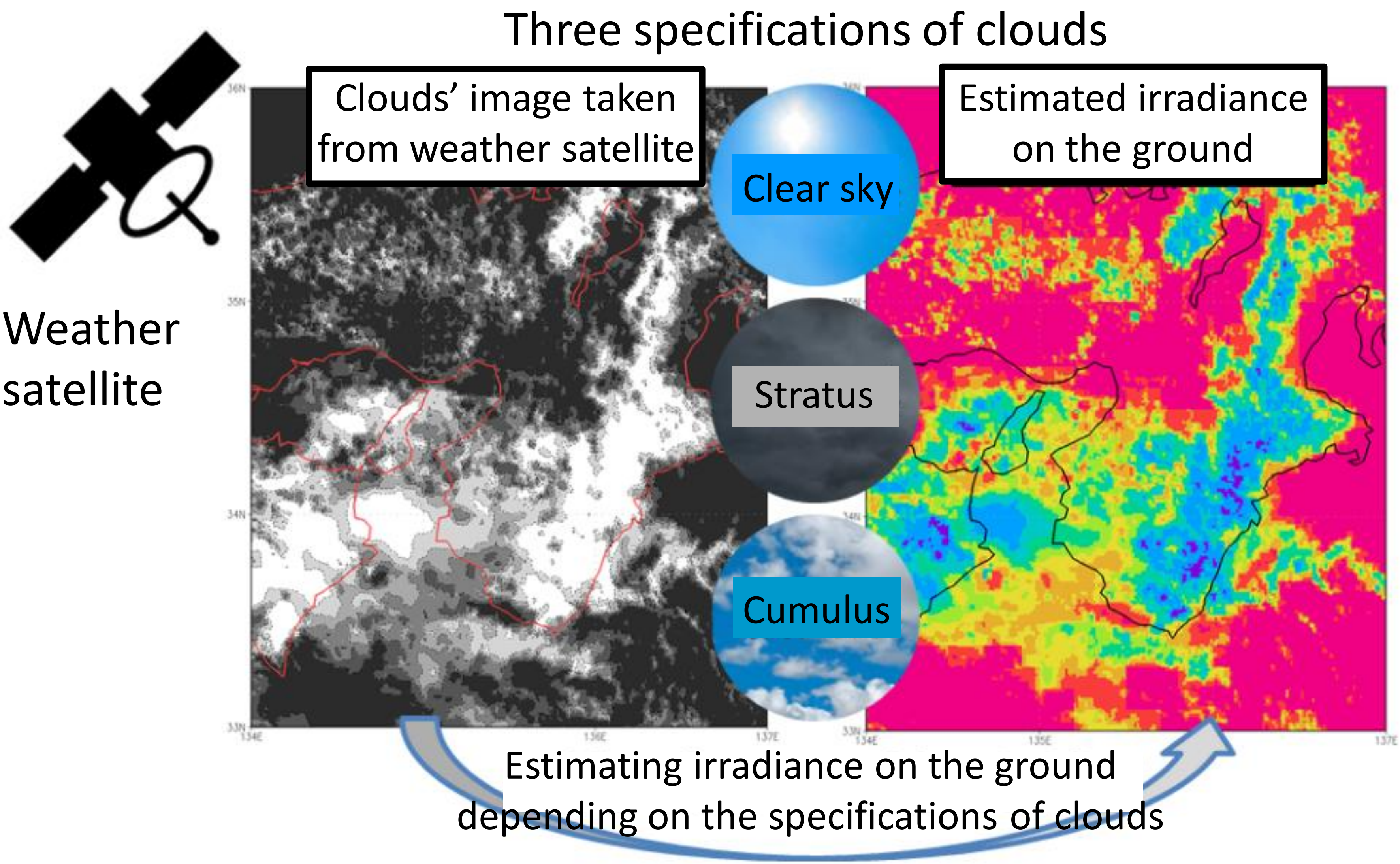
Source : FEPC

Conceptual diagram of estimating irradiance on the ground



Source : JEPIC

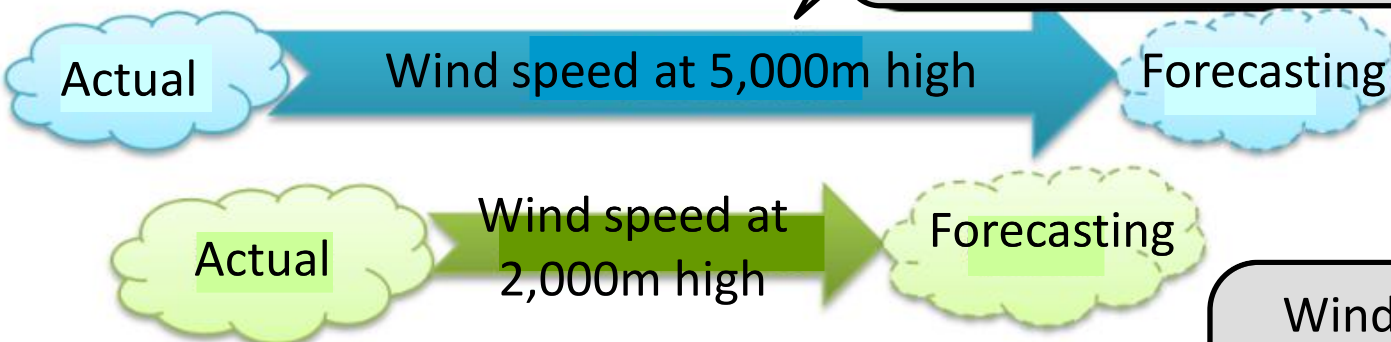
Images of estimating irradiance on the ground in Kansai area



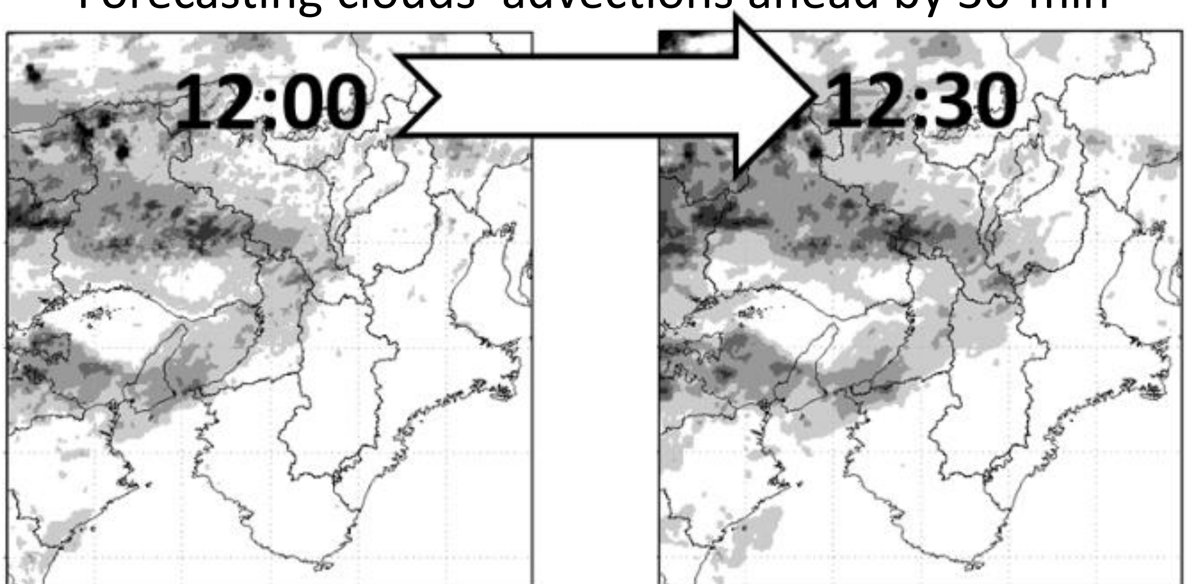
Source : JEPIC

Images of forecasting clouds' advections in Kansai area

Utilizing wind speed depending on the height of clouds, clouds' advections are forecasted.



Forecasting clouds' advections ahead by 30-min



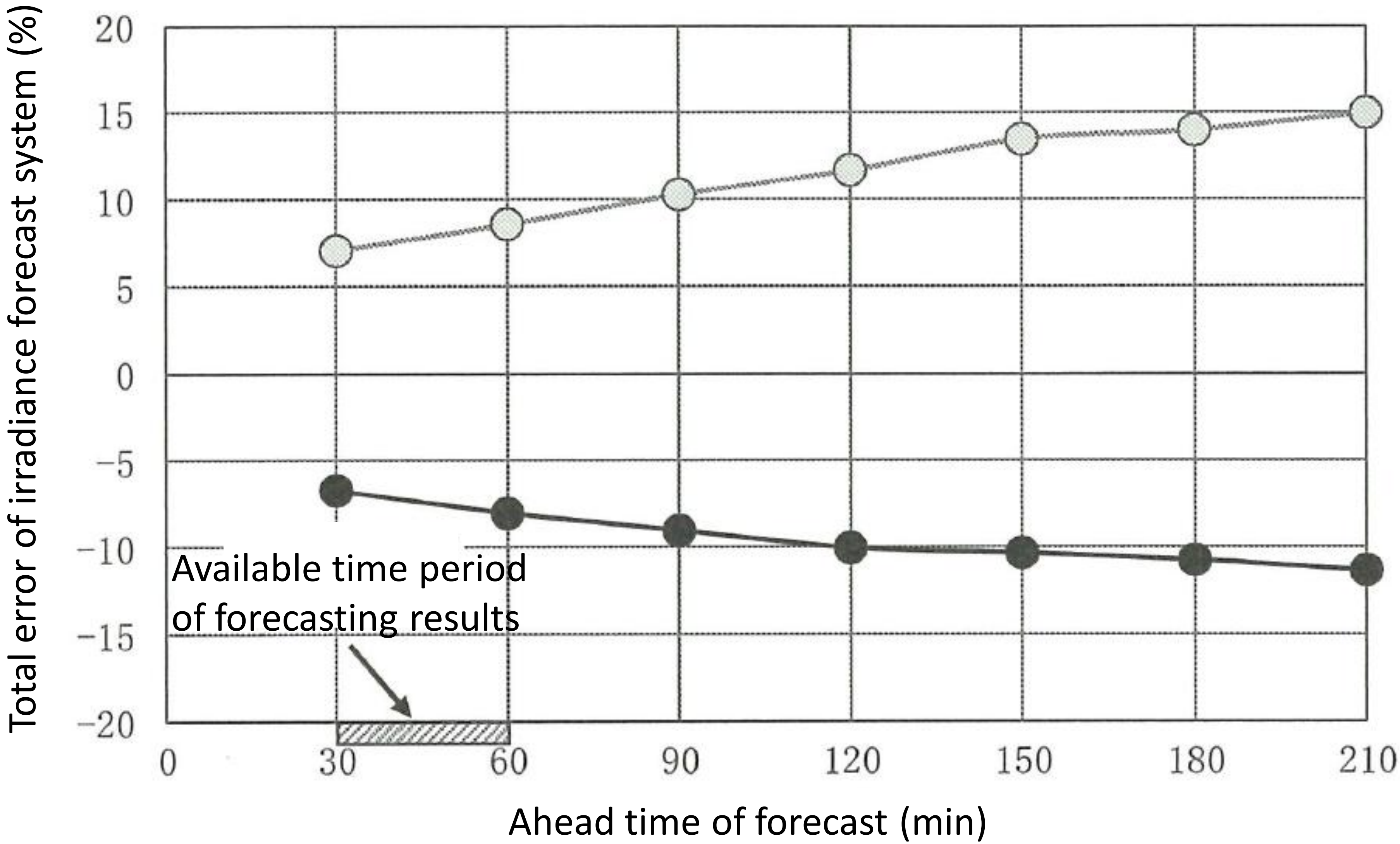
Wind speed is calculated and forecasted by WRF system.

WRF : Weather Research and Forecasting

When clouds' advections are forecasted, irradiance on the ground is also forecasted.

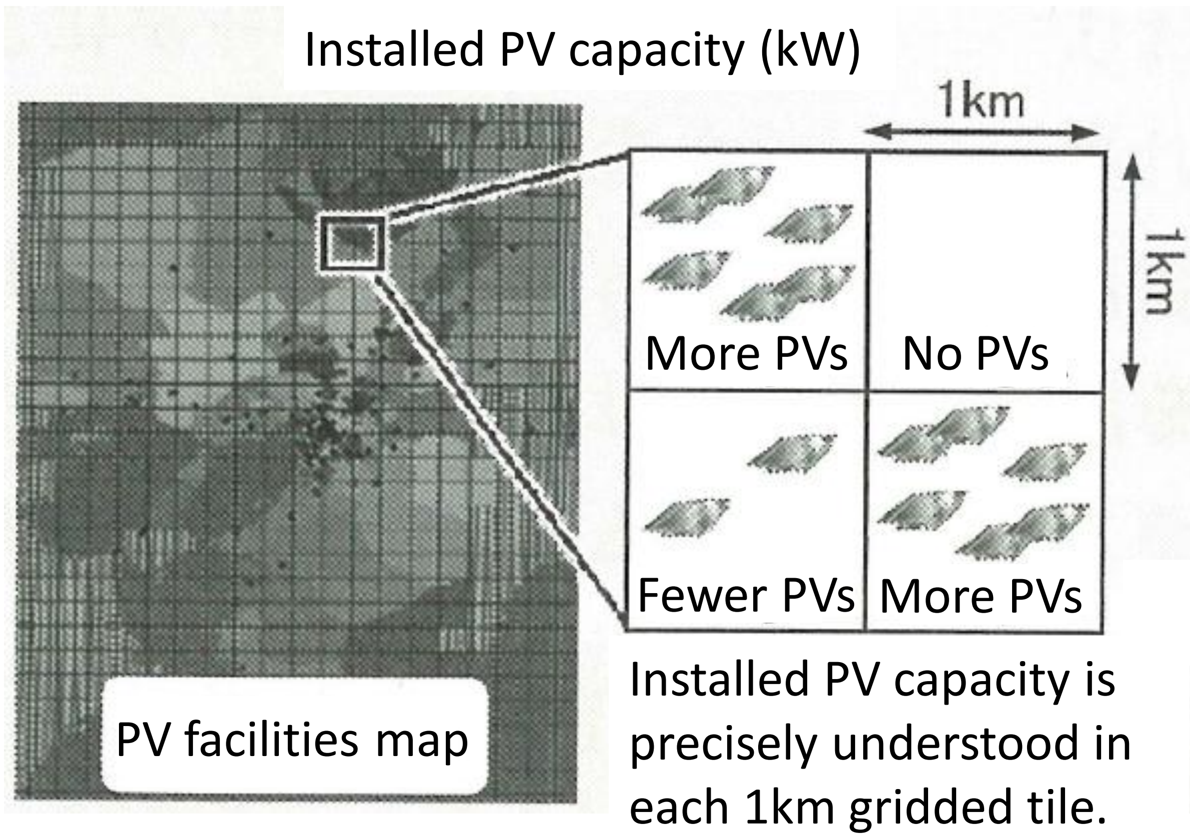
Source : JEPIC

Total error of irradiance forecast system

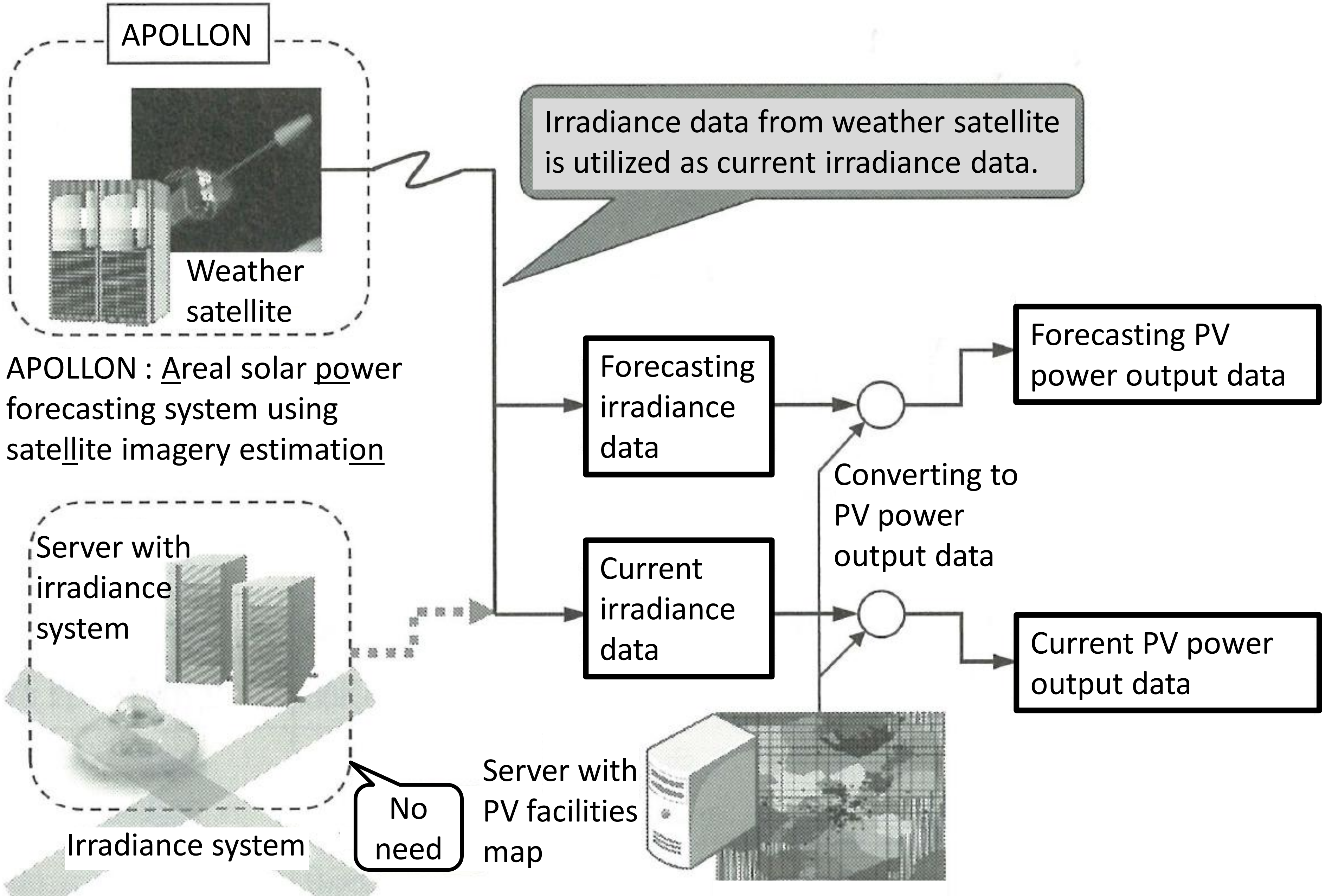


Source : JEPIC

PV facilities map in Kansai area, Japan



Conceptual diagram of PV power output forecast system



Source : JEPIC

Conclusion

- When two primary methods aforementioned can be achieved, accurate measurements and forecasts for PV power output can also be achieved. And by utilizing accurate PV power output, power system control will be much easier, and problems on the characteristics of power systems will be overcome.
- On some Japanese isolated islands, many PV power sources are increasingly connected to power systems, and the control of power systems is much more difficult. Therefore, electric power utilities may demand PV owners to reduce power output.
- By applying the aforementioned methods to Japanese isolated islands, there will be less of a need for electric power utilities to demand a reduction in PV power output.