NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Overview of Solar Integration Studies

Solar Power: Making High Penetration Possible

SPI Workshop

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Quiz – true or false?

1. When the sun shines on the PV panel on my roof, nothing changes back at the utility because that power flow is so tiny.
2. When the sun shines on the PV panel on my roof, it actually increases CO_2 emissions because the coal plants are forced to run at a partial load at lower efficiency.
3. Each PV installation should ideally have storage because what utilities want is a flat block of energy like what a baseload coal plant provides.

How do high penetrations of solar impact utility operations?

- How do the variability and uncertainty of solar impact operations?
- Do you need more backup/reserves?
- Do you need storage?
- Do you need storage at the solar plant to firm up the output?
- How much curtailment will potential projects face?
- How do fast fluctuations in solar impact operations? How can we mitigate that?

Variability and Uncertainty

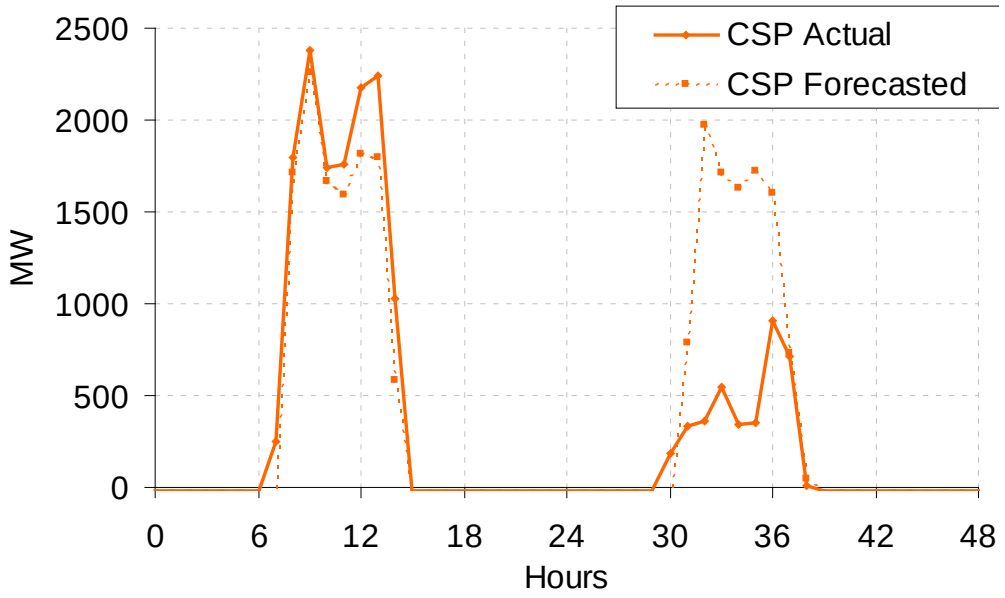
Variability: Solar generator output varies as the intensity of its energy source (sun)

- Several timescales: minute (regulation), hour (ramping), diurnal, seasonal

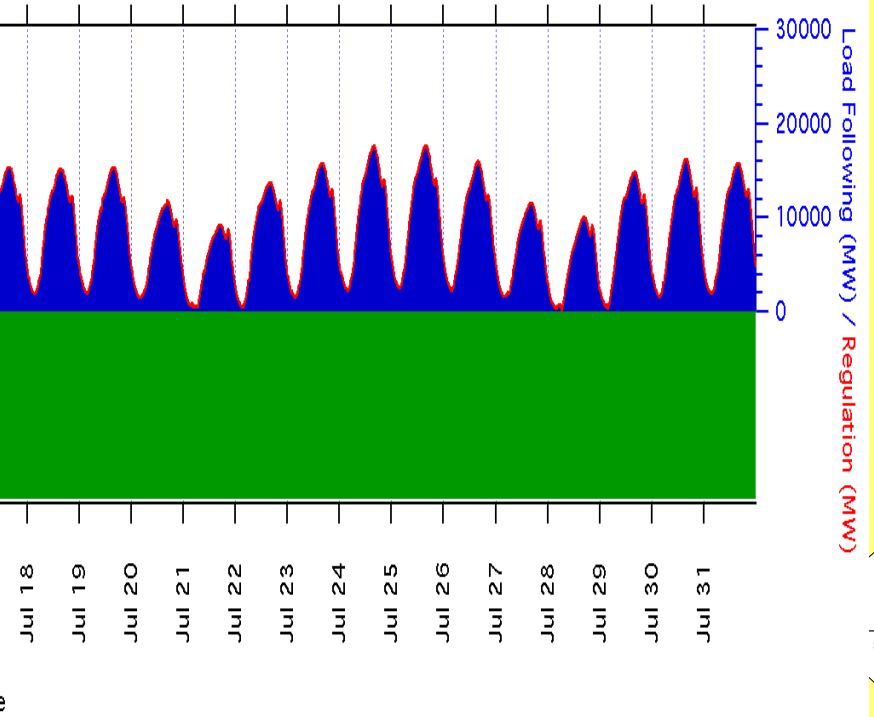
Uncertainty: Solar generation uncertainty is similar to “load”

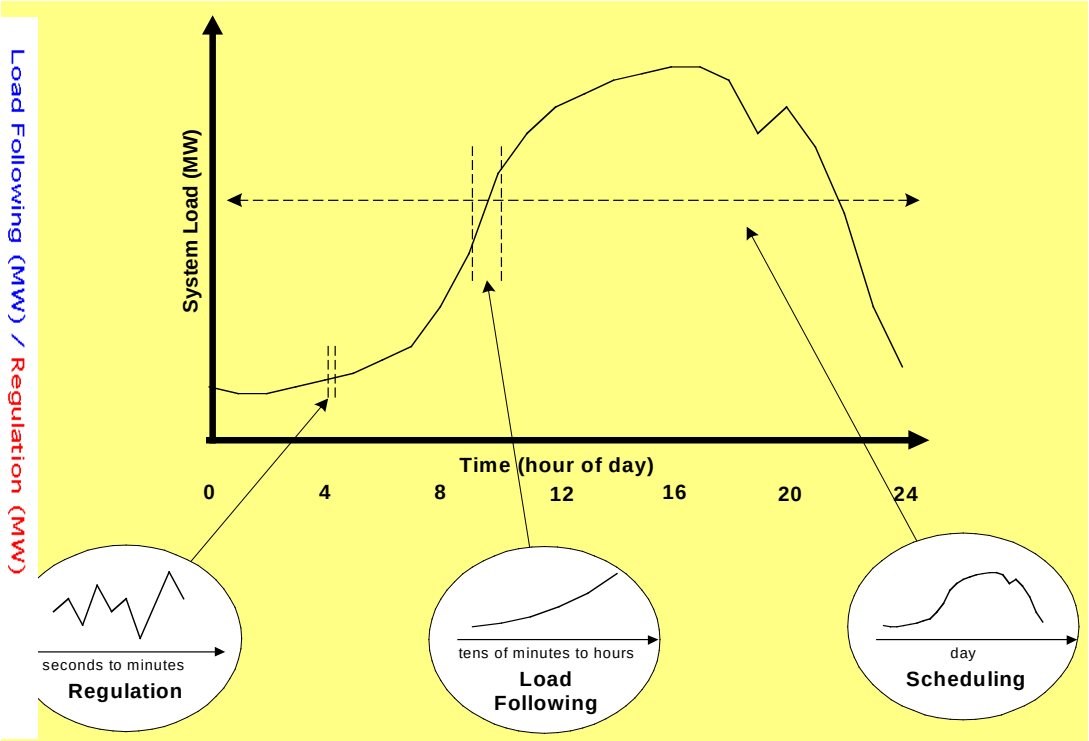
- Not dispatchable – output is predicted by a forecast
- Actual power output is different that forecast output

A perfect forecast eliminates **uncertainty**, but there is still **variability**



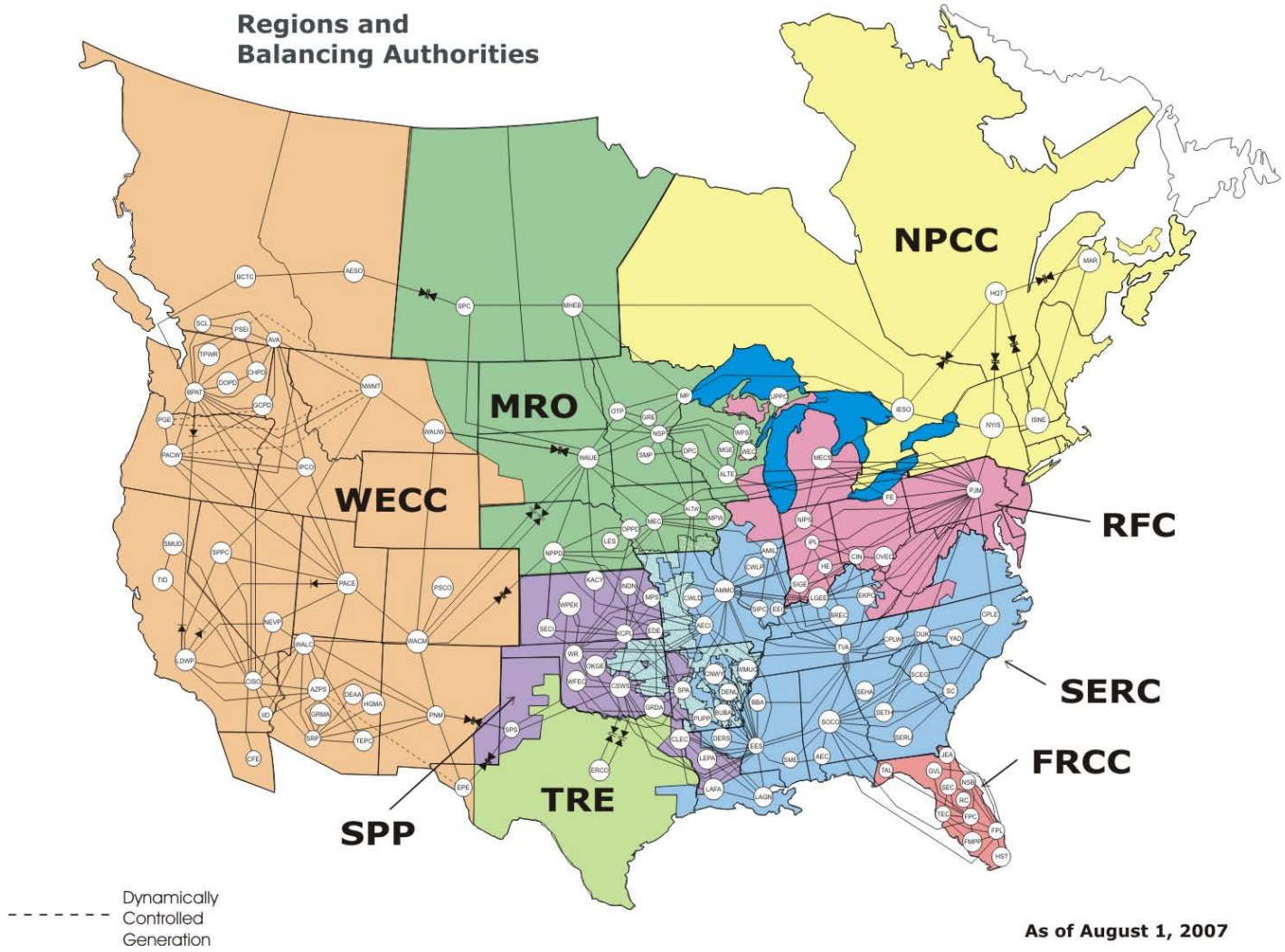
Utility Scheduling and Dispatch





Hours to Day ahead: use load forecast to commit units
10 minutes to few hours: manually adjust generator set points
Seconds to minutes: AGC automatically adjusts generator output

Integration into Wholesale Markets

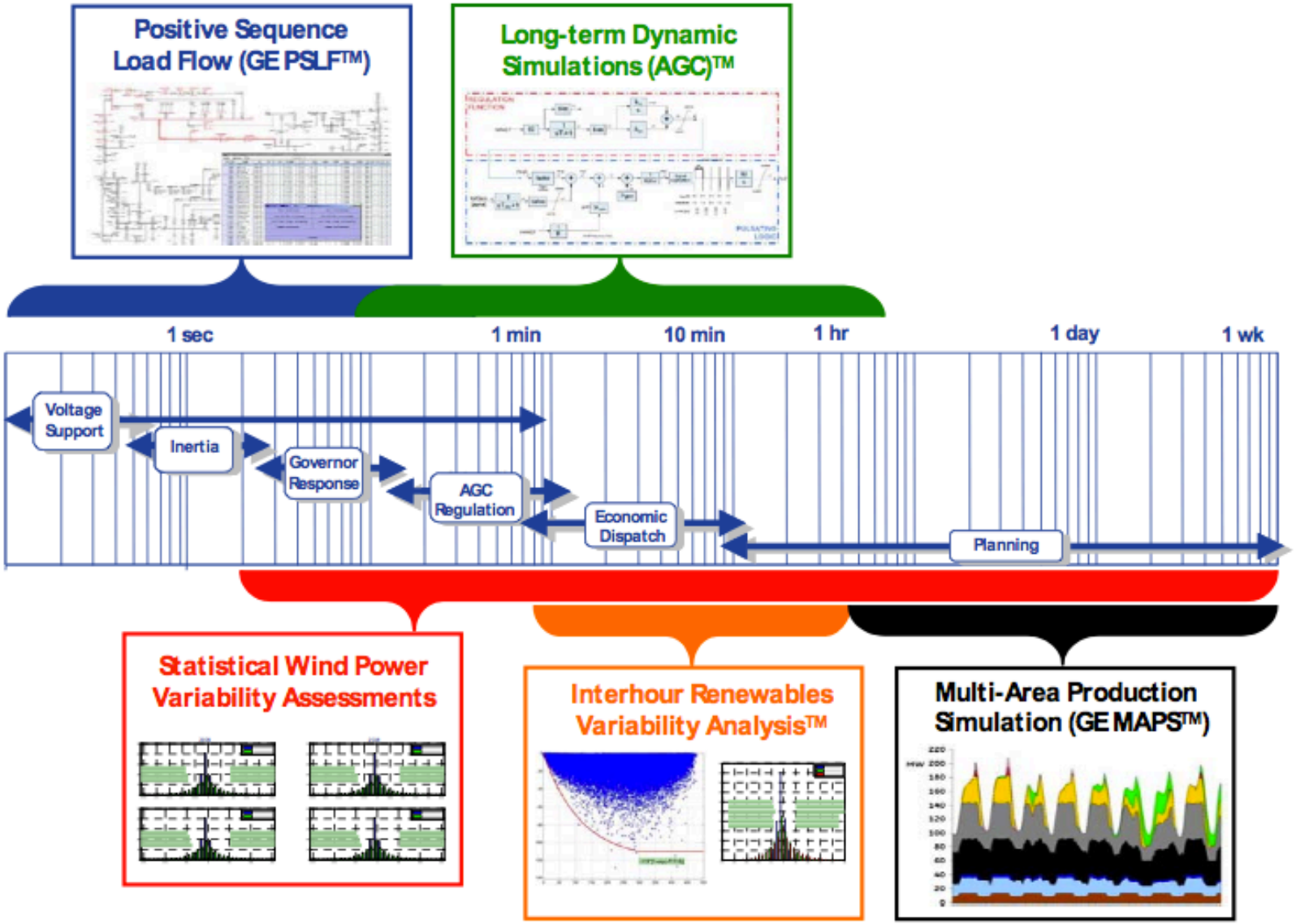


Source: www.nerc.com

Recent Solar Integration Studies

- Western Wind and Solar Integration Study (WWSIS)
  - 15 GW solar
  - High solar exploration: 67 GW
- California: 20% CAISO; CEC Intermittent Analysis Project (IAP)
  - 20% CAISO: 2246 MW solar
  - CEC IAP: 3 GW solar
- Hawaii: Oahu Wind Integration and Transmission Study (OWITS)
  - 100 MW PV
- Xcel/PSCO
  - 800 MW solar

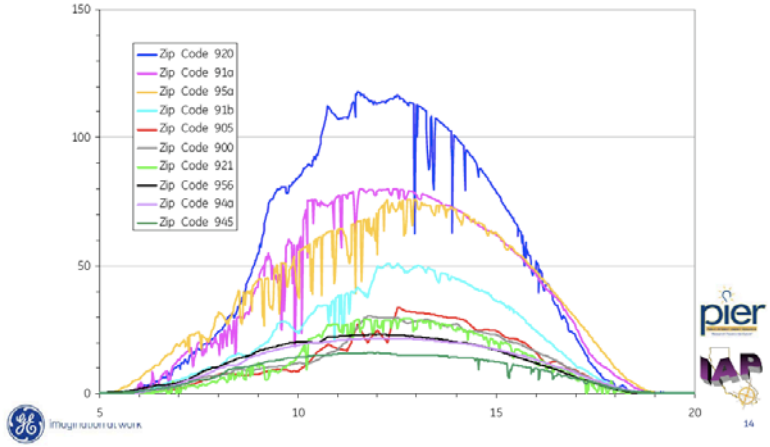
What kind of analysis is done?



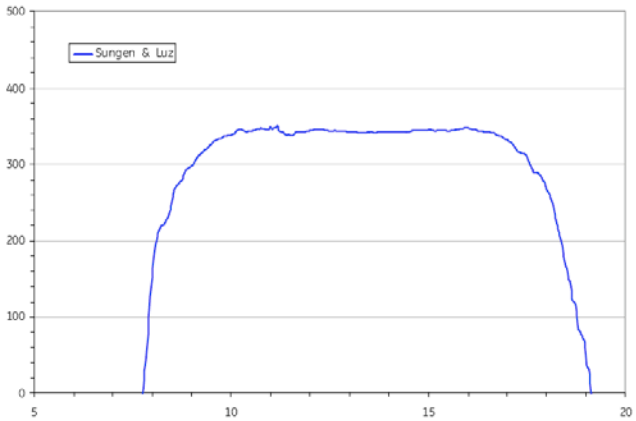
Source: GE Energy

Solar data inputs

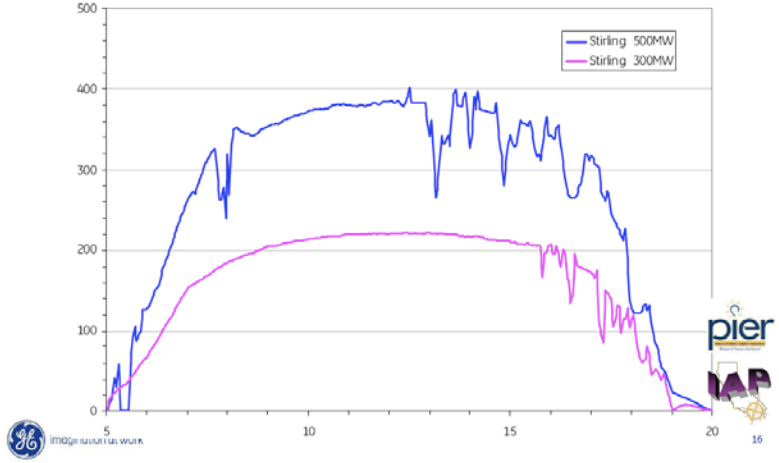
Example PV Solar Zip Code Profile for a July Morning



Example Concentrating Solar Project Profile for a May Day



Example Stirling Solar Project Profile for a May Day

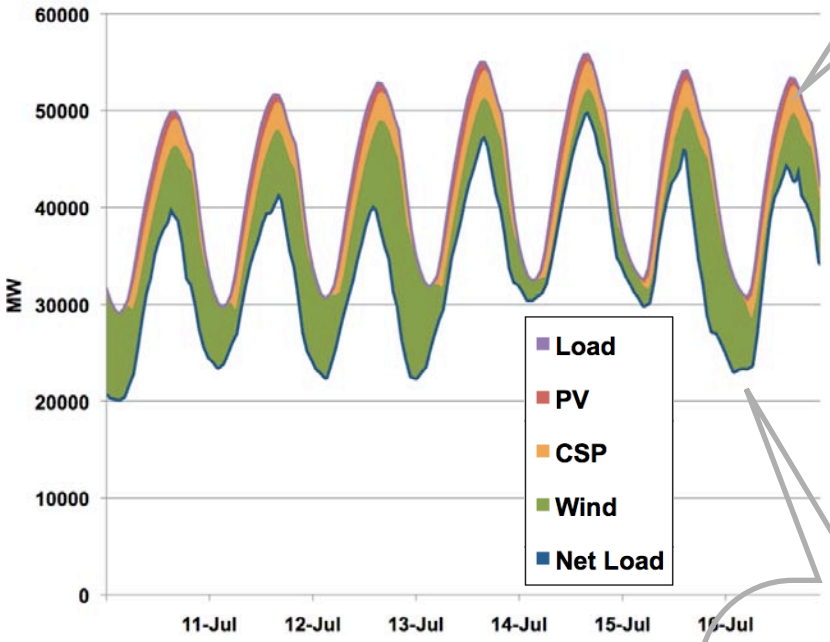


imagination at work

Source: CEC/GE 2007

How does the system operate with high penetrations of variable generation?

Mid-July



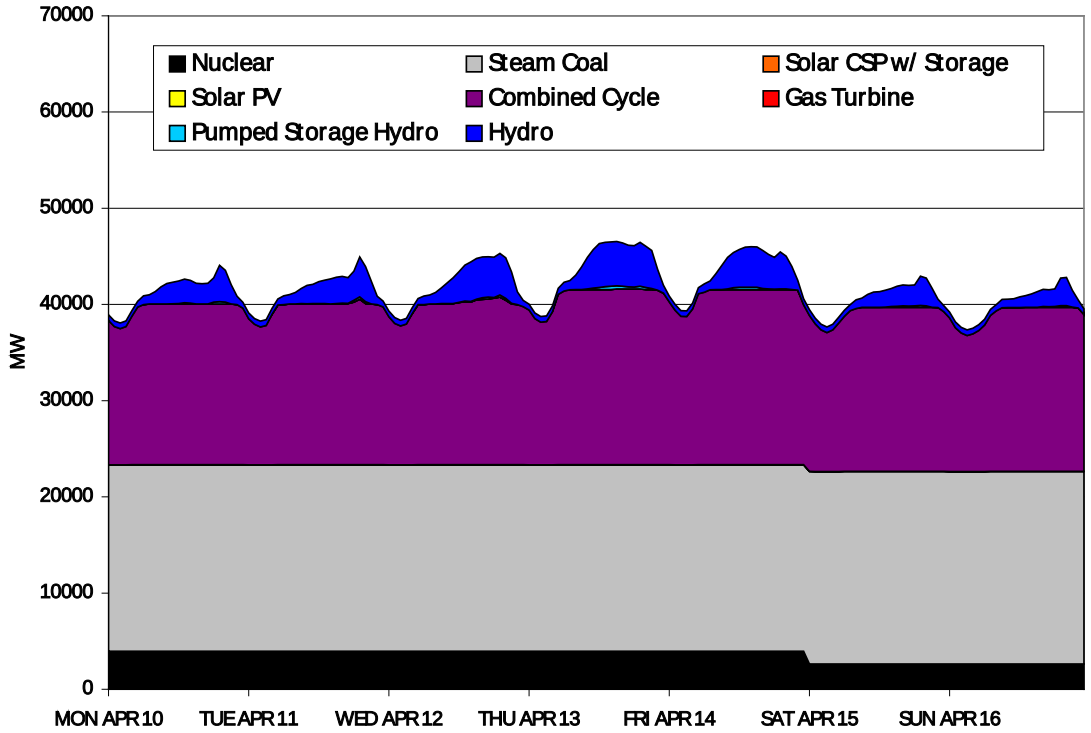
Load

The operator formerly managed to load but now has to manage the net load

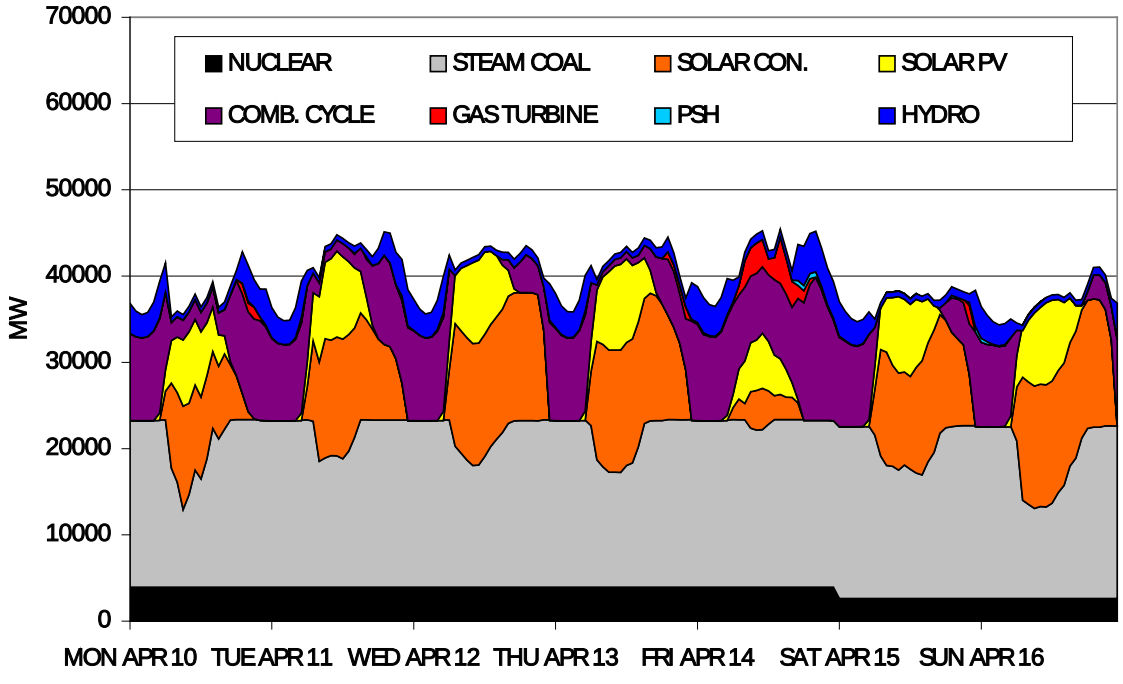
Net Load = Load - Wind - Solar

Source: GE/NREL - WWSIS 2010

Operations with high solar penetration



← No Solar

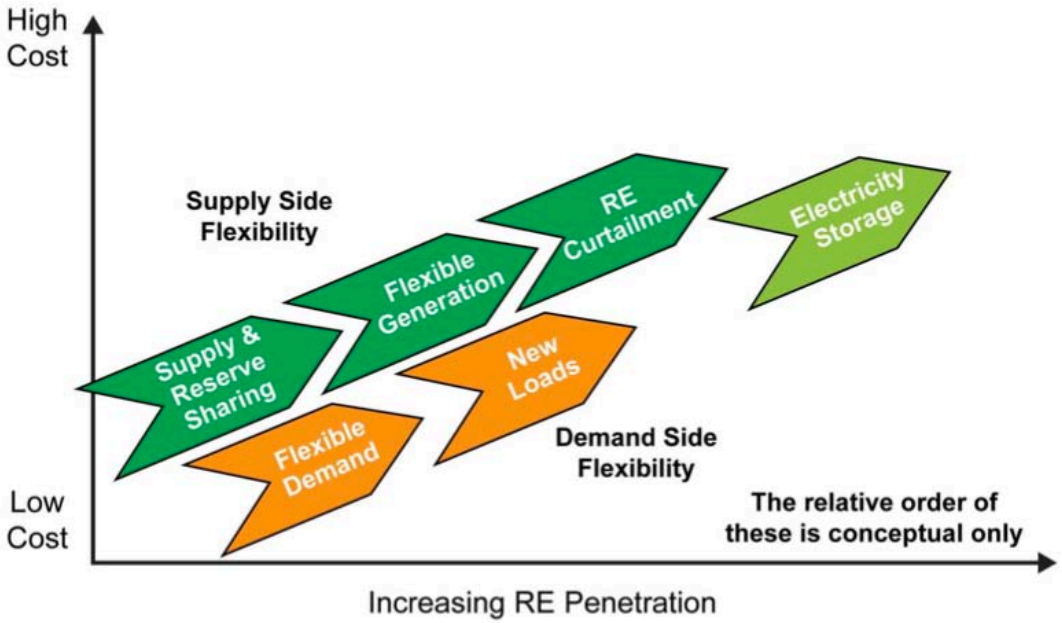


← 25% Solar in WestConnect
15% Solar in rest of WECC

Source: GE/NREL High Solar 2010

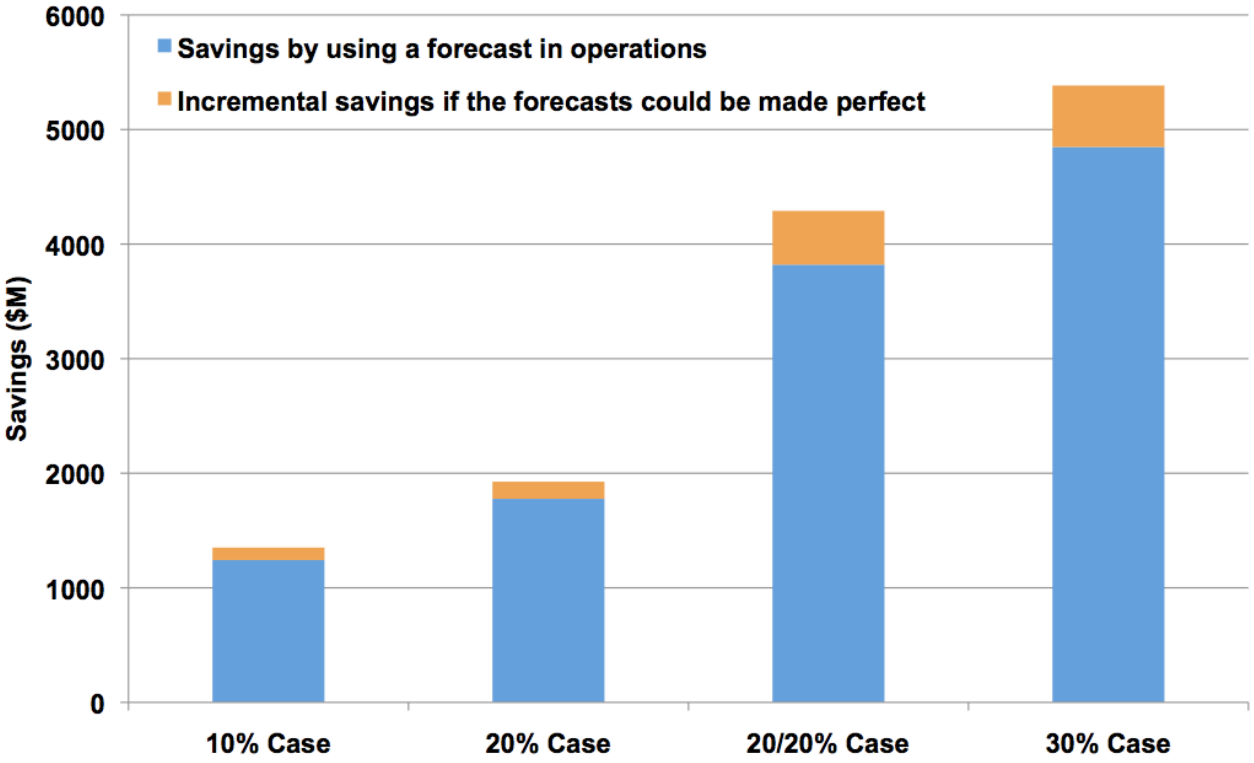
Utilities need more flexibility to accommodate high penetrations of solar

- Balancing Area cooperation
- Intra-hour scheduling of generation and interchanges
- Reduce self-scheduled generation
- Incorporate forecasting in operations
- Increased reserves
- Increased utilization of transmission; expand transmission
- Increased flexibility of dispatchable generation
- Demand response
- Storage



Source: DOE

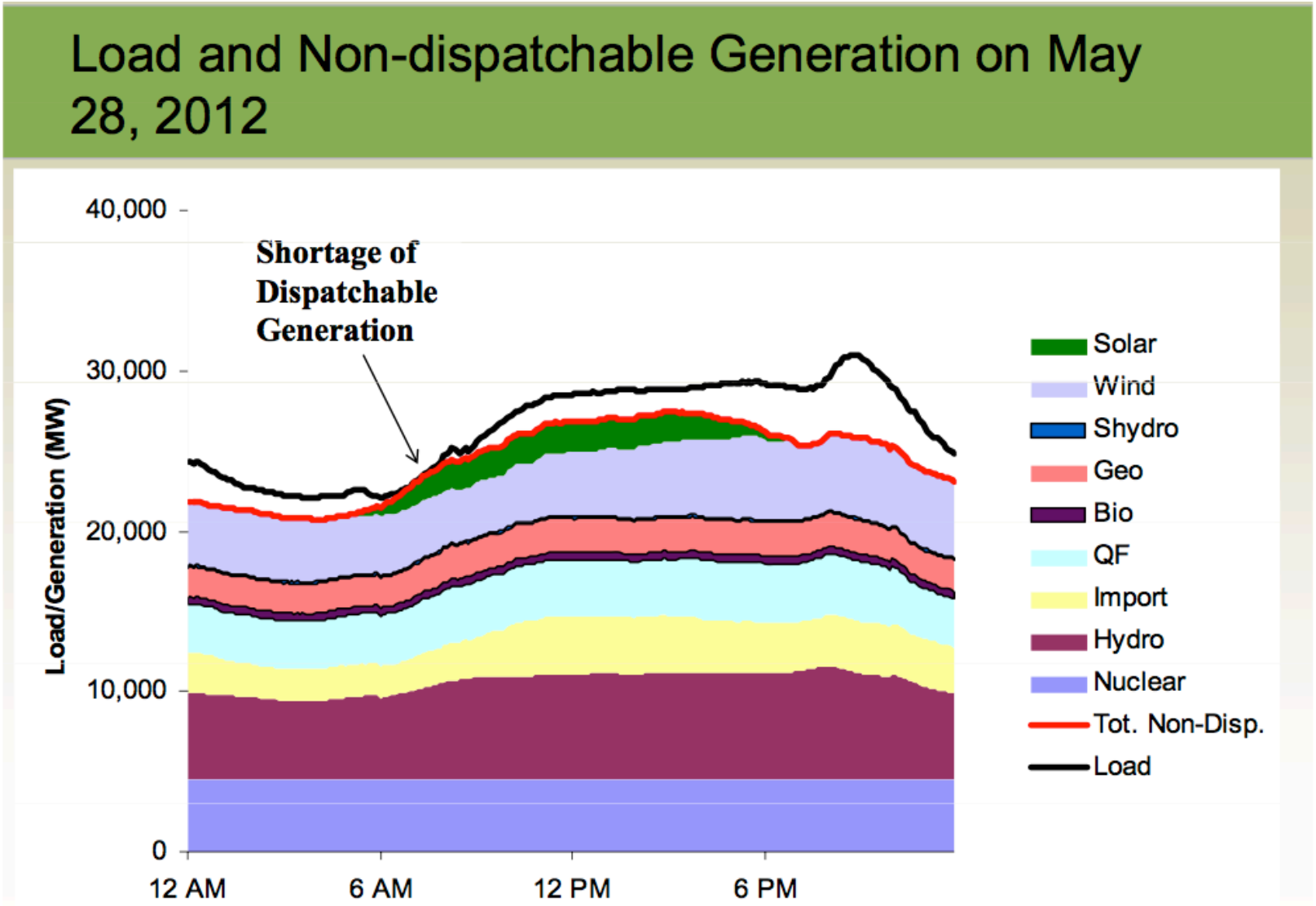
Using a forecast in operations saves money!



Using a forecast in operations saves up to 14%. If forecasts were perfect, an additional 1-2% could be saved.

Source: GE/NREL - WWSIS 2010

Need for flexibility: No ability to move down

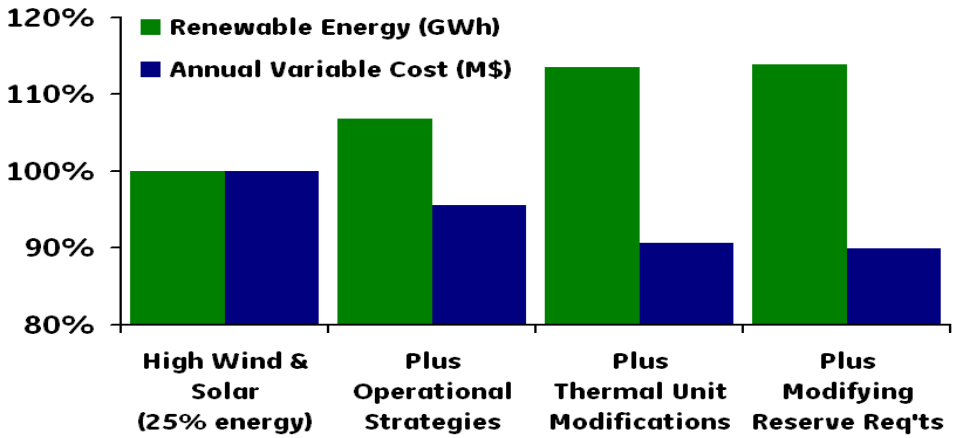


Source: CAISO 2010

Mitigation options that can decrease curtailment and utility operating costs

In Hawaii, various strategies were examined:

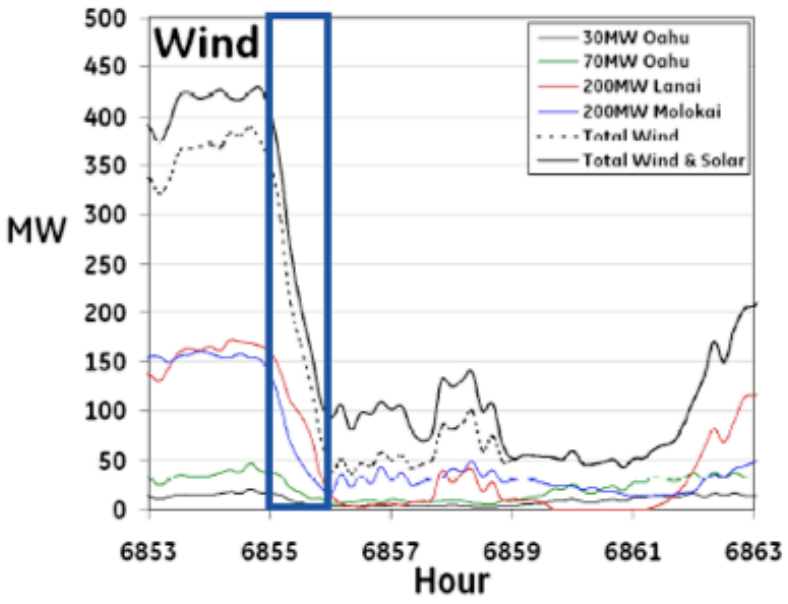
- Operational Strategies:
  - 4 hour ahead forecasting in commitment
  - Modify regulating reserve requirements based on forecast
- Thermal unit modifications
  - Reducing minimum power of baseload units
  - Seasonally cycle off some baseload units
- Modify reserve requirements
  - Reduce reserve requirements by using fast-starts and load control

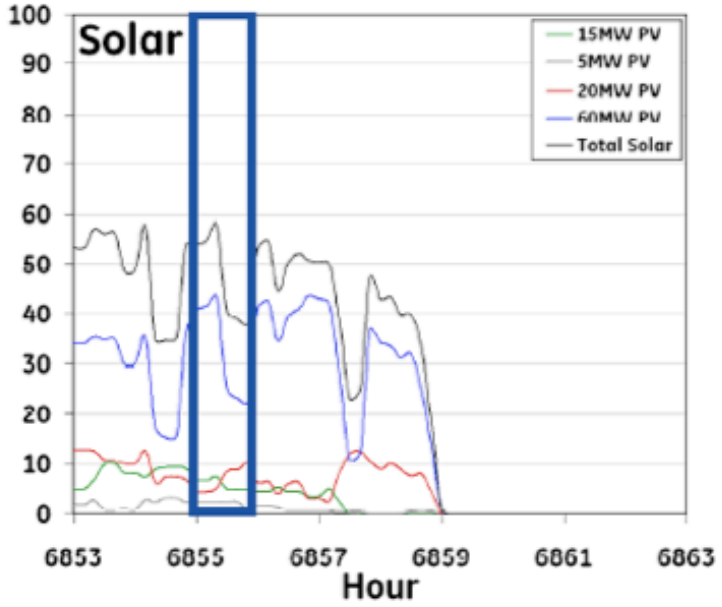


Source: GE/HECO/HNEI/NREL

Do you need more reserves?

- Contingency reserves (in case generator or transmission fails) – solar and wind ramps are not contingency events
- Operating reserves (load variability)
  - WWSIS finds demand response to be an attractive alternative to increasing reserves, and reserve up-margins to be higher with solar
  - CAISO finds self-scheduling to be a significant barrier
- Regulating reserves (small fast up-down changes in load)
  - CAISO finds need for additional regulation, up to 30-40% more in some seasons



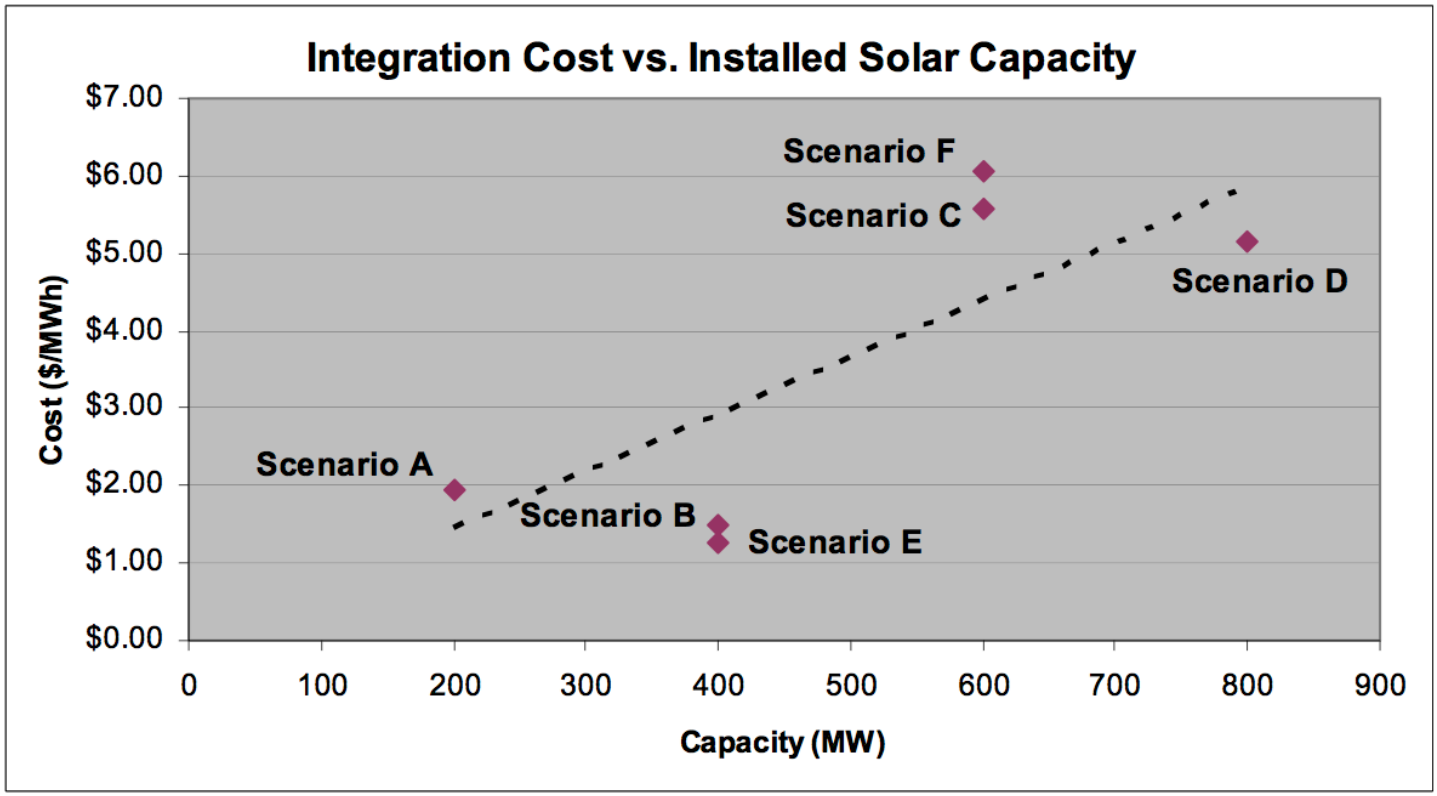


Source: GE/ HECO Hawaii

What does it cost to integrate solar into the grid?

Table 3: Summary of Solar Integration Costs in $/MWh for Base Case Gas Assumption

Scenario	Solar Nameplate Capacity (MW)	Solar Energy (GWh)	Integration Cost ($/MWh of Solar Energy)
A	200	626	1.96
B	400	1044	1.49
E	400	948	1.25
C	600	1484	5.58
F	600	1531	6.06
D	800	1944	5.15



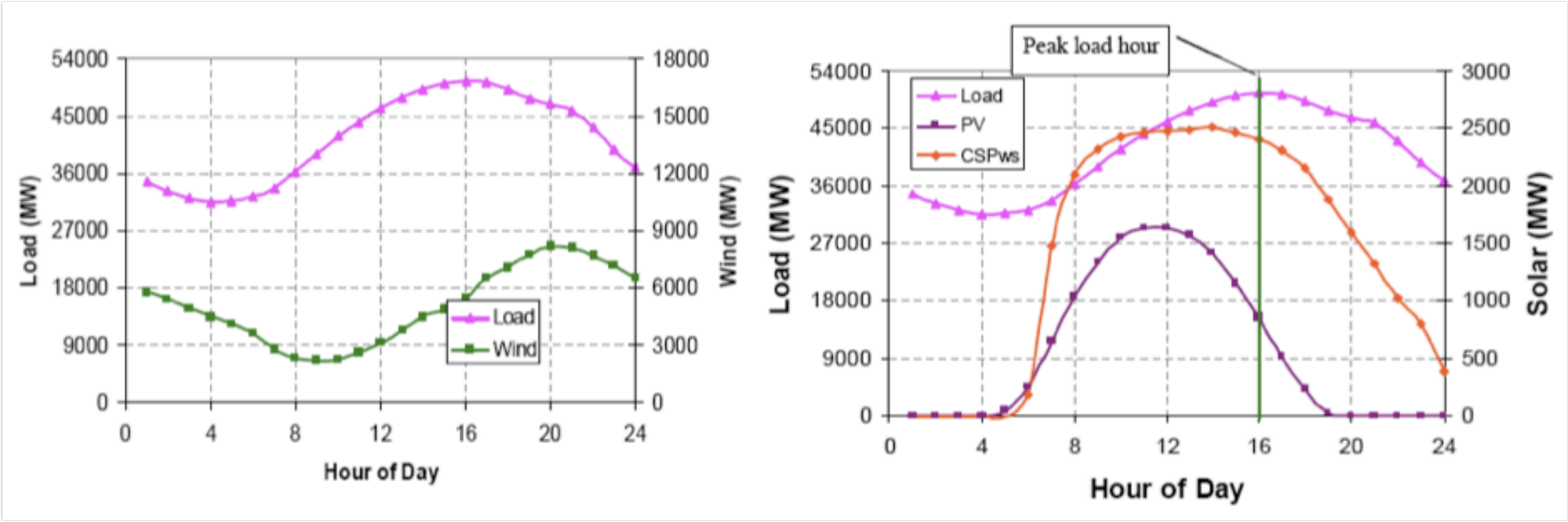
Xcel/Enernex 2009

How much capacity value does solar provide?

Wind: 10-15%

PV: 25-30% (based on DC rating)

CSP with storage: 90-95%



Source: NREL/GE WWSIS 2010

For more information

- Western Wind and Solar Integration Study: www.nrel.gov/wwsis For high solar case study – email debra.lew@nrel.gov
- CAISO 20%: www.caiso.com/2804/2804d036401f0.pdf
- CEC IAP: www.energy.ca.gov/pier/project_reports/CEC-500-2007-081.html
- Hawaii OWITS: to be published on NREL website
- Xcel/PSCO: email debra.lew@nrel.gov