# Western Wind and Solar Integration Study

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**Power Engineers Renewables Rendezvous**
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# Can we integrate 35% renewables in the West?

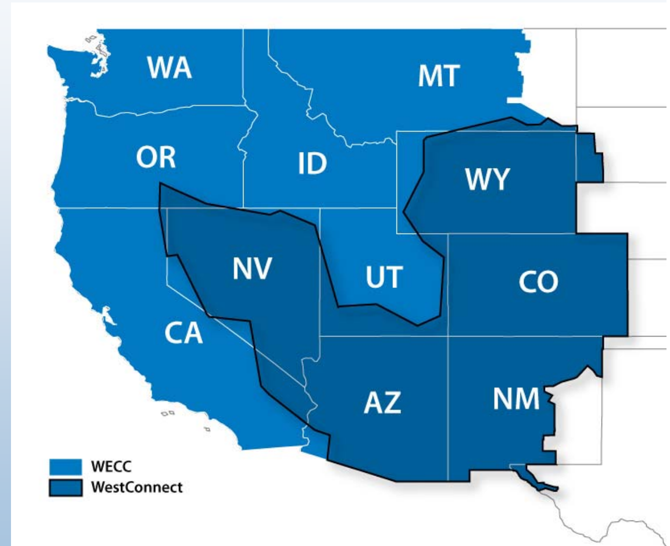
Goal - To understand the costs and operating impacts due to the variability and uncertainty of wind, PV and concentrating solar power (CSP) on the WestConnect grid

- How do local resources compare to remote, higher quality resources via long distance transmission?
- Can balancing area cooperation help manage variability?
- What is the role of storage?
- Increased reserve requirements?
- Geographic diversity – how much is there and does it help?
- How can hydro help?
- What is the value of forecasting?

# Footprint of Study
# WestConnect outside of CA

WestConnect is a group of transmission utilities that collaborate on cost-effective market enhancements

- Arizona Public Service
- El Paso Electric
- NV Energy
- Public Service Company of New Mexico
- Salt River Project
- Tri-State G&T
- Tucson Electric Power
- Xcel Energy
- Western Area Power Adm





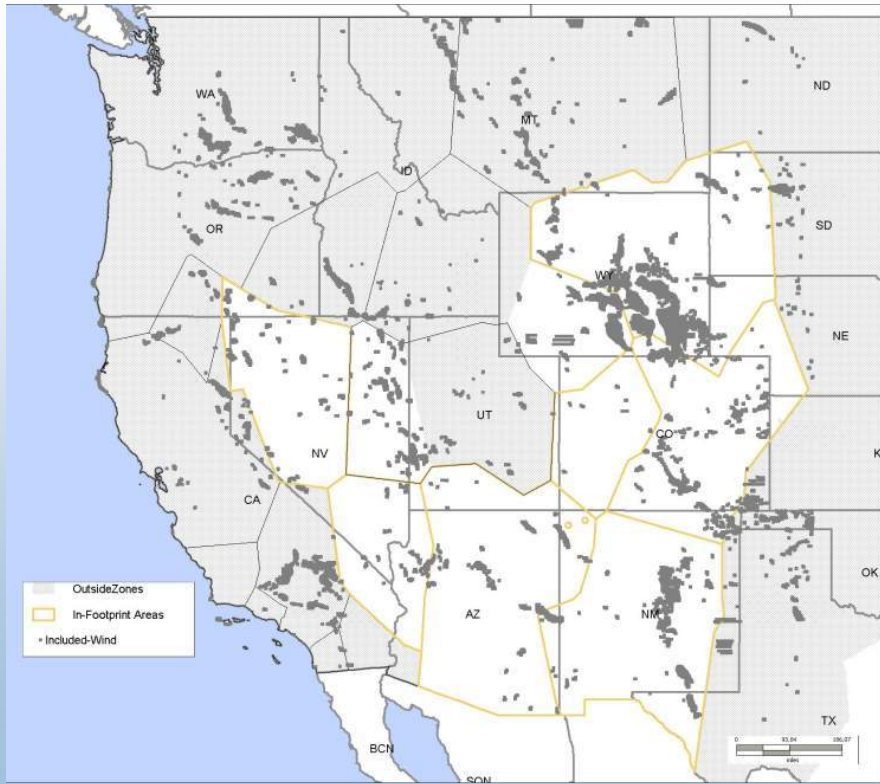

# Scenario Overview

| Name | In Footprint | | Rest of WECC | |
|---|---|---|---|---|
| | Wind | Solar | Wind | Solar |
| Preselected | Existing plants in 2008 | | | |
| 10% | 10% | 1% | 10% | 1% |
| 20% | 20% | 3% | 10% | 1% |
| 20/20 | 20% | 3% | 20% | 3% |
| 30% | 30% | 5% | 20% | 3% |

- Baseline – no new renewables
- In-Area – each state meets its target from sources within that state
- Mega Project – concentrated projects in best resource areas for maximum cost benefit
- Local Priority – Balance of best resource and in-area sites

Solar is 70% CSP and 30% distributed PV. CSP has 6 hours of thermal storage. Penetrations are by energy.

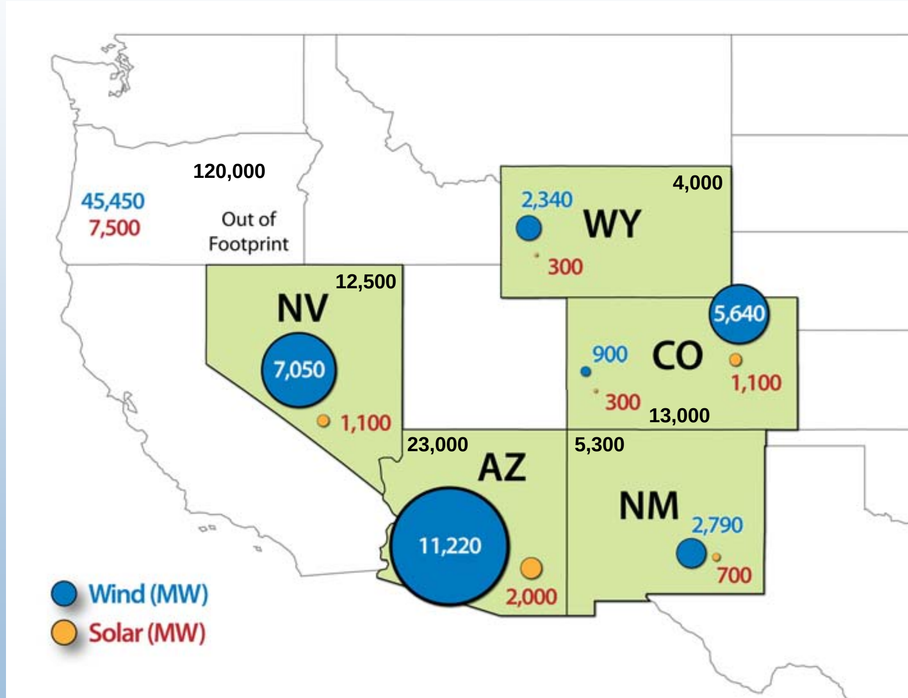
# Available Wind Sites





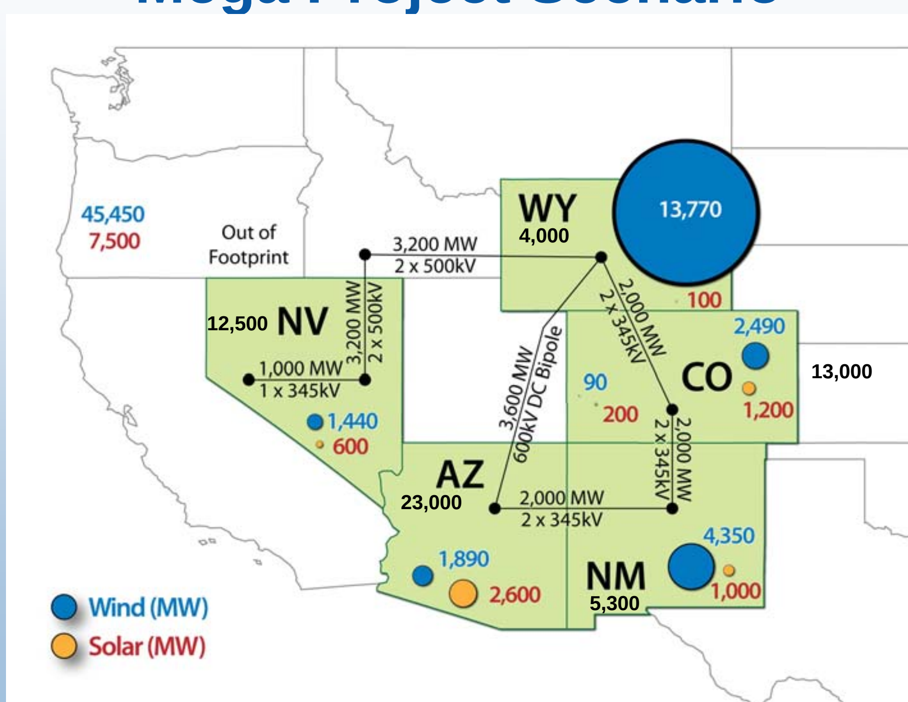

# Available Solar Sites

# 30% Wind + 5% Solar In Area Scenario

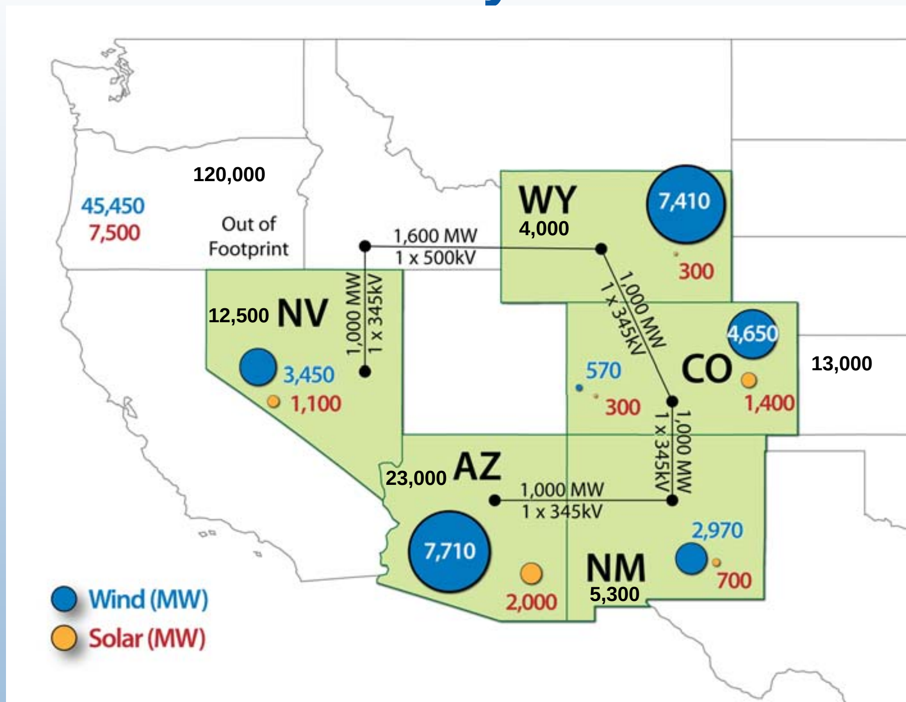





# 30% Wind + 5% Solar Mega Project Scenario



# 30% Wind + 5% Solar Local Priority Scenario






# What did we model?

- We don't expect 35% renewables by 2017 but needed a realistic baseline of the power system
- Modeled WECC power system for the year 2017 three times, with load and weather data from 2004, 2005, 2006
  - Important to use time-synchronous load and weather data to capture load/weather correlations
- Fixed targets for wind and solar energy independently

# Scope of this Study

***( and requisite disclaimers )***

- Main Focus . . . Is it technically possible to operate the system with 30% wind energy and 5% solar energy?
- Operational impact study, not a transmission planning study.
- Not a full cost-benefit analysis. Doesn't include capital cost of generation, but rather operational costs savings.
- Does not optimize the balance of generation to meet 2017 load, but rather assumes a business-as-usual portfolio expansion in addition to the renewables
- Economic commitment and dispatch of generators. Did not model bilateral contracts.
- Considered new inter-state transmission requirements, but not in-state expansions
- Operating costs included fuel, start-up costs, ,normal maintenance. Did not include costs due to increased wear and tear due to cycling of thermal units.

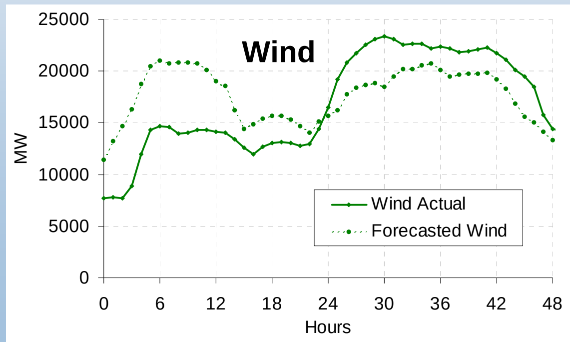


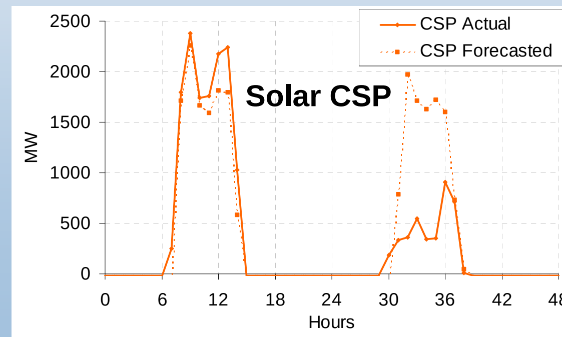
# Assumptions

- Extensive balancing area cooperation (significant focus of study)
- Economic commitment and dispatch of generators, while respecting transmission limits and generator cycling capabilities and minimum turndowns
- 2017 nominal dollars
- $2/MBTU coal, $9.5/MBTU natural gas
- $30/ton carbon cost
- Contingency reserves: 6% of load, half is spinning and half is non-spin
- Subhourly modeling is based on 5 min economic dispatch

# Variability and Uncertainty

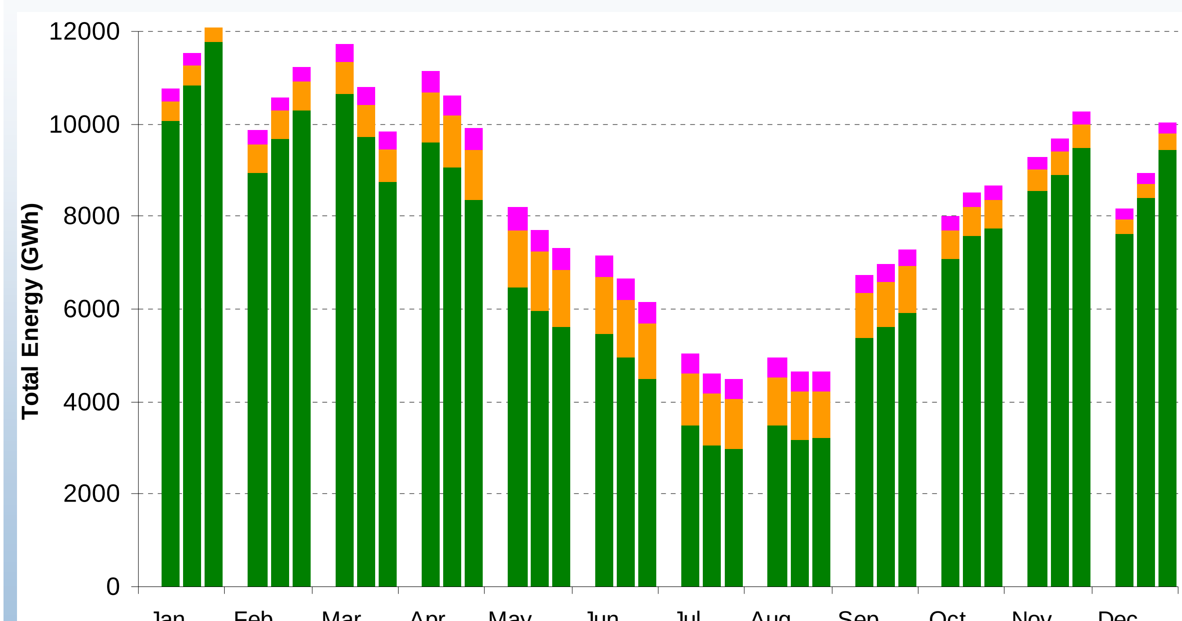
- **Variability:** Wind and solar generator outputs vary as the intensity of their energy sources (wind and sun)
  - Several timescales: minute (regulation), hour (ramping), diurnal, seasonal
- **Uncertainty:** Wind and solar generation are similar to “load”
  - Not dispatchable – output is predicted by a forecast
  - Actual power output is different that forecast output
- A perfect forecast eliminates **uncertainty**, but there is still **variability**



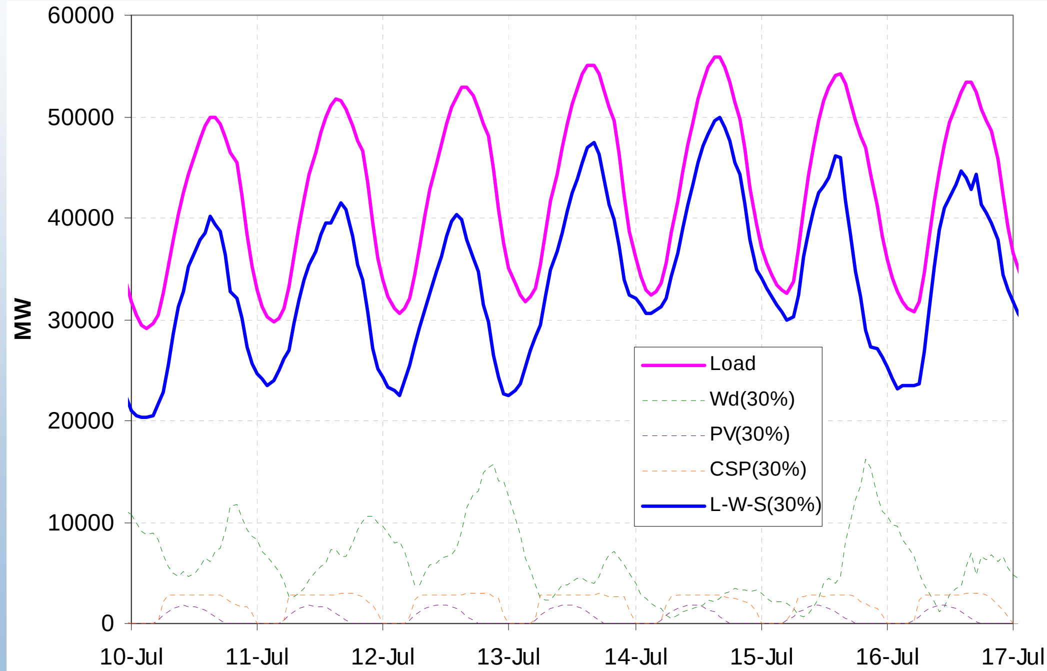



# Footprint Monthly Energy from Wind and Solar for all three Scenarios (30% Penetration Level)



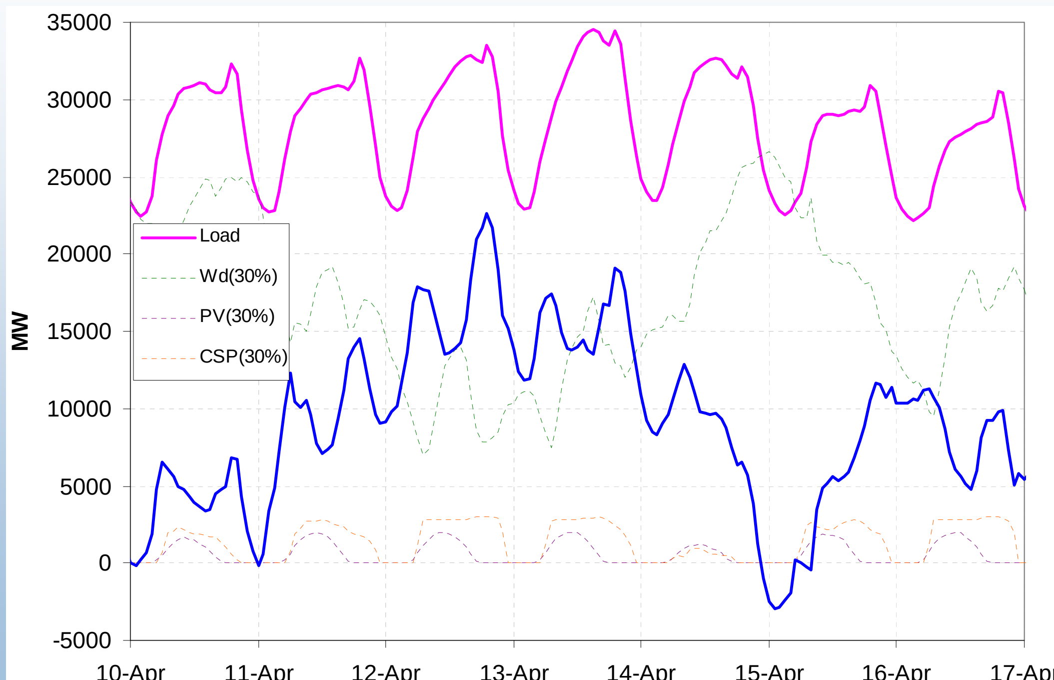

Much less difference in wind and solar energy between the scenarios than across months

## Study Footprint Total Load, Wind and Solar Variation Week of July 10th (30% IA Scenario)



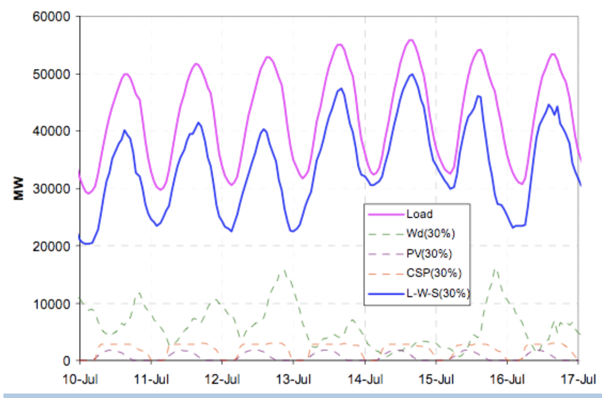



## Study Footprint Total Load, Wind and Solar Variation Week of April 10th (30% IA Scenario)

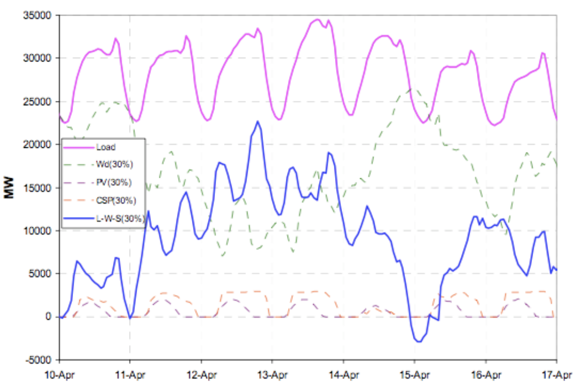


# How does the system operate with 35% renewables?

## July 2006 – a tame week



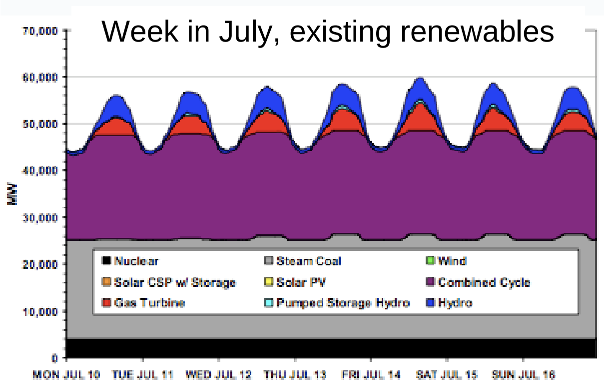

## April 2006 – the "worst" week of 3 years

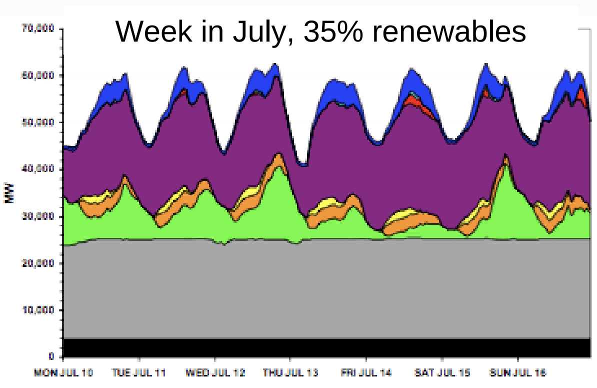


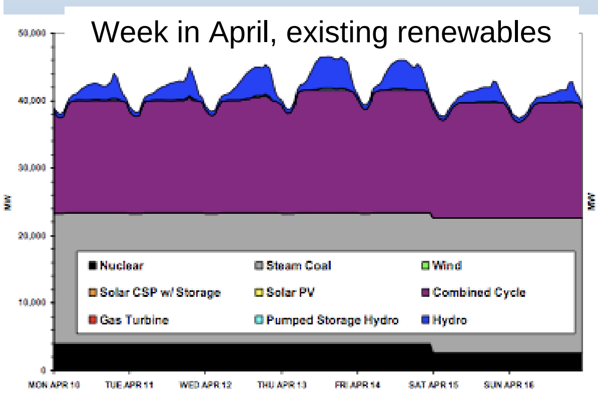

**The operator formerly had to manage the pink load trace, but now has to manage the blue net-load trace**

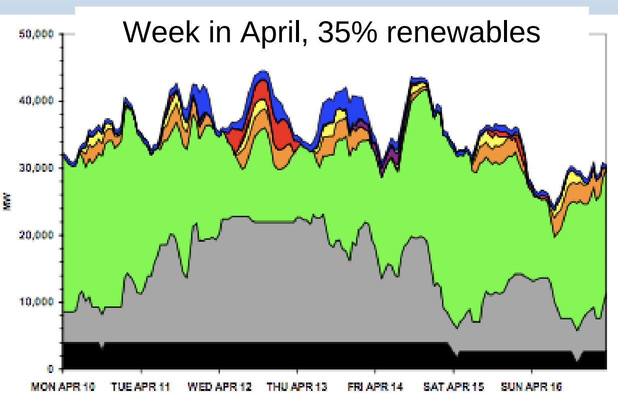


# Operations during these weeks



# Key Findings

- We find it feasible for WestConnect to accommodate 30% wind and 5% solar
- What makes this possible?
  - Extensive balancing area cooperation
  - Subhourly economic dispatch
- What factors have a large impact on the economics of accommodating wind and solar?
  - Renewable energy penetration in the *rest of WECC* significantly affects performance and economics
  - Operating costs increase with more hydro/coal plant constraints
  - Use of forecasts in unit commitment
- How often is wind curtailed?
  - Curtailment is due to uncertainty in the wind forecast. At 30% wind, less than 0.5% of wind (800 GWh) was curtailed

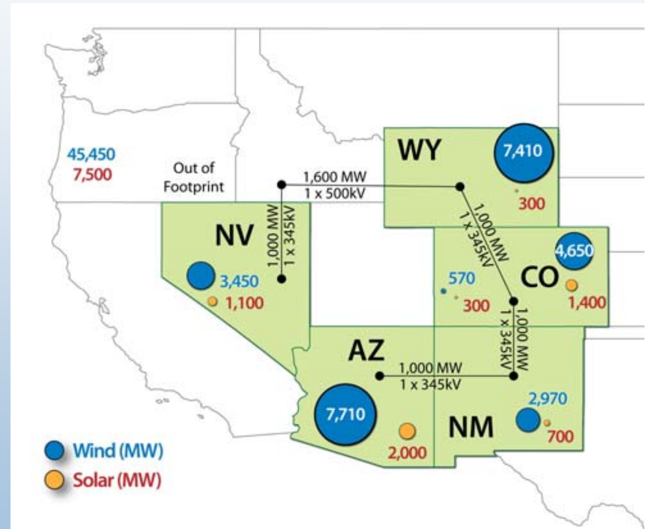


# Do we need storage or increased reserves?

- Load is always met but there are contingency reserve violations if we use the WECC rules of 6% of load
  - To meet the contingency reserve shortfalls, demand response is a lot cheaper than holding more operating reserves for every hour of the 8760 hours of the year
- Net load variability reserves are estimated at 1-5% of online wind production (not nameplate capacity). Cost of increased reserves is less than $1/MWh (of renewable energy).
- We find slightly higher use of existing storage. Additional storage is not justified based solely on price arbitrage. Did not examine the economics of storage for reserves.
- Further analysis of reserves would be beneficial

# Do we need to build more transmission?

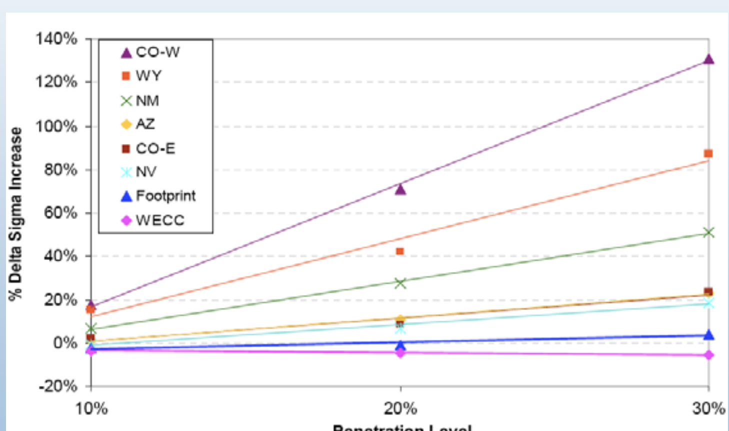
- Absolutely need some new inter-area of transmission to bring renewable resources to load.
- Could start integrating lower penetrations of renewables in the Local Priority scenario while long distance interstate transmission is being built, provided there is open access and full utilization of existing transmission.

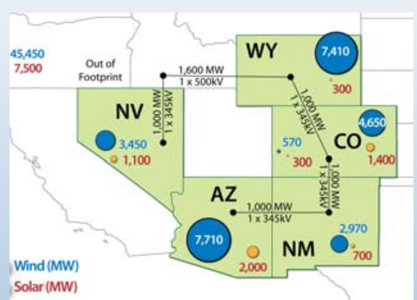





# Balancing Area Cooperation is Essential

- Aggregating diverse wind and solar resources over larger areas reduces variability
- Aggregating load over larger operating areas means more balancing resources



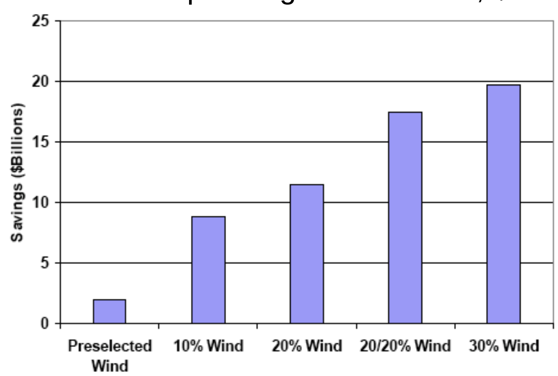




*Plot shows net-load variability as % increase over load-only variability, for increasing penetration of wind generation*

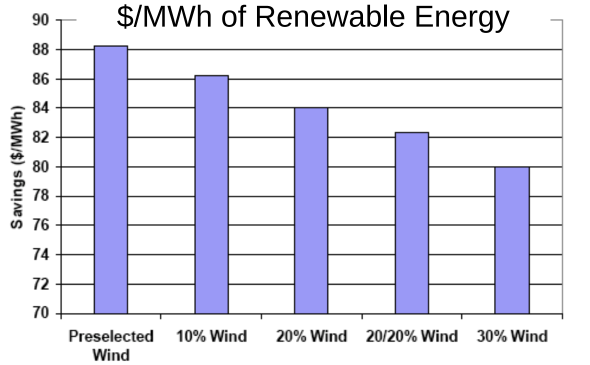
**WECC can save $2B by allocating spinning reserves over 5 regions rather than 108 BAs**

# What are some of the benefits of 35% renewables?

Total Operating Costs Saved, $B




Operating Cost Savings in $/MWh of Renewable Energy



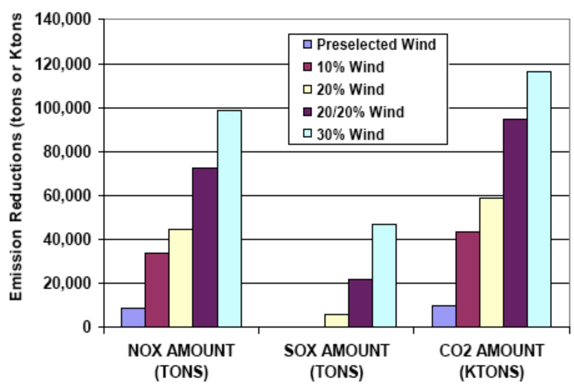

**WECC saves 40% in annual operating costs (fuel and emissions)**

**This does not include any capital costs.**
**Some cost savings would be used to recover capital costs.**
***(2017$ with $9.5/MBTU gas and $30/ton CO2 assumed)***

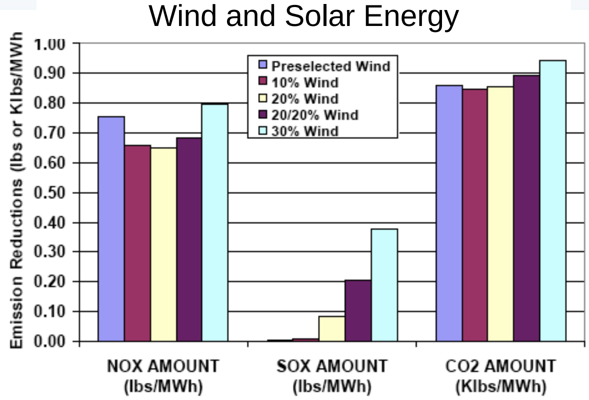


# Emissions reduction benefits

Total Emissions Reductions in WECC



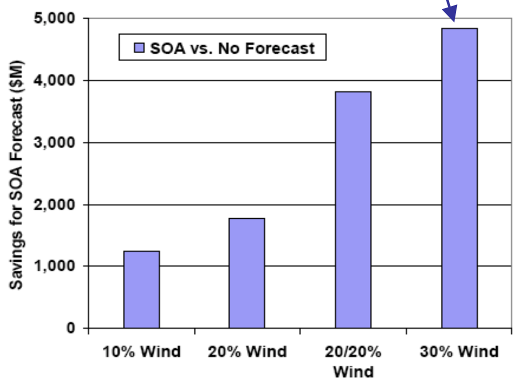

Emissions Reductions per MWh of Wind and Solar Energy



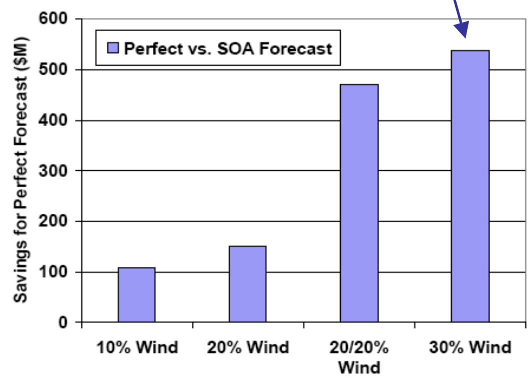

**Assuming $9.5/MBTU gas, renewables mostly displace gas. Coal starts to be displaced at higher penetration levels.**

# Incorporation of state-of-the-art wind power forecasts is essential

Nearly $5B/yr savings in WECC when using SOA forecast for day-ahead unit commitment




Over $500M/yr additional savings possible if day-ahead forecast was perfect



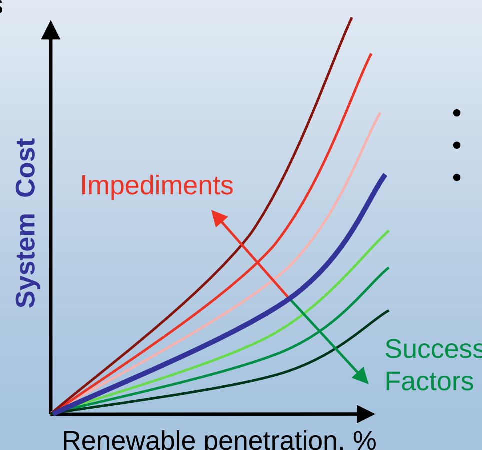

**State-of-the-art wind forecasts reduce WECC operating costs by $12-20/MWh of wind energy. Perfect forecasts reduce that by an additional $1-2/MWh.**



# Lessons Learned ...

**Impediments**
- Lack of transmission
- Lack of control area cooperation
- Inflexibility due to market rules and contracts
- Unobservable Distributed Generators (DGs)
- Inflexible operation strategies during light load & high risk periods

**System cost**
- Unserved Energy
- RPS miss
- Higher COE
- Higher Emission
- Higher O&M




**Success factors**
- Forecasting
- Thermal fleet
  - Higher quick starts
  - Deeper turn-down
  - Faster ramps
- More spatial diversity
- Grid-friendly renewables
- Ancillary services from
  - Renewable generation
  - Demand response
  - Distributed generation

# Questions?

- Final report is being prepared and will be available in April
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