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# Integrating High Penetrations of Solar in the Western United States

## Results of the Western Wind and Solar Integration Study Phase 2

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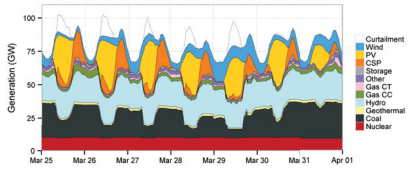
## STUDY OVERVIEW

**Objective – To examine costs of cycling, emissions impacts of cycling, and compare wind and solar impacts**

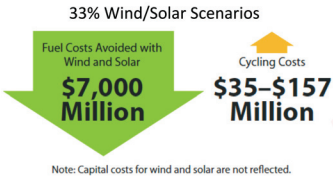
- **Modeled the western grid based on transmission planning models and methodologies of the Western Electricity Coordinating Council**
- Results are specific to the grid and generator characteristics of the West
- **Examined grid operations; not a transmission planning study**
- **Used commercial software PLEXOS to model grid operations on 5-minute basis for year 2020**
- **Scenarios examined ~100,000 MW of wind and solar**
  - All wind and solar is sited in U.S. portion of Western Interconnection. 2020 peak Western Electricity Coordinating Council load is 171 GW, of which 147 GW is in the United States. Concentrating solar power has 6 hours of storage

## HIGH SOLAR (25% SOLAR, 8% WIND)



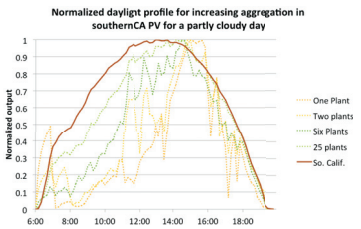

- Spring is most challenging for grid operations. Solar leads to coal rampdowns
- Solar is 60% photovoltaic and 40% concentrating solar power with 6 hours thermal storage

## FROM A SYSTEM PERSPECTIVE, CYCLING COSTS ARE RELATIVELY SMALL



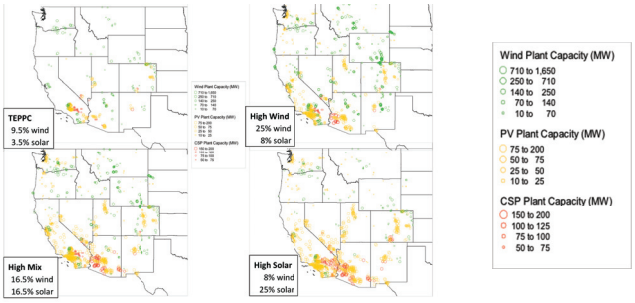

- The average fossil-fueled plant sees an increase in O&M costs of $0.47 to $1.28 per MWh of fossil-fueled generation
- Cycling reduces production cost savings by $0.14 to 0.67 per MWh of wind/solar

## PV AGGREGATION REDUCES VARIABILITY

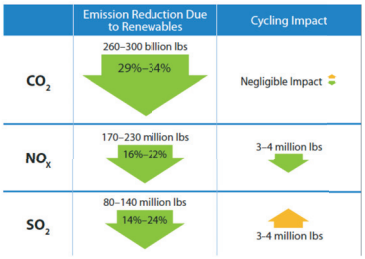



With a larger number of PV systems spread out geographically, variability due to cloud cover is reduced. Variability from sun movement is dominant.

## SCENARIOS COMPARE WIND AND SOLAR




## EMISSIONS IMPACTS OF CYCLING ARE RELATIVELY SMALL




- Wind- and solar-induced cycling can increase or reduce emissions from a fossil-fueled plant, depending on plant type, wind/solar mix, and penetration

## SOLAR REQUIRES LESS RESERVES THAN WIND

| Scenario | Contingency (MW) | Regulation (MW) | Flexibility (MW) |
|---|---|---|---|
| No Renewables | 3,361 | 1,120 | 0 |
| TEPPC | 3,361 | 1,158 | 1,193 |
| High Wind | 3,361 | 1,236 | 2,599 |
| High Mix | 3,361 | 1,211 | 2,035 |
| High Solar | 3,361 | 1,207 | 1,545 |

**Contingency reserves are unchanged with wind/solar**
**High Wind/Solar requires up to 10% more regulating reserves than the No Renewables Scenario**
**High Wind Scenario requires flexibility reserves of 3% of installed wind/solar capacity. This is reduced to 1% for the High Solar Scenario**

## CONCLUSIONS

- **Emissions induced by cycling are much smaller than benefits**
  - Wind- and solar-induced cycling can increase or decrease emissions from a fossil-fueled plant, depending on plant type, wind/solar mix, and penetration
- **Wind and solar increase cycling costs by $35M/yr to $157M/yr**
  - From fossil-fueled perspective, cycling O&M increases by $0.5 to $1.3 per MWh of fossil-fueled generation
  - From system perspective, cycling reduces production cost savings by $0.14 to $0.67 per MWh of wind/solar
- **Wind and solar impact fossil-fueled plants differently but production cost savings is similar**
  - High Solar case leads to more ramping of coal plants; requires fewer reserves than High Wind case
  - Solar variability from cloud cover is smoothed with aggregation of dispersed systems; PV variability dominated by sun movement
  - Reduced curtailments with a balance of wind and solar on system
- **As with any analysis, conclusions are specific only to grid footprint studied**

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