

Characteristics of Wind and Solar Power

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Renewable Electricity Generation in the U.S.

Operating Wind Farms

Wind farms > 5 MW



Land use can be benign



Or, Not so Benign









Wind sometimes fails for many days



BPA Balancing Authority Total Wind Generation





15 Days of 10-Second Time Resolution Data

10

Smoothing by Adding Wind Farms ... has diminishing returns



Source: Katzenstein, W., E. Fertig, and J. Apt, The Variability of Interconnected Wind Plants. Energy Policy, 2010. **38(8)**: 4400-4410.



Hydroelectric Power has Droughts





Wind Probably Does Too



Source: Katzenstein, W., E. Fertig, and J. Apt, The Variability of Interconnected Wind Plants.

Energy Policy, 2010. 38(8): 4400-4410.

Operating Solar PV

Units > 5 MW



Comparison of Wind with Solar PV 4.6 MW TEP Solar Array (Arizona)

(b)

1250

750

Minutes



3000

1000

0

250

≥ 2000





January 2004 – December 2005

CO₂ and NO_x from natural gas that fills in



Emissions Factors



20



Final Comments

None of this means that wind or solar (if costs ever come down) can't be used at large scale, but wind/solar will require a portfolio of fill-in power (some with very high ramp rates, some with slow), good land use planning, and R&D to optimize emissions control for fast and deep ramping.



Thank you

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