Integration of Renewable Energy in Wholesale Markets

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Setting the policy context

- Most (2/3) of capacity coming online in 2019 is wind (11 GW) and solar (4 GW)

- Policy drivers include renewable portfolio standards, tax credits (though phasing out), net metering allowances, average cost retail pricing

- Intermittency adds uncertainty to demand for dispatchable plants

- Even with certainty, duck curve results in fast ramping of technologies designed for baseload uses

- Limited penetration of real time pricing or battery and other storage options beyond hydro

U.S. electric capacity additions and retirements, 2019 gigawatts (GW)

planned additions (24 GW): other, 2%; solar PV, 18%; wind, 46%; natural gas, 34%
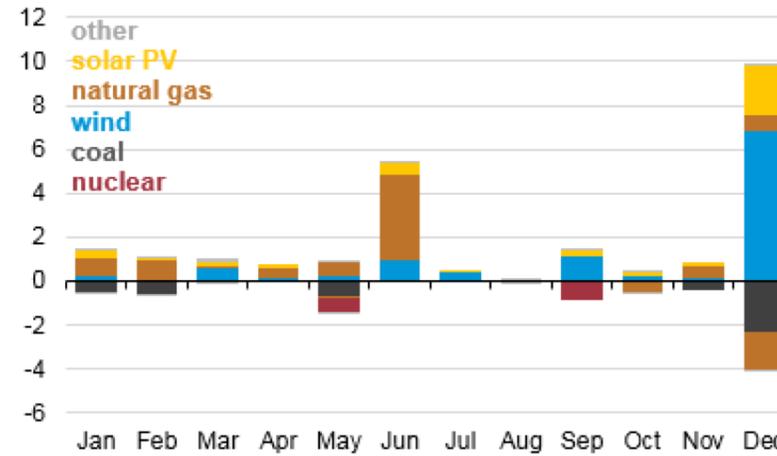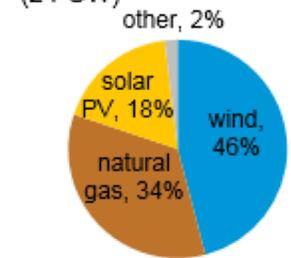
planned retirements (8 GW): nuclear, 18%; other, 2%; coal, 53%; natural gas, 27%
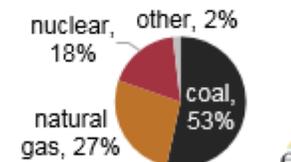
California Independent System Operator Duck Curve[1]

Net load - March 31

Ramp need ~13,000 MW in three hours

Overgeneration risk
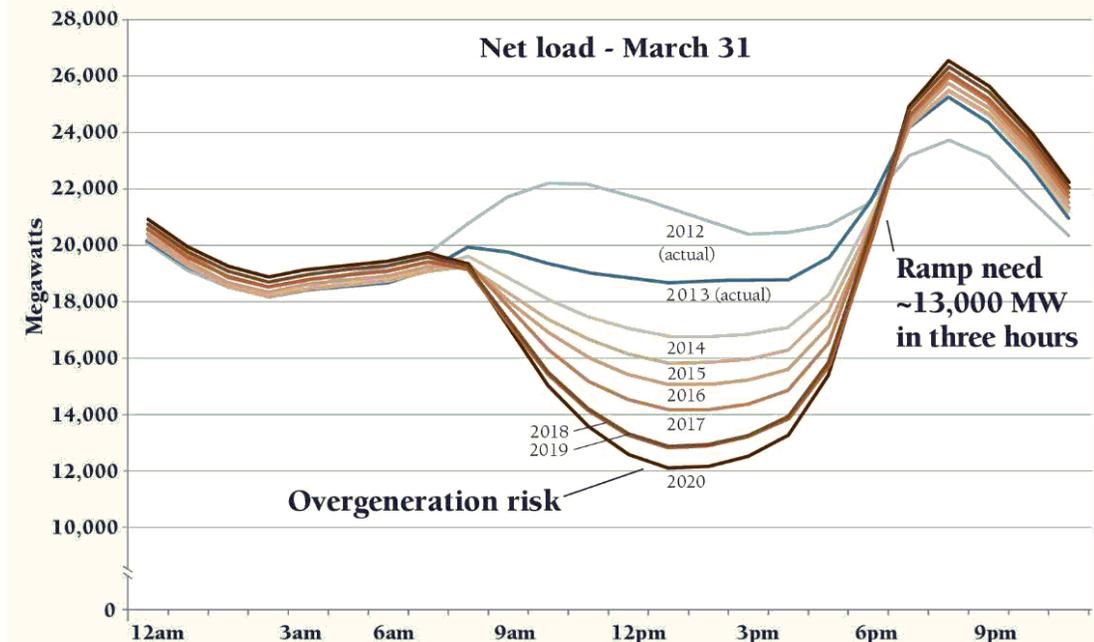
Rooftop Solar Penetration and the Spillovers to Gas-Fired Generator Efficiency in Western Australia

- Western Australia has 2.5 million people

- The grid has seen a large penetration of solar PV in recent years

- Fuel prices are falling and renewables are rising, yet electricity prices are flat

- This paper shows that fuel costs have increased and that margins are up.

Rooftop: comments

- Is there a literature on market power in Western Australia? More details on the market would be helpful.

- Consistent story? Baseload earning higher profits, but not worth it for them to start up because of low daytime prices?

- Gas prices down in 2017? Thought that LNG was driving UP gas prices

- Equation 1 controls for output from gas and coal. Endogeneity concern. Instrument with temperature (like in Fabrizio, Rose and Wolfram).

- Equation 1 key variable is always increasing (solar capacity not generation) so correlated with time trends. Not easy to identify as not have a control group.

Adjustment on the Margin: Evaluating Emissions Reduction Policies in the Face of Short-Run Adjustment Costs

- Power plants face issues of unit commitment like ramp rates, startup costs, minimum down time, etc.

- This paper uses machine learning techniques to examine how power plant operations, and therefore emissions, are a function of current load but also realized past load and future expected load.

- For example, low expected load in one hour results in a plant not starting up. This limits its ability to produce in the next hour

- This paper uses estimates to measure the benefits of renewables and battery storage and finds that ignoring ramping can change the environmental implications of storage

Adjustment on the Margin: Comments

- Dynamics/unit commitment problem
  - Cullen (2013) – Wind in ERCOT on power plants operations. Controls for lags of demand and wind
  - Novan (2015) – Relatedly, finds no notable difference when controlling for these dynamics vs static model in ERCOT
  - Mansur (2008) – Measuring production inefficiencies in restructured markets
- California estimates
  - Paper discusses the market at CAISO sometimes but WECC others.
  - If CAISO, then need to model imports from the rest of the WECC
- Linear model
  - More on intuition of negative coefficients on ramping
  - Concern that past ramp and future ramp highly correlated. Coefs opposite signs most hours
- Machine learning
  - Some estimates control for ramping but not for fixed effects that proxy for fossil entry & exit, renewables, fuel prices, seasonality, etc.
  - When are we sure that there is no omitted variable bias in these models?

General questions

- How does renewable penetration affect grid reliability?

- How does renewable penetration affect the costs of ancillary services?

- How does renewable penetration affect the non-fuel operating and maintenance costs? They may have become worse as plants ramp up and down more.
  - One estimate is that these NFOM costs (per MWh) doubled in California from 2006 to 2016