The Renewable Energy Integration Challenge: Mitigation Options

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NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.
Overview

• What challenges do higher penetrations of wind and solar pose for grids?
• How much wind/solar can be integrated?
• What solutions are available to address variable nature of wind, solar?
• What are the costs of integration?
• What can policymakers do?
Renewable Energy Integration Challenges

Variability and Uncertainty

- **Load varies each minute**
- **Wind, solar add to variability**
  - output not always available
  - daily or seasonal patterns
- **Wind and solar are uncertain due to weather changes**
  - Solar has predictable daily pattern, but cloud cover changes rapidly
  - Winds can be stronger at night and in winter

**PV Output 1 Plant versus Large Number of Plants**

Source: WWSIS-2 (2013)
Variability Smoothed Over Wide Area

Variability is reduced with more wind or solar plants and spread over a wider area

Source: NREL Wind Plant Data

(Approximately 8 hours)
How much wind/solar can be accommodated?

- No physical limit found in studies... it depends on system, operations and economics
- Regional integration studies show up to 35% RE can be integrated
  - if adequate transmission
  - operational changes can provide additional flexibility

Sources: Eastern Wind Integration and Transmission Study, Jan 2010; Western Wind and Solar Integration Study, Mar 2010
What Does More Variability Mean for Power Systems?

• More flexible reserves are needed to balance load & generation each day
  o each wind plant does not need to be backed up by a conventional plant
  o reserves are managed for the whole system; existing units can be used
  o sometime wind increases (or decreases) with load, which helps the system

• Conventional power plants may need to be ramped up and down or cycled on and off more

Source: NREL
Fossil Plant Cycling and Emissions Impacts

- **Wind and solar can affect dispatch of fossil plants** (starts, ramps or plants run at part load)

- **Wind- and Solar-Induced Cycling Can Have a Positive or Negative Impact on Emissions**

- **System-wide impacts of cycling in West:**
  - Negligible impact (<0.2%) on CO₂ benefit
  - Improves NOₓ benefit by 1%–2%
  - Lessens SO₂ benefit by 2%–5%

Source: WWSIS-2 (2013)
How Can Systems Handle More Variability?

- **Improved institutional flexibility**
  - Faster energy markets
  - Shorter intervals for transmission scheduling
  - Balancing over a large geographic area to net out variability
  - Advanced forecasting techniques
  - Better utilize existing transmission capacity

- **A more flexible generating fleet**
  - Modify existing plants to improve start-up time, ramp rate, and lower minimum operating load
  - New flexible generating plants

- **Demand response**
  - Some loads can respond rapidly (up and down) with automation

- **Adequate transmission**

- **Energy storage**
  - ex., pumped hydro, batteries, compressed air, electric vehicles

Source: U.S. DOE
Flexibility Options: Costs Vary

Each power system is different: solutions vary

Source: NREL
What are the Costs of Integrating RE?

- Integration costs are difficult to calculate
- Some entities have estimated costs
- Costs can be reduced with forecasting and operational changes
- Most generation sources have costs with integrating them on the grid (e.g., nuclear ramping limitations)

<table>
<thead>
<tr>
<th>Year</th>
<th>Study</th>
<th>Wind Capacity Penetration</th>
<th>Integration Cost ($/MWh)</th>
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<tr>
<td></td>
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<td>Regulation</td>
<td>Load Following</td>
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<tr>
<td>2003</td>
<td>Xcel-UWIG</td>
<td>3.5%</td>
<td>0</td>
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<tr>
<td>2003</td>
<td>We Energies</td>
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<td>Xcel-MNDOC</td>
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<td>PacifiCorp-2004</td>
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<tr>
<td>2010</td>
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<td>63%</td>
<td>-</td>
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</table>

Source: LBNL Wind Market Report
Options for Cost-Effectively Integrating Wind/Solar

Operational and market tools, flexible demand and supply side resources

1. Improve wind and solar forecasting
2. Encourage geographic diversity of resources
3. Retool demand response to complement variable generation
4. Access greater flexibility in the dispatch of existing generating plants
5. Focus on flexibility for new generating plants
6. Expand subhourly dispatch & scheduling
7. Implement an energy imbalance market

WGA Report: Meeting Renewable Energy Targets at Least Cost: The Integration Challenge
http://www.westgov.org/
Improve wind and solar forecasting

- Forecasting helps utilities and grid operators anticipate the amount of renewable energy generations – reduces uncertainty
- Advanced forecasting improves scheduling of other resources to reduce reserves, fuel consumption, and operating, maintenance costs
- Substantial cost savings and reduction in integration costs:
  - Xcel Energy found that 1% improvement in forecast error saved $800k (PSCO)

Policy and regulatory options:

- Encourage expanded use of wind, solar forecasting by utilities and balancing areas
- Encourage regional forecasts or exchange of forecasts among balancing areas
- Encourage forecasting improvements

Source: Alstom 2010.
Increase Flexibility of Generation

- Access greater flexibility in the dispatch of existing generating plants
  - Some plants can be retrofitted to increase flexibility by lowering minimum loads, reducing cycling costs and increasing ramp rates.
- Focus on flexibility for new generating plants
  - Requires rethinking resource adequacy analysis to reflect the economic benefit of flexibility service
  - Changes to resource planning and procurement frameworks

Policy and Regulatory Options
- Conduct a flexibility inventory for existing resources
- Analyze the potential for retrofitting less flexible generating plants
- Review incentives/disincentives for plant owners to invest in increased flexibility
- Examine and amend guidance for evaluating flexibility needs in utility resource planning
- Use competitive procurement processes to evaluate alternative flexible capacity solutions
Encourage Geographic Diversity

Geographic diversity reduces variability

- Variations in output from wind and solar plants are reduced over a large area
- Diversity lowers aggregate variability and forecast errors, reducing reserves needed

Policy and Regulatory Options

- In transmission plans and utility resource plans/RFPs, consider siting wind and solar to minimize variability of aggregate output and better coincide with load profiles
- Support right-sizing of interstate lines (increasing project size, voltage, or both to account for credible future resource needs) that access renewable resources

Source: Dennis Schroeder
Encourage Demand Response

- Shift customer load up and down to complement wind and solar through direct load control and real-time pricing with automation
- Demand response (DR) may be less expensive than supply-side resources and energy storage technologies

Policy and Regulatory Options

- Allow DR to compete on a par with supply-side alternatives in utility resource planning and acquisition
- Consider potential value of enabling DR when evaluating advanced metering
- Examine ratemaking practices for features that discourage cost-effective DR – e.g., demand charges that penalize large customers for higher peaks when they shift loads away from periods of limited energy supplies
Concluding Remarks

• Higher penetrations of wind, solar can be managed through operational changes

• All power systems differ depending on generation mix, operations, markets, etc. --- solutions differ

• Policymakers can play a role in helping to manage higher penetrations of RE by encouraging:
  o new generation sources to be flexible
  o flexible loads – i.e., demand response
  o use of forecasting
  o transmission investments
  o installed RE technologies can support the grid
  o geographic diversity of RE, if appropriate

Source: Steve Wilcox