

# Remodeling the Grid

## Challenges, Solutions, and Costs Associated with Integrating Renewable Resources

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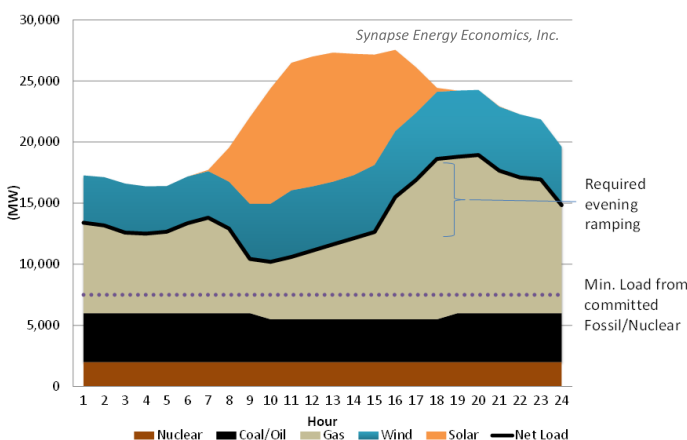
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### The Challenge

Over the last ten years, the amount of utility-scale wind and solar capacity in the United States has jumped from 9 GW to 75 GW. New installations are projected to continue, spurred by environmental regulations and declining costs to build and operate renewable technology. While system operators are well equipped to meet much higher levels of renewable energy penetration than currently exists on the grid, they will have to make incremental changes to the grid in order to bring on even higher levels in the long term.

The thrust of the challenge is that the existing U.S. power grid was designed for fossil fuels, and renewable resources behave differently than fossil resources. Wind and solar output fluctuates throughout the day and can change relatively rapidly and unpredictably. Older coal and nuclear plants have limited capabilities to respond to these changes as they have high minimum operating levels and an inability to increase their output level at a rapid rate. As a result of these limitations, represented in Figure 1, these older resources impose cost on the system.

**Figure 1. Hourly dispatch with high levels of solar and wind**



*System operators are already implementing measures to integrate large amounts of wind and solar, at costs usually less than \$5 per megawatt-hour of energy produced.*

### The Solutions

Electric system operators are already employing solutions to address the easily solved issue described above, and already have the planning and operational tools at their disposal to accommodate even higher levels of renewables.

One low-cost method for integrating renewables is to increase cooperation between system operators across the country. By increasing the size of the system over which supply and demand must be balanced, the flexibility to balance swings in wind and solar generation with fossil resources is increased. For instance, the western Energy Imbalance Market will soon cover seven states and 44 million people, improving the ability of operators in all participating areas to manage renewable integration. Some markets are already so large that flexibility constraints are not an issue: In its latest renewable integration study, the PJM Interconnection found it could accommodate up to 30 percent variable renewable energy with no major issues.

Just as increasing the size of the system can facilitate renewable integration, so too can increasing the geographic diversity of where the generators are located. Geographic diversity can reduce the chances of rapid

swings in generation related to weather patterns.

In addition to incremental changes to supply-side operations, there are also low-cost methods of influencing consumers' behavior to facilitate larger amounts of renewables. These include programs that incentivize consumers to reduce electricity use during peak demand hours (called "demand response") and reducing ramping requirements accordingly.

## The Cost

Synapse conducted a literature review of existing integration cost studies and found that the cost of the incremental investments and actions needed to facilitate the addition of renewable energy is on the order of \$5 per megawatt-hour for both wind and solar.

Since there is no universally accepted method for conducting an integration cost study, the methodology of the studies Synapse reviewed varies.

The wind integration cost studies Synapse reviewed represent systems ranging for 3,200 MW to over 600,000 MW, with penetration levels ranging from 2 to 43 percent. Costs of the larger systems in the subset of studies are less than \$5 per megawatt-hour (half a cent per kilowatt-hour). The costs by level of penetration are presented in Figure 2. Note that the difference in the assumed level of penetration does not seem to be a major driver of integration costs.

The solar integration cost studies Synapse reviewed present costs similar to or lower than the costs of integrating wind energy. This may be because solar presents additional value when it comes to reliably meeting demand, or because the studies assume a lower level of penetration (2 to 29 percent).

The five solar integration cost studies summarized in Figure 3 found costs that ranged from \$1.50 to \$6.30 per megawatt-hour, with sensitivities as low as \$0.50 per megawatt-hour.

For a more detailed report on the sources, methodology, and assumptions used in these studies, visit <http://synapse-energy.com/A-Solved-Problem>.

Figure 2. Wind integration cost by level of penetration

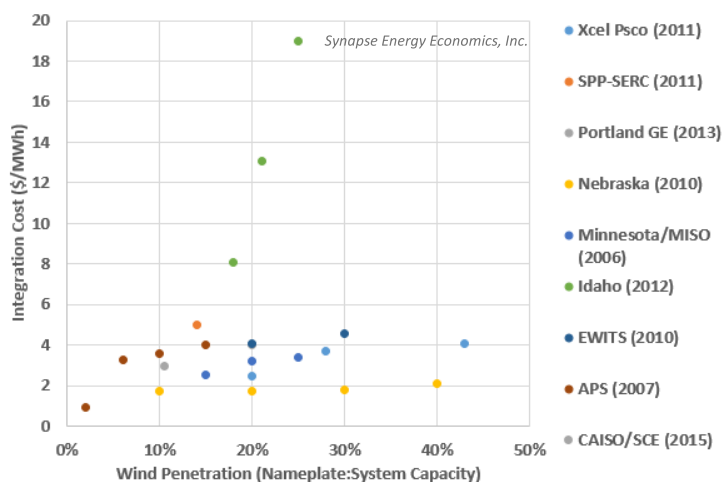
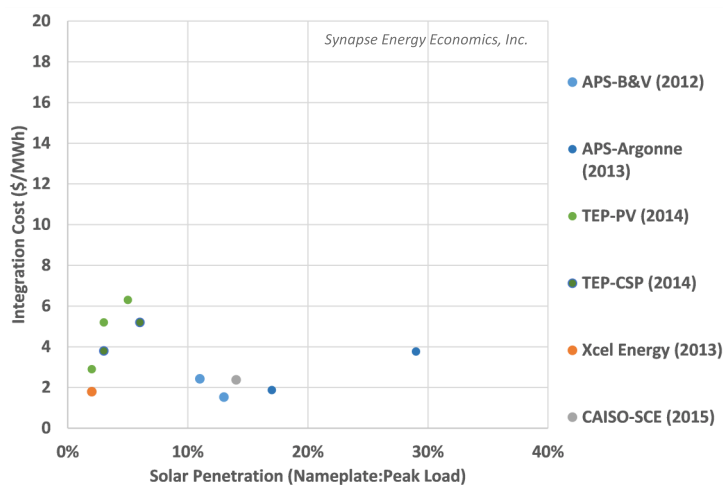


Figure 3. Solar integration cost by level of penetration



## ABOUT SYNAPSE

Synapse Energy Economics, Inc. is a research and consulting firm specializing in energy, economic, and environmental topics. Renewable energy and distributed generation represent a core area of Synapse's expertise. Synapse analyzes the policy treatment, regulations, costs and benefits, employment impacts, rate impacts, emissions, grid integration issues, siting issues, and technical and economic potential of renewable energy and distributed generation technologies.