Bernard S. Lee
David E. Gushee

Massive Electricity Storage Makes $ense

Our previous *CEP* articles *(1, 2)* argued the need for massive electricity storage (MES) for power generated from renewable sources, such as wind and solar. From a technical standpoint, the integration of MES with the generation of raw renewable power to produce dispatchable power for grid transmission is analogous to the processing of raw natural gas at the wellhead to produce dispatchable pipeline-quality gas for pipeline-grid transmission.

As regulatory agencies evolve appropriate policy to enhance the integration of renewable power into the U.S. transmission grid, it may be helpful to compare costs for two hypothetical cases. A major block of new wind capacity (5,000 MW) is built in a remote, sparsely populated area typical of the locations with the most favorable wind flow patterns. Because wind generators have a capacity factor of approximately 33%, it is necessary to install 15,000 MW of nameplate wind capacity for either case, so the windmill cost is not included in the cost comparison. To connect to major consumption centers, a dedicated 1,000-mile transmission line is built. This scenario appears to be the logical path of much of the future major growth in wind power.

Case 1. MES is installed at the site of renewable power generation, and dispatchable power is delivered to the transmission line.

• To convert raw wind power to 5,000 MW dispatchable power, install MES equal to 20% of nameplate capacity, or 3,000 MW. At $3,000/kW, the investment cost is $9 billion.

• To deliver power to customers, build a 1,000-mile-long, 765-kV transmission line with a capacity of 5,000 MW. At $6.6 million/mi *(3)*, the investment cost is $6.6 billion.

• Total investment (excluding windmills) = $15.6 billion.

Case 2. Raw renewable power, without MES, is attached directly to the transmission line, which bears the responsibility to deliver dispatchable power to customers.

• Since raw wind power is attached directly, the transmission line must be sized to carry nameplate peak power of 15,000 MW.

• This requires three 765-kV, 5,000-MW lines at a cost of $6.6 billion each.

• Total investment (excluding windmills) = $19.8 billion.

The Case 2 cost estimate is conservative, as experience in Europe has shown that transmission grids carrying raw wind power require strengthening to upgrade the raw power to the necessary consistent voltage and frequency.

This conceptual cost comparison shows that the integration of MES at the windmills is 22% cheaper than direct grid attachment (exclusive of the cost of the windmills). This does not count the considerable cost of the extra right-of-way to build three transmission lines instead of one, the cost of strengthening the transmission lines, and the higher operating costs for a transmission grid handling intermittent power inputs. These factors will increase the advantage of the MES case.

Our trilogy of papers on MES *(1, 2, 4)* has been prepared to raise public awareness of the critical need for MES in order to make renewable power from wind and solar dispatchable. The key take-away points are:

1. Although direct attachment of raw renewable power to the grid is tolerable at low levels of grid penetration, when penetration reaches 15–20%, grid instability requires MES.

2. When storage is included, renewable power (whether wind or solar) will be competitive with new fossil and nuclear plants, even without accounting for climate change regulations, carbon taxes, and nuclear security concerns.

3. The energy market and the regulatory agencies understand and can handle dispatchable power, but are struggling with how to adjust rates for intermittent power.

4. Integrating MES at the point of generation so that only dispatchable power is attached to the transmission grid is the logical and economic choice, and should help renewable power gain acceptance by consumers. Dispatchable renewable power is no different from dispatchable fossil, nuclear or hydro power.

5. The MES cost should be allocated to the power generation cost and reflected in the cost of dispatchable power, thus requiring no new regulatory policy or regime, simplifying the regulatory process at both the federal and state levels, and expediting the integration of renewable power into the national grid. CEP

1. Lee, B. S., and D. E. Gushee, "Electricity Storage: The Achilles' Heel of Renewable Energy," *CEP*, 104 (3), pp. S29–S32 (Mar. 2008).
2. Lee, B. S., and D. E. Gushee, "Renewable Power: Not Yet Ready for Prime Time," *CEP*, 105 (4), pp. 22–25 (Apr. 2009).
3. Chupka, M, *et al.*, "Transforming America's Power Industry: The Investment Challenge 2010–2030," Brattle Group report prepared for The Edison Foundation, p. 35 (Nov. 2008).
4. Lee, B., and D. Gushee, "Massive Electricity Storage," an AIChE White Paper, AIChE Government Relations Committee (June 2008).

BERNARD S. LEE (bslee8@q.com) retired from Institute of Gas Technology as its president. He holds bachelor's and doctoral degrees in chemical engineering from Polytechnic Institute of Brooklyn and is a Fellow of AIChE.

DAVID E. GUSHEE (gushee1930@embarqmail.com) retired from Congressional Research Service as a senior specialist in environmental policy. A Fellow of AIChE and a past chair of AIChE's Government Relations Committee, he holds a BS in chemical engineering from MIT.