Balancing the Zero-Emissions Grid: The Role of Gap-Rightsizing Resources

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A zero-emissions grid requires a system architecture capable of balancing supply and demand. High capacity factor dispatchable emission-free resources (DEFRs) can provide a stable, low-emissions supply foundation, while lower capacity factor DEFRs can support periods of system stress. Gap-rightsizing resources can be deployed to address residual firm capacity needs by shifting surplus generation and reshaping load profiles. By reducing peak demand and smoothing net load variability, these technologies may lower total system costs and reduce system-level risks, including the potential deferral of transmission, distribution, or peaking capacity investments. This brief is focused on gap-rightsizing DEFRs, specifically long-duration energy storage (LDES) and virtual power plants (VPPs).

KEY INSIGHTS

- Gap-rightsizing resources help balance supply and demand, addressing the firm capacity gap.
- Deploying these resources may help defer capital investments, and limit the runtime of existing peaker plants.
- Gap-rightsizing resources are intended to complement, rather than replace, firm capacity resources.
- Targeted market and regulatory reforms could help deployment at scale by providing financial incentives that support investment.

What is a VPP?

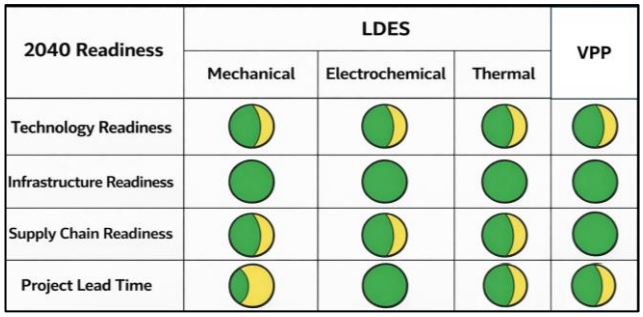
A VPP can be defined as a network of decentralized power-generating units, flexible loads, and storage systems aggregated to operate as a unified resource.

In 2025, EPRI supported the New York State Energy Research and Development Authority (NYSERDA) in a technoeconomic assessment of technologies capable of achieving a zero-emissions grid by 2040 (Zero by 40: Technoeconomic Assessment). This brief highlights selected insights from that work. For additional insights from the study, visit esca.epri.com.

Technology Readiness and Deployment Timelines

LDES: LDES technologies span mechanical, electrochemical, and thermal categories and reflect a range of technology readiness levels. Many LDES technologies are nearing or entering commercial deployment following pilot-scale validation. Broader scaling is expected to require additional supply chain development, with material availability and manufacturing risks varying by technology type and deployment strategy.

VPPs: Technologies required for VPPs to perform traditional demand response functions are mature. VPPs have delivered advanced grid services in pilot projects. Since VPPs leverage distributed energy resources (DERs) that are already deployed at commercial scale, they typically do not require additional large scale physical infrastructure.



Technology Readiness of select gap-rightsizing DEFRs. Fully green indicates an advantage for the technology, while fully yellow indicates a challenge for the technology, with partial shading indicating the technology falls in the middle.

LDES and VPPs generally feature shorter project timelines than large-scale baseload projects, facilitating earlier deployment while longer-lead assets progress towards completion.

Emissions Profile and Other Considerations

During operation, LDES and VPPs do not produce direct greenhouse gas or co-pollutants. LDES charging may be associated with emissions if supplied by emitting generation, as efficiency losses require more input energy than is discharged.

Both technologies are energy limited and are not intended to replace non-energy-limited firm capacity. VPP performance depends on the availability and participation of DERs, while LDES capabilities are constrained by storage duration and efficiency losses.

Cost Dynamics and Market Design

VPPs are generally expected to have lower dollar-per-MWh costs than LDES, though cost estimates remain uncertain and vary by scope and application. A key barrier to large-scale deployment of these gap-rightsizing resources is the limited availability of compensation structures and market mechanisms that incentivize the attributes that these resources can offer to the grid.

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