BACK POCKET INSIGHT

P178 RESOURCE PLANNING FOR ELECTRIC POWER SYSTEMS

KEY INSIGHTS

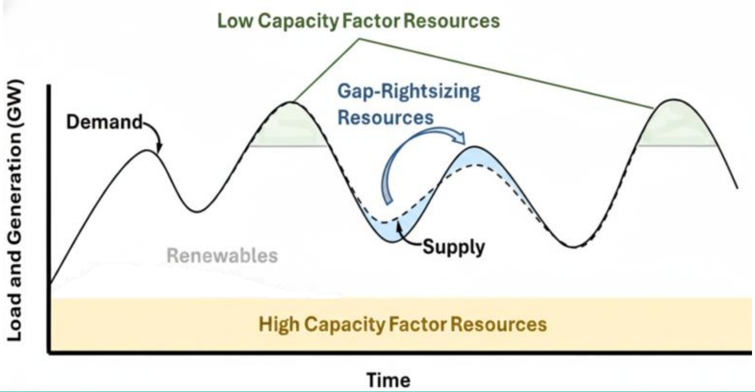
- Building a zero-emissions grid is a system architecture challenge.
- VRE resources require DEFRs to maintain system adequacy and stability.
- DEFRs can address different system operational needs:
  - High capacity factor resources anchor the system.
  - Low capacity factor resources support the system during peak hours.
  - Gap-rightsizing resources support the system by shifting demand and shaving peaks.
- Diversification reduces technology, supply-chain, permitting, and fuel risks.

Architecting the Zero-Emissions Grid

by Anand Kumar, Romey James, Todd Gorgian, and Robin Bedilion

A zero-emissions power grid requires more than the large-scale deployment of **variable renewable energy (VRE)** resources. While VRE resources can provide a significant portion of the clean electricity supply, their variability introduces operational challenges. Addressing these challenges requires **dispatchable emissions-free resources (DEFRs)** to provide capacity and energy under a wide range of operating conditions.

DEFRs differ in cost structure and in their technical capabilities that shape their operating behavior and system contributions. An effective zero-emissions grid architecture therefore relies on a portfolio of DEFRs that can collectively meet diverse grid requirements based on their cost and performance attributes.



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.

Resource Roles in the Zero-Emissions Grid Architecture

High Capacity Factor Resources: The foundation of the zero-emissions grid is formed by high capacity factor DEFRs designed to operate for most hours of the year. This group includes technologies such as advanced nuclear, fossil generation with carbon capture and storage, next generation geothermal, etc. These resources are typically characterized by high upfront capital costs and relatively low operating costs. They are well-suited to meeting persistent load growth and providing the essential services that maintain grid stability.

Low Capacity Factor Resources: The high capacity factor resources support steady-state system needs but are not optimized to manage infrequent but high-impact stress events. Low capacity factor DEFRs operate at the edge of system conditions to address these challenges. Technologies such as generation fueled by hydrogen, renewable natural gas, and renewable diesel are dispatchable and can ramp rapidly, but their operational role is shaped by relatively high costs. These resources can support peak load conditions and prolonged renewable shortfalls.

Gap-Rightsizing Resources: Between the high capacity factor and low capacity factor resources are gap-rightsizing resources, such as long-duration energy storage and virtual power plants. These resources do not generate primary energy but influence how other clean resources are utilized. By shaving peaks and shifting demand, gap-rightsizing resources can narrow capacity shortfalls and improve utilization of clean generation resources.

Together, the high capacity factor, low capacity factor, and gap-rightsizing resources form an integrated architecture that aligns resources technical capabilities with system needs.

Managing Risk Through Diversification

A diversified DEFR portfolio also mitigates exposure to risks. Individual technologies face varying risks related to technology readiness, cost trajectories, project timelines, supply chain, fuel availability, and operational maturity. Relying on multiple resource groups reduces dependence on any single pathway.

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