EPRI

BACK POCKET INSIGHT

P178 RESOURCE PLANNING FOR ELECTRIC POWER SYSTEMS

KEY INSIGHTS

- High capacity factor DEFRs provide a clean foundation, delivering reliable baseload energy while providing grid stability.
- Technology readiness varies widely, with nuclear, CCS, and enhanced geothermal each facing different maturity levels and project timelines.
- While nuclear and geothermal are effectively zero-emissions, CCS carbon intensity depends on the carbon intensity of the fuel supply in addition to the power generation.
- Costs remain uncertain - Standardizing design and siting assets at brownfield sites can compress development timelines and reduce costs.

Anchoring the Zero-Emissions Grid: Planning for the Clean Baseload Resources

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

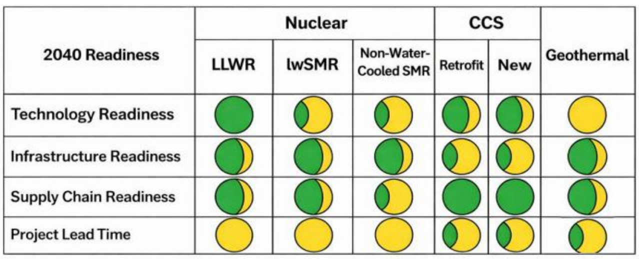
A zero-emissions grid requires a structural foundation capable of maintaining stability while delivering reliable energy. High capacity factor **dispatchable emission-free resources (DEFRs)** can provide a firm foundation. These DEFRs are suitable to meet existing and growing baseload demand, potentially reducing reliance on high cost, low capacity factor resources and minimizing the footprint of intermittent renewable deployment. Additionally, these DEFRs with large rotating thermal generators inherently provide physical inertia and voltage regulation, attributes that are required for grid stability. This insight is focused on high capacity factor DEFR technologies, including advanced nuclear, fossil fuel plants with carbon capture and storage (CCS), and next generation geothermal.

Technology Readiness and Deployment Timelines

Readiness varies across technologies. Deploying an advanced large light water reactor (LLWR) could take ~10-12 years, though timelines are highly variable.

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.

Light water small modular reactors (SMRs) and non-water-cooled SMRs are less mature than LLWRs but could see faster project timelines. Enhanced geothermal technologies have seen deployment in some regions, but generalizable timelines are uncertain. CCS implementation extends beyond capture equipment to include CO_2 transport and storage infrastructure.



Technology Readiness of select high capacity factor 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.

Emissions Profile and Other Considerations

Emissions: Nuclear and geothermal generation are effectively emissions-free. Although CCS can remove 90%+ of combustion emissions at the point of generation, overall carbon intensity also depends on the upstream fuel supply emissions.

Land Use and Siting: While these technologies generally require less land per unit of capacity than variable renewables, siting may pose challenges.

Safety and Other Considerations: For nuclear, safety and waste management are significant considerations. Similarly, CCS safety and environmental considerations include potential air quality impacts, pipeline integrity, groundwater interaction. Geothermal development requires precautions to mitigate risks regarding groundwater contamination and induced seismicity during drilling and stimulation.

Cost Uncertainty and Integration Strategies

Cost Drivers: Geothermal costs are highly site-specific. Future nuclear capital costs exhibit a wide uncertainty range. While natural gas with CCS is expected to be lower cost than nuclear, overlap exists in cost estimates due to uncertainties.

Brownfield Advantages: Locating new nuclear or CCS projects at retired or existing thermal sites can lower capital costs and speed deployment by leveraging existing transmission, water access, community support, workforce, etc.

Deployment Strategy: Shifting from custom designs to standardized designs, and serial build programs could drive cost reduction.

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