Strategies for a net-zero future

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National Renewable Energy Laboratory
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Getting to 100%: six strategies for the “last 10%”

Mai, Trieu, et al. "Getting to 100%: Six strategies for the challenging last 10%." *Joule* 6.9 (2022)

Wind/solar + diurnal storage

CAPEX: $$ OPEX: $ Constraints: ⟷ Maturity: ↑

Considerations: transmission requirements, land use, social acceptance, weather-dependence

Other renewable resources (bio/geo/hydro)

CAPEX: $$ / $$$ OPEX: $ / $$ Constraints: ↑ Maturity: ↑

Considerations: geographic constraints, competition for biomass supply

Nuclear or fossil with carbon capture

CAPEX: $$$ OPEX: $$ Constraints: ⟷ Maturity: ↓

Considerations: supply chain, regulatory and cost uncertainties, security, upstream emissions, CO_2 transport and storage

Seasonal storage (hydrogen)

CAPEX: $ OPEX: $$$ Constraints: ↓ Maturity: ↓

Considerations: hydrogen transport and storage, competition for hydrogen

Carbon dioxide removal (direct air capture/BECCS)

CAPEX: $$$ OPEX: $$$ Constraints: ↕ Maturity: ↓

Considerations: CO_2 transport and storage, biomass availability, cost uncertainty

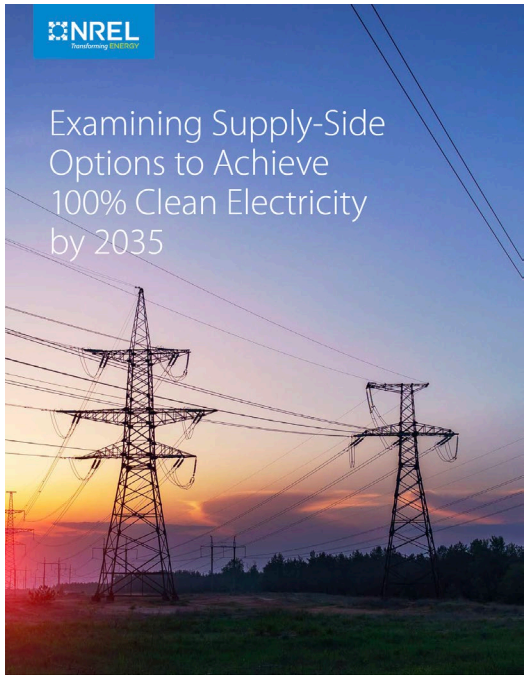
Demand side resources

CAPEX: $ OPEX: ? Constraints: ? Maturity: ⟷

Considerations: communications and control equipment, reliability

Multiple pathways to a zero-carbon future

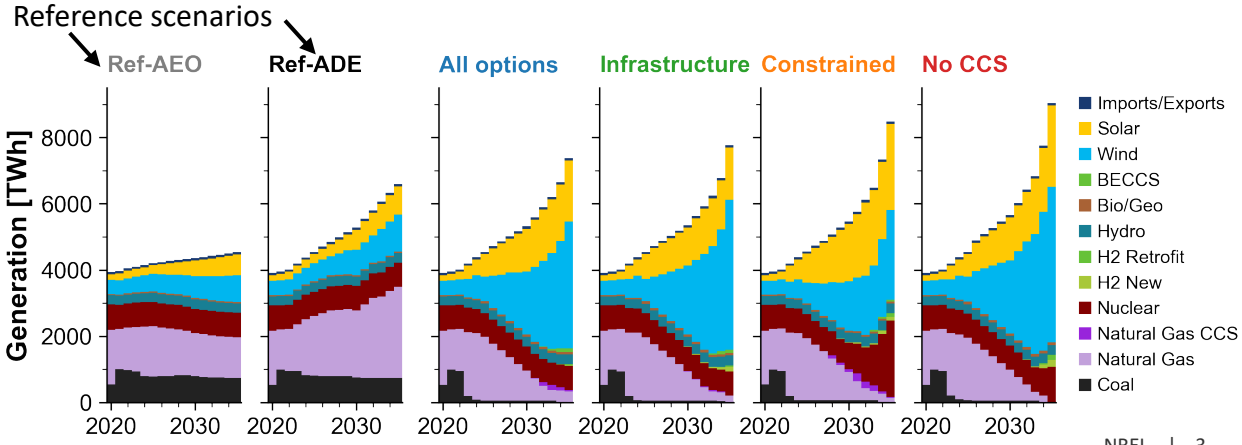
https://www.nrel.gov/docs/fy22osti/81644.pdf



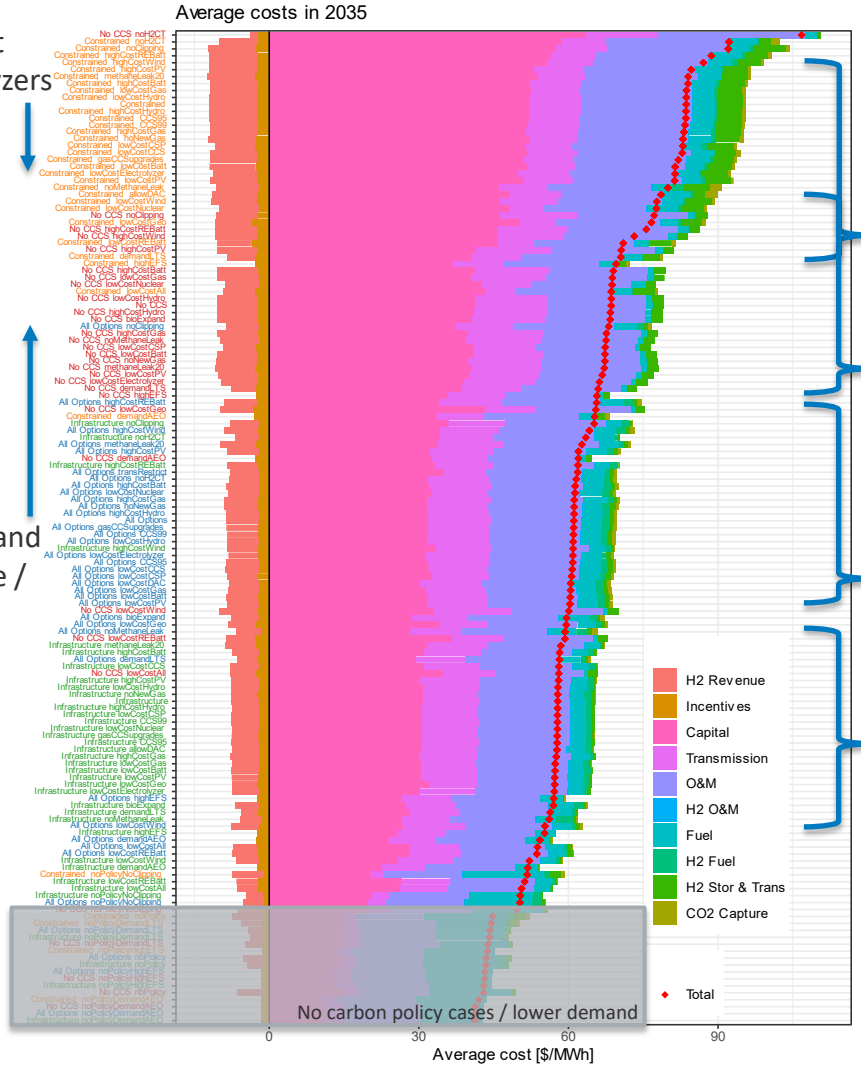
100% decarbonized by 2035

+ electrification trajectory consistent with net zero economy-wide by 2050

	All options	Infrastructure	Constrained	No CCS
RE siting	Reference	Reference	**Limited**	Reference
CCS	Ref **+ DAC**	Ref (CCS/BECCS)	Ref (CCS/BECCS)	**No CCS**
Transmission	Reference	**+ HVDC macrogrid**	**No interregional; 5× cost**	Reference
Other	Reference	**Lower** H_2, CO_2, bio transport & storage adders	**Higher** H_2, CO_2, bio transport & storage adders	Reference



What technologies affect costs the most?

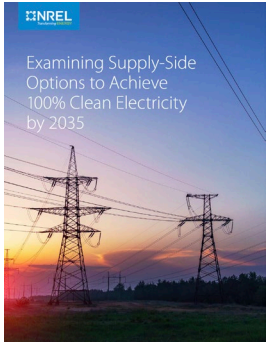


Constraints on VRE siting/transmission

No CCS pathways

Pathways with direct air capture

HVDC macrogrid / low cost hydrogen tech



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RD&D can potentially help move from one cost regime to another, but magnitude of impact subject to multiple factors

Questions?

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