# Getting to 100%: Six strategies for the challenging last 10%

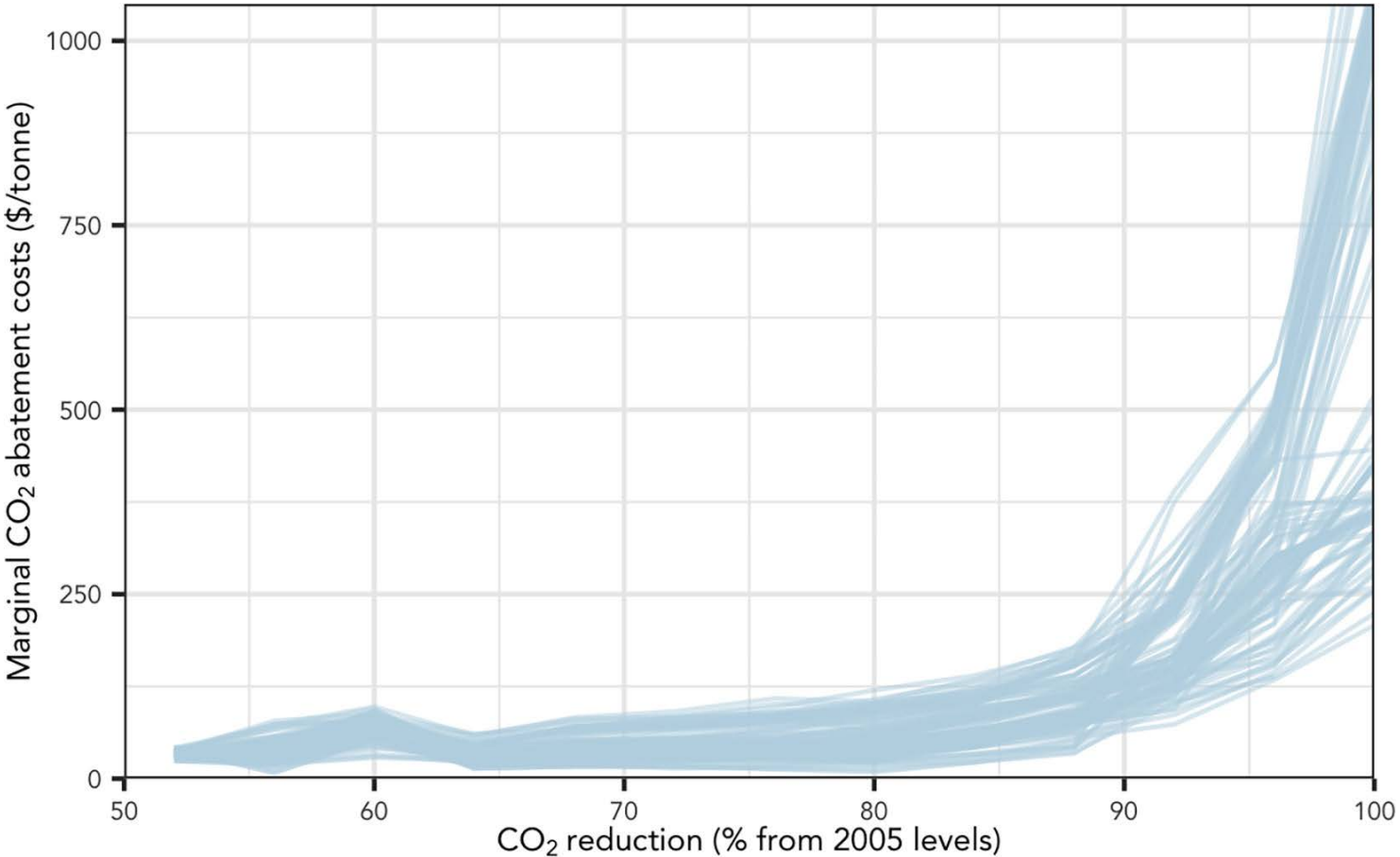
Presenter: Wesley Cole

Coauthors: Trieu Mai, Paul Denholm, Patrick Brown, Elaine Hale, Patrick Lamers, Caitlin Murphy, Mark Ruth, Brian Sergi, Daniel Steinberg, Samuel Baldwin

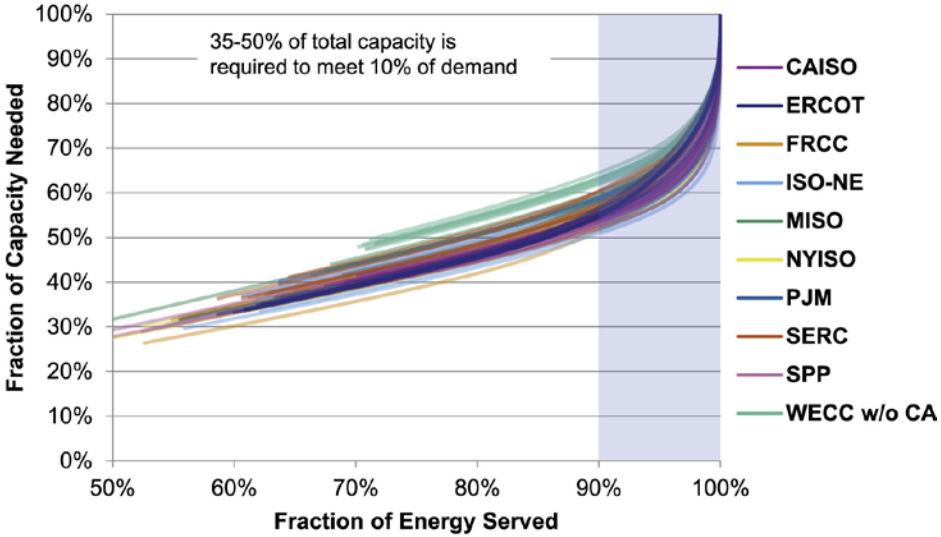
April 18, 2024

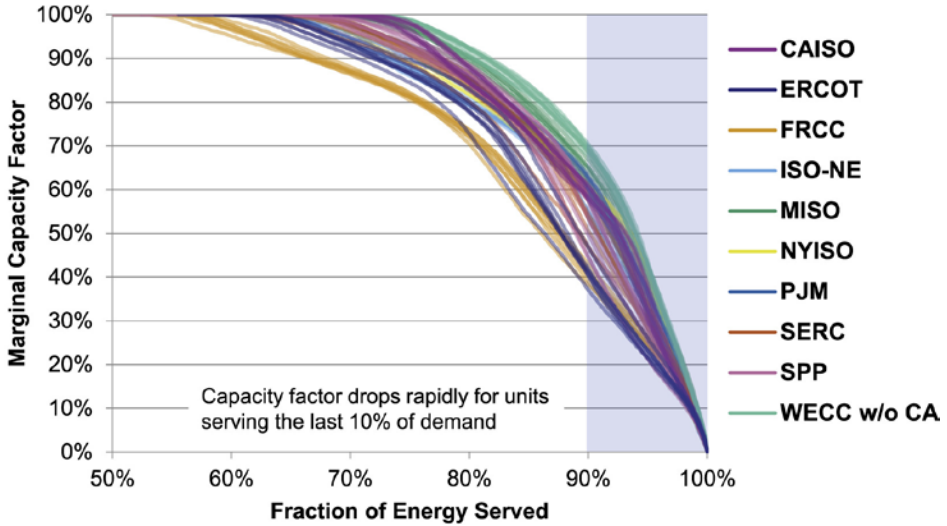
Paper available at https://www.sciencedirect.com/science/article/pii/S2542435122004056

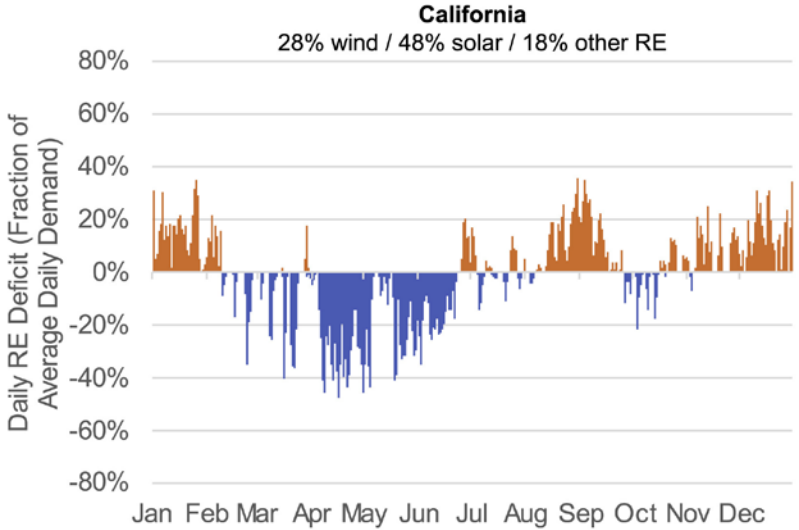
# The Challenge of the Last 10%



# Meeting 100% of Demand: The Peaking Problem

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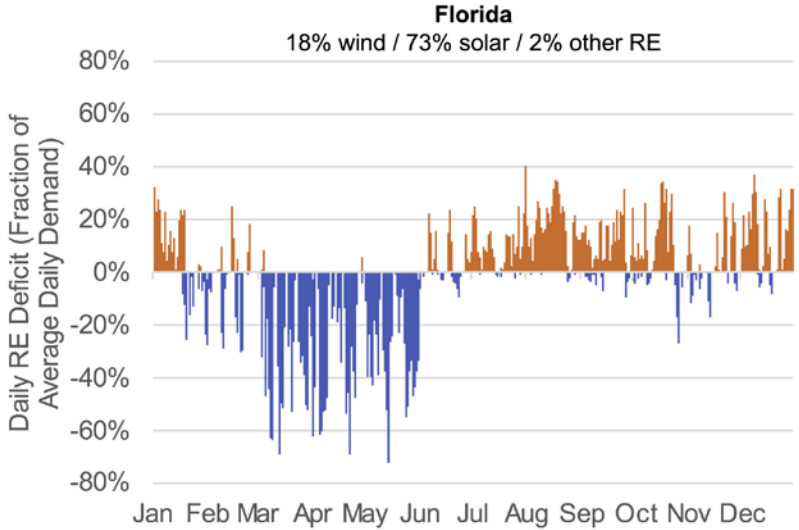
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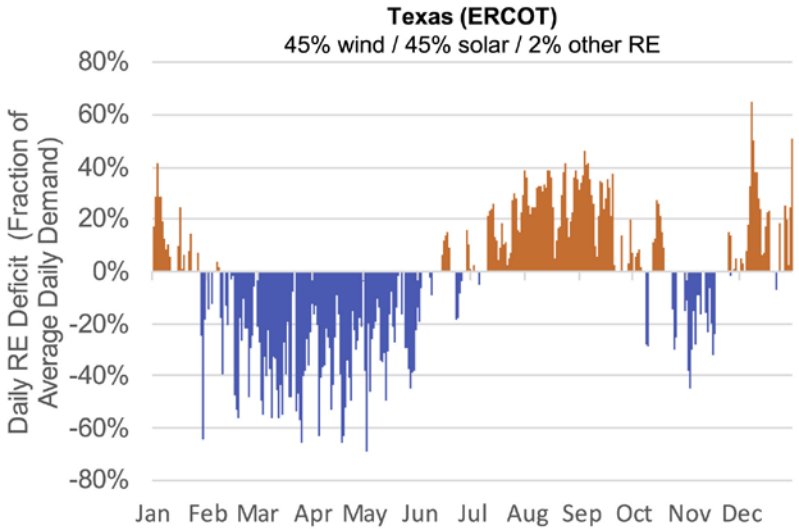
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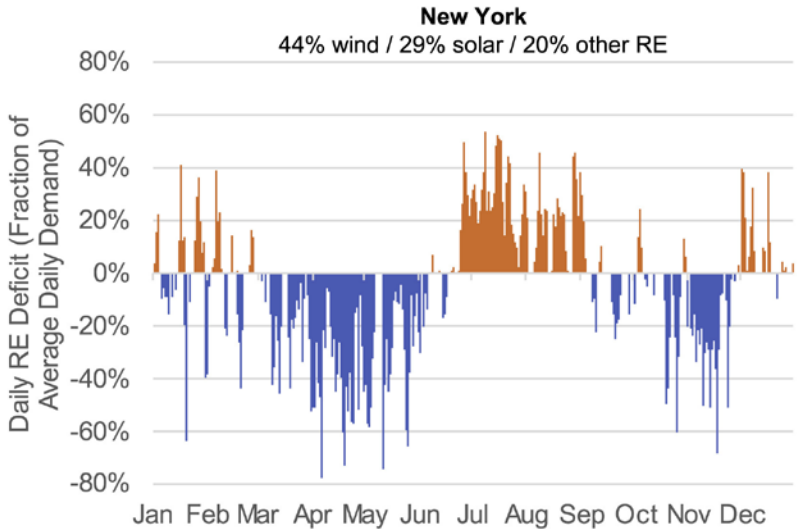
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**Table 1. Properties of the ideal solution for the last 10% emisisons reductions and six potential strategies**

| Strategy[a] | Example technologies | Economic factors[b] | Resource constraints | Technology maturity | Other considerations |
|---|---|---|---|---|---|
| Ideal solution | n/a | low capex, low opex | low | high | low environmental impact, synergistic interactions with other sectors |

[a]Many of the six strategies listed will also be used for the first 90% and, for these, the table focuses on additional amounts used to solve the last 10%.
[b]Capex refers to capital cost expenditures. Opex refers to operating cost expenditures.
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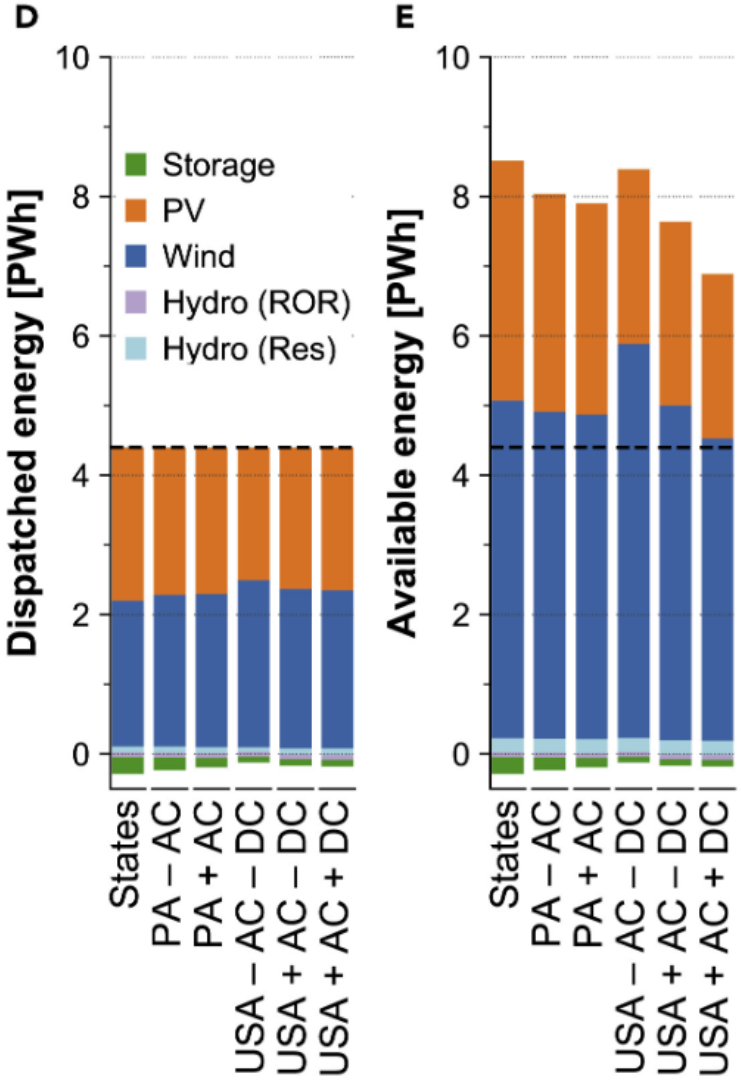
# Example of Overbuilding




Source: Brown and Botterud (2021), The Value of Inter-Regional Coordination and Transmission in Decarbonizing the US Electricity System

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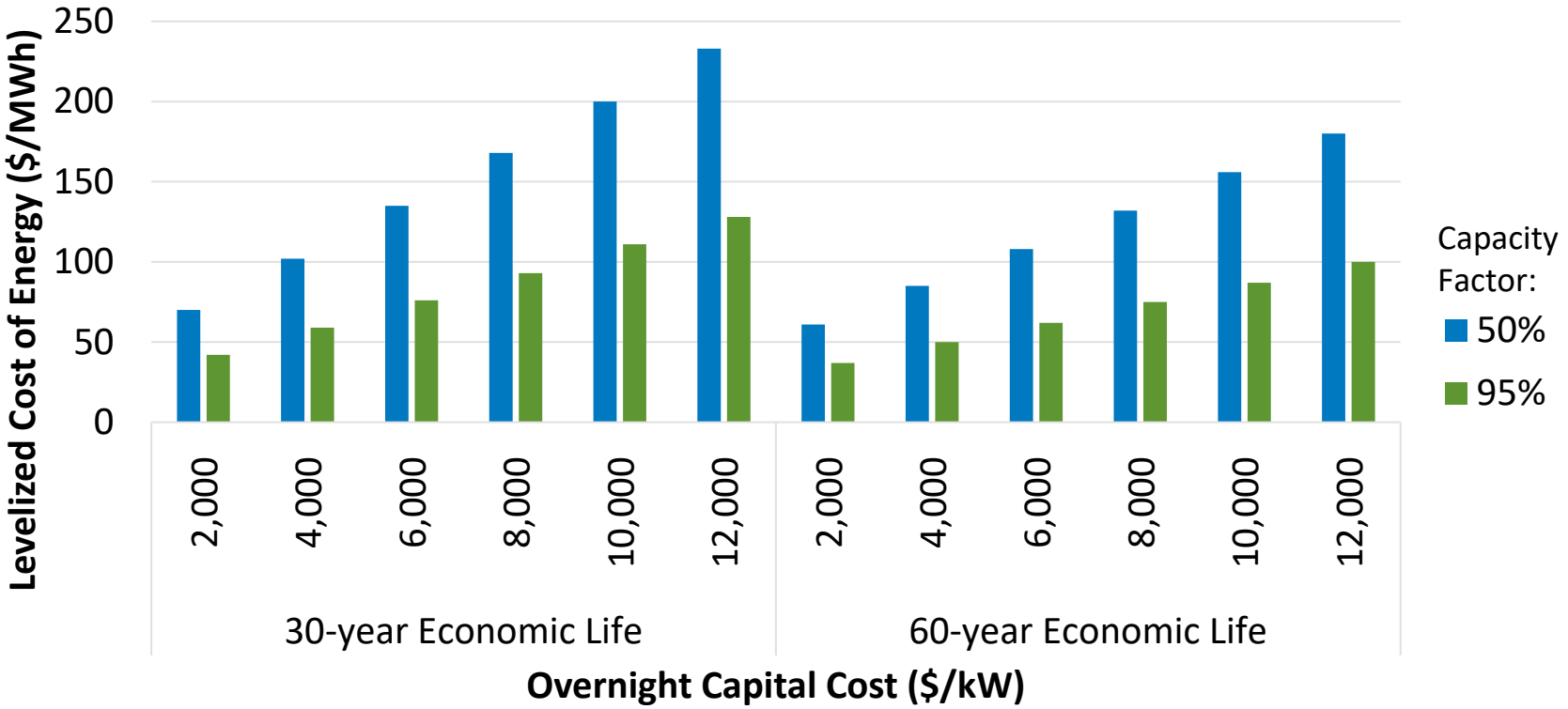
# Impact of Utilization

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| Seasonal storage | $H_2$ combustion turbine | low capex, high opex | low | medium | $H_2$ storage and transport, $H_2$ competition |
| | $H_2$ fuel cell | potential for low capex, high opex | low | low | $H_2$ storage and transport, $H_2$ competition |

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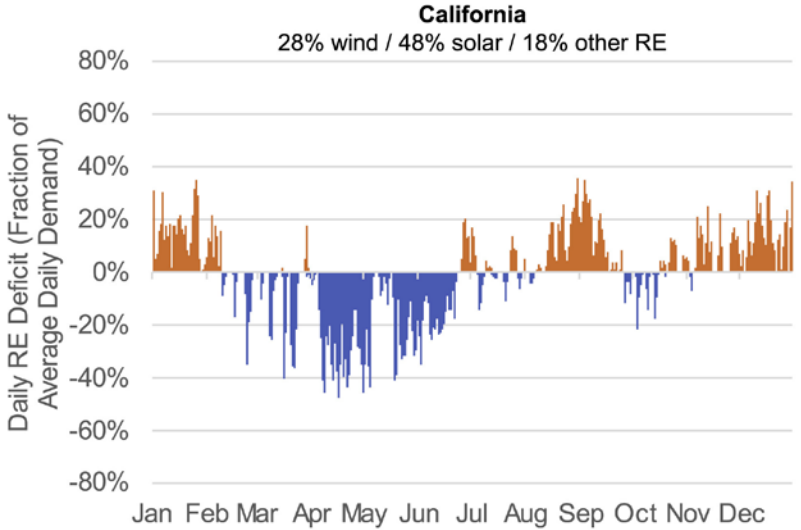
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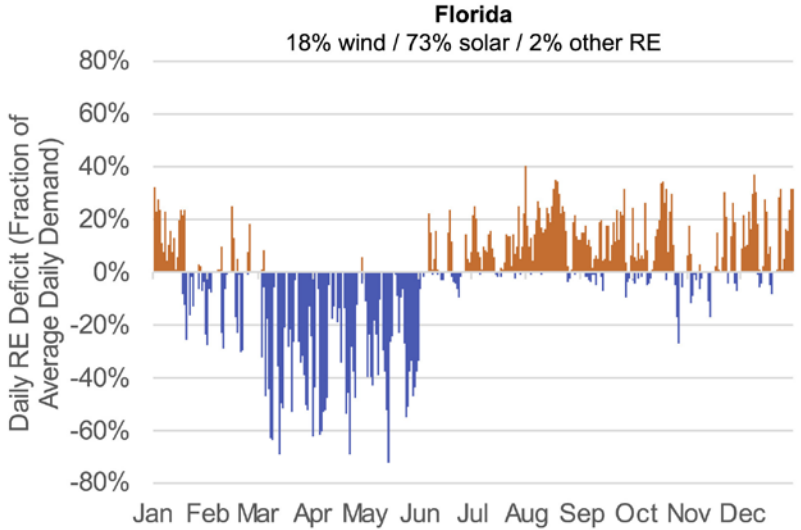
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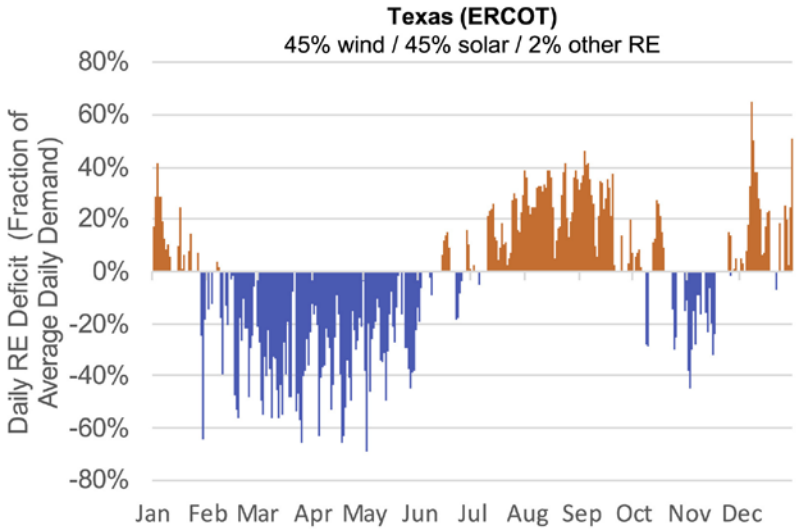
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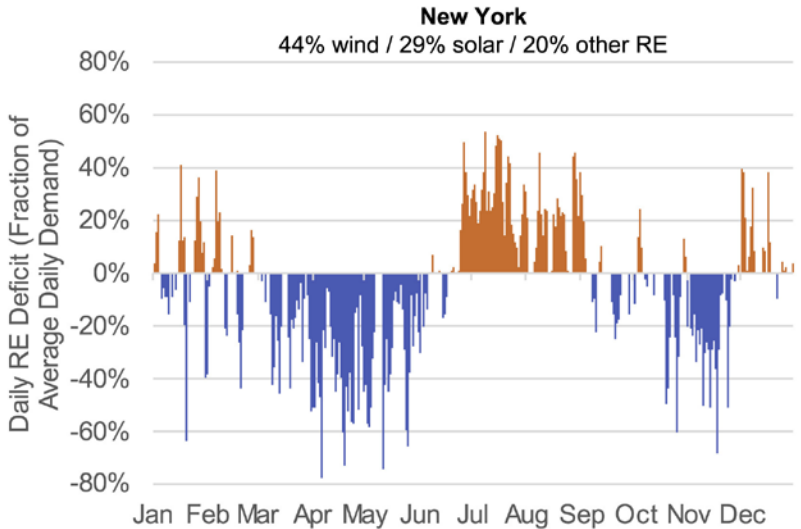
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| Carbon dioxide removal | bioenergy with carbon capture and storage | high capex,[c] high opex | medium-high | low | biomass sustainability and competition, $CO_2$ storage and transport |
| | direct air carbon capture and storage | high capex,[c] high opex | low | low | $CO_2$ storage and transport |

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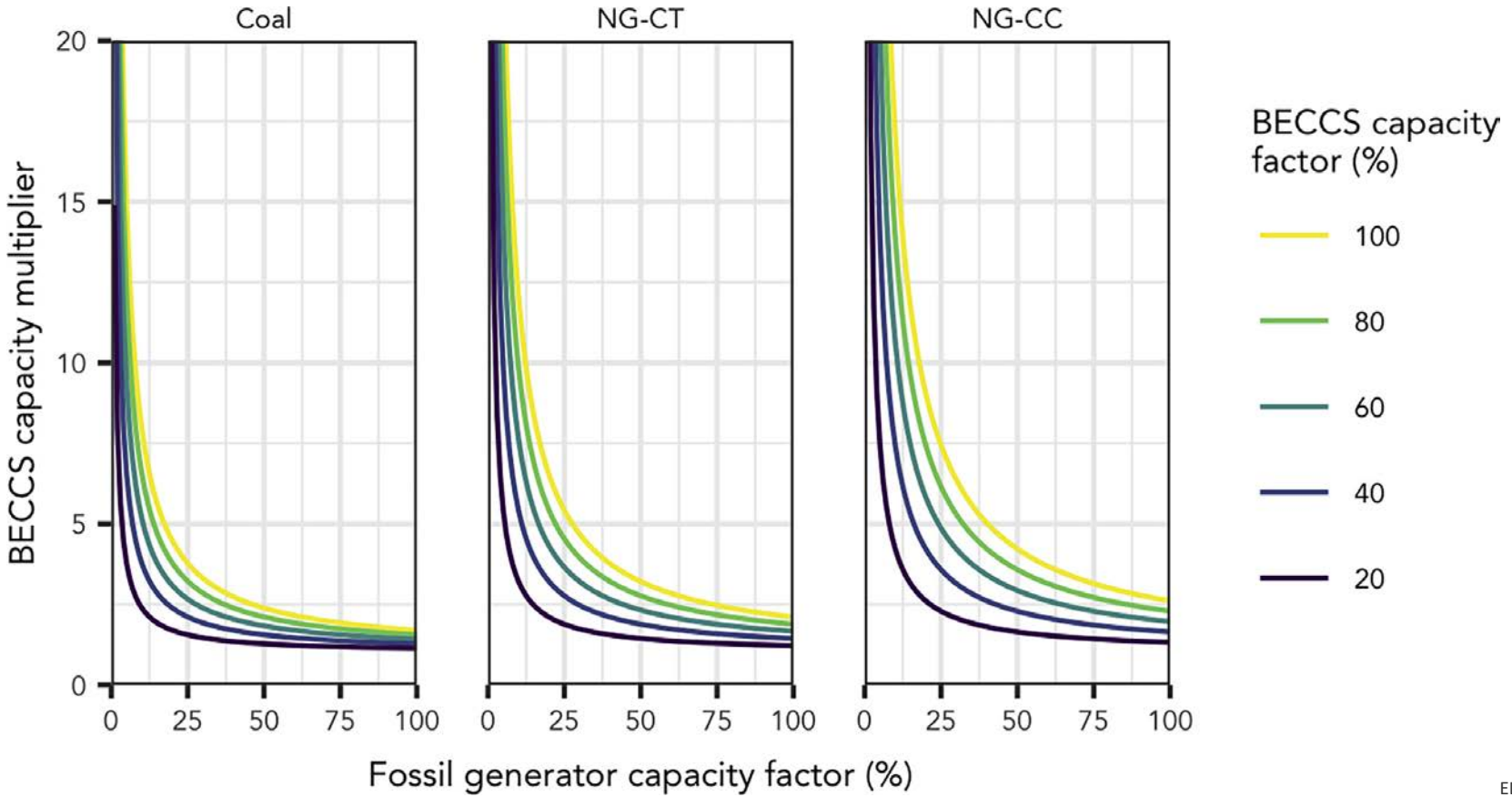
# BECCS Capacity Multiplier



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| Demand-side resources | varied | low capex, uncertain opportunity cost | unknown | medium | communications and control equipment, reliability |

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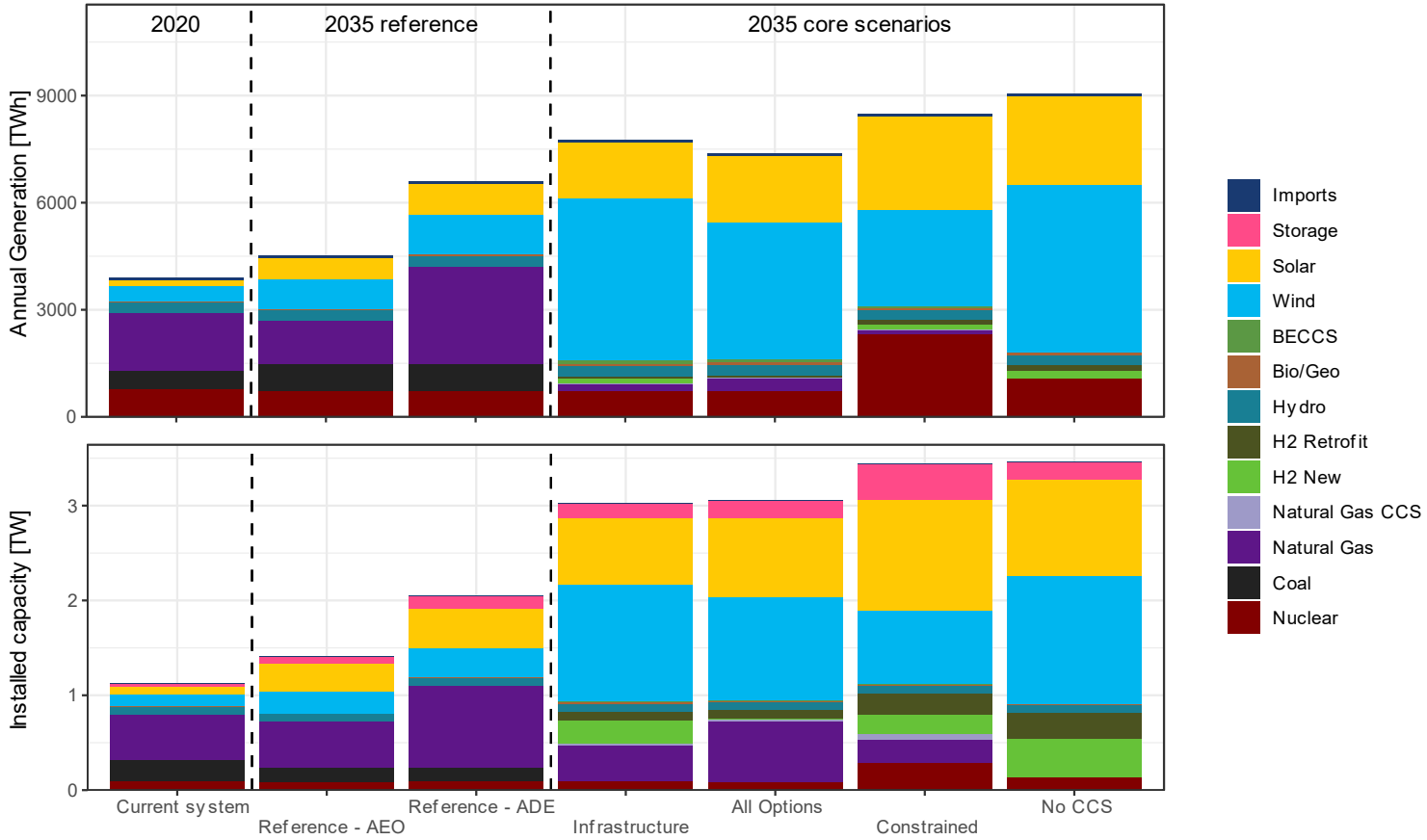
# Example of a Decarbonized Future




Source: Denholm et al. (2023), Examining Supply-Side Options to Achieve 100% Clean Electricity by 2035

# Feel free to follow up!

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