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Interconnection Cost Implications of Future Electricity Capacity Expansion in the USA: A Multi-sector Approach

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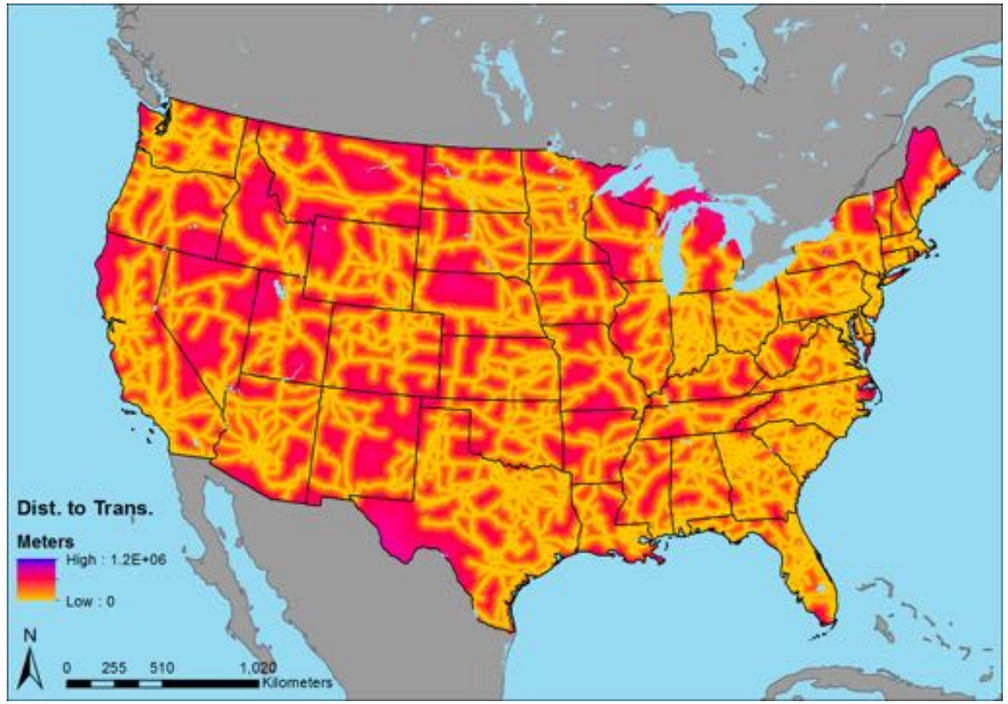
Why Evaluate Interconnection Costs?



Distance to 240 KV & up (EIA; HIFLD 2018)

- Investment timing, magnitude, location
- Identify potential vulnerabilities
- Availability limitations
- Asses innovation and system evolution tradeoffs

Our Research Objectives

When evaluating alternate energy futures…

- What is the magnitude, timing, and distribution of interconnection costs in the US?

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When evaluating alternate energy futures…

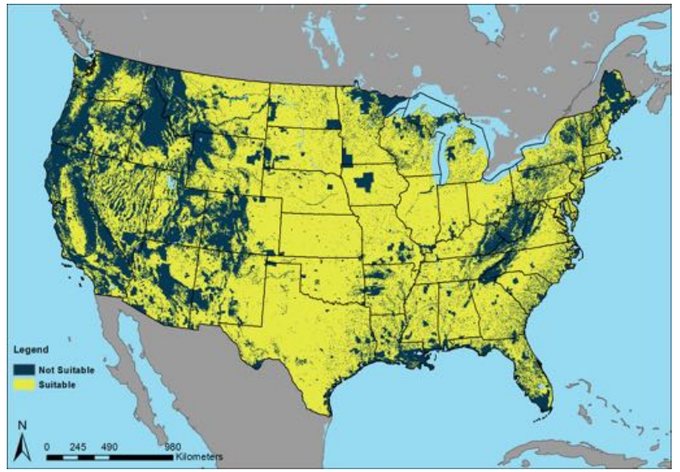
- What is the magnitude, timing, and distribution of interconnection costs in the US?
- Under what conditions are changing costs observed regionally (certain techs, siting barriers, combined effects)?
- Set the stage for future research by gaining an understanding of what multi-scale analysis can provide.

Scenarios

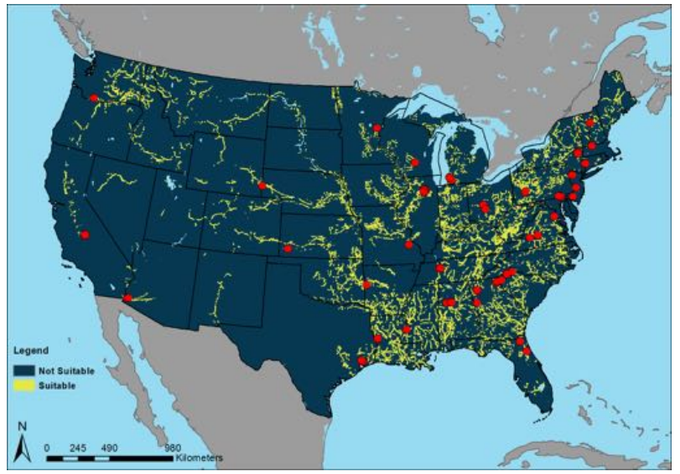
- **Reference**: Counterfactual scenario for comparison purposes
- **Renewables:** Rapid progress in renewable techs and increased renewables deployment
- **High electrification:** This scenario assumes high electrification of the buildings, transport and industrial sectors through increased penetration of end-use technologies such as electric appliances, and electric cars; increased capacity expansion
- **Demography**: Heterogeneous growths patterns within the U.S. Demonstrates the effects of change in the geographic distribution of electricity demand.
- **Economy-wide low-carbon**: Systematic transition to a low-carbon economy.

CERF

- Electricity capacity expansion feasibility
- 1 km^2 resolution
- On-the-ground suitability
- Technology competition based on regional economics and infrastructure
- Sites plants (lat/long) for least expensive option, interconnection cost, net locational cost



Common Suitability



Nuclear Least Cost Sites - 2010

Vernon, et al. JORS, 2018

CERF's Interconnection Cost Calculation

$$\textit{Interconnection Cost}\left(\frac{\$}{yr}\right)$$
$$= \textit{Distance to nearest suitable transmission line (km)}$$
$$\times\ \textit{Electric Grid Interconnection Capital Cost}\left(\frac{\$}{km}\right)$$
$$\times\ \textit{Annuity Factor}$$
$$+\ (\text{if gas-fired})\ (\text{Distance to nearest suitable gas pipeline (km)}$$
$$\times\ \textit{Gas Interconnection Captial Cost}\left(\frac{\$}{km}\right)$$
$$\times\ \textit{Annuity Factor})$$

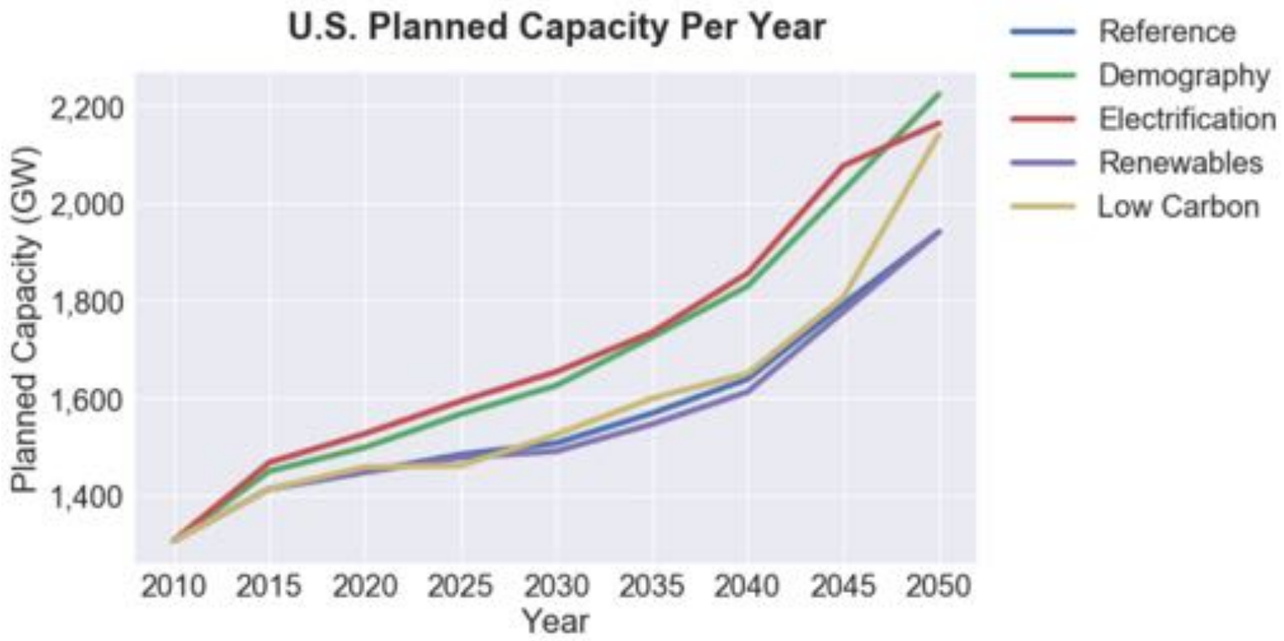
where,

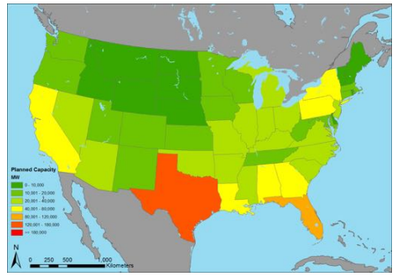
$$\textit{Annuity Factor (AF)} = \frac{d \times (1+d)^n}{(1+d)^n - 1}$$

where,

d = *real annual discount rate (%)*
n = *asset lifetime (years)*

GCAM USA - Planned Capacity

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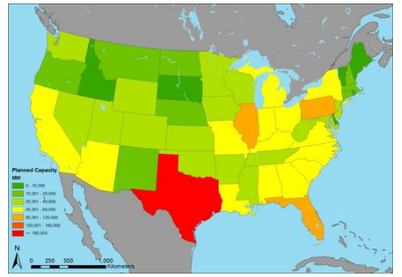
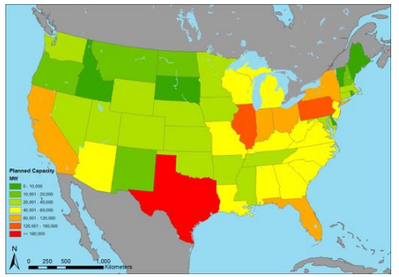
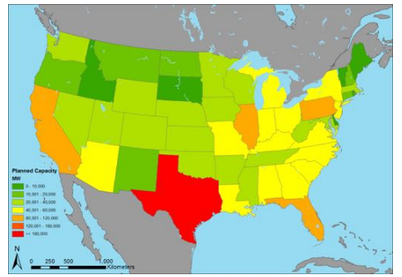
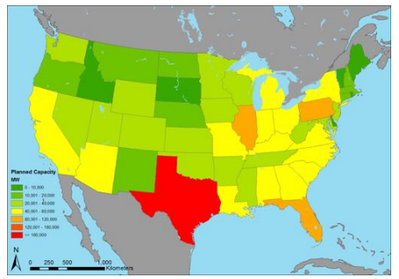

Reference - 2050


Demography - 2050


Electrification - 2050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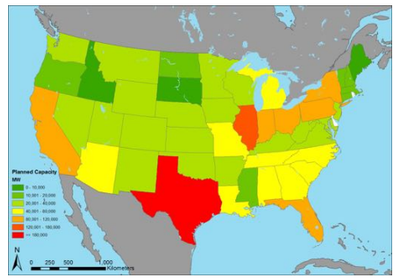
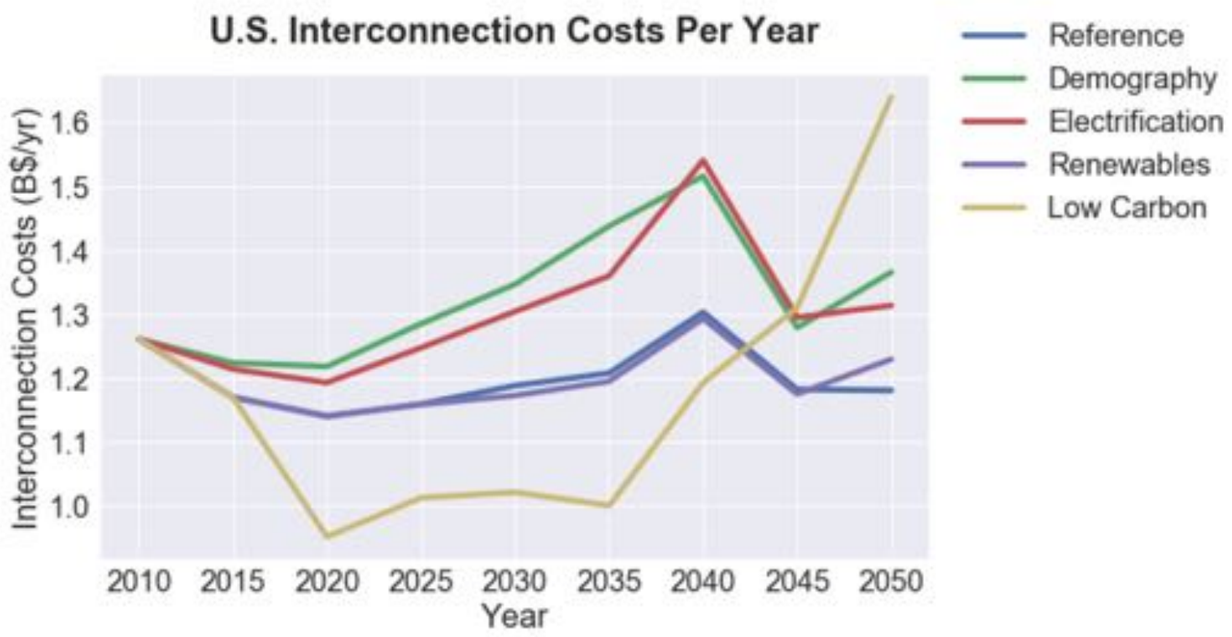
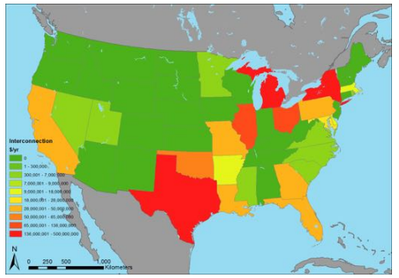

Low Carbon - 2050

Interconnection Costs

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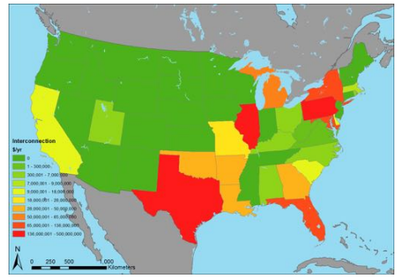
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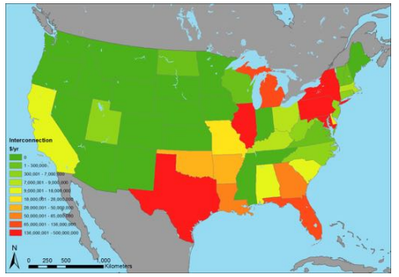
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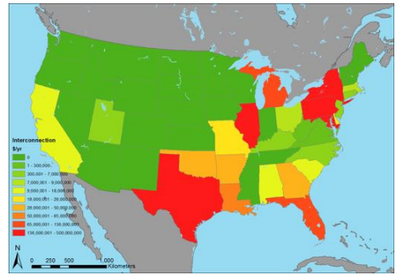
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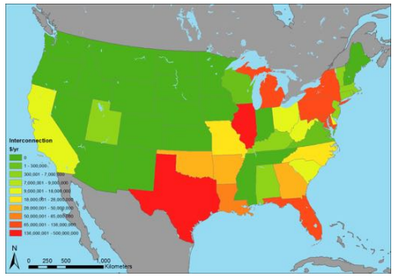
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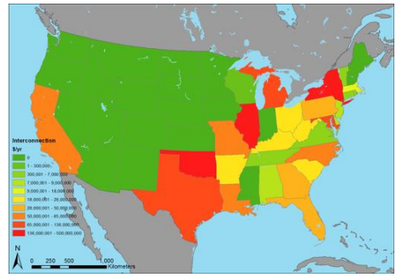
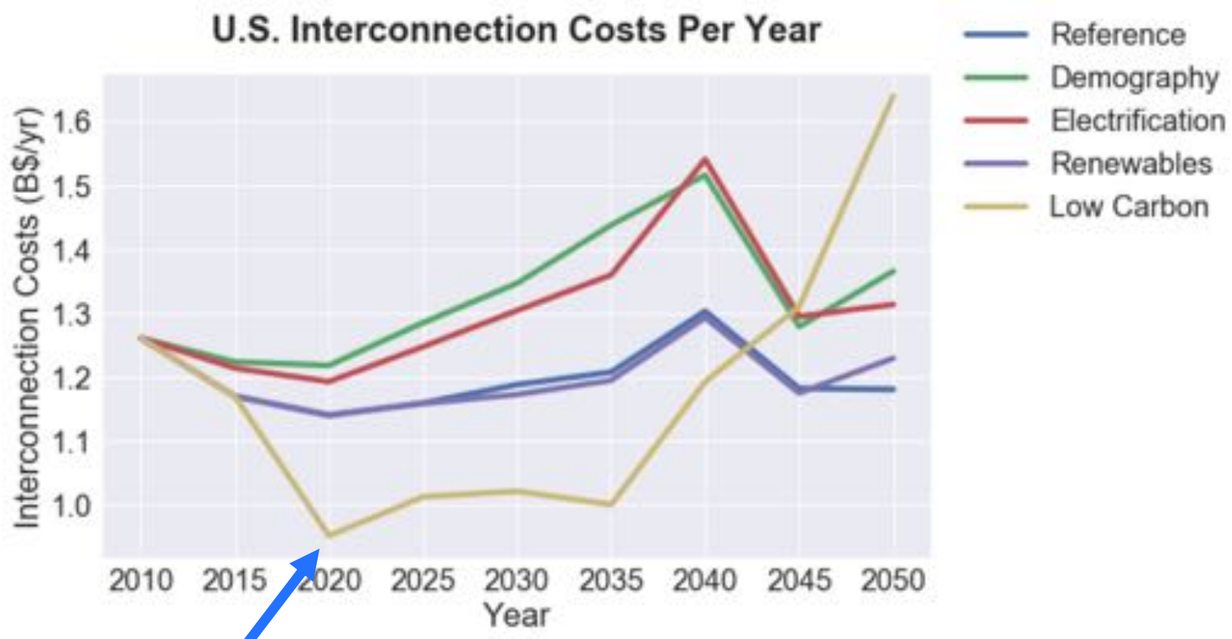
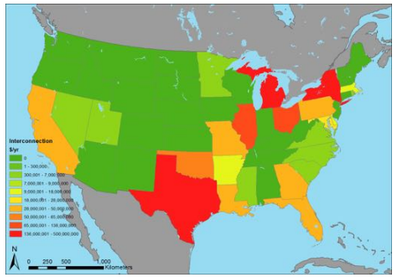

Low Carbon - 2050

Interconnection Costs



Decrease in Coal



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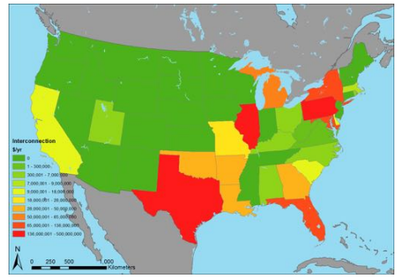

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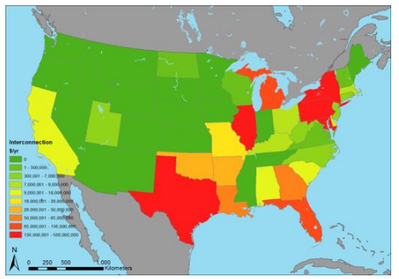

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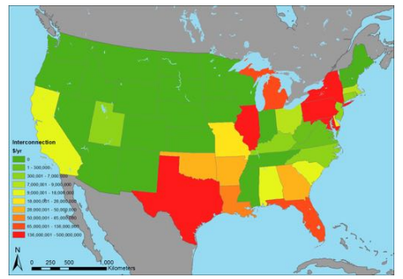

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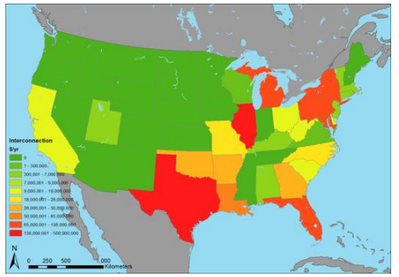

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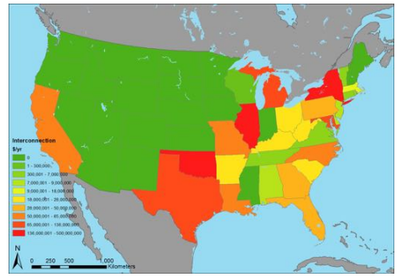
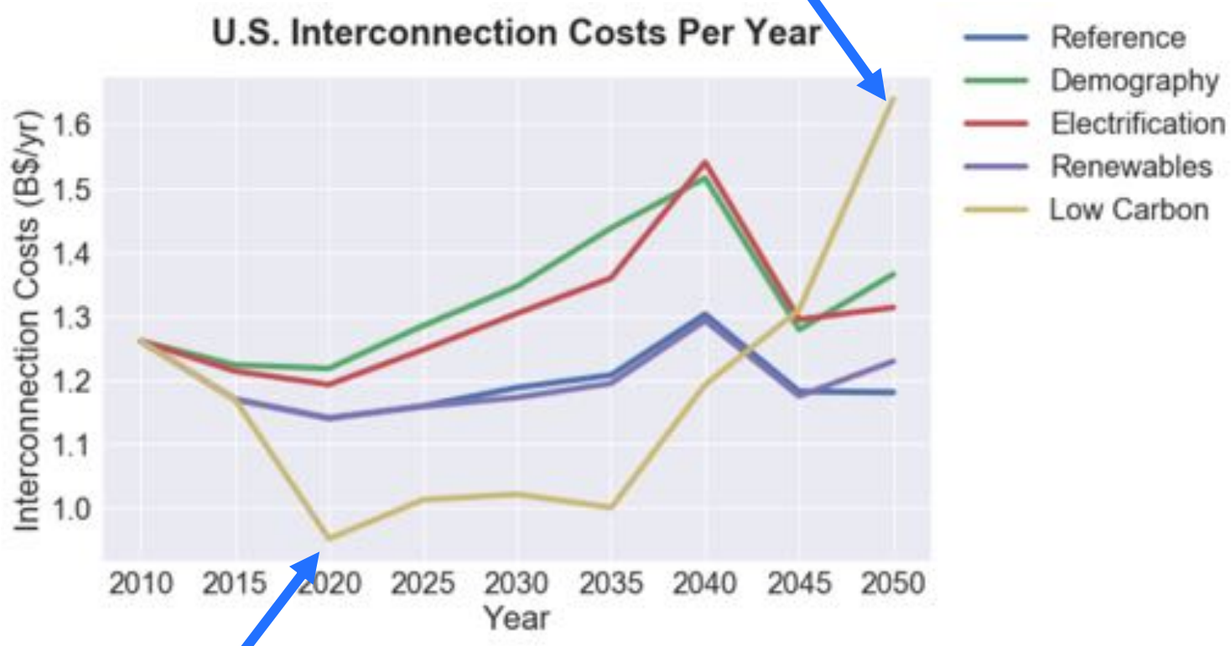


Low Carbon - 2050

Interconnection Costs

Increase in wind and solar



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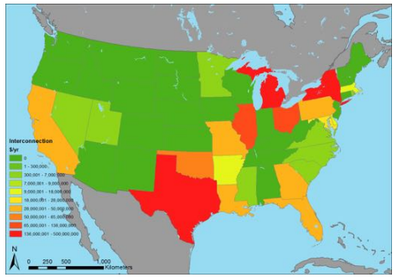
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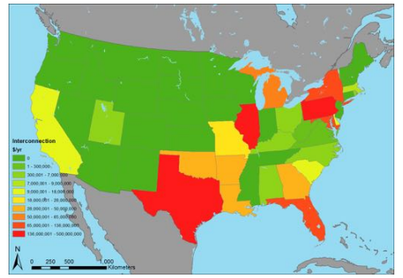
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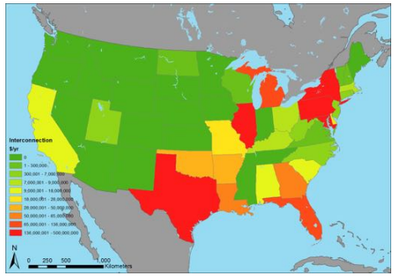
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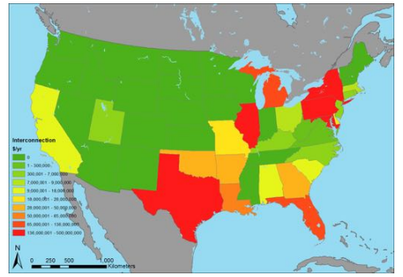
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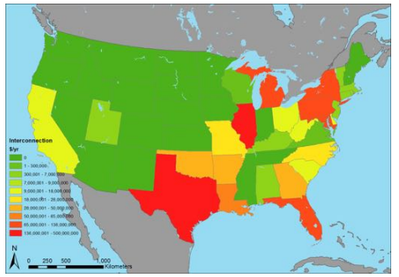
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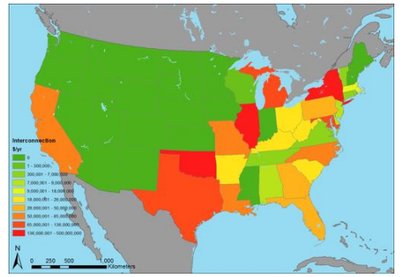
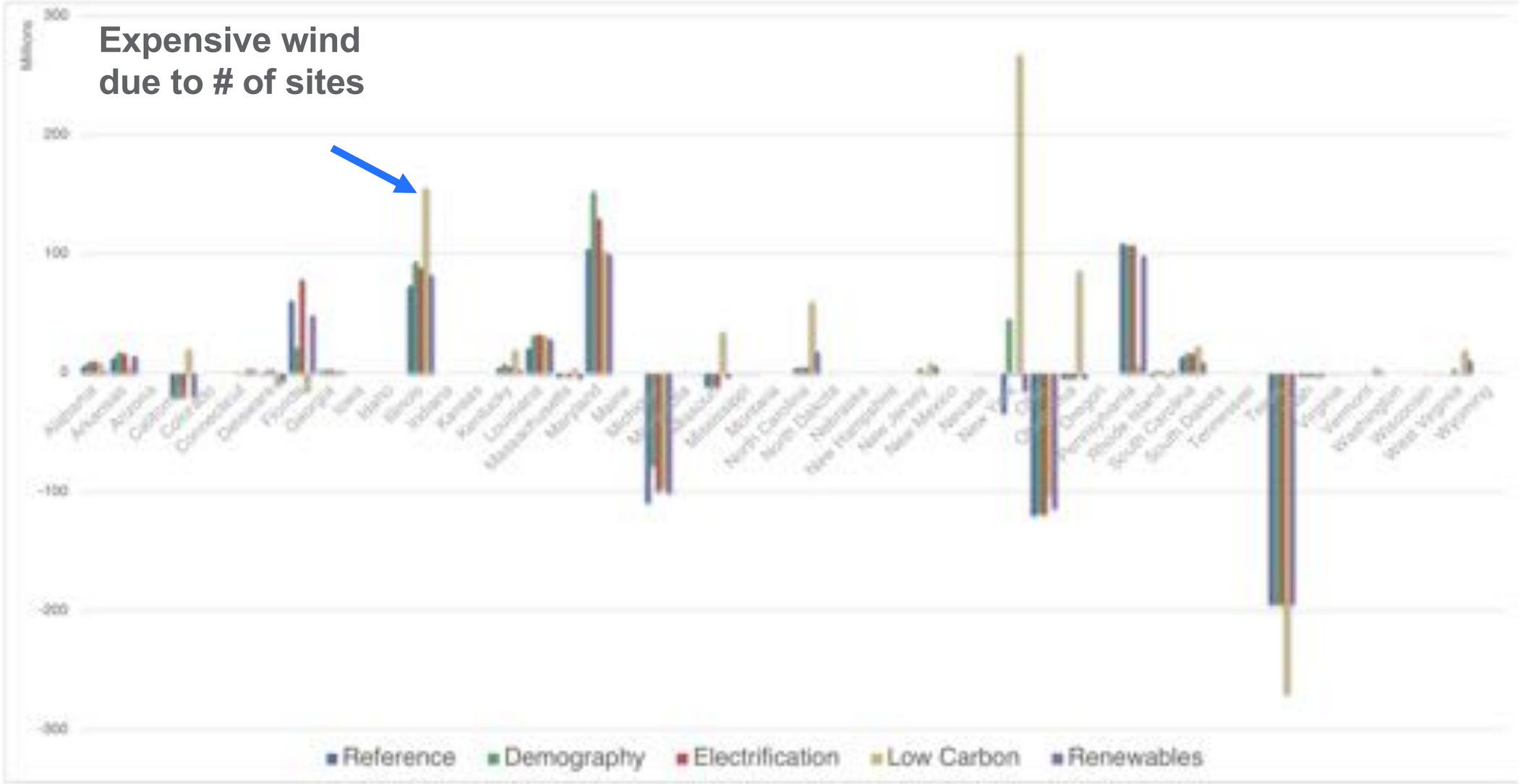

Low Carbon - 2050

Interconnection Costs Change from 2010 to 2050



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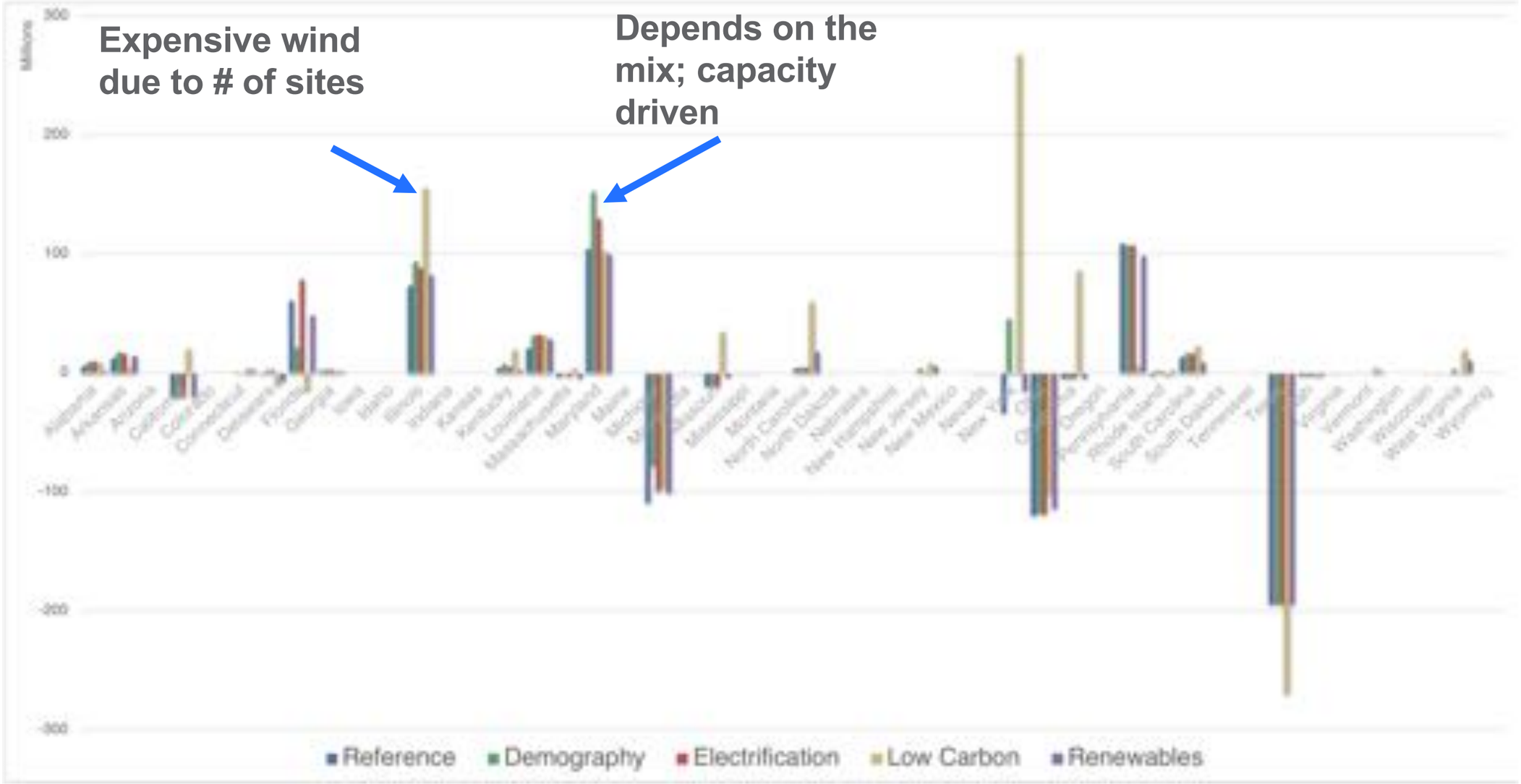

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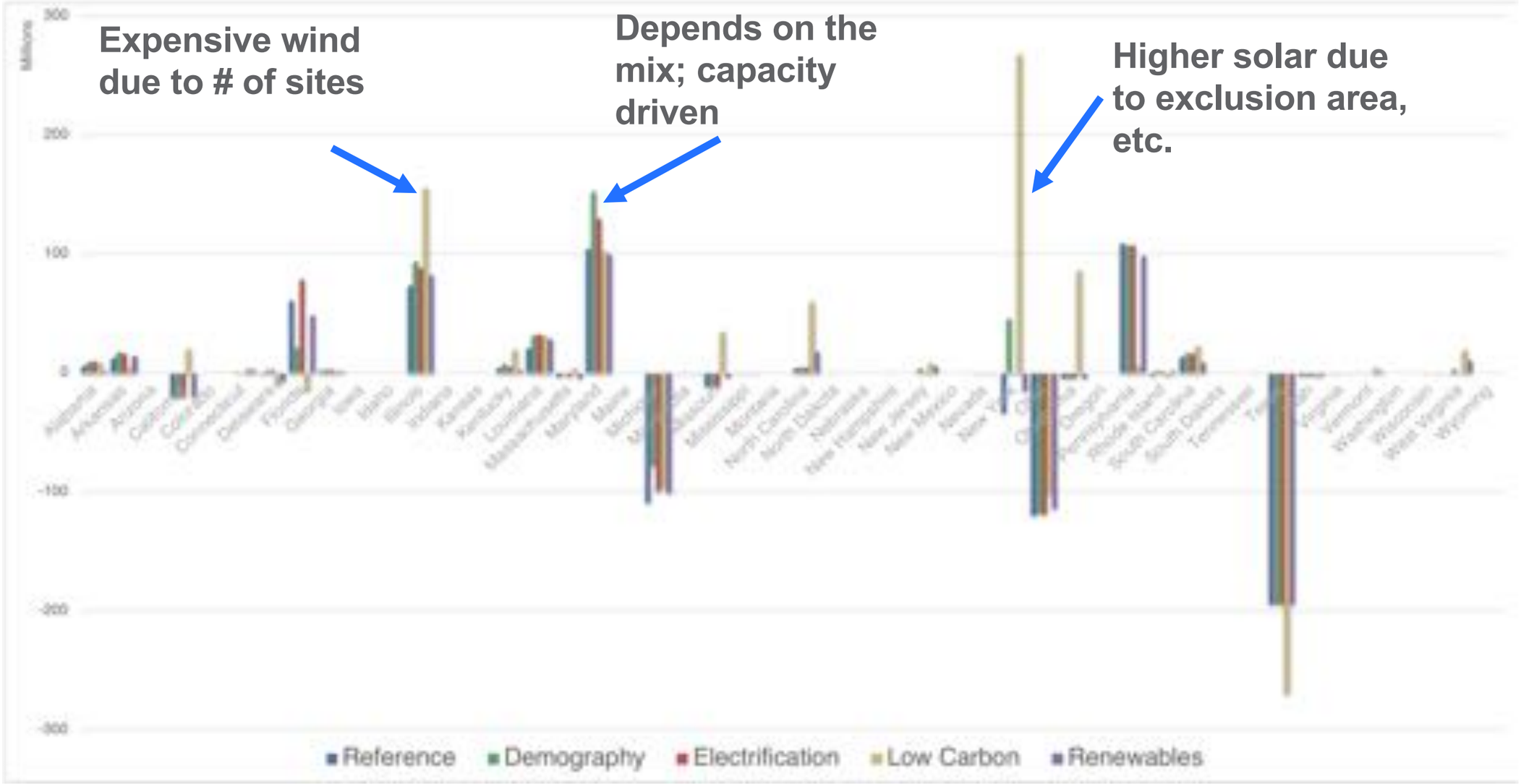

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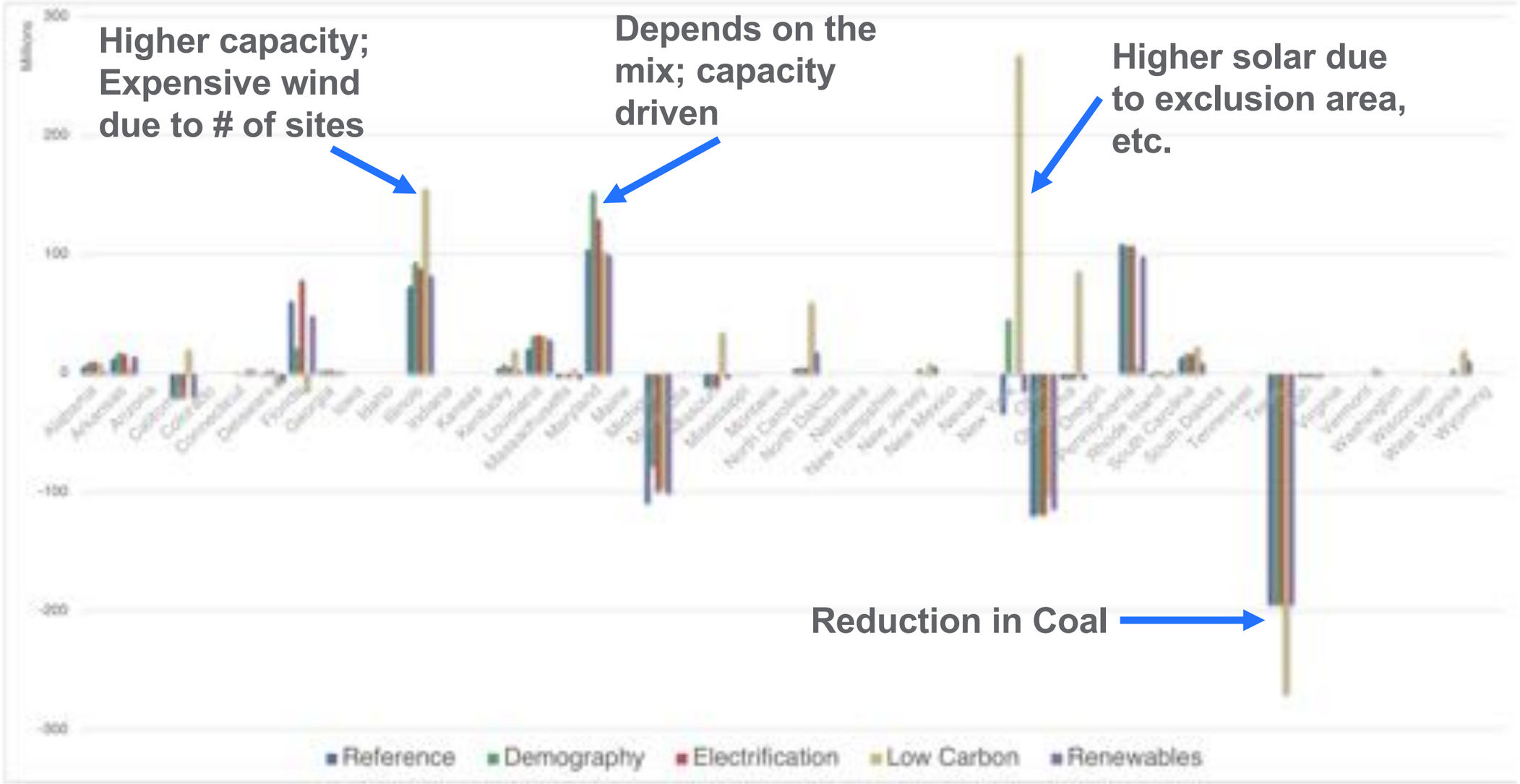
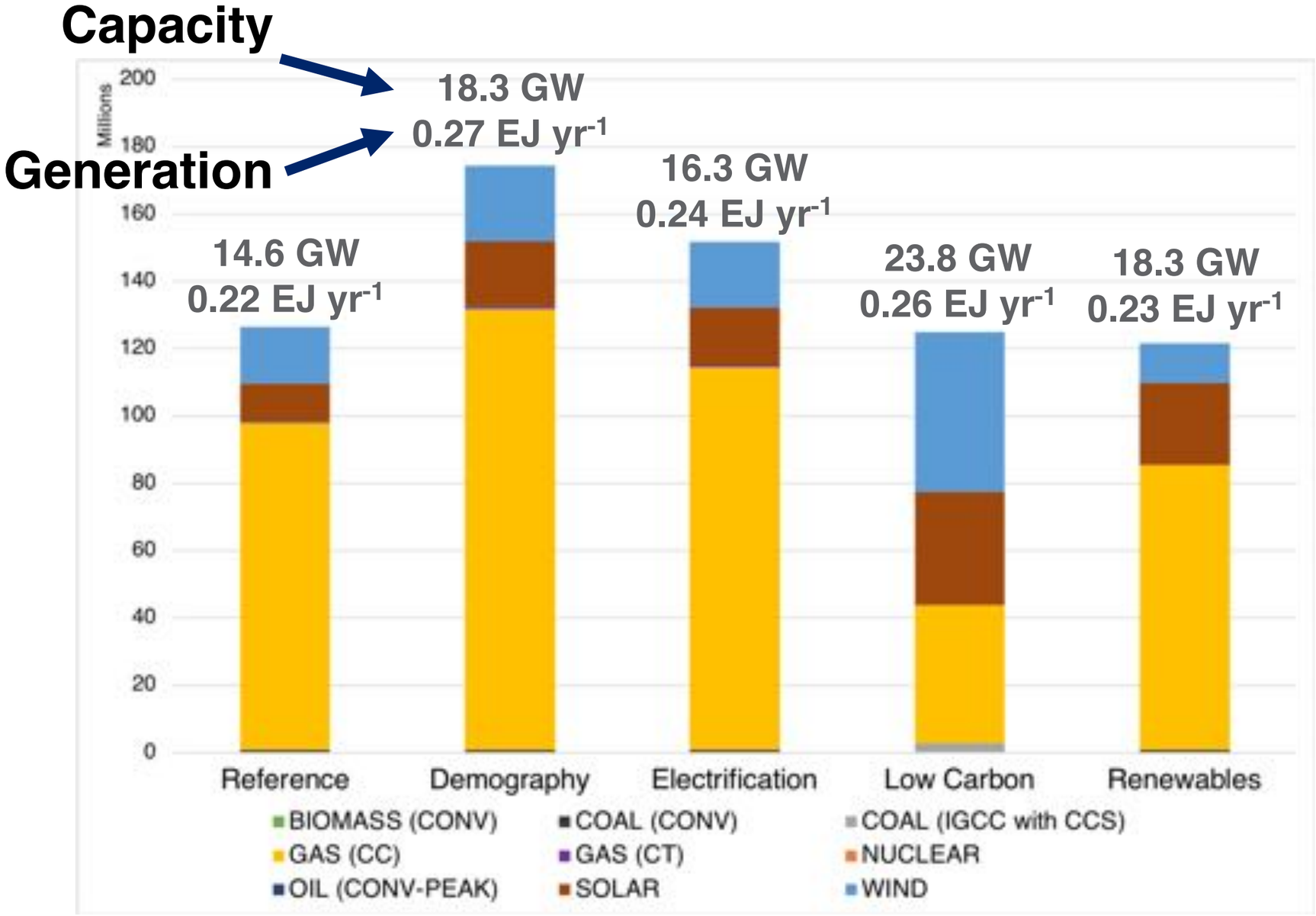


Maryland – multiple pathways



Year 2050

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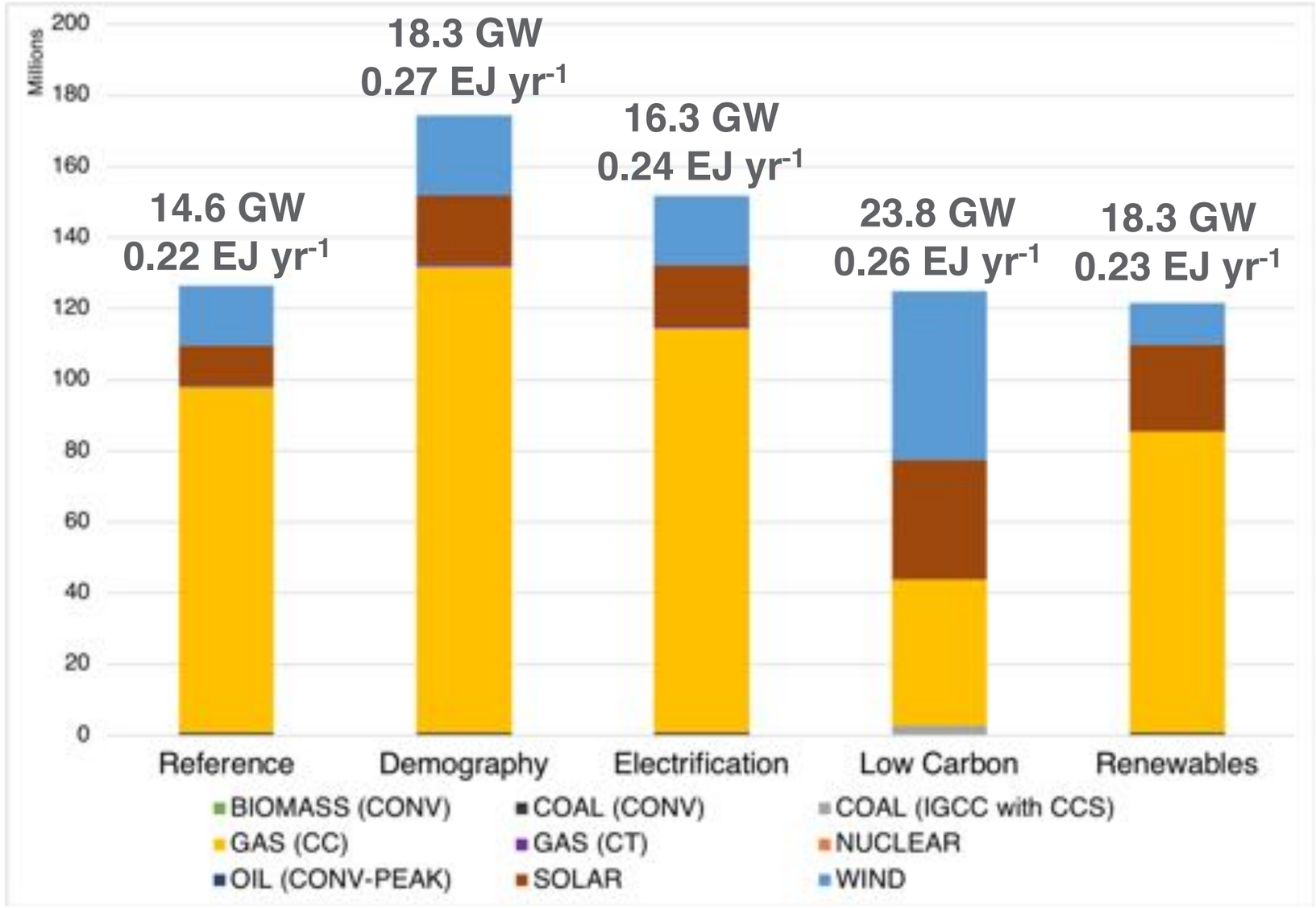

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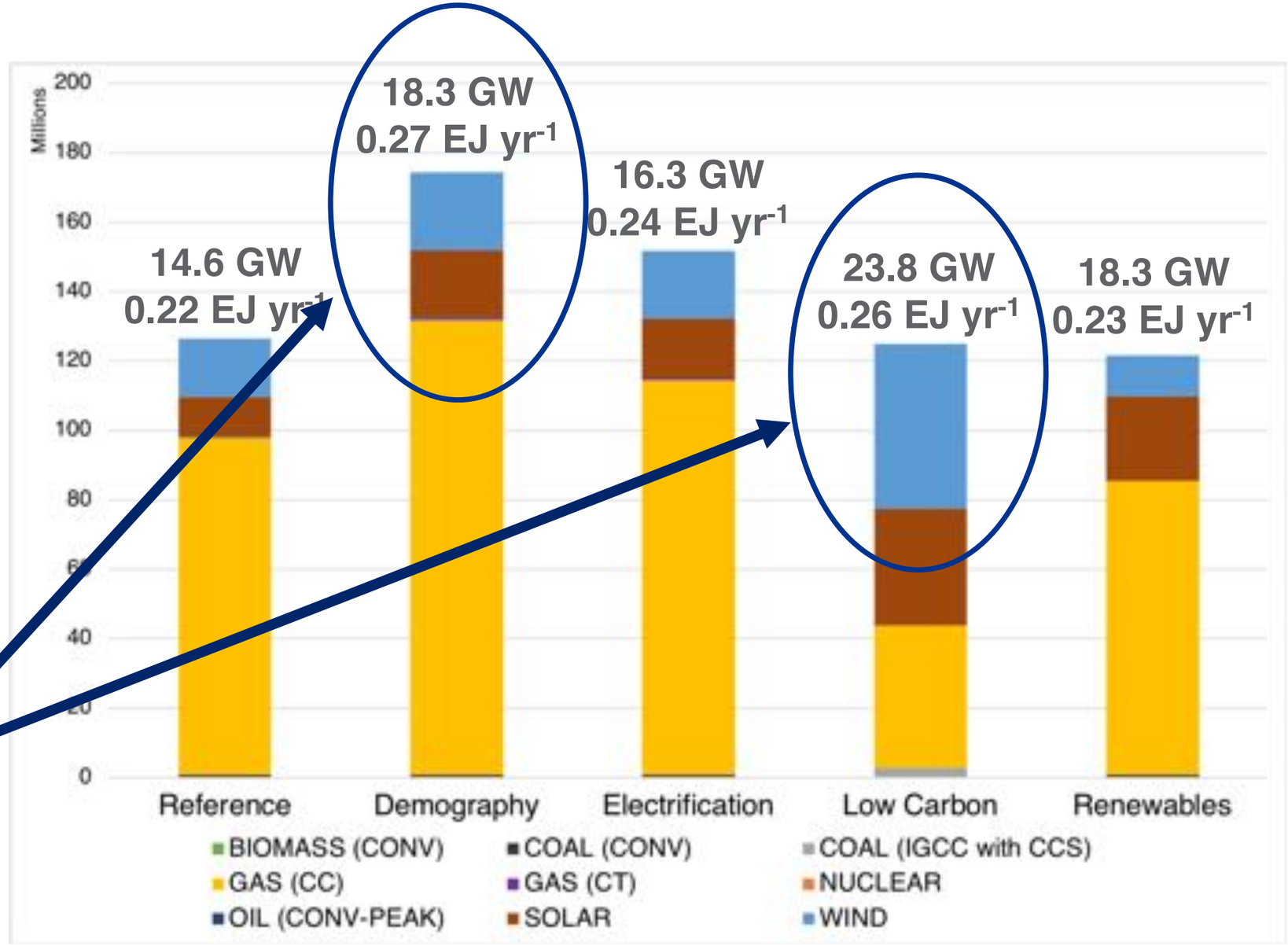
Maryland – multiple pathways

Solar and Wind replacing Gas Combined Cycle – less expensive



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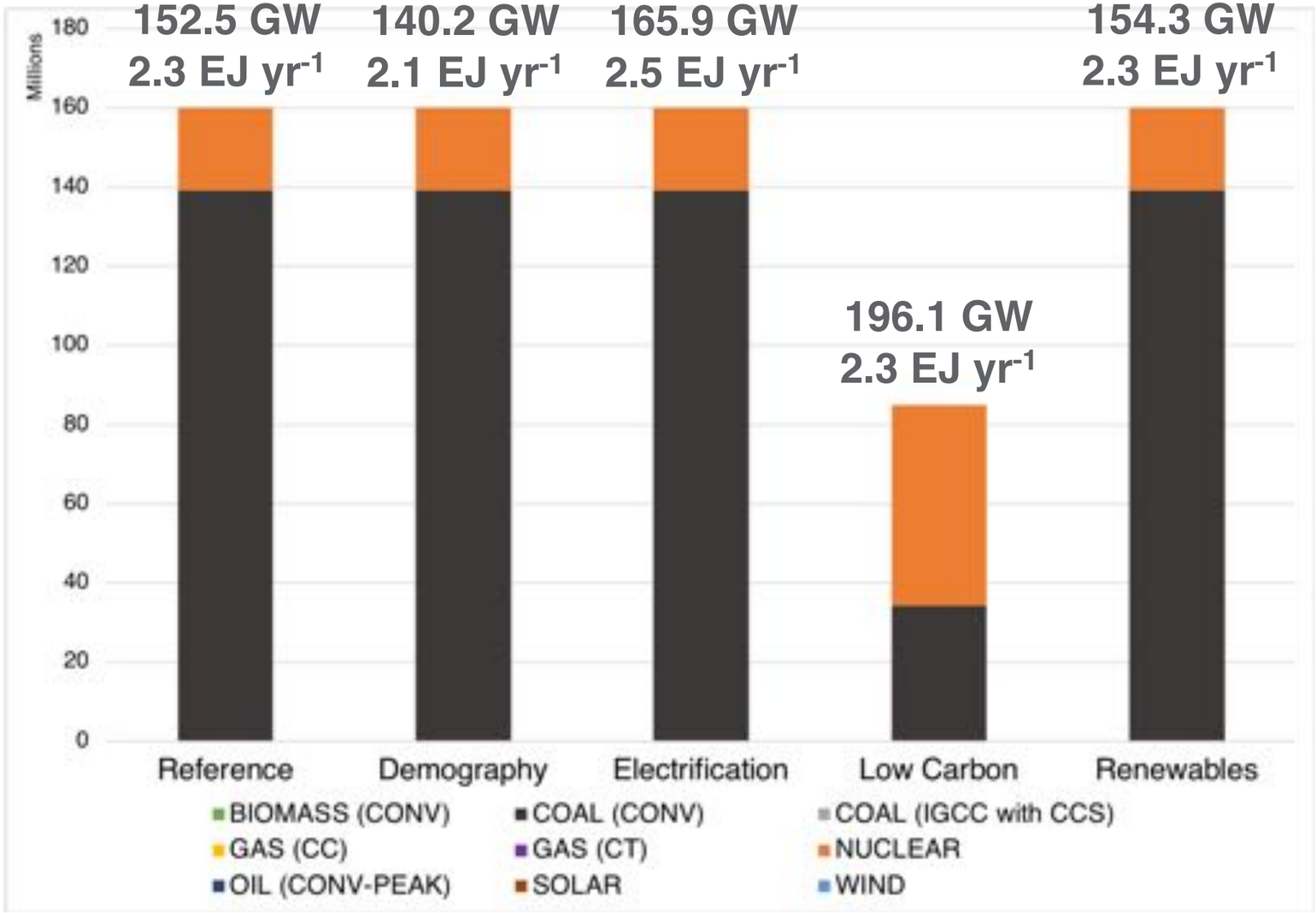
Texas – Expensive Conventional Coal



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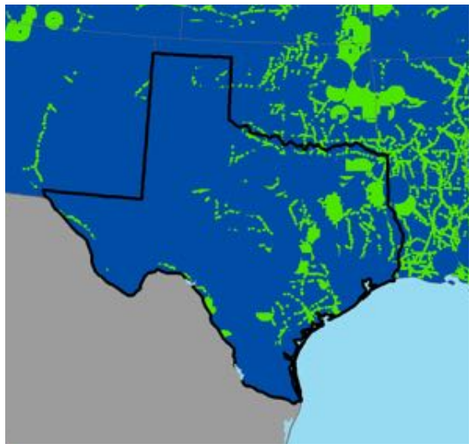
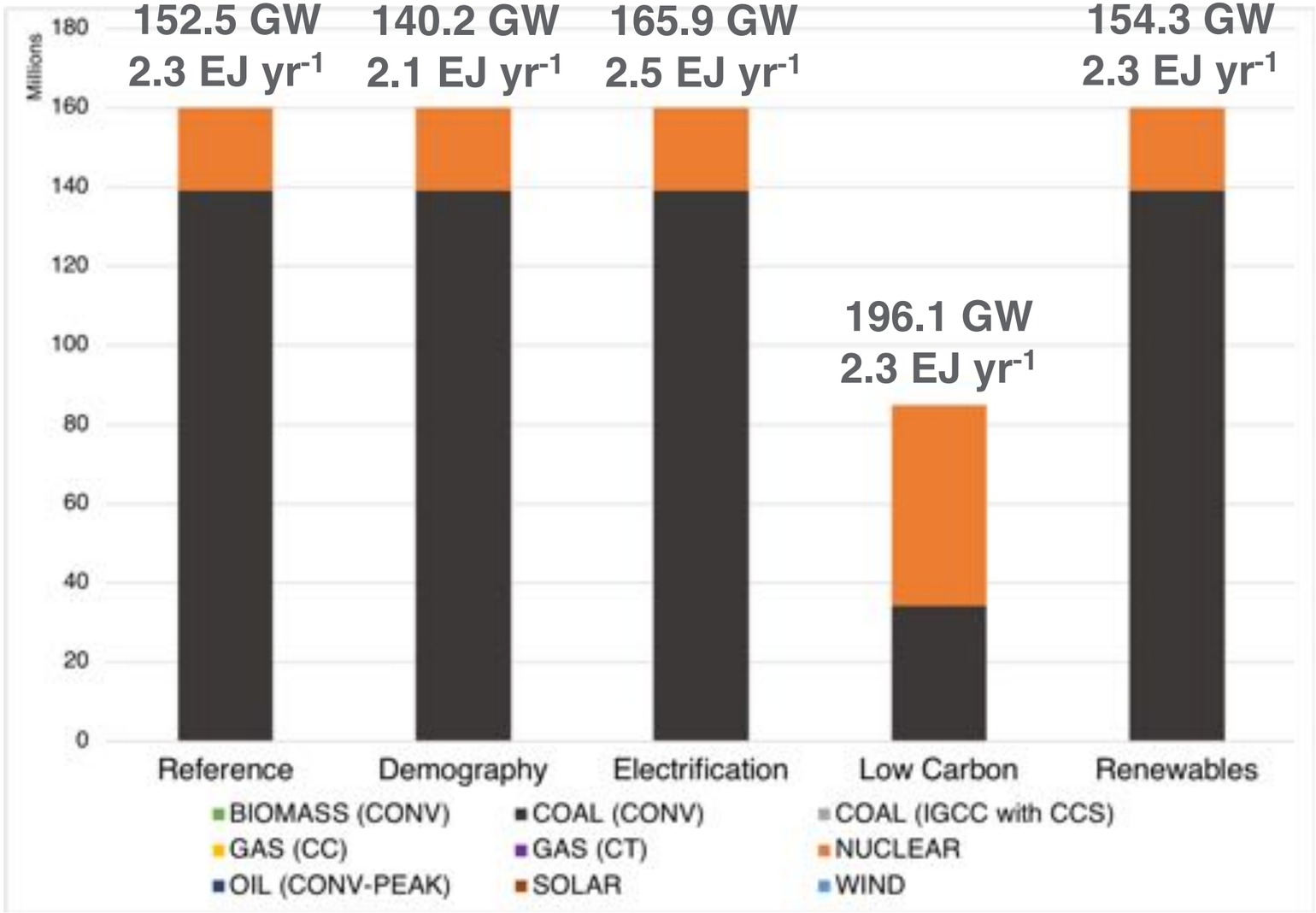


Coal Suitability
Blue = Not Suitable
Green = Suitable



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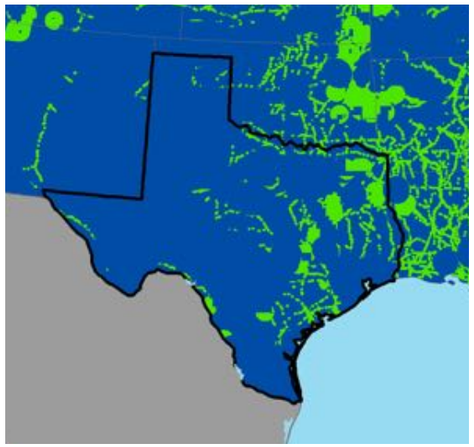

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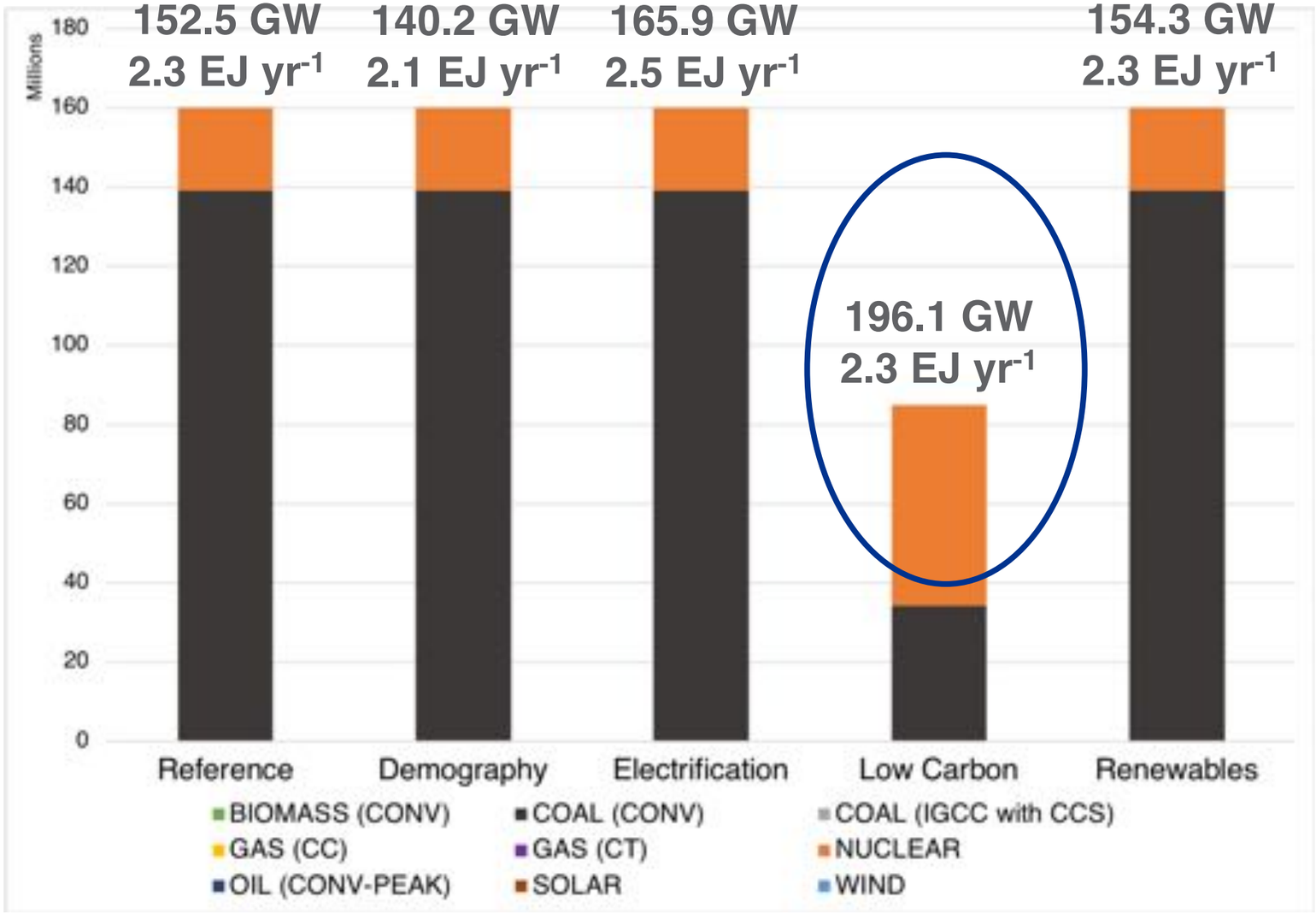

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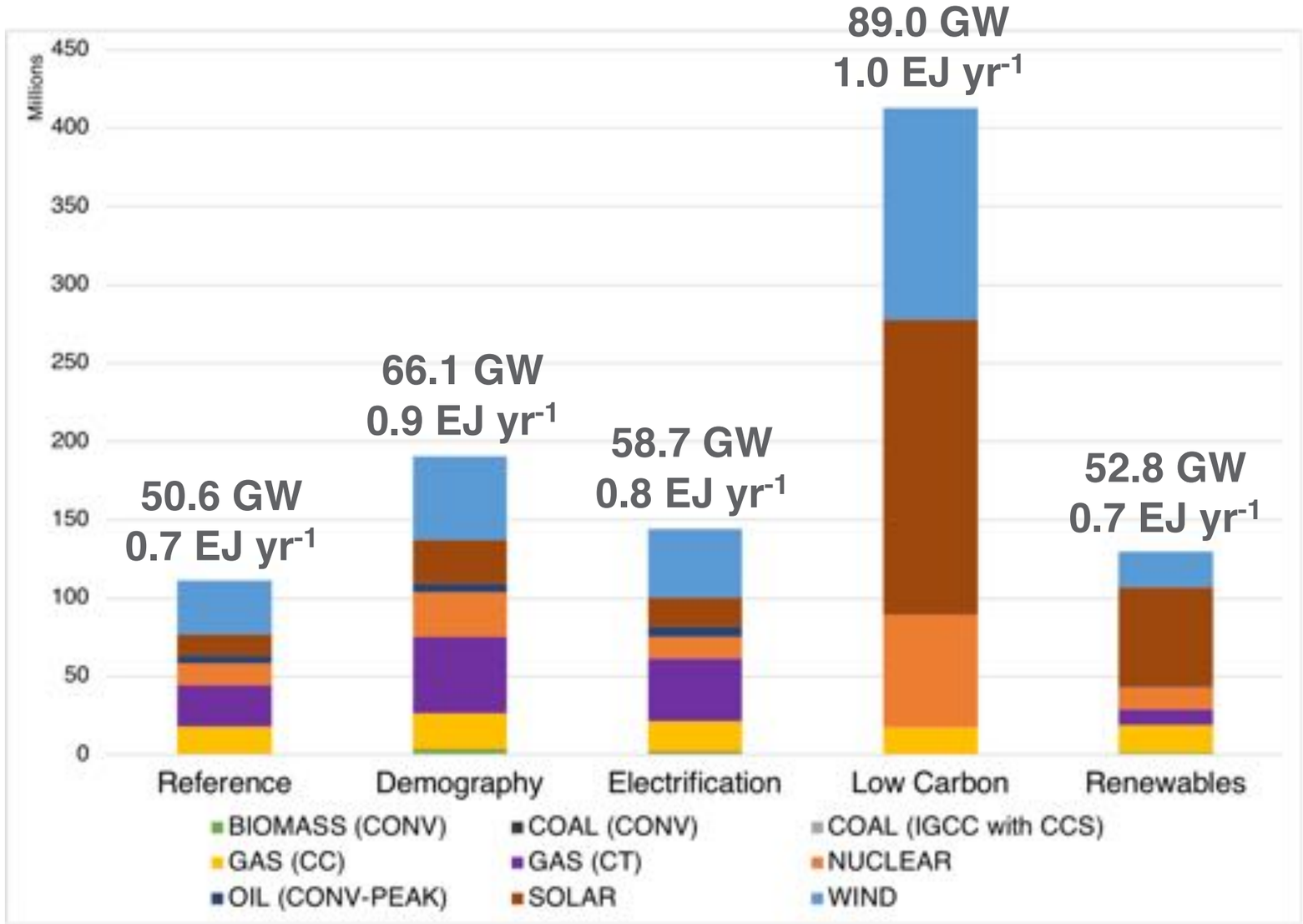
New York – Expensive Solar



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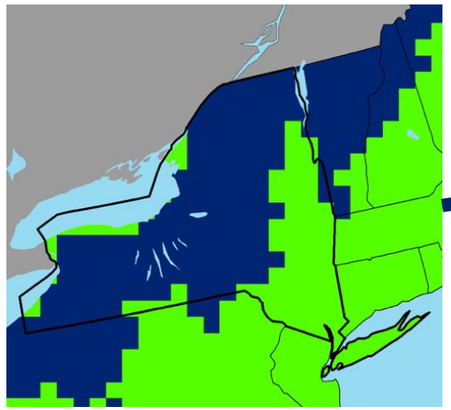

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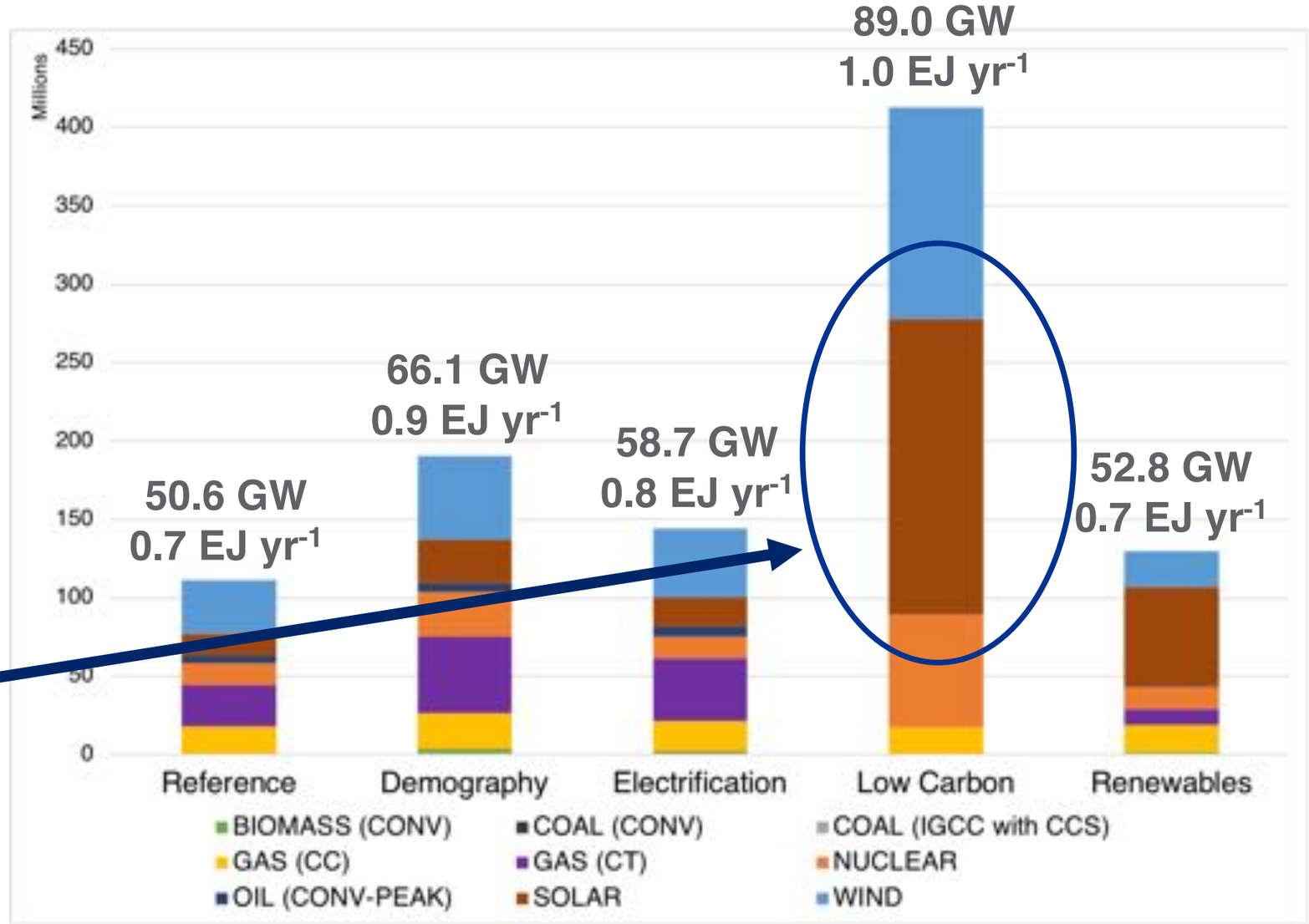

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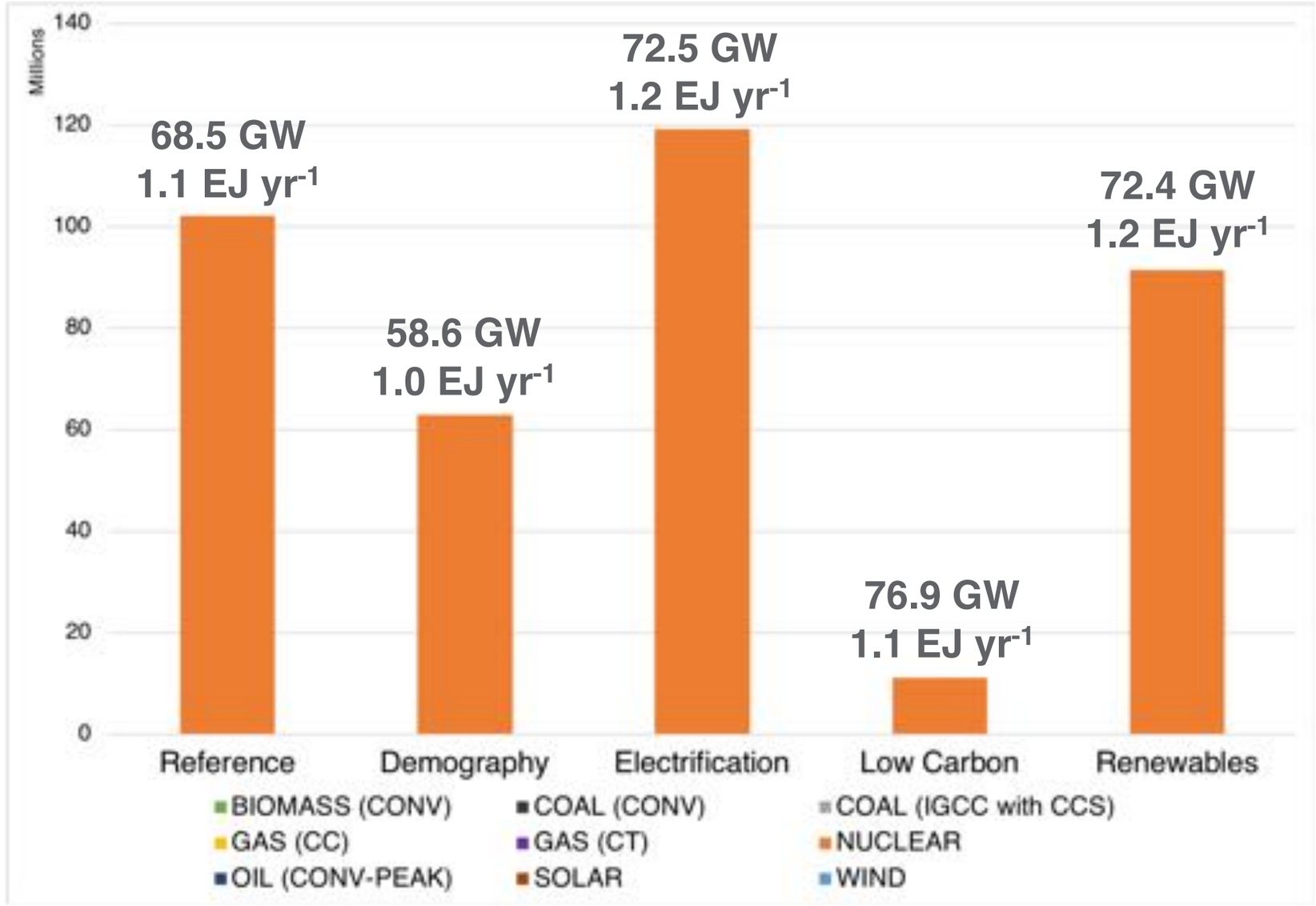
Florida – Lacking Infrastructure



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Key Insights

- Interconnection cost response to an electricity expansion plan varies by state
- Scenarios need to account for state and technology level barriers to siting
- A combination of strategies that incorporate state-specific idiosyncrasies may provide the best option

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Next Steps

- Harmonize production cost model locational marginal pricing
- Dynamic cooling water availability
- Explore uncertainty in projections and in suitability limits
- Much more

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