Modernizing Minnesota's Grid

An Economic Analysis of Energy Storage Opportunities

MISO-wide Electricity Co-Optimized Planning Scenarios

Prepared By:

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Prepared For:

Minnesota Public Utility Commission

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Overview

I. Background and the WIS:dom optimization model

II. Main modeling results and analysis

III. Conclusions

IV. Modeling inputs and assumptions

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I. **Background and the WIS:dom optimization model**

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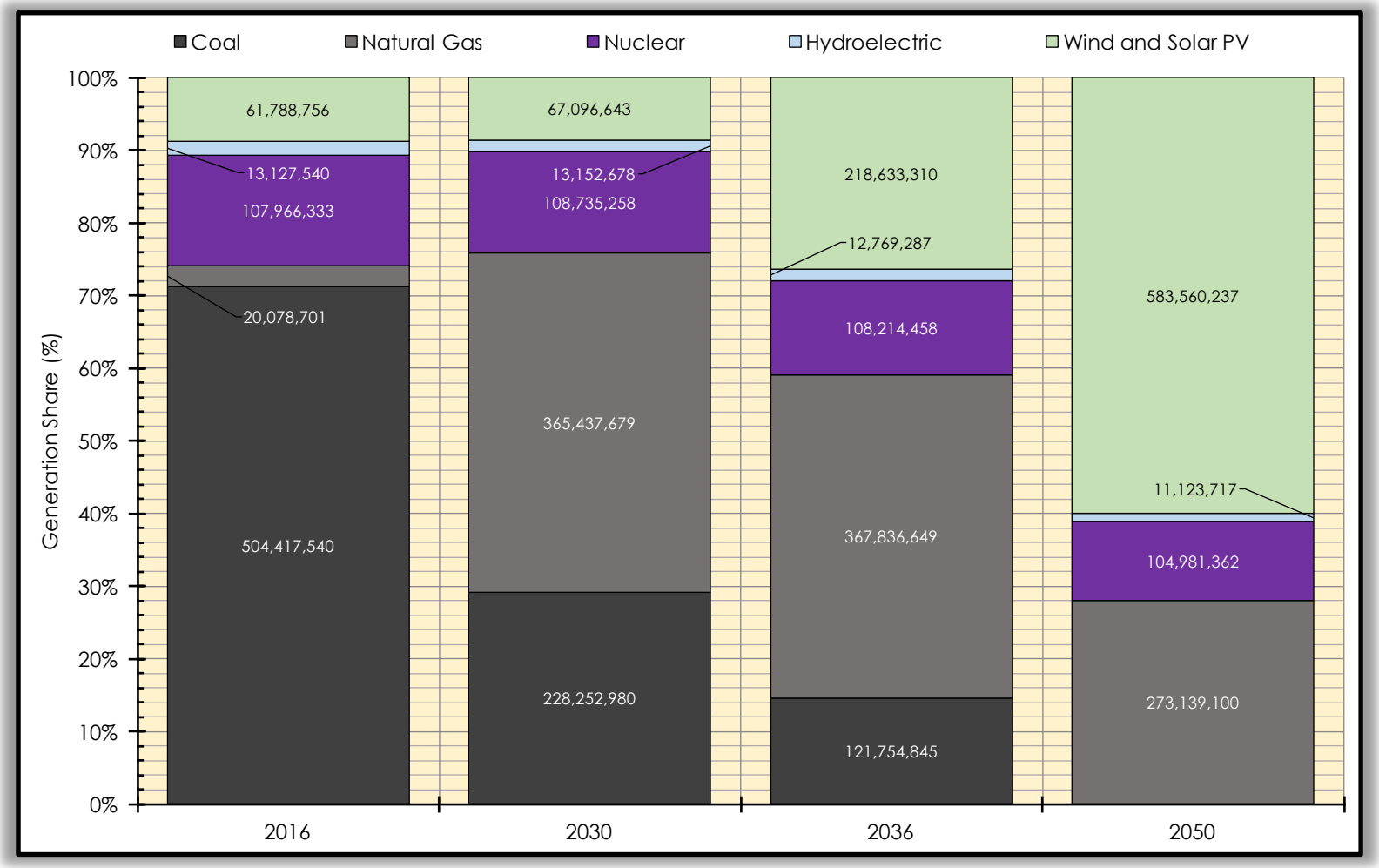
MISO high penetration renewable energy study for 2050

- In 2016, Vibrant Clean Energy, LLC (VCE) produced a high renewables study for the Midcontinent Independent System Operator (MISO).

- The study found that MISO could reduce emissions by 80% compared with 2005 levels at reasonable cost by expanding generation from wind and solar PV along with complementary natural gas and transmission.

- The present system level analysis is an expanded version of the previous MUISO study carried out by VCE.

MISO high penetration renewable energy study for 2050



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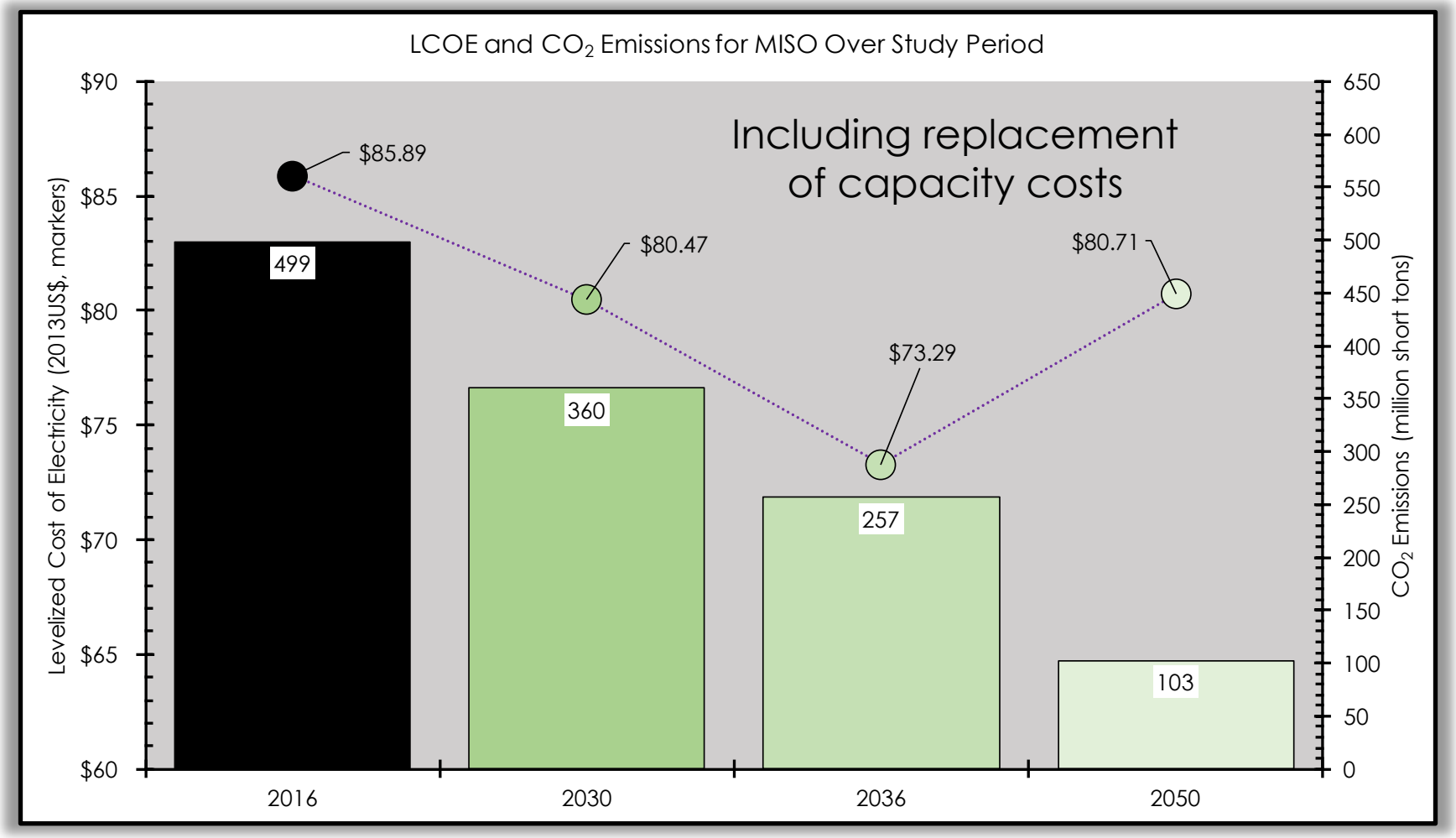

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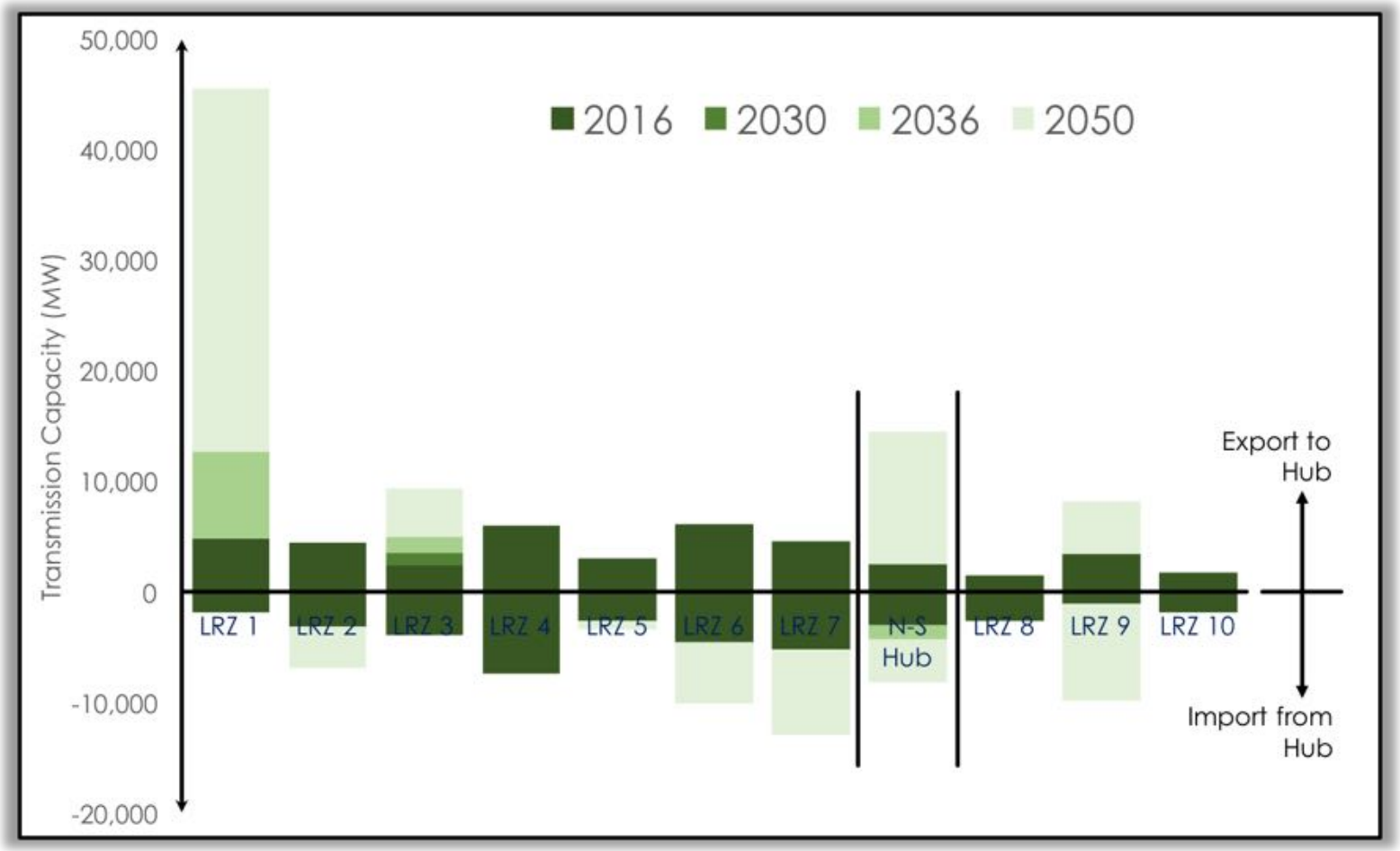

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The WIS:dom Optimization Model

- WIS:dom is the ***only*** model to combine:

i. Continental-scale (globally capable), spatially-determined transmission and generation expansion (3-km, hourly);

ii. Transmission power flow, planning reserves, and operating reserves;

iii. Weather forecasting and physics of weather engines;

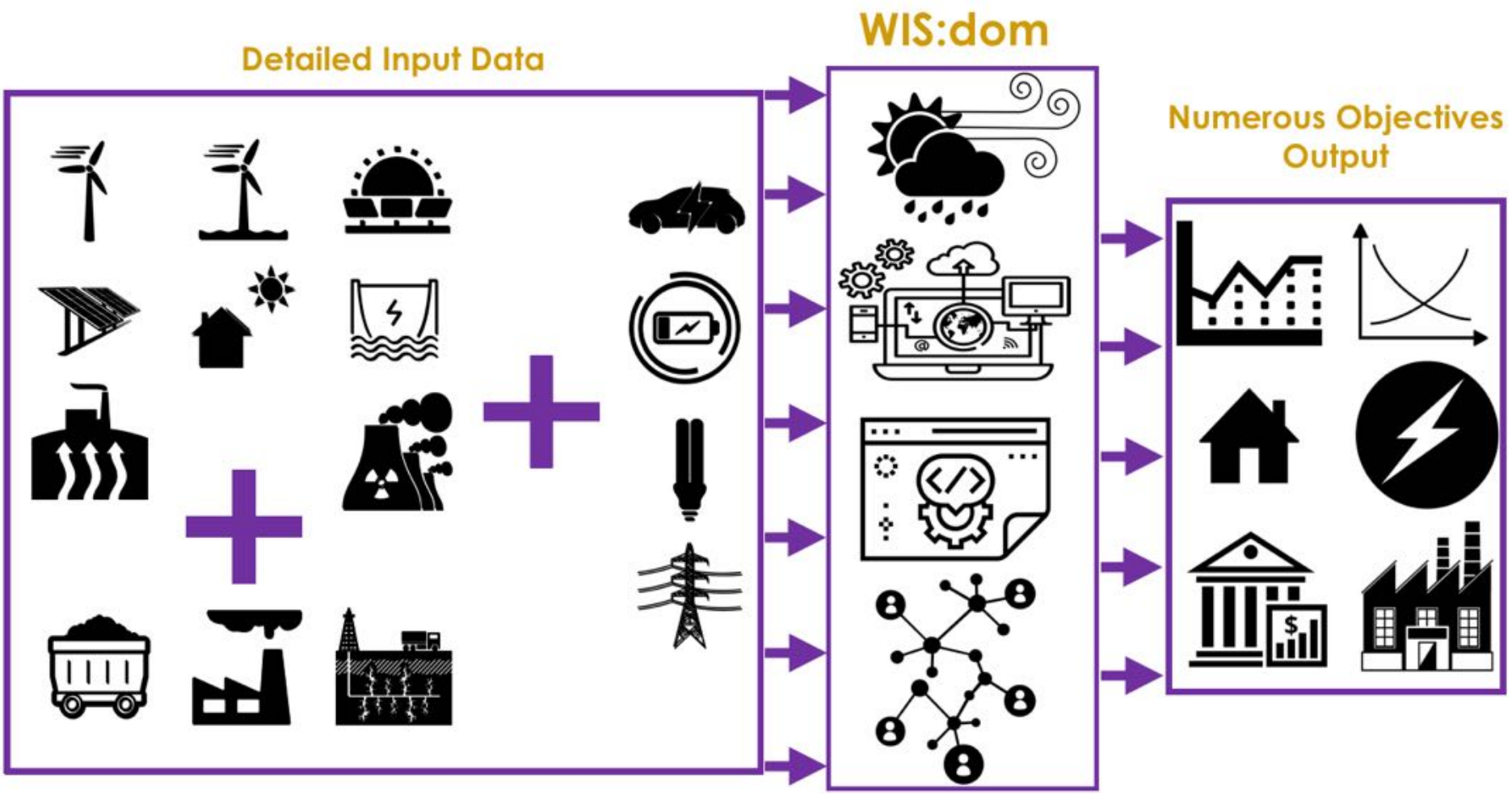
iv. Detailed hydro modeling;

v. High granularity for weather-dependent generation;

vi. Large spatial and temporal horizons;

vii. Detailed investment periods (1-year, 2-year, or 5-year) out past 2050.

The WIS:dom Optimization Model



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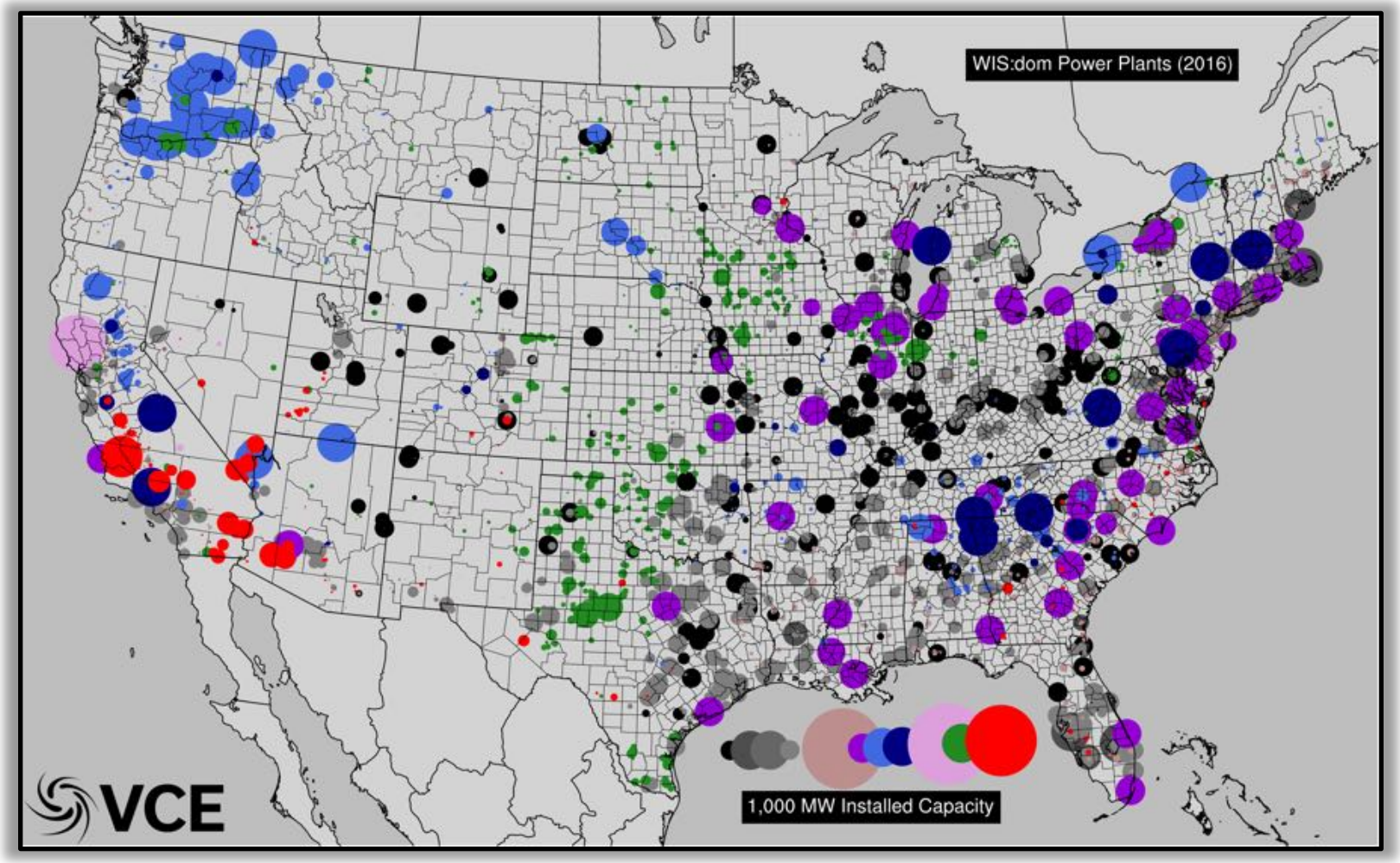

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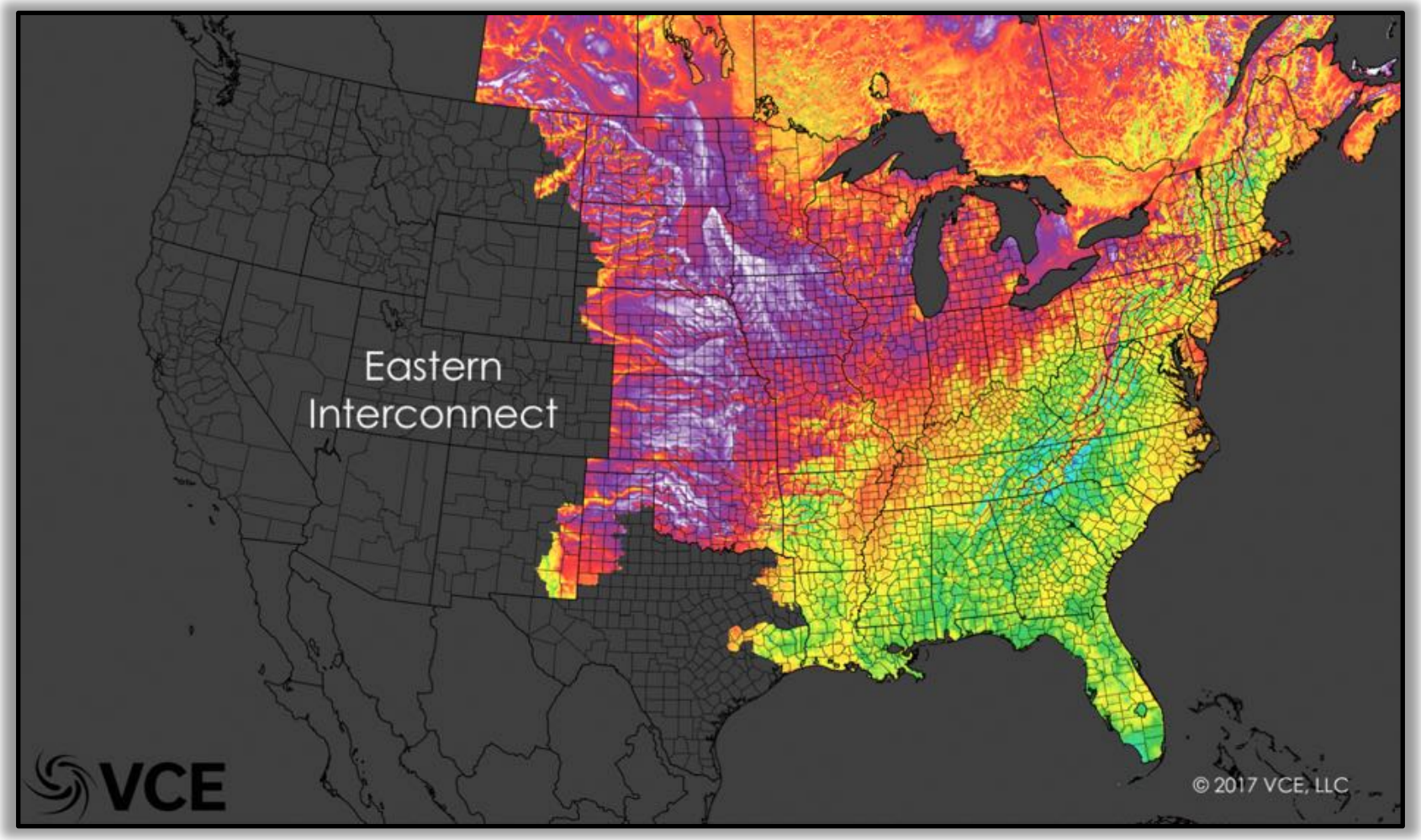
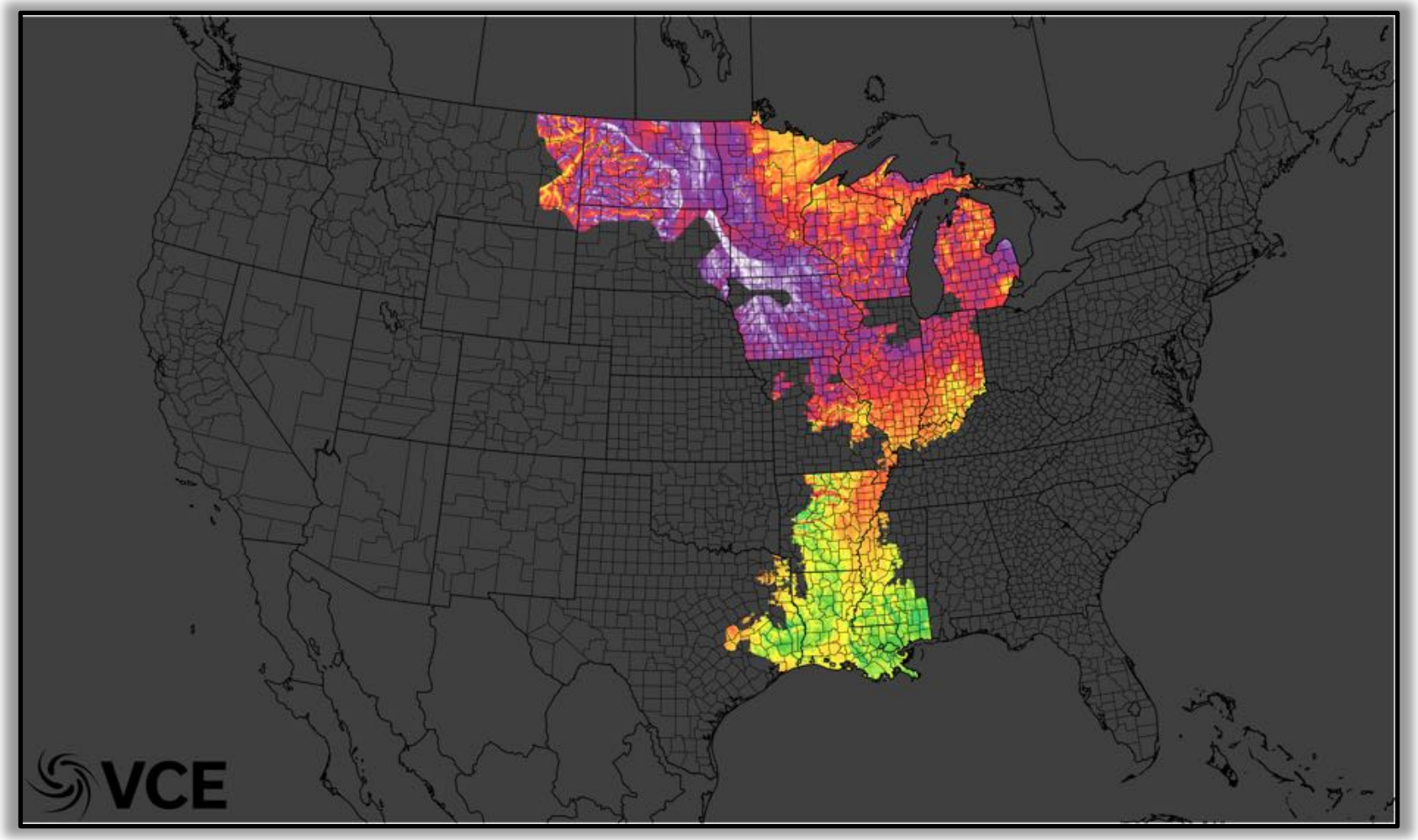


The WIS:dom Optimization Model - MISO



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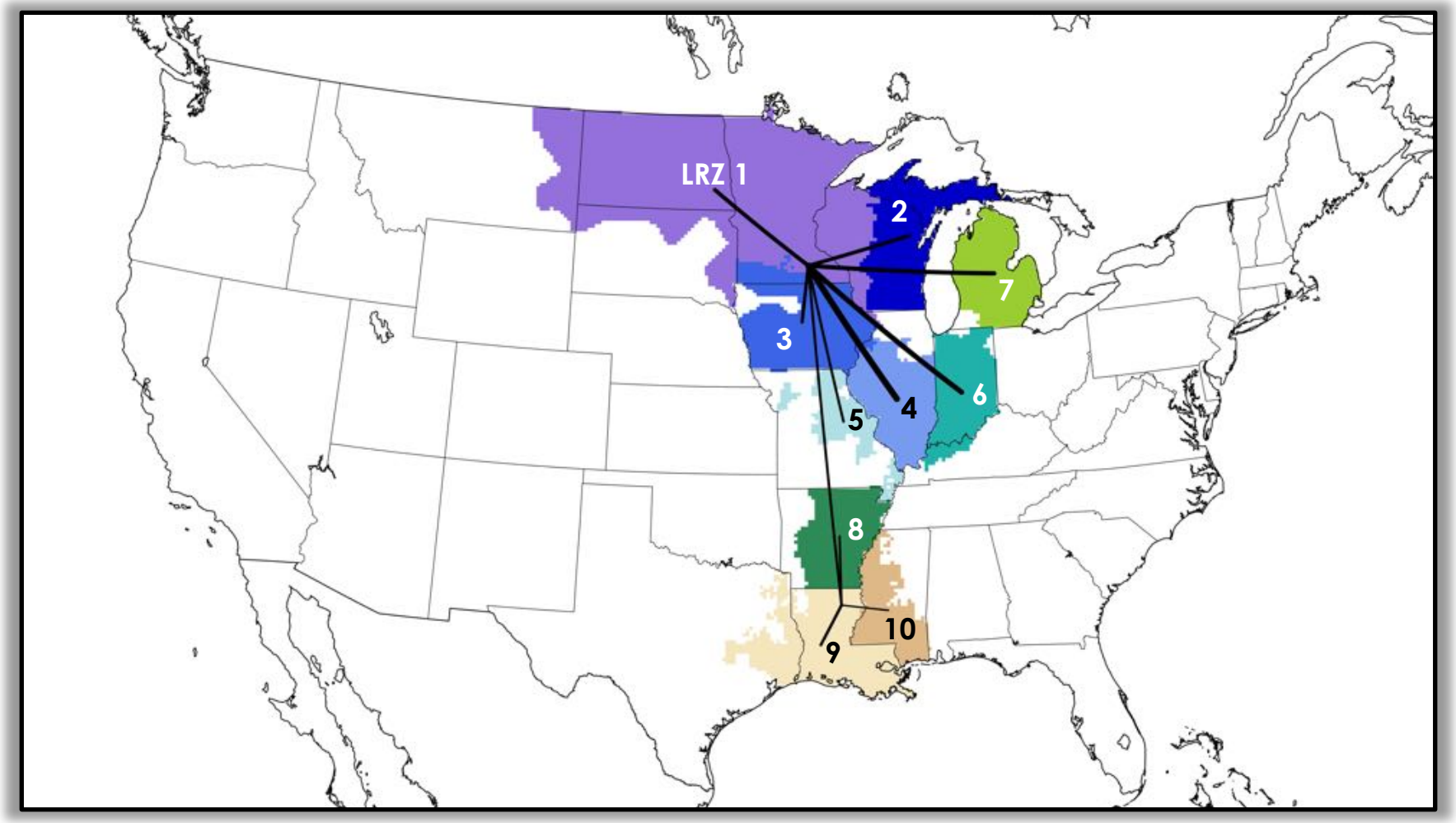

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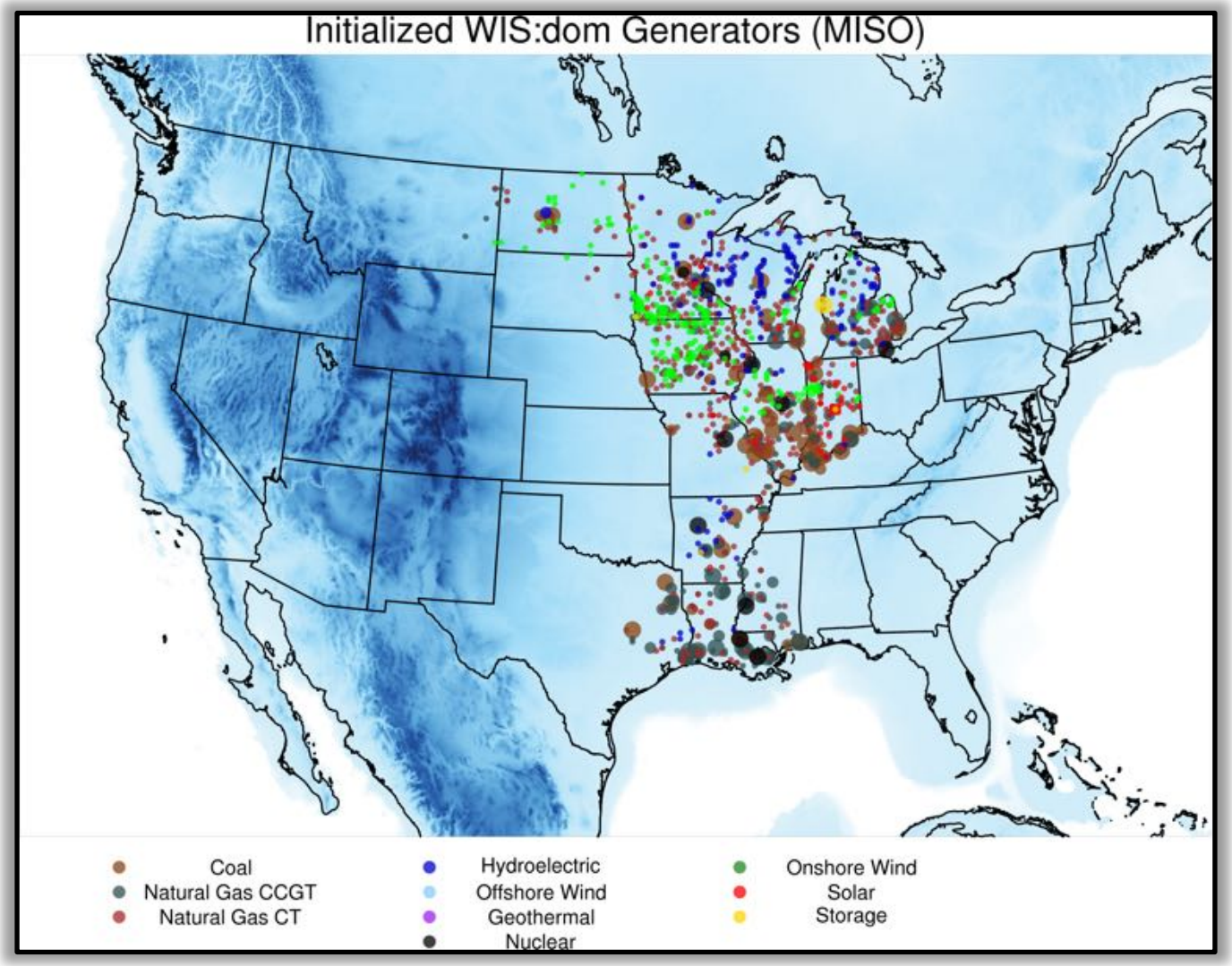

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Key Findings

- Electric Storage in MN reduces the levelized cost of electricity throughout the MISO footprint and is always selected by 2045 when available;

- MISO is capable of reducing GHG emissions by 80% by 2050 without storage; however, with storage as an option, LCOE is reduced and less fossil fuel generation is required;

- The efficacy of electric storage is increased when used in combination with transmission expansion;

- Less transmission expansion is required when storage is selected, when all other considerations are held equal.

Key Findings (continued)

- More storage is selected by the WIS:dom optimization model when the ITC is applied to storage as well as solar PV;

- Findings are consistent and supportive of the MRITS study – MN can support 40%+ variable generation.
  - *Current study finds least-cost configurations throughout MISO based upon hourly, high granularity weather data for variable renewables;*
  - *WIS:dom finds economic and constrained scenarios to determine an agnostic envelope parameter space for role of different technologies;*

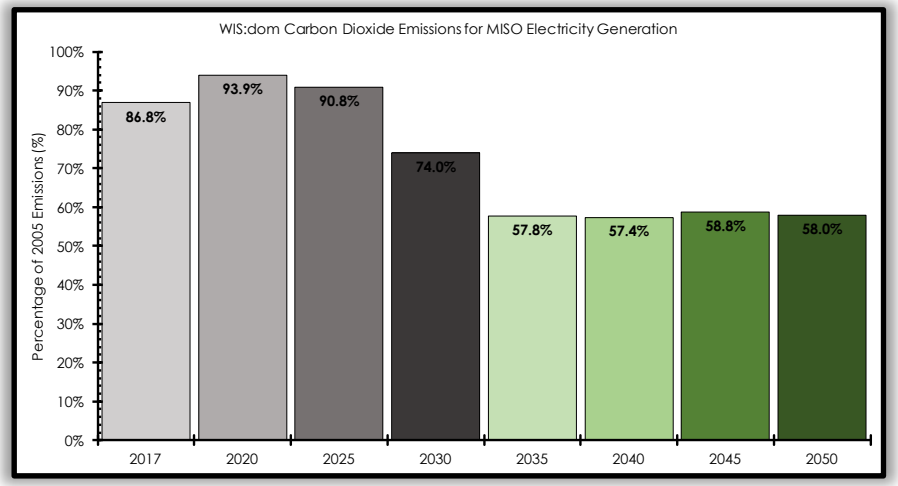
- Storage provides lower costs, higher resiliency (greater portfolio diversity), reserves, sustainable resource use, and increased transmission efficiency.

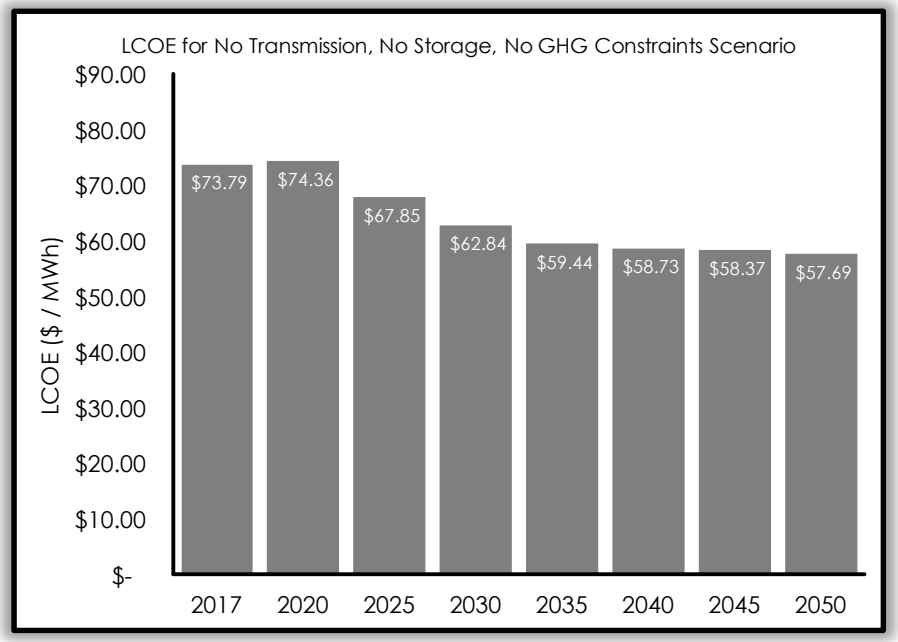
WIS:dom Simulation Matrix For Study

	Run Number	Transmission	No Transmission	Storage	No Storage	Forced Storage	Aggressive Storage	Carbon Constrained	Description
Standard Solar Costs	1		X	X					STORAGE
Transmission Allowed	2	X		X					
	3		X				X		AGGRESSIVE STORAGE
	4	X					X		
	5		X	X				X	STORAGE; CARBON CONSTRAINED
	6	X		X				X	
	7		X				X	X	AGGRESSIVE STORAGE; CARBON CONSTRAINED
	8	X					X	X	
	9		X		X				NO STORAGE
	10	X			X				
	11		X		X			X	NO STORAGE; CARBON CONSTRAINED
	12	X			X			X	
	13		X			X			FORCED STORAGE
	14	X				X			
	15		X			X		X	FORCE STORAGE; CARBON CONSTRAINED
	16	X				X		X	
Storage ITC	JE01		X	X				X	STORAGE ITC; CARBON CONSTRAINED
Transmission Allowed	JE02	X		X				X	
	JE03		X	X					STORAGE ITC
	JE04	X		X					
	JE05		X	X				X	STORAGE ITC; CARBON CONSTRAINED; CAPPED FOSSIL FUELS
	JE06	X		X				X	

Results archive is found through: http://www.vibrantcleanenergy.com/media/reports/

J09: No Transmission Expansion, No Storage, No GHG Constraints





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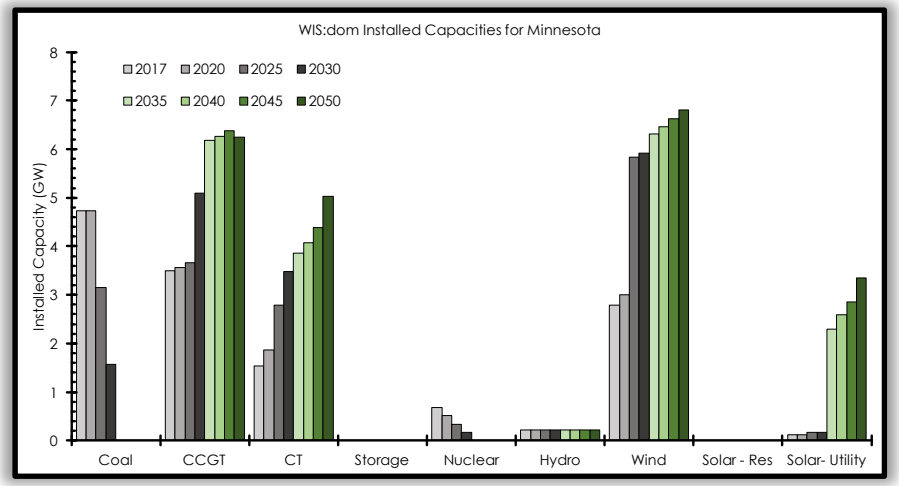
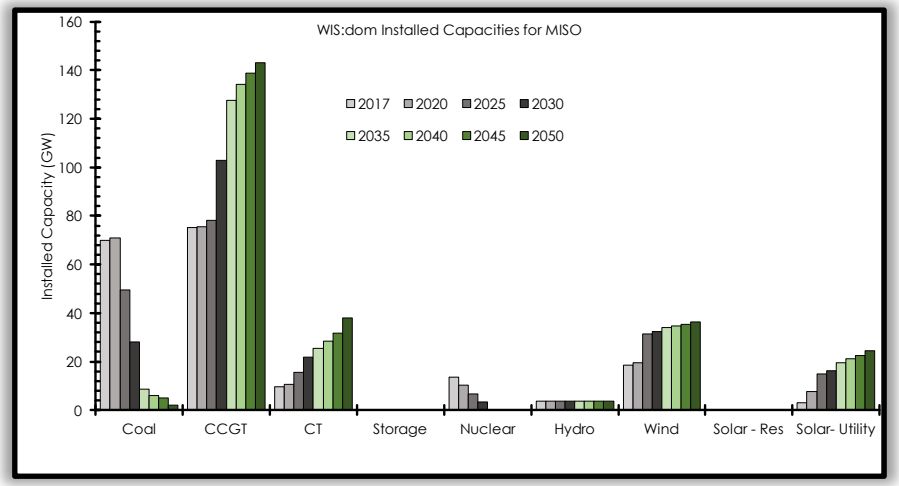
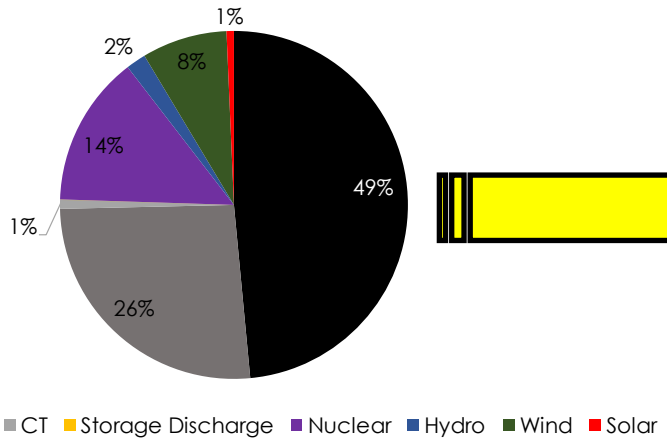
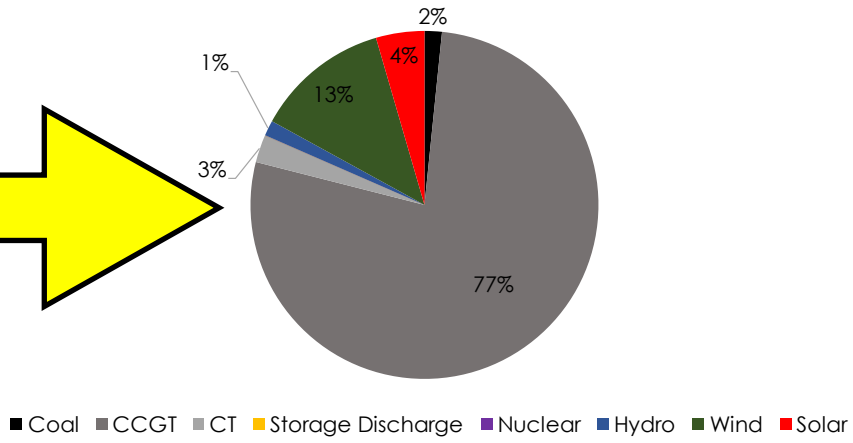




WIS:dom Estimated Electricity Generation By Source (2017)



WIS:dom Estimated Electricity Generation By Source (2050)



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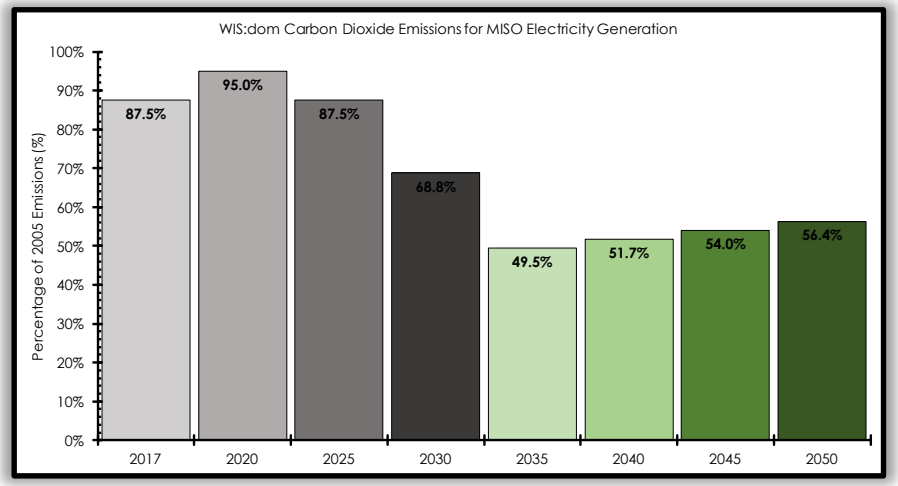
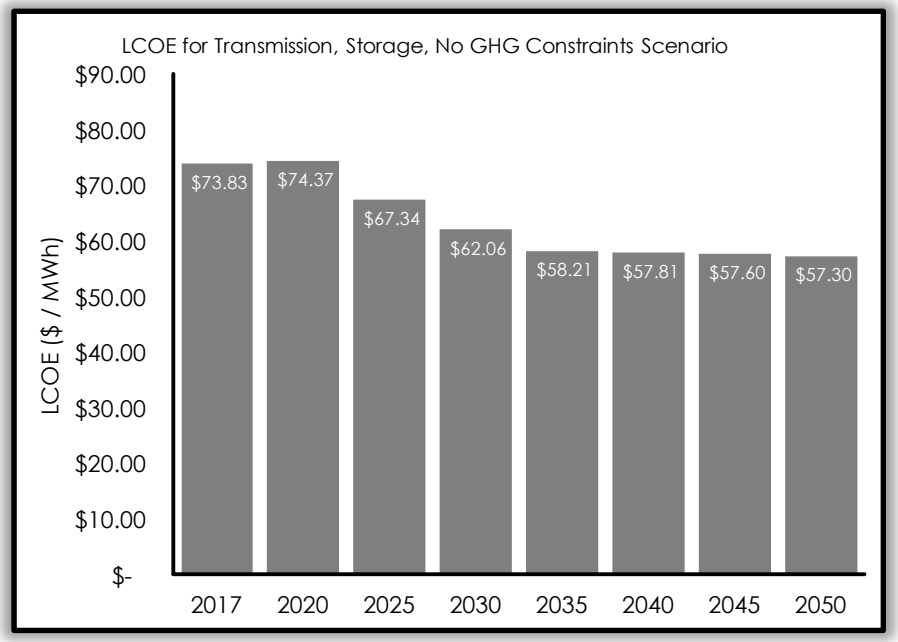
J02: Transmission Expansion, Storage Allowed, No GHG Constraints





By allowing storage to participate (along with transmission) the GHG emissions decrease and so does the cost of electricity

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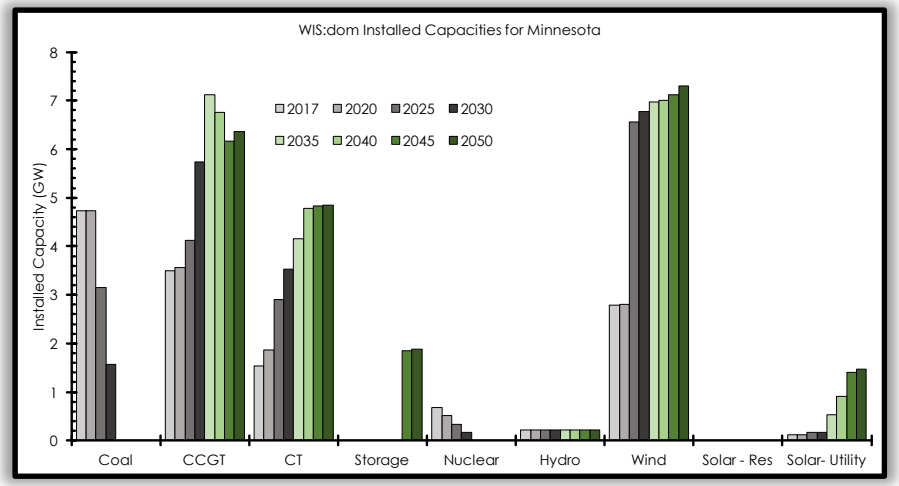
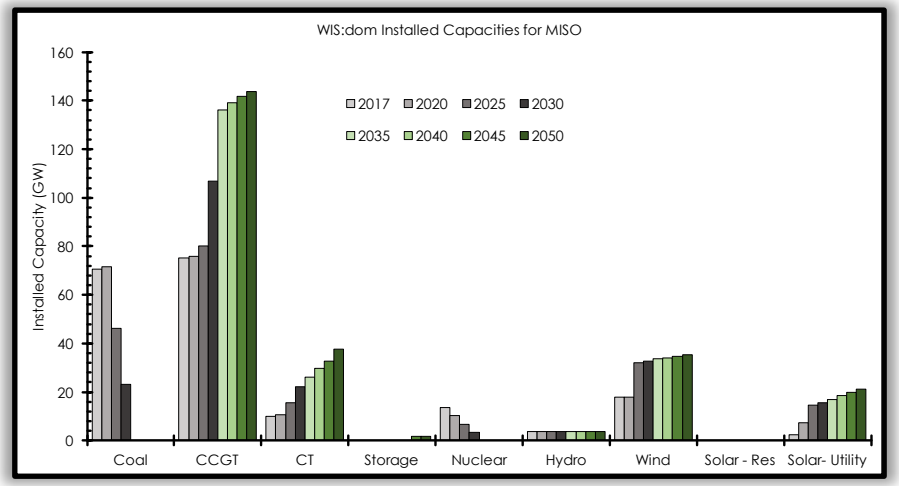
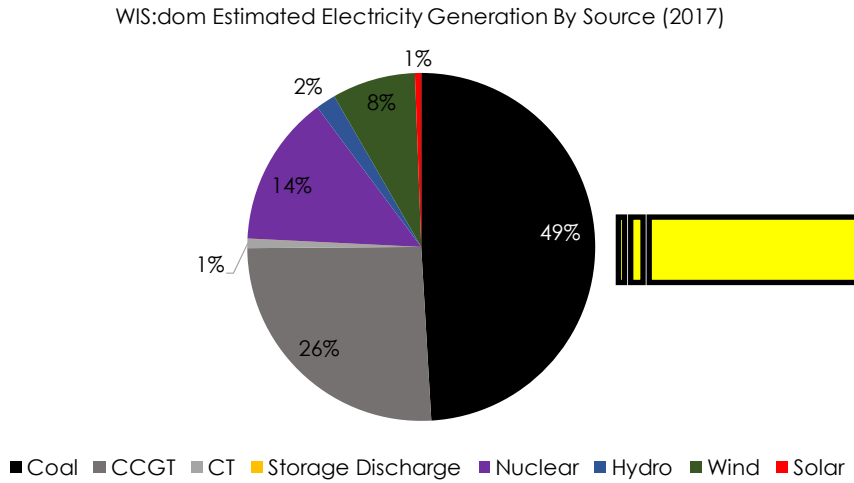
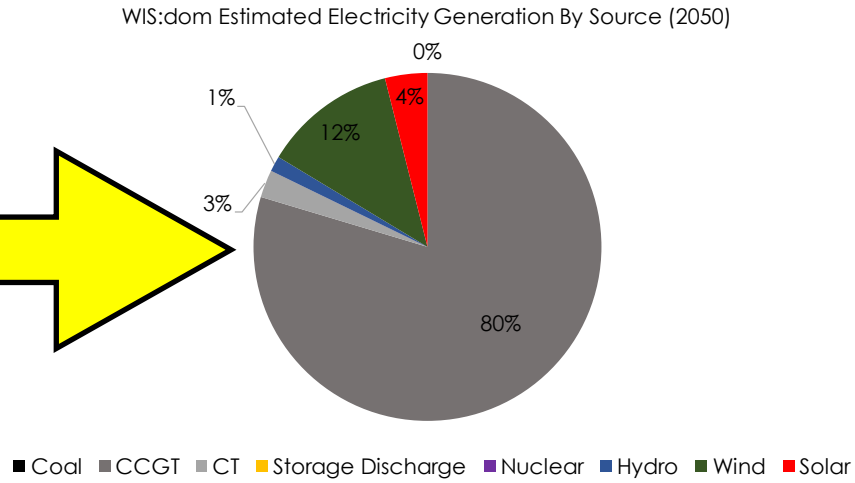
J02: Transmission Expansion, Storage Allowed, No GHG Constraints









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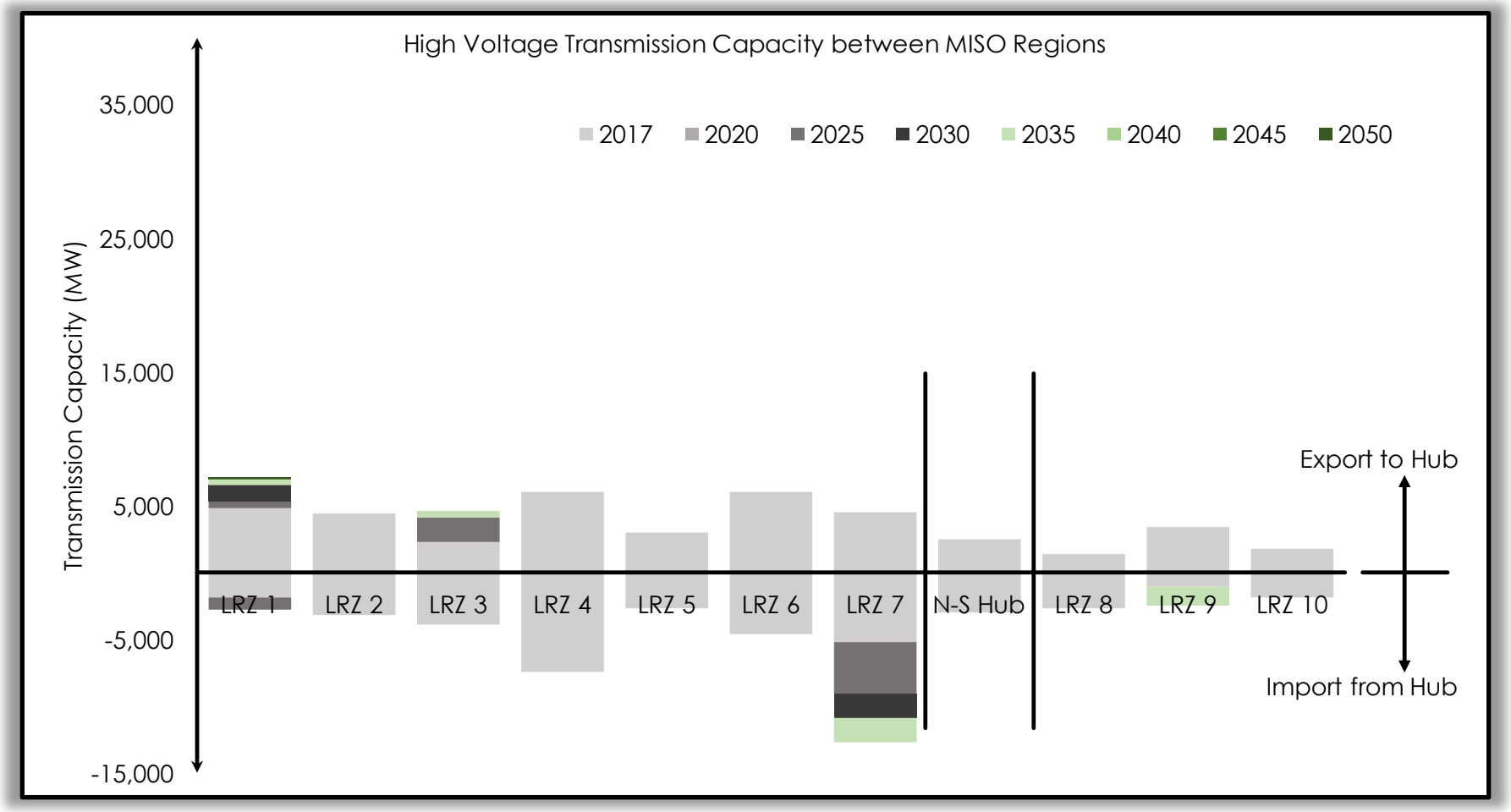

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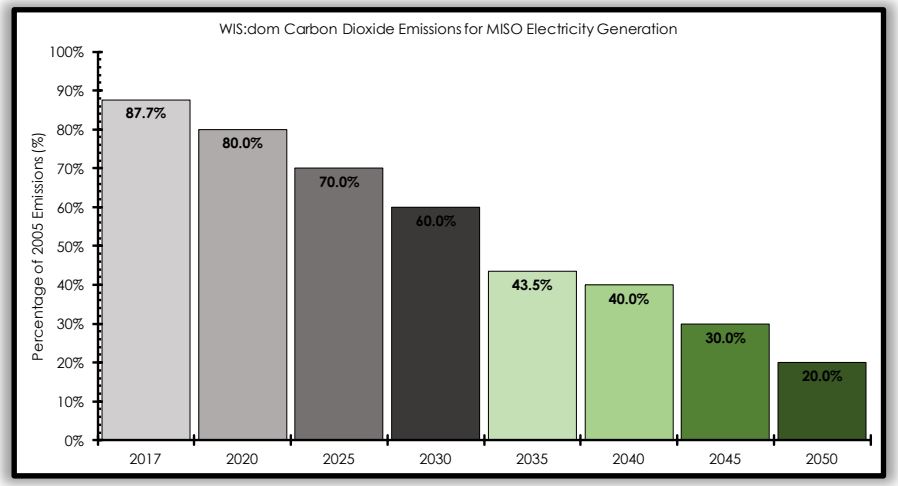
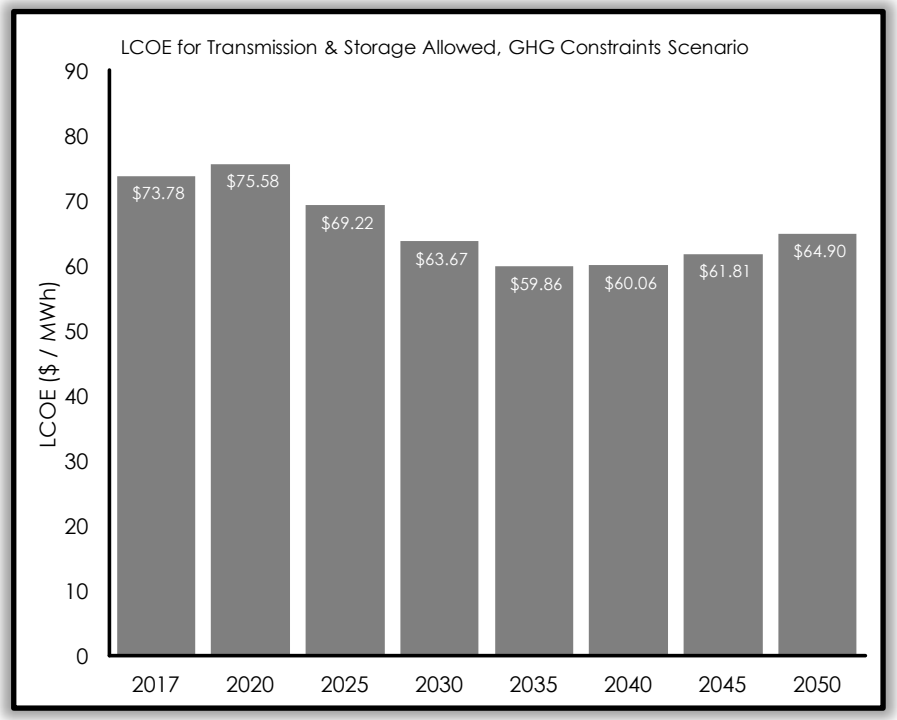
J06: Transmission Expansion, Storage Allowed, GHG Constrained





Storage (with transmission) assist in the reduction of GHGs at lower cost than without storage and facilitate higher amounts of RE

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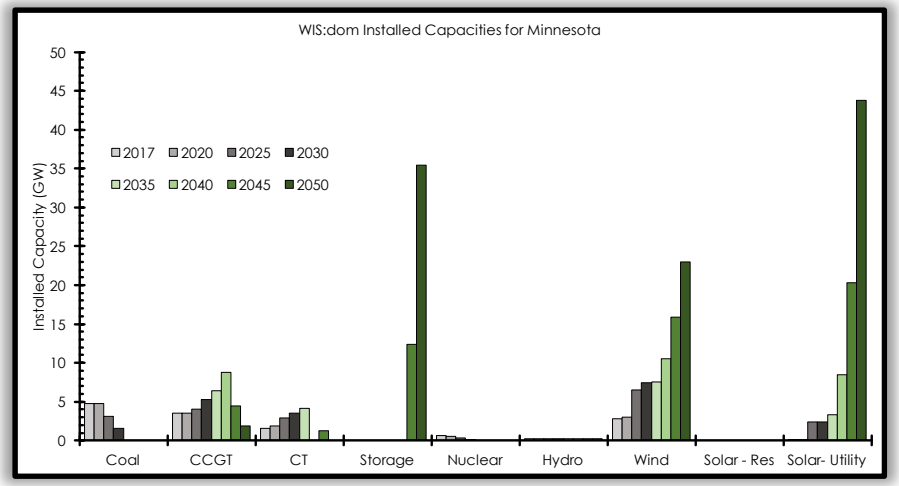
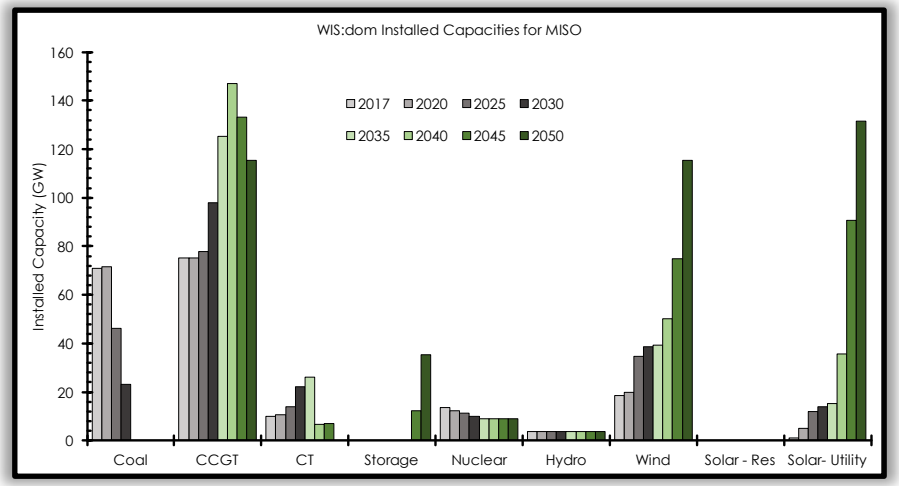
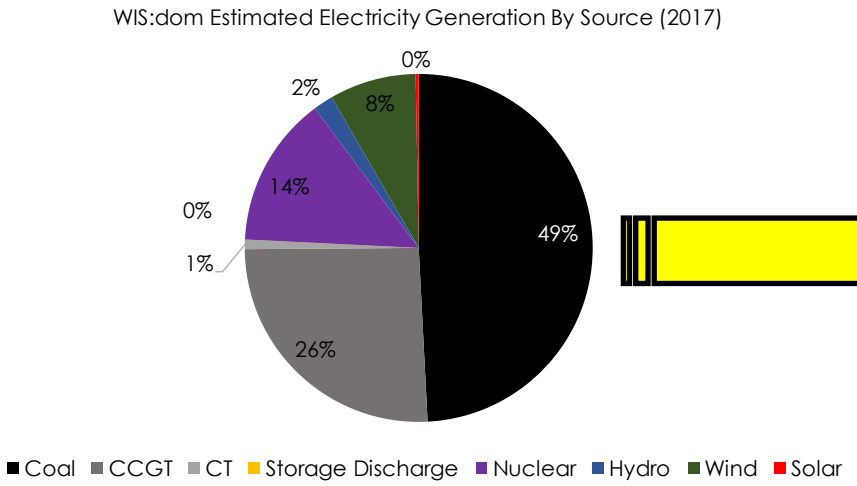
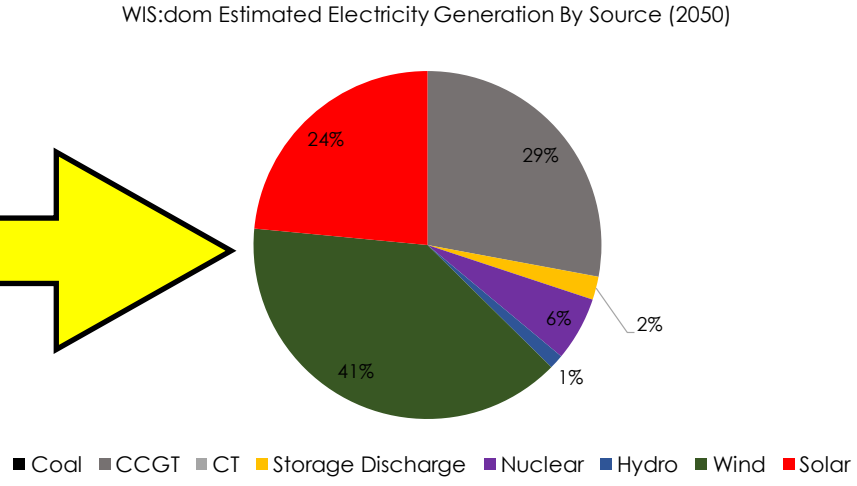
J06: Transmission Expansion, Storage Allowed, GHG Constrained









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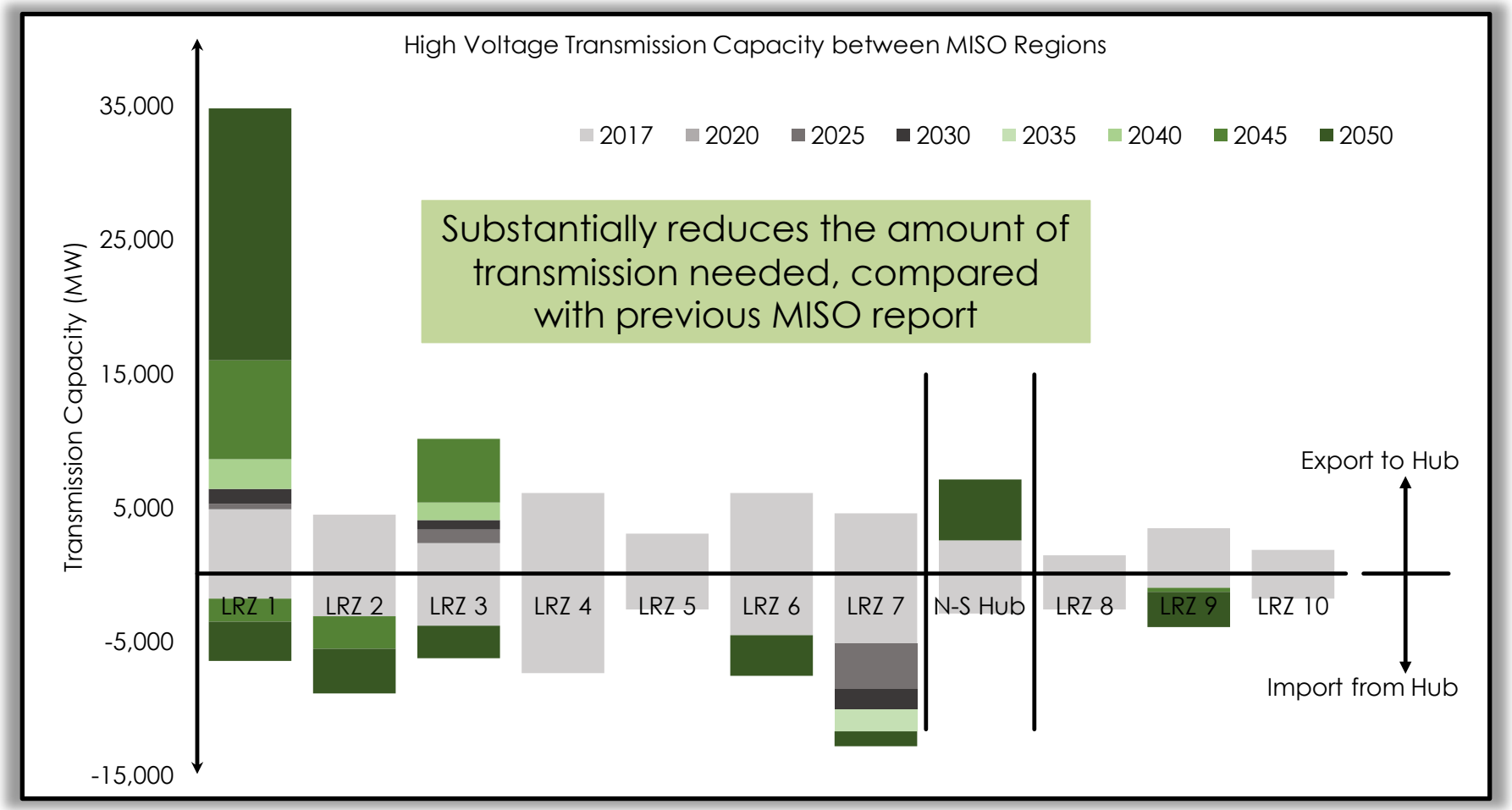

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Conclusions: Summary From Other Cases

- Forced storage scenario results in an increase in LCOE of 0.2% compared with the J09, but with ***3% lower GHG emissions***. *Forced storage increases by 3 GW each investment period to 24 GW by 2050*.

- Storage including ITC results in earlier adoption by the WIS:dom model of storage. It facilitates a reduction in LCOE of 0.5% and an additional ***6 GW*** of storage by 2050.

- Whenever transmission expansion is allowed, WIS:dom selects more storage than when it is not allowed.

- More solar PV is selected by WIS:dom when more storage is available.

- Storage competes with and reduces CTs in some regions of MISO as storage becomes economical. Particularly in the "forced storage" scenario.

- All other results are consistent with those shown; more transmission results in more storage deployed, emission targets increase storage deployment, increased storage promotes more solar PV deployment.

Conclusions

- Adopting storage now adds no significant cost or risk to the MN energy portfolio; rather it facilitates a more diverse future portfolio.
- Storage assists with reaching RPS goals/targets and can lower the cost of energy across MN and MISO.
- Storage helps reduce the burden on transmission when high renewables exist.
- Storage replaces CTs on a cost basis by (at least) 2040, much earlier if ITC is included.
- Storage is a useful tool in providing a "least-regrets, least-cost" energy transition strategy.

Thank You

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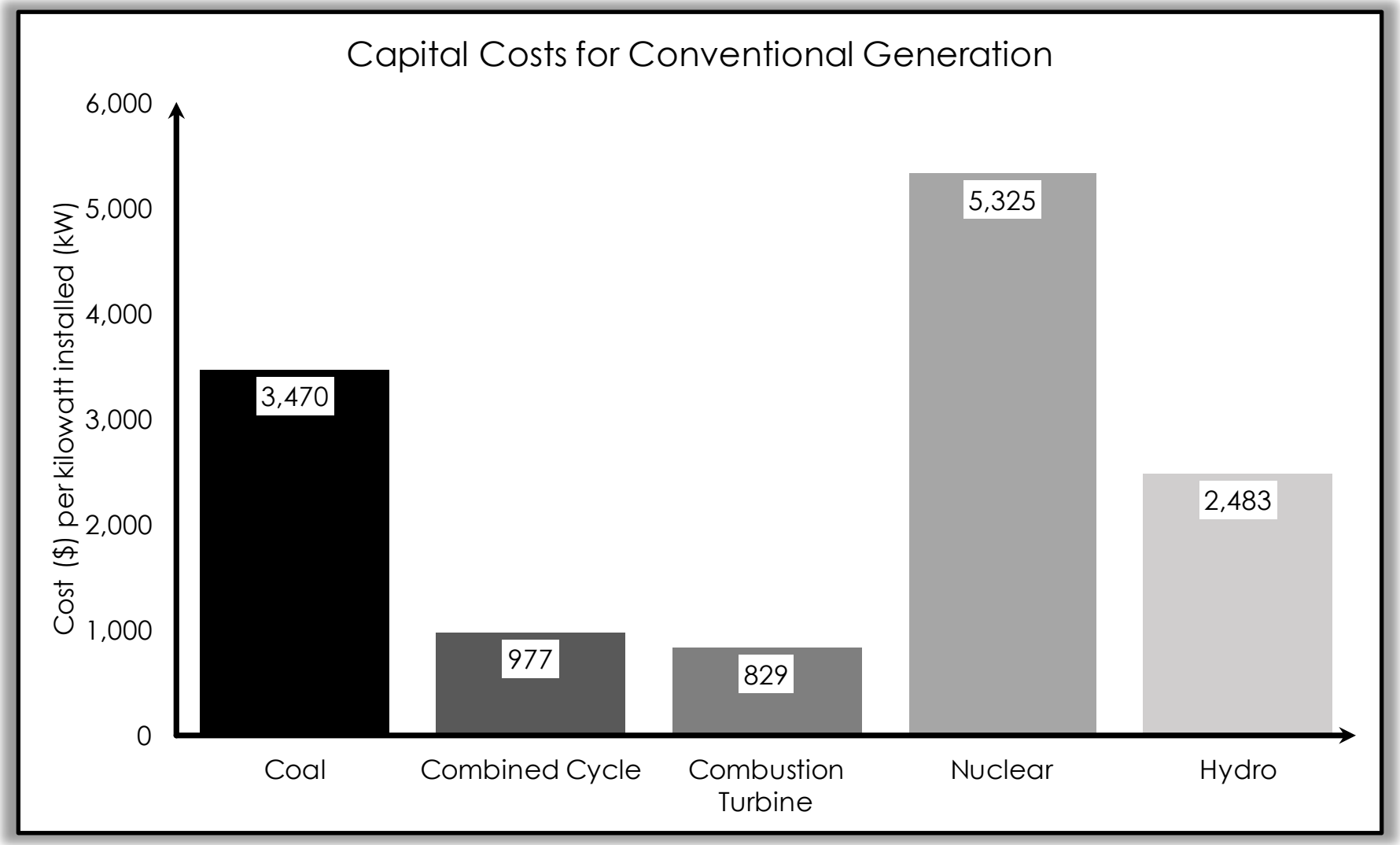

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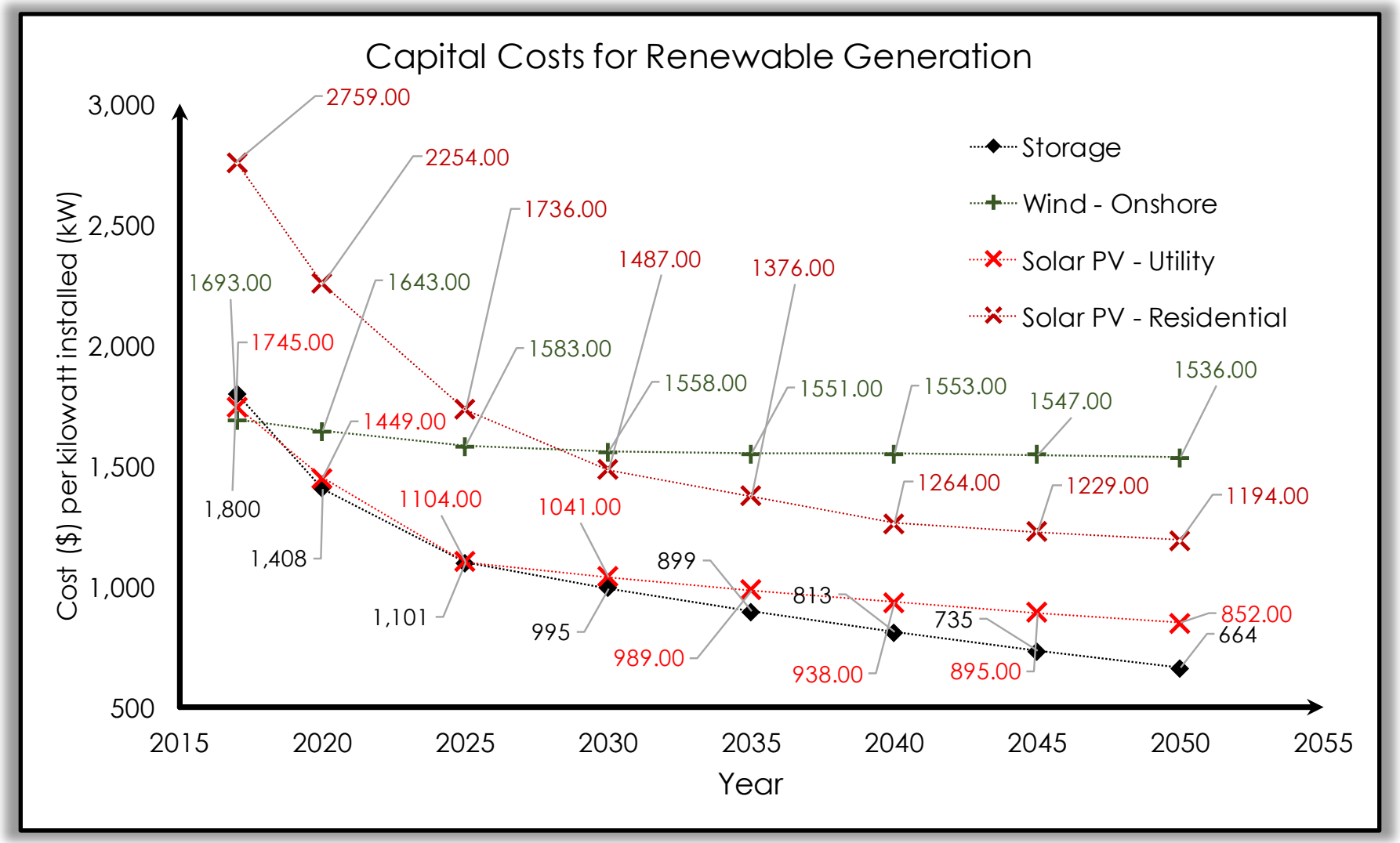

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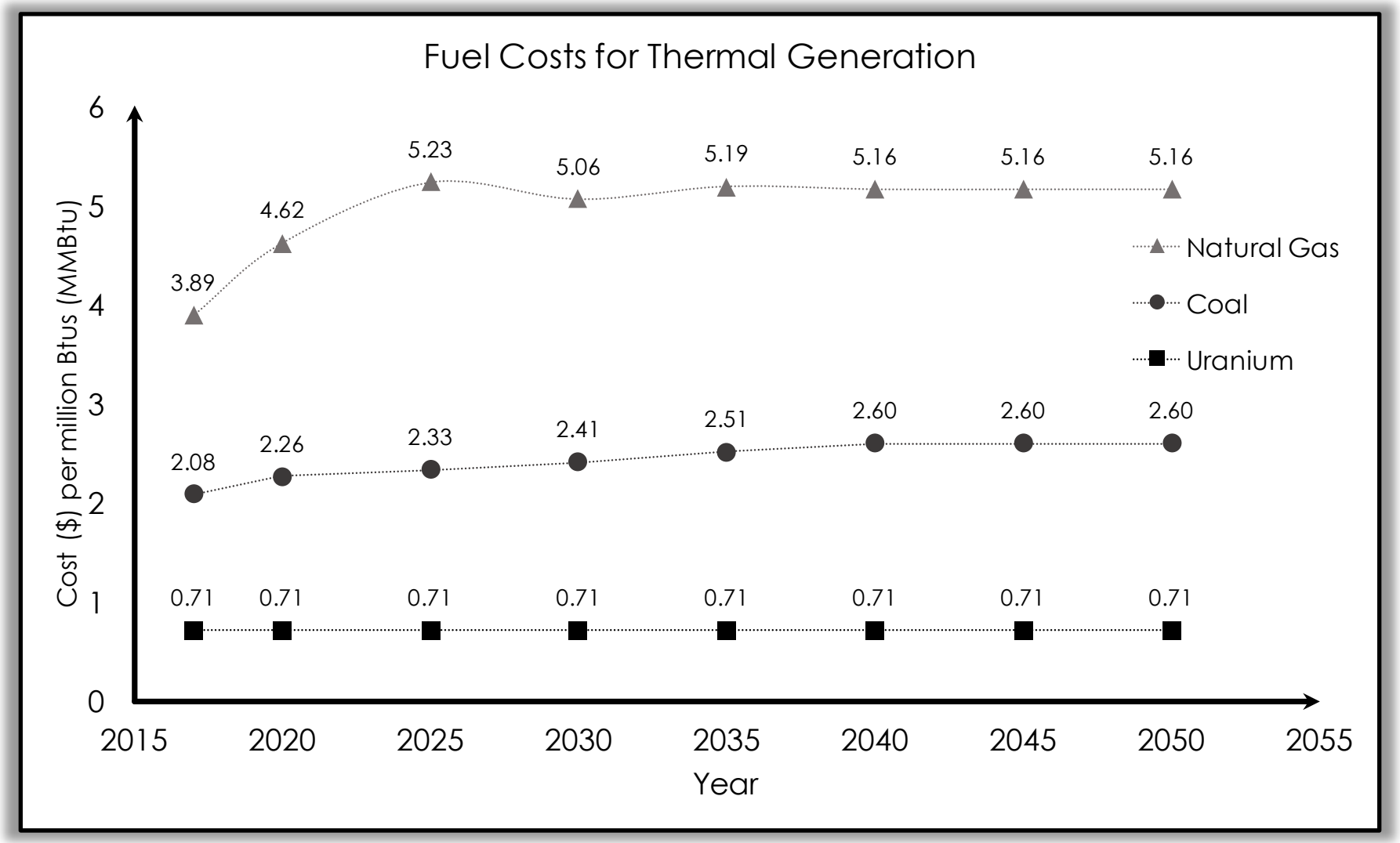

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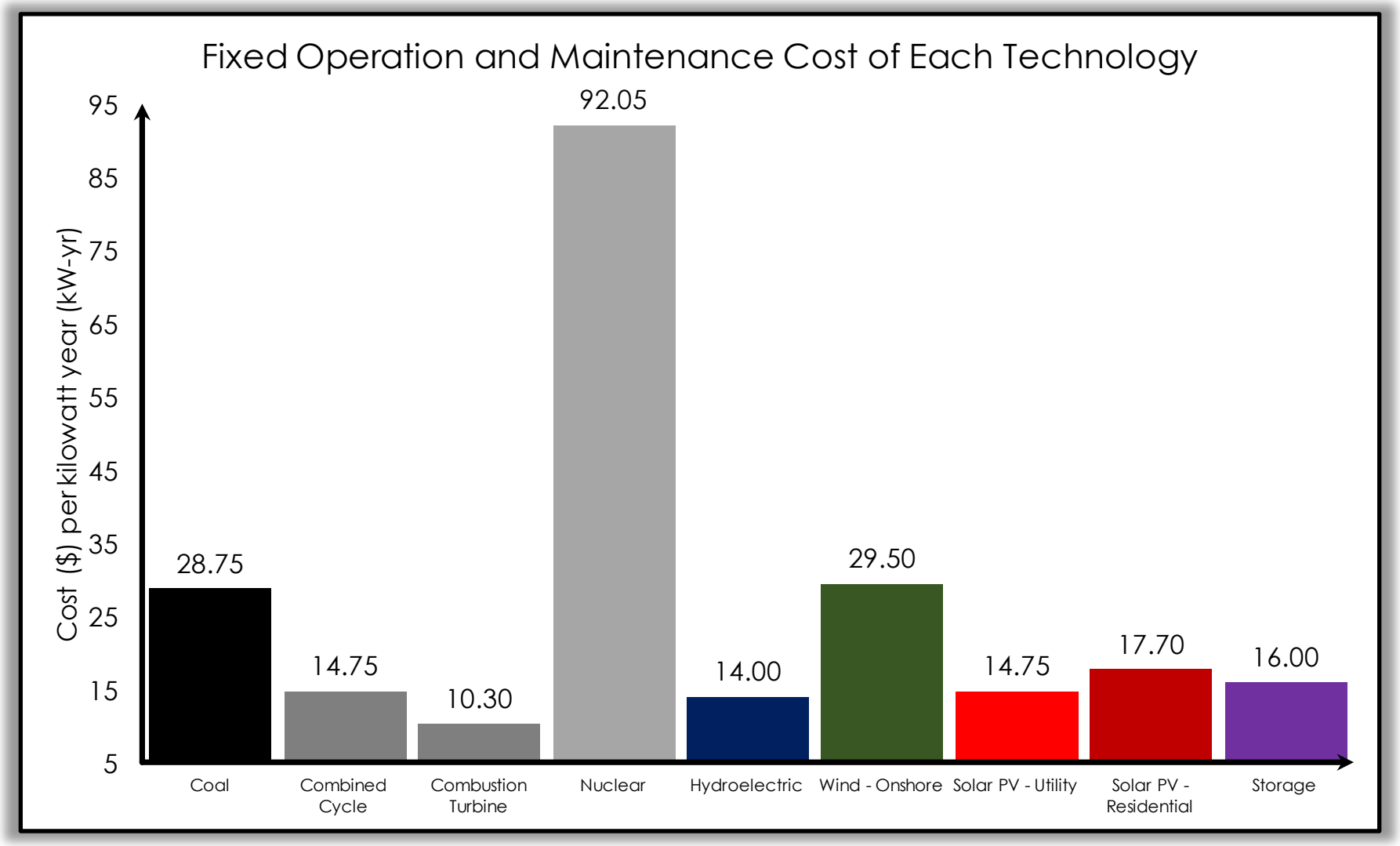

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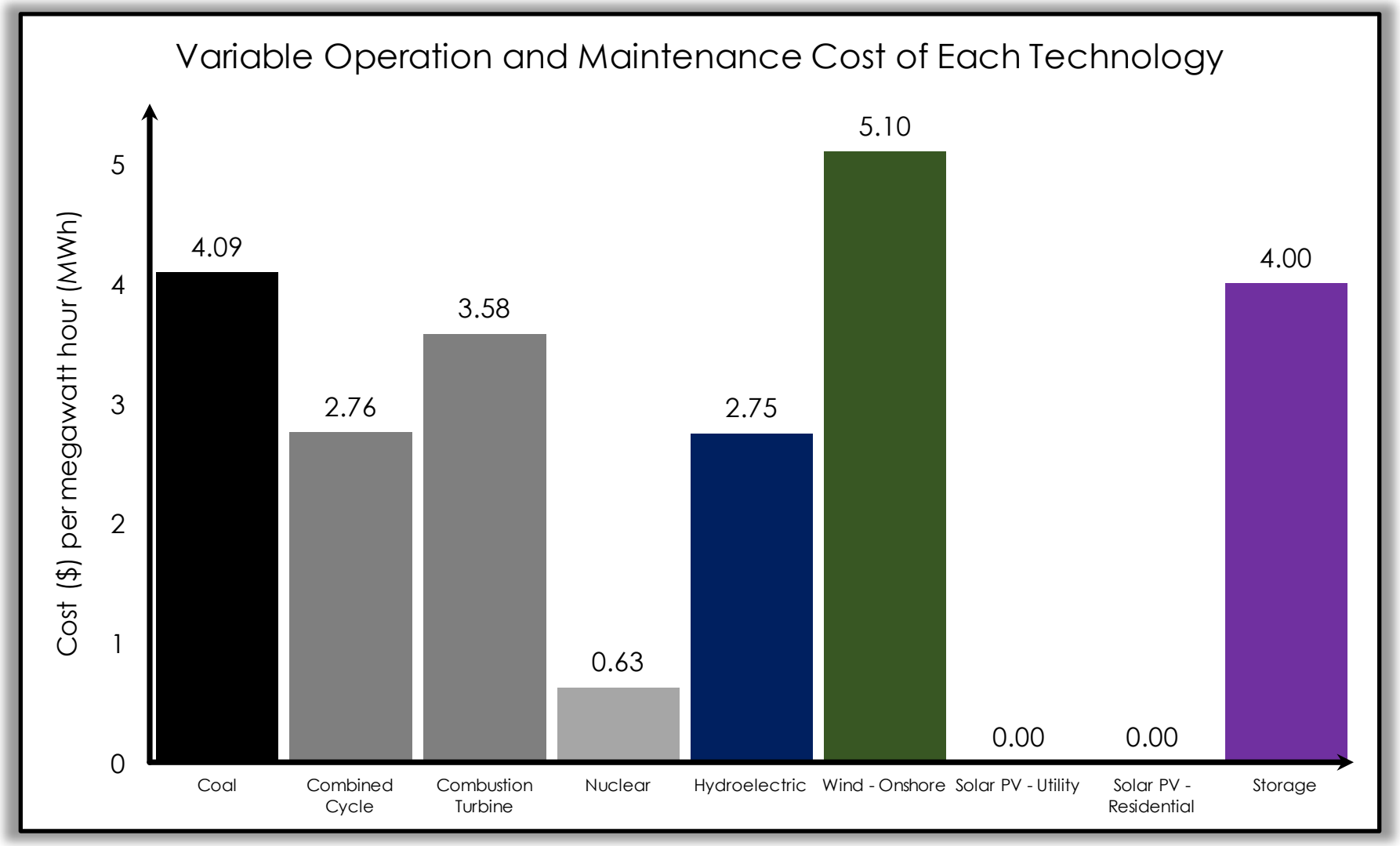

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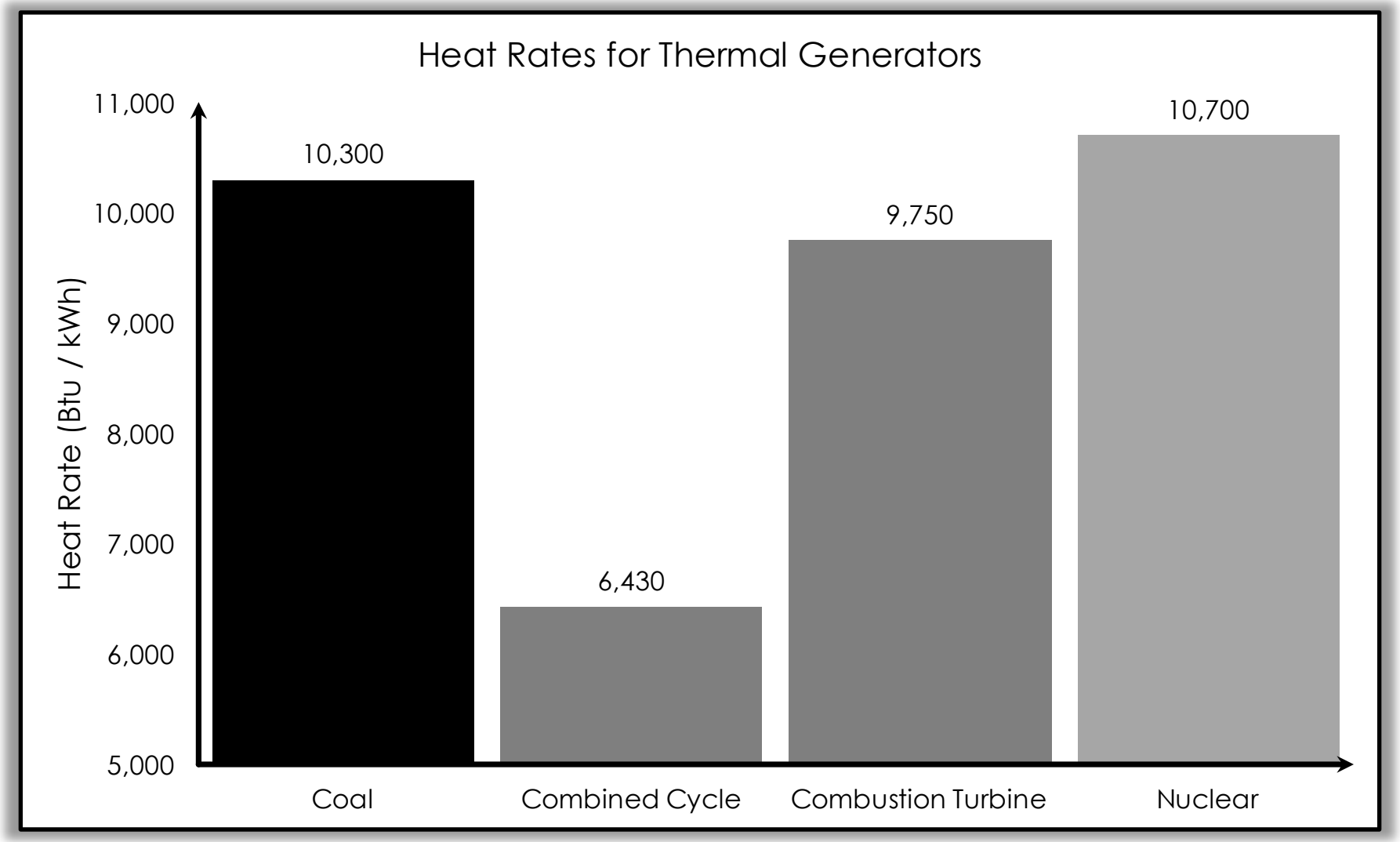

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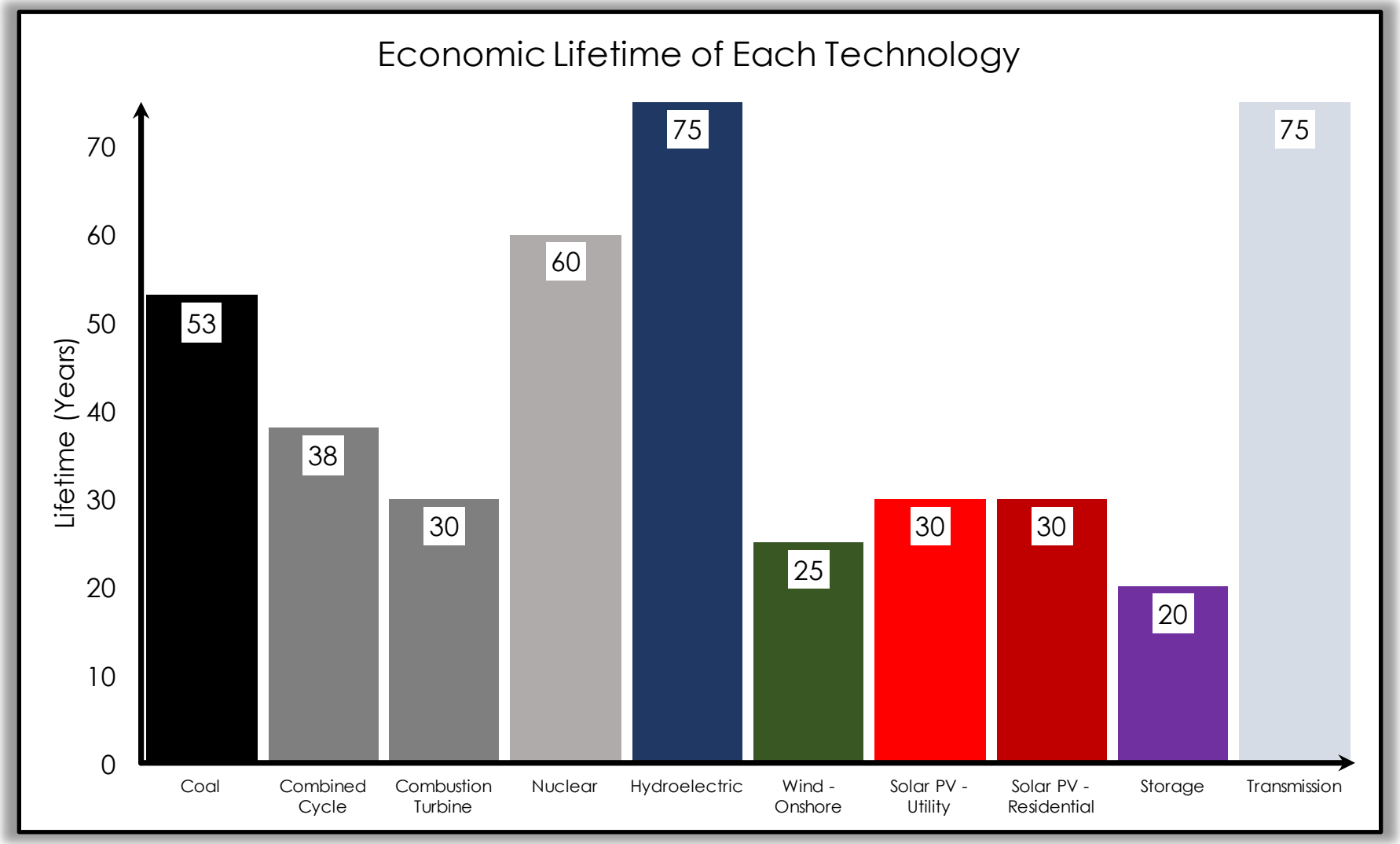

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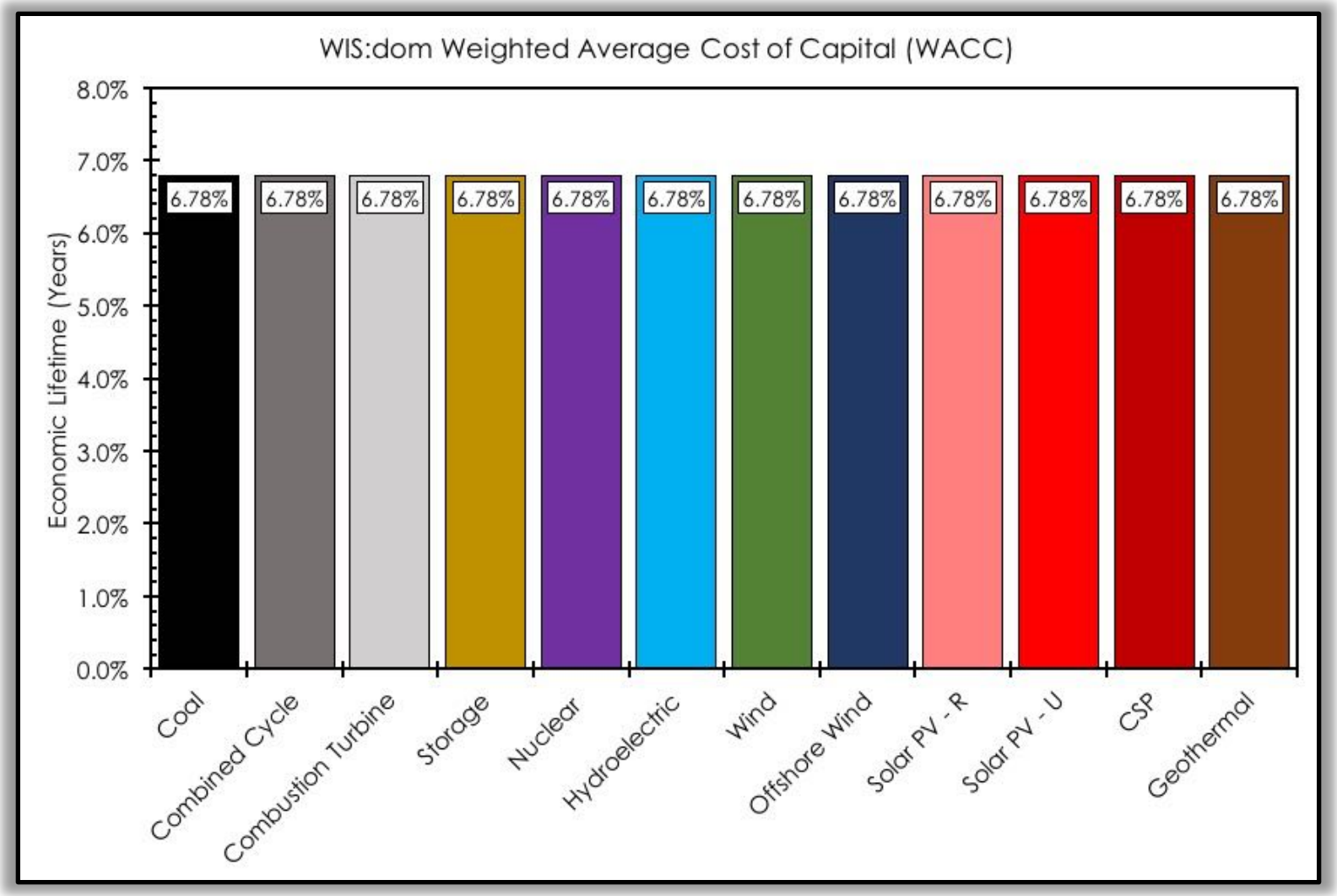

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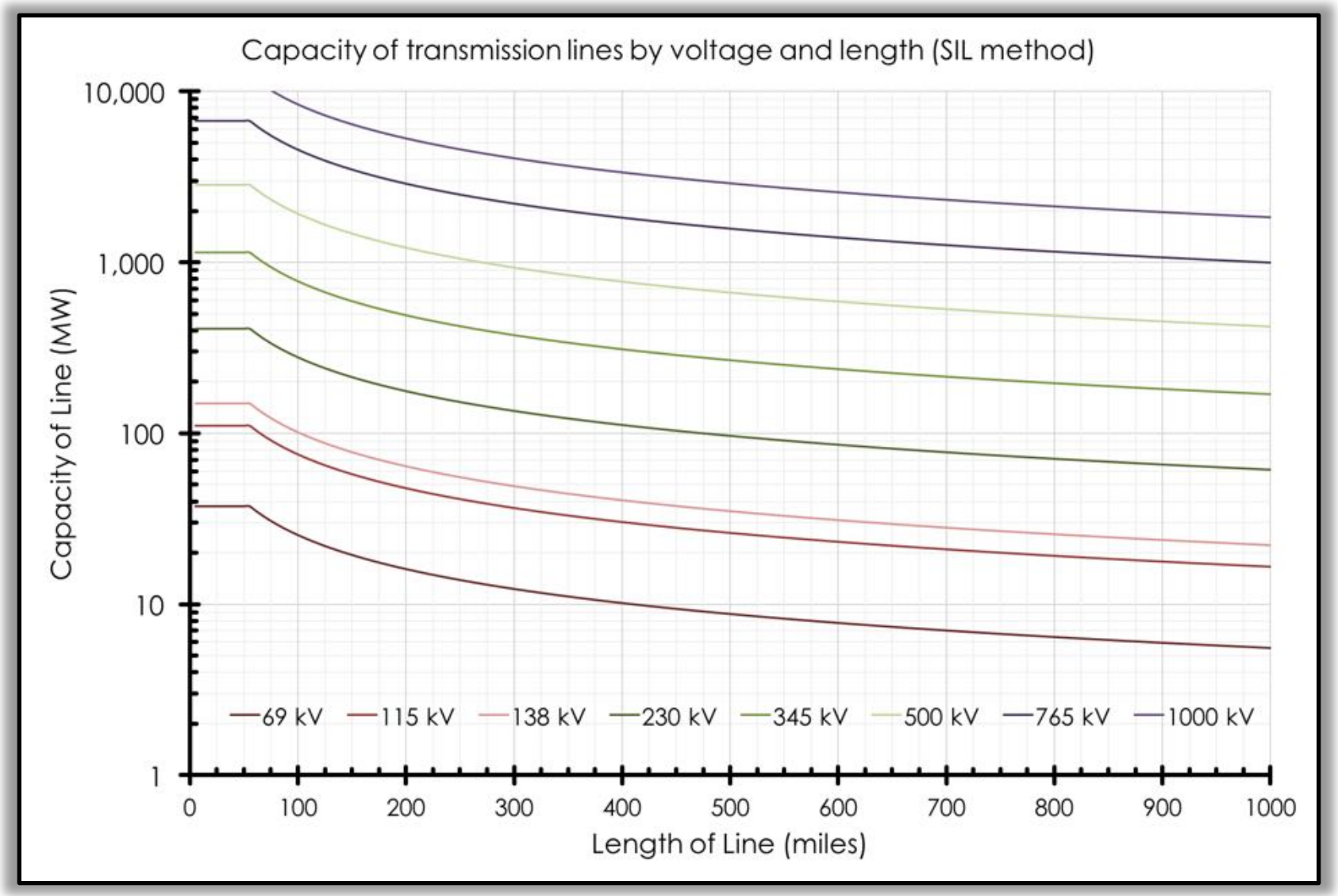

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