Reliability and Decarbonization

Resource Adequacy and Resilience

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Outline

- Observations on ERCOT, February 2021
- ERCOT wind generation profile
- System cost of replacement energy (SCoRE)
- Coal plant retirements
- Cost of carbon capture and storage (CCS)

Forecast Vs Actual Load - ERCOT

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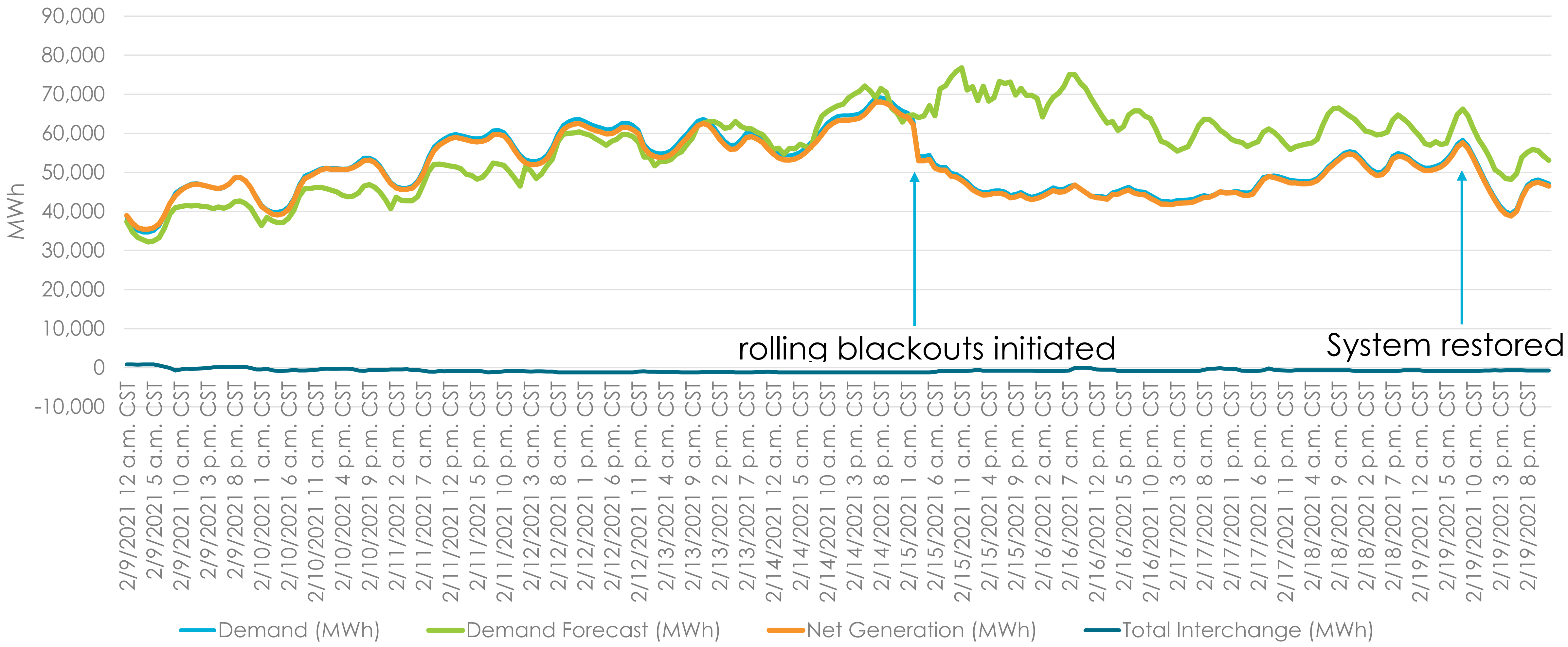
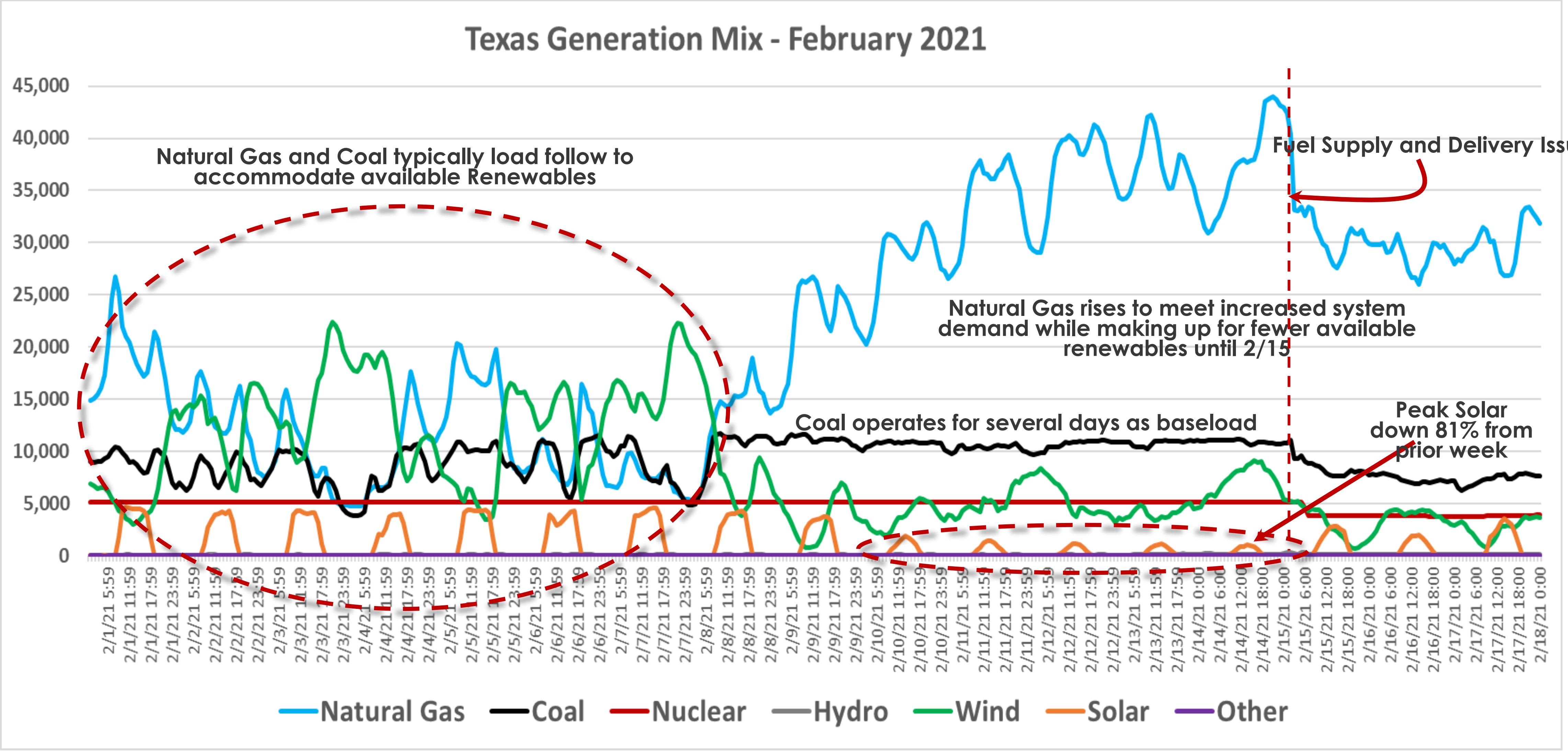


U.S. DEPARTMENT OF ENERGY

Source: https://www.eia.gov/beta/electricity/gridmonitor/expanded-view/electric_overview/balancing_authority/ERCO/ElectricityOverview-13/edit

ERCOT Generation Mix



ERCOT – Loss of Renewables

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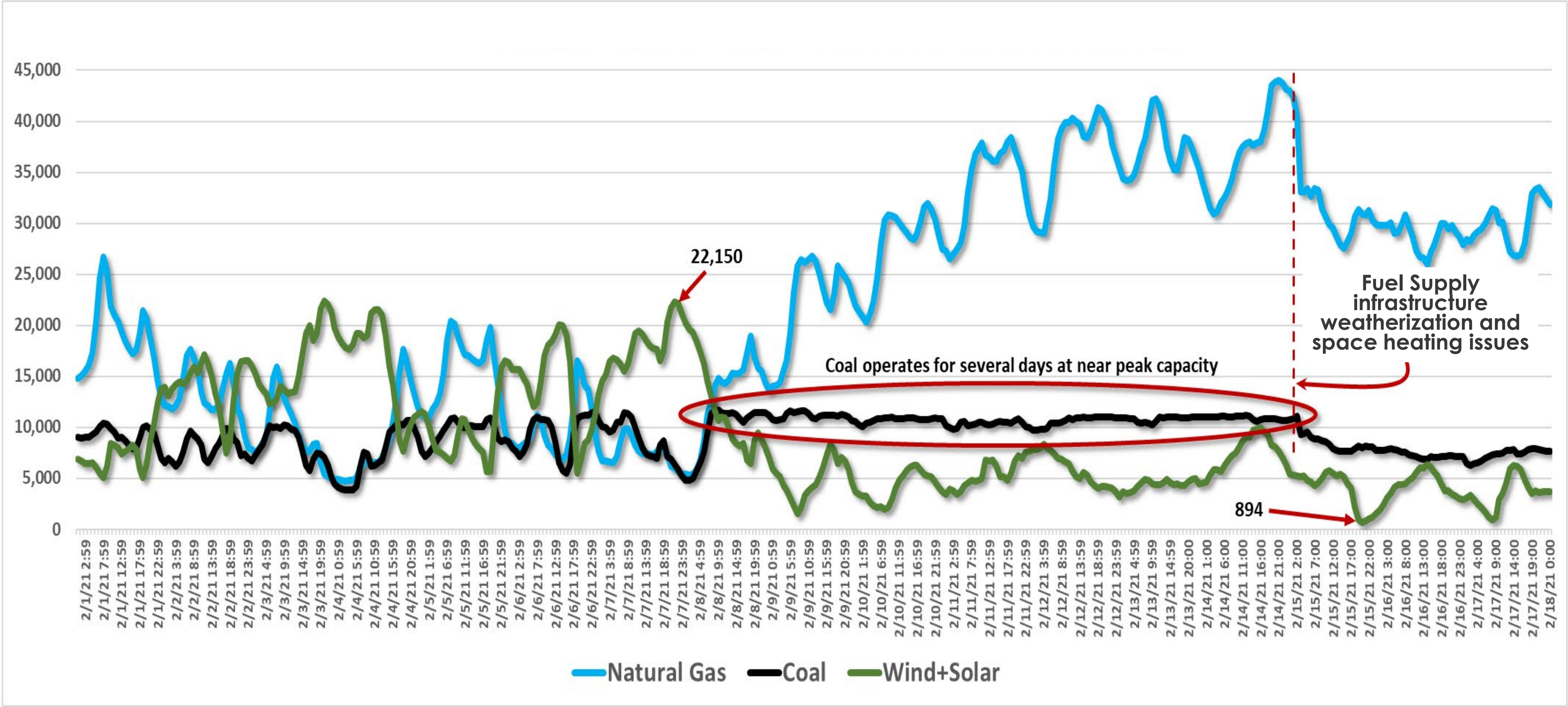
Too Much Stress on one fuel source



Reference – Rice U

IAEE *Economics of Energy & Environmental Policy*

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The Texas Deep Freeze of February 2021: What Happened and Lessons Learned?

Peter Hartley,[a] Kenneth B. Medlock III,[b] and Elsie Hung[c]

ABSTRACT

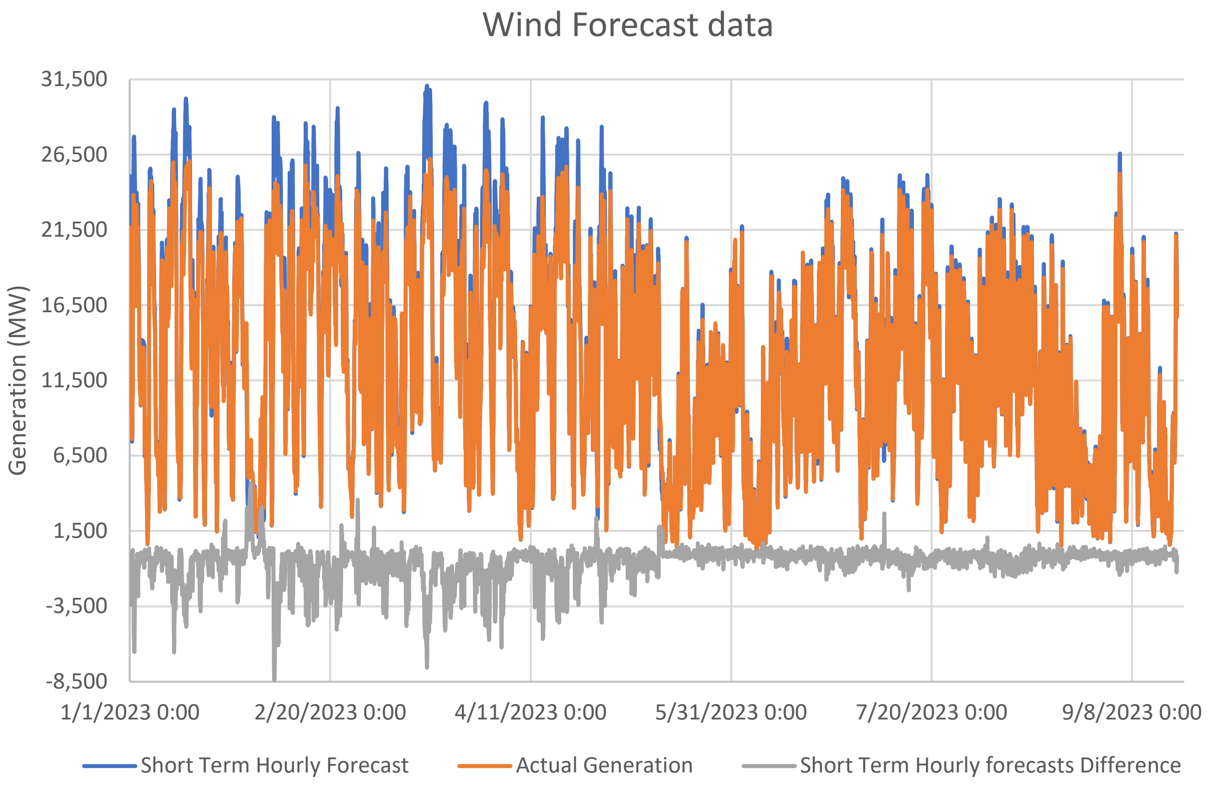
Although various factors were blamed for the extended power outage on the ERCOT electricity grid in February 2021, no single problem fully explains the calamity. All forms of generation experienced capacity deratings, but failure to identify and address risks along fuel supply chains was a major contributor. Moreover, most proposed remedies do not fundamentally address what occurred. Some may be driven by opportunistic lobbying. We make several recommendations, some of which are already being implemented.

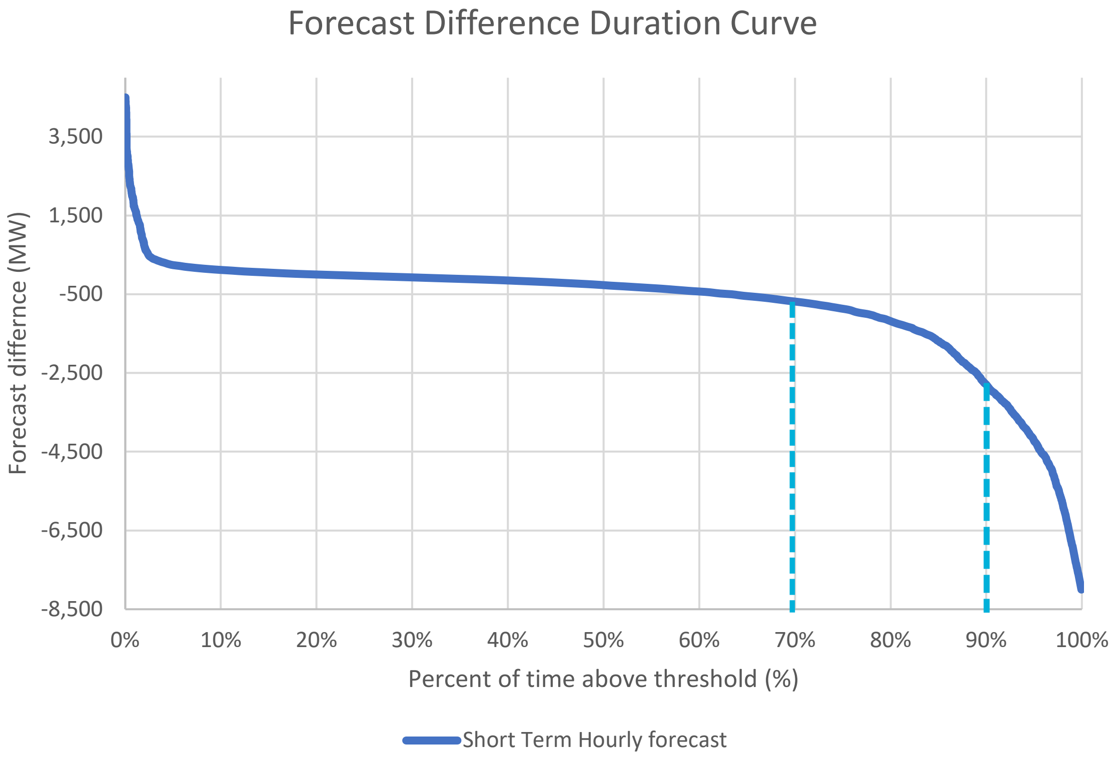
Keywords: Electricity Markets, Natural Gas, Wind, Market Structure, Reliability, Winterization

https://doi.org/10.5547/2160-5890.12.2.phar

ERCOT 2023 Wind Generation data

Short Term and Resource Power Potential Hourly Forecasts Vs Actual Generation



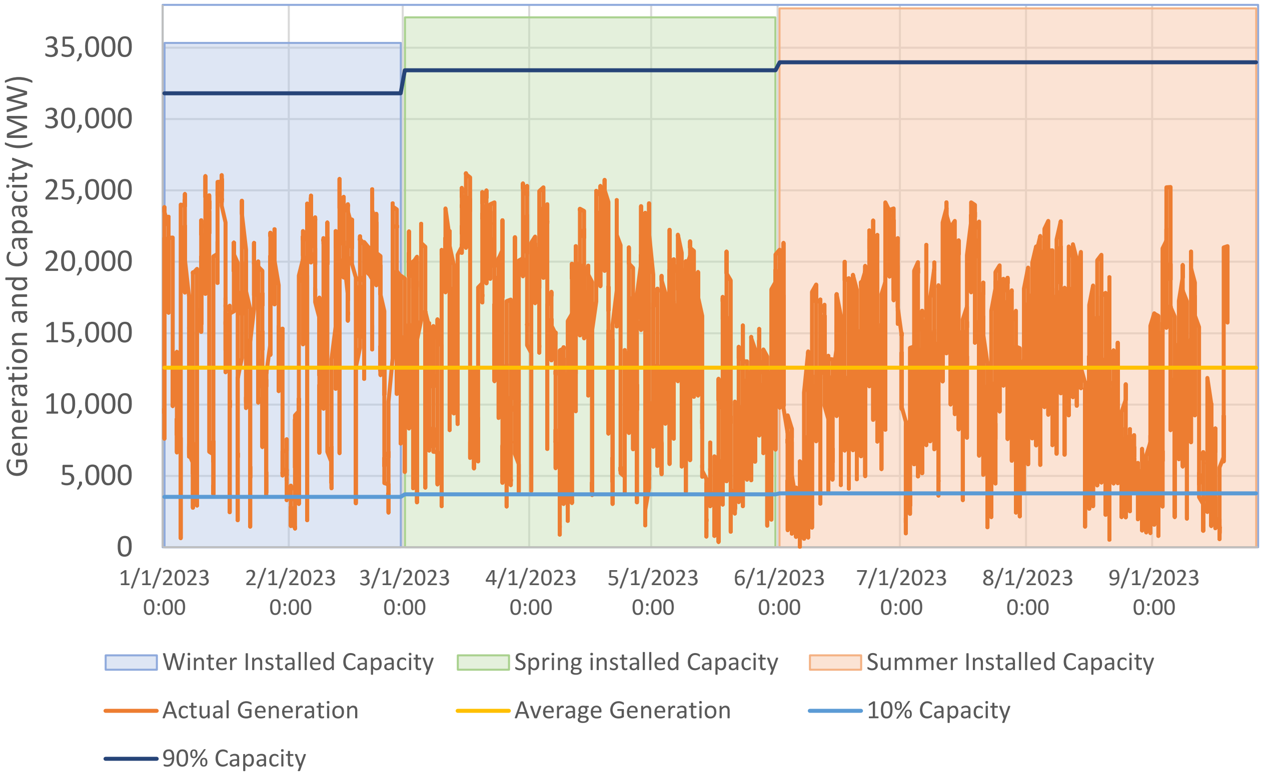


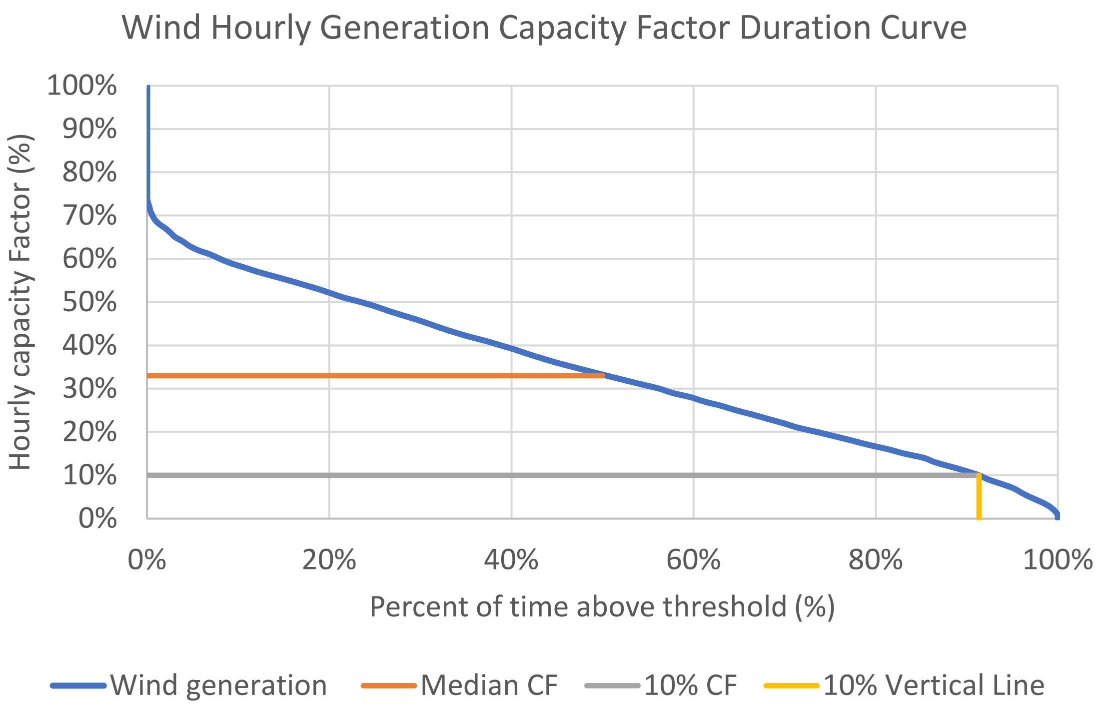
Generation forecast error minor most of the time but often significant, reaching ~8,400MW

Generation and forecast data from Hitachi Energy Velocity Suite. Actual generation values are impacted by curtailments

ERCOT 2023 Wind Generation data

Actual Generation





Maximum: 74% of installed capacity; Median 33% of IC; 10% or less of IC 9% of time

Generation and forecast data from Hitachi Energy Velocity Suite. Actual generation values are impacted by curtailments
Seasonal Installed capacity totals from ERCOT Winter, Spring, and Summer SARA

Total System Cost

Energy

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A tool for measuring the system cost of replacement energy

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ABSTRACT

Replacing legacy high carbon technologies (LHCTs) with new low carbon technologies (NLCTs), particularly NLCTs featuring variable renewable resources, can disproportionally influence the costs associated with maintaining a reliable and competent grid system. Traditional cost metrics and publicly available tools that make use of these metrics fail to capture the total systems cost (TSC) implications of such changes, highlighting the need for a tool that will capture these implications. This paper presents the results of a tool developed to estimate the System Cost of Replacement Energy (SCoRE) when NLCTs replace LHCTs in an operating region. The SCoRE estimates potential changes in the TSC resulting from the replacement. The SCoRE tool is applied to the Electric Reliability Council of Texas (ERCOT) operating region. LHCTs, namely coal- and natural gas-fired power plants are replaced by NLCTs including solar photovoltaics and wind, with and without energy storage, and coal and natural gas power plants equipped with carbon capture and storage (CCS). The results showcase the TSC implications of different replacement scenarios, which for ERCOT include larger increases in the TSC if LHCTs are replaced with wind and solar, in lieu of natural gas power plants equipped with CCS, for all decarbonization targets considered.

System Cost of Replacement Energy (SCoRE)

NETL SCoRE Tool

Objective

- Electricity systems changing with significant changes in the mix of power generation technologies
- Traditional cost metrics – e.g., LCOE – fail to capture the additional costs of supporting certain capacity along the grid (e.g., storage or transmission)
- Need for a tool to estimate changes in total systems cost (TSC) from modifications motivated by decarbonization

Approach

- Dynamic tool estimates changes in TSC as new, low carbon technology (NLCT) replaces the capacity from a legacy, high carbon technology (LHCT)
- Technology replacements to achieve a decarbonization target
- Compare technologies' full implementation costs to implement maintaining reliability
  - Ensure zero loss of load events

Energy Vol. 275, A Tool for Measuring the System Cost of Replacement Energy
Journal of Environmental Informatics Letter, Total Systems Cost: A Better Metric for Valuing Electricity in Supply Network Planning and Decision-Making

SCoRE Tool

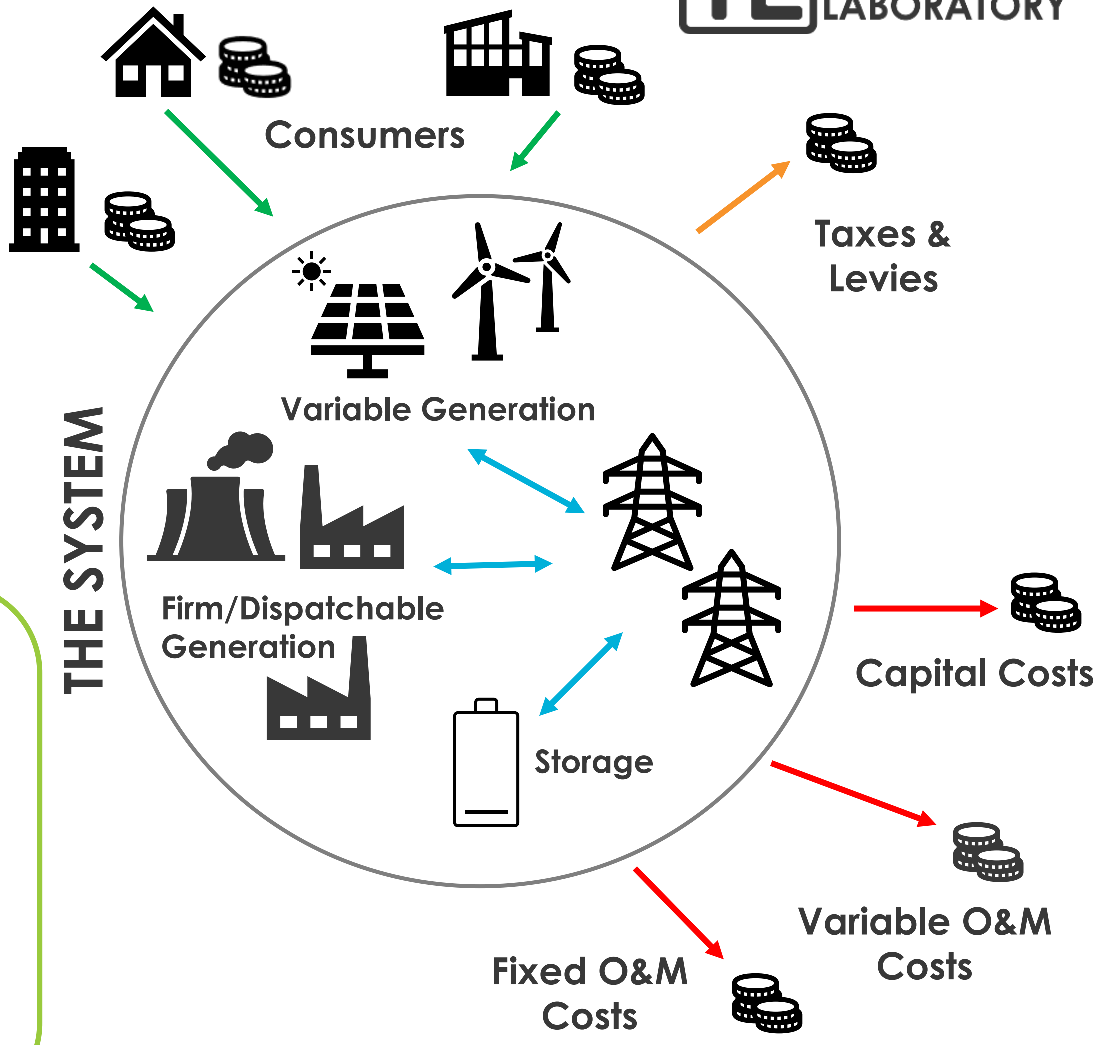
General Framework for Development

- **Changes in the TSC from replacing a LHCT with a NLCT**

$$SCoRE_{ij}^{a} = \frac{TSC_j - TSC_i}{E_{ji}} = \frac{\Delta TSC_{j-i}}{E_{ji}} \quad (1)$$

$$TSC = \sum_{a=1}^{a_{max}} \left(CRF * CAPX_{a,t} + FOM_{a,t} + VOM_{a,t} + FUEL_{a,t} + INT_{a,t}\right) \quad (2)$$

- TSC_i : TSC under a non-replacement scenario
- TSC_j : TSC under a replacement scenario
- E_{ji} : Generation from replacement scenario
- CRF : Capital recovery factor
- $CAPX$: Capital costs
- FOM : Fixed O&M costs
- VOM : Variable O&M costs
- $FUEL$: Fuel costs
- INT : Integration costs
- a: Replaceable capacity
- a_{max} : Maximum replaceable capacity
- t : Year



Source: Byrom, S, Bongers, G., Boston, A. and Garnett, A. (2021, April). Total System Cost: A better metric for valuing electricity in supply network planning and decision-making. *Journal of Environmental Informatics Letters*.

SCoRE Evaluation Flow Chart

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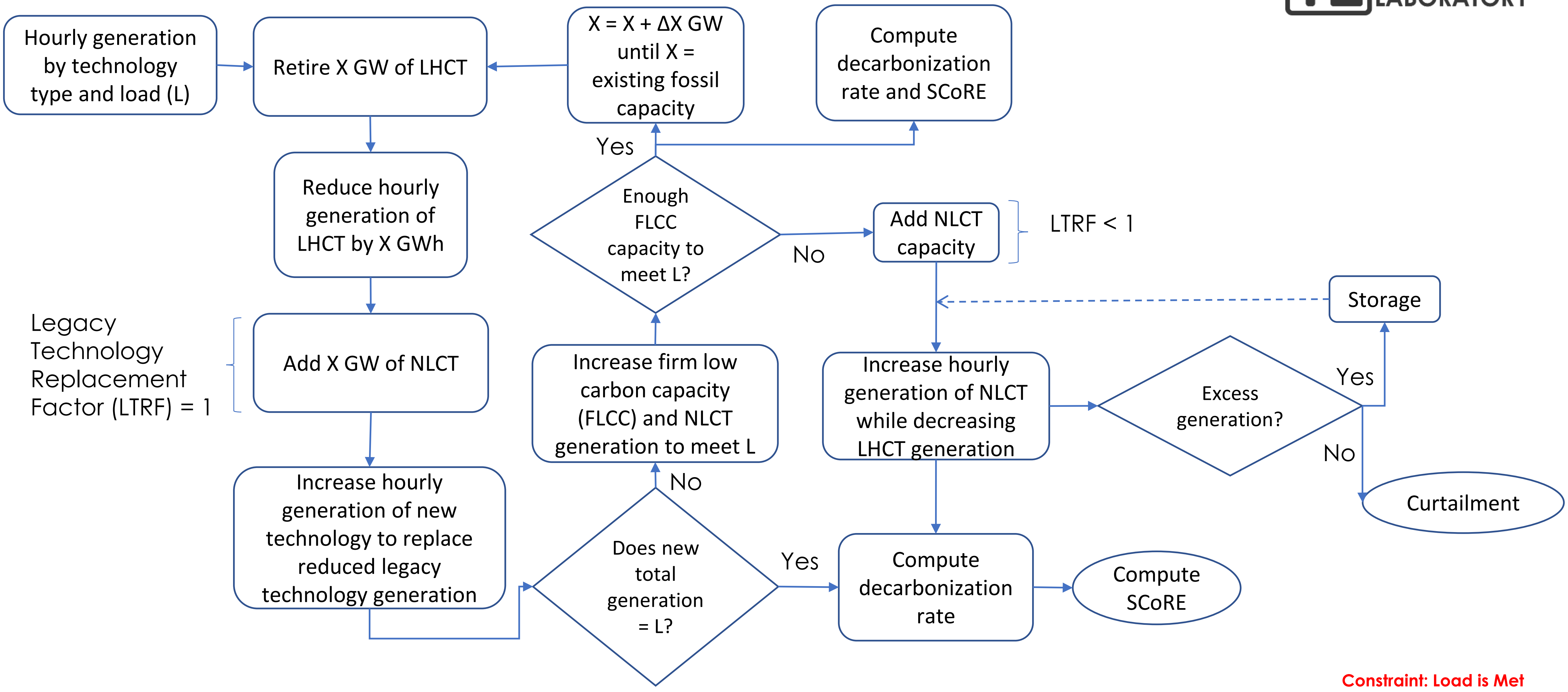


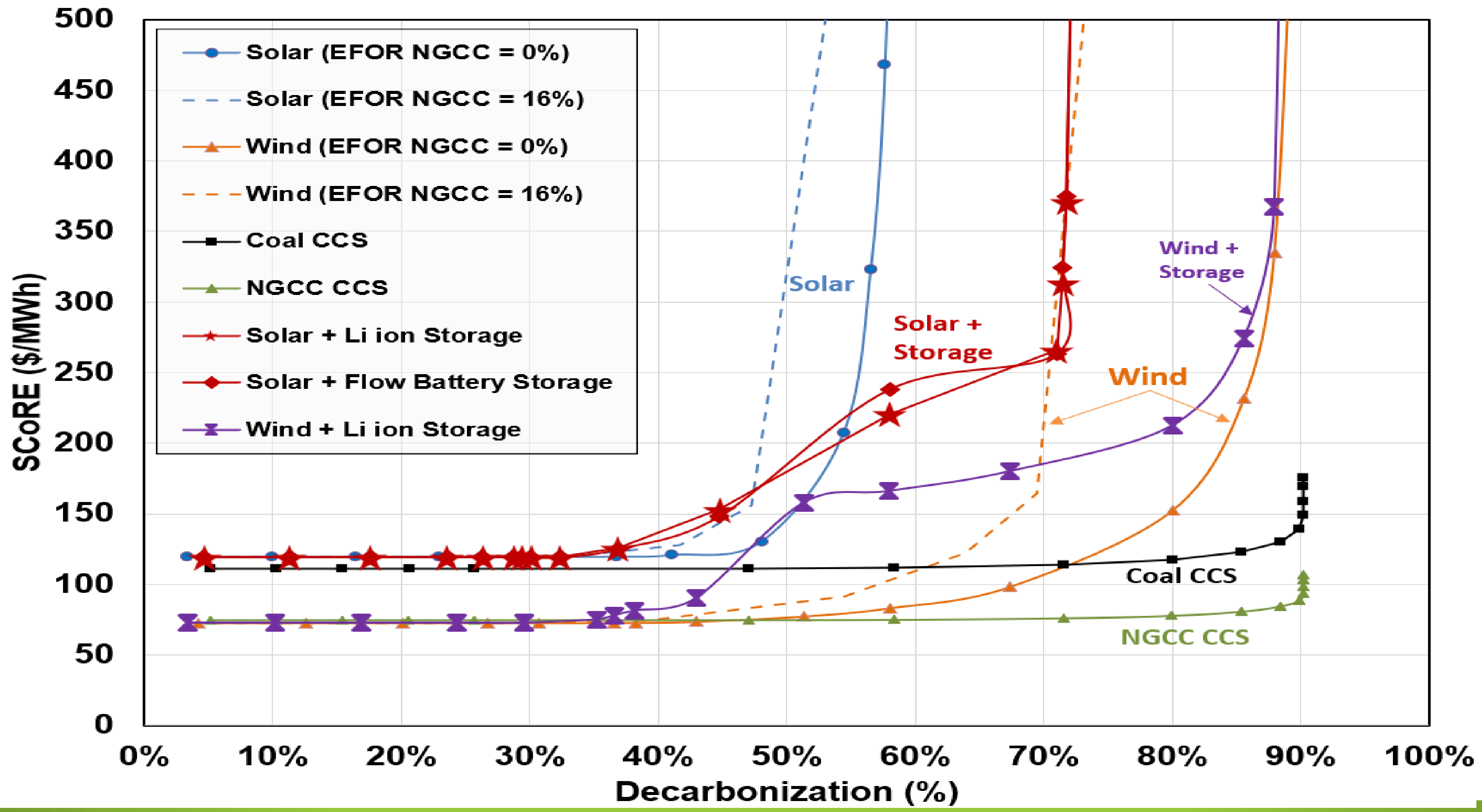
Technology Pathways to Decarbonization

Summary of Scenarios Considered

Scenario	NLCT description	Label
1	Solar PV	Solar
2	Land-based Wind	Wind
3	CFPP with CCS	Coal + CCS
4	NGCC with CCS	NGCC + CCS
5	Solar PV + Li-ion Battery Storage	Solar + Li-ion
6	Solar PV + Flow Battery Storage	Solar + Flow Battery
7	Land-based Wind + Li-ion Battery Storage	Wind + Li-ion

Results

Summary of Primary Results



Results Continued…

Scenario	NLCT	LHCT Replaced (%)	MAXFC (GW)	TDR (%)	New Capacity at TDR (GW)	ADR %
1	Solar	24%	15.9	48	50	58
2	Wind	23%	15.5	68	78	90
3	Coal + CCS	100%	58.4	88	41	90
4	NGCC + CCS	100%	58.4	88	41	90
5	Solar + Li-ion	24%	15.9	45	64	72
6	Solar + Flow Battery	24%	15.9	45	64	72
7	Wind + Li-ion	23%	15.5	43	26	88

TDR: Point at which SCoRE value associated with a New Low Carbon Technology begins to increase exponentially
ADR: Maximum decarbonization rate achievable with a NLCT
LHCT: Legacy High Carbon Technology

Conclusion

- Spreadsheet based tool developed for computing SCoRE
  - Applied to ERCOT 2019
  - General methodology – currently tool can accept data from any year and any ISO
- SCoRE evaluated for decarbonization through exclusive paths
  - Solar only
  - Wind only
  - Coal w/ CCS
  - **NGCC w/ CCS – Lowest SCoRE, TDR = 88%, ADR = 90%**
  - Solar + Li-ion Storage
  - Solar + Flow Battery Storage
  - Wind + Li-ion Storage
- SCoRE values are similar for some NLCTs
  - Beyond 40% reduction, NGCC with CCS is a competitive pathway to decarbonization in ERCOT

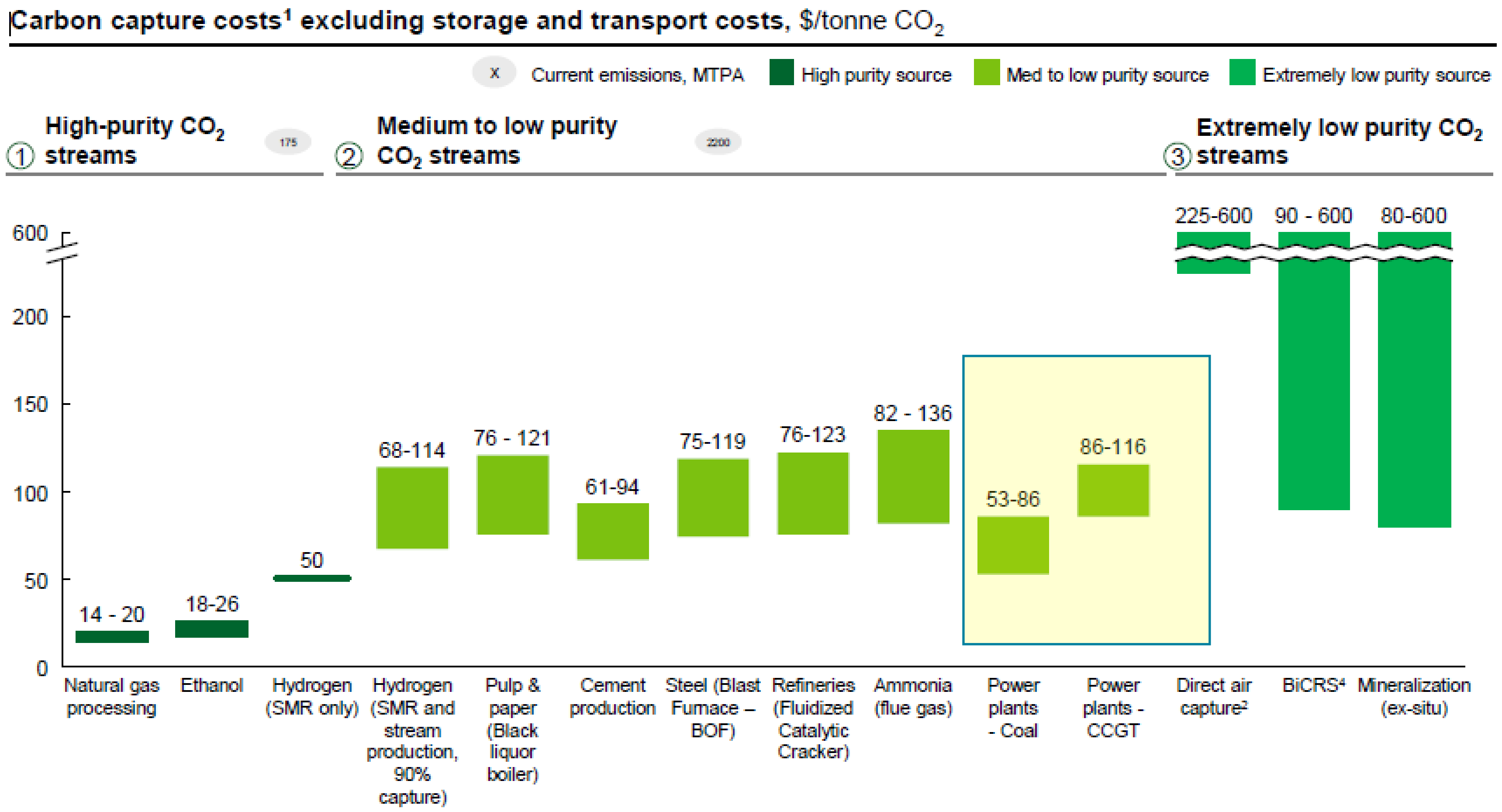
Anticipated Coal Plant Retirements

	Coal Capacity 2022	Coal Retirements 2023-2028	Retirements Converting 2023-2028
MISO	49,400	25,600	3,300
PJM	43,900	21,100	3,400
SPP	20,800	6,000	1,400
TOTAL	114,100	52,700	8,100

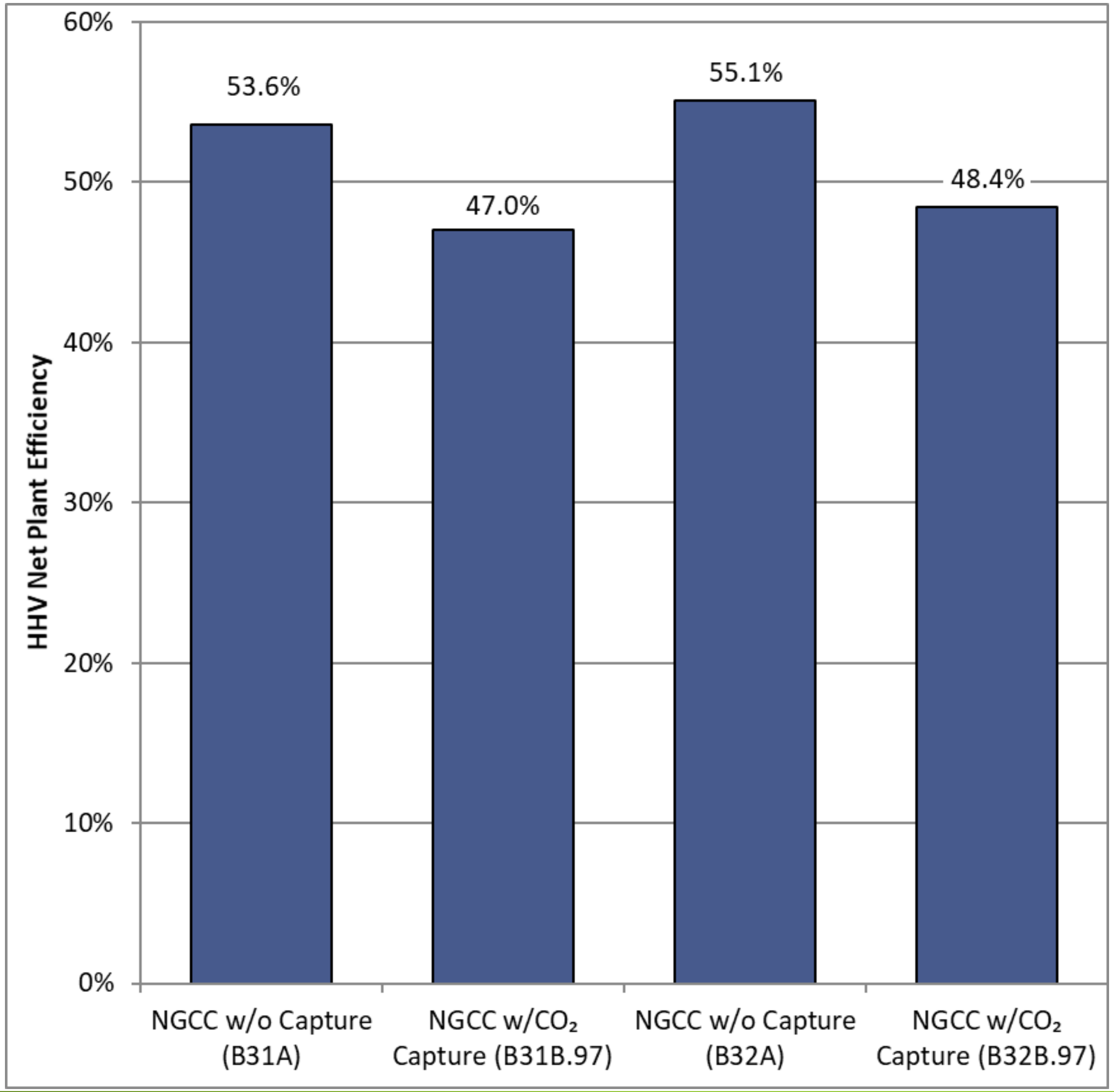
Source: America's Power

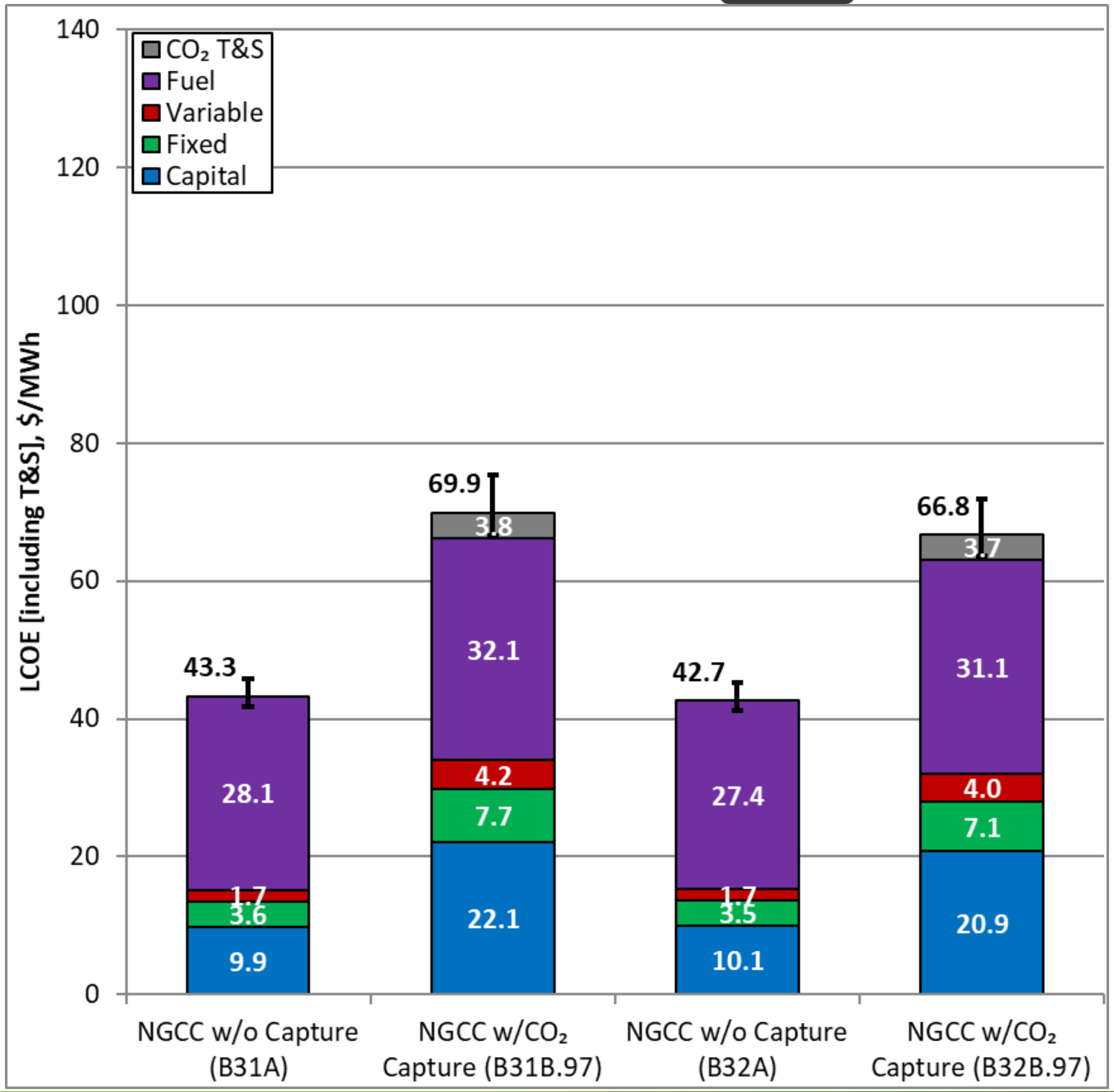
DOE Carbon Management Liftoff

Retrofit costs



Natural Gas Combined Cycle with 97% CO_2 Capture vs. No Capture (Greenfield)





Pulverized Coal with 99% CO_2 Capture vs. No Capture (Greenfield)

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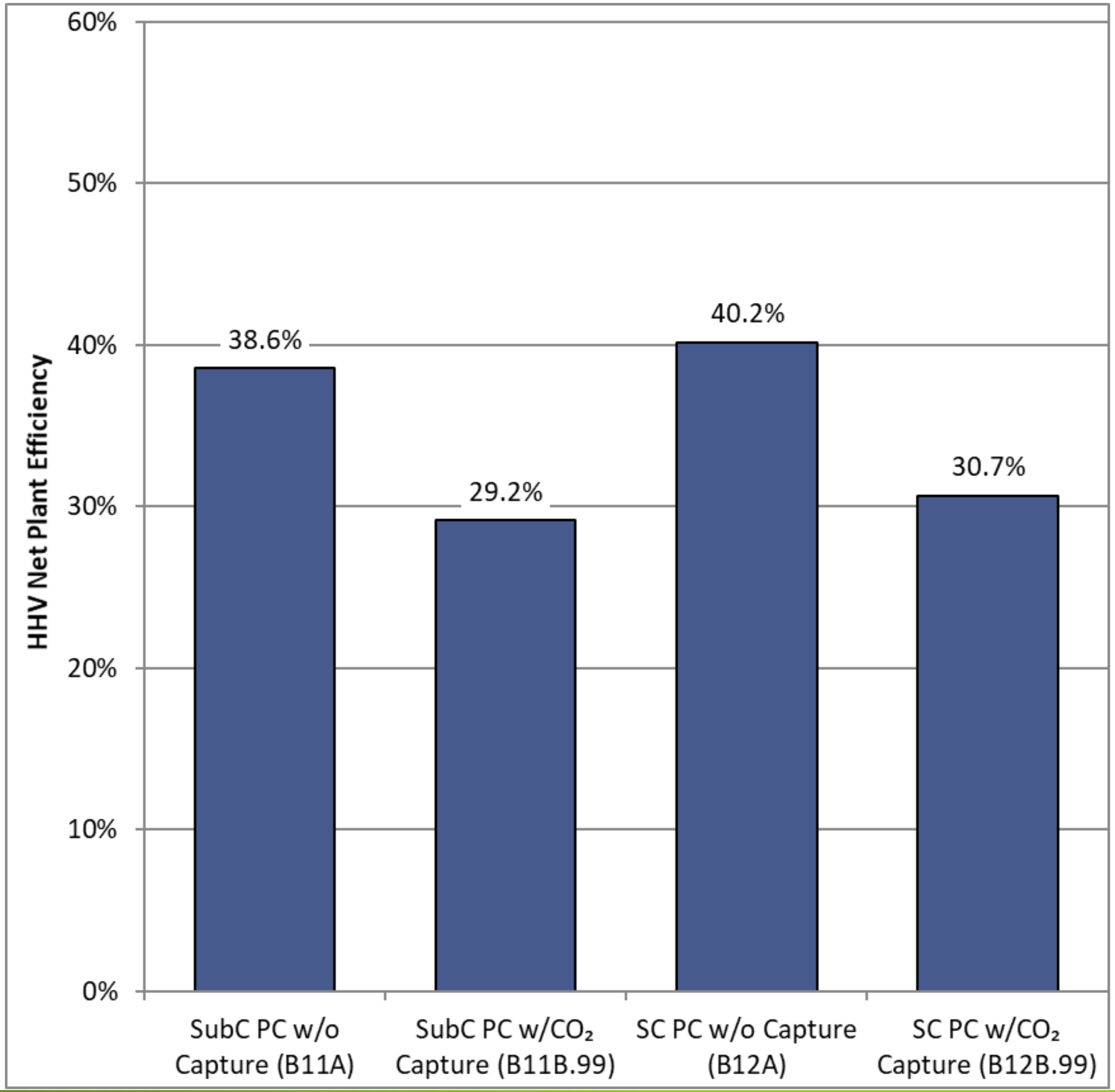

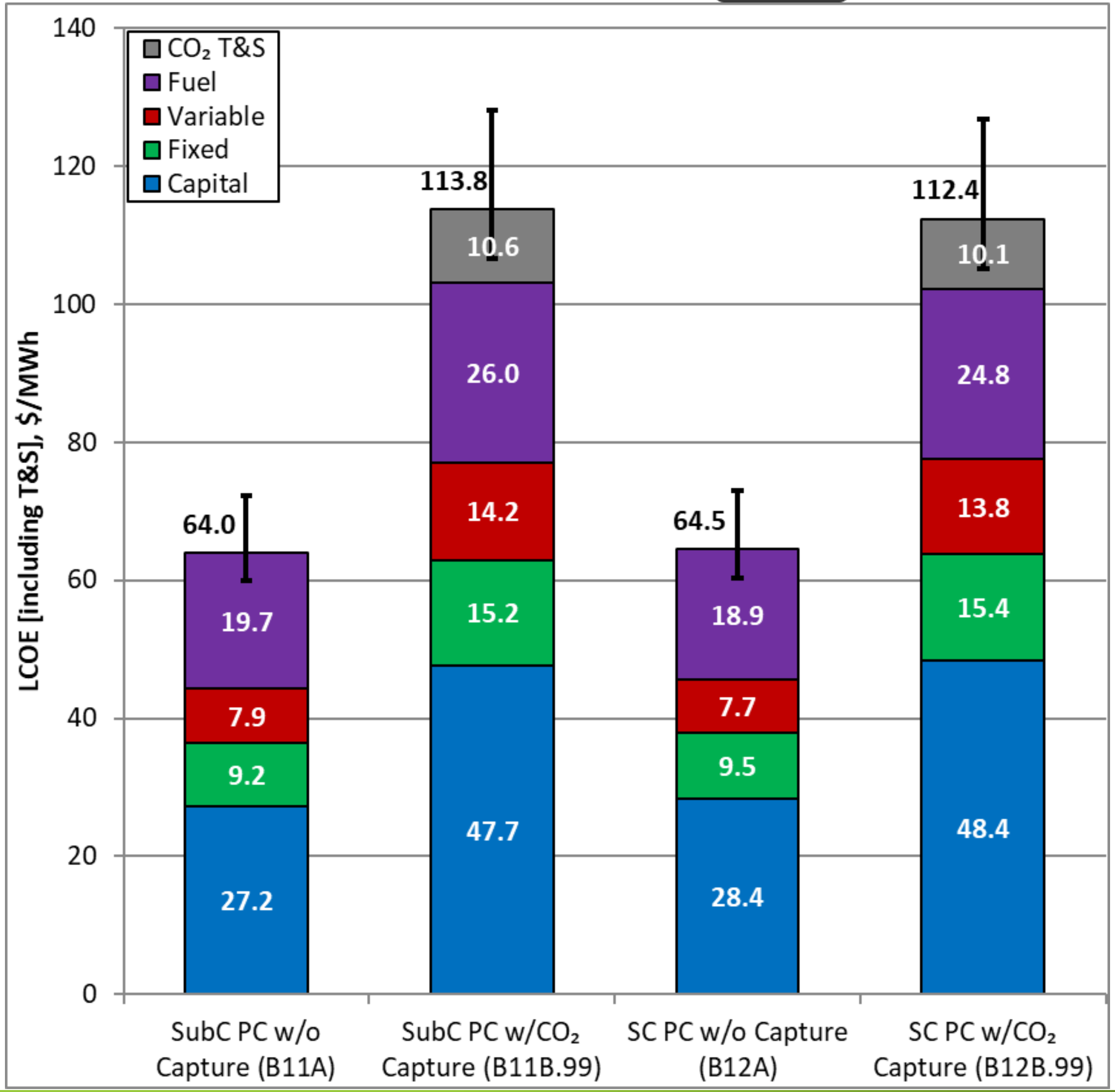

Inflation Reduction Act Incentive

Electricity and Industrial Sectors Only

Inflation Reduction Act – Selected Tax Incentives

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Electricity & Industrial Sectors

- **45: Production Tax Credit for Electricity from Renewables** (placed in service before 2025) - 0.3 cents/kW, can increase by 5x if prevailing wage and apprenticeship (PWA) requirements are satisfied, with 10% bonus credits for "domestic content" and "energy community" siting available
- **45Y: Clean Electricity Production Tax Credit** (projects placed in service in 2025 or thereafter) – similar credits to §45 above, now includes all zero-GHG emitting technologies
- **48: Investment Tax Credit for Energy Property** (pre2025 facilities)– 6% of qualified investment for renewable energy facilities, can increase by 5x if PWA requirements are satisfied, with 10% point bonus credits for "domestic content" and "energy community" siting criteria available
- **48E: Clean Electricity Investment Tax Credit** (post 2025) – similar credits to §48 above, now includes all zero-GHG emitting technologies
- **48(e): Low-Income Communities Bonus Credit** – 10-20% point adder for qualified projects sited in low income areas
- **168(e)(3)(B): Cost Recovery for Qualified Facilities, Qualified Property, and Energy Storage Technology** - treated as 5-year property for depreciation purposes

Inflation Reduction Act – Selected Tax Incentives

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Electricity & Industrial Sectors

- **45U: Zero-Emission Nuclear Power Production Credit** - 0.3 cents/kWh, can increase by 5x if PWA requirements are satisfied
- **48C: Advanced Energy Project Credit** - 6% of taxpayer's qualifying investment
- **45X: Advanced Manufacturing Production Credit**- domestic manufacturing of components for solar and wind energy, inverters, battery components, and critical minerals. Credit varies by technology
- **45Q: Credit for Carbon Oxide Sequestration** - $17/metric ton of carbon dioxide captured and sequestered; $12/metric ton for carbon dioxide that is injected for enhanced oil recovery or utilized. Those amounts are $36 and $26, respectively, for direct air capture facilities. can increase by 5x if (PWA) requirements are satisfied
- **45V: Clean Hydrogen Production Tax Credit** - $0.60/kg multiplied by the applicable percentage. The applicable percentage ranges from 20% to 100% depending on lifecycle greenhouse gas emissions. can increase by 5x if PWA requirements are satisfied