

Power Market Dynamics

Presented to: Energy & the Economy Meeting

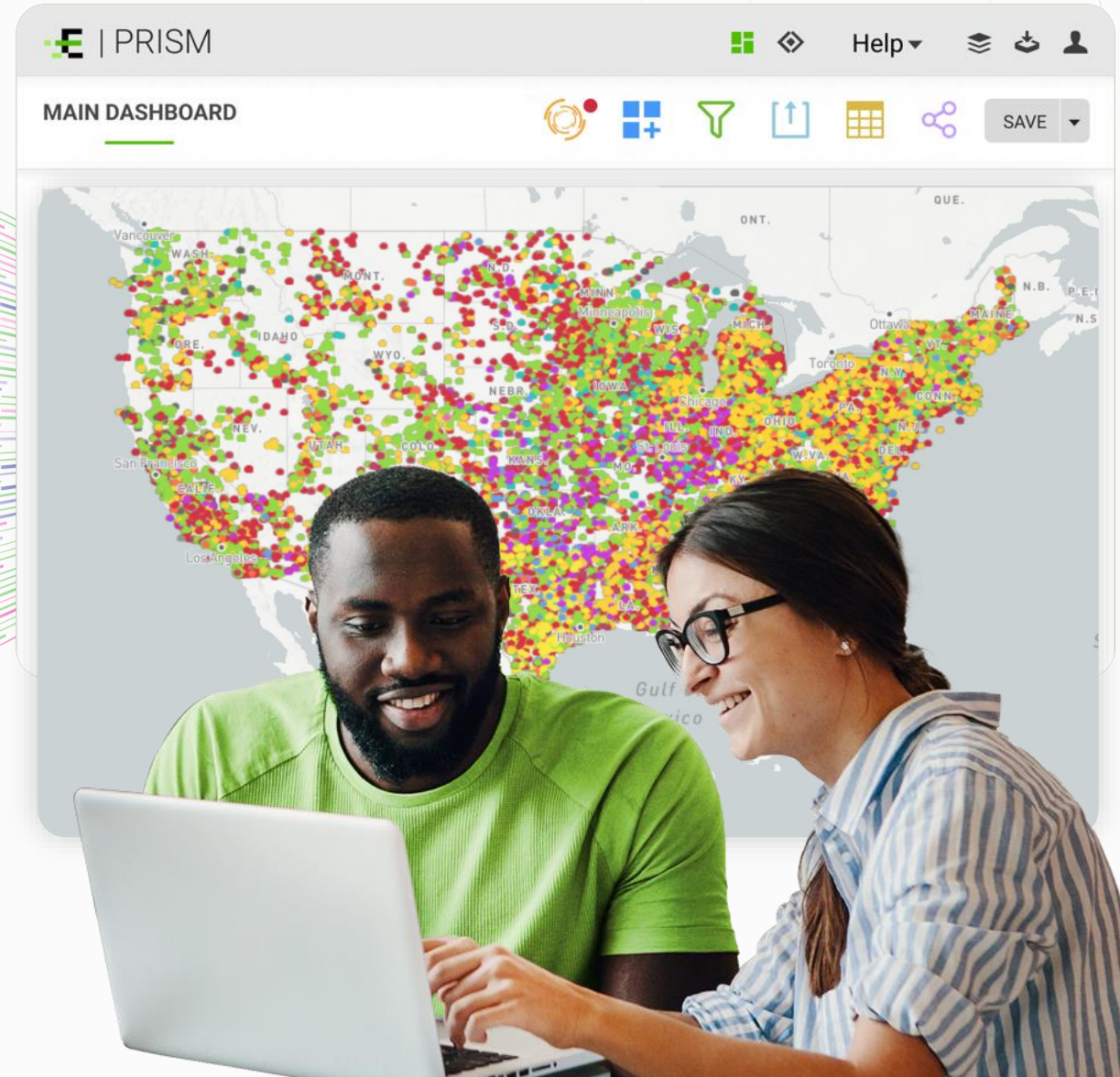


Federal Reserve Bank of Kansas City

DENVER / OKLAHOMA CITY / OMAHA

BERNADETTE JOHNSON | GM, POWER & RENEWABLES

NOVEMBER 2023



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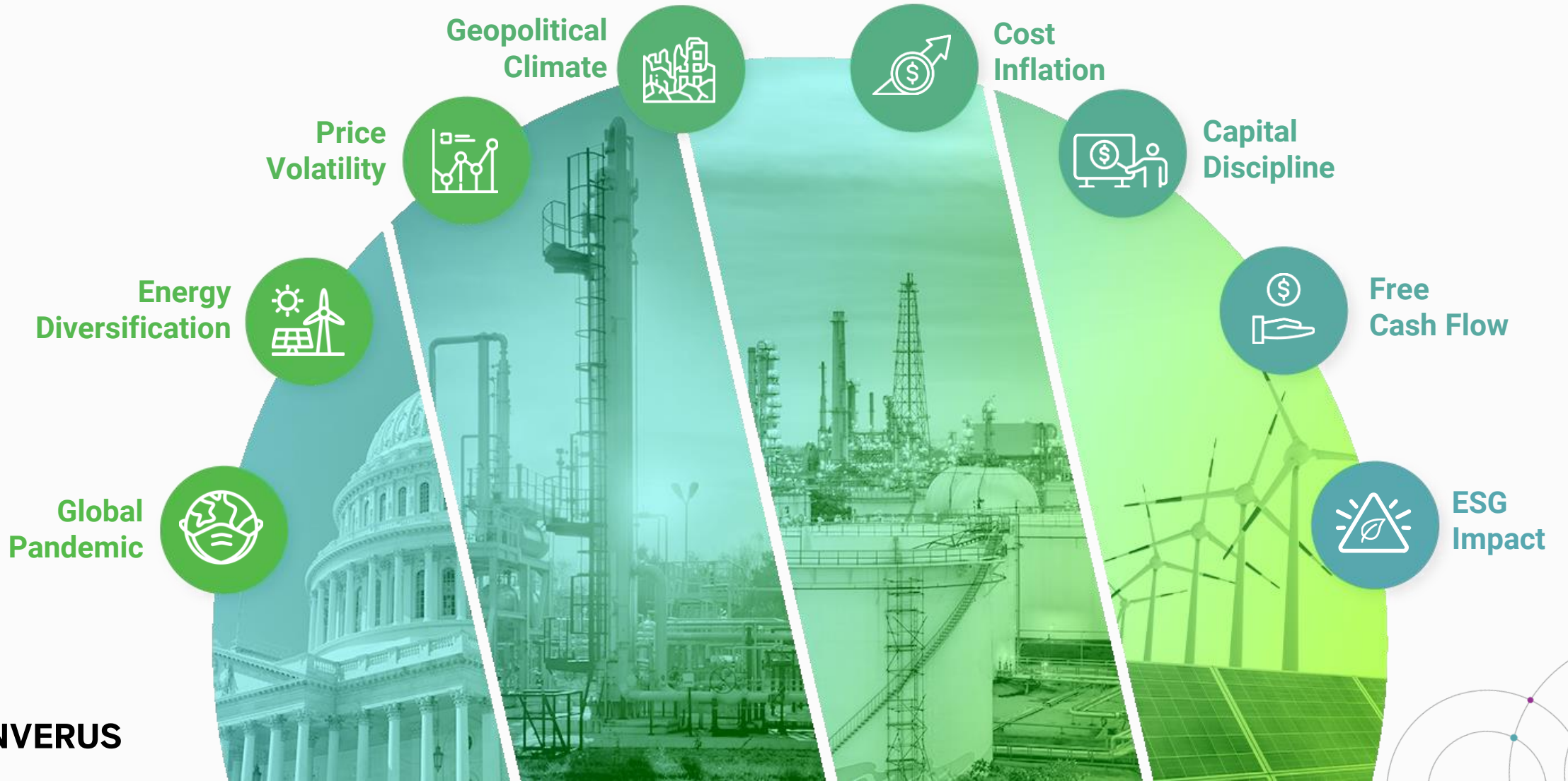
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THE ENERGY INDUSTRY **HAS CHANGED**



THE HEADWINDS: A SUMMARY



WHAT WE SAY WE NEED FOR THE ENERGY EVOLUTION



Hydrocarbons ↓ | Need to decline at a rapid rate to meet Well Below 2°C ambitions.



Investment ↑ | Need public and private investment to fill in demand gaps with technology.



Collaboration ↑ | Global collaboration at levels never seen before.

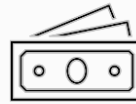


Government Intervention ↑ | Global government intervention at levels never seen before.

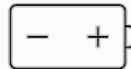
WHAT WE NEED TO CONSIDER ABOUT THE ENERGY EVOLUTION



Hydrocarbons ↓ | Lack of investment will cause price volatility and shocks to world economies.



Emissions ↓ | Efforts to reduce emissions require higher cost measures short term.



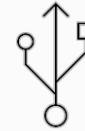
Storage ↑ | Industrial-scale storage key to reliability of grids throughout the electrification.



End-Use ↑ | Need to address the energy needs of transport, industry, & buildings.



Infrastructure ↑ | Redundant infrastructure and early abandonment of existing infrastructure is costly.



Digitalization ↑ | Digitalization of new and existing infrastructure and cybersecurity risk mitigation is costly.



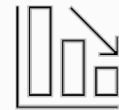
Access ↑ | Need to address immediacy of access to electricity and clean cooking.



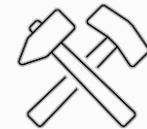
Financing ↑ | More financing for developing and emerging economies to address emissions.



Supply Diversification ↓ | Hydrocarbon production becomes more concentrated, making supply riskier.



Hydrocarbon Revenues ↓ | Hydrocarbon revenues decline, making resource-rich economies unstable.

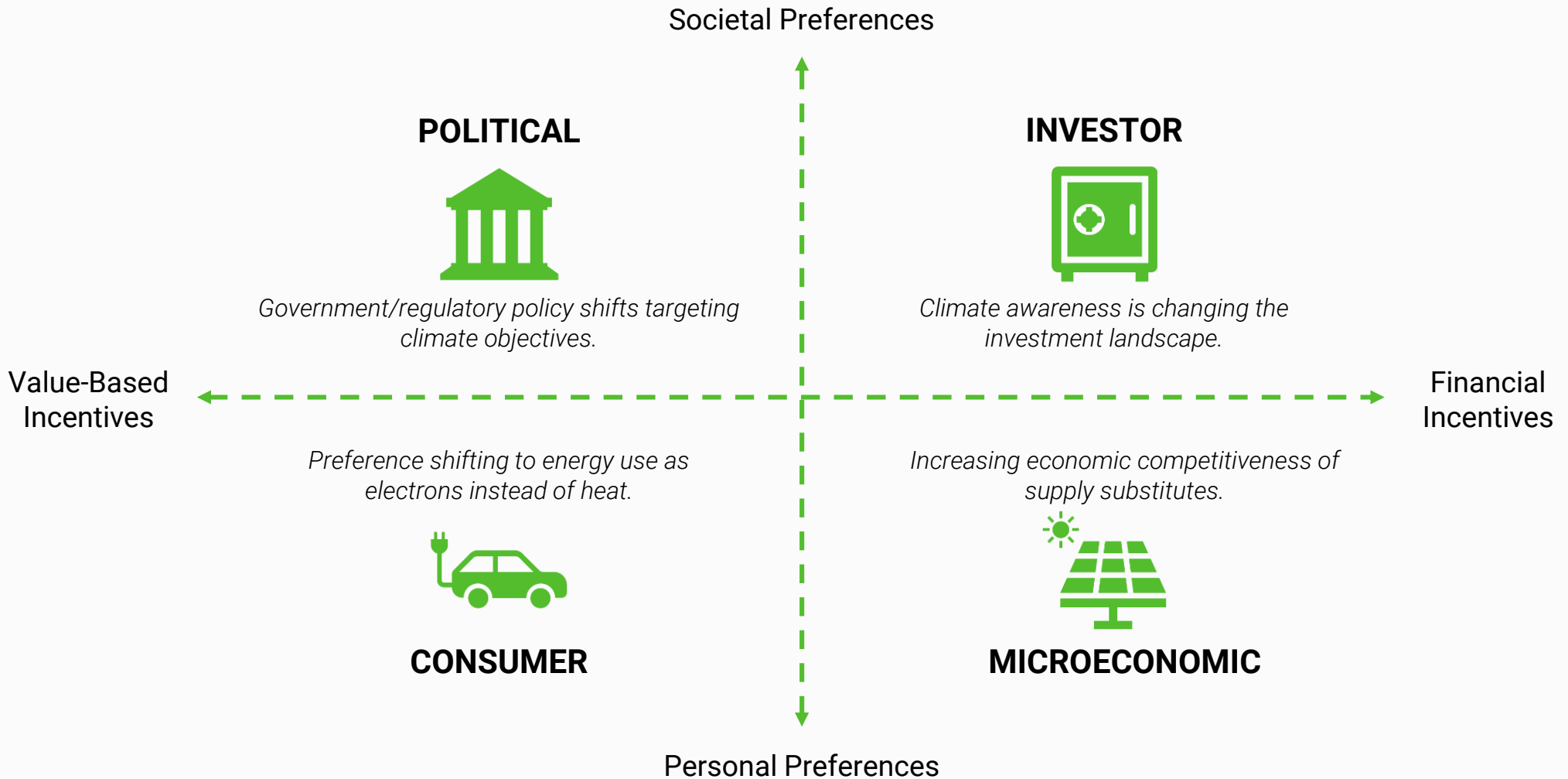


Mining ↑ | Require more minerals, which are concentrated in fewer countries with weak ESG practices.

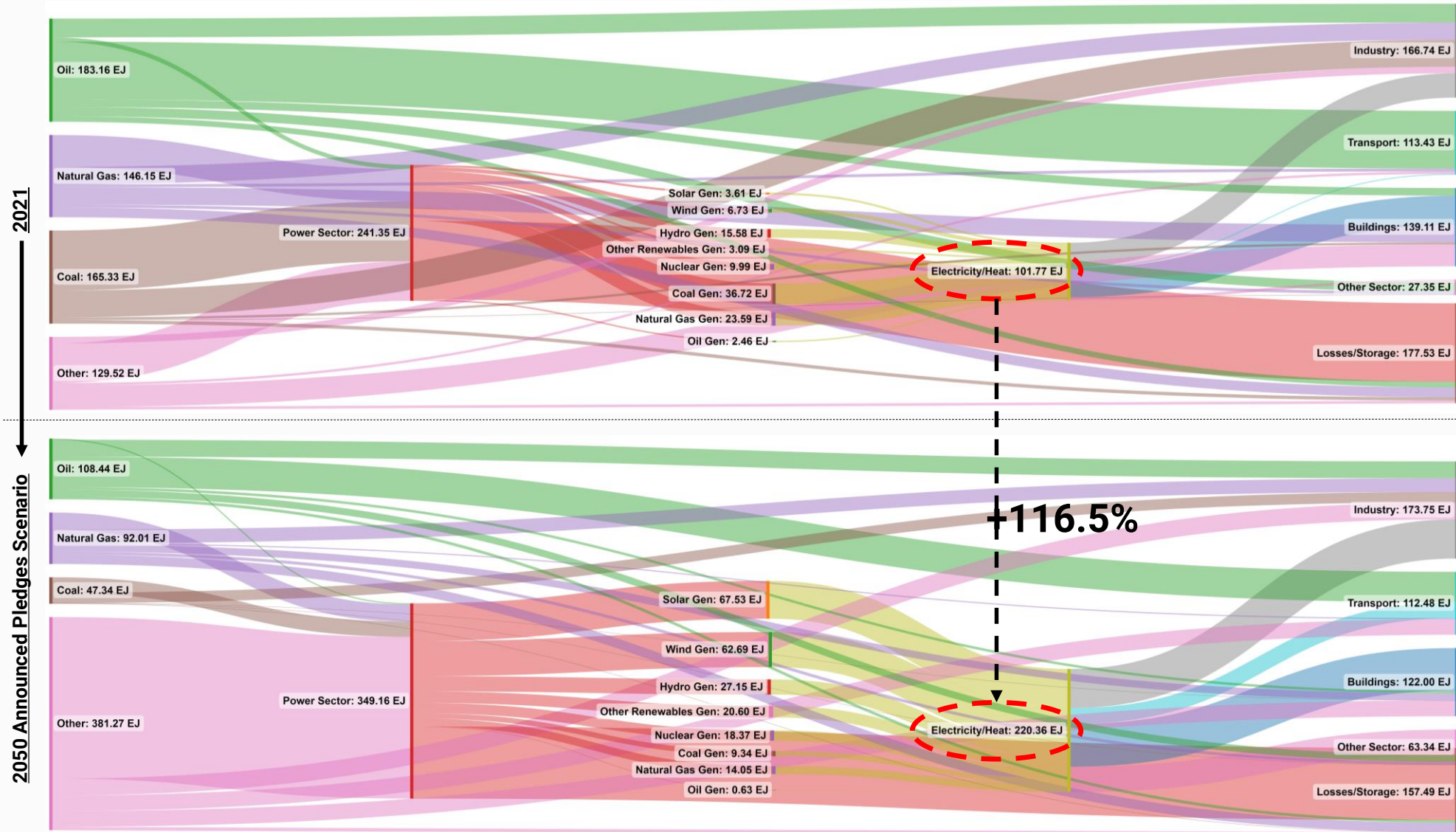


Workforce ↑↓ | Changes in energy mix will impact workers and communities differently.

THE FOUR FORCES OF THE ENERGY EVOLUTION

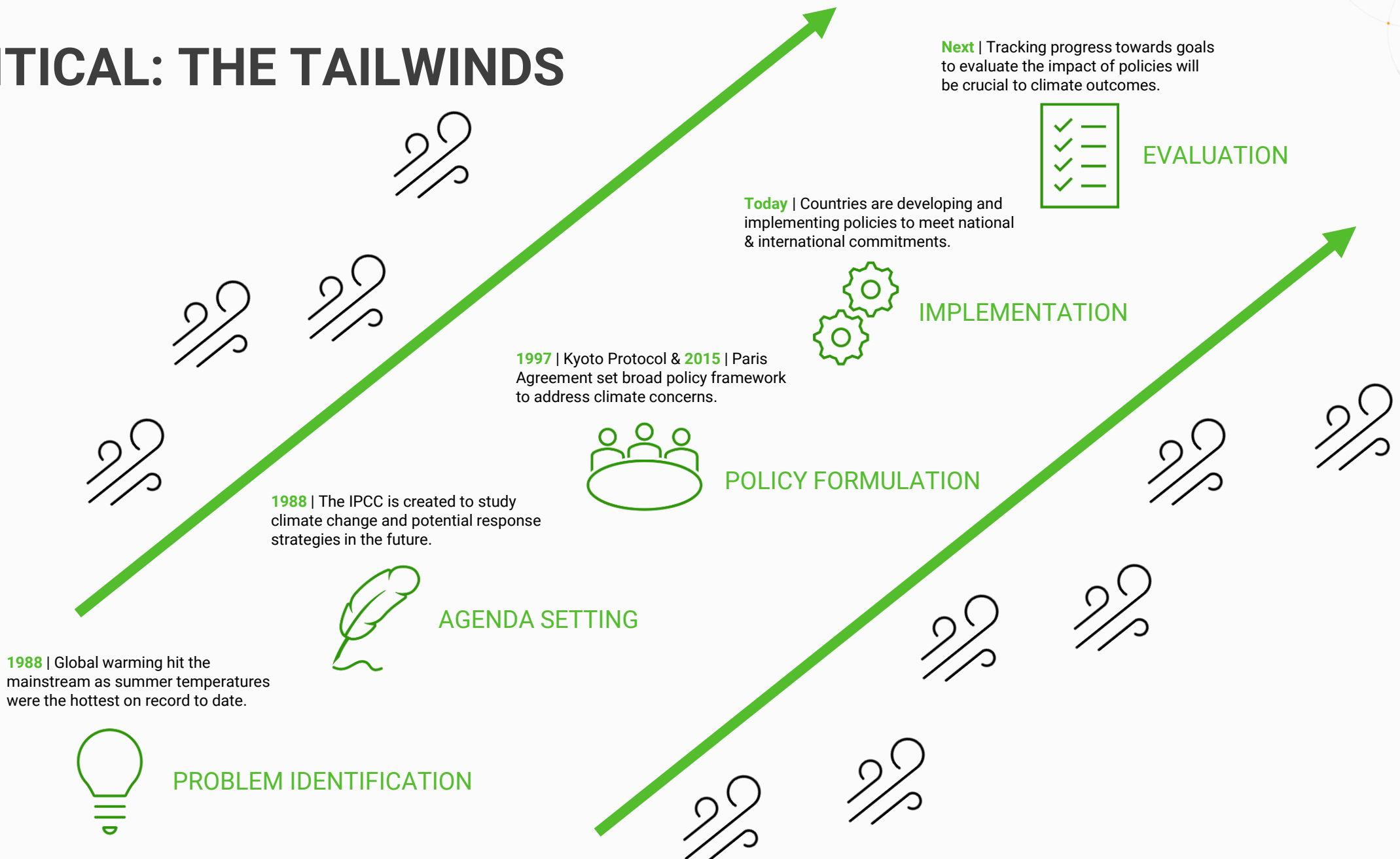


CONSUMER: PREFERENCE FOR ELECTRONS



Source | Enverus, IEA

POLITICAL: THE TAILWINDS

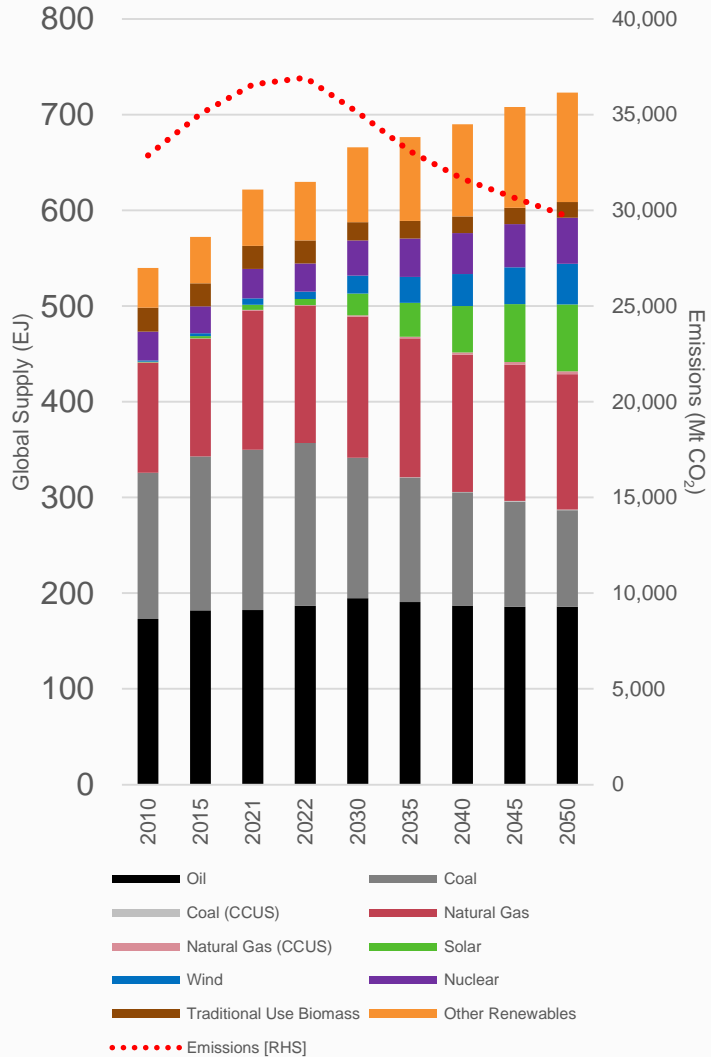


Source | Enverus

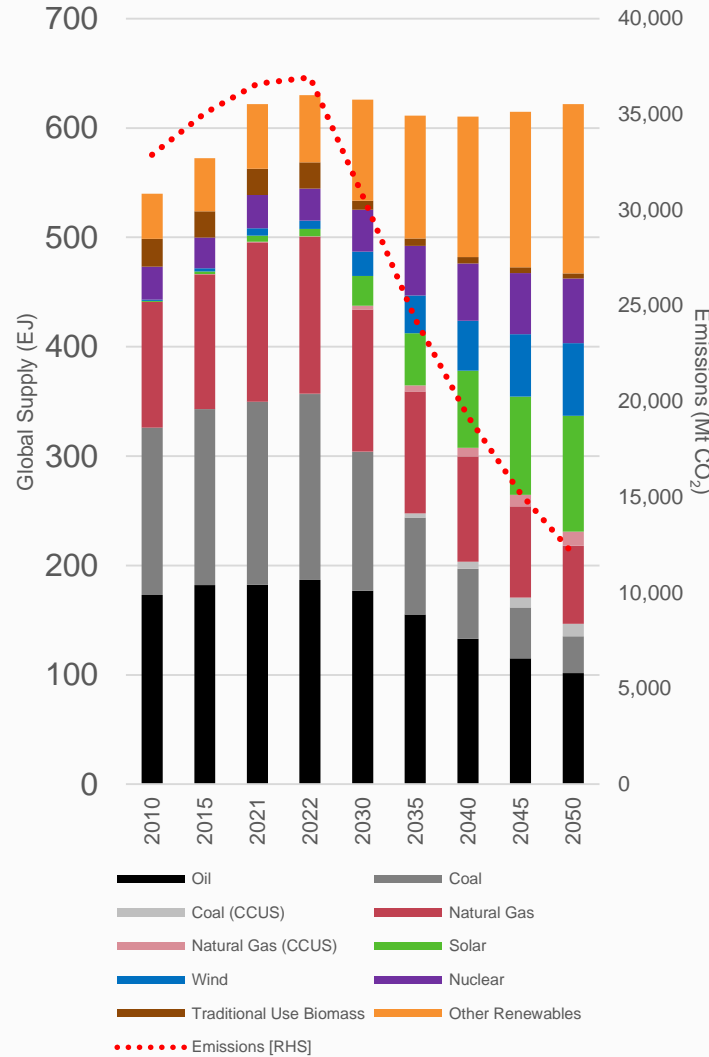
POLITICAL: AMBITION REQUIRES EVALUATION



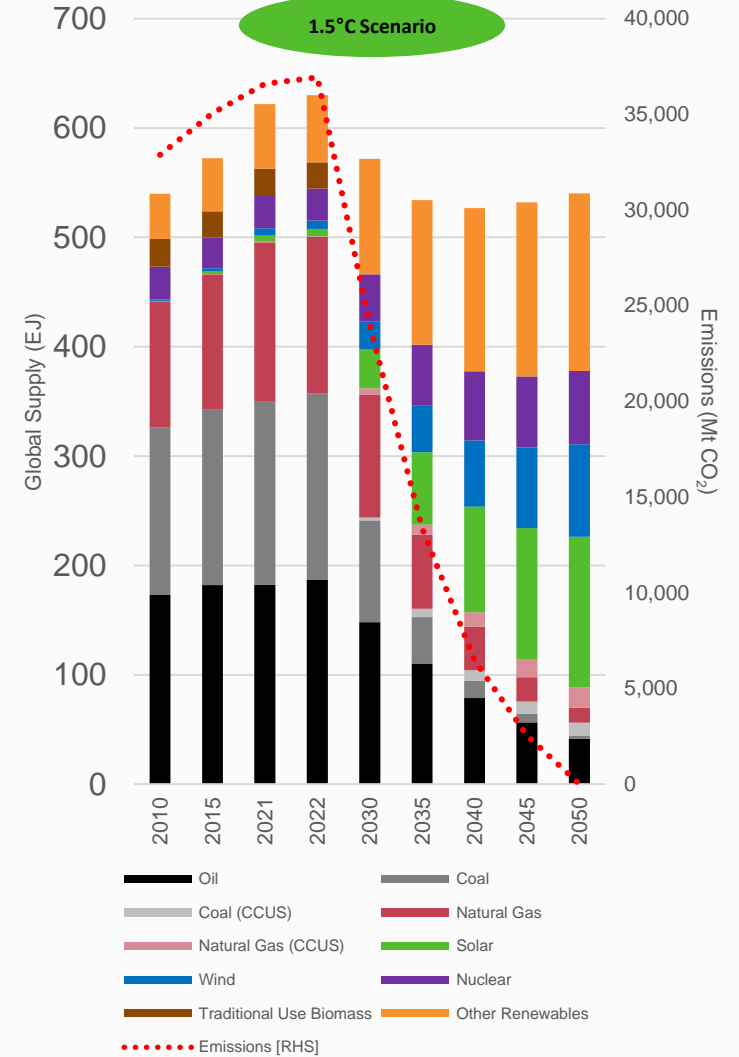
Stated Policies Scenario



Announced Pledges Scenario



Net Zero Emissions by 2050 Scenario



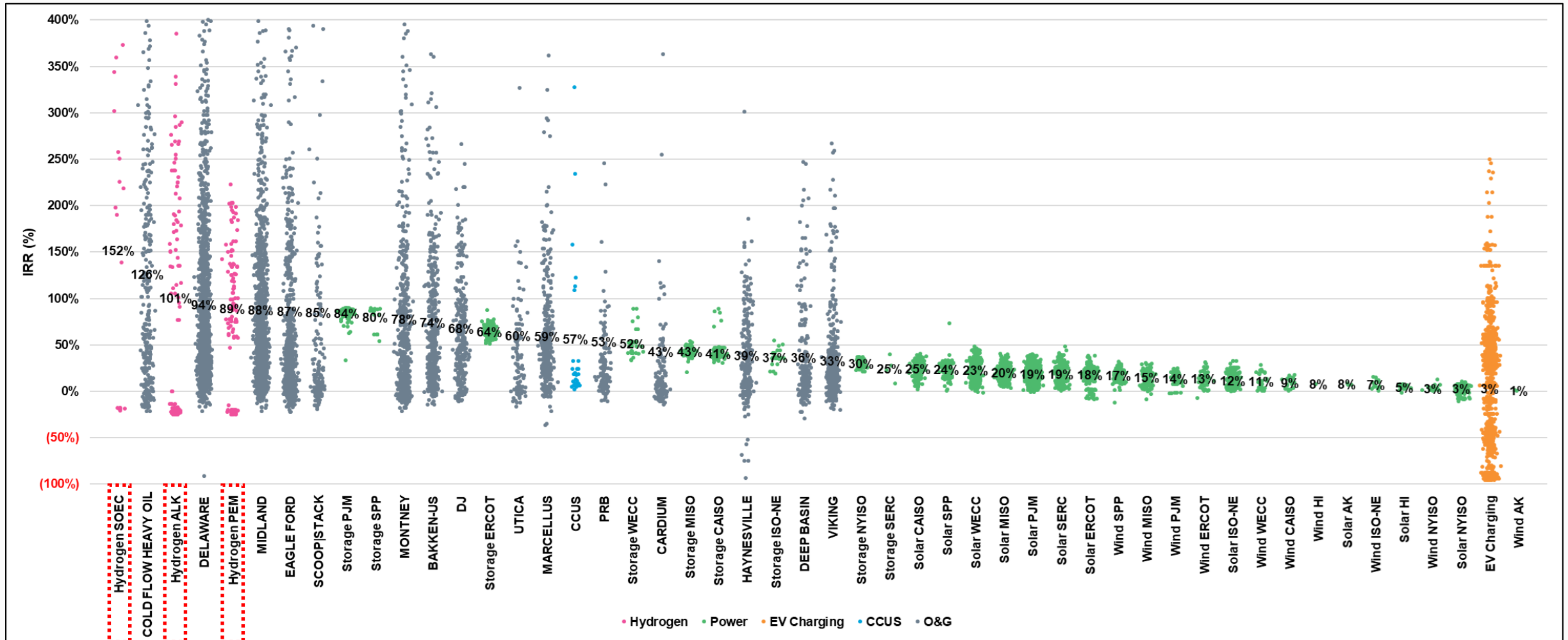
Source | Enverus, IEA

MICROECONOMIC: COMPETING INVESTMENTS



FIGURE | Energy Technology Economics Comparison

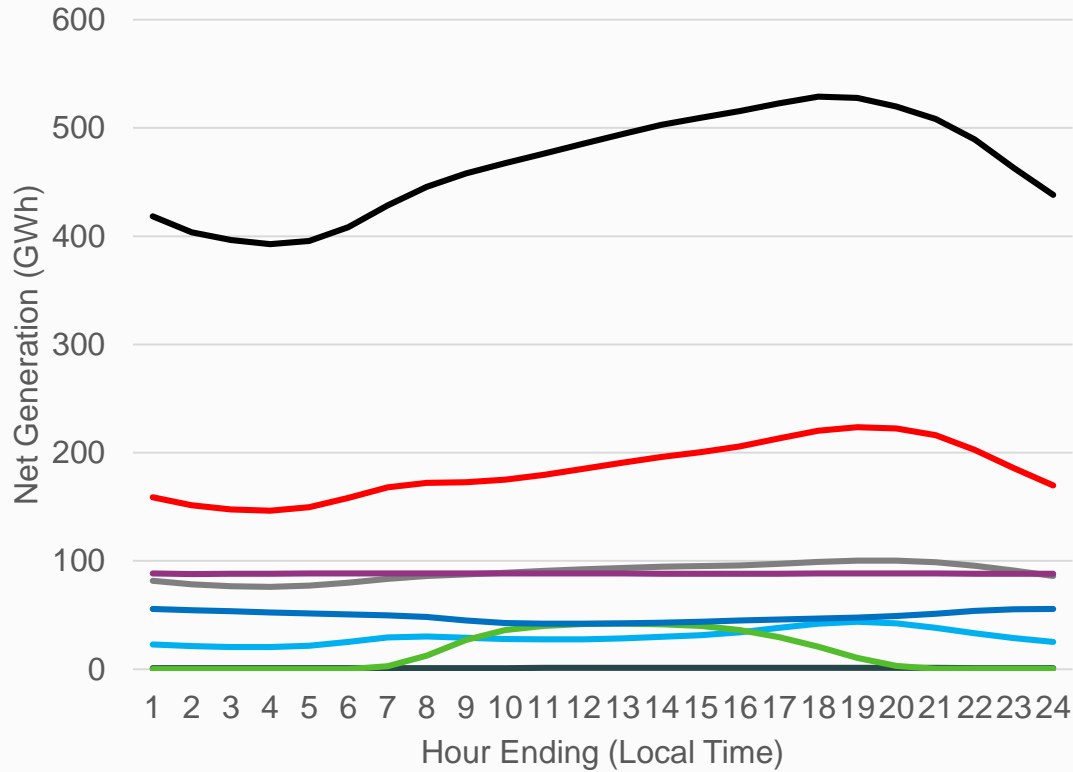
Assumptions | 2023/24 Vintage | Oil & Gas : \$60 WTI/\$3 HH | Generation: \$40/MWh | Storage: LTM Combo Strategy | Hydrogen: \$1.50/kg, No Transport | EV: 5% Utilization



Source | Enverus P&R - NAV & Economic Analysis, Enverus Intelligence - Energy Transition Research

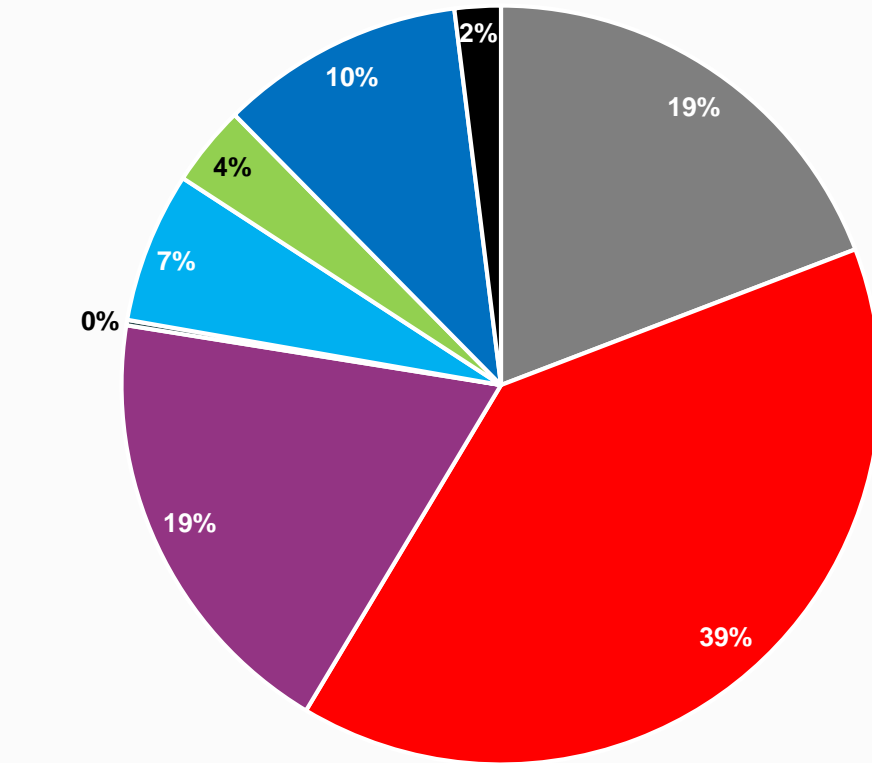
24/7 RENEWABLES | THE PROBLEM

Avg Hourly Net Gen by Technology (Jan 2022-Oct 2023)



- Total
- Coal
- Natural Gas
- Nuclear
- Petroleum Products
- Hydro & Pumped Storage
- Solar
- Wind

Avg Hourly Net Gen by Technology (Jan 2022-Oct 2023)

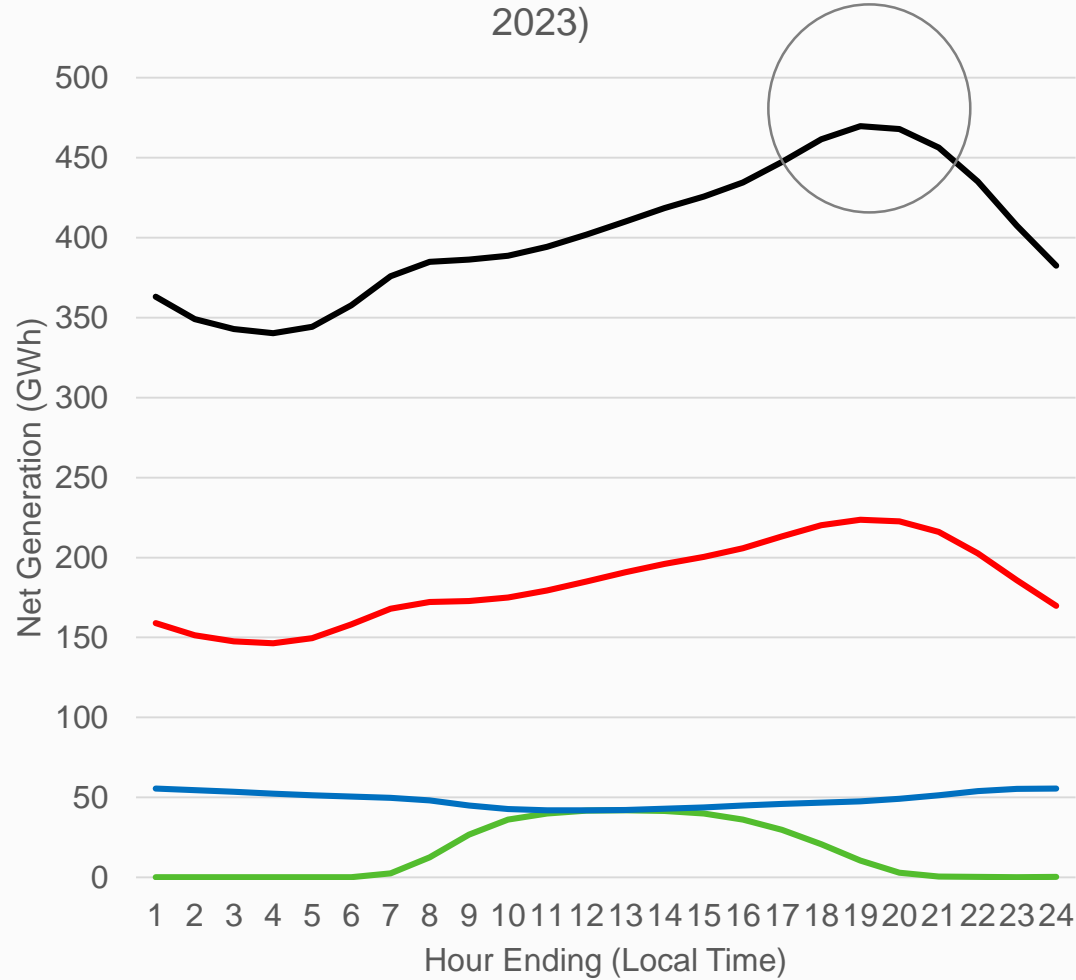


- Coal
- Natural Gas
- Nuclear
- Petroleum Products
- Hydro & Pumped Storage
- Solar
- Wind
- Other

Source: Enverus, Balancing Authorities, EIA

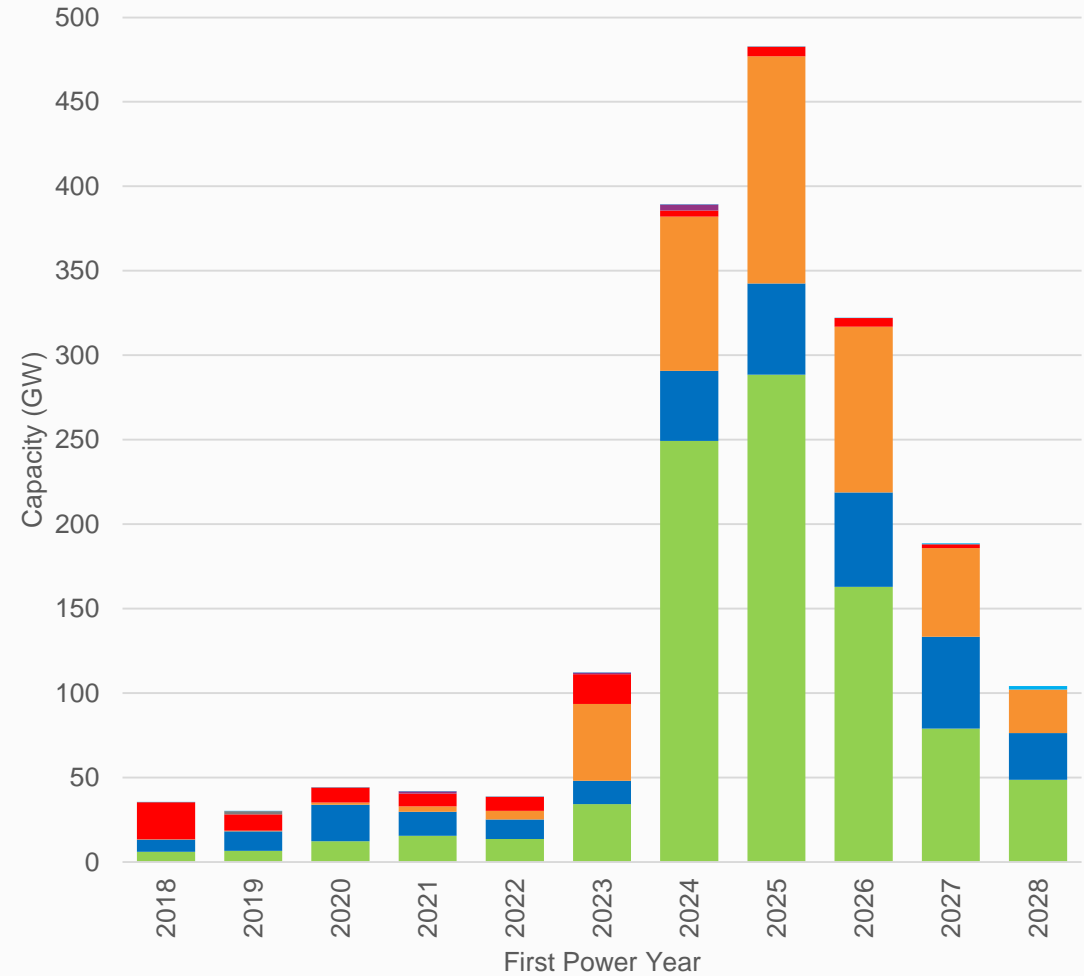
24/7 RENEWABLES | WHAT ARE WE DOING?

Avg Hourly Net Gen by Technology (Jan 2022-Oct 2023)



— Demand excl. Solar + Wind — Natural Gas — Solar — Wind

Capacity Operating and in Queues by Technology

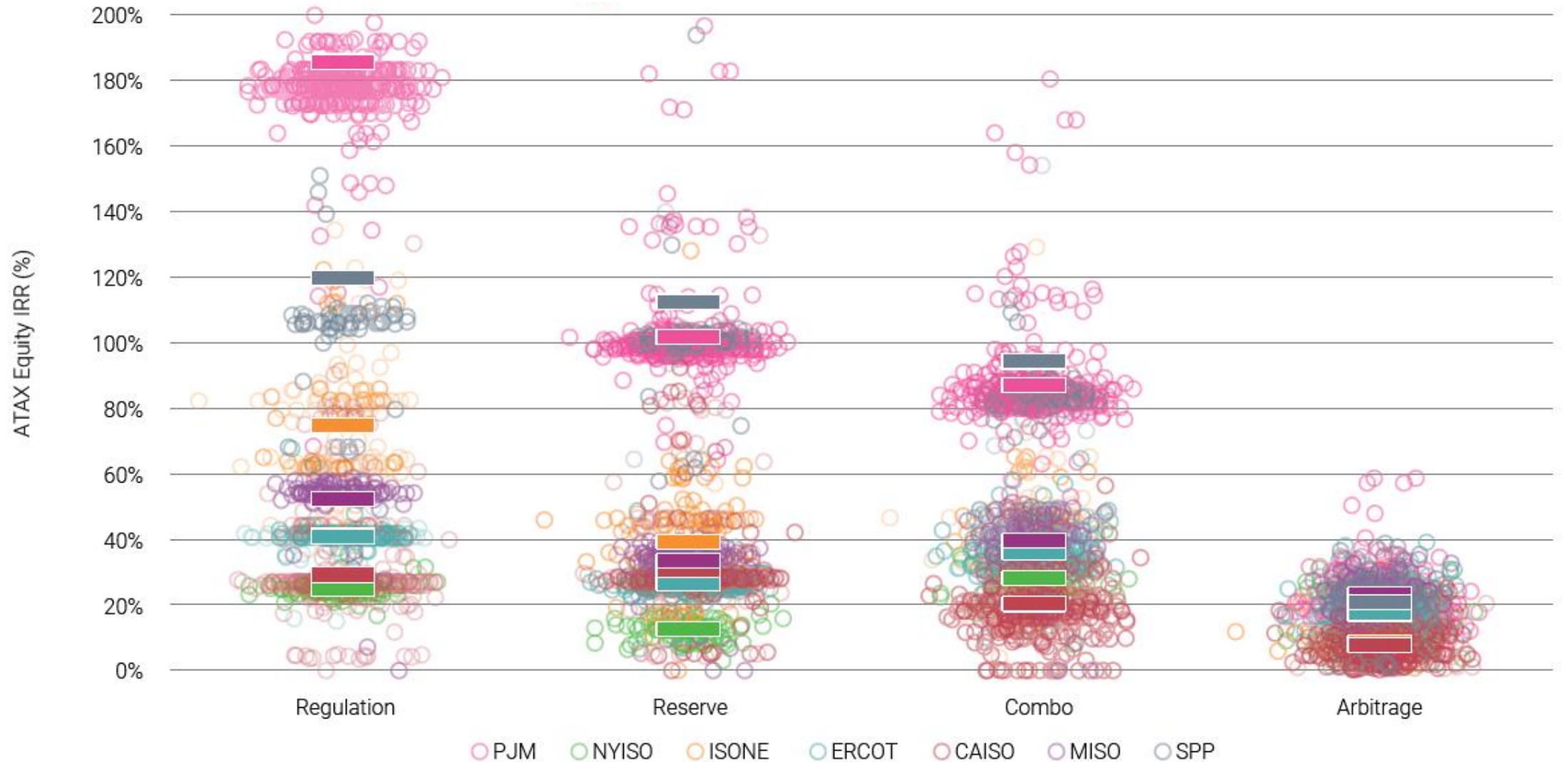


■ Solar ■ Wind ■ Storage ■ Natural Gas ■ Coal ■ Nuclear ■ Hydro

Source: ENVERUS P&R – Project Tracking, Balancing Authorities, EIA

STORAGE | RETURNS LOOK GOOD FOR NOW...

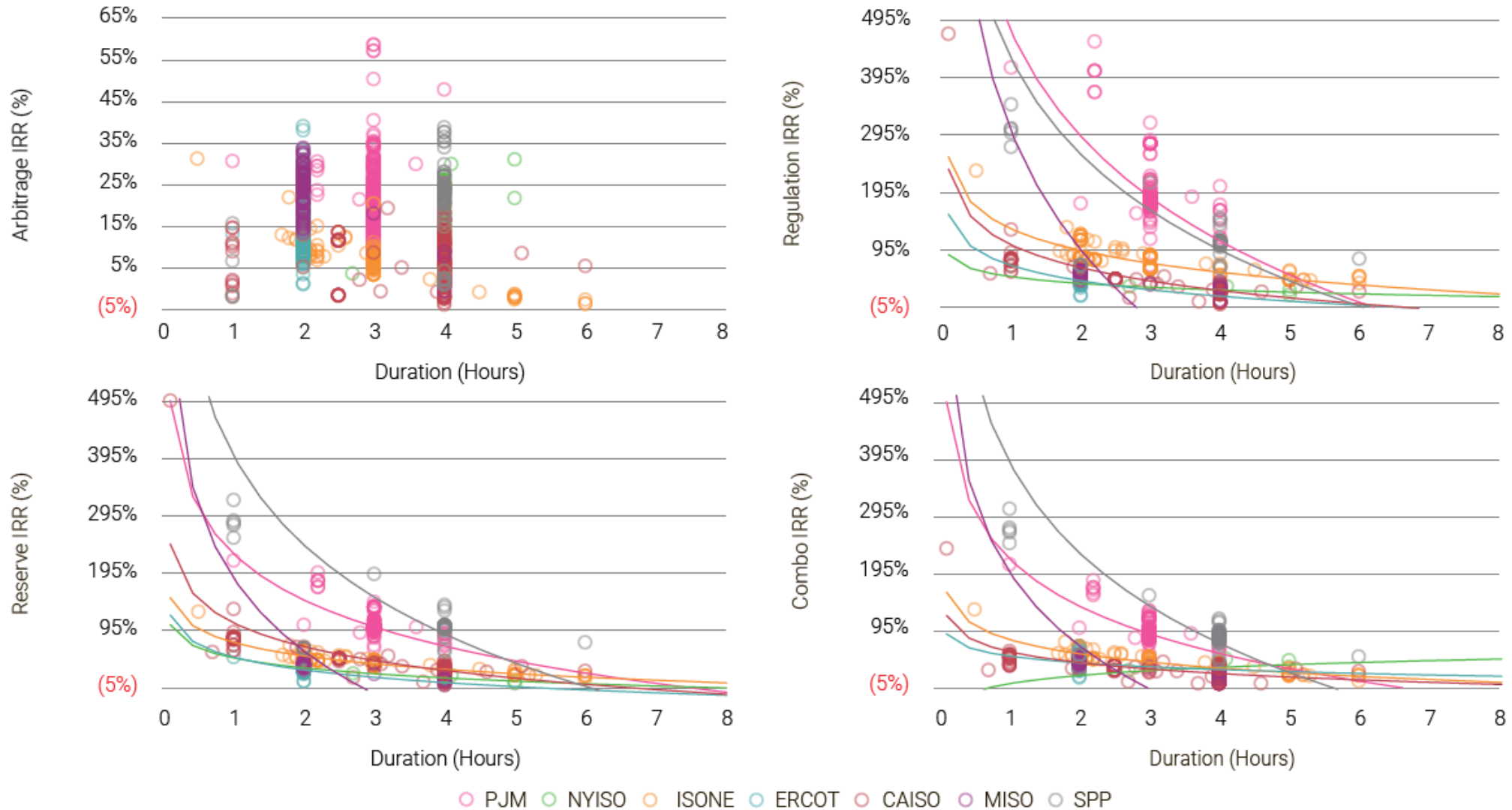
FIGURE | Storage Strategy Returns Benchmarking



Source: Enverus P&R – Economics, Enverus Intelligence

STORAGE | ...ARBITRAGE EATS ITS OWN TAIL...

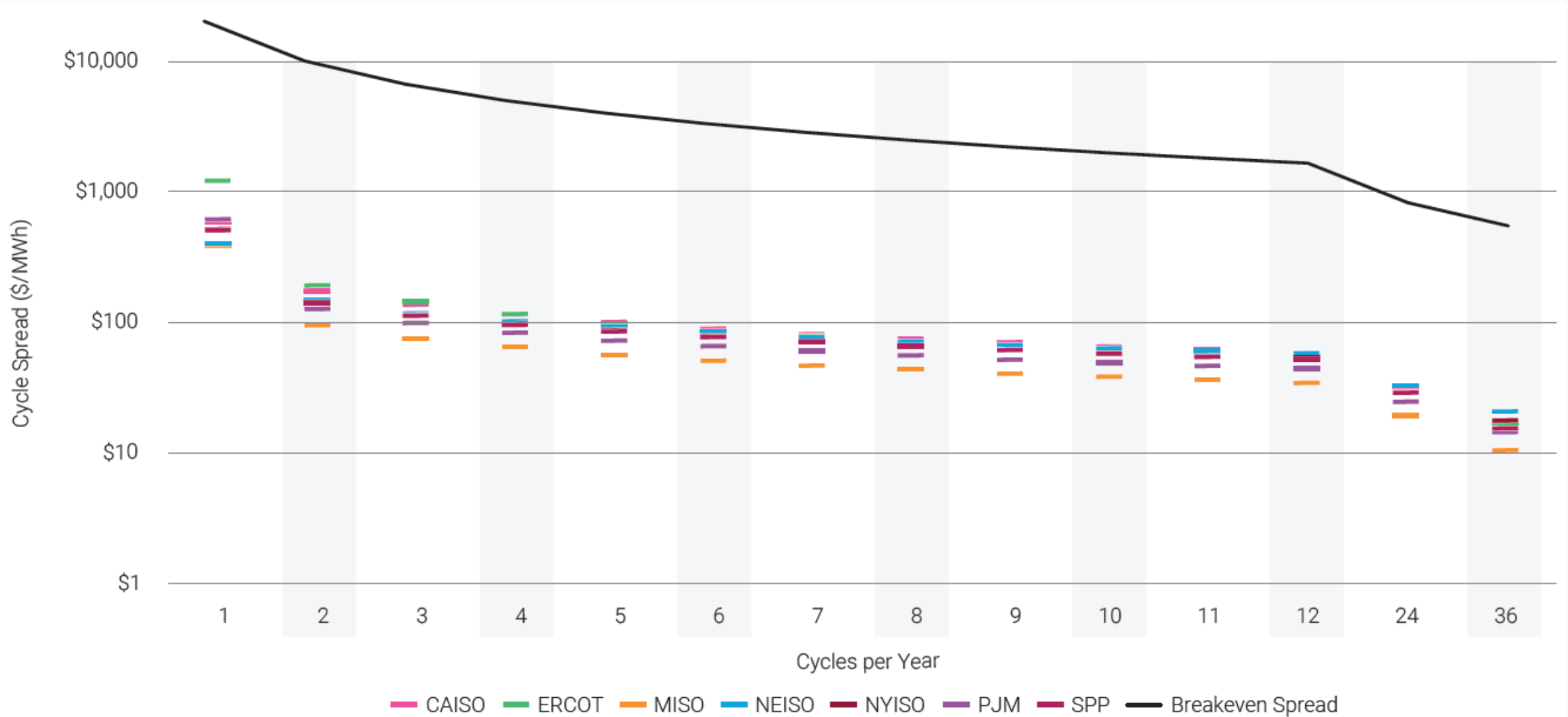
FIGURE | Duration Impact on Returns



Source: Enverus P&R - LMP, Enverus Intelligence

STORAGE | ...AND LONG-DURATION IS FAR FROM ECONOMIC.

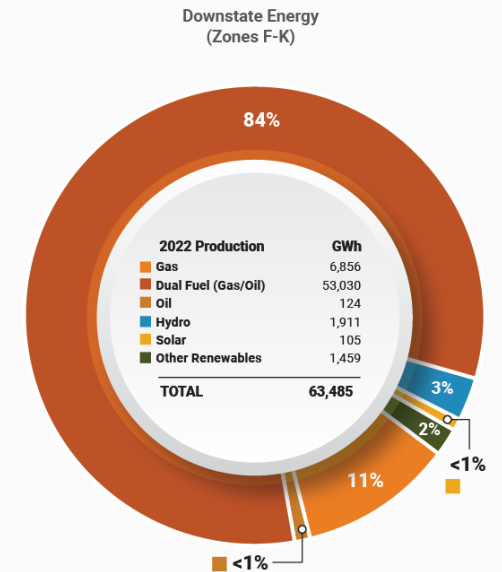
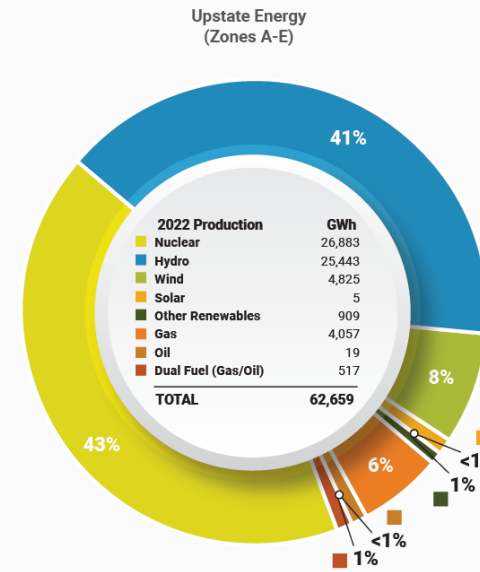
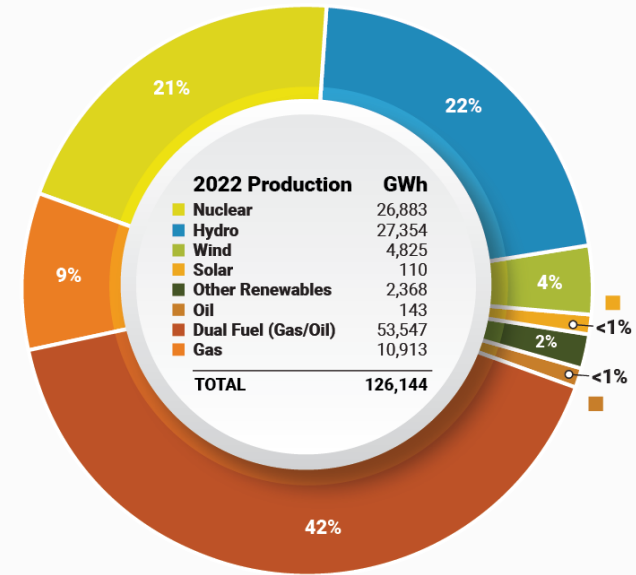
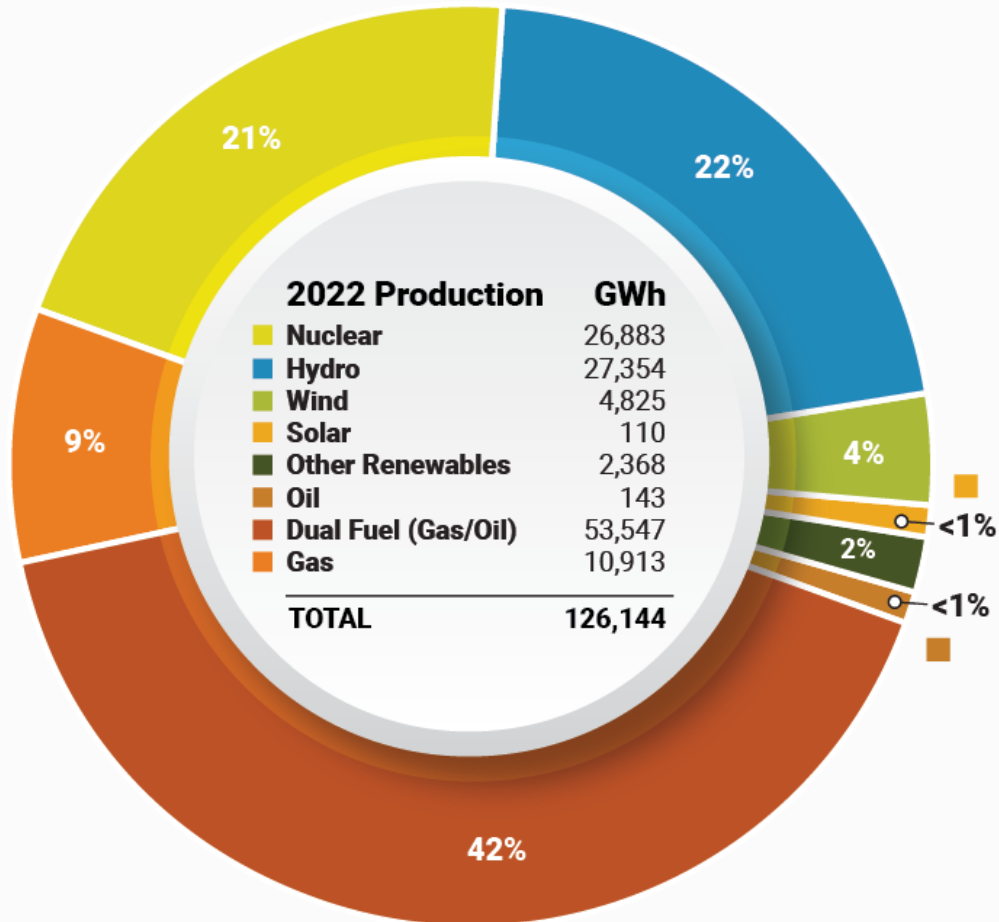
FIGURE | Achievable and Breakeven Spreads by ISO



Source: Enverus P&R - LMP, Enverus Intelligence

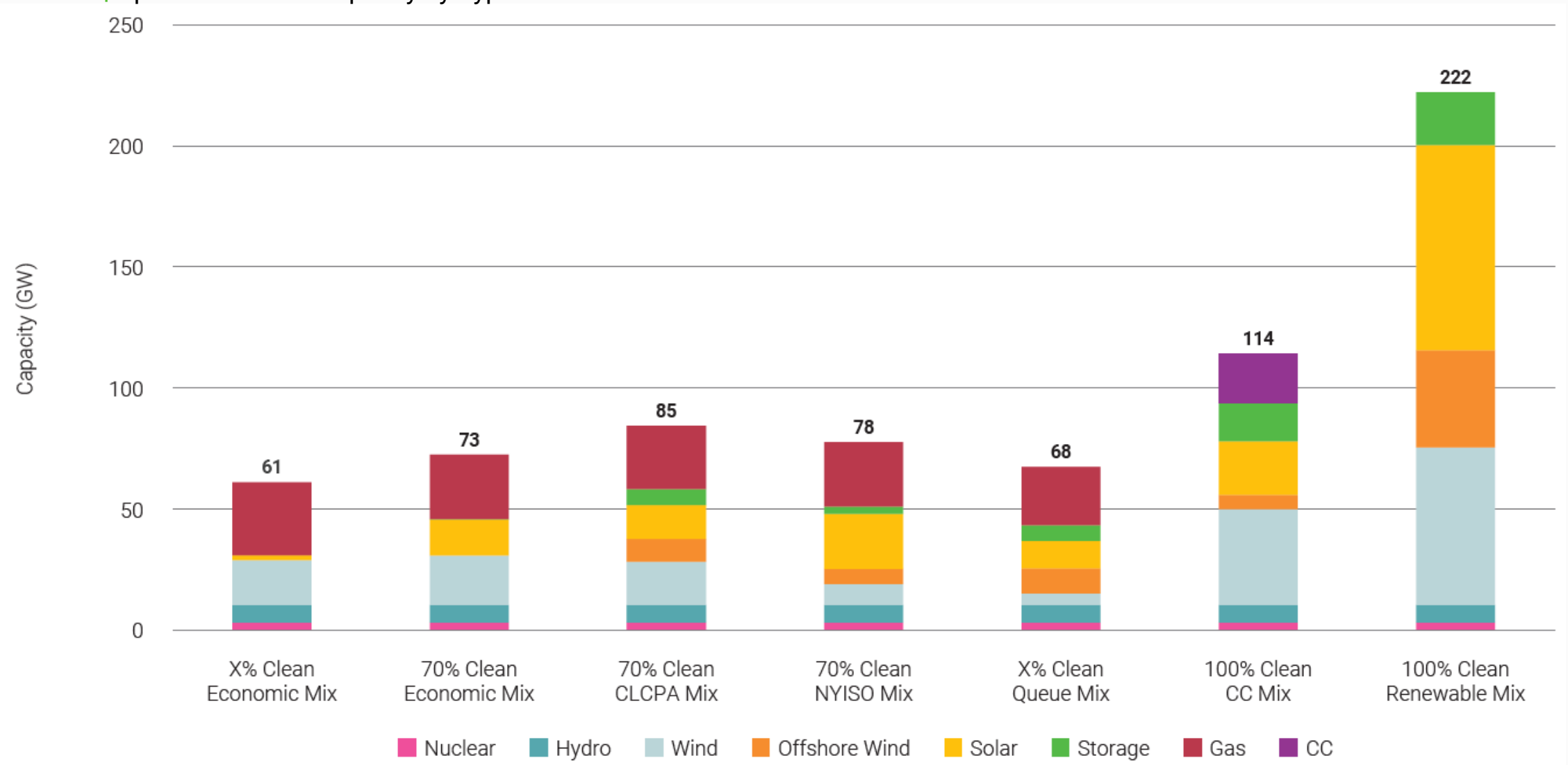
CURRENT STATE OF NYISO

NYCA Energy Production by Source



NYISO | 70X30 MANDATE – WITH WHAT TECHNOLOGIES?

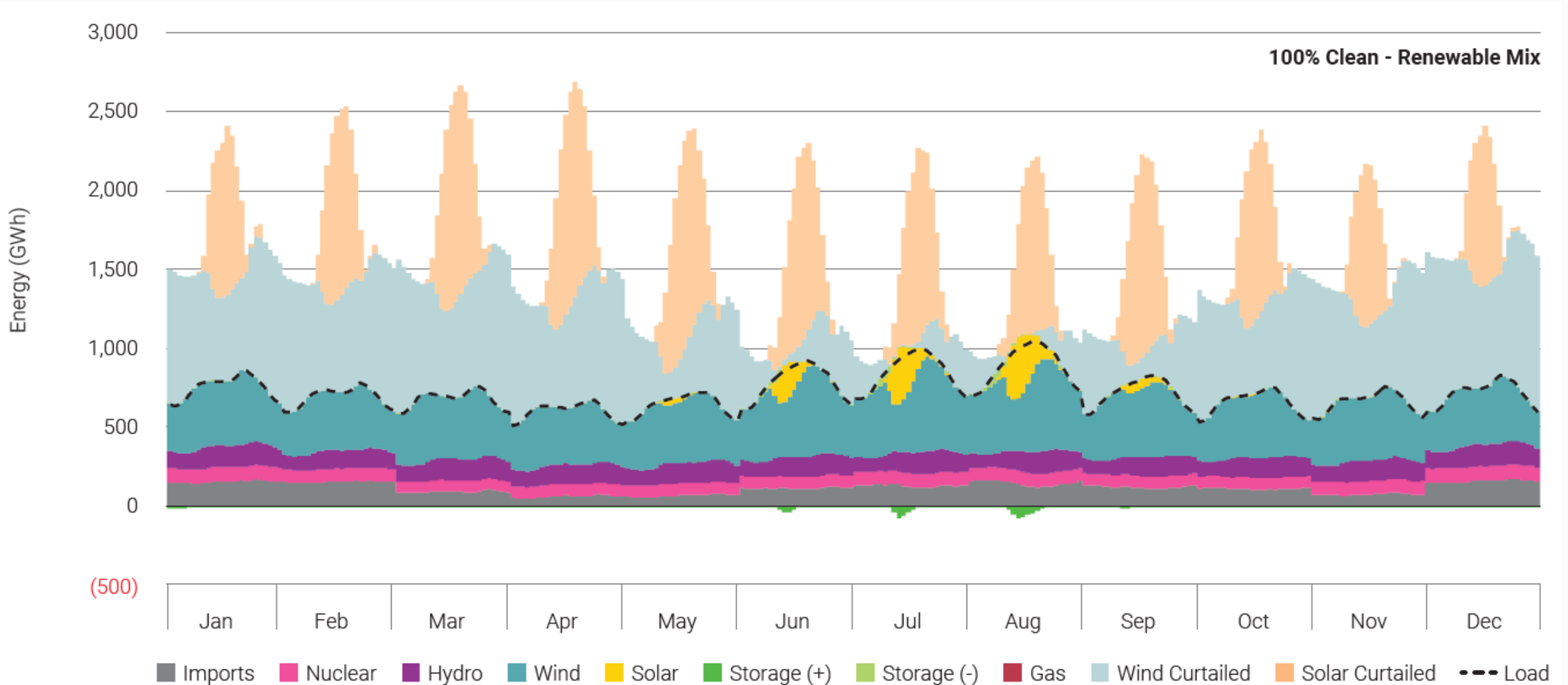
FIGURE | Optimal Installed Capacity by Type



Source: Enverus Intelligence

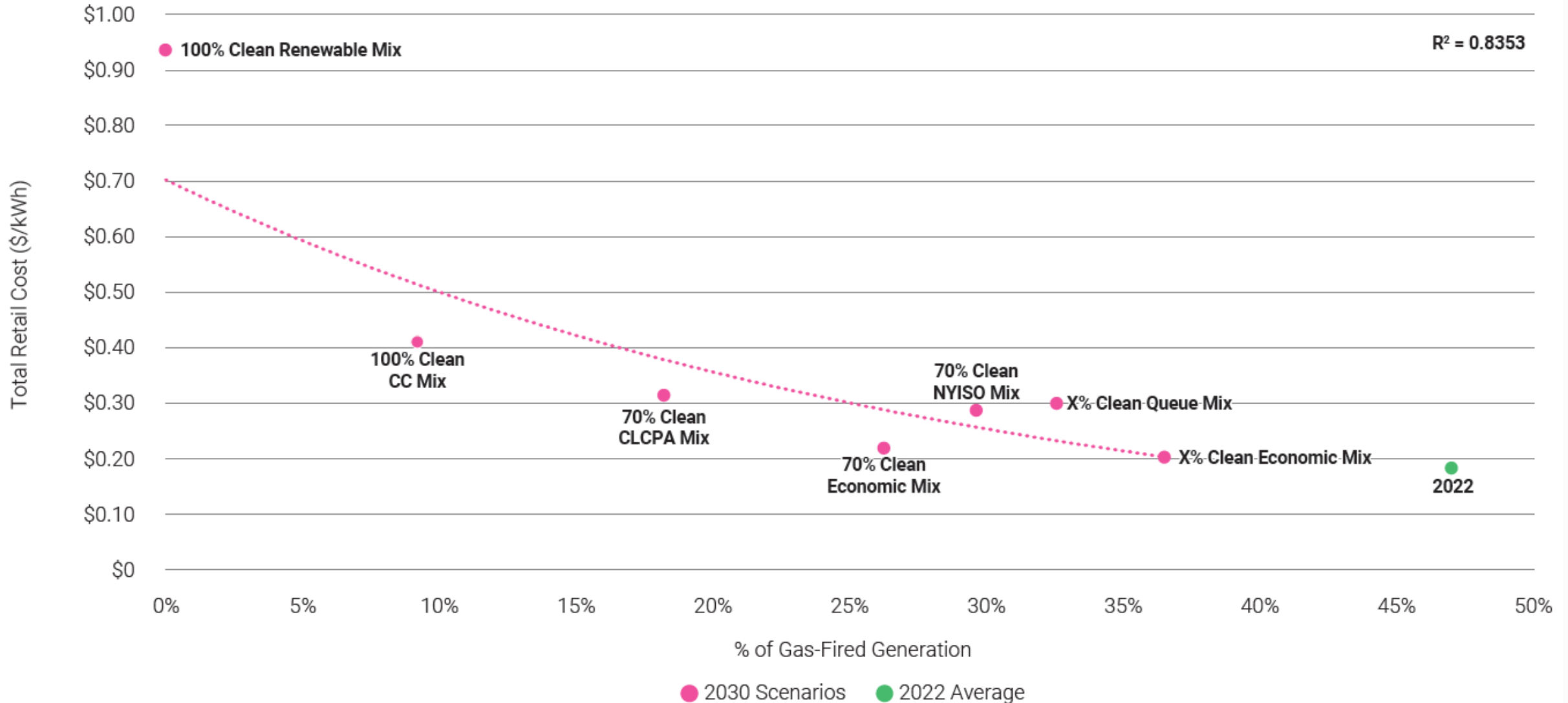
NYISO | 70X30 MANDATE – WHAT A WASTE

FIGURE | Average Generation Profile for 100% Carbon Free Renewable Energy



NYISO | 70X30 MANDATE – AT WHAT COST?

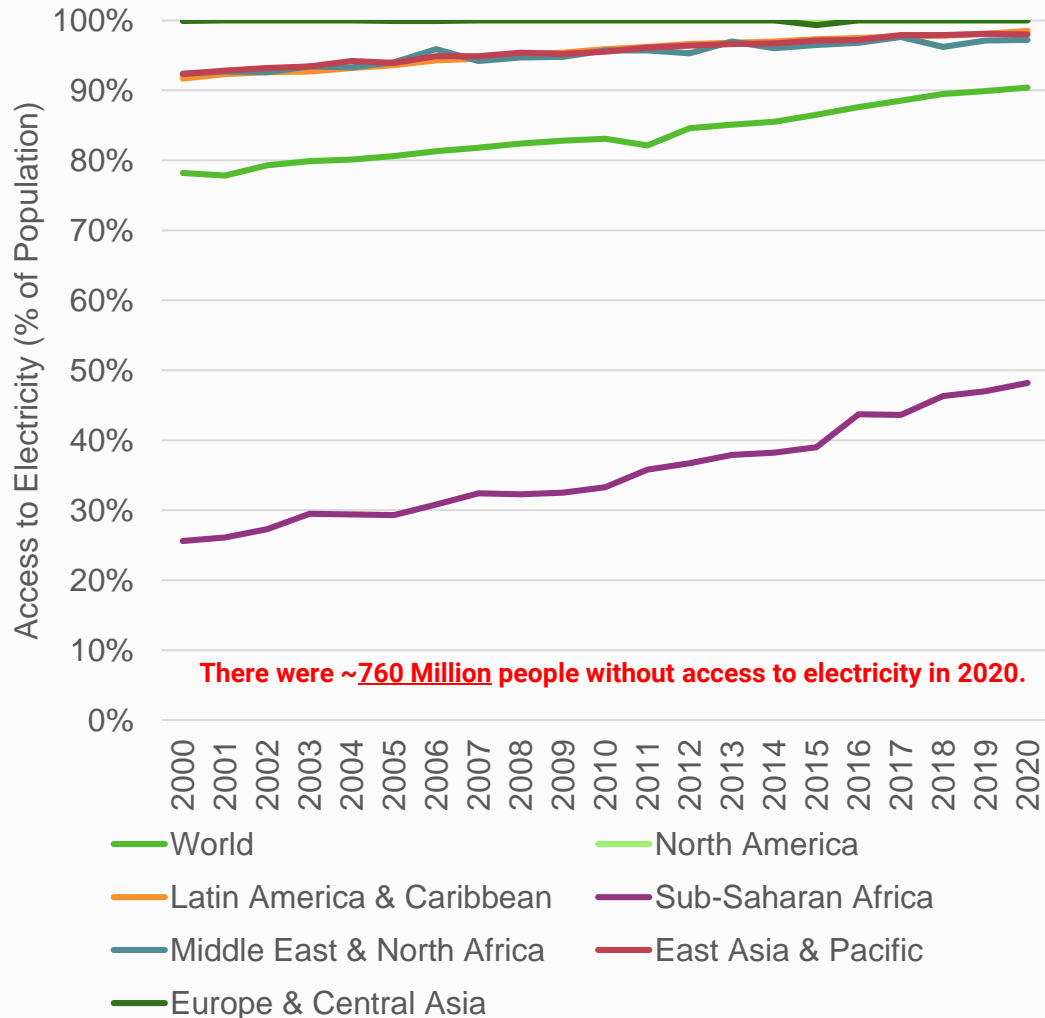
FIGURE | Cost of Flexibility in NY Power System



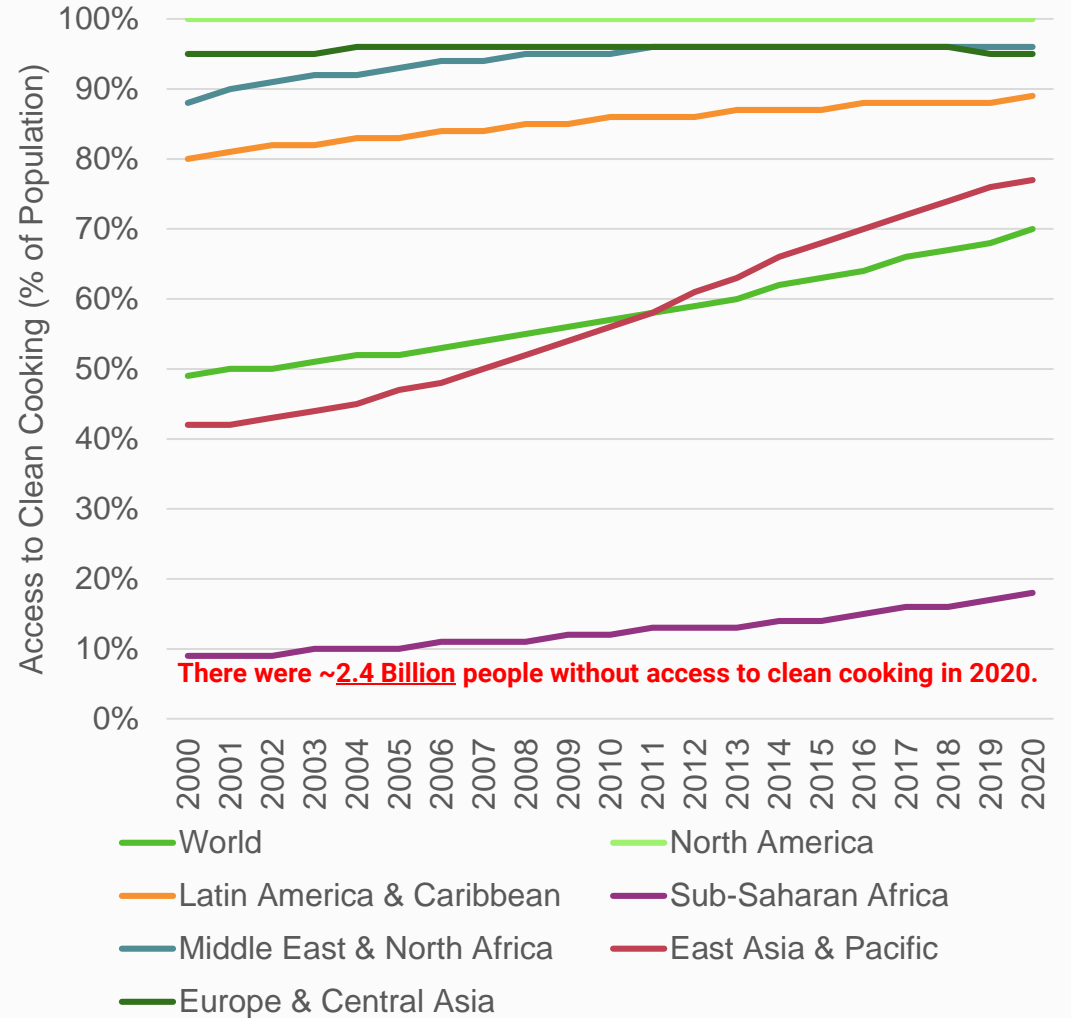
THE HEADWINDS: EQUAL ACCESS



Access to Electricity



Access to Clean Cooking



Source | World Bank

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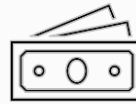


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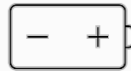
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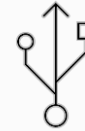
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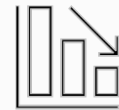
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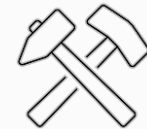
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Workforce ↑↓ | Changes in energy mix will impact workers and communities differently.



THANK YOU!



Bernadette Johnson

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