



HEC Hydrogen Sessions

Wind to Hydrogen

July 9, 2021

**Brad Bradshaw
President, Velerity
President, Hydrogen Energy Center
brad@velerity.com**

Hydrogen Energy Center

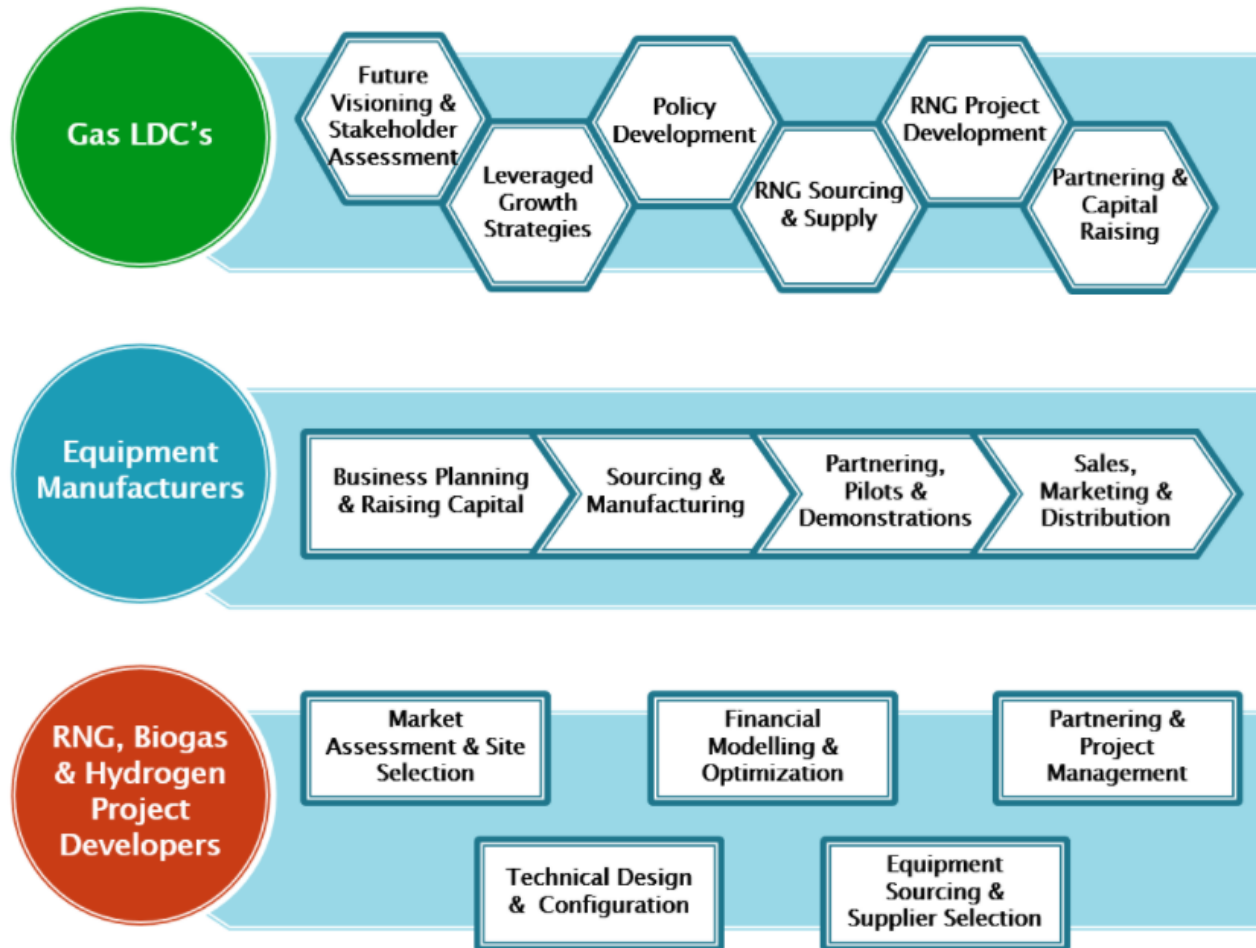
HEC is a nonprofit professional society focused on accelerating the hydrogen as an enabling solution for renewable energy

HEC provides public forums, conducts research and implements projects focused on accelerating the clean energy future

Consider supporting this important effort by becoming a member:

- Influence the course of renewable hydrogen energy technology and policy.
- Be a part of projects that build hydrogen solutions.
- Have full access to white papers, technical reports, and meeting minutes from our projects and from other organizations.
- Network with other members who are actively building a clean hydrogen future

Velerity – Helping organizations realize their ambitions and take advantage of market opportunities



Velerity – Illustrative Clients



What is driving the race for hydrogen?

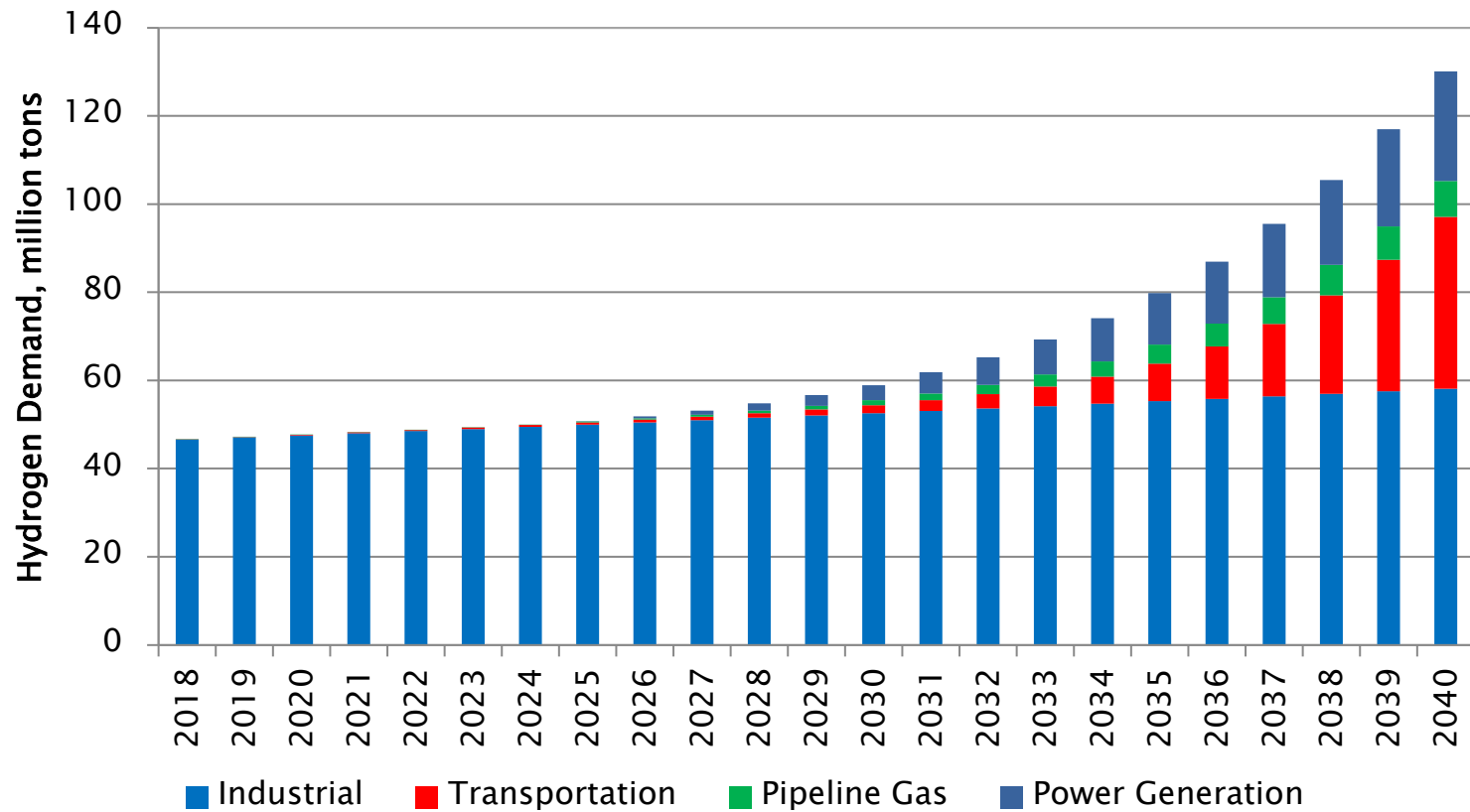
- ▶ Renewable energy overproduction
 - Curtailment
- ▶ Low-cost renewable energy
- ▶ Decarbonization

Illustrative hydrogen applications and examples

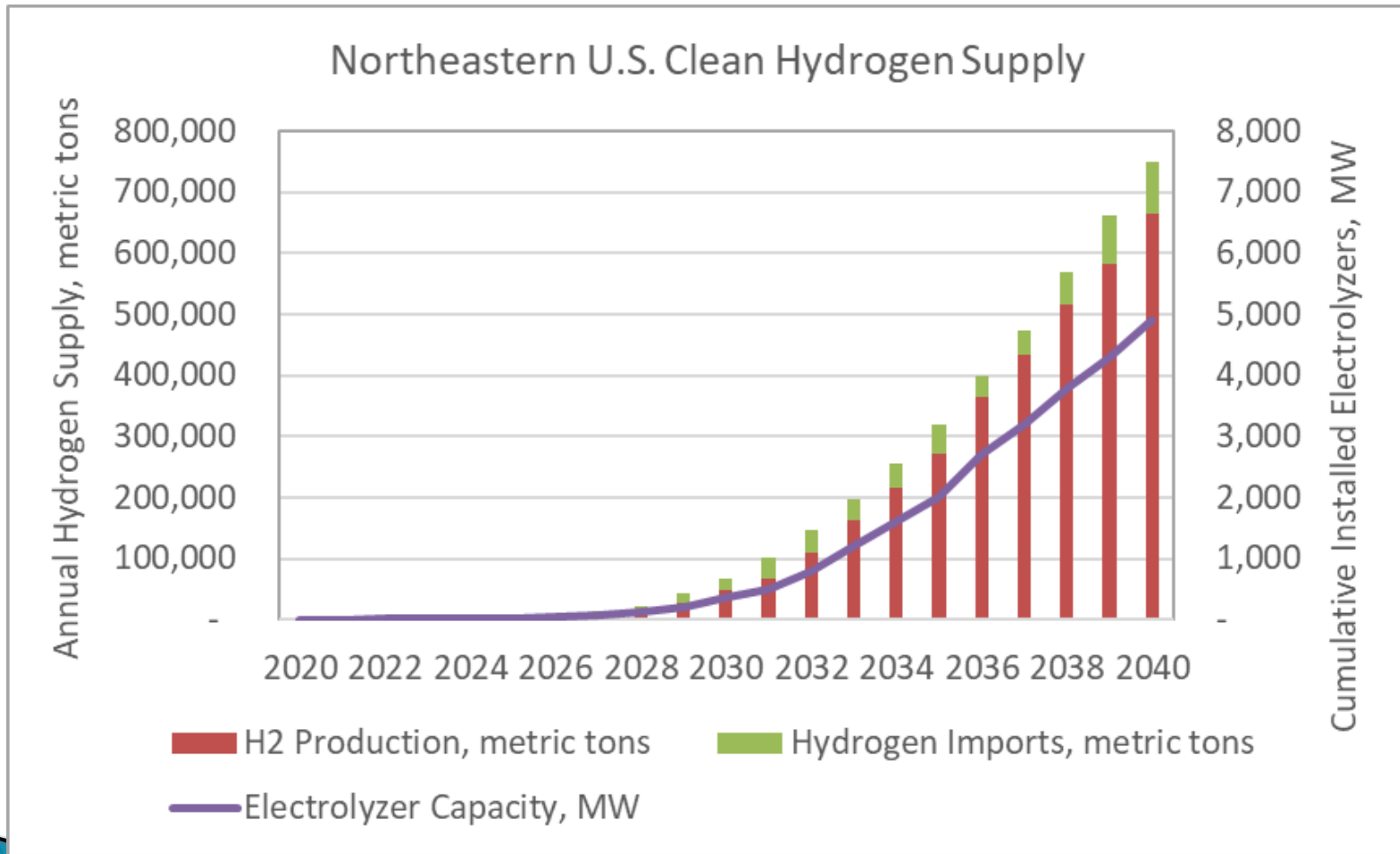
- ▶ **Heavy Vehicle Refueling** – Companies including Hyzon Motors, Nikola and Hyundai are developing heavy trucks that run on hydrogen, in addition to operating trains and ferries on hydrogen
- ▶ **Passenger Car Refueling** – Toyota has deployed approximately 10,000 Mirai's that run on hydrogen, as well other manufacturers pursuing fuel cell passenger cars including Hyundai, BMW, Hyperion XP-1 and Riversimple
- ▶ **Telecommunications Backup Power** – Approximately 30,000 cell towers around the world have fuel cell backup power systems, manufactured by companies such as Ballard Power, Hydrogenics, and Plug Power (Reli-ON)
- ▶ **Powering Forklift Trucks** – PlugPower and Nuvera, among others, have deployed approximately 40,000 fuel cell powered forklift systems
- ▶ **Reducing Chemical Plant Carbon Intensity** – Ammonia, methanol and ethylene production utilize significant amounts of grey hydrogen. Iberdrola is investing \$174 million to supply green hydrogen to Fertiberia to produce ammonia.
- ▶ **Hydrogen Blending for Reducing Natural Gas Carbon Intensity** – ATCO in Alberta, Canada is blending up to 5% hydrogen with natural gas for 5,000 residential customers;
- ▶ **Industrial Heat Applications** – Linde Gas and Ovako in Sweden are using hydrogen to provide heat for steel manufacturing

The global hydrogen market is positioned to grow significantly in coming decades

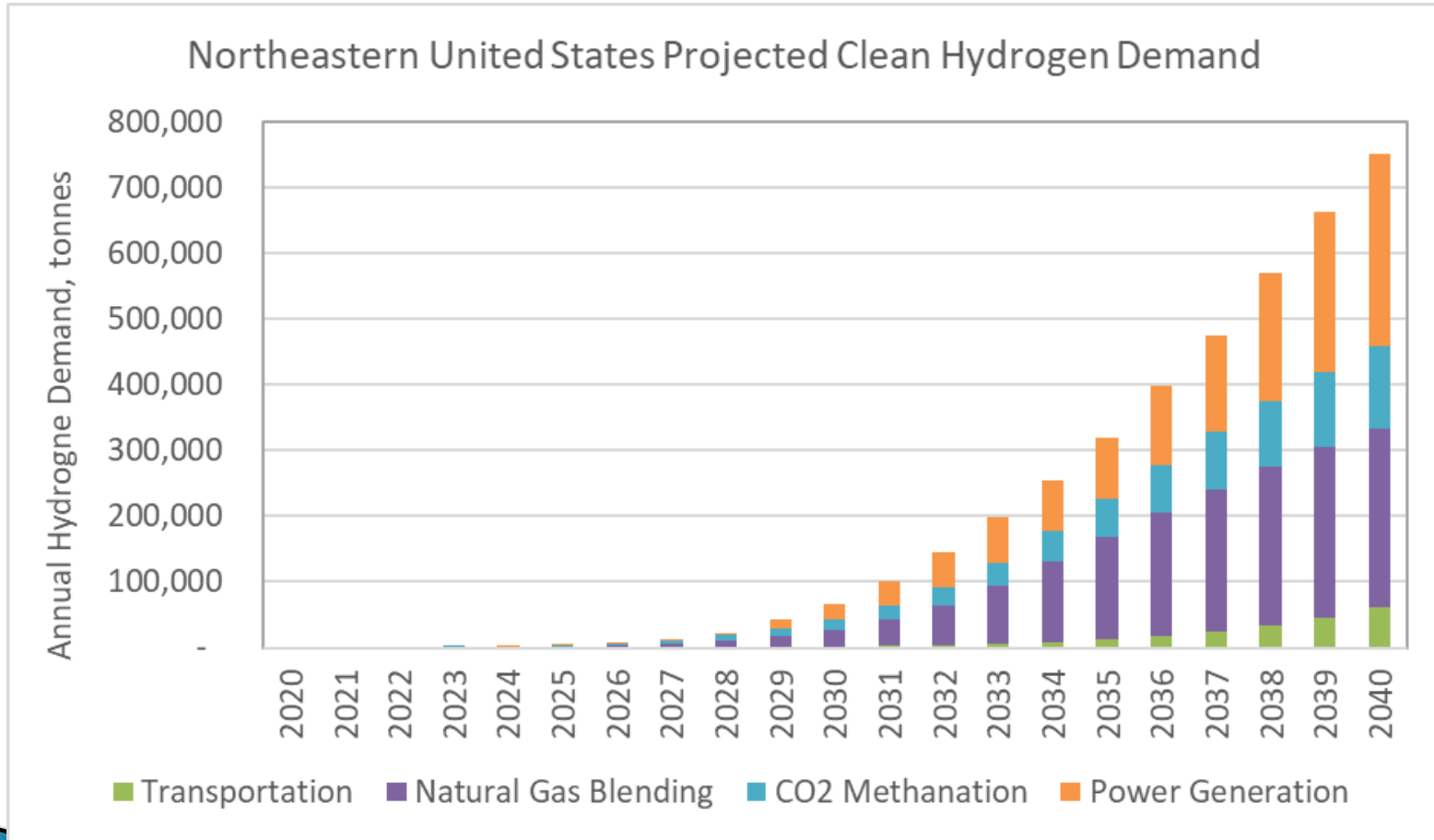
Global Hydrogen Market



Depending on market dynamics, the Northeastern U.S. hydrogen market may grow significantly by 2040, including 5 GW of electrolyzers



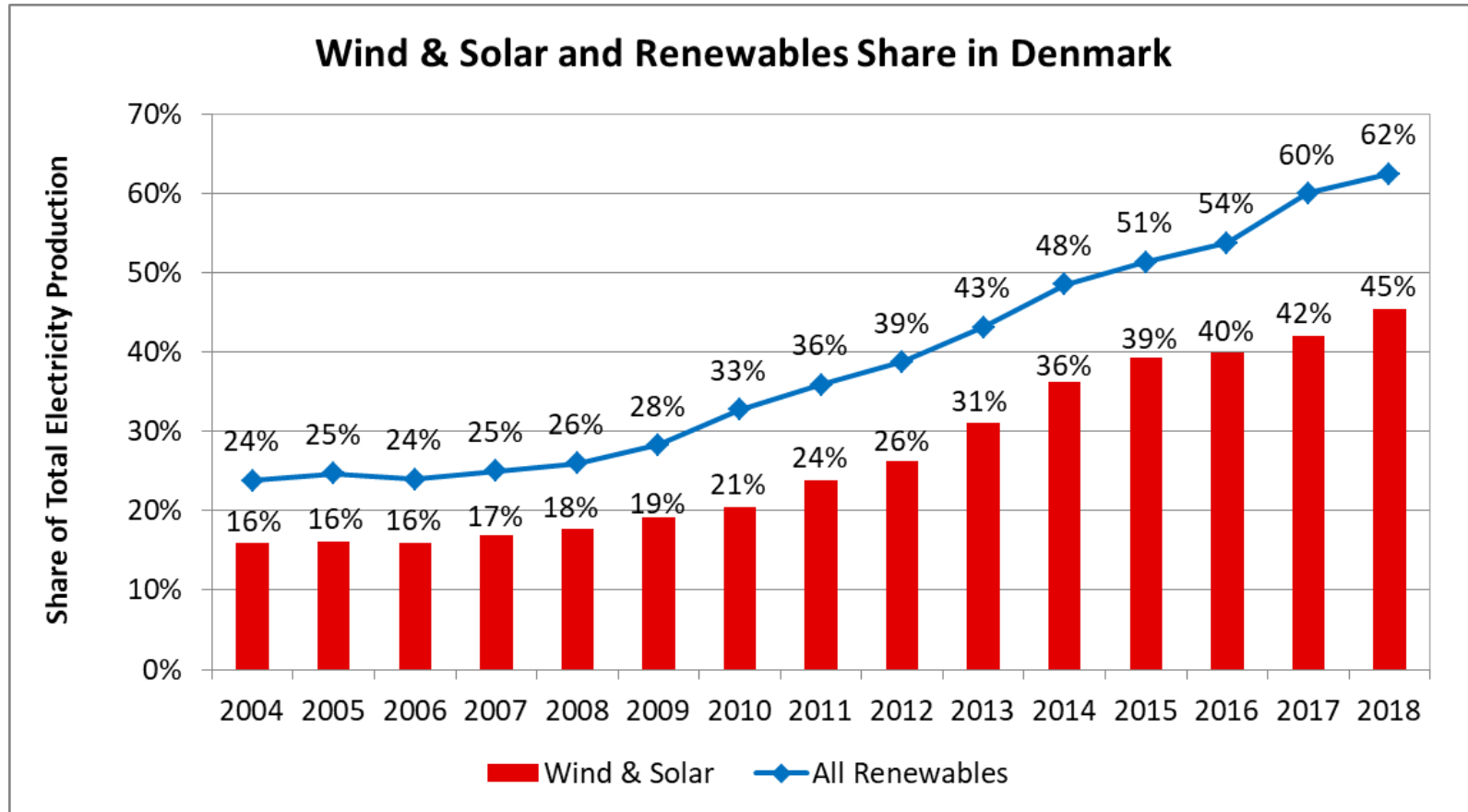
The demand for hydrogen in the Northeast will be driven primarily by pipeline blending and power generation



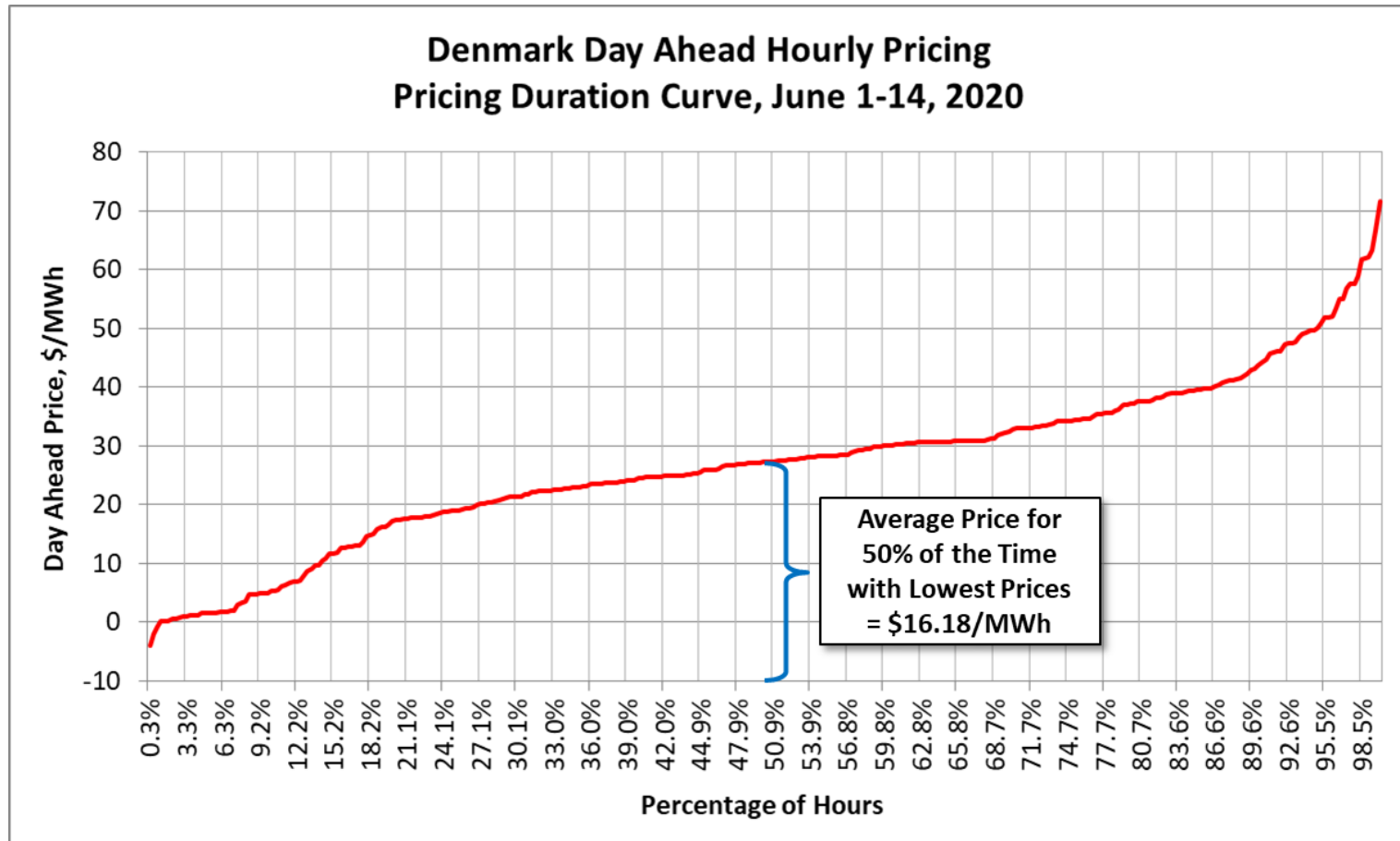
The key drivers behind the deployment of electrolyzers by wind project developers include:

- High and Increasing Market Penetration of Variable Renewable Energy;
- Increasing Curtailment;
- Increasing Proportion of Zero, Low and Negative Power Prices; and
- Increasing Support for Green Hydrogen to Displace Natural Gas.

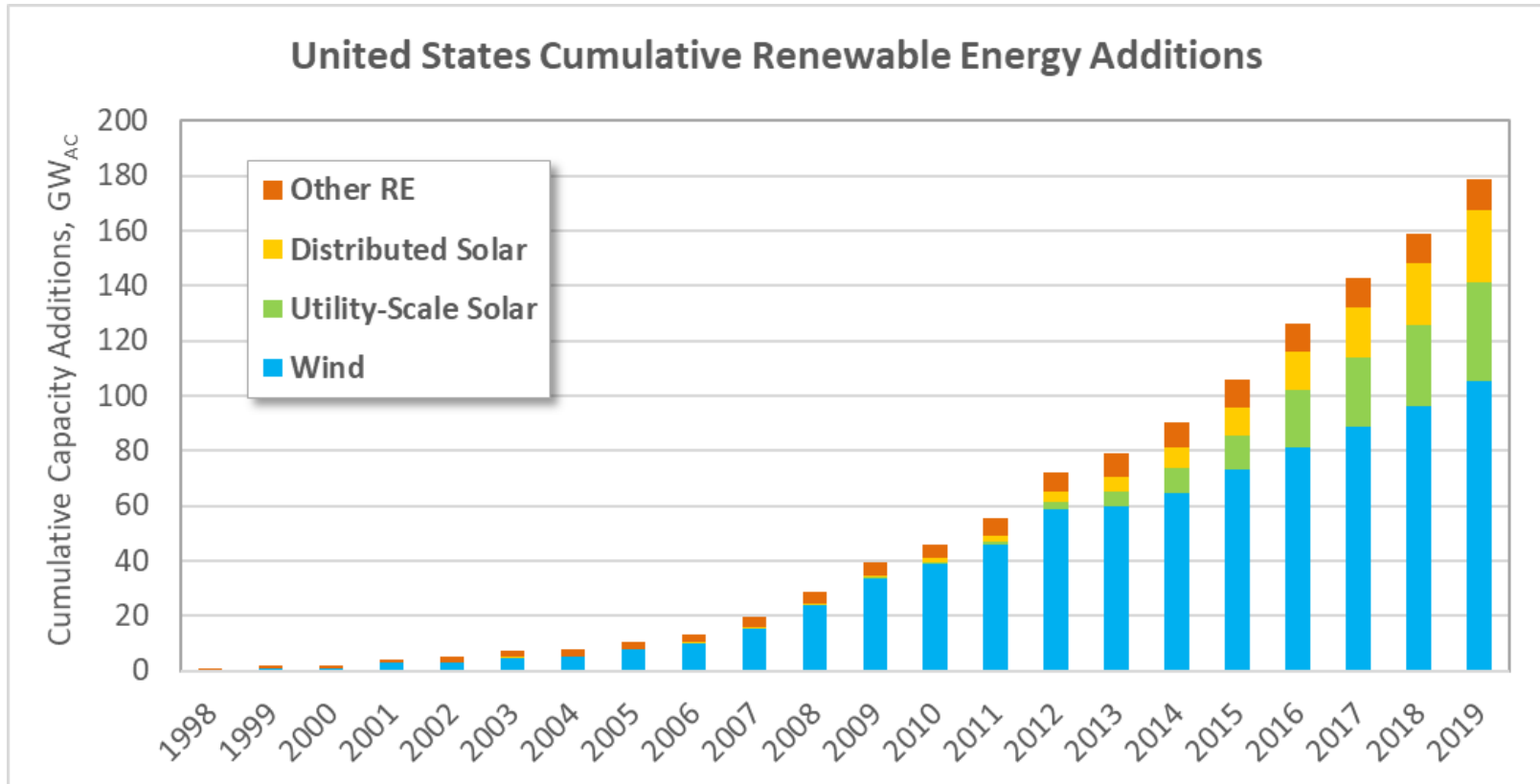
Denmark provides a case study in high variable renewable energy penetration



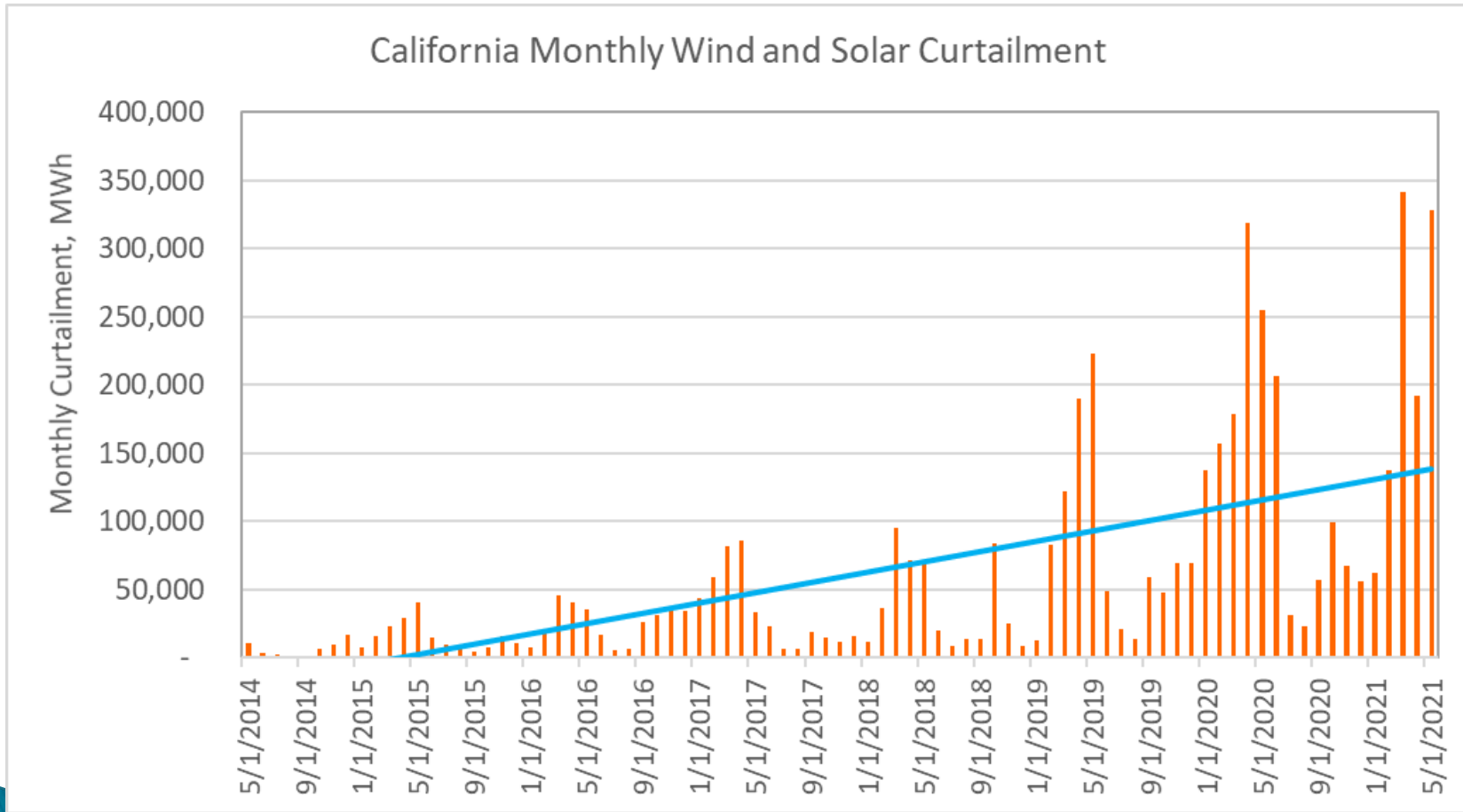
The hourly day ahead market shows long time regimes of low prices



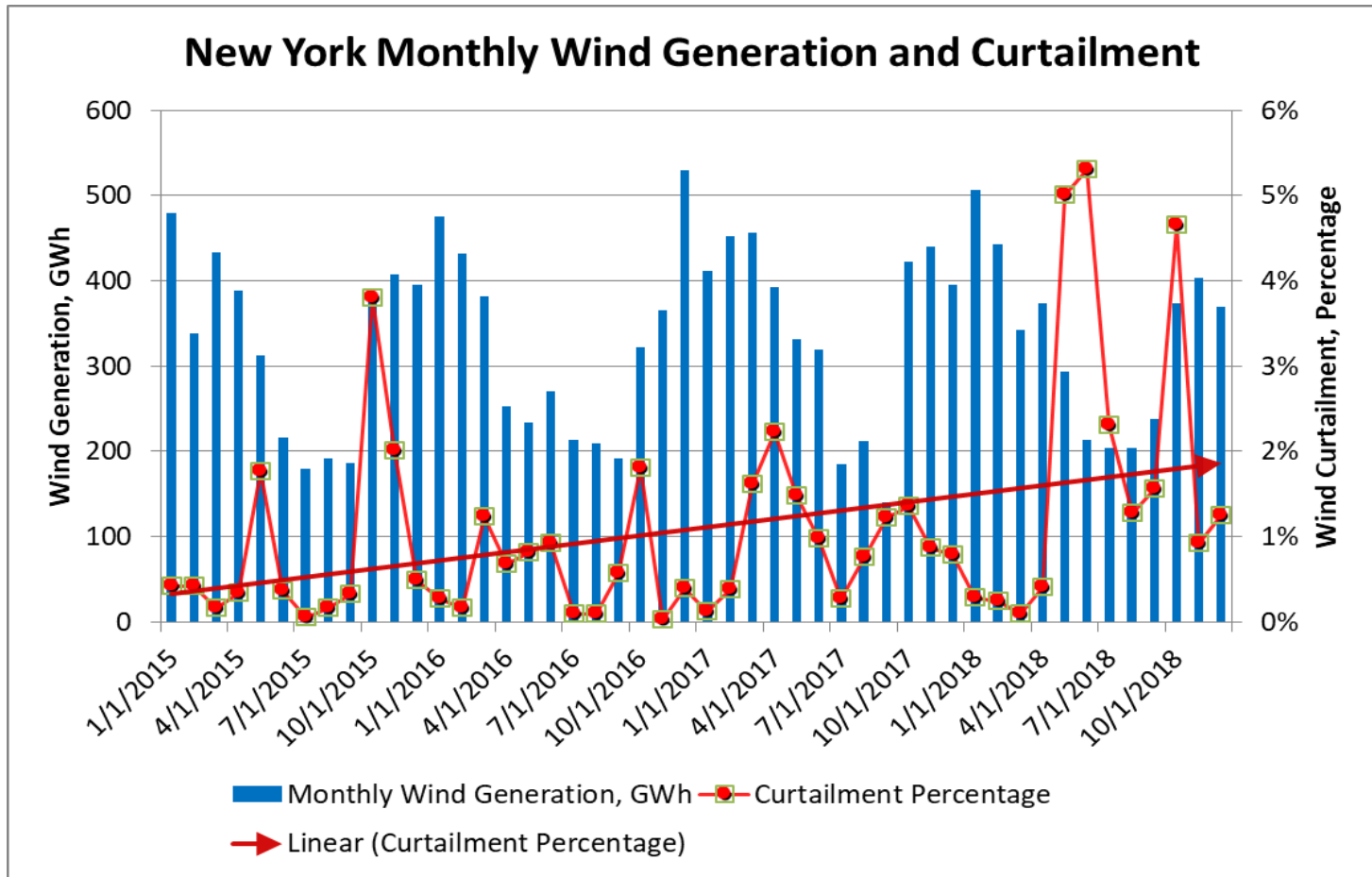
Variable renewable energy continues to climb, with calls for accelerating deployment



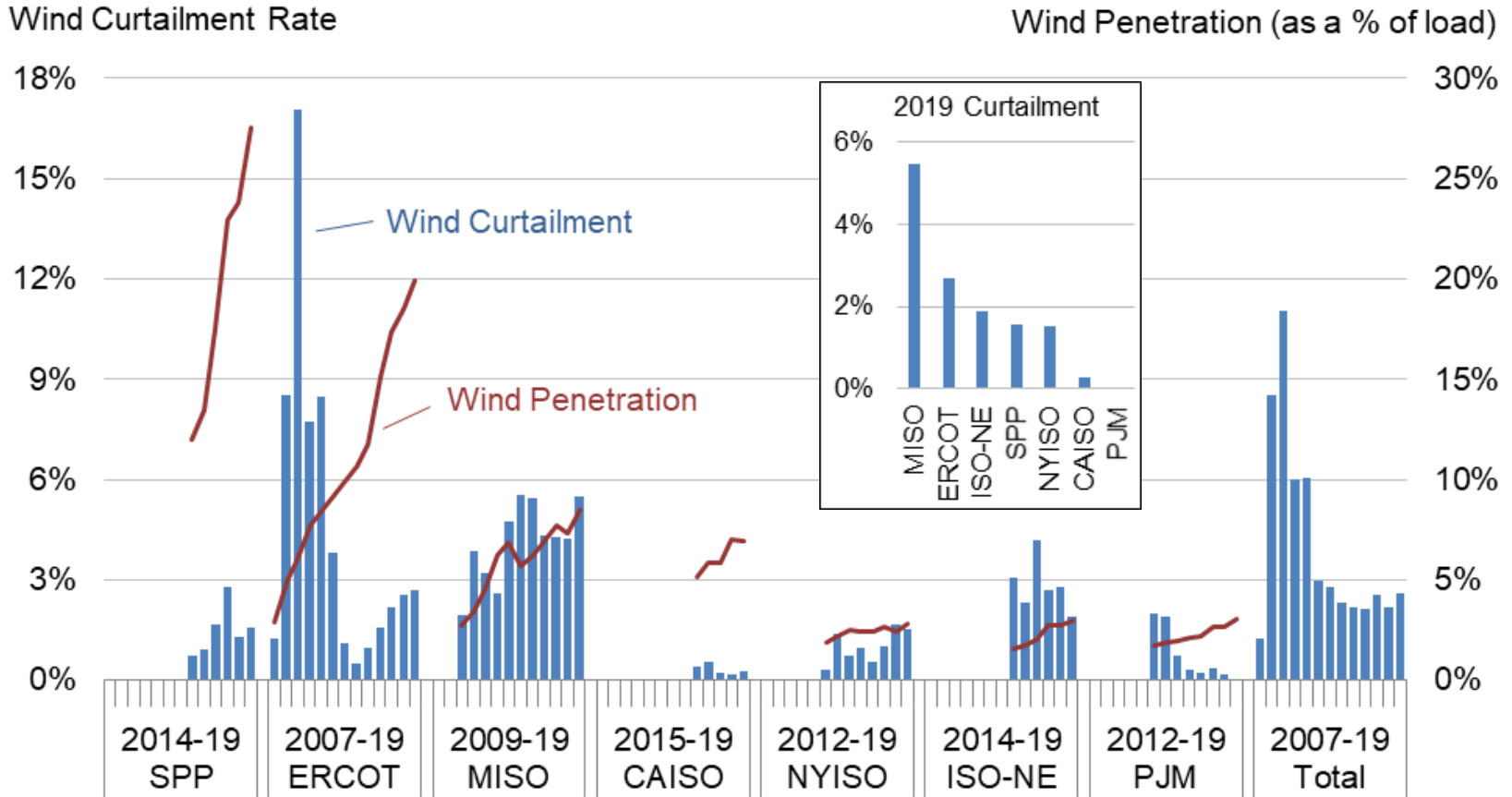
Curtailment is becoming significant in California, growing over 50% per year for the past eight years, reaching 1.6 million MWh in 2021



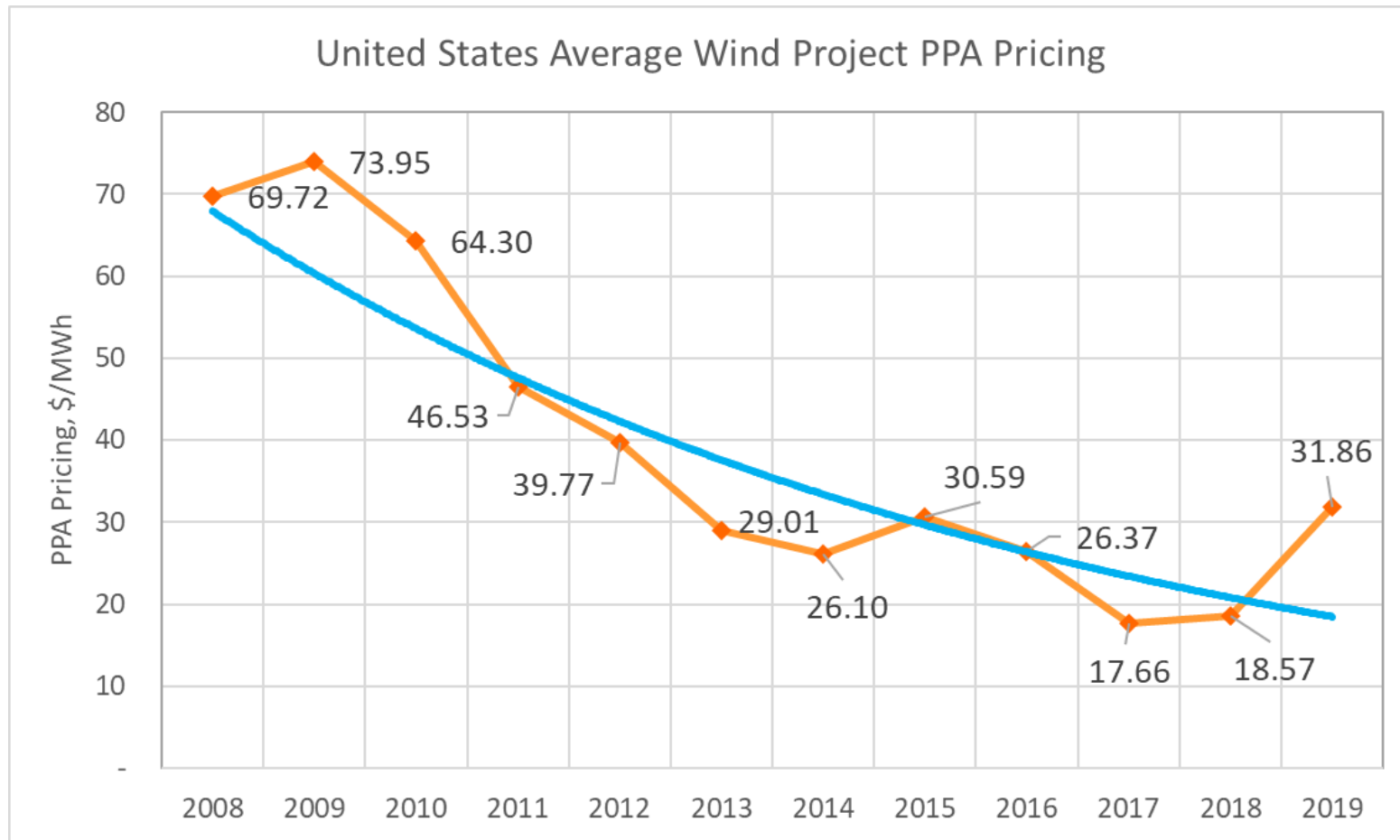
In New York, approximately 2% of all wind power was curtailed in 2018, a percentage which is growing



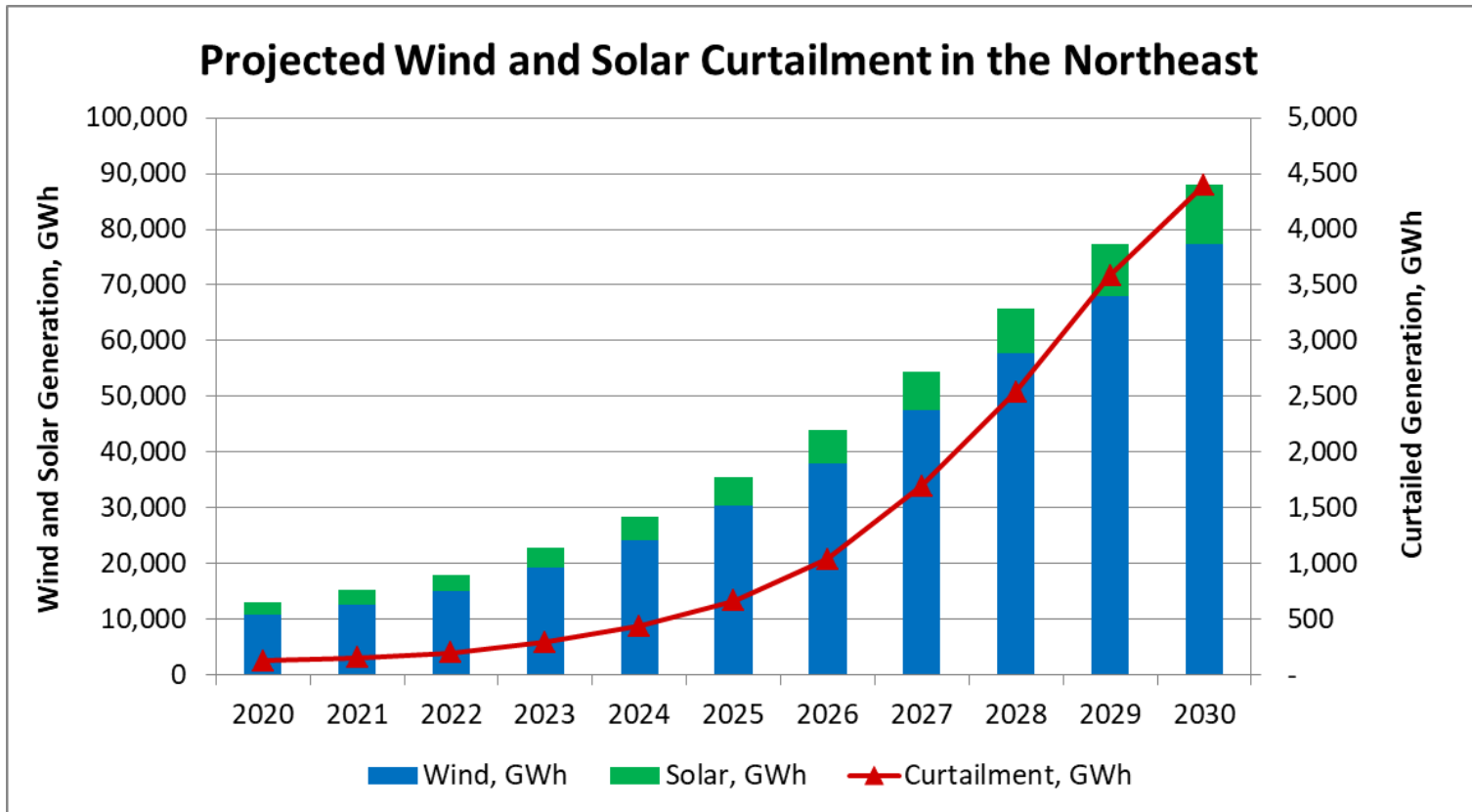
Nationally, wind curtailment ranges from near 0% to over 5% of all wind power generated



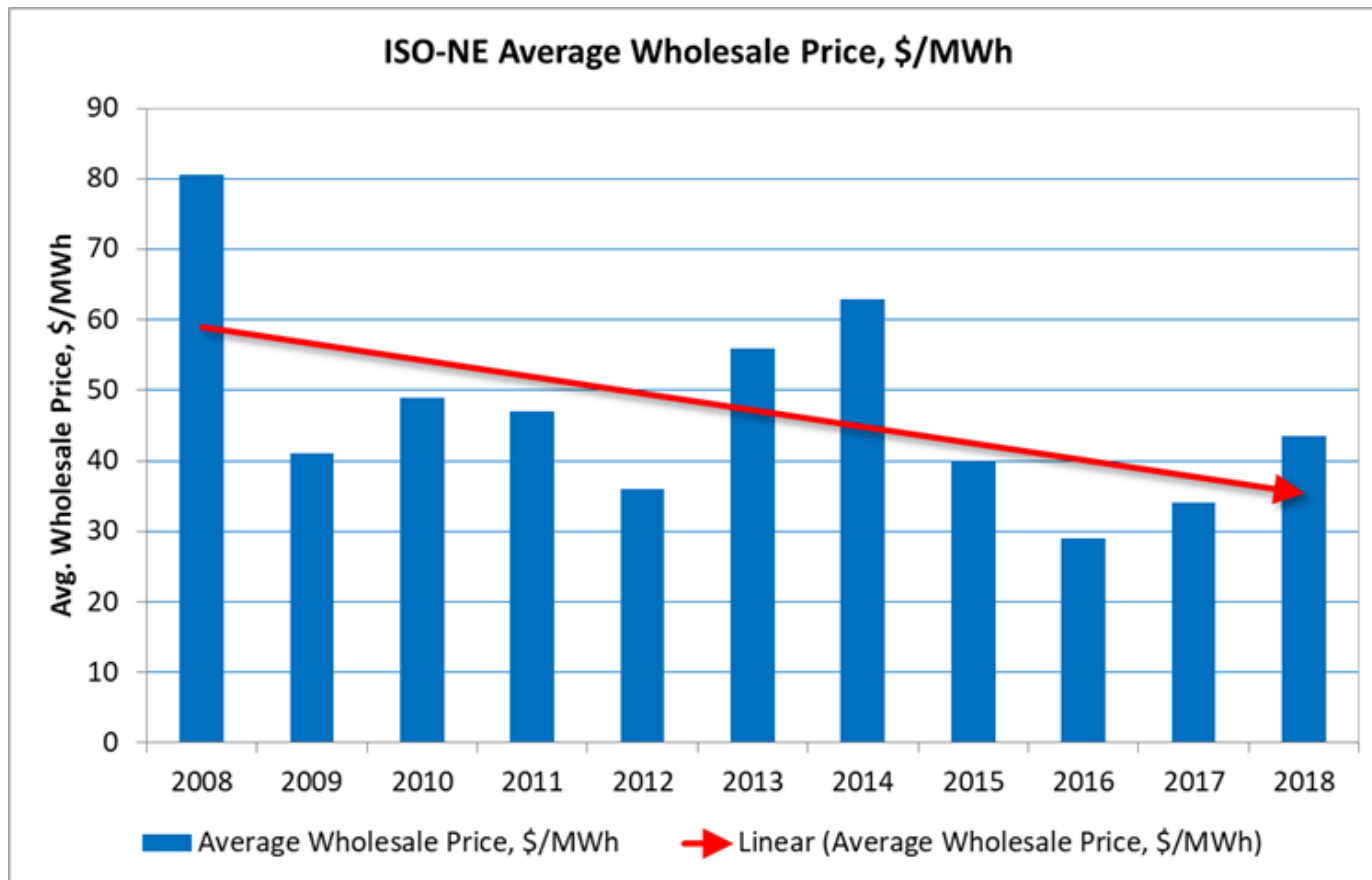
Wind PPA prices continue to fall in the United States, reaching an average of about 2.5 cents per kWh in the past few years



Curtailment in the Northeastern United States is expected to grow considerably, especially with the advent of off-shore wind development



Wholesale prices are expected to continue to fall as well, making hydrogen generation economics more favorable



Wind to hydrogen projects – slide 1

Project	Electrolyzer Capacity	Energy Source	Use	Quantity	Partners
HYPOR Oostende	300 MW on-shore electrolyzer	4 GW off-shore wind	Pipeline injection	Utilize curtailed power and intermittent oversupply	Port of Oostend DEME Concessions PMV
Orsted Hornsea Two	100 MW onshore electrolyzer	1.4 GW off-shore wind	Philips 66 oil refinery	6% of electricity output	IITM Power Orsted Philips 66
Dolphyn	2 MW off-shore 10 MW off-shore 4 GW off-shore	4 GW floating off-shore wind	Heat 1.5 million residences	100% output	
Lhyfe	~720 kW on-shore electrolyzer ~6.5 MW	19.5 MW off-shore wind	Fuel for buses and garbage trucks in La Roche-sur-Yon		
NortH2	2030: 3-4 GW on-shore electrolyzers 2040: 10 GW on-shore electrolyzers	3-4 GW off-shore wind 10 GW off-shore wind	Pipeline injection	100% output	Shell Gasunie Groningen Seaports

Wind to hydrogen projects – slide 2

Project	Electrolyzer Capacity	Energy Source	Use	Quantity	Partners
Green Fuels for Denmark	250 MW on-shore electrolyzer	250 MW off-shore wind	Hydrogen for transport	100% output	Copenhagen Airports Scandinavian Airlines A.P. Moller Maersk DSV Panalpina DFDS
AquaVentus	2025: 30 MW 2030: 5 GW	Off-shore wind	Pipeline injection	100% output	RWE Vattenfall Shell E.ON Siemens
Southwest Ireland	50 MW	8 GW Off-shore wind	Hydrogen for industry	Utilize curtailed power and intermittent oversupply	EI-H2 Zenith Energy
HNH – Southern Chile	1.4 GW	1.8 – 2 GW on-shore wind	Hydrogen for ammonia production and export	100% output	Austria Energy Okowind EE

Wind to hydrogen projects – slide 3

Project	Electrolyzer Capacity	Energy Source	Use	Quantity	Partners
SeaH2Land	1 GW	2 GW off-shore wind	Industrial use including steel production, ammonia, ethylene and transport fuel	Large proportion	Orsted ArcelorMittal Yara Dow Benelux Zeeland Refinery
CrossWind – Hollandse Kust	200 MW	759 MW off-shore wind	Shell refinery	Large proportion	Shell Eneco
Element One – Lower Saxony	100 MW	Off-shore wind in the North Sea	Pipeline injection	Unknown	TenneT Gasunie Deutschland Thyssengas
Atlantic Shores – NJ	10 MW	1,509.6 MW off-shore wind	Pipeline injection	Small proportion	Shell EDF South Jersey Industries

Illustrative wind to hydrogen economics

