Burning Questions:
Hydrogen's role in & impacts on the Northeast electric power sector

Kai Van Horn, National Grid USA
Alex Klein, National Grid USA
Mahraz Amini, National Grid USA

ESIG Fall Technical Workshop
October 24-27, 2022
Minneapolis, MN

nationalgrid

PUBLIC

Our team leverages detailed modeling to provide insight across a range of scenarios / pathways for decarbonizing the northeast

Capacity Expansion Modeling

Used for developing high-level views on multiple scenarios to 2050

- Simulates long-term capacity and energy mix relative to policy & reliability needs
- Uses reserve margins consistent with 1-in-10 loss of load planning standard
- Co-optimizes Tx & supply build

output → input

Production Cost Modeling

When we need detailed views on Tx flows, hourly operations and prices

- Simulates detailed hourly dispatch for focus years
- Nodal / unit-level detail
- Full representation of transmission system with enforcement of key constraints

Scenarios / Questions of Interest

- Pace & scale of policy achievement
- Extent of electrification
- Trajectory of technology costs
- Role of renewable natural gas & H2 in a decarbonized power sector
- Impact of constraints on transmission build on supply needed to meet policy
- Impact of specific policies (e.g., IRA)
- Value of transmission for integrating OSW

Today I will be presenting the results of one of many net zero scenarios we have run. These results are not a forecast of future outcomes, but rather intended to shed light on the potential value of H_2 in a net zero future.

Note: Enelytix is our primary modeling platform for system expansion and operations simulations. Other modeling and analysis conducted with purpose-built models.

Presentation overview: burning questions

Questions	Findings
1. Why pursue H2 in the US northeast?	Building a hydrogen economy is best suited to regions with high energy consumption density, access to clean energy, and a strong commitment to net-zero, making the US northeast an ideal location for a green hydrogen hub.
2. What is the scale of the need for H2-fired power generation in the US northeast?	Meeting system needs in a net zero world could require replacing 10%-55% of existing fossil generation with H2 generation by 2050, influenced by the pace of transmission build-out, degree of electrification, the cost of H2, and the availability of lithium-ion battery storage.
3. What are the electric sector impacts of scaling green H2 in the US northeast?	Meeting projected levels of H2 demand with in-region green H2 production in 2050 could require electrolysis equivalent to 13%-42% of demand, and an 8%-40% increase in renewables builds in the region.

1

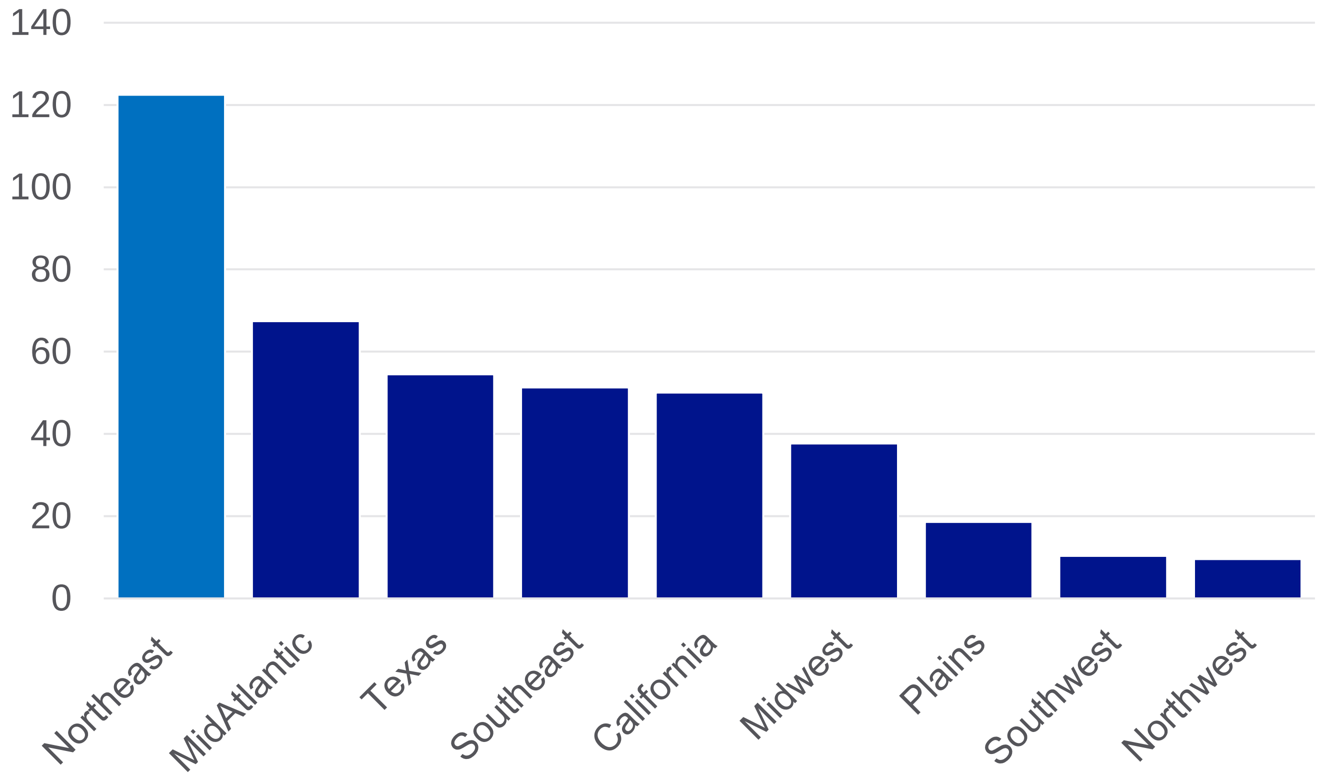
Why pursue H2 in the US northeast?

nationalgrid

The Northeast has high energy consumption density, which makes using existing infrastructure critical to decarbonization

Highest energy consumption density in the US

Billion Btu of total energy consumed per sq mile



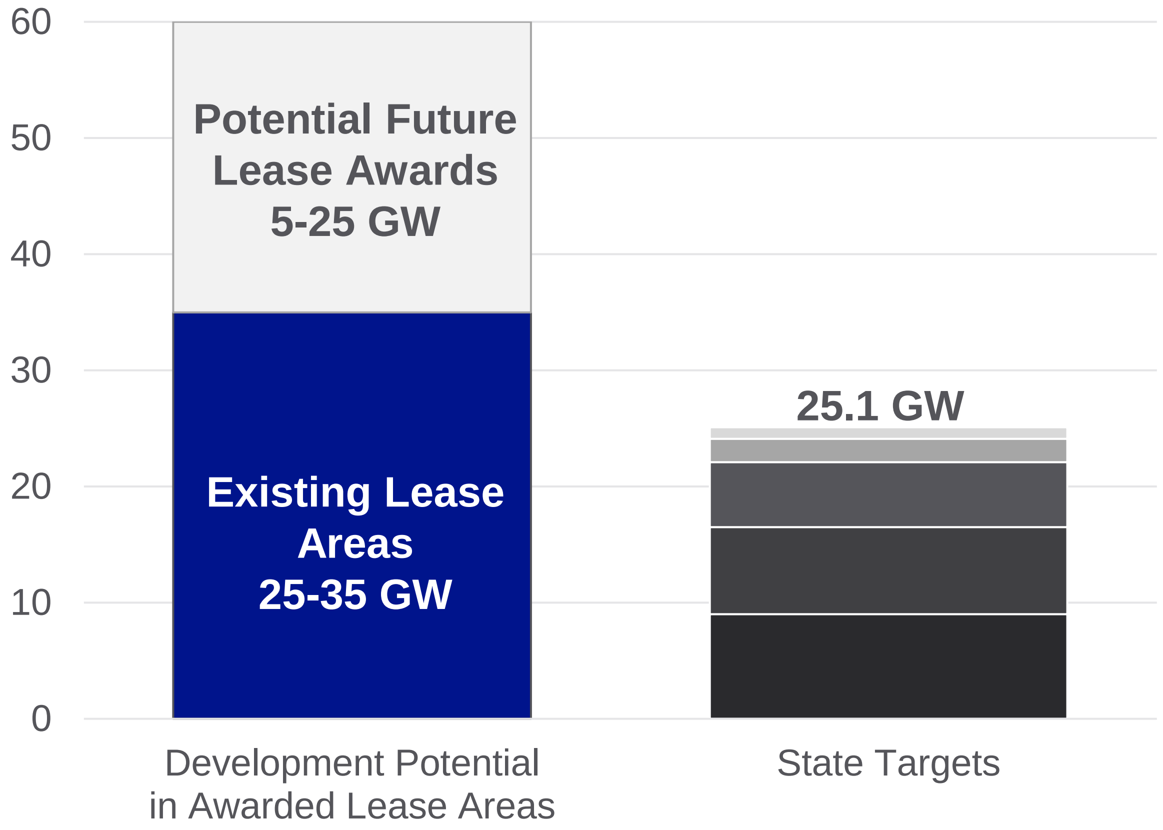
- New Jersey (#1), Massachusetts (#2), Rhode Island (#3), Connecticut (#5) and New York (#10) are among the top 10 most energy dense states in the country.
- The need to move substantial amounts of energy in a small highly populated space make it important to leverage existing infrastructure where possible.
- There is a lack of available land to build out the infrastructure needed to fully electrify the Northeast economy without significantly impacting communities.

Source: US DOE SEDS data

Northeast includes the states part of the Northeast Hydrogen Hub bid: NY, MA, NJ, CT, RI

Northeast OSW resource potential presents an opportunity to produce green H2 to displace fuel imports

Available lease capacity exceeds state goals in the Northeast
GW of offshore wind potential within awarded offshore lease areas vs state targets



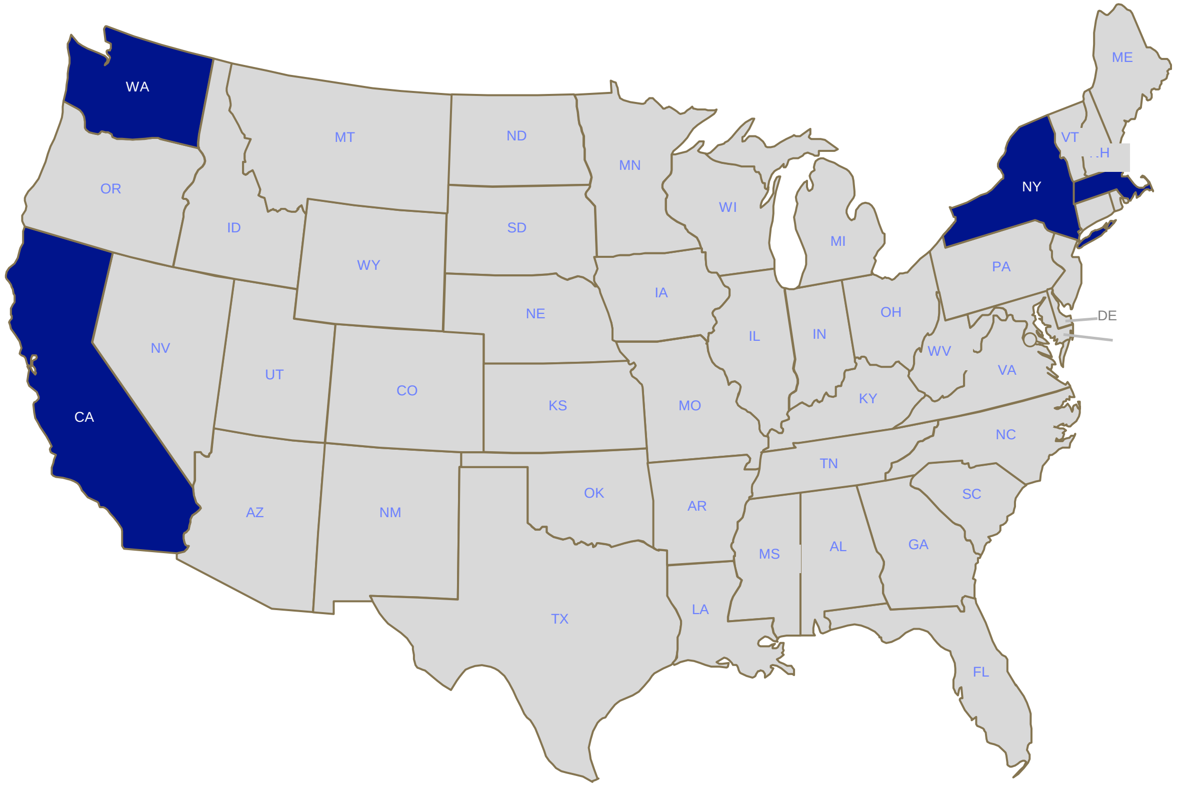
- There is more than enough capacity within existing offshore wind lease areas to exceed state 2035 procurement targets along the NE Atlantic coast
- Future lease auctions could unlock a further 5-25 GW of capacity in the central Atlantic and Gulf of Maine. Several states also expected to increase their offshore wind targets.
- Capacity to site OSW exceeds the ability of the electric sector to absorb it all. Green H2 can result in fully utilizing OSW technical potential.

Source: US Market Fundamentals analysis.

States in the northeast are leading the way in terms of commitment to a Net Zero Future

Commitment to a Net Zero Economy

States that have passed economy-wide net zero legislation



- New York and Massachusetts are leading the way on economy-wide net zero legislation in the US, making low carbon fuels essential for reliability and resilience.
- **Our outlook** highlights that long-duration storage will be critical to achieving the region's economy-wide goals & that H2 is among the technologies best positioned to fill that role.

Note: Other states have passed legislation to get to 100% clean energy in just the electricity sector

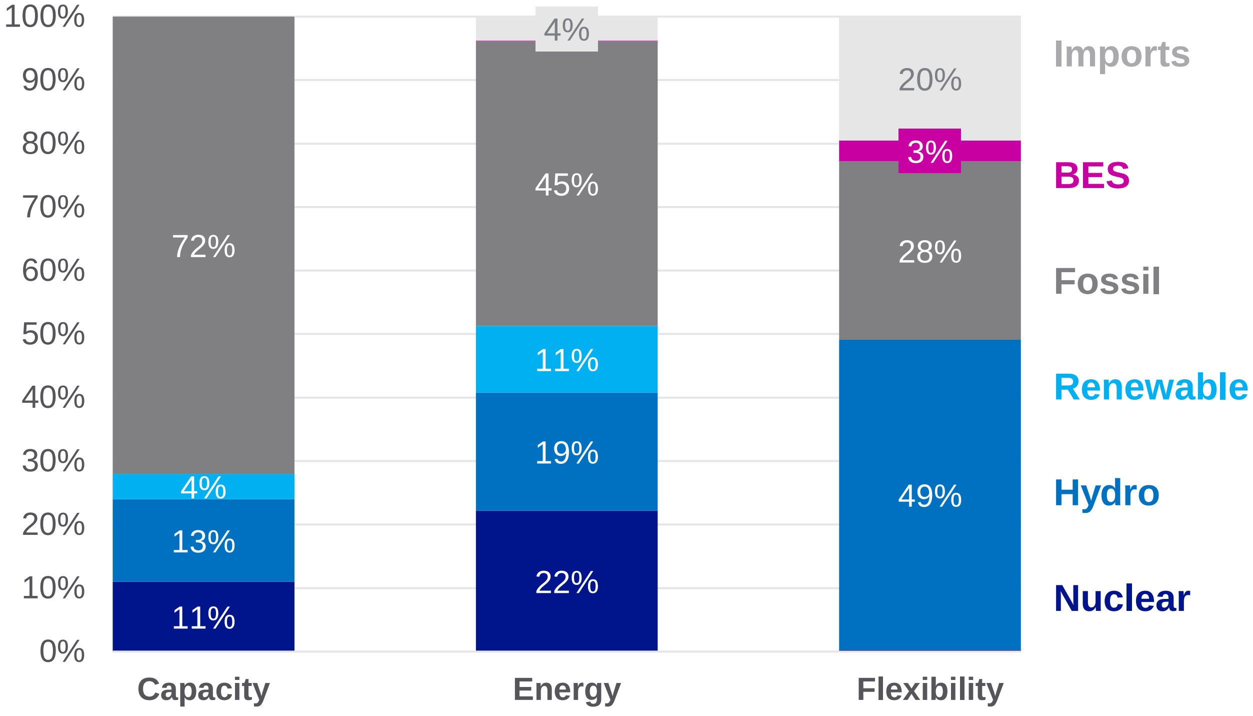
2

What is the scale of need for H2-fired power generation in the US northeast?

Today, fossil resources play a critical role in providing the services needed to operate the power system reliably

Sources of needed power system services in 2020

% of service by source, 2020 for the US Northeast



Needed system services:

- **Capacity**: availability to generate energy in times of high need (e.g., due to high load, or outages)
- **Energy**: to meet demand throughout the year
- **Flexibility**: balancing variability in supply and demand and responding to uncertainty (e.g., operating reserves)
- **Other A/S**: voltage support, black start (excluded from this analysis)

Today the fossil fleet provides:

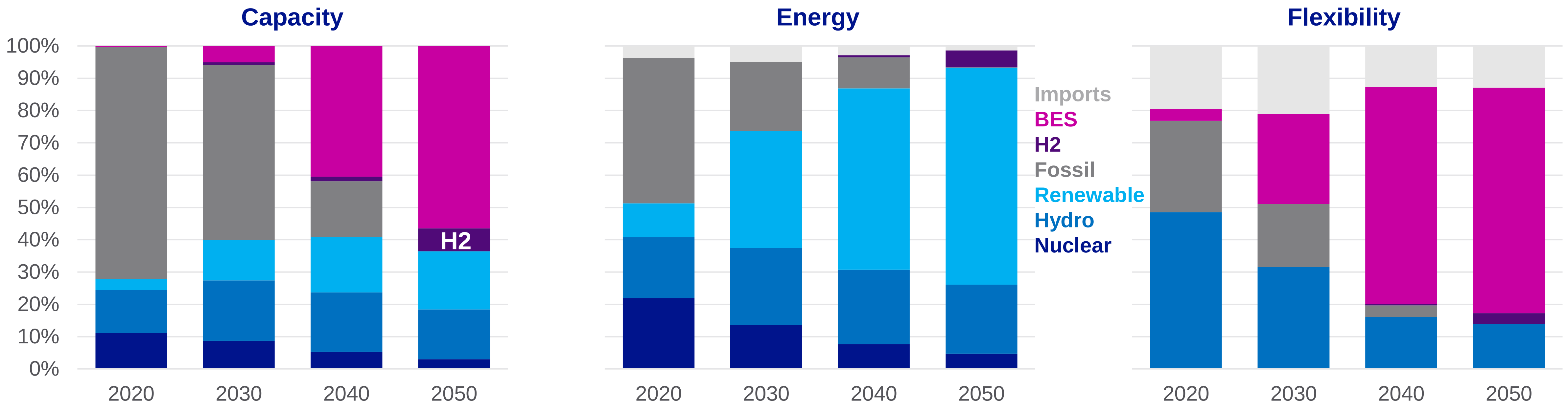
- >2/3 of capacity
- ~1/2 of total energy
- ~1/4 of flexibility

Notes: Capacity is calculated as the percentage of resource contributions to total capacity needed to meet or exceed capacity requirement, adjusted for capacity value (i.e., ELCC). Energy is calculated as the percentage of resource contributions to meeting annual demand. Flexibility is calculated is the percentage of resource contribution to meeting total ramping needs throughout the year (up ramps and down ramps).

H2 contributes to all future service needs, but battery storage & renewables likely to be majority providers

Our outlook for Northeast power system service needs & sources 2020 to 2050

% contribution to service needs by resource type



- As the lowest cost option, batteries contribute the lion's share of capacity
- H2-fired gen provides for ~10% of the need by 2050

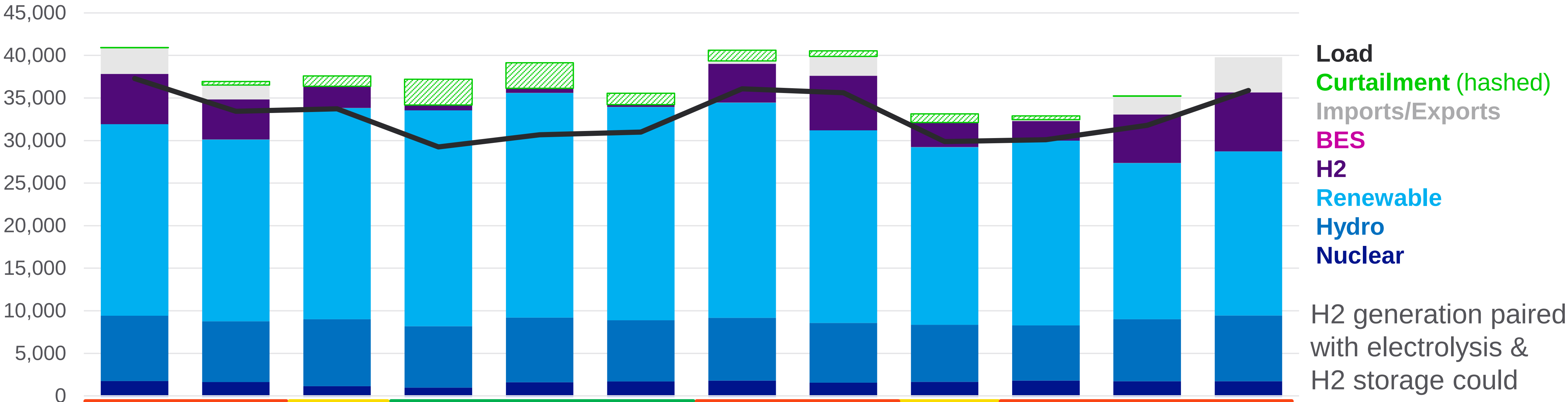
- Non-hydro renewables deliver >2/3 of total energy by 2050, and 80% of the incremental needs from today
- H2 contributes ~12% of the energy needed in 2050, mainly during key periods

- Batteries become the dominant source of flexibility looking to 2050
- H2 contributes <5% of flexibility needs, but this could grow if H2 costs fall, or battery builds are lower (e.g., due to higher costs).

Source: Market Fundamental simulations & analysis

Renewable supply / load mismatches within months & across seasons highlight important opportunity for H2 or other LDS

Northeast monthly total generation in 2050
GWh of generation by type



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
% Renew.*	92%	95%	100%	110%	111%	106%	99%	94%	100%	99%	93%	88%
% H2	8%	7%	4%	1%	1%	0%	6%	9%	5%	4%	9%	10%

seasonal deficit of clean energy

seasonal surplus of clean energy

Intra-month deficit of clean energy

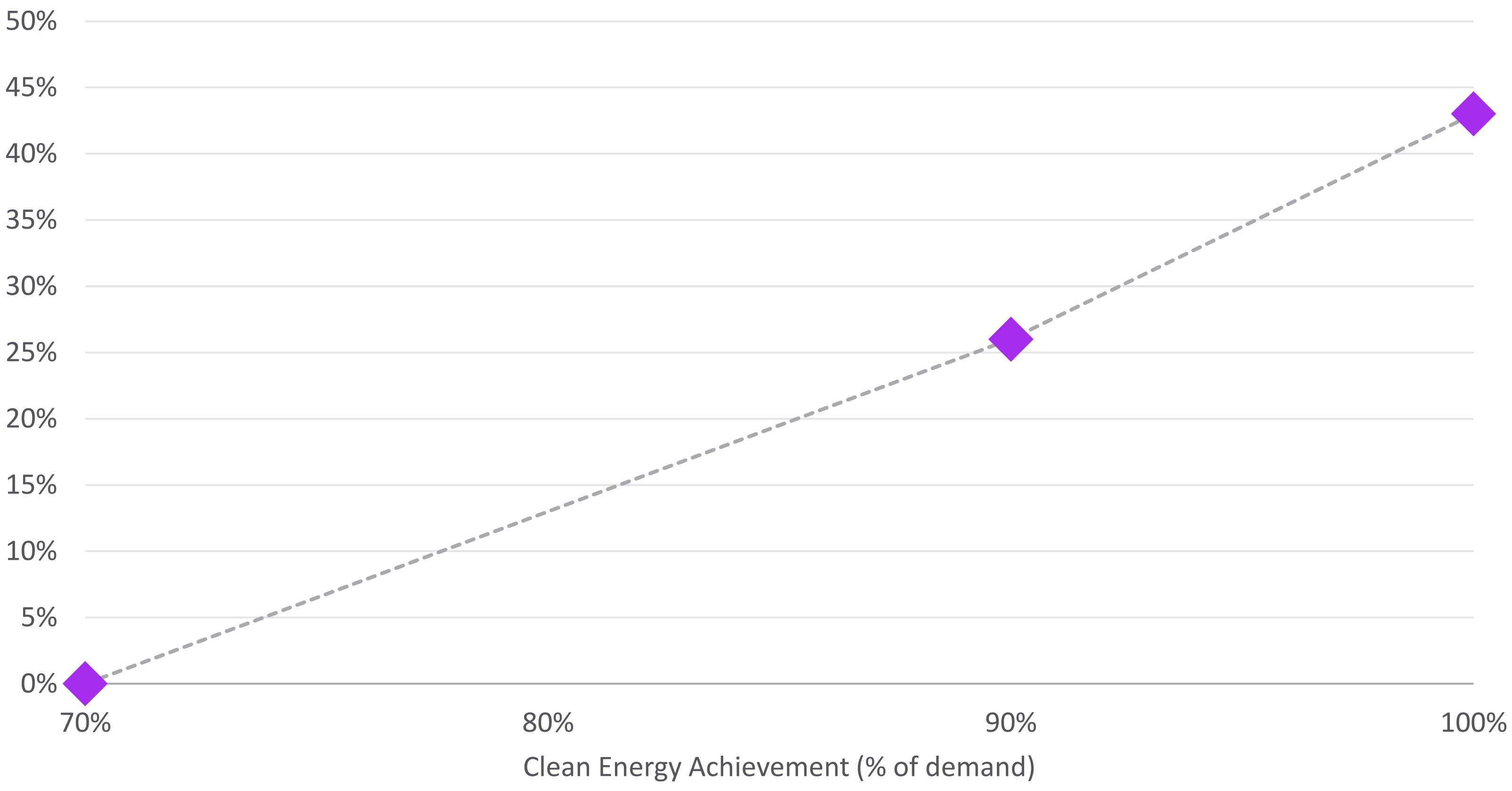
H2 generation paired with electrolysis & H2 storage could serve as the needed long-duration storage (LDS) resource

Notes: *excluding imports; Totals over 100% indicate that there is battery charging and/or exports

H2 generation becomes increasingly important for meeting seasonal needs as the system approaches 100% clean energy

H2 generation capacity factors as system nears 100% clean energy

% H2 annual capacity factor vs % northeast-wide clean energy achievement

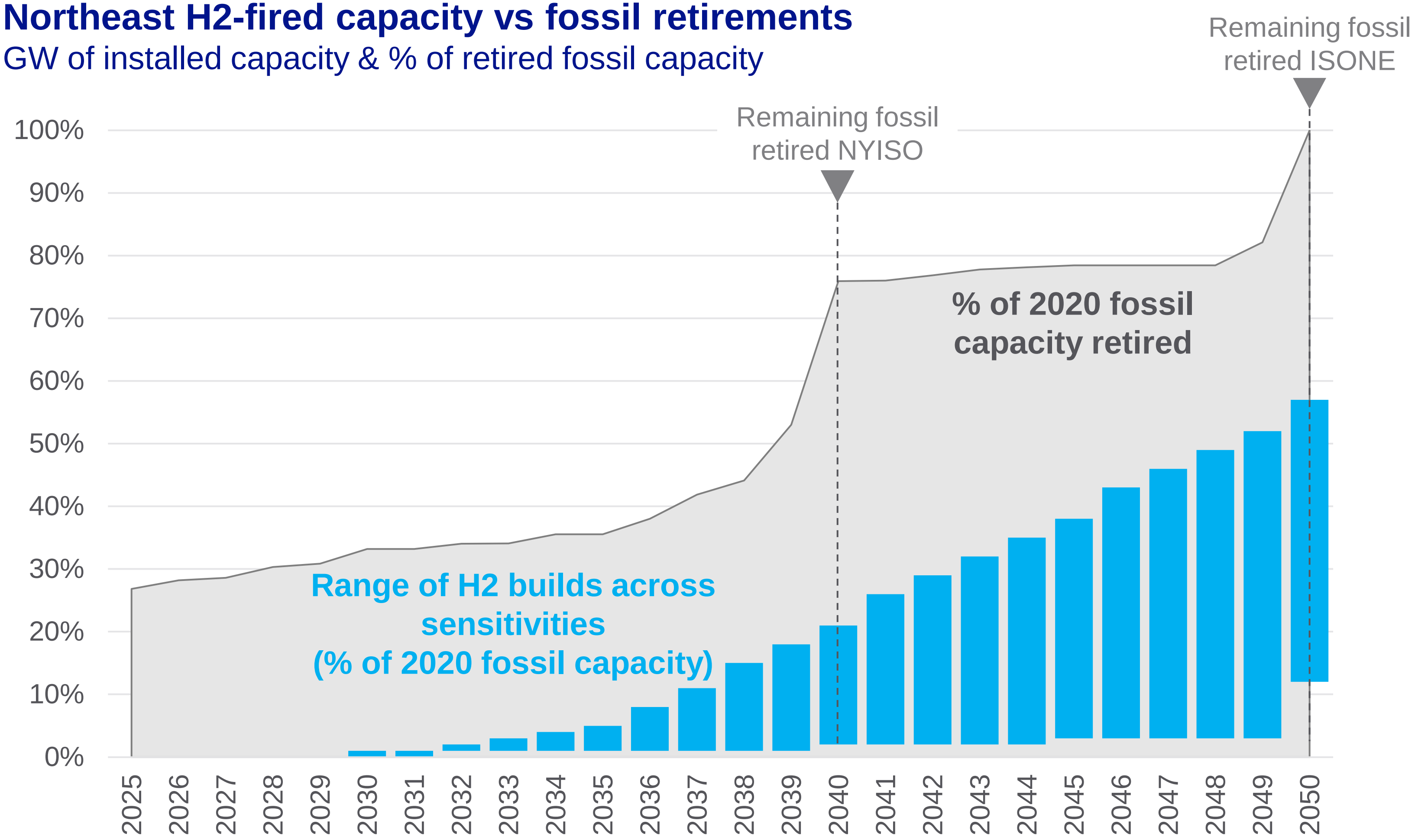


Source: Market Fundamental simulations & analysis

- At regional clean energy achievement below ~70%, we see existing fossil used to meet seasonal needs.
- As system approaches 100% clean energy, the needs increase at the same time the contribution of fossil to meeting those needs decreases, which drives the use of alternatives such as H2 generation
- The scale of H2's role may vary due to factors such as fuel prices & the degree of ISO-to-ISO exchange

The pace & scale of H2 plant builds is closely linked to retirement of fossil resources, Tx build out, and the cost of alternatives

Northeast H2-fired capacity vs fossil retirements
GW of installed capacity & % of retired fossil capacity



Source: Market Fundamental simulations & analysis

Meeting system needs in the Northeast by 2050 under net zero could require replacing 10%-55% of existing fossil with H2 generation

- Success in building out the transmission system and the extent to which electrification occurs are major drivers of the scale of H2 builds
- Battery storage builds are also an important driver due to the large share of future capacity/flexibility they provide—if battery builds are limited by supply chain or other issues, we expect higher H2 builds
- The cost of H2 also plays a major role, determining the extent to which H2 generation is used for energy/flexibility vs capacity

3

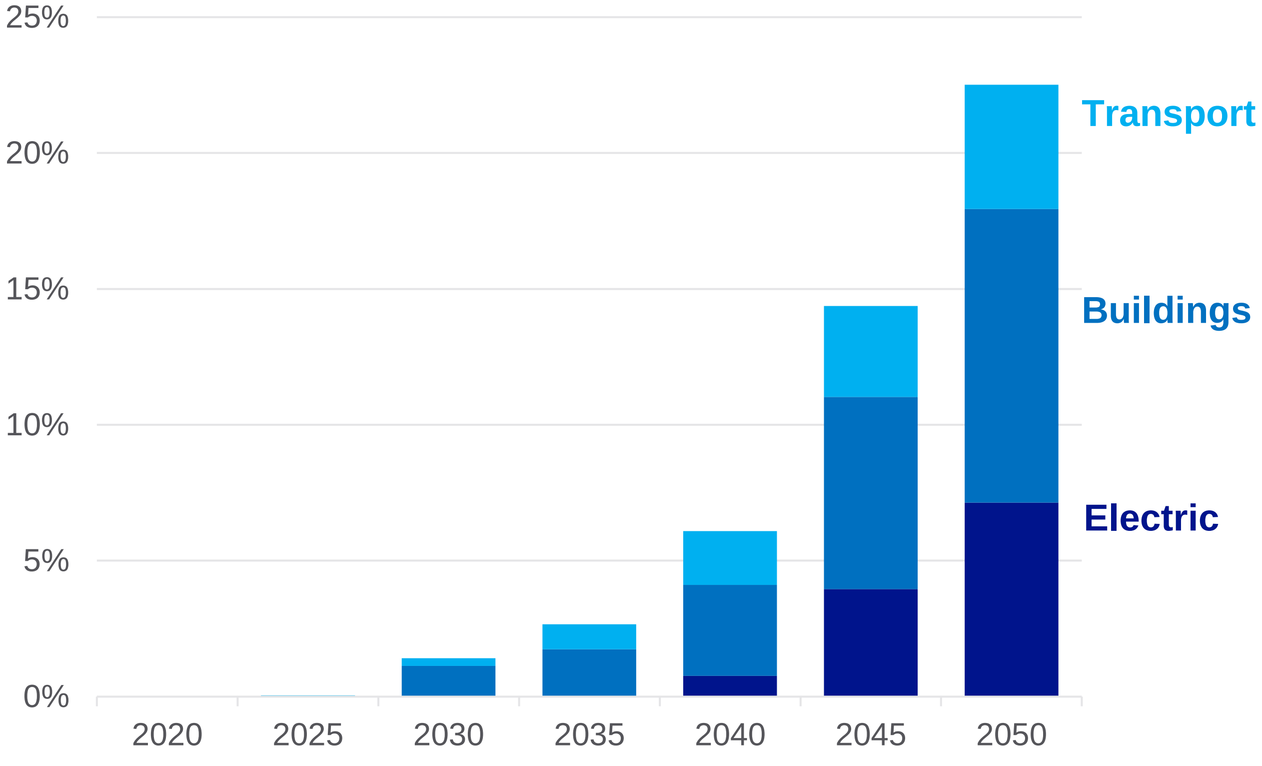
What are the electric sector impacts of scaling green H2 production in the US northeast?

nationalgrid

By 2050, demand for H2 in the Northeast region has potential to hit a level equivalent to ~20% of today's natural gas demand

An outlook for H2 demand in the US Northeast

% H2 consumption relative to current northeast natural gas demand



Source: Market Fundamentals analysis. View represents one scenario of future H2 demand and is not a forecast of future H2 demand..

Sources of H2 demand

Electric sector

- H2 demand from H2-fired power generation

Building sector

- H2 blending for residential, commercial, & industrial needs in existing systems
- H2 for backup heating needs and needs for heating fuel in hard-to-electrify geographies

Transport sector

- H2 for using in medium and heavy-duty transport

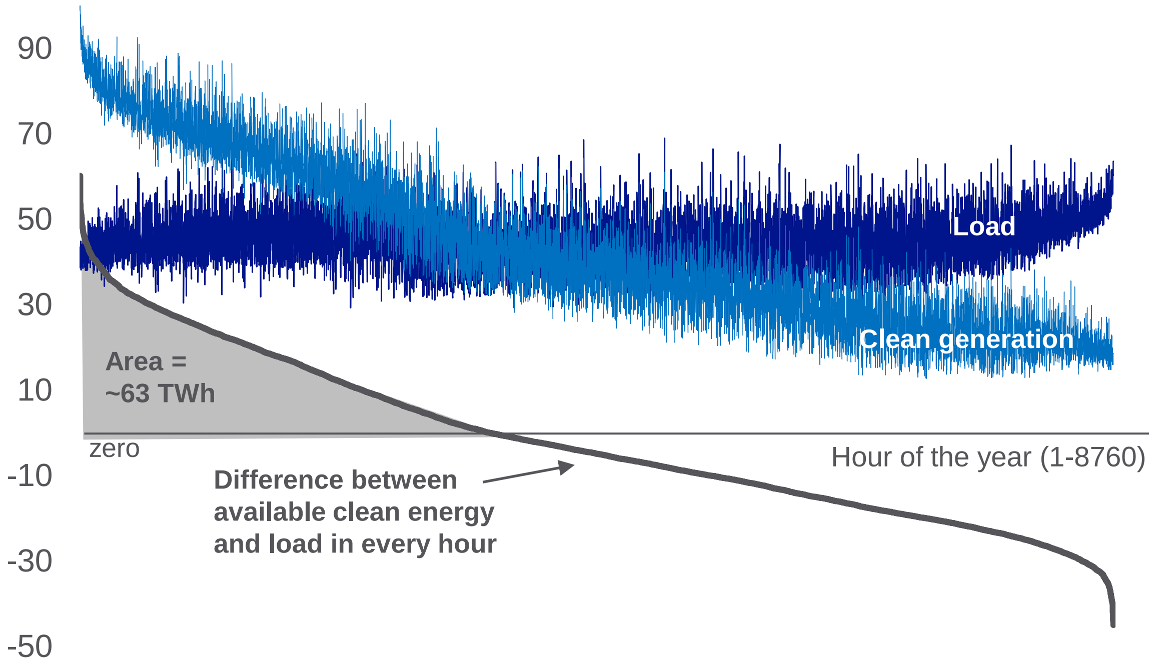
Other potential sources of H2 demand

- Industrial process heat
- Aviation

Although clean generation in 2050 exceeds load in 40% of all hours, electrolyzing curtailment may be a minor source of H2

Clean generation exceeds load in 40% of hours 2050

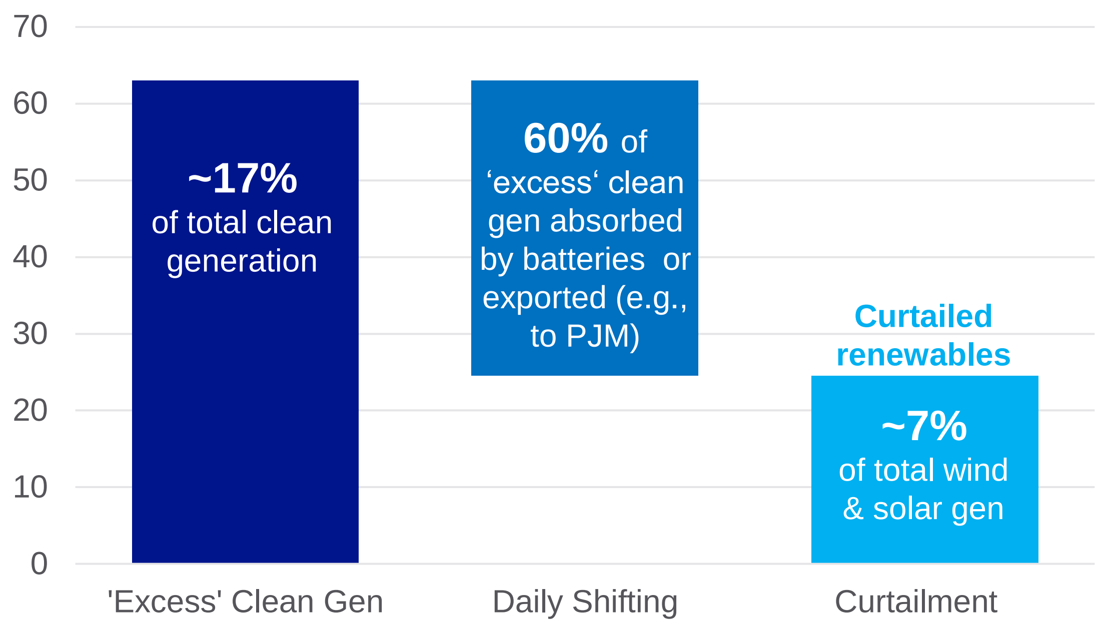
GW in every hour in 2050



- In the most extreme hours, clean generation can exceed load or fall short of load by ~45-60 GW highlighting a huge need for storage
- Before accounting for storage, clean energy generation exceeds load in ~40% of all hours in 2050 = 63 TWH/y in 2050

Batteries the most economical to shift this excess gen

TWh of annual energy in 2050 in the US Northeast

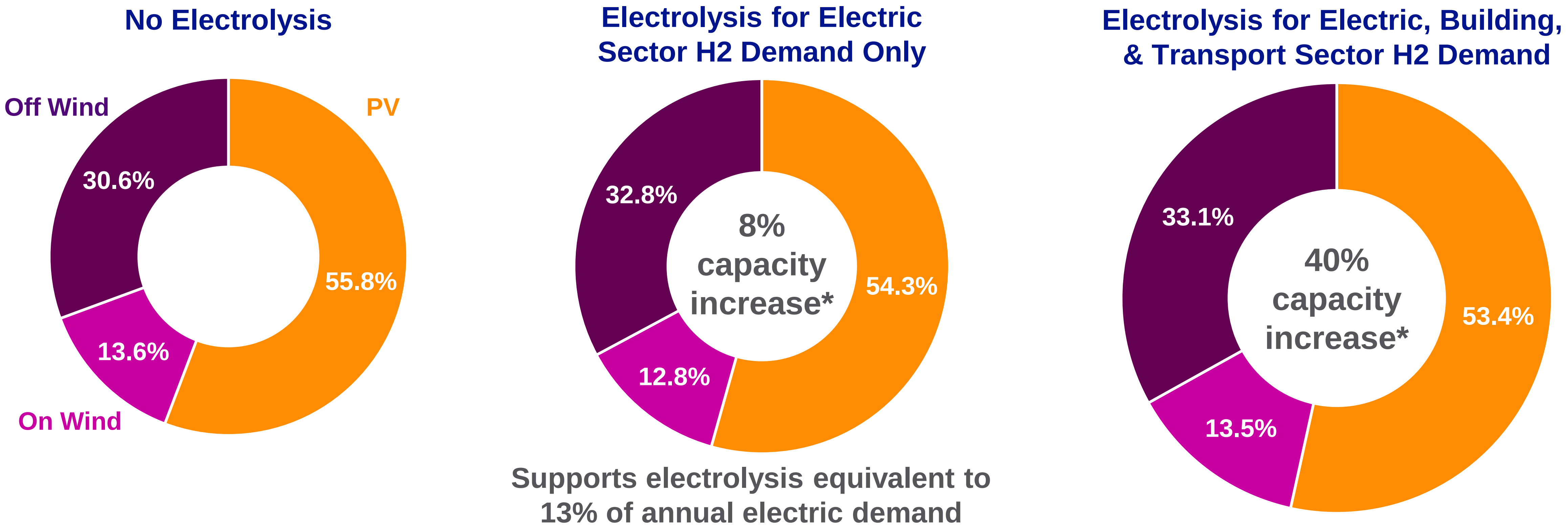


- 100% of the 'excess' clean generation could produce enough H2 to meet ~60% of scenario H2 demand for power, buildings & transport
- After accounting for intra-day battery charging and exports, **curtailment only be enough to produce up to 15% of scenario H2 demand**

Note: clean generation includes hydro, wind, solar, biomass and nuclear

Meeting H2 needs via electrolysis may require up to 40% increase in renewables build by 2050, including an ~50% increase in OSW

Northeast renewables build to meet policy targets & electrolysis demand by 2050
Fraction of installed capacity by renewable type and H2 demand scenario



Supports electrolysis equivalent to 13% of annual electric demand

Supports electrolysis equivalent to 42% of annual electric demand

Source: Market Fundamental simulations & analysis. *relative to no electrolysis scenario

4

What are the key policy considerations to support H2-fired generation?

nationalgrid

There are several policy avenues available for jumpstarting H2-generation's use in the electric sector

Policy Objective	Technology Prescriptive → Policy Approach →		Technology Agnostic
Maintain electric system reliability while transitioning to 100% clean in electric sector	**H2 Generation Capacity Target** **Description:** MW goal for H2-gen capacity (MW) backed by mandatory long-term procurement contracting **Examples: N/A** **Efficacy:** ● explicit H2 requirement	**Long Duration Storage Target** **Description:** MW goal for LDS capacity (MWs and/or MWhs) backed by mandatory long-term procurement contracting **Examples:** California PUC called for a 1 GW of LDS procurement for 2026, defined as technologies offering 8 to100 hours of duration. **Efficacy:** ● no explicit H2 requirement	**Clean Capacity Market** **Description:** Capacity market reformed to account for capacity's clean environmental attributes **Examples:** Massachusetts' Clean peak standard, and recent proposals for a clean capacity market structure in several states **Efficacy:** ● no explicit H2 requirement
Scale-up H2 demand to support a new local industry	**H2 Fuel Subsidy/ Tax Credit** **Description:** Subsidy for H2 production that helps close the cost gap with **Examples:** Federal $3 per kg production tax credit proposal **Efficacy:** ● explicit H2 requirement	**H2 Energy Gen Standard (HEC)** **Description:** Establish an annual H2 generation target (MWh), like an RPS **Examples:** N/A. Will be important to structure policy so generators are incentive to produce H2 when power prices are highest to limit impact on ratepayers. **Efficacy:** ● explicit H2 requirement	**CO_2 Price / Carbon Tax** **Description:** Establish a higher regional carbon price (beyond RGGI) sufficient to result in NG-H2 switching **Examples:** RGGI, NYISO's stalled carbon pricing initiative, California cap & trade system. **Efficacy:** ● CO_2 price needed to bridge H2-NG price gap in near term unlikely

Anticipated efficacy of policy at spurring H2 investment ● strong ● moderate ● weak

Speaker bio

Dr. Kai Van Horn

Manager, US Market Fundamentals
National Grid USA

Kai is an expert in leveraging electricity system modeling, analysis, and visualization to illuminate the impacts of the energy transition, and develop and communicate strategic responses. In his current role, he leads a team exploring pathways to deep decarbonization in the northeast and the challenges and opportunities they create for utilities and their customers.

Kai received a Ph.D. in Electrical and Computer Engineering (Power Systems Focus) from the University of Illinois at Urbana-Champaign.

LinkedIn Profile

Disclaimer: All results and any errors in this presentation are the responsibility of the author and do not represent the opinion of National Grid or its subsidiaries. Results shown herein are indicative and are solely intended to illustrate a range of potential needs/impacts for hydrogen in the power sector. The scenarios shown are just a few of many possible scenarios.