The Future Role of Hydropower in the Northeastern US and Beyond

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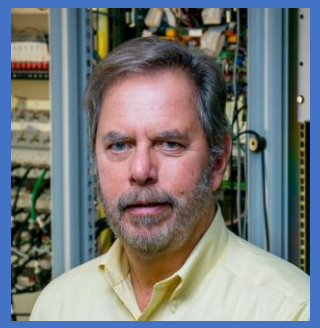
Flashover LLC

Background

- A look at the future role of hydropower in the Northeastern US and beyond and how it can best support the reliable and economic evolution of decarbonization efforts
- Challenges driven by the integration of 10s of GWs of variable energy resources
- Work supported by DOE and NREL as part of the extensive activities of the DOE Water Power Technology Office

John Simonelli
Managing Director, Flashover LLC is a recognized SME on System Planning & Operations, after spending 40 years with ISO New England, he now provides consulting expertise across the industry



Nicholas W. Miller
Principal, HickoryLedge LLC after 3/8 century of experience and research on bulk power systems at GE, Nick currently provides consulting expertise to private and public institutions on grid integration

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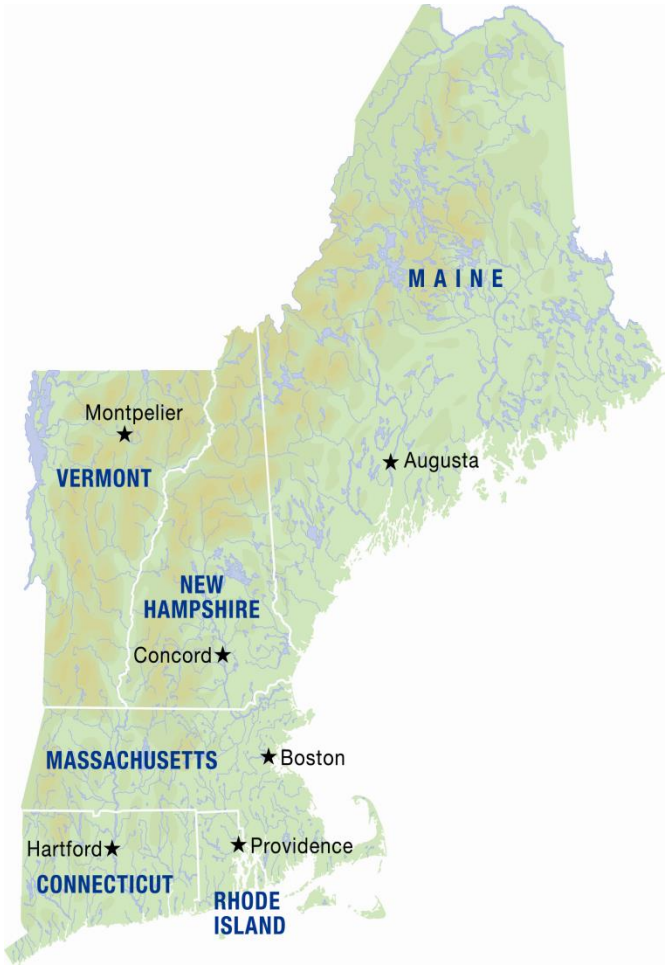
Outline

- Summarize the current New England System
- New England Duck Curve
- What the Potential Future Holds
  - Renewables, load, ties to neighbors
- Challenges
- Hydro's Potential Contributions
- Moving the Ball Forward

New England Region

- Population 14.8 million
- More than 350 generators and 9,000 miles of high-voltage transmission lines including electrical interconnections to New York and Canada
- 31,500 megawatts (MW Capacity Obligation) of total supply and 767 MW of demand resources
- All-time peak demand of 28,130 MW set on 02/09/2006
- $3.0 billion energy market and $2.7 billion capacity market with more than 500 active participants



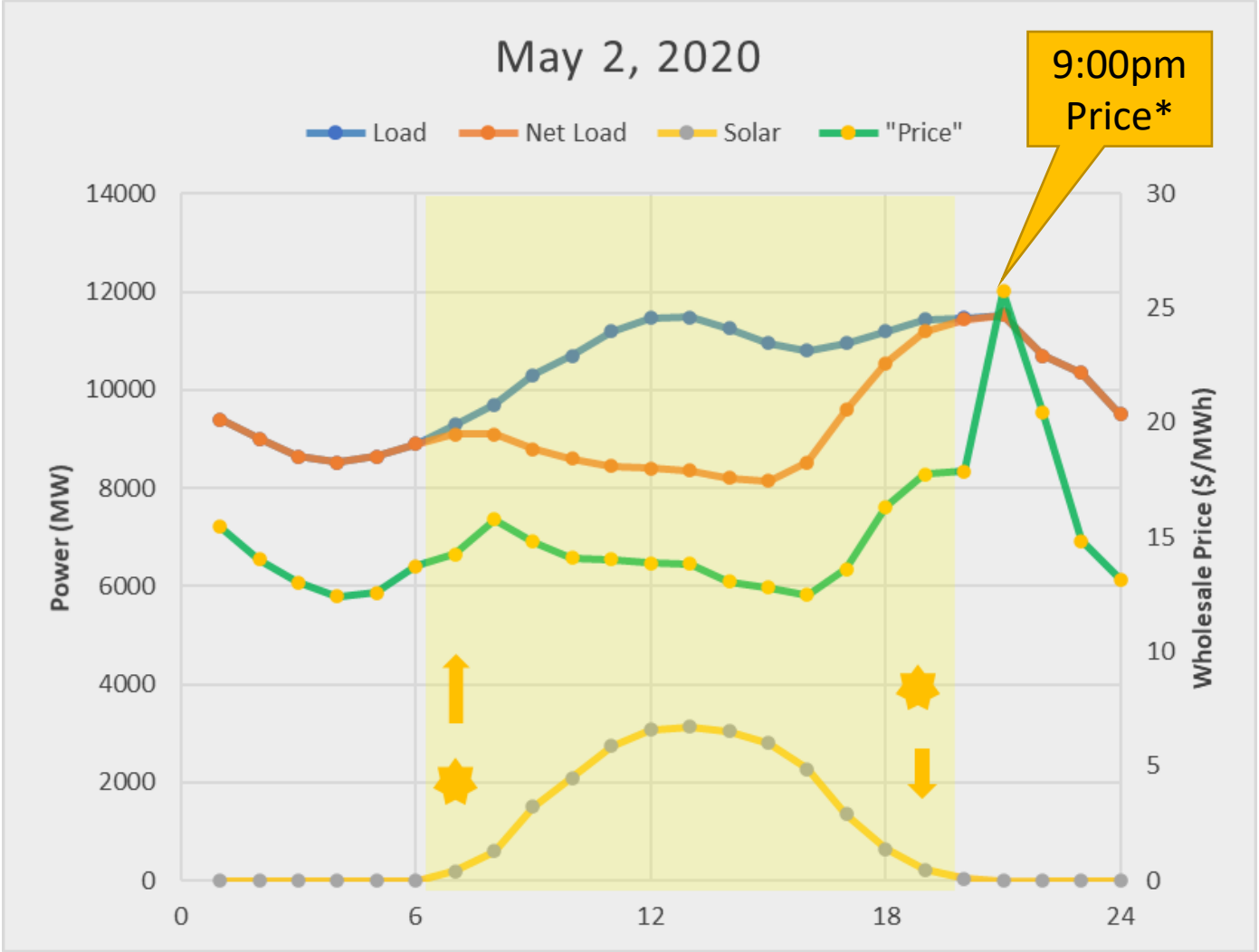
New England Region

- ISO-NE is the Independent System Operator for the Region
  - Under FERC jurisdiction
- Major Responsibilities
  - Operating the Regional Power System (NERC registered RC, BA, TOP)
  - Administering Wholesale Electricity Markets
  - Managing Regional Power System Planning (NERC registered PA, TP, RP, TSP)
  - Independent of companies doing business in the market
  - No financial interest in companies participating in the market
  - Neutral as to resource fuel type

New England's Duck

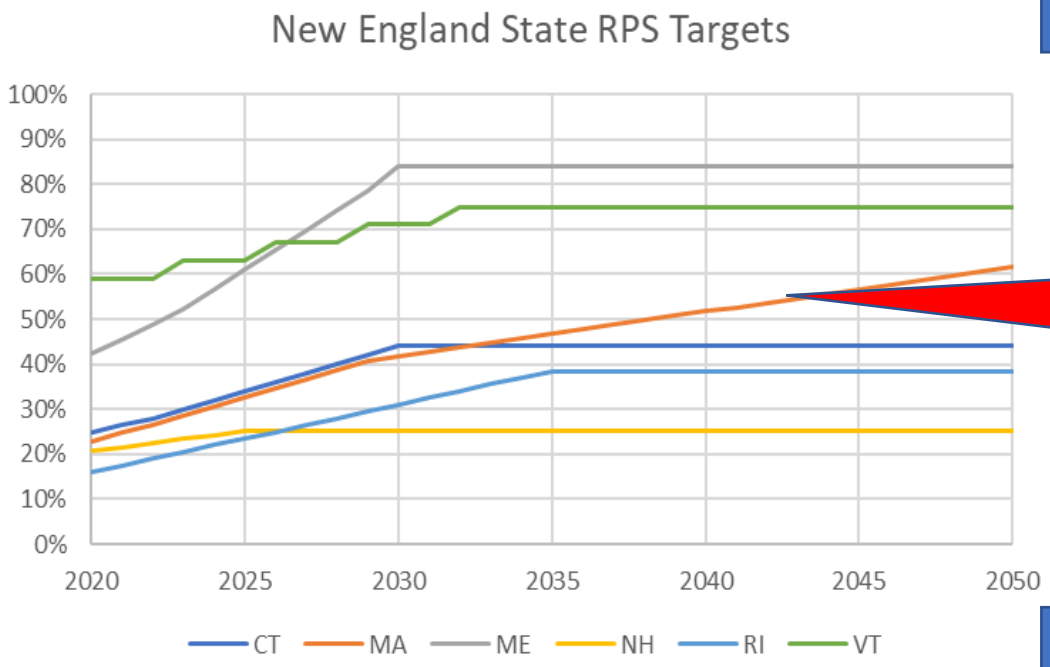
An example:

- High Solar Day May 2, 2020
- Significant BTM PV impact
- Midday price depression
- Evening price spike



*ISONE Day-Ahead LMP 5-22-20

New England: Ambitious Plans & Limited Ties



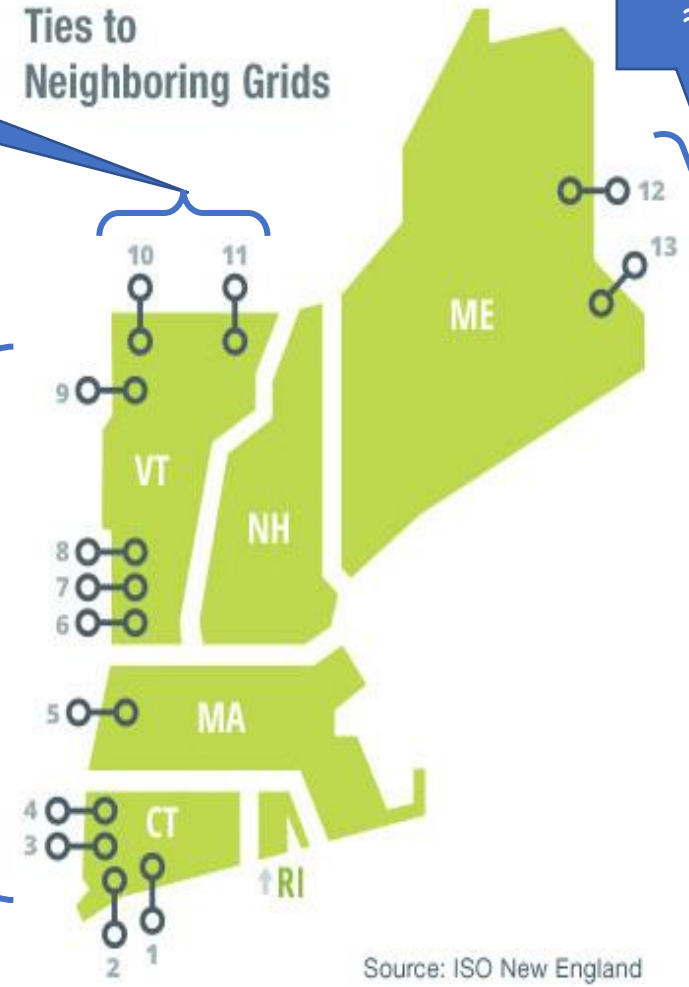
New England Renewable Portfolio Standard Targets

HVDC to Quebec ≈ 2250 MW

AC to Maritimes ≈ 1000 MW

Ambitious state mandates

Ties to NYISO ≈ 1400 MW

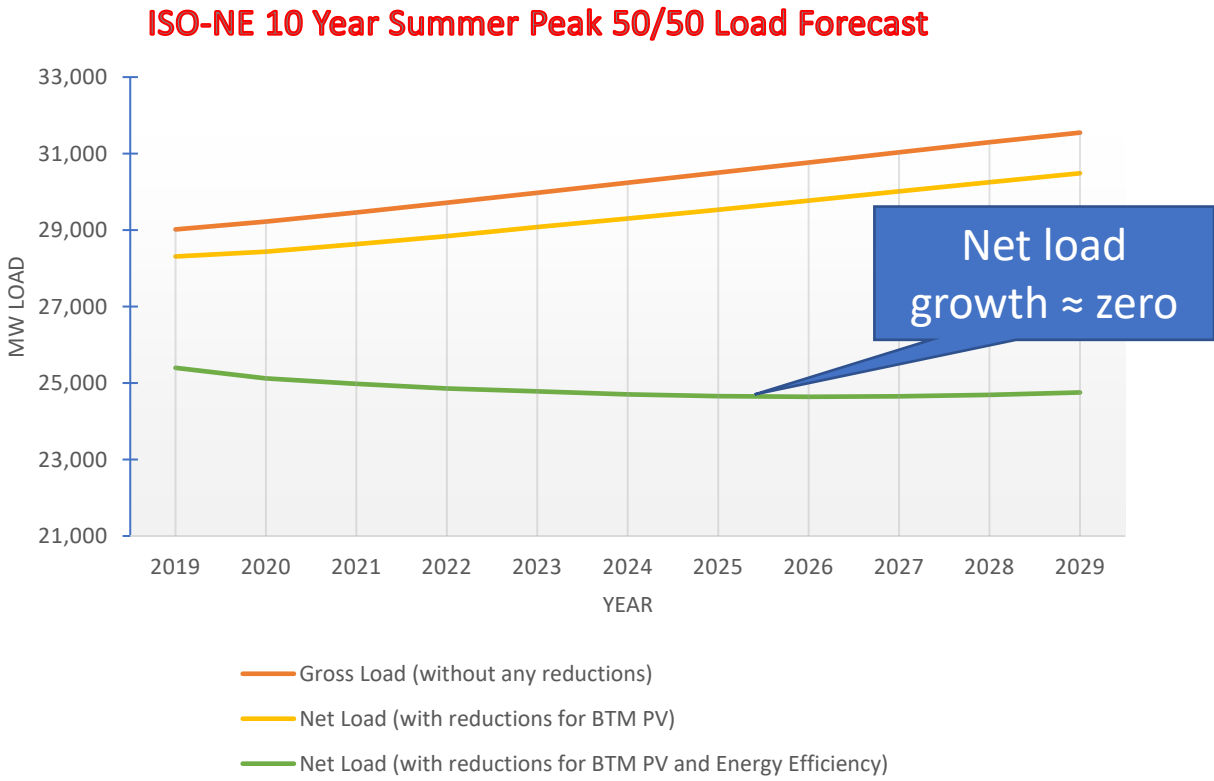


Source: ISO New England

New England Generation Mix and Flat Load

Resource	2020	2029	Daytime Spring Available '29
Fossil/Thermal/Nuke	31475	30808	15374
Hydro*	1994	2093	2093
Storage	1799	3878	-4250
Solar PV**	1457	5348	4712
Onshore Wind	1361	2377	428
Offshore Wind	30	11381	3423
Totals***	38148	55952	21819

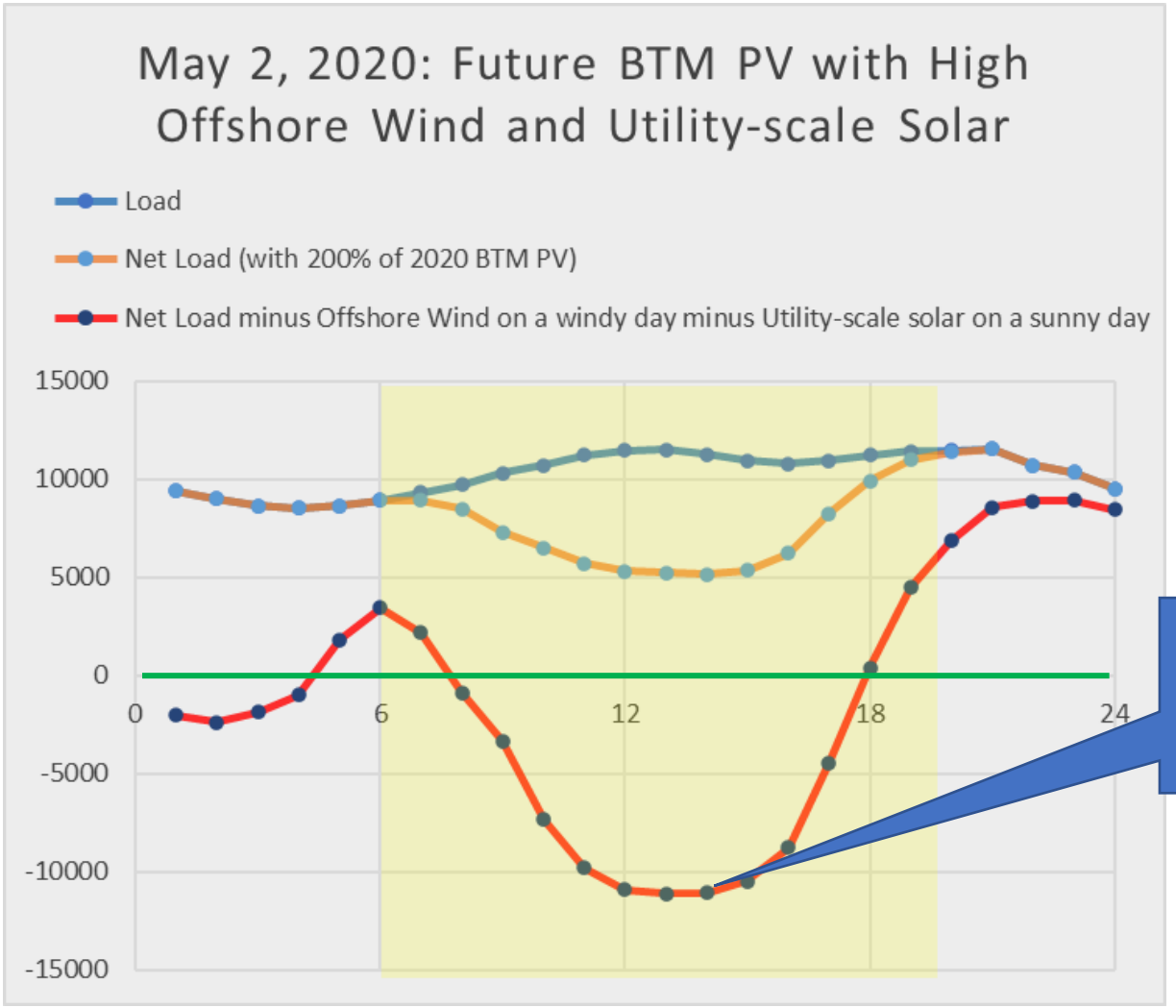
* 37% of hydro is run-of-river; balance has pondage
** includes some PV+BESS
*** Assumed typical spring outages and wind capacity factors



Sources:
ISO-NE CELT 2020 CELT Report (tab 1.1 Summer Peak)
ISO-NE Interconnection Request Tracking Tool (06/18/2020)
ISO-NE Non-Price Retirement Requests and Retirement De-list Bid spreadsheet (06/18/2020)

New England in the Years to Come

- Combined BTM Solar and Offshore Wind impact on Net Load
- Possible “what if” future duck curve challenge
  - Illustrative, not exhaustive
    - Expected wind & solar on light load day
  - What challenges does it present from operational perspective?
    - Over generation
    - Renewable curtailments & out of merit must run (sub-optimal dispatch)
    - Congestion



It’s not just MWs and MWhs

- System needs critical Essential Reliability Services (ERS) to maintain reliability:
  - Keeping frequency healthy: inertia & frequency response
  - Keeping voltage healthy: voltage regulation and reactive power supply
  - Keeping protection working and inverters (wind, solar, BESS) stable: maintaining short circuit strength
  - Putting the system back together: black start & system restoration
  - Following the variations: Reserves and Ramping
- ERS can become scarce with increasing renewables/changing resource mix and retirements.
- Hydro can provide all ERS
- Some of these services are presently under-valued or lack market signals for investment

Hydro's critically important services

Frequency control:

Primary & fast frequency response (PFR and FFR)

- Hydro primary frequency response *can* be excellent
- Advanced Pumped Storage has *best in industry* performance; FFR possible
- No market signals to invest in upgrades and undervalued (no FFR market yet)

Voltage control:

Excitation systems

- Hydro (older) may benefit from upgrades to increase the speed of excitation and increase lead/lag reactive capability
- Locational aspects (especially remote areas) v. important
- Condenser mode increasingly valuable
- No market signals to invest in upgrades and limited market revenue stream

Inertia:

Contributes to grid stability; supports reduced (RoCoF)

- Increasing recognition of value/need and many systems starting to monitor
- Condenser mode increasingly valuable
- No market signals to explore higher inertia hydro designs and undervalued no market yet)

Hydro's critically important services, con't

System restoration & blackstart:

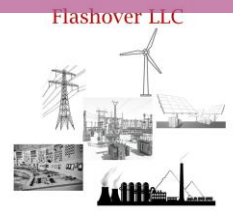
- Hydro already important to system restoration
- With retirements and increasing focus on grid resilience, expect higher attention
- Market mechanisms usually cost recovery only; sometimes completely absent
- Mechanisms to encourage investment mostly absent

Ramping and Regulation services:

- Operational agility, ability to support ramping valuable
- Some emerging efforts to determine ramping needs
- Market constructs emerging to pay (e.g. "Flexiramp service")
- Already an important role for hydro; expect increased value with changing resources mix

Short circuit contribution:

- Required for protection systems and to support inverter stability
- Highly locational; remote areas high value (esp. in proximity to wind)
- Increasing recognition of value/need
- Condenser mode increasingly valuable
- Not paid service today



Moving the Ball Forward: Hydro's future role

- Getting the most out of Hydro Flexibility
- Address the overgeneration challenge
- Constraints on Hydro Operation
- A new look at planning
- Paying for it all

Moving the Ball Forward: Hydro's future role

- Getting the most out of Hydro Flexibility
  - Actively look for ways that existing hydro can offer more; e.g. condenser mode, physical plant upgrades, etc.
  - Look for positive impacts on stability limits; inertia; short circuit/protection
  - Investigate value of Variable Speed PSH
- Address the overgeneration challenge
- Constraints on Hydro Operation
- A new look at planning
- Paying for it all

Moving the Ball Forward: Hydro's future role

- Getting the most out of Hydro Flexibility
- Address the overgeneration challenge
  - Pumped storage offers large scale storage options
  - Pumped storage is proven technology with long in-service expectation
  - Works well with other options that will also be required
- Constraints on Hydro Operation
- A new look at planning
- Paying for it all

Moving the Ball Forward: Hydro's future role

- Getting the most out of Hydro Flexibility
- Address the overgeneration challenge
- Constraints on Hydro Operation
  - Be mindful of emerging *increases* in operational constraints on mechanical components, environmental and other externalities (non-traditional power outputs)
  - Help set priorities on when flexibility most valuable and constraints are most costly; help resolve conflicts
- A new look at planning
- Paying for it all

Moving the Ball Forward: Hydro's future role

- Getting the most out of Hydro Flexibility
- Address the overgeneration challenge
- Constraints on Hydro Operation
- A new look at planning
  - Factor in the contribution and value of hydro provided ERS
  - Making PSH a regional asset by considering its value on a more global footprint by including potential benefit to neighboring RC/BA/markets
  - Factor in increased value of moving toward Variable Speed PSH as opposed to traditional PSH
  - Create market structures to incent needed development and share costs
- Paying for it all

Moving the Ball Forward: Hydro's future role

- Getting the most out of Hydro Flexibility
- Address the overgeneration challenge
- Constraints on Hydro Operation
- Making PSH a regional asset
- Paying for it all
  - Create incentives for investment (in hydro) that creates additional systemic benefits
  - Revisit capacity market structures to better value functionality of high-performance resources, especially advanced PSH
  - Consider market structures that allow hydro resources (and other resources) to realize revenues from both energy/capacity/ERS markets *and* regulated return for systemic benefits

Moving the Ball Forward: Hydro's future role

- Getting the most out of Hydro Flexibility
- Address the overgeneration challenge
- Constraints on Hydro Operation
- Making PSH a regional asset
- Paying for it all

➢ **Hydro will be even more important in the near future and eventually a deeply decarbonized future**

Questions

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