Metrics-based Storage Evaluation:
Key Considerations for the VESTF

PRESENTED BY

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PRESENTED TO

Virginia Energy Storage
Task Force (VESTF)

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In this presentation

- Virginia's aggressive decarbonization goals will drive a need for massive amounts of energy storage – potentially well beyond the legislative mandate of 3,100 MW by 2035

- This raises crucial – and complex – questions for the VESTF:
  - What type(s) of energy storage will be most cost-effective in meeting the state's long-term goals?
  - How will this change over time?
  - How to deal with future uncertainty?

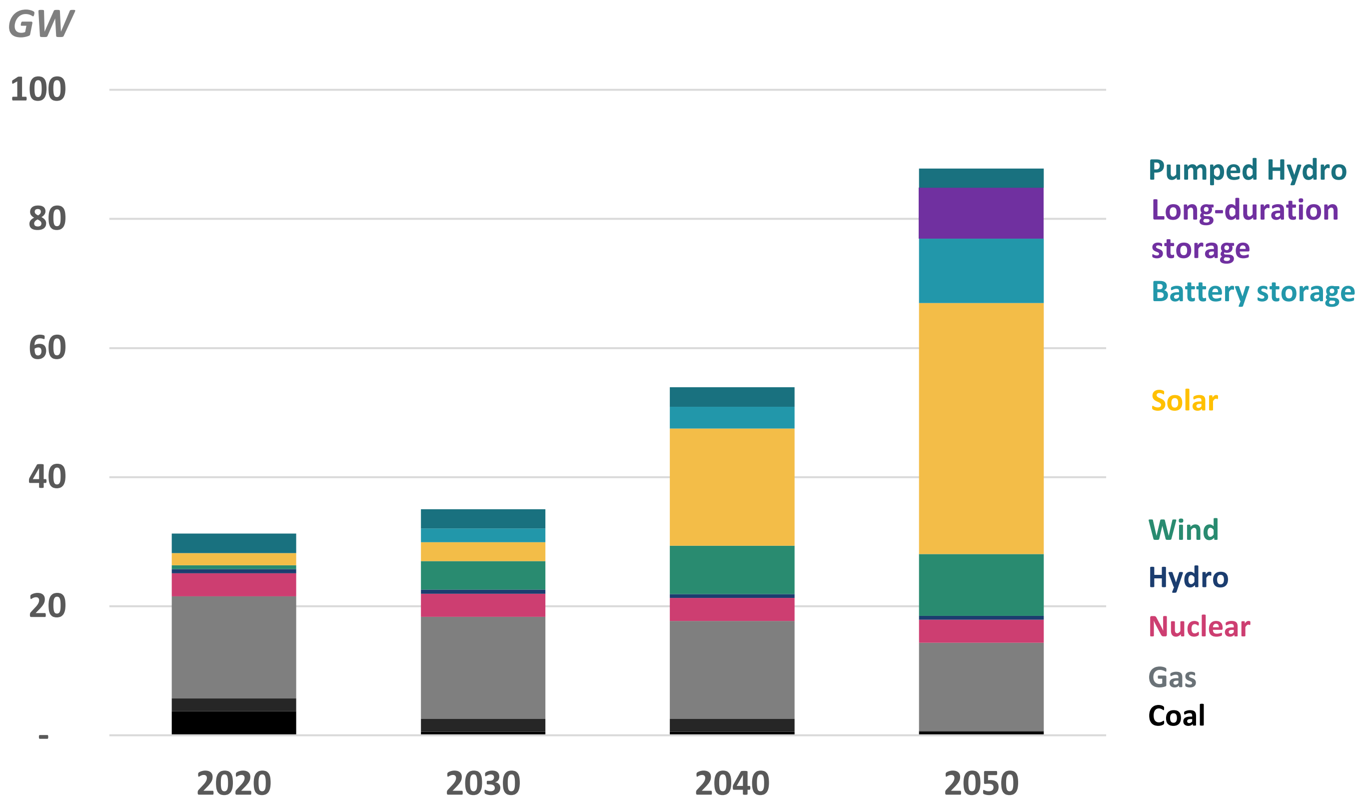
- In this presentation, we discuss important considerations for developing a metrics-based evaluation of energy storage resources, based on system planning experience in Virginia and other jurisdictions across North America

Introduction

- The Virginia Clean Economy Act will drive major development of renewable generation and clean resources
- A preliminary Brattle simulation of a fully decarbonized Virginia power grid by 2045 indicates:
  - **7 to 10 GW of battery storage** additions by 2050, with another **6 to 8 GW of long duration storage** (or other clean dispatchable generation)
  - Solar dominates capacity additions (nameplate)
  - Some fossil generation remains for reliability purposes, and rarely runs

Virginia's evolving capacity mix

2020 – 2050, illustrative



Sources and Notes: Illustrative modeling using Brattle's gridSIM model, simulating 100% carbon-free generation in Dominion service territory by 2045.

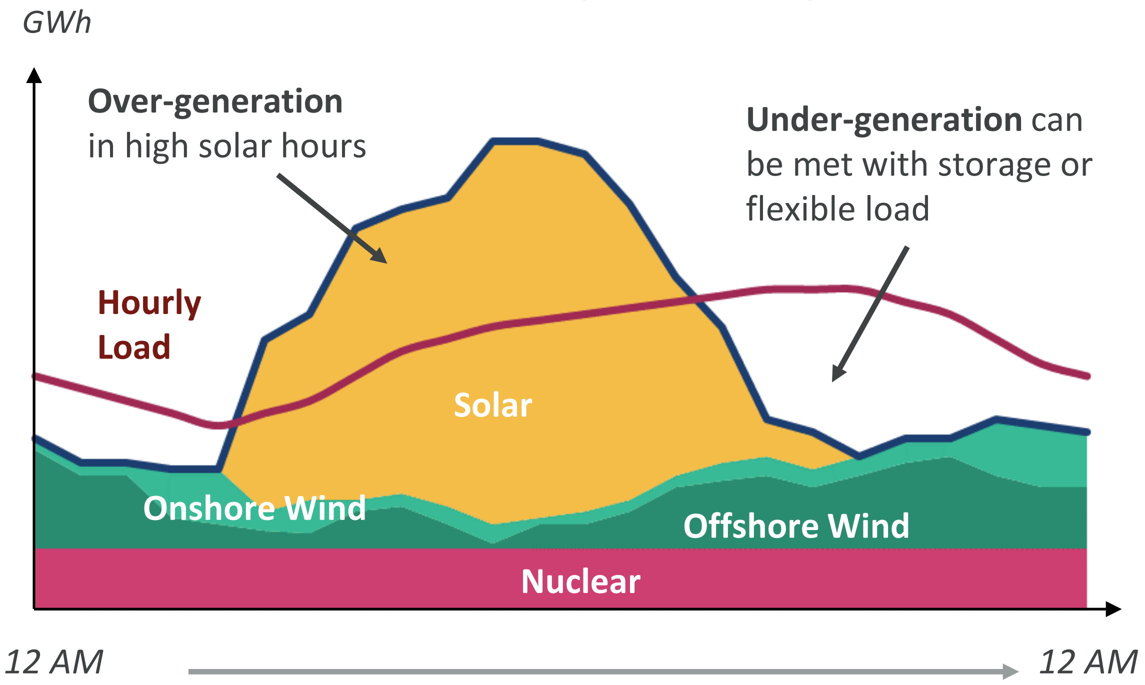
The value of energy storage in decarbonizing systems

1.	**Achieving RPS and emission reduction mandates**	Storage can **shift solar output to later hours**, reducing emissions and facilitating compliance with Virginia’s 100% renewable energy mandate.
2.	**Serving load at least cost**	Storage can reduce the costs of serving load by **offsetting the need to run peaking generators and reducing solar curtailments.**
3.	**Reliably meeting peak demand**	Deploying storage can **reduce the need to build other power plants** to meet peak load, and provide resilience during emergency conditions.
4.	**Providing flexibility and ramping**	Some storage technologies can **effectively provide regulation and synchronized reserves**, reducing ancillary services costs.
5.	**Retail customer services**	Storage can **improve customer reliability and reduce distribution system costs** when located strategically on the distribution network.

Note: See appendix for a discussion of the challenge in “stacking” these value streams in Virginia.

Decarbonized systems present both hourly and seasonal balancing challenges

Hourly Balancing Challenge



Batteries and load flexibility can provide short-term balancing.

Notes: Illustrative examples.

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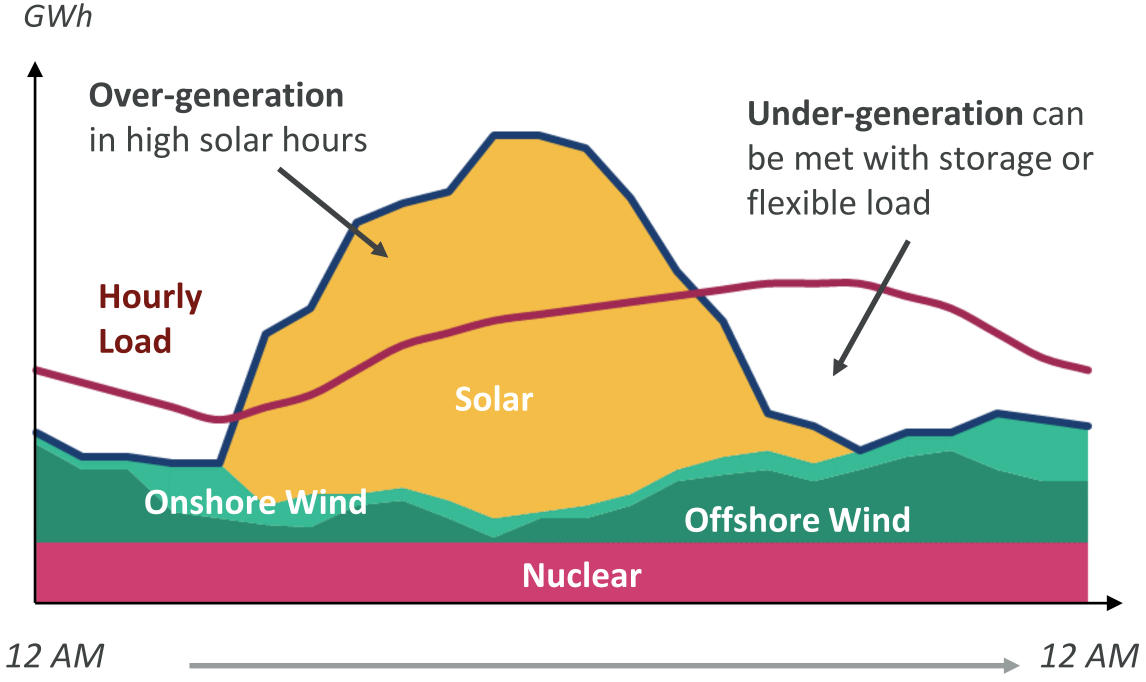
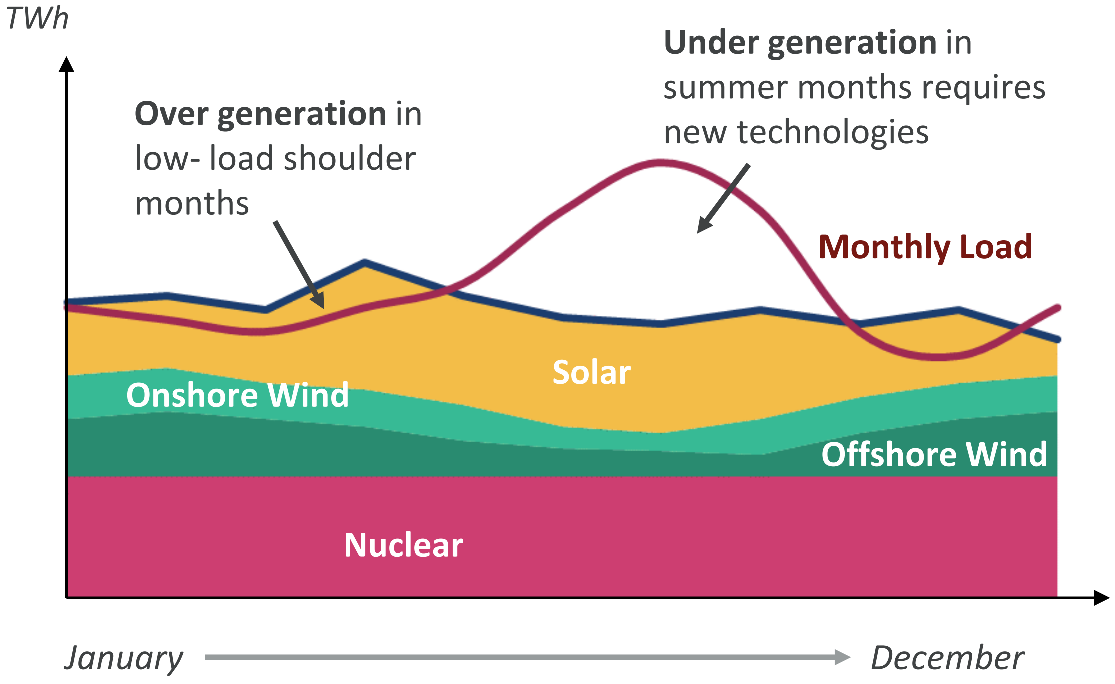


Over-generation in high solar hours

Under-generation can be met with storage or flexible load

Batteries and load flexibility can provide short-term balancing.

Seasonal Balancing Challenge



Over generation in low- load shoulder months

Under generation in summer months requires new technologies

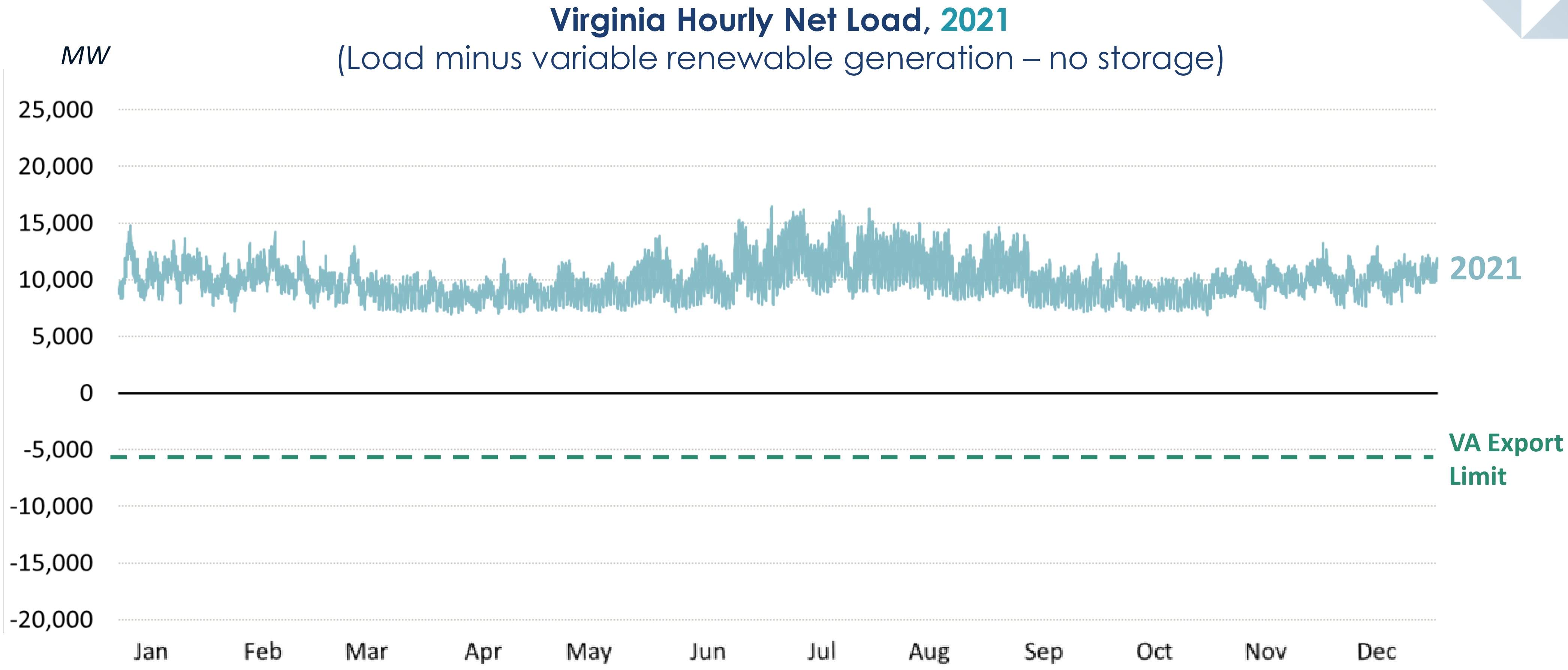
Seasonal balancing is the more difficult challenge, requiring __new technologies__ such as seasonal storage or zero-emission dispatchable generation.

Notes: Illustrative examples.

At current levels of renewables deployment in VA, gas generation and imports are sufficient to balance the system

Positive net load:
Dispatchable gen / storage needed to meet load

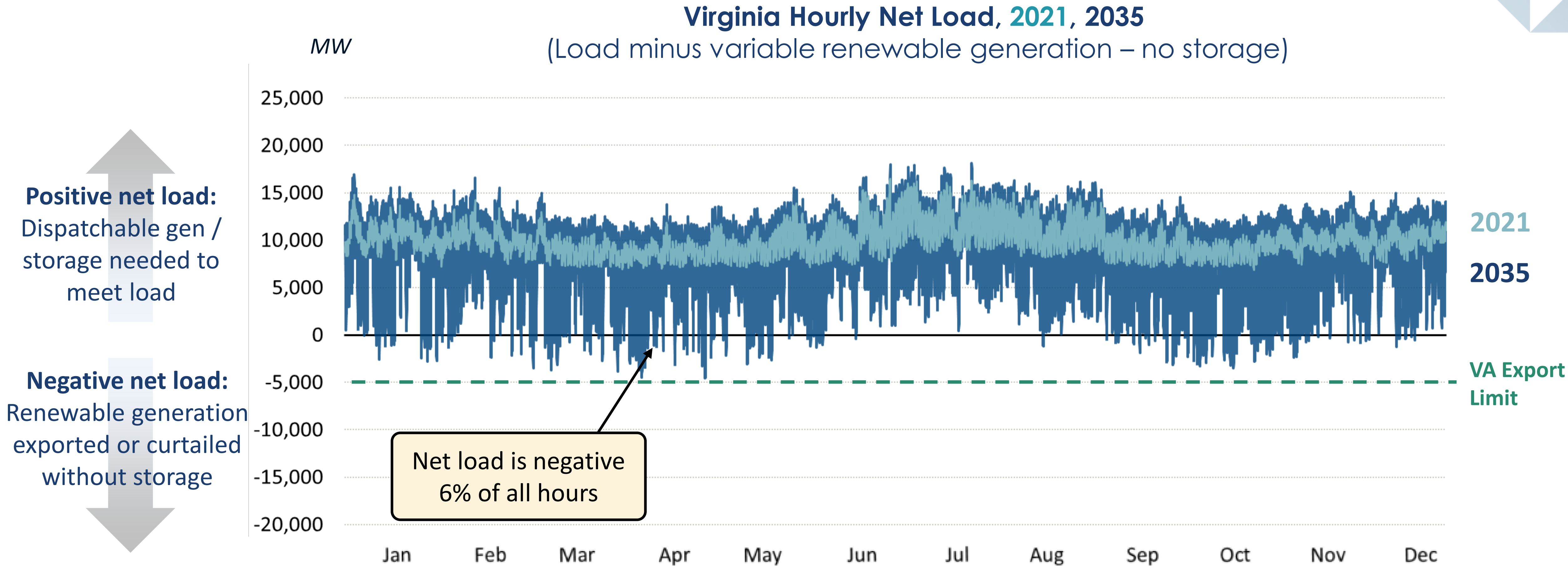
Negative net load:
Renewable generation exported or curtailed without storage



Virginia Hourly Net Load, 2021
(Load minus variable renewable generation – no storage)

Source and notes: Analysis based on Dominion 2019 hourly load shape and Dominion 2020 IRP Plan B.

By 2035, integrating renewables will become more difficult; renewable generation occasionally could exceed load



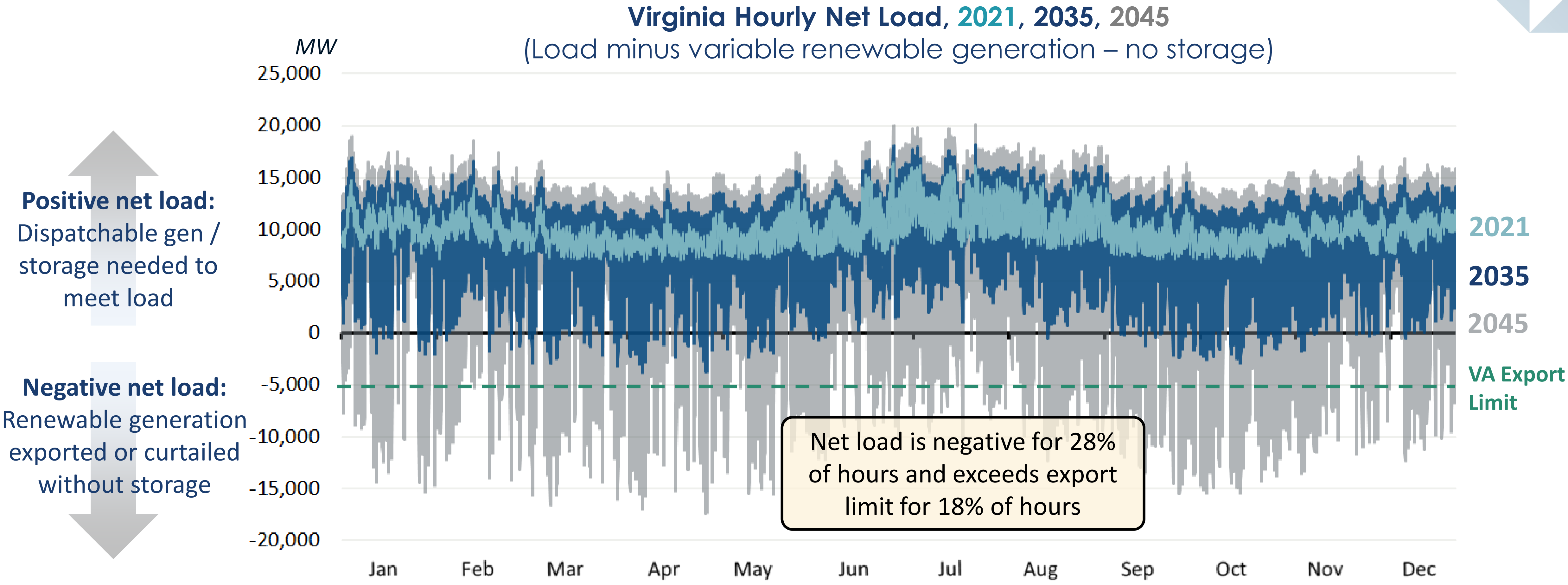
Positive net load: Dispatchable gen / storage needed to meet load

Negative net load: Renewable generation exported or curtailed without storage

Net load is negative 6% of all hours

Source and notes: Analysis based on Dominion 2019 hourly load shape and Dominion 2020 IRP Plan B.

By 2045, integrating renewables will require large amounts of storage to avoid curtailments in many hours



Positive net load: Dispatchable gen / storage needed to meet load

Negative net load: Renewable generation exported or curtailed without storage

Net load is negative for 28% of hours and exceeds export limit for 18% of hours

Source and notes: Analysis based on Dominion 2019 hourly load shape and Dominion 2020 IRP Plan B.

Many storage technologies have the potential to address these challenges

Storage Category	Example Developers
Electrochemical (e.g., Li-Ion, zinc-based, flow)	• Ambri • NantEnergy • Zinc8 • Eos
Mechanical (e.g., compressed air)	• Quidnet • Hydrostor • Highview Power
Thermal (e.g., stone, steel thermal storage)	• LUMENION • Azelio • 1414 Degrees

- Most existing storage in the U.S. is pumped hydro
- Most planned storage currently is 2-4 hour lithium ion
- A variety of technologies in development will attempt to tackle the longer-term challenge of cost-effective multi-day supply, including hydrogen

Which storage technologies to build - and when - depends on several factors

Key considerations when evaluating storage technologies in Virginia include:

- Operational/technical capabilities of storage technologies
- Storage costs - today and in the future
- Pace of renewable generation development
- Expected rate and nature of load growth – particularly electrification impacts
- Availability of other dispatchable resources on the system (e.g. gas generation, imports)
- Acceptable levels of dependence on market purchases and sales

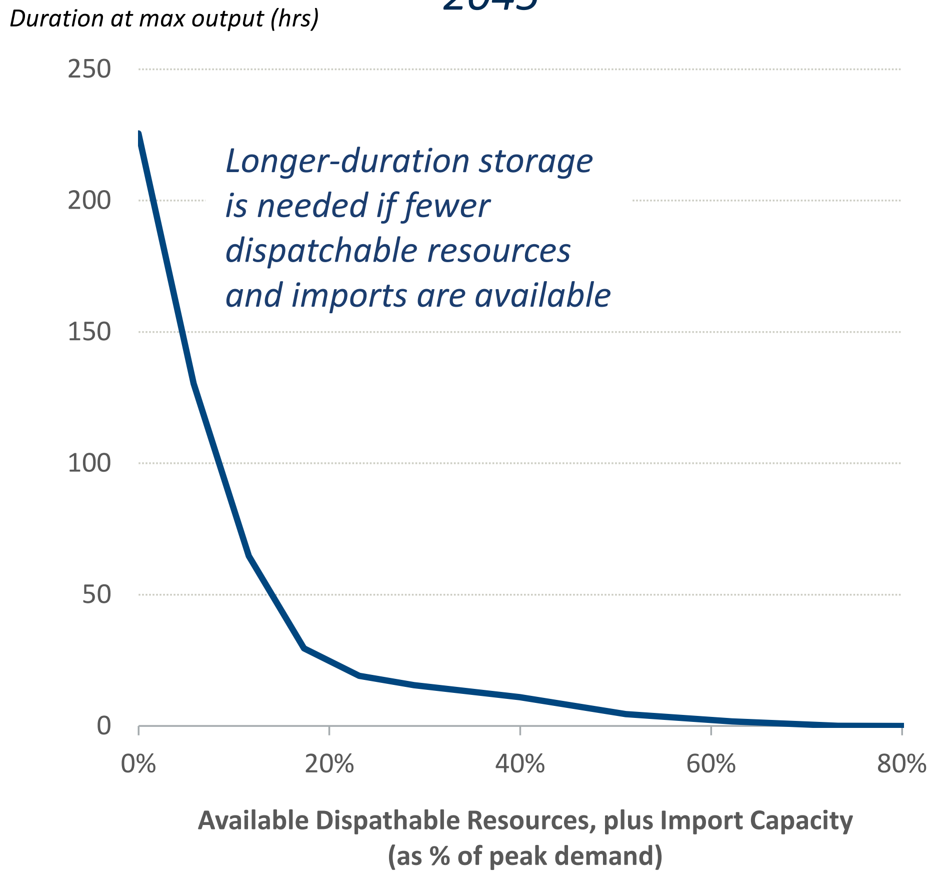
Example: The impact of dispatchable resources and imports on energy storage needs

To maintain system reliability in 2045, a storage fleet's average duration needs to be…

- ***Short (~4-hrs)*** if dispatchable capacity is at least 5 GW and import capacity is unchanged
- ***Long (65-hrs+)*** if all dispatchable capacity is retired and import availability is less than 40% of current levels
- ***Seasonal (200-hrs+)*** if all gas capacity is retired and imports are eliminated, allowing all load to be served by local zero-carbon resources

Avg. Storage Size (Duration) Required to Maintain Reliability

2045



Longer-duration storage is needed if fewer dispatchable resources and imports are available

Note: Illustrative analysis based on Dominion's 2020 IRP. Assumes storage has 86% round trip efficiency.

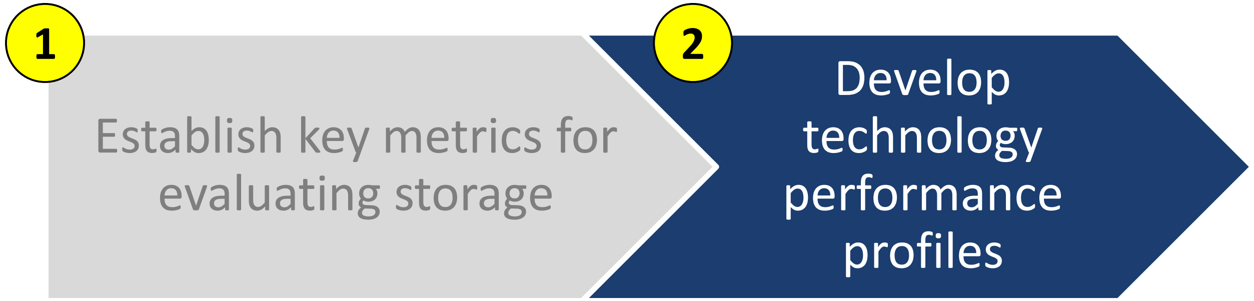
A proposed framework for evaluating storage needs

1

Establish key metrics for evaluating storage

- Focus on Task Force’s top priorities
- Cost-effectiveness / affordability is the overarching goal
- Non-economic considerations also are relevant

A proposed framework for evaluating storage needs



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2 Develop technology performance profiles

- Profile includes range of cost forecasts, operational characteristics
- Develop profile for each storage technology

A proposed framework for evaluating storage needs

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2 Develop technology performance profiles

3 Model storage additions

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- Simulate least-cost planning to determine cost-effective storage development pathway
- Similar to IRP, but with energy storage under a microscope
- Evaluate for a range of scenarios

A proposed framework for evaluating storage needs

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4 Scorecard-based evaluation of findings

- Focus on investment decisions that are robust across a range of scenarios
- Revisit regularly as technologies and system conditions evolve

Potential metrics for evaluating storage opportunities

- **Net economic benefit (i.e., impact on customer bills)**
- Reliability performance across a range of weather conditions
- Technology readiness level (see appendix)
- Safety risk
- Supply chain risk
- Degree of dependence on imports

Key considerations when modeling storage value

Realistic representation of storage performance

- Degree of operational foresight into future market prices/conditions
- Ability to "stack" multiple value streams

Accounting for the declining incremental value of energy storage

- As peaks flatten, economics begin to tilt in favor of longer duration storage

Accurate representation of connections to neighboring regions

- Import/export capability will become increasingly important
- Will neighboring regions have excess renewables supply at the same time as VA?

Accounting for how grid operations will evolve as the system decarbonizes

- Need to better integrate renewables
- Need to maintain reliability and resiliency in face of growing climate challenges

Transparency

- Storage operations are inherently complex, but model results will need to be accessible to a wide range of stakeholders with diverse backgrounds

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Additional Brattle storage resources

- "New York's Evolution to a Zero Emission Power System", Roger Lueken, Sam Newell, Jurgen Weiss, Stephanie Ross, Jill Moraski, presented to NYISO stakeholders, June 22 2020
- "Solar-plus-Storage: The Future Market for Hybrid Resources," Ryan Hledik, Roger Lueken, Judy Chang, Hannes Pfeifenberger, Jesse Cohen, and John Imon Pedtke, December 2019.
- "Determining Optimal Storage Deployment Levels," Ryan Hledik and Roger Lueken, Energy Storage Association webinar, December 11, 2018.
- "The Economic Potential for Energy Storage in Nevada," Ryan Hledik, Judy Chang, Roger Lueken, Johannes Pfeifenberger, John Imon Pedtke, Jeremy Vollen, October 1, 2018.
- "Storage-Oriented Rate Design: Stacked Benefits or the Next Death Spiral?" Ryan Hledik, Jake Zahniser-Word, Jesse Cohen, *The Electricity Journal*, October 2018.
- "Getting to 50 GW? The Role of FERC Order 841, RTOs, States, and Utilities in Unlocking Storage's Potential," Roger Lueken, Judy Chang, Johannes P. Pfeifenberger, Pablo Ruiz, and Heidi Bishop, Presented at Infocast Storage Week, February 22, 2018.
- "Battery Storage Development: Regulatory and Market Environments," Michael Hagerty and Judy Chang, Presented to the Philadelphia Area Municipal Analyst Society, January 18, 2018.
- "Stacked Benefits: Comprehensively Valuing Battery Storage in California," Ryan Hledik, Roger Lueken, Colin McIntyre, and Heidi Bishop, Prepared for Eos Energy Storage, September 12, 2017.
- "The Hidden Battery: Opportunities in Electric Water Heating," Ryan Hledik, Judy Chang, and Roger Lueken, Prepared for the National Rural Electric Cooperative Association (NRECA), the Natural Resources Defense Council (NRDC), and the Peak Load Management Alliance (PLMA), February 10, 2016.
- "The Value of Distributed Electricity Storage in Texas - Proposed Policy for Enabling Grid- Integrated Storage Investments," Ioanna Karkatsouli, James Mashal, Lauren Regan, Judy Chang, Matthew Davis, Johannes Pfeifenberger, and Kathleen Spees, Prepared for Oncor, March 2015.

Appendix

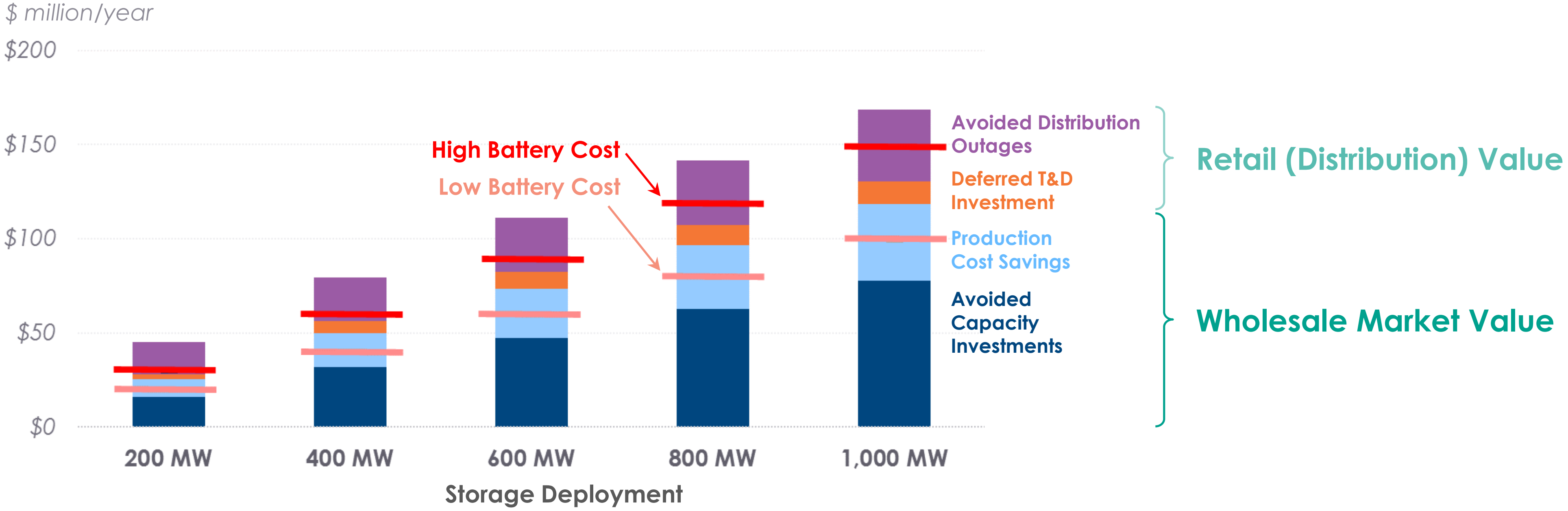
Technology Readiness Level (TRL): A metric for characterizing technological maturity

Technology Readiness Level			*Performance Threshold*
Deployment	**9**	**Full-Scale System Proven in Operational Environment**	**Full-scale plant operating with commercial off-take**
	8	**System Complete and Qualified**	**Initial or demonstrator (commercial scale) plant operational**
	7	**System Pilot Demonstration in Operational Environment**	**Pilot Project operational**
Development	**6**	**Technology Demonstrated in Relevant Environment**	**Pilot Plant under construction/testing**
	5	**Technology Validated In Relevant Environment**	**Pilot Project & technology announced, but still under development**
	4	**Technology Validated in Lab**	**Prototype functions successfully**
Research	**3**	**Experimental Proof Of Concept**	**Prototype under construction**
	2	**Technology Concept Formulated**	**Prototype design complete**
	1	**Basic Principles Observed**	**Research paper published**

Source: Derived from material developed by Sargent & Lundy.

Virginia’s market/regulatory structure could be a barrier to realizing the full value of energy storage

Currently, there are limits on the ability to “stack” retail and wholesale value streams



Total System Benefits and Costs of Storage at Various Deployment Levels

Brattle Simulation of Nevada Power System, 2030

Sources and Notes:

Hledik et al. (2018). The Economic Potential for Energy Storage in Nevada