# Utility-Scale Storage in High-RE Power Systems

## If, When, What Type, How Much, and Where?

Jessica Katz, NREL | Asia Clean Energy Forum | June 2018

# Overview

**In power systems with increasing levels of variable RE…**

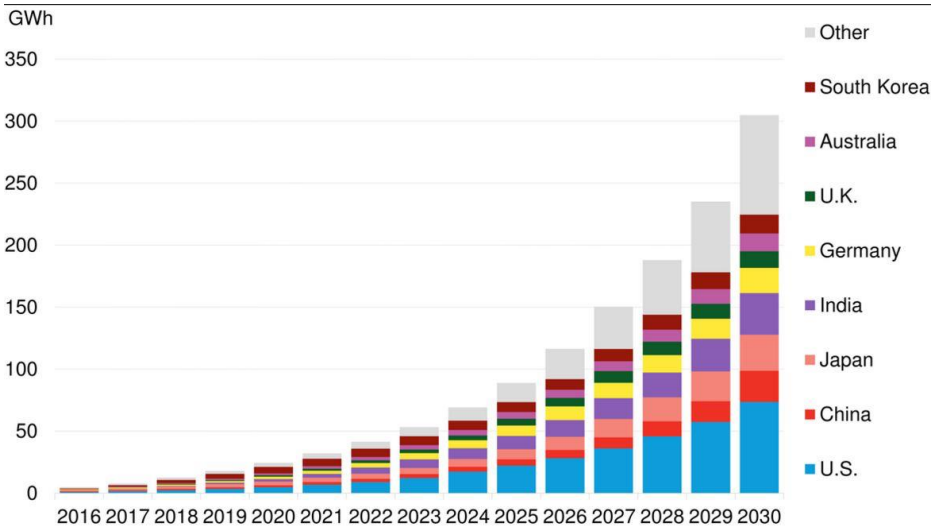
- **What type** of storage will be valuable?
- **When** does storage become cost-effective?
- Under what conditions will widespread storage deployment be feasible? (**If?**)
- **How much** storage is appropriate?
- **Where** should storage be located?

*Answers to these questions are complex and system-specific. Some trends are emerging…*

# Global trends: Decreasing price, increasing hype

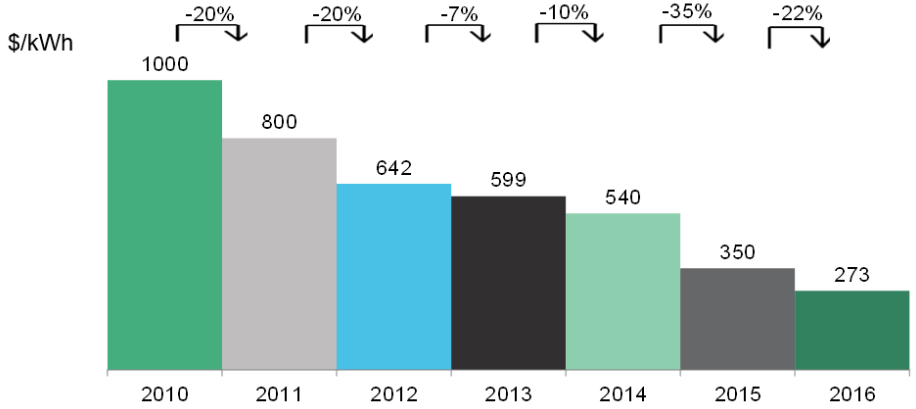
**Global Cumulative Storage Deployments, 2016-2030 (GWh)**

*Source: Bloomberg New Energy Finance (November 2017)*




**Lithium-ion battery price survey, 2010-16 ($/kWh)**

*Source: Bloomberg New Energy Finance, Lithium-ion Battery Costs and Market (July 2017)*



# **What type** of storage will be valuable in a high RE system?

- Applications for energy storage are defined by the following parameters:
  - **Power capacity**: rate of charge or discharge (in kilowatts or megawatts
  - **Energy capacity**: amount of stored energy (in kilowatt-hours or megawatt-hours)

Source: Tesla

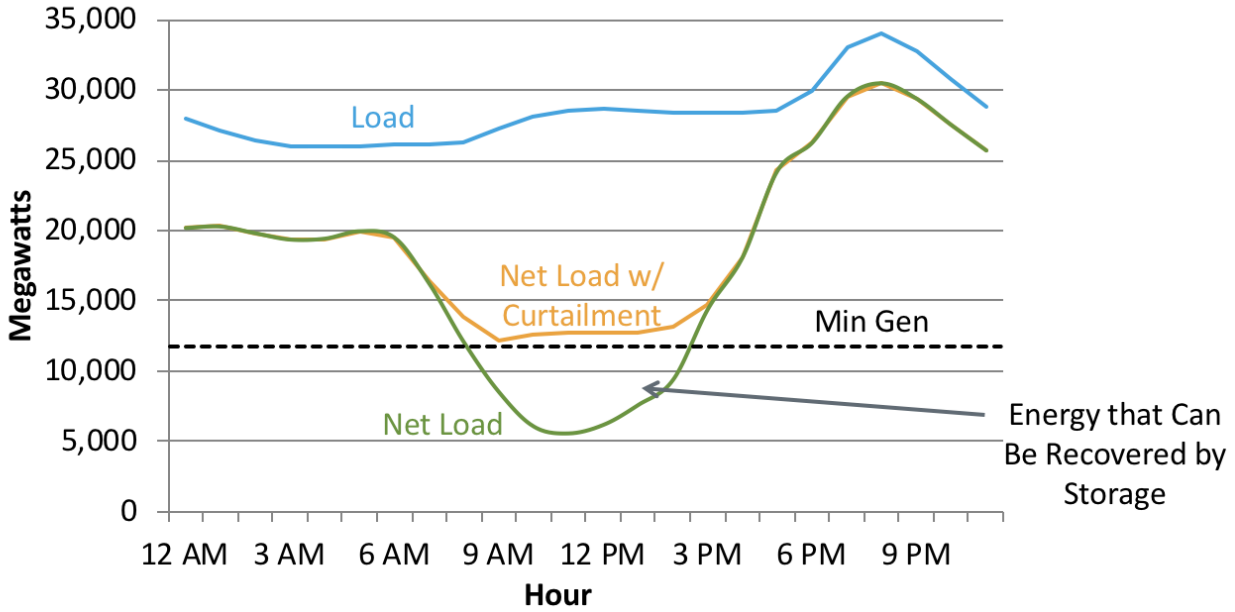
  - **Storage duration**: amount of time storage can discharge at its power capacity before depleting its energy capacity

*E.g., a battery with 1 MW of power capacity and 4 MWh of usable energy capacity will have a storage duration of 4 hours.*

# Example services from storage in a high RE system

- Shorter duration (<1 hour)
  - Regulation reserves to balance short-term variability
  - Fast frequency response to replace lost inertia
  - Voltage support as RE is deployed in remote locations
- Longer duration (>1 hour)
  - Energy shifting to recover curtailed RE, arbitrage prices
  - Peaking capacity resource

*Other flexibility resources can also provide these services*




Source: Denholm et al., *Overgeneration from Solar Energy in California: A Field Guide to the Duck Chart*, 2015

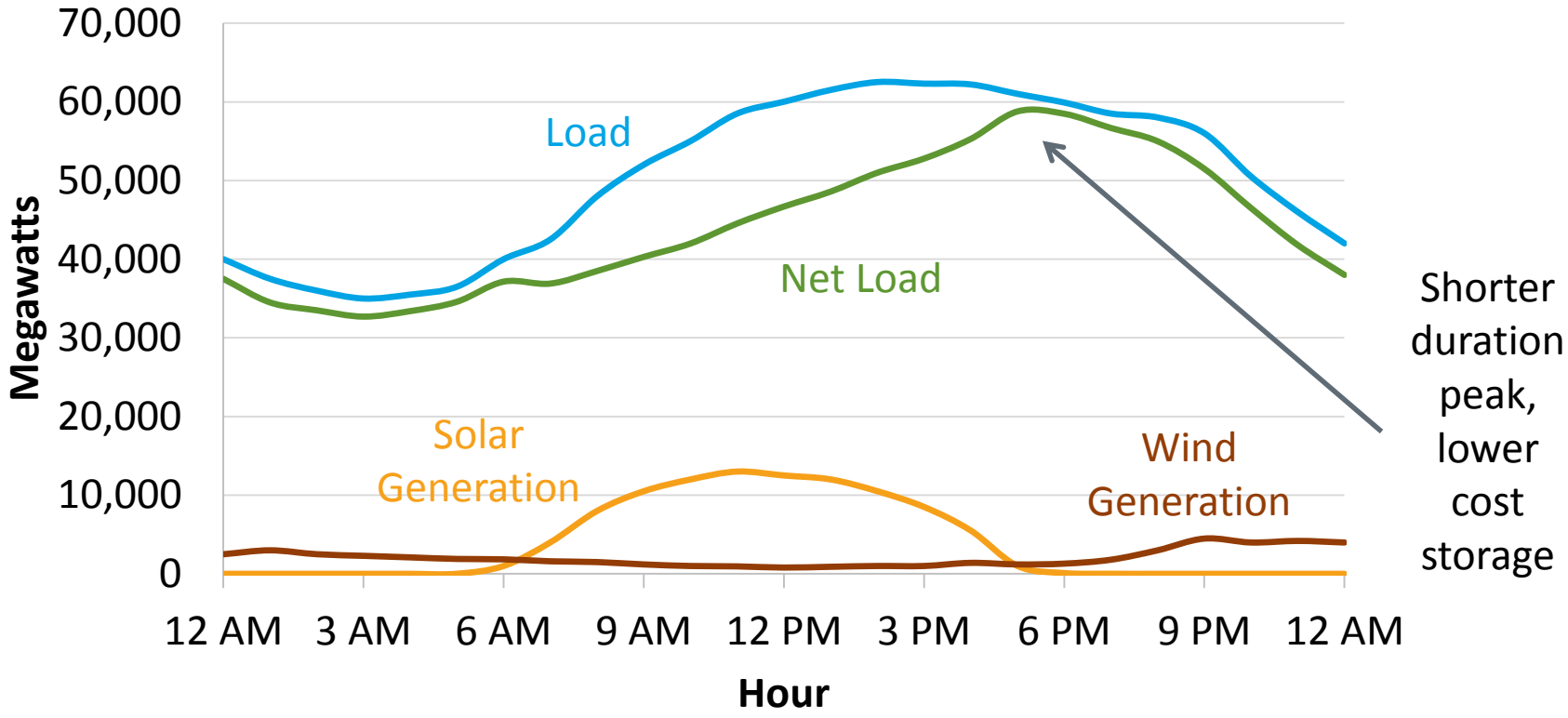
# **When** does storage become cost effective?

*Storage is always useful, but might not be economic*

- Several power systems have already achieved >10-20% variable RE penetration without significant energy storage
- NREL's grid integration studies show U.S. power systems can achieve 35% variable RE penetrations through lower-cost flexibility options (e.g., system operations, demand response)
- At higher penetration levels, storage could be of value
  - Tipping point is system-specific and depends on storage cost, generation mix, fuel prices, ancillary service requirements

# Higher penetrations of RE will change the economics of battery storage

- Renewable energy can lower the cost of using batteries for peak demand reduction

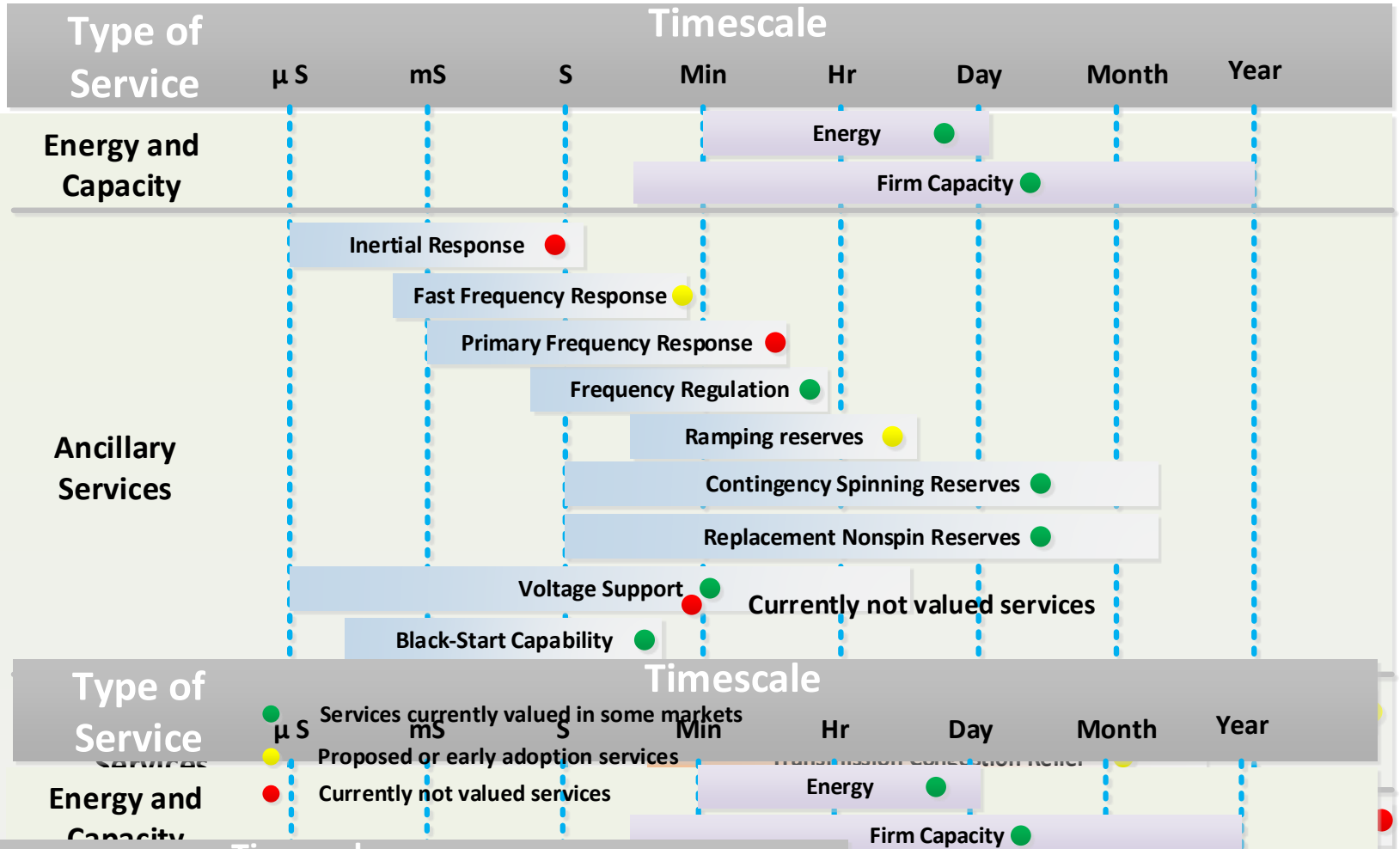



Some power systems are nearing a tipping point for 4-hour storage providing capacity services instead of conventional generators

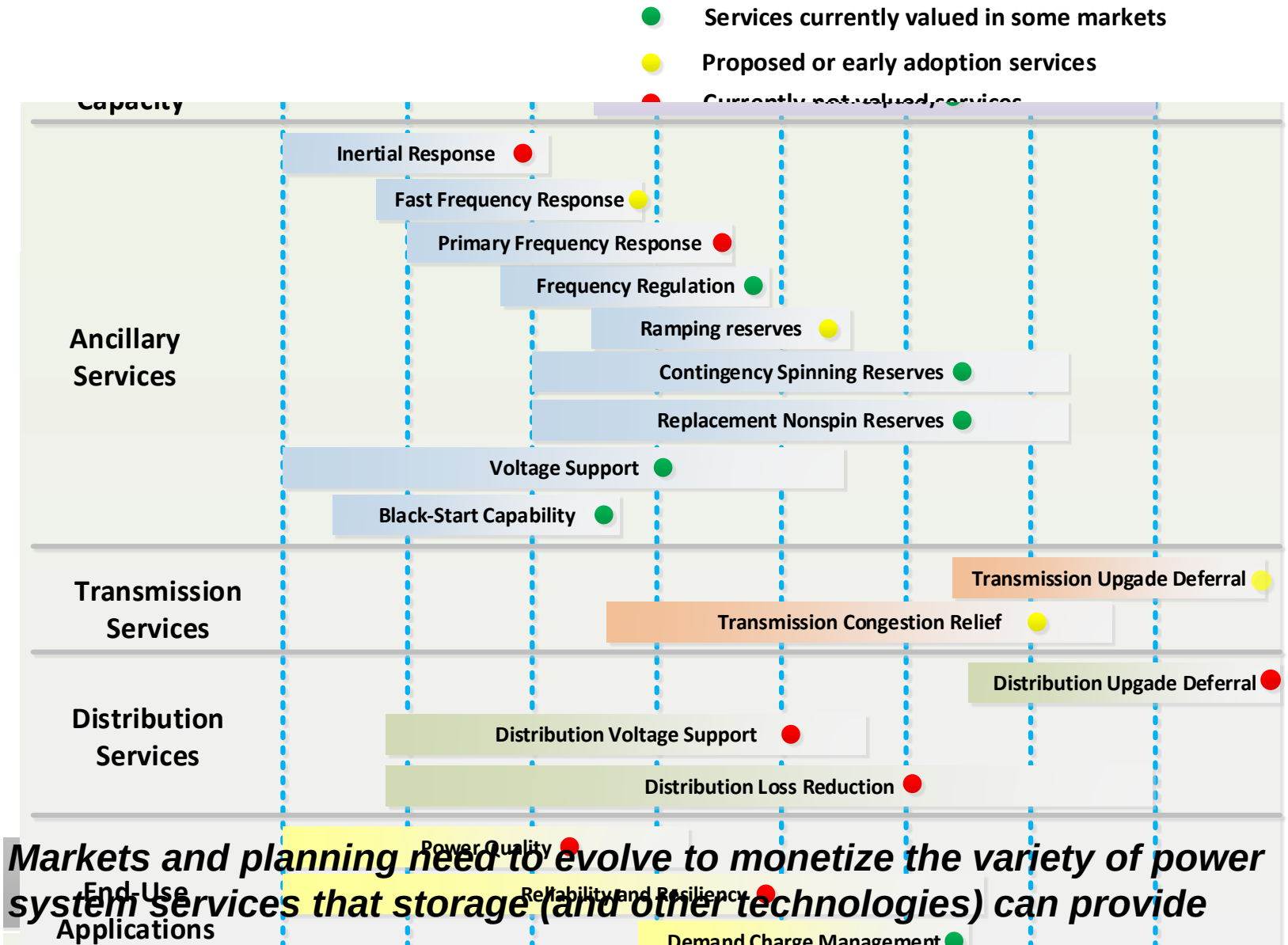
Source: Denholm et al., *Overgeneration from Solar Energy in California: A Field Guide to the Duck Chart,* 2015

# Under what conditions will widespread storage deployment be feasible? (**If?**)

***Multiple value streams… but where are the markets?***



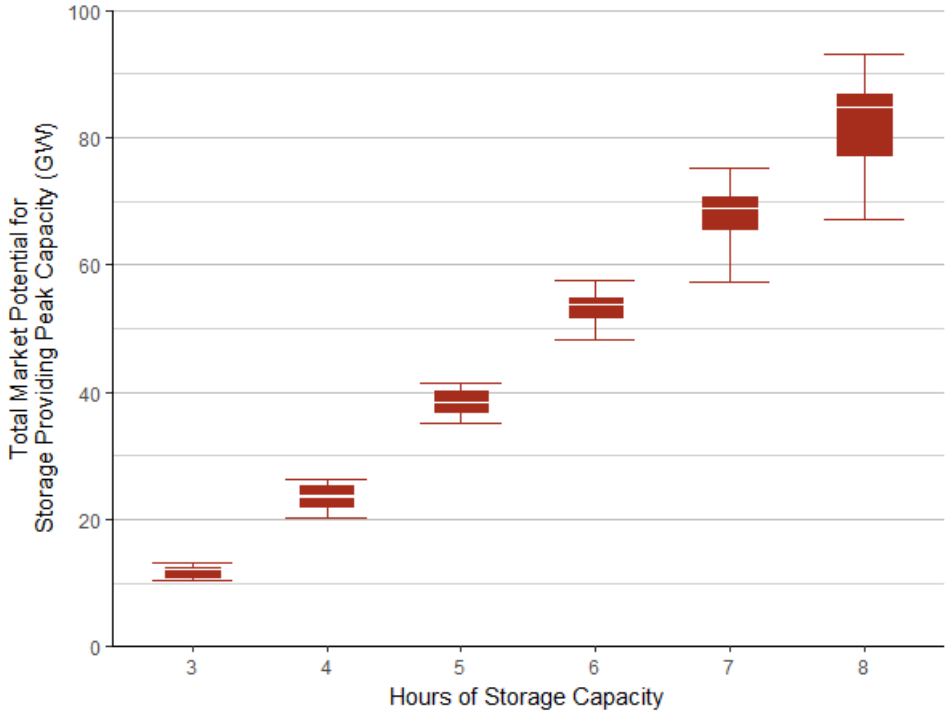
# Under what conditions will widespread storage deployment be feasible? (**If?**)




***Markets and planning need to evolve to monetize the variety of power system services that storage (and other technologies) can provide***

# **How much** storage is appropriate?

- Driven by market saturation for different services. E.g., markets in the U.S.:
  - Frequency regulation: 2.5GW
  - Replace peaking capacity from retired plants: 100GW
- More variable RE could increase the need for grid services, but not linearly
  - Integration studies show a relatively small increase in operating reserve requirements as solar and wind are added
  - Regulation reserve requirements have decreased in Texas as wind penetration has increased




Source: P. Denholm, NREL

***Storage will compete with other flexible resources to serve these markets. Best practice is to define technology neutral needs of the system and allow different resources to compete to efficiently meet these needs.***

# **Where** should storage be deployed?

1. Flexible siting to provide system-wide benefit
   - Defer investments in transmission and distribution
   - Avoid transmission and distribution losses
2. Coupled with other generation technologies (e.g., solar + storage, gas + storage)
   - Enhance unit flexibility
   - Reduce costs through shared componentry
   - Provide streamlined acquisition for off-takers
   - Can lead to inefficient levels of storage if required with all variable RE (ignores benefits of geographic diversity)

*Southern California Edison hybrid battery storage, gas turbine peaker system*

# Summary and takeaways*

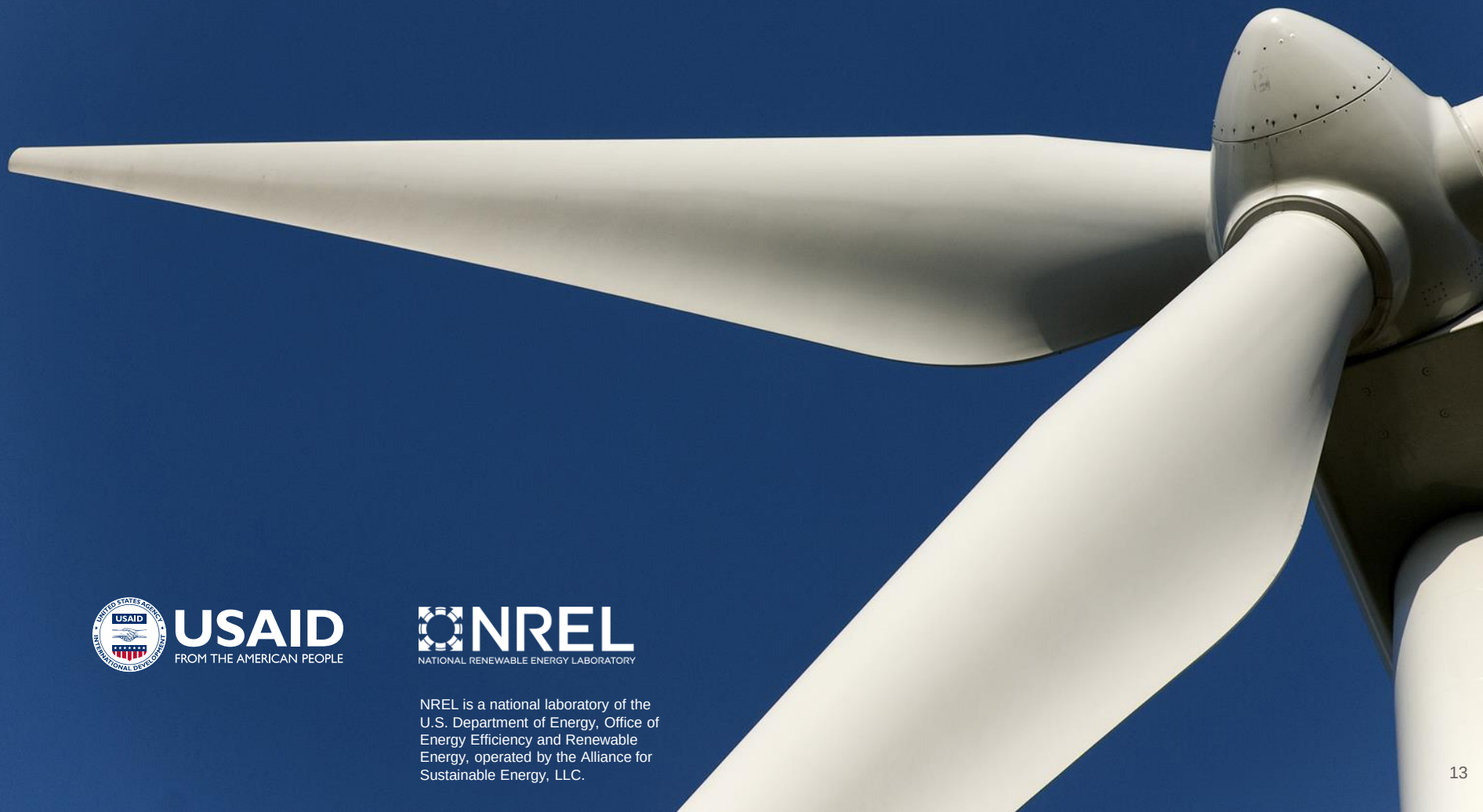
***In power systems with increasing levels of variable RE, deploy utility-scale storage…***

- Of TYPES that will deliver services that are underprovided and/or likely to diminish as the power grid evolves
- WHEN storage technologies are more cost-effective than other sources of power system flexibility
- IF storage is cost-effective *and* policy, regulatory, and market frameworks clearly monetize value stream(s)
- IN QUANTITIES commensurate with the market share for the particular service(s) storage can cost-effectively provide
- WHERE it can provide the most value at the system level; or, strategically as a hybrid with other generators (not just RE!)

*Major generalizations with many caveats! Analysis (e.g., grid integration studies) can help identify the system-specific potential for storage.

Thank you!

**http://greeningthegrid.org**



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