



# Energy Storage and Impact on Renewable Power Grid Integration

Fifteenth Annual Symposium on Energy  
April 12, 2019, Syracuse University

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# NREL at a Glance

1,998

**Employees,**  
Plus more than

**600**

early-career researchers  
and visiting scientists



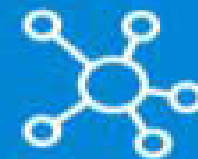
**World-Class**

facilities, renowned  
technology experts

nearly  
**820**

**Partnerships**

with industry,  
academia, and  
government



**Campus**

operates as a  
living laboratory

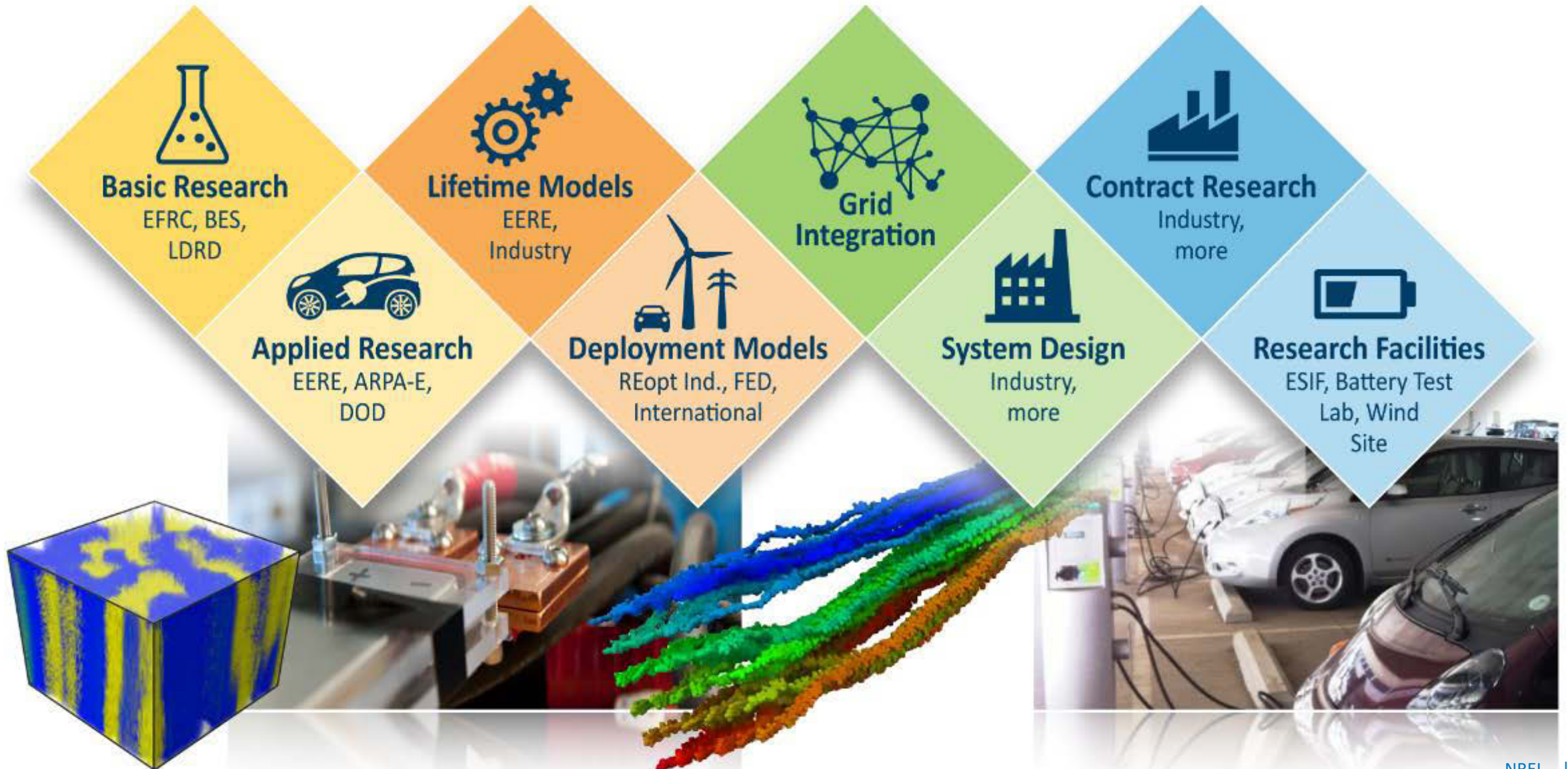
**\$1.1B**  
annually

**National  
Economic  
Impact**

- NREL is the only DOE national laboratory dedicated to RE and EE: Love of Mission
- Strong growth since 2006
- Fundamental R&D, analysis, and deployment activities around the globe



# NREL's Energy Storage Capabilities: A Full Portfolio



# Energy Storage (and Batteries specifically) are all over the energy news...

Tesla's giant battery in Australia made around \$1 million in just a few days

China is now investing in battery manufacturing like they invested in PV manufacturing in 2008! I've seen the huge facilities...

- Speaker, GTM Solar Summit

## Xcel Attracts 'Unprecedented' Low Prices for Solar and Wind Paired With Storage

Bid attracts median PV-plus-battery price of \$36 per megawatt-hour. Median wind-plus-storage bids came in even lower, at \$21 per megawatt-hour.

**EurekAlert!**  
The Global Source for Science News

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PUBLIC RELEASE: 3-APR-2018

NREL research overcomes major technical obstacles in magnesium-metal batteries

DOE/NATIONAL RENEWABLE ENERGY LABORATORY

The latest analysis by research company BloombergNEF (BNEF) shows that the benchmark levelized cost of electricity,<sup>[1]</sup> or LCOE, for lithium-ion batteries has fallen 35% to \$187 per megawatt-hour since the first half of 2018. Meanwhile, the benchmark LCOE for offshore wind has tumbled by 24%.



# Energy Storage Systems: From Watt-Hours to Gigawatt-Hours

APPLICATIONS

MODES

A range of **modes** allows a wide variety of **applications**.

And **larger production volume** leads to **greater cost reduction**.

Transportation, inverters (auxiliary energy), UPS...

Large auxiliary power supply, renewable electricity sources, electricity grid services...

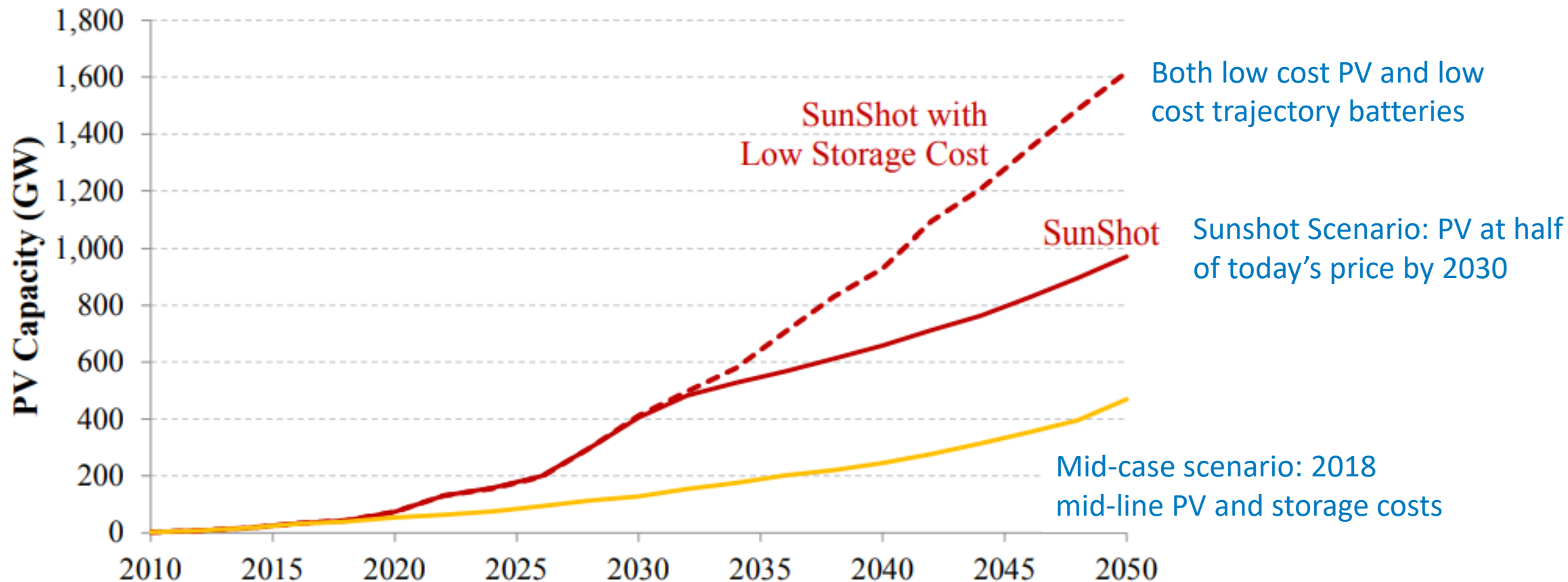
MWh – GWh

kWh – MWh

Wh



# Cheaper PV + cheaper batteries = more of both



- SunShot 2030 for Photovoltaics (PV): Envisioning a Low-cost PV Future
  - <https://www.nrel.gov/docs/fy17osti/68105.pdf>
  - Mid-case storage cost reductions (~\$260/kWh by 2030), whereas the other assumes low storage costs (LSC) are achieved (~\$130/kWh by 2030)
  - NOTE: distributed and utility-scale not broken out above.

# But... are batteries the answer to everything?

... are batteries and energy storage necessary for integrating variable solar and wind?

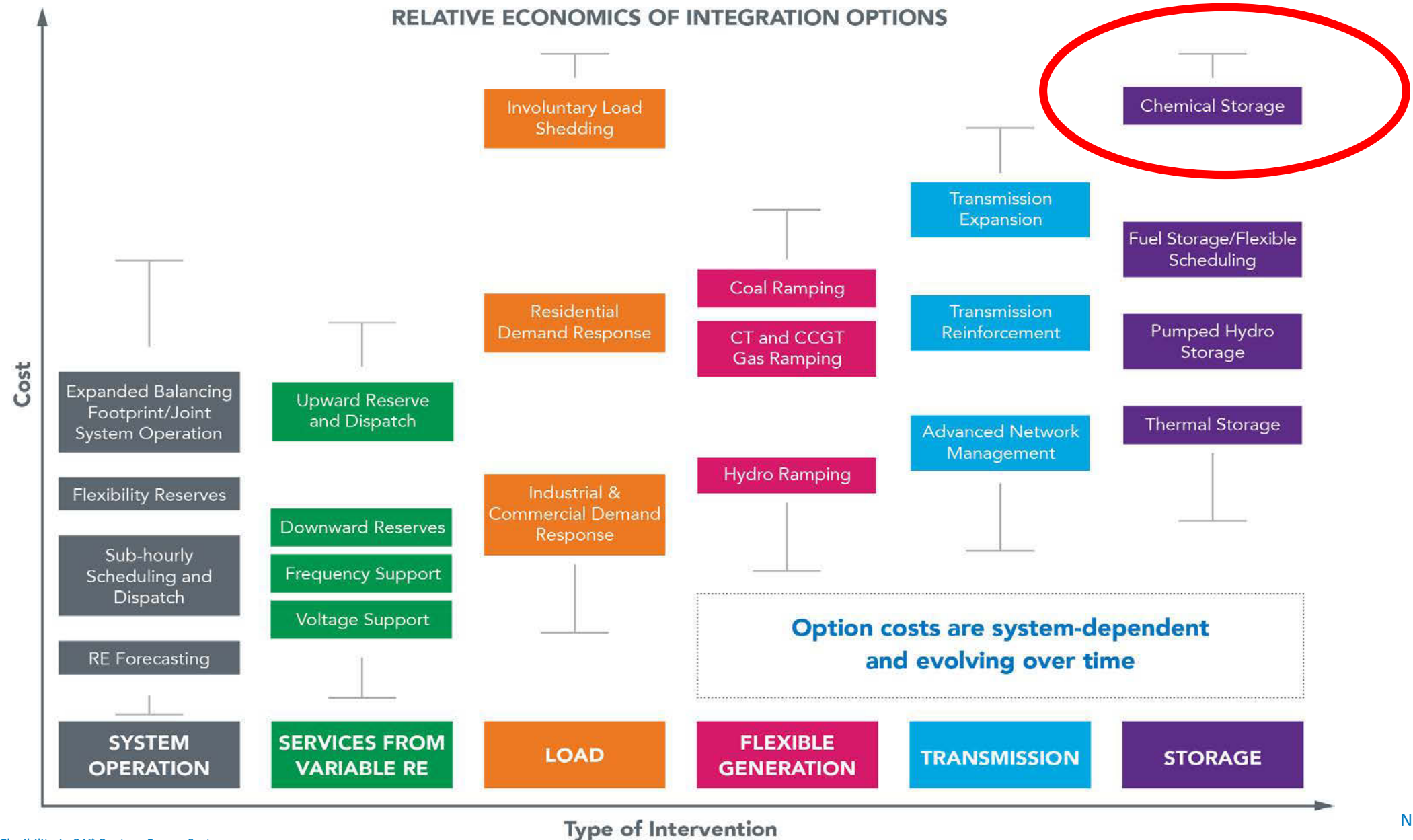
... at what levels of solar and wind (10%, 30%, 100%)??

...what specific roles does storage play??

...what are the other methods for integrating more solar/wind into the grid?



# Grid Flexibility can come from many sources





# Two Examples of Potentially Cost Effective Storage Applications

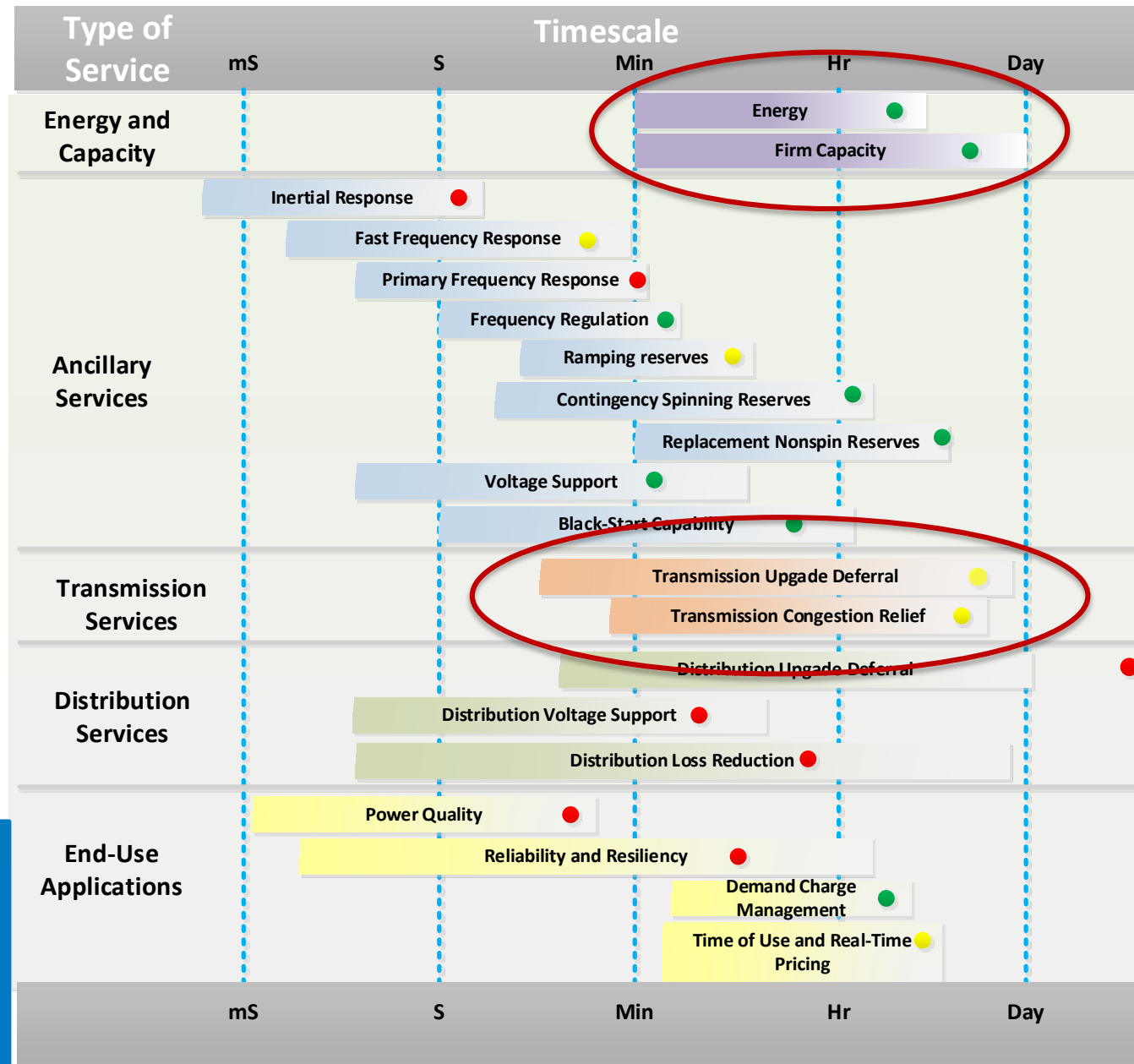
## Peaking Capacity

Longer duration  
(>1 hour)

- Peaking capacity resource
- Energy shifting to recover curtailed RE, arbitrage prices
- Can also provide transmission services

- Services currently valued in some markets
- Proposed or early adoption services
- Currently not valued services

What type?



# Two Examples of Potentially Cost Effective Storage Applications

What type?

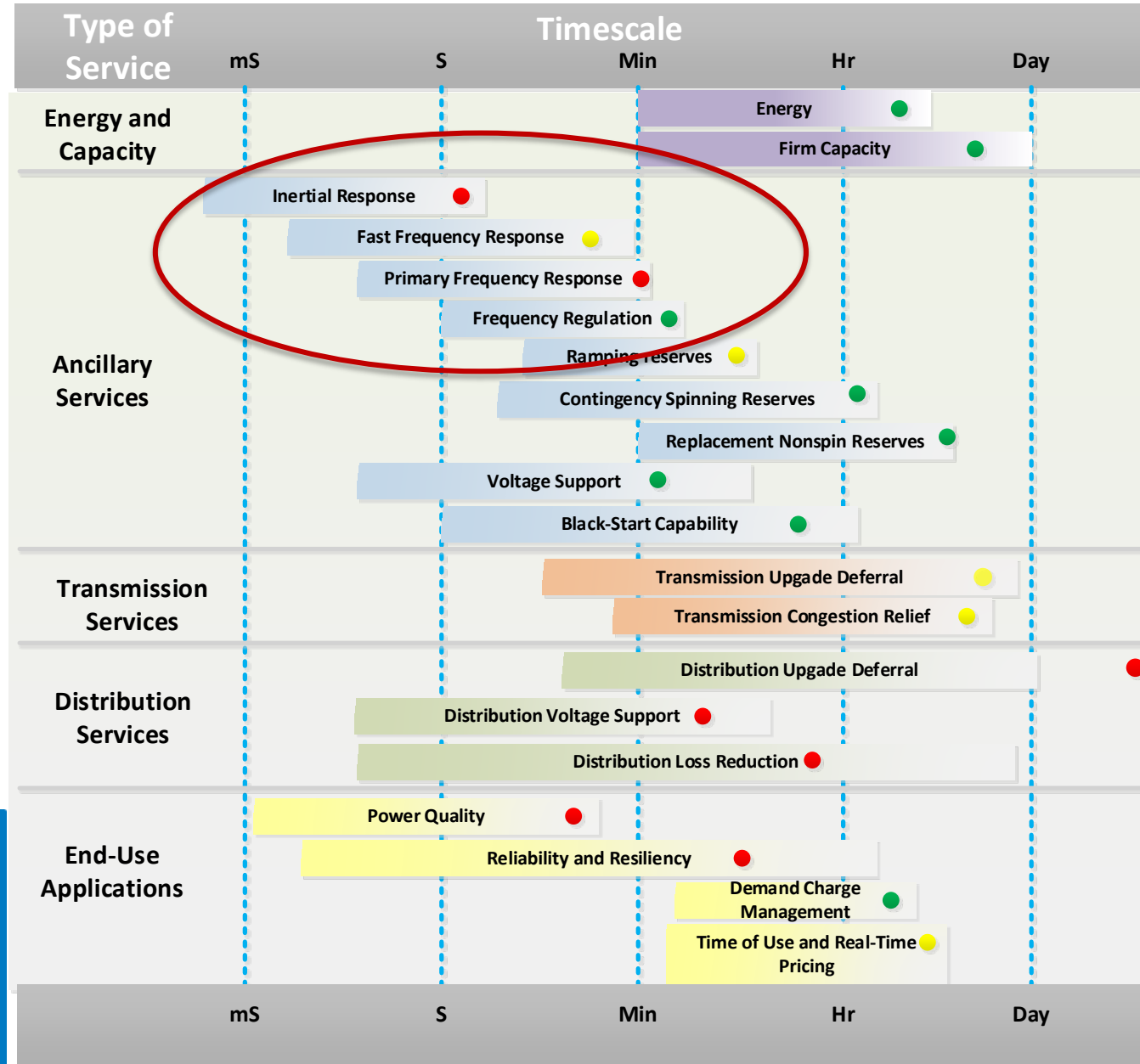
## Operating Reserves

### Shorter duration

(<1 hour)

- Regulation reserves to balance short-term variability
- Fast frequency response to replace lost inertia

- Services currently valued in some markets
- Proposed or early adoption services
- Currently not valued services



# General Insights on Storage for Power Systems

- In most power systems, storage is not yet needed to integrate larger amounts of variable RE.
- Storage applications need to consider duration, location, and ability to combine and monetize multiple services
- Storage is increasingly cost competitive for short-duration ancillary services, and long duration applications that combine some elements of capacity, energy and transmission services
- As RE penetration increases, this increases the value of storage, and storage becomes an increasingly valuable tool for RE integration
  - There are important potential tradeoffs when considering co-location of storage with RE or siting storage closer to load
- Storage costs continue to drop – therefore, we need to monitor closely



# Thank You

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NREL/PR-6A20-73776

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Office of Energy Policy and Systems Analysis. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.

