Energy Storage Technologies for Operating Nuclear Power Plants

Heat Storage for Gen IV Reactors for Variable Electrify from Base-Load Reactors

July 23-24, 2019

Exelon

Exelon overview

$21B
Being invested in utilities through 2021

$52M
In 2017, Exelon gave approx. $52 million to charitable and community causes

#1
zero-carbon energy provider in America

210 TWh
Customer load served

35,200
Megawatts of total power generation capacity

10M
Six utilities serving 10M electric and gas customers, the most in the U.S.

34,600
employees

$33.5B
Operating revenue in 2017

FORTUNE 100
Exelon is a FORTUNE 100 company

2M (Approx.)
Exelon's Constellation business serves residential, public sector and business customers

11,470
transmission line miles for utilities

9.5M
Smart meters installed

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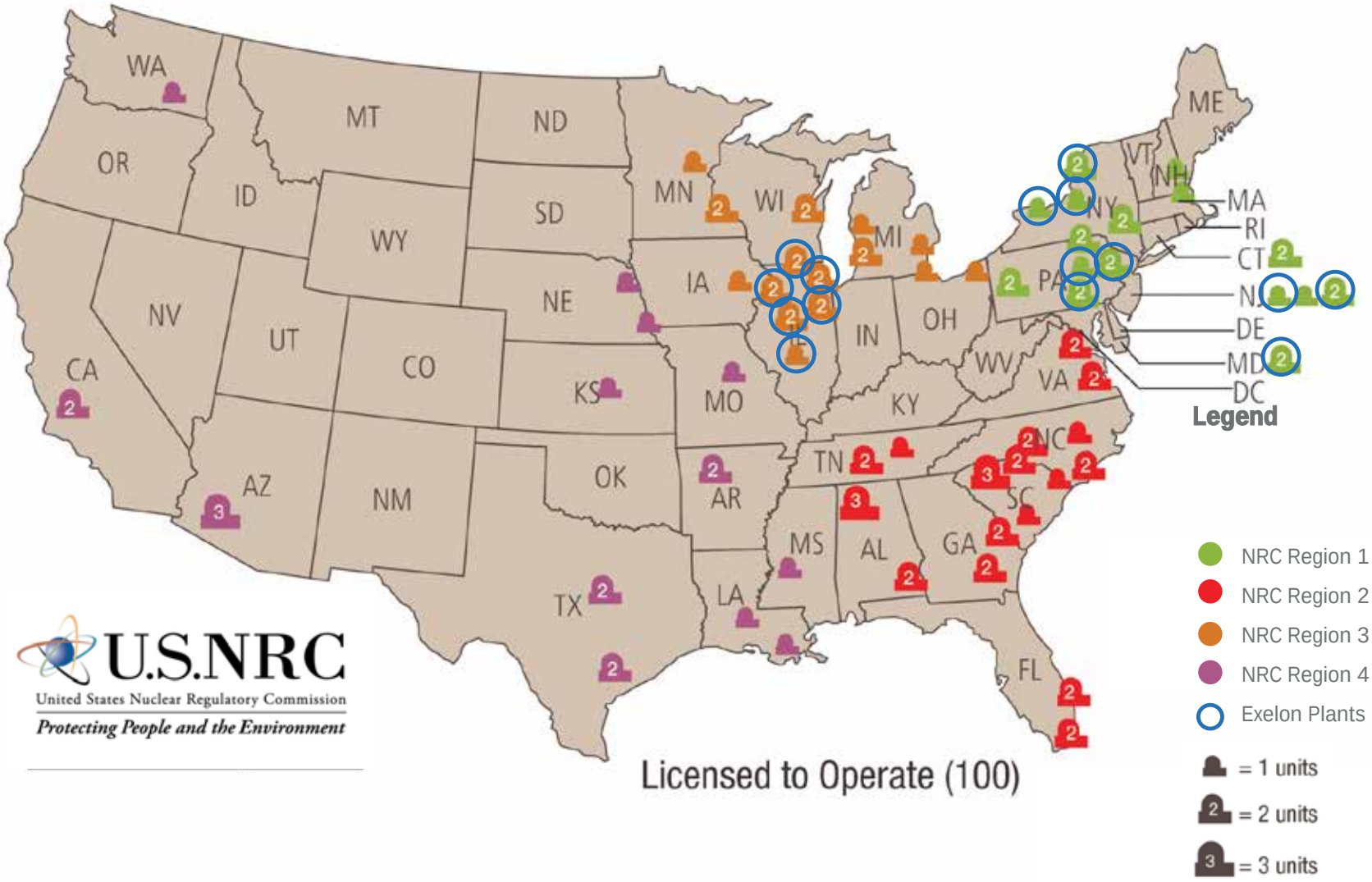
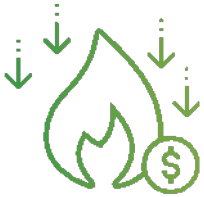
Exelon nuclear plants are located in competitive electricity market regions



Nuclear plant profitability has decreased, due to a confluence of factors



Natural gas prices (which fuels marginal generators in many regions) have dropped by more than 50%

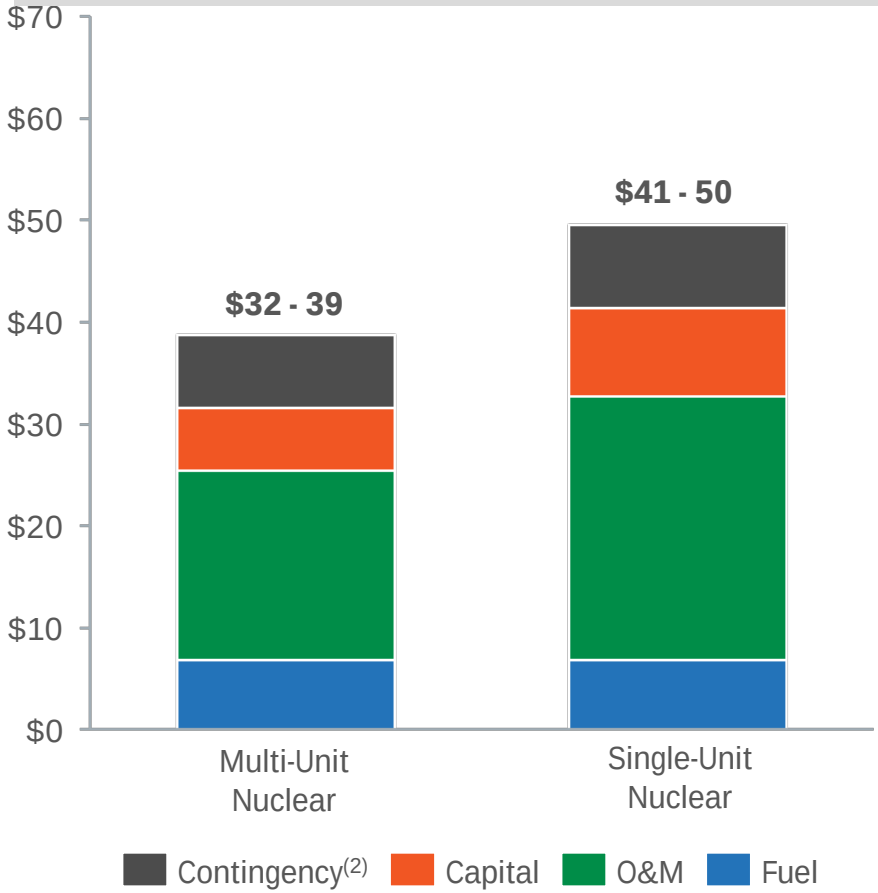
Load growth is down due to both the economy and increased energy efficiency programs

Renewables penetration has suppressed wholesale energy prices in some regions

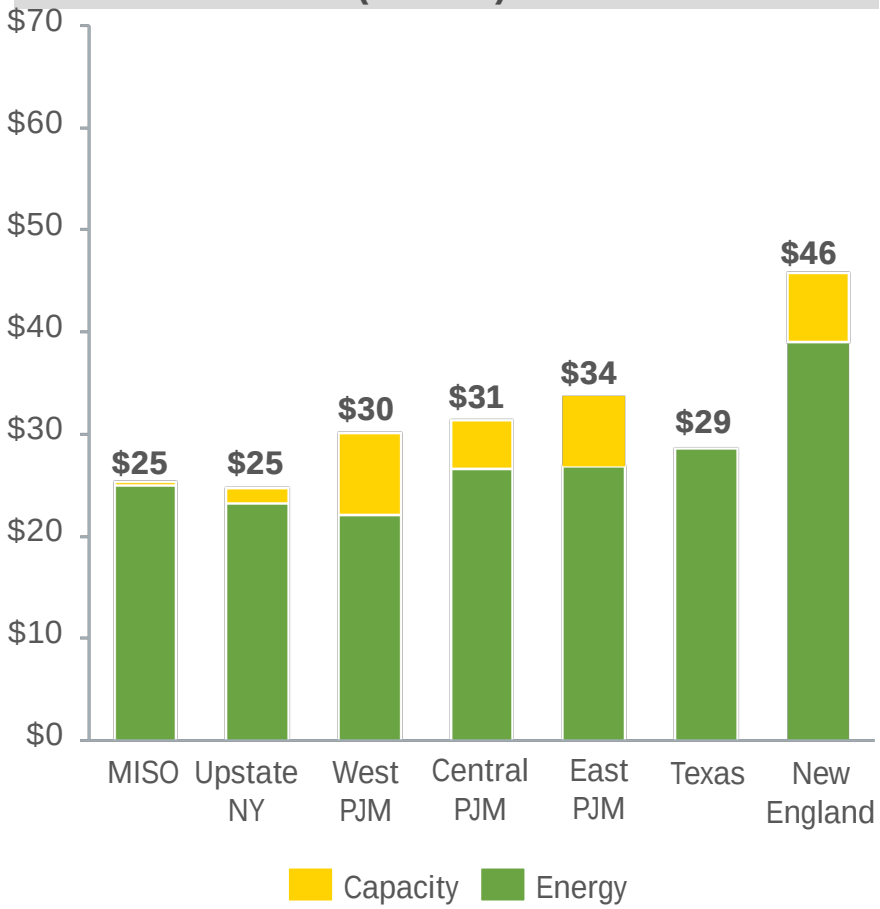
Across the U.S. nuclear fleet, operating costs have increased (albeit with reductions in recent years)

Merchant nuclear plants in all regions of the country face a shortfall of market

Average 2016 Nuclear Costs ($/MWh)[1]



2021 Forward All-In Nuclear Market Prices ($/MWh)[3]



(1) Source: Nuclear Energy Institute, "Nuclear Costs in Context," August 2017
(2) Contingency (or risk) is calculated as 10% of total costs plus $4/MWh
(3) Based on 6/4/2018 NYMEX forward energy prices for relevant hub less 2015-2017 average basis differential to nuclear plants

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Closing nuclear plants is detrimental to achieving carbon reductions goals

Between 2013 and 2014, **four nuclear plants that generated more electricity than all solar electricity produced in the U.S.** in 2014 were prematurely closed. Their closure resulted in the **carbon dioxide equivalent of adding three million new cars on the road**.

If all at-risk reactors close, the US will **lose the power equivalent of five times all solar power generated** in 2015, and emissions will rise, adding the carbon dioxide-equivalent of **13 million new cars on the road**.

Nuclear plants generally employ **400 – 700 workers each**, at salaries that are more than **30% higher than typical wages** in their areas.

*EnvironmentalProgress.org

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Energy storage technologies and deployment

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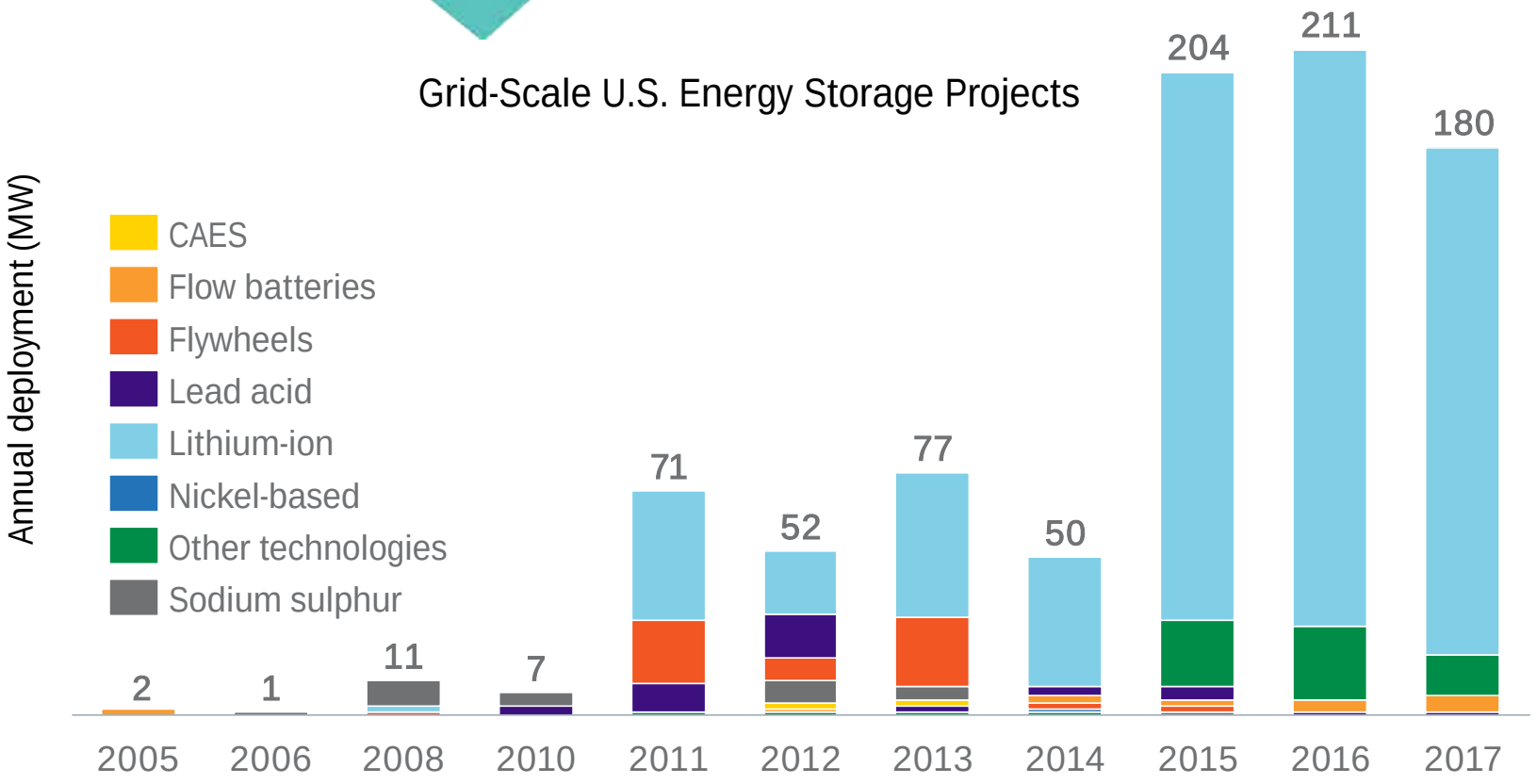
Lithium-Ion Batteries Dominate U.S. Energy Storage Projects



- As of May 2018, the cumulative capacity of grid-scale energy storage deployed in the U.S. was 955 MW. (Scope: grid-scale systems have > 500 kW or > 500 kWh / system)
- Over 90% of the energy storage projects deployed in the U.S. in 2017 used Li-ion batteries.
- Wholesale market rules determine battery installation opportunities for grid-scale systems, such as the 2015 deployment of Li-ion battery energy storage projects to serve the frequency regulation market in PJM.

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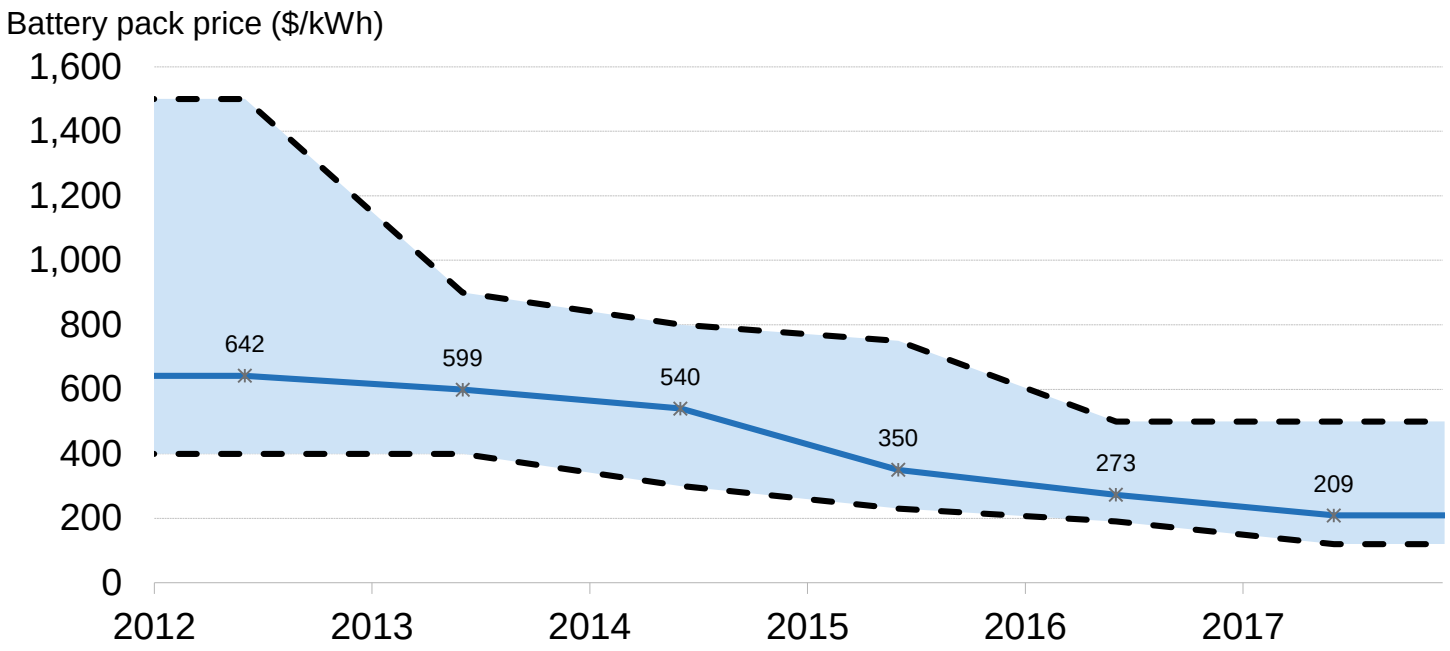
Li-ion battery pack prices are dropping



- Reported battery pack purchase prices ranged between $120/kWh and $500/kWh in 2017, primarily due to differences in order volume.
- High-volume orders from EV manufacturers obtained the lowest prices, and the volume-weighted average of Li-ion battery pack prices was $209/kWh.
- Fully-installed costs for a battery energy storage system ranged from $400 - $1400 / kWh in 2017.

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FERC Order 841 on Energy Storage

FERC Order 841 sets tariff rules for wholesale market participation of energy storage resources

Timeline

Nov. 2016	Feb. 2018	Feb. 2019	Feb. 2020
Rulemaking issued for Order 841	FERC Order 841 approved	Tariff rules due from RTOs/ISOs	Implementation of new tariff rules expected

FERC Order 841 Content

FERC Order 841 directs wholesale market operators to devise new tariffs that will:

- Allow energy storage resources to participate in wholesale market as **both a buyer and a seller of electricity**
- Establish a minimum size, not to exceed 100 kW, for energy storage resources to participate in RTO/ISO markets
- Allow storage to provide **energy**, **capacity** and **ancillary services** (including black-start and reactive power services)

Context

- California (CAISO) already allows energy storage to participate in wholesale power markets
- California is also moving towards implementing rules to govern "revenue stacking" for energy storage projects that provide multiple energy services
- PJM has hosted working groups towards developing rules for energy storage participation

Implications

- FERC Order 841 will reduce barriers and encourage a level playing field for energy storage resources to participate in inter-state wholesale electricity markets
- As markets mature, energy storage will compete against conventional peaking plants

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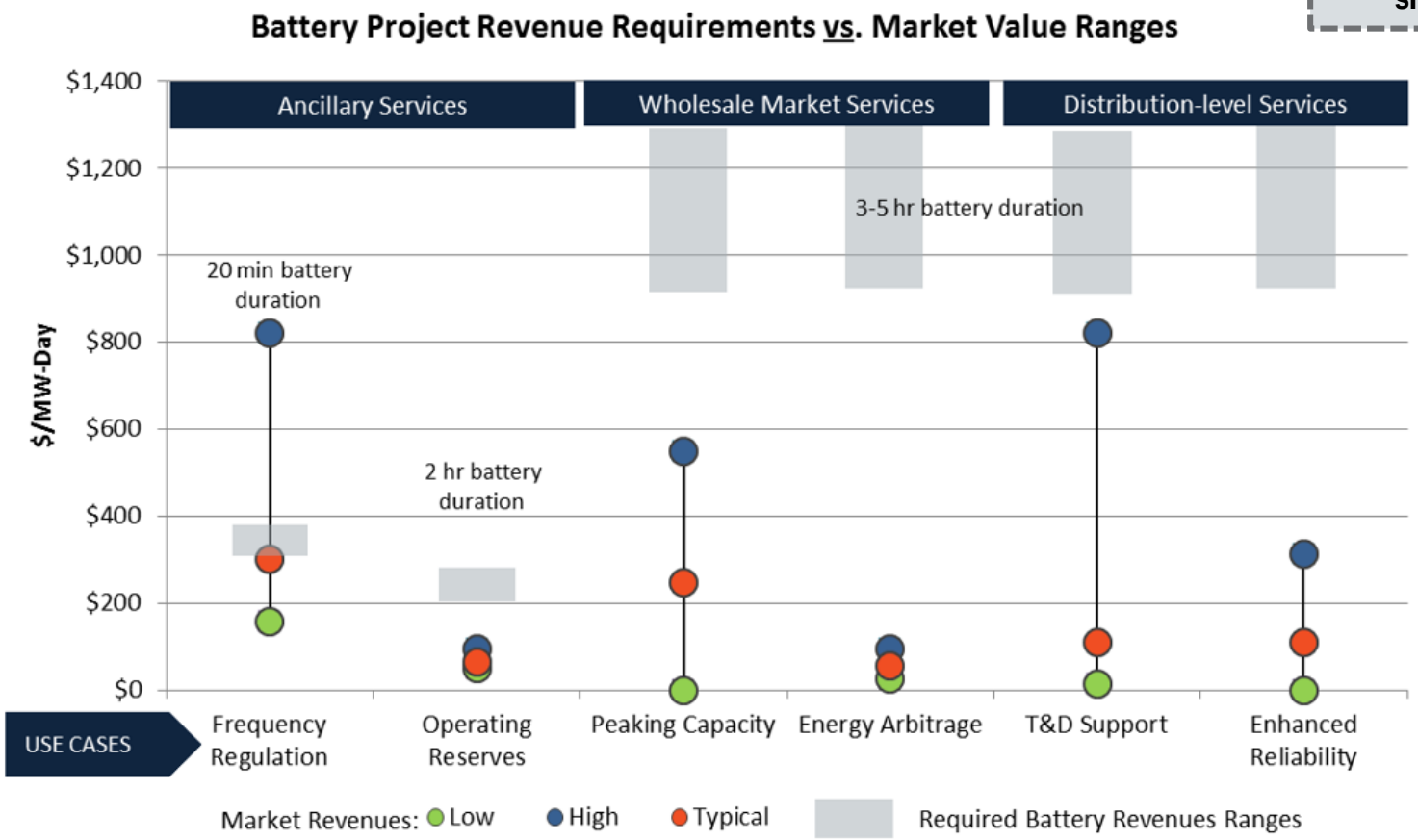
Market Opportunities for Grid-Connected Batteries

2016 market snapshot



- Frequency Regulation has dominated wholesale-market battery applications to date.
- Peaking Capacity and T&D Support applications may also become competitive as battery revenue requirements shrink and market participation rules evolve.

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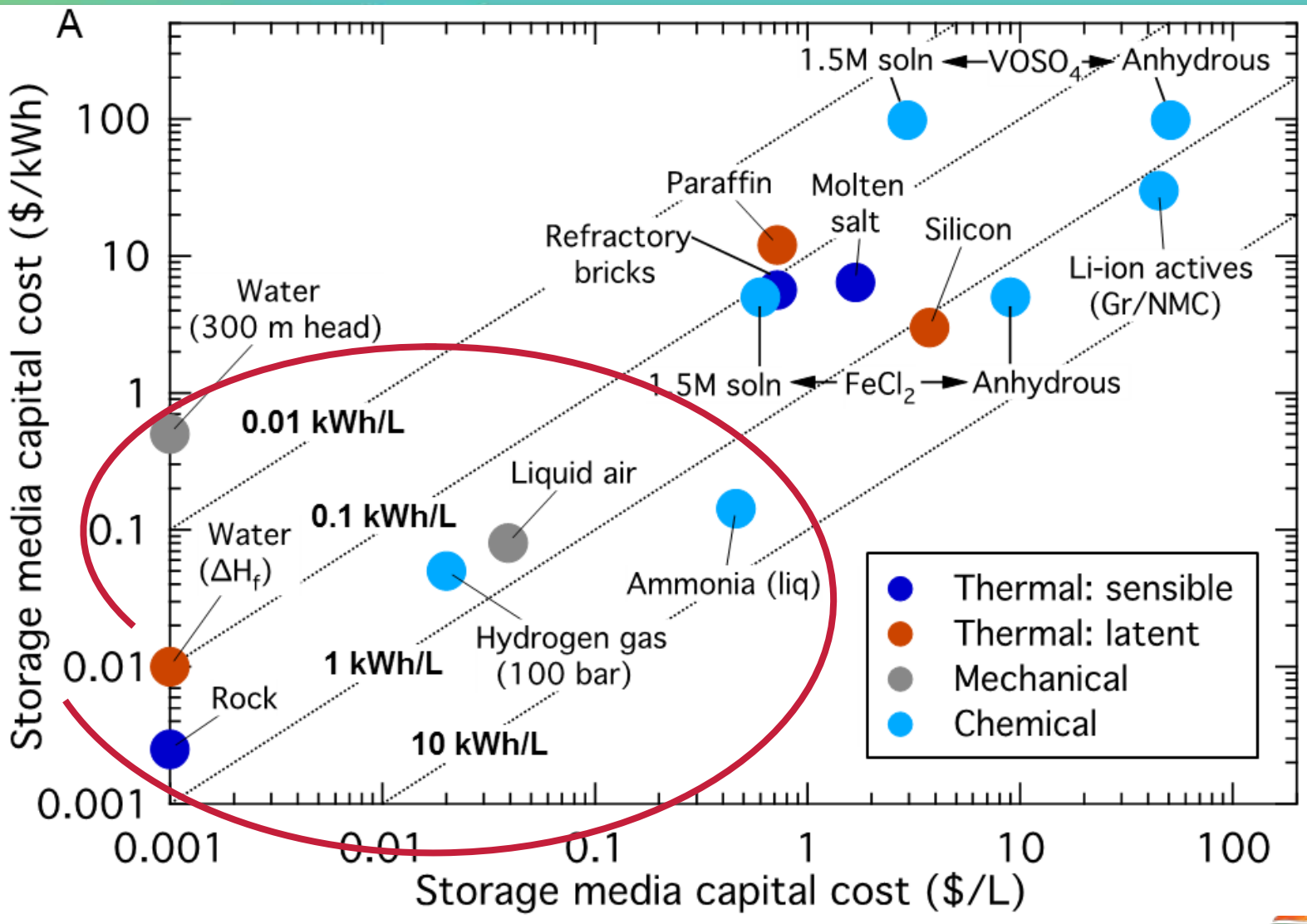
Other storage options are possible



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