Perspectives on Long Duration Electricity Storage

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The (v2) thinking behind the DAYS program

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Joule *4*, 21-32, January 15, 2020

Perspective

Long-Duration Electricity Storage Applications, Economics, and Technologies

Paul Albertus,[1,4,*] Joseph S. Manser,[2,4] and Scott Litzelman[3]

The United States electricity grid is undergoing rapid changes in response to the sustained low price of natural gas, the falling cost of electricity from variable renewable resources (which are increasingly being paired with Li-ion storage with durations up to ~4 h at rated power), and state and local decarbonization policies. Although the majority of recent electricity storage system installations have a duration at rated power of up to ~4 h, several trends and potential applications are identified that require electricity storage with longer durations of 10 to ~100 h. Such a duration range lies between daily needs that can be satisfied with technologies with the cost structure of lithium-ion batteries and seasonal storage utilizing chemical storage in underground reservoirs. The economics of long-duration storage applications are considered, including contributions for both energy time shift and capacity payments and are shown to differ from the cost structure of applications well served by lithium-ion batteries. In particular, the capital cost for the energy subsystem must be substantially reduced to ~3 $/kWh (for a duration of ~100 h), ~7 $/kWh (for a duration of ~50 h), or ~40 $/kWh (for a duration of ~10 h) on a fully installed basis. Recent developments in major technology classes that may approach the targets of the long-duration electricity storage (LDES) cost framework, including electrochemical, thermal, and mechanical, are briefly reviewed. This perspective, which illustrates the importance of low-cost and high-energy-density storage media, motivates new concepts and approaches for how LDES systems could be economical and provide value to the electricity grid.

Introduction and Applications for Long-Duration Energy Storage

The United States (US) electricity grid is undergoing rapid changes that create opportunities for new electricity storage applications and may benefit from new electricity storage technologies. First, the levelized cost of electricity (LCOE) from wind and solar photovoltaics is now lower than the new natural-gas-combined cycle power plants, even as sustained low natural gas prices are shifting the fuel mixture away from coal and, in some cases, nuclear.[1] However, unlike the preceding century in which the electricity system was based on a stable supply of chemical fuel, the electricity output from wind and solar installations is variable over time scales ranging from seconds to years. The second major change is a move toward decarbonization. At the time of publication, six US states had policies of 100% clean energy or renewable energy targets signed into law with more under consideration within various state legislatures; many countries, regions, and cities are also pursuing such policies.[2] Third, states, municipalities, and industries are considering technology options to increase the resiliency of their grids, in part due to rising weather variations and storms, such as Hurricane Maria, which devastated Puerto Rico and the US Virgin Islands.[3] In each of these cases, cost-effective long-duration electricity

Context & Scale

The feasibility of incorporating a large share of power from variable energy resources such as wind and solar generators depends on the development of cost-effective and application-tailored technologies such as energy storage. Energy storage technologies with longer durations of 10 to 100 h could enable a grid with more renewable power, if the appropriate cost structure and performance—capital costs for power and energy, round-trip efficiency, self-discharge, etc.—can be realized. Although current technologies such as lithium-ion batteries are suitable for a number of applications on the grid, they are not suitable for longer-duration storage applications.

Although 10 to 100 h energy storage will help facilitate the integration of renewable power on the grid, it is not long enough to last for seasons, and is not sufficient to enable a grid with 100% renewable power. Given the capital-intensive nature of scaling up a storage technology that can be impactful to the overall electricity grid, rigorous technical and economic evaluations at the laboratory and pilot scale are required. Several major classes of

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Our paper has an improved economic model vs. the DAYS FOA

Revenue over project life		Total cost over project life
• Energy: \$/kWh-cycle • Capacity: \$/kW-y	=	• Installed capital cost of energy • Installed capital cost of power • Cost of inefficiency • Operations and maintenance • Component replacement

Example of need to pay close attention to techno-economic models: with low cost ("free" at times?) renewables, does efficiency matter?

- Low discharge efficiency: increases operation cost, AND \$/kWh delivered capital cost, other capital costs.
- Low charge efficiency: increases operation cost, AND cooling, power conversion, other capital costs.

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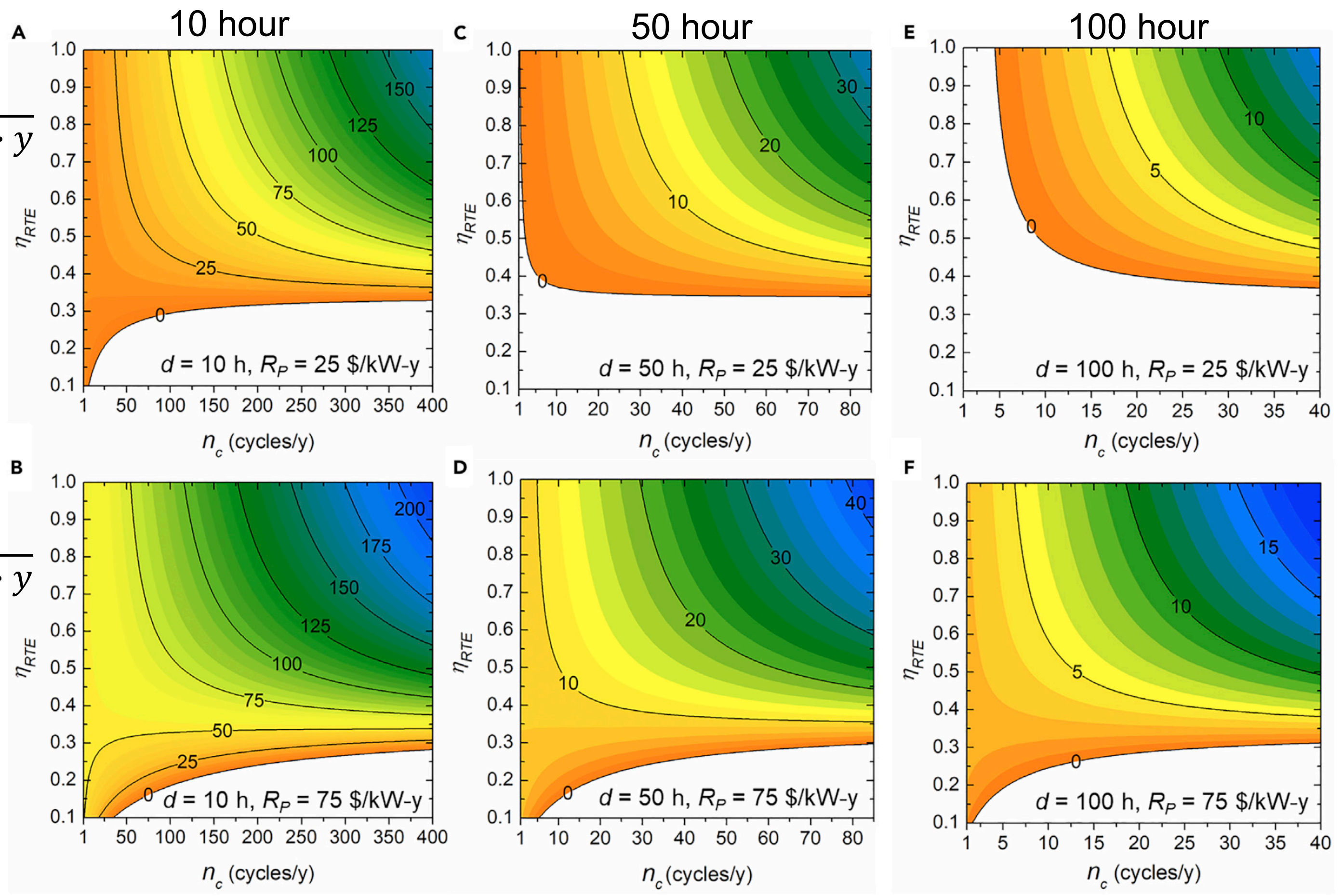
The economics figures better explore the important variables

Indexed colors show the total allowable installed capital cost ($/kWh)

$25 \frac{\$}{kW \cdot y}$

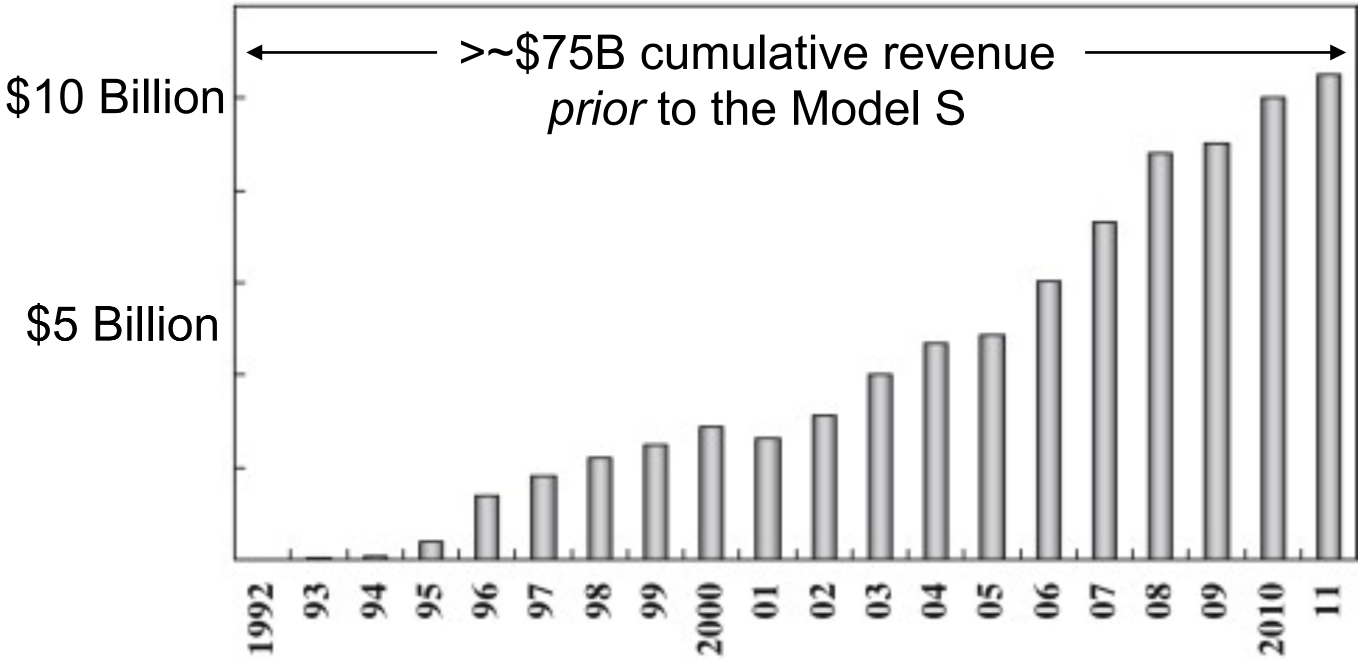
$75 \frac{\$}{kW \cdot y}$



Energy payment: 0.05 $/kWh-cycle, Charging price: 0.025 $/kWh, VOM=0.002 $/kWh-cycle, FOM=1% of installed capital cost ($/kWh-y), no storage medium replacement

Li-ion grew with large markets outside grid, and government support

Li-ion annual revenue by year



2012

Tesla Model S

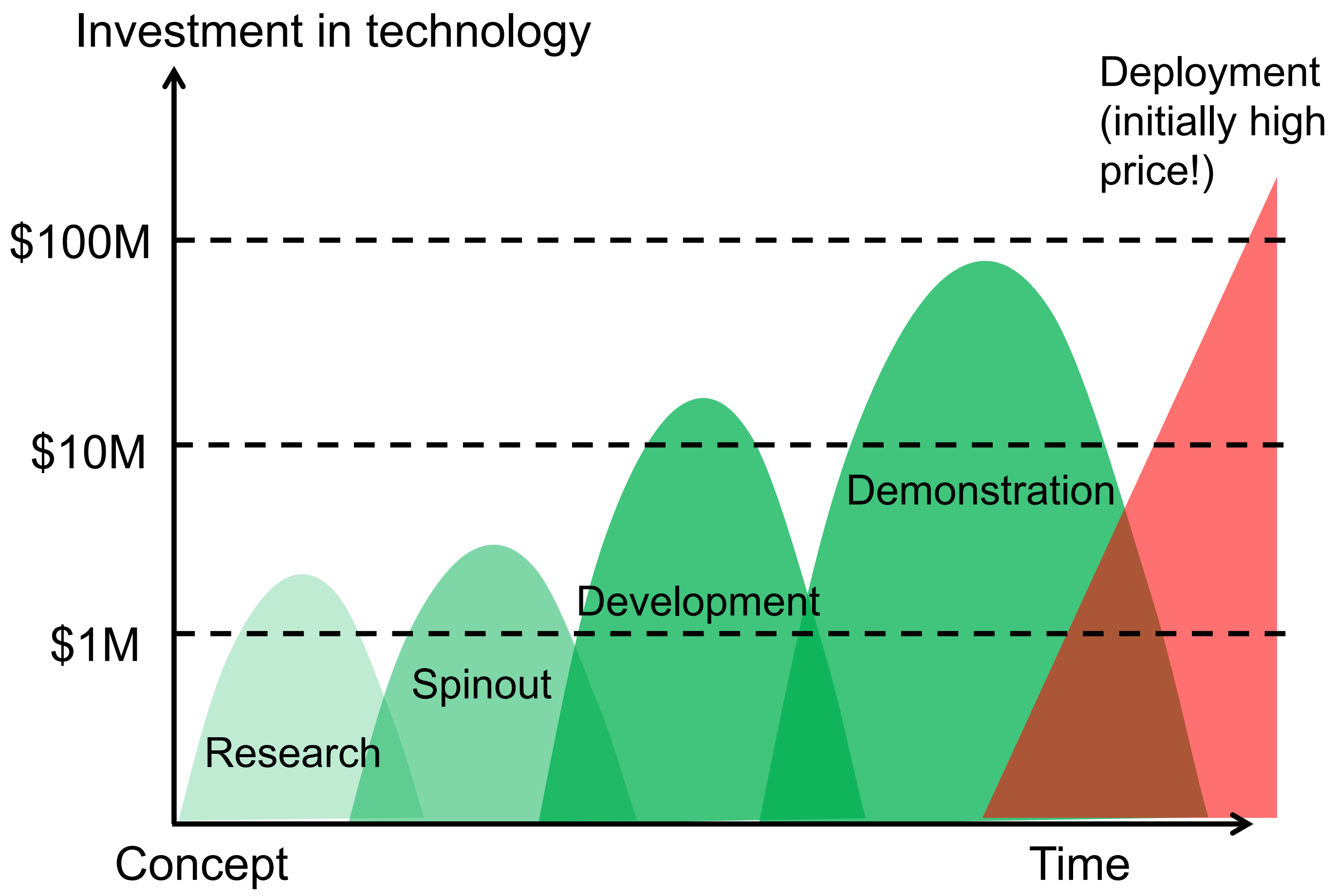
2014

Tehachapi Energy Storage Project

- 8 MW, 32 MWh
- Automotive Li-ion cells from LG
- Utility owned (SoCal Edison)
- Multiple use cases
- DOE/SoCal Edison funded

Li-ion revenue figure: Yoshino, Lithium-Ion Batteries, “1– Development of the Lithium-Ion Battery and Recent Technological Trends,” 2014, pp. 1-20.

New storage technologies specifically for grid typically hit a wall



If LDES is to reach scale, key questions:

- There are several technologies, targeting a range of durations. How should RD&D support be structured?
- Who will support demonstration projects when technical risk remains, especially for large projects?
- Should / what policies be put in place to support LDES deployment, especially its early phase?

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