Energy Storage Futures, Vol 5, Role and Impact in 2050

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1. Introduction

The National Renewable Energy Laboratory (NREL) over the last year released a study titled "Storage Futures Study," hereafter SFS, and a multi-section report. The high level goal of this is to model energy storage systems' implementation out to 2050.

I tracked each of the report's sections with a much shorter volume.

Section 1 of this report focused on the types of utility-scale energy storage systems and the services that they provide to the electric grid. Our Volume 1 of Energy Storage Futures was a summary of this section, and is linked below.

https://energycentral.com/c/gr/energy-storage-futures-volume-1-types-and-services

Section 2 of this report collected and refined data to use as an input for the model of the future of storage system out to 2050. Our Volume 2 of Energy Storage Futures was a summary of this section, and is linked below.

https://energycentral.com/c/cp/energy-storage-futures-volume-2-model-input-data

Section 3 of this report evaluated the economic potential of diurnal storage. As storage systems penetrated the utility-scale storage market over the last decade, they first penetrated the ancillary services market, which was rather small, then the market for peaking power which was much larger. The next step in this process was to evaluate the economic potential diurnal storage, which is defined as storage with a duration of up to 12-hours. Our Volume 3 of Energy Storage Futures was a summary of this section, and is linked below.

https://energycentral.com/c/cp/energy-storage-futures-vol-3-diurnal-storage-economics

Section 4 of this report evaluated distributed storage. Because distributed storage is almost always paired with photovoltaic (PV) solar generation, this form of generation comes along for the ride. Our Volume 4 of Energy Storage Futures was a summary of this section, and is linked below.

https://energycentral.com/c/cp/energy-storage-futures-vol-4-distributed-pv-plus-storage

I had assumed that the next SFS section 5 would further refine the model's inputs, however when I recently read it for the first time, I found that this section is merely a brief discussion of what constitutes "Long Duration Energy Storage." This will have no impact on the overall goal of modeling energy storage systems' implementation out to 2050. Thus I will not include a summary of SFS section 5 as one of my volumes. There is a link to this section below for those that wish to read this discussion.

https://www.nrel.gov/docs/fy22osti/80583.pdf

SFS section 6 reports the final result of this study, and this volume is a summary of this as Volume 5 and my final summary of this series.

The service I hope to have provided for the readers of this series was to filter out information that I felt had little chance of materially affecting the output over the period that this model simulates, and thus really reduce the reading-time for these summaries.

2. Storage in 2050

The following is an excerpt from the executive summary of this SFS Section.

Due to rapid technology cost declines and significant potential value of energy storage, we could see hundreds of gigawatts of storage on the future grid… This report—the sixth in the series—assesses the hourly operations of high storage power systems in the U.S., with storage capacities ranging from 213 GW to 932 GW…[1]

We find that the high storage (and often high variable generation) power system scenarios envisioned successfully operate with no unserved energy and low reserve violations, showing no concerns about hourly load balancing through the end of 2050…

On a daily basis, we find storage operations are heavily aligned with the availability of solar photovoltaics (PV), which has a predictable daily on and off cycle that aligns well with the need for storage to charge and discharge. Wind, on the other hand, has a less apparent daily cycle and often experiences long periods of over-generation stretching for many hours or days, which is much longer than the duration of storage we explore here. Although storage can play a key role in utilizing energy from both PV and wind, the synergies with PV are more consistent. On an annual basis, storage effectively provides time-shifting and peak-load reduction services in all configurations and grid mixes. Although storage has a low annual capacity factor, which is inherently limited by its need to charge, it has a very high utilization (in many cases over 75%) during the top 10 net load hours across scenarios and years—when the system needs capacity and energy the most—indicating a strong contribution to the system's resource adequacy.

Lastly, we also find that storage increases the efficiency of many types of power system assets. For instance, we find that in these future grid scenarios, storage reduces total electricity system carbon dioxide emissions by utilizing over-generation from zero-marginal emissions sources like wind and solar to displace generation from the coal and natural gas fleet. In addition, storage can prevent start-ups of those generators and thus reduce emissions of criteria pollutants, which can disproportionally impact those in poor health with low income, particularly those living near thermal power plants. Storage also impacts the operation of the transmission grid. We find that storage increases utilization of some transmission lines (quantified by the amount of observed congestion) while reducing the congestion observed on other lines. Exactly how storage impacts nearby transmission by either increasing or decreasing usage depends on the local conditions, but we find that more often than not, storage encourages higher utilization of transmission assets…

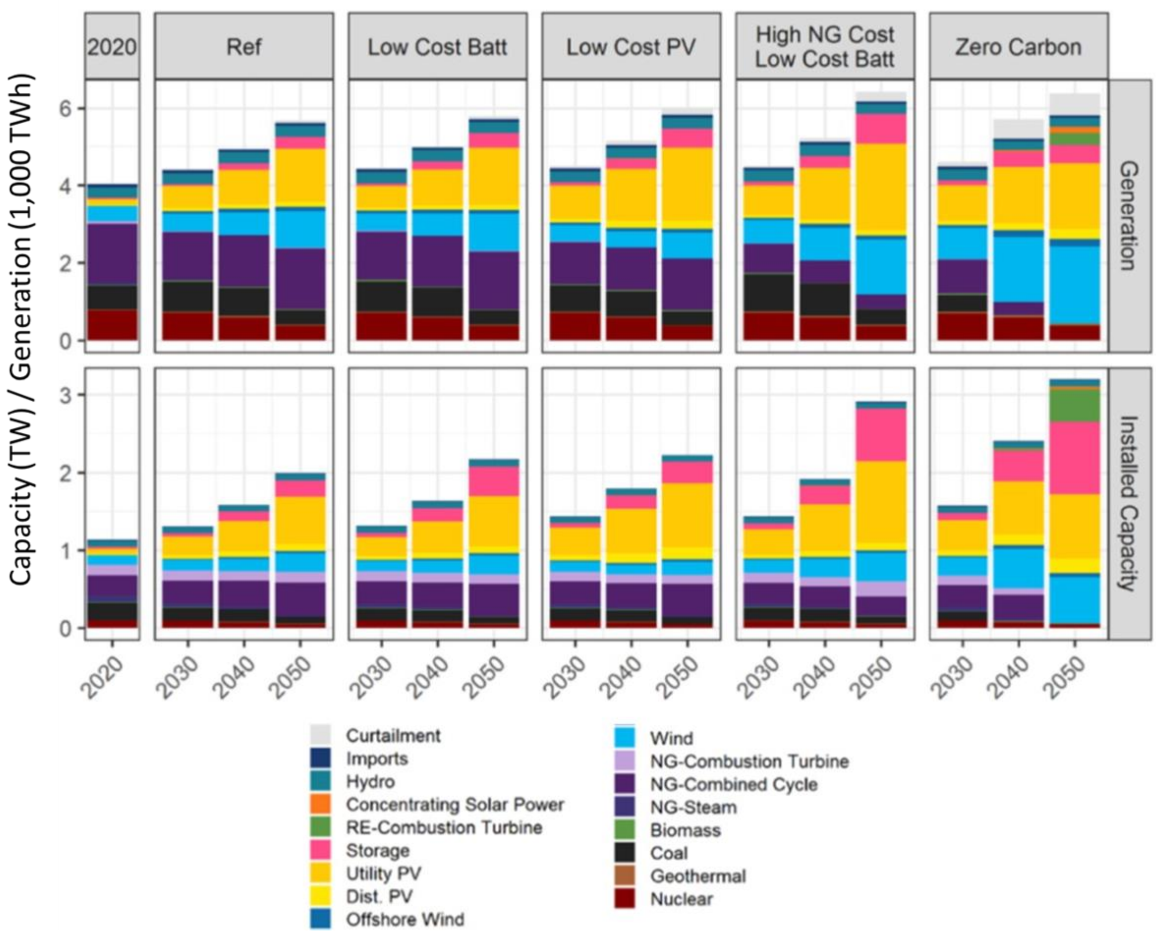
Collectively, the results of this and previous Storage Futures Study analysis show the growing opportunity for diurnal storage (that is, storage with up to 12 hours of duration) to play an important role in future power systems. This analysis shows how greater deployment of diurnal storage can increase efficiency of operations by reducing over-generation, decreasing generator starts and emissions, and increasing utilization of the transmission system. Furthermore, storage plays an important role in providing capacity during the top net load hours. Future work could examine the role of longer-duration storage resources, especially under highly decarbonized grid conditions, such as those approaching 100% clean energy.

[1] Jennie Jorgenson, A. Will Frazier, Paul Denholm, and Nate Blair, SFS Section 6, "Grid Operational Impacts of Widespread Storage Deployment," https://www.nrel.gov/docs/fy22osti/80688.pdf

3. Scenarios and Results

This analysis focuses on the following five key scenarios implemented in ReEDS…

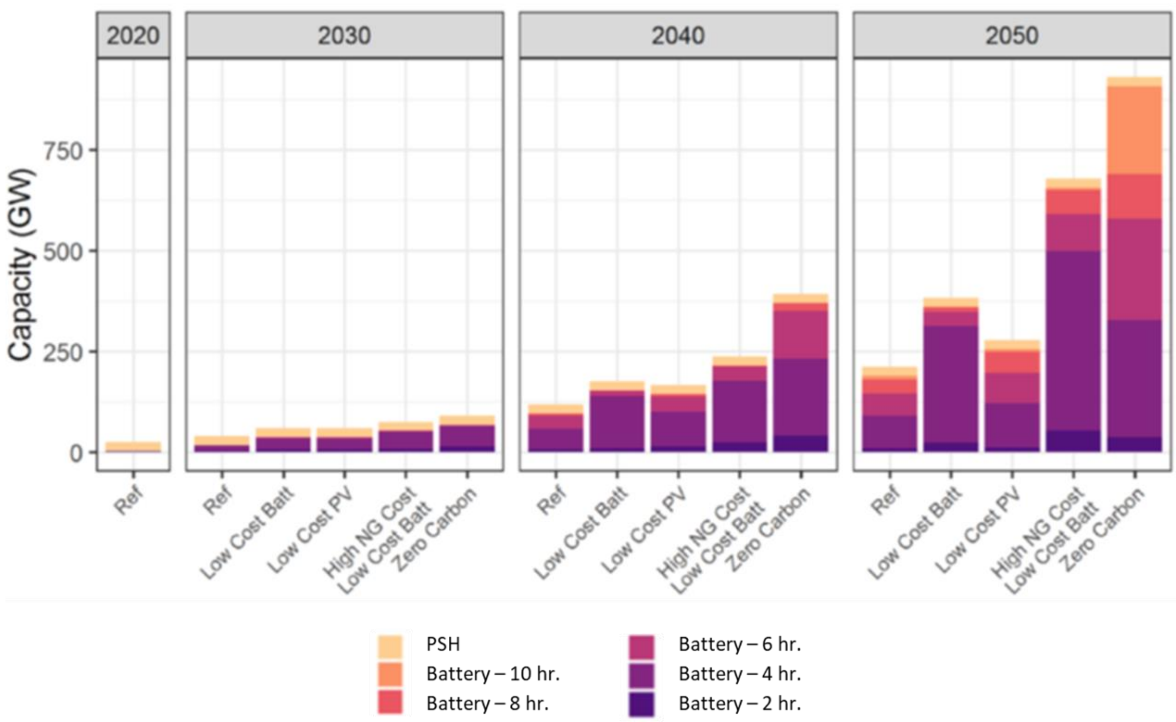
- *Reference scenario (Ref): This scenario follows all reference assumptions for cost and technology evolution through 2050.*
- *Low-Cost Battery scenario (Low-Cost Batt): This scenario adopts the lowest-cost trajectory for batteries.*
- *Low-Cost PV scenario (Low-Cost PV): This scenario adopts the lowest-cost trajectory for solar photovoltaics (PV).*
- *• High Natural Gas Cost, Low-Cost Battery scenario (High NG Cost/Low-Cost Batt): This scenario adopts the high-cost trajectory for natural gas fuel and the lowest-cost trajectory for batteries.*
- *Zero Carbon scenario: This scenario reflects the Zero Carbon Energy scenario from the Solar Futures Study, which achieves even higher deployment of storage technologies (in megawatts) than the four scenarios above (U.S. Department of Energy 2021).*[2]



[2] The Zero Carbon Energy scenario, which is known as the Decarb scenario in the Solar Futures Study, achieves 95% decarbonization by 2035 and 100% carbon-free generation by 2050 with moderate load growth and demand response assumptions.

The figure above shows the shows the capacity and annual generation broken down by generator type for each of the five scenarios for 2020–2050. All scenarios show expansion in solar PV, wind, and storage capacity, which is due in large part to declining technology costs for these three resources. These sources replace nuclear, coal, and in some cases gas generation. The displacement of gas generation and capacity is most obvious in the High NG Cost/Low-Cost Batt scenario, which uses a high natural gas price trajectory as well as the Zero Carbon scenario, which requires replacement of all coal and natural gas fueled generation by the end-year of 2050. The three other scenarios (Ref, Low-Cost Batt, and Low-Cost PV) follow a mid-case for a natural gas price trajectory, resulting in continued substantial natural gas generation and capacity through 2050.

The figure below shows the installed storage capacity broken down by technology type for the same scenarios and years (PSH = pumped storage hydro). Note that storage durations greater than 12 hours were not considered for deployment in the larger Storage Futures Study. In 2020, nearly all storage is existing pumped storage hydropower. By 2030, we see a dramatic increase in the deployment of the lower-duration battery storage technologies (2- and 4-hr battery configurations), as those are assumed to have the lowest cost given their smaller energy capacity. In 2040, 4-hr batteries continue to dominate, but we start to see deployment of 6-hr battery technologies. By 2050, 4-hr batteries are still the most dominant storage technology in all scenarios, but some scenarios (particularly the Zero Carbon scenario) show deployment of longer-duration batteries such as 8- and 10-hr batteries. The longer-duration batteries become more cost-competitive in future years as a result of price declines. In the case of the Zero Carbon scenario, longer-duration batteries are also more valuable because of their ability to shift energy over longer periods and to provide a higher capacity credit. And finally, even the case with the least deployment of storage over the modeled time horizon (the Ref scenario) depicts a roughly tenfold increase in storage capacity through 2050.



3.1. Final Comment

SFS section 6 devoted many pages to their methods, and revisited some of the information presented in earlier sections with many graphic charts. Some may find additional important insights here, however I did not. If you would like to review this section, click on the link in reference 1.

Taken as a whole, SFS is a very important work that points out that energy storage systems facilitate at least one path to a very-low-carbon to zero-carbon future at mid-century, thus avoiding even worse affects from climate change than are already baked into our environment.