
# The Energy Storage Imperative:

## A GUIDE FOR GRID PLANNERS IN THE RENEWABLES ERA

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Uncertainty is the bane of the planner. Yet, across the world today, electric grids are undergoing unprecedented disruption as renewables rapidly take root, displacing other energy sources.

"The pace at which renewable energy penetrates the global energy system is faster than for any fuel in history," observed BP's February 2019 "Energy Outlook" report.[1] The near future, they assert, will be one in which "85% of the growth in energy supply is generated through renewable energy and natural gas, with renewables becoming the largest source of global power generation by 2040."

Storage has a vital role to play. But the current dominant technologies in use today – pumped hydro and lithium ion (Li-Ion) – cannot sufficiently provide the durable, flexible and distributed storage required.

## LOOKING BEYOND THE EARLY DAYS OF GRID STORAGE

On the power grid today, Li-Ion batteries primarily serve applications that require short- to medium-discharge – things like volt/VAR support or smoothing renewable output and ramping. Navigant summarized the use of Li-Ion in a 2018 report, "These short duration applications have provided the foundation for the growing energy storage industry over the past several years. However, there is a finite need for these applications on the grid."[2]

As electric power generation moves toward majority renewables worldwide, the conversation has begun to shift. "Lithium-ion owns the grid storage market now, but that might not always be the case," Greentech Media's Julian Spector noted.[3] Li-Ion faces significant drawbacks in offering price stability, long life cycle, high reliability and risk reduction that grid planners need.

Similarly, pumped hydro has significant drawbacks for use in a distributed grid. Recognized for its versatility for short- to long-duration operations, high durability and low cost, it nevertheless faces limits. Pumped hydro presents practical obstacles in siting and permitting it where planners need to place it – for example, at a remote solar farm in the desert, or amidst wind farms on the Great Plains, or in major cities. These make it likely to be suitable only for selected deployments alongside distributed resources. The planning process for pumped hydro projects can also be extremely long, with projects taking ten years or more to execute.

Industry analysts foresee this shift toward longer duration storage. But for planners – who in many cases, already have majority renewable grids in their current medium-term projections – the timeline for making informed decisions on viable long duration storage is now.

## IMMINENT MANDATE TO CHANGE

For many grid planners, renewable mandates are a major driver of this change. Increasingly, international, federal, state and local governments are setting aggressive goals for renewable resources. In the U.S., 29 states and the District of Columbia have renewable portfolio standard (RPS) policies.[4] This represents 63% of the total U.S. retail electricity market.[5] In 2018 and 2019, several states strengthened and expanded their requirements while none weakened or removed them. This trend will likely continue.

### The 100 Percenters

While each state government has its own language and terms, making parallel comparisons inexact, it is clear that – whether called "carbon free" or "carbon neutral" or "clean energy" – a 100% renewables goal is in the sights of at least six. The District of Columbia's target date comes first, by 2040. California, Hawaii, New Mexico and Washington state aim for 2045; Nevada 2050. Hawaii was the first to set a 100% target. California was the second. Its 100% target is comprised of a “60% renewable generation share of sales by 2030 and an additional 40% generation share of sales of carbon-free resources by 2045, for a total of 100% carbon-free power by 2045.”[6]

Often the road to 100% includes interim goals. New Mexico’s 2019 requirements expanded on its initial goal of 20% by 2020, adding new dated targets as follows:

**New Mexico’s RPS by Year**

| | |
|---|---|
| 2020 | 20% |
| 2030 | 50% |
| 2040 | 80% |
| 2045 | 100% |

New Mexico’s policy applies only to investor owned utilities; cooperatives have until 2050 to reach the 100% “carbon free generation” goal.[7] The state’s approach mirrors that of Hawaii, one of the earliest to put its RPS on the path to 100%.

**Hawaii’s RPS by Year**

| | |
|---|---|
| 2010 | 10% |
| 2015 | 15% |
| 2020 | 30% |
| 2030 | 40% |
| 2040 | 70% |
| 2045 | 100% |

### Other State Goals

In New England, **Connecticut** set its renewables target to 40% by 2030.[8] **Massachusetts** raised its RPS growth rate to 2% annually (for each year from 2020 to 2029), putting the state on the path to 35% renewables by 2030, at which point it plans to assess progress and potentially add new targets.[9]

In 2018, **New Jersey** set new goals for 2030, too. Originally on a yearly percentage growth track (like Massachusetts), it instead set three specific and bigger goals of “21% by 2021, 35% by 2025, and 50% by 2030.” The state further specified that “a certain percentage of the overall target must be met with solar technologies.”[10]

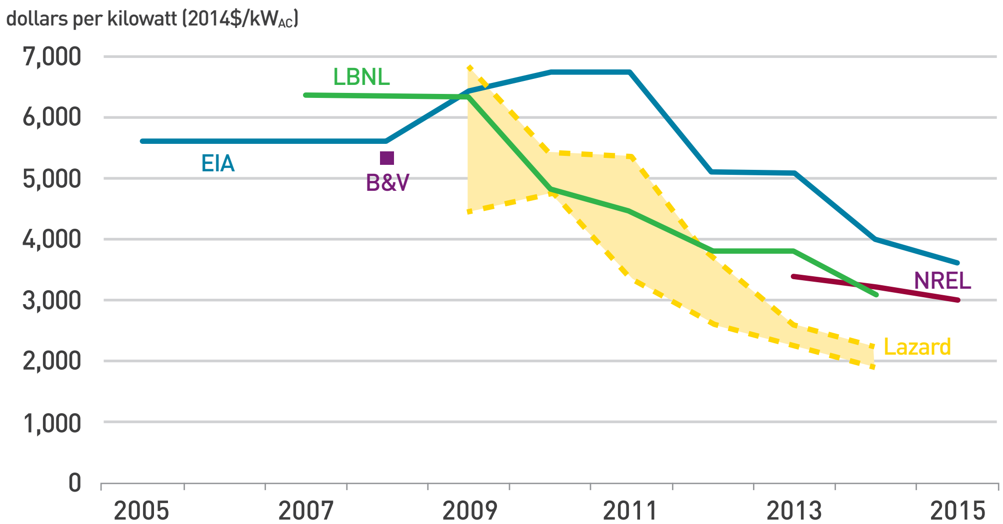
**New York** has had RPS since 2004 and, having reached its latest target of 29% renewables by 2015, moved to a more aggressive Clean Energy Standard (CES) in August 2016. The CES requires “utilities and other retail electricity suppliers to acquire 50% of the electricity sold in the state from clean energy resources” by 2030.[11] It also established an offshore wind procurement program with a target of 2,400 MW by 2030. More ambitious targets may also lie ahead. A June 2019 bill, not yet passed at the time of this paper’s publication, proposed measures to put New York at 100% as early as 2050.[12]

## A GROWING “ECONOMIC MANDATE”

While mandates are one influence, actual renewable energy growth has outpaced even legally required levels of adoption. Berkeley Labs observed that while total (non-hydro) renewable generation grew by 332 TWh from 2000 to 2017, RPS policies had required only a 150 TWh increase over the same period. Mandates would appear, then, to have been a factor in no more than 45% of total growth, with other factors also driving growth.

Even without policy incentives, economics continue to drive renewable adoption. Capital costs for wind and solar have consistently fallen over the past decade, both in installed capital cost and in levelized cost of energy (LCOE) of the power produced. “Figure 1” from the U.S. Energy Information Administration (EIA), is typical of the trend. It shows findings from several distinct and independent sources to summarize the dramatic drop in solar capital costs[13].

**Figure 1:** Annual estimated capital costs for utility-scale solar PV technologies from various agencies, 2005-2015




**SOURCES:** EIA, *Annual Energy Outlook (2003-2015)*; LBNL, *Tracking the Sun 2014*; *Utility-Scale Solar (2013-2014)*; Black & Veatch (B&V), *Cost and Performance Data for Power Generation Technologies*; NREL, *Annual Technology Baseline 2014*; Lazard, *Levelized Cost of Energy (version 3-8)*

“Wind and solar have reached grid price parity and are moving closer to performance parity with conventional sources,” Deloitte reported in 2019. This means that beyond achieving parity in purchase price, renewable resources are also demonstrating parity in the levelized cost of their energy. The report observes, “In fact, the unsubsidized levelized cost of energy (LCOE) for utility-scale onshore wind and solar PV generation has dropped even with or below most other generation technologies in much of the world.”[14]

## EMERGING RECOGNITION OF NEED FOR LONG DURATION

These changes to the grid, coupled with price declines driven by a massive build-out of manufacturing capacity for electric vehicles, are driving strong demand for Li-Ion batteries. These batteries are seeing wide deployment in a variety of applications, serving both behind-the-meter customers and utilities and power plant operators in front of the meter. Many observers assume that Li-Ion batteries will continue to be the technology of choice for grid storage as renewable penetration increases.

But as the grid changes and analysts model the evolving requirements for storage, it is increasingly clear that planners and operators need new, more robust technologies to serve the use cases created by the new paradigm. Most importantly, these uses will require storage technologies capable of daily long-duration, deep discharge duty cycles. “The growing penetration of renewable energy generation is the single most significant driver of demand for long duration energy storage,” according to Navigant.[15]

Change is coming; as grid planners try to prepare, many want to understand and anticipate its timing. When exactly does reliance on short duration, especially on the majority Li-Ion resources most used today, no longer suffice? Navigant’s observations may indicate the tipping point occurs when renewables represent half of the resources on a grid. “At relatively low penetrations (below 15%) variable renewable generation such as solar and wind has a relatively small impact on the stability and efficiency of large power grids. As the penetration increases further, approaching ambitious 50% or even 100% targets established in some jurisdictions (now including Hawaii and California), significant impacts can be seen in grid stability and both technical and economic efficiency."[16]

### THE NEW KEYS TO RENEWABLE GRID PLANNING

It is in the integrated resource planning (IRP) process that many utilities are understanding the need to diversify storage resources. Most U.S. states today require utilities to file an IRP or at least a long-term plan of some kind. Many states are revising their approaches, generally to strengthen requirements. The IRP's importance for the resource mix on the grid is profound. An IRP compels a utility to plan "for meeting forecasted annual peak and energy demand, plus some established reserve margin, through a combination of supply-side and demand-side resources over a specified future period."[17]

## Chasing 100+ Hours...

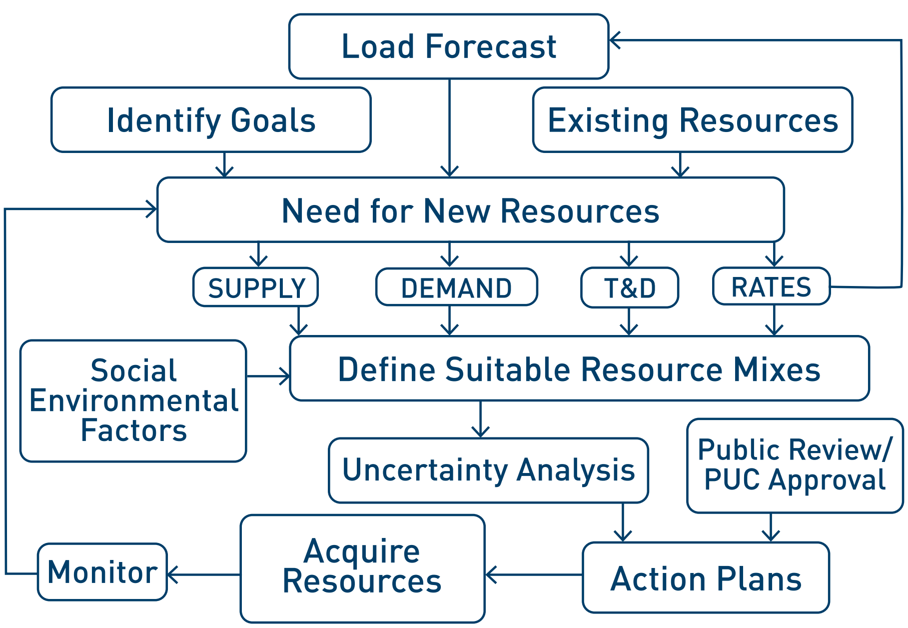
The need for even longer duration storage is beginning to be understood. In September 2018, the U.S. Department of Energy's Advance Research Projects Agency – Energy (ARPA-E) took a big step forward, launching the Duration Addition to Electricity Storage (DAYS) program. *DAYS will provide $28 million to fund research on solutions that expand duration significantly beyond the four hours that most today define as "long" duration. DAYS aims to drive development of solutions that can sustain up to 100 hours.

*https://arpa-e.energy.gov/sites/default/files/documents/files/DAYS_ProgramOverview_FINAL.pdf

For IRPs to be effective, ensure future reliability and meet policy goals on clean energy at lowest cost to consumers, planners need a thorough understanding of the capabilities, costs and performance attributes of the technologies, including energy storage, that are available to them. They must consider both the anticipated load and generation mix and the performance and cost parameters of the new power generation and storage technologies that are becoming available. Planning well for the era of integrated renewables requires an understanding, especially, of the longer duration storage solutions that can best address new and emerging challenges.

Let's take a deeper look at some of the key functional **issues** planners will encounter in the majority renewables grid. The "Integrated Resources Planning Flow Chart, Hirst 1992," adapted from *Integrated Resource Planning for State Utility Regulators*[18], illustrates best practices for the planning process.

**Figure 2:** Integrated Resource Planning Flow Chart, Hirst 1992




*The IRP process provides several opportunities for long duration storage to effectively solve key issues.*

## PLANNING FOR MORE FREQUENT CYCLING

As the grid increasingly relies on intermittent renewable resources like wind and solar, storage will need to respond more frequently to balance supply and demand. This increased cycling – and the need to hold batteries in a charged state ready to respond when needed – can lead to accelerated degradation and reduced lifespan of Li-Ion batteries. As Navigant recently noted, "Depending on the specific services a system will provide and the required number of cycles per day, the calendar life for Li-Ion batteries in grid storage applications may be as low as three years before capacity degradation results in usable capacity below 75% of initial nameplate."[19]

In these scenarios, if batteries reach end of life every three years, planners would need to anticipate replacement up to seven times during a typical 20-year planning period. Planners would need to factor in additional costs for labor, materials and any environmental impact fees, recycling costs and applicable hazardous waste disposal rules. More durable long-duration resources like flow batteries can deliver the durability planners require for these new use cases.

## PLANNING FOR T&D CONGESTION RELIEF

One of the most promising applications for energy storage on the grid is the use of batteries as transmission and distribution assets. In an environment of flat overall load growth, public resistance to major new infrastructure and safety concerns about power lines and substations in environmentally sensitive areas, it's becoming increasingly difficult to finance and permit new transmission and distribution(T&D) lines, substations and other traditional grid infrastructure. But the proliferation of distributed generation and the increasingly intermittent power generation mix is creating points of congestion, localized peak power constraints and areas of curtailment. Storage can address these challenges in a cost-effective, safe and environmentally compliant manner.

There are two ways in which storage can contribute as a T&D asset. Planners can use batteries to address requirements for additional capacity as a substitute for more expensive, harder to permit and more disruptive traditional grid technologies (new or reconductored lines, new or expanded substations, etc.). We're already seeing a proliferation of Non-Wires Alternative (NWA) RFPs from utilities seeking to use batteries instead of more traditional wires solutions.

Storage can also function as a T&D asset to address renewables integration. As a generation asset, batteries can operate on-site at individual wind and solar generation plants to enable these facilities to provide firmer power to off-takers seeking to match production to load and T&D capacity. Alternately, batteries can work as T&D assets to address intermittency at the system level. In this scenario, grid owners can operate large, high-energy, long duration batteries placed at strategic locations to accept and manage intermittent power at the system level. In the coming years, planners will analyze which approach (or combination of approaches) is technically and commercially optimal. The answers will likely differ by location, depending on the generation mix, grid infrastructure and load patterns of each. In many cases, laws and regulations will need to be adapted to enable ratepayers to realize the benefits of using storage in this manner as a T&D asset.

Flow batteries – with their durability, long duration, safety and ability to serve nearly anywhere – are well suited to provide the high-energy flexible capacity required for these new applications.

## PLANNING FOR RESILIENCY AND REDUCED RISK

Grid planners also face new challenges in anticipating the need for reserve capacity in a majority renewables grid. Beyond the certainty of needing to plan to address moments – or even hours – of intermittency, today's grid planners must address longer gaps due to meteorological fluctuations.

"In a future where 70% of power is generated by solar panels, it is easy to imagine a scenario where a couple of cloudy days in a row could create a gap in meeting customer demand, Michael Jacobs, senior energy analyst as the Union of

Concerned Scientists, told Utility Dive" in an October 2018 article. Longer duration storage can play an increasingly essential role in ensuring resiliency. Flow batteries that can cycle for ten or eleven hours on a sustained basis could address these high-energy needs.

Weather or disaster-related outage scenarios require similar capabilities. Storage with longer duration has greater ability to provide emergency backup power for longer periods. And solutions like flow batteries – that can serve nearly anywhere, are nonflammable and stable in a range of temperatures – are well suited for use in emergency situations where all these factors can be notoriously unpredictable.

### Safety

Safety is always a top priority for grid planners. A series of utility electrical fires – most notably the 2018 Camp Fire in Paradise, California, which killed 86 people, caused $16.5 billion in damages[20] and led to PG&E's bankruptcy – have brought new focus to the subject. Utilities are seeking innovative technologies that reduce the fire risk of grid infrastructure in sensitive areas. Some are exploring how energy storage could serve as a substitute for transmission lines in areas of high fire risk, providing resiliency with nonflammable resources. Utilities are likely to be conservative and seek batteries with inherently low fire risk. Recent Li-Ion battery fires in the US and Korea may raise questions about using this technology in these safety-critical applications. Aqueous flow batteries can provide this distributed energy with a chemistry that has stronger inherent safety.

### Flexibility and Futureproofing

The optimal use cases for renewable resources are still developing. There is much planners cannot yet know, so flexibility is vital. Even in today's scenarios, it's clear Li-Ion faces limitations due to its significant degradation anticipated under many of the most promising applications. As market conditions continue to evolve, planners need solutions with more, not less, flexibility. Flow batteries do not face the same restrictions as Li-Ion. They can cycle more frequently, remain at high charge longer and generally operate more intensively without impacting system life. Because of this, flow storage holds promise for a growing number of uses. This may be a boon to planners and project owners looking to protect their investments even as technology, regulations and markets continue to evolve.

### Supply Chain Reliability

As the global energy storage industry expands, the availability and cost of component commodities can shift. Li-Ion appears particularly vulnerable, due to its reliance on rare earth materials which have seen price volatility and intermittent scarcity. Flow batteries that use mass-manufactured, low cost chemicals from a broad supply base mitigate these risks.

## UNDERSTANDING THE LONG DURATION SOLUTIONS

Knowledge is the best tool for addressing uncertainty. This paper has explored many but not all the factors at play as planners must make decisions to anticipate the best ways to adapt to historic changes in the energy industry.

As grid planners update their integrated resource plans, many face energy mandates and economic factors driving them to incorporate storage. An understanding of long duration storage can provide vital insights to inform their strategies, replacing uncertainty with knowledge to reduce risk and improve planning.

Flow batteries' unique ability to hold a charge and discharge energy without degradation holds tremendous promise for planners looking for flexible technologies to meet new challenges. These include the need to shift peaks, strengthen resiliency, meet reserve capacity requirements and reduce line congestion. Planners who learn more about long duration flow batteries, can equip themselves to fulfill their essential mission to uphold power reliability, safely and cost-effectively amidst an evolving industry.

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## Footnotes

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