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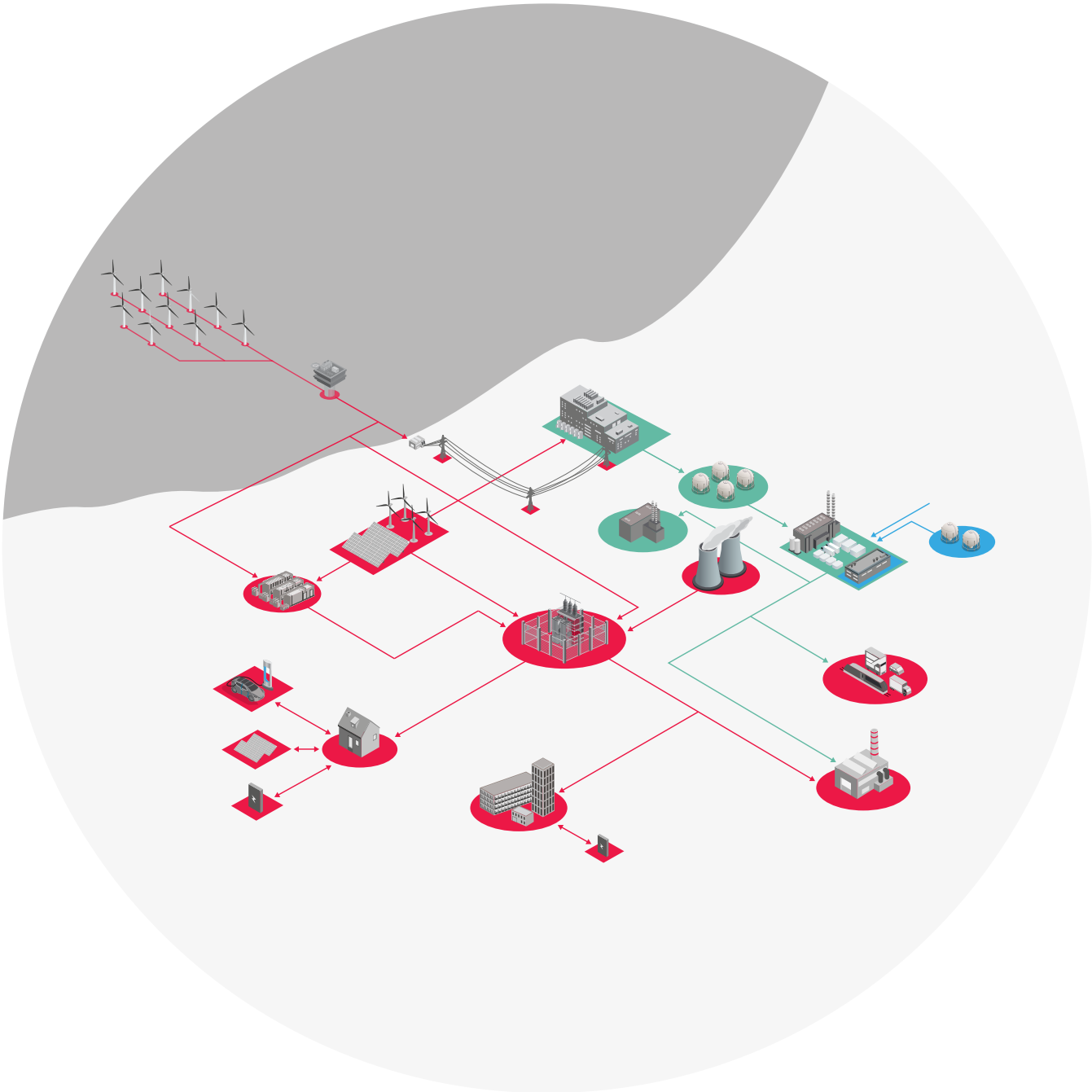
Future of Energy 2035

What will a future US energy storage look like?



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OVERVIEW

The future of energy storage

The US energy market is in the midst of a fundamental shift; transitioning from a traditional supply and demand model to a much more complex market of distributed energy resources, intermittent generation capacity and empowered energy consumers. Enabling this transition in large part is the growing role of energy storage.

This perspective piece has been written as if it were now the mid-2030s and summarizes how the energy transition specifically regarding energy storage technologies took place over the previous 15-20 years.

As of 2019, the US has nearly 900 MW of installed utility-scale battery storage, and this is expected to rise to 2,500 MW by 2023[1]. By 2050 the US is expected to have 17-98 GW of battery storage capacity.

This transition will continue to expand as energy storage technologies continue to evolve, while prices decrease. As of 2019, the majority of the US population now resides in states with 100% clean or renewable energy goals and legislation, including 24 states and Puerto Rico[2]. The transition to renewable and clean energy sources will be coupled with the expansion of energy storage options.

1 - Utility Scale Battery Storage, US EIA
2 - Weiss & Hagerty, 2019

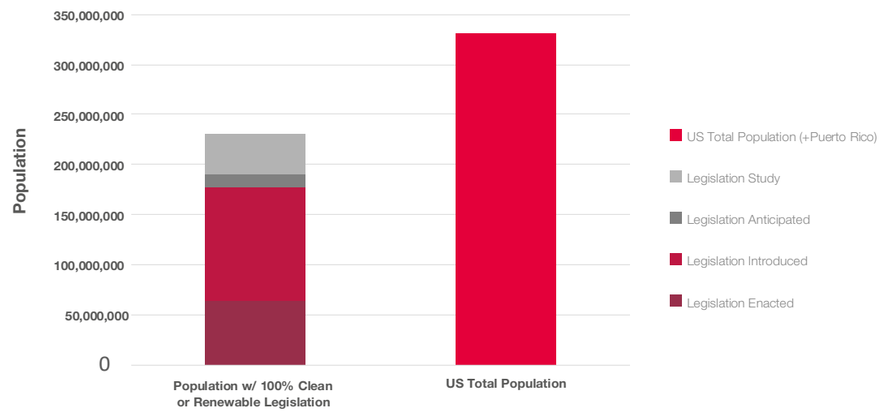


Figure 1. 2019 US Population of States with 100% Clean or Renewable Energy Legislation

CONTEXT

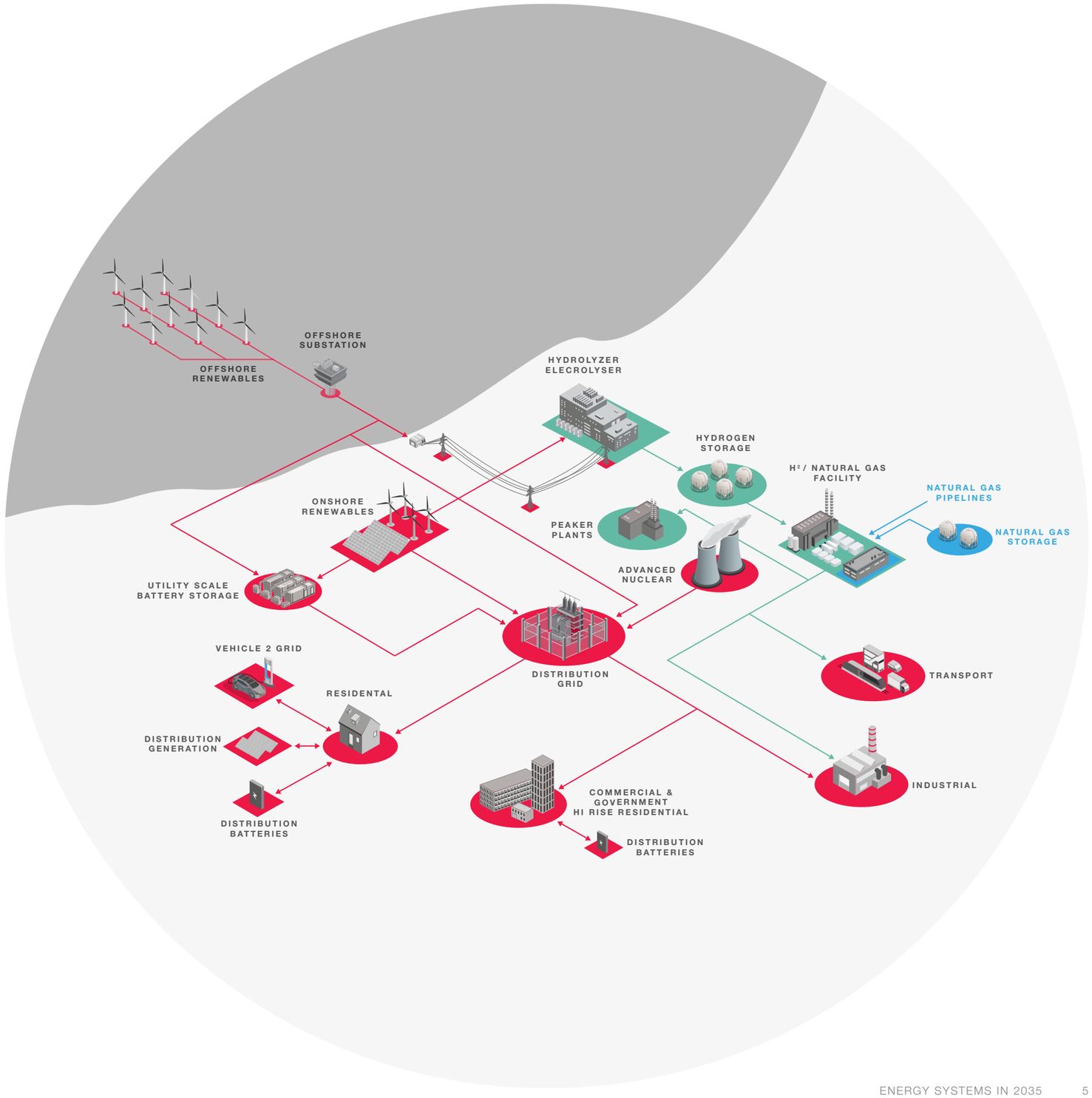
What will the future of energy storage in the US look like?

By 2035 the US energy market has significantly ramped up distributed energy resource deployment and utility-scale renewable generation. All regions of the US have seen substantial growth, enabled in large part by wide-spread adoption of energy storage technologies. Technological advances, a large decrease in storage cost and favorable policy frameworks at the state, regional and federal level have all contributed to high market penetration.

Behind-the-meter (BTM) and front-of-meter (FOM) distributed storage capacity has grown significantly from its early years as highly subsidized combined power purchase agreement tenders. These nascent programs introduced by utilities to address residential, commercial and industrial demand have led to advances in grid-based communication software and updated business models, turning previously discontinuous storage assets into dispatchable energy hubs. The creation of virtual power plants that can also maximize Internet of Things (IoT) networks has dramatically enhanced utilities' ability to meet the needs of intermittent renewable generating systems.

At the utility development scale, a wider range of industrial battery energy storage systems (BESS) technologies have been incorporated to help balance the grid. Commercial solar, onshore-, and offshore-wind power plants are now regularly coupled with large-scale storage co-located at the site. Storage technologies are mature and varied, including high-capacity lithium-ion storage modeled off the early success in the electric vehicle industry, as well as pumped hydro facilities, a growing use of flow batteries, and hydrogen fuel cells.

Batteries have proven to be effective for load shifting and resilience with additional storage strategies being employed to provide demand and grid support services across the various regions. Accelerated electrification in the Northeast put stress on the existing electricity grid as winter demand more than doubled, but a combination of large-scale BESS and the introduction of commercial electrolysis to produce storable hydrogen gas was employed to meet the region's needs. In the Western United Stated, climate risks such as the increased frequency of wildfires and subsequent Public Safety Power Shutoffs, have been mitigated in large part by the adoption of public-private partnerships to fund distributed battery storage systems. Adoption of these partnerships across the country provides community resilience from flooding in the South, tornadoes in the Midwest, hurricanes along the East Coast, and heatwaves throughout the country



TRANSPORTATION

As electric vehicle sales began to boom in the early 2020s, vehicle-to-grid integration began to be seen as a means to provide distributed and dispatchable storage capacity to the grid.

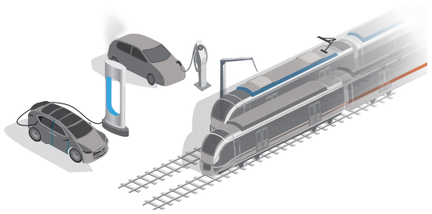
Market uptake of electric vehicles across sectors has continued the momentum of the early 2020s, positioning electric vehicles as the majority share of commercial fleet vehicles and over a third of private cars in the US[2]. Technology advances in battery chemistry and EV manufacturing processes have substantially reduced costs, and the abundance of charging infrastructure installed over the last decade has eased trepidations around range concerns for private vehicle owners. Policy has played a major role in the adoption of EVs as well, particularly through government-backed programs to expand publicly available EV charging infrastructure and economic incentives make EVs cost-competitive with traditional internal combustion engine vehicles.

The U.S. has undergone a transformation of its fleet, with advances in battery chemistry and public policy signals leading to a ramp up in electric mobility by 2035. Public transportation needs and fuel economy standards coupled with increased production and smarter design using big data have driven down cost for the individual consumer, resulting in a surge in the deployment of charging infrastructure.

2 - Global EV Outlook, US EIA

Utility companies have recognized the opportunity to expand dispatchable energy storage through the electric fleet and created smart car programs. Discharging energy into the grid during peak hours can be used to offset electricity costs incurred by individual customers or take the form of PPAs for commercial scale EV charging operators. Smart car programs for EV owners allow utility customers to receive credits for providing energy to the grid using their home EV charging batteries. Additionally, the advancement of sophisticated controls for grid services allows customers to use discharge stations to receive credit to their account.

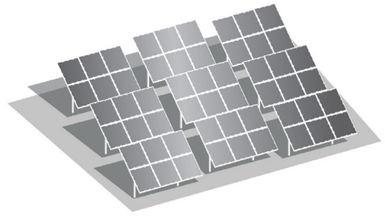
Use of fuel cell EVs for long haul trucking and drayage routes has continued to expand due to state and federal funding. This has allowed for the creation of sustainable hydrogen business models and spurred the development of further green hydrogen technology advancements and cost reductions.



ENERGY SUPPLY

By 2035, distributed generation has grown substantially across the US, with particularly high concentrations in states where government-backed incentive programs and mandates for large scale or rooftop solar drove early market adoption.

High levels of renewable generation have forced utilities to identify new operating practices that balance supply and demand. Distributed systems are now linked to central control systems, providing utilities a new dispatchable energy resource by way of virtual power plants. In California, aggregated distributed energy resources have served to flatten the “duck curve” that challenged grid management; a grid management phenomenon that occurred in the 2020s due to the high output of solar PV in California reducing to zero at sunset at the same time that evening energy demand spiked.



Large scale utility batteries are now routinely paired with utility-scale solar and wind arrays. Acting as virtual peaker plants, the batteries are operated in a similar manner to older coal and natural gas peaker plants allowing utilities to quickly dispatch large quantities of energy to balance the grid during sharp demand spikes.

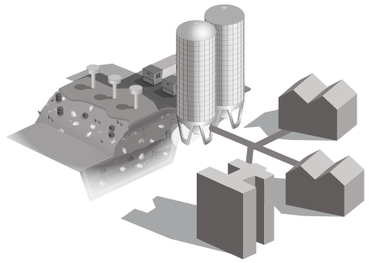
Batteries are not the only form of storage transforming the sector. Vast natural gas pipeline networks serve as a substantial energy storage asset, with weeks’ worth of fuel available on demand. The industrial sector continues to tap into carbon capture and storage (CCS) technologies to enhance productivity and meet climate policy mandates. Hydrogen gas produced at electrolysis centers linked to utility-scale renewable energy generating centers begins to provide new industrial storage applications.

As well as opportunities to decarbonize peaker plants which are still largely powered by natural gas.

HEATING & COOLING

A rise in hydrocarbon fuel bans at the municipal and state level combined with increased efficiencies for heat pumps led to a broad electrification movement. Sparking an interest in new heating and cooling technologies coupled with more efficient building envelope design.

Heating remains a major challenge to the overall electrification goals of many regions in the US, particularly in the Midwest and Northeast where the transition to electric heating has nearly doubled winter electricity demand. Thermal energy storage is utilized in the industrial and large-scale commercial sectors to capitalize on the high heat processes, reducing wasted energy. District heating systems using low-temperature hot water sourced from air-source and ground-source heat pumps have also been incorporated particularly on campuses and new development projects.



Cooling demand across the country has grown substantially, spawned by an increase in heat stress from climate change manifesting in a greater number of hot days, higher overnight temperatures, and more frequent heat waves. The impacts are particularly felt in dense urban environments. As a result, both peak cooling demand and baseline summer electricity demand have grown. While peak cooling demand typically coincides with peak solar production helping to match the curves in places with high solar generation resources, distributed energy storage in the residential sector helps meet nighttime cooling loads and flatten the demand curve in regions with less solar. As with heating, thermal energy storage plays a major role in the commercial and industrial sectors.

3 - (Weiss & Hagerty, 2019)

RESIDENTIAL

Single family homes have seen a substantial rise in the number of dedicated battery systems and dispatchable vehicle-to-grid capacity. Residents and owners of multi-family buildings have also embraced the energy storage transition, incorporating battery storage systems to optimize energy consumption and enhance energy bill management.

Residential energy-storage installations increased more than 200 percent annually from 2014-2018[4]. Many customers chose to install solar with storage to allow for flexibility and to take advantage of utility incentives. Government incentives for residential solar and storage allow for a continued upward trend in the adoption rate, as prices decrease, and resources become more accessible.

Utilities were slow to integrate these distributed resources into their services at first, but early successes of virtual power plants (VPP) in Vermont, California, Utah and abroad in Australia and Europe served to prove the business case for utility investment.

Multi-family housing communities lag behind single family homes in providing energy storage. These communities operate as VPPs when possible, modeled after early adopters in California and Utah. In communities where the resources to organize a VPP do not exist, utilities rely on grid services and leverage EV discharging to provide energy storage from this typology.

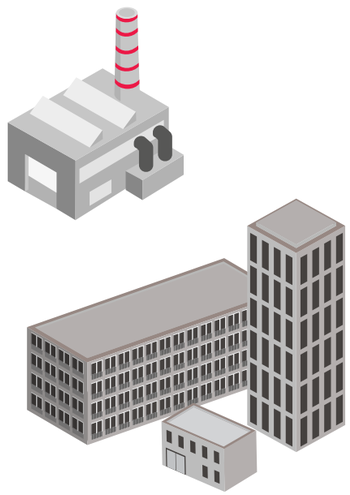
4 - (McKinsey & Company)

COMMERCIAL AND INDUSTRIAL

Commercial and Industrial properties still rely on natural gas and hydrogen to provide high heat loads. Battery and thermal energy storage are used based on the property needs for load and site resilience.

While the residential sector has primarily shifted to all-electric, the commercial and industrial sectors still rely on gas for commercial space and water heating as well as high heat industrial processes. Energy efficiency measures are taken to reduce the overall loads and thermal storage in industrial facilities is used to improve the efficiency of heating operations. Commercial facilities use battery and thermal storage to mitigate demand charges and improve resilience.

Commercial facilities such as airports install microgrids allowing them to stay functional during extreme events that may threaten power supply.

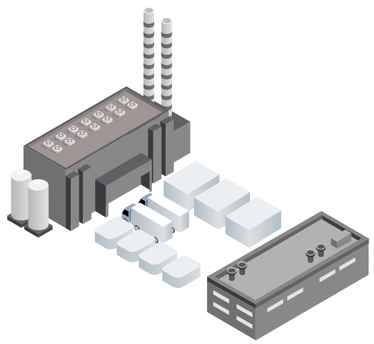


ADVANCED CONTROL AND EFFICIENT MARKET PARTICIPATION

With significant energy storage and demand response capabilities now located throughout the electrical grid, markets have adapted to maximize control and dispatch access, better leveraging potential benefits.

Initial energy storage and demand response markets were fractured, with many different utility and ISO markets that such systems could participate in. Many of these programs were complex and often mutually exclusive. Along with the proliferation of energy storage, advanced communications and sophisticated optimization algorithms emerged to enable energy storage systems to provide grid services at a level never before possible.

Wholesale and retail market revenue opportinuties are consolidated on common, open marketplaces to enable technologies to quickly, and more accurately, react to market needs. The democratization of market dispatch has increased and standardized the access to revenue streams for customer-side energy storage and demand response. Payback periods have reduced, resulting in widespread adoption of such systems.



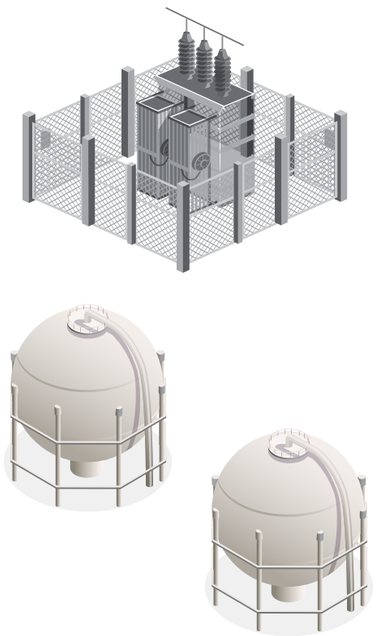
ENERGY SUPPLY RESILIENCE

The proliferation of distributed generation, electrical and thermal energy storage, and fuel diversity has created an energy system which is much more resilient.

Spurred by rapid technological improvements and declining prices, as well as key state and federal grants to test new technologies, the energy systems of 2035 are more diverse than ever. Energy generation technologies typically used for large scale deployment (i.e. nuclear[5], solar PV and thermal, offshore and onshore wind, hydro, etc.) can now be deployed at a smaller scale. All new utility-scale renewables are provided with some form of energy storage while electrical and thermal energy storage are now common place in most new building construction.

The diversity of energy sources, coupled with significant amounts of energy storage at all levels of power and gas distribution systems, has resulted in a networked energy system which is far more reliable and resilient than ever before. Sophisticated controls coupled with real-time asset monitoring have resulted in the ability to more reliably detect and adapt to failures quickly. Most buildings and neighborhoods have some level of energy generation and/or storage which can be used to provide resilience during a utility failure. High-speed communication systems provide status updates throughout the energy systems to allow the distributed energy assets, both utility and customer scale, to react to changes and ensure operation of critical systems.

Solar PV paired with battery storage (solar-plus-storage) has become standard as a resilience system for individual buildings, replacing older diesel or gas-fired emergency generators. This adoption began with municipal portfolios seeking an electricity resilience solution for critical facilities that aligned to their decarbonization goals, and soon spread to other sectors. Residential customers as well have adopted solar-plus-storage systems. Such systems now provide energy resilience to medical baseline customers who depend on durable medical devices in their homes, as well as for mitigating the effects of power loss, such as for public safety power shutoffs implemented in California in early 2020 for wildfire prevention.

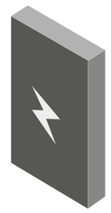


5- The availability of nuclear energy generation at a reduced scale is provided through advanced small modular reactors (SMRs). SMRs vary in size from several megawatts to hundreds of megawatts. This report assumes that the Nuclear Regulatory Committee has approved SMRs and deployment of several systems has taken place between 2020 and 2035 (Advanced Small Modular Reactors, US DOE)

END OF LIFE BATTERIES

With the rapid expansion of battery production and market uses, various end-of-life (EOL) reuse and recycling programs began to appear, largely due to heightened environmental awareness and regulatory requirements.

Early chemical battery designs (e.g lithium-ion, nickel-based and sodium-based batteries) made batteries difficult to recycle. Increased battery production capacity and the growing demand for raw materials drove the industry to innovate around EOL management, adopting a circular economy approach to the industry. Design enhancements included multiple second-life applications, design for disassembly, clearly articulated material passports, and advanced environmental and waste mitigation. Continuous improvement in battery technology also led to a reduction in precious materials, a more transparent supply chain as well as a more environmentally friendly and socially conscious manufacturing processes.



Early pioneers spotted the opportunity to use EOL electric vehicle batteries to provide energy storage for buildings. As the first wave of electric vehicles began to retire, these second life electric vehicle batteries became a low-cost source of storage capacity across the U.S.

RESOURCES

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