Note: This proposal is the work of an independent advisory committee to GSA, and as such, may or may not be consistent with current GSA or other Federal Policy. Mention of any product, service or program herein does not constitute endorsement.

GSA Green Building Advisory Committee Advice Letter on Building Energy Storage

August 23, 2021

Kevin Kampschroer
Chief Sustainability Officer and Director,
Office of Federal High-Performance Buildings
U.S. General Services Administration (GSA)

RE: Recommendations for the Adoption of Energy Storage in Federal Buildings

Dear Mr. Kampschroer:

This letter summarizes recommendations of the Green Building Advisory Committee (the Committee), based on the work of its Building Energy Storage (BES) Task Group. Please see the list of Task Group members and observers below. The BES Task Group was formed to identify opportunities to employ the GSA's large portfolio of buildings as a resource toward accelerating the reduction of greenhouse gas emissions by helping to make the electricity grid cleaner while at the same time saving taxpayer dollars. In a growing number of cases, this can be accomplished by installing building energy storage systems that can dynamically lower the federal government's electricity bills through reducing the maximum electricity demand in federal buildings and/or shifting energy use away from peak rate times to times of the day when electric energy is cheaper. Not only can this provide the GSA with financial benefits, it can potentially provide additional benefits such as better support for the nation's electricity grids, improved resiliency and energy security at the building scale and lower total carbon emissions due to a building's energy use.

Background

On January 27, 2021, the Administration issued an Executive Order on Tackling the Climate Crisis at Home and Abroad. Meeting national climate change goals requires greatly increasing the proportion of renewable energy generation on the electric grid as well as improving how and when it is utilized. Critical steps to reaching these ambitious goals include rapidly ensuring all new and existing buildings run on electricity only, electrifying transportation, converting power generation to renewable sources and installing energy storage systems to help to match the demand for electricity with generation by the renewable sources.

As clean, renewable energy becomes more plentiful and less expensive, a new challenge for utility companies is matching the generation of electricity from renewable sources to the demand for power on the grid. Power supply and demand on electricity grids need to match on a real time basis and since both wind and solar (the primary sources of renewable energy) are variable, this advice letter focuses on the use of building energy storage systems to help to balance the demand for electricity with its generation.

Energy storage is being deployed at grid scale in centralized utility installations, however onsite building and campus scale energy storage can be a critical part of the solution to these challenges - usually installed "behind-the-meter", where building management maintains control of the system - and can be optimized to provide long term savings on electricity bills and increase utilization of carbon-free power. For federal facilities, the benefits of this strategy can be both financial and environmental, saving the federal government on energy bills as well as reducing greenhouse gas emissions by allowing facilities to store clean energy when it is abundant and then use it during hours when the energy delivered by the grid has higher-carbon content.

Key Recommendations

This letter summarizes the current state of the market. Building and utility scale energy storage systems are gaining attention and traction, and support from the GSA at this point could make a major impact on accelerating the adoption of building energy storage as a key strategy for reducing greenhouse gas emissions as well as saving the federal government on its energy bills - a win/win strategy.

There are several building energy storage technologies that are explored in this advice letter, each with its own benefits and drawbacks: capital costs, application, maintenance requirements, storage capacity and duration, space requirements, safety concerns, end of life concerns and system integration are all important elements to be considered when exploring potential energy storage systems for GSA facilities. The technology continues to evolve, with promising new storage technologies in research and development, however the focus of this letter is on currently available technologies that have been deployed on real projects and have proven track records. These technologies have not only been deployed on federal facilities, they are also being installed in private sector facilities, where the financial returns have made them compelling to investors. The BES Task Group concluded and the Committee concurs that now is an opportune time for the GSA to encourage its staff to look carefully at BES systems and implement them where feasible.

Sincerely,

David Kaneda, Chair
Green Building Advisory Committee

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Building Energy Storage (BES) Task Group - Advice Letter

BES Task Group Vision

Federal facilities are designed, built, retrofitted and operated to reduce greenhouse gas emissions, optimize energy consumption, and maximize the use of renewable energy on the electrical grid, through the strategic use of building energy storage.

BES Task Group Mission

The BES Task Group will explore introducing onsite energy storage into federal facilities and options to finance it through various procurement mechanisms. The BES Task Group will summarize the potential benefits of onsite energy storage including long term savings on energy bills; increased utilization of clean, carbon-free power; more resilient buildings; and a more robust electricity grid as well as challenges to its implementation. The goal is to support federal staff in making informed decisions to incorporate BES technologies into current and future projects to save taxpayer dollars and improve the environmental performance of the federal building portfolio.

I. Executive Summary

BES is a key strategy for optimizing buildings for decarbonization of the economy and supporting the grid of the future. Behind-the-meter energy storage can provide the General Services Administration (GSA) with numerous benefits including reducing electric bills (peak demand and other use charges), increasing utilization of renewable energy, utilizing the lowest carbon intensity power from the grid, providing demand response capability and increasing resiliency by powering essential functions in times of need. As the grid is increasingly powered by clean but intermittent renewable energy (wind picks up and drops off, solar generation stops at night), energy storage assumes an essential place in our overall energy system. Building energy storage is therefore key to the Administration's efforts to address the climate crisis.

BES can take multiple forms, including battery storage and both passive and active thermal storage. This advice letter focuses on battery storage, with lithium-ion being the most dominant battery technology; and active thermal energy storage. Other storage technologies are at various stages of research, development and deployment and may become major market options in the future.

Benefits: With prices of batteries falling dramatically, integrating BES systems into new and existing facilities is making greater financial sense. They help support grid integration and harmonization, allowing building operators to take advantage of lower time-of-use (TOU) electricity rates and reducing electrical demand charges which reduces demand overall on the power grid. BES helps make power plant utilization more efficient, even in the context of conventional fossil-fuel generation, as energy can be stored when power plant loads are low, and released when grid loads peak. This is what creates the fundamental value proposition for building energy storage. It can lead to utility bill savings for individual buildings, and demand reduction for the overall grid. BES also offers protection against renewables value erosion - a hedge against renewable subsidies diminishing over time, or sunsetting entirely. It can also reduce the carbon footprint at both the building and grid level, as the peak power demands are often satisfied with the dirtier power production. BES can also enhance building resilience, by storing power in reserve on-site for unexpected outages. If designed for "islanding" (allowing a building to continue to run when the grid goes down), BES can be integrated with renewable energy systems to maintain power over days or weeks. BES can also be a signal of environmental and societal leadership for the decision-makers and stakeholders.

Challenges: BES presents several challenges, some local to the building itself, and others more global. For lithium-ion batteries, beyond the fundamental challenge of providing building owners an appropriate return on investment, fire safety is a significant concern and local regulations can be varied and restrictive. In addition, raw material sourcing and end of life disposal present environmental and social justice concerns. For any type of energy storage, cybersecurity is also a concern, as energy storage systems are controlled by computers on networks, which could be compromised, and therefore must be addressed. Finally, designing, installing and maintaining energy storage systems can require expertise that may require specialist staff or contracting methods that support successful deployment for the life of the investment.

Financing: Different financial structures are possible. Capital costs can be outsourced to private vendors, with payback structured from demand reduction payments from the utility or from arbitraging the differential price of power between times of low load and peak load, etc. Utility Energy Service Contracts (UESC) or Energy Savings Performance Contracts (ESPC) are two possible structures. There are also federal and local subsidies which can help with the overall financial model. Local subsidies vary significantly across the United States. Non-energy benefits should be factored into financial evaluations including the value of added resilience (taking into consideration where BES can substitute for diesel, natural gas or propane standby generators wholly, or in part). BES works especially well with onsite renewable generation, such as rooftop or parking lot solar development. For example, BES can enhance the financial returns from onsite solar development using energy arbitrage for TOU pricing. This aspect of energy storage dovetails with a previous Green Building Advisory Committee's (GBAC) Advice Letter: Renewable Energy Outleasing from July 2020.

II. Problem Statement

On January 27, 2021, the Administration issued an Executive Order on Tackling the Climate Crisis at Home and Abroad. The US has since rejoined the Paris Climate Agreement and the President set a goal to make the US climate neutral by 2050. On April 22, 2021, at a White House sponsored Earth Day Climate Summit with world leaders, the President further committed the US to reducing its greenhouse gas emissions by 50%-52% below its 2005 emissions levels by 2030. Meeting national climate change goals requires greatly increasing the proportion of renewable energy generation on the electric grid as well as how and when it is utilized.

Four critical steps to reaching these ambitious goals are:

1. Electrifying new and existing buildings
2. Electrifying transportation
3. Rapidly increasing the installation of renewable energy sources to generate enough energy to supply the electrical grid with adequate carbon free energy for electric buildings and electric transportation.
4. Installing energy storage systems to help to match the demand for electricity with the generation of electricity

As clean, renewable energy rapidly becomes less expensive and more common across the US, that fourth step: matching the generation of electricity from renewable sources to the demand for power on the electrical grid has become a new challenge for utility companies.. Buildings, which use almost 75% of the power generated in the US, have peak energy demands that are not always coincident with renewable energy production. This mismatch has already led to undesirable consequences in locations with high renewable penetrations: Hawaii occasionally experiences periods where more solar energy is being generated than can be used, causing the utility companies to have to shut down or "curtail" the output of photovoltaic systems, wasting renewably generated energy. California has had to pay neighboring states to take excess renewable energy that it could not use.

With current technology, the lowest cost sources of renewable energy – and indeed the lowest-cost electricity sources in general – are solar photovoltaics (PV) and onshore wind turbines[1]. However, power supply and demand need to match on a real time basis. Since both wind and solar are variable resources, whose energy output fluctuates depending on weather conditions, this creates grid-scale challenges and adds to costs at multiple levels from the wholesale energy provider all the way down to the retail energy consumer.

Recognizing this challenge, the U.S. Department of Energy (DOE) announced on March 10, 2021, the beginning of design and construction of the Grid Storage Launchpad (GSL), a $75 million facility located at Pacific Northwest National Laboratory (PNNL) in Richland, Washington that will boost clean energy adaptation and accelerate the development and deployment of long-duration, low-cost grid energy storage. The facility will include 30 research laboratories, some of which will be testing chambers capable of assessing prototypes and new grid energy storage technologies under real world grid operating conditions to continue to search for solutions to this challenge.

[1] *https://about.bnef.com/blog/scale-up-of-solar-and-wind-puts-existing-coal-gas-at-risk/*

This advice letter also focuses on the fourth step: Installing building scale energy storage systems to help to match the demand for electricity with the generation of electricity. A key strategy for more efficiently utilizing these variable renewable resources described in step 3 being employed today is to install energy storage systems that can store excess renewable energy when it is abundant and release that energy for use when it is scarce (e.g. store excess PV generated power at midday and utilize it at night). Energy storage installed in buildings, like with other building grid-integration strategies discussed in previous advice letters, can help to match renewable energy production and building energy demand to balance energy production and demand in real time, creating new opportunities for more effectively utilizing renewably generated energy while trimming costs for both customers and grid operators. See GBAC Advice Letter: Building & Grid Integration from December 2018.

Energy storage is often deployed at a grid scale, in centralized large-scale installations. However, onsite BES can be a critical part of the solution to these challenges when installed "behind the meter" in federal buildings and optimized to provide long term savings on electricity bills and increase utilization of carbon-free power. For federal facilities, the benefits of this strategy can be both financial and environmental, potentially saving the Federal Government on energy bills as well as reducing greenhouse gas emissions by allowing facilities to store clean energy when it is abundant and use it during high-carbon hours.

There are several types of BES that are explored in this advice letter, each with benefits and drawbacks. Capital costs, storage capacity and duration, space requirements, safety concerns and system integration are all important elements to be considered when exploring potential energy storage systems for GSA facilities.

Although lithium-ion batteries are the leading battery storage technology today, there are other storage technologies worthy of consideration. Thermal energy storage systems have been in use for decades, and new developments in thermal energy storage are occurring, including phase change materials and enhanced controls that can transform existing equipment such as water heaters into thermal energy storage resources. Promising storage technologies such as vanadium flow batteries and clean hydrogen generation for fuel cells are in development. There is even an emerging market for "second life" lithium-ion batteries. For example, Nissan typically replaces electric vehicle batteries when capacity drops below 60-70%.[2] These have been redeployed in buildings where weight to energy storage capacity ratios are not as critical as in an electric vehicle and their low cost has made them attractive to building owners.

III. Previous Advice Letters related to Greenhouse Gas Emissions

Reducing the environmental impacts, improving indoor environmental quality and addressing climate change have been areas of focus of the GSA's GBAC since its inception in 2011. This advice letter is one of a series of letters that have been issued that focus on the growing awareness of the threat of climate change to the environment and the role that both new and existing buildings, and especially federal buildings, can play in helping to directly reduce greenhouse gas emissions and provide leadership in moving the building industry to more rapidly adopting measures to mitigate these emissions.

The GSA GBAC has the advantage of including private sector members from across the US, who are thought leaders on this issue and who can help to identify and highlight emerging strategies in reducing greenhouse gas emissions related to building design, construction, and operation before they have become mainstream. The committee is then able to provide detailed advice letters that highlight opportunities for the federal government to lead in adopting these strategies and explain the practical details of why, how and when these new ideas and trends might be incorporated into GSA projects.

Past advice letters related to reducing greenhouse gas emissions include the following:

September 2014: **Recommendations for the Adoption of Net Zero Energy Buildings by All Federal Agencies** *https://www.gsa.gov/cdnstatic/GBAC_NZE_Proposal_-_9-22-14.docx*

April 2016: **Strategic Portfolio Planning for Sustainability, Resilience, and Footprint Consolidation** *https://www.gsa.gov/cdnstatic/GBAC_Port_Prioritiz_Advice_Ltr_FINAL_7-8-16_508.pdf*

[2] *https://www.caranddriver.com/research/a31875141/electric-car-battery-life/*

November 2016: **Expanding the Concept of Energy Use Intensity (EUI)**
https://www.gsa.gov/cdnstatic/GBAC_EUI_Proposal_FINAL_508.pdf

November 2016: **High Performance Lease Criteria and Sample Lease Language**
https://www.gsa.gov/cdnstatic/GBAC_HP_Leasing_Criteria_-_FINAL.pdf

October 2017: **Power Purchase Agreement Advice Letter**
https://www.gsa.gov/cdnstatic/Adv%20Comm%20PPA%20Advice%20Letter%2012-15-17.pdf

October 2017: **High-Performance Building Adoption**
https://www.gsa.gov/cdnstatic/Adv%20Comm%20HPBA%20Advice%20Ltr%2012-15-17.pdf

December 2018: **Building & Grid Integration**
https://www.gsa.gov/cdnstatic/Bldg%20Grid%20Integration%20Advice%20Letter%202-21-19%20-%20508.pdf

December 2019: **Building & Grid Integration: Proposed Roadmap**
https://www.gsa.gov/cdnstatic/Bldg%20Grid%20Integration%20Advice%20Letter%20Phase%20II%2012-9-19.pdf

December 2019: **Data-Integrated Building Systems (DIBS)**
https://www.gsa.gov/cdnstatic/DIBS%20Advice%20Letter%2011-12-19.pdf

July 2020: **Renewable Energy Outleasing** https://www.gsa.gov/cdnstatic/FINAL_REO_TG_Advice_Ltr_7-9-20_-_508.pdf

February 2021: **Policy Recommendations for Procurement of Low Embodied Energy and Carbon Materials by Federal Agencies**
https://www.gsa.gov/cdnstatic/GSA%20GBAC%20Low%20EC%20Procurement%20Policy%20Advice%20Letter-2-17-21.pdf

The advice letters listed above highlight specific opportunities to integrate advanced practices in the design, construction and operation of federal facilities. They also demonstrate how the federal government can lead and influence the larger building market through its example. Recommendations developed by various GBAC Task Forces for GSA to consider are intended to accelerate movement toward a future where greenhouse gas emissions related to federal facilities are mitigated, while improving overall environmental and financial performance, as well as occupant comfort and well-being. This advice letter is another in the series and focuses on how BES can be incorporated into federal facilities to reduce carbon emissions related to the operation of a building, reduce operating costs and potentially provide resilience and energy security through the ability to continue to run if the local utility electricity grid fails.

IV. Findings

This Task Group finds that on-site BES systems provide an opportunity for GSA to achieve multiple benefits including utility bill savings, facility resiliency, grid support, and environmental benefits - while simultaneously accelerating the adoption of these technologies in the building industry.

In 2020, the U.S. had over 23.2 GW of capacity in energy storage compared to 1,100 GW of installed utility scale electrical generation capacity from all sources.[3] Most of this storage is operated by organizations charged with balancing the power grid, such as Independent System Operators (ISOs) and Regional Transmission Organizations (RTOs). ISOs and RTOs are "independent, federally-regulated non-profit organizations" that control regional electricity pricing and distribution.[4]

[3] *U.S. Energy Information Administration (EIA) (2020) Form EIA-860. U.S. EIA (2020) Electric Power Monthly April 2020.*
[4] https://www.eesi.org/papers/view/energy-storage-2019#:~:text=Pumped%2Dstorage%20hydropower%20(PSH),in%20the%20past%2010%20years.

There are multiple benefits associated with deploying BES in federal buildings outlined below. Further research and analysis is warranted to better frame the potential order of magnitude of the benefits from adding energy storage to future GSA projects. Beyond the immediate impact to on bill electricity cost savings, this should include analysis of the potential magnitude of direct and indirect benefits to stakeholders such as improved resilience in federal buildings, more stable local electrical utility grids, reduced transmission infrastructure costs, reduced real time carbon emissions, faster reduction of BES system costs, increased energy security, accelerated adoption of energy storage into private sector buildings through federal leadership by example, and ultimately accelerated conversion to a carbon free economy.

Energy Storage Technologies

From an energy storage standpoint, building energy loads can be classified into two categories: thermal loads and electrical loads. Thermal loads are end use loads that require thermal energy (heat) or lack of thermal energy (cool). For example, heating or cooling buildings throughout the day or creating hot or cold water are thermal loads. Passive thermal storage strategies such as opening windows at night to cool down the mass of a building when conditions are conducive are not considered in this Advice Letter.

Electrical loads are loads that are not thermally related and require electrical energy to operate. For example, you cannot run a cell phone off of heat - you need electricity to operate it. Electricity on the other hand can be used to provide heating or cooling through electrical resistance heating or heat pump technology making it a more versatile form of energy storage.

Thermal Energy Storage

Although this advice letter focuses primarily on battery technology, active thermal energy storage should also be mentioned. Most buildings create cooling instantaneously with electricity and HVAC compressors. However, thermal energy storage is a technology that has been used for centuries to allow humans to collect thermal energy and use it later. There are two common strategies for storing thermal energy. The first is using water heaters to create hot water and store it for later use. The second is using chillers to create chilled water or ice for later use in cooling a building.

Domestic tank storage type water heaters and large central water heaters are a common modern-day example of thermal storage: water is heated in a large tank over an extended period of time, so that hot water can be available on demand when needed. There are three methods for heating water in storage water heaters: heat pump, electric resistance and gas (both natural gas and propane). In an effort to reduce the environmental and climate impacts of water heating, heat pumps are replacing electric resistance and gas-fired water heaters for creating hot water in new construction and water heater replacements due to their much greater efficiency and use of electricity.

Today, water heaters are increasingly manufactured with communications capabilities and smart control modules that enable the water heater to operate as a demand response (DR)-capable, intelligent, grid-connected thermal energy storage system. The CTA-2045 universal port and OpenADR communications standard defines key capabilities and interface requirements that enable water heaters to become thermal batteries. Multiple states, including Oregon and Washington, require CTA-2045 and California requires JA13 compliant water heaters in new construction through the energy code, and more states are expected to follow their lead. The Advanced Water Heating Initiative (AWHI) has a Connectivity and Controls working group that is focused on continuing to develop these capacities, deploy them in advanced water heaters, and transform the water heater market across the US. GSA can use its power as a market leader to help transform this market toward highly efficient, grid-connected water heaters by specifying the procurement of smart, highly efficient heat pump water heaters in new and existing federal facilities. On May 18, 2021, the U.S. Secretary of Energy, announced plans for the U.S. Department of Energy's Building Technologies Office to partner with the AWHI[5].

When specifying a water heating system for its DR capability, the system (unitary storage-type or central) should be sized appropriately to provide the needed supply of hot water, while also being large enough to provide DR capacity. Larger storage tanks can be selected, or higher storage temperatures (with a temperature mixing valve)

[5] *https://www.energy.gov/eere/articles/department-energy-launches-national-initiative-clean-heating-and-cooling-systems*

can provide that added capacity.

Although one can store electrons in a battery and then use them to instantaneously cool a building, it is often more cost and energy efficient to use a chiller to "store the cooling" instead. To do this either cold water or ice is made during off-peak utility rate periods or when renewable energy is readily available and is stored in insulated storage tanks. The stored cold water or ice is used later to cool buildings during on-peak periods when electric energy is expensive or limited.

Stored thermal energy for cooling is used in approximately 10,000 buildings in 60 countries around the world, with a total electrical storage equivalent of 10 GWh[6]. These systems have been installed primarily based on the economics around electric rate arbitrage and system size reduction.

1. Peak Electric load reduction: On the hottest days of the cooling season, the instantaneous creation of cooling is approximately 40% of the total building electric peak demand. A thermal storage cooling system can be designed to address any portion of that amount.
2. Time of Use Electric Rates: An increasing number of utilities offer TOU electric rates (typically lower electric rates at night) which can provide savings if cold water or ice is generated when rates are at their lowest.
3. Demand Response: Thermal storage can easily be a DR asset with one major advantage. Most DR measures impact in some way the comfort of the people in the building (lower lighting levels, warmer room temperature setting, fewer elevators running, etc). With thermal storage the use of DR is completely invisible to the occupants.

The above measures can be accomplished with battery energy storage systems, but the levelized installed cost of thermal storage is about 1/3 of electrical storage.[7] Thermal storage can also be installed with electrical storage to cover loads that cannot be offset using thermal storage alone, can make the entire energy storage system lower overall cost per kWh. A further capital cost reduction from thermal storage, that cannot be attained by battery storage systems, is available by using the chiller and storage system simultaneously. In some cases, 20% of the total building electric demand can be met, with no additional first cost for the storage, because the installed cost of the thermal storage tanks is offset by the reduced cost of the smaller chillers, cooling towers, pumps and electrical capacity.

Finally, one of the most compelling reasons for the use of thermal storage is safety and low environmental risk. Most TES plants use water as their storage medium, with no fire, environmental, material supply or end of life issues, with proven service lifetimes of 50+ years. Since many of the loads in a building are thermal related, the logic for using safe and proven thermal energy storage is sound. They are also closed loop systems, meaning that the chilled water or ice created is cycled through the system and reused rather than discarded.

The most innovative and optimally designed thermal storage system can provide both cooling and heating for a building when used with heat pumps, greatly increasing their coefficient of performance (COP) and providing benefits during all seasons and also expand their value proposition.

Battery Storage and Lithium-ion Batteries

By far, the fastest growing form of energy storage in the US is lithium-ion batteries. Most analysts expect lithium-ion battery prices to continue to fall and capture the majority of energy storage growth over the next 10 years[8]. A key advantage that battery storage has over thermal storage is that it stores electricity which offers the capability to locally provide all of the energy required to operate a building, whereas thermal storage can only store heating or cooling, and even then requires a source of electrical energy to run the fans and pumps needed to deliver the thermal energy throughout a building.

In the past decade, the focus of technological advancement for battery storage has been mainly on lithium-ion

[6] *CALMAC and other manufactures approximate collective data by Mark MacCracken (Pres. of CALMAC Corp)*

[7] *Trane Technologies study*

[8] *https://www.energy.gov/sites/prod/files/2020/12/f81/Energy%20Storage%20Market%20Report%202020_0.pdf*

batteries. First commercially produced by Sony in the early 1990s, lithium-ion batteries were originally used primarily for small-scale consumer items such as cellphones. Recently, they have been used in electric vehicles and for larger-scale stationary battery storage. Lithium-ion batteries have become the dominant form of battery storage today and account for more than 90 percent of the global stationary battery storage market. Compared to other battery options, lithium-ion batteries have high energy density and are lightweight. [9]

The cost of energy storage, solar and wind energy have all dramatically decreased, making solutions that pair storage with renewable energy more cost competitive – Figure 1. The rapid adoption of electric vehicles (EVs) worldwide has exponentially increased the volume of lithium-ion batteries being manufactured, which has helped to

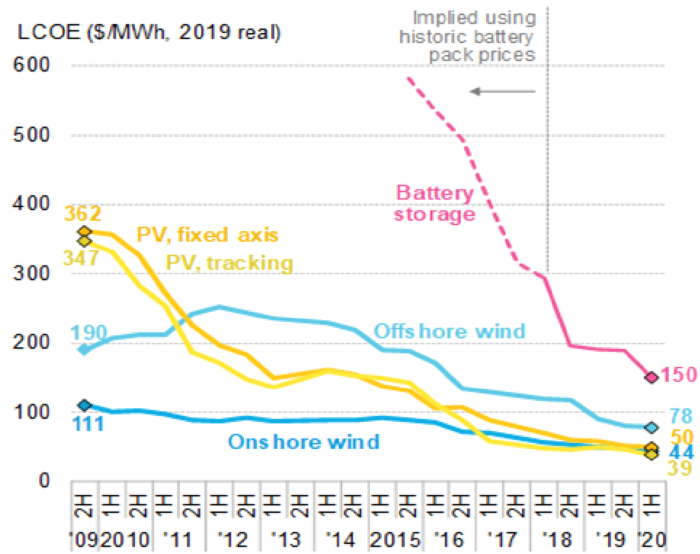

Figure 1 - Historic Costs of Renewable Energy and Battery Storage

https://www.energy-storage.news/news/bloombergnef-lcoe-of-battery-storage-has-fallen-faster-than-solar-or-wind-i

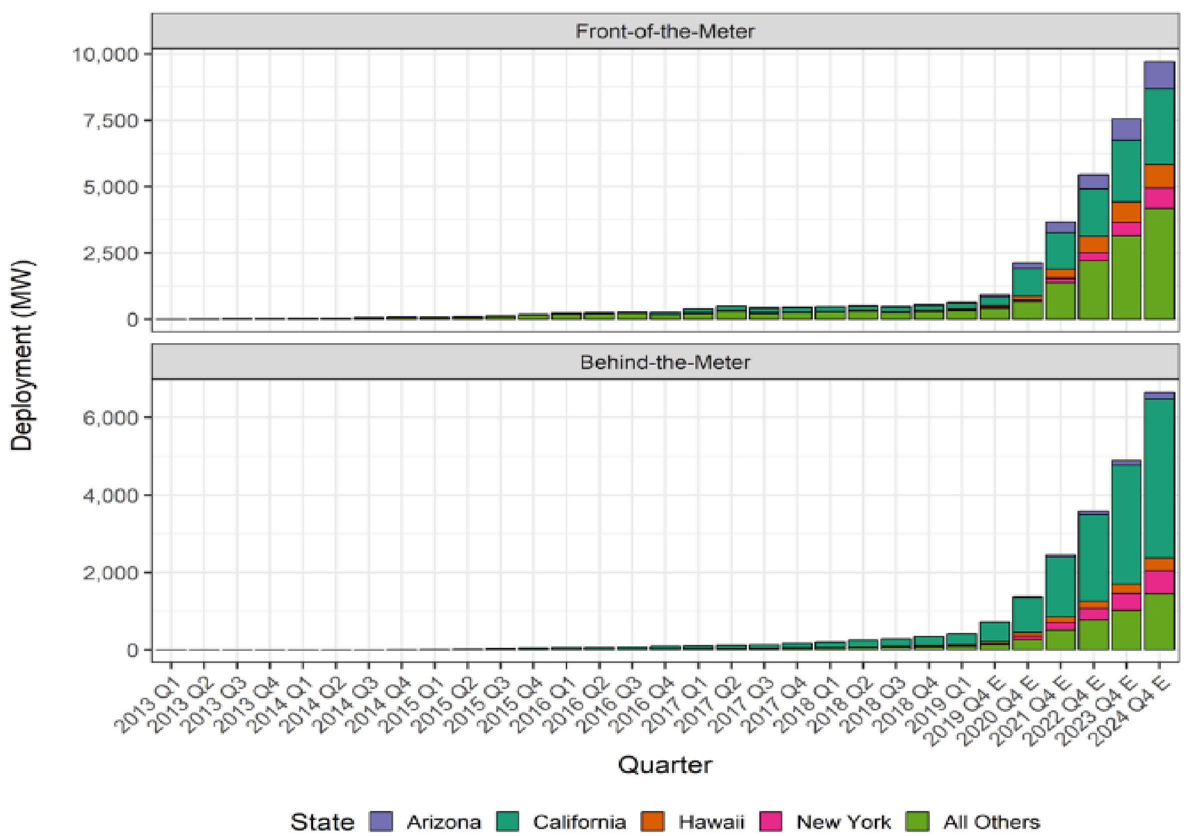

Figure 2 - US Deployment of Energy Storage by Capacity of Behind-the-Meter and Front-of-the-Meter Systems, Historical and Projected

https://www.nrel.gov/docs/fy20osti/75283.pdf

[9] https://www.eesi.org/papers/view/energy-storage-2019

drive the cost of batteries down. From 2010 to 2016 battery costs for electric vehicles fell 73 percent.[10] A recent GTM Research report estimates that the price of BES systems and grid-scale utility installations, which use the same types of batteries as EV's, will fall eight percent annually through 2022[11]. Current projections indicate that lithium-ion batteries will cost less than $100/kWh by 2023: the point of price parity between EVs and internal combustion vehicles.[12]

Similar to PV systems a decade ago, as the costs continue to fall, the adoption of energy storage technology both in buildings and at the utility scale is ramping up, making energy storage a technology worth considering for federal projects to reduce electricity bill costs – Figure 2. At the same time, natural disasters and other external conditions are driving resiliency concerns to the fore, which is pushing designers and building owners to consider energy storage as a resiliency strategy[13]. The findings in the Resilience Section explain opportunities unique to battery storage that GSA should study when considering on-site energy storage systems.

Benefits of Deploying Energy Storage

There are multiple benefits associated with deploying BES in federal buildings: behind the meter storage can provide utility cost savings, generate revenue, reduce a building's carbon footprint, and provide resilience in the event of a grid outage. Finally, in the drive to provide carbon free power 24 hours a day, 365 days a year, BES coupled with renewable energy sources will likely be a common strategy.

The BES Task Group has identified six value propositions that BES systems can offer:

1. Reduce electric utility bills via demand charge reduction, energy arbitrage and/or utility demand response programs.
2. Support utility grids by developing grid-interactive systems which can contribute to stabilizing the electrical grid.
3. Help to protect the value of existing renewable assets.
4. Reduce carbon emissions by increasing utilization of renewable energy.
5. Provide standby power or create microgrids that can provide resilience or increase energy security, especially when used in conjunction with on-site renewable energy.
6. Allow the federal government to show leadership by adopting strategies that support reducing greenhouse gas emissions.

A small but growing number of buildings in the commercial and residential building sectors, including federal buildings, are already installing BES systems to take advantage of these benefits. Several examples are described in Appendix 1.

Electricity Bill Savings

The most common use of BES systems is to provide electric utility bill savings in the form of demand charge reduction and/or energy arbitrage. In the future there may also be opportunities to reduce renewable, transmission and distribution fees.

Demand charges often offer the greatest potential savings on an electrical bill[14]. They are billed based not on the total amount of electrical energy a facility consumes (kWh), but rather based on the maximum amount of electrical power the facility draws from the grid at any time each month (kW) - sometimes measured only during specific times of the day – Figure 3. To reduce demand charges, a battery system is charged during times of low electricity demand from the grid and discharged during periods of high demand. This has the effect of reducing the peak amount of electrical power required from the grid each month (maximum demand) during applicable

[10] *https://data.bloomberglp.com/bnef/sites/14/2017/07/BNEF-Lithium-ion-battery-costs-and-market.pdf*

[11] *https://www.eesi.org/papers/view/energy-storage-2019*

[12] *https://www.bloomberg.com/news/articles/2020-12-16/electric-cars-are-about-to-be-as-cheap-as-gas-powered-models*

[13] *https://www.ul.com/news/could-lithium-ion-batteries-be-future-disaster-recovery-efforts*

[14] *https://www.nrel.gov/solar/demand-charge-battery-storage.html*

periods. Demand charge savings can be more easily achievable for facilities with short periods of maximum demand and predictable loads, such as office building air conditioning loads that predictably peak on hot days in the afternoon.

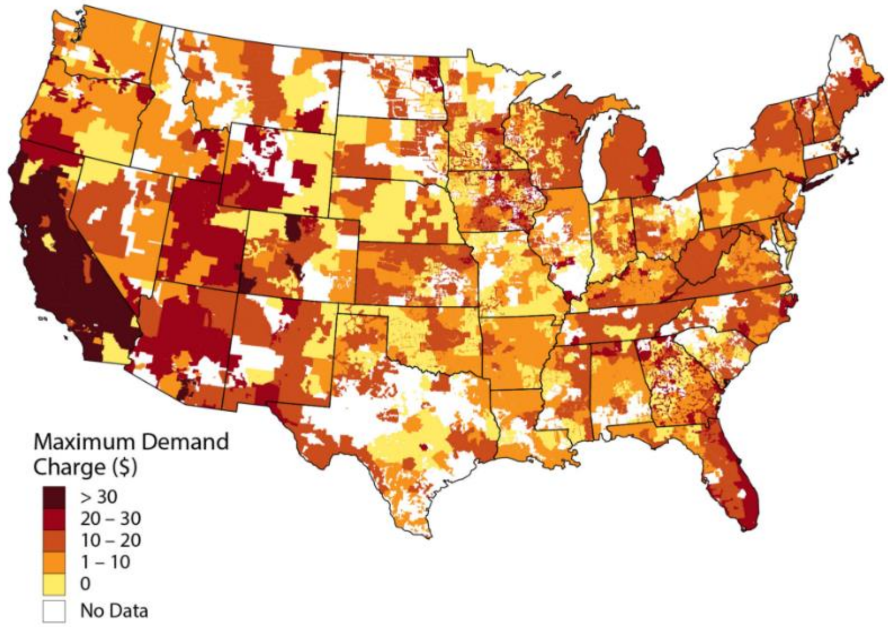

Figure 3 - US Maximum Demand Charges

https://www.nrel.gov/solar/assets/pdfs/2017-us-demand-charges-webinar.pdf

The value proposition of demand charge reduction can be enhanced by additional on-site generation technologies like solar PV, which may reduce a large amount of the demand so that the BES only needs to be discharged for a few hours to generate savings (resulting in a smaller BES system and lower capital cost).

In a case where electricity rates vary through the course of a day, the same battery system may also provide additional savings through energy arbitrage. In this use case, the battery is charged when the energy charge ($/kWh) component of utility cost is low and discharged when the energy cost is higher. This is especially relevant for sites with PV systems where the rates are higher when the PV system is generating little or no energy. These savings are more easily achieved when rates have a predictable time of use component (set hours each day) rather than real time pricing that can vary for every hour of the day throughout the year and is much less predictable. Time-varying electricity rates called Time of Use (TOU) rates are becoming more common in multiple regions nationwide.

Utility Demand Response Programs

FERC orders 841 and 2222 require transmission system operators to "remove barriers to the participation of electric storage resources in the capacity, energy, and ancillary service markets".[15] These orders will improve the financial value proposition of energy storage.

GSA has an opportunity to aggregate services within certain ISO/RTO jurisdictions to perform transmission level services that support utility grids. Battery systems can generate revenue through participation in utility programs such as Transmission Peak Demand Reduction, where the utility pays the site to lower their demand, typically for a few hours, a few times per year, when the utility's system-wide load is high. Depending on how this reduction is calculated, it is not always feasible to achieve both demand charge savings *and* savings from demand response programs because demand reductions may be included in the new baseline load used for calculating demand response reduction.

Although these mechanisms are in early stages, certain markets (Hawaii, Massachusetts, etc.) are developing programs to compensate owners for energy storage flexibility and demand response (for example, National Grid's ConnectedSolutions Program in MA),[16] which building operators with BES can take part in.

These demand response services not only produce revenue for the owner, they support grid stability through helping to reduce energy use during periods of high grid demand.

[15] https://www.ferc.gov/media/order-no-841

[16] https://www.nationalgridus.com/RI-Home/ConnectedSolutions/

Protection from “Value Erosion” of Renewables

Energy storage can be used to hedge against value reductions that impact ROI/IRR/payback, due to changes in utility rate structures or policies. Several examples include:

1. In March 2021, a California utility shifted the time of its peak TOU rates from 12 - 6 PM to 4 - 9 PM, reducing the value of the energy generated by onsite PV systems which typically reach peak production around noon.[17] Energy storage systems allow building owners to store the energy their buildings generate during off peak or partial peak times and dispatch it for self consumption during the most expensive 4 - 9 PM peak rate time.
2. California is also considering modifying its Net Energy Metering (NEM) 2.0 Program. One of the proposed changes under consideration for NEM 3.0 is reducing compensation for solar export.[18] If this was to occur, onsite storage of solar power for self consumption that was previously exported would be a key strategy to maximizing the value of that energy.
3. In Hawaii, which has the highest average electricity rate in the US[19], solar interconnection is sometimes allowable in non-export mode only[20], so batteries can often cost effectively store excess energy generated by onsite PV and dispatch it to the building for self consumption later in the day or during the evening when solar power is no longer available.
4. In Nevada, customers have entered Tier 4 NEM whereby excess solar production is compensated for at 75% of the retail rate.[21] Using energy storage to store excess solar production and consume it later in the day will allow building owners to capture the additional 25% that they would otherwise lose if exported.

Carbon Footprint Reduction

Deploying energy storage can also help reduce a building’s carbon footprint. Fundamentally, this is possible because the carbon intensity of the electricity grid varies throughout the day. This is specially true where grids have a high percentage of carbon free renewable energy generated by solar energy during the day, and then depend on fossil fuel sources at night. By charging batteries, heating or cooling water, or deploying other energy storage mechanisms, building operators can shift energy use away from high-carbon intensity hours and toward low-carbon intensity hours, thus decreasing their total carbon footprint.

Deploying energy storage in conjunction with on-site renewable energy technologies may allow for increased self-consumption of zero-carbon energy, either by allowing an increase in the on-site utilization of the renewable energy system and/or by reducing curtailment of a renewable energy system. This can help reduce the annual carbon footprint of the building while reducing stress on the electricity distribution grid.

Dispatching energy storage systems to generate savings or revenue may also align with opportunities to decrease a building’s carbon footprint. For example, an on-site solar PV system generating electricity during the middle of the day may be offsetting lower-carbon utility-owned PV or stored hydro. However, if the electricity generated by the on-site PV system is instead used to charge a battery that is dispatched later in the day during peak rates, it could offset the use of utility energy resources with higher carbon content like coal or natural gas. In order to accurately capture if energy arbitrage or demand reduction (or more generally, load flexibility) actually saves money and reduces carbon emissions, accounting needs to be done at hourly or sub-hourly time-intervals. It is important to co-optimize across multiple value streams, including both cost and carbon, when considering how, when, and where to deploy energy storage systems.

Resilience

Battery storage also has the potential to enhance resilience by providing back-up power in the event of a grid outage and extending the building’s ability to maintain habitability, albeit at reduced power levels. These

[17] *https://rise.esmap.org/data/files/library/united-states/California/EE/United%20States_California_Time-of-Use%20rate%20plans.pdf*
[18] *https://news.energysage.com/net-metering-3-0/*
[19] *https://www.staradvertiser.com/2021/04/21/breaking-news/hawaii-is-most-expensive-state-in-america-for-energy-bills/*
[20] *https://www.hawaiianelectric.com/products-and-services/customer-renewable-programs/private-rooftop-solar/quick-connect*
[21] *https://puc.nv.gov/Renewable_Energy/Net_Metering/*

capabilities are typically enhanced when paired with onsite PV: “solar-plus-storage” systems. Depending on the size of the PV system, weather and building power needs, PV coupled with battery storage to form a microgrid can supply electric power to recharge batteries and/or supply the building, extending the run time of a building using batteries alone. Battery storage and microgrids can reduce losses due to power outages, as well as improving facility and resource productivity by reducing downtime due to scheduled/unscheduled outages. They can also provide emergency community shelter during a natural disaster by enabling facility resources to ride through temporary or sustained outage events and providing power and communications resources.

Battery storage has long been used as an uninterruptible power supply (UPS) for critical loads like computers and servers. In this application, the battery is typically kept at or close to a 100% state of charge, and is not used for additional revenue-generating purposes. During a grid outage, a battery storage system can provide power continuity for a short duration, until a secondary power supply that can provide power for a longer duration can be brought online.

Today’s grid-connected batteries can be dispatched to provide value such as utility bill savings, grid services, and/or to store excess generation from distributed energy resources (DER’s) such as PV or a fuel cell while the grid is operational. If configured with appropriate islanding controls, batteries combined with other DERs can provide power for extended periods of time in the event of a grid outage. These systems, known as microgrids, can decrease the size of generation assets used solely for back-up power, increase energy security by extending limited fuel supplies, and provide a second layer of back-up redundancy.

When optimally sized, battery/PV microgrids can potentially run for days independent of the grid or external fuel supplies only using battery storage plus solar energy. This strategy has recently piqued widespread interest in California, where the threat of wildfires have caused utility companies to perform large scale shutdowns of power grids, often for days at a time, during hot, windy conditions to reduce the threat of sparking a fire.

Finally, sites could host a large-scale renewable energy and storage system where they are not the primary energy consumer. While the grid is operational, the host-site would not use the power generated. Instead, the off-taker (often a utility) would operate the system and take the benefits of the stored power. However, in the event the grid goes down; with proper islanding controls, the host site could utilize the storage technology to power critical loads. This strategy requires an active partner such as a utility, but can often offer substantial benefits at low capital cost.

Environmental and Societal Responsibility and Leadership

There is awareness and concern locally, nationally and internationally related to the impacts of climate change. BES systems can help GSA to demonstrate leadership and help the real estate and construction industries to reach the federal, state, and utility zero net energy, renewable and clean energy and ultimately 24/7 zero carbon goals that have been set and continue to evolve with deadlines as early as 2030.

There are many examples available of such goals, including:

1. Federal: The Administration’s target to reduce greenhouse gas emissions 50-52% below 2005 levels by 2030 - April 22, 2021.[22]
2. Federal: Executive Order on Climate-Related Financial Risk - May 20, 2021.[23]
3. State: California’s mandate requiring all cars and passenger trucks sold in California to be zero emission by 2035 - September 23, 2020.[24]
4. Utility: Consumers Energy’s (Michigan) plan to eliminate coal use and reduce carbon emissions by 2040 -

[22] https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-president-biden-sets-2030-greenhouse-gas-pollution-reduction-target-aimed-at-creating-good-paying-union-jobs-and-securing-u-s-leadership-on-clean-energy-technologies/

[23] https://www.whitehouse.gov/briefing-room/presidential-actions/2021/05/20/executive-order-on-climate-related-financial-risk/

[24] https://www.gov.ca.gov/2020/09/23/governor-newsom-announces-california-will-phase-out-gasoline-powered-cars-drastically-reduce-demand-for-fossil-fuel-in-californias-fight-against-climate-change/#:~:text=Following%20the%20order%2C%20the%20California,percent%20improvement%20in%20oxides%20of

February 24, 2020.[25]

Policies and Incentives

There is a patchwork of federal, state, city and utility incentives, programs and pilots to support energy storage installation projects across the US. Although some will not directly benefit federally owned systems, there are still potential indirect benefits from systems owned by third parties. Some examples include:

Federal Investment Tax Credits (ITC)

Energy storage technologies installed on a commercial property are eligible for a credit under the ITC as long as the battery is charged by a renewable energy system more than 75 percent of the time. The exact value of the federal tax credit for batteries depends on how frequently the battery is charged by a renewable energy system. To claim the full value, the battery needs to be charged by renewable energy 100 percent of the time, otherwise the credit is based on the proportion of renewable energy it receives.

For example, a battery that is charged by solar 80 percent of the time is eligible for 80 percent of the 26 percent ITC – equivalent to a 20.8% percent credit (80% x 26% = 20.8%). If this battery costs $5,000 to install, it would be eligible for a $1,040 tax credit ($5,000 x 20.8% = $1,040).

Federal buildings can access the benefit of the ITC via an Energy Savings Performance Contract, Utility Energy Service Contract or Power Purchase Agreement (See Procurement Options).

State Incentives

At the state level, storage is typically integrated into existing distributed generation policies and programs, although there may be some limitations on imports and exports. The majority of states have some sort of net metering or net billing policy in place to compensate solar customers for the excess generation delivered to the grid and these policies have implications on storage economics. Other states have specific incentives in place to accelerate deployment of storage such as tax credits, property or sales tax incentives, grants, rebates, or performance-based incentives - Figure 4.

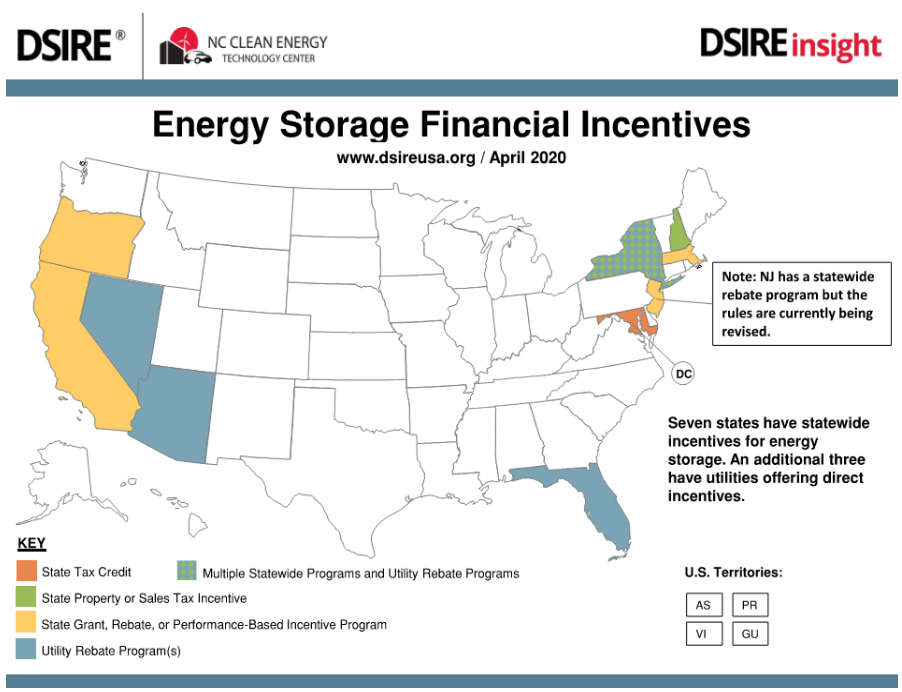

Figure 4

http://www.dsireusa.org/resources/detailed-summary-maps/

A regularly updated, detailed, searchable listing of available state and utility policies and incentives including incentives for incorporating energy storage technology into buildings can be found at the Database of State Incentives for Renewables & Efficiency (DSIRE) website.[27]

[25] https://www.consumersenergy.com/news-releases/news-release-details/2020/02/24/16/03/consumers-energy-commits-to-net-zero-carbon-emissions-takes-stand-for-the-planet

[27] https://www.dsireusa.org/

In California for example, the California Energy Commission's Self-Generation Incentive Program (SGIP) offers rebates for installing energy storage technologies in both residential and commercial facilities. The program consists of a series of declining incentive rates ($/kWh) for storage systems of different capacities and allots a maximum budget to each incentive rate.

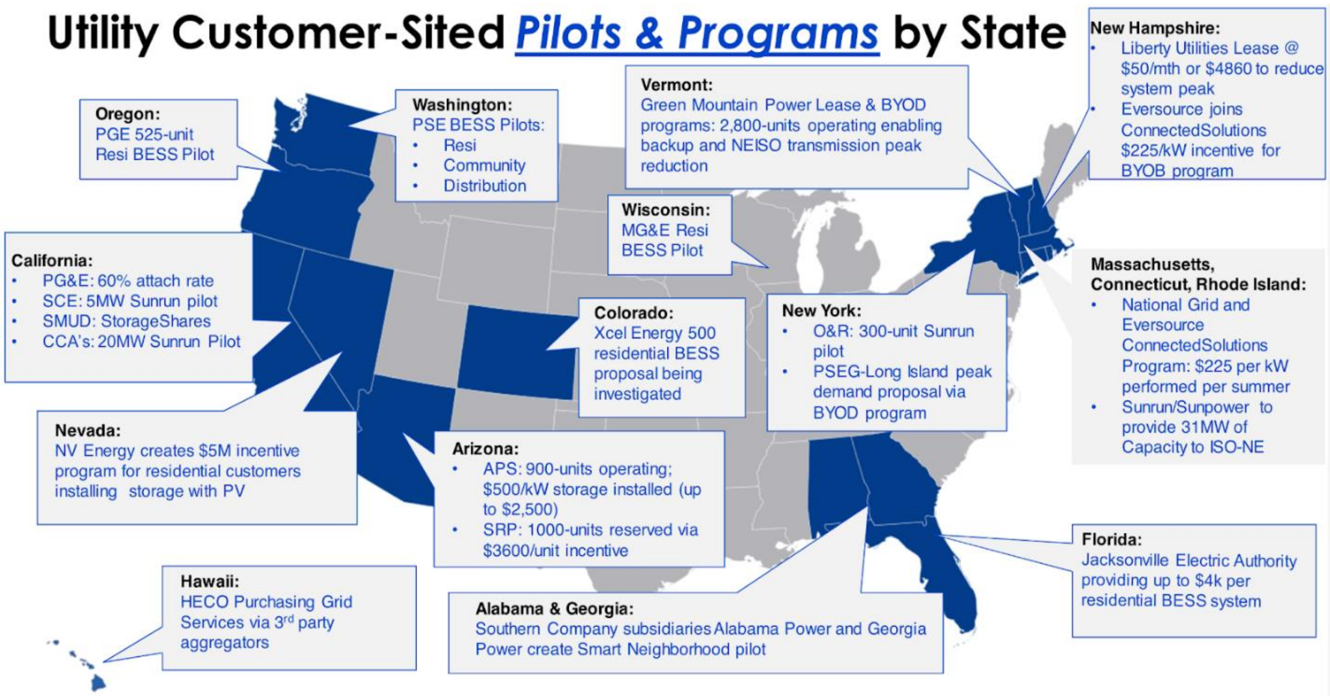

Figure 5 - courtesy Electric Power Research Institute

Utility Programs

A growing number of utility companies see the benefit of encouraging building scale energy storage on their grids. More than 20 U.S. utility programs exist today to compensate energy storage owners for energy storage services. Figure 5 shows various utility energy pilots and programs.

Figure 6 shows a typical example of one such utility program: the ConnectedSolutions program provided by National Grid / Eversource in New England.

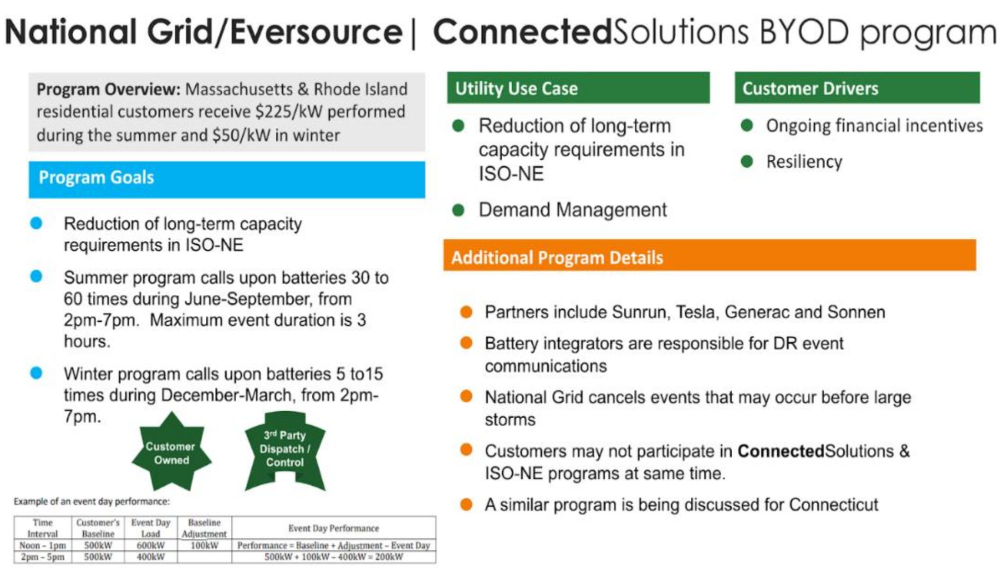

Figure 6 - courtesy Electric Power Research Institute

Impact of Policies and Incentives

The implementation of battery storage systems can be accelerated by state, local, and federal incentives and policies. While federal agencies cannot directly take advantage of tax incentives, one approach is to work with a private developer who will own, operate, and maintain the system and can monetize the incentives and pass most or all of the value through to the federal agency to make a storage system more cost-effective. The federal investment tax credit allows for battery systems coupled with renewable energy systems to receive that same tax advantage, as long as the storage system is predominantly charged by renewable energy. The Modified Accelerated Cost Recovery System (MACRS) allows for capital cost recovery through tax deductions.[28]

Procurement Options

Procurement options currently available to implement an energy storage project may include traditional appropriations, a utility energy service contract (UESC), an energy savings performance contract (ESPC), or a special facilities agreement with the serving utility called a utility service contract (USC). Where allowable, a power purchase agreement (PPA) may be used to implement storage in combination with other generation sources, and there are other situational options that are addressed at the end of this section. Energy storage can also be implemented as part of a microgrid project to serve critical loads and provide energy savings. Much of the information for this section was adapted from the Financing Microgrids in the Federal Sector paper. [29]

Appropriated Funds

If sufficient government funding (i.e., direct appropriations) is available, an energy storage project could be procured and implemented through standard procurement procedures. However, there are challenges associated with dependence on appropriations as the sole funding source for a project, such as funding limitations and competing priorities that define the amount of funding available at any given time. Appropriations are typically requested on an annual basis, making it difficult to plan and budget for potential battery pack and inverter replacements. In addition, the government should typically obtain annual funding to support an O&M contract for the energy storage system. In many cases, the performance of an energy storage system requires ongoing monitoring, management, and industry-specific expertise that may not be available to federal agencies, that is critical to ensuring that the energy storage system provides savings and/or performs during grid outages as intended.

Utility Energy Service Contracts and Energy Savings Performance Contracts

If an energy storage project is life-cycle cost effective, it can be implemented using private funding under a federal performance contracting mechanism, such as a Utility Energy Service Contract (UESC) or Energy Savings Performance Contract (ESPC). With a UESC, an agency contracts with an eligible serving utility for energy- and/or water-efficiency improvements and demand reduction services. UESCs have been successfully used for more than 20 years to award nearly 2,000 energy efficiency, water efficiency and renewable-energy projects, investing $2.8 billion and assisting the Federal Government efforts to reduce energy intensity by more than 47%.[30] An ESPC is a competitively awarded contract between an agency and an energy service company (ESCO), with streamlined approaches to satisfy the competition requirement. GSA's deep energy retrofit program used ESPC's to award 32 contracts totaling $570 million in 73 locations, providing an overall energy savings of 34 percent and generating $33 million in annual savings.[31]

UESCs and ESPCs are most often pursued because an agency lacks the funds to implement a desired energy project with appropriations. With either of these mechanisms, the contractor provides the upfront capital for design and installation and is paid from annual savings generated by the project over a maximum contract term of up to 25 years. Energy storage cost savings could include reduction in on-peak energy charges, peak demand charge reduction, storage of additional variable generation such as PV for later use, or other grid services such as demand response and ancillary services. If energy storage is not cost-effective as a stand-alone energy conservation measure (ECM), bundling storage with ECMs that have a shorter payback into the project could leverage additional cost savings to pay for the project as a whole.

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[28] *For details see: https://www.nrel.gov/docs/fy18osti/70384.pdf*

[29] *https://www.energy.gov/sites/prod/files/2020/08/f77/financing-microgrids.pdf*

[30] *https://www.energy.gov/sites/prod/files/2019/01/f58/uesc_enabling_documents_jan_19.pdf*

[31] *https://www.gsa.gov/about-us/newsroom/congressional-testimony/public-private-partnerships-for-federal-energy-management#:~:text=GSA%20developed%20this%20process%20with,ESPC%20services%20to%20the%20government*

Legislation requires that plans for equipment operations and maintenance (O&M), repair and replacement, recommissioning, and M&V be included for all ECMs, and system commissioning must be completed and documented prior to project acceptance. Annual measurement and verification (M&V) of system performance is required by ESPC legislation. Under a UESC, performance assurance can be accomplished through M&V or as part of the recommissioning services. In both mechanisms, the actual measurements and resulting savings must be documented annually for the full term of the contract. While this results in added costs to the project, proper O&M and performance measurement is critical to ensuring that the energy storage and associated ECMs sustain performance over the contract term.

Energy Sales Agreements

ESPC Energy Sales Agreements (ESAs) use the ESPC authority to implement distributed energy projects, such as PV and energy storage, on federal buildings or land. ESAs are similar to power purchase agreements (PPAs), which are further described below, but are implemented as an ECM within an ESPC. The ESA ECM is initially privately owned to potentially qualify for tax incentives. The federal agency purchases the electricity the system produces with guaranteed cost savings in the form of a lower electric rate than currently paid to the electric utility. While energy storage can be implemented as part of an ESA ECM, standalone energy storage projects would be unlikely to qualify for an Energy Sales Agreement, as they store and dispatch power, but do not generate electricity. Storage ECMs are typically combined with an onsite generation technology, such as PV, into a single ECM.

The ESCO owns, operates, and maintains the ESA ECM, and any tax incentives (e.g., investment tax credits, accelerated depreciation, state/local incentives), RECs, or other incentives can be applied by the ESCO to reduce the ESA ECM price to benefit the agency. ESPC ESAs provide two major advantages as compared to PPAs, a similar procurement option and described in more detail below. First, while civilian agencies are generally limited to a 10-year PPA term, a 20-year maximum term is allowed for ESA ECMs. The longer term makes it possible to finance projects that would not be economic in only 10 years. The second advantage is the ability to implement ESA ECMs as part of a comprehensive ESPC project to achieve energy efficiency, reduce costs, and leverage savings.

Utility Service Contracts

A Utility Service Contract (USC) is a bilateral agreement between a serving distribution utility and a federal agency. An agency may enter a USC for electric or natural gas service connection, for demand side management services, or for “special facilities services" among other service options. A USC allows for special facilities to be financed, installed, owned, and maintained by the utility on the customer’s side of the meter. Development of an energy storage system may be initiated as a special facilities service if the utility and agency agree. This may be an option when an agency is interested in a comprehensive energy storage solution, and when energy savings and available appropriations combined are inadequate to cover the upfront energy storage system cost. An advantage of a USC is that an agency can pay the utility for the energy storage over time with a “facilities charge,” or pay upfront with agency funds, or a combination of the two.

For example, if a site needs to improve energy resilience where a utility is considering upgrades to improve power reliability or quality, energy storage at a large customer site may provide a mutually beneficial solution. The utility and the customer will discuss technical solutions, associated costs, and benefits to both parties. If an energy storage system is beneficial to the utility grid, it may be possible to share implementation costs. An agency should check with their eligible serving utilities to determine what programs or services they may be able to offer.

Power Purchase Agreements

Power purchase agreements (PPAs) allow federal agencies to implement on-site distributed energy projects with no or minimal up-front capital costs. The developer finances and installs the equipment, and the agency buys the power at a cents/kWh rate based on a competitive procurement. The PPA may or may not include a minimum power purchase provision in the contract. The developer owns the equipment, assumes performance risk, and provides O&M, repair, and replacement of equipment for the term of the contract. Similar to an ESA, a PPA would typically be used for projects that combine energy storage with other variable generation sources, such as a renewable energy system, rather than for energy storage alone.

Authority to use this mechanism and the contract term allowed varies across the federal government – the longer the allowable contract term, the more flexibility in financing DERs. Civilian agencies must either obtain delegation from the GSA to use their authority per Federal Acquisition Regulation Part 41 (40 U.S.C. 501) to enter into a PPA, or use the GSA or the Defense Logistics Agency (DLA) to conduct the procurement. Civilian agency PPAs are limited to a 10-year term. For federal facilities located in their territory, the Western Area Power Administration (WAPA) has authority to enter into a PPA on their behalf for a 20-year term (possibly longer). The Department of Defense (DOD) has a 30-year authority (10 USC 2922a) that can be used for PPAs at DOD sites.

Other Procurement Approaches (Situational)

Enhanced use lease (EUL): A few agencies have the authority to use an EUL agreement, which allows underutilized federal real property to be leased for energy development in exchange for in-kind consideration or payment. In this scenario, an agency may be able to enter into an EUL that exchanges a land lease for development of utility-scale energy generation and energy storage. The generation and storage systems provide power to the commercial grid under normal conditions and can be configured to provide power to the federal facility in the event of a utility grid outage as in-kind consideration. Due to the small footprint of most energy storage systems, this approach is typically only pursued for utility-scale solar-plus-storage or wind-plus-storage applications which have larger land requirements. This can be a great option for agencies with large parcels of underutilized real property but is contingent upon their serving a utility's interest in developing a project on their site. Under this approach, all installation, operation, and maintenance costs are covered by the utility. This is similar to a process for leasing space for installing renewable energy outlined in the GBAC Advice Letter: Renewable Energy Outleasing dated July 2020 for renewables.

Utility privatization (UP): UP is another situational approach that may have potential for financing energy storage, if a site has an existing UP contract. UP transfers ownership of the entire facility electric distribution system, as well as responsibility for its operation, maintenance, repairs, upgrades, and energy systems performance, to a third-party utility provider. The owner of the privatized system may be able to install the energy storage system, with the agency repaying the costs through UP payments over the term of the contract.

The Department of Defense has special authority for public-public partnerships, where it can co-invest with local municipalities and other government agencies to expand, upgrade, replace, or transform critical infrastructure systems, including energy generation and storage.[32]

Barriers and Challenges

It is important to be aware of both financial, technical and political concerns that create barriers to incorporating energy storage systems into federal facilities. Key concerns include predicting financial performance, fire safety of lithium-ion battery storage systems, environmental impacts of mining raw materials for batteries and the end of life handling of batteries.

Financial Risk

The energy storage systems are not "standard equipment" in federal facilities and therefore not typically budgeted for. The first cost of lithium-ion BES systems are relatively high and although system costs are falling, it becomes difficult to accurately predict the expected first cost of a system. In addition, accuracy of energy modelling to predict utility bills coupled with significant changes in utility rate structures in some locations increase the risk that BES systems might generate less savings than predicted. In addition, energy costs and rate structures vary widely from utility to utility, making the same system cost effective in one location and not in another. Developing a cost-effective system that addresses these concerns is a challenge for GSA project managers.

Another challenge is that lithium-ion battery energy storage at the building scale is a rapidly evolving emerging technology. As such, many in the building industry are unfamiliar with designing lithium-ion BES systems making the perceived risks higher and designers hesitant to recommend deploying them. As of yet there are few published examples of successful lithium-ion BES projects.

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[32] *https://www.rand.org/pubs/research_reports/RR1419.html*

The following approaches must be addressed and integrated into energy storage project methods:

1. Finding procurement mechanisms to capture the value of energy storage, which may not inherently generate energy cost savings.
2. Developing methods to monetize the resiliency value these systems provide.
3. Calculating how behind-the-meter customers can monetize the value these systems provide to the utility grid; honing the capability to forecast supply and generation.

Creating financial models that encourage the installation of energy storage systems at federal facilities could help expand and accelerate the market and could create a virtuous cycle by providing proven methodologies for financing BES systems, thereby increasing the number of BES systems installed into federal buildings, encouraging manufacturers to produce more products and driving down the costs of these systems. Minimizing peak electrical demand in buildings is a proven method for reducing electricity bills through demand charge reduction or application of TOU rates. The Department of Defense has done some research on calculating the value of resilience related to energy generation and storage.[33] From a macro systems standpoint, reducing utility infrastructure costs for serving peak demand periods can lead to lower demand charges and delivery charges.

Lithium Ion Battery Concerns: Fire Safety

The technology and chemistries available for high energy-dense storage may present fire risks in the event of a catastrophic failure. To date, the installation of lithium-ion BES systems requires a significantly higher level of protection when installed indoors in occupied structures. While failures in the US are rare, the potential for significant property damage, injury, and business continuity disruption has informed fire code development to provide a high level of protection based on a hazard mitigation assessment of the technology used. An example of two different chemistries and the associated hazards is outlined in a comparison paper addressing between two common cell chemistries, NMC and LFP.[34]

While most lithium-ion BES systems include fire suppression, data suggests that flammable gas generation from a thermal runaway presents a greater explosion hazard that is not consistently addressed by manufacturers. An explosion study should be performed based on the data from the UL9540A test to determine adequate mitigation measures. These concerns should also be given consideration when siting lithium-ion BES systems.

Stationary BES systems installed in the US are guided by several building, electrical, and fire codes. BES systems should meet national codes and standards promulgated by the National Fire Protection Association (NFPA), the International Code Council (ICC), the American National Standards Institute (ANSI), the Institute of Electrical and Electronics Engineers (IEEE) and national laboratory standards. Key product safety standards include UL 9540,UL 1642, UL 1973, UL 1741, and UL 62109.

As this document addresses federally owned facilities, the most relevant codes will be the NFPA1 Fire Code and the International Fire Code (IFC). Both of these documents require that any BES system be listed to UL 9540. This product safety standard includes large scale fire testing to UL9540A that will be used to determine the risks of any particular technology and chemistry. That data will inform the design of any required fire protection systems for the specific location at which the BES system will be installed.

Another key recommendation is the active inclusion of local authorities having jurisdiction (AHJ's) such as building and fire officials in early-stage project planning. This will serve both as education to further streamline future deployments, and identify potential project issues needing mitigation measures.

Lithium Ion Battery Concerns: Raw Material Sourcing

Lithium and cobalt are critical components of lithium ion batteries. As their use increases exponentially, there have been concerns raised about the human and environmental impact of extracting the rare earth minerals used

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[33] *https://www.acq.osd.mil/EIE/Downloads/IE/FY%202019%20AEMR.pdf*

[34] *https://smartgrid.ieee.org/newsletters/august-2020/safety-comparison-of-li-ion-battery-technology-options-for-energy-storage-systems*

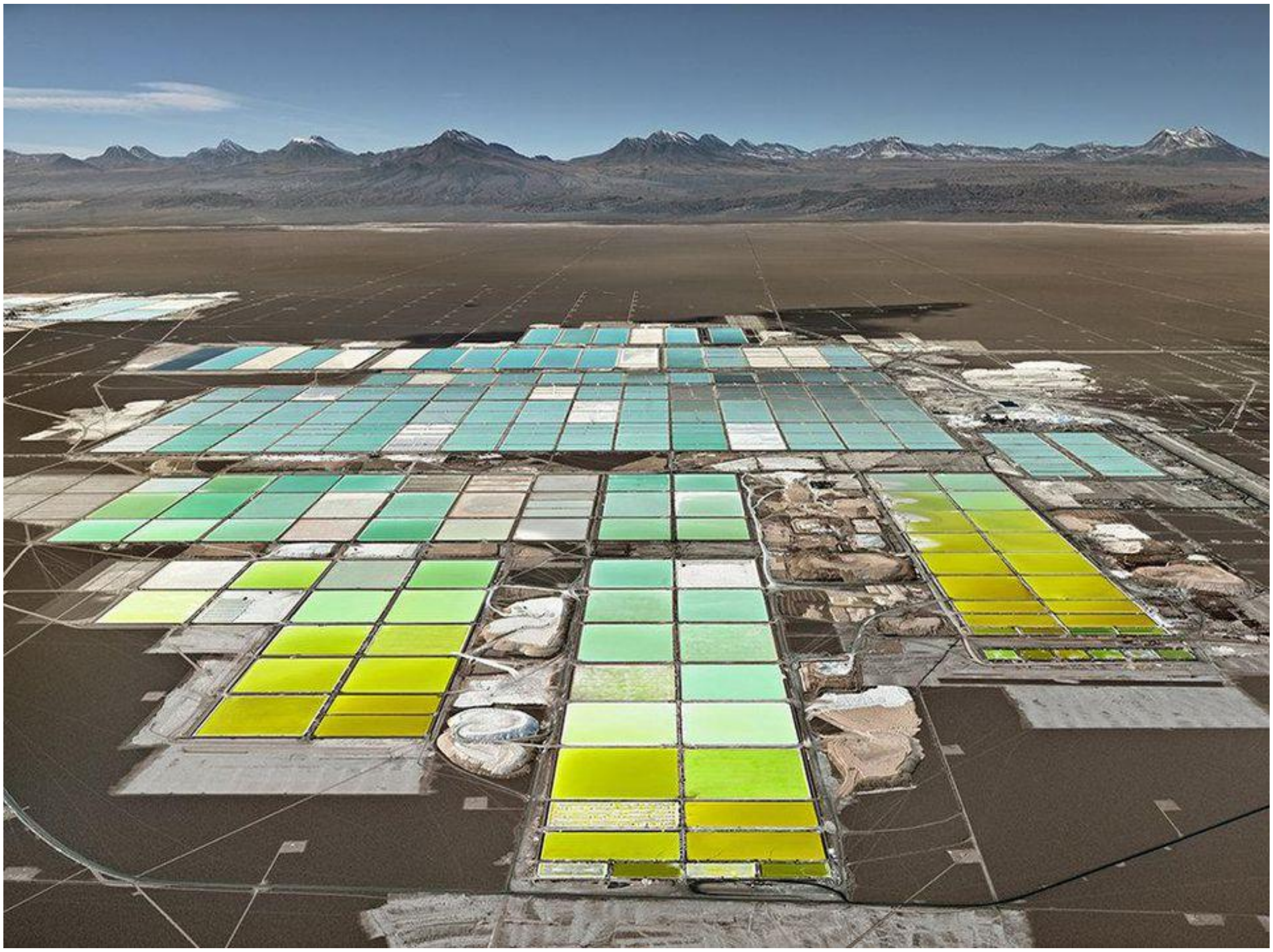

Figure 7 - Lithium Extraction Facility, Atacama Desert

https://www.forbes.com/sites/jamesellsmoor/2019/06/10/electric-vehicles-are-driving-demand-for-lithium-with-environmental-consequences/?sh=324922ba62e2)

in batteries.

Approximately 30% of lithium comes from the Atacama Desert in Argentina, Bolivia and Chile, one of the driest places on earth, which holds more than half the world's supply of the metal beneath its salt flats – Figure 7. Although relatively low in cost, the extraction process requires 500,000 gallons per tonne of lithium, consumes 65 per cent of the region's water causing contamination and impacting local farmers.[35] Another key ingredient of lithium ion batteries is cobalt used to make the cathodes in the battery. The Democratic Republic of the Congo, accounts for over two-thirds of global production of the cobalt. About 20% is sourced from "artisanal mines", where some 40,000 children work in dangerous conditions. Cobalt mines also contain sulphur minerals that generate sulfuric acid and can devastate downstream aquatic life.[36]

As with other types of mining operations, sourcing of the raw materials for lithium ion batteries has the potential to become a political issue despite the net positive impact that these batteries can provide the environment. Awareness of the issue and attention to options on where materials are sourced are recommended.

Lithium Ion Battery Concerns: End of Life

Although the majority of lithium-ion batteries used for building energy storage have not yet reached their end of life, the lifecycle of lithium-ion battery technology to date has almost entirely one-way, from manufacture to

[35] *https://www.wired.co.uk/article/lithium-batteries-environment-impact*

[36] *https://unctad.org/news/developing-countries-pay-environmental-cost-electric-car-batteries*

consumption to disposal, with little thought given to reuse or recycling. NREL assessed the current state of the market and found that reusing and recycling batteries could create U.S. market opportunities, stabilize the supply chain, reduce environmental impacts, and ease resource constraints; and that a circular economy would derive more value from BES systems. Materials could be reused, recycled, or refurbished for multiple lifetimes rather than once-and-done – Figure 8. Currently just 5 percent of spent cells are recycled. Most end up in a smelting furnace which is powered with fossil fuel, which presents environmental problems, and much of the aluminum and lithium are not currently recovered.

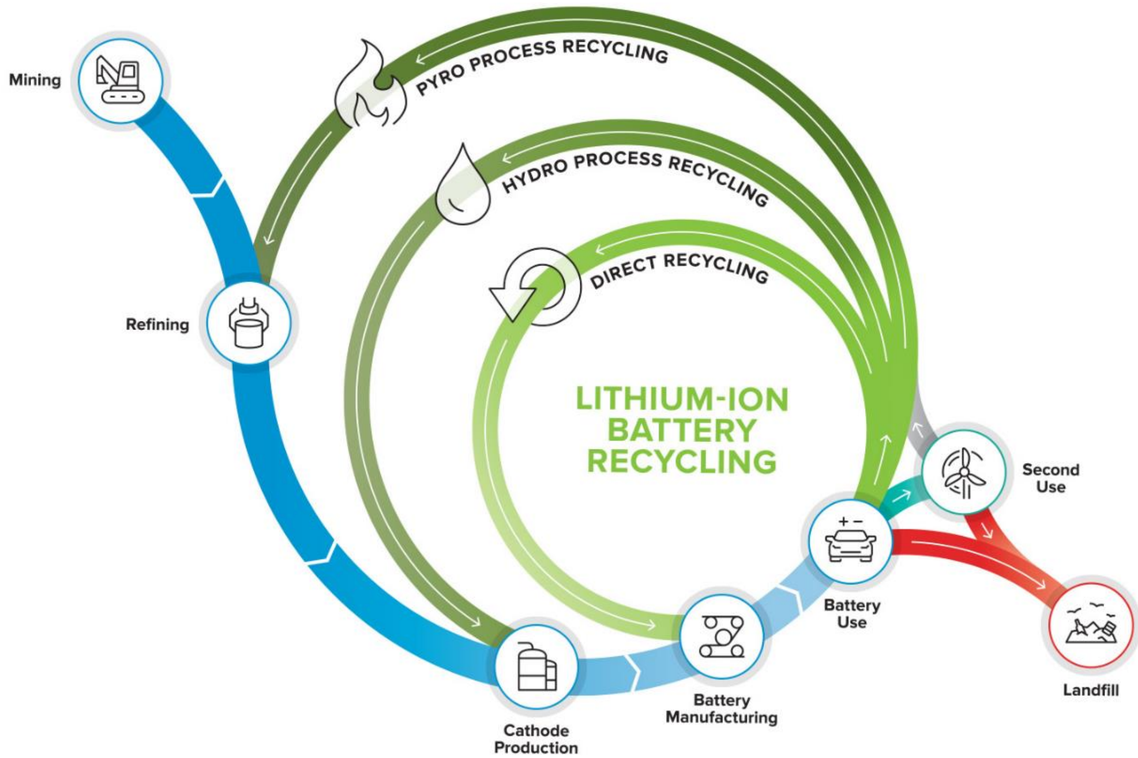

Figure 8 - Lithium Ion Battery Recycling Diagram - Argonne National Laboratory

https://www.anl.gov/article/doe-launches-its-first-lithiumion-battery-recycling-rd-center-recell

Researchers have named three barriers to recycling batteries:

1. Non-standard Technology - Lithium ion battery designs vary making it hard to design a process that will work with all batteries.
2. Lack of Infrastructure - Although battery manufacturing and use is increasing dramatically, relatively few batteries have reached end of life and little recycling capacity has been built to date.
3. Process Development - The process for recycling batteries is nascent, so information, regulation, and investment is scant and not standardized.[37]

As the demand and price of raw materials for batteries have increased, start ups are racing to develop recycling technologies. Only one U.S. lithium-ion battery recycling facility exists today: Redwood Materials (est. 2017) has started to recycle Panasonic batteries from the Tesla Gigafactory in Sparks, Nevada, at a facility in nearby in Carson City, Nevada. They claim that they can recover 95 to 98 percent of a battery's nickel, cobalt, copper, aluminum, and graphite, and more than 80 percent of its lithium.[38] They also recently reached an agreement to recycle for Envision AESC which produces batteries for the Nissan Leaf in Smyrna, Tennessee.[39] Li-Cycle, a

[37] https://pv-magazine-usa.com/2021/02/25/nrel-looks-at-barriers-to-lithium-ion-battery-recycling-and-sees-opportunities/

[38] https://www.wired.com/story/the-race-to-crack-battery-recycling-before-its-too-late/

[39] https://www.cnbc.com/2021/02/23/former-tesla-exec-inks-new-recycling-deal-as-battery-costs-soar-.html

Canadian company the largest lithium-ion recycler in North America plans to build a facility in New York.[40] To help jumpstart the process, the DOE launched the ReCell Center in 2019, a battery recycling research center at the Argonne National Laboratory.[41]

Cybersecurity

Integrating cybersecurity capabilities into BES systems will increase resiliency, and help to ensure data integrity. For companies interested in conducting business with the US Federal Government, it is crucial to keep abreast of the US Government's increasing interest in security related to the Internet of Things (IoT) and to include Operational Technology (OT). The "Internet of Things (IoT) Cybersecurity Improvement Act of 2020" requires the National Institute of Standards and Technology (NIST) to issue standards and guidelines related to increasing cybersecurity in relation to IoT. Not only does cybersecurity relate to battery storage capabilities, it also relates to the system management and analytical platforms. Most importantly, management, and analytical platforms hosted in the cloud must be FedRAMP compliant to be used by the US Federal Government.[42]

Building Energy Storage Planning Process

The Green Building Advisory Committee recommends that GSA develop a process for analyzing BES options in GSA projects, with the goal of implementing BES into more projects and capturing the benefits of BES. Figure 9 shows a graphic of a process developed by the California Department of General Services to review the economics of incorporating Solar and Solar plus Storage into their upcoming projects. GSA could develop a similar process to consider incorporating BES into their upcoming projects. This process could serve as a guide to provide a "roadmap" for GSA staff to migrate from the status quo to a vision of Federal buildings featuring energy storage. Such a roadmap should describe various options and sequential steps to get there and include team member responsibilities. Below is a roadmap developed by California's Department of General Services for their Solar plus Storage projects, which they are using for developing Solar plus Battery Energy Storage projects – Figure 10. This process could be adapted to GSA's particular approach and needs.

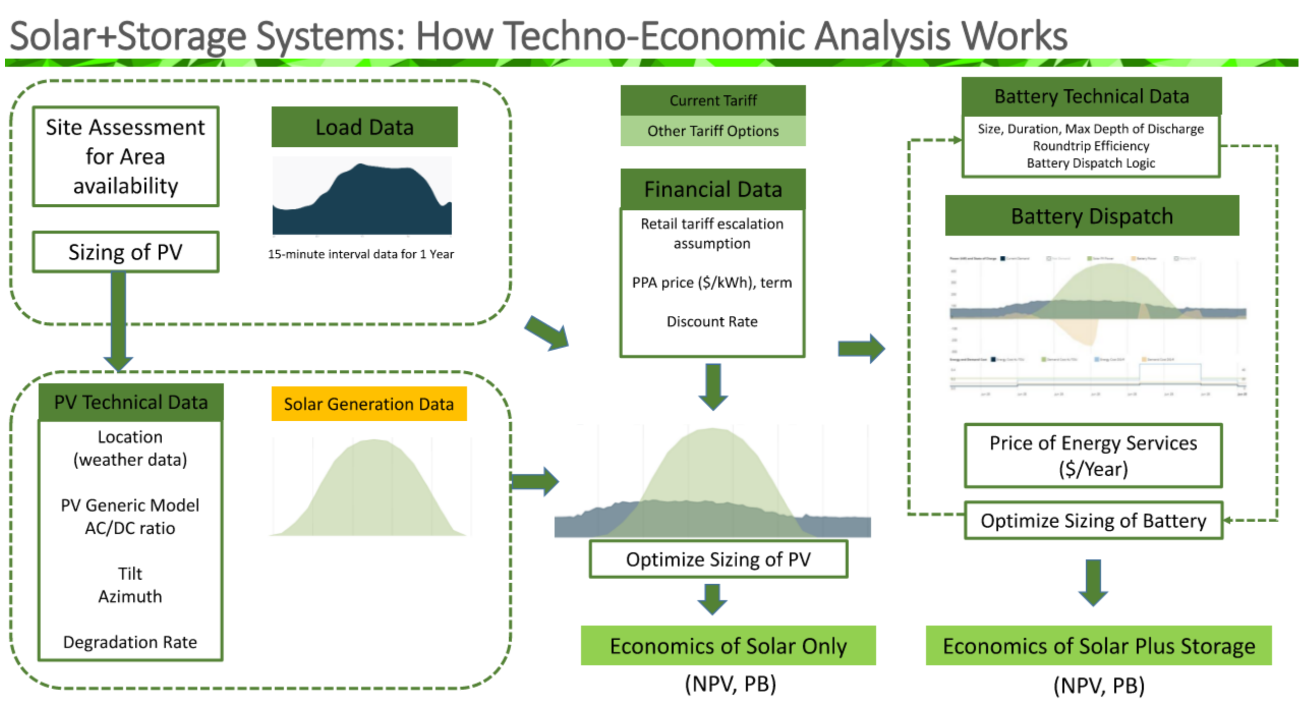

Figure 9 - courtesy California Department of General Services

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40 https://spectrum.ieee.org/energy/batteries-storage/lithiumion-battery-recycling-finally-takes-off-in-north-america-and-europe

41 https://www.energylivenews.com/2019/02/25/us-government-opens-new-battery-recycling-centre/

42 https://www.fedramp.gov/

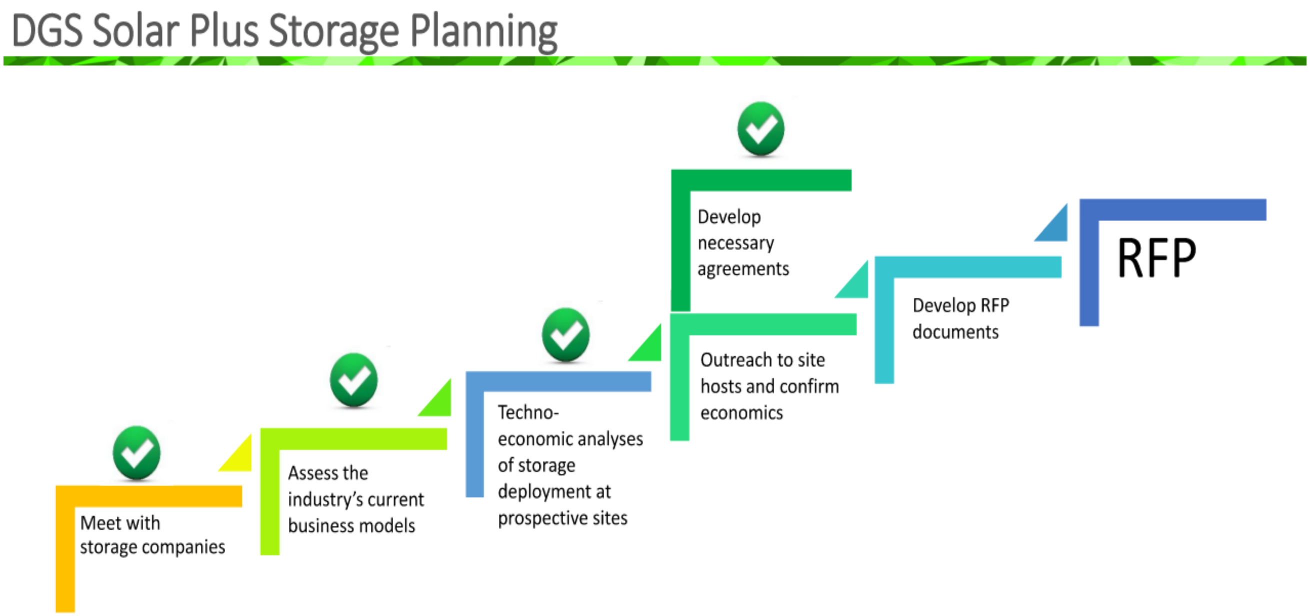

Figure 10 - courtesy California Department of General Services (DGS)

Suggested GSA Building Energy Storage Roadmap - Outline

1. Review of federal energy policies as they pertain to energy storage for federal buildings
2. Benefit analysis:
    a) Develop information on various rate structures that are likely to support federal uptake
        i) Perform rate analysis
    b) Analyze other non-billing benefits
        i) Carbon emission reduction
        ii) Standby power
        iii) Resilience
        iv) Energy security
3. Identify project opportunities
    a) Selection of a target project(s)
4. Meet with potential storage companies to understand product offerings
    a) Review available third-party financing options offered by storage companies. Examples of storage agreements may include:
        i) Third party financing (ESPC, UESC, PPA, etc) for solar + storage
        ii) Third party financing (ESPC, UESC, PPA, etc) for solar + fixed payment for storage
        iii) Existing solar + fixed payment for storage

iv) Existing solar + third party financing (ESPC, UESC, PPA, etc) for storage

b) Confirm environmental, technical and economic benefits of storage companies offerings

5. Planning, design and commissioning Federal building

   a) Incorporate energy storage into a project

6. Upon completion of a project, collect data and develop case studies. Use lessons learned from early pilot programs to refine criteria and develop practices to integrate into standard procedures.

V. Recommendations

Key recommendation of the Green Building Advisory Committee include:

1. Analyze incorporating building energy storage technology on all current and future GSA projects, and incorporate building energy storage technology if the cost/benefit analysis and first cost considerations make it reasonably feasible.

2. Develop a detailed roadmap to guide GSA staff through the process of identifying opportunities to incorporate building energy storage technology into current or future building projects and to streamline the decision making process to support adoption of the technology.

3. Conduct further research to determine the potential magnitude of benefits to stakeholders including the Federal government, private building owners, communities and utility companies from a financial, environmental and social equity standpoint.

4. Develop detailed case studies of completed projects that include the financial performance of the system and the actual benefits realized as well as the challenges encountered during design, construction, commissioning and operation of the system to help GSA staff considering installing building energy storage on a project to better understand what worked and what to be wary of.

5. Support the development of the nascent lithium ion battery recycling industry with the goal of reducing the impact of manufacturing lithium ion batteries on the environment as well as reducing dependence on potentially unreliable foreign sources of raw materials or finished products.

6. Continue to track the development of emerging storage technologies to ensure projects use best in class technology.

V. Conclusion

Building energy storage is a key strategy for moving toward decarbonizing the US economy, creating the grid of the future and supporting the Administration's efforts to address the climate crisis. It can also reduce utility bills for individual buildings, help match renewable energy supply with demand on the grid and make power plant utilization more efficient. This combined with the rapidly falling cost of energy storage technology creates the fundamental value proposition that is piquing interest in both the public and private sectors. Although utility scale energy storage is also growing rapidly, similar to photovoltaic systems it appears that there is a place for both utility scale and building scale energy storage installations. Building energy storage offers the added benefit of being capable of providing building resilience and energy security by improving the reliability of the power supply in individual buildings in addition to serving as a signal of environmental and societal leadership for the federal government by helping to reduce carbon emissions. The committee recommends that building energy storage be considered for all projects and implemented where the benefits to stakeholders and cost benefit analysis make it feasible.

Appendix 1 - Case Studies

Department of Defense: US Army Base, Fort Carson	
Location	Colorado Springs, CO
Storage technology and Capacity	In 2019, a 4.25 MW/8.5 MWh battery energy storage system (BESS) was installed.
Goals & Use	The peak energy shaving battery consists of hundreds of smaller lithium batteries grouped together to make a single storage device for power. It charges at night when power is cheaper and uses stored electricity during the day when energy use peaks and the utility costs are at highest levels
Economics	The 4.25 MW/8.5 MWh BESS is part of an energy savings performance contract (ESPC) that was awarded in August 2017. According to NREL, the REopt™ model evaluated the savings potential of over $500,000 a year for up to 20 years.
Year Completed	2019
Partner	U.S. Army Corps of Engineers, National Renewable Energy Laboratory, Colorado Springs Utilities, Lockheed Martin, AECOM, Geli, and Main Electric
Further Information	https://reopt.nrel.gov/projects/case-study-ft-carson.html https://www.energy.gov/sites/default/files/2019/05/f62/23-fupwg-spring-2019-smidt.pdf

Image: Ft. Carson - Peak Shaving Microgrid

General Services Administration and Food & Drug Administration: White Oak campus	
Location	Silver Spring, MD
Storage technology and Capacity	The system consists of a 55 MW central utility plant microgrid and includes multiple generators including two black-start generators, a 30kW PV array, three types of chillers, 2 million gallons of thermal energy storage, multiple boilers, and the integrated plant controls.
Goals & Use	The project consists of a multi-fuel, integrated central utility plant microgrid that will meet the heating, cooling and energy of the entire campus
Economics	GSA collaborated with Honeywell under an energy savings performance contract (ESPC) project for the Food and Drug Administration's (FDA) Federal Research Center at White Oak Campus in Silver Spring, Maryland. It is estimated to save $5.8 M in annual energy cost savings.
Year Completed	2013
Partner	GSA, FDA, and Honeywell
Further Information	https://www.energy.gov/sites/prod/files/2013/10/f3/espc_ss_whiteoak.pdf https://www.energy.gov/eere/femp/honeywell-helps-deliver-resiliency-and-cost-savings-food-and-drug-administrations-white

Image: GSA and FDA - White Oak campus

Department of Defense: U.S. Marine Corps, Miramar	
Location	San Diego, CA
Storage technology and Capacity	This project consists of a 200kW solar and battery storage system. The battery storage includes zinc-bromide EnergyPod®2 flow battery (25kW/125 kWh), lithium-ion battery (250 kW / 600 kWh), and 6 Bi directional charges / hybrid electric vans.
Goals & Use	The 200kW solar and battery storage system provides 100% renewable energy to the island and backup power.
Economics	The DoD ESTCP demonstration project ($3M) was funded in 2012. During normal grid conditions, the PV system offsets power purchased from the electricity grid. Under the ESTCP project, the Primus Power battery was used to demonstrate peak shaving.
Year Completed	2019
Partner	DoD ESTCP, Raytheon, ONR ESTEP, and the California Energy Commission.
Further Information	https://www.nrel.gov/energy-solutions/partner-mcas-miramar.html

Image: Department of Defense - U.S. Marine Corps Miramar

General Services Administration: Schwartz Federal Building and Courthouse	
Location	San Diego, CA
Storage technology and Capacity	This project is a 750kW / 1,425 kWh Lithium Ion Battery Energy Storage System (BESS) supplied by Tesla (Powerpack 1). Modules packaged in 250 kWh blocks of energy: Two hours of capacity at 750 kW continuous net discharge power Or four hours of capacity at 375 kW continuous net discharge power
Goals & Use	There's a control system to charge and discharge BESS to optimize utility consumption and minimize costs. Demand cost savings is achieved by discharging battery during peak times and recharging during off peak times.
Economics	This project reduces the site's energy costs by reducing monthly demand and associated charges through Energy Savings Performance Contract (ESPC). The monthly on peak demand reduction is $19/kW. The monthly non-coincident demand reduction is $24/kW.
Year Completed	2018
Partner	Ameresco, Tesla, and GSA
Further Information	GSA San Diego Battery Energy Storage Overview Presentation (Edward J. Schwartz Federal Building and U.S. Courthouse 3 December 2020)

Image: GSA: Schwartz Federal Building and Courthouse