Behind-The-Meter Battery Energy Storage:

Frequently Asked Questions

What Is Behind-The-Meter Battery Energy Storage?

Energy storage broadly refers to any technology that enables power system operators, utilities, developers, or customers to store energy for later use. A battery energy storage system (BESS) is an electrochemical device that charges or collects energy from the grid or a distributed generation (DG) system and then discharges that energy later to provide electricity or other services when needed. BESS can provide grid and customer services, acting as both a load (while charging) and a generation asset (while discharging). Behind-the-meter (BTM) BESS refers to customer-sited stationary storage systems that are connected to the distribution system on the customer's side of the utility's service meter.[1] BTM BESS, along with DG and other grid assets deployed at the distribution level, are broadly referred to as distributed energy resources (DERs). Figure 1 provides some examples of DER (including a BTM BESS) that are increasingly being deployed in power systems around the world as technology costs decline and customer interest grows.

BTM BESS differ from front-of-the-meter storage systems, both interconnected at the distribution system and the transmission system (e.g., utility-scale storage systems), in many ways, including who owns the systems, where they are installed, and the size and number of systems installed. These characteristics influence the role of BTM BESS on the grid. Figure 2 outlines a few key characteristics of BTM BESS and how they impact the integration of BTM BESS into the power system.

As of the time of this writing, the primary cost-effective battery chemistry available for BTM applications is lithium-ion.[2] The trend toward lithium-ion has been driven, in part, by steep price declines in the price of lithium-ion technologies—over 89% from 2010 to 2020—with further price

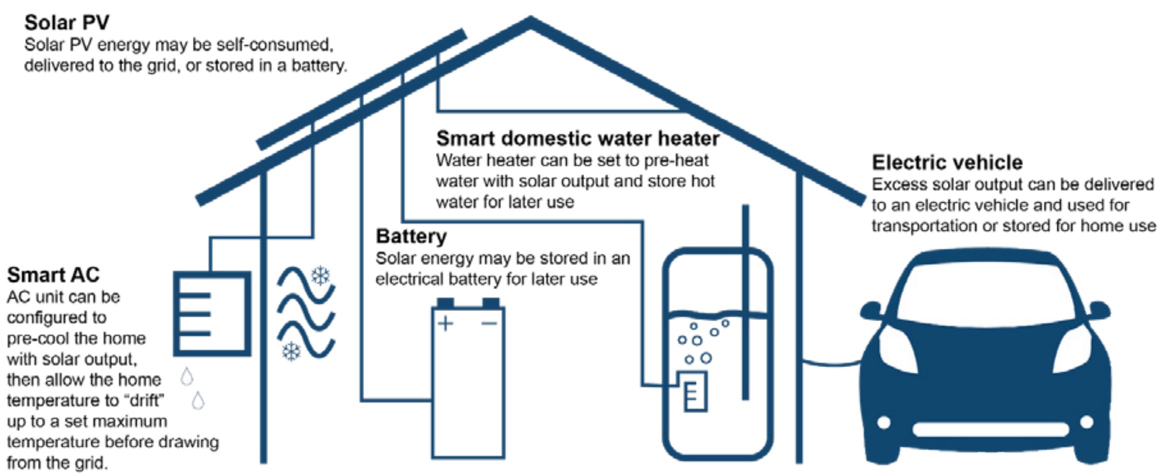
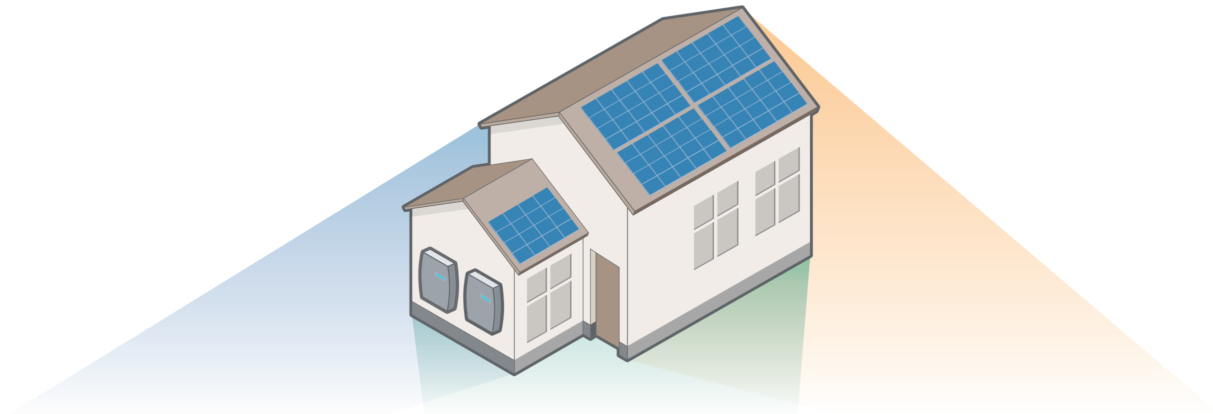


Figure 1. A selection of DERs customers can deploy BTM in combination with, or apart from, distributed solar photovoltaics (PV)
Source: (O'Shaughnessy et al. 2017). Note: This report only covers BTM battery energy storage, although it can interact with other DERs.

1. Customer-sited, off-grid battery storage systems, which are not connected to the grid, are not covered in this fact sheet. Additionally, while electric vehicles can act as BTM storage systems and provide services to the customer and power system, this fact sheet does not cover them.
2. For additional information on various technology options for energy storage, see Kim et al. (2018).



SIZE AND QUANTITY:
BTM systems have smaller capacities, but there are more of them.

PROBLEM:
This complicates their integration as utilities struggle to process applications.

SOLUTION:
Well-designed **interconnection processes** can help streamline this process while ensuring they do not negatively impact the power system.

SITING AND OPERATION:
Utility-scale systems are sited and dispatched to meet power system needs. BTM systems are installed and operated to meet customer needs.

PROBLEM:
Customer needs are not necessarily aligned with power system needs.

SOLUTION:
Well-designed **compensation mechanisms** and **other policy instruments** can help align interests, ensuring BTM systems are deployed and operated to benefit all power system stakeholders.

VISIBILITY:
System operators and utilities have limited visibility into the BTM system operation (i.e. they only see the difference between customer demand and storage operation).

PROBLEM:
This can impact planning exercises and regular operating practices.

SOLUTION:
Well-designed **interconnection requirements** can ensure sufficient metering and telemetry equipment installed to help utilities; however, the burden these requirements can represent for installing customers should be carefully considered.

Figure 2. Unique characteristics of BTM BESS, resulting issues, and solutions

declines anticipated (Frith 2020).[3] These price declines, in turn, have spurred a growing interest in the adoption of BTM BESS and the implications of integrating BTM BESS into power system operations.

This fact sheet provides a brief overview of stationary BTM BESS.

Why Do Customers Adopt BTM BESS?

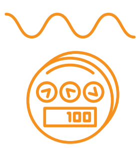
BTM BESS adoption is mainly influenced by customer decisions, as the systems are installed on customer premises, provide savings or other benefits to the customers, and customers are typically the principal investors in the system. The primary drivers for customer adoption of BTM BESS to date are opportunities for bill reductions, improving energy resilience, and mitigating power quality. For additional information, see Zinaman et al. (2020).

Customer Bill Savings: BTM BESS is often paired with DG to reduce energy bills and/or enhance compensation. Bill reduction is primarily achieved through demand charge reduction (lowering the maximum power consumed, typically per month) and energy arbitrage (shifting electricity consumption from high to low energy cost periods). The ability of customers to reduce their bills depends on what a customer pays for electricity (the retail tariff rate) and what they are paid for exports (the sell rate). For more information, see "Compensation Mechanisms for BTM Storage." Additionally, depending on the presence of utility or third-party programs, customers may be interested in investing in BTM BESS and granting other power system stakeholders access to their systems in exchange for payments (see "What Emerging Business Models Can Support BTM BESS Deployment?").

Customer Reliability and Resiliency: Customers may be interested in having reliable access to power after a disruption to the grid, particularly if these interruptions occur relatively frequently or the customer faces steep consequences for interruption in supply (e.g., a hospital) (Anderson

3. Note that this figure only refers to battery pack prices, which represent only a portion of total energy storage system costs. Additional cost categories include labor for installation, additional monitoring and telemetry equipment, and developer overhead to fund customer outreach and advertising programs.

et al. 2019; Elgqvist forthcoming). Continuous cost declines in renewable DG and energy storage have made them a viable alternative and/or complement to traditional diesel generators because they can reduce the size of the diesel generator needed, do not rely on fixed fuel supplies, and can generate revenue while the grid is operational. Customers may become increasingly interested in resilient solutions as climate change increases the frequency and intensity of natural disasters such as flooding and tropical storms, causing increasing interruptions to the utility grid (Fried, Hellmuth, and Potter 2019).



Customer Power Quality: Many customers, in particular industrial customers, rely on an uninterrupted supply of high-quality power. These industries, such as semiconductor manufacturers, may be willing to invest in BTM BESS to ensure power from the grid within very tight voltage or frequency tolerances.

Can BTM BESS Provide Power System Services?

In addition to the "customer-facing" services described previously, BTM BESS has the potential to provide a wide range of additional services to other power system stakeholders. The following is a nonexhaustive list of services that BTM BESS can provide to utilities and power system operators. While technically capable of providing these services, additional steps may be necessary to tap into this potential (see Text Box 1). For a more in-depth description of these services, see Bowen et al. (2019) or Denholm et al. (2019).

Energy and Capacity: BTM BESS can provide both energy and peaking capacity services by discharging stored energy either from an associated DG system or imported earlier from the grid. Encouraging BTM BESS to perform energy arbitrage or provide peaking capacity may rely on explicit signals from power system operators or may be indirectly encouraged through price signals. In South Australia, a virtual power plant pilot project is under development to aggregate 1,000 BTM BESS to act as a single 5-MW power plant. In addition to providing services to customers, this virtual power plant will be used to perform energy arbitrage in the wholesale market, benefiting retailers, and help meet peak demand, benefiting system operators (AGL Energy Limited 2018).

Ancillary services: The supply and demand of energy must be carefully balanced to maintain the safe operation of the power system. To account for fluctuations in the demand and supply of energy, system operators procure a wide array of ancillary services on timescales ranging from milliseconds to several minutes (Denholm et al. 2020). Energy storage technologies such as lithium-ion batteries are well-suited to provide ancillary services as they: (1) react exceedingly quickly and accurately to signals, and (2) can switch from being sources of generation (discharging) to sources of load (charging). In Hawaii, a virtual power plant comprising BTM BESS and other DER is planned to help provide frequency support to the grid, including fast frequency response. These services are expected to become more critical as the small island grid transitions to higher levels of renewable energy in line with its 100% target (HECO and OATI 2019).

Transmission and Distribution Upgrade Deferral: Just as system operators need to ensure sufficient generating capacity to meet demand in all hours of the year, there must also be sufficient transmission and distribution capacity to deliver that power. As the loads on the utility grid grow, a utility may need to upgrade the distribution and transmission system capacity. Energy storage can defer the need for additional transmission or distribution capacity investments by charging during low-demand periods and discharging to meet local demand during high-demand periods, essentially reducing the power that must be transmitted from centralized resources during traditional periods of grid

Text Box 1. Enabling Power System Services From BTM BESS

Although BTM BESS can provide a wide variety of services to the power system, enabling these may require additional infrastructure, more complex operating practices, and changes to compensation mechanisms. "Implicit" approaches such as using retail tariffs to incentivize certain behaviors may require more advanced metering infrastructure and additional administrative oversight, as well as customer education programs, to enable and encourage customer participation. More "explicit" approaches such as directly dispatching DER, either through aggregators or directly by utilities and power system operators, may require additional metering, telemetry infrastructure, cybersecurity considerations, and operational changes to ensure safe and reliable procurement of services from BTM BESS. This additional metering or communication infrastructure, while critical for service provision, may increase the price of the storage system beyond what a customer can afford.

In New York, the transmission system operator is developing a "Dual Participation" model that will allow DERs such as BTM BESS to provide services to customers, utilities, and the wholesale energy market. The model attempts to address issues related to: (1) ensuring bulk power system reliability; (2) ensuring appropriate visibility into DER operation for all parties; (3) ensuring the DER has access to the most value streams possible; (4) preventing double payment for services; and (5) "coincidence" (when a DER is contracted to provide conflicting services to multiple entities in the same time period) (Lavillotti 2019). These rules will ensure customers can pursue value through both on-site services (bill reductions, backup power) and revenues through markets.

congestion. As BTM BESS are located on the distribution system, they are uniquely suited to providing distribution deferral services. Faced with a potential $1.2 billion distribution upgrade, the New York utility ConEdison opted instead to defer the upgrade by relying on a portfolio of investments, including customer-sited BTM storage, to reduce demand and remain within existing infrastructure capacity limits (Schwabe, Statwick, and Tian 2018). The use of a broad set of nontraditional investments, such as DG, BTM BESS, demand response, or energy efficiency, to offset the need for traditional transmission and distribution investments is known as **non-wire alternatives**.

How Can Power System Decision Makers Encourage the Adoption of BTM BESS?

Policymakers, regulators, and other power system stakeholders may be interested in encouraging the adoption and influencing the operation of BTM BESS, either in the interest of policy priorities (e.g., customer choice or decarbonization efforts) or as a means of providing valuable power system services. Customers, however, will adopt and operate storage to match their own energy needs or objectives, which may or may not be aligned with the broader needs of the power system. Fortunately, there are several tools available to help align the interests of customers and other power system stakeholders, including goal setting, financial incentives, and compensation mechanisms. These offer a powerful means for directing the adoption and operation of BTM BESS to contribute to power system objectives.

Setting Goals for BTM BESS: Policymakers, regulators, and utilities may be interested in increasing the presence of BTM storage on the grid, particularly among certain customer classes or in certain regions. Existing targets for utility-scale storage, if present, can be modified to include specific targets for BTM storage. For instance, in response to directives from policymakers to increase the presence of energy storage in line with environmental objectives, the California Public Utilities Commission (CPUC) established mandatory energy storage targets for systems connected to the transmission system and distribution system, both behind and in front of customers' meters (CPUC 2013). These goals, whether mandatory or aspirational, can send a clear message to developers and customers on the long-term support for BTM storage, potentially bolstering nascent markets.

Financial Incentives for BTM BESS: Providing financial incentives, such as low-interest loans, grants, or tax credits, can drive targeted adoption of BTM BESS among specific regions and customer classes, particularly if there is a concern that BTM BESS is out of reach for low-income customers. For instance, California regulators expanded financial assistance for BTM BESS for under-privileged customers in areas prone to wildfires as part of their broader mission to promote energy resilience and equity (CPUC 2020). Incentives can also come with conditions to ensure that BTM BESS are being operated in ways that benefit multiple power system stakeholders. For instance, the utility Green Mountain Power offered financial assistance with purchasing BTM BESS in exchange for limited control during certain hours of the year, allowing the utility to reduce operating expenses (Green Mountain Power 2021b). Existing financial incentives for DG can also be expanded to include BTM BESS, either paired with DG or in stand-alone systems.

Compensation Mechanisms for BTM BESS: Compensation mechanisms govern: (1) what power flows between the customer, the DER system, and the power system are allowed, tracked, and billed; (2) the rate customers pay for purchasing electricity from the power system; and (3) the rate at which customers are rewarded for electricity sold back to the power system (Zinaman et al. 2017). Compensation mechanisms can be designed to reward exports by and incentivize the adoption of DG and are in some jurisdictions being expanded to include DG plus BTM BESS (Zinaman, Bowen, and Aznar 2020). Choices around the design of compensation mechanisms can influence whether customers are likely to pair energy storage with DG (see Text Box 2).

Text Box 2. Net Metering vs. Net Billing for Energy Storage Systems

Two common frameworks for compensation mechanisms for electricity exported to the grid include net energy metering and net billing, both of which have different impacts on the relative benefits of pairing storage with DG.

Under net energy metering, customers receive bill credits for electricity exports in excess of on-site consumption. These credits can be used to offset consumption from the grid in the current or future billing cycles. In this way, the power system itself acts as a form of financial energy storage, and, as such, net energy metering is unlikely to incentivize the pairing of BTM storage with DG.

Under net billing, customers are compensated for electricity exports at a predetermined sell rate, while paying for consumption from the power system at their normal retail tariff rate. The ratio of the sell rate and the retail tariff rate plays an important role in whether storage is incentivized. If the sell rate is lower than the retail tariff rate (as is typically the case), customers pay more for consumption from the grid than they are rewarded for exports to the grid. This encourages customers to avoid consumption from the grid when possible by storing excess generation from DG for use at a later time, therefore incentivizing pairing their DG system with BTM BESS.

For more information on the impact of compensation mechanisms on BTM BESS, see Zinaman et al. (2020).

Some jurisdictions are introducing more complex retail tariff elements into their compensation mechanisms, like time-of-use rates or demand charges. These elements can be more likely to incentivize pairing BTM BESS with DG, as complex rates often offer more opportunities for customers to reduce their bills with BTM BESS relative to flat volumetric rates alone. Such complex tariff elements also help to align DER operation and consumption with power system needs. However, these benefits must be weighed against the increased effort to administer such tariffs, as well as a customer's ability to reasonably respond to additional complexity.

How Can Decision Makers Promote the Efficient, Safe, and Reliable Interconnection of BTM BESS?

Interconnection is the process of safely and reliably integrating a given DER into the broader power system. Poor interconnection procedures can act as a barrier to DER like BTM BESS by either: (1) presenting customers and developers with opaque and difficult-to-navigate application processes; (2) requiring too much effort on behalf of the utility to process applications, leading to long delays for customers and developers; or (3) allowing BTM BESS to interconnect that are likely to cause issues. The three categories of rules outlined below can help jurisdictions safely and efficiently interconnect BTM BESS while ensuring interconnecting systems are capable of meeting power system objectives. Many of the same rules and approaches already used to safely and reliably integrate other DERs like distributed PV can also be implemented for BTM BESS.

Application processing determines the information customers and developers must provide the utility to submit a complete application and how the utility must handle these applications once received. Finding ways to automate or streamline the application process can help utilities make the most of their limited resources and ensure a relatively painless experience for adopting customers, removing a stumbling block for the growth of BTM BESS and other DERs.

Grid requirements dictate the behavior and capabilities of equipment interconnecting to the power system, typically through model equipment and interconnection standards developed by international bodies. Two important standards for DER such as BTM BESS are IEEE 1547-2018 and UL 1741 SA, which help ensure interconnecting systems are capable of appropriately reacting to power system conditions, as well as cover other important elements for DER such as communication and cybersecurity protocols. Additional standards specific to energy storage are currently under development.

Technical review processes govern how systems are reviewed for their potential impact on the grid by the utility before being allowed to interconnect. Some regulators have allowed for expedited review processes in constrained portions of the grid if the developer or customer agrees to limit discharging back to the grid (e.g., Hawaii's Customer Self Supply tariff option (HECO 2019)). Well-designed technical review processes help utilities prioritize additional review for systems most likely to cause issues, while allowing accelerated interconnections for systems unlikely to cause issues. This streamlined process can enable the adoption of storage and help utilities use their limited resources more efficiently (Horowitz et al. 2019).

Text Box 3. Ensuring Safety for BTM BESS

The New York State Energy Research and Development Authority (NYSERDA) has developed a set of guidelines for reviewing and evaluating BESS, which rely on utilizing codes, standards, and training. This includes guidance on the adoption of legislation and regulations for safe and reliable adoption of BESS, permitting considerations for residential and small commercial BESS, and an inspection checklist for code enforcement officers or third-party inspectors. In 2020, the New York State Uniform Fire Prevention and Building Code, which outlines the required statewide guidelines for building construction and fire prevention, was modified to include the latest safety considerations for energy storage systems (NYSERDA 2020).

Given the dense urban areas in New York, building-related requirements are provided for both "occupied" and "unoccupied" areas to minimize fire and chemical hazards to occupants and also minimize the conditions under which fires occur, including ensuring adequate ventilation to prevent any gas and air buildup around modules, which can lead to fires (Gokhale-Welch and Stout 2021). In combination with existing codes, regulations, and industry standards, these provisions help ensure the safe permitting, siting, and deployment of BESS.

What Are Some Key Safety Issues Surrounding BTM BESS?

As BTM BESS are sited on customer premises, it is important for these systems to operate safely. Two critical safety concerns for storage systems include unintentional islanding and, for lithium-ion batteries that make up the majority of new BTM BESS installations, thermal runaway.

Unintentional islanding refers to instances in which energy stored in the BTM BESS re-energizes a portion of the distribution network without the knowledge of utilities. This can delay service restoration, damage utility equipment, and pose hazards to utility workers who assume a segment of the grid is not energized (Enayati 2018). Although rare, unintentional islanding can happen if an energy storage system (or a distributed PV system) continues to export power to the grid during an outage. Many technical requirements (e.g., IEEE 1547–2018) now stipulate specific measures to detect and prevent unintentional islanding, while explicitly allowing for intentional islanding, such as BTM systems providing energy to a critical section of the grid during a major outage (e.g., in a microgrid application).

Thermal runaway refers to a process unique to electrochemical energy storage systems in which the temperatures within the storage system increase to a critical point beyond which internal chemical reactions create a self-sustaining process of heat generation that can ultimately lead to fires or an explosion. Thermal runaway is especially a concern for lithium-ion batteries, and this danger can be compounded in BTM BESS that may be housed in dense urban areas and may not come equipped with the same extensive fire suppression equipment as utility-scale systems. Technical standards governing the testing, installation, operation, and maintenance of these systems can help to mitigate such safety issues (e.g., NFPA 855 in the U.S.). See Text Box 3 for information on how New York state has sought to approach safety considerations for energy storage systems. Figure 3 shows example safety measures for BTM BESS installations that can be implemented to reduce the risk of fire and other hazards.

- Recommended BTM BESS inspection procedures and frequency
- Fire detection and suppression systems
- Firefighting measures posted on-site
- Emergency stop protocol
- Ventilation
- Siting considerations
- Signage with 1-2-3 stepwise procedures for potential issues such as leaked fluid, off-gassing, damaged container, etc.

Figure 3. Select examples of safety measures and considerations for BTM BESS

What Emerging Business Models Can Support BTM BESS Deployment?

BTM BESS's high upfront capital costs combined with its ability to provide a wide-ranging set of services to many different power system stakeholders has prompted the development of business models that allow different actors to share in the benefits and costs of these systems. The process of pursuing multiple value streams from a power system asset at different times and on different timescales is referred to as "value-stacking." Value-stacking can be important for assets such as energy storage to help recoup the high upfront capital investments required.

Customers may ultimately be less interested in ownership of an energy storage system than accessing the services that energy storage can provide to them (such as backup power). Such customers may not have the means or desire to invest in a storage system but would be willing to pay a small addition to their normal electricity bills in exchange for specific services like accessing stored power during grid outages. Additionally, utilities and developers typically have better access to capital to invest in energy storage systems, and they would also be interested in having access to other services energy storage can provide when not servicing customers. Under **energy-storage-as-a-service** business models, developers or utilities own and operate BTM BESS in exchange for paying the upfront costs of the storage system. Customers, in exchange for regular monthly payments, will have access to the services of the energy storage system for the rest of the time, using the system to reduce bills or power critical loads during grid outages.

Alternatively, customers may invest in energy storage but only use a fraction of the energy storage's capabilities (e.g., using it to reduce demand charges during a billing cycle or for backup service provision). In these cases, customers may be interested in allowing other stakeholders access to the storage system when they are not using it, in exchange for reduced bills or regular payments. Under **bring-your-own-device (BYOD)** business models, utilities or developers pay for access to a customer's energy storage system during periods where the storage system would otherwise be unutilized.

The utility Green Mountain Power in Vermont utilized both of these business models when looking to reduce its demand charges from the transmission system operator (Green Mountain Power 2021b; 2021a). It offered to pay customers with existing storage systems and to subsidize storage purchases for customers interested in storage, in exchange for using those BTM assets during system peaks each month. When not used by the utility, customers could use storage to help lower their utility bills and during system outages.

Additional business models have evolved to utilize BTM BESS for the provision of power system services. Although individual systems may have unutilized capacity, customers often do not have the sophistication or scale to offer their services to markets or power system operators. **Virtual power plants** have evolved to aggregate these systems on behalf of such customers and coordinate them to act as a single plant (see Figure 4). Although barriers and questions still exist (see Text Box 4), such business models can help the power system operate more efficiently and improve the coordination between transmission and distribution system operators while yielding additional financial benefits for customers. Aggregation can happen across broad swaths of the power

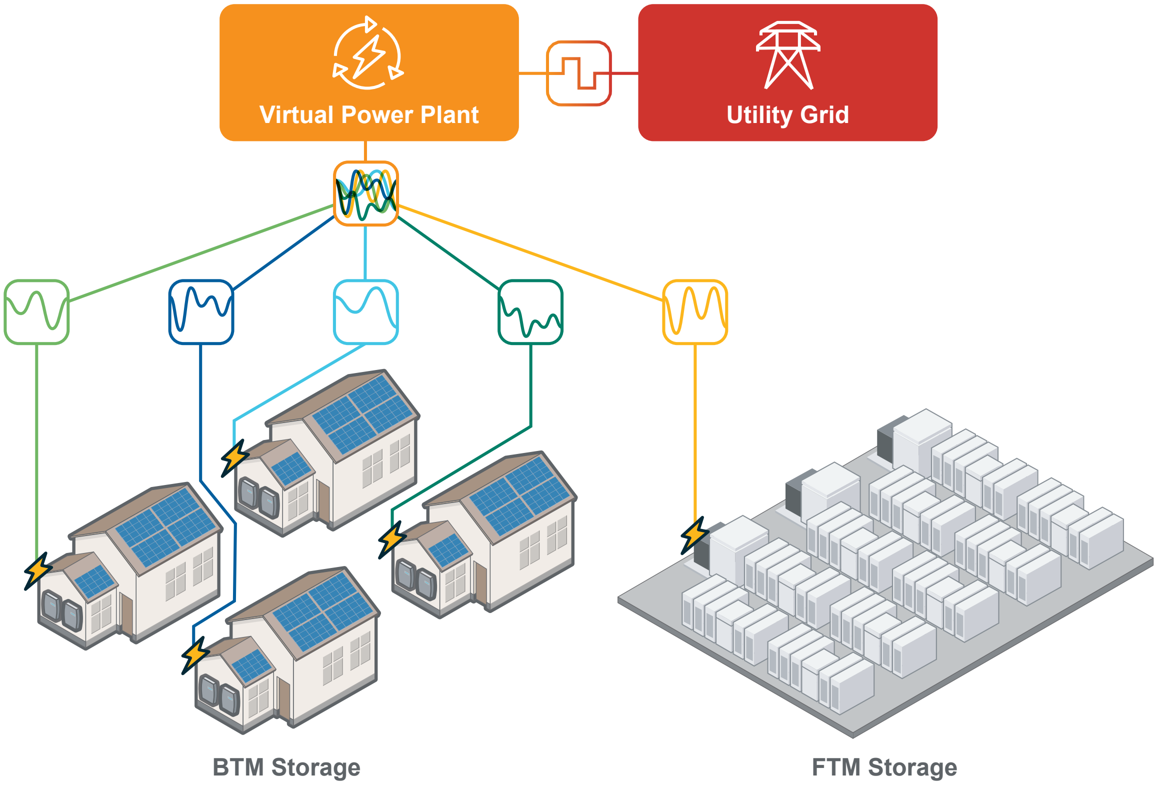


Figure 4. Illustrative example of virtual power plant aggregation

sector, such as when providing energy, peaking capacity, or frequency services, or can be concentrated to specific regions in the power sector experiencing issues, such as in non-wire alternative applications.

What Are Important Barriers to Address for BTM BESS?

As a relatively new energy asset, a critical barrier for the widespread adoption of BTM BESS is its high costs, which may prevent it from being cost-effective for many customers. As technological innovations continue and manufacturing capacity increases globally, these BESS costs are expected to decline. However, despite these cost declines and the many opportunities BTM BESS affords, key technical, regulatory, and financial barriers can continue to impede the development of a BTM BESS market. Addressing these barriers can enable customers to deploy BTM BESS sooner while ensuring benefits to multiple power system stakeholders.

Technical barriers include difficulties in adequately interconnecting, coordinating, and monitoring BTM BESS. These can be addressed through solid interconnection practices, which can allow utilities to quickly process applications while ensuring BTM BESS behave in a reliable manner. Additional barriers include poor performance, inadequate communication infrastructure, and insufficient cybersecurity for the BTM BESS (see this fact sheet for more information on DERs

Text Box 4. BTM BESS and Aggregation Barriers

Many more BTM systems must be coordinated and dispatched to provide equivalent levels of services relative to utility-scale systems. Aggregation is the process of combining multiple smaller assets to act as a larger asset for the provision of specific power system services. Such aggregation can be important for extending access to additional sources of value for BTM BESS, particularly for system services to utilities and power system operators.

Aggregation of DER, such as BTM BESS and DG, is a fairly new concept; best practices for rules governing DER are still being developed. Such rules might bar or enable aggregations of DER: (1) in different locations within the power system; (2) of different technology/types; and (3) of different ownership types. Stakeholders should work together closely to determine what sorts of restrictions of DER aggregation are important to enforce, which may depend on both the local power system context as well as the service being provided.

Under FERC Order 2222, regulators in the United States have attempted to expand the role of BTM assets (including storage) on the power system (FERC 2020). This regulation directs market operators to offer participation models for aggregated resources that allow the BTM assets to provide all power system services of which they are technically capable.

and cybersecurity). These issues can be addressed by ensuring compliance with up-to-date grid requirements. Utilities and regulators can and often do make compliance with such requirements a precondition for interconnection. Adequate communication infrastructure is particularly important for jurisdictions looking to provide services to the power system with BTM BESS. See Section 6 of Zinaman et al. (2020) for a more in-depth discussion on the role of interconnection practices and grid requirements in ensuring DER capabilities.

An additional concern for BTM BESS owners is degradation, which refers to a wide range of mechanisms and processes that can affect BESS performance over its lifetime. Degradation occurs in all energy assets, including all types of energy storage, solar PV, and others. Degradation in battery chemistries, including lithium-ion, can have a wide variety of physical and chemical causes that are still under investigation. While all energy assets will degrade over their lifetimes, the rate of degradation for BESS is influenced by several factors, including the temperature in which it is operating, operating windows, and charging and discharging rates (Edge et al. 2021). Lithium-ion BESS can typically last 10 years with minor impact on performance; however, depending on these factors, customer assets may need to be replaced sooner (NREL 2021).

Poor installations, or use of uncertified equipment, can also hamper system performance and prevent it from adequately providing services to either customers or the power system. This can impact adopting customers by not meeting expected performance and reducing revenues or bill savings they might have anticipated. This can also impact the power system if it leads to reliability or safety issues. If quality concerns are pervasive in a given market, it can lower investor confidence and create a poor reputation for BTM BESS, impacting future market development. Regulators can help the development of a BTM BESS market by providing customers, investors, and utilities with quality assurance through regulations aimed at ensuring a minimum standard for the installations, performance, and safety of any equipment that is allowed to interconnect.[4]

Regulatory barriers primarily take the form of ambiguity in the applicability of existing rules or incentives. Existing incentives or rules for DERs can often be expanded with minor modifications to include stand-alone BTM BESS or BTM BESS coupled with DG systems. Clearly including BTM BESS in such rules and regulations can help reduce uncertainty for customers and developers when deciding to deploy BTM BESS. Similarly, storage may in effect be barred from providing system services due to language or rules designed for more traditional assets such as conventional generators. Developing rules and regulations in a technology-agnostic manner (or updating existing rules) can help ensure that new DER like BTM BESS can equally provide and be compensated for all system services of which they are technically capable (Bhatnagar et al. 2013).

Financial barriers involve those that make financing for BTM BESS difficult for adopting customers. Financing can be critical for the adoption of BTM BESS given its high capital costs. This is a particularly relevant barrier if power system objectives involve encouraging the adoption of BTM BESS among particular customer classes such as among low-income customers. While the issue of upfront capital can be addressed in part by access to loans and other incentives, alternative or complementary approaches can include incentivizing novel business models that help various power system stakeholders share the costs and benefits of BTM BESS. These can include third-party, or utility-owned and -operated BTM storage. An additional barrier for customers considering pairing BTM BESS with solar PV installations is the two

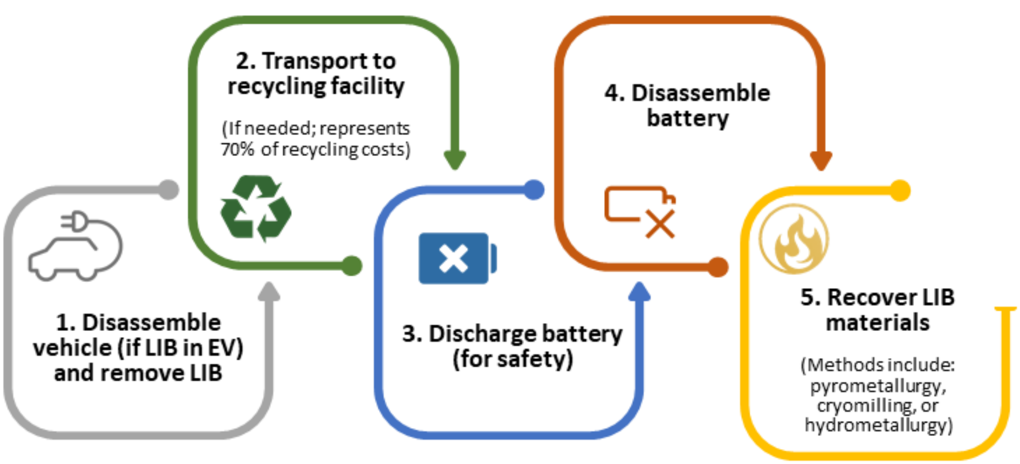


Figure 5. Lithium-ion battery recycling process from electric vehicles

4. For an overview of how quality concerns around DER can impact market outcomes and how system stakeholders can address these concerns, see Karandikar et al. (2020). Although this report refers specifically to distributed solar PV, many of its lessons and approaches can be broadly applied to BTM storage as well.

technologies' different lifespans, with solar PV lasting in excess of 25 years and BTM BESS lifespans closer to 10 years. This requires customers to plan for replacing the BTM BESS within the paired system's lifetime.

What Are the Recycling and Reuse Considerations for Battery Systems?

Many BTM BESS are composed of materials that are classified as hazardous for both the environment and human health, raising concerns about how these systems are handled, transported, stored, recycled, and disposed of after their useful life has been exhausted. Lithium-ion batteries, which make up much of the stationary and mobile battery energy storage market share, can be considered hazardous due to the toxicity of its materials (e.g., cobalt in some battery chemistries), depending on local regulations. Lithium-ion batteries can also be considered hazardous due to the reactivity or flammability of their electrolytes (see thermal runaway under "What Are Some Key Safety Issues Surrounding BTM Storage BESS?"). Furthermore, some battery technologies rely on rare earth metals that may be expensive or destructive to source, driving additional economic and environmental considerations for recycling and repurposing used batteries.[5] Although less frequently used for BTM applications, lead-acid batteries, nearly ubiquitous in the transportation sector today, offer a success story to emulate for the recycling of lithium-ion batteries, which have come to dominate BTM applications and are the primary chemistry for electric vehicles (ESMAP 2020). Some considerations for bolstering the reuse and recycling of battery systems include (ESMAP 2020; Curtis et al. 2021):

- The collection of spent batteries can be effectively managed by the same entities that are responsible for their distribution.
- Developing a set of similar or uniform designs for lithium-ion batteries can drastically simplify the recycling process, and batteries should be designed with ease of disassembly in mind.
- Similar or uniform designs can aid in reuse applications by enabling automated disassembly and diagnostic processes.
- Support for research and development and analyses to address investor uncertainty and increase the lifetime value of battery materials in the early stages of the recycle and reuse battery market (e.g., determining the value of, and markets for, reused and recovered lithium-ion battery materials, or developing refurbishment processes and improving recycling technology) (see Section 2.3.1 of Curtis et al. (2021) for more information).
- Ensuring a high quality of the end recycled product (e.g., lithium), by carefully avoiding material contamination wherever possible.
- Clear, consistent, and stringently enforced regulation across jurisdictional levels surrounding the safe handling, transport, storage, and disposal of battery components can help drive the development of robust economic recycling practices.
- Policies to incentivize the reuse or recycling of batteries over their disposal.

Figure 5 highlights the major steps in the process of recycling lithium-ion batteries from electric vehicles.

In addition to recycling, the reuse of lithium-ion batteries can minimize negative impacts and reduce the overall costs associated with battery manufacturing. Reusing batteries from electric vehicle applications in BTM stationary applications may prove particularly beneficial, as batteries that are no longer sufficient for transportation applications may still be able to adequately function in BTM roles for many years before service quality deteriorates.

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5. Following the convention laid out in ESMAP (2020), we define recycling and reuse as two separate activities, where recycling refers to "the retrieval of specific elements in a produced technology for subsequent use in other technologies, perhaps, including other batteries," and reuse refers to "putting the battery technology as a whole to a second use that is quite distinct from its primary production purpose," such as using EV batteries in stationary storage applications.

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For more tools and resources related to energy storage, visit the Greening the Grid Energy Storage Toolkit.

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