International Renewable Energy Agency

BEHIND-THE-METER BATTERIES

INNOVATION LANDSCAPE BRIEF

IRENA
International Renewable Energy Agency

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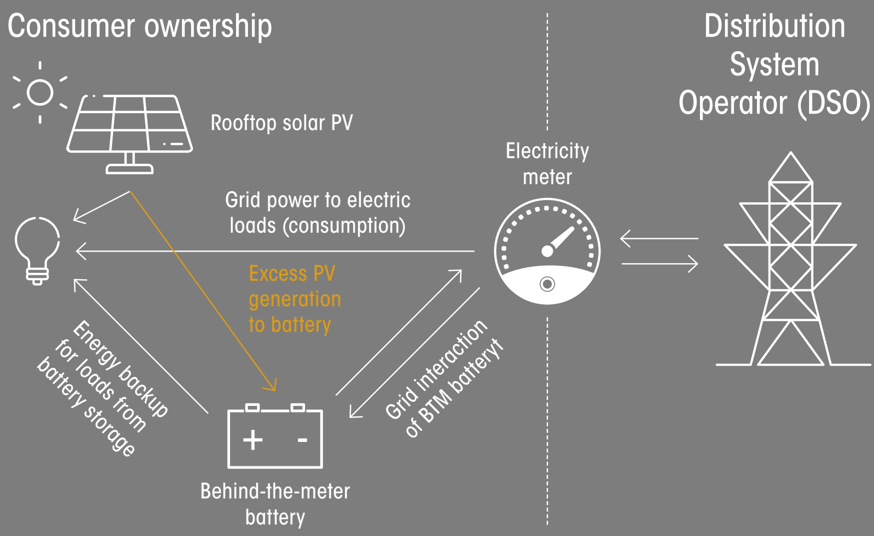
1 BENEFITS

BTM batteries can help consumers decrease their electricity bill, through demand-side management.

Increased demand flexibility can unlock the integration of high share of variable renewables in the grid.

Aggregated BTM batteries can provide support for system operation, while also deferring network and peak capacity investment.



2 KEY ENABLING FACTORS

- Reducing upfront cots
- Enabling regulatory framework
- Reducing soft costs, such as connection and permitting costs

3 SNAPSHOT

- 40% of recent rooftop solar photovoltaic (PV) systems in Germany have been installed with BTM batteries
- 21 000 BTM battery systems were installed by 2017 in Australia. The aim is to reach 1 million BTM batteries by 2025.
- 500 kW BTM batteries installed for Morgan Stanley in US reduced peak demand by 20%

WHAT ARE BTM BATTERIES?

Behind-the-meter (BTM) batteries are connected **through electricity meters** for commercial, industrial **and** residential customers. **BTM batteries range in size from 3 kilowatts to 5 megawatts and are typically installed with rooftop solar PV.**

BEHIND-THE-METER BATTERIES

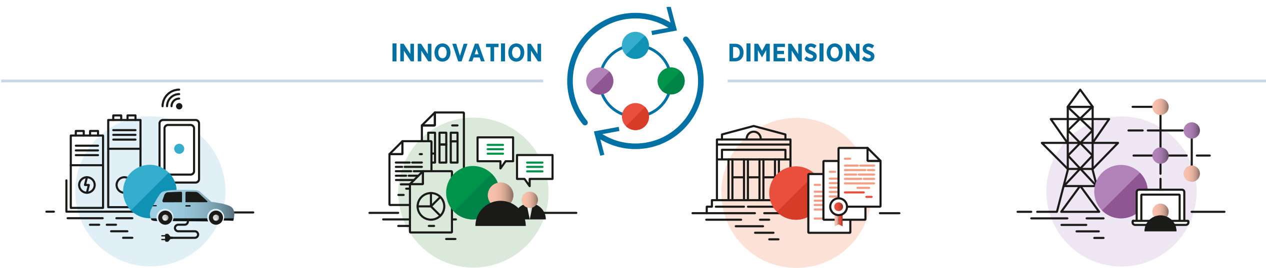
Behind-the-meter (BTM) batteries at the **individual or household level,** combined with the right incentives, can unlock **demand-side flexibility** and ease system integration of electricity from wind and solar **energy.**

ABOUT THIS BRIEF

This brief is part of the IRENA project "Innovation landscape for a renewable-powered future", which maps the relevant innovations, identifies the synergies and formulates solutions for integrating high shares of variable renewable energy (VRE) into power systems.

The synthesis report, *Innovation landscape for a renewable-powered future: Solutions to integrate variable renewables* (IRENA, 2019a), illustrates the need for synergies among different innovations to create actual solutions. Solutions to drive the uptake of solar and wind power span four broad dimensions of innovation: enabling technologies, business models, market design and system operation.

Along with the synthesis report, the project includes a series of briefs, each covering one of 30 key innovations identified across those four dimensions. The 30 innovations are listed in the figure below.



ENABLING TECHNOLOGIES

1 Utility scale batteries
2 Behind-the-meter batteries

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6 Internet of Things
7 Artificial intelligence and big data
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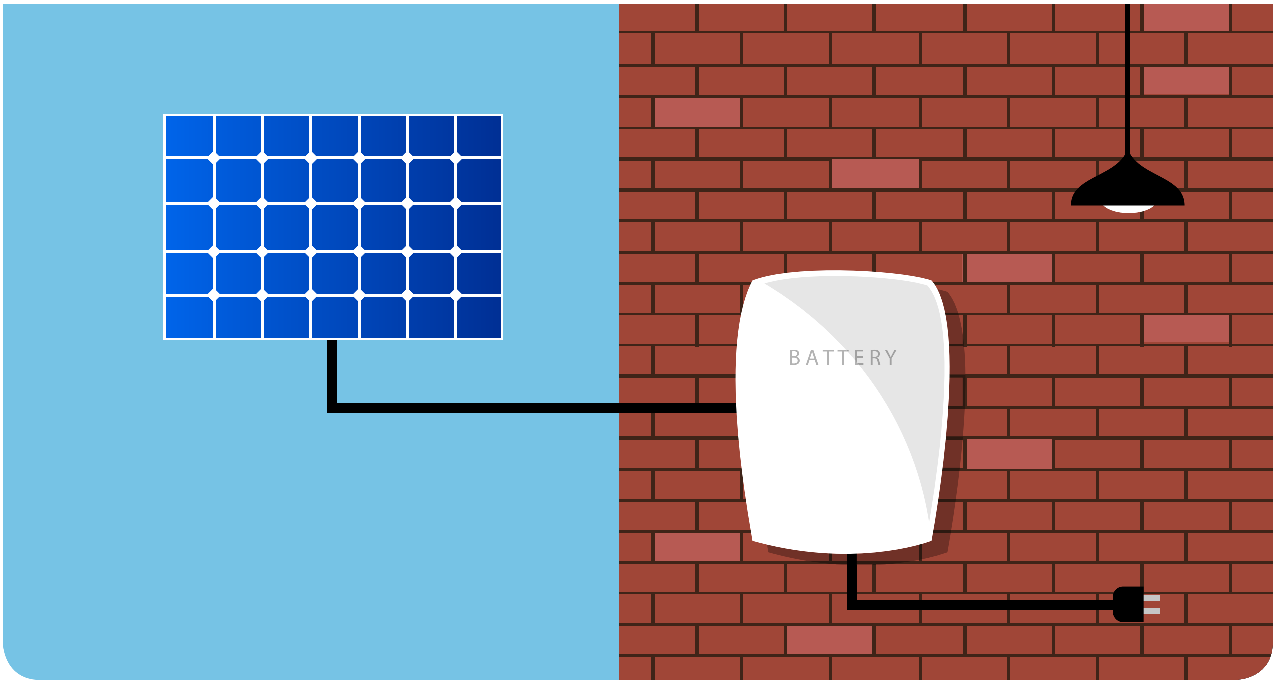
This brief provides an overview of behind-the-meter (BTM) battery storage, also referred to as small-scale battery storage, and its role in supporting the integration of VRE in the grid. The brief explains the benefits that BTM batteries can bring both to the power system and to consumers, as well as the role of BTM battery storage in microgrid and mini-grid settings.

The brief is structured as follows:



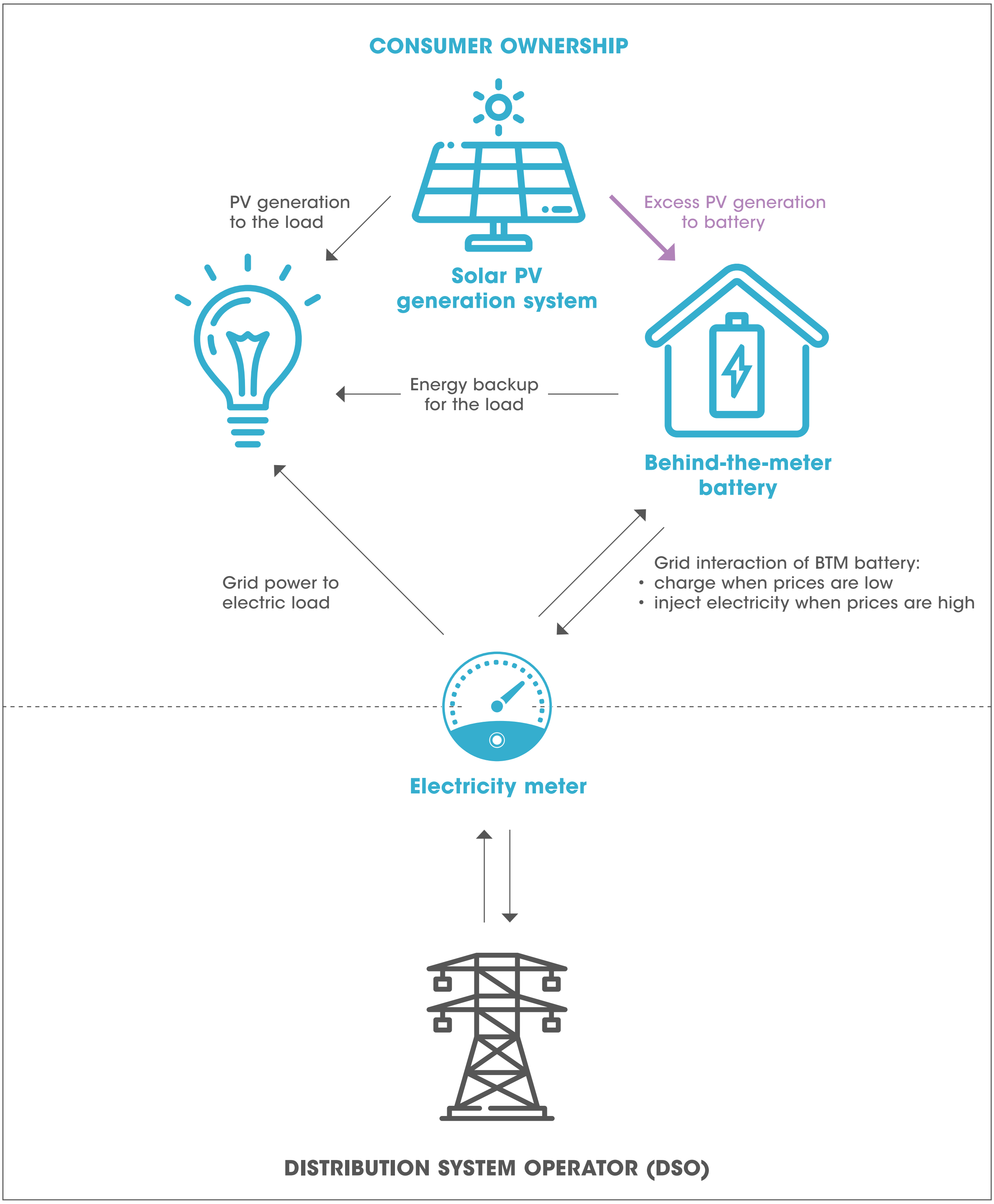
I. DESCRIPTION

Battery storage systems are being deployed at multiple levels of the electricity value chain, including at the transmission, distribution and consumer levels. According to the Energy Storage Association of North America, market applications are commonly differentiated as: in-front of the meter (FTM) or behind-the-meter (BTM). FtM batteries are interconnected to distribution or transmission networks or in connection with a generation asset. They provide applications required by system operators as *e.g.* ancillary services or network load relief. BTM batteries are connected behind the utility meter of commercial, industrial or residential customers, primarily aiming at electricity bill savings (ESA, 2018). This brief focuses on describing the various applications of BTM battery storage also called small-scale stationary batteries. The size of a BTM battery can vary from 3 kilowatts (kW) to 5 megawatts (MW). Typically, residential consumers' batteries can reach 5 kW/13.5 kilowatt-hours (kWh), whereas a battery for a commercial or industrial system is typically 2 MW/4 megawatt-hours (MWh).

The deployment of small-scale battery storage systems is increasing in power systems across the world. For example, approximately 40% of small-scale solar PV systems in Germany have been installed with battery systems in the last few years (IRENA, 2017). In Australia, around 21 000 small-scale battery systems had been installed by 2017, and the goal is to reach 1 million BTM batteries by 2025 (Martin, 2018). This increase has been driven by the falling costs of battery storage technology, due mainly to the growing consumer market and to the development of electric vehicles (EVs) and plug-in hybrid EVs (PHEVs), along with the deployment of distributed renewable energy generation and the development of smart grids.

Battery storage systems deployed at the consumer level – that is, at the residential, commercial and/or industrial premises of consumers – are typically "behind-the-meter" batteries, because they are placed at a customer's facility. They are typically beyond the direct control of the distribution system operator; however, several initiatives exist in which consumers are remunerated for allowing the distribution system operator to withdraw electricity from the battery when needed. Examples include Green Mountain Power's Tesla Powerwall programme in the United States (US) and Eneco's CrowdNett programme in the Netherlands. Figure 1 shows a schematic diagram of a household system using a rooftop solar PV panel and a BTM battery storage system.

Figure 1: Grid-connected BTM energy storage configuration



A BTM battery installed at the consumer's premises can store electricity that either is produced from on-site solar rooftop PV systems (if applicable) or is drawn from the distribution grid, generally when electricity prices are low. This stored electricity can then be used to meet the consumer's electricity needs, or it can be injected back into the distribution grid when electricity prices are high.

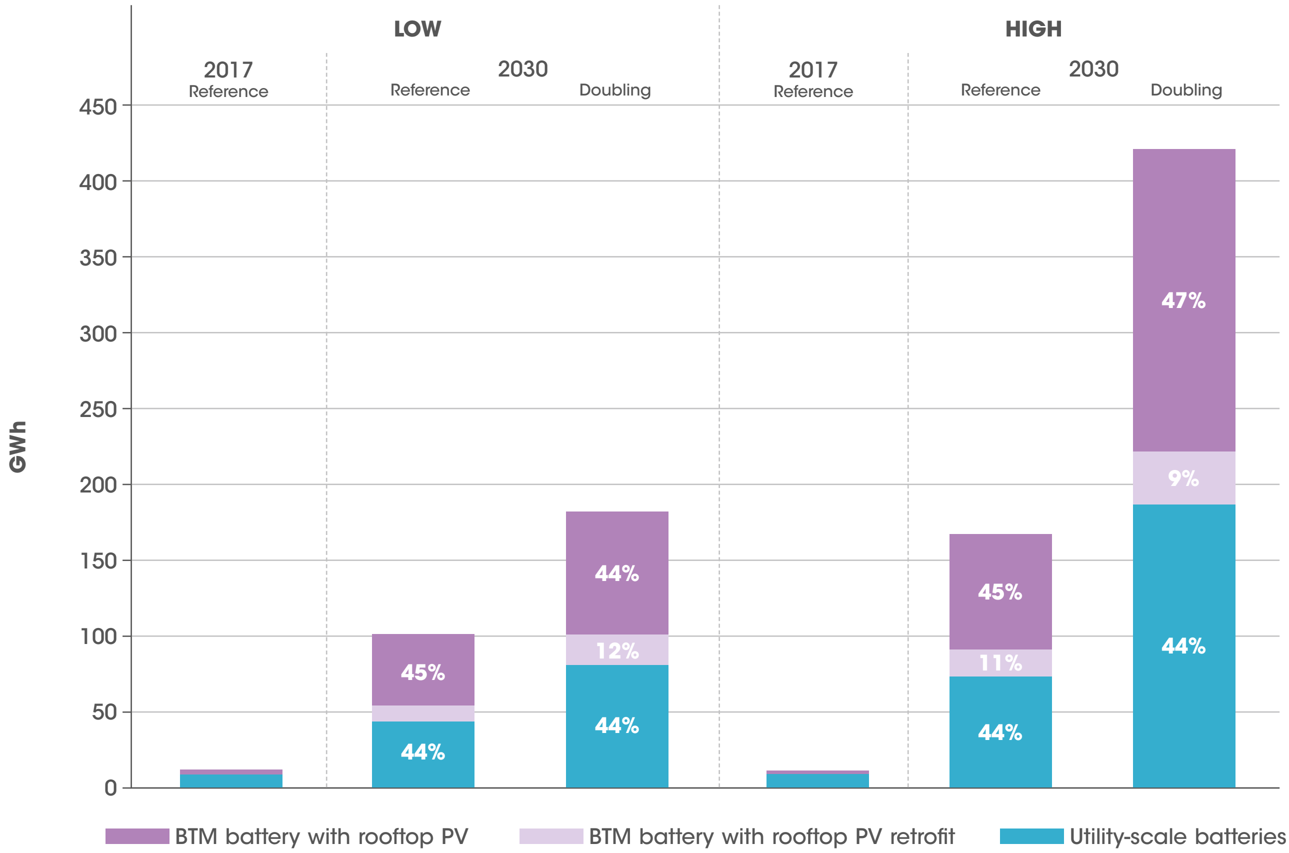
The key value proposition that led to the initial deployment of BTM battery storage systems was their ability to provide back-up power to consumers when a black-out occurs in the system. Consumers and system operators alike are interested in using BTM battery storage systems to improve the resilience of the power supply. These applications have been dominated by lead-acid and lithium-ion battery technologies, the costs of which have been driven down by the deployment of BTM batteries in residential and commercial PV systems, which has enabled cost savings in electricity bills (where time-of-use tariffs are in place). Figure 2 depicts the current levelised cost of three storage technologies (lithium-ion, lead-acid and advanced lead) for different battery sizes and different applications.

Figure 2: Levelised cost of storage comparison (USD/MWh)

Source: LAZARD, 2018

Although currently utility-scale battery systems dominate in terms of energy capacity deployed, the share of small-scale battery systems is expected to increase dramatically, pushed mainly by the deployment of distributed solar PV, as illustrated in Figure 3.

Figure 3: Stationary battery storage's energy capacity growth, 2017–2030



Note: GWh = gigawatt-hour; PV = photovoltaic; BTM = behind-the-meter
Source: IRENA, 2017

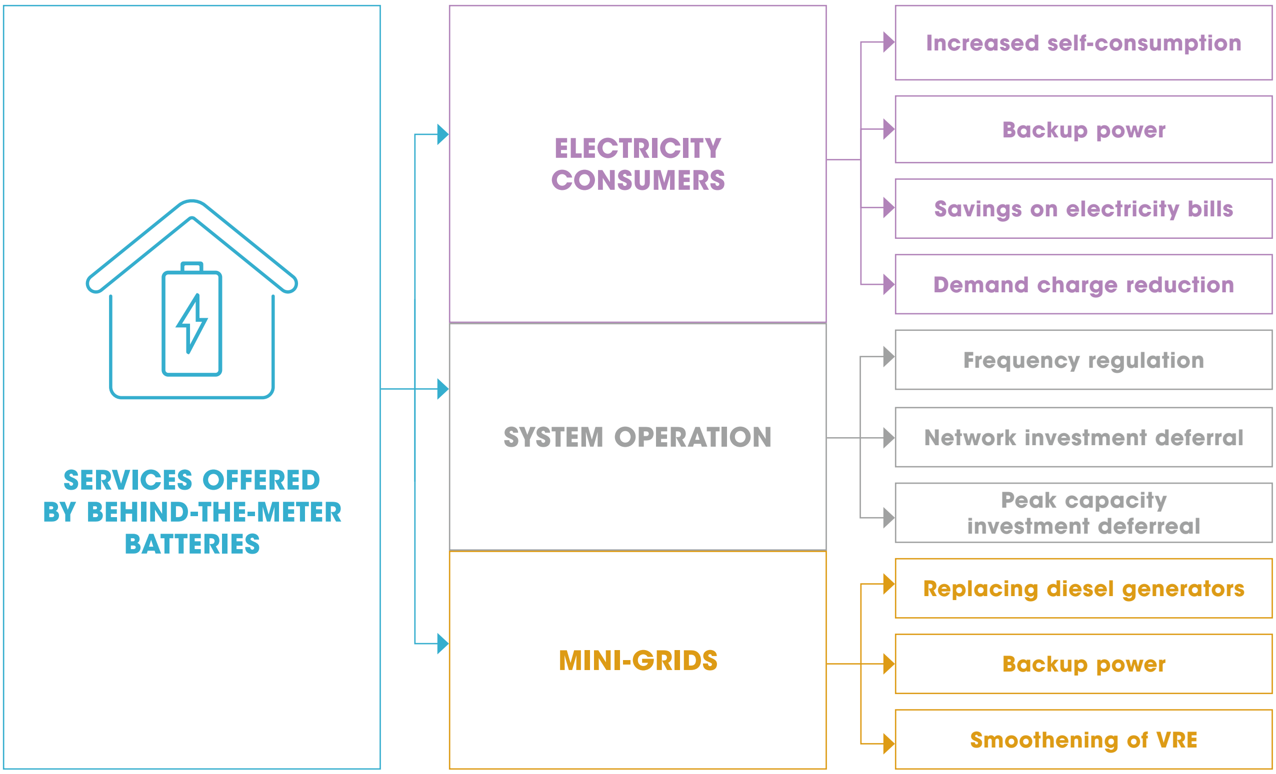
The share of VRE generation in the energy mix would need to grow from nearly 10% in 2019 to around 60% in 2050 (IRENA, 2019a) to be align with Paris Agreement. Almost half of PV deployment could be achieved in a distributed manner in the residential and commercial sectors, at both urban and rural sites (IRENA, 2019b).

II. CONTRIBUTION TO POWER SECTOR TRANSFORMATION

Behind-the-meter battery storage can enable the integration of VRE in the power system in various ways. Firstly, it supports the integration of local renewable energy generation by maximising self-consumption and its revenues. In jurisdictions where time-of-use electricity tariffs are in place, consumers can reduce their electricity bills by using the stored electricity when tariffs are high and maximising self-consumption from the solar rooftop when the battery is coupled with a solar PV system. This was, for example, the key driver of BTM battery deployment in Germany.

Secondly, BTM battery storage systems can provide voltage and frequency support, as well as other services, for system operators that help to integrate higher shares of VRE in the grid. In addition, batteries are an important tool to offset traditional grid investments in transmission, distribution and generation, by helping to reduce the peak load in the system. Finally, in renewable-based mini-grid systems, small-scale batteries play an important role in providing stability to the grid and replacing diesel generators. Figure 4 summarises the key services offered by BTM batteries.

Figure 4: Services provided by BTM battery storage systems



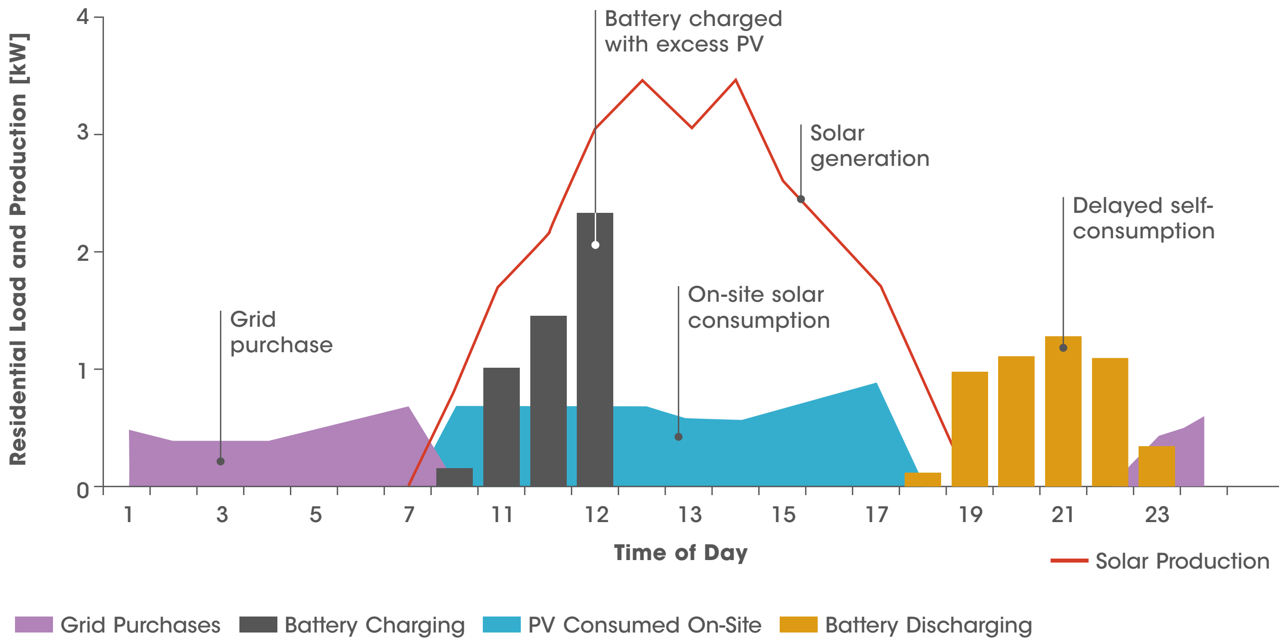
Services provided for electricity consumers

Increased self-consumption from distributed renewable generation

The excess electricity from distributed generation technologies, such as rooftop solar PV systems, can be stored in BTM batteries and used for local consumption when needed. In some geographies, where electricity injected into the grid is not remunerated, BTM battery storage would lead to increased self-consumption of the electricity produced by solar PV systems. In this way, BTM battery storage facilitates the deployment of distributed renewable energy technologies.

In places with high penetration of rooftop solar PV systems, distribution system operators could face challenges in absorbing increased variable generation from VRE sources. Therefore, maximising the local usage of such variable generation and minimising exports to the grid could benefit the system in some cases, and avoid issues related to the backflow of variable power. Figure 5 shows a typical solar PV generation curve, as well as the battery charging and discharging cycle increasing the hours of self-consumption.

Figure 5: Typical solar PV production and battery charging/discharging schedule



Source: Fitzgerald et al., 2015

Back-up power

BTM battery storage solutions can play a critical role in increasing the energy resiliency of consumers, by providing back-up power in case of grid outage. BTM battery storage can provide back-up power at various scales, ranging from sub-second-level power supply for important industrial operations, to 24-hour back-up by pairing with an on-site solar PV system.

For instance, Green Mountain Power (GMP), an electric utility in Vermont, the US, is piloting a project called "Resilient Home". GMP is installing Tesla battery systems at the premises of its customers, who are able to use the batteries for back-up power. Interested customers pay USD 30 monthly for two batteries. This is significantly less expensive than the actual cost of the batteries and the installation, which reaches USD 7 000; however, in return, GMP is able to access the energy in the batteries to support its grid, like a virtual power plant (GMP, 2019; Lambert, 2018).

Savings on the electricity bill

Increased self-consumption by installing rooftop solar PV coupled with BTM battery systems can lead to significant electricity bill savings. When time-of-use tariffs are implemented, BTM battery storage systems allow consumers to reduce electricity costs by charging the batteries during off-peak hours, when tariffs are lower, and discharging them during peak time intervals, when tariffs are high.

Demand charge reduction

Demand charges are generally determined based on the highest electricity usage requirement (in terms of kW) for the consumer within a specified time period (usually ranging from 15 minutes to 3 months), depending on the utility. Demand charges can be significant for commercial and industrial consumers, especially during periods of peak demand. On-site battery storage systems can be used to manage peak loads and reduce demand charges.

For example, Poway Unified School District in the US state of California deployed a 6 MWh BTM battery storage system, provided by ENGIE Storage, across 12 campuses to curb steeply rising demand charges. This is expected to result in savings of approximately USD 1.4 million over 10 years (ENGIE Storage, 2018).

Services provided for system operators

Frequency regulation

BTM storage systems can provide frequency support to the grid by rapidly ramping its power output up or down, which helps smoothen the output of VRE generation. One precondition for these services is the ability of BTM storage to participate in the ancillary service market, usually through aggregators[1]. Alternatively, depending on the regulation, consumers can offer the availability of their battery to the operator in exchange for financial compensation. In this way, the operator can use the battery to balance the system at any time, thus providing the needed flexibility to integrate high shares of VRE. California already allows distributed energy resources, including rooftop solar, energy storage, PHEVs and demand response to participate in the wholesale electricity and ancillary service markets (CAISO, 2019).

In the Netherlands, Eneco Group, one of the largest Dutch utilities, started CrowdNett, a virtual power plant with a network of BTM batteries (Eneco, 2016). These batteries can be installed by homeowners and are used to improve self-consumption of solar energy as well as to provide grid services. Apart from increasing self-consumption and yielding bill savings to consumers, these batteries can participate in both electricity and ancillary service markets, yielding benefits to the grid as well. The battery owners receive financial compensation of up to EUR 500 per year for allowing the utilities to use their batteries for grid services. CrowdNett also has conducted pilots in Germany and Belgium (Eneco, 2018).

Network investment deferral

Distribution and transmission system operators invest in upgrading the system in order to meet anticipated demand growth. These upgrades are generally needed to meet the peak demand, which occurs for a small number of hours in the entire year. Even if the immediate anticipated demand growth is 1-3%, investments in network upgrades made by system operators can typically result in increasing the capacity of substations or lines by up to 25%, due to the standardised size of the equipment (RMI, 2015). This causes overinvestment vis-à-vis anticipated demand growth. BTM battery storage, together with the right incentives in place, can help consumers shift their demand so that it reduces the system's peak demand, thus decreasing the need for grid reinforcements.

1 Aggregators are third parties that bundle distributed energy resources to engage as a single entity (also referred to as virtual power plants) in power or service markets; see the Innovation Landscape brief *Aggregators* (IRENA, 2019c).

Meeting peak demand through locally stored electricity reduces the need to draw power from the transmission system operators, thereby decreasing grid congestion and deferring network investments. Using distributed energy resources to avoid investment in the grid is also known as "virtual power lines". For example, UK Power Networks, a distribution network operator in the United Kingdom (UK), recently announced its plan to create London's first virtual power plant comprising solar panels and a fleet of batteries across 40 residences in the city. A trial concept was conducted in February 2018, wherein a fleet of 45 BTM batteries was used to meet peak demand. The project is expected to provide an alternative to the traditional approach of increasing network capacity to meet peak demand (UK Power Network, 2018).

In the US, the New York utility Con Edison is deploying a project to utilise BTM storage as part of an effort to defer a USD 1.2 billion substation. The initiative is part of Con Edison's Brooklyn-Queens Neighbourhood programme under New York's Reforming the Energy Vision initiative (Lalle, 2017).

Peak capacity investment deferral

To meet the peak demand in the power system, system operators need peak capacity resources. The utilisation level of such peak capacity is very low, however, and thus results in a high cost of power to consumers. For example, a study commissioned by the US state of Massachusetts estimated that the top 10% of the hours when electricity rates were the highest accounted for 40% of annual electricity spending (Customized Energy Solutions et al., 2016).

BTM storage systems can help defer investments in these expensive peak capacity resources in two ways. Firstly, they can reduce the peak demand itself by providing stored energy to consumers during peak times, thus reducing the need to procure energy from peak capacity resources. Secondly, BTM storage systems, through aggregators or retailers, can participate in capacity markets and compete with other participants to offer capacity. This can reduce the share of conventional generation-based capacity resources in the market while reducing prices in capacity markets. Further, since the peaking capacity requirement can vary from a very small amount to thousands of megawatts, aggregators of BTM storage systems can provide the right amount of storage capacity in exchange for capacity payments, thus avoiding investments in standard-sized peaking capacities.

For example, the utility Southern California Edison in the US selected a roster of energy storage projects to supply local capacity needs in the system, instead of the 262 MW natural gas peaker plant it had chosen previously. The utility is planning for a 100 MW/400 MWh system, complemented by a portfolio of smaller units, ranging from 10 MW to 40 MW. One developer, Swell, which aggregates fleets of home batteries, won a 14 MW contract for BTM demand response (Spector, 2019).

Services provided for mini-grids

BTM storage systems can replace diesel generators in renewable energy-based mini-grids. They can be used to provide back-up power when renewable generation is not available, as well as frequency and voltage to support the renewables' variability. BTM batteries can smoothen variable generation and shift the generation curve of small solar PV and wind systems connected at the consumer end to meet peak demand.

For example, Electro Power Systems, a French storage developer and system integrator, has expanded a microgrid with 1.8 MWh of battery storage along with a 1.75 MW solar PV solution in Somalia. The microgrid serves more than 50 000 people and helps the local region meet 90% of its electricity demand from renewables and battery storage (Colthorpe, 2017a).

Potential impact on power sector transformation

The increasing adoption of BTM battery storage systems can help consumers greatly reduce their electricity costs. It will further help to stabilise the grid and to effectively absorb variable power from renewable energy sources.

- Poway Unified School District in California installed a 6 MWh BTM storage system. The expected **savings of this project are around USD 1.4 million over 10 years**, and the main application is demand charge reduction (ENGIE Storage, 2018).

- Green Mountain Power plans to install 2 000 Tesla Powerwall 2 units at its customers' premises in Vermont (US) to provide **back-up power** and support the grid. The utility expects consumers to incur **between USD 2 million and USD 3 million** in savings across the programme's lifetime. With regard to grid benefits, the batteries installed, via peak shaving, helped cover Vermont's peak demand in July 2018 and **saved the utility USD 500 000** (Brooks, 2018).

- Advanced Microgrid Solutions (AMS) completed a battery-based storage project for Morgan Stanley in the US, which resulted in a **20% peak demand reduction**, using 500 kW / 1 000 kWh Tesla Powerpack batteries. Peak demand charges for commercial and industrial consumers in the US can constitute up to 50% of their bill. This system is integrated into the existing building management system (Colthorpe, 2017b).

- Stem, an energy storage company, has provided a BTM battery storage fleet of 1 MW capacity situated across 29 customer sites in Oahu, Hawaii to help the Hawaiian Electric Company **integrate more renewable energy** in the Oahu grid. Testing has confirmed that the fleet is able to manage different load shapes and characteristics to serve the utility (Stem, Inc., 2017a).

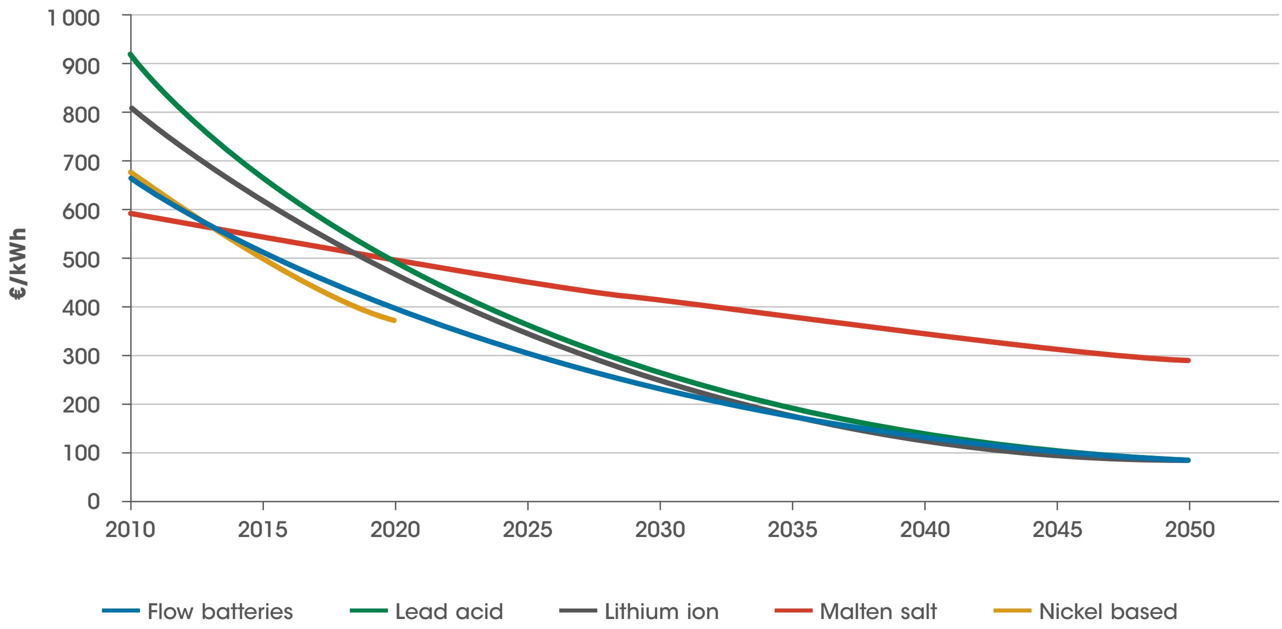
III. KEY FACTORS TO ENABLE DEPLOYMENT

Although the BTM battery storage market is growing at a rapid pace, its further growth can be accelerated by overcoming the existing challenges related to high upfront costs. These challenges should be addressed through various government and private sector initiatives, incentive schemes, robust regulatory frameworks and knowledge dissemination among various stakeholders.

Reducing upfront costs

A further reduction in the upfront costs of BTM batteries would be the key enabler for this market to grow. Figure 6 provides an illustration of pricing trends and forecasts for BTM energy storage technologies. This represents an average of costs across all types of consumer markets and assumes systems with a two-hour discharge duration (for example, 5 kW/10 kWh).

Figure 6: Battery system cost trends in EUR/kWh



Source: Ecofys et al., 2016

The costs of BTM storage systems have declined considerably in the past few years. Although system costs are expected to continue to fall, the growth of this market depends on the tariff structures and incentives that are available for BTM customers and on the proactivity of local retailers and system operators.

Active interventions by state/federal governments – such as upfront subsidies/rebates or funding of pilots – can be important catalysts to promote BTM storage systems, especially before the industry gains economies of scale and overcomes the high initial soft costs.

The California Public Utilities Commission in the US has established a Self-Generation Incentive Program (SGIP) to help reduce the initial costs of storage for consumers. SGIP provides rebates for qualifying distributed energy systems installed on the customer's side of the utility meter. The incentive rate declines over time as the market matures. On a state-wide basis, approximately USD 330 million has been allocated for storage projects above 10 kW and around USD 48 million has been allocated for storage projects below 10 kW (CPUC, 2019).

Similarly, the Swedish government has a subsidy scheme to cover 60% of the upfront cost of a residential storage system up to a maximum of USD 5 400. Battery, wiring, management systems and installation will all be eligible for payment under the subsidy. The subsidy is part of Sweden's plan to boost PV utilisation and to establish a smarter, more flexible grid (Hanley, 2016).

Enabling regulatory framework: Time-of-use tariffs and net billing

An important enabler for BTM batteries is a regulatory framework in the retail market that seeks to maximise benefits for consumers, while incentives demand-side flexibility. Time-of-use tariffs, for example, are demand response enablers, allowing consumers to adjust their electricity consumption (including the use of BTM storage) to reduce their electricity bills. Time-of-use tariffs allow consumers to observe the periods of low and high electricity prices and thereupon decide when to charge the battery (see the Innovation Landscape brief *Time-of-use tariffs* [IRENA, 2019d]).

BTM batteries could also benefit from net billing schemes, mainly when batteries are coupled with generation technologies. Net billing compensation is based on the value of the kWh consumed or injected in the grid. It incentivises prosumers to provide stored energy to the grid when remuneration is high and to store the generated electricity during low-demand time intervals (see the Innovation Landscape brief *Net billing schemes* [IRENA, 2019e]).

Reducing soft costs such as interconnection and permitting

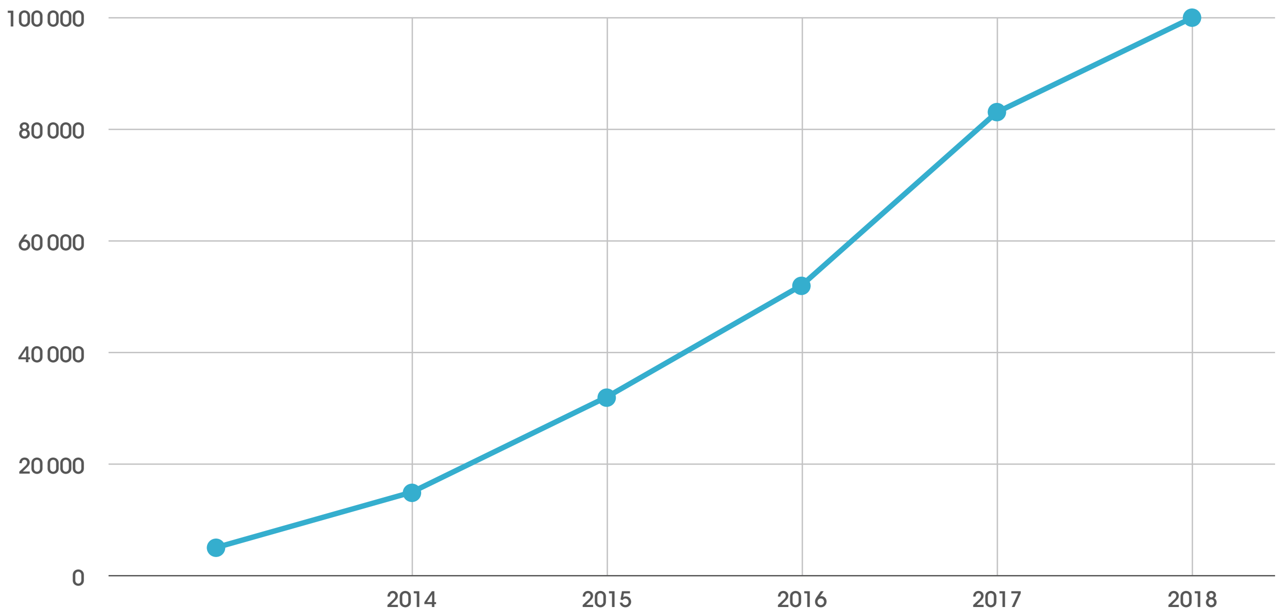
"Soft costs" such as interconnection, permitting and development costs can account for a significant share of the installed cost of BTM storage systems, particularly where the industry has not yet gained scale. Regulators should consider reducing the process time for interconnection and permitting, which results in notably higher all-in costs for storage developers and customers.

IV. CURRENT CONTEXT AND EXAMPLES OF ONGOING INITIATIVES

Growth in BTM battery storage is being driven by residential, commercial and industrial consumers that can deploy these systems at scale and harness significant savings in their energy bills. This trend is expected to accelerate as costs of energy storage are expected to decline further, making storage even more viable for consumers. Australia, China, Germany, Italy, Japan, the Netherlands, the UK and the US are examples of countries where BTM batteries are being deployed.

In Germany, around 100 000 commercial and residential solar PV with BTM storage systems had been implemented by summer 2018 (Rathi, 2018). This number is expected to double by 2020 (Parkin, 2018).

Figure 7: Household battery storage systems in Germany from 2013 to 2018



Source: Rathi, 2018

Several companies that are using BTM storage systems across various geographies are described below.

sonnenCommunity (Germany)

The sonnenCommunity is an aggregator in Germany consisting of around 10 000 customers with battery storage, solar PV generation or both. Launched in 2015, the sonnenCommunity was used mostly for peer-to-peer trading within the virtual power plant. In 2017, the virtual power plant became available to the power grid to provide frequency regulation. Compared to other alternatives, such as pumped hydropower storage, this distributed "virtual" storage resource can react very quickly (sub-second), making it a great provider of primary frequency services (sonnenCommunity, 2018). Typically members of sonnenCommunity can cover 80% of their electricity needs by utilising power from their solar and/or battery systems. The remaining electricity may have to be purchased from the grid (St. John, 2016).

In 2016, measures to manage grid congestion cost Germany around EUR 800 million, a large part of which was for wind curtailment (Grey Cells Energy, 2018). Re-dispatch measures are necessary in the country, where the wind energy produced in the north cannot be transported to the industrial centres located in the south. In response, in 2017 sonnen partnered with the German grid operator TenneT to launch the pilot project sonnen eServices. This project integrated batteries into the power system via a blockchain solution (developed by IBM). In this pilot project, a network of residential solar batteries was made available to help reduce the limitations imposed on wind energy at times of insufficient transport capacity.

Advanced Microgrid Solutions (United States)

Advanced Microgrid Solutions (AMS) uses different storage technologies and a data analytics software programme to provide commercial and industrial consumers with battery storage systems to optimise their energy usage. It also allows the fleet of battery storage systems to provide grid services to the system operators. The data analytics software uses multiple data points, such as consumption as well as retail and wholesale energy prices, in addition to energy efficiency metrics, to develop a customised energy profile for each customer. The software then optimises the energy usage in real time, at the building and fleet levels, to reduce costs.

AMS is operating the world's biggest virtual power plant, in the form of a 27 MW/142 MWh fleet of batteries located at commercial and industrial sites across the territory of the utility Southern California Edison. The fleet delivered more than 2 gigawatt-hours of battery power for the utility in one year (St. John, 2019).

Also, AMS managed to reduce the peak demand by 20% for Morgan Stanley, using 500 kW/1 000 kWh Tesla Powerpack batteries. At California State University, AMS has implemented a 2 MW/12 MWh storage system, spread across three sites, which has resulted in peak energy cost savings of USD 3.3 million.

Stem (United States)

Stem, a US energy services provider, helps commercial and industrial customers reduce their energy bills by using energy stored in their batteries during periods of peak demand. The company combines the battery storage with a cloud-based analytics system to identify the best time to draw energy from the battery storage (Colthorpe, 2017c). It also utilises a fleet of deployed customer-sited storage systems to provide grid services to system operators.

In 2014, Stem won a contract with Southern California Edison to provide 85 MW of local capacity by 2021 (St. John, 2019). Stem also has provided emergency grid relief in California by utilising its fleet of BTM battery storage devices. In June 2017, when an unprecedented heat wave struck the state, wholesale electric prices started rising. Stem dispatched 1.6 MW of stored energy from its fleet of storage systems within one hour to seven critical areas of the grid to provide demand response services (Stem, Inc., 2017b).

Stem also operates the 162 kW/180 kWh battery storage system installed at offices in San Francisco. The intended application for the system is to provide demand charge management for Adobe along with demand response services to the California Independent System Operator. The project is expected to result in cost savings of approximately USD 255 600 over a 10-year period (Stem, Inc., n.d.).

Other examples of BTM battery projects

Table 1 List of some projects using BTM batteries

Project name	Location	Service provided	Description
Johnson Control International's 100 kW/ 182 kWh BTM energy storage system at its APAC headquarters	Shanghai, China	**Demand charge reduction** **Increased self-consumption**	The intended application of the BTM battery is to reduce utility costs through demand charge management along with providing storage for the installed solar PV system and providing charging the EVs (Johnson Controls, n.d.).
Case Western Reserve University's 125 kW/ 65 kWh lithium-ion BTM storage system	Ohio, US	**Backup power** **Frequency regulation** **Renewable energy smoothening**	The system has been integrated with an existing wind power plant and may be integrated with a solar plant. The intended application is to smoothen the output from the wind plant, to provide back-up power to university and to provide frequency regulation services to the grid (Johnson Controls, n.d.).
Clemson University's 50 kW/160 kWh BTM battery storage system	Wisconsin, US	**Electricity bill savings**	The intended application for this system is to shift demand of the building to off-peak hours, thus generating saving on electricity bills based on time-of-use tariffs (Johnson Controls, 2017).

V. IMPLEMENTATION REQUIREMENTS: CHECKLIST

TECHNICAL REQUIREMENTS

Hardware:

- Deployment of BTM batteries
- Metering equipment, such as smart meters or devices built into the storage systems (required to provide real-time power consumption and production information)
- Smart meters

Software:

- Aggregation software with algorithms calculating the optimal operation of each unit
- Real-time communication between the aggregator and the hardware system
- Distribution system management software ensuring reliability and safe operations

POLICIES NEEDED

Policies should be aimed at:

- Appropriately valuing and capturing the unique set of benefits that energy storage systems can provide (*e.g.*, valuation through demand-side management studies, and capturing of value through wholesale market or demand-side management programme participation)
- Simple and fast interconnection and permitting processes
- Low-cost funding programmes to reduce upfront cost burdens of installing the battery.

REGULATORY REQUIREMENTS

Retail market:

- Time-of-use tariffs and net billing schemes to incentivise demand response programmes and therefore maximise the benefits of BTM storage for consumers
- Provisions for allowing distributed energy resources, including BTM energy storage assets to provide grid services
- Definition of technical and operational standards
- Establishment of clear, fair and non-discriminatory valuation and remuneration frameworks
- Establishment of fair and non-discriminatory charges

Distribution and transmission system:

- Allowing transmission and distribution system operators to procure market-based flexibility services from distributed energy resources, including BTM batteries
- Establishment of local markets for distribution system operators to procure services to avoid grid congestion and ensure reliability
- Increased co-ordination between distribution and transmission system operators

Wholesale market:

- Allow participation of aggregators and/or distributed energy resources in electricity wholesale markets and ancillary service markets
- Allowing decentralised resources to provide services to central/local grids
- Clear price signals to guide aggregators and BTM batteries operations

STAKEHOLDER ROLES AND RESPONSIBILITIES

Regulators:

- Defining the vision for BTM storage systems deployment – the BTM implementation roadmap, planning and optimising the location of BTM storage systems

Aggregators:

- Provide grid-related services to distribution and transmission system operators, if the market is established
- Information exchange with distribution system operators related to capacity, location and type of distributed energy resources

ACRONYMS AND ABBREVIATIONS

AMS	Advanced Microgrid Solutions
BTM	behind-the-meter
EUR	Euro
EV	electric vehicle
FTM	front-of-the-meter
GMP	Green Mountain Power
PHEV	plug-in hybrid electric vehicle
PV	photovoltaic
SGIP	Self-Generation Incentive Program
UK	United Kingdom
US	United States
USD	US dollar
VRE	variable renewable energyy

UNITS OF MEASUREMENT

kW	kilowatt
kWh	kilowatt-hour
MW	megawatt
MWh	megawatt-hour

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