CARBON TRUST

Energy Storage

A technology guide for SMEs

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Preface

Reducing energy use and using cleaner energy sources makes perfect business sense; it saves money, enhances corporate reputation and helps everyone in the fight against climate change.

The Carbon Trust provides expert, effective advice to help SMEs take action to reduce carbon emissions, and the simplest way to do this is to use energy more efficiently.

This guide provides an overview of battery electricity storage. It introduces the different types of systems available, the benefits, and the system costs, paybacks and parameters that must be considered by SMEs looking to implement this technology.

Contents

Introduction

Battery energy storage systems are rechargeable battery systems that make it possible to store energy, either directly from the grid during cheaper tariff times or from renewable sources like solar arrays for use later when grid prices are higher.

Businesses have long sought ways to cost-effectively store cheap electricity directly from the grid or from a renewable source. The stored electricity can be consumed on demand when required, such as when consumption-peak tariffs mean energy is more expensive, or during a blackout for emergency power.

Energy storage systems absorb and store energy for use at another time. The most common solutions use mechanical, potential, thermal or chemical energy, such as pumped hydro, mechanical flywheels, compressed air or batteries. Since flywheels are expensive, compressed air inefficient and hydro obviously location specific, it is clear why battery energy storage is surging in popularity.

The transition towards energy storage systems is being driven by three trends:

Decarbonisation

- One drawback of the rapid deployment of low-carbon energy sources is that it is becoming increasingly difficult to forecast energy generation, maintain grid stability, ease congestion and combat market volatility.

Digitisation

- The ability to make fast decisions regarding dynamic and nodal energy pricing is due to the surge in connected devices and smart sensors, while intelligent control systems and internet-enabled software optimise power plants and the grid.

Decentralisation

- The growing penetration of distributed energy resources, like renewables and storage, is creating more "prosumers" (when you both consume and produce a product) and increasing the distribution grid complexity[1].

Combining battery storage with green energy generation, like solar photovoltaic (PV) arrays, allows businesses to generate their own electricity. There is often a time disparity between the generated electricity supply and the demand, leading to excess electricity being exported back to the grid.

As a result, selling this excess reduces the benefit to the business; onsite generated electricity is of more value when fully utilised by the site. The use of batteries to store this excess electricity allows businesses to use 100% of the generated electricity, to offset the higher cost of importing from the grid. Additionally, depending on their electricity supply contract, businesses can face variable electricity costs depending on the time of day, or year they use electricity (time-of-use tariff). Battery energy storage systems allow businesses to store electricity from the grid when prices are low, and then use it to reduce their demand when costs are high. Similarly, some businesses are charged based on the maximum demand for electricity they take from the grid. The use of battery storage allows business to reduce their maximum demand on the grid and hence their capacity charges.

> Businesses exporting electricity are only paid a fraction of the cost of electricity they import

[1] "Industrial Grid Energy & Battery Energy Storage Solutions | GE Power." Ge.Com, 2019, www.ge.com/renewableenergy/hybrid/battery-energy-storage.

While battery energy storage is a reliable and viable technology, system costs remain prohibitively high for a typical SME's investment criteria. As such, systems are often only financially attractive for utility level installations where additional cost benefits are available to add to the system value chain. However, the battery storage industry predicts that production costs will continue to fall as they have done significantly in recent years.

Who is this publication for?

Battery energy storage systems can be employed by anyone both commercially and residentially, but this guide is mainly intended for SMEs. This overview covers:

- The different types of system available and their suitability
- The benefits of battery energy storage systems
- System costs, paybacks and parameters

Before considering any energy storage system, first ensure that energy is being used as efficiently as possible across the organisation. Generating energy on-site for it to be used in an inefficient process makes no sense; energy efficiency must be prioritised.

Benefits of battery energy storage

System benefits can vary considerably from one application to another

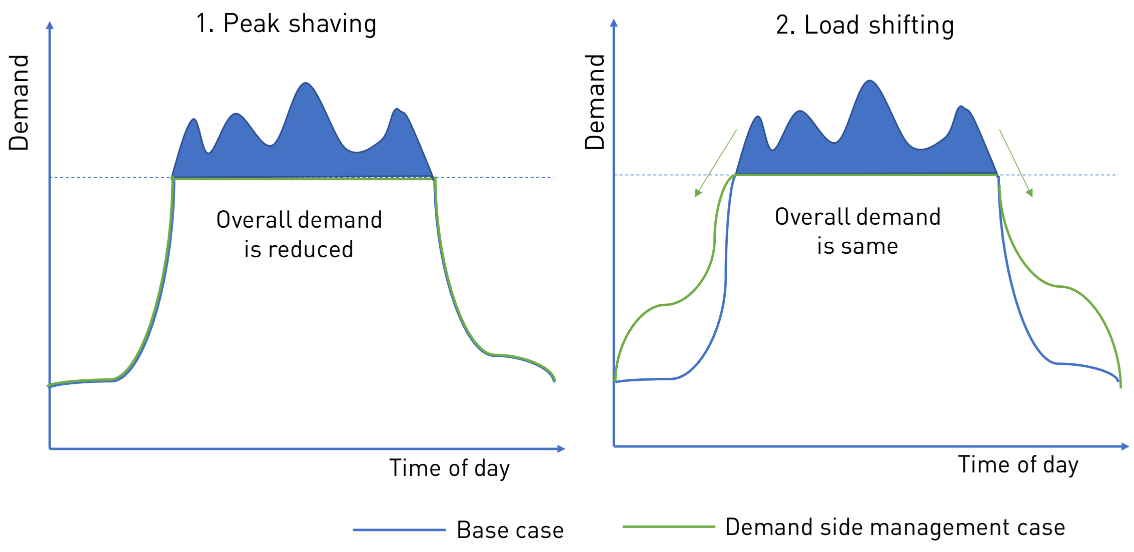
The economic benefits of battery energy storage systems are very business specific, with paybacks dependent on the load profile, tariff structure and system charges.

The potential benefits include:

Bill management

- Battery energy storage can reduce or even eliminate demand charges from utility bills. Where an SME has a variable electricity cost (time-of-day tariff), between 30% and 70% of the utility bill may be made up of demand charges. Battery storage allows for electricity to be absorbed and stored from the grid in off-peak hours, when costs are low, and used instead of the grid when demand and prices are higher. This is achieved through peak shaving (reducing consumption during peak times) or load shifting (shifting consumption from the grid to off-peak hours). Figure 1 illustrates these two concepts.
- Battery energy storage systems contain advanced technology that regular batteries do not and so can perform these complex tasks like peak shaving and load shifting that were previously impossible. Peak shaving in a commercial setting is the most important application of energy storage, as reducing consumption saves on cost.
- Reduction in third-party costs and power network system charges, e.g. **RO, DUoS, TNUoS.** These charges are proportionate to energy consumption so can be reduced by taking less energy from the grid.

Figure 1: Two examples of Demand Side Management - load shifting and peak saving



[1] "How Battery Energy Storage Works." Ideal Energy Solar, 18 Apr. 2018, www.idealenergysolar.com/how-battery-energy-storage-works/.

[2] Stoker, Liam. "Batteries and the Blackout: How Energy Storage Saved the UK's Grid." Energy Storage News, 28 Oct. 2018, www.energy-storage.news/blogs/batteries-and-the-blackout-how-energy-storage-saved-the-uks-grid.

Renewable integration

- Energy storage allows for the maximum level of onsite consumption of renewable power generation sources. It also can smooth the output of green sources, where wind is not always reliable and solar produces cyclically (day vs. night). Utilising all of the energy produced by the PV array maximises the value of the generated power and allows solar energy to mimic the consistency of fossil fuel energy sources[2].

Income from a power aggregator company

- A third-party aggregator is a third-party provider of storage services who aggregates multiple, small-scale storage assets and manages them like a single ("virtual") large asset.
- By setting up a virtual power network made up of numerous individual systems, an aggregator can offer a number of services to the grid. Aggregators pass on a portion of the earnings to the storage system owners.

Backup and emergency power

- Battery energy storage systems provide reliable emergency power that takes over automatically, minimizing the disruption and costs associated with power cuts. At 4:52pm on Friday 9 August 2019, the UK suffered its first wide-scale blackout in more than a decade thanks to a lightning strike. More than one million people experienced power outages and significant disruption. 3:47 minutes later, the National Grid's reserve capacity batteries discharged and grid frequency had been restored to normal operating limits[3]. This large-scale example shows the power of battery storage systems, and also showcases an example where an SME could continue to operate normally despite the grid failing.

System selection and sizing

Some typical options for battery energy storage systems

If considering this technology for your business, we recommend consulting an expert for advice and always obtaining several quotations from different suppliers. Ensure that you have implemented other no- and low-cost energy efficiency opportunities first. It is important to seek advice and fully understand the terms and conditions of any service agreements and contracts to make sure you are taking the right approach for your business. Also, see our guide on commissioning an energy efficiency project.

A battery energy storage system comprises three main components, illustrated in Figure 2:

The battery

- Batteries consist of individual cells connected into modules and then into packs

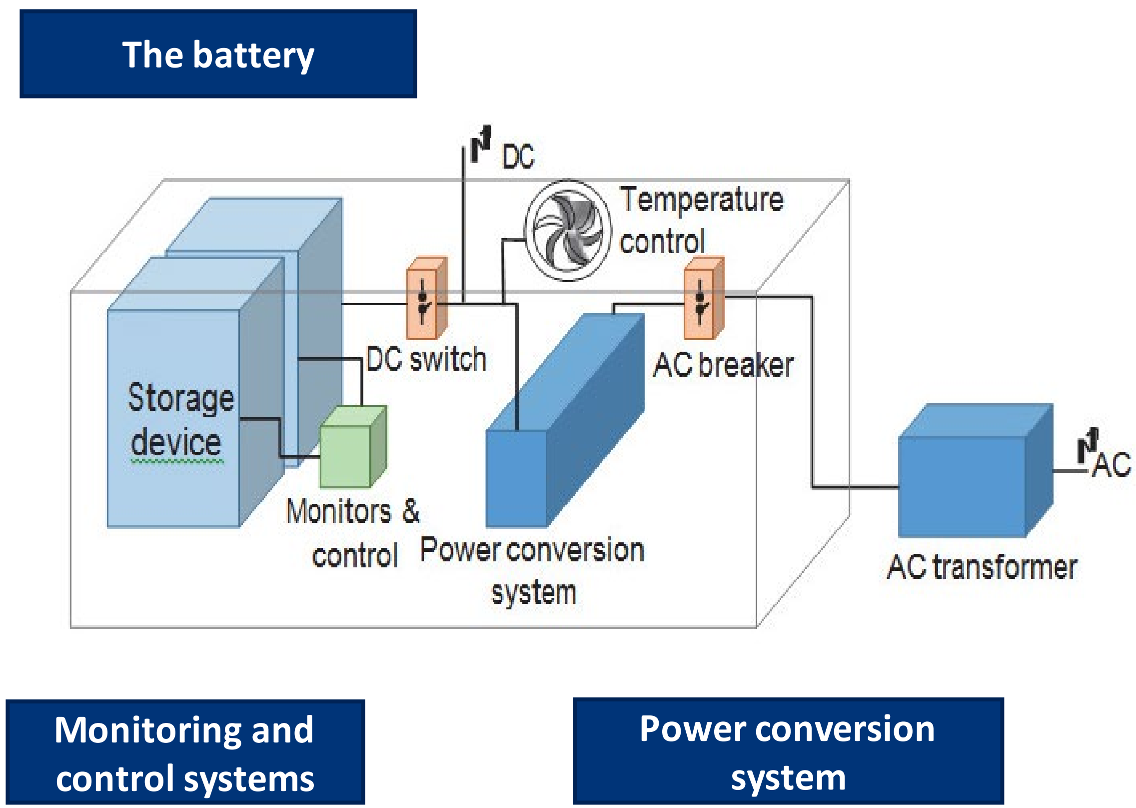
The power conversion system

- Converts DC power from the battery to AC power for grid use or site demand. With the use of a rectifier, AC flows back to the battery for charging after conversion to DC power

Monitoring and control systems

- Referred to as the battery management system, ensures safety and maximises performance.

Figure 2: Battery Storage system



Source: Battery storage for renewables: market status and technology outlook, IRENA, 2015

Lithium-ion batteries

The chemical composition of the battery affects the performance of the storage system. Lithium-ion batteries are the market leader. While options other than lithium-ion exist, many are unsuitable at this stage, as detailed below:

- Flow batteries – still in development, only some in commercial deployment
- Lead acid – low tolerance to cycle rate (no. of charges to discharges), therefore impractical

SME scale

- Sodium – still in development, unproven in commercial deployment
- Zinc – unproven in commercial deployment

Utility scale

Battery energy storage is becoming more viable a technology for SMEs thanks to prices dropping faster than expected. This is mostly driven by the growing market for consumer electronics and demand for electric vehicles[4].

Lithium-ion batteries, the most common battery option for energy storage:

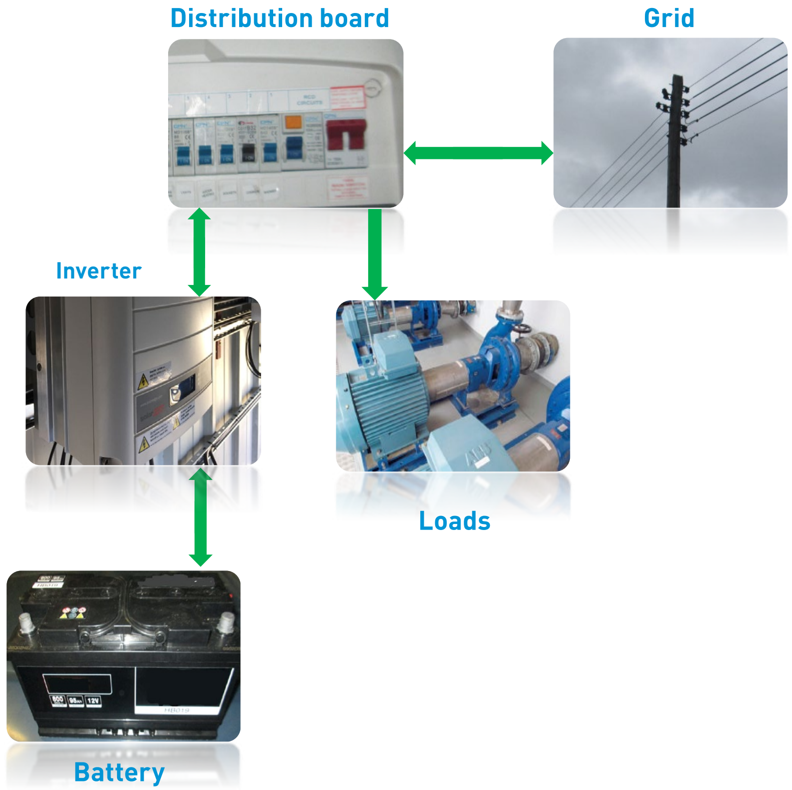
- are already widely used in consumer products
- have low standby losses
- are highly efficient (80-90%)
- have a high tolerance to cycle rate
- cost just $176/kWh (£136/kWh) in 2018, compared to $1,160/kWh (£894/kWh) in 2010[5]

Typical system options

Some options for battery energy storage projects which may be suitable for SMEs to consider are illustrated below:

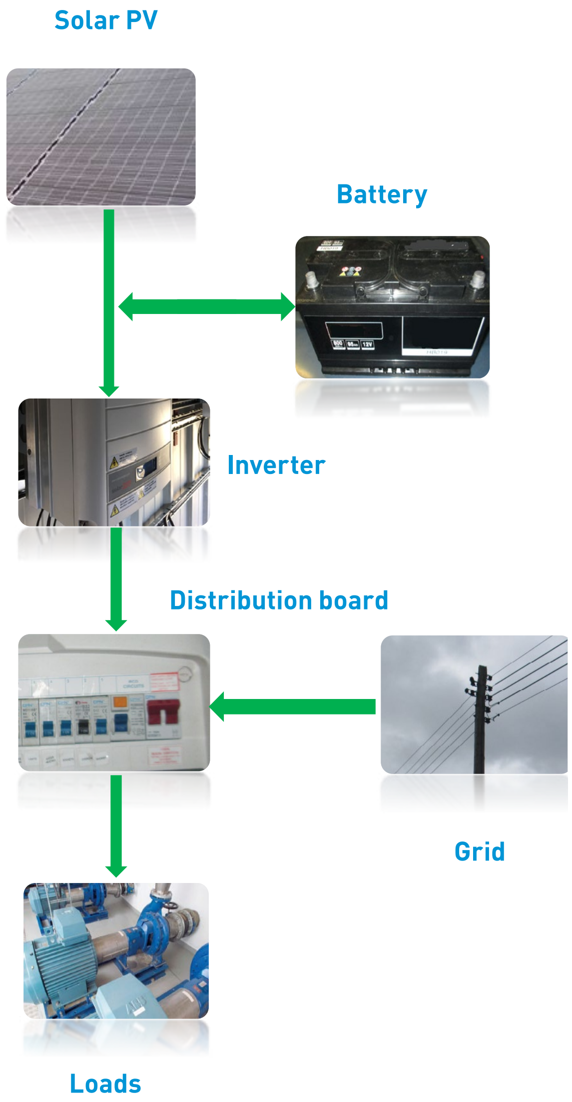
1. Battery storage only (illustrated below)

- Battery storage absorbs cheap electricity from the grid, storing it until the cost of the electricity increases.
- When the time-of-use tariff increases, the cheaper stored power is utilised to help offset the cost increase.



[4] Frankel, David, and Amy Wagner. "Battery Storage: The Next Disruptive Technology in the Power Sector." McKinsey & Company, 2017, www.mckinsey.com/business-functions sustainability/our-insights/battery-storage-the-next-disruptive-technology-in-the-power-sector.

[5] Goldie-Scot, Logan. "A Behind-the-Scenes Take on Lithium-Ion Battery Prices." Bloomberg NEF, 5 Mar. 2019, about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/.

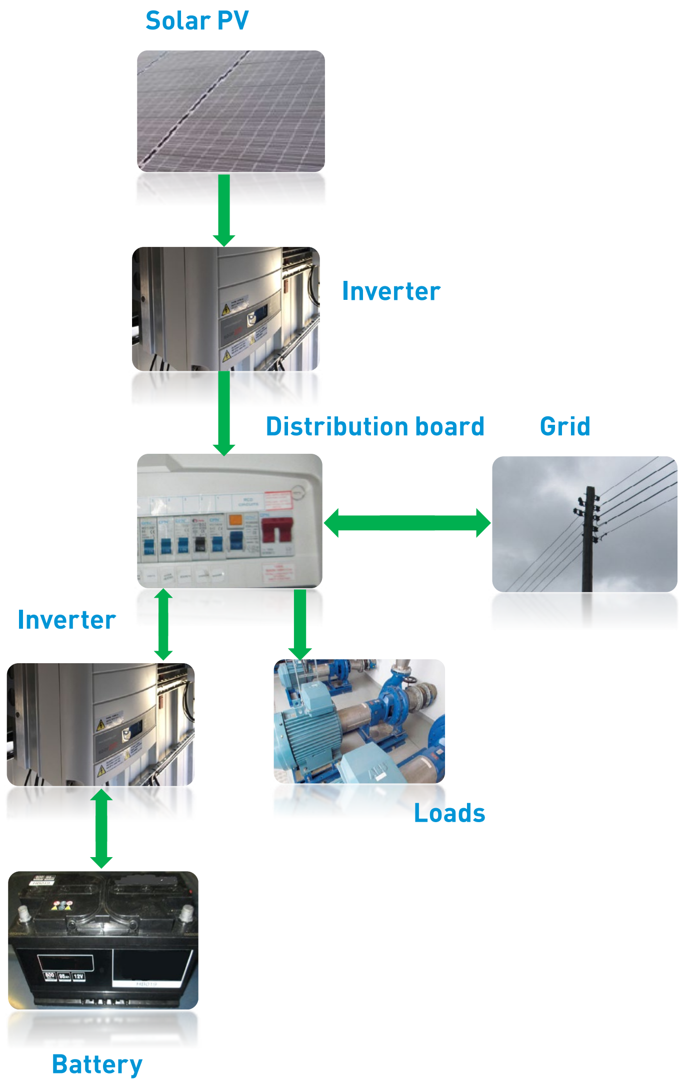


2. PV + DC Battery Storage (illustrated left)

- Battery is connected to the PV side of the solar inverter.
- Reduction in feed-in-tariff due to energy used in charging and discharging.
- No need to inform **DNO.**
- Cannot charge using cheaper electricity.
- More complicated install.
- Not typically recommended as a retrofit due to possible equipment compatibility issues.

3. PV + AC Battery Storage (illustrated right)

- As per PV array, except when an excess of PV is generated, power is absorbed by the battery storage which discharges to reduce imported electricity, higher time-of-use tariffs and other system charges.
- System can still operate as per battery storage scenario should the storage be insufficiently charged by the PV array.
- No effect on PV feed-in tariffs.
- Needs **DNO** approval.
- More suitable as a retrofit to an existing PV system.



Increasingly, battery energy storage systems are being offered as a solution to capturing surplus electricity generated by a solar PV system for use later in the day. Until recently, they were prohibitively expensive for domestic market businesses. These systems vary in their size, operation and cost and they are not right for everyone. Whilst solar PV systems are the most common at the moment, using other forms of renewable generation like small-scale wind turbines is another option and the benefits are the same.

While DC-coupled battery storage systems are often cheaper and more efficient by up to 3% since the battery and solar panels share the same inverter, there is limited access to power. The battery must be installed near the inverter and they operate in different optimum temperatures, so there may be an efficiency trade-off. AC-coupled units require separate inverters for the battery and solar panels, so battery faults won't affect the panels and vice versa. They provide more power and installation is more flexible.

Modern battery energy storage systems simply plug into an existing power network and usually include a built-in inverter and computerized control systems. This benefits the owner as they are all-in-one, turnkey systems that are simple to install, largely maintenance-free, and don't require any effort or expertise[6].

System sizing

As outlined above the type of system chosen will depend on whether the installation is a retrofit or not. The optimum size of a battery storage system will depend on a site's electrical profile.

> For an SME with an annual consumption of <70,000 kWh, a 5kWh battery storage size would typically be appropriate.

> For an SME with an annual consumption of up to 170,000 kWh, a 15kWh battery storage would typically be appropriate.

[6] "How Battery Energy Storage Works." Ideal Energy Solar, 18 Apr. 2018, www.idealenergysolar.com/how-battery-energy-storage-works/.

System costs, paybacks and parameters

Considerations when developing a business case

System costs

System costs are dependent on **system type and size.**

Market analysis indicates that current typical costs (as of Sept 2018) range between **£1,000** and **£1,500 per kWh installed**, dependent on system size. Business case revenue streams are dependent on a number of highly changeable variables, e.g. electricity price, system charges, site consumption profile. Any business case needs to be based on a robust sensitivity analysis to the variables taken across the asset's lifetime to ensure the risks are understood. Similarly, when entering into an agreement with an aggregator, ensure that any business case has an associated sensitivity analysis.

System paybacks

System paybacks are dependent on a variety of changeable and often site-specific factors:

- System type
- System cost
- System use
- Electricity consumption profile
- Electricity tariffs and system charges

Taking the above variables into account (as of Sept 2018), system paybacks are in range of 5 – 15 years.

System parameters

Other system parameters that should be considered:

- System capacity
  - Variable dependent on the site profile, size of any PV array and the site profile against PV output
- Storage capacity vs. useable capacity
- Product warranty
  - This can vary from 5-10 years with limited cycles
- Check the number of cycles is guaranteed
- Technologies type
  - Depending on system use, perhaps look at longer discharge/higher cycle flow batteries

Case Study 1

Factory installing a Lithium-battery system to mainly reduce network charges and then supplement revenue with frequency response services. The storage unit will charge off the grid during non-peak times and then discharge during peak times to reduce grid withdrawal and associated peak rates (network charges and peak load). The total installed cost of such as system could be approximately £2800/kW, plus £20/year maintenance costs.

Use case description	Location of asset	Services delivered	Benefits
Industrial & commercial electricity storage used to time shift energy usage	Demand side – industrial site	• Reduce grid withdrawal during peak times for energy and network • Emergency backup	Reduce grid withdrawal during peak times for energy and network (TNUoS)[7] and Distribution use of system (DuoS)[8] charges reduces total bill

Source: DNV GL, Energy Storage Use Cases for BEIS, 2016

[7] Transmission Network Use of System (TNUoS) charges recover the cost of installing and maintaining the transmission system in England, Wales, Scotland and offshore. Transmission customers pay a charge based on which geographical zone they are in, whether they are generation or supply and the size of that generation or supply

[8] DNOs on-going business including maintaining, repairing and replacing network assets is collected through the application of Distribution Use of System (DUoS) tariffs. These charges are then recovered from end users as part of their total energy bill

Case Study 2

Factory installing a Lithium-battery system to mainly reduce network charges and then supplement revenue with frequency response services. The storage unit will charge off the generation on-site during non-peak times and then discharge during peak times to reduce grid withdrawal and associated peak rates (network charges and time of use tariff and peak load). This helps to better match on-site demand with renewable generation output and in doing so shape their demand curve to reduce electricity costs. The total installed cost of such as system could be approximately £2800/kW, plus £20/year maintenance costs.

Use case description	Location of asset	Services delivered	Benefits
Industrial & commercial site with installed solar PV integrated electricity storage to time shift energy generated or energy usage	Demand side – industrial site	• Smoothing renewables output • Reduce grid withdrawal during peak times for energy and network • Emergency backup	• Utility bill reduction by reducing demand at times of network peak and by avoiding Transmission use of network (TNUoS)and Distribution use of system (DuoS) charges reduces total bill • Improved utilisation of micro-generation

Source: DNV GL, Energy Storage Use Cases for BEIS, 2016

Future developments

As lithium-ion battery costs reduce this technology will become more accessible for SMEs

Cost reduction in battery energy storage projected by the industry varies widely among energy storage technologies, but lithium-ion capital costs are expected to decline as much as 36% over the next five years. This is primarily driven by the projected demand for batteries for electric vehicles.

The lead that lithium-ion has over other battery types is expected only to widen, as batteries produced in a wave of new factories in China, the U.S., Thailand and elsewhere will further drive down prices, which have already plunged 85% since 2010. However, breakthroughs in battery technology may solve some of the current issues with lithium-ion batteries. Solid-state batteries promise, among other things, to remove the flammable liquid that can cause lithium-ion batteries to occasionally catch fire. New fast-charging sodium batteries that use a glass electrode instead of a liquid one may provide three times as much energy density as lithium. While lithium-ion are small and light, they have a short operating life. For the commercial utility-scale battery market, longer-lasting, safer, cheaper and more scalable vanadium-flow batteries may soon become the one to compete with. They are non-flammable, compact, reusable over semi-infinite cycles, discharge 100% of the stored energy and do not degrade for more than 20 years. Vanadium is twice as abundant naturally as lithium, and the extraction process uses industrial waste products. V-flow batteries outcompete lithium-ion and any other solid battery and are less than half the cost per kWh, and while they take up a lot more space, this is an acceptable condition for industry and utility. For the moment however, investment in lithium-ion is the sensible path for SMEs.

Considering battery energy storage systems as a whole, market reforms may soon allow broader market access for SMEs, introducing additional income stream layering possibilities. New business models are emerging as competition begins to develop such as 0% capital leasing arrangements, and aggregator offerings are changing.

[9] "Levelized Cost of Storage 2017." Lazard.Com, 2 Nov. 2017, www.lazard.com/perspective/levelized-cost-of-storage-2017/.

[10] Renewable Energy World. (2019). Why Lithium-Ion Technology is Poised to Dominate the Energy Storage Future - Renewable Energy World. [online] Available at: https://www.renewableenergyworld.com/2019/04/03/why-lithiumion-technology-is-poised-to-dominate-the-energy-storage-future/#gref

[11] Conca, J. (2019). Energy's Future - Battery and Storage Technologies. Forbes. [online] 26 Aug. Available at: https://www.forbes.com/sites/jamesconca/2019/08/26/energys-future-battery-and-storage-technologies/#3d4f79c244cf

Conclusions

Battery energy storage has the potential to provide business benefits and investment costs are predicted to fall

The best way to fight climate change is to use energy more efficiently. Batteries are an essential element for success in a sustainable world that relies on intermittent sources like solar and wind, or that is concerned with resilience in the face of increasingly frequent natural disasters .

Battery energy storage systems allow businesses to cost-effectively store cheap electricity directly from the grid or from a renewable source, for use on demand at another time. This guarantees power during blackouts and removes the reliance on the grid during peak-demand pricing hours, allowing for business as usual. Battery energy storage can reduce all charges associating with drawing energy from the national grid, cutting costs and increasing efficiency for SMEs. While the benefits of battery energy storage are very business specific, it can provide bill management, renewable integration, aggregator income and emergency power to businesses willing to invest.

Lithium-ion battery systems are the most common being a proven commercial product, and can be used purely to absorb power from the grid or in connection with a renewable onsite source, either as a retrofit of an existing system or as a new installation.

System costs and paybacks are very business specific, but generally cost between £1,000 and £1,500 per kWh installed and paybacks occur in the range of 5 – 15 years. Projects must have a robust cost sensitivity analysis to determine the costs across the asset lifetime, and cost effectiveness is primarily driven by battery costs. Current battery costs dictate that systems are only financially attractive at utility-level installations, where additional cost benefits are available to add to the system value chain. While battery storage is a reliable and viable technology, system costs remain prohibitively high for a typical SME's investment criteria. However, the battery storage industry predicts that production costs will continue to fall.

Remember! These storage systems only make sense for already efficient organisations – energy efficiency is still far more economical than installing a battery energy storage system into an inefficient organisation.

[12] Conca, J. (2019). Energy's Future - Battery and Storage Technologies. Forbes. [online] 26 Aug. Available at: https://www.forbes.com/sites/jamesconca/2019/08/26/energys-future-battery-and-storage-technologies/#3d4f79c244cf

Glossary

- **PV** – Photovoltaics. Solar power.
- **RO** – Renewable Obligation. Introduced by the Government to support large-scale renewable electricity generation in the UK.

  A portion of your RO cost is proportionate to energy consumption, so can be reduced by taking less energy from the grid.
- **DUoS** – Distribution Use of System. The cost of operating and maintaining the regional electricity network.

  A portion of the DUoS charge is proportionate to energy consumption, so can be reduced by taking less energy from the grid.
- **DNO** – Distribution Network Operator.
- **TNUoS** – Transmission Network Use of System. The cost of installing and maintaining the transmission system.

  A portion of the TNUoS charge is proportionate to energy consumption, so can be reduced by taking less energy from the grid.
- **Feed-in tariff** – Payments offered for the energy that solar PV systems generated. Introduced by the Government to support the uptake of renewable energy generation technologies.
- **Maximum demand** - highest level of electrical demand monitored in a particular period usually for a month period.

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The Carbon Trust provides a range of tools, services and information to help you implement energy and carbon saving measures, no matter what your level of experience.

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www.carbontrust.com/greenbusinessfund

The Carbon Trust is an independent company with a mission to accelerate the move to a sustainable, low-carbon economy. The Carbon Trust:

- **advises businesses, governments and the public sector on opportunities in a sustainable, low-carbon world;**
- **measures and certifies the environmental footprint of organisations, products and services;**
- **helps develop and deploy low-carbon technologies and solutions, from energy efficiency to renewable power**

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