

# Energy Storage

The final piece  
of the jigsaw

wsp





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## Executive summary

Storing energy on a large scale will cut energy bills for all, reduce CO<sub>2</sub> emissions, support the transition to the all-electric city, and could open the door to 100% renewable energy supply.

It's an area which is evolving fast.

Even a few years ago energy storage was considered far too expensive to deploy on a meaningful scale.

Today there's a wide range of technologies available from batteries to pumped hydro, and from hydrogen to flywheels and compressed air. Technology innovation is driven by the need to find a way to store intermittent, renewable electricity cheaply and also by financial incentives provided by National Grid and others to encourage users to cut use when demand is at its peak.

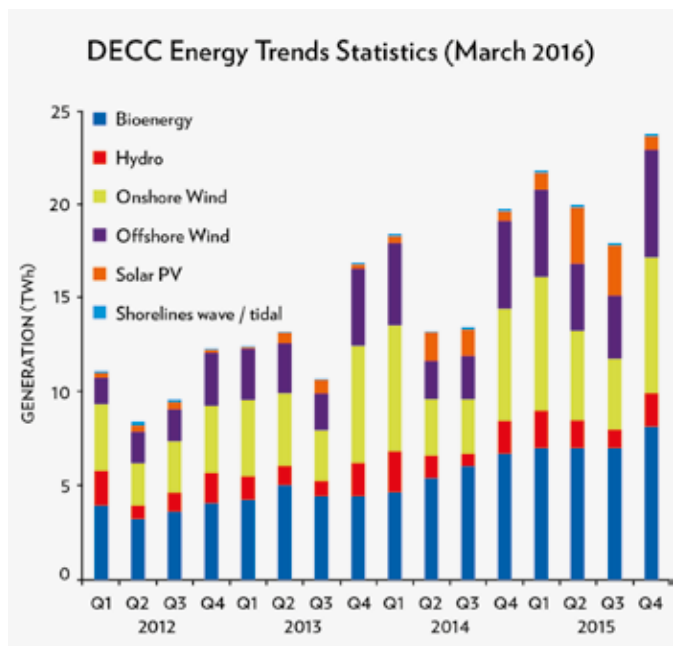
It's opening up opportunities for all. The next decade will see rapid deployment of lithium ion battery technology across homes, factories, offices and of course vehicles. Driven by lower costs, financial incentives and improved technology efficiency this will complement the larger work on storage already being delivered by network operators.

Energy users and developers need to respond to this change. Just as with energy efficiency and renewables, there's already a range of developers offering solutions, financial incentives and a bewildering array of acronyms. So companies need to get on the front foot.

The immediate action for energy users and developers is to find a clear and practical understanding of energy storage, and to then develop a practical strategy to make the most of this emerging opportunity.

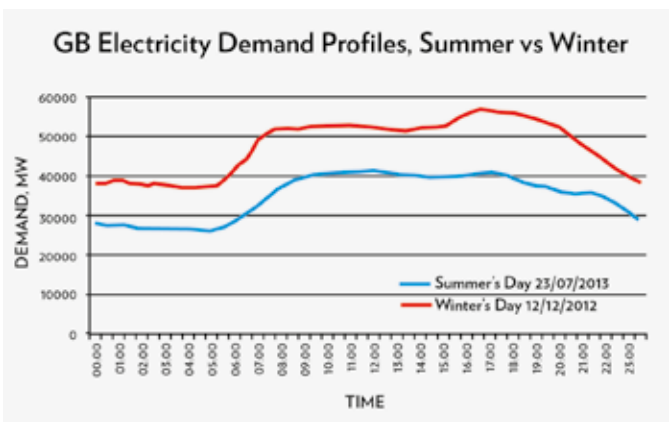
# The Need for energy storage

The UK renewables landscape has seen a large shift in recent years. Solar farms and wind turbines have now become commonplace and renewable energy as a proportion of total electricity generation has increased year on year. In March 2016, the Department for Energy and Climate Change (DECC) released its latest energy trends data showing that renewables' share of electricity generation reached a record level of 24.7% in 2015. Despite a recent reduction in wholesale energy prices, generation tariffs and incentives, renewable electricity generation still remains viable (mainly as a result of falling capital costs) and there are still targets in place for renewable energy generation; so the trend is likely to continue to grow.



However, there are physical restrictions to this growth. A lack of infrastructure capacity in some areas of the UK (for example the south west of England and Scotland), has meant installations have all but ceased. Instead they have moved where there is still capacity, but these are less windy or sunny climates, which is not ideal.

Apart from renewables, the National Grid has always been faced with the challenge of balancing generation with a fluctuating intermittent electricity demand. It may be a cliché, but boiling water for a cup of tea at half time, just after our favourite soap, or as soon as we get home from work is one of the biggest challenges the National Grid has to face each day, and it's not one which will go away soon.



National Grid graph.  
Figure 1

In Figure 1 the typical electrical demand profile in Great Britain over a day in the summer and winter is shown. This changing demand must be balanced minute by minute and there are several mechanisms for doing this. On the demand side the grid encourages non-domestic users to reduce demand during peak periods by charging more for electricity, (see DUoS and Triads charges below). For domestic customers, with the exception of Economy 7 and 10, electricity prices do not change during the day, (although there is discussion of this happening as all consumers will have smart meters from 2020). On the supply side we pay for generators to stand idle, ready to provide power, and in some cases even require them to operate at below full capacity, which reduces efficiency and increases emissions.

Storage is at least part of the solution to these challenges and costs; it can act as additional supply when there is insufficient generation, and additional demand when there is too much generation.

# Storage Technologies

There are a host of technologies that are available in the marketplace or that are developing.

Here is a selection of the most important:



## 1. Lithium-Ion batteries

**What is it?** Lithium Ion batteries have become widespread in recent years especially in the field of consumer electronics, (in mobile phones, laptops, etc.). Lithium-Ion batteries allow these gadgets to be smaller and lighter compared to using traditional lead acid batteries as they have three times the energy density, (how much energy they can store per unit of volume).

### MAIN USES

- Increasingly the market is coalescing around lithium-ion technologies as the standard battery type for the near future
- Local, site level use

### ADVANTAGES

- Simple to integrate at a site level
- Most likely to go to scale at site level
- Long life (2,000-3,000 cycles) and a deep depth of discharge (80% DoD compared to 30-50% for a lead-acid equivalent)

### DISADVANTAGES

- Still expensive, but costs coming down fast

In the future lithium-ion variants, supercapacitors and redox flow batteries offer the potential for much greater efficiency and capacity.



## 2. Lead Acid Batteries

**What is it?** Lead acid batteries consist of an anode and cathode submerged in an electrolyte consisting of water and sulphuric acid and is typically the type of battery found in cars. These batteries are relatively low cost but heavy and have a shallow depth of discharge (DoD). Commercially they are used around the world for vehicle batteries, emergency lighting and as uninterruptable power supplies. The main problem with these is a relatively short lifespan compared to the alternatives as well as the environmental impacts associated with the technology.

### ADVANTAGES

- Inexpensive
- Established and understood technology

### DISADVANTAGES

- Short lifespan
- High product environmental impact



## 3. Flywheels

**What is it?** Flywheels store energy in the form of kinetic rotational energy. Spinning, sometimes at '000s of RPM, they are often used in uninterruptible power supplies.

### ADVANTAGES

- Very responsive in providing a lot of power in the event of a power loss

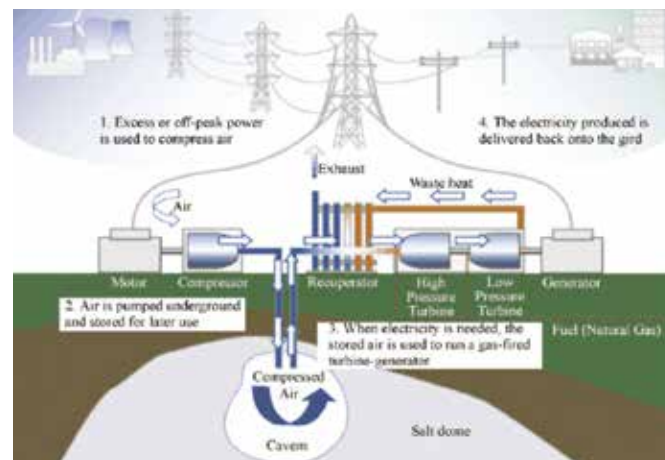
### DISADVANTAGES

- They are expensive per unit of energy
- Not good for providing energy over long periods



## 4. Compressed Air Energy Storage (CAES)

**What is it?** CAES uses energy to compress air, sometimes in underground formations or in man-made containers, when it isn't needed and then releases the compressed air through turbines to generate energy when it is required. Typically the round-trip efficiency of this process is around 70%.



<http://www.gov.scot/Publications/2010/10/28091356/4>

### ADVANTAGES

- Works best at large scale serving our electrical grid.
- Offer the ability to store energy over periods of hours or longer

### DISADVANTAGES

- Expensive
- Varies from site to site
- May require particular geological conditions

## 5. Hydrogen

**What is it?** The Hydrogen Economy has been discussed for decades as the future and is beginning to find uses, particularly in vehicles where hydrogen fuel-cell vehicles can drive for long distances emitting nothing but water. In our electrical system hydrogen can be produced using renewable energy when it is available through various processes and then used in turbines or fuel cells to generate energy when we need it.

### ADVANTAGES

- Can store energy for long periods – even over seasons
- Can be transported

### DISADVANTAGES

- Expensive to generate
- Difficult to store
- Low round-trip efficiency at only around 37%

## 6. Thermal storage

**What is it?** Anyone with a hot water tank uses thermal storage. Thermal storage can take many forms including hot water, phase-change materials, packed bed storage and even using underground aquifers. In buildings this form of storage is normally used to reduce the size of plant required by allowing smaller systems to run for longer. In the future it may be used more to store excess power as heat to reduce demand later. For example systems already exist that allow homeowners to use solar power they are not using in the day to heat up their water tank for use in the evening.

### ADVANTAGES

- Simple to understand and cheap
- Commonly used

### DISADVANTAGES

- Can't be reconverted to electricity
- Difficult to store for long periods

## 7. Pumped storage

**What is it?** Pumped Storage power stations take water from lower elevations during times of low electricity prices to be stored in reservoirs at higher elevations. During times of high electrical demand, when prices are higher, the water is released to produce power through turbines with very quick response times possible. There are four grid scale pumped storage power stations in the UK and all are located in either Scotland or Wales in mountainous regions.

<https://commons.wikimedia.org/wiki/File:Stwlan.dam.jpg>



### ADVANTAGES

- Established technology at grid scale
- Fast response times

### DISADVANTAGES

- Specialist nature of the site required means future deployment is limited
- Potential for large environmental and spatial impact

# The incentives for energy storage

There's two main ways that energy storage can cut costs for end users:

## 1. Daily price variations

For many larger energy users, the cost of electricity changes over a day largely as a result of network charges. Lowest costs are during the night, peak costs are an early evening in winter. The Distribution Use of System (DUoS) charges give non-domestic users an incentive to reduce energy demand at peak times. These costs vary regionally and are most expensive where our networks are most constrained, such as in parts of Scotland and the SW of England. Compared to an average annual total unit price of 9-10p per kWh, DUoS charges can add as much as 6p/kWh at peak times for small industrial users, nearly doubling prices. Energy storage provides an opportunity for end users to benefit by charging batteries during times of low demand/cost and using the energy during more expensive times.

The additional benefit of reducing/removing electricity demand during high demand periods is that this is highly likely to correspond with electricity Triad periods. Triads are slightly different in that they are a charge for energy suppliers based on their energy demand at the three peak demand points over the winter, separated by a period of ten days. Triads generally occur between 5pm-6pm on winter evenings. These charges help to pay for the costs of the National Grid system and energy suppliers often pass through these costs directly on to large consumers.

In the future, as a result of the Capacity Market mechanism, many consumers will begin to see an additional Capacity Market Charge that will be calculated in much the same way as Triads, but with the cost being directly related to the site's level of consumption during peak times. Furthermore, introduced regulations mean that a greater number of consumers will be using half hourly meters with costs more directly linked to the time of consumption rather than a deemed profile of usage.

## 2. Balancing Services

### FREQUENCY RESPONSE

To keep in line with electricity supply regulations, the National Grid must manage generation in order to keep up with demand. This can be difficult as both demand and supply are both constantly changing.

In practice, this means maintaining a system frequency (the measure of the balance between supply and demand) close to 50Hz $\pm$ 1% and ideally  $\pm$ 0.4%. This can be difficult as demand is constantly changing and with the increasing amount of renewables on the grid, so is generation. If demand is greater than generation, the frequency falls while if generation is greater than demand, the frequency rises. If these don't balance the country would see blackouts and/or damages to equipment; at 52.0Hz generators begin tripping and at 47.0Hz the grid begins to shut down.

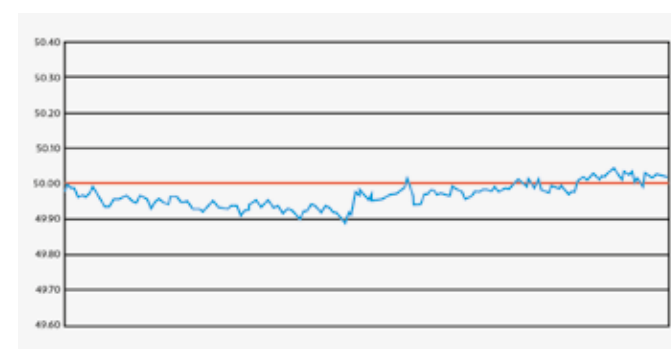


Figure 2: UK National Grid Frequency (Hz) over a one hour period

The National Grid has a number of mechanisms available to manage system frequency, some of which involve contracting with third party service providers to reduce/increase demand or generation.

The most recent service to be developed is Enhanced Frequency Response, defined by National

Grid as being frequency that achieves 100% active power output at 1 second (or less) of registering a frequency deviation. This is expected to suit battery technologies in particular, with 64 developers and 888MW of projects pre-qualifying in the initial interest stage. Projects that are successful will be contracted with National Grid to provide this service, receiving revenue in return for managing system frequency.

### SHORT TERM OPERATING RESERVE (STOR)

Short Term Operating Reserve is an instrument by the National Grid where reserve power is called upon in either the form of additional generation or demand reduction. This needs to be a minimum of 3MW of generation or steady demand reduction (this can be over a number of sites) for at least 2 hours with 240 minutes of receiving instructions from the Grid. This would require large scale energy production and is more suited to diesel generators and similar. Under this scheme, batteries could be used as additional generation or as a means to reduce demand for larger consumers.

### FAST RESERVE (FR)

Fast Reserve is similar to STOR, but must be dispatched within 2 minutes from receiving instruction from the Grid and must deliver 50MW of generation (or demand reduction) and this can be an aggregation of several systems. Large batteries (or aggregated systems) may be able to access this scheme by way of exporting power or reducing system demand when required.

## Energy storage definition and regulation

One of the major regulatory issues around energy storage is how it is defined; is it a form of generation or consumer or neither? Existing regulation and licenses refer to energy suppliers, DNOs, system operators and generators whilst embedded generators are typically defined as intermittent or non-intermittent. DECC are currently engaged in an exercise to resolve how it should be defined and licensed.

Many argue that further regulation change is needed in order to facilitate the development of grid scale storage, particularly in the way that DNOs are not currently able to own or operate generation assets due to licence conditions.

## Revenue Stacking

When operated in isolation, individual schemes such as Triad avoidance or STOR may not provide the level of income required to be financially viable for a battery project. However, where a number of these revenue streams can be accessed at the same time, the financial case improves. So called "revenue stacking" involves different layers of income based on the schemes or contracts that a site is subject to.

## Aggregation

In many cases small storage systems, or those with large amounts of storage spread over a large number of sites may not be able to participate in some of the available schemes because of the scale required. Aggregation provides a way around this problem; by controlling many systems as one it offers the opportunity to act as one larger system able to benefit from these schemes. This aggregation can be undertaken by third parties or by the company's energy management function.

# Energy storage in practice

Here are five practical examples showing how energy storage could work and is being delivered in practice for different groups of organisations. For simplicity we have looked at scenarios where sites benefit from one system for using energy storage. In reality most energy storage deployments now aim to benefit from more than one scheme, thereby maximising the return, (so called revenue stacking), or have more than one use, such as also providing an uninterruptible power supply, (UPS). Whilst this is likely to offer the best solution in many cases it does require careful analysis to ensure that there is no double-counting of the energy storage and that participation in one does not compromise another

As with many other large energy investments, the scenarios shown here would be beyond the investment horizon of many commercial entities, and we expect energy storage to be delivered primarily by third party investors. This means that those wanting to benefit from energy storage may not need to provide capital or be subject to project risks, but will instead use a shared benefit model.

## Example 1 - The Medium sized manufacturer

### THE BUSINESS

A. Widget Limited is a London based manufacturing company – their annual average unit rate for electricity is approximately 10p/kWh. Average electrical demand is around 200kW and the firm manufactures throughout the day. Widget’s energy consumption is metered on a half hourly basis and doesn’t cut production at times of higher energy prices.

| Time Band | p/kWh Charge |
|-----------|--------------|
| Red       | 4.246p/kWh   |
| Amber     | 0.215p/kWh   |
| Green     | 0.005p/kWh   |

Table 1: 2016/17 Distribution Network Charges for an LV site in London

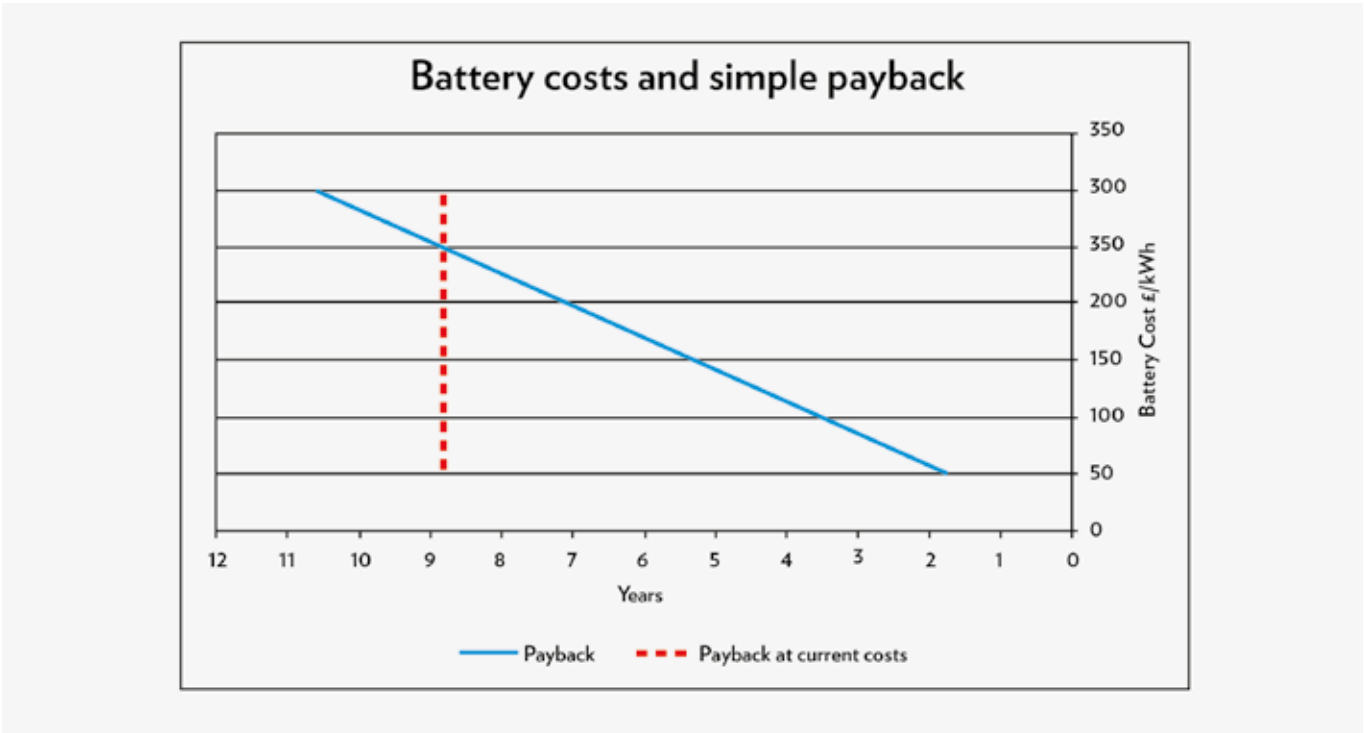
### THE SOLUTION

Widget could install a 600kWh battery with a 10 year life and 80% depth of discharge at a cost of approximately £150,000. This charges when energy is cheap for use during times of higher price – certainly the peak, red, periods and even mid, amber, pricing times. It also gives some TRIAD avoidance benefit.

Annual cost savings for the investment, based on 2015 prices, are £17,000, giving a simple payback of around nine years. This is probably beyond the point of being commercially attractive to a manufacturer but third party suppliers offering free systems on shared revenue models are very interested at this level and with prices falling and anticipated to reduce in much the same way as Solar PV costs have in recent years then self-funding may become more of an option, particularly with the revenue stacking opportunities discussed.

| Benefit                                                     | Value per annum |
|-------------------------------------------------------------|-----------------|
| 200kW Evening Red band avoidance (16.00-19.00) Gross Saving | £6,623          |
| 200kW TRIAD avoidance (2016/17 charge applied) Gross Saving | £10,374         |
| Capacity Market charge avoidance                            | TBC             |
| Total Annual Benefit                                        | £16,997         |

Table 2: Battery Savings - Manufacturer in London



The graph above shows where the simple payback line would lie indicatively today, but the payback line allows you to project at what cost it would become attractive depending on your payback horizon. Of course this may not be funded by A. Widgets, but by developers offering this service on a shared benefit model.

## Example 2 – The regional District Network Operator

A. REGIONAL DNO CO. IS A REGIONAL DISTRICT NETWORK OPERATOR (DNO), WHO OWNS AND OPERATES THE DISTRIBUTION NETWORK FOR ONE OF THE 14 LICENCE AREAS IN BRITAIN.

In the past, A. Regional DNO Co. only had to manage the delivery of power from the transmission system down to consumers, but with the increase in distributed generation A. Regional DNO Co. has to manage power flows in both directions. The electrification of heat and transport has also increased the peak demand on the distribution network, and it is now reaching the limits of the network capacity.

A. Regional DNO Co. has decided that instead of increasing the capacity of the network by upgrading and replacing existing equipment, they will use locally based energy storage to reduce the peak demand. They have looked at the most likely future demand and generation

scenarios, and estimated that over the next five years the peak demand will only exceed existing network capacity for between ten and twenty days each year. On those days the peak is of a short enough duration for it to be possible to recharge the energy storage between the peaks.

A. Regional DNO Co. has had previous experience of local demand reducing unexpectedly when a local manufacturer moved production outside of the UK, leaving part of their network underutilised. There is always some uncertainty over future local demand and distributed generation, and hence a risk of investing in a network upgrade which is not needed for the long term. Using energy storage will postpone the network upgrade investment by several years until it is clear that it will be needed, and will extend the operational life of the existing network equipment.

At present DNOs are not permitted to operate energy storage which is classified as generation assets and therefore have to use a third party to provide this locally based energy storage service. The same third party energy storage could be used to provide other services, including frequency response.

Example 3 –  
The family – one for the future?

THE SMITH FAMILY LIVE IN A SEMI-DETACHED PROPERTY IN THE ENGLISH COUNTRYSIDE. DURING THE PEAK OF THE FEED-IN TARIFF BOOM, THEY INSTALLED A 4KWP SOLAR PV SYSTEM ON THEIR ROOF TO REDUCE BILLS AND AS AN INVESTMENT FOR FUTURE RETURNS.

The solar panels on the Smiths’ roof produce energy during the day, with any power produced used to offset electricity imported from the grid. While Mr. and Mrs. Smith are at work and the children at school during the day, there is little electricity demand, and so power is exported to the grid and an export tariff is paid to the family at 4.84p/per kWh. (The FiT scheme assumes that 50% of the energy generated is exported and so this is paid regardless of how much energy is exported.)

When combined with on-site generation, such as this rooftop Solar PV system, a battery installation can help to maximise the energy generated used on-site. Energy used on site will offset grid electricity consumption of approximately 12-15p/kWh. It is always advantageous to use as much electricity on site as possible and reduce the amount of electricity needed to be purchased. An energy storage system allows the family to store electricity and use it later on in the day when they are at home and so reduce electricity costs further.

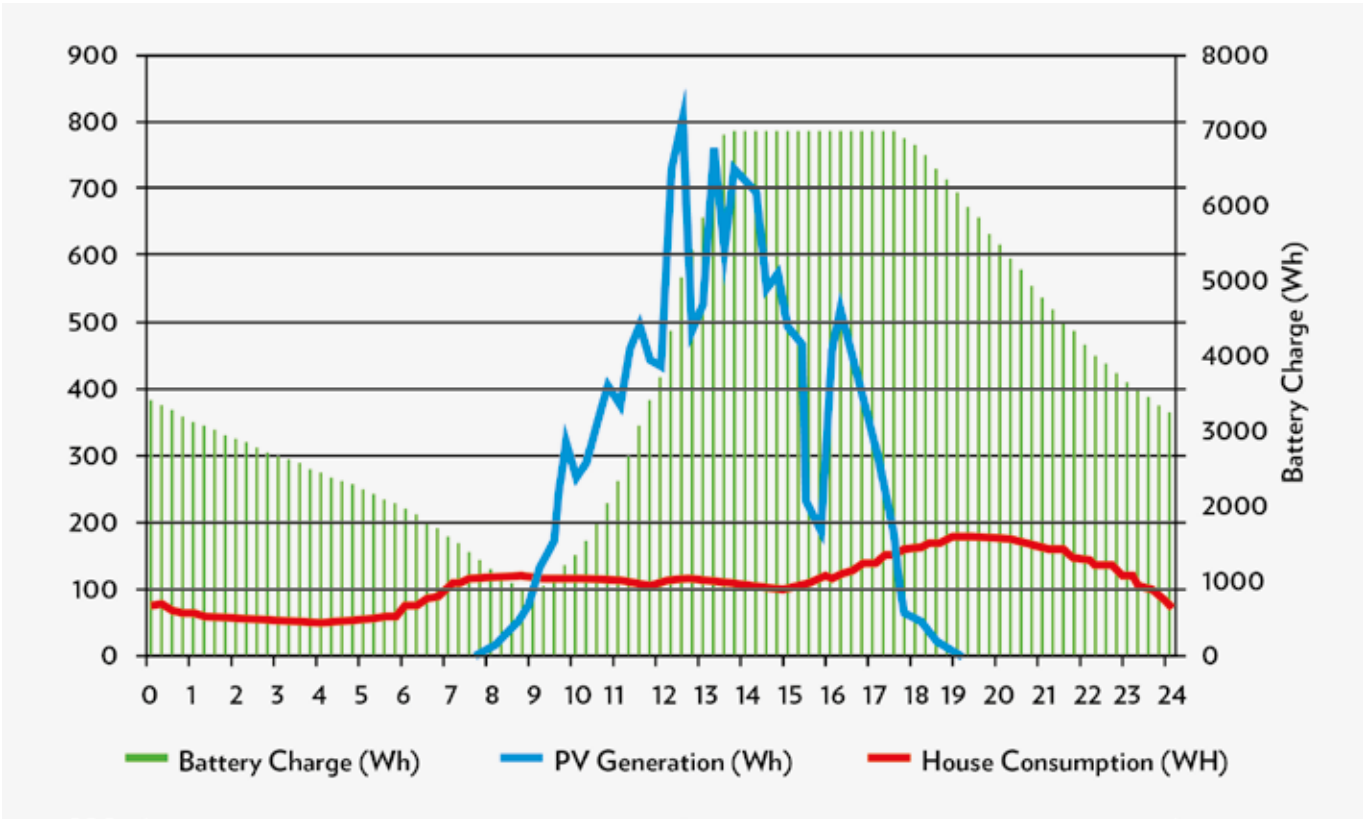
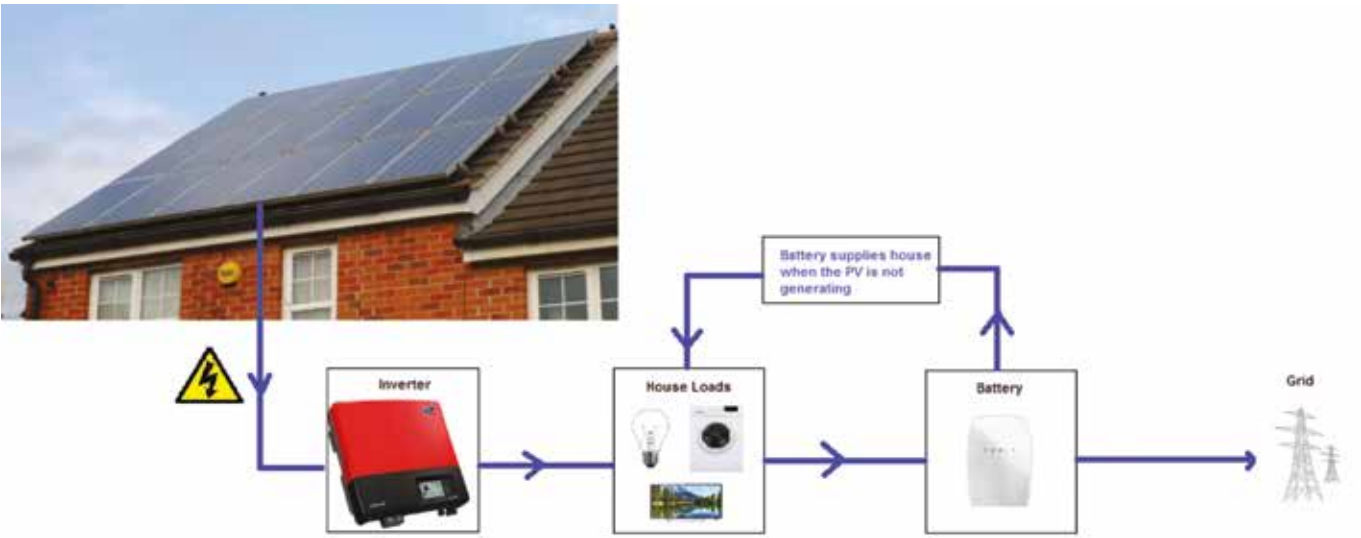


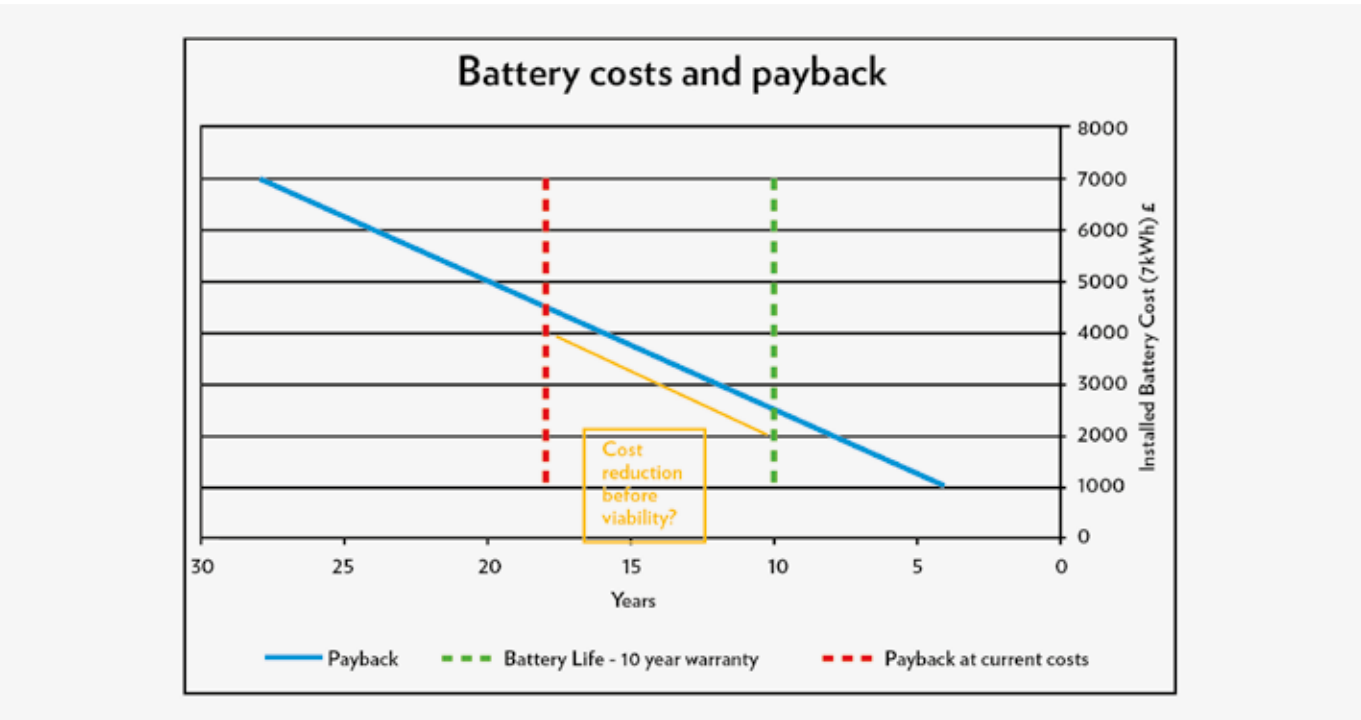
Figure 3: Typical Day Domestic PV tied with Storage

Figure 3 models the PV system with energy storage – it uses the family’s energy consumption figures (which are typical for a UK domestic household), as well as their summer PV generation figures and illustrates the benefits of a 7kWh battery.



As the PV generation drops away in the evening, the battery system meets household demand using electricity stored during the daytime – without this the house would be importing electricity from the grid and failing to make the most of the PV system. Rather than only saving money when the PV is generating during the day (when no-one is at home) the Smiths are increasing their savings by using more “free” electricity and becoming increasingly independent of the grid.

This is still likely to be too expensive at the moment with batteries such as this costing around £2,000 and still requiring other equipment, and the saving being only around £250 a year. Many studies consider the impact of time of use charging, half hourly pricing and other mechanisms currently seen in the commercial sector but not used in the domestic one. These changes, if they occur and if the general public accepts such dramatic changes to the way they purchase electricity, would change the economics. There are also market opportunities for developers to use aggregation of home storage via smart controls to offer larger scale services to the grid.



### Example 4 - Happy Hotels Ltd.

HAPPY HOTELS LTD.IS A HIGH QUALITY INDEPENDENT HOTEL OPERATING IN RURAL DORSET. THEY CURRENTLY HAVE 100KWP OF SOLAR PANELS INSTALLED ON A THIRD OF THEIR ROOF AND PLAN TO EXPAND THIS.

Happy Hotels Ltd. is located in a region with limited additional distribution network capacity available for further renewables deployment. Currently infrastructure only exists for 100kW of generation, which has already been installed; therefore there is no room for any other renewable generation without incurring significant costs. This means despite Happy Hotels having suitable roof area available to them and funding in place, they are not able to proceed with the project as the grid connection costs of doing so are prohibitive. However, over the course of a year the average amount the plant will generate is around 10% of the 100kW peak capacity and even in the summer will very rarely deliver this output.

By integrating batteries the PV system could smooth out peaky generation, storing excess energy during times when the 100kW threshold is exceeded. Rather than simply limiting exported power from the site, energy would be stored for future use. This gives Happy Hotels the option to install much greater amounts of solar electricity generation capacity.

In this example Happy Hotels will be able to install an additional 200kWp of solar generation capacity with no need for additional investment to infrastructure. For wind turbines the same principles apply, with batteries enabling connection points to be used closer to maximum capacity rather than being matched to peak demand. The added benefit of this is that DNO can defer or even completely avoid investment in network reinforcement in areas where the grid is currently constrained while still supporting current levels of renewable energy deployment.

The benefits and payback involved in this scenario are difficult to model because of the site specific

nature of connection charges and technologies. However, the principle shows that energy storage could support further uptake of renewable energy technologies in areas that previously may have been limited by high connection costs.

### Example 5 - Solar Developer Co.



SOLAR DEVELOPER CO. IS A COMPANY SPECIALISING IN THE LEASING AND DEVELOPMENT OF LAND FOR THE INSTALLATION OF CIRCA 5MW SOLAR FARMS.

Typically a solar farm sells power to the grid at an agreed price under a power purchase agreement (PPA). Typically the value of this would be approximately £30 per MWh today. In order to increase the value of the energy they are producing, Solar Developer Co. have decided to use a battery in order to benefit from higher energy prices at peak times. High volumes of solar generation during the day can have the effect of supressing hourly market prices, for example around lunchtime when solar generation is at its peak. Therefore Solar Developer Co. believes that Energy storage offers the potential for them to optimise revenue from their generation assets by trading energy on more short term contracts or through auctions such as the N2EX.

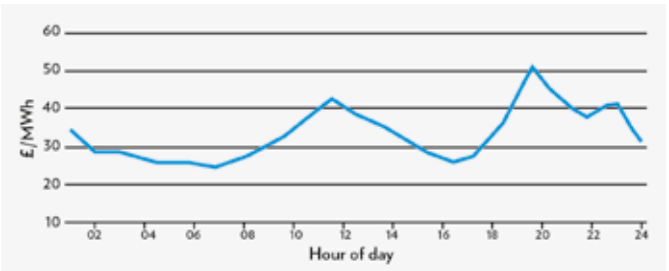


Figure 4: Example N2EX price chart for a week in May 2016

In the 12 months prior to 31<sup>ST</sup> March 2016, the average N2EX auction price was approximately 40% higher between 5pm and 7pm compared to between 9am and 3pm (£39.78/MWh - £55.48/MWh).

In the UK, the current arrangements for DNO charging also potentially benefit non-intermittent generators that can increase exported power during red time bands due to embedded benefit payments. Again the red time bands are also likely to correlate with National Grid Triad periods, opening up further income that previously would not have been available to solar installations.

Assuming a site is located in the South West of England, the Triad benefit could be worth as much as £48.58 for every kW of power exported during the Triad periods. Similarly, embedded benefits for a non-intermittent generator can be significantly higher during peak times compared to intermittent generators – for example a site connected at high voltage to WPD South West’s network would receive up to 5.041p/kWh exported power during the red time band compared to just 0.374p/kWh for an intermittent generator.

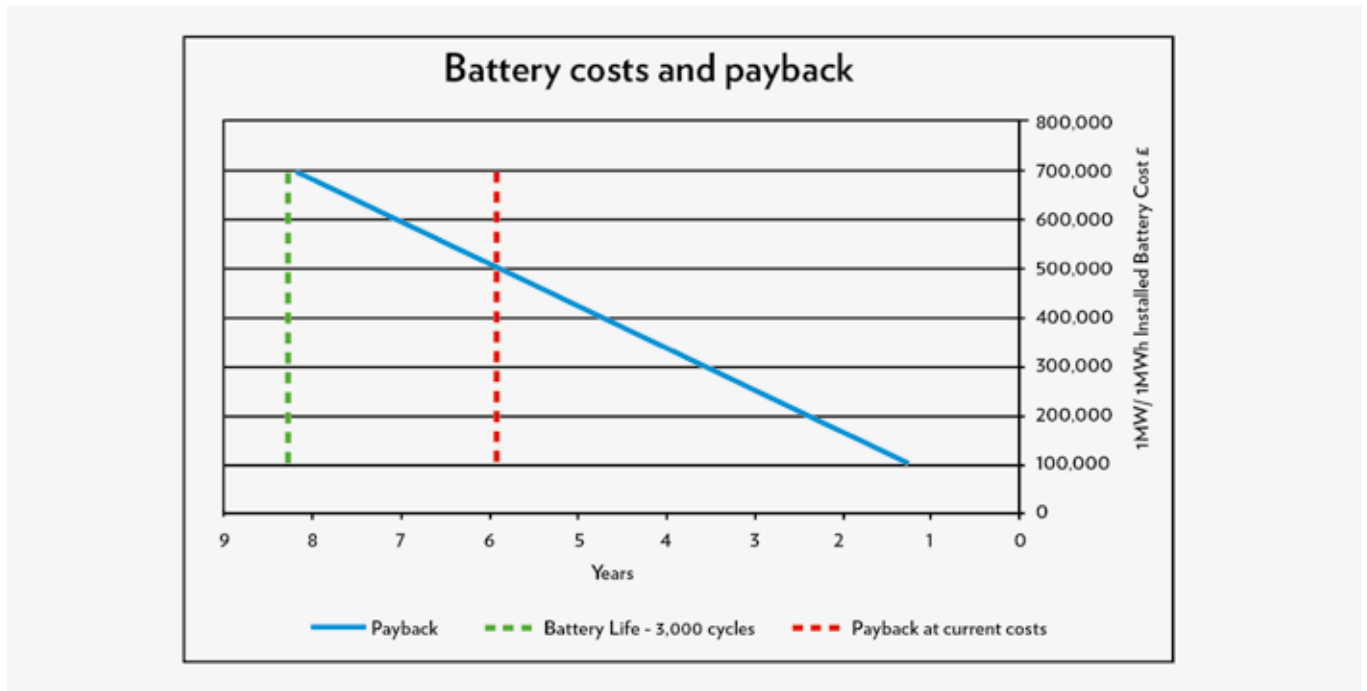
The below scenario assumes that a 1MW (2MWh) battery has been installed on a solar farm in the South West of England. It has been sized and designed such that it is charged with power from

the solar farm every day of the year. In reality, we know that business models will have to account for winter days when solar generation is low – perhaps by using remote monitoring systems to “top up” the battery with grid electricity when needed although the need to import grid electricity will have obvious cost implications. During system design, consideration should also be given to the ratio of PV and battery capacity due to the impact of lower income received during amber and green time bands

| Benefits                    | Potential Value p.a. |
|-----------------------------|----------------------|
| GDUoS Red Band              | £24,408              |
| TRIAD Benefit               | £48,580              |
| Peak Power Price Benefit    | £11,461              |
| <b>Total Annual Benefit</b> | <b>£84,449</b>       |

Further income could be derived from other schemes where applicable – for example, solar developers have expressed a keen interest in the Frequency Response services implemented by National Grid.

This particular scenario does come with some caveats regarding risk of changes to the value of these benefits in the future.



## Other Opportunities

In the future there may be other opportunities and methods for benefitting from energy storage. Some examples include:

### LEASING CAPACITY

Rather than using batteries to increase Solar PV capacity on site, batteries can be installed to reduce peak export to the grid. This could allow the generator to lease part of their connection to a third party located close by. This third party may not be able to install any renewable generation due to the cost of connection capacity, but by using a previously granted connection along with a battery this opportunity may now be open to them.

### FLEET DOMESTIC

By aggregating many domestic/commercial energy storage systems it will be possible to operate on different schemes, such as the Fast Response market or offer frequency response, increasing the overall value of the systems.

### BLACK START CAPABILITY

Many facilities such as hospitals and power stations already have “black-start” capability. This is the ability to carry on fully operational even when the electricity grid has gone down. This then allows little pockets of generation to connect together and expand until the entire power grid comes back online. These are traditionally diesel generators,

which require regular testing and maintenance. Although it is unlikely and possibly ill-advised to completely replace these system with batteries today they may be able to add additional capacity to these systems, or work in conjunction with them to provide a more flexible, cost effective solution.

Many infrastructure facilities are also installing diesel generator to act as standby generators in the event that the mains power grid fails, again batteries can provide an alternative.

### ELECTRIC VEHICLE OWNERS

As the cost of batteries falls and capacity increases, we expect the uptake of electric vehicles to increase. Not only will the cost reduce, but range will increase providing an increase level of comfort for those worried about running out of charge. The increase in electric vehicles brings with it many environmental and health benefits as explained in our All-Electric Cities paper.

### SHIFT AWAY FROM INTERMITTENT ENERGY GENERATION

Energy storage opens up the possibility of renewable electricity generation (in particular via wind and Solar PV) to shift from an intermittent energy source to a technology capable of providing electricity on demand, particularly as penetration rates reach levels that would require curtailment otherwise, (disconnecting them when they are generating too much energy).



# Glossary

## CAPACITY

Typically expressed in kWh (kilo-Watt hours) or MWh (Mega-Watt hours) and is a measure of the amount of electrical energy stored in the device. This may or may not take into account the depth of discharge (see below).

## CAPACITY MARKET LEVY

The capacity market levy is applied to energy bills in order to cover the costs of the UK capacity market mechanism. Part of the Levy to be introduced in November 2016 will operate in much the same way as Triads – essentially penalising consumers for drawing demand off the grid at peak times. Costs will begin to ramp up as capacity market payments to participants continue.

## CHARGE / DISCHARGE RATES

This is expressed in kW and defines the speed and limit the storage device can load or unload electrical energy. This is important to ensure that the storage system can provide the energy quick enough.

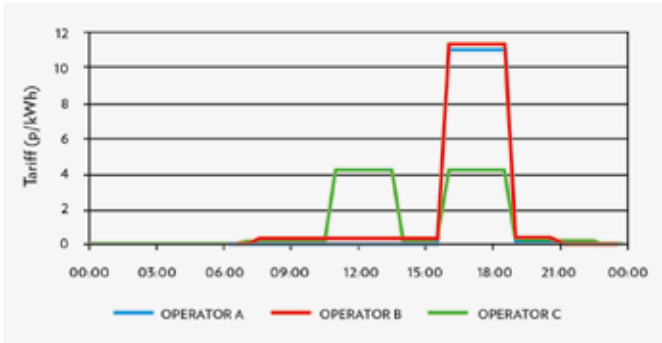
## DEPTH OF DISCHARGE

This is the amount of stored energy which the battery can discharge before affecting the lifetime of the battery. A shallow depth of discharge would mean that only a small amount of the battery can be regularly used meaning that a larger battery is needed and therefore increasing capex. In general, if a battery is consistently fully discharged and recharged its lifetime will be shorter than if it is only partially discharged / charged. Lead acid

batteries can normally discharge only to 50% whilst Li-ion batteries are able to consistently discharge to 80%.

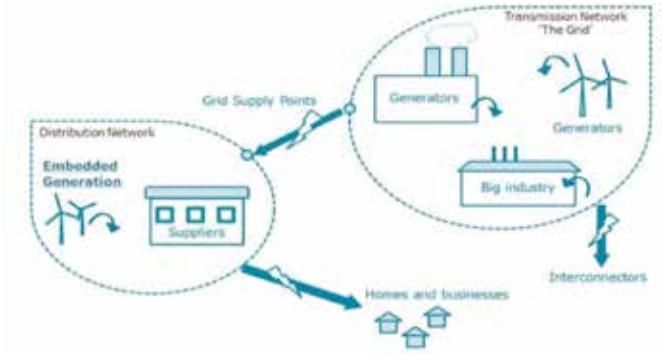
## DUOS

Distribution Use of System charges are a way for DNOs (the local network operator) to recover their costs via customer energy bills. For high demand customers the charge incurred (p/kWh) varies depending on the time of day it is used. The time bands are split into three over a 24 hour period where ‘Green’ is the lowest tariff; ‘Amber’ is an intermediate tariff and ‘Red’ the highest. The 14 different network operators use different rates across each period and can also vary the times at which each band is operating. Typically ‘Red’ bands cover a period between 5pm and 7pm and are flanked either side by ‘Orange’ periods, with ‘Green’ periods throughout the night.



For embedded generators, distribution use of system charges are often paid to the generator as an “embedded benefit” through the generators PPA.

## EMBEDDED GENERATORS



This term applies to generation equipment (e.g. Wind Turbines, Solar Farms etc) that are connected at distribution level as opposed to at National Grid (Transmission) level.

[https://www.elexon.co.uk/wp-content/uploads/2016/01/Embedded\\_Generation\\_v7.0.pdf](https://www.elexon.co.uk/wp-content/uploads/2016/01/Embedded_Generation_v7.0.pdf)

## ENERGY DENSITY

Measures the energy (in kWh) gravimetrically or volumetrically, e.g. kWh/m<sup>3</sup> or kWh/kg.

## HALF HOURLY METER

The UK electricity market is settled and balanced on a Half Hourly basis. Larger electricity consumers have meters that measure electricity consumed in every Half Hour period. New UK regulations (P272) mean that a greater number of UK consumers will now be settled on a Half Hourly basis.

## LIFETIME

This is how long the battery can be utilised before it reaches the end of its useful life (or commonly when it reaches 80% of its original capacity, though definitions may vary slightly between manufacturers). This can be stated in kWh or number of cycles and is often linked to the depth of discharge.

## POWER DENSITY

Measures the power (in kW) per mass or volume, e.g. kW/m<sup>3</sup> or kW/kg. Depending on the requirement one may be more important than the other.

## RESPONSE TIME

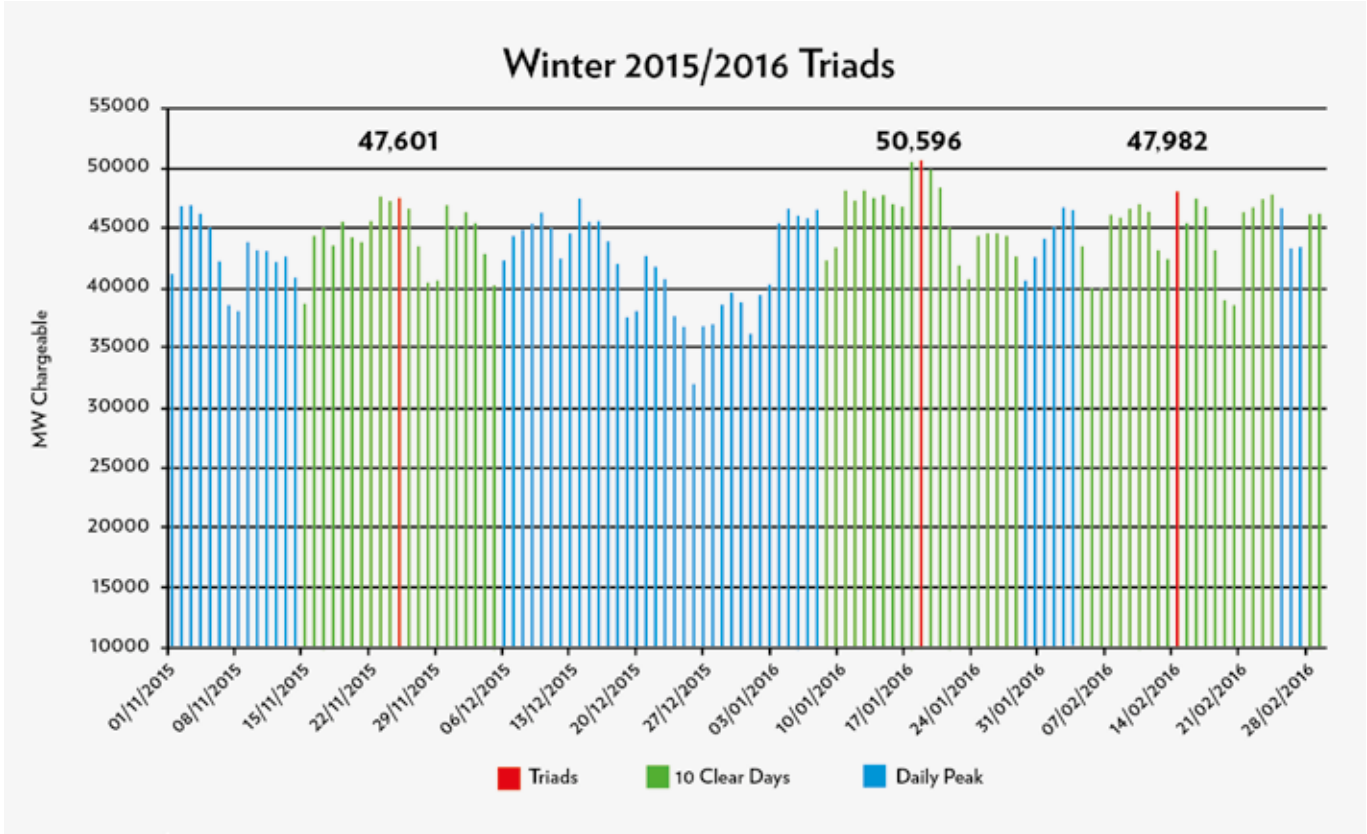
This is a measure of how quickly the energy storage can be accessed. For batteries this is more or less negligible as it is more or less instantaneous and measured in fractions of a second. This is one crucial benefit they have over some other forms of storage, which take a longer time to ramp up, in providing certain services.

## TNUOS (TRIADS)

Transmission Network Use of System charges are levied on energy suppliers and generators using the National Grid network. Historical data from between November and February is retrospectively analysed with three ‘Triad’ periods determined where demand is the greatest; these must be at least ten days apart. These tend to occur between 17:00 – 17:30 or 17:30 – 18:00. Once identified, all users are charged a premium for the average amount of energy used during these three periods. Electricity suppliers pass these costs through to consumers, with those using Half Hourly meters often charged in accordance with the demand drawn during the three Triad periods. TNUoS charges depend on the local DNO regions, but for 2016/17 they vary between £40.24/kW in Southern Scotland and £51.87/kW in London – these charges have been rising in recent years with tariffs in Northern Scotland rising by as much as 74% from last year.

As they have the effect of reducing demand on the National Grid network, embedded generators are typically paid a Triad benefit through the terms of their PPA with an energy supplier. This is because in contracting with distribution connected generators, the energy suppliers Triad exposure is reduced. Triad payments are usually paid by the supplier according to the generators average level of output over the three Triad periods. Note that Triads are typically on winter evenings, when solar farms are unlikely to be generating without energy storage.

# Glossary



## VOLTAGE

In the context of network charges, the voltage of a grid connection is important because the DNO charges or embedded benefits vary with voltage. Generally speaking, Low Voltage refers to sites connected at 240 or 410 volts, whereas High Voltage connections are 11kV or 6.6kV and Extra High Voltage for anything above this.





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