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REA
RENEWABLE ENERGY ASSOCIATION

Development of decentralised energy and storage systems in the UK

A report for the Renewable Energy Association

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1. Executive summary

This report has been prepared by KPMG LLP at the request of the Renewable Energy Association (REA). The report assesses the key trends relating to the development of decentralised energy and storage, the key benefits, and the barriers to its introduction. It sets out some potential opportunities for the deployment of decentralised energy systems, using a number of decentralised energy scenarios. We identify some policy and regulatory measures that could assist the efficient development of decentralised energy, as part of a potential implementation strategy.

The cost of decentralised energy technologies is falling rapidly. Recent technology innovation and production enhancements mean that the costs of solar power and wind power are falling. The greatest cost reduction has been experienced by solar, and some forms of energy storage are expected to follow a similar cost reduction path. With tools for customers to manage their energy use, decentralised energy systems could help lower energy costs for consumers, and contribute to decarbonisation and security of supply objectives.

For example, when solar photovoltaic (PV), storage and energy demand management are combined into **decentralised energy systems**, they **offer the potential for greater benefits to be realised**. Such integration of other energy components such as electric vehicles, heat pumps or Combined Heat and Power (CHP) may be realised at a domestic, business, or local level. Decentralised energy solutions are likely to have an increasingly important role to play in the national energy landscape, especially if they become more commercially attractive to consumers and businesses than their current energy services.

The continued growth of decentralised energy solutions may potentially transform the GB energy industry from a national energy market administered by government, regulator and utilities, to where this encompasses **a new market where local integrated energy solutions are determined by consumers, businesses and communities**. This is already underway, fuelled by the rapid penetration of distributed solar PV. A further boost to decentralised energy markets could occur if storage installations become more economic and can be effectively integrated into the energy system.

However, uncertainty surrounds how these new solutions may participate in energy markets, particularly in combination. Existing energy market rules and regulations have been largely created with large scale generation in mind and are complex for smaller participants. While work to enable the growth of this new complementary market sector is in progress, barriers still exist. **Enabling new distributed energy and storage to participate in existing energy markets should allow benefits to be realised,** and offer a 'no regrets' approach. Clear market rules and innovation incentives should help new technologies make the difficult jump from pilot projects to commercial operation.

Decentralised energy and storage trends

Cost reductions – Since 2012 the costs of domestic-scale solar PV costs have fallen by 40%[1], with global wind costsfalling by 60% since 2009[2]. Further cost reductions are expected. Lithium ion battery storage costs are currently falling rapidly.

Variable renewable generation – Currently, there is estimated to be well in excess of 20 GW of wind and solar generation connected to the GB energy system. According to analysis performed for the Committee on Climate Change, this is forecast to increase significantly over coming years causing increased requirements for new storage, demand response, and interconnectors to provide balancing

[1] Source: KPMG analysis

[2] Source: Lazards, 'Levelised Cost of Energy Analysis v9.0'

and reserve services. This will fill the periods when variable generation is not available, and to supply energy at peak demand periods when electricity prices may be more volatile.

Opportunities for deployment

Benefits – Increased deployment of decentralised energy and storage offers important benefits to the national energy sector, including:

- Lower overall energy costs as the risk of potentially high peak energy prices is reduced;
- New generation and network investment for peak capacity is not required;
- Reducing the risk of negative prices at times of low demand, when the energy system is dominated by 'must run' nuclear and renewables;
- Consumer or local energy management helps balance local demand and supply, thereby contributing to security of supply;
- Reduced UK dependence on imported fossil fuels, at a time when North Sea oil and gas production is declining (a trend that may accelerate give current low prices); and
- An increased contribution to decarbonisation by enabling greater penetration of variable renewable generation within the energy system.

Revenue sources – There is potential for decentralised energy and storage to earn revenues from three main sources, namely:

- National system energy balancing, reserve and capacity services, contracted by the national System Operator, including the Capacity Market.
- Grid investment deferment, contracted by network companies.
- Energy supply revenues, through participation in national energy markets, probably contracted through an energy supplier or aggregator.

Economic case studies

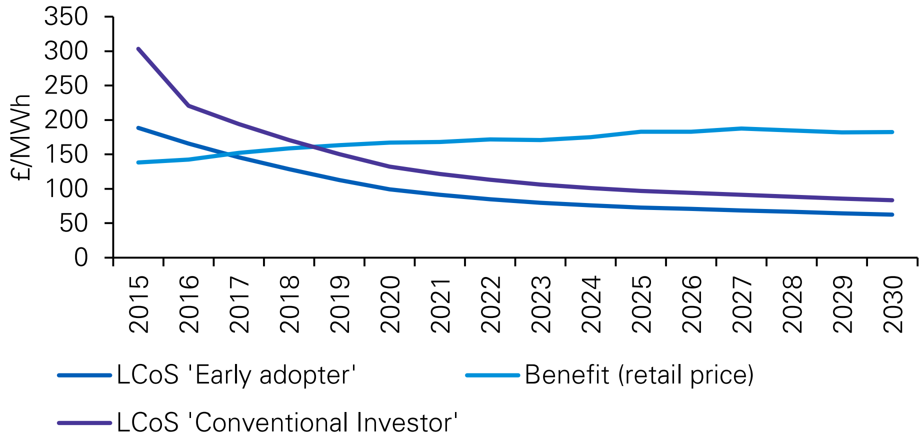
We have analysed the following alternative business models for deployment of decentralised energy and storage:

Small scale – Where domestic or business prosumers producing their own power develop their own decentralised energy and storage systems.

Our analysis shows that these may soon be economic for both domestic and business prosumers in certain circumstances, allied with an appetite for early deployment due to non-financial buying criteria[3]. For example, we expect that it may become economic for households with existing generation assets to 'retrofit' storage from around 2017.

Levelised Cost of Storage versus Benefits, domestic prosumer 'storage retrofit' scenario'

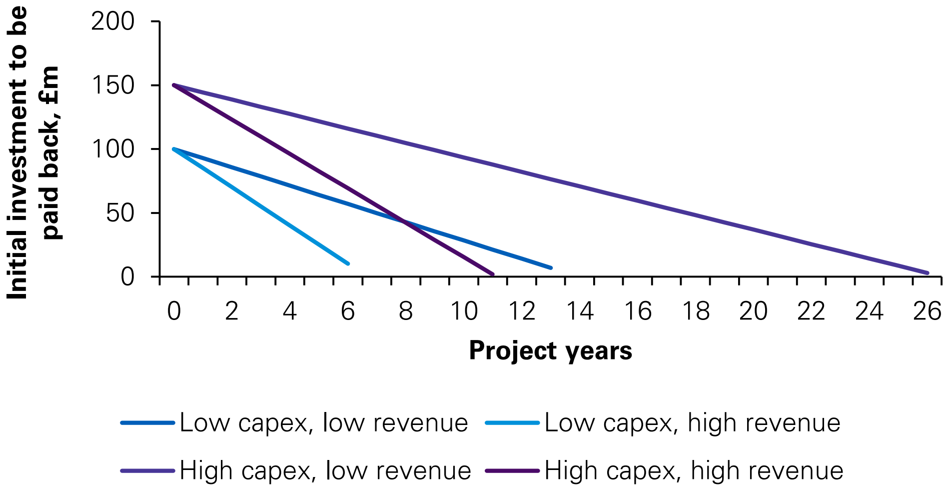
[3] For example, some consumers may gain value from owning a technology that is 'cutting edge', or from being self-sufficient in energy.



Large scale – where decentralised energy and grid level storage resources participate in national energy markets, either directly or as city scale energy schemes.

Our analysis shows that large scale decentralised energy resources, especially demand response and storage, are already economic in certain circumstances, although barriers to securing funding may remain.

Payback periods on initial capital investment, grid scale lithium ion battery



Challenges and barriers to be addressed

Our analysis shows that decentralised energy systems are already approaching the point where they can participate in existing national energy markets, including markets for energy, reserve capacity, and other grid services such as investment deferral and frequency response. However, there are a number of **barriers to market participation** for decentralised energy and storage resources, including:

— Existing energy and reserve markets are generally designed around incumbent generators and their historically defined operating characteristics. These generators may already have recovered their capital costs, and are able to compete on a marginal cost basis.

— The market rules, industry regulations, charging arrangements, and institutional framework are complex and generally designed for large sophisticated market participants. Many decentralised energy systems will be much smaller scale and may be deterred by this complexity and cost.

There are a number of **market and regulatory changes** that should encourage decentralised energy resources and give storage simple and fair access to energy and reserve markets. These include:

- Enhancing potential participation in existing national energy, reserve and grid support markets through **long term contracts** that support and encourage decentralised energy investment and associated changes to mechanisms such as the Capacity Market (see section 7.1).
- Enabling **new local energy market arrangements** that encourage small scale storage, demand response, solar, and other energy components to combine and add value for consumers. A range of alternative market arrangements may be required as consumer preferences emerge.
- Ensuring **price signals** are sufficiently strong to encourage investment, for example by making changes to settlement arrangements in order to charging more reflective of customers' actual usage, or through time of use tariffs.
- Ensuring **rules and regulations are simple and proportionate** to enable integrated energy solutions at a consumer and community level to both realise benefits and protect consumers.
- Setting out a **clear definition for energy storage** and changes to the grid system to create a new licence category for storage.
- Making sure energy networks **continue to receive sufficient funding** if Distribution Use of System (DUoS) revenues decline as prosumers opt to go 'off grid'.

2. Introduction

2.1 Background

In the UK, the cost of solar PV, onshore wind, and energy storage is rapidly declining, and new tools for customers to manage their energy consumption are becoming available. These combined developments have the potential to transform the UK energy industry from one dominated by large-scale generation, to one where decentralised energy solutions have an increasingly important role to play. Lower technology costs, allied with innovative integrated energy solutions have the potential to offer better long-term value for money for consumers compared to existing industry arrangements. There should also be benefits in terms of decarbonisation and security of supply.

There is a growing industry recognition that the wide-scale adoption of decentralised energy resources, and especially storage, in energy systems is rapidly approaching, but uncertainty surrounds how and when it may be realised.

The current industry framework is complicated, with legacy processes and costs. Transformation to a decentralised energy world will probably require changes to policy, market, regulatory, and planning frameworks, while removing barriers to technology and business innovation. These may drive significant change in the overall energy system responsibilities to one where, for example, distribution system operators ('DSOs') (or other aggregators) play a greater role for purchase of generation, storage and demand response to balance energy supply in their regions. Community energy solutions may play a key role, and new trading arrangements are likely to be required.

REA recently commissioned KPMG to prepare a Solar PV report ('UK solar beyond subsidy: the transition'), which concluded that a strategy for development of future decentralised energy systems is required. This report seeks to further inform this strategic debate by addressing the key issues surrounding the future development of economic, efficient, and decarbonised decentralised energy systems.

2.2 Structure of this report

This report has been developed by KPMG using our own assumptions together with those from REA members. The report covers the following main areas:

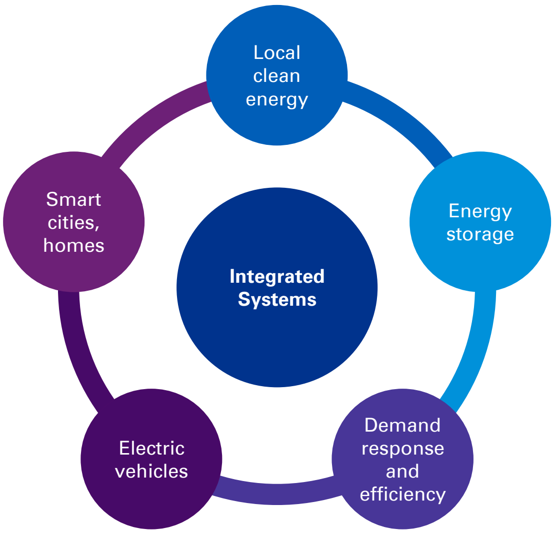
- The current and future role of decentralised energy in the UK energy system.
- High level analysis of key trends relating to the introduction of decentralised energy and storage, including economic and technology trends. High level review of potential costs and benefits to UK economy, decarbonisation, energy costs, and security of supply.
- Review of potential challenges and barriers to storage/solar/demand response and other technology deployment and of policy measures/support mechanisms that could assist deployment, including policy and regulatory changes.
- Conclusions, setting out key findings and recommendations, and a proposed strategy for the development of decentralised energy and storage systems.

3. Decentralised energy - Context

3.1 What is decentralised energy?

There are varying definitions of the decentralised energy sector. Commonly used definitions refer to components ranging from smart grids, demand response, local renewable generation, heat networks, heat pumps, to smart homes and electric vehicles. What is clear is that the appetite for decentralised energy solutions and business investment decisions is increasing, driven by government policies and subsidies, technology developments and business/consumer demand for more localised integrated energy solutions. Such systems have the potential to offer economic benefits compared with national energy systems, as consumers manage their own energy in a more integrated way.

The following diagram illustrates the key components that are expected to make up a future decentralised energy system, including the need for integration which sits at the heart of these systems. Such a system may typically include local generation supply and manageable local demand connected to the grid for import/export and backup. A storage capability for supply and demand balancing is a key enabler of a decentralised energy system.



Decentralised energy solutions can bring innovations which could transform the way the industry operates. In particular, innovations in the transport sector such as electric vehicles and hydrogen fuel cell vehicles will provide challenges to the existing industry business models. These new business models offer opportunities for a new industry to develop, and challenge the fundamental business models and regulatory systems that have evolved over recent decades, also blurring the line between utilities as currently delineated.

3.2 The growth of variable generation

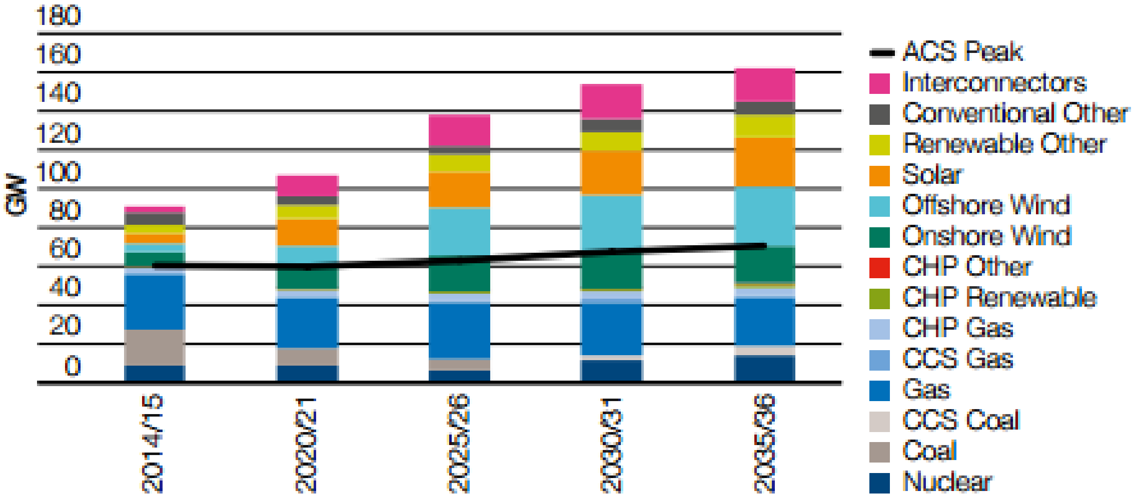
As with many other countries, the UK faces significant challenges in addressing all the elements of the ‘energy trilemma’, namely:

- Security of supply
- Affordability
- Decarbonisation

Many of the country’s older coal-fired power stations already face restrictions on their hours of operation under the EU Industrial Emissions Directive (IED). In addition, Secretary of State for Energy and Climate Change Amber Rudd has recently signalled that the Government will consult to close the UK's remaining unabated coal-fired power stations by 2025, with restrictions on their use from 2023[4]. Capacity margins in the electricity system have been falling in recent years. In its 'Winter Outlook 2015/16' report, National Grid predict a de-rated capacity of 5.1%, having procured additional contingency balancing reserve compared to 2014/15[5].

The UK has challenging EU targets for renewable deployment in 2020, by when it is required to source 15% of its energy from renewable sources. Meeting this target is likely to require upwards of 30% renewable electricity by 2020. In the longer term, EU member states have committed to a reduction of greenhouse gas emissions of 40% (compared to 1990 levels) and to source 27% of energy from renewable sources by 2030. In addition, the Committee on Climate Change has recommended for the Fifth Carbon Budget period (2028-2032) total UK emissions of 1,765MtCO2e, equivalent to a 57% reduction compared to 1990 levels. The UK Government's support mechanisms for low-carbon electricity (Contracts for Difference, Renewables Obligation and small-scale Feed in Tariffs) have incentivised strong levels of deployment of renewable electricity, particularly wind and solar. National Grid project continued strong growth in renewables over the next two decades, with solar capacity exceeding 20GW in some of their scenarios.

Figure 1: National Grid UK Capacity projections- Gone Green Scenario[6]



Wind and solar generation are both variable technologies whose output is dependent on meteorological conditions which are now more accurately forecastable. Over the coming years there will be increasing amounts of variable renewable generation. For example at the end of the second quarter of 2015 there was around 13.7GW of wind (onshore and offshore) on the UK system[7], and DECC anticipates that around 20GW will be on the system by 2020[8].

With current market models, increasing levels of renewables will pose significant challenges for the system operator in terms of balancing the system and is expected to result in:

— **Increased demand for balancing services delivered through reserve markets.** Even with improvements in analysing weather patterns, the exact level of renewable generation at a given

[4] See https://www.gov.uk/government/speeches/amber-rudds-speech-on-a-new-direction-for-uk-energy-policy

[5] National Grid, '2015/16 Winter Outlook Report', http://www2.nationalgrid.com/UK/Industry-information/Future-of-Energy/FES/Winter-Outlook/. Additional capacity procured through Supplemental Balancing Reserve (SBR) and Demand Side Balancing Reservie (DSBR). Without this additional capacity, margin would have been 1.2%.

[6] National Grid, Future Energy Scenarios 2015, file:///C:/Users/ajones4/Downloads/FESCover.pdf

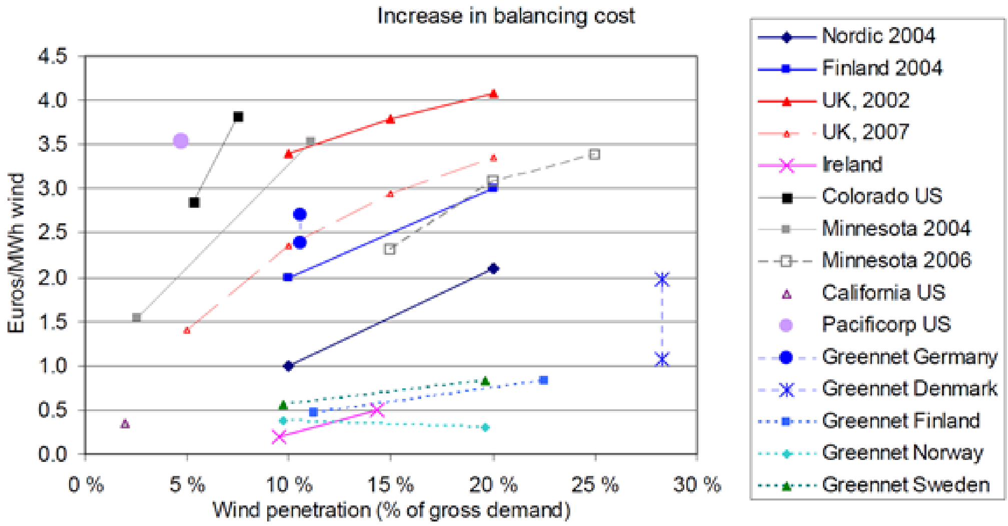
[7] For more details see https://www.gov.uk/government/statistics/energy-trends-section-6-renewables.

[8] DECC, EMR Delivery Plan, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/223655/emr_consultation_annex_e.pdf

point in time remains uncertain, making it harder for National Grid to match supply with demand on a second by second basis. Various studies have shown how balancing costs increase with greater levels of wind generation, as shown in the chart below.

— **More volatile electricity prices.** Depending on wind speed/solar irradiation at any point in time, the residual load which has to be borne by conventional generation varies, e.g. if solar irradiation is high, a cheaper plant sets the market price. As a result, wholesale prices will become more dependent on meteorological conditions.

Figure 2: Relationship between wind penetration and system balancing costs[9]



In addition, wind and solar generation is currently mostly non-dispatchable, meaning that periods of high output can coincide with periods of low electricity demand. This could lead to very low, or even negative wholesale electricity prices, i.e. generators will pay consumers (through the System Operator) to take excess electricity to avoid the costs of curtailment. Indeed, negative wholesale electricity prices have already been observed in European markets with high levels of renewables penetration. For example, Tennet reported a price of -60 Euros/MWh for 11th May 2014 in Germany, due to high levels of wind generation and low Sunday demand[10].

A significant proportion of the variable capacity that has been added in the UK in recent years has also been distributed, i.e. located at the point of demand, rather than feeding into the high-voltage transmission grid. The dominant decentralised energy technology is solar PV, which can be easily installed on the rooftops of homes and businesses. As the costs of solar PV continue to fall, to the point where it becomes economic without the financial support currently offered under the Feed in Tariffs scheme, capacity will continue to increase, making distributed generation an increasingly important part of the UK's energy mix. With increased penetration of distributed, variable energy resources, it might be more efficient in future for some system balancing to take place at a local level, with local markets for flexibility services alongside those that currently exist at a national level. At a national level, while some forms of flexibility services will decline as fossil-fired generation closes, there are expected to be increased flexibility services available from new electricity interconnectors being built or planned between the UK and continental Europe (although these may not provide some of the services required such as frequency response).

[9] Graph taken from IEA, 'Design and operation of power systems with large amounts of wind power'.

[10] Tennet, 'Market Review 2014 H1'.

3.3 Potential role of decentralised energy and storage in the future energy system

The future energy system faces the challenge of decarbonising at least cost while also ensuring that security of supply is met for an essential public service. Decentralised energy is considered to comprise a number of separate elements, namely:

— Demand – Short and long-term demand response, including energy efficiency measures.
— Generation – Normally solar panels or wind turbines installed by domestic/commercial customers.
— Energy storage – Both intra-day and inter-seasonal.

Decentralised energy is not new. The UK electricity and gas systems originated as distributed systems that were gradually combined over the last century to create integrated national networks and markets that allowed economies of scale to be achieved. Further cost reductions were realised for consumers once the industry was privatised and energy markets introduced around 25 years ago.

Demand response has traditionally been a 'last resort' requirement of the GB grid System Operator, National Grid, and its effectiveness as a routine power system resource has been limited. However, recent years have seen an increased use of demand response resources as the need for these type of resources increase. The different demand response resources are set out in the table below:

Table 1: Demand response (DSR) resources

Type of DSR	Description
Distributed generation	Generation technologies connected to the local (distribution) network that can increase or decrease output, e.g. thermal power stations or CHP plants
Industrial and Commercial back-up generation	Emergency back-up generators that can carry out DSR by increasing or decreasing output
Industrial and Commercial demand-led DSR	Industrial and commercial customers can provide DSR by reducing or shifting their demand e.g. power consumed for air conditioning
Domestic demand-led DSR	Domestic customers can provide DSR by reducing or shifting their demand e.g. postponing the charging of electric vehicles
DNO Smart Grid technologies	Energy storage and voltage control systems can be run by DNOs to manage the network and provide DSR

Demand response resources have hitherto participated in the following ancillary services and capacity markets[11]:

— **Short Term Operating Reserve (STOR):** For winter 2014/15, out of 3,444MW of STOR procured by National Grid, 237MW was classified as 'load reduction'.
— **Capacity Market:** of 49.3GW procured in the first Capacity Market auction, 8MW came from proven DSR units (small scale fossil fuel generators), 166MW came from unproven DSR units and around 4GW came from gas and diesel reciprocating engines. In the second auction over 600MW of capacity from small scale fossil fuel generators was procured.

Renewable, distributed generation – Decarbonisation incentives for renewable energy, allied with significant cost reductions have led to over 20 GW of new wind and solar generation being installed to date. Over 8 GW of solar was installed by Q3 2015, the vast majority of which is installed in homes,

[11] Source: Frontier Economics, 'Future Potential for DSR in GB'.

businesses and in projects connected to distribution networks[12]. The following charts show the installation rate and solar PV cost reduction profile in the UK over recent years.

Figure 3: Solar PV cumulative capacity in UK, 2008 to Q3 2015

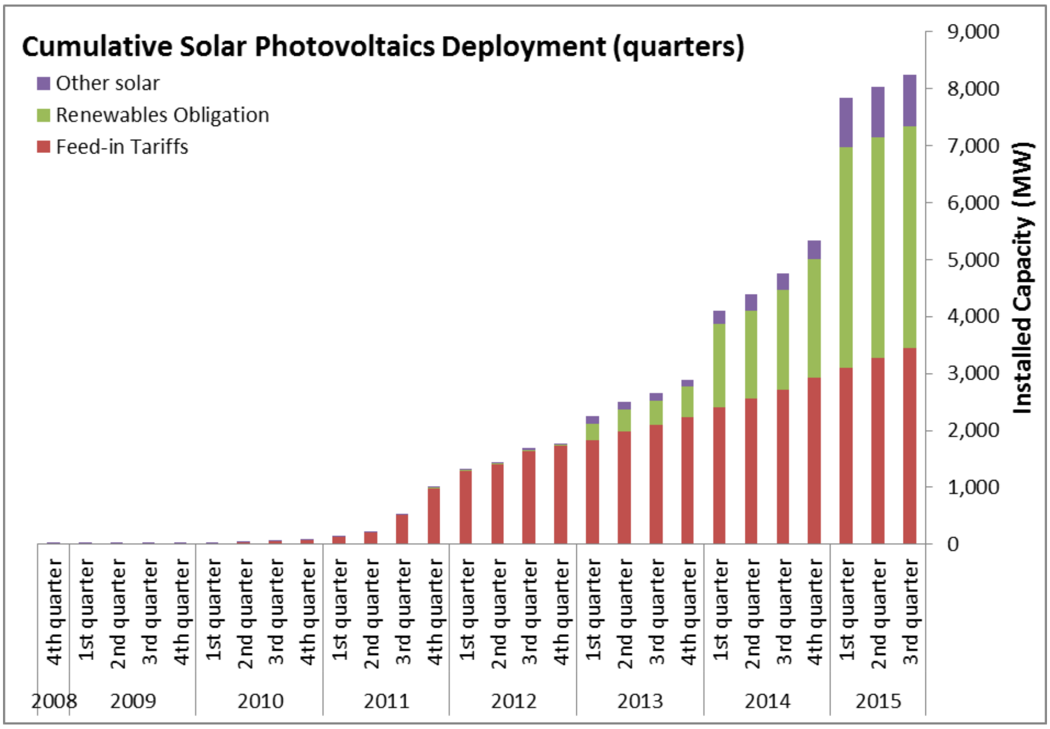
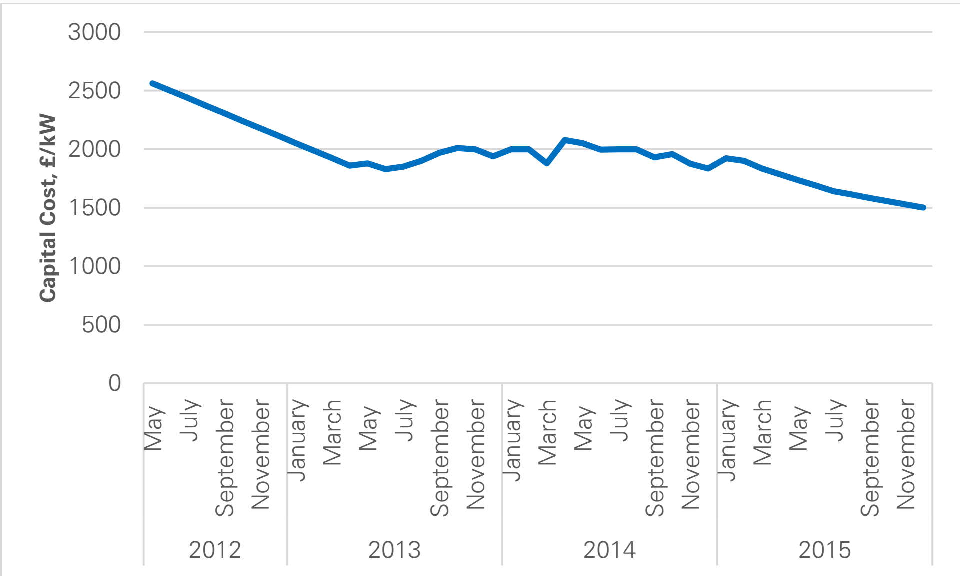


Figure 4: Cost reductions for domestic (less than 4kW) solar PV systems in the UK[13], 2012 to 2015



[12] Source: DECC, Energy Trends Section 6 (Renewables), https://www.gov.uk/government/statistics/energy-trends-section-6-renewables.

[13] May 2012 value taken from Parsons Brinckerhoff, 'Small-scale generation costs update', May 2012. Data from April 2013 to March 2015 taken from DECC, 'Solar PV Cost data' (median values used), https://www.gov.uk/government/statistics/solar-pv-

While the reduction and removal of government subsidies are expected to slow the deployment rate, cost reductions in wind and solar PV are expected to continue. Grid parity is close to being realised for solar PV[14], meaning that it will be able to compete with other generation technologies. However, similar to demand response, solar and many other variable renewable technologies face challenges in providing firm energy requirements needed by customers and energy suppliers.

Energy storage can play an important role in addressing these challenges. It offers the chance for renewable electricity to be stored at times when it is less valuable (i.e when demand is low or when renewables output is high) and used when it is more valuable (when demand is high or renewables output is low). This can be over different timescales, from intra-day (when energy is shifted from low value to high value periods within the same 24-hour period) to inter-seasonal, where energy is stored in summer when demand is lower and used in winter when demand is greater. This would have multiple benefits.

— Firstly it would maximise the value of renewable energy thus speeding up their ability to compete subsidy-free with fossil fuel generation.
— Secondly it would defer or remove some of the costs of grid reinforcement.
— Thirdly it would allow communities and households to become more self-sufficient in their use of energy, which could potentially drive greater awareness of and involvement in decarbonisation.
— At a more strategic level, increased penetration of decentralised energy generation and storage reduces the need for new centralised generation capacity to be built, as well as reducing the need to use peaking plant. DECC projections of future large-scale energy capacity suggest that around 90GW of new plant will be required between now and 2030. Decentralised generation and storage offer an alternative way of meeting peak demand, and of managing the risks around the construction of large-scale energy assets.

Indeed, the need for energy storage is expected to grow over the coming years. In their analysis for the Committee on Climate Change, NERA/Imperial College's scenarios assumed a total of 5-10GW of storage by 2030, up from 2.7GW today[15].

3.4 Potential revenues from storage

As the costs of storage fall, it can create value in a number of ways throughout the electricity system depending on the context in which it is used. In this section we describe the services storage can provide, broken down into:

— **Supply revenues:** These are services provided to final consumers of electricity which enable them to increase the value of on-site generation, manage the costs of electricity consumption, or reduce charges for access to the electricity network.
— **Ancillary services:** These are the markets run by National Grid in its role as electricity system operator to ensure that supply and demand are balanced at all times and at least cost.
— **Capacity market:** This was set up by DECC as part of Electricity Market Reform and is now administered by National Grid. The Capacity Market is an auction where units bid in to receive revenue for capacity they make available if required by National Grid. Total capacity required is set in advance by DECC. Successful bidders are paid the price per MW at which the auction

cost-data. Value for July 2015 taken from data provided by REA to KPMG for 'UK Solar beyond subsidy: the transition'. Value for December 2015 based on REA stakeholder feedback.

[14] For larger solar farms feeding their electricity back into the grid, grid parity is assessed by comparing the levelised cost of solar PV to the electricity wholesale price. For solar PV that is used to meet on-site demand, grid parity is assessed by comparing the levelised cost to a weighted average of the electricity retail price and the value of electricity not used on site and exported back to the grid.

[15] See https://d2kjx2p8nxa8ft.cloudfront.net/wp-content/uploads/2015/10/Power-sector-scenarios-for-the-fifth-carbon-budget.pdf

clears. The capacity market auction for capacity in 2019/20 concluded recently, and the provisional clearing price is £18/kW for new-build plant[16].

— **Grid services:** These are services storage could provide to network owners as an alternative to other types of investment e.g. if storage can reduce peak demand a network operator may be able to defer adding capacity to the network.

Figure 5: Revenue streams for electricity storage

Supply revenues	Balancing/ reserve revenues	Grid revenue
• Energy arbitrage • Increased on-site renewable use • Back up power • Bill management • Reduced demand-based charges (Triad)	• Reserve • Fast response • Frequency regulation • Voltage control • Capacity market	• Network upgrade deferral (transmission and distribution) • Congestion relief

These are described in more detail below.

3.5 Supply revenues

Storage can provide value to final consumers of electricity in the following ways:

— **Bill management/energy arbitrage:** If a consumer faces a variable cost of electricity (time of use tariff), as industrial and commercial currently do and as domestic consumers will start to do so from 2017, storage allows energy to be stored at times when electricity prices are low and used at peak when electricity prices are high, thereby reducing energy costs.

— **Increased on-site consumption of renewable energy generation:** For many properties with solar PV, there is a mismatch in the profile of electricity demand and solar output, with solar producing less energy at the morning and evening peaks. Electricity that is not used tends to be exported back to the distribution system, and is typically purchased by the property's electricity supplier for a price below the market price for electricity[17], reflecting the lower value of variable generation. Storage allows more energy to be used on-site, and therefore used to offset purchases of electricity at the retail price, meaning less electricity is exported at a low price.

— **Back up power:** Storage offers a means to prevent interruptions to a property's power supply, for example due to power cuts. This is likely to be particularly important for those individuals and organisations for whom the cost of an interruption in supply is high, for example data centres. It has been estimated that there may be up to 20GW of industrial and commercial back-up generation in Great Britain[18].

— **Reduced demand-based charges:** National Grid uses the Triad charging system to manage peak electricity demand. The system charges of large industrial and commercial users which are metered on a half hourly basis are determined by their 3 highest half hours or demand between

[16] https://www.emrdeliverybody.com/Capacity%20Markets%20Document%20Library/2015%20T-4%20Capacity%20Market%20Provisional%20Results.pdf

[17] If the property has a FITs contract, the price received for exported electricity (the export tariff) is 4.85p/kWh

[18] Source: Frontier Economics: Future Potential for DSR in GB'

November and February. Storage can be used to reduce the metered demand of such customers at peak, and is therefore a means of ensuring lower triad charges.

3.6 Balancing/reserve revenues

National Grid, in its role as System Operator, administers markets for a number of ancillary services designed to ensure that electricity supply and demand are balanced in real time. As outlined above, the costs of balancing supply and demand are likely to increase over the years to come due to the increased penetration of variable renewables such as solar PV and wind.

National Grid runs various ancillary services markets to meet the different energy requirements it has in balancing the system. Different storage technologies will be best suited to play into particular markets. Some of the ancillary services National Grid procures are described in the table below, showing which storage technologies would be able to participate in these markets:

Table 2: Selected National Grid ancillary services[19]

Market	Description	Technical requirements	Indicative suitable storage technologies[20]
Fast Reserve	Rapid and reliable delivery of active power through increased output from generation, or reduction in consumption. Used to control frequency changes that could result from sudden changes in generation or demand. Can be firm service, or optional service.	Active power delivery must start within 2 minutes of the despatch instruction at a delivery rate in excess of 25MW/minute, and the reserve energy should be sustainable for a minimum of 15 minutes. Must be able to deliver minimum of 50MW.	Pumped hydro Battery storage
STOR	Used for periods where actual demand is greater than forecast demand, or plant is unavailable, between 4 hours ahead of real time and real time.	Minimum of 3MW generation or steady demand reduction Deliver full MW within 240 minutes of receiving instructions from NG, although majority of units must do so within 20 minutes. Provide full MW for at least 2 hours when instructed.	Pumped hydro Demand Side Response Battery storage
Firm Frequency Response	Provision of dynamic or non-dynamic response to changes in frequency. Tenders can be for low-frequency events or high frequency events.	Have suitable operational metering. Deliver minimum 10MW response energy. Be able to operate in frequency sensitive mode (dynamic response) or change MW relay via automatic relay.	Pumped hydro Battery storage
Enhanced Frequency Response	New service which National Grid is currently procuring through a tendering exercise. Aim is to use the service to maintain system frequency closer to 50Hz during normal operation.	Achieve 100% of full output within 1 second of registering a frequency deviation.	Anticipated to be primarily of interest to battery storage.

[19] For more information see http://www2.nationalgrid.com/uk/services/balancing-services/

[20] This is not intended to be an exhaustive list of technologies that could potentially participate in these markets.

3.7 Grid congestion and investment deferral revenue

Faced with growing peak demand as populations and economic activity increase, transmission and distribution networks are required to upgrade their network in order to ensure it has sufficient capacity to maintain an acceptable level of security of supply. Energy storage can create value for electricity networks by allowing networks to defer (or avoid entirely) the need to invest to upgrade transmission or distribution equipment, and consequently to extend the life of existing kit.

Storage can also provide a means of relieving congestion on transmission networks, especially in areas with high levels of renewable generation.

4. Decentralised Energy and Energy Storage

4.1 What is energy storage?

In essence, energy storage uses devices or materials to store energy until a point in time where it can more usefully be used. It has been used by mankind for centuries, for example in the stockpiling of reserves of wood and coal to burn for heat. Indeed, the Sun 'stores' energy generated at the inception of the universe which is only now being used by humans for heat and electricity.

Unlike other natural energy storage systems and materials such as wood and coal, electricity must be used as soon as it is created, or converted into another form of energy such as kinetic or potential. The principal technology for storing electricity has traditionally been pumped hydro storage, which began to be used widely in the 1930's with the advent of reversible hydroelectric turbines which could operate as both turbine generators and in reverse as electric driven motor pumps.

Electricity storage has been available at small scale in consumer electronics markets since the early 1990's, in the form of rechargeable batteries. More recently, their use has spread to the transport sector in batteries for electric vehicles. Now, falling costs and innovation mean electricity storage technologies are starting to emerge at larger scales, which can be used over a much wider range of applications and locations than pumped hydro storage.

There are a range of storage technologies which are either already deployed or currently under development. These include (among others) various types of batteries, pumped hydro storage, flywheels and compressed air storage. These provide storage solutions at all scales, from domestic systems through to grid-size solutions. The key characteristics and uses of a selection of these technologies (both commercially deployable and under development) are set out below.

4.2 An overview of different storage technologies

4.2.1 Pumped hydroelectric storage

This is the oldest technology for the storage of electricity, having been first deployed in the 1880's in Austria, Switzerland and Italy. It works by storing energy in the form of water in the higher of two reservoirs, to where it is pumped from the lower reservoir during periods when the plant is not in use. When electricity demand is high, power is generated by releasing the water through turbines. When demand and electricity prices are low the upper reservoir is replenished by using electricity to pump water back to the higher reservoir. Its fast response means that it is very useful for responding to system frequency deviations, while in the context of smart grids it can also time-shift large amounts of output from solar and wind farms for hours (or even days) as required by using this energy to pump water back up to store in the higher reservoir.

Pumped hydro storage has typical efficiencies ranging from around 70 to in exccess of 80% for state of the art turbines[21]. The technology is fully-proven, and the resource through which energy is stored (water) is highly abundant. However there is a limited number of suitable sites for large pumped hydro projects in the UK, since the need for an altitude differential between the two lakes limits it to mountainous locations such as the Scottish Highlands or Snowdonia. Such suitable sites for large projects are far from UK centres of energy demand, meaning that there are likely to be significant costs involved in connecting projects to the grid. However, a UK pumped storage developer (QBC) has

[21] AEA Technology plc, Energy Storage and Management Study, 2010, quotes a range of 70-80% for pumped hydro projects.

recently conducted a survey and found 15GW of potential sites for pumped hydro storage, using a variety of locations including brownfield land, coastal features and drinking water reservoirs[22]

An innovation that may widen the number of sites where pumped hydro storage can be deployed is seawater pumped storage, where the sea acts as the lower 'lake' from which water is pumped up from and released into. There is currently one seawater pumped hydro project that is operational, in Okinawa Island, Japan.

Pumped hydro storage has the highest capacity of known and tested storage technologies. The four existing projects in the UK range in size from 300MW to 1,700MW, as set out in the table below:

Table 3: UK pumped hydro storage projects

Project	Year of Commissioning	Capacity (MW)
Dinorwig	1984	1,728
Foyers	1975	305
Cruachan	1965	440
Ffestiniog	1963	360

4.2.2 Compressed air energy storage (CAES)

In a CAES plant, air is stored under pressure during periods of low demand/electricity prices. The storage unit is typically an underground cavern, although ground-level storage can also be used. When there is high demand for electricity, the compressed air is released, and decompresses in a turbine driving a power generator. Underground storage systems can store greater amounts of energy (up to 10MGWh). There are currently two operational CAES systems worldwide, one in the USA and the other in Germany.

Due to the low storage density of air, storage facilities need to be very large. Salt caverns are ideal for this purpose, as they are flexible, with no risk of loss of pressure in the storage, or of any reaction with the oxygen in the air or in the host rock. In CAES systems, the compression of air results in very high temperatures, which have to be extracted during the compression process using coolers.

4.2.3 Lithium-based batteries

Lithium-ion batteries first came on the market in the early 1990's, when they were used predominantly in consumer applications. Since then they have been developed for use in a wide range of storage applications, ranging from batteries to store energy from household solar installations to larger batteries capable of providing grid ancillary services, as well as electric vehicles.

Lithium-based batteries encompass a wide range of sub-chemistries, each with specific operational and performance characteristics. Lithium-ion cells are built into multi-cell modules, which are then connected to form a battery string at the required voltage. This makes them scalable and can therefore be used in very small systems such as car and household applications right up to grid scale (MW) applications.

4.2.4 Flow-type batteries

Flow-type batteries accumulate and deliver energy via reversible electrolyte reactions, which are stored in separate tanks. In flow-type batteries, power is determined by the number of cells and their size, while capacity depends on the volume and concentration of the electrolyte. Various electrolyte 'couples' are possible, although currently only Zinc/Bromine and all-vanadium batteries have reached

[22] See http://www.theengineer.co.uk/issues/march-2015-digi-issue/pumped-storage-a-new-project-for-wales/

commercialisation. Zinc bromine batteries can be combined into large modules capable of storing up to 500kWh, while all-vanadium batteries can be upscaled into modules than can store up to 400kWh.

The 'decoupling' of power and capacity means flow type batteries are extremely flexible and can be tailored to complement the characteristics of a particular generating asset. They are suitable for use at a wide variety of scales, from storage requirements of around 500kWh up to hundreds of MWh.

4.2.5 Aqueous, sealed batteries

This type of battery offers high energy outputs compared to other battery technologies, potentially making it more suitable for energy arbitrage applications than ancillary services. It can help shift load from peaks to troughs through wholesale markets as renewable electricity generation increases as a percentage of the generation mix.

These are designed to deliver power in typically 4-6 hours, so a 10MW battery would have a 40-60MWh energy storage capacity. For this type of high energy storage, Levelised Cost of Energy (LCOE) and £/kWh capital cost metrics can be used for comparison with other technologies.

4.2.6 Cryogenic energy storage (CES)

Cryogenic energy storage (CES) stores liquefied air or liquid nitrogen at atmospheric pressure. CES has three core processes. Firstly, charging takes place when demand/prices are low, as electricity is used to drive an air liquefier. The gas is then cleaned, compressed and cooled until it is converted to liquid. It is then stored in an insulated tank at low pressure. When demand/prices are high, the liquid is pumped to high pressure, and then heat is applied, transforming the liquid to a high-pressure gas used to drive a turbine generator.

Although the overall CES system is novel, the individual technologies that comprise it are already used extensively in other sectors, particularly the air separation industry that uses identical equipment. The liquid storage units required are already used for bulk LNG, oxygen and nitrogen storage, and at large scale (a 200,000t tank would be capable of storing 10GWh of electricity). This makes it a technology that could provide grid-scale solutions.

4.2.7 Hydrogen energy storage (HES)

Hydrogen is produced in large quantities (around 55 million tonnes per year worldwide). Some of this is so-called 'brown' hydrogen (derived from hydrocarbons) although an increasing amount of 'green' hydrogen is being produced through water electrolysis.

HES works by using electrolysis to convert electricity at times of low prices/demand into hydrogen. The hydrogen can then be re-electrified using fuel cells, or burned in CCGT power stations. Although efficiencies for this process are currently low at around 30-40%, hydrogen offers much higher storage potential than other technologies. For example, a storage facility of 500,000 metres cubed could store up to 167GWh of hydrogen, equivalent to 100GWh of electricity.

4.2.8 Pumped heat electrical energy storage (PHEES)

Pumped heat electrical energy storage (PHEES) works by using electricity to power a storage engine connected to two thermal stores containing a substance such as gravel. When prices/demand are low, electricity is used to drive a heat pump which heats one thermal store while cooling the other. To release the energy, the heat pump is reversed to become a heat engine, taking heat from the hot thermal store and delivering it to the cold store, and thereby producing mechanical work. The heat engine drives a generator which produces electricity.

Gravel provides a low-cost, abundant means of storing heat. Plant sizes are expected to be in the range of 2-5MW.

4.2.9 **Flywheels**

Flywheels use electricity generated when prices/demand are low to accelerate the flywheel to a high speed, ie energy is stored in mechanical form. Stored energy is then converted by slowing the flywheel down by generating power through a generator. Single flywheel units can typically deliver 100kW of power and store 25kWh, but individual units can be aggregated into a much larger system.

Flywheels offer rapid response, and are low maintenance across a long operational life (20 years). However they must be housed in robust containers, and the use of precision engineering equipment means they are high cost. In addition, developers may choose to house the flywheels underground so as to reduce noise and visual impact (this solution has been adopted on the County Offaly flywheel project in Ireland).

5. Storage Technology Costs

As outlined above, there are many storage technologies that could deploy in UK energy markets. There is a high degree of uncertainty around the current and future costs of many of these technologies due to a number of factors, such as:

— **Unproven nature of technologies:** many of the technologies above remain commercially unproven, with further research required to arrive at a design that can be deployed safely at an acceptable cost. Further development of such technologies will be to a degree dependent on securing funding for further R&D and demonstration projects. If such financing is not secured, costs will not fall as quickly as expected.

— **Site-specific technology costs:** several technologies described above require certain geographical characteristics e.g. mountains, underground caverns. The particular characteristics of a site mean that a bespoke solution is required, meaning that there is a high degree of variance in cost between different sites.

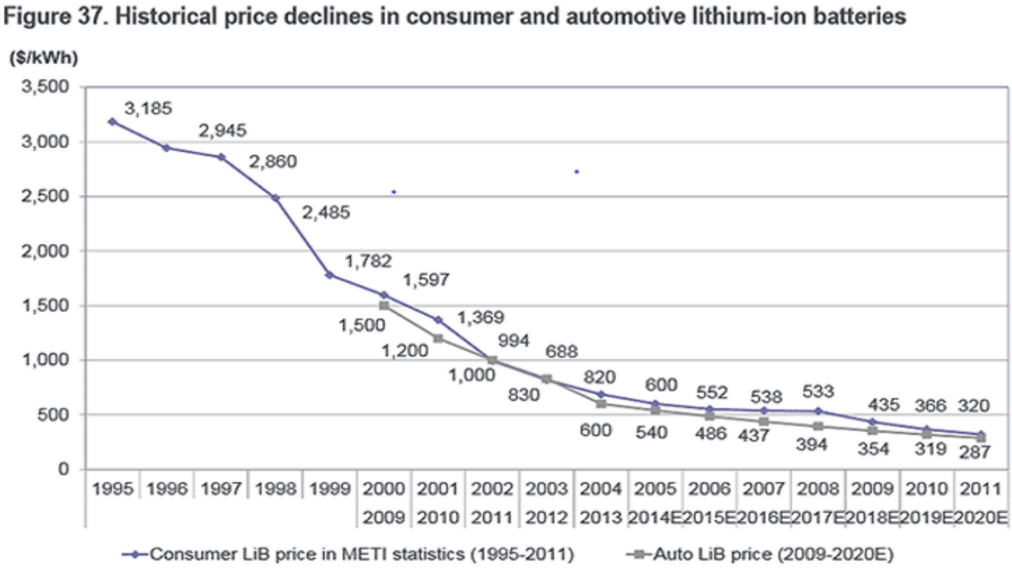
— **Differences in storage services provided:** some storage technologies are applicable across a wide range of applications and markets. For example, many battery technologies could potentially offer storage services at scale (for example to improve the performance of the transmission grid, or to improve the integration of large-scale renewable energy projects with the transmission grid) while also being suitable to provide 'behind the meter' services at a much smaller scale (e.g. batteries for homes to store excess energy from solar PV panels). Besides differences in unit cost stemming from scale economies, a technology used at smaller scale could have different frequency of use/lifetime than when used at larger scale.

For the analysis in this report, we have sought to use published sources of cost data, supported by input from stakeholders in the storage sector. We have focused the analysis on a single technology (lithium ion batteries) as this can be used in applications at all scales, and is expected to see further significant cost reductions in years to come.

5.1 Historical cost reductions

Lithium ion batteries have already experienced steep reductions in cost in recent years. The chart below shows a cost reduction curve for Lithium Ion batteries between 1995 and 2011 in the consumer and automotive sectors:

Figure 6: Prices of lithium ion batteries[23]



More recently, battery technologies with applications in the energy sector have shown steep reductions in cost. For example, Deutsche Bank reported that Lithium-Ion batteries in commercial and utility markets achieved cost reductions of 50% in 2014[24].

5.2 Current and future technology costs

Even for a relatively well-established technology like lithium ion batteries, there remain very large ranges around costs in published sources.

With projections of future cost, there are similar uncertainties around how these will evolve. However, there is a considerable degree of consensus around the scope for further significant cost reductions in a wide range of battery technologies, with many forecasts predicting annual cost reduction of upwards of 10% per year over the coming years[25].

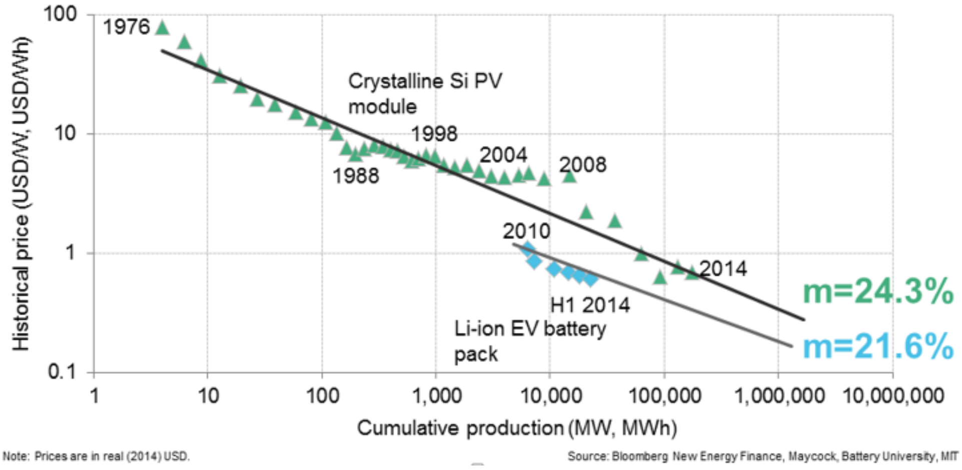
Indeed, feedback received from industry stakeholders indicates that the cost reduction profile for batteries is likely to resemble that of solar PV modules, with costs falling rapidly as increasing global demand allows manufacturers to cover the high fixed costs of establishing a manufacturing facility over a greater number of units sold.

[23] Source: Citi Global Perspectives and Solutions, 'Battery Storage Market set to reach 240GW by 2030'

[24] Conclusions from Deutsche Bank report quoted at http://cleantechnica.com/2015/03/04/energy-storage-could-reach-cost-holy-grail-within-5-years/

[25] Deutsche Bank quoted as predicting cost reductions of 20-30% per year at http://cleantechnica.com/2015/03/04/energy-storage-could-reach-cost-holy-grail-within-5-years/

Figure 7: Solar PV and Lithium Ion experience curve comparison[26]



Balance of system (BoS) costs comprise the other major element of overall system cost[27]. There is considerable uncertainty around the extent to which balance of system costs will fall in the coming years. While inverters are a mature technology, storage inverters are currently significantly more expensive than solar PV inverters, and over the coming years the price gap between them could shrink[28].

For control systems that regulate the storage and discharge of electricity in and from the battery, solutions for smaller-scale systems are likely to be fairly standardised, meaning there is scope for economies of scale during production. However, as systems grow larger, and are required to regulate the operation of the battery in an increasingly sophisticated way solutions are likely to be more bespoke, meaning it is harder to apply learning from one project to another. Development and exploitation of this area is a focus for the Information Technology and Telecommunications industries and the UK has an opportunity to take a leadership role in this sector.

5.3 Cost reduction profiles

Based on published analysis and feedback from industry stakeholders, we estimate the following cost reduction profiles for lithium ion batteries (capex only[29]) at different scales which we use in our analysis. As outlined above, there is considerable variation in estimates of the current cost of storage, therefore the chart also shows indicative ‘high’ and ‘low’ values around the central assumption used in the analysis[30]. We expect there to be rapid cost reductions over the course of the next five years, in line with published estimates, but for these to get slower in the 2020’s as further sources of increased efficiency in manufacturing processes become harder to identify.. These profiles are used in our analysis below. More details on the assumptions behind these profiles are set out below in Appendix 1. As previously indicated, there remains a good deal of uncertainty around the capital costs of batteries due to the nascent nature of the technologies- the estimates presented here are our ‘best estimates’, but there is likely to be considerable variability in cost across different manufacturers and system specifications:

[26] Bloomberg New Energy Finance Summit, April 2014.

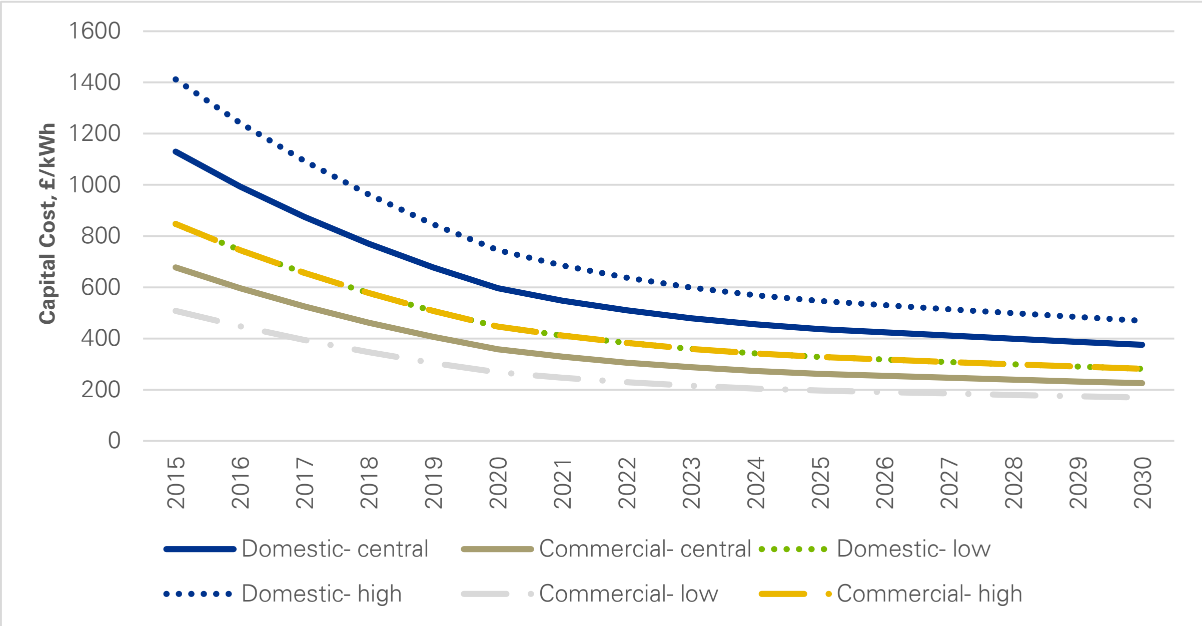
[27] A recent Greentech Media report estimated that Balance of System costs for large scale battery systems are currently around $670/kW, which at current exchange rates is around £460/kW. Compared to our lower end estimate of total installed cost for large-scale battery systems of £1,000kW, this would imply that balance of storage costs are around 50% of total system cost.

[28] Source: https://www.greentechmedia.com/research/report/grid-scale-energy-storage-balance-of-systems-2015-2020

[29] Capex in this report is used to refer to total cost of installation, ie equipment such as modules, batteries and inverters plus balance of system costs.

[30] Low and high values are set 25% either side of the central value.

Figure 8: Lithium Ion battery capex reduction profile:



The figure shows a steady cost decline of 12% per annum through to 2020, followed by slower reductions through the 2020's.

6. Decentralised Energy Market Models

6.1 Case studies

In this section we look at the ways in which decentralised energy deployed in tandem with storage could tap into the sources of value outlined above in a variety of contexts, and assess when these revenue streams will make the deployment of decentralised energy with storage economic.

We have adopted a case study approach, using examples at small-scale (domestic and commercial investors who deploy storage in tandem with rooftop solar PV) and large-scale (batteries used to participate in the ancillary services markets run by National Grid, and community energy solutions).

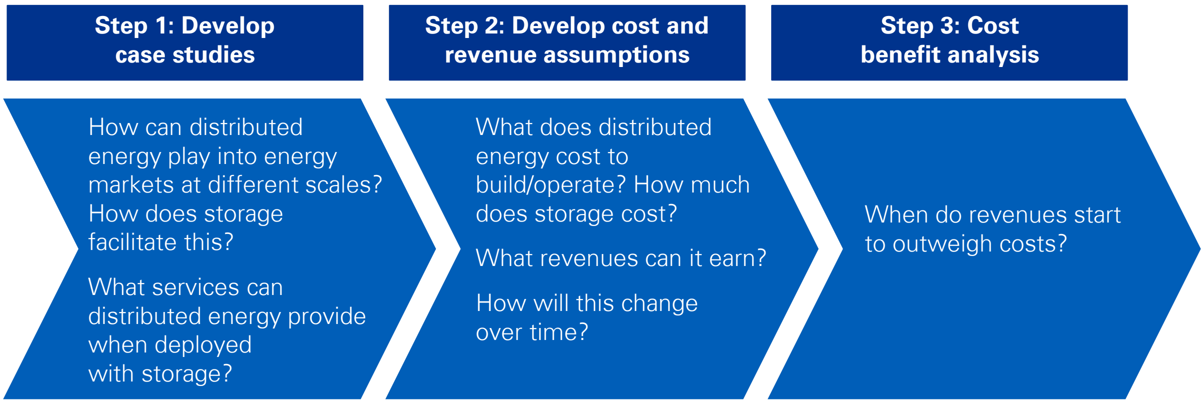
We have analysed the following alternative business models for deployment of decentralised energy and storage:

— **Small scale** – Where domestic or business prosumers develop their own decentralised energy and storage systems.

— **Large scale** – Where decentralised energy and storage resources participate in national energy markets, either directly or as city scale energy schemes.

To analyse this we have adopted an approach consisting of threee principal phases outlined below:

Figure 9: Analytical approach outline



6.2 Small scale decentralised energy – 'Prosumers'

6.2.1 What are 'Prosumers'?

Prosumers are defined as end energy consumers who install decentralised energy and storage on site, ie at the point of final demand. Prosumers can be 'domestic' ie householders installing decentralised energy and storage on their property, or 'commercial' ie businesses doing so on commercial premises. The most commonly used decentralised energy technology in these contexts is solar PV, while batteries are the only feasible storage technology for deployment by prosumers due to their compact size and relative ease of installation.

In the UK, deployment of solar PV has been widespread due to the financial incentives on offer under Feed in Tariffs (FITs), while batteries remain a nascent technology in terms of installation numbers. Going forward, there are two main circumstances in which decentralised energy and storage could be deployed together. Firstly, decentralised energy and storage can be installed at the same time.

Secondly, storage can be 'retrofitted' to a home or business that has already installed decentralised energy[31]:

Decentralised energy has significant benefits for householders and businesses. It offers the opportunity to generate zero carbon energy in place of electricity from the grid which is still generated predominantly from fossil fuels. In addition, it offers homes and businesses a hedge against rising energy prices and increases certainty over energy costs, by reducing the amount of electricity which has to be purchased from electricity suppliers, the price of which is liable to change over time.

Storage enhances the value householders and businesses can extract from their investment in decentralised energy. Firstly, it allows increased on-site consumption of the energy produced by the decentralised energy resource, since energy generated when the demand of the household/business is low can be stored and used when demand is higher. In addition, storage offers the potential for enhanced energy security, as energy can be stored and used as back up power in the event of an interruption to the supply of electricity from the grid. Furthermore, by reducing peak demand for grid electricity, it can lead to reduced demand-based network charges (for industrial and commercial users).

In order to assess when decentralised energy combined with storage is likely to become economic, we have developed two sub-cases as follows:

— Household/business installs solar PV and a battery unit simultaneously;
— Household/business 'retrofits' a battery unit at a property which already has solar PV.

The costs and benefits of each sub-case are considered in more detail below for both domestic and commercial prosumers.

6.2.1.1 **Sub-case A (Solar + Storage)**

Installing storage alongside solar PV will allow the household or business to store and use more of the energy produced than would be the case with solar PV alone. The most value will come for those households and businesses whose demand profile, when combined with storage, ensures that they are able to consume all of the energy produced by the solar PV system (net of energy lost during storage process). This will allow them to reduce their consumption of grid electricity to the maximum extent possible. A prosumer using storage to allow for 100% of the energy produced by the solar PV system is used as a 'best case' scenario in our analysis below.

If the household/business is unable to consume some of the electricity produced by the solar PV system, this electricity must be exported back to the grid or spilled. The Feed in Tariff in the UK currently offers a 'route to market' for exported small-scale electricity via the export tariff, which offers investors a payment of 4.85p/kWh for electricity exported back to the grid. However, recent policy announcements for an overall cap on FITs expenditure out to March 2019 imply that the scheme will not remain open indefinitely to new investors[32]. We therefore consider a 'worst case' scenario in our analysis, where post-FITs there is no route to market for excess electricity produced, meaning any electricity not used on site must be spilled (and is therefore worthless).

In these scenarios, we assess the costs of both the solar and storage units against estimated benefits.

[31] In future, the introduction of time of use tariffs may give consumers who choose not to invest in decentralised energy the incentive to buy a storage system by offering the opportunity to use energy stored when electricity prices are lower at times of peak prices.

[32] Existing investors will continue to receive generation tariff and export tariffs even if the scheme is shut to new investors, for the 20 year duration of their Feed in Tariff.

6.2.1.2 **Sub-case B (storage retrofit)**

For a domestic prosumer with an existing solar PV installation, it is almost certain that this will have been installed under the Feed in Tariff with deemed exports. Retrofitting storage allows additional consumption of the energy produced by the solar PV unit and hence reduced purchases of grid electricity. Deemed exports mean that there is no trade off from increased on site consumption in the form of reduced export revenues, since the export tariff will continue to be paid on 50% of the electricity produced. For domestic prosumers who retrofit storage, we consider only the case where the householder has a Feed in Tariff for the electricity their solar PV unit produces.

Where exports are metered, as is the case for solar PV installations of greater than 30kW capacity, there will be a trade off, since more electricity consumed on site implies less revenue from electricity exports. For commercial prosumers retrofitting storage, we therefore consider only the case of an organisation whose exports are metered.

In these scenarios, we assess the costs of the storage unit alone against benefits, ie the costs of the solar unit are assumed to be 'sunk'.

6.3 Prosumer cost and benefit/revenue assumptions

6.3.1 Domestic prosumers

6.3.1.1 **Solar and storage cost and performance assumptions**

We have assumed that domestic prosumers would install/own a solar PV system of less than 4kW capacity, plus a storage unit of 2kWh capacity. The capital costs of the solar PV system (used in Solar plus Storage scenarios only) are derived from KPMG's 2015 report for the REA on the economics of solar PV in the UK[33]. The cost assumptions for the storage unit on Sonnenbatterie's price for its sonnenCommunity system[34]. Assumptions around opex, lifetime and storage round trip efficiency are based on feedback from stakeholders interviewed for this report and published sources. These assumptions are set out in Appendix 1.

These cost and performance assumptions are then combined with 'hurdle rates' for domestic prosumers in order to calculate a 'levelised cost of storage' (LCoS) (for scenarios where storage is retrofitted to a household with existing solar PV) and a 'levelised cost of solar plus storage'[35]. As a lower end assumption, we have assumed that domestic prosumers would have a hurdle rate of 0%. This is a proxy for the preferences of 'early adopters' who seek to be among the first owners of a new technology, or for those who place great value on the less tangible perceived benefits of storage, such as increased energy security/independence or environmental benefits. Levelised costs calculated with a 0% discount rate constitute a lower bound. As an upper end, we have assumed a hurdle rate of 4.2%, consistent with DECC's assumed hurdle rates for solar PV in its FITs analysis[36], to capture 'conventional' household investors looking for a financial return on their investment.

6.3.1.2 **Benefits/revenue assumptions**

Once levelised costs have been calculated, they are compared to the revenue/benefits a prosumer receives from having distributed generation and storage. Once the revenue/benefits from storing and using a unit of distributed electricity and greater than the costs of producing that unit of electricity,

[33] KPMG, 'UK Solar beyond subsidy: the transition'

[34] This retails at 3,050 Euros before VAT.

[35] The levelised cost of solar plus storage takes account of the energy losses during the storage process in the levelised cost. The levelised cost of storage does not take account of losses during the storage process. These are accounted for instead through the benefits comparator.

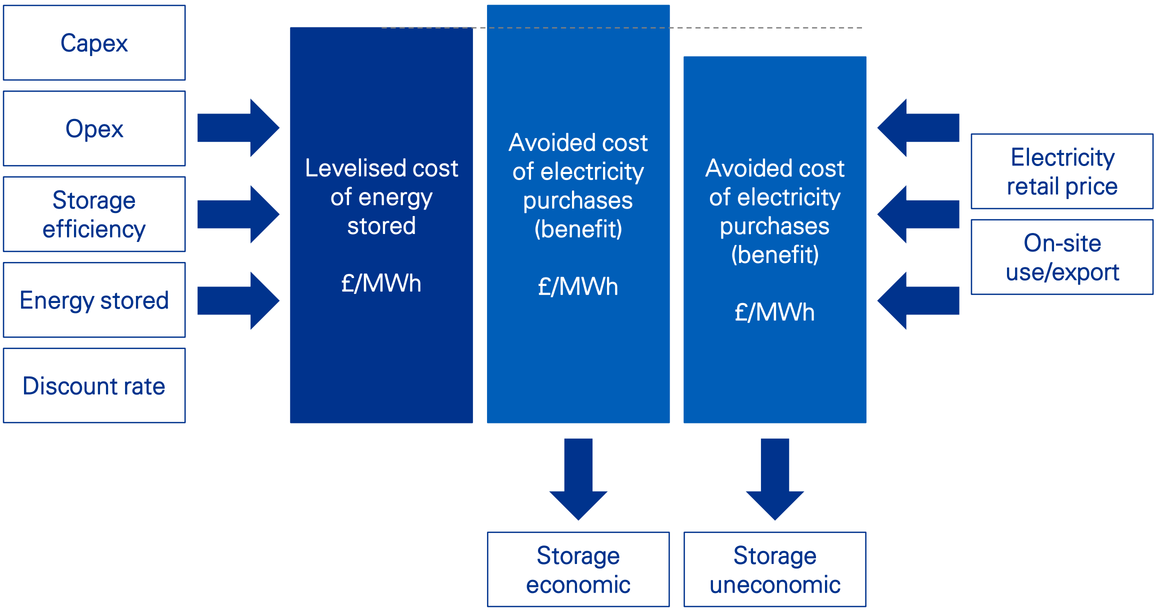
[36] Parsons Brinckerhoff, Small-scale Generation Costs Update, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/456187/DECC_Small-Scale_Generation_Costs_Update_FINAL.PDF

investing in distributed electricity and storage becomes attractive The main benefit/revenue of distributed generation and storage is to reduce a prosumer's demand for grid electricity.

Given this, the starting point for estimating benefits is therefore the electricity retail price. The electricity price series is taken from DECC's Updated Energy Projections (UEP)[37]. If a prosumer is able to use storage to allow the onsite consumption of all decentralised energy produced, the benefit is greatest, as every unit of decentralised energy produced is used to offset electricity purchases at the retail price. If the prosumer cannot store and use all the distributed electricity produced, the benefit of having decentralised energy and storage is less, since the excess power must be exported back to the grid at less than the retail price, or simply spilled (in which case it has no value). In scenarios where some electricity is exported, the estimate of benefits is based on a weighted average of the retail price and the value of exported electricity[38].

This approach is summarised in the chart below:

Figure 10: Approach to assessing economics of decentralised energy plus storage for prosumers



For solar plus storage examples, estimates of the benefits are assessed as follows for the 'best case' and 'worst case' scenarios. These form the basis for comparison with the levelised costs of solar

— **100% of energy generated used onsite ('best case'):** In this case the levelised cost of solar plus storage is compared to the full value of the retail price of electricity.
— **75% of energy used on site, 25% spilled ('worst case'):** Here costs are compared to 75% of the retail price.

£/MWh benefits under these scenarios are set out below. These are used to assess the economics of decentralised energy and storage:

[37] DECC, Updated energy and emissions projections 2015, https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2015

[38] This is assumed to equal 4.85p/kWh, the current value of the FITs export tariff

Table 4: Estimate of benefit (unadjusted and adjusted retail price) for solar plus storage (domestic)

Benefit (£/MWh)	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
100% onsite use	145	150	160	167	172	176	177	181	180	184	193	193	197	194	191	192
75% onsite use, 25% spilled	109	112	120	125	129	132	133	136	135	138	144	144	148	146	144	144

In sub-case B, exports of electricity are assumed to be deemed, since it is likely that the solar PV unit would have been installed under the FITs scheme. Where exports are deemed, there is no trade-off between higher on-site consumption and lower export revenue, since export tariffs are made on fixed proportion of total output. The basis for estimating the benefits from a storage retrofit is therefore the retail price of electricity[39].

Table 5: Estimate of benefit (adjusted for losses during storage process), storage retrofit (domestic)

Benefit (£/MWh)	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Retail price (net storage losses)	138	142	152	159	163	167	168	172	171	175	183	183	187	185	182	182

6.3.2 Commercial prosumers

6.3.2.1 Solar plus storage cost and performance assumptions

We have assumed that commercial prosumers would install/own a solar PV system of approximately 100kW capacity, plus a storage unit of 4MWh capacity. The capital costs of the solar system are derived from KPMG's 2015 report for the REA on the economics of solar PV in the UK[40]. The cost assumptions for the storage unit are based on the unit costs for Sonnenbatterie's sonnenCommunity battery, with an additional reduction of 40% to account for economies of scale. Assumptions around opex, lifetime and storage round trip efficiency are based on feedback from stakeholders interviewed for this report and published sources. These assumptions are summarised in Appendix 1. Capex reduction profiles are set out in Figure 8 above.

As in the domestic prosumer case studies, cost and performance assumptions are combined with hurdle rates to calculate levelised costs. As with the domestic prosumer case, we assume a lower bound hurdle rate of 0%, to account for firms who invest in solar and storage for non-financial reasons, for example to signal their environmental responsibility or to enhance their corporate image. These give a lower bound on costs. As an upper end, we have assumed a rate of 6.2%, consistent with DECC's assumed hurdle rates for solar PV in their FITs analysis[41]. This captures firms seeking to make a positive financial return from their investment in storage.

[39] In retrofit examples, the energy losses through the storage process are captured through the benefits comparator, rather than through the levelised cost of storage (or solar plus storage). This means that the benefits comparator is lower than the equivalent in solar plus storage examples:

[40] KPMG, UK Solar beyond subsidy- the transition

[41] Parsons Brinckerhoff, Small Scale Generation Costs Update

6.3.2.2 Benefits/revenue assumptions

As with domestic prosumers, the electricity retail price series used to monetise the benefit of increased on-site consumption of decentralised energy is taken from DECC's Updated Energy and Emissions Projections (UEP)[42]. The services sector price series has been used here.

For solar plus storage scenarios, we assume that the combination of solar and storage allows companies to use 100% of the electricity used on site. As in the domestic prosumer case where 100% of decentralised energy produced is used on site, the relevant comparator here is the full value of the retail electricity price. This series is set out in the table below:

Table 6: Electricity retail price comparator (services sector), solar plus storage scenarios (commercial)

£/MWh	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Electricity price, Services sector	99	108	113	113	120	125	131	133	136	144	150	151	152	147	146	148

In retrofit scenarios with metered exports, there is a trade-off between reduced demand for grid electricity (as more electricity produced on site can be consumed) and reduced exports (as electricity that would have been exported is instead used on site). For firms retrofitting storage in this way, the benefit of storage is therefore the retail electricity price net of the value of exported electricity.

Non-domestic customers will tend to have time of use electricity tariffs with variable prices for peak and off-peak periods. If a commercial prosumer is able to use storage to consume more electricity at times of peak prices, the benefit will be the difference between peak electricity prices and the value of exported electricity. It is uncertain how variable peak and off-peak prices under time of use tariffs will be in future. We have therefore developed two scenarios for what peak prices will be in the future:

- **Worst case/no time of use tariff:** peak price is the same as the average retail price as estimated in the DECC series;
- **DECC price plus 10p/kWh:** this assumes peak prices are 10p/kWh higher than the average price in the DECC projections.

The assumed value of exported electricity is the Feed in Tariffs export tariff (currently 4.85p/kWh). The benefit of storage retrofit is set out below for each of the above scenarios:

Table 7: Storage retrofit net benefit scenarios (commercial)

£/MWh	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Average electricity price – Export Tariff	46	53	58	58	64	69	74	76	79	86	91	92	93	89	88	89
Average price + 10p/kWh – Export tariff	136	143	148	148	154	159	164	166	169	176	181	182	183	179	178	179

[42] https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2015

6.4 Cost benefit analysis – Prosumers

6.4.1 Domestic prosumers

6.4.1.1 Solar plus storage

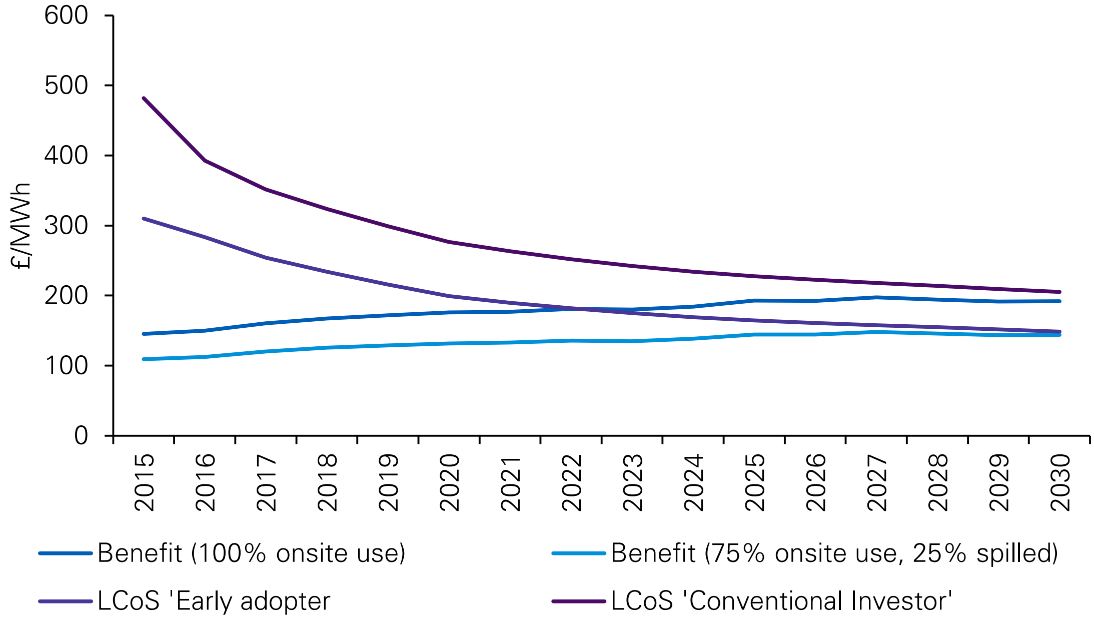
Figure 11 below sets out the results of the comparison of the costs of installing and running solar PV and storage units versus the benefits from storing and using the energy the solar PV unit produces rather than buying electricity from the grid.

The LCoS ('levelised cost of storage') lines represent the projected costs of installing and running solar plus storage each year out to 2030. These are downward sloping due to expected falls in the costs of both solar PV and batteries. The lower, 'early adopter' LCoS shows costs per unit of electricity stored and used for a household with a 0% discount rate who can be characterised as buying storage for non-financial reasons. The higher, 'conventional investor' LCoS shows costs per unit of electricity stored and used for a household looking to make a financial return from its investment in solar PV and storage.

On the chart these estimates of LCoS are compared against the benefits of owning and using solar PV and storage. The higher, '100% onsite use' line estimates these benefits for a household that is able to consumer all the electricity produced and stored by the solar PV unit on site. The lower, '75% onsite use, 25% spilled' line estimates benefits for a household that is only able to consume 75% of the solar PV unit's energy on site, spilling the rest in the absence of a route to market for its exported electricity. These lines are upward sloping, reflecting expected increases in the price of electricity in real terms over the coming years.

The points at which the LCoS and benefits lines meet gives an indication of where solar PV plus storage starts to become an attractive investment for households with particular usage patterns and investment preferences. For example, an 'early adopter' household which is able to store and use all of the energy produced by the solar PV unit will find the investment attractive from around 2022. However, a 'conventional investor' looking for a positive return from investing in solar PV (without subsidy) and storage will only find the investment attractive from around 2030, even if the household is able to use 100% of the electricity used on site.

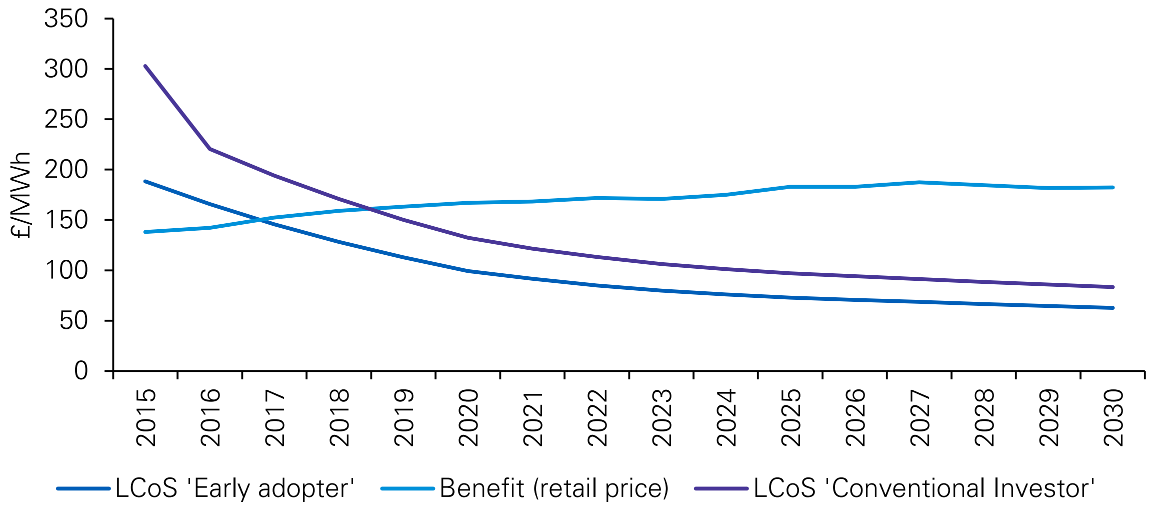
Figure 11: Costs of solar plus storage versus benefits (domestic prosumers)



6.4.1.2 **Storage retrofit**

For storage retrofit, installing a battery means that extra electricity produced by the solar unit can be stored and used on-site. The LCoS (of storage only, rather than solar plus storage) is therefore compared to the retail electricity price for both investor types (‘early adopter’ and ‘conventional investor’). Retrofit investors are assumed to have a Feed in Tariff with deemed exports, ie an increase in energy used and stored on site will lead to no reduction in their export tariff income. Our analysis indicates that for ‘early adopter’ households with existing decentralised energy resources and a Feed in Tariff with deemed exports, retrofitting storage is likely to be an attractive investment from around 2016. Even for those ‘conventional investor’ households seeking to make a positive return from storage, it will start to become an attractive investment within the current decade:

Figure 12: Costs of storage retrofit versus benefits (domestic prosumers)



6.4.2 **Commercial prosumers**

6.4.2.1 **Solar plus storage**

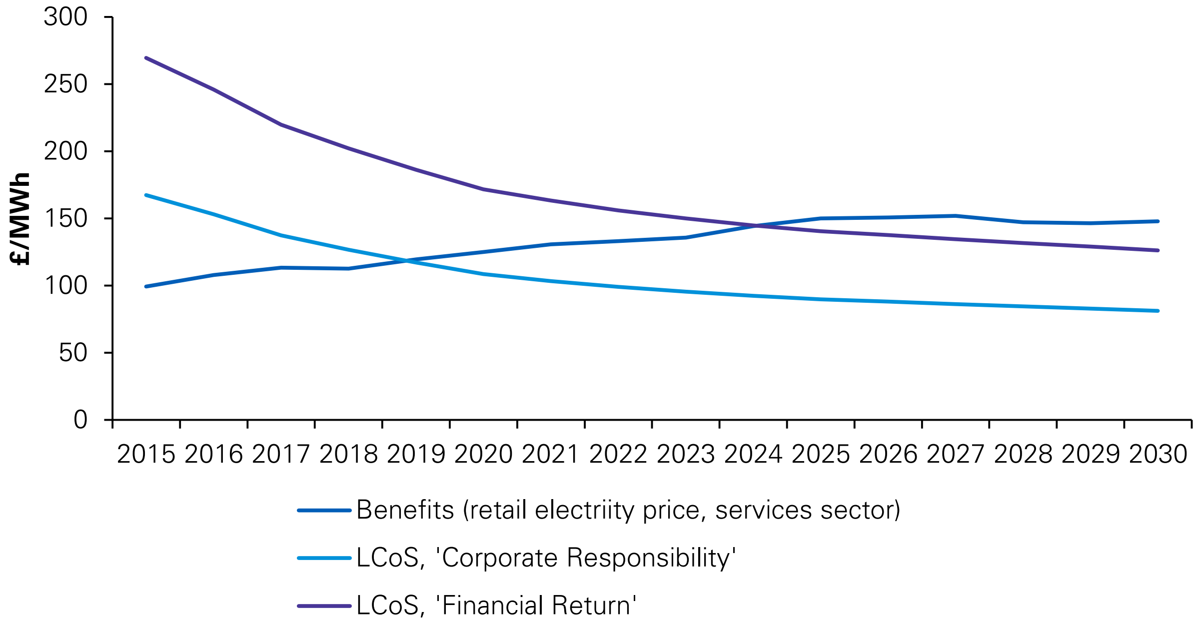
Cost benefit analysis for commercial prosumers is conducted on similar lines to domestic prosumers, with two different investor types with zero and positive discount rates. A point of divergence with the domestic prosumer analysis is that a single usage pattern is used to generate an estimate of benefits- it is assumed that all commercial prosumers will be able to use all of the energy produced by the solar PV unit due to the closer alignment of demand profile and solar PV output[43].

LCoS for firms with a 0% discount rate, ie firms who invest in solar PV and storage for non-financial reasons, is shown by the LCoS ‘corporate responsibility’ line. LCoS for firms looking to make a positive financial return from their investment is shown by the LCoS ‘financial return’ line. Both LCoS estimates are compared to the electricity price for the services sector from DECC’s UEP projections.

We estimate that for those firms seeking to invest in storage to enhance their environmental or corporate responsibility credentials investing in distributed generation in the form of solar PV plus storage will be an attractive investment from around 2018/19. For those firms seeking to make a financial return from their investment, distributed generation with storage is likely to become an attractive investment in the mid-2020’s:

[43] Business demand tends to be higher during the day, when solar output peaks.

Figure 13: Costs of solar PV plus storage versus benefits (commercial prosumers)

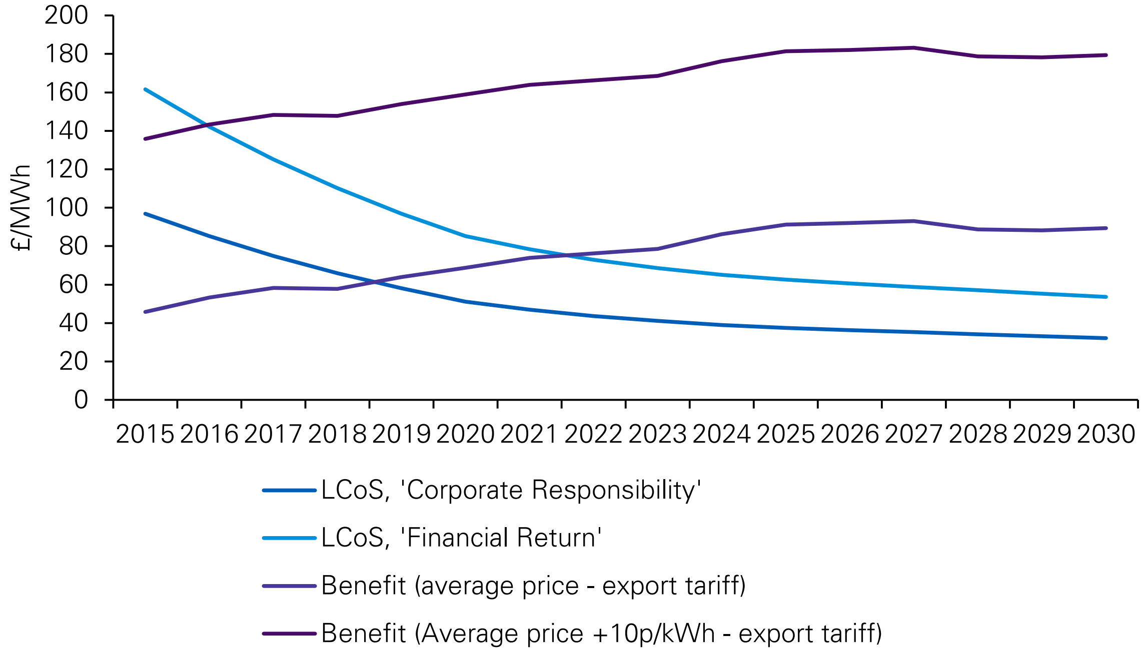


6.4.2.2 Storage retrofit

For firms seeking to retrofit storage on premises with existing solar PV panels, we calculated the storage-only LCoS for the same investor types as in the Solar plus Storage case study above. Given that firms retrofitting storage may have a Time of Use Tariff, we estimate the benefits for an investor who is able to use the storage unit to offset electricity purchases at peak prices (assumed to be the average price plus 10p/kWh) as well as a prosumer who offsets electricity purchases at average prices.

For commercial prosumers able to use storage to offset electricity purchases at peak prices, storage may already represent an attractive investment, even for those investors looking for a financial return. Even if the prosumer only offsets electricity purchases at average prices, storage retrofit is likely to be economic for all investment types from the early 2020's onwards.

Figure 14: Costs of storage retrofit versus benefits (commercial prosumers)



6.5 Large scale – Grid scale and community energy solutions

As outlined earlier in this report, National Grid already administers markets for a range of ancillary services designed to ensure that supply and demand are balanced in real time. At present these markets are dominated by large-scale technologies, mainly conventional peaking plant and large-scale hydro pumped storage projects. Individual decentralised energy units lack the flexibility and the scale to compete with existing technologies in these markets.

However, an emerging trend in electricity markets is the rise of larger community/city based projects where supply is decentralised. There are many potential models for projects of this kind, including:

— DSO – Distribution System Operator operating regional energy system (buying and selling flexible energy for balancing).

— Peer-to-peer models where a group of premises buy and sell electricity from one another, with each premise becoming a retailer and bypassing conventional electricity suppliers[44].

— A council/city-led model. One model here that has been rolled out in the UK is so-called ‘white labelling’, where traditional energy companies can target particular market segments and capitalise on the brand of a local authority as an energy provider, with the council positioning itself as an energy retailer, whilst using a licensed retailer to manage all regulatory and settlement requirements.

— An alternative is whereby cities/local councils seek to enter the supply market and procure energy on behalf of their residents. An extension of this would be for cities/councils to set up vertically integrated energy supply companies that generated low-carbon energy locally and then supplied it to their residents. The council would also be able to act as an aggregator, procuring demand side response (DSR) from its businesses and residents and selling this in national markets. Alternatively, it could procure ancillary services on a local level e.g. by investing in batteries and provide balancing services at a local level.

[44] Although a ‘back up’ electricity supplier may be required if there are constraints on decentralised energy supply.

— Community/City Energy Manager – Appointment of a new decentralised energy manager, possibly selected by franchise/contract, similar to contracting out of business support services.

However, there are currently significant obstacles to the widespread adoption of these model. Some of these are regulatory: energy markets tend to be complex, and designed largely for companies acting nationally and enjoying advantages of scale and scope. Even following Ofgem's 'Licence Lite' reforms, designed to create a simpler supplier licence that bypassed industry rules and codes to an extent, licences remain complex. In addition, the energy metering and settlements system does not currently allow half hourly settlements at the household or local level, meaning that it is impossible to match local consumer demand to local generation, although the roll out of smart meters could overcome this barrier.

Other barriers are economic. Both generation and storage assets have high fixed costs, meaning that smaller local markets may not be large enough for economies of scale to be realised. Similarly, it is unlikely that communities would be able to make the scale of investment in storage and generation required to compete in national balancing markets. The same logic would apply for communities looking to provide aggregator services- they would be competing with entities not geographically constrained and therefore able to achieve greater scale. It is therefore unlikely that a business case for local balancing services could be made without some form of local financial support mechanism, which could be justified in terms of perceived benefits from increased energy independence, low carbon generation etc.

6.5.1 Grid scale storage

We therefore analyse the economics of the grid-scale ancillary services market model for storage below. We analyse the case Lithium Ion batteries in one of the ancillary services markets operated by National Grid (Firm Frequency Response). Firm Frequency Response (FFR) was highlighted by stakeholders as a market well suited for lithium ion batteries, although it should be noted that they will also be able to compete in other ancillary services markets, such as STOR, Fast Reserve. Moreover, in future storage may be able to compete in the Capacity Market provided certain market barriers are addressed (see Section 7.1 for more details). We assume it would provide dynamic FFR as opposed to non-dynamic. FFR providers are paid for availability only, in the form of £/hr availability and nomination fees.

6.5.2 Grid scale demand response

According to DECC, some 2.4 GW of demand response is already available in GB, largely through business load and economy 7. Some demand response is already procured by National Grid for reserve and for capacity auctions. In the 2015 capacity auctions, around 470MW of DSR was awarded contracts at the clearing price of £18/kW for the 2019/20 year.

At a grid level, demand response will be able to access many of the same revenues available to storage.

6.6 Grid scale storage cost and benefit/revenue assumptions

6.6.1 Cost and performance assumptions

Cost and performance assumptions for lithium ion batteries are set out in Appendix 1. We have developed low and high capex assumptions to capture the wide range of potential project costs. In addition, grid scale storage must buy electricity to store. We assume that it could buy electricity for £38/MWh. This is the average value of the wholesale price in the 8 lowest price periods up to November 2015[45].

[45] Price data taken from https://www.apxgroup.com/market-results/apx-power-uk/ukpx-rpd-historical-data/

6.6.2 Benefits/revenue assumptions

Grid scale batteries are assumed to participate in the FFR market. Payments in the FFR market consist of an £/hr availability fee only. Among providers of dynamic response services there is considerable variation in the level of availability fee received, and there are no existing battery storage projects with contracts, meaning that it is hard to develop a benchmark for the level of fee a battery could command. Given this uncertainty, we have developed low and high assumptions for availability fee. In the low case, the plant receives £1,150/hr and in the high scenario it receives £2,050/hr. These are based on the FFR contracts for Ratcliff and Aberthaw units respectively.

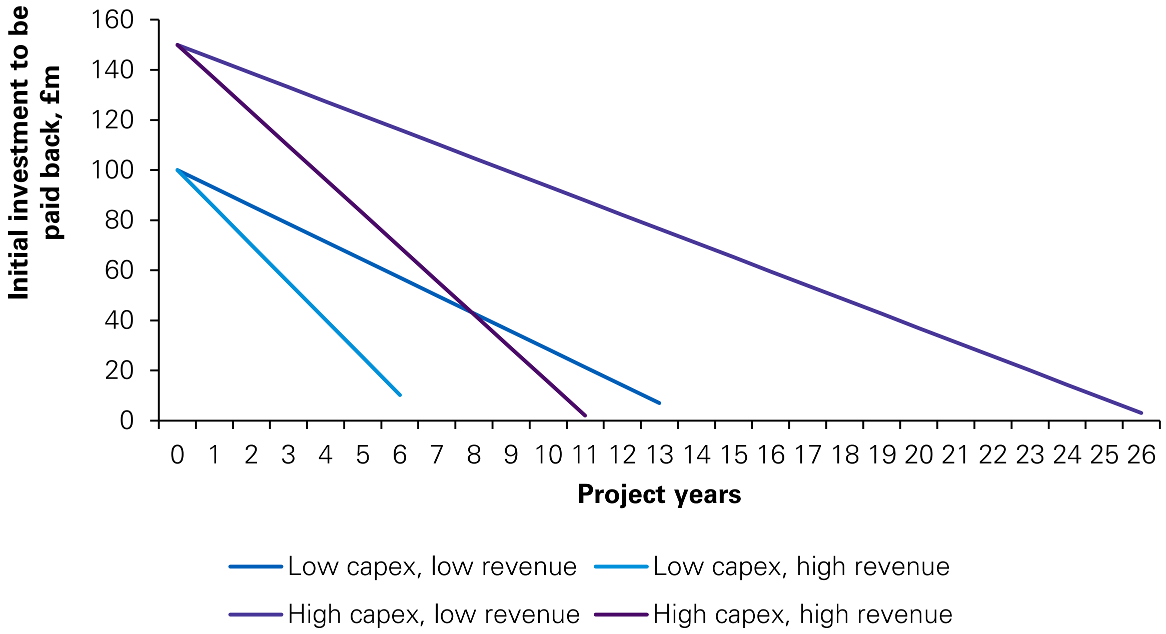
It should be noted that these represent a set of current market assumptions for national energy and reserve markets. In the future, competition in these markets will be taking place alongside distributed energy solutions and will probably cause these assumptions to change. Therefore, these assumptions should be treated as indicative for the purpose of developing scenarios for this report.

6.7 Cost benefit analysis – Large scale

6.7.1 Lithium ion batteries

For grid scale services, we have calculated 'payback periods' which estimate how long it would take for lithium ion battery projects providing FFR to repay the initial capital investment under different cost and revenue scenarios. These are illustrated in the chart below:

Figure 15: Payback periods on initial capital investment, grid scale lithium ion battery



The above chart illustrates that battery projects with lower levels of initial capital investment and access to high availability fees may already be economic investments if long term contracts were to be available. Given that all these capital costs are expected to fall over future years, and that greater demand for reserve services is expected, then payback periods may continue to fall.

7. Challenges and opportunities

The previous sections in this report have found relatively positive high level economic cases for decentralised energy deployment, but practical implementation faces a number of significant barriers. This section reviews some of the work done to date by industry, government and on exploitation of decentralised energy resources, and identifies the barriers to deployment and potential solutions.

7.1 Market opening for decentralised energy – Challenges

One of the key challenges is that people have different understandings of decentralised energy. For network companies, it may be a smart grid that can intelligently integrate the actions of all the users connected to it, for consumers of all sizes it may be a means of reducing energy costs and gaining additional revenues from energy services, and so on. Is it a market for demand response, storage, solar, heat pumps, electric vehicles, or all of those and more?

This report has already explained some of the regulatory and policy challenges acting as barriers to new decentralised energy resources. DECC and Ofgem, in conjunction with the existing industry and prospective new entrants, are undertaking initiatives to try and understand what needs to be changed to enable this development. Some of the key issues include:

- Ensuring full value is captured by giving better price signals for distributed generation, demand response and storage, for all the services they are able to provide. This is sometimes called 'missing markets'.
- Ensuring clear visibility of service requirements and potential providers. For example, National Grid's proactive 'power responsive' initiative has resulted an increase of demand response provision by a range of providers.
- Addressing issues around the Capacity Market that make it difficult for some storage to access. These include providing sufficient length of contract to enable new projects to secure the necessary investment (7-15 years have been suggested by industry), specifying time restrictions (so storage and DSR providers know how long they would have to supply power for) and incentivising technologies that can provide the quickest response.
- Ensuring consumer protections as well as meeting their needs. Both large and small scale consumers may not enjoy the same level of protection with decentralised energy solution providers e.g. demand response is not suitable for all organisations/applications and cannot be used in certain situations.
- Clarifying the role of aggregators, who may combine decentralised energy resources into a scale for participation in markets; clarifying the role of DSO's who may take a more active role in regional system balancing, and the national System Operator; clarifying the role of large prosumers and city/community decentralised energy providers.
- Clarifying grid connection and network charging arrangements to ensure non-discrimination and cost-reflectivity; ensuring that storage has fair treatment for grid charges. It will also be important that charging arrangements allow for energy networks to be suitably funded, in the event that significant numbers of prosumers decide to go 'off grid' (and hence avoid having to pay network charges).
- Clarifying the definition of storage and putting the appropriate legal and regulatory arrangements in place; clarifying and simplifying regulatory arrangements for engaging with energy markets, networks and others.

In addition to these policy and regulatory factors there are a number of barriers that are more commercial in nature, including:

7.1.1 Economics and investment

Unlike renewable energy technologies that benefited from long term subsidies or contracts, it appears that the components of, or integrated conmbinations of, decentralised energy solutions will need to compete for revenues in various segments of the energy market, where the following challenges exist:

— The market does not currently offer the long term contracts that are likely to be necessary to support major capital investment.

— There is a lack of strong price signals and associated market platforms for decentralised energy services; for example, domestic energy prices do not reflect marginal wholesale cost, and price signals are distorted by socialisation of green levies and network costs.

— Competitors may have an advantage e.g. legacy fossil generators with sunk capital costs, diesels without carbon caps.

— Classification as an energy efficient product would allow possibility of a lower VAT rating and Enhanced Capital Allowances (ECA's).

— Integrated decentralised energy business models are as yet unproven; while a variety of examples exist, a dominant business model has yet to emerge.

7.1.2 Technology and deployment

While distributed generation such as solar PV are well established, demand response, storage, and components such as heat pumps and electric vehicles are not. In this respect, it may be expected that there will be technology and deployment challenges for early projects. This could potentially be alleviated by grant funding for test phase projects. It will also be important to address the funding gap between demonstration projects, which have enjoyed some support in recent years, and commercialisation, where conventional lenders may be unwilling to lend to unknown technologies.

7.1.3 Who are the counterparties for decentralised energy services?

As discussed earlier in this report, there are a variety of potential business models that could be developed for decentralised energy resources. Ultimately, each of them will comprise a value chain where someone provides and gets paid for the services provided. Some examples of the potential counterparties to decentralised energy service contracts are discussed below:

— National System Operator (National Grid) – This would essentially maintain the status quo, where the System Operator (regulated by Ofgem) runs tenders for reserve, balancing and grid congestion services. It has well established market platforms which could be improved as scale increases. This regime has the advantage that it should tie directly into national requirements for capacity and reserve across the entire grid network.

— Distribution System Operator – This new model proposes that each local network company also contracts for decentralised energy services to potentially undertake local balancing and management of grid flows. While this has the potential advantage of allowing local purchasing of decentralised energy services, these may be limited unless the National System Operator responsibilities are reduced. Administrative set up costs and time may be significant.

— Decentralised Energy Aggregator – These entities exist at the moment to combine demand response resources for example, and could be extended into other areas for engagement with prosumers and grid scale resources. A peer to peer energy business might operate in a similar way. Again, set up costs may be significant.

— Energy Supply Company – This could be a city, community, or decentralised energy owner, seeking to sell energy and reserve services into their respective markets. It could also be one of the incumbent energy suppliers.

7.2 Key issues to be addressed

Our analysis shows that there are number of barriers to market participation by decentralised energy and storage resources. In particular, the market rules, industry regulations, charging arrangements, and institutional framework are complex and generally designed for large sophisticated market participants. Decentralised energy resources will be much smaller scale and deterred by this complexity and cost.

There are a number of market and regulatory changes that could give decentralised energy and storage solutions simple and fair access to energy, reserve, and grid reserve markets. Key matters for governing bodies to address include:

- Establishing clear and fair rules for the treatment of energy storage in the energy system, and a level playing field for all decentralised energy technologies. This could include:
  - Introducing a licence class specifically for storage projects.(i.e. clarifying it is neither ‘generation’ nor ‘demand’.
  - Setting targets for storage capacity, including access to CfDs and finance.
- The GB Capacity Market is critical for providing market based investment signals for new capacity. There are numerous calls to reform the Capacity Market to clarify investment signals for various technologies. In this context, energy storage providers are seeking longer term contracts and technology-appropriate commercial and performance arrangements.
- Identifying clear price signals for all decentralised energy services, and establish frameworks are for engaging with the market, even at small scale.
- Ensuring decentralised energy regulatory and market arrangements accommodate evolving market needs of decentralised energy providers, while protecting consumers.
- Enabling implementation of changes by clarifying the roles and objectives of counterparties and associated industry institutions in the development of decentralised energy solutions.

8. Conclusions

This report has examined emerging new decentralised energy business models, which combine storage with solar, demand response, energy efficiency and integrated control. The introduction of new energy storage and decentralised energy systems offers long term benefits in terms of decarbonisation, affordability, security of supply, and economic growth.

8.1 Key findings

8.1.1 Market trends

Solar and storage cost reductions are continuing

Since 2012 costs for domestic solar PV systems in the UK have fallen by 40% and further cost reductions are expected. Similarly, Lithium ion battery storage costs are also falling at a similar rate of around 10% per annum.

A more flexible energy system is needed

Currently, there is estimated to be well in excess of 20GW of wind and solar generation connected to the GB energy system. This is forecast to increase significantly over coming years causing increased requirements for storage or demand response to provide reserve services. This will fill the periods when variable generation is not available, and to supply energy at peak demand periods when electricity prices may be more volatile.

8.1.2 Economic case studies

We have analysed the following alternative business models for deployment of decentralised energy and storage:

Small scale – where domestic or business prosumers develop their own decentralised energy and storage systems. Our analysis shows that these may already be economic for both domestic and business prosumers in certain circumstances, allied with an appetite for early deployment due to non-financial buying criteria.

Large scale – where decentralised energy and storage resources participate in national energy markets, either directly or as city scale energy schemes. Our analysis shows that large scale decentralised energy resources, especially demand response and storage, are already economic in certain circumstances, although investors' unfamiliarity with these new technologies may mean that funding barriers to commercial deployment continue to exist.

8.1.3 Addressing market barriers

Our analysis shows that decentralised energy resources are approaching the point where they can participate in existing national energy markets, including markets for energy, reserve capacity, and other grid services such as investment deferral and frequency response. However, There are a number of market and regulatory changes that should encourage decentralised energy resources and storage simple and fair access to energy and reserve markets. These include:

- Enhancing decentralised energy participation in existing national energy, reserve and grid support markets by including, wherever possible, long term contracts that support new investment, and improving the rules around the Capacity Market.
- Identifying clear price signals for all decentralised energy services, and establish frameworks are for engaging with the market, even at small scale.

— Establishing clear and fair rules for the treatment of storage in the energy system, and a level playing field for all decentralised energy technologies.
— Ensuring decentralised energy regulatory and market arrangements accommodate evolving market needs of decentralised energy providers, while protecting consumers.
— Enabling implementation of changes by clarifying the roles and objectives of counterparties and markets for storage contracts, and associated industry administrative institutions.

8.2 Benefits of decentralised energy

Increased deployment of decentralised energy and storage offers several important benefits to the national energy sector, including:

— Lower overall energy costs as the risk of potentially high peak energy prices is reduced.
— New generation and network investment for peak capacity is reduced or not required.
— Reducing the risk of negative prices at times of low demand, when the energy system is dominated by 'must run' nuclear and renewables.
— Providing energy supplies when the national system has tight margins, thereby enhancing security of supply.
— Consumer or local energy management helps balance local demand and supply, thereby contributing to security of supply.
— An increased contribution to decarbonisation by enabling greater penetration of variable renewable generation within the energy system.
— Motivating businesses and consumers to take a more active role in choosing their local energy solutions and realising the benefits thereof.
— An integral role in the roll-out of electric vehicles, both in terms of ensuring effective connection to the grid and also using vehicle batteries as decentralised energy storage.
— Bringing new entrants, potentially from other industries, with new ideas and business models.
— A contribution to economic growth and jobs as new energy businesses and technologies emerge.

8.3 Looking forward

This report has identified and made suggestions about addressing some of the barriers that currently exist for decentralised energy business solutions. Looking forward, a number of strategic considerations are emerging:

— The pace of technology development and the growth of competitive markets in this area is challenging to existing energy systems and market arrangements, such as the separation of networks and supply. It will be important to ensure clear market and regulatory rules are in place to provide investor confidence, such as reforms to the Capacity Market, and recovery of network costs.
— Whole energy system strategies, including gas, heat, and transport will be impacted by the development of these (mainly electricity) decentralised energy solutions.
— Decentralised energy solutions are becoming world markets, and other countries are actively starting to exploit these low carbon, flexible energy resources.

Each of these has potentially significant impacts on the future direction of energy strategies and policies, and will need to be considered as part of future strategic and business analysis.

Appendix 1 Cost and Performance Assumptions

Domestic storage and solar

The tables below set out cost and performance assumptions for domestic scale solar PV and storage installations. All financial values are in 2015 prices.

Our capex assumption is based on Sonnenbatterie's price for their sonnenCommunity battery. There is assumed to be no opex, and the lifetime of the system has been set at 20 years. Although the lifetime of lithium ion batteries has been estimated at 10,000 cycles, which would suggest a lifetime of closer to 30 years, it is likely that at 20 years battery degredation would mean that the battery itself would have to be replaced to maintain the requisite level of performance. The costs of battery replacement would typically be treated as opex and smeared across the lifetime of the project, meaning that a lifetime of longer than 20 years would not be consistent with the 'zero opex' assumption. This reasoning also applies to batteries installed by commercial prosumers.

Given that solar and storage together form a system, the lifetime of the solar PV system is also assumed to be 20 years, even though it is likely that solar PV would perform at an adequate level for longer than 20 years (provided inverters were replaced as required).

Table 8: Cost and performance assumptions for domestic storage system

Assumption	Value	Source/detail
Current Capex[46] (system) (£)	2,260	Based on quoted price for sonnenCommunity battery
Opex (% of capex)	0%	Based on stakeholder feedback, domestic batteries are assumed to be maintenance-free
System useable energy (kWh)	2	As per Sonnenbatterie system
Cycles per year	300	Assuming storage would not operate on winter days with least sunlight
Efficiency	90%	Lazards LCoS report[47]
Lifetime	20 years	To ensure consistency with zero opex assumption.

Table 9: Cost and performance assumptions for domestic solar PV system

Assumption	Value	Source/detail
Current Capex (£/kW)	1,500	Stakeholder feedback
Opex (£/kW/year)	20	Parsons Brinckerhoff costs update for DECC FITs review
Load Factor (kWh/kW/yr)	909	KPMG report for REA
Degredation (%/year)	0.5	KPMG report for REA
Lifetime	20	For consistency with lifetime of storage unit

[46] In this appendix capex refers to the total cost of installation, i.e. costs of electrical equipment such as solar PV modules, batteries and inverters plus balance of system costs.

[47] Lazards, Levelised Cost of Storage Analysis, Version 9, November 2015

Commercial storage and solar

Table 10: Cost and performance assumptions for commercial storage system

Assumption	Value	Source/detail
Current Capex (£/kWh)	680	Based on sonnenCommunity battery cost, minus 40% to account for economies of scale
Opex (% of capex)	0%	Smaller scale batteries assumed to have zero maintenance
System useable energy (kWh)	4,000	Based on assumptions in Lazards LCoS report
Cycles per year	350	Based on assumptions in Lazards LCoS report
Efficiency	90%	Based on assumptions in Lazards LCoS report
Lifetime	20 years	For consistency with ‘zero opex’ assumption

Table 11: Cost and performance assumptions for commercial solar PV system

Assumption	Value	Source/detail
Current Capex (£/kW)	900	Stakeholder feedback
Opex (£/kW/year)	10	Parsons Brinckerhoff costs update for DECC FITs review
Load Factor (kWh/kW/yr)	909	KPMG report for REA
Degredation (%/year)	0.5	KPMG report for REA
Lifetime (years)	20	For consistency with storage lifetime

Table 12: Cost and performance assumptions for grid scale storage system

Assumption	Lithium ion	Notes
Current Capex (£/kW)	1,000 (low) 1,500 (high)	Stakeholder feedback
Opex (% of capex)	3%	Stakeholder feedback
Efficiency (%)	91%	Based on assumptions in Lazards LCoS report
Plant size (MW)	100	Based on assumptions ion Lazards LCoS report

The cost reduction profiles for lithium ion battery capex out to 2030 are set out in graphic form in Figure 8 above. The underlying annual reductions, plus the annual reductions for solar PV, are set out in the table below. The profile for batteries reflects published projections of cost reduction out to 2020, with reductions of around 12% per year. Cost reductions are then assumed to grow less steep from 2020 until 2030. The cost reduction profile for solar PV is based on that developed for KPMG’s report for the REA, with a steeper cost reduction factored in for 2017 to account for the anticipated ending of Minimum Import Pricing (MIP) on solar panels imported into the EU from China.

Table 13: Cost and performance assumptions for domestic solar PV system

%/year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Battery	12%	12%	12%	12%	12%	8%	7%	6%	5%	4%	3%	3%	3%	3%	3%
Solar	4%	10%	3%	3%	4%	2%	2%	2%	2%	3%	2%	2%	2%	2%	2%

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