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Energy Storage: Delivering Renewable Energy's Full Potential

The Paris Agreement, dated December 2015, gives some comfort that renewable energy generation will be ever more important in years to come. However, the likely future of renewables is one where they can be competitive without subsidy. In some cases, that is already a reality but there is still a long way to go. Energy storage is likely to be a game changer in helping renewables along this road.

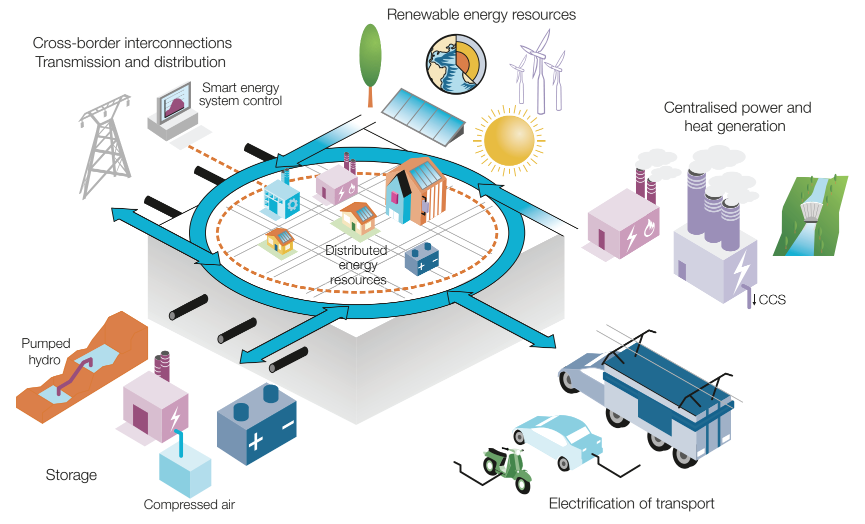
The December 2015 Paris Climate Change Conference saw the conclusion of the first real global deal on actions to deal with climate change for the period after 2020. 195 countries agreed to take action to limit global temperature rises to 2°C and pursue efforts to go even further towards a 1.5°C limit. Although no specific emission limits are included in the Paris Agreement, each country committed to submit its plans for emission cuts and update these every five years. Ultimately, the Agreement aims for net zero carbon emissions in the latter half of this century. Work will continue on the detail of this Agreement and agreement of implementation mechanisms at the COP 22 meeting in Marrakech in November 2016 and beyond.

The Paris Agreement does not focus on renewable energy generation, but it is clear that a huge growth in the global renewable energy sector is absolutely crucial to meeting these emission aims: The International Energy Agency (IEA), for example, sees renewable energy contributing 32% of the effort towards the 2°C scenario between 2016 and 2050[1]. Its figures estimate that renewable electricity generation rose by 5% in 2015, accounting for 23% of all electricity generation. The IEA expects renewable electricity generation to grow by more than 30% between 2014 and 2020.

Energy storage, a crucial piece in the new technology jigsaw

Global efforts to decarbonise (including raising generation capacity) will increasingly rely on development of technology to help make the supply and use of energy more reliable, cost-efficient and flexible. The development of more *interconnector* capacity between national and regional grids[2] will allow energy to be transferred more freely across borders to manage reliable supplies, including reducing wasted energy generated from renewable energy sources and helping to ameliorate the problem of intermittent generation technologies. There will be a growing emphasis on *demand side flexibility* which uses technology and data to manage consumer demand (for example by shifting demand to off-peak periods). A *smart grid* incorporates this technology and data to manage supply and demand on a larger scale across a whole grid network (at distribution or transmission level). This allows connection of greater levels of renewable resources to the network, and control of demand and real-time pricing at commercial and domestic consumer level: This helps not only

Smart distribution grids at the heart of a transformed power system



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[1] With energy efficiency contributing 38%, carbon capture and storage and nuclear taking up 19% combined. Source: IEA Energy Technology Perspectives 2016.

[2] One notable example is the Medgrid project currently being considered to link the European electricity network to Africa.

balancing supply and demand, but also encourages energy efficiency.

Although not a new concept, *energy storage* is destined to become a crucial element of the energy networks of the future, helping to ensure that energy is available when and where it is needed and is not wasted. Storage has a major role supporting centralised grids, and is also likely to be important in large-scale interconnection going forward. Increasingly, the old-style centralised grids of the past are being complemented by *distributed energy networks* or *micro-grids,* where typically smaller renewable sources produce energy for consumption at nearby locations (e.g. business parks, housing estates or factories). At this more local level, energy storage plays a key part in the development of *micro-grids* and *smart grids*. The remainder of this article focuses on issues related to energy storage (primarily issues relating to electricity storage).

Applications of Storage and Technologies

Energy storage can be used by actors in different parts of the energy supply chain for a number of broad purposes:

- Supply stage (generation): Storage systems can help in dealing with electricity demand and supply imbalances and temporary disturbance to supplies. Importantly, storage can also assist in overcoming the problems associated with the intermittency of much renewable energy generation and thereby facilitating an increase in the amount of renewable energy in the power system, and reducing the need for high levels of back-up thermal generation capacity. It can also be used to improve the prices available for sale of energy by allowing supply at higher-priced peak periods and has the potential to enable renewable generators to participate in capacity and system balancing sales.
- Transmission/distribution stage: Use of energy storage can improve the efficiency and stability of grids and reduce peak loads. In particular, it can help grid operators avoid or delay costly upgrades to major grid infrastructure. Grid networks will often procure "ancillary services" for the purposes of ensuring the reliability and stability of grids – storage, amongst other technologies can assist in providing these services.
- Demand stage (end-users): A key driver for end-users to install energy storage systems is energy management. Rather than exporting surplus power back to the network for a minimal financial benefit, energy storage systems allow end-users who also generate power, to store the energy and reduce their need to import higher priced electricity from the network. End-users may seek to use the energy storage system to export electricity to the grid (i.e. as a generating system) or import electricity from the grid (i.e. as a load) or a combination of the two. This can also assist in balancing the overall supply and demand equation.

The role storage can play at the supply, transmission/distribution and demand stages largely depends upon the length of time for which the energy can be discharged and the speed it can be released for use. Supply and Demand stage storage tends to focus on longer periods of storage and/or discharge. Transmission/distribution uses often require rapid release for short durations, in particular in relation to balancing services. It can be seen that the same storage facility can be used for different purposes, and potentially even at different stages of the generation-to-consumption cycle. Additional flexibility and value is created by the ability for storage to operate as electricity to electricity, heat to heat, electricity to heat (and vice versa). Ironically, it is the very flexibility and variety of uses of energy storage that contribute to some of the issues which can present a barrier to storage at a large scale mentioned below under the heading "*Addressing barriers to the Energy Storage market*".

Technologies

Current energy storage technologies fall broadly into six categories classified by the way in which they store energy: mechanical, thermal, electrical, chemical, electrochemical or thermochemical. Examples of the major technologies are described in the box inset.

Major Energy Storage Technologies

Mechanical

- Pumped hydropower – water is pumped from a low reservoir to a higher reservoir in off-peak periods. Water is released back down to the lower level, generating electricity. Facilities are usually limited by geography and involve major capital investment in infrastructure.
- Compressed air storage – air is compressed using off-peak electricity. When needed, electricity is generated by forcing the compressed air through a turbine.
- Flywheels – flywheels rotate at high speed storing energy which is then released by slowing the flywheel down.

Thermal

- Underground energy storage – these systems pump heated or cooled water into aquifers or boreholes so that it can be used at a subsequent time for cooling or heating. Pit storage is a similar concept using shallow dug pits which are insulated to hold the hot or cooled water.
- Molten Salt – salt, often from a concentrated solar power plant, is heated until it becomes liquid and then stored until use in generating electricity. A variant uses ice to store and release latent heat as it changes between liquid and solid.
- Water and solid media storage – a simple form of energy storage using materials or insulated vessels to store and release heat (e.g. in domestic water tanks or within bricks or other solid materials found in domestic heaters).

Electrical

- Supercapacitors – these use an electrostatic field between conductive plates to store energy.
- Super-conducting magnetic energy storage – electricity is introduced to a supercooled coil and stored for subsequent release.

Chemical

- Hydrogen storage – electricity is used to produce hydrogen and oxygen through electrolysis. Oxygen is also stored and then later recombined with the hydrogen to generate electricity, for example, using a fuel cell (or used for other purposes). This technology has the potential for very large scale/longer duration energy storage.

Electro-chemical

- Classic batteries – an electric current charges the battery by causing reactions in the chemicals in the battery, and then later releasing electricity through opposite chemical reactions. They are well suited for electricity balancing purposes, since reaction time can be very rapid.

Thermo-chemical

- Solar fuels – a development stage technology where sunlight is used to separate water into constituent chemicals.

Significantly, storage technologies are evolving and some technologies are more mature than others. For example, pumped hydropower storage (PHS) has been fully commercialised for many years, whereas large scale battery storage is largely still at demonstration and deployment stage. Other technologies such as thermochemical storage are only in the research and development phase. Innovative ideas for storage continue to emerge, such as recognition of the potential to use an expanding fleet of electrical vehicle batteries (when they are not otherwise in use on the roads) for electricity storage able to store excess generation and release it back to the grid if not otherwise required.

Current global installed electricity storage is estimated at 140GW. 99% of this is pumped hydropower storage attached to grids, with the remaining 1% made up from batteries, compressed air, flywheels and hydrogen storage[3]. While electricity storage is already widely seen off-grid at local level, potential for its application at large scale and on-grid has the potential to revolutionise energy networks around the world. The greatest potential for energy storage growth is in technologies which (unlike hydropower) do not have significant locational constraints[4], which have the flexibility to provide large scale power to the grid (i.e. acting like power stations) and also fast-response ancillary services to networks, and all with minimal environmental/safety concerns.

Investment in energy storage systems is also being driven by the rapidly reducing costs of technology. By way of example, the baseline costs for mature technologies including lithium-ion batteries is projected

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[3] International Energy Agency Technology Road Map – Energy Storage 2014.

[4] Belgium, for example, suffers from a lack of areas in which additional pumped hydro facilities could be located, although underground mines might provide further possible sites.

to decline by 53% by 2025 and by 68% by 2035, and the baseline costs of emerging technologies such as molten salt are projected to decline by 79% by 2025 and 85% by 2035 (*AMEC, 2015*).

Renewable Generation and Energy Storage

The cost of renewable power generation has been decreasing steadily over the last few years, and numerous examples are emerging where the levelised cost of generation from established technologies is matching or undercutting fossil or nuclear generation cost[5]. Reducing costs have been reflected in many cases by reductions in renewable energy incentive support, with pressure for such reductions driven equally by concerns about budgetary constraints. Over time it seems likely that many such subsidies will be removed or gradually phased out. Subsidies are still needed, in particular, for less established technologies, but there are growing calls for incentive support to be focused on the system benefits of renewable generation – i.e. in helping to protect the overall security of supply through assisting in balancing grids and ensuring their stability, in circumstances where network infrastructure is increasingly constrained. This is where renewable generators can take advantage of energy storage. Indeed, a number of regulatory or incentive regimes already require energy storage services to be provided as part of renewable energy projects (either formally or in practice), which is a trend likely to increase over time (See further below under *"Addressing barriers to the Energy Storage market"*).

Energy storage is increasingly needed for integration of renewable energy sources to grids. The International Renewable Energy Agency has estimated that 150GW of battery storage and 325GW of pumped hydropower will be needed if it is to meet its 2030 target for 45% of power generation to come from renewable sources. Storage can perform a number of useful purposes in this regard:

- Long-term variability of output – storage can be used to store energy when it is not needed and deliver it when needed (and potentially when is more valuable), e.g. sale at peak periods of surplus wind energy generated at night, or solar energy generated before peak periods. It can also be used to deal with uncertainty over weather forecasting – i.e. not knowing whether the sun will shine or the wind will blow.
- Short-term variability of output – short-term fluctuations in renewable energy (i.e. wind speed changes and solar) require corresponding "ramping services" somewhere else on the grid to smooth the flow of electricity. These services can be provided by energy storage.
- Power quality – where significant volumes of renewable generation are introduced to grids, power quality problems affecting grid operation may be caused by significant variations in voltage. This is particularly the case where the share of renewable energy on the grid goes above 20% (see for example, Denmark, Germany and Spain) at which point the effective operation of grids can be impacted.

A number of different technologies may be used to provide one or more of the services mentioned above. In particular, currently the development of battery technology is seen as a major opportunity for renewables projects, with developers increasingly considering the co-location of battery storage and generation facilities.

Australia's first utility scale integrated solar and battery project

Clifford Chance has advised on the financing of Australia's first integrated solar and storage project of scale, which achieved financial close in August 2016. Located in Far North Queensland, the project comprises a 13MWp/10.8MWac solar PV array with an integrated grid-connected 1.4MW/5.4MWh lithium-ion battery. The project received a AUD17.4 million grant from the Australian Renewable Energy Agency (ARENA) and benefits from a power purchase agreement with Origin Energy which runs until 2030.

The project is aiming to be the first in the world to test a concept known as 'islanding', effectively isolating the local town of Lakeland from the main electricity grid. During the pilot, the town will be powered purely by solar and batteries for several hours. Grid-connected, utility scale batteries are likely to be a game-changer in the energy sector, assisting in solving the challenges of intermittent generation from renewable sources. The potential applications of these integrated technologies are far-reaching, including by enhancing energy reliability at the fringes of the grid as well as off-grid generation and storage.

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[5] See Next Generation Wind and Solar Power – from cost to value (IEA 2016). The IEA notes that reported costs for land-based wind have fallen to USD30-35/MWh in Morocco, and USD49/MWh for solar PV in Peru.

Addressing barriers to the Energy Storage market

The benefits and potential of energy storage are increasingly apparent, but there are a number of barriers to the large-scale growth of storage capacity. While these differ depending on the market and jurisdiction, they tend to be either technical, market-related or regulatory.

Technical issues

IJGlobal released a report in November 2015 which concluded that it was still early days for battery storage systems and that technical reliability would need to be proven and "predictability of cash flow [is] low". However, it is expected that battery chemistries and applications are likely to reach proven technology status in the next few years.

Many energy storage technologies are still technically inefficient in terms of energy losses. Some technologies (e.g. flywheels) suffer from losses due to friction in their moving parts and from contact with the air. Other systems require major cooling (e.g. SMES and supercapacitors) which affects their efficiency, or struggle to remain efficient at high temperatures (e.g. underground thermal energy storage systems).

The geography and climate of the country in which the energy storage system will be deployed may also have a detrimental impact on the lifetime estimation of the system (particularly batteries). By way of example, the higher temperatures may cause battery failure earlier than expected.

There are also safety and environmental issues in relation to some storage technologies. For example, a number of fire incidents involving battery installations have highlighted the actual or perceived risk of such installations. Concerns also remain over the environmental effects of underground thermal storage upon geology and water quality. Further research and development needs to be undertaken to refine the technologies and overcome these issues.

Market and regulatory issues

Although the costs of construction and operation of energy storage facilities are reducing, there are still economic barriers to their full commercialisation. Beyond support for research and development costs, opinions differ on whether specific subsidies are required for energy storage. However, most seem to agree that commercial deployment of energy storage needs to be achieved on a level playing field with other technologies performing similar roles in terms of support and market access. Storage also needs to receive remuneration for the varied services that it can provide.

Some subsidy systems exist for battery storage at generator level. Examples include low-interest loans and repayment subsidies for storage attached to Solar PV (under 30kWp) under the German "kfW-Programm Erneuerbare Energien "Speicher" – 275 Kredit" scheme. Australian Capital Territory has a grant scheme to encourage businesses and homes to invest in energy storage over the next five years. Other examples include tax incentives – for example a 30% investment tax credit applicable to eligible energy storage facilities in the USA. The European Association for Storage of Energy/European Energy Research Alliance have called for *capacity mechanisms*[6] to be opened up to energy storage facilities. These mechanisms can also provide financial support for renewables: An example is the UK's competition-based capacity market which is open to energy storage although, significantly, no storage project was awarded a contract under the most recent capacity market auction in 2015.

Regulatory disincentives to investment in energy storage systems are many and varied. A few significant examples include the following:

- *Negative effect of incentives and rules encouraging renewable energy generation*: Criticisms have been levelled at some existing renewable energy support mechanisms such as fixed rate feed-in tariffs (FiT) and their impact at the generator level. For example, the UK's microgeneration FiT mechanism can incentivise generators to export energy rather than store it since generators obtain the same remuneration irrespective of whether electricity is dispatched at peak time or non-peak time. In the Netherlands, rules allowing consumers to net-off electricity taken from the grid against self-generated energy are seen as disincentives to use energy storage. In any event, these types of schemes need to be reassessed to ensure a level playing field for storage, and in particular that disincentives to energy storage are removed.
- *Storage services – ownership and access*: In deregulated markets, competition rules (such as the EU so-called *unbundling rules*) require that generation asset owners do not also

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[6] Capacity mechanisms seek to ensure system stability and reliable electricity supplies at all times. They do this by procuring commitments to provide additional generation capacity if called upon at times of system stress during the committed period. This can be through supply of energy through additional generation or release of stored energy, or by reducing demand on the end-user side. Payment is made for maintaining capacity available.

own or control transmission assets. Energy storage tends to be classified as "generation and/or consumption" or has no distinct classification. In this way it is not clear the extent to which grid network operators can operate storage in compliance with these rules. Whilst such rules might be useful to prevent network operators distorting competition from generators by using their own storage facilities, they should not be allowed to prevent use of, or access to, storage facilities for genuine network efficiency or security purposes[7]. Also energy storage businesses often rely on the provision of different types of service in the market at the generation, transmission and consumption stages (so-called *benefits stacking*). Clarification and reform of rules that disincentivise full use of storage need to be considered[8]. In particular, there is a growing consensus that energy storage should be classified as a separate asset class to reflect its varying roles in the market.

- *Access to markets:* Rules can often affect the ability of storage owners to supply energy to the energy markets. For example, in the Netherlands, in order to supply the primary energy market, suppliers must be able to provide energy on demand on a 24/7 basis. This is clearly impossible for energy storage services. There is undoubtedly a role for regulatory regimes to assist with providing access to the market for energy storage: for example Puerto Rico introduced a regulatory requirement for renewable energy providers to provide balancing obligations. The European Association for Storage of Energy is calling for similar rules at EU level[9]. Other countries have acted to address market issues in different ways: The US State of California has introduced a mandatory requirement upon utilities to procure 1.3GW of grid storage capacity by 2020. In Morocco, IPP tenders for solar PV plant often require energy storage to help with network balancing. In certain parts of China, generators subject to curtailment restrictions during periods of low demand can store power for use in peak periods, helping to speed up their return on investment.
- *Fees and taxes:* Fees and taxes often have a discriminatory impact on energy storage. For example, there is frequently a double-tax burden on energy storage operators (e.g. in Belgium, Germany and the UK). In the UK, the *climate change levy* is applied on electricity imported to charge a storage device, and applied again later upon consumption of the electricity.

As far as ancillary services are concerned, complaints are frequently made that the true value of storage as a provider of services (and particularly its flexibility and capacity) is not recognised by the market, and revenues that can be achieved for storage services are lower than they should be as a result. It can be difficult to price services effectively, because the costs of providing these services are often not transparent. For example, in the UK, certain balancing services have historically been procured under bilateral agreements with generators. It can be difficult therefore to understand whether storage will be competitive with other technologies which could provide the same service (e.g. generation or demand flexibility). These problems will be of greatest concern for standalone energy storage businesses, although they will also affect generators providing ancillary services through their own storage facilities. A greater level of tendering for services is likely to reduce these problems by providing better price signals. Adopting a more bureaucratic "net metering" system, the Italian regulator GSE calculates the relative value of electricity fed into the grid against the costs of electricity consumed, and remunerates eligible renewable generators for any positive balance[10]; electricity storage used by generators is permitted within this calculation, and generators are therefore more fully compensated for the value that storage provides to the grid. It also allows them to understand when it is more economic to self-consume as opposed to provide electricity to the grid.

Where now?

Meeting global climate change targets through massive increases in renewable energy capacity can only happen efficiently with a major uptake of technologies like energy storage. As such, this is a very exciting time for the energy storage sector – Total's agreed €950 million acquisition of French battery manufacturer Saft, and Engie's acquisition of an 80% stake in Californian Battery Manufacturer Green Charge Networks, both in May 2016, are just two of a raft of M&A transactions in the past months highlighting the growing interest in the sector.

However, there is a huge need for continued research and development to

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[7] The Australian Energy Commission is currently investigating issues around control of energy storage (e.g. control by network owners over storage facilities owned by retail suppliers or customers) and the impact upon the efficient functioning of the energy market.

[8] The USA has made significant efforts at federal level to amend market rules to facilitate the provision of services across the energy system by storage providers.

[9] Balancing obligations are already generally required under EU State Aid rules for renewable generation projects to qualify for financial incentive support.

[10] The *scambio sul posto* mechanism is available for generation plants up to 200 kW.

commercialise promising technologies, as well as for market and regulatory change, if we are to realise at scale the potential benefits of energy storage. This needs to be undertaken on a whole-energy market scale and may require action across national borders. A good example is the European Union's cross-cutting initiative to integrate storage into the next stage of energy market reform through its research programmes[11], new electricity market design, and energy efficiency and renewable energy packages. These are intended to dovetail with the EU's actions to implement its new commitments under the Paris Agreement. The USA has been at the forefront globally of energy storage development and this is continuing.

In addition to legislation promoting research and development of renewable technologies including storage, in June 2016, the Obama Administration announced new executive actions and 33 state and private sector commitments designed to facilitate at least 1.3GW of additional storage procurement or deployment in the next five years.

In addition to a federal government commitment to increase its storage capacity, these announcements include state level investments in storage pilot projects and related studies, commitments from municipalities to storage capacity targets, and major plans for deployment by the private sector. Similar scale visions will be needed across the globe to make the most of this opportunity to cement energy storage within the energy networks of the future.

Although not the primary focus of COP22, the Marrakech meeting and its related side events will provide an ideal forum to discuss future renewable energy and energy storage innovation and commercialisation, in particular given the huge potential for growth in renewable energy in Africa where economic development is fundamentally reliant upon a rapid growth in electricity supply capacity. Finance for renewable energy projects in regions with developing economies will be key to these efforts, and Clifford Chance has partnered with Casablanca Finance City to sponsor, and assist in the preparations for, a Climate Finance Day in the run-up to the COP22 conference for stakeholders to discuss the challenges and identify ways forward[12].

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[11] Under the umbrella of its Horizon 2020 research and innovation programme and Strategic Energy Technology Plan.

[12] For more information about the Climate Finance Day which takes place in Casablanca on 4 November 2016, see http://climatefinanceday2016.com/.

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