INSIGHTS: CHARGING AHEAD – RENEWABLES COUPLED WITH STORAGE

Storage capabilities being developed for renewable energy resources have the potential to dramatically transform the global energy sector, as they provide the ability to balance electricity supply and demand. The most crucial role could prove to be the ability to boost the flexibility of renewable energy power sources. Batteries can solve the reliability challenge posed by variable renewable energy sources, by storing electricity at times when wind and solar projects are producing excess electricity. As the share of renewable power in global energy mix increases, so will the value of battery powered storage projects. At Aquila Capital we firmly believe that new renewable projects will increasingly be coupled with batteries, owing to the value of their enhanced flexibility.

Lithium remains the battery storage technology of choice at present. We expect its dominance to continue. The cost of Lithium-ion battery fell 70% between 2010 and 2017. Based on research conducted by Bloomberg New Energy Finance (BNEF), the costs of lithium batteries is expected to reach 100 USD/kWh by 2025 (versus 209 USD/kWh at present). Lithium also has the highest energy density compared with other storage technologies currently deployed. These cost and technical advantages should secure the technology's dominance in the electrification of the transport sector. That in turn will benefit renewables storage, this is owing to economies of scale in the manufacturing of Electric Vehicle (EV) batteries. EV battery manufacturing capacity has trebled over the course of the past three years.

Lithium batteries are therefore a key component in the future development of renewable energy. From a first mover advantage standpoint, Aquila Capital has gained valuable experience in relation to our investment activities carried out on the ground in Japan. In Northern Japan in 2016, we commenced construction of what was then the largest solar and storage project in Asia. The commercial operation date for this project is envisaged in 2018. The project comprises a 38MW photovoltaic power plant coupled with a 19.8 MW/11.4 MWh lithium battery.

In this whitepaper, we share crucial insights gleaned from our development of this project, including the technical and market specific expertise we gained. In addition to this, we describe how we will apply this knowledge for the benefit of similar projects in Europe.

Why will renewable energy resources require storage?
Renewable energy is massively impacting Europe's energy market. In Germany, renewables already provide 38,5% (2017) of electricity supply, and are displacing fossil fuel energy production. There is still so much more to come as European initiatives seek to have 80% of electricity produced from renewable sources by 2050. The signing of the Paris Agreement has cemented this commitment.

As the share of renewable energy increased and older, high-carbon generation disappears, it will become increasingly important to tackle the variable nature of renewable power, to maintain continuous supply. Storage will prove to be an important part of this process, by ensuring renewable energy can be dispatched more efficiently in line with demand factors. A recently published study conducted by the U.S. National Renewable Energy Laboratory (NREL)[1] predicted that from 2020 new solar photovoltaic (PV) plants coupled with storage would be more cost-effective than PV-only solar power. This is owing to the importance of solar power meeting the demands of evening energy peaks, when the price in the wholesale market is at its highest and solar generation is low or non-existent

Battery storage can play a crucial role in supporting renewable power directly, and in facilitating the accompanying grid infrastructure. In Europe, modernisation of the electric grid to accommodate growth in renewable energy is expected to require around EUR 650 billion of investment over the next two decades[2]. Such investment can be mitigated in part by supporting grid-scale storage projects which reduce the need for grid build-out at the point of network bottlenecks.

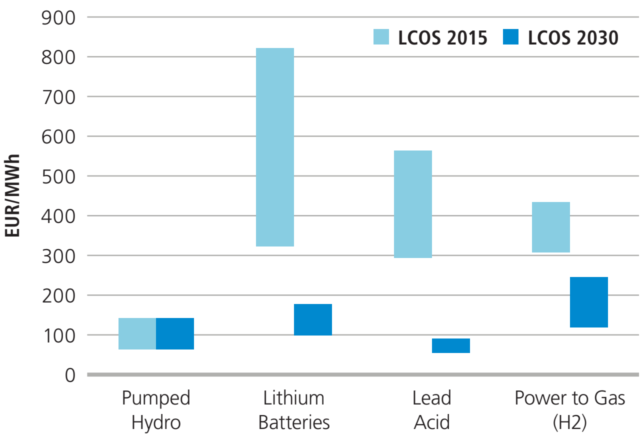
This year, the research company IHS has predicted that installed battery storage will grow from 1.3 GW of storage projects deployed globally in 2016 to an expected 4.7 GW in 2020 and 52 GW by 2025. This corresponds to a compound annual growth rate of 16%. We are already seeing large-scale battery storage installed in Japan, Australia and California.

[1] https://www.nrel.gov/docs/fy17osti/68737.pdf
[2] http://www.europarl.europa.eu/RegData/etudes/STUD/2017/595356/IPOL_STU(2017)595356_EN.pdf

Which type of batteries?

Aquila Capital has increasingly recognised the challenges and opportunities posed by the growth in renewable power. We have closely followed the technological evolution of storage, which is not just a single technology, but rather it refers to an array of technologies implemented at different stages of development.

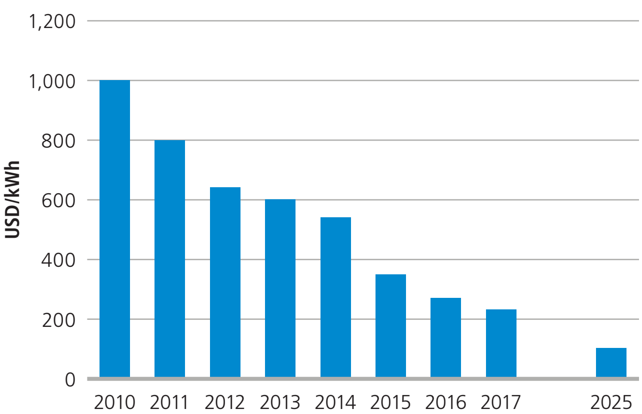
Levelised Cost of Storage 2015 and 2030



Source: World energy council

The most mature energy storage technology is pumped hydropower. Pumped hydropower is generally utilised for relatively long periods of charge and discharge (at multiple hours). As a proven technology, it represents the vast majority, around 99% of installed storage capacity, according to the International Energy Agency[3]. But it is strongly dependant on local topography, and it has high capex cost and long construction times (more than 5 years).

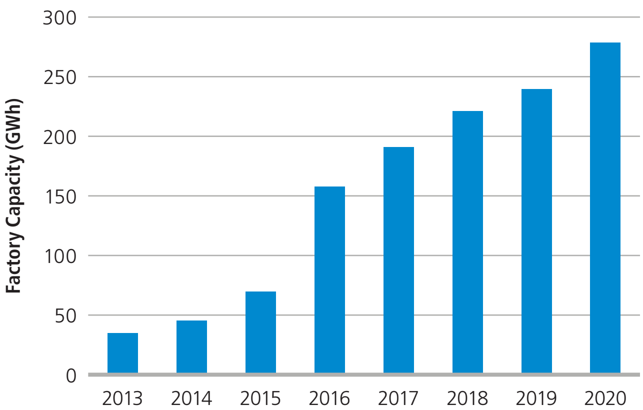
Lithium-ion Battery Price Evolution



Source: BNEF[4]

Lithium-ion battery storage is considered the second most mature technology, and the one with the greatest disruption potential. Given this potential, it has attracted multiple new entrants and R&D investment. The fact that lithium appears to be the technology of choice for the electrification of the transport sector will benefit renewable energy storage, through associated economies of scale and cost reductions. Since 2010, lithium-ion battery pack costs have fallen to around 230 USD/kWh, from 1,000 USD. BNEF expects costs going forward to fall to 100 USD/kWh by 2025. As costs fall, new applications will emerge, especially in the energy market, with potentially significant ramifications for future energy systems, including power market design and the integration of variable renewable power. At present, lithium batteries are the only technology which is able to get secure funding and bankable projects.

Battery Manufacturing Capacity



Source: Deutsche Bank[5]

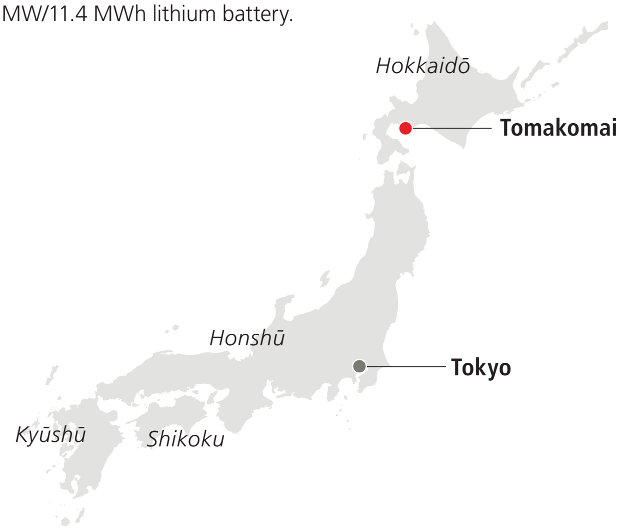
In 2013, the total global production capacity for lithium-ion batteries was around 35 GWh, with the vast majority of this production being focused on mobile phones and laptops. The success of the first electric vehicles and the growing automaker commitment to electric mobility is spurring massive new battery manufacturing capacity. At present, the global battery manufactory capacity amounts to 102 GWh and is largely based in China. After taking into account new manufacturing announcements – primarily in China, South Korea and Japan – BNEF expects that global battery manufacturing capacity will more than double by 2020, to 260 GWh. BNEF forecasts installed battery capacity in renewable power applications to grow from 1 GWh at present, to 81 GWh by 2024.

At Aquila Capital, we expect lithium batteries to outperform other forms of storage technology. This would be due to cost reductions, economies of scale achieved in manufacturing and its bankability (given a major supplier focus from the likes of companies such as Samsung, Panasonic and LGCHEM). Examples of other emerging storage technologies are vanadium redux flow, adiabatic compressed air energy storage, flywheels, power to gas and supercapacitors. Most of these technologies are in the early stages of development.

[3] *http://www.iea.org/publications/freepublications/publication/TechnologyRoadmapEnergystorage.pdf*
[4] *https://data.bloomberglp.com/bnef/sites/14/2017/07/BNEF-Lithium-ion-battery-costs-and-market.pdf*
[5] *http://rocktechlithium.com/wp-content/uploads/2016/11/Deutsche-Bank-Lithium-Research.pdf*

Insights cleaned from our solar and storage project in Japan

Aquila Capital started construction of the Tomakomai battery storage project in late 2016. At the time of construction, the Tomakomai project was the largest solar application for battery storage in Asia. The plant is located in Northern Japan in the island of Hokkaido and comprises of a 38MW photovoltaic power plant coupled with a 19.8 MW/11.4 MWh lithium battery.



Location of the solar park „Tomakomai"

Project Summary

Name of the project	Tomakomai
Location	Hokkaido, Japan
Solar feed in tariff (FiT)	40 ¥/kWh (approx. €0.31/kWh)
FiT Duration	20 years
PV Size	38.4 MWp
Battery Size	19.8 MW / 11.4 MWh
Battery application	Frequency control
Battery role	Fulfil HEPCO feed-in grid requirements

Since the nuclear reactor disaster at Fukushima, Japan has had to scramble to fill the gap left by the temporary closure of its entire nuclear power generation, using renewable energy and conventional gas and coal generation. Japan has since become one of the largest markets for renewables, alongside China and the United States. In 2016 alone, Japan added 14.3 GW of solar PV, nearly a quarter of global new installed capacity. This renewable energy transformation follows an earlier lead by European countries including Germany, the UK, Italy and Spain. Japan has led Europe in battery applications in renewable power. Aquila Capital can now leverage its Japanese experience in storage, to address renewables growth and network challenges in Europe and around the world.

For the Tomakomai project, the sole application of the battery is for asset management initiatives – to ensure that feed in solar production from the plant meets the frequency requirements of the grid and the local energy utility, Hokkaido Electric Power Company (HEPCO). HEPCO required such feed-in control as a condition to qualify for generous feed-in tariffs associated with the solar power project. The Tomakomai project receives a 20-year solar feed-in tariff of 40 JPY/kWh (approx. 0.31 EUR/ kWh), which is more than sufficient to cover the additional cost of the battery.

What experience have we gathered in our Tomakomai project, which we can now profitably apply further afield?

Developing battery storage adds an extra layer of complexity to a renewable-only project, including debt finance. An important priority was to identify the right lithium battery technology for the specific application and the right software, given the wide range of available suppliers and battery technologies. Every battery project is different and a particular application will define the specific lithium battery type and size. For example, one would select a power-intensive battery for ancillary services or output smoothing and a more energy-intensive battery for a renewable energy time-shifting application.

As an investor, it is of foremost importance to ensure we achieve our target cash flows over the 20 years of the solar feed-in tariff and to fulfil our battery warranties. We demonstrated our ability to identify established, proven, local partners in a ground-breaking project such as this, by selecting the leading lithium-ion battery manufacturer (LGCHEM) and battery software integrator (FUJI). FUJI will fulfil remote battery system monitoring using automated systems to minimise downtime and maximise efficiency and profitability. For the debt financing we secured a non-recourse debt facility from a reputable Japanese bank.

A valuable insight we gained from developing the Tomakomai project was in minimising the developmental lead time. Being provided as a pre-installed and containerised system, the battery can be deployed in weeks rather than months. This proves beneficial both for new projects such as ours and to renewable power retrofits.

The outlook for energy storage in Europe

Europe does not have a common regulatory approach to energy storage. The two principal markets at present are for frequency control in Britain and Germany. The most common application for batteries in Europe besides frequency control is for load-shifting in off-grid islands. Islands from the Faeroes (Denmark) to Graciosa (Spain) and Tilos (Greece) have installed batteries to allow higher levels of renewable power penetration.

Britain is the most appealing market, because of multiple potential battery storage revenue streams. Battery storage in Britain benefits from three possible revenue streams over a variety of timescales, enhancing the potential business case. These opportunities comprise of a monthly firm frequency response tender; a four-year enhanced frequency response tender; and a 10-year demand-side response tender under the country's capacity market. Germany offers a pooled market for batteries to participate in its weekly frequency control tenders, including providers from Austria and France. One downside is that battery participation in these tenders has already put downward pressure on prices and frequency control revenues.

Challenges facing grid-scale battery deployment in Europe

The biggest overall barrier to energy storage in the current EU legislative landscape is the lack of a clear regulatory definition, which has led to its classification as both generation and load, and thus multiple charging. The EU Directive 2009/72/EC refers to generation as assets that produce electricity, which could include batteries, and involving charges related to network access. In individual member states, however, batteries have also been assigned to the end-user network, thus incurring taxes related to electricity consumption. In other words, the definition of batteries is confusing and outdated.

A second challenge is the number of available income streams. Battery systems may require multiple sources of revenue to be bankable. For example, as noted above, the pace of battery price reductions means that short-dated contracts, such as Germany's weekly frequency control tenders, may face increasing price pressure, as new battery systems come on line, effectively out-competing recently installed systems.

Opportunities for grid-scale battery deployment in Europe

Improved economics of battery systems, as a result of cost reductions, technology development and improved regulations, will help add new applications and revenue streams.

Until now, the main role for lithium batteries was in power-intensive, fast response applications such as frequency control at the below 30-minute timescale. However, technology development has vastly increased energy densities, while improving manufacturing economies of scale have sharply reduced production costs. This is increasing the duration of lithium battery applications, to the two to four-hour scale, a range previously attributed to non-lithium technologies, such as PHP and flow batteries. Very recently, lithium has become not only competitive but the go-to technology for four-hour storage, as illustrated by renewable power projects integrating lithium batteries in the United States and Australia. These projects are substituting peaking capacity power plants. Lithium is thus expanding its potential opportunity in Europe.

Battery OEMs will further assist this expanding opportunity, as they gather more data on the working parameters of batteries, and begin to extend their warranties for use in different, simultaneous applications.

For renewable projects coupled with storage we expect four main applications in Europe:

- **Frequency control:** Batteries in renewable projects can deliver a second application besides power generation, to provide ancillary services to keep the grid stable at 50Hz
- **More predictable electricity output:** Batteries coupled with renewable power can ensure output in four-hour intervals, and thus help avoid balancing market penalties for incorrect forecasts.
- **Reduced renewable power curtailment:** Curtailment is a growing problem at times of unforeseen surpluses for example in wind power, because of transmission and distribution network constraints. Battery storage can relieve surpluses, for discharge when T&D capacity constraints are relieved. Such an application will become increasingly important as renewable power in Europe is forced to participate in power markets on an equal level as conventional technologies, making curtailment a more constant threat.
- **Compliance with ramp rate grid codes:** These codes limit the rate of power injected into the grid. Where renewable power plant is located in an area with poor grid connections, the maximal output of the energy plant is capped at a specific power level by the energy utility. In this case, the battery can charge when there is overproduction, and discharge it when the power plant is producing under the maximum permitted level.

Contact Details | Aquila Group
Valentinskamp 70
20355 Hamburg
Germany
Tel.: +49 (0)40 87 50 50-199
E-mail: info@aquila-capital.com
Web: www.aquila-capital.com

Hamburg · Frankfurt · London · Luxembourg · Madrid · Oslo · Zurich · Invercargill · Singapore · Tokyo

A publication of Aquila Capital Concepts GmbH. As of March 2018. Author: Boris Beltermann.