25 September 2014 | 56 pages

Global

Energy Darwinism II

Energy Storage: Game Changer for Utilities, Tech & Commodities

- Equities
- Commodities

- **EQUITY RESEARCH VIEW** — we estimate that a reduction in system costs of battery storage to $230/MWh, which is possible within 7-8 years, combined with solar generation, would make self-consumption financially attractive in a number of developed economies. That should further accelerate development lowering system costs towards $150/KWh, thus eliminating subsidies. We estimate up to a 240GW global market for energy storage by 2030 (>$400b), excluding car batteries.

- **The ongoing maturity of renewables** — means the amount of subsidy they need is declining and instead funds can be diverted into battery storage. Given the widespread and overlapping benefits of deployment to the economy, we would also see scope for subsidies to be funded by government budgets rather than consumer energy bills. Commercialization of battery storage would also eliminate intermittency as a bottleneck in renewables adoption.

- **We see mixed effects for utilities** — starting with reduction in load factors, supply volumes and power spreads, which should impact negatively power generators in US and Japan and vertically integrated names in Europe. The global energy services market, which we expect to grow to €200b by 2020, should provide new opportunities for some utilities but we expect low margins and tough competition such that an estimated 5-7% earnings upside potential won't be enough to offset generation & supply pressures. We view electricity distribution companies as long-term winners as they should see energy storage included in their RAB / rate base. We would have some very long-term concerns for gas distribution companies as the need for CCGTs as back-up diminishes. We expect battery storage to have a meaningful penetration in the global electricity market within the next 15 years, which should intercept the utility's asset replacement lifecycle of 30-35 years and cause some very significant – and in cases terminal – challenges.

- **For technology companies** — the emergence of the utility battery storage market should be a third pillar of growth, alongside vehicles and consumer electronics, with the added benefit that pure price competition is less likely to be a problem. Also, the storage battery market is likely to develop as an infrastructure business that involves the supply of services and solutions, not just hardware. We view GS Yuasa, NEC, Toshiba and Panasonic, among others, as well positioned to benefit.

- **COMMODITIES STRATEGY** — We see coal & oil as most negatively impacted, as battery-backed-up renewables become a true baseload substitute for coal and as oil peaking-power capacity is withdrawn. A maximum of 4m bbls/day of oil demand could be impacted. Gasoline demand should also be affected as improved battery efficiency accelerates electric vehicle penetration.

Equity Research

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EQUITY RESEARCH VIEW

Executive Summary

Equity Research Utilities Team

Over the last two years Citi has analysed and written about how individual developments in renewables and fracking (shale gas) have challenged and are transforming the energy market, both on the commodity front (coal, oil, gas) and on the utilities end.

Figure 1. Citi has been publishing on the disruptive effects of technological development to the energy space for more than 2 years

Source: Citi.

Note: The Citi GPS product referenced is not intended to constitute research, as that term is defined by applicable regulations, and one or more of the authors are not independent research analysts

In this report, we focus on energy storage, which we view as a technological advancement that can tie together all the other disruptive changes we have seen in the past decade. On the one hand, it is going to create a new revenue stream for technology companies, but on the other it could permanently alter the utilities' business models, with very negative repercussions for conventional power generation and end-user supply, only partially offset by new opportunities for RAB / rate base growth and energy services development. Commodity stocks should also be impacted, with demand profiles for primarily oil and then coal likely to face a decline, all else equal.

In this report we focus on battery storage, although other competing technologies are also possible (e.g. Abengoa's molten salt with CSP) and we believe the impetus for system costs to decline – to what we consider is a possible $230/KWh early next decade – will be driven both by: 1) the substantial economic benefits (for example just for the US economy, the Department of Energy sees $79b economic benefit in nominal terms, using 2.5% inflation, over a 10-year period from time-of-use energy cost management) and by 2) the strategic consideration of energy independence, which this year has become all too relevant in Europe, with the tensions between Russia and Ukraine and Scotland's secession referendum.

We view knock-on effects of battery storage development for electric vehicles (e.g. Tesla's Gigafactory in Texas), setting of environment goals (e.g. UN Climate Change talks in 2015 and EU-2030 talks in 2014/15) and regulatory developments (e.g. California 2020 storage mandate and UK and French capacity markets for 2017/18) as key for the acceleration of energy storage development and deployment.

Ultimately, we see battery energy storage for electricity systems as a potential 240GW market by 2030 (excluding car batteries) with system costs potentially dropping to $230/KWh by early next decade, which would make it cheaper than the average household electricity bill.

How to Invest in the Theme

We see the following industries as likely to be affected from developments into battery energy storage for electricity markets:

Technology Companies

The emergence of the utility battery storage market should be a third pillar of growth for these companies, alongside vehicles and consumer electronics. The battery business has thus far not delivered strong profits. However, in energy battery storage, compared with consumer electronics and auto batteries, pure price competition is less likely to be a problem because storage battery systems must meet stringent reliability standards (safety and lifespan), which require high-level quality control and technical expertise. Also, the storage battery market is likely to develop as an infrastructure business that involves the supply of services and solutions, not just hardware. We believe companies will be able to increase added-value through energy management and aftermarket services. We therefore believe storage batteries could be highly profitable.

We view GS Yuasa, NEC, SMA Solar, Toshiba, STMicroelectronics and Panasonic, among others, as well positioned to benefit.

Energy Utilities

We forecast mixed effects that will also vary with time for the global energy utility space.

We see negative pressures on the profitability of conventional merchant generation both near and longer term as consumers will be able to increase self-consumption, meaning lower power plant utilization and wholesale prices.

We also see negative pressures medium term for supply companies as volumes sold decline with the increased penetration of renewables, facilitated by energy storage. Longer term, some of the supply companies should be able to offset some of the pressures by moving into energy services, helping households and corporations manage integrated renewables-battery systems and energy-efficient buildings. However, competition in that segment is likely to be high from non-utility players.

In Europe, where a big part of the sector is vertically integrated, utilities will see some of their divisions negatively impacted and some positively. The balance of these effects will partly be determined by how quickly the managers of the positively impacted divisions (networks, renewables, services) will be able to re-allocate resources away from the negatively impacted divisions (traditional generation, supply).

We see positive effects for regulated utilities and electricity network companies, as they should be able to add energy storage to their asset base and earn a regulated return on it. We have already seen examples of that (e.g. Terna in Italy) and expect the US utilities in particular to be able to benefit the most.

Longer term, the integration of battery storage into electricity systems, when also combined with demand response and smart meters, should make the long-term power demand-supply balance much more predictable. This, in turn, should reduce the risk for power investments and create a much more efficient system with fewer redundancies and less risk of stranded cost creation. We believe this should ultimately translate into lower costs of capital for electricity investment, the flipside of which should also be lower allowed returns on such investments.

Figure 2. Stocks under Citi coverage that could be impacted positively or negatively over the next 5-10 years

	Europe	US	Japan / Asia Pacific
Stocks positively affected			
Utilities / Renewables			
	EDF (EEN, T&D)	EIX	Origin Energy
	EDP (Renewables)	DUKE	
	Terna	PNW	
	Red Electrica		
	SSE (Distribution)		
	GDFSuez (Services)		
	Veolia (Dalkia)		
	Centrica (Services)		
	Iberdrola		
	Abengoa		
Technology / Chemicals			
	STMicroelectronics		GS Yuasa
	SMA Solar		NEC
	Umicore		Panasonic
	BASF		Toshiba
	JMAT		Hitachi
	Clariant		Sony
Commodities			
Stocks negatively affected			
Utilities / Renewables			
	RWE	EXC	Kansai
	Fortum	ETR	Chubu
	Verbund	FE	
	EDF (Nuclear Generation)		
	Gas Natural		
	Centrica (supply)		
	SSE (Generation & Supply)		
Technology / Chemicals			
Commodities			
	Big Oil	Big Oil	

Source: Citi Research

Industry Analysis

How Battery Storage Fits into Power Markets

For electricity systems, the main likely benefits of increased deployment of energy storage can be grouped under four headings:

1. **Peak capacity:** This is the ability of stored energy to be provided to the system during peak hours. In such a scenario, storage would effectively be replacing a peaking gas-fired plant. The storage technology used for such a role would need to be able to ensure 100% availability at peak times.

2. **Time shifting:** This is the ability of energy to be stored when produced during low-cost hours (for example, during the night when demand is low or when the wind speed is higher or the sun is stronger) and then provided to the system when prices are higher. Although in certain cases this could look similar to the peak capacity provision function, it is of lower priority with regards to system needs and is of particular value for energy systems with high renewables penetration, which could cause power prices to even be negative (generators paid to stop producing) depending on the weather conditions.

3. **Spinning reserve/ancillary services/back up supply/frequency regulation:** This is the ability of storage to be used for grid services such as providing emergency supply if some generation capacity becomes unavailable or balancing short-duration imbalances.

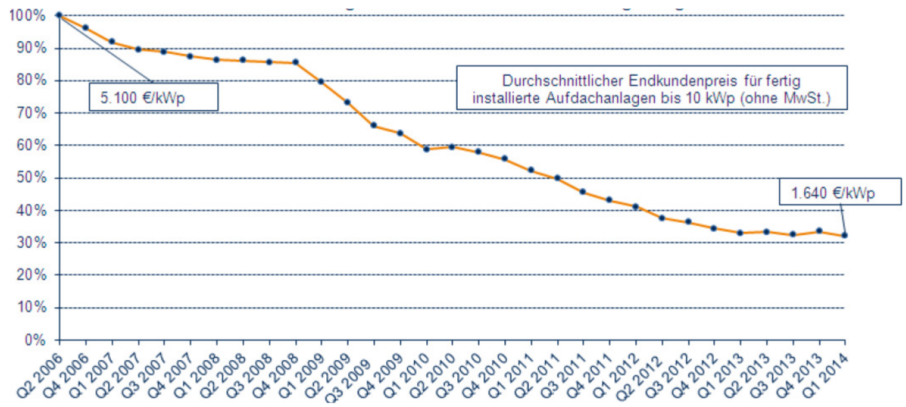
4. **T&D investment deferral/T&D support:** This is the ability of battery storage to offload transmission or distribution lines and therefore delay or potentially even cancel (depending on the load growth scenario) the need for an upgrade or replacement of the existing T&D capacity as well as improve overall transmission stability.

Depending on the targets that battery storage will be utilized to achieve, as well as the installation cost of each storage unit, battery storage can be located on any part of the value chain: generation, distribution and end-customer. According to a 2000 report from the Sandia National Laboratories, sponsored by the US Department of Energy, "if storage were very inexpensive and efficient, it would all be located at customer sites." However, this would assume adequate space in each house, a larger number of storage units than under other scenarios and substantial costs associated with the maintenance of the multitude of decentralized storage units. As such, the optimum mix according to the report would be for storage to be located primarily at the distribution level, which resonates to us.

The sharp drop in installation costs for renewables and particularly solar, as shown in Figure 3, is starting to marginalize conventional generation in certain parts of the world and particularly Europe. It has also started raising expectations about the full decarbonisation of electricity markets, with Germany already having an ambitious target in place to reach 55-60% power generation from renewables by 2035 and 80% by 2050.

These two factors of (i) increased growth in renewables and (ii) reduced utilization of conventional generation have brought storage technologies to the forefront of recent discussions on the future of the electricity markets. As a market for storage grows, we expect that costs will show a similar path to that of renewables, creating a virtuous circle of increased deployment and lower system costs.

Figure 3. Installation costs of solar in Germany have declined almost 70% in 8 years



Source: BSW-Solar, Photovoltaic Preisemonitor, 2/2014

In this report we analyse the potential market for battery storage in the global electricity market over the next 15 years and examine the implications for both the utilities sector and for battery manufacturers.

Figure 4. Summary of battery storage needs globally by 2030

	Low estimate (GW)	High estimate (GW)	Citi(e) in GWh per day
Europe battery storage needs			442
2030 general energy storage needs	63	121	
of which existing pumped hydro	42	42	
of which addressable by car batteries			~72
US battery storage needs			173
2030 general energy storage needs	30	55	
of which existing pumped hydro	22	22	
of which addressable by car batteries			~138
Japan battery storage needs			150
2030 general storage needs	13	59	
of which existing pumped hydro	0	0	
of which addressable by car batteries			~60
LatAm battery storage needs			40
2030 general storage needs	10	15	
of which existing pumped hydro	1.0	1.5	
of which addressable by car batteries			-
RoW / Asia battery storage needs			240
2030 general storage needs	45	125	
of which existing pumped hydro	30	70	
of which addressable by car batteries			~166
Total battery storage needs			1,045
2030 general storage needs	66	240	
of which existing pumped hydro	95	135.5	
of which addressable by car batteries			~435

Source: Citi Research

Potential in the European Electricity System

63-121GW of potential market for storage by 2030 across Europe, of which 42GW can be addressed by existing pumped hydro facilities.

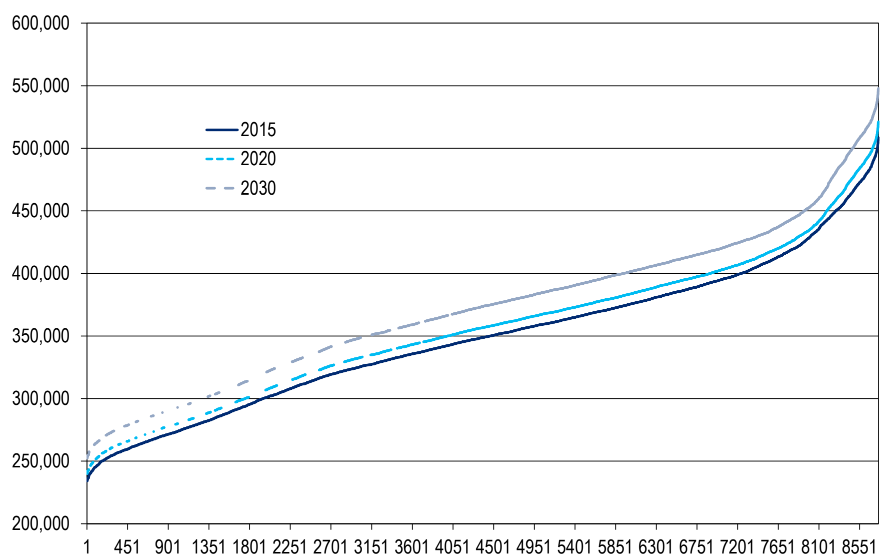
We estimate 20-39GW of possible storage requirements in the geographic area of Europe (excluding Turkey and Russia) by 2020 and 63-121GW by 2030, the range being a function of level of interconnectivity and energy demand growth. Assuming 7 hours of utilization this translates to 441-847GWh of daily demand, 72GWh of which could be covered by electric vehicles.

Pumped hydro storage in Europe is around 42GW and can therefore address a big portion but not all of the storage requirements. We believe the realized market in the front years is likely to be lower as mechanisms such as (i) strategic reserves formed by otherwise mothballed thermal plants and (ii) renewables output curtailment will be used due to cost efficiency. However, as storage costs decline and as the amount of storage needs rises, the realized market should be closer to its actual potential by 2030, with batteries likely to play a big role.

Capacity Offerings

Across the interconnected European grid (excluding Russia and Turkey) we estimate that in 2015 peak demand will be just above 500GW whereas by 2030 it will exceed 550GW. At any given time at least 230GW of generation capacity will need to be available in 2015 and that number rises to 260GW by 2030. For 50% of the time (4,380 hours during the year) more than 350GW of available capacity will be required in 2015 (385GW in 2030) and for 20% of the time more than 395GW of available capacity (436GW in 2030) will be needed. We assume ~0.5% annual demand growth, which might prove optimistic in light of the energy efficiency measures that are being promoted.

Figure 5. Pan-European electricity load in MW – sorted and plotted against time



Source: Citi Research estimates

Renewables (ex hydro) to make up 22% of Europe's nameplate capacity by 2015E, 28% by 2020E and 36% by 2030E.

Figure 6 shows our expectations of the nameplate (nominal size) capacity in Europe that can be called upon during that timeframe to cover electricity demand needs.

Figure 6. Nameplate generation capacity in Europe by type in MW

	2015E	2020E	2030E
Baseload generation	351,779	311,091	284,717
Gas fired generation	191,273	194,134	205,215
Renewables	213,875	278,753	365,352
Hydro	188,310	192,334	193,729
Total	**945,237**	**976,312**	**1,049,012**

Source: Citi Research estimates

We bundle together plants such as nuclear or lignite, whose economics and technical restrictions call for more steady runs, under the baseload category. Given planned nuclear closures and the age of some of the thermal plants, as well as environmental restrictions, we expect that group to decline from 352GW in 2015 down to 285GW by 2030. We show separately gas-fired generation which can be much more flexible in its operation and which we expect to increase somewhat from 191GW in 2015 to 205GW in 2030. We note that CCGTs that have been seasonally or otherwise mothballed are still included in those figures as for the right economic signals they can come back on line again. Finally, we split renewables into two categories; subsidized renewables, such as wind and solar, and hydro. Renewables is by far the fastest-growing category, going on our estimates from 213GW in 2015 to 365GW by 2030.

According to the EU's 2013 Reference Scenario, by 2025 intermittent renewable energy (wind, solar, tidal, etc) will reach 394GW out of a total installed capacity of 1,061GW. By 2035 this will have risen to 510GW out of 1,195GW and by 2050 to 650GW out of 1,374GW. Our own forecasts are a bit more conservative on the pace of deployment of wind, with a big part of the expansion expected to be from offshore projects, where factors ranging from logistics to local opposition have so far proven stronger obstacles than anticipated. Nevertheless we expect stronger co-ordination and determination at the EU level to eventually overcome such obstacles over the longer term.

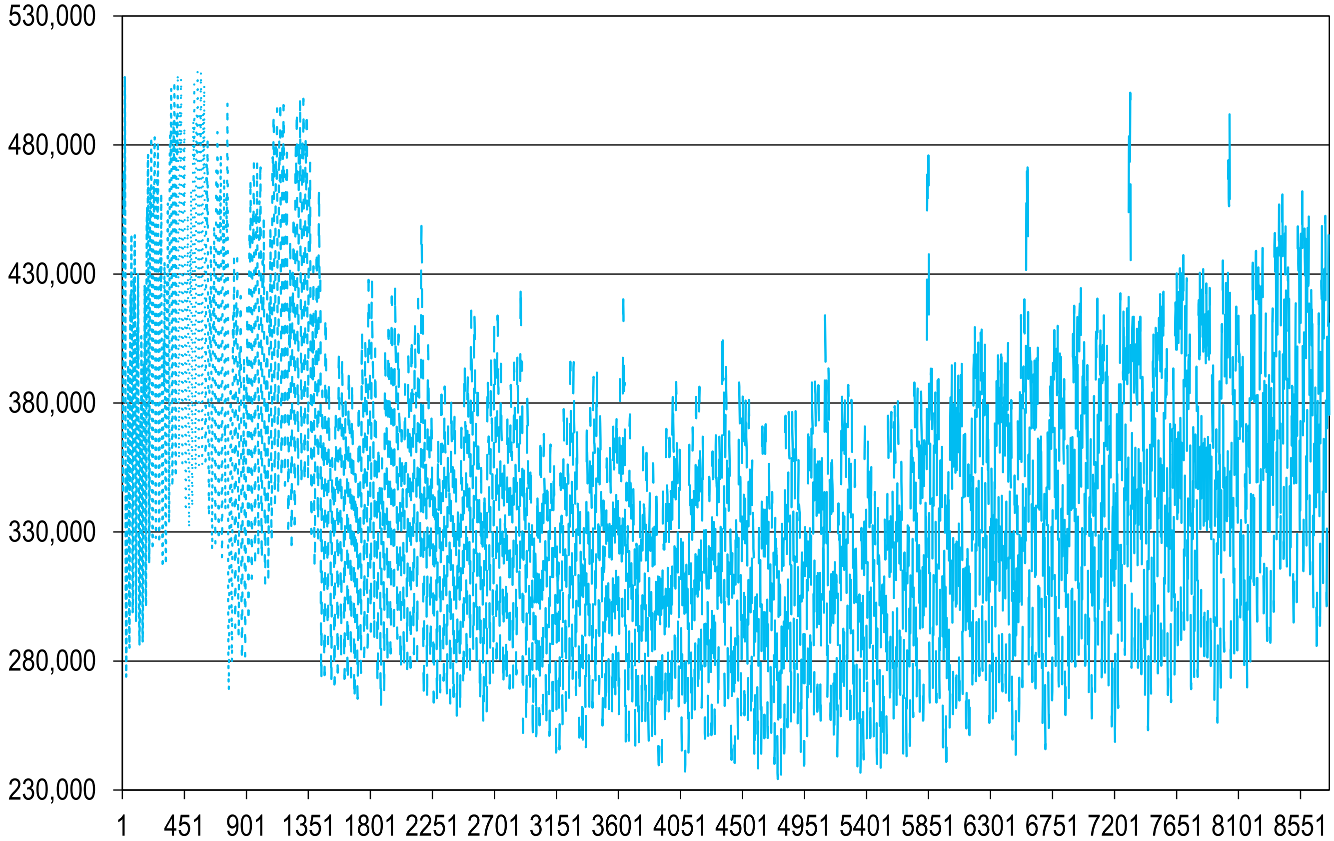
It becomes clear that assuming 90% availability for conventional generation and 25% availability for renewables, demand requirements should be well covered throughout the coming 15 years. Even if we drop the availability for renewables and hydro to 20% (historical data point to availability of offshore wind of more than 40%, onshore wind of ~20% and solar of ~13%), the demand-supply balance remains robust.

We see Pan-European demand-supply as well balanced in the next 10-15 years, but the timing of demand needs with supply availability as increasingly divergent as renewables penetration grows.

The issue, however, is matching the timing of the demand requirements with the timing of power generation availability.

Figure 7 takes another look at the pattern of the electricity demand, this time focusing on the seasonal variations. The winter peaks (first 1,300 hours of the year, i.e. ~2 months) and the summer troughs (hour 3,600 to 5,850, i.e. May through August) become very clear.

Figure 7. Pan-European electricity load in MW (y-axis) through the course of the year (in hours on the x-axis)



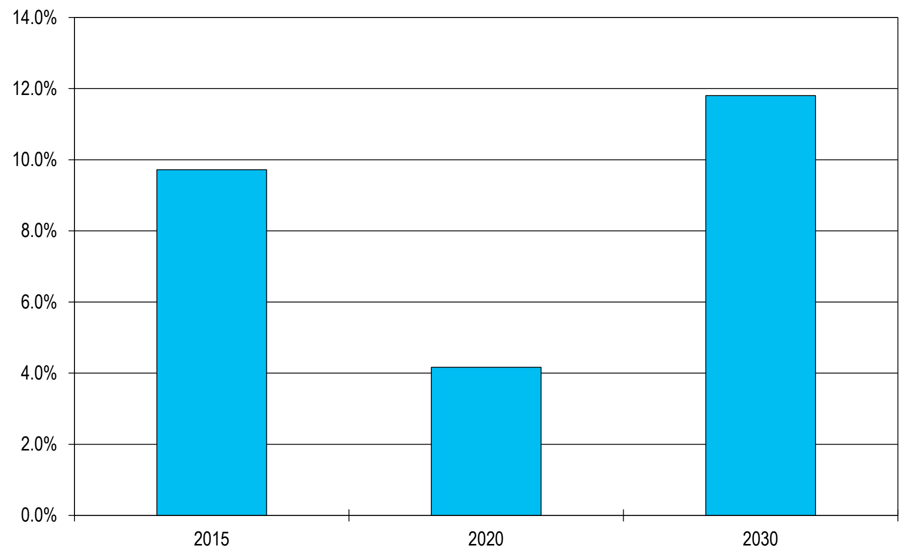
Source: ENTSOE-E, Citi Research

Looking at these timing variations of the demand load during the year and taking into consideration the availability of each type of plant depending on the time of day and season of the year, we can then estimate the residual load, i.e. the portion of the demand in MW that is left uncovered once 'must run' (wind, solar and some types of cogen or hydro) or 'inflexible' plants (nuclear, lignite) are utilized to their maximum availability. The effects of the growing penetration of renewables over time are evident in Figure 8, in the following page.

During spring/summer months and in mid-morning/early afternoon we see growing risk of excess capacity from renewables that cannot be absorbed even in a fully interconnected system across Europe.

Already by 2015 we expect to be seeing negative residual load – i.e. excess production from renewables and other 'must run' or 'inflexible' technologies over and above demand requirements and before any production from coal or gas plants – almost 10% of time. By 2020E, that portion temporarily declines as planned closures of nuclear plants (Germany, France, Belgium), and an assumed slow pace of installations of offshore wind, balance the market somewhat better. However, by 2030E the increased penetration of renewables, and the assumption that no other nuclear plants are shut down prematurely, leads to an increase in the portion of the time that Europe experiences negative residual load to almost 12%.

Figure 8. Portion of the time of negative residual load (i.e. 'must run' and 'inflexible' technologies have covered 100 % of demand without coal and gas plants running)



Source: Citi Research estimates

One crucial assumption in our analysis is that Europe is fully interconnected. This means we examine all of Europe as one system and therefore excess renewable capacity in any country is assumed to be able to flow to wherever the demand is before it is considered excess (i.e. negative residual load) in our own analysis.

Infrastructure bottlenecks and local/national attitudes to security of supply could exaggerate storage demand beyond a base case level.

In reality, substantial bottlenecks exist not only between countries but also within countries (e.g. the North-South corridors within Italy and Germany and interconnectivity between the Balkans and Central Europe and Iberia with Central Europe). Moreover, production times of renewables are highly correlated across neighbouring countries and therefore grid congestion at the time that such power exchanges are needed is very likely. If we were to consider these bottlenecks and look at Europe as a sum of regional power markets rather than a copperplate, then the amount of excess load and therefore storage requirement would be even higher.

We therefore see scope for battery storage to come into the European electricity system to cover for the amount of excess renewable generation that, even with 100% interconnection across the region, would otherwise have to be curtailed. Assuming no curtailment of renewables, we estimate 18GW of storage capacity will be needed by 2020 and 44GW by 2030, which, on the assumption of 7 hours' worth of output in the storage unit per day, translates to 126GWh for 2020 and 308GWh for 2030 on daily demand.

We note that in an analysis by DIW (German Institute for Economic Research) in 2013 "Residual Load, Renewable Surplus Generation and Storage Requirements in Germany" the authors found that, under a scenario of 1% curtailment for renewables during excess production times, with 23% of conventional generation as inflexible (similar to the assumption we made in our own analysis) and assuming no interconnections, Germany alone by 2032 would need 40GW of storage capacity. On our estimates, by 2030 Germany should have close to 25GW of export capacity, which suggests that 15GW of storage capacity would be potentially required.

If we therefore take into consideration these restrictions in the flow of electricity, we derive 73GW of storage requirement by 2030E across Europe or 511GWh in daily demand.

Larger curtailment of renewables output could eliminate the need for storage in the next 5 years, although that could be environmentally sub-optimal.

There is also the option that grid operators and regulators might opt for the curtailment of renewable output at times of excess production. Generally that would be unwelcome as it would go counter to the raison d'etre of renewables. As by default renewable production is intermittent, curtailing it during its maximum potential would not only reduce its ability to contribute towards environmental targets but would also be costly (renewable operators would have to be paid for forgoing production). For example, in a 2013 report on electricity trends in the coming decade, the Institute of Energy Economics at the University of Cologne estimated that curtailment of renewables in Germany could rise to 8TWh p.a. by 2022 – i.e. a full 100bps reduction in the load factor. Our analysis assumes that curtailment trends do not change from current levels.

Our analysis points to the months of March and June as likely to face material excess supply due to patterns in production by wind and solar as well as demand trends. Nevertheless most of these excesses have durations of hours or days rather than weeks or months. **Therefore when considering battery technologies, within the next 15 years we see much higher requirements for short-term charge and discharge cycles than longer-term needs**. If offshore wind installations or conventional generation shutdowns outpace our expectations, we could see requirements for longer-term storage as well.

Ancillary Services

Beyond capacity requirements, storage can be used for ancillary services such as frequency regulation and balancing. In simple terms, such services are used to reconcile temporary differences lasting seconds or minutes caused by fluctuations in generation and loads. In traditional power systems, power generation units stand ready to increase or decrease output to dampen these fluctuations. Growing penetration of renewables is likely to increase these fluctuations. Large-scale thermal plants that participate in such balancing services suffer wear and tear. Battery storage can be used to address these issues.

Battery storage solutions increasingly considered more suitable than conventional generation for the provision of ancillary services.

For example in a 2011 report prepared by the California Energy Commission it was stated that "the use of energy storage technology has the capability to be faster than regulation by a gas or stream turbine. This faster response time can minimize momentary electricity interruptions, particularly at the distribution level, which are more costly than sustained interruptions."

Currently frequency regulation services are about 2.5% of peak load. Given the expected growth in renewables by 2020 we would expect that figure to be closer to 5.5% by that time and closer to 9% by 2030. That would effectively mean a 17GW increase by 2020 and a further 22GW increase by 2030. If we assume that 10% of the increase by 2020E and 80% of the increase by 2030E will be provided by battery systems (the rest by more intense utilization of current methods) that points to a market for battery storage of ~2GW by 2020 and 19GW by 2030. Assuming 4-hour utilization, that would imply 8GWh and 86GWh of storage demand by 2020 and 2030, respectively.

Growth in penetration of electric vehicles could cover the demand for ancillary services to be provided by battery storage.

According to the EU 2013 Reference Scenario, by 2020 around 1% of the car stock in Europe will be electric vehicles (a further 8% will be hybrids), with a rapid rise to 4% by 2030 (a further 25% will be hybrids). Using similar assumptions to those employed by the IEA in its 2009 report on the "Prospects for Large-Scale Energy Storage in Decarbonised Grids", we derive about 72GWh of available daily energy for storage by 2030E, implying scope to cover the entire requirements for ancillary services in the European grid (assuming full interconnectivity and proportional distribution of electric vehicles to the energy demand centers), on our estimates.

Figure 9. Potential storage requirements in Europe in GW for capacity and ancillary services usage

	Assuming full interconnection of Europe	Assuming only planned interconnections	Assuming 1% annual demand reduction through efficiency
2020E	20	37	39
2030E	63	92	121

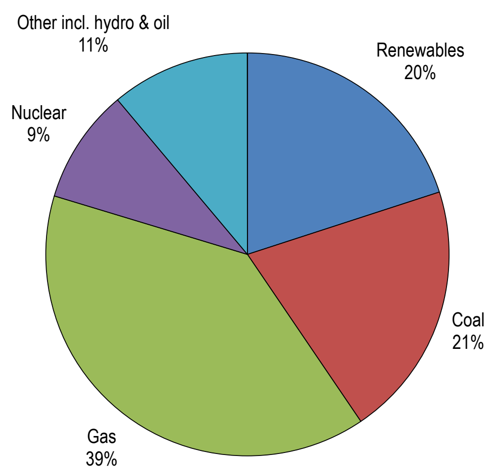
Source: Citi Research estimates

Potential in the N. American Electricity System

We estimate that overall nameplate capacity in the US will rise modestly from 1,090GW in the end of 2013 to 1,115GW by 2020. Within that, however, the contribution from renewables (wind and solar) should rise from 5% to 13.5% as particularly coal plants and less so nuclear and gas lose market share. By 2030 we forecast renewables (excl. hydro) to rise to 20% of US power generation capacity. This is a bit more aggressive than the EIA 2014 Energy Outlook, which calls for renewables to be 17% of US generation capacity by 2030 under its reference case. Adding also Canada, Figure 10 below shows our expectations for the North American fuel mix by 2030.

In a 2010 report prepared by Sandia National Laboratories for the US DOE Energy Storage Systems Program, each possible application of electricity storage is analysed for its maximum potential. The highest potential is identified in the areas of time-of-use energy costs management, transmission congestion relief, load following and renewables energy time-shift and capacity firming.

Figure 10. Generation capacity mix, 2030



Source: Citi Research estimates

There is, however, substantial overlap between each potential application for electricity storage; for example, transmission congestion in the future could well be driven by increased penetration of renewables, both of which issues could be addressed with electricity storage systems. Therefore, summing the potential for each application would give us an exaggerated figure for the size of the storage market in North America. Moreover, individual states in the US have their own electricity systems, which have different rules (e.g. capacity vs. energy markets), targets (e.g. renewables penetration), demand profiles (e.g. residential vs. industrial usage) and generation mixes.

We see the most – non-overlapping – potential in transmission support and renewables integration. Combined, we estimate market potential of 47GW for energy storage requirements by 2030. This is towards the top end of the 30-55GW range that the IEA estimated for 2050 in its "Prospects for Large-Scale Energy Storage in Dacarbonised Power Grids" working paper in 2009, but we think the faster penetration of renewables since then justifies that increase. Furthermore, the IEA report was focusing solely on storage as a method of renewables integration.

On our numbers, 22GW of those storage needs can be covered by the existing hydro pumped storage capacity, leaving 25GW or 173GWh of daily storage needs (assuming 7 hours' utilization) that could be addressed by battery systems by 2030E.

Case Study: California

CA regulatory move to spur batter storage could set precedent in other US states.

In the second half of 2013 the California Public Utilities Commissions issued a final decision under which the three utilities Southern California Edison (SCE), San Diego Gas & Electric and Pacific Gas & Electric (PCG) are expected by 2024 to have contracted for 1.325GW of energy storage for their operations with specific interim annual targets. The proposed targets increase by 30-55% every two years. The first solicitation for new energy storage capacity will be required to occur no later than December 1st 2014. California was the first state in the US to issue such a mandate.

The energy storage mandate represents 2% of the existing generating capacity in California and 22% of the current installed renewables base in the state. An analogous storage mandate across the entire North America would translate to about 20GW of new energy storage procurement by 2020, with further growth required through 2030 to address further penetration of renewables.

Both SCE and PCG have 90MW December 2014 targets. SCE estimated that existing storage and prior RFO storage will account for ~74MW of its target. PCG proposed that 12MW of its existing storage, which consists primarily of 8.5MW of battery pilots and other storage at the distribution level and 3.5MW of storage at the customer level, be included. We do not expect hydro storage to be included in this procurement cycle. Under the CPUC decision, utilities will be allowed to own 50% of the total target. As a result, CA utilities propose to own transmission and distribution reliability-related storage project which may be built by a third party and subsequently purchased by utilities and put into the rate base. Third parties may own storage providing wholesale market products.

Potential in the Japanese Electricity System

We forecast 150GWh in storage battery demand in FY3/31.

We forecast 150GWh of demand for storage batteries in Japan's electric power industry in FY3/31. There are two key applications for storage batteries: 1) to deal with transmission capacity that exceeds interconnectable capacity and 2) to adjust for long and short frequency volatility. We forecast 90GWh of demand for the former and 60GWh for the latter.

Lack of interconnectable capacity on expansion in solar resulting from FiTs.

Installation of renewable energy sources has been given a push by Japan's feed-in tariff (FiT) system and we forecast solar power generation capacity of 68.3GW and wind power capacity of 11.3GW in FY3/31. However, we envisage interconnectable capacity of 55.4GW for solar and 19.2GW for wind and hence expect demand for storage batteries to emerge to fill the transmission capacity shortfall in solar.

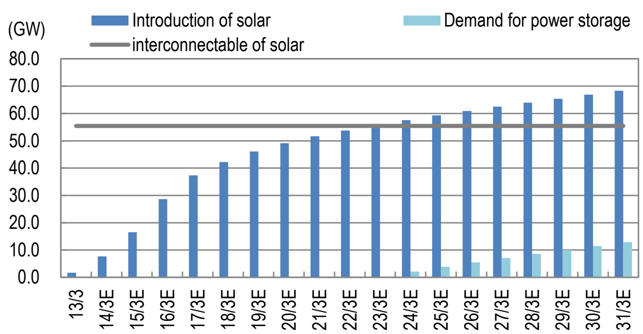
We forecast 90GWh of demand for storage batteries on the solar interconnectable shortfall.

We estimate storage battery demand from surplus power volume in May, which is an off-peak demand month for electric power and when surplus power is likely to be at its maximum owing to the increase in solar power generation capacity. According to calculations made in 2008 by the Ministry of Economy, Trade, and Industry, if output is not reined in, then May interconnectable capacity is around 20GW. We think, however, that it is above 20GW, as 1) the hypothesis dates from 2008 and usage of interconnections between power companies is likely to have grown, and 2) we think power companies are budgeting conservatively for interconnectable volume. Based on announcements of interconnectable solar capacity by Kyushu Electric (6.0GW, about 35% of actual supply capacity) and Hokkaido Electric (0.7GW, 14%), we estimate interconnectable capacity at 55.4GW (about 32% of total Japanese supply capacity). Given the above, we forecast that storage battery demand will emerge from FY3/23 and that it will reach around 90GWh in FY3/31 (we assume that storage battery will need seven hours' worth of output).

Not expecting wind power output to exceed interconnectable capacity.

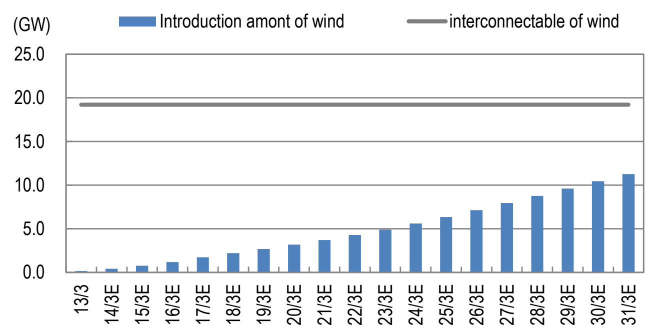
We have run similar estimates for wind interconnectable capacity as for solar; we estimate 19.2GW (around 11% of Japan's total power generation facility capacity). We are forecasting wind power installed capacity of 11.3GW in FY3/31 and do not therefore expect wind power to create demand for storage batteries.

Figure 11. Solar installed capacity, interconnectable capacity, and storage battery demand



Source: Ministry of Economy, Trade & Industry of Japan, Citi Research estimates

Figure 12. Wind installed capacity and interconnectable capacity



Source: Ministry of Economy, Trade & Industry of Japan, Citi Research estimates

Anticipating around 60GWh in demand for frequency volatility

We expect much of the storage battery capacity necessary for frequency volatility to be covered by EVs and zero-energy buildings. Based on the outlooks from the government and private-sector bodies, we estimate storage battery capacity from EVs and zero-emission buildings at 120GWh in 2030. We also envisage daily solar and wind power generation at 220GWh (assuming a load factor of 16% for solar and 20% for wind power). We estimate that storage capacity equivalent to approximately 80% of daily power volume will be required for frequency volatility. As a result, we estimate that 60GWh of storage battery capacity will be needed to cover the shortfall.

Expansion in interregional connectivity and the degree of early adoption of storage batteries by Hokkaido Electric and Kyushu Electric could affect our forecasts.

We can see two factors that could affect our forecasts: 1) growth in interconnectable capacity on expansion in interregional connectivity; and 2) the possible expansion in storage battery demand at Hokkaido Electric and Kyushu Electric. On Japan's main island of Honshu, where the two major demand centers of Tokyo and Kansai are located, interconnectable capacity could expand, depending on the management of interregional connectivity, and demand for storage batteries could fall short of our expectations. Also, Hokkaido Electric and Kyushu Electric, which have taken the lead in applying for permits for and bringing in renewable energy, could turn more proactive on bringing in storage batteries. Both firms already have solar facility capacity — if we include projects for which permits have been applied — that

exceed their interconnectable capacity. We see little chance that all projects for which permits have been applied will end up built, but both firms could be quicker than we envisage to bring in storage batteries, depending on how they respond to the interconnectable capacity issue.

Figure 13. Japan's electric power companies: Renewable energy capacity, applied-for capacity, and interconnectable capacity (as of December 2013)

(GW)	Tokyo	Chubu	Kansai	Chugoku	Hokuriku	Tohoku	Shikoku	Kyushu	Hokkaido	Total
Solar installation	2.89	2.10	1.45	1.00	0.19	0.67	0.63	2.58	0.18	11.7
Solar applications	-	-	-	4.65	-	2.76	1.27	3.83	1.94	-
Interconnectable solar	19.6	9.50	10.4	2.90	0.90	4.50	0.90	6.00	0.70	55.4
Wind installation	0.37	0.20	-	0.30	0.14	0.61	0.16	0.43	0.32	-
Wind applications	-	-	-	0.23	-	-	0.24	0.28	0.11	-
Interconnectable wind	6.70	3.30	3.60	1.00	0.45	2.00	0.60	1.00	0.56	19.2
Total interconnectable	26.3	12.8	14.0	3.90	1.35	6.50	1.50	7.00	1.26	74.6

Note: Our estimates for solar and wind interconnectable capacity for Tokyo Electric, Chubu Electric, and Kansai Electric and for solar interconnectable capacity for Chugoku Electric, Hokuriku Electric, Tohoku Electric, and Shikoku Electric.
Source: Company data, Citi Research

Potential in Emerging Markets

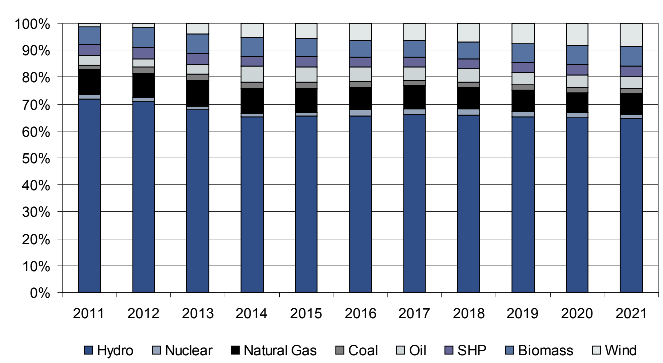
Brazil

Smart grid projects are at an incipient stage, solar remains expensive, regulation is well behind: we think it is too early for Brazil to offer scope to unlock the potential of battery storage.

Brazil has a unique positioning in the world with its hydro-based generation capacity. Approximately 73% of its installed capacity is based on hydropower sources. The 2013-2030 Brazilian expansion plan focuses on renewables (hydro/wind/biomass), as shown in Figure 14. Given its current economics, solar has not yet been considered an important source for the expansion of the power matrix.

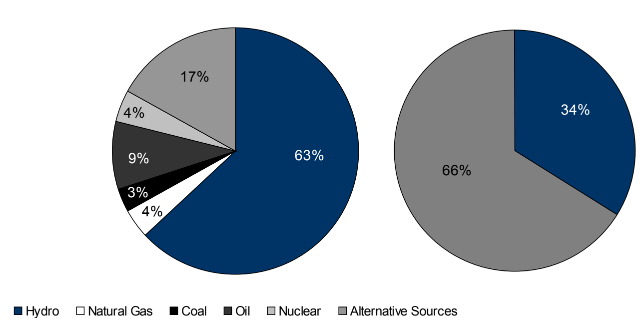
Although Brazil has large untapped hydro potential (19.9GW planned through 2018-2022, or 15% of existing capacity; Brazil explores 30% of its total potential), the country has been building only run-of-river plants since the early 2000s and storage capacity has remained almost flattish since then. Due to the drought faced in 2013-2014, we expect discussions over the relevance of reservoir plants in the system's expansion to gain momentum.

Figure 14. Installed capacity evolution



Source: EPE (Energy Research Bureau), Citi Research estimates

Figure 15. Installed capacity matrix expansion – contracted (left) and expansion (right) 2013-2020



Source: EPE, Citi Research estimates

With base load largely served by hydropower generation, the marginal cost of storing power in a normal hydrology scenario should be prohibitive. In a normal hydrology environment, hydropower generation can address 90% of the demand (59GWa). Existing reservoirs can serve six months of current power demand in a weak hydrology scenario. Although Brazil is currently under a severe drought; hydropower output still accounts for 76% of expected 2014 demand. Additionally, Brazil has invested in thermal generation capacity in recent years. Thermal capacity stands at 17 GW.

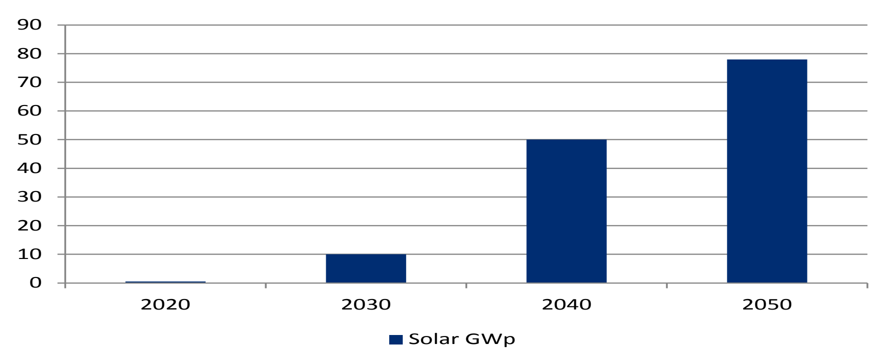
Battery storage would only be economical if power could be stored for months in order to displace instant hydropower and thermal generation in dry months as opposed to the daily and/or weekly charge-discharge cycles more likely needed in developed market. Grid stabilization, another possible use for battery systems, is currently being effected by low-cost hydro generation, with some backup turbines used as spinning reserve (usually 5 GW, or c.3-5% of peak demand).

An upgrade of the existing grid (smart grid) and increased use of distributed generation (solar) would certainly foster the use of battery storage. The implementation of a smart grid has been long discussed in Brazil. However, so far, very few initiatives are being developed by local distributors. The main focus of the grid upgrade would be to lower losses in power distribution (currently high at 14.1%) and to give consumers flexibility on the use of energy, by enabling bidirectional power flows and development of distributed/on-site generation (mainly solar). By enabling two-way power flows, consumers could sell power to the grid and regulators could implement net metering/net billing pricing schemes. However, regulation is still incipient. The main issue remains the economics of the on-site generation and the impacts on regulated tariffs.

Low-cost hydro generation means that renewables system costs need to fall even further before becoming economic.

According to recent studies published in Brazil, solar capex ranges between US$1.800/kW and US$2.700/kW. Given the low load factor (18.5%), taxes and required returns, the implied levelized price of solar generation would range between R$400/MWh (for centralized, large-scale production) and R$650/MWh (for residential use). Few distribution companies have end-user tariffs above this level. Therefore at current costs, we believe the market for solar would need to be incentivized to create enough demand. That could happen though subsidized financing, tax breaks, long-term capacity contracts (regulated contracts), feed-in tariff schemes and lower toll charges. Recently, the Energy Research Bureau (EPE) launched a study forecasting solar source could reach grid parity by 2022, boosting investments by residential consumers. The EPE estimates solar could reach 78GW by 2050 (5.7% of the country's expected installed capacity). However, this would not necessarily translate into growth of battery usage since the plans for the Brazilian smart grid focus on instant injection of excess generation into the grid.

Figure 16. Solar – EPE's estimate for installed capacity



Source: EPE, Citi Research

Nonetheless, solar still seems to us a distant reality in spite of a sharp decrease in manufacturing costs in recent times. In the last regulated market auction, the average winning bids stood at R$112/MWh, with wind farms selling most of the power required by the pool. That said, it would likely take years for solar to displace the cheapest source available today (some experts estimate ten years for solar to challenge wind power prices). However, under capacity agreement and given its low variance in power output, solar seems to be close to displacing other fossil-fuel-fired sources (we estimate prices need to be around R$240-400/MWh for this source to become competitive).

The absence of feed-in schemes is a deterrent. Authorities have been recently discussing the role of solar in expansion of the power matrix. There are indications that the government could consider setting up a specific auction for solar in the near future, in order to create enough demand to unlock the potential of the power source in the country. Centralized solar generation is only likely to be competitive if the correct incentives are put in place (contracting framework, financing, tax breaks, lower tolls, other incentives).

Electric cars – no relevant production and use in Brazil.

Brazil has no relevant production and use of electric cars, nor does the country have an incentive program in place. Some power distribution companies have pilot experiences with electric vehicles but the market is really small (less than 0.01% of new vehicles in Brazil use electric power). There have been discussions on the granting of tax breaks (especially IPI) to encourage consumption, but thus far no meaningful move has been made.

Figure 17. Licensing cars in Brazil

	2011	2012	2013	Until Mar-2014
Gas	376,798	273,913	189,112	45,098
Electric*	200	117	491	219
Flex	2,848,122	3,162,874	3,169,111	682,859
Diesel	200,622	197,215	221,189	47,180

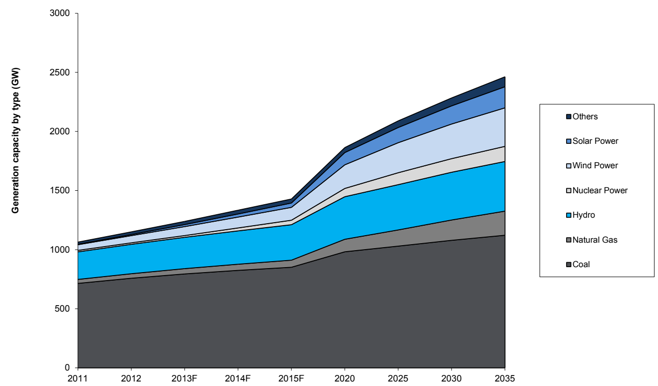
*Hybrid Cars Source: ANFAVEA, Citi Research

China

China is set to add about 1,200GW of generation capacity by 2030E. Although coal will remain the single biggest fuel source for power generation in the country, hydro, renewables and nuclear are set to grow their market share. Just for solar, the government in the latest Air Pollution Prevention Plan raised the installation target to 70GW by 2017 vs 20GW installed today. For 2014 the target is 8GW of rooftop / distributed solar and 6GW of utility-scale solar. That said, in H1 14 distributed solar installations alone stood at 1GW, which, although below the target run-rate, is more than FY13 installations combined. Households can earn as much as CNY0.9/kWh if they produce electricity with rooftop solar and sell it to the grid.

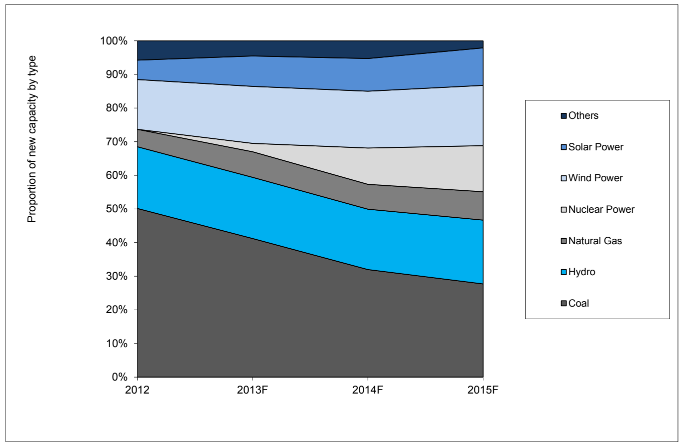
We therefore expect coal will fall from >50% of new capacity additions at the start of this decade to well below 30% by 2020. Formulation of the country's 13th 5-year plan (2016-20) started only recently but there has already been extensive press speculation on possible coal or emissions caps. Overall we would expect, much like the 12th plan, climate-friendly considerations to be maintained and extended.

Figure 18. China - Generation capacity by type (GW)



Source: BP Statistical Review.

Figure 19. China - New generation capacity by type (GW)



Source: BP Statistical Review.

China already has about 16GW of pumped hydro storage, and another ~10GW under construction, and plans to bring the total number to 50GW by 2020. At the same time, together with Japan, it is funding $200m in flow battery projects and as far back as 2012 it claimed the largest energy storage station in the world, in the 36MW grid storage facility in Zhangbei.

The International Energy Agency, in a working paper dating 2009, estimated China's energy storage needs (including pumped hydro) in the range of 60-120GW by 2050. Given the acceleration seen in renewables penetration, we see scope for the upper end of this range to move even higher. Wind curtailment is already necessary at high percentages (30% occasionally) in regions of the country due to subscale interconnectivity of the grid.

As opposed to Europe and the US, where a large portion of battery storage will most likely be associated with solar and EVs, in China there is significant need for grid-scale batteries more closely associated with wind variations.

We believe the Chinese battery storage market has the potential to become the largest in the world, although more focus will likely be placed on it in the 2021-25 National Plan rather than the 2016-20 National Plan.

Storage Batteries: A Third Growth Market

Equity Research Technology Team

Huge potential as the third major application for rechargeable batteries.

We believe storage batteries will be the third major driver of demand for rechargeable batteries after the consumer electronics and auto battery markets. Storage batteries are being incorporated into renewable energy systems and smart grids. In Japan, power shortages became a serious national issue after the March 2011 disaster and interest in storage battery systems as a way of stabilizing power supply is increasing. The market for storage batteries is still embryonic and unlikely to affect investment behaviour any time soon, given its small size. However, the long-term potential is substantial, in our view, and as the market gathers real momentum we expect large benefits for related companies. In this section, we provide an overview of the supply side — the battery market.

What Characteristics Do Power Storage Batteries Need?

Five key battery specs: energy density, power density, lifespan, safety, cost.

The viability of rechargeable batteries is determined by five specs: energy density, power density, lifespan, safety, and cost. The importance of each differs depending on the purpose for which the battery is used. The small and light batteries used in smartphones, tablets, and other mobile devices must have high energy density and be inexpensive. Batteries used in EVs and HEVs, in contrast, must meet exacting standards in all five categories: high energy density, to allow a practical travel distance before recharging is necessary, high power density to accelerate a vehicle, safety to avoid the risk of combustion, a lifespan of years to make them practical for vehicles, and low cost to facilitate EV/HEV market penetration.

Storage batteries must be cost-efficient, have long lifespans, and be safe.

For storage batteries, cost, lifespan, and safety are the most important specs. The volume of electricity generated by solar power and wind power systems fluctuates because of the vagaries of the weather. Storage batteries used in these power systems must be able to cope with minute changes in power output. Also, it is assumed that storage batteries will be used for many years as part of the industrial infrastructure, and as such they must have longer lifespans than consumer electronics and auto batteries. Safety is also non-negotiable as fires could potentially cause significant damage to power grid infrastructure and large-scale outages. Energy density and power density are not so important.

Which Rechargeable Battery Technology Is Best Suited to Storage Batteries?

What is the most promising rechargeable battery technology for storage batteries?

Lead-acid, lithium-ion, sodium-sulfur (NAS), and redox flow batteries are rechargeable batteries that can be used for energy storage (Figure 20). We believe lithium-ion and redox flow batteries are the leading candidates to become mainstay storage batteries.

Lead-acid batteries are widely used as industrial-use storage batteries.

Currently, lead-acid batteries are widely used by industry as storage batteries: in offices, factories, and base-stations as backup power sources or during cuts to consumption at peak demand periods. But lead-acid batteries place a heavy burden on the environment, while their cost is unlikely to decline significantly as the technology is mature, and charging/discharging is slow. Different battery technology is needed for power system storage batteries.

Lithium-ion batteries are probably the best option.

Lithium-ion batteries are probably the best option, in our view. Depending on the materials used, they can have long lifespans, be extremely safe, and cope with small changes in power output. We believe lithium-ion batteries are the technology most likely to be used for storage batteries because a certain level of production knowhow and cost competitiveness has already been acquired in the development of consumer electronics and auto batteries and they can easily be adapted for various applications. We see potential for lithium-ion batteries to be developed for office and residential use because of their compactness and simplicity.

Interest centres on iron-based materials for positive electrodes and lithium titanate for negative electrodes.

A feature of lithium-ion batteries is that various types of materials can be used for positive (cathode) and negative (anode) electrodes (Figures 21-22). Battery specs can be adjusted by using different combinations of materials. Normally, consumer electronics batteries use cobalt-based or ternary-compound cathode materials for and graphite or silicon-based anode materials. Auto batteries mainly use manganese or ternary-compound cathode materials and graphite anode materials.

As storage batteries must have long lifespans and be extremely safe, iron-based materials and lithium titanate are attracting interest as cathode and anode materials, respectively. These materials are not suitable for consumer electronics and auto batteries because they have low energy density. However, stable molecular structures mean that a long life and safety can be assured, making them ideal for storage batteries. Toshiba's super-charge ion battery (SCiB) has an operational life of more than 10,000 charge-discharge cycles. Also, there have been reports of batteries that use iron-based cathode materials and lithium titanate anode materials achieving more than 30,000 charge-discharge cycles in lab tests.

Redox flow another technology attracting interest.

Redox flow batteries are gaining attention as a next-generation technology. These batteries store energy through chemical reduction and oxidation reactions between vanadium ions with different oxidation states. The ions are contained in vanadium sulphate electrolyte solutions stored in separate tanks. There is no risk of combustion, the batteries have a life of more than 10,000 charge-discharge cycles, and battery capacity can easily be raised by increasing the size of the electrolyte tanks. On this basis, we believe they will be suitable for large-scale energy storage infrastructure used in electricity grids.

Combustion risk an issue for NAS batteries.

NAS batteries are used mainly in large energy storage facilities. They are charged or discharged through a chemical reaction between sulfur and sodium. NAS batteries have high energy efficiency, being only one-third the size of lead-acid batteries, and also a long life. However, they must be kept at 300°C and combustion is a risk.

Figure 20. Comparison of major storage device technologies: Lithium-ion batteries offer high voltages and storage densities

Battery type	Lithium ion	Nickel Hydrogen	Nickel Cadmium	Lead Acid	NAS	Redox Flow	EDLC	Lithium ion Capacitor
Discharge potential (V)	2.4-3.8	1.2	1.2V	2.1	2.08	1.4	0-3	2.2-3.8
Power density (W/kg)	400-4,000	150-2,000	100-200	100-200	-	-	1,000-5,000	1,000-5,000
Energy density (Wh/kg)	120-200	70	50	35	100	30	2-20	10-40
Cycle life (times)	500-6,000	500-1,000	500-1,000	500-5,000	4,500	10,000>	50,000>	50,000>
Charging efficiency	95%	85%	85%	80%	75-85%	80%	95%	95%
Cost	Poor	Good	Good	Excellent	Poor	Poor	Very poor	Very poor
Safety	Poor	Excellent	Good	Good	Very poor	Excellent	Excellent	Excellent
Cathode material	Lithium compounds	Nickel hydroxide	Nickel hydroxide	Lead oxide	Sulfur	Carbon	NA	NA
Anode material	Graphite	Hydrogen storing alloy	Cadmium hydroxide	Lead	Sodium	Carbon	NA	NA
Electrolyte	Organic solvent lithium salt	Potassium hydroxide solution	Potassium hydroxide solution	Dilute sulfuric acid	βAlumina	Vanadium sulfate solution	NA	NA
Characters	Risk of combustion	Self-discharge Memory effect	Memory effect Cadmium is toxic	Easily deteriorated Lead is toxic	Operation at 300°C Risk of combustion	Pump circulation Vanadium is toxic	Good power density Self-discharge	Good power density Self-discharge

Source: Company data, Citi Research

Figure 21. Comparison of main cathode material technologies

Cathode Material	LFP	LMO	LCO	LNO	Ternary compounds
Material	$LiFePO_4$	$LiMn_2O_4$	$LiCoO_2$	$LiNiO_2$	$LiNi_xMn_yCo_zO_2$
Discharge potential (V)	3.4	3.8	3.7	3.6	Depending on input ratio
Current capacity (Ah/Kg)	160	120	150	180	Same as above
Energy density by weight (Wh/Kg)	544	456	555	648	Same as above
Energy density by volume (Wh/L)	1,953	1,915	2,831	3,110	Same as above
Crystal Structure	Olivine structure	Spinel structure	Layer structure	Layer structure	Same as above
Natural resources (Kton)	Unlimited	6,800	960	4,600	Same as above
Cost	Material cost is low carbon coating	Cost of manganese is low	Cost of cobalt is high	Cost of nickel is expensive	Same as above
Life cycle	Excellent	Good	Poor	Poor	Same as above
	Maintaining long cycle life	Good cycle life. Degradation under high temperatures	Short cycle life	High output reduces capacity and ultimately output	Same as above
Safety	Small combustion risk	Small combustion risk	Risk of combustion	Risk of combustion	Same as above
Application	Automobile Industry	Automobile Industry	Consumer	Consumer	Automobile Consumer
Main supplier	Sumitomo Osaka Cement, Mitsui Zosen, Chinese makers etc	Toda Kogyo, Nippon Denko, Mitsui Kinzoku, Chinese makers, etc	Nichia, Tanaka Chemical, Nippon Chemical Industries, AGC Seimi Chemical, L&F, Umicore, Chinese makers, etc	Toda Kogyo, Tanaka Chemical, AGC Seimi Chemical, etc	Nichia, Mitsubishi Chemical, Tanaka Chemical, Toda Kogyo, L&F, Umicore, Chinese makers, etc

Source: Company data, Citi Research

Figure 22. Comparison of main anode material technologies

Anode material	Hard Carbon	MCMB	Natural Graphite	Artificial Graphite	LTO	Silicon
Discharge potential (V)	0.2-0.4	0.2	0.2	0.2	1.5	0.2
Energy density by weight (Wh/Kg)	400-800	372	372	372	175	4,007
Energy density by volume (Wh/L)	Less than graphite	840	840	840	500弱	9,336
Crystal structure	Amorphia	Layer structure	Layer structure	Layer structure	Spinel structure	Layer structure
Chemical reaction	Interstitial reaction	Intercalation	Intercalation	Intercalation	Intercalation	Intercalation
Cost	Good	Good	Excellent	Good	Poor	Poor
Characters	Electrical potential tends to be lower	Middle range between artificial and natural graphite	Low cost structure	Good output characteristics	Higher safety Long life span	Next generation material
Application	Automobile	Middle-end in consumer	Low-end in consumer Automobile	High-end in consumer	Automobile Industry	High-end in consumer
Main supplier	Kureha	JFE Chemical, BTR, ShanShan Tech, etc	Hitachi Chemical, Mitsubishi Chemical, Nippon Carbon, BTR ShanShan Tech, etc	Hitachi Chemical, BTR, ShanShan Tech, etc	Titan Kogyo	Mitsui Chemical

Source: Company data, Citi Research

Will Storage Batteries Be Cost-Effective?

Drastic cost cuts needed.

Cost is the biggest obstacle to the spread of storage batteries. The cost of rechargeable batteries for energy storage would have to be reduced drastically for the storage battery market to gain real momentum. In 2012, Tohoku Electric ordered a storage battery system from Toshiba for a pilot project. The battery system has storage capacity of around 20MWh and the order was worth around ¥10bn (~$90m). Based on this, we estimate the grid-introduction cost for storage battery systems at ¥500,000/kWh (around $5,000/kWh). This is 20x higher than the cost of pumped storage hydroelectricity (PSH). Many Japanese electronics makers sell residential-use storage batteries, but most products cost more than $1,000/kWh, still a long way from a mass-market product price.

PSH grid cost of $230/kWh a future target for storage batteries.

We consider the PSH grid cost of $230/kWh as a future target for storage batteries to be a viable industrial infrastructure. PSH stores energy by drawing water from reservoirs to a higher elevation, using night-time surplus power (off-peak electricity) to drive the pumps. In this sense, PSH can be described as a storage battery system that uses a dam. At this time PSH is the only energy storage method capable of providing enough capacity suitable for grid use. However, dams must be built to provide the reservoir of water needed, and locations and environmental destruction are major issues. If storage battery costs can be reduced to below $230/kWh, we believe demand for storage batteries as grid surplus power storage infrastructure could expand.

Consumer electronics/auto battery cost trends.

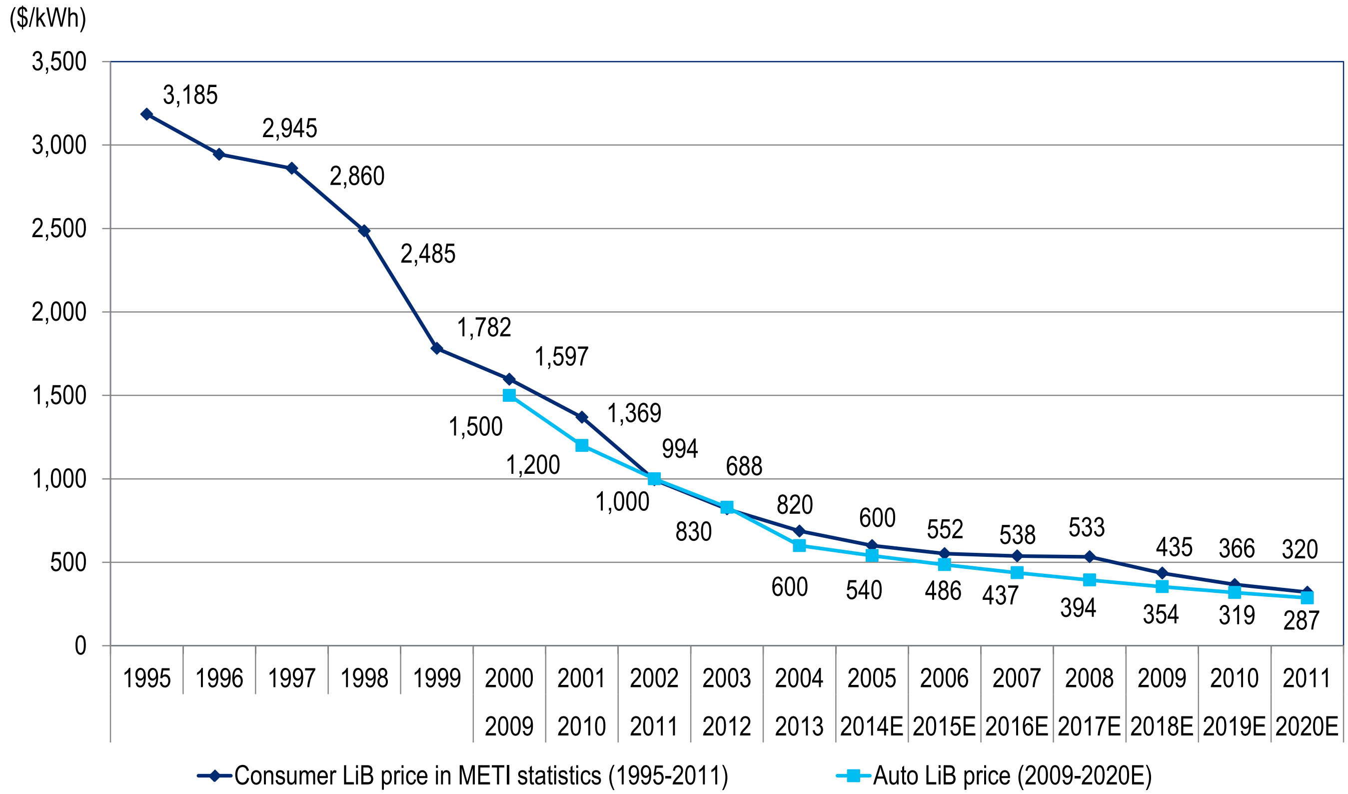
Consumer electronics and auto battery price trends are a useful reference when analyzing storage battery costs. Lithium-ion batteries were first used in electronics products in the 1990s. Initially, they cost more than $2,000/kWh and were only used in high-end products. Eventually, mobile phone market expansion resulted in the cost falling at an annual rate of more than 10%, and now lithium-ion batteries used in low-end handsets cost less than $200/kWh.

In 2010, when the first commercial EVs appeared, auto batteries cost $1,000/kWh. The cost has fallen with EV/PHEV market growth. We estimate it is now around $500/kWh and forecast that volume growth and CoGS improvement will result in an annual decline of around 10% moving forward. Based on this history, we expect the cost of energy storage lithium-ion batteries to be high in the nascent market stage and then steadily decline as demand expands.

Using auto-use battery know-how key to establishing a lead

The production processes and know-how for large storage-use lithium-ion batteries and auto-use batteries are similar. By drawing on auto battery technology, battery makers may also be able to supply storage batteries at a lower price in the initial market phase. We believe companies that are leaders in auto-use battery technology could derive early-mover benefits in the storage battery market.

Figure 23. Historical price declines in consumer and automotive lithium-ion batteries



Note: We assume JPY100/$ for consumer lithium-ion battery prices. Our estimates for automotive lithium-ion batteries.
Source: Company data, TSR, METI, Citi Research.

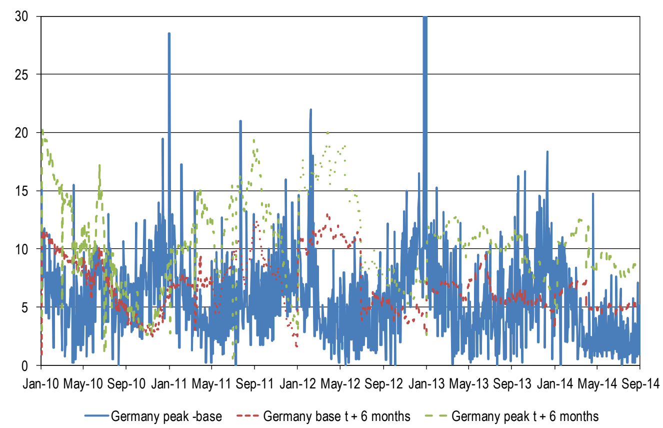
Battery Storage Economics – $230/MWh Is the Medium-Term Target

One element that all academic research agrees upon when it comes to the economics of battery storage within an electricity system is the difficulty that exists in quantifying them.

This is because a big portion of the benefits relate to opportunity costs, i.e. avoided expenditure, and also because battery storage can fulfil more than one role at the same time, e.g. it can be used to store electricity produced during low-price hours and sell it at high-price hours but also to delay the investment into a new peaking/back-up power plant.

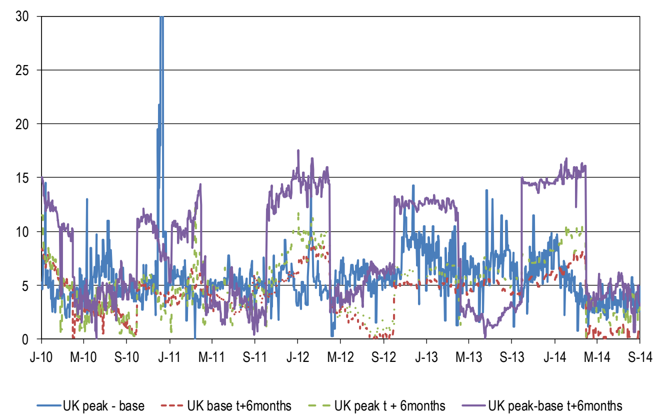
The simplest metric that is relevant for battery storage economics is the price differential at different times, e.g. peak vs off-peak or winter vs summer. The bigger that differential the stronger the incentive for battery storage to be developed. Figures 24-26 show such pricing differentials in regions of Europe and the US. We have focused in the more liquid wholesale markets, although this doesn't mean that pricing differentials might not be stronger elsewhere. We show daily pricing differentials, but we know that intraday spikes and troughs also exist, which would provide relevant commercial signals for battery storage.

Figure 24. Germany differentials across power price products



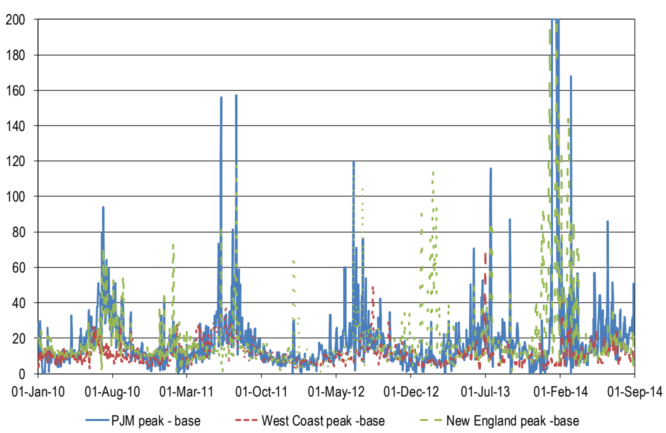
Source: Bloomberg, Citi Research

Figure 25. UK differentials across power price products



Source: Bloomberg, Citi Research

Figure 26. US differentials across power price products



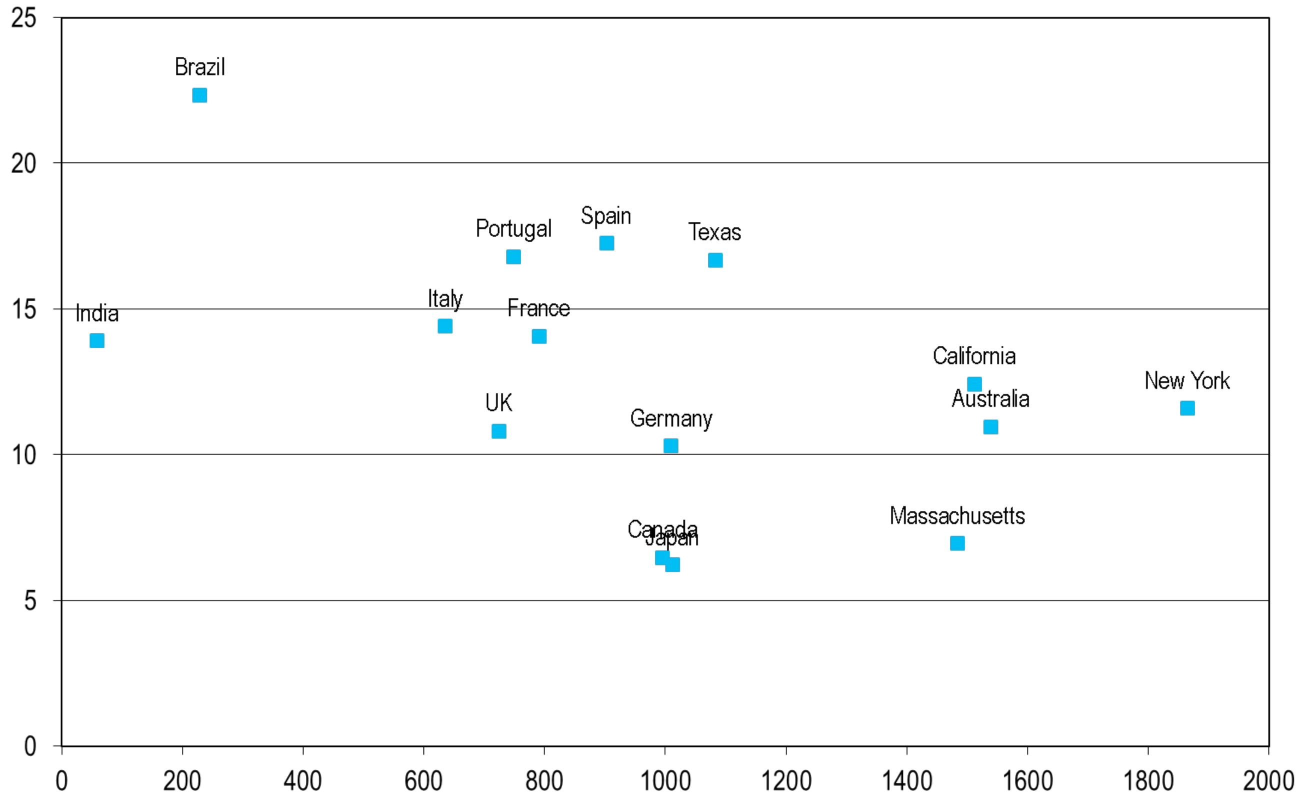
Source: Citi Research

It is clear from the above graphs that in Europe there is on average a €10/MWh margin to be had from pricing differentials at different times of the day and year. In the US that spread is closer to €15/MWh on average but varies by geography.

Beyond just time shifting in the wholesale market, though, battery storage can also be utilized to avoid investment in new thermal power plants, which will be used only as back-up to renewables. In the retail market, it can be used in conjunction with solar, as a way to avoid reliance on the grid and therefore minimize bill payment. Excess output could then be sold to the grid generating extra income.

Figure 27 shows average payback periods globally of about 13 years for standalone solar PV systems at the end of 2014E. Our analysis points to the payback period for solar PV with battery storage falling to less than that – 12 years – on average globally as of 2020, as shown in Figure 28.

Figure 27. Payback in years (Y axis) vs average annual household electricity bill in € (X axis) for solar PV at end-2014



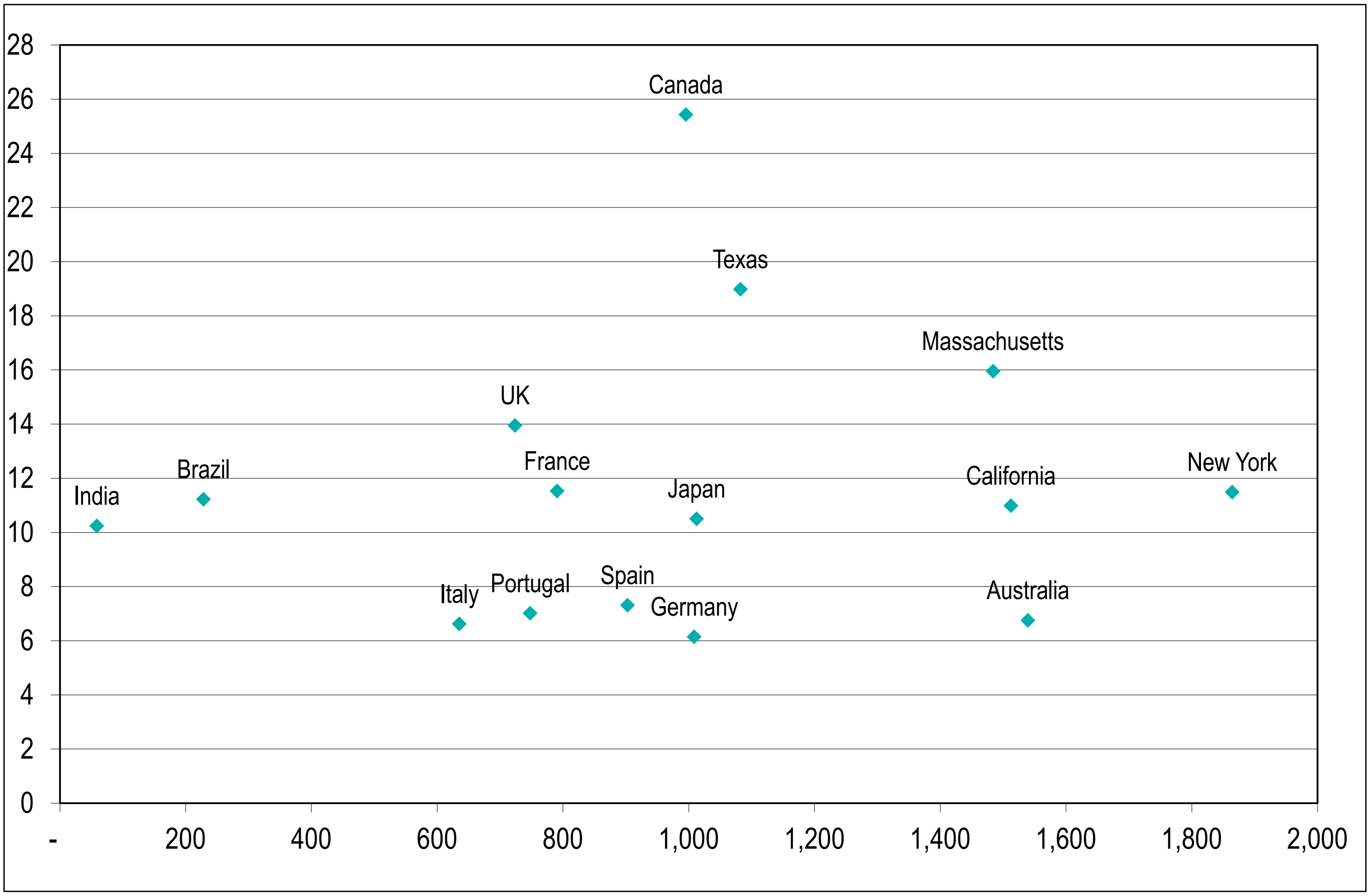
Source: Citi Research estimates

As we showed in Energy Darwinism - The evolution of the energy industry, socket parity for domestic solar was reached as early as 2013 in Italy, Spain, Germany, Portugal, Australia and South West US, while Japan should reach parity within 12 months and South Korea and the UK by the end of this decade.

In Figure 27 above we show the payback period of solar PV for an average household assuming an average 3.5KW installation, €1,500/KW all-in installation cost and ca. €50 annual maintenance outlay. With average annual household bills around the world at ca. €1,000, payback tends to be around 13 years. Over a 20-year period, we estimate the pre-tax IRR generated from 'income' from avoided bills and excess volume sale to the grid is 6.3% on average globally.

Figure 28 shows a similar picture but this time for solar PV with battery storage. This way a bigger portion of the solar output is self-consumed rather than sold to the grid so the 'income' is primarily avoided electricity bills rather than energy sales. We assume a $230/KWh cost for battery, a decline in installation costs of solar to €1,200/KW and unchanged household bills vs today. The implied payback period declines to 12 years and the IRR over 15 years (assuming a shortened life for batteries) rises to 5.7%

Figure 28. Payback in years (Y axis) vs average annual household electricity bill in € (X axis) for solar PV with battery storage in 2020



Source: Citi Research estimates

What Will Catalyse Battery Storage Commercialization?

In a similar manner to how renewables evolved, we expect battery storage to become more widely deployed through a combination of policy and technology advancement.

On the policy front, we would identity the December 2015 UN Climate Change Conference in Paris, which aims to reach a global and binding agreement on greenhouse gas emissions, as key. Such an agreement, if reached, would necessitate a bigger push for energy efficiency, demand response, renewables and e-mobility, making battery storage a crucial piece of the energy system puzzle.

But even if a global binding agreement is not reached, the European Union is likely to agree on 2030 environment targets, which should end up promoting the use of battery storage in the region.

The new market energy design to be implemented in the UK and the energy transition debates taking place in France and Germany are all likely to involve battery storage as an option at a first stage and as driver at a second stage.

In the US, the success or not of California's mandated 1.3GW of battery storage procurement plan for utilities by 2020 and its potential replication by other states, will also be an important driver for facilitating battery storage commercialisaiton.

On the technology front, the increased penetration of electric vehicles should continue to push down the cost of batteries for cars with parallel effects for energy systems battery costs. Projects such as Tesla's Gigafactory to be set in Nevada, with plans for 2020 battery production (in GWh) from that setting alone to exceed today's global production, will substantially contribute on that front.

Also, in addition to the large technology players, a number of independent companies like AES Energy Storage, and Sonnenbatterie (partnership with RWE) all have ambitious commercial plans and the more they grow in customer numbers and partnerships, the more likely it is that battery storage costs will be declining.

Implications for Utilities

Equity Research Utilities team

We estimate that solar systems have already reached socket parity in most parts of Continental Europe, South West US and Australia and will do so in Japan by 2016 and in the UK and Brazil by early 2020s. That means that, even with no subsidies, it is economic for households in those regions to install rooftop solar.

The introduction of battery storage in a distributed generation system would increase upfront costs for households but would improve their ongoing cash flow position as it would minimize power purchases from the grid.

Distributed energy has developed fast over the past decade. There is ~150GW of solar installed globally, a growing portion of which is rooftop solar PV rather than utility-scale capacity.

Figure 29. # of households with solar PV

Australia	1,000,000
Germany	1,400,000
France	300,000
UK	510,000
India	7,000,000
Japan	1,400,000

Source: Company data, Citi Research

A number of corporates have also embraced distributed energy, with the Solar Energy Industry Association in the US showing that as of mid-2013 3.4GW of solar had been installed in 32,800 business facilities with corporates such as Walmart, Costco, Kohl's, Apple, IKEA, VW, Target and Toys "R" Us leading the charge. Walmart has a target to grow the production or procurement to 7TWh of renewable energy annually by end of 2020 vs 2.2TWh today. Apple targets to power all its corporate offices, retail stores and datacenters entirely with renewable sources. IKEA aims to produce more energy than it uses by 2020 through deployment of renewables.

Improvements in battery storage both in terms of operational performance and economic terms should expand and accelerate the trend of corporates and households looking to become self-sufficient.

Living 'off-grid' could be closer to becoming a reality.

According to Physics Nobel Laureate and recent US Secretary of Energy (2009-13), Dr Steven Chu, in 5-10 years from today for a cost of $10-12,000 a household will be able to install a solar-battery system that will enable it to live ~80% off grid. In his March 2014 speech in the University of Chicago Institute of Politics, he argued that utilities need to change their business models or else they risk becoming obsolete. He stated that the technological advancements and reduction in the costs of these technologies, such as solar and battery storage, can be as extremely disruptive to electricity production and generation and drew a direct analogy with the effect that FedEx had on the Post Office.

Most utilities still appear far from prepared (or even preparing) to deal with the consequences.

More importantly he said that, although he has been talking to utilities about that for a couple of years, their response seems to be any of (i) "tell us what to do", (ii) "deer in the headlights" or (iii) "we will fight this". This initially sounded like none of the utilities has in place a plan to adjust for these changes but times may be changing. Dr. Steven Chu argues that the right business model adaptation would be for utilities to partner with installation/construction companies (see p. 31 for a case study on Arizona), use their low cost of debt to fund purchases of distributed energy capacity and storage and then rent this out to their customers. This is very consistent with views that we expressed for the European Utilities sector in our 2013 report Pan-European Utilities - The Lost Decade: Where Next?, and we find it surprising that a year later attitudes have yet to change.

For the US more specifically, we certainly started highlighting this phenomenon in several pieces we published over the past year including; Rising Sun: Implications For US Utilities and Evolving Economics of Power and Alternative Energy. Our key takeaway when thinking about solar DG/battery storage and the impact on utilities is that we do not ascribe to the notion that solar is the death of the utility model. We see winners (i.e. regulated utilities who will earn a fair return on what they spend including transmission and distribution wires related expenditures, which will increase as more renewables are built) and losers (i.e. certain unregulated/hybrid utilities whose outlook is predicated primarily on the economic dispatch of power generating assets) within the US utility sector. **Key takeaway: US utilities will 'eventually' adapt and join the party. Why? Several reasons, including: (1) it makes economic sense to do so, (2) fuel diversity needs and, (3) good hedge against upcoming EPA environmental legislation.**

What remains very pertinent in the US is the idea that solar should be viewed as a complement to natural gas…not a supplement, given ever-increasing shale production (i.e. LCOE of a combined cycle gas turbine that operates between 70%-75% of the day is ~$0.07/KWh), which has helped keep electricity rates relatively low. In the US, we think solar should continue to be viewed as a peaking resource but battery technology could begin to change role.

Fuel diversification is also a consideration as decoupling of power prices from gas prices is often sought.

But, besides utilities' incentive to build solar based on pure economics, the need to diversify their fuel mix is crucial to insulating them from volatility and the likely upward movement in gas prices over the longer term, a need that was well documented when we surveyed electric utilities in the US. A case in point is that the US is experiencing a period of transition as coal and certain nuclear plants are being less relied upon due to economics, pollution and/or government policy. Due to government policy and the gas price environment, the primary economic options are new natural gas plants and a look at renewables. Key utility commissioners and regulators do not want the entire system to be dependent on natural gas prices, which are becoming increasingly global in nature, so incentives and protections are likely to be in place for regulated utilities to adapt to the change.

The last remaining incentive which should drive utility adoption of solar is a hedge against several EPA-driven environmental rules, which are constantly increasing the value of solar for a US utility. For this discussion, see our recent piece called: EPA Unveils Climate Proposal: Equity/Commodities Views - Positive for Equities with Nuclear, Nat Gas, Renewables Exposure.

In the end, we think a middle ground solution could be struck on the compensation issue for DG. Either: (1) a set fixed charge for T&D or (2) a credit that only reflects the utilities' replacement power cost of generation. Eventually, for DG to work at a larger scale with the support of the utilities, we expect changes to the compensation structure for the off-grid solar providers in the near future. These changes more specifically could potentially include: (1) a bill credit that is lowered from the current avoidance of full retail rates to one that resembles the utilities' replacement cost of power (i.e. gas peaker) and/or (2) a demand charge (fixed charge for T&D) to be tacked on to off-grid solar homeowners' electric bills. These items provide a middle ground solution, in our view, with net metering battles clearly evident in several states like CA and AZ.

Is Arizona a Good Case Study on How The Utility Model Can Adapt in the US?

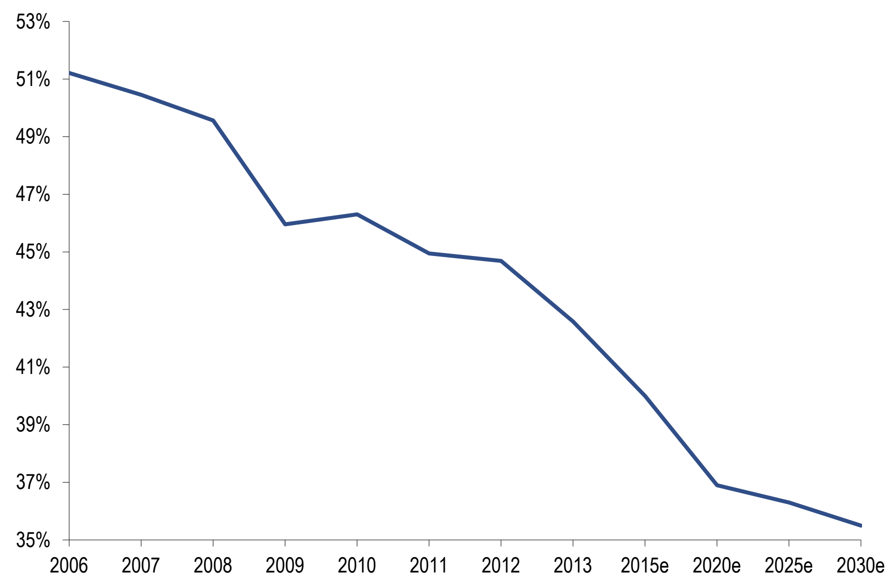
We view PNW's recent rooftop solar entry as a hedge on solar growth. On the Q2 earnings call, management detailed plans to install and service rooftop solar for ~3000 residential customers (20 MW) as a means to a) meet its renewable energy state target and b) adapt to the challenges of increasing solar adoption and distributed generation. Essentially, APS will install the panels and provide a $30 credit per month to the customer in exchange for returning electricity from the panels to the grid. Moreover, the program should appeal to a broader market than many current solar providers due to the absence of creditworthiness as a criterion. More importantly, with this unprecedented strategy, we believe PNW is pursuing an inventive solution to the broader problem of how traditional utilities can deal with load loss with DG. The industry will closely follow these proceedings.

Implications for Conventional Generation

Because, on our estimates, renewables with battery storage is due to reach grid parity in large parts of the world within 15 years, which is inside the typical 30-35-year economic lifecycle of utility assets, we concur with the conclusions reached by the Rocky Mountain Institute in its report "The Economics of Grid Defection: When and Where Distributed Solar Generation Plus Storage Competes with Traditional Utility Service" that the current business model of parts of the sector will be terminally challenged in these regions.

We expect centralised power generation (coal, gas, nuclear and lignite plants) to be the first to feel the effects. Figure 30 shows the load factors of all conventional generation in Europe, i.e. all capacity excluding renewables. The downward trend is evident with the exception of a small bounce in 2010 when electricity demand rose meaningfully as certain countries started exiting recession and temperatures were colder y-o-y. According to the EU Reference Scenario published late in 2013, load factors will continue to decline to ~35% by 2030 across the EU-28 member states.

Figure 30. Load factors of traditional generation capacity in key European markets



Forecasts from EU Reference Scenario 2013 for EU-28
Source: ENTSO-E, Nordel, Eurostat, NG SYS, Citi Research

Those assumptions do not assume any material take-up of battery storage, so load factors could end up being even lower with the possibility of growing penetration of battery storage or in reality we are more likely to see accelerated closures of thermal power plants with those remaining open operating at more normal load factors. In either scenario the profitability of thermal generation is likely to decline. Within listed utilities, conventional generation makes up 33% of European utilities' EBITDA.

In Europe we would see RWE, Fortum, Verbund and EDF as most negatively exposed to these trends. In US we would highlight Sell rated EXC, ETR and FE. In Japan, these trends are potential negatives for all regional power companies such as Kansai and Chubu, because they have historically built reserve capacity or generation mix.

Implications for Transmission and Distribution Grids

There is a mixed effect on electricity networks from growing penetration of battery storage.

On the one hand, it will lead to a rising number of 'prosumer households'; electricity will be generated from rooftop solar panels, stored in battery systems and then used when needed. This will, in turn, result in lower utilization of transmission and particularly distribution networks, effectively creating stranded network assets over the longer term. Regulators would at that stage have to decide whether continuing to remunerate these under- or un-utilised assets is economic. We therefore see a risk of returns being lowered for certain segments of the asset base.

Furthermore certain projects involving the connection of remote regions or island locations to the main grid might be cancelled, if climatic conditions allow for a renewables powered-, battery storage-enabled local system.

On the positive side, battery storage can be used and installed throughout the value chain and, particularly when looking at the uses of storage for ancillary services, we would expect transmission system operators to have a key role to play in the build-out of utility-scale battery storage. Such investment would likely be attractively remunerated. For example, Italian transmission utility Terna invested €31m in energy storage projects in 2013 and is planning to raise that to about €120m this year, which is to be included in the group's RAB. The program was launched in early 2012 and called for up to a €1b investment in battery storage over five years, and recent press reports (Reuters) suggested the group's new management will likely continue pursuing this strategy.

Also looking at potential positives, the commercial development of storage is likely to have a feedback loop into growing penetration of renewables in the fuel mix. However, the best locations for renewables installations in terms of, for example, wind speeds or radiation hours are not necessarily where the demand centers are, and therefore interconnections between the sunny and windy locations and where the demand or the battery storage is located will need to be built out. This should help drive growth for electricity transmission grids.

With the scope for a sizeable portion of electricity consumers to go 'off the grid' not really a likelihood for at least two decades and possibly longer, depending also on behavioural factors, the effects to be felt by network operators in the medium term are more likely to be positive, in our view.

There could, however, be downside risks for gas network operators sooner. ~30% of natural gas globally is used in power generation. Although environmental and cost considerations are likely to help gas gain market share vs coal and nuclear, particularly in developed economies, an overall decline in the utilization of all three technologies in favour of renewables and battery storage could have negative implications for overall gas demand (see p. 43-44 for more details on these effects). Such a decline could be exacerbated if a portion of households switch away from gas and into solar with battery home systems for heating and cooking. Therefore we see the potential for a long chain of knock-on implications to have a quicker negative impact on utilization and therefore remuneration of gas grids than electricity grids. Even in those cases, however, we think the effects should be felt more than a decade from now.

Implications for Services / New Business Models

Over the last two years we have highlighted extensively – most notably in The Lost Decade: Where Next and Energy Darwinism - The Evolution of the Energy Industry – the implications that disruptive technologies such as renewables and battery storage could have on the role of utilities. Although our experience of many utilities management teams supports Dr Steven Chu's assessment that the companies are mostly unprepared or, even worse, of the opinion that they can successfully fight these changes, not all utilities fall under those categories and, even for those who do, there are elements within the management structure that recognize the far-reaching changes and are looking for ways to embrace them. In Europe, GDFSuez has set Energy Services at the core of its strategy and has earmarked part of its inorganic growth budget for expansion on that front.

It is very difficult at this stage to provide an estimate of how big the earnings opportunity could be for utilities willing to embrace new services business models. It is even more difficult to estimate which portion of the opportunities utilities will actually be able to capture as a number of other industries – retail, telecom, technology, equipment – could muscle in the market. The global energy services market is today ~€400b, with the residential market ca. 20% but growing fast. If we exclude the construction materials and appliances part of the market, where utilities are not involved, we are looking at a ca. €250b global energy services market in which utilities can participate. Just in the US, the Berkeley Lab in a September 2013 report expects the industry to double in size by 2020 with the revenue share from distributed generation growing and the maximum potential of the market at ca. €100b p.a.. The European potential is closer to €80b p.a., excluding the residential market, according to a 2012 GDFSuez presentation. We see scope for growth in battery storage to maintain the annual pace of growth of that market in high single digits over 2020-30 in the developed economies.

In our view, a best case scenario would be for the part of the global energy services market relevant to utilities to reach €600b by 2020.

At that stage we would expect:

1. Competition from non-utilities type businesses (such as Schneider, Schindler, ABB, Siemens, GE, Vinci, etc) to materially restrict the amount of business that utilities can capture. A 2013 report by Bain & Company argues that out of the eight streams of revenue in the energy services market, utilities have a "high ability to win" in only two.

2. The B2B business to remain the biggest market at 60-70% of the total opportunity. Industrial customers tend to (i) switch more often and (ii) have better negotiating power on prices than residential consumers. They are also more likely, in our view, to choose large multinational players to cater to their needs rather than localized utilities.

3. The competition between utilities also to be intense, with the new entrants in the supply market having a competitive advantage in deploying new 'smart' technologies and not being weighed down by internal conflicts of interest over how a growing energy services business could cannibalise their traditional business when compared with large integrated utilities.

With these considerations in mind, we estimate the 2020 potential market for utilities at less than €200b.On a standard margin of 5-10% for such contracts, that would imply ~€15b in added EBITDA to potentially come to the global listed utilities sector by 2020E. This compares to >€200b of EBITDA generated by the global utilities sector currently under our stock coverage – i.e. 5-7% upside potential. This is not likely to be enough to offset the parallel negative pressures on power generation & traditional supply activities, in our view.

We therefore expect the positive effects of these new markets to be limited. They will nevertheless most likely be concentrated, and the utilities we would view as best positioned to tap the new services market are GDFSuez, Centrica and Veolia from the European names and Buy-rated EIX and DUK in the US.

Figure 31. Possible relative winners and losers from commercialization of battery storage in the Global Utilities space (under Citi coverage)

	Europe	USA	Japan
Negative effects from pressures in Traditional Generation business (near-term)	RWE	EXC	Kansai
	Fortum	ETR	Chubu
	Verbund	FE	
	EDF		
	Endesa		
Positive effects from faster deployment of Renewables (near-term)	EDF	PNW	
	EDP		
Positive effects from growth in rate base for battery storage (medium-term)	Terna		
	EDF		
	Red Electrica		
	SSE		
Negative effects from less utilisation of gas networks (long term)	GDFSuez		
	Enagas		
	National Grid		
	Snam		
Positive effects from energy services markets (medium-term)	GDFSuez	EIX	
	Veolia	Duke	
	Centrica		

Source: Citi Research

Implications for Technology Companies

Will storage batteries be a profitable business?

Equity Research Technology team

Both investors and companies have honed in on the growth potential of consumer electronics and automotive lithium-ion batteries. However, battery business earnings have not necessarily been strong. This is because battery makers are squeezed by severe pricing pressure from automakers, PC/mobile phone makers, and other users on the demand side, and unavoidably high procurement costs, mainly for electrode materials and separators, on the supply side. In addition, competition among battery makers is intense. Battery makers' earnings structures are prone to unprofitability because of their position between process assembly industries and commodity industries. This is a structural problem.

Consumer electronics and auto battery businesses are not necessarily profitable

Storage battery profitability could be high, depending on business models

But we believe storage batteries could be highly profitable, although this will depend on business models. Compared with consumer electronics and auto batteries, pure price competition is less likely to be a problem because storage battery systems must meet stringent reliability standards (safety and lifespan), which requires high-level quality control and technical expertise. Also, the storage battery market is likely to develop as an infrastructure business that involves the supply of services and solutions, not just hardware. We believe companies will be able to increase added-value through energy management and aftermarket services. GS Yuasa has secured an OPM of 15% in its industrial lead-acid battery business by providing high-quality products and creating an aftermarket service structure.

Shift from a sales model to a service model

To compete in the storage battery market, we believe battery makers will have to convert from a hardware sales business model to a service model that includes aftermarket services and the ability to propose solutions. In addition to reducing battery costs, we think battery makers will have to come up with solutions that increase convenience for users and make a long-term commitment to infrastructure.

What is the outlook for storage battery market entry and competition?

Quality and electric circuit/heavy electric-system knowhow should give Japanese companies an advantage in the storage battery market

We believe Hitachi, Toshiba, NEC, Panasonic, Sony and GS Yuasa, are among Japanese battery makers likely to benefit from storage battery market growth. Storage batteries must have long lifespans and be extremely safe, making them a good fit for the high quality and technical expertise for which Japanese companies are known. More than just battery cell technology will be needed to succeed in the storage battery market: inverter and other electric circuit technologies and heavy electrical systems knowhow and sales networks will also be important. These are also fields in which Japanese companies excel. Asian companies, mainly from South Korea and China, have used cost competiveness to build a strong presence in the market for consumer electronics lithium-ion batteries. But they do not possess the electric circuit and heavy-electrical systems know how needed for storage battery systems.

Japanese companies putting more resources into storage battery systems as interest grows

Japanese companies, mainly integrated electronics makers, are putting more resources into storage batteries as a growth business. Toshiba has received a large order from Tohoku Electric for a lithium-ion battery storage battery system. In April 2014, Sony announced the establishment of a large-scale energy storage joint venture with Hydro Quebec. Panasonic is developing residential storage batteries. GS Yuasa is conducting feasibility tests on industrial-use lithium-ion batteries for Kyushu Electric. Sumitomo Electric Industries, the top maker of redox flow batteries, has received a large storage battery order from Hokkaido Electric.

What is the state of storage battery business development at individual companies?

Hitachi

Hitachi's battery business is a joint undertaking with subsidiary Hitachi Chemical and the latter's subsidiary Nissin Electric. Its LiBs are used in intermediate-capacity grid stabilization, power generation at factories and offices, and cost equalization. Hitachi is focusing on the US ancillary energy storage market and initiated a demonstration project for a movable (truck-mounted container-type) 450kWh LiB in June. The company has also teamed with Demansys Energy, a US company involved in the smart grid, for batteries used in grid stabilization.

Battery materials are made by Hitachi Chemical, battery cells and packs by Nissin Electric and Hitachi Chemical, and battery systems by Hitachi Chemical and Hitachi. Hitachi itself handles most of the engineering work on large-scale products for the grid. These include battery packs, power conditioners, control systems, and communication systems.

We estimate sales and profits for Hitachi's battery business based on related segments at Hitachi Chemical. The industrial battery business overall (including lead batteries) had sales of ¥30bn and OP of ¥1bn in FY3/14 by our estimate (<1% of group operating profit). The business is still in the developing stage and now poised for full-scale growth in our view. We expect sales to increase by c¥5bn in FY3/15.

Toshiba

Toshiba makes LiBs at its Kashiwazaki plant, supplying them for use in a wide range of storage applications extending from households to the grid. Household batteries are marketed under the eneGoon brand, industrial batteries under the SciB brand, with the latter sold for use in offices/factories, solar/wind power generation facilities, and grid substations. While there are numerous similarities across the various products, their sales and related service are handled by different business segments depending on end-user.

The business currently centers on the Japanese market, where Toshiba sold a 40MW LiB system to Tohoku Electric Power last November. At the time, this was the largest ancillary LiB to be installed in a grid substation worldwide. Toshiba also delivered small-scale 2MW and 3MW storage systems to Kyushu Electric Power this past March for use in grid stabilization on remote islands. Overseas, demonstration projects for 1MW–2MW ancillary energy storage systems are underway in Italy, the US, and Spain.

Sales and profits have not been disclosed, but we understand the Tohoku Electric project generated sales of nearly ¥10bn (<1% of group operating profit). This included power conditioners and control systems. The two smaller projects for remote islands had combined sales of c¥1bn.

NEC

NEC shifted tack toward full-scale involvement in grid storage systems with its March 2014 acquisition of A123 Energy Solutions. A123 incurred a FY12/13 operating loss of ¥2bn on sales of ¥3.2bn by our estimate, but NEC is targeting sales of ¥10bn in FY3/16, which would put them above break even. The longer-term goal is sales of ¥100bn and an operating margin of at least 10% (~7% of group operating profit).

The business already has 11 customers for grid storage systems and a track record of multiple megawatt-class projects. NEC's ample experience in mass production has led to progress in system standardization and software development, which we think implies potential for higher margins.

NEC will be cultivating additional customers going forward and targets data centers, mobile phone base stations, factories, and sports stadiums.

NEC has also been fully involved in household batteries since 2013. It purchases battery cells from GS Yuasa and turns them into systems at its Kofu plant. Sales are primarily to households and commercial buildings.

Panasonic

Panasonic's battery business centers on consumer electronics and automotive applications, with industrial applications accounting for only a modest portion of the overall operation. We think this may be inevitable given the company's long history as a consumer electronics manufacturer.

Within industrial applications, Panasonic is currently securing a foothold in LiBs for mobile phone base stations. The company is also working to commercialize LiBs for use as emergency power sources for homes, offices, and data centers.

Panasonic's industrial batteries are 18650-type cylindrical LiBs, the same type it makes for Tesla Motors. FY3/14 sales were c¥10bn by our estimate, likely centered on household applications. Panasonic targets sales of ¥100bn by FY3/19 (~1% of group revenue).

Sony

Sony is a leading LiB maker. The business centers on smartphone and tablet applications, with industrial applications just getting off the ground. However, Sony announced in April that it will team with Canadian power company Hydro-Quebec to establish a joint-venture for the development of a large-scale grid storage system, which will give it a foothold in this area. While there are no plans so far for full-scale commercialization, previous patent negotiations between Sony and Hydro-Quebec lead us to believe that the partnership will accelerate the commercialization process.

GS Yuasa

GS Yuasa makes automotive lead-acid and lithium-ion batteries and also industrial batteries, mainly for energy storage. The industrial battery power supply business, which makes lead-acid batteries for the domestic market, contributes around half of GS Yuasa's profit (we forecast FY3/15 sales of ¥86bn and OP of ¥13bn). GS Yuasa's main strength is an extensive domestic sales network, which has enabled it to secure a backup battery market share of around 50%. Industrial batteries, mainly for energy storage, contribute around 30% of the sales of the overseas business (we forecast FY3/15 sales of ¥180bn and OP of ¥10.7bn).

GS Yuasa is focusing on industrial lithium-ion batteries as a business of the future. Lines at the Kusatsu and Kyoto plants, which are auto lithium-ion battery production bases, have been converted to industrial battery production. Currently, GS Yuasa is mainly supplying batteries to Kyushu Electric for a frequency variation control system, a thermal power station in Chile for energy storage, railway companies, and to Boeing for the 787. Industrial lithium-ion battery sales came to ¥4.1bn in FY3/14. We understand power system and large energy storage system enquiries are increasing and we believe GS Yuasa has potential to develop the business in several different directions.

GS Yuasa's automotive lithium-ion battery business has gained traction ahead of rivals. Blue Energy, a joint-venture subsidiary with Honda, became profitable in FY3/14 H2. We expect battery makers that have a lead in the auto field to also gain early-mover merits in storage batteries.

SMA Solar

SMA Solar is a European solar inverter manufacturer with global footprint. The company predominately focuses on residential and utility-scale inverter manufacturing, but also has operations in the battery storage space. With its battery inverter series sunny island (residential) and sunny central storage (utility) SMA is offering energy storage and off-grid solutions. Combining the inverter function with Li-Ion battery storage units allows solar operators to manage power consumption more efficiently and increase self-consumption. This battery inverter category is currently a fraction of the overall SMA group but on a longer-term view has potential to be significantly large. On top of its battery storage inverter product, SMA operates a service division (4% FY14E sales) which provides power management solutions to individual households. This division should offer attractive growth opportunities as "off-grid" living becomes an economically viable solution.

With its battery inverter series and its service division SMA is uniquely positioned to reap the benefits as the battery storage theme plays out. Not only does solar penetration and therefore inverter demand gain significant traction with intermittency becoming less of an issue, but we also believe that demand for its service division and power management will grow exponentially as living off-grid becomes reality.

Abengoa

Abengoa is predominantly an EPC company that constructs solar, wind, electricity generation and transmission assets globally. It also operates a biofuels and concessions division.

Among its technologies Abgengoa has extensive expertise in CSP technology (concentrated solar power). Recently the company announced that it was selected to build a 110MW solar thermal towers in Chile (Large Chilean project win highlights solar prospects). This technology deploys molten salt storage with capacity of 17.5 hours which effectively allows electricity to be dispatchable 24 hours a day. Currently CSP is more expensive than renewables on a $/MWh lifetime basis, however has the optionality to store electricity compared to solar PV and wind plants. Undoubtedly, CSP has potentially for cost reductions, however alternative storage solutions such as Li-Ion batteries can be a competitive threat and could potentially erode CSP's storage advantage compared to solar PV and wind energy.

Figure 32. Companies mentioned

Company	RIC	Rating		Curr	Price	Company	RIC	Rating		Curr	Price
ABB	ABBN.VX	1		CHF	21.6	NEC	6701.T	1		JPY	373.00
Abengoa SA	ABGek.MC	1	H	EUR	4.234	Nichias	5393.T			JPY	727.00
Apple	AAPL.O	1		USD	102.77	Nippon Carbon	5302.T			JPY	192.00
Blue Energy	BUL.AX			AUD	0.05	Nippon Chem Ind	4092.T			JPY	160.00
Boeing	BA.N	1		USD	127.26	Nippon Denko	5563.T			JPY	279.00
BP	BP.L	1		GBP	4.6605	Nissin Electric	6641.T			JPY	654.00
Centrica	CNA.L	2		GBP	3.144						
Chubu Electric	9502.T	2		JPY	1265	Origin Energy	ORG.AX	1		AUD	15.29
Chugoku Electric	9504.T	2		JPY	1426	Panasonic	6752.T	3		JPY	1315.00
Costco Wholesal	COST.O	1		USD	125.28	PG&E	PCG_pa.A			USD	27.64
Duke Energy	DUK.N	1		USD	74.04	Pinnacle West	PNW.N	2		USD	56.10
EDF	EDF.PA	2		EUR	25.365	Red Electrica	REE.MC	2		EUR	65.34
Edison Intl	EIX.N	1		USD	56.8	RWE	RWEG.DE	3		EUR	31.36
EDP	EDP.LS	3		EUR	3.389	Schindler	SCHN.S	2		CHF	131.60
Enagas	ENAG.MC	1		EUR	25.02	Schneider Electric	SCHN.PA	2		EUR	60.87
Endesa	ELE.MC	3		EUR	30	Shikoku Electric	9507.T	2		JPY	1407.00
Enel	ENEI.MI	3		EUR	4.058	Siemens	SIEGn.DE	1		EUR	94.28
Entergy Corp	ETR.N	3		USD	76.86	SMA Solar Tech	S92G.DE	2	H	EUR	22.12
Exelon Corp	EXC.N	3		USD	34.13	Snam SpA	SRG.MI	3		EUR	4.30
Fedex Corp	FDX.N	1		USD	158.53	SOC	5232.T	2		JPY	370.00
FirstEnergy Corp	FE.N	3		USD	34.475	Sony	6758.T	1		JPY	1896.50
Fortum	FUM1V.HE	3		EUR	19.38	Southern Ca	SCE_pe.A			USD	23.77
Gas Natural	GAS.MC	2		EUR	23.21	SSE	SSE.L	3		GBP	15.09
GDF Suez	GSZ.PA	2		EUR	19.215	STMicroelectronics	STM.PA	3		EUR	5.91
						Sumitomo Elec	5802.T			JPY	1615.50
GS Yuasa	6674.T	1		JPY	639	Tanaka Chemical	4080.T			JPY	500.00
Hitachi	6501.T	1		JPY	834.2	Target Corp	TGT.N	2		USD	63.39
Hitachi Chem	4217.T	1		JPY	2035	TEPCO	9501.T	-	-	JPY	382.00
						TERNA	TRN.MI	3		EUR	3.89
Hokkaido Electric	9509.T	1		JPY	907	Tesla Motors	TSLA.OQ			USD	250.03
Hokuriku Electric	9505.T	2		JPY	1454	The AES Corp	AES.N			USD	14.48
Honda	7267.T	1		JPY	3773.5	Titan Kogyo	4098.T			JPY	265.00
Iberdrola	IBE.MC	1		EUR	5.581	Toda Kogyo	4100.T			JPY	401.00
Kansai Electric	9503.T	1		JPY	1028	Tohoku Electric	9506.T	1		JPY	1224.00
Kohls	KSS.N	1		USD	61.91	Toshiba	6502.T	1		JPY	503.40
Kureha	4023.T			JPY	552	Umicore	UMI.BR	3		EUR	35.88
Kyushu Electric	9508.T	2		JPY	1163	Veolia Environment	VIE.PA	2		EUR	13.74
L&F	066970.KQ			KRW	6920	Verbund	VERB.VI	3		EUR	15.39
Mitsui Chem	4183.T	2		JPY	316	Vinci	SGEF.PA			EUR	45.53
Mitsui Eng & Shp	7003.T			JPY	246	Volkswagen	VOWG.DE	1		EUR	169.15
Mitsui Min & Sml	5706.T			JPY	301	Walmart	WMT.N	2		USD	75.63
National Grid	NG.L	2		GBP	8.81						

Source: Citi Research. Sept 23rd Additional companies: BASF SE (BASFn.DE; €75.37; 2); Clariant AG (CLN.VX; SFr16.12; 1); Johnson Matthey PLC (JMAT.L; £30.24; 2)

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COMMODITY STRATEGY

Identifying Long-Term Transformational Implications

From a macro perspective, the rise of economically competitive, widely deployed energy storage would have a profound impact on traditional, fossil energy sources. Six overarching impacts include:

1. Renewables: Storage would reduce both the cost of intermittency and the physical grid constraints that prevent deeper renewables penetration. The result would be a boost to the growth of renewables in our view.

2. Coal: If storage can be competitively used to "firm" intermittent resources, renewables can become a true substitute for baseload generation. In many markets, baseload is dominated by coal-fired power. And because of growing policy pressure to displace coal in markets ranging from the US to China, policy is likely to emphasize the substitution of firm renewables for coal-fired generation.

3. Oil: Where oil is still used in the global power sector, it is often used in a peaking capacity. If storage is also deployed as a utility-scale peak shaving asset, storage might start to push out the stubborn oil-based generation still holding on as peaking capacity. If one considers oil use in Saudi Arabia and other Middle East countries for summer "peaking", we estimate the savings in oil would be around 500-k b/d on an annualized basis.

4. Natural gas: In the near to medium term, natural gas's complementarity with renewables makes gas a winner in any scenario with increased renewables, as gas continues to be the best option to balance intermittency in many places. But it too would pose challenges to the utility model in many countries, as any former base load fuel supply would bring lower returns to the utility based on lost peak/high priced demand loads.

5. Gasoline: If storage were developed that promoted the growth of electric vehicles, this would significantly erode gasoline demand let alone demand growth, which, along with strong North American production, would put pressure on oil prices.

6. The structure of power markets: Electricity is one of the few non-storable commodities. Large scale storage could change that, linking spot prices to forward prices in a transformation that would make electricity markets trade more like oil or gas markets. The implications for power forward curves and asset finance could be significant.

We first examine the specific economics of storage before examining how these longer term trends may unfold. In general, we focus on applications of storage for use in utility scale arbitrage or integration with renewables in a "firming" capacity. Niche ancillary, balancing, or operating reserves markets may be attractive, but will have comparatively lesser impacts on commodities on a large scale.

Storage Economics: Zeroing in on Specific Commodity Impacts in Specific Regions

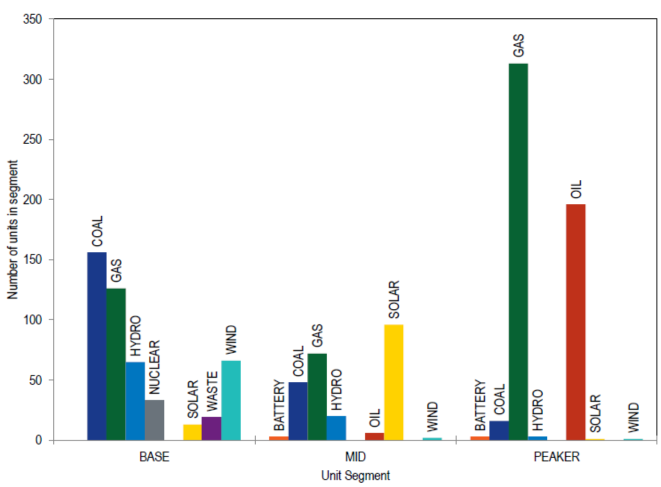
From a more micro perspective, determining how energy storage would impact specific commodities requires examining how generation economics interact with storage economics. We illustrate a simple model for the competitiveness of utility scale storage in competitive, wholesale power markets on a marginal cost basis. This model demonstrates how storage would compete with existing technologies and therefore impact specific commodities. In this case we assume storage serves an arbitrage function, seeking to buy cheap power and sell costly power. We later consider the "firming" function of storage, which seeks to transform intermittent resources to baseload resources.

Utility Scale Storage Economics

The economics of storage are fundamentally about buying low-priced power and selling high-priced power. Returns to storage assets not coupled to generation assets are therefore a function of the difference between the price of power at off-peak times (cost) and the price at on-peak, high demand times (revenue). Utility scale storage owners are therefore at the mercy of the power markets to determine both their costs and their revenues. This is the key to understanding the competitiveness of storage.

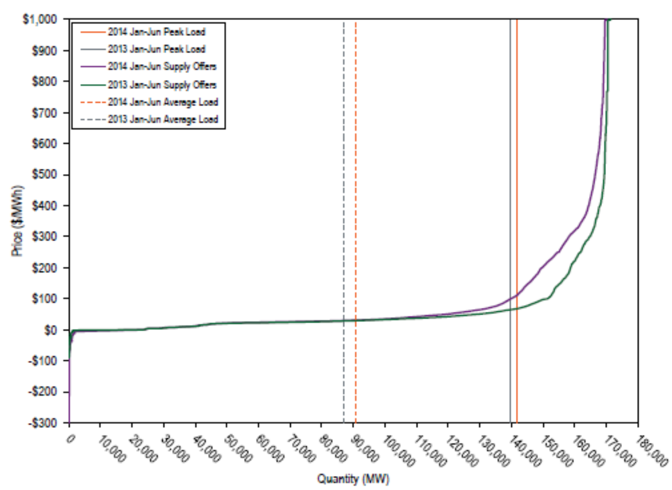
The revenues to storage owners are the same to owners of all generation types – those derived from selling power at the market clearing price for power. Storage has no advantage here.

Figure 33. PJM Fuel Source Position in Gen Stack 1H 2014: Position on supply stack determines exposure to potential battery storage



Source: Monitoring Analytics. "Quarterly State of the Market Report for PJM: January through June". Aug 2014. With permission. Note: Used for illustrative purpose only.

Figure 34. Average PJM Real-time Supply Curves 1H 2014: Battery storage is unlikely to compete with bottom of curve, but could displace the top



Source: Monitoring Analytics. "Quarterly State of the Market Report for PJM: January through June". Aug 2014. With permission. Note: Used for illustrative purpose only.

Where things get more interesting is on the cost side. When seeking to buy power at off peak times, storage owners will pay the market clearing price, which is the price bid in by the marginal generation unit (assuming competitive markets). Key questions for understanding commodity impacts are, (1) what is that unit, and (2) where does it sit in the generation stack? The answers will vary by region.

In some renewables-saturated regions like ERCOT or Germany, the marginal unit setting off-peak prices might be wind, and prices may be close to zero or even negative. In these cases storage will be able to provide electricity more cheaply than almost any thermal unit, and as a result should displace gas, coal, and oil generation (nuclear may run for operational reasons).

But in many regions, the marginal off-peak unit will be a relatively efficient coal or gas unit (see above “base” assets in PJM figures). Because the marginal cost of storage is the same as that of marginal unit (buying large quantities of off peak power may actually shift the marginal unit higher on the curve), storage will have a difficult time competing with all the thermal units which are inside the marginal unit and lower on the generation stack. Efficient coal and gas plants that run as baseload during off-peak times, and therefore low on the generation stack, will have better spark or dark spreads than the “storage spread”. This implies that the most efficient thermal plants should be safe from storage.

Plants that are high on the generation stack, however, should be the first to suffer. As storage sells its power on-peak, it will reduce demand for electricity from generation assets by the quantity it offers on the market. In many markets, expensive peaking units should be the first to go. As storage capacity grows and it can displace units lower on the generation curve, older coal and gas units are likely to be next. Nuclear should generally be safe as is likely to have lower marginal costs than storage in many regions. Worth noting is that because storage serves a peak shaving function, as total installed storage capacity grows, returns to storage should decline.

Figures above illustrate how to apply this analysis to a specific market, in this case PJM. If we assume storage buys power during average load periods and sells at peak periods, storage captures the spread between the two red lines, displacing the top of the curve but unable to displace anything below the point at which it purchases power. The left figure above indicates which plants this might be in PJM. If we assume storage buys baseload power and sells peak, some “base” coal and gas plants are safe, while other “peaker” coal, gas, and oil plants are exposed.

The key conclusion is that in competitive wholesale markets, the impact of utility scale storage on commodities will depend on the specific generation features of a given market. Generally, however, peaking oil and gas units and older coal units look most exposed.

Distributed vs. Utility Scale

The impacts of storage in the context of distributed generation may be more straightforward where users consume the power they store, as in the case of a home which integrates solar and storage and consumes all of the output. In this case, we would simply expect aggregate reductions of wholesale power demand as storage enhances the appeal of and ability of distributed generation to provide a fully “off the grid” product. As consumers draw less from the grid, the trends Citi has identified for solar in numerous reports simply become more pronounced. While the scale of any eventual effect is far from clear, directionally it is bearish gas and coal.

Where distributed storage owners with integrated renewables can store and sell back to the grid, they will be attempting to sell on-peak and therefore displacing peak units, as discussed previously.

In all of these cases we have intentionally focused on the variable cost economics and not emphasized capital cost and other complications; we feel this is the most indicative of how storage would interact with commodity markets, especially given the lack of clarity on the evolution of specific storage technologies and capital costs. Additionally, storage investment decisions are likely to be driven by expectations of earnings, which are a function of the factors we have discussed here.

Impact 1: Impact on Renewables

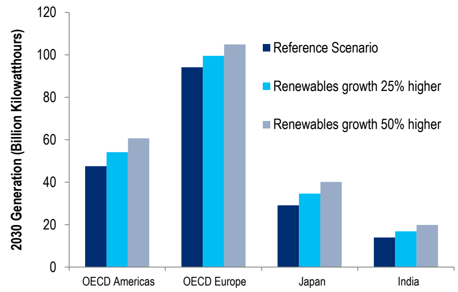
Solving the Intermittency Problem Is the Holy Grail of Renewables

The challenges associated with intermittency are well documented. As such we will not discuss them at length here. Storage could help solve these challenges, and in the process eliminate costs and constraints on growth of renewables penetration.

Utility scale storage could reduce or eliminate those costs, enabling deeper penetration of renewables in power sectors globally

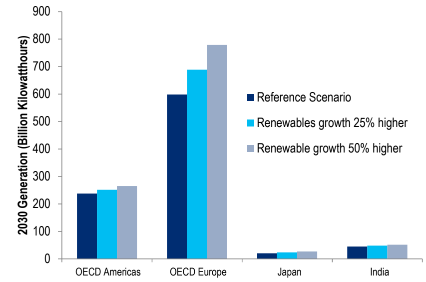
To capture these effects, we run three scenarios in Citi's global power model that increase our base forecast of renewables growth rates in major countries by 25% and 50%. Those results are shown in in the figures below.

Figure 35. Solar Generation Scenarios with Enabling Storage



Source: Citi Research

Figure 36. Wind Generation Scenarios with Enabling Storage



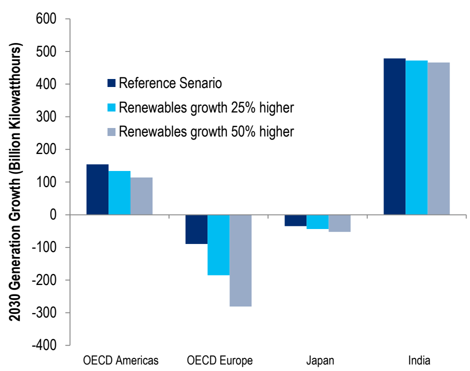
Source: Citi Research

Impact 2: Impact on Coal

With storage available to "firm-up" renewables, renewables become a true baseload substitute for coal. While firm renewables may in fact compete with both gas and coal as baseload, increasing policy pressures to reduce coal use in both competitive markets and non-competitive markets such as China will make storage pressure coal more heavily.

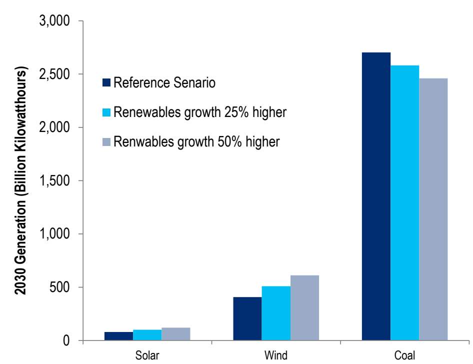
In order to show the possible scale of impacts by 2030, we assume all incremental wind and solar made possible by storage in the above scenarios displaces coal. The figures below illustrate the significant potential impact.

Figure 37.Coal Generation Growth Drops More Aggressively



Source: Citi Research, EIA IEO 2013.

Figure 38. China's Coal Generation Drops, but remains Large

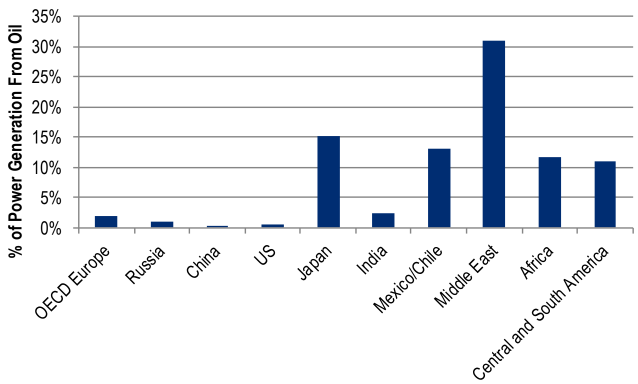


Source: Citi Research, EIA IEO 2013.

Impact 3: Impact on Oil

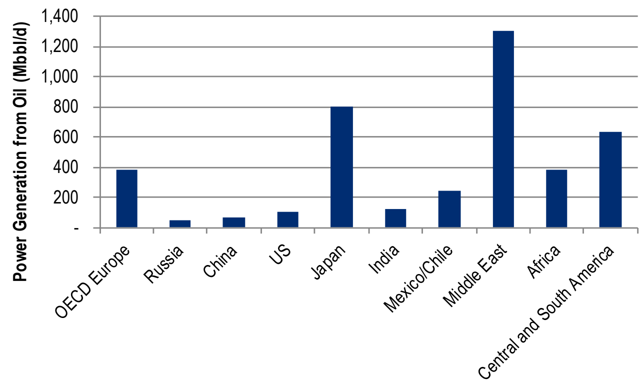
As shown above, because peaking oil capacity is at the top of the generation stack, it is likely one of the first casualties of widely deployed storage for arbitrage purposes (both utility scale and distributed). The left figure below shows which countries still rely on oil in their power sectors and thus might experience a backing out of oil demand in the power sector. The right below figure translates this to potential impact on oil demand. In total, backing all oil out of the global power sector at 2013 consumption levels might decrease oil demand by a maximum of just over 4 million bbls/day, or ~4.5% of global oil consumption .

Figure 39. Storage might back out peaking capacity in Japan, Mexico, and Latin America (Saudi Oil use is partially baseload)



Source: Citi Research, EIA.

Figure 40. The hypothetical impact on oil markets could be meaningful

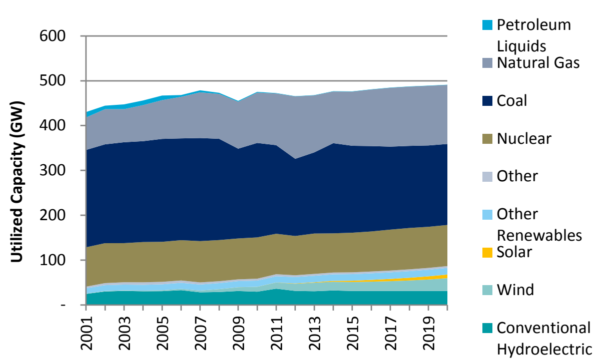


Source: Citi Research, EIA.

Impact 4: Impact on Natural Gas

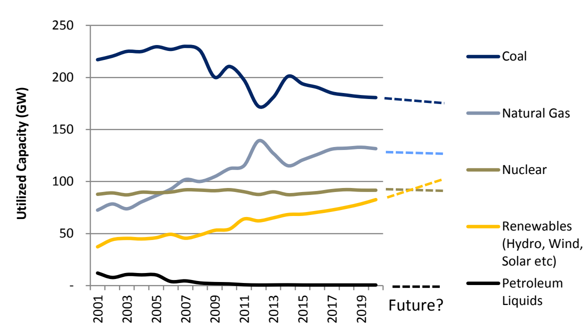
In the US, gas-fired generation may be only a temporary bridge between the age of coal and the age of renewables, as the growth in gas demand for power generation could be less significant than is commonly believed. Gas is commonly thought of as the substitute fuel for coal in power generation once coal plants retire. But rising renewables generation should increasingly take over market shares of coal- and gas-fired generation, particularly in an environment of slow electricity demand growth such as is the case in advanced economies.

Figure 41. Total generation in utilized capacity (GW) only showing modest growth as demand growth stalls, but coal could remain resilient



Source: EIA, Citi Research

Figure 42. Rapid rise of renewables limit the potential for much stronger gains in gas demand



Source: EIA, Citi Research

To deal with reliability issues from higher penetration of renewables generation, gas and energy storage are critical.

Here's where gas could play a major role: A lack of sufficient backup resources provided by fossil generation could force some of these variable generation resources to shut in order to maintain system integrity: due to operational stability, wind resources have at times been curtailed. In absence of storage, to avoid these instances or domino effects from happening, electrical system operators and other physical market players need to have accurate forecasts and flexible generation resources to handle changes in voltage and frequency.

In addition, an increasingly effective way of deploying renewables is the use of small-scale energy storage that provides energy only for a short time, particularly for solar, as discussed earlier in this report. Suppose solar generation is strong in late afternoon so much so that the electricity generated could more than satisfy demand. The extra energy could be stored in batteries and released to meet demand in part of the evening. While this kind of renewables deployment is not as widespread, it is being adopted in an increasing number of places.

Intermittency of renewables generation and increasing difficulty in forecasting electricity demand also make gas and energy storage complementary.

The accuracy of electricity demand forecasting has been decreasing since the late 2000s. Empirical models based on correlation between utility and economic and technology factors are suffering from variations generated by the development of smart grids, the PHEV industry as well as changes in customer behavior.

In an environment with greater long-term planning uncertainty coupled with greater short-term uncertainty from higher penetration of intermittent renewables, grid stability demands new resources that can deliver flexibility and therefore stability to the grid. Both storage and gas meet those challenges.

Especially in the early days of storage's maturation, gas should create a role in the market that storage can gradually fill. Gas should also make investors and operators more comfortable with taking storage technology risk. Few ISOs would bet grid stability on unproven storage technology alone, but storage in combination with gas is highly symbiotic. Storage will likely also buy power from cheap, baseload gas in regions where low prices are prevalent (US, for example).

Impact 5: Impact on Gasoline

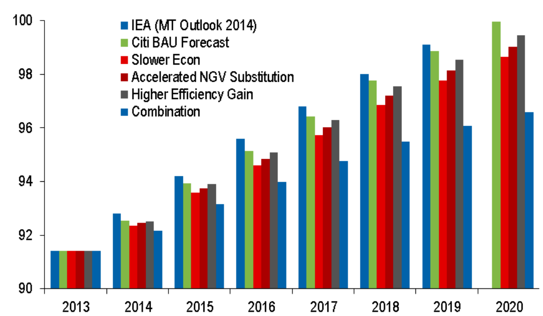
A jump in the efficiency of battery storage for vehicles – as envisioned with the Tesla Giga Factory – could rapidly accelerate the penetration of electric vehicles in the transport sector. The most direct impact would be an increase in the efficiency of the transport fleet and a displacement of gasoline demand. Electric Vehicles (EVs) or certain hybrid vehicles would become much more affordable when energy storage is made more available. The increase in these alternative-fuel vehicles should displace conventional gasoline-powered vehicles. The result of this displacement should be shown in both lower growth of gasoline demand (and over time curtailed gasoline demand) as well as higher fuel-efficiencies, because alternative-fuel vehicles simply use less fossil fuel. Trucks, with their higher power requirement, should see much less penetration of EVs, so that diesel (or substituted natural gas) demand would not be affected as much.

The transportation sector, which accounts for 57% of oil demand, continues to benefit from improving efficiency and emissions standards. Per-tonne fuel efficiency in aviation has increased 1.2% p.a since 2005, sales of hybrid vehicles accounted for 1.6% of global vehicle sales in 2013 and shipping vessels globally are averaging all-time low speeds of below 6 knots/hour (the slower the ship, the more economical the fuel usage).

Road vehicle efficiency continues to improve globally, with fuel economy improving 2-5% annually across the majority of recorded countries. The US, which is at the bottom of the pile in terms of fuel economy standards (see fig 4), has seen average fuel economy of new cars rise 4.6-mpg since 2008 (~4% CAGR) according to the Consumer Federation of America. Fuel economy mandates tend to be prioritized more in OECD countries, although China does have mandated levels around 5-mpg higher than the US, yet with gasoline demand still majority OECD based then as fuel economy improves, significant inroads can be made into transportation demand for oil. In 2013 OECD gasoline demand was ~14-m b/d whilst non-OECD demand was ~9.3-m b/d and together they accounted for ~26% of total oil demand.

Citi estimates that mandated fuel economy increases in the US will cut gasoline consumption in the US by 0.9-m b/d in 2020 from 2013 levels, and that the combined impact of higher fuel efficiency and accelerated fuel substitution can cut global oil demand growth to just 0.5–m b/d by the end of the decade. The chart below shows Citi's forecasts for oil demand under various scenarios, and compares Citi's Business as Usual (BAU) forecast to the IEA's Medium Term Outlook from 2014. While the IEA's forecast does incorporate higher fuel economy mandates and some degree of fuel substitution, Citi is more optimistic on both.

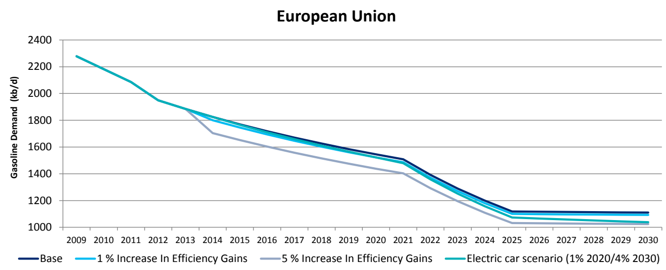
Figure 43. Global Oil Demand Forecasts Under Various Scenarios (m-b/d, 2013-20E)



Source: IEA, Citi Research

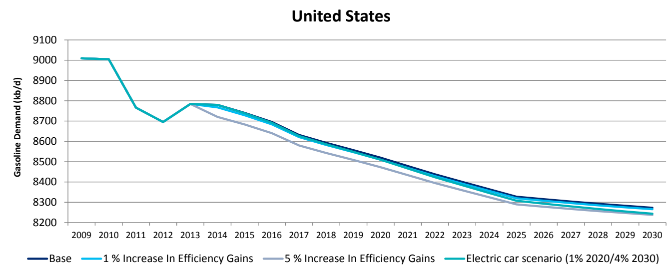
Below we show modeled estimates of gasoline demand under base case and various scenarios, including one with a 1% penetration of electric cars by 2020 and a 4% penetration by 2030. We witness an accelerated moderation of OECD gasoline demand moderates while growth non-OECD demand bends slightly.

Figure 44. EU Gasoline Demand Declines Faster



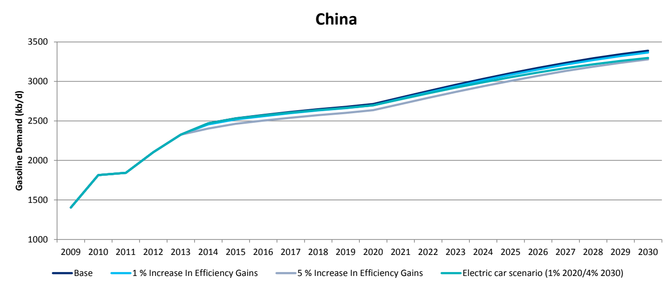
Source: Citi Research

Figure 45. US Gasoline Demand Drops Further



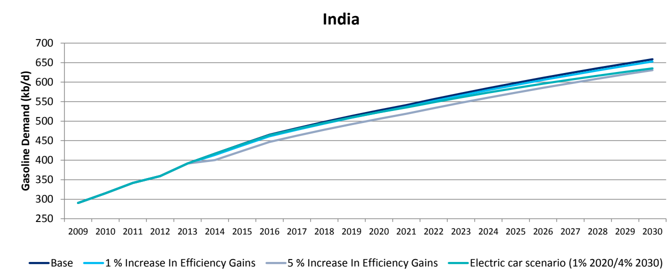
Source: Citi Research

Figure 46. China's Gasoline Demand Growth Moderates



Source: Citi Research

Figure 47. India's Gasoline Demand Growth Bends Lower



Source: Citi Research

Impact 6: Storage Would Change the Fundamental Structure of Power Markets

Electricity is currently one of the few non-storable commodities – energy storage might change that and the electricity markets along with it. Storage would create electricity "inventories", making electricity markets more similar to commodities markets like those for gas or coal.

What links spot markets to forward markets in most commodity markets is the cost of carry (storage, interest, insurance). There is no cost of carry for power now because power can't be meaningfully stored. But just as oil tankers opportunistically become floating storage tanks and help shape the forward curve, energy storage would create a stronger link between spot and forward prices, fundamentally altering the relationship between spot and forward power. Arbitrage relationships would give forward power curves stricter structure.

As storage technologies mature over time, storing power for longer timeframes and at greater scales, this would strengthen the liquidity and visibility of forward curves, which, in turn, would make financing all types of energy assets simpler and cheaper. As developers are better able to transfer project price risk to those who want it, cost of capital and - where regulated – allowed returns, for all types of power, including renewables, should come down.

Appendix A-1

Analyst Certification

The research analyst(s) primarily responsible for the preparation and content of this research report are named in bold text in the author block at the front of the product except for those sections where an analyst's name appears in bold alongside content which is attributable to that analyst. Each of these analyst(s) certify, with respect to the section(s) of the report for which they are responsible, that the views expressed therein accurately reflect their personal views about each issuer and security referenced and were prepared in an independent manner, including with respect to Citigroup Global Markets Inc and its affiliates. No part of the research analyst's compensation was, is, or will be, directly or indirectly, related to the specific recommendation(s) or view(s) expressed by that research analyst in this report.

IMPORTANT DISCLOSURES

Citigroup Global Markets Ltd has been appointed as financial advisor to Enel Spa on the announced sale of the company assets in Romania.

Due to Citi advising Karoon Gas Australia Ltd on the sale of their equity interest in the Browse Basin exploration permits to Origin Energy Limited (the Company), Citi Research restricted publication of new research reports, and suspended its rating and target price on 2 June 2014 (the Suspension Date'). Please note that the Company price chart that appears in this report and available on Citi Research's disclosure website does not reflect that Citi Research did not have a rating or target price between the Suspension Date and 4 June 2014 when Citi Research resumed full coverage.

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Citigroup Global Markets Inc. owns a position of 1 million USD or more in the debt securities of FirstEnergy Corp

Citigroup Global Markets Inc. owns a position of 1 million USD or more in the debt securities of Apple Inc

Citigroup Global Markets Inc. owns a position of 1 million USD or more in the debt securities of Boeing Co

Citigroup Global Markets Ltd is acting as Joint Global Coordinator and Joint Bookrunner in relation to the proposed IPO of Abengoa Yield Plc.

Citigroup Global Markets Inc. owns a position of 1 million USD or more in the debt securities of Kohl's Corp

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An employee of Citigroup Global Markets or its affiliates is a trustee of Target Corp. Citigroup Global Markets Inc. owns a position of 1 million USD or more in the debt securities of Target Corp

Citigroup Global Markets Inc. owns a position of 1 million USD or more in the debt securities of Exelon Corp

Citigroup Global Markets Limited is acting as Joint Bookrunner on the announced Acelerated Equity Offering in Iberdrola Shares.

Citigroup Global Markets Inc. owns a position of 1 million USD or more in the debt securities of Electricite de France SA

Citigroup Global Markets Inc. owns a position of 1 million USD or more in the debt securities of Wal-Mart Stores Inc

Citigroup Global Markets Inc. owns a position of 1 million USD or more in the debt securities of Entergy Corp

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