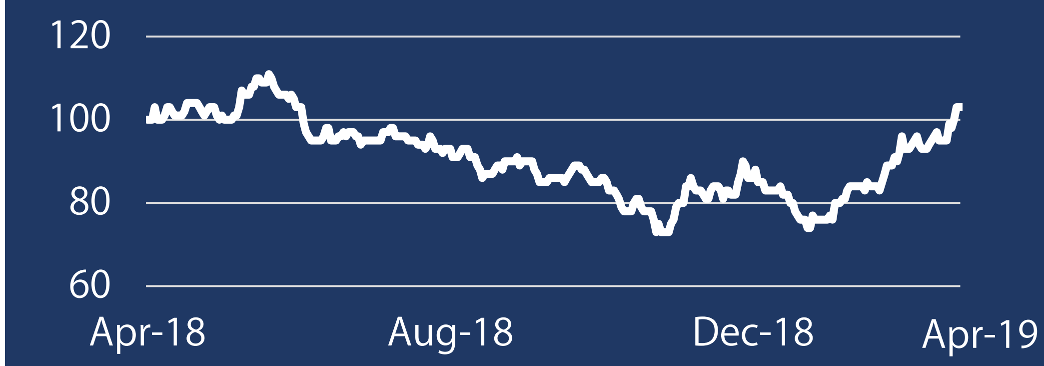
OXFORD ALPHA FUND

Renewable Energy

Upstream, Downstream and Storage

MAC Global Solar Energy Index



1 April 2019

From Zero (Emission) to Hero

We believe that grid parity has largely been achieved and that integration costs and storage costs are largely overstated; we are consequently bullish on both the solar modules and storage sectors.

Key Theses:

1) **Unsubsidised Grid Parity:** Grid Parity has been achieved in most states and it is consensus' **overestimation of integration costs and storage costs** that are limiting adoption.

2) **Solar is our Pick: Solar Photovoltaic (PV) is most attractive** due to scalability and implementation ease. We find other renewable generation methods such as CSP and Wind unactionable and unattractive.

3) **Solar Inseparable from Storage:** Unlike traditional energy generation, renewable energy brings with it the problem of intermittency and storage is the only solution for electricity levelling. **Lithium-ion batteries are best placed to benefit** from the influx of storage in the grid in addition to other sources of demand.

4) **Upstream:** We find the polysilicon industry unattractive because **supply continues to outstrip demand** as China becomes self-sufficient.

5) **Isolating Modules:** We observed that falling PV prices are mostly driven by **cost reductions rather than margin erosion**. Modules manufacturers will benefit from improved efficiencies even when subsidies are retracted. We **expect margins to recover** and we **prefer high efficiency module manufacturers** as they have historically been protected from margin contraction.

Possible Positions

Upstream	
First Solar	NASDAQ:FSLR
Canadian Solar	NASDAQ:CSIQ
Downstream	
Sunrun Inc	NASDAQ:RUN
Emphase	NASDAQ:ENPH
Storage	
Panasonic	TYO:6752
CATL	LON:CATL
BYD	SHE:002594
LG Chem	KRX:051910

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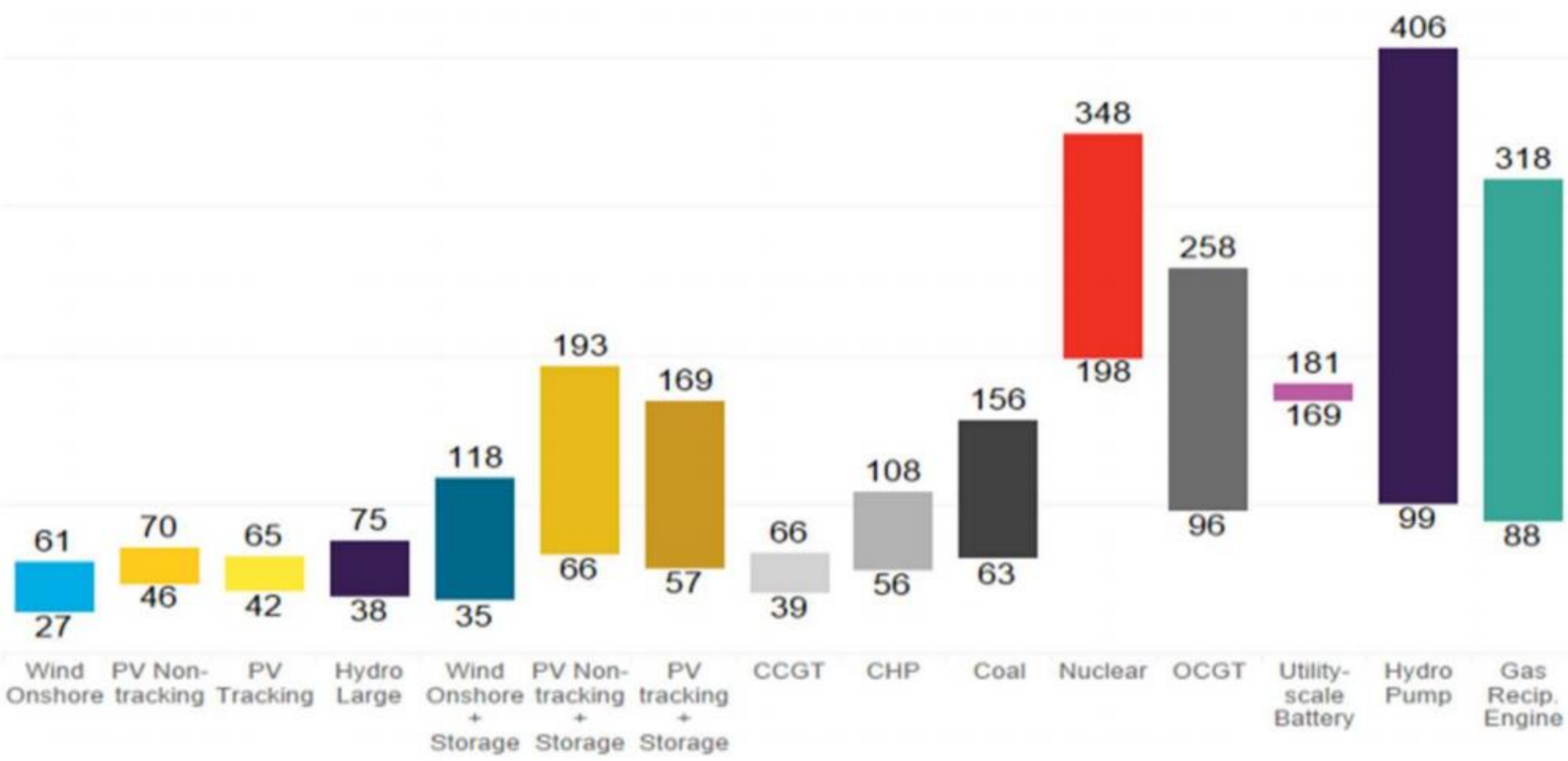
Renewable Energy's Unit Cost Continues to Decline

The Case for Renewable Energy: While the social case for zero carbon emission and alternative energy has been undisputed, the same might not have been said for the economic case. As the **levelized cost of electricity (LCOE) for both Wind and Solar declines**, the switch to alternative energy becomes even more obvious.

Exhibit 1: LCOE Range in USA ($/MWh) Provides Case for Alt Energy



Source: Bloomberg New Energy Finance

No Safe and Straightforward 'Catch All' Proxy for Renewables

The Obvious Part: Economies of scale, technological innovation on the supply side and auction-based pricing, incentives and unit economics on the demand side will likely present opportunities for utilities, IPPs, corporates and homeowners to participate in **low-cost and low-capacity renewable energy**. As emerging markets provide the majority of electricity demand growth, we expect to see a shift towards renewable energy in this geographies.

Disruption Does not Equate Good Investment: However, renewable energy assets are often co-located with end-use, allowing end-customers to both own and operate them. The solar industry can be divided into an upstream manufacturing segment and downstream installation and/or financing segment. **The upstream is plagued by intense competition and downwards pricing pressure, while the downstream is often characterised by highly capital-intensive business models**. There are also further headwinds, such as regulations and tariffs.

Where the Opportunities are: We do find that there could be **pockets of opportunities** in specific portions of the value chain. Notably, high efficiency module manufacturers and storage solutions for renewable energy in order to overcome the intermittency problem.

LCOE & Grid Parity

Solar costs have been going down, and will go down further

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LCOE & Its Drivers

In order to assess the viability of renewable energy sources, the first and foremost factor to consider is **grid parity**, or the savings from energy generation from alternative sources over conventional sources. The key gauge on the renewable side is its **levelised cost of electricity** (LCOE), a measure of the unit cost of energy generated by a particular system over its lifetime. Our first thesis is that on the cost side, **LCOE has declined sharply and will continue to decline.**

When analysing LCOE, four major drivers are typically considered:

The first two are the **solar intensity** and the **financing cost**. The stronger the sunlight, the higher the energy output and the lower the cost. Financing cost typically represents the cost of equity and/or debt of setting up a project. We see these two drivers as exogenous and likely to remain constant in the near future.

Our main theses will revolve around the last two drivers: **system-related cost** and **governmental support schemes**. System costs include initial capital spending, subsequent operation and maintenance (O&M), and decommissioning costs, whereas governmental support schemes include subsidies through tax credits on investments and "net metering," a mandate that renewable energy generated in excess of demand can be sold back to utility companies at the retail rate.

Exhibit 2: Framework of LCOE Drivers

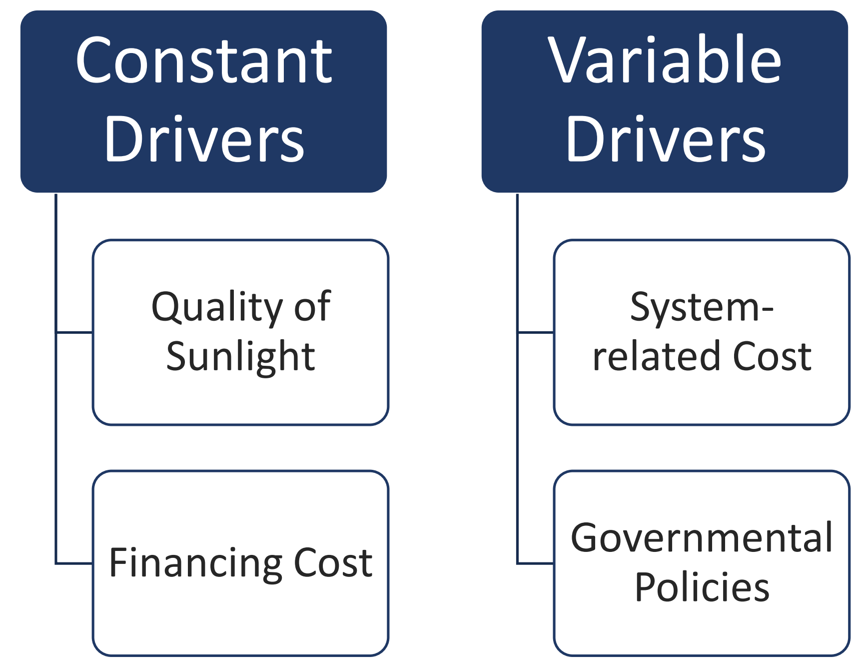
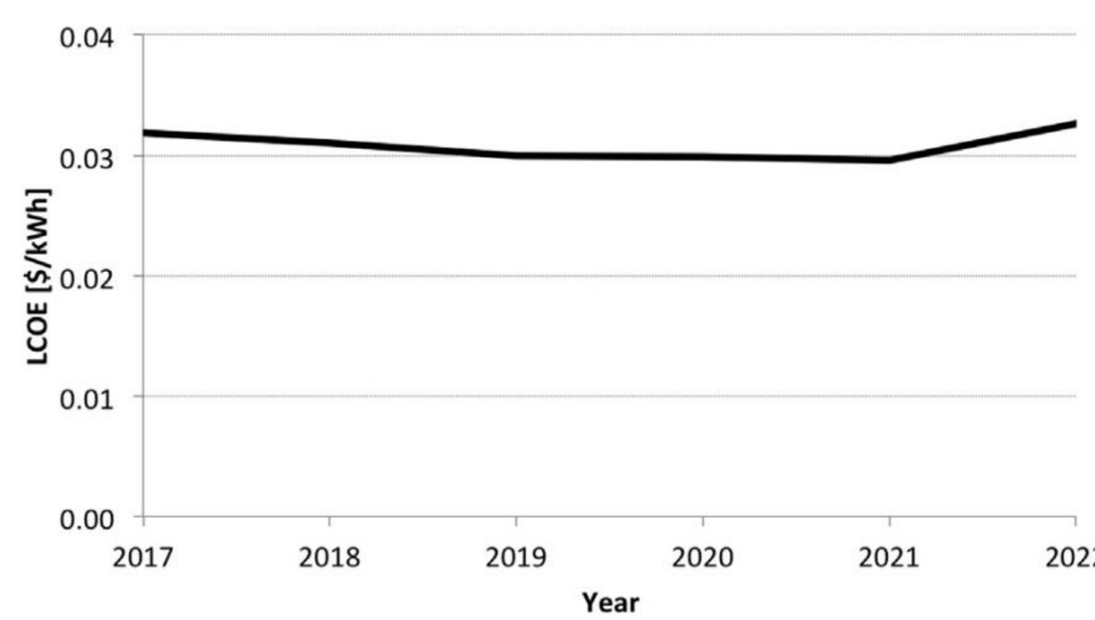


Exhibit 3: LCOE Path with Complete Policy Removal



Source: Comello et al 2018

Projected Pathway for LCOE

In terms of LCOE drivers, we see that while system costs and policy support will likely move in opposite directions in terms of their impacts on LCOE, there is likely to be a **continued decrease in LCOE within the next 5 years.**

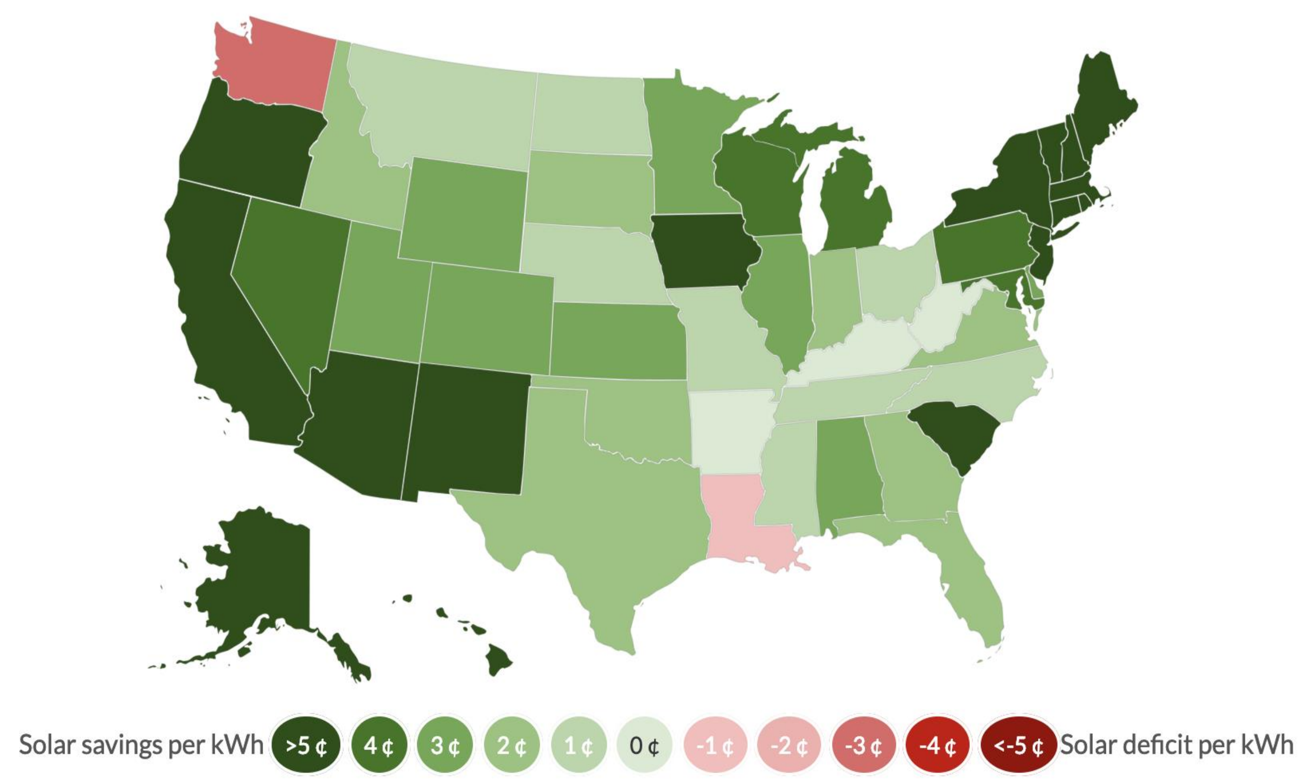
System prices are projected to decline further. Module prices have been declining following an 80% learning curve, and the declines in recent years have been steeper. BOS component costs, which contribute to a larger proportion of the capital cost, are projected to be declining by 6.5% year-over-year up to 2025. On the policy side, specific mechanisms associated with renewable energy sources are largely regional, but it is **conceivable that supports will be gradually phased out** as solar becomes more competitive.

However, when considering both probability and magnitudes, the **cost declines outweigh the policy removals**. Based on past trends of technological improvements, **price declines are almost certain, whereas the removal of subsidies and other policy supports are largely speculative**. On the magnitude side, the most conservative cost decline estimates balance out with the most aggressive subsidy cuts. Studies have shown that the continuation of historical trends of the 80% learning curve would largely balance out with a gradual phasing out of federal policy support leading up to 2022.

Unsubsidised grid parity is largely achieved

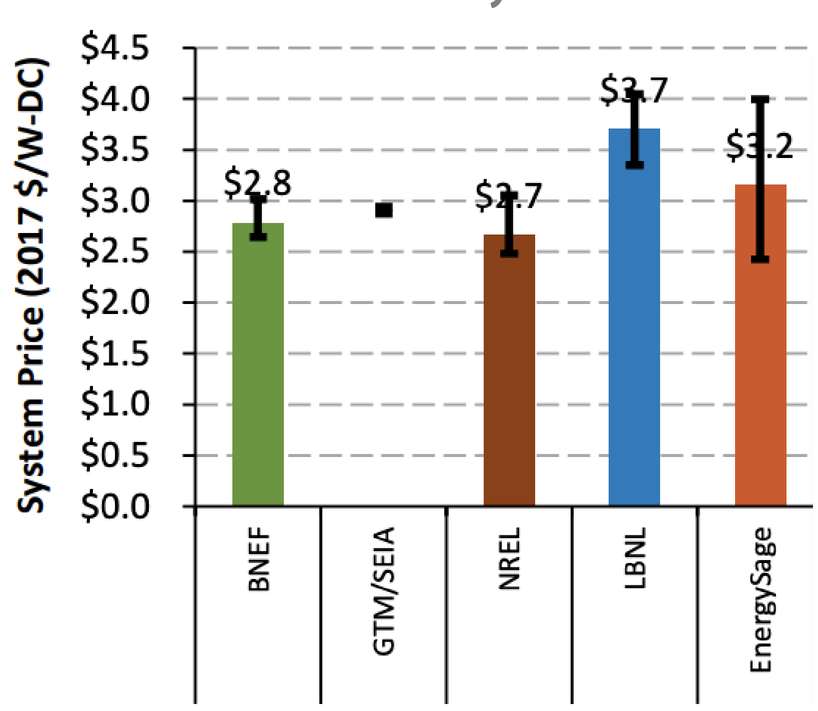
Grid parity occurs when an alternative energy source LCOEs are less than or equal to the price of power from the electricity grid. This brings about our second thesis: **grid parity has already largely been achieved independent of subsidies and cost decline projections**. The attached map reflects the current level of solar savings across all 50 US states. As seen by the map, 16 states are already showing over 5 cents per Kilo-Watt-hour of savings from solar, and only 2 states are showing grid prices lower than the costs of solar.

Exhibit 4: US Solar Grid Parity with System Cost of $3.25 per Watt



Source: Sunmetrix

Exhibit 5: US Solar System Prices



Source: NREL

Exhibit 6: Utility Scale Prices

	Dec-18	Dec-17
New England	20.7	19.18
Middle Atlantic	15.33	15.39
East North Central	12.86	12.9
West North Central	10.83	11.1
South Atlantic	11.2	11.29
East South Central	10.93	10.96
West South Central	10.44	10.38
Mountain	11.46	11.54
Pacific Contiguous	15.08	14.45
Pacific Noncontiguous	28.46	26.11
U.S. Total	12.47	12.45

Source: EIA Electric Power Monthly

Tailwinds Yet to be Priced In

In addition to the graph above, we see additional upside for grid parity in real life because of the lack of subsidies and the time lag of model inputs.

The current map reflects the prices of installing solar **without the 30% renewable energy credit supported by the federal government**. Once accounting for the subsidy, we see all states reaching solar saving with over 30 states reaching 5 cents or more of saving.

Additionally, the above map assumes a system cost of $3.25 per Watt and uses utility grid data from December 2017. In terms of system prices, the Q2-Q3 2018 data from NREL shows an **average of $3.1 per Watt** across 5 national surveys, and the prices have conceivably decreased further in the meantime **(Exhibit 6)**. As for utility scale prices, both the national total and several larger regions such as New England and the Pacific regions have seen increases, indicating additional unaccounted-for competitiveness of solar-based generation methods.

Both of these factors combined show that **unsubsidized grid parity has been achieved in almost all states given current system and utility scale prices.**

LCOE & Grid Parity
INTEGRATING INTEGRATION COSTS

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Integration Costs are Low and Counterbalanced

Conventional analysis of grid parity focuses on comparing the LCOE and grid prices directly, but some critics of renewables have pointed to costs other than the levelised costs. **The most significant cost of implementing solar in practice is integration cost. We believe that while integration costs exist, they are both too low to pose significant impact to our central thesis and counterbalanced by solar's unique synergistic effects**.

Integration costs refer to the various costs incurred when a new power system is integrated into the existing power plant systems. More specifically, the integration costs are broken into three parts:

1. **Grid cost**: Costs to bring the electricity to where it is demanded
2. **Balancing cost**: Cost to offset differences between actual production and forecasts
3. **Utilization effect**: Costs (or benefits) from interaction with other power plants, most significantly, the increase in the specific generation costs of other power plants due to the reduction of their full load hours

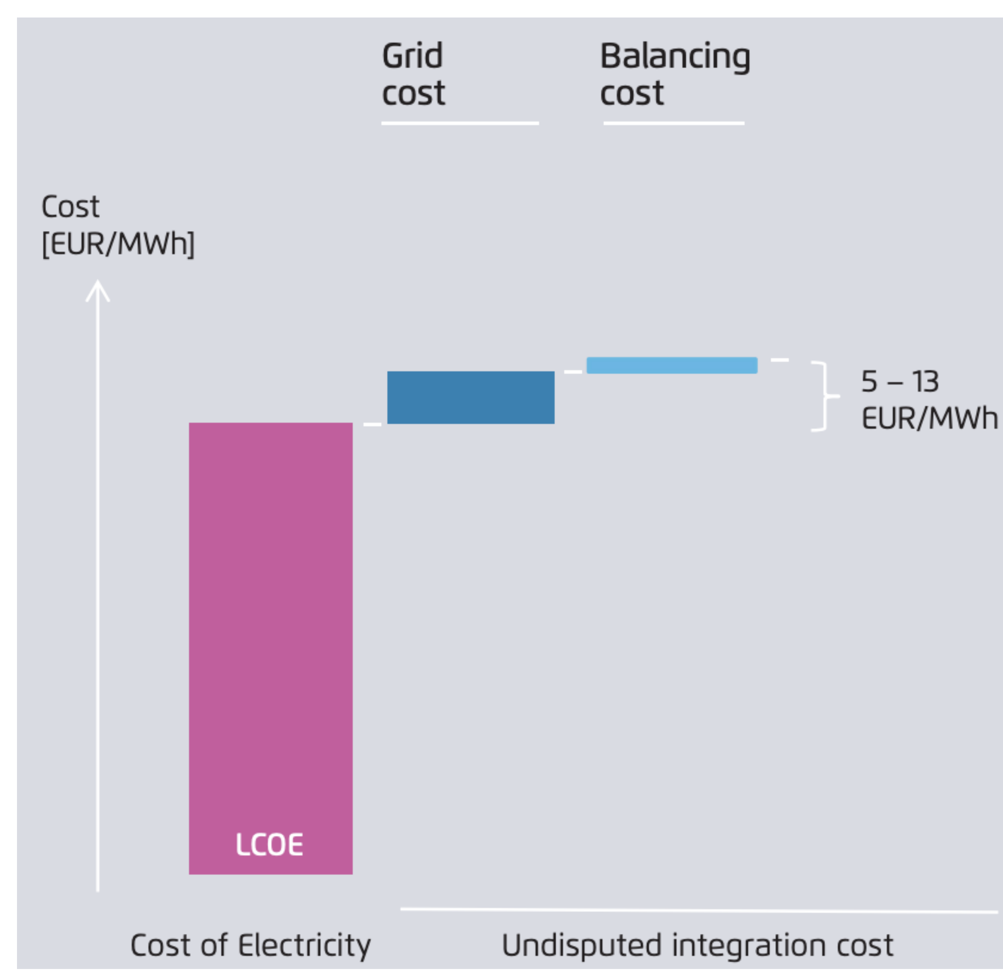
Magnitude of Integration Costs

Across many recent studies, the undisputed integration costs (grid costs and balancing costs) are around 8 Euros per Megawatt-Hour, which is less than 1 cent per Kilowatt-Hour. Following our analysis before, incorporating these costs will not impact the directions of grid parity in most US states.

In addition, the integration cost framework only takes into account the energy generation and absolute cost involved with energy sources. However, when actually comparing the cost of solar to grid prices, synergies are typically present under the current time-of-day pricing model. Time-of-day pricing charges higher electricity prices during the day and lower rates during the night. Since solar has the unique benefit of generating more power during the day, there are additional price advantages in place to counterbalance integration costs.

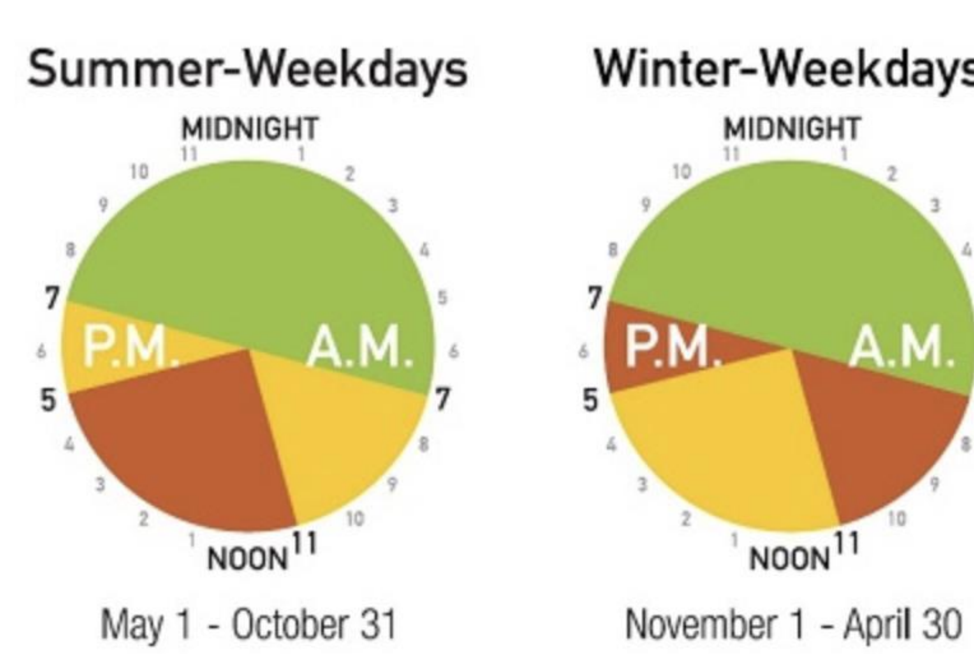
Admittedly, there are limitations on the accounting of integration costs due to their regional nature. As integration costs are largely reliant on both the specific grid set-up and real-time solar power generation, there are large variances across geographical regions on integration costs. Utilization effects face the additional challenge of needing to consider both the level of renewable energy penetration and the differing treatments of greenfield and brownfield cases. Thus, there are many disputes on the direction and magnitude of such effects. **Our conviction is that utilization effects are largely neutral to our thesis, as the places facing high utilization effects (mainly due to high levels of solar penetration) will inherently have lower grid and balancing costs.**

Exhibit 7: Undisputed Integration Costs



Source: Agora Energiewende

Exhibit 8: Sample Framework for Time-of-Day Pricing



Source: Alectra Utilities

Storage & Project Economics
Store away that pessimism

Economic case still holds after accounting for storage needs

In addition to incorporating integration costs to the grid, critics of solar have pointed to the lack of accounting for storage systems within the LCOE model. In relation to our theses, we acknowledge that integrating storage system for solar energy will be the trend in the long run (the necessity for storage will be discussed later), but we see that the **economic case for solar still holds after accounting for storage needs**.

As the introduction of storage systems to solar projects was quite recent, there is limited data available for analysis. To resolve that issue, Lazard recently produced a report on the Levelised Cost of Storage (LCOS) for solar, which attempts to calculate the cost of storing energy per Kilowatt-Hour. Within Lazard's LCOS 4.0, its most recent report, the LCOS is calculated to be between 10 and 30 cents per Kilowatt-Hour. However, it is important to realise that the impact of storage system on solar projects is **not a direct addition of LCOS to LCOE**. More specifically, storage systems bring in additional revenue by **allowing energy arbitrage and reduction of demand charges**, given the time-of-day pricing system discussed earlier.

Consensus & Projected Trends

Lazard has pointed to two important findings that support our thesis of economic case still holds after integrating storage systems. Firstly, even at marginally higher cost compared to traditional sources, **commercial grade solar plus storage system is already viable at the commercial level**. This is due to a combination of two main factors: shared infrastructure in terms of inverters at relatively low levels of solar penetration and the increasing benefits of storage as a way to overcome demand charges built into the retail grids. Secondly, **cost of storage is projected to decline further**. The main drivers of technological improvements and over-capacity are expected to remain in the near future. Further explanation on the price movements of lithium ion technology specifically will be provided later.

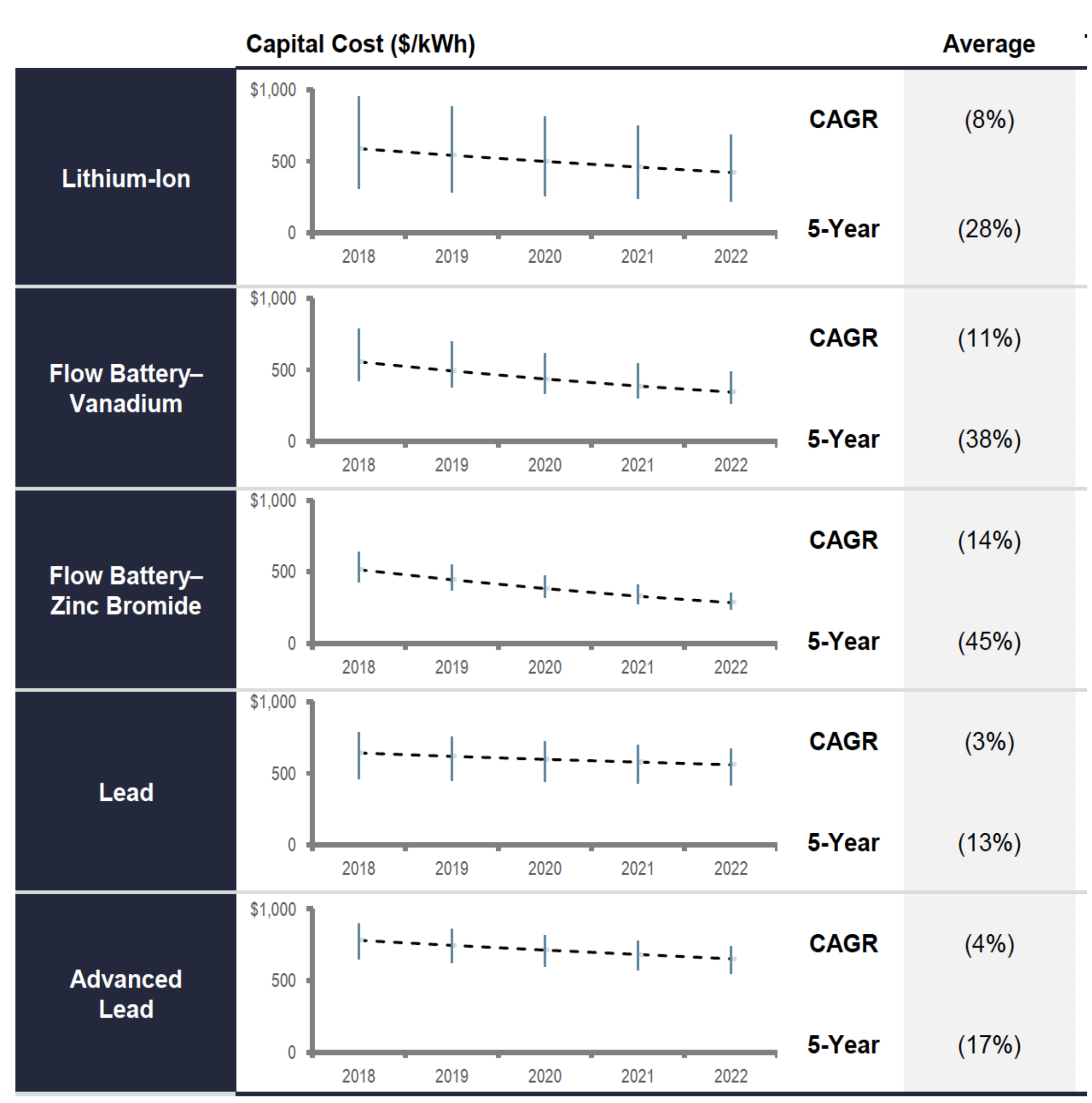
Consensus Overestimates

Our conviction in the competitiveness of solar + storage comes from more than the consensus view: **we believe that Lazard overestimates LCOS by a factor of potentially as great as 6** by overlooking several important factors in the current space.

Firstly**, policy support** was not accounted for. As mentioned earlier, all solar-related investments are eligible for the 30% Investment Tax Credit within the US, and the battery storage system is part of the plan. Including various support schemes at the local level, as much as 50% of the cost can be discounted.

Secondly, **duration was treated as exogenous**. The duration for a particular PV storage system is the time it takes to fully charge and is calculated by the ratio of power rating and the average energy storage. Lazard assumes a constant duration of 2 hours for commercial projects and 4 hours for wholesale projects, but recent studies have shown that under optimal condition, the duration can extend to 6 hours on average, linearly reducing the levelised cost by a factor of 3.

Exhibit 9: Capital Cost Path for Different Technologies



Source: Lazard

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Value Chain Outline

The solar upstream value chain can be disaggregated into two parts: **polysilicon production** and **solar module manufacturing**.

While polysilicon is an important input factor for the module industry, the polysilicon industry has suffered under **increasing pressure on margins and global trade relationships**. The US share in polysilicon production has fallen from a peak of 29.1% to a low of 11.3% between 2010 and 2017 as a result of Chinese tariffs. Similarly, German Wacker Chemie AG has seen a slump of 27% in polysilicon revenues after China announced its 531 Policy and its plan to be self-sufficient by 2019. As non-Chinese poly producers are slowly cut off from the value chain further declines in revenue are to be expected.

Ample supply of polysilicon is also threatening the health of the industry. Threshold polysilicon prices have hit a low of $10/kg without much hope of price recovery. According to Rothschild, polysilicon production should rise by 32% in 2019. Demand, on the other hand, will only grow by a meagre 5-10%. This means, there may be an oversupply of as much as 120000 MT polysilicon. The increasing adoption of monocrystalline wafers, which require less polysilicon (3g/Wafer versus 4.9g/Wafer previously), should put further downward pressure on the demand for poly.

The solar module market is the next highest in the value chain. Production of modules is both capital and technology intensive. **Module process have declined strongly, but declines were not enough to offset the increase in demand**. In China, a 20.1% annual growth in output contributed to 17.9% growth in module revenues. ACMR-IBISWorld predicts that industry revenue will continue to grow at 7% until 2022. Solar module prices have not deviated strongly from the learning curve, indicating that most price decline is actually caused by increases in efficiency. Margins for the top 5 module manufacturers have decreased, but not as drastically as expected. Decreases in input material prices have helped maintain steady gross margins.

Exhibit 10: Solar PV Value Chain

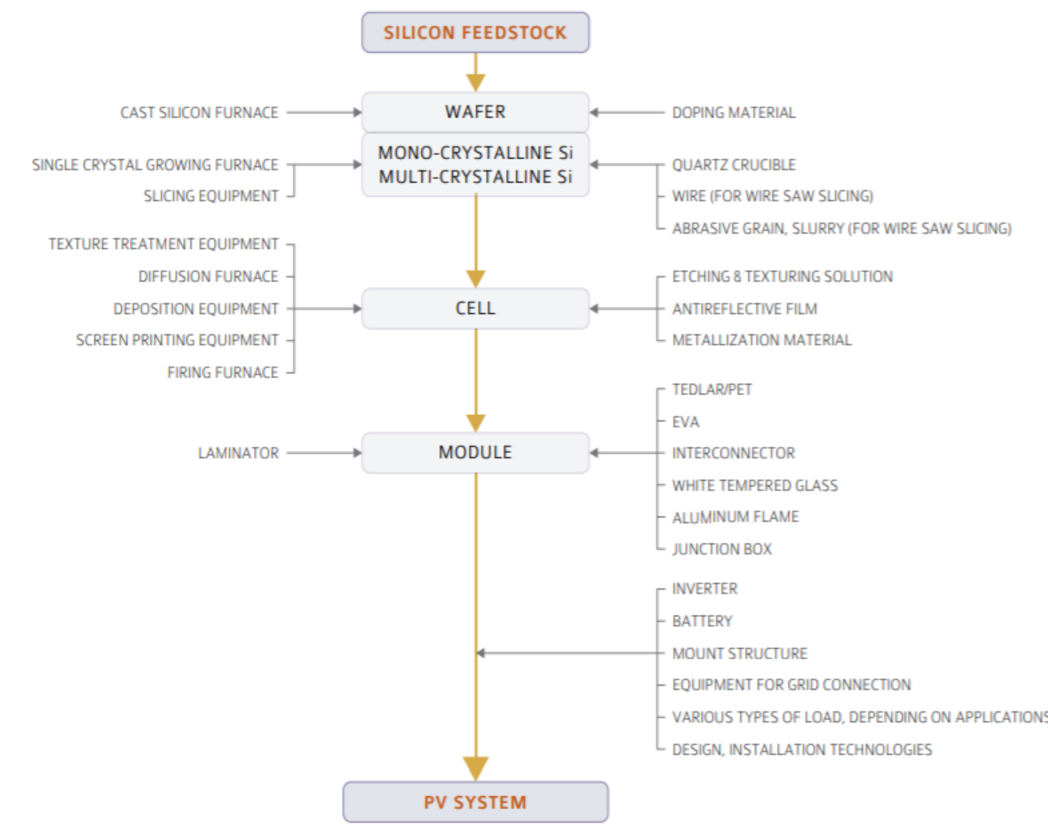
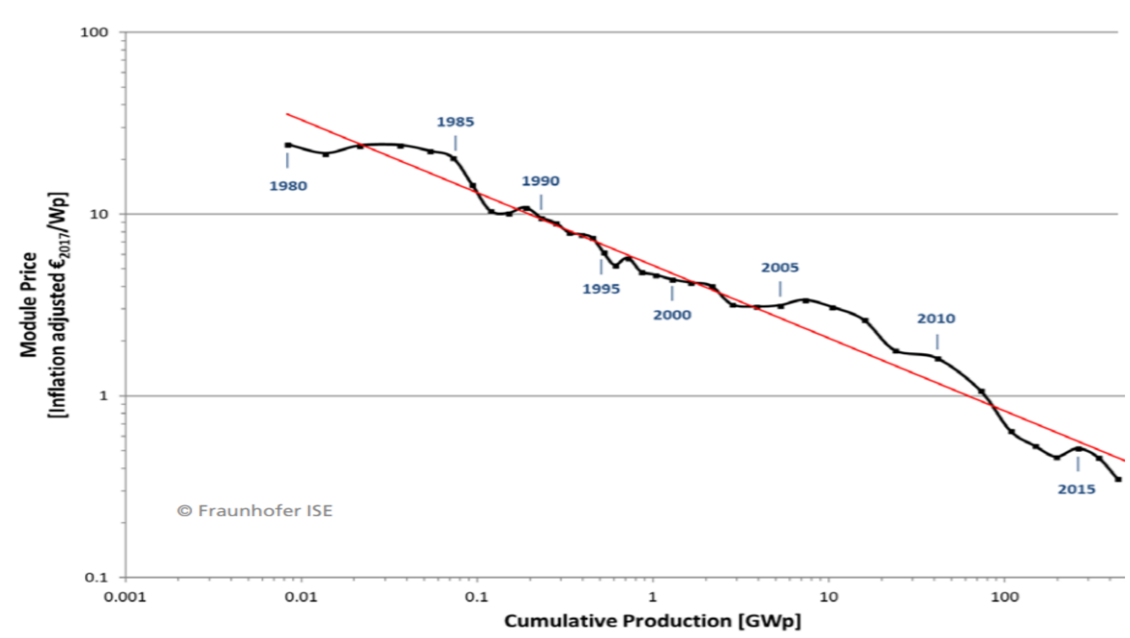
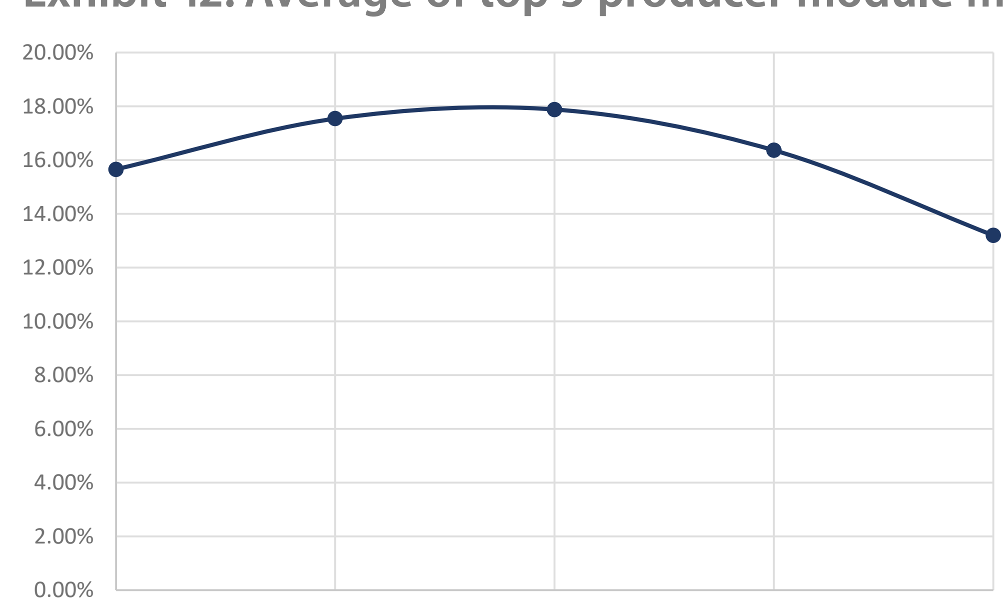


Exhibit: 11 Average solar module learning curve



Source: Fraunhofer Institute for Solar Energy

Exhibit 12: Average of top 5 producer module margins



Source: CapitalIQ

Upstream: Modules
Photovoltaic Pricing volatility?

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PV Margin Erosion is Highly Exaggerated

Photovoltaic modules are priced relative to the watts they generate. In the previous years PV module prices have declined by about 80% between 2009 and 2015. One main driver for this is the increase in power-efficiency, which decreases $/W prices. Sol Systems expects the module capacity to increase by 5-10W annually. For typical 250W modules this means a **large fraction of the decline in relative module prices is not actually a decline in prices themselves**.

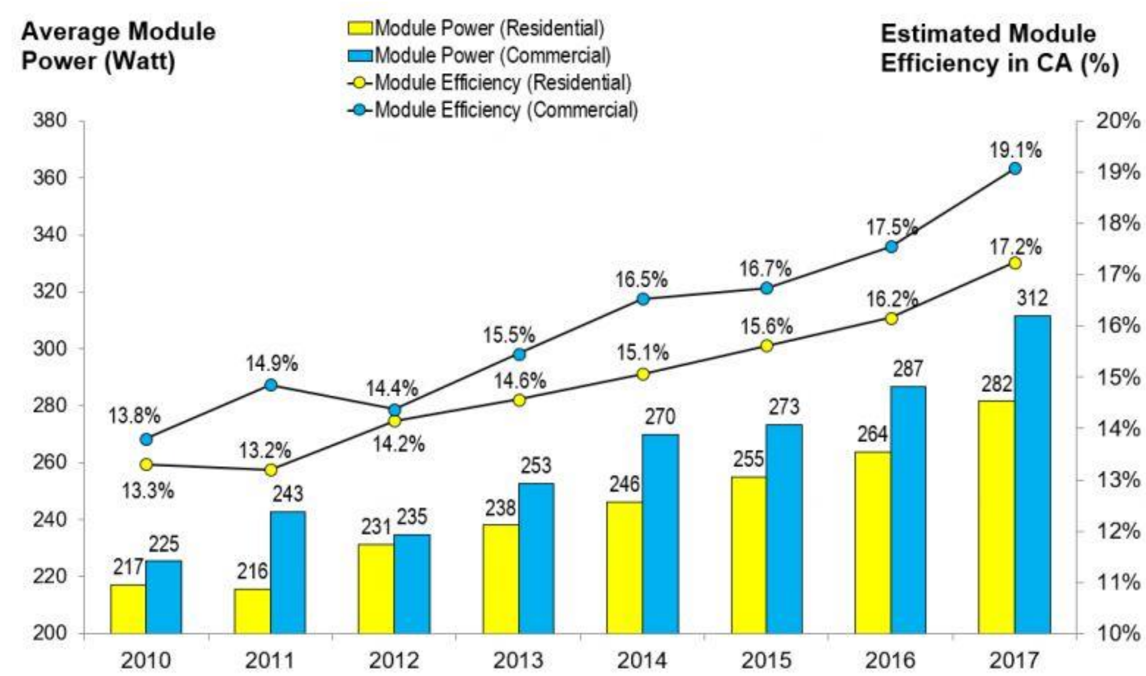
The second driver is decreases in production costs and improvements in technology. Chinese polysilicon prices have declined by 5.13% between Dec 2018 and Mar 2019. These declines typically lead to lower module prices. Economies of scale have also helped large producers cut costs. On the technological side, **every doubling of PV capacity coincides with a 20% drop in module costs, as suggested by the solar PV learning curve**. As more modules are produced, this will naturally contribute to lower prices at neutral margin impact.

Oversupply has been a problem for PV modules historically. Lack of capital discipline and regulatory changes have left the market awash with modules. China's unanticipated 531 Policy has led PV demand in China to drop by about 40%, leaving producers with excess modules. **Industry consolidation and factory closures should both reduce the risks of this happening again**.

Trina Solar and current price trends indicate module price stabilization in 2019. Other sources, including JinkoSolar and IRENA forecast further price drops of as much as 59% by 2025. Both highlight that **most price decrease will be due to reductions in manufacturing cost, suggesting neutral margin impact in either case**. In fact, First Solar is already anticipating margin increases for 2020. On a forward-looking basis, theses of margin erosion incorrectly extrapolate past supply shocks into the future. **It is highly likely that margins will improve above industry consensus.**

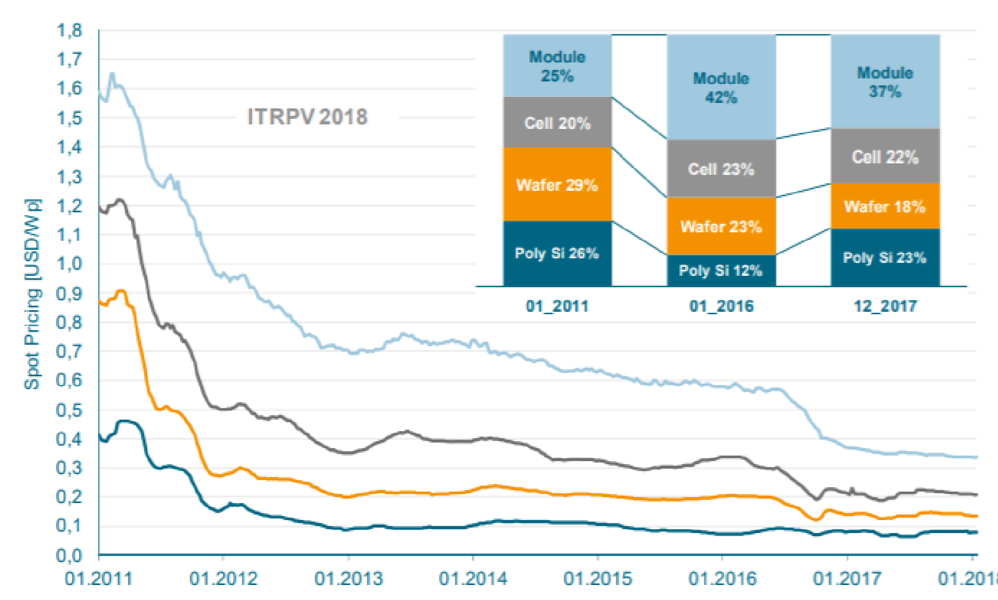
High-efficiency modules have brighter margin prospects. Typical customer include residential areas and businesses, both of which are less cost-sensitive than utilities. The top 3 high-efficiency producers have faced minimal margin deterioration compared to the top 5 module producers overall.

Exhibit 13: Average module power



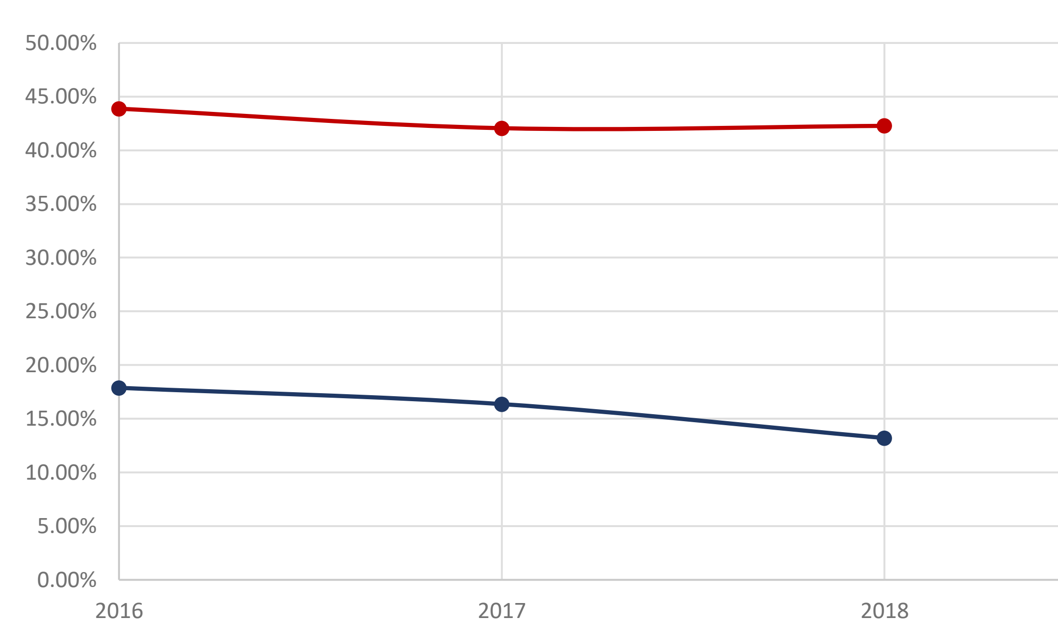
Source: NREL

Exhibit 14: Average solar module prices



Source: International Technology Roadmap for Photovoltaics 2019

Exhibit 15: High-efficiency module margins



Source: CapitalIQ

Energy Storage Technologies

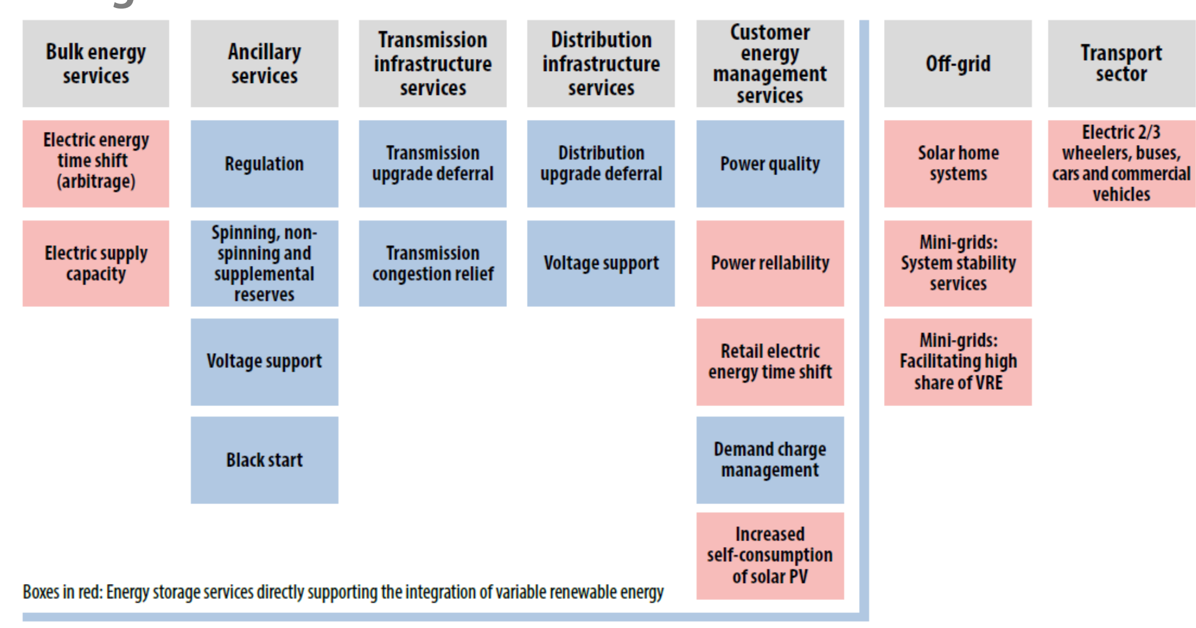
Energy storage in VREs: Storage is important for enabling system flexibility – a key asset as the share of variable renewable electricity (VRE) increases. At very high shares of VRE, electricity will need to be stored over days, weeks or months.

Direct application of electricity storage enables transport sector dominated by electric vehicles (EVs), enables effective, 24-hour off-grid solar home systems, supports 100% renewable mini-grids, and a host of other electricity grid-related improvements. Electricity systems already require a range of ancillary services to ensure smooth and reliable operation. Supply and demand need to be balanced in real time in order to ensure supply quality (e.g., maintaining constant voltage and frequency), avoid damage to electrical appliances and maintain supply to all users. **All electricity systems require a degree of flexibility** services, which allow grid operators to react to unexpected changes in demand or to the loss of large chunks of supply (e.g. large stations tripping offline, loss of an interconnection). Flexibility through storage gives operators the tools to rapidly restore system equilibrium.

Li-ion battery technology is the most viable among storage technologies to service PV technology. Advantages of Li-ion include high roundtrip efficiency, high power density, ample supply chain availability, falling cell and system costs, and favorable performance metrics. These favorable cost and performance characteristics of Li-ion batteries have stimulated interest in combining PV with Li-ion battery energy storage to provide dispatchable energy (i.e., energy on demand) and reliable capacity (i.e., grid stability). Among non-pumped hydro storage techologies, Li-ion batteries have led the global market in terms of additions since the end of 2012; within the US alone, it held a 98.8% market share in Q4 2017.

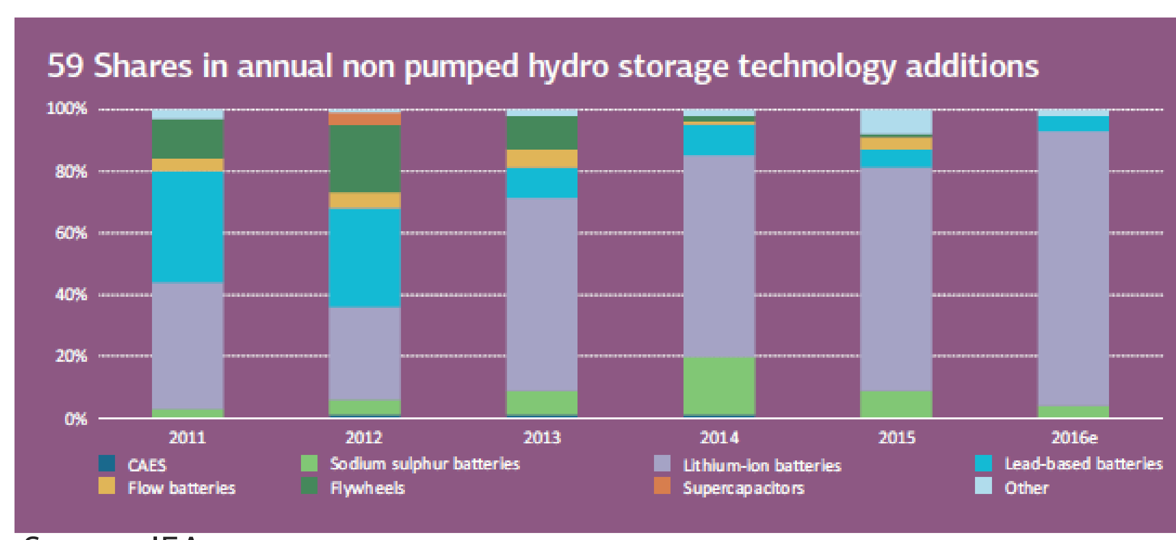
With our projected growth of the solar PV market, **we project an explosion of privately-financed growth in the use of Li-ion batteries for grid-scale energy storage**, entrenching it as the dominant design in this market.

Exhibit 16: Services that can be provided by electricity storage



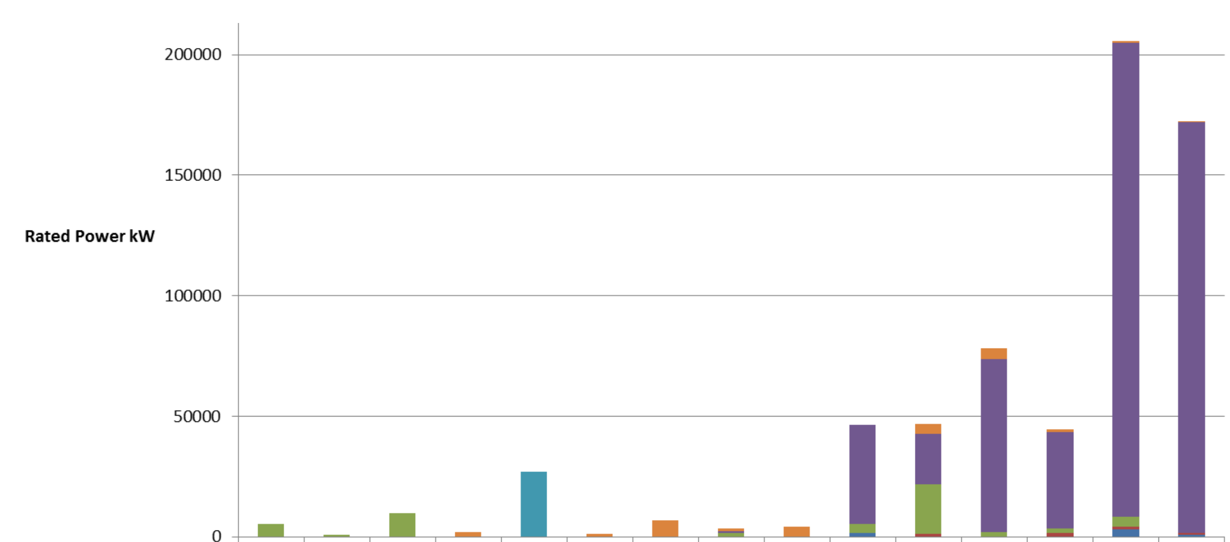
Source: NREL

Exhibit 17: Shares in annual non pumped hydro storage technology additions, 2011 - 2016



Source: IEA

Exhibit 18: US battery project additions by technology, 1996 - 2016



	1996	1997	2000	2001	2003	2006	2008	2009	2010	2011	2012	2013	2014	2015	2016
Sodium based Battery				2000		1200	7000	1000	4000		4025	4465	1300	470	105
Nickel based Battery					27000						85				
Lithium-ion Battery								1000		41001	20789	71572	39788	196436	170032
Lead-acid Batter	5250	1000	10000					1500	108	3625	20641	2074	2100	4200	60
Flow Battery										250	1160	100	1490	1318	1010
Electro-chemical										1500				3000	750

Source: MIT Energy Initiative

Li-ion Batteries and PV Deployment

In the 2000s, the grid-scale storage market was made up of small one-off projects that used a diversity of technologies. **Cost has historically been the barrier to deployment of integrated PV and storage technologies. However, improvements in Li-ion batteries as a method of storage have changed these economics rapidly**.

USA as market leader: Regional deployment of Li-ion is the highest in the USA, followed by Europe.

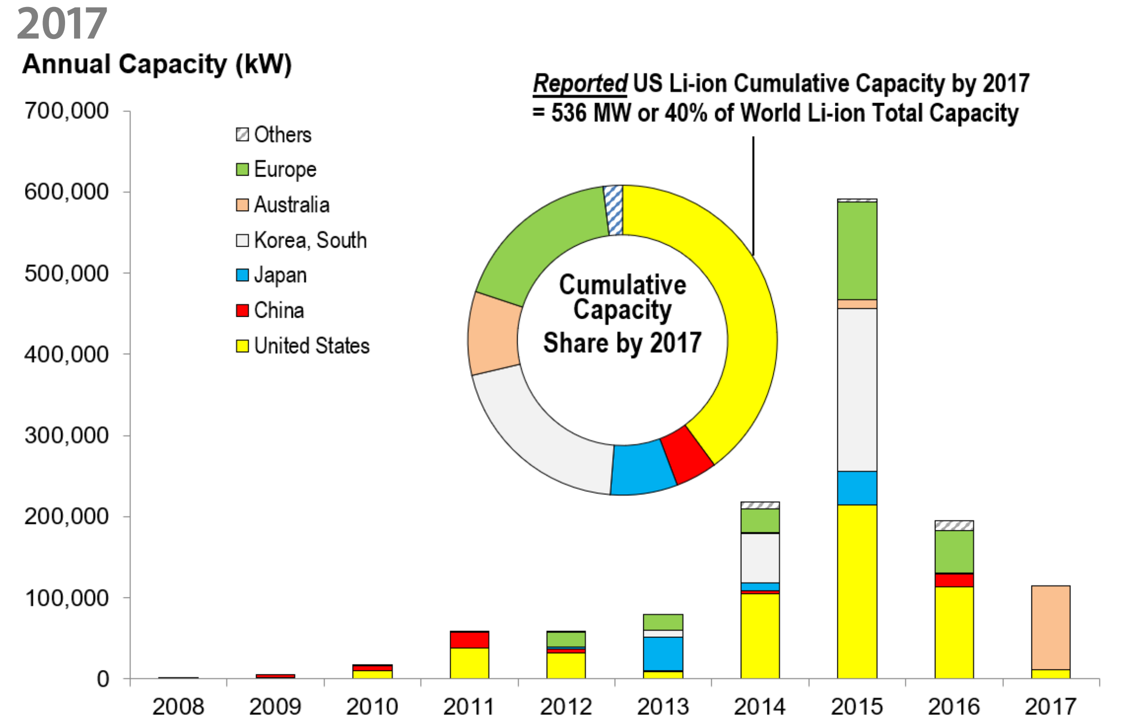
Historic deployment at utility-scale level: Of the U.S. Li-ion capacity through 2017, approximately 495 MW (92% of the capacity) was deployed in the utility-scale sector (systems larger than 1,000 kW), 8% in the commercial sector (systems of 10–1,000 kW), and less than 1% in the residential sector (systems smaller than 10 kW.

Future deployment at residential-scale ('behind the meter'): The International Renewable Energy Agency highlights that there is significant potential for growth in applications behind-the-meter, notably in order to increase the self-consumption share of the output of rooftop solar PV. Such growth is likely to be influenced by the economic opportunities to provide electricity time-shift services to increase self-consumption, or avoid peak demand charges in the residential and commercial sectors. Behind-the-meter storage could become the primary-use case for 60-64% of total BES energy capacity in stationary applications in 2030. This growth is contingent upon the presence of:

- Good regulatory structure (e.g. Germany)
- High electricity prices, generating an incentive to sell back-to-grid (e.g. Europe, Japan)
- Solar resources
- Relatively low grid feed-in remuneration (e.g. Australia)

Nonetheless, the utility-scale market for BES will continue to grow strongly, from an estimated 10 GWh in mid-2017 to between 45 GWh and 74 GWh in the Reference case and 81-187 GWh in the Remap Doubling case.

Exhibit 19: Li-ion storage deployment by region, 2008–2017



Source: DOE Energy Storage Database 2018

Exhibit 20: Battery electricity storage energy capacity growth in stationary applications by sector, 2017 – 2030

Source: IRENA Energy Storage and Renewables 2017

Cost Reduction Potential

Co-locating the PV and storage subsystems produces cost savings by reducing costs related to site preparation, land acquisition, permitting, interconnection, installation labour, hardware (via sharing of hardware such as switchgears, transformers, and controls), overhead, and profit. Such lower costs could facilitate PV-plus-storage project development, and the itemized cost savings could incentivize deployment of co-located PV-plus-storage systems.

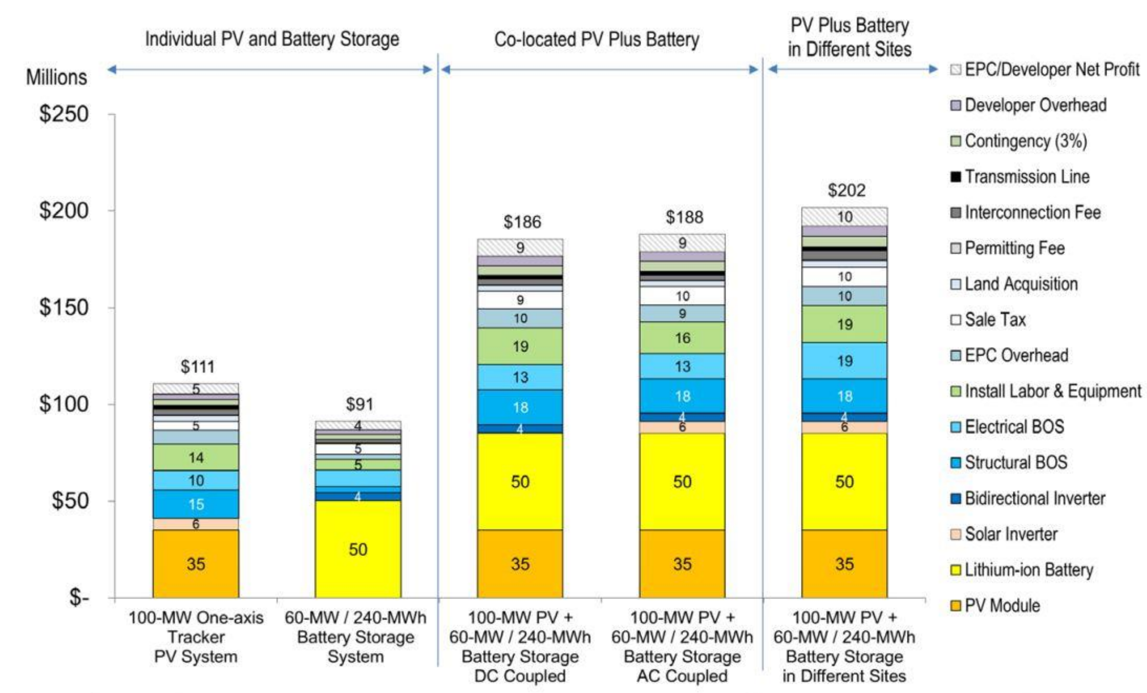
Further cost reductions (standalone, installed): The total installed cost of a standalone Li-ion battery could fall by an additional 54-61% by 2030 in stationary applications. Already, the cost of Li-ion batteries have fallen by as much as 73% between 2010 and 2016 for transport applications.

It is recognized that Li-ion batteries in stationary applications have a higher installed cost than those used in EVs due to the more challenging charge/discharge cycles that require more expensive battery management systems and hardware. In Germany, however, small-scale Li-ion battery systems have seen their total installed cost fall by 60% between Q4 2014 and Q2 2017. Benefitting from the growth in scale of Li-ion battery manufacturing for EVs, the cost could decrease in stationary applications by another 54-61% by 2030. This would reflect a drop in the total installed cost for Li-ion batteries for stationary applications to between USD 145/kWh and USD 480/kWh, depending on battery chemistry.

Moreover, cost decreases may still occur across the manufacturing value chain.

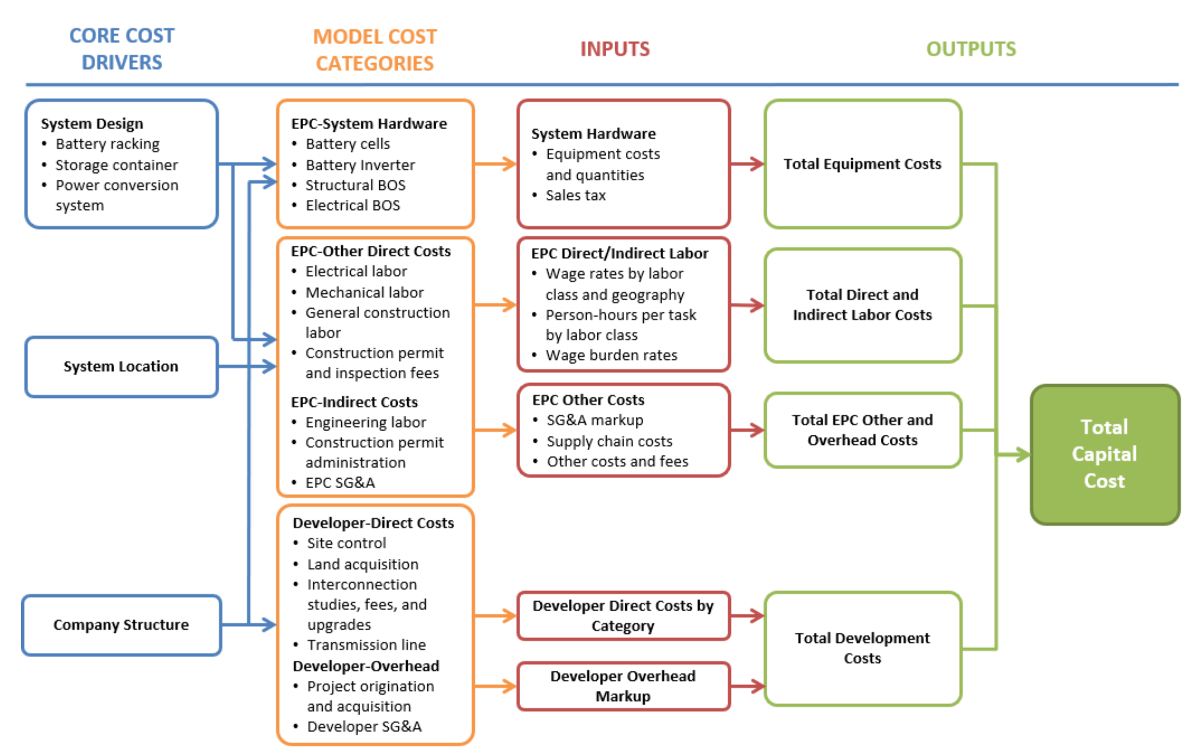
As installed costs decrease, continued improvement in technology will increase performance. The calendar life of Li-ion batteries could increase by approximately 50% by 2030, while the number of full cycles possible could potentially increase by as much as 90%. At the same time, round-trip efficiencies will improve a couple of percentage points to between 88% and 98%, depending on battery chemistry.

Exhibit 21: Cost benchmarks for PV + Storage systems



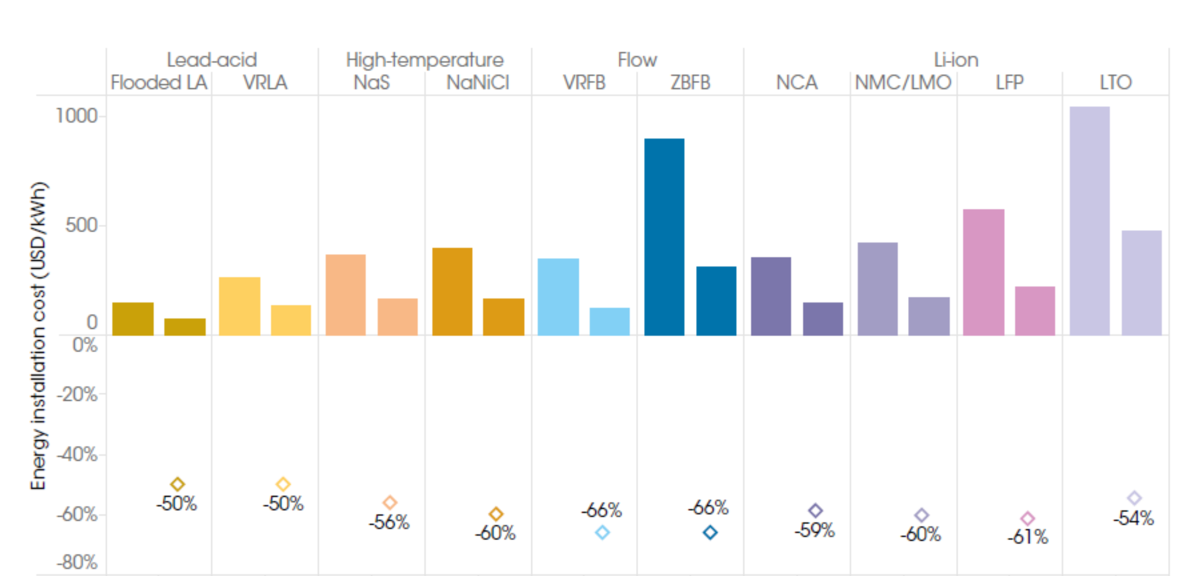
Source: NREL

Exhibit 22: Structure of the bottom-up cost model for standalone storage systems



Source: NREL

Exhibit 23: Battery electricity storage system installed energy cost reduction potential, 2016-2030



Source: IRENA Energy Storage and Renewables 2017

Energy Storage
Price movements and causes

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Price Dynamics

Li-ion prices have been **falling steadily** since 2014 despite cobalt prices shooting up until early 2018.

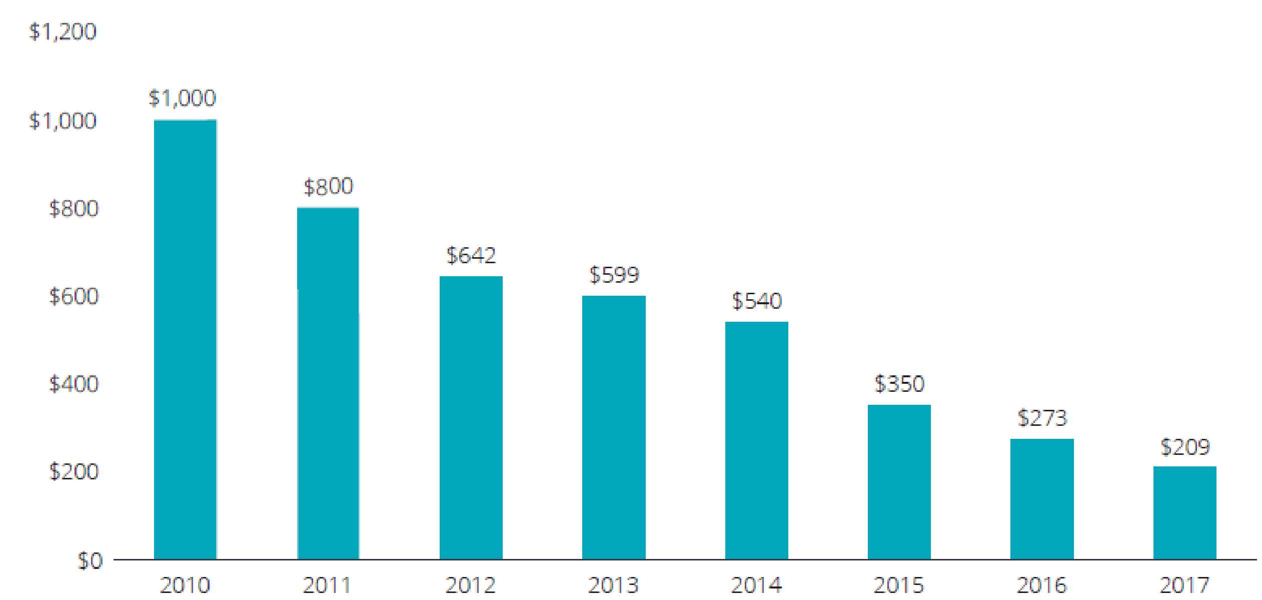
The price reduction has been fairly secular to the cobalt prices, and continued to decrease as cobalt returned to its 2016 levels. The reduction has been on the back of two trends:

Technological improvements in components: This is a good trend and more innovation is expected in the future, including reduced dependence on cobalt.

Overcapacity: There has been an oversupply and excess capacity problem over the last few years as battery manufacturers faced intense competition to sell their product. As electric vehicle makers pondered producing their own batteries, suppliers were pressured to offer favourable pricing to secure contracts.

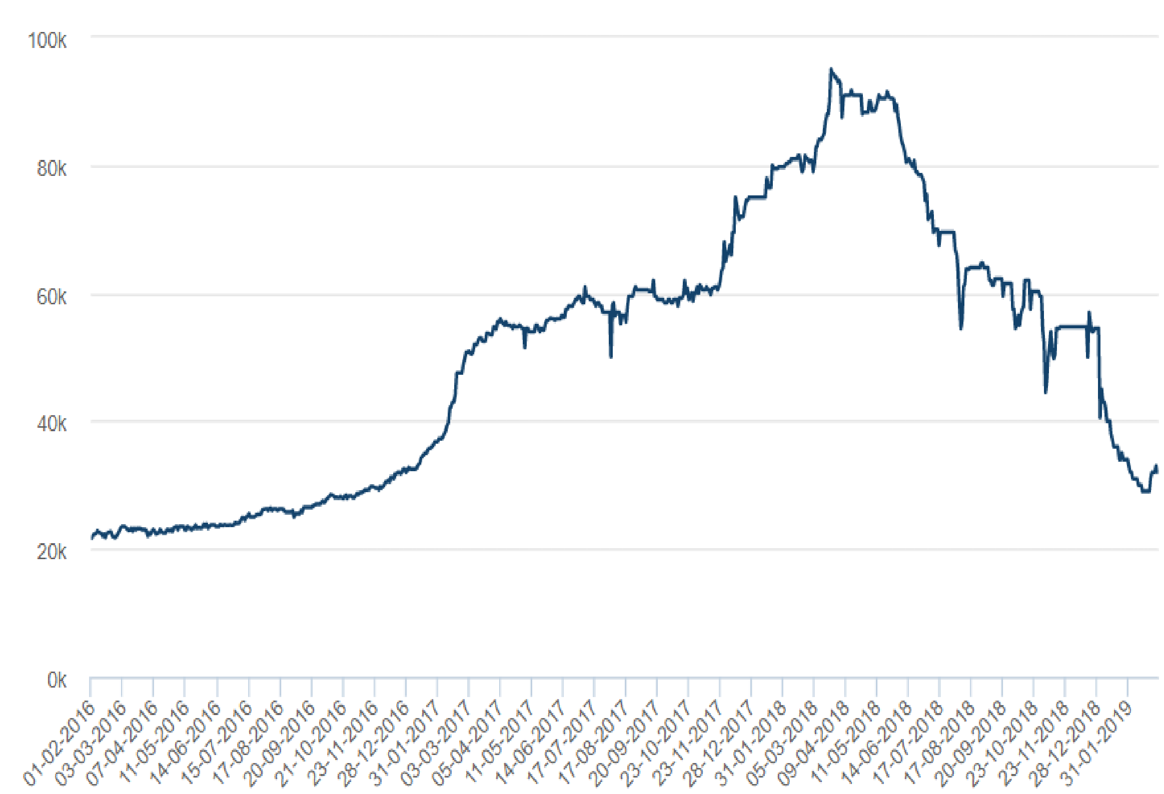
However, it is not all bad, as manufacturers continue to raise funding for more capacity as they anticipate demand to shoot up. The Li-ion batteries' supply chain is complex and fragmented, thus susceptible to bottlenecks, especially for the separators. Technology is also helping reduce the dependence on cobalt, which will ensure more secular trends.

Exhibit 24: Average Li-ion battery prices



Source: Bloomberg New Energy Finance Price Survey

Exhibit 25: Historical Cobalt prices



Source: London Metal Exchange

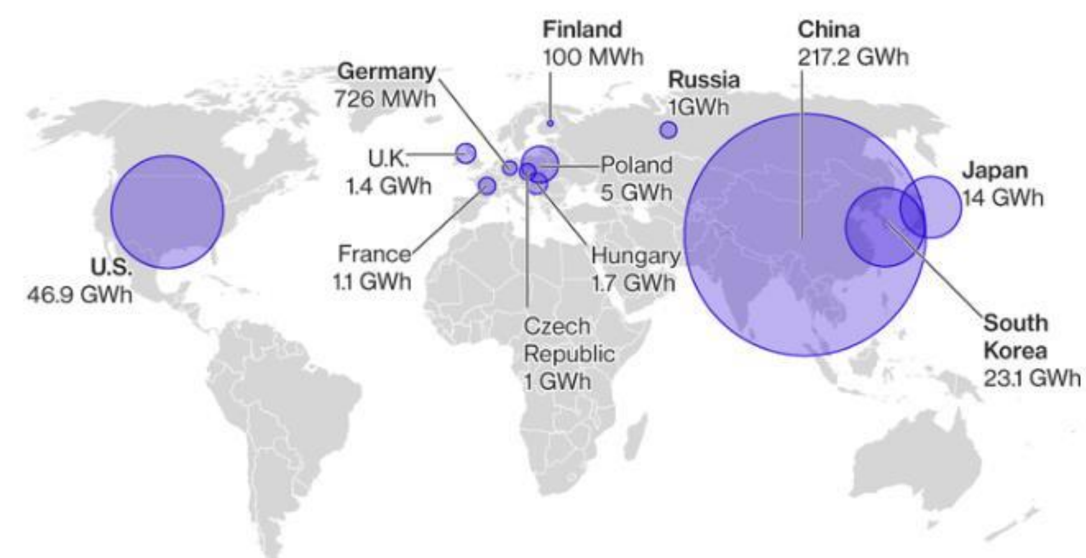
Market Leaders & Movements

Ramping up production: All major suppliers of Li-ion cells (Samsung SDI, China Aviation Lithium Battery Co. Ltd., LG Chem and SK innovation) are now investing in new worldwide production capabilities.

Where: The bulk of the capacity has been announced in Asian facilities. Government backing has been strong: Korea has set a target of controlling 30% of the global market in 2020, while cutting costs by half; China published its first national plan for the battery industry in October 2017, and has preferential treatment for domestic battery producers (e.g. only electric vehicles powered by BYD and CATL batteries were allowed to receive subsidies under guidance issued in 2016).

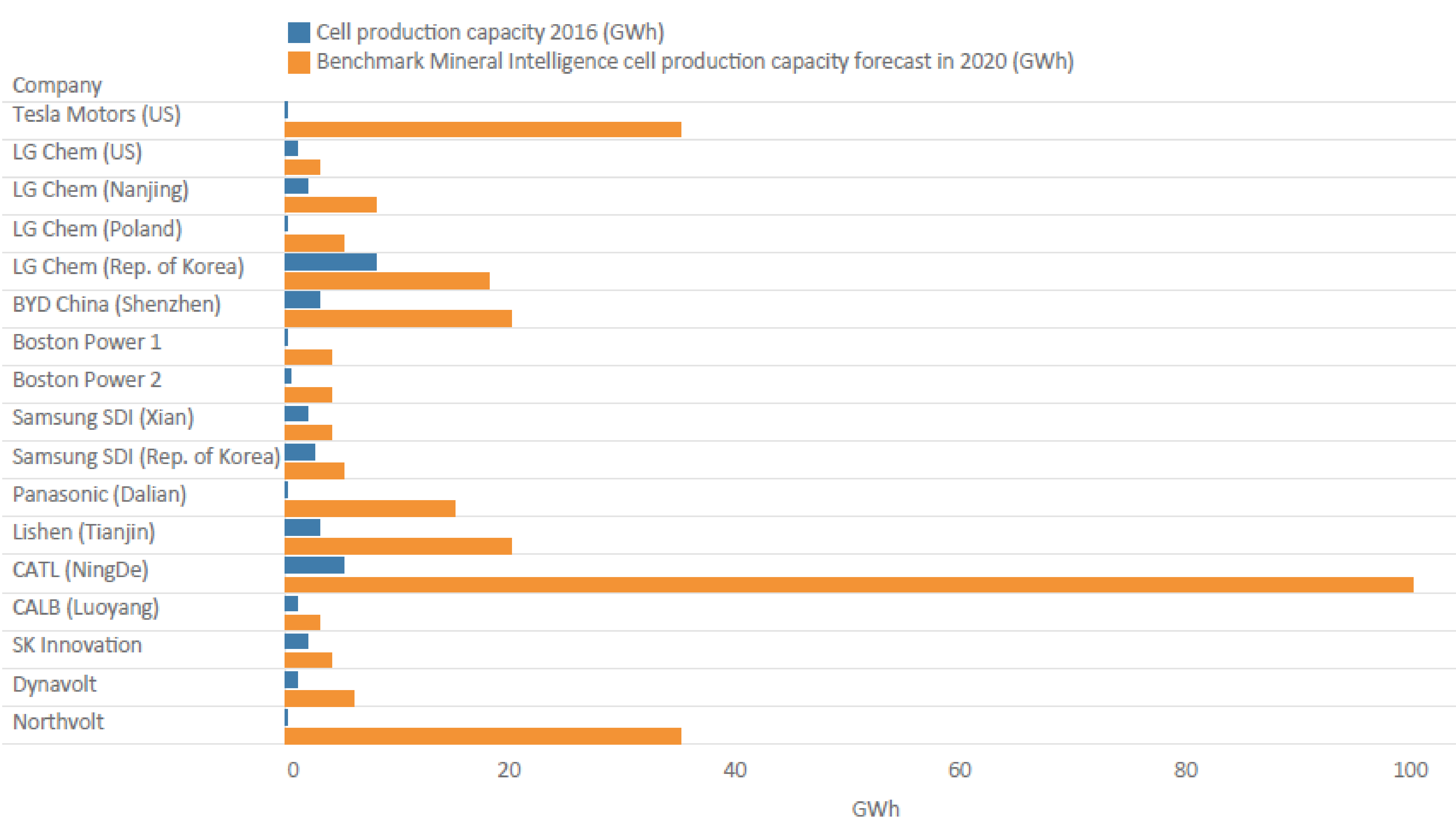
Investment: Companies (e.g. Volkswagen, Daimler) are investing billions of Euros into facilities for pack assembly for stationary and mobile applications (pv magazine, 2017b; Bloomberg, 2017). This will likely drive continued price declines for Li-ion cells and packs.

Exhibit 26: Planned and Existing Battery Cell Production Capacity



Source: Bloomberg New Energy Finance

Exhibit 27: Li-ion yearly production capacity expansion, 2016 and 2020 estimates



Source: International Renewable Energy Agency, 2017

Future Challenges

Contingency on renewables deployment: IRENA and IEA's forecasts are both contingent on decarbonization of the global energy system.

Competing options: Battery storage **competes** with other options to manage resource fluctuations, including dispatchable renewables (e.g., bioenergy, biogas, reservoir hydro, CSP, power-togas or power-to-hydrogen). This makes **battery storage as the least-cost solution highly uncertain**, given that Li-ion technology developments between 2030 and 2050 must be considered highly speculative.

Grid design: The grid is designed primarily for one-way flows from generators to customers, but storage, along with other distributed assets, **depends on two-way flows** that require additional investments in complementary infrastructure.

Market mechanisms: Market designs and rate regulators typically **fail to fully value the services that storage can provide** and make it difficult for storage asset owners to earn adequate compensation, inhibiting the introduction of new business and financial models.

Although storage provides a value somewhere in the system (e.g. by shifting and reducing peak load), there is **no formal means of valuing and monetising on that service for the storage owner**. For example, deploying a battery on a congested point of the network may mean that the network operator could be spared additional investment in transmission and distribution upgrades. However, there is **no formal mechanism for the storage operator to capture this generated value**. The mechanisms that do exist (e.g. arbitrage, peak demand management) tend to undervalue the service provided to the system as a whole. This leads to a situation in which the **costs of storage are privatised while the benefits are socialised**.

Regulation: Laws and regulations may classify storage devices as generation assets and arbitrarily limit the services that they can provide and who may own them.

Moreover, some EU countries are not open for competition, or **do not allow storage assets to compete**. System services such as frequency control in Italy for example are not market based, while other markets such as Spain impose large size requirements and other regulatory barriers that preclude storage assets from participating. Large size requirements above the 10 MW mark are generally prohibitive for storage developers if aggregation of multiple resources is not allowed.

Competitors and incumbents: Incumbent providers may exercise their leverage with legislators and regulators to block or slow changes that would lower these barriers.

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