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See slide 11 for more information.

Lithium-ion Battery Costs and Market

Squeezed margins seek technology
improvements & new business models

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July 5, 2017

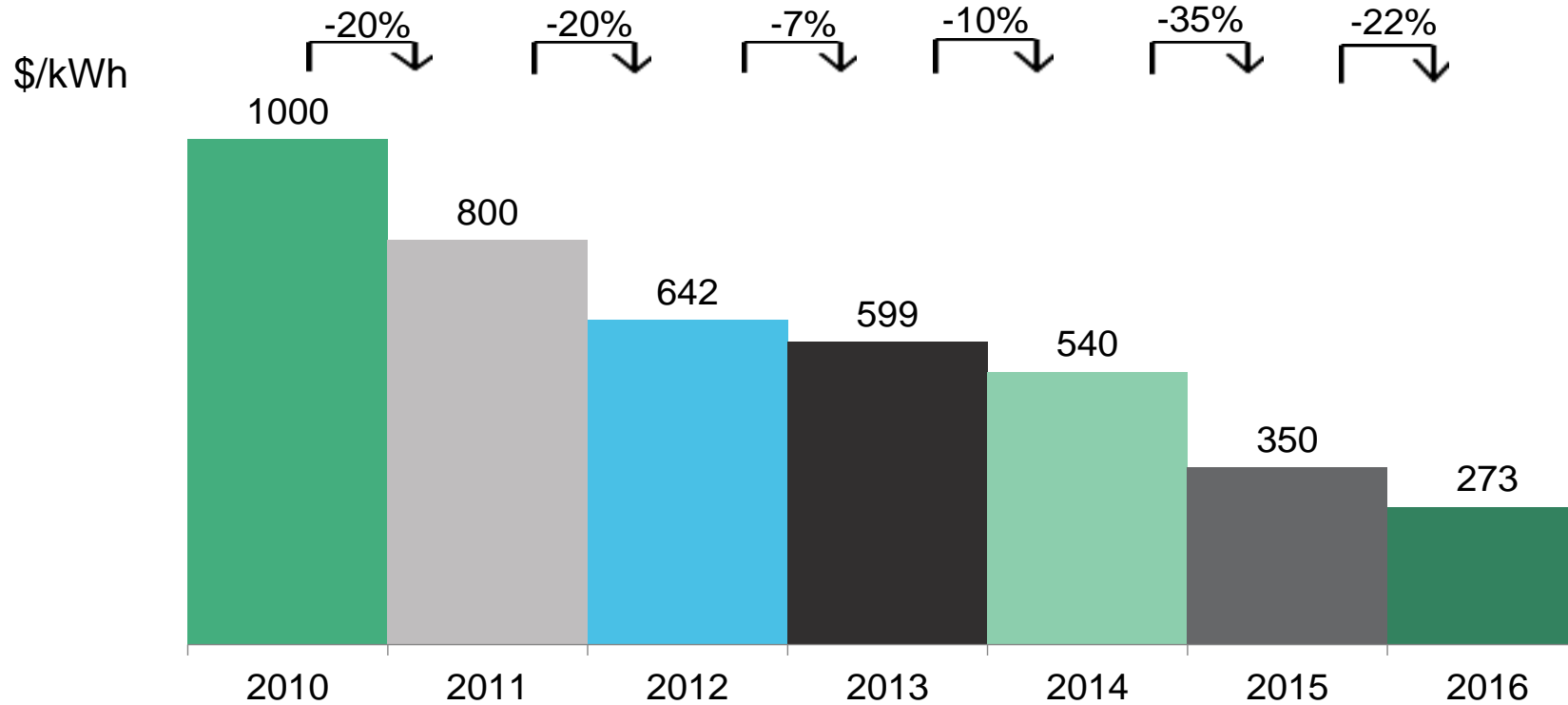
Executive Summary

- 1) **Oversupply is depressing battery prices.** Passenger EV sales were lower than expected in 2011-H1 2015, meaning demand for lithium-ion batteries was low. The manufacturing industry suffered – and is still suffering -- from oversupply. To increase utilization, manufacturers have been lowering prices and competing fiercely with one another.
- 2) **Tightening of the battery market.** However, BNEF forecasts large demand growth for lithium-ion batteries, and battery manufacturers have announced further capacity build despite oversupply. They need to attract investment for this, although revenue from sales is still quite low, and say how they plan to make a profit from the new investment.
- 3) **Supply chain economics will make it tougher to meet demand.** Without the supply chain in place, the battery market will not be able to meet future demand. The supply chain for battery components (cathodes, anodes, electrolyte and separators) is a complex business. There's a looming shortage in production capacity for components, particularly the separator. EV sales growth in China, in particular, is creating separator supply bottlenecks.
- 4) **What's in store? Further battery price decreases.** BNEF forecasts lithium-ion battery pack prices will continue to fall to as little as \$73/KWh.
- 5) Implications on company strategy:
 - Battery manufacturer strategy.** Producers need to improve margins on battery manufacturing to attract new investment. They can do this by improving technology to reduce production costs to bring down their cost forecasts. They are also entering the stationary storage market aggressively to increase market share.
 - Car company strategy.** Car companies want to reduce battery prices to improve their vehicle economics. They can do this by signing large, long-term contracts with suppliers; by entering other battery markets, and repurposing used EV batteries for a second-life.

The price of lithium-ion batteries in 2016 was \$273/kWh – a drop of 73% since 2010.

- The steep decrease in prices in the past few years is in part due to technology improvements and economies of scale.
- However, fierce competition between the major manufacturers has been instrumental in bringing down prices.

BNEF lithium-ion battery price survey, 2010-16 (\$/kWh)



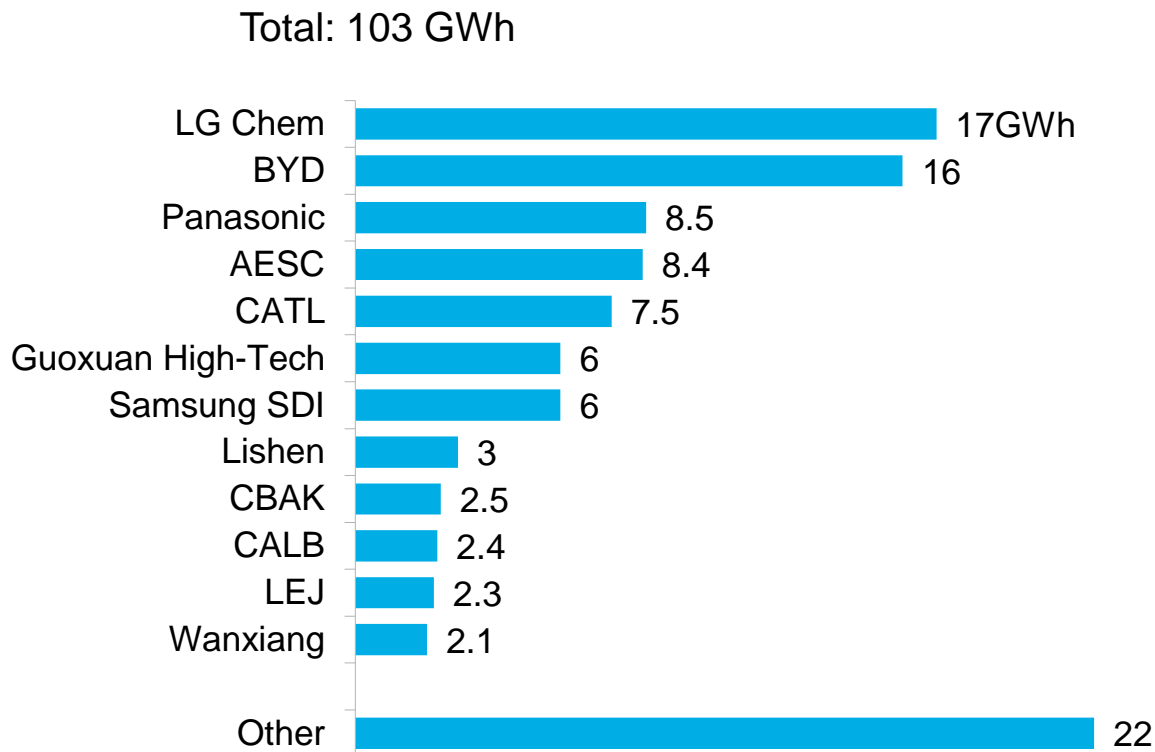
Notes: This includes cells plus pack prices. For years where there were two surveys, the data in this chart is an average for the year.

Source: Bloomberg New Energy Finance

Lithium-ion battery sales for passenger EVs are picking up, but installed capacity is still much larger.



Installed lithium-ion battery manufacturing capacity, Q1 2017 (GWh)



- Passenger EV sales were lower than the market expected from 2011 to H1 2015, meaning that lithium-ion battery sales were also lower than forecast.
- But 2016 and 1H 2017 have seen an increase in passenger EV sales, leading to quarterly battery demand of more than 6GWh.
- Panasonic has dominated sales due to its relationship with Tesla Motors. BYD has grown its market share significantly while AESC – supplying to the Nissan Leaf – shrinks.
- In 2016, new EV sales consumed over 20 GWh, while installed capacity was five times this size.
- Demand for batteries from electric buses far outstripped that of other passenger vehicles in 2016.

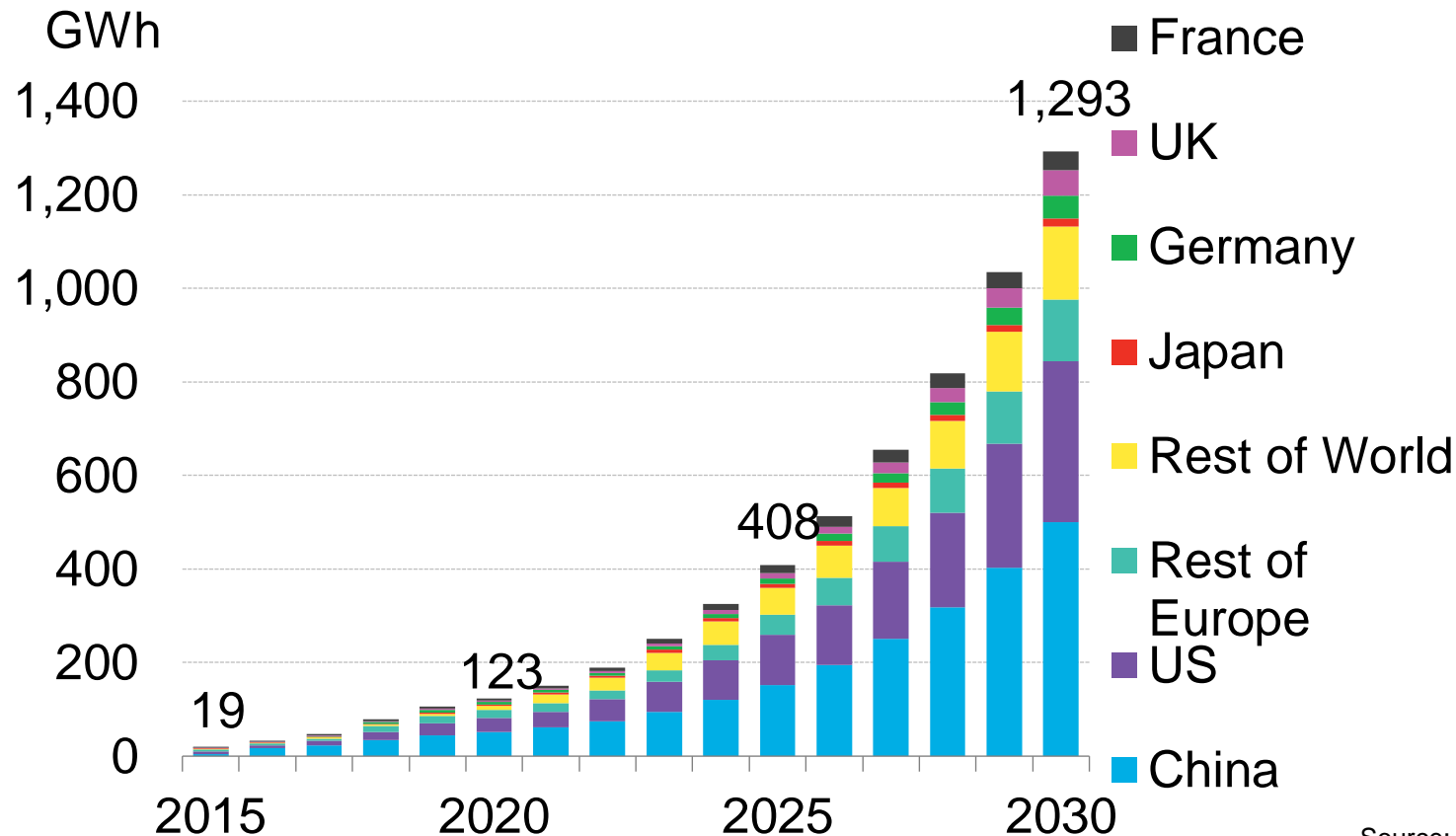
Source: Bloomberg New Energy Finance.

BNEF sees strong growth in passenger EV demand and the lithium-ion battery market

In its EV sales outlook, BNEF forecasts annual demand for lithium-ion batteries from new EV sales of 408GWh in 2025 and 1,293GWh in 2030

As well as demand from EVs, stationary-storage market demand will be 65GWh in 2025. BNEF forecasts behind-the-meter stationary storage alone will top 200GWh in 2030.

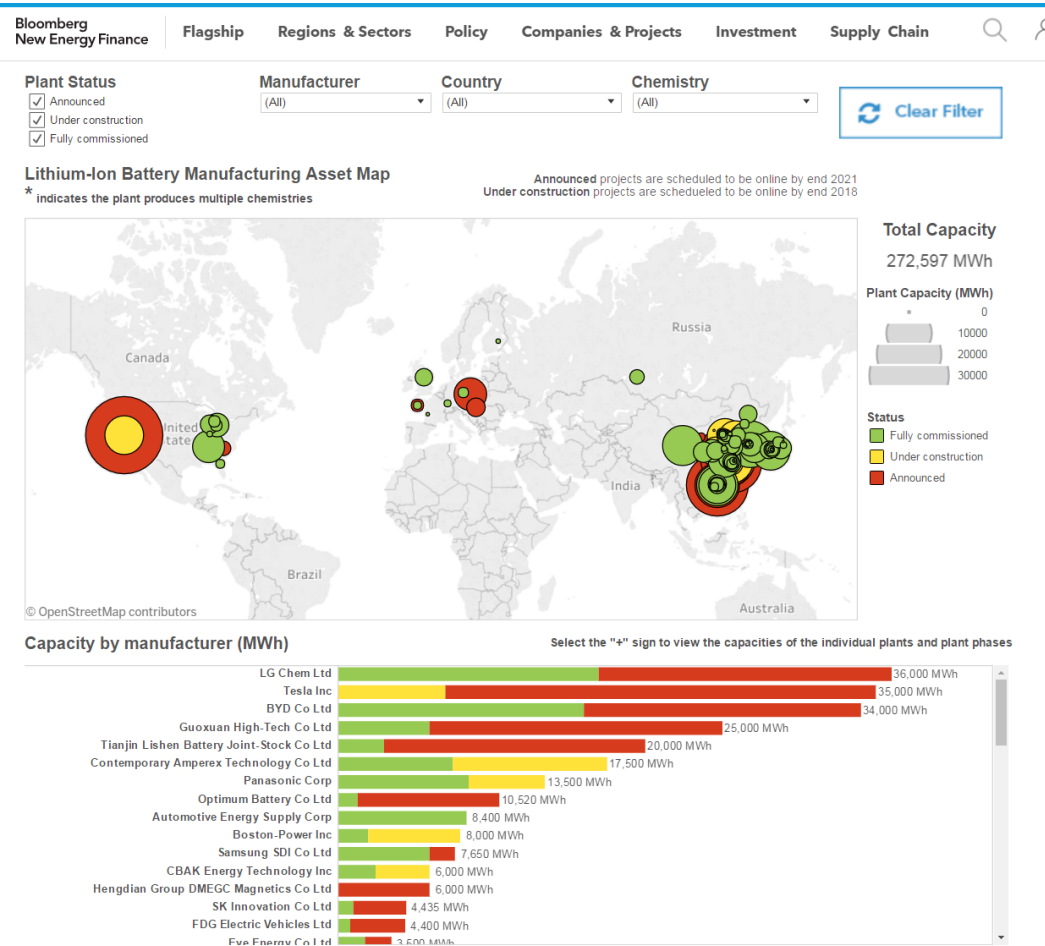
Forecasted demand for lithium-ion batteries from EVs, 2010-30 (GWh)



Source: Bloomberg New Energy Finance.

Despite overcapacity, plants continue to get built

- BNEF's proprietary battery manufacturing capacity tool illustrates commissioned, under construction and announced battery plants.
- The tool shows an additional 154GWh of capacity will get built in the next five years, bringing global capacity to 273GWh by 2021.

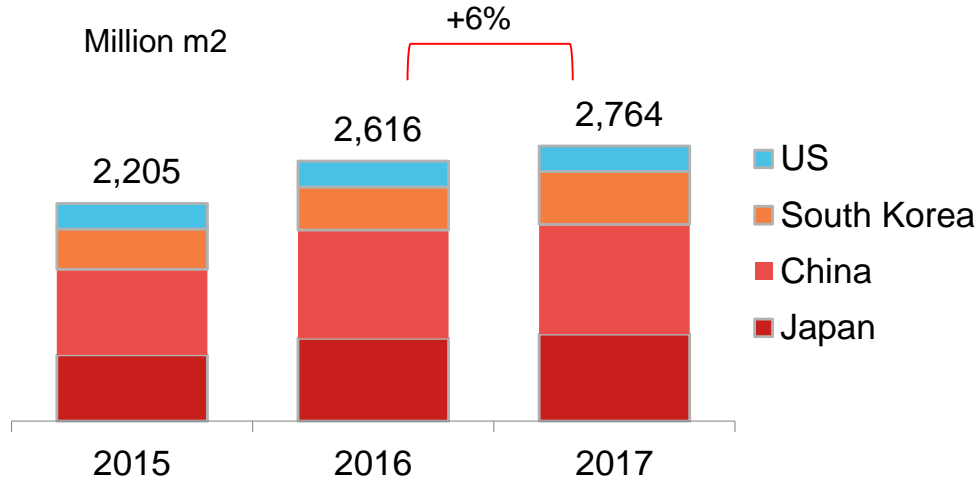


- Battery manufacturers agree with our growth projections and think demand from EVs and stationary storage will rapidly increase.
- This means that battery companies, no matter how poor their sales to date have been, are raising money to build new capacity.
- *Ultimately, this is driving them to reduce battery prices, in order to sell more batteries and increase utilisation, to ultimately show investors it is important that they expand manufacturing capacity.*

Source: Bloomberg New Energy Finance

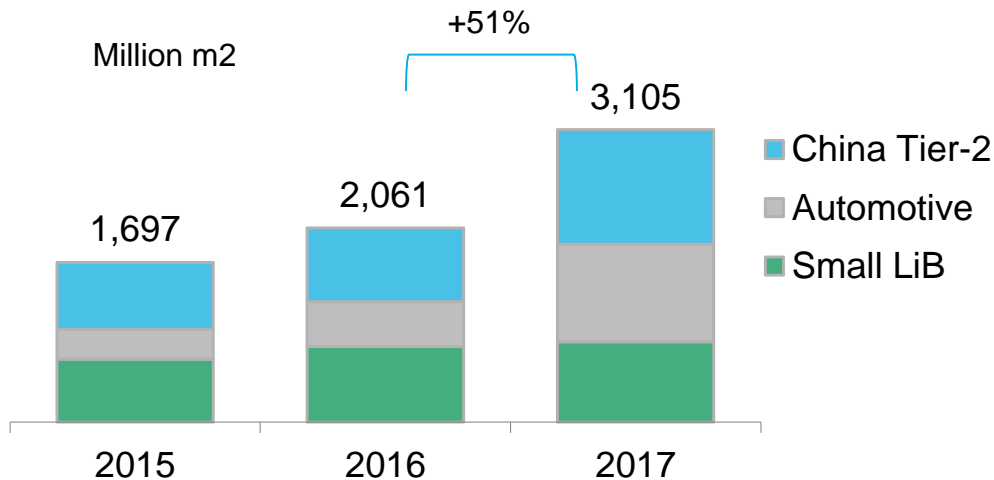
But without the supply chain in place, the battery market will not be able to meet demand

Separator manufacturing capacity



- Batteries are made of cathodes, anodes, electrolyte and separators
- Each have their own complex supply chain
- There is a looming shortage in production capacity, and a lack of producers, for a few of the components...
- ... especially the separator. Making separators is a complex, low margin business.
- The growth in sales of EVs in China may be the cause of separator supply bottlenecks

Separator sales



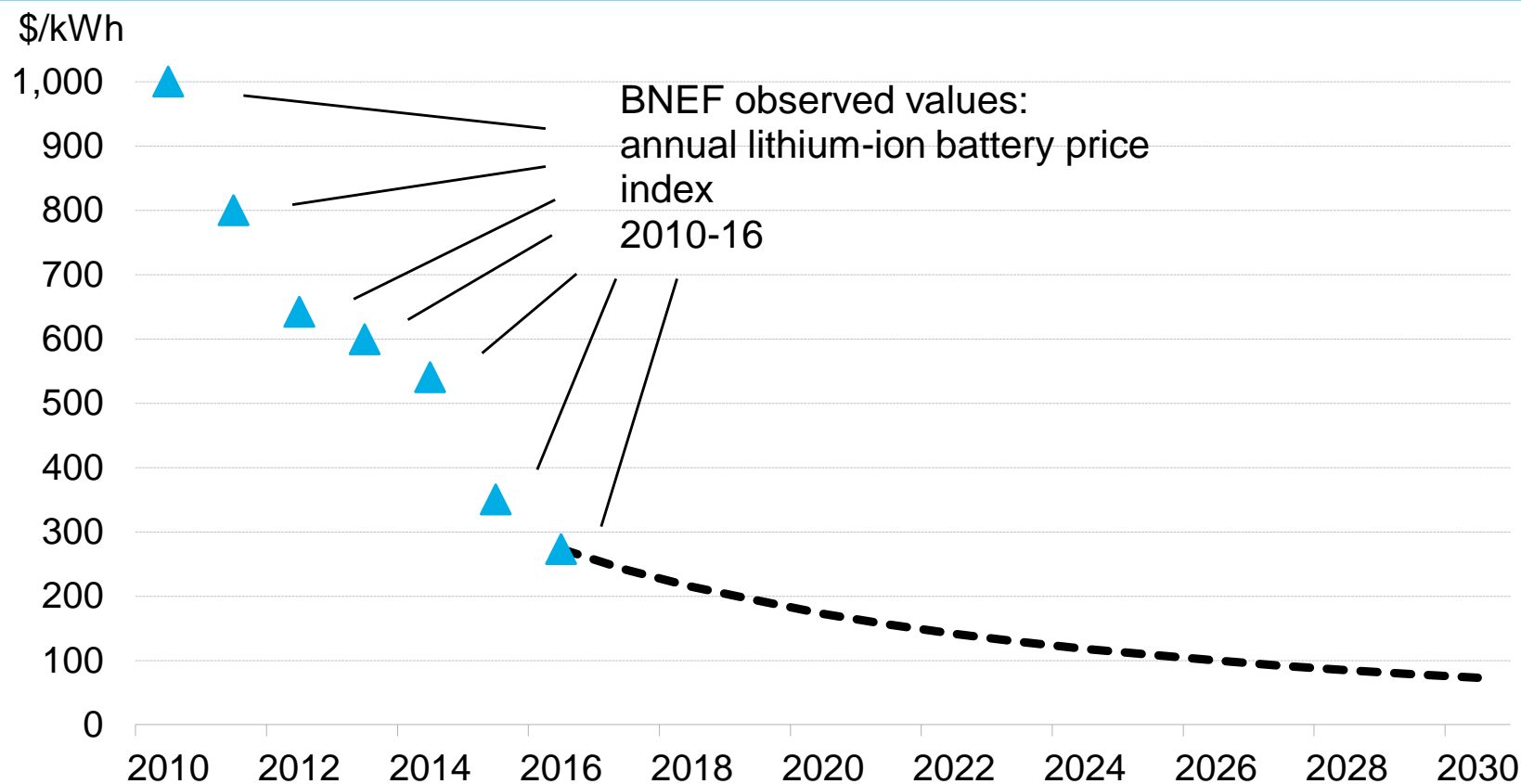
- This is just a selection of the detailed component database BNEF provides to clients – on cathodes, electrolytes, anodes and separators. The database shows plant-by-plant data and market share information on manufacturers.
- BNEF's regional analysts track the status of the Chinese EV and battery market in depth.

Source: Bloomberg New Energy Finance, Techno Systems Research Co.

BNEF forecasts lithium-ion battery pack prices will fall to as little as \$73/kWh



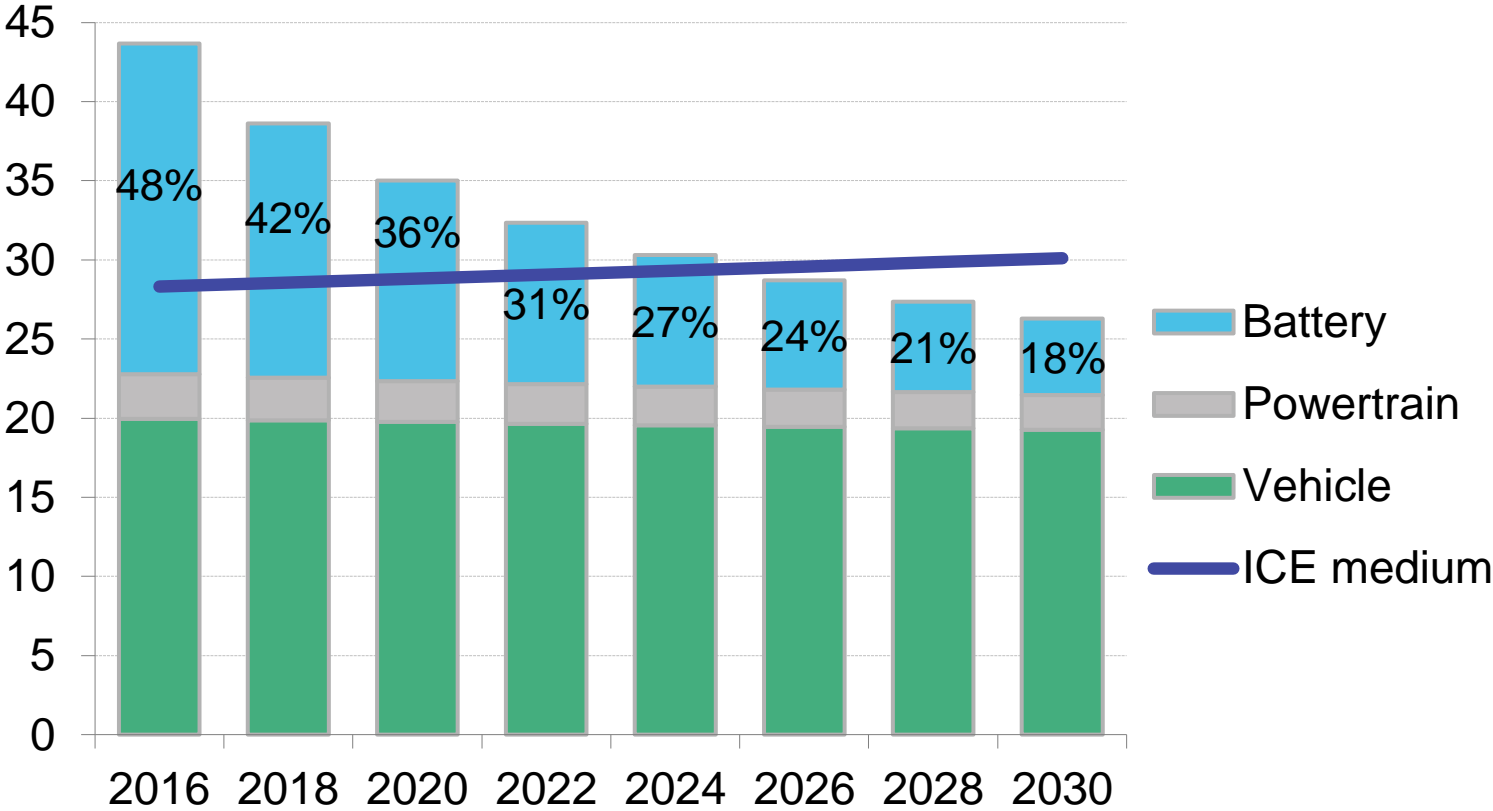
- Intense price competition is leading manufacturers to develop new chemistries and improved processes to reduce production costs.
- Production costs have also come down significantly. Our models calculate that producing a battery in a Korean manufacturing plant in 2017 costs \$162/kWh, dropping to \$74/kWh in 2030.
- The BNEF battery price survey provides an annual industry average battery price for EVs and stationary storage. The learning rate (the price decrease for every doubling of capacity) is 19%.



Source: Bloomberg New Energy Finance

Batteries are the main reason why passenger EVs are more expensive than ICEs today

BEV and ICE pre-tax prices in the U.S. for medium segment price, 2010-2030 (thousand 2016\$ and %)



Source: Bloomberg New Energy Finance

The drive for profit is bringing car company and battery manufacturer relations to a head

Electric vehicle company strategy

Stationary storage

- The stationary storage market – utility, commercial & industrial, and residential scale – is growing rapidly. BNEF forecasts a growth from 1GWh installed today to 81GWh by 2024.
- The C&I and residential markets especially can be influenced by branding to buy battery systems from companies like Mercedes-Benz or Tesla.
- Car companies are launching battery products to increase market reach and sales.

Second-life

- BNEF forecasts that 95GWh of used EV batteries will come out of cars by 2025, and 26GWh could be used in stationary storage.
- This is an attractive market for car companies as it extends the revenue lifetime of the EV battery and a market for used EV batteries would also increase EV resale value.
- Daimler, GM, BMW and Nissan are actively engaged in second-life repurposing.

Battery manufacturer strategy

- Car companies entering stationary storage and looking to repurpose used EV batteries eats into the share and potential of battery manufacturers' market
- They may find themselves competing directly with their EV customers.
- EV companies are also hinting they may begin making their own batteries rather than relying on their suppliers for suitable prices and volumes.
- This is leading battery companies to offer very attractive future contracts and become more aggressive by lowering prices for the stationary storage market to fight competition.

GLOSSARY OF TERMS

EV- electric vehicle

BEV – battery electric vehicle

PHEV – plug-in hybrid electric vehicle

LiB – lithium-ion battery

kWh – kilowatt-hour

MWh- megawatt-hour

ICE – internal combustion engine

Related BNEF research

BNEF covers battery technology and battery providers with analysis ranging from deep dives and forecasts to surveys and analyst reactions to market events. Proprietary interactive tools include the [battery manufacturing capacity database](#) and the [electric vehicle data hub](#).

Technology

Lithium-ion technologies

- Max capacity: battery energy density improvements ([web](#)|[terminal](#))
- Li-ion chemistries and technologies ([web](#) | [terminal](#))
- Li-ion EV marketplace, supply chains and costs ([web](#) | [terminal](#))
- Used EV batteries for stationary storage ([web](#) | [terminal](#))
- Li-ion battery recycling ([web](#) | [terminal](#))

Lithium-ion costs

- Li-ion battery price survey ([web](#) | [terminal](#))
- Li-ion battery cost breakdown and forecast ([web](#) | [terminal](#))
- Potential cost reductions in EV Li-ion batteries ([web](#) | [terminal](#))
- Bottom-up cost scenarios for Li-ion batteries ([web](#) | [terminal](#))

Alternatives to lithium-ion

- Emerging storage technologies: looking beyond lithium ([web](#) | [terminal](#))
- Power-to-gas: a technology overview ([web](#) | [terminal](#))
- Power-to-gas: flexibility at what cost? ([web](#) | [terminal](#))
- Stationary Fuel Cells ([web](#) | [terminal](#))

Other components:

- Storage power electronics ([web](#) | [terminal](#))

Competitive landscape

Company profiles

- 2017 Battery vendors ([web](#) | [terminal](#))
- 2016 Solutions providers ([web](#) | [terminal](#))
- 2017 Chinese battery vendors ([web](#) | [terminal](#))
- Residential storage providers ([web](#) | [terminal](#))
- Will China's EV battery makers rule the global market? ([web](#) | [terminal](#))

Automotive companies & storage

- Car companies and stationary storage ([web](#) | [terminal](#))
- What does Tesla's Model 3 mean for EVs and storage ([web](#) | [terminal](#))
- BMW charges forward ([web](#) | [terminal](#))

Recent acquisitions / major partnerships

- Total acquires Saft ([web](#) | [terminal](#))
- Engie first utility mover ([web](#) | [terminal](#))
- Doosan snaps up 1Energy ([web](#) | [terminal](#))
- Murata acquires Sony's battery business ([web](#) | [terminal](#))
- Sonnen partners with AutoGrid ([web](#) | [terminal](#))
- Enel acquires Demand Energy ([web](#) | [terminal](#))

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