EXTRACT

The Tesla Battery Report

Tesla Motors: Battery Technology, Analysis of the Gigafactory and Model 3, and the Automakers' Perspectives

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Detailed Report Outline

1. **Success of the Model S & EV Market Direction**
2. **The Model 3 Promise & Questions**
3. **EV Battery Technology: Tesla vs. Conventional**
    - Design, life, safety
    - Cost
4. **The Gigafactory: Investment, Challenges, Benefits**
5. **Tesla Battery Annual Production Cost Estimate (Japan/U.S.) *vs.* Volume from 2013 to 2022**
    - Cells
    - Modules & packs
6. **Tesla's Impact on the EV/Battery Industry**
7. **EV Market & EV Battery Market Forecast to 2025**
8. **The Stationary Energy-Storage Systems Business**
9. **Conclusion: Likely Scenarios for Tesla's Future**
10. **Appendix**
    - Key characteristics of modern electric vehicles
    - Key characteristics of Tesla vehicles and battery
    - EV battery technology background
        - Cell design
        - Key materials
        - Module and pack design

In 2013, Tesla shattered many of the industry's deep-rooted convictions…

- That it is almost impossible for a newcomer to break into the automotive business
  - From 2013 to 2015 Tesla's Model S was the # 1 luxury vehicle and #2 EV seller in the U.S.
- That practical EVs must be limited to a range of 100-150 miles
  - Tesla designed and produced a >240-mile EV, which is 2-3X the range achieved by everyone else at the time
- That EVs are more suitable as small urban vehicles
  - Tesla model S, a large luxury EV, is selling well in the luxury car market
- That EVs are hard to sell and customers will not pay extra $ for them
  - In 2013, in the U.S., Tesla sold more $90K+ sedans than well-established brands such as Mercedes and BMW
- That EVs imply a large financial loss for carmakers
  - Tesla 'almost' broke even during the first year of mass production

Besides crushing the auto-industry's convictions about EVs, Tesla had many extraordinary success stories…

- Took over a mature auto plant from Toyota-GM and refurbished it
- Initially got exceptional reviews for Model S vehicle attributes from consumer reports and other car magazines
- Got high safety rating from NHTSA for the Model S
- Historically delivers on some big promises
    - 2013 volume exceeded plan and forecast
    - Successfully installed and is operating hundreds of fast-charging stations in several markets
- Has earned strong customer satisfaction and loyalty

Some typical comments from major automakers

Brilliant image and some smart business and technical moves, BUT:

- Tesla has sold less than 200k luxury cars and is not making money.
- Tesla has not proven that EVs are mass-market capable. It still only addresses a unique niche market that is not cost-sensitive and in which the buyer often owns 2 or more cars, which makes the EV's limitations less of a problem (prior to the April 2016 Model 3 orders).

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- The small-cell battery approach is risky for long-term reliability and the chemistry used by Tesla is too prone to cells catching fire.

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Battery-EV Efforts by Major Automakers 2012-2016

(Excluding China)

- **Committed** → Tesla
- **Developing Markets** → Renault, Nissan (Earliest)
- **Developing Markets** → BMW, VW group (Increased emphasis in 2016)
- **Developing Markets** → Daimler, JLR
- **ZEV Compliance Only/Mostly** → Fiat Chrysler, Hyundai, Honda, Ford, GM,?
- **Fuel Cell Focus** → Toyota, although new development of EV also

The Reasons for Tesla's Model S Success?

- High-end niche market, **Sure**
- Long driving range, **Definitely**
- Connectivity features, **Yes**
- Strong vehicle integration, **Not really: many nice features but reliability has been below average**
- Brilliant, admired CEO who uses twitter as main marketing channel, **Yes, admired at least in relation to stock valuation and raising money**
- Silicon Valley high-tech, out-of-the-box practice and image, **Sure**
- Loyal customer base (due to the reasons above), **Yes**
- Other?

The Model S is an exciting car but the average sale price is twice what was promised in 2009!

- Tesla promised a $45k sedan when in 2009 it received the government loan to develop the Model S.
- The average selling price for the Model S is around $95k.
- Tesla has a history of delivering on some but not all of its promises; it has been particularly off on pricing, schedule, and cash-flow projections.
  - *The Model X was launched two years behind schedule…*

The Market Response

- Tesla reportedly collected 325k reservation orders during the first seven days after the Model 3 was revealed. This is more than twice the number of cars the company has produced over the past 5 years.
- Orders were accompanied by a refundable $1,000 deposit.
- At a $42k average sale price proposed by Tesla, this is equal to bookings of $13.6 billion.
- According to some investors, the whole exercise may have much to do with raising expectations, thus raising the share price and the suppliers' confidence, before an anticipated equity offering, and perhaps many orders will be canceled.
- U.S. customers have the incentive to buy the car while they can still claim the federal tax credit of $7,500, since this credit will start to shrink for Tesla customers sometime in 2018.

❖ What is the likely annual demand after a late 2017 launch and backlog clearing? Its seems higher than what most automakers expected!

Tesla's Model 3 Surprise – 3

- At the May 4, 2016 quarterly shareholders' briefing, Tesla communicated that, due to the high demand, it would accelerate production of the Model 3 to achieve 500k units annually as early as 2018 rather than in 2020 as previously planned, and 1 million in 2020.
- This is an almost impossible task for any car company, let alone one that experienced a 2-year delay on its last small-volume vehicle, the Model X.
- The analysis is mixed: yes, Tesla received a strong positive signal from the market, but also Tesla's vehicle launches have had above-average delays and quality problems. Accelerating production ramp-up is quite risky…
- **There is not enough time for vehicle validation.**
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- What will Tesla be able to produce during the 2018-2020 time scale?
- Will Tesla actually deliver cars for $35k—this would amount to delivering 80% of a Model S car at barely half the price…
- Will sales actually be profitable?
- What is the likely annual demand after the probable 2018 volume launch and filling of back orders?
- Battery pricing, reliability, and durability will clearly play a role in the answer. This is discussed further in this report.

It is quite possible that Tesla can attract market in excess of 200k cars annually; the key is in Tesla's ability to execute profitably.

Model 3 Current Conclusions

- There seems to be a substantial market for a small sporty luxury EV with autopilot, fast-charge capabilities, and a >200-mile range for a base price of $35k.
- Tesla leverages its image and willingness to invest to create a market in the small luxury category. This is a substantial market for the premium brand makers, though quite a minor one for the largest automakers.
- If such a price is realistic, smaller and simpler EVs with 200-mile ranges can be made for under $30k and take market share from ICE vehicles.
  - But the calculations of the automakers, who until now where envisioning a smallish market potential, show that $35k is not a realistic price for such a car.
- Subsidies, credits, and government perks are a big factors that contribute to consumer interest. Will they ignite a market that will be able to sustain itself when some of the subsidies and perks subside, since they cannot be maintained in true mass-market conditions?
- Will Tesla's bet become the way out of the "Catch 22" situation that has hampered the industry from making volume investments due to the uncertainty of the market?
- Market size versus vehicle price is the billion-dollar question.

Tesla's Modules and Pack

Tesla Module (85 kWh Model S) with 444 individual cells

Modules showed side by side

Closed pack with BMS unit at the front

Li-Ion Cells Employed in EVs 2008-2016

Cell Maker	SOP	Chemistry	Capacity	Configuration	Used in:	
	Year	Anode/Cathode	Ah		Company	Model
Li Energy Japan	2008	G/LMO-NMC	50	Prismatic	MMC	i-MiEV
AESC	2010	G/LMO-NCA	33	Pouch	Nissan	Leaf
LG	2012	G/LMO-NMC	16	Pouch	Ford	Focus
A123Systems	2012	G/LFP	20	Pouch	Chevy	Spark
Panasonic	2012	G/NCA	3.1	Cylindrical	Tesla	Model S
LG	2012	G/LMO-NMC	36	Pouch	Renault	Zoe
Litech	2013	G/NMC	52	Pouch	Daimler	Smart
Toshiba	2013	LTO-NMC	20	Prismatic	Honda	Fit
Samsung	2013	G/LMO-NMC	63	Prismatic	CFA	500
SK Innovation	2014	G/NMC	38	Pouch	Kia	Soul
Samsung	2015	G/LMO-NMC	63	Prismatic	BMW	i3
Panasonic	2015	G/NMC	25	Prismatic	VW	e-Golf
AESC	2015	G/LMO-NCA	40	Pouch	Nissan	Leaf
Panasonic	2015	Gr-Si/NCA	3.4	Cylindrical	Tesla	Model X
LG	2016	Gr/NMC	56	Pouch	Chevy	Bolt
Panasonic	2017	Gr-Si/NCA	4.9	Cylindrical	Tesla	Model 3

A large variety of cell configurations and capacity with no conversion

- ✓ Custom EV platforms allow for the implementation of larger batteries
- ✓ Larger batteries allow for the use of low-power computer cells
  - ✓ Low average power-to-energy ratio
  - ✓ Large thermal mass
- ✓

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- ✓ Tesla recommends less than full charge for normal use
  - ✓ **Due to the longer range, normal charging can be 85% SOC or lower, which greatly enhances battery life**
- ✓ Tesla's module design with many cells in parallel allows for single-cell failure without bringing the whole battery down
  - ✓ Thus the Tesla pack is more robust against single-cell failure.
- ✓ Tesla has developed significant know-how in module, pack, and vehicle integration and the small-cell approach presents some advantages
- ❖ However, cycle life is lower and utilizing a very large number of cells and four welds per cell is unattractive from the standpoint of reliability

Automakers and the Small Cylindrical Cell Approach

- Most automakers have evaluated the cell and pack designs and decided against using them in their EVs.
- This is true even for new vehicles with ranges >200 miles.
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  - Reliability; too many components and processes
  - Limited cycle life and anticipated reduction in power over life
  - Battery power at low state of charge is only slightly above motor power, and with anticipated battery power fade over life, the battery can, over time, limit vehicle power at low state of charge

3.4-Ah 18650 Cell Price 2016

600 Million Cells (7GWh Japan), 2016

3.4 Ah 18650 Cylindrical, 7 GWh, 2016 Japan plant			
NCA 80,15,5 Cathode, Annual Volume, 500 Million cells			
Component	$	$/kWh	% of cost
Cathode	0.48	39	27%
Materials	**1.08**	**88**	**62%**
Depreciation	0.24	19.6	14%
Labor	0.07	5.7	4.0%
Utility	0.07	5.7	4.0%
Manuf ovhd	0.04	3.3	2.3%
Yield losses	Available with Report Purchase		
R&D			
SGA			
Cell cost			
Profit, 8%			
Price			

May 2016 – Gigafactory Schedule Accelerated

- At the May 4, 2016 quarterly briefing, Tesla announced accelerated ramping-up of the Model 3 to a production rate of 500k units by the end of 2018.
- This will require the full 35-GWh automotive cell production on line in the Gigafactory.
- To our understanding, until March 2016, Panasonic had only committed capital for about 7GWh (on the order of $225 million). This 7-GWh capacity was largely installed in 2016.
- Tesla disclosed that it committed to purchase $1.7 billion worth of cells from Panasonic Gigafactory lines. At $140/kWh this is equal to only 11.7 GWh, which is equivalent to about 195k EV packs. The timeframe was not disclosed.
- To meet the 2018 production plan announced in May 2016, Panasonic had to immediately ramp up its 2014 commitment fivefold, to about $1.2 billion, and procure, ship, install, and commission very large production capacity by December 2017.
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What will be included in the Gigafactory?

- Site and Infrastructure: Tesla
- Buildings: Tesla
- Pack Production: Tesla
- Module Production: Tesla
- Cell Production: Panasonic
- Key Processed Materials: Materials suppliers (who?)
  - potentially cathode, anode, electrolyte, separator, can, and header

Cylindrical 18650 vs. Pouch

Same

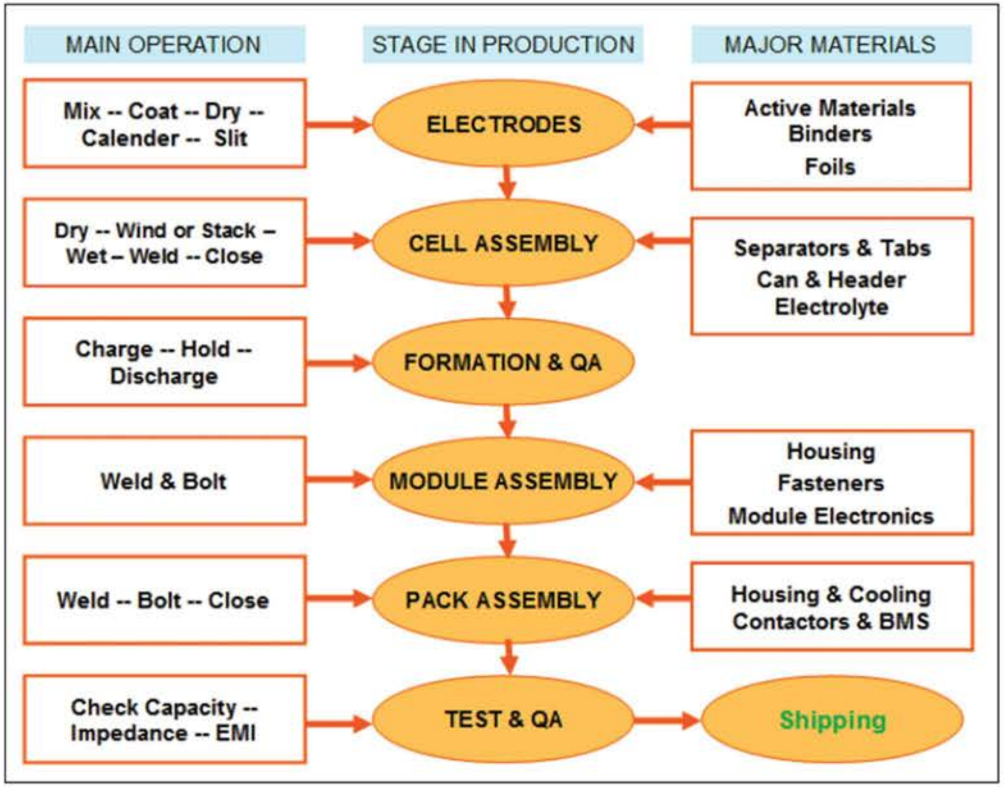
Currently more mature for 18650

In the future should be less expensive for larger cells

More expensive for cylindrical

Same

Same



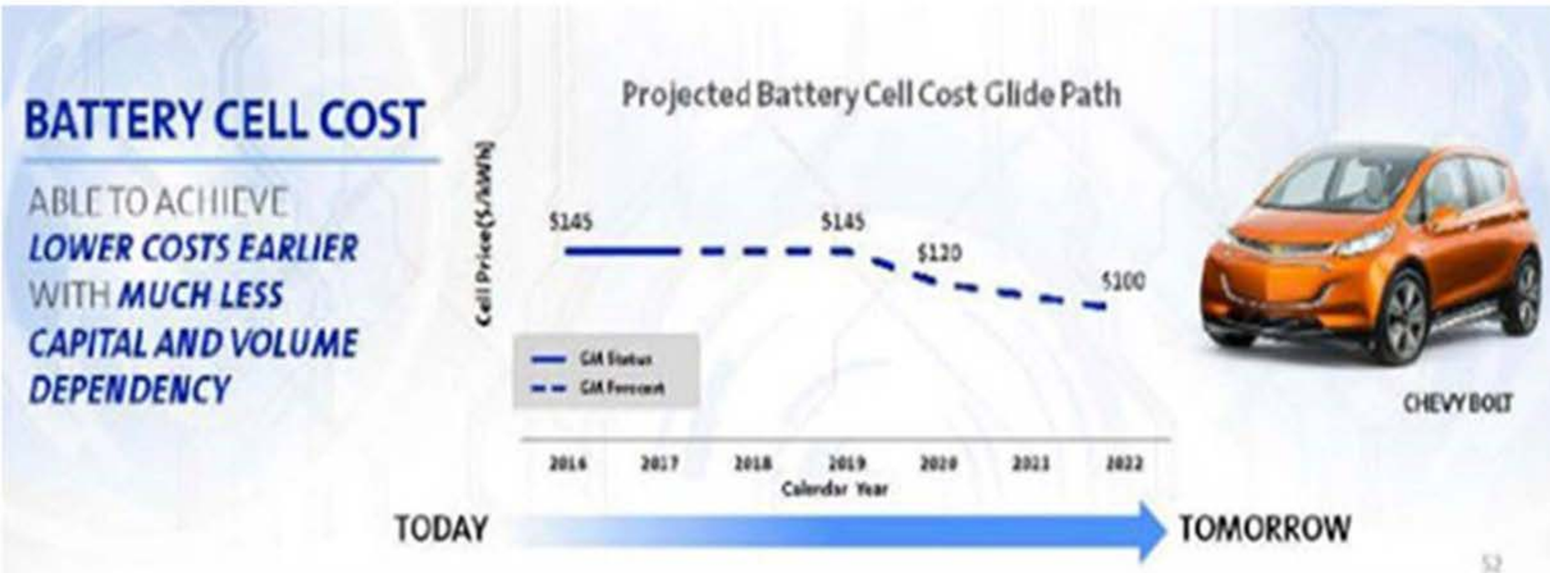
- Cylindrical cell manufacturing per Wh is more economical today, predominantly due to the maturity of the manufacturing processes
- Large-cell module manufacturing cost is inherently lower

High depreciation charges, no reduction in cost

4.9 Ah 21700 Cylindrical, 14-21 GWh, 2018 US plant			
NCA 83,13,4 Cathode, Annual Volume			
Component	$	$/Rated kWh	% of cost
Cathode	0.75	42	31%
Materials	**1.47**	**83**	60%
Depreciation	0.37	21	15%
Labor	0.12	7	4.9%
Utility	0.05	3	2.1%
Manuf ovhd			
Yield losses			
R&D			
SGA	Available with Report Purchase		
Cell cost			
Profit, 5%			
Price			

EV Cell Pricing Chevy Bolt (GM)

suggesting a path to cell pricing of $100/kWh by 2022



The industry is targeting this price level. These are the risks:

- Is there profit at today's and tomorrow's prices?
- Will metal pricing go up again?
- Manufacturing subsidies: for how long?
- Will most materials need to be produced in China?

56-Ah EV Pouch Cell Pricing – 2018

56 Ah EV Pouch Cell Price			
NMC 6,2,2 Cathode, Pouch, 24 Million Cells / Year			
Component	$	Per kWh	%
Materials	18.3	88	63%
Factory Depreciation	3.7	18	12.9%
Manufacturing Overhead	1.49	7	5.2%
Labor	1.20	6	4.1%
Un-yielded COG			
Scrap, 3%			
Yielded COG			
SG&A			
Burdened Cost			
Warranty & Profit			
Price			
Gross Margin			

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21700 Cell Materials Cost – 2020

4.9 Ah 21700 Cylindrical, 21 GWh, 2020 U.S. plant				
NCA 83,13,4 Cathode, Annual Volume, 800 Million cells				
	Units	Amount	$/unit	$/cell
Cathode Active Material	kg	0.0292	23	0.67
Anode Active Material Graphite + 4% SiOx	kg	0.0143	11	0.16
Separator				
Electrolyte				
Copper Foil				
Can, Headers & Terminals				
Other: Al, Al2O3, binders, carbon additives				
Total Materials				
$/Wh				

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21700 Cell Price 2020

4.9 Ah 21700 Cylindrical, 21 GWh, 2020 US plant			
NCA 83,13,4 Cathode, Annual Volume, 800 million cells			
Component	$	$/kWh	% of cost
Cathode	0.67	38	33%
Materials	**1.32**	75	**64%**
Depreciation	0.30	17	15%
Labor	0.09	5.1	4.4%
Utility	0.04	2.4	2.1%
Manuf ovhd			
Yield losses			
R&D			
SGA	Available with Report Purchase		
Cell cost			
Profit, 7%			
Price			

Will Tesla enjoy a reduction in cell pricing compared to its competitors? Apparently not, compared to the other giga-producers…

- LG now has EV-battery production contracts with more than two thirds of the major automakers (outside China).
- LG provides automakers with very aggressive pricing for pouch cells. It may not enjoy much profit for a while but the inherent costs of the two technologies are similar.
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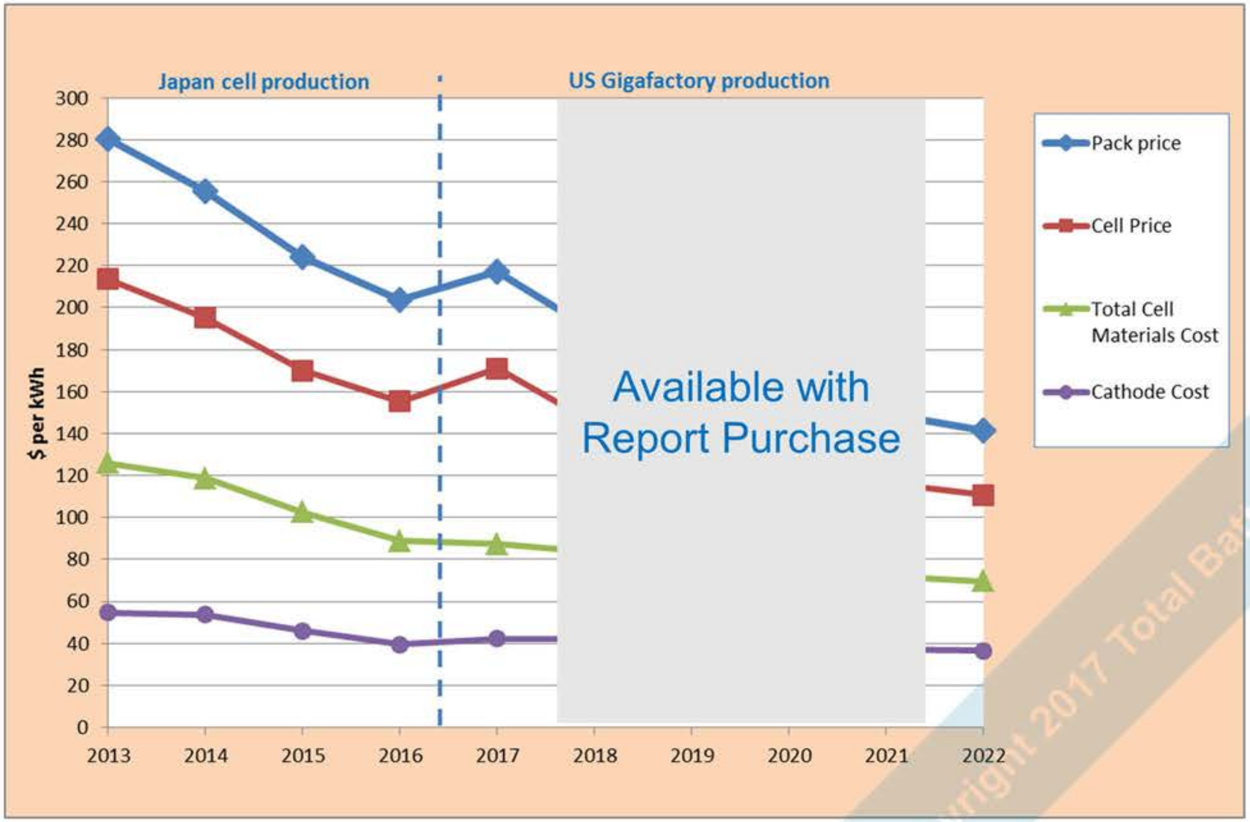
60-kWh Pack Cost Estimate 2020

Assumes:

- 200-250k packs/year
- 10 modules per pack
- 340 cells per module

60 kWh Tesla Pack	250k packs / year 2020		
Cost of module components	per module (10s34p)	per pack (100s34p)	in $ per kWh
Enclosures	$ 18.0	$ 180	
Cooling components	$ 18.0	$ 180	
Electronics	$ 20.0	$ 200	
Fasteners, interconnects, and other	$ 10.0	$ 100	
Subtotal non-cell components	$ 66.0	$ 660	11.0
Cells (4.9 Ah)	**$ 732**	**$ 7,317**	**122**
Module integration	Total program		
NRE	Available with Report Purchase		
CapEx (Land, building, tooling, equipment, & startup)			
Overhead			
Labor			
Subtotal integration cost			
Total modules cost			
Pack components			
Mechanical			
Electrical			
Thermal			
BMS			
Subtotal			
Pack integration			
NRE			
CapEx (Land, building, tooling, equipment, & startup)			
Overhead			
Labor			
Subtotal integration			
Total pack cost			
Pack minus cells			
Profit and warranty, beyond cells			
Pack price			
% cells			

Cathode Cost, Total Cell Materials Cost, Cell and Pack Price per kWh - 2013 to 2022



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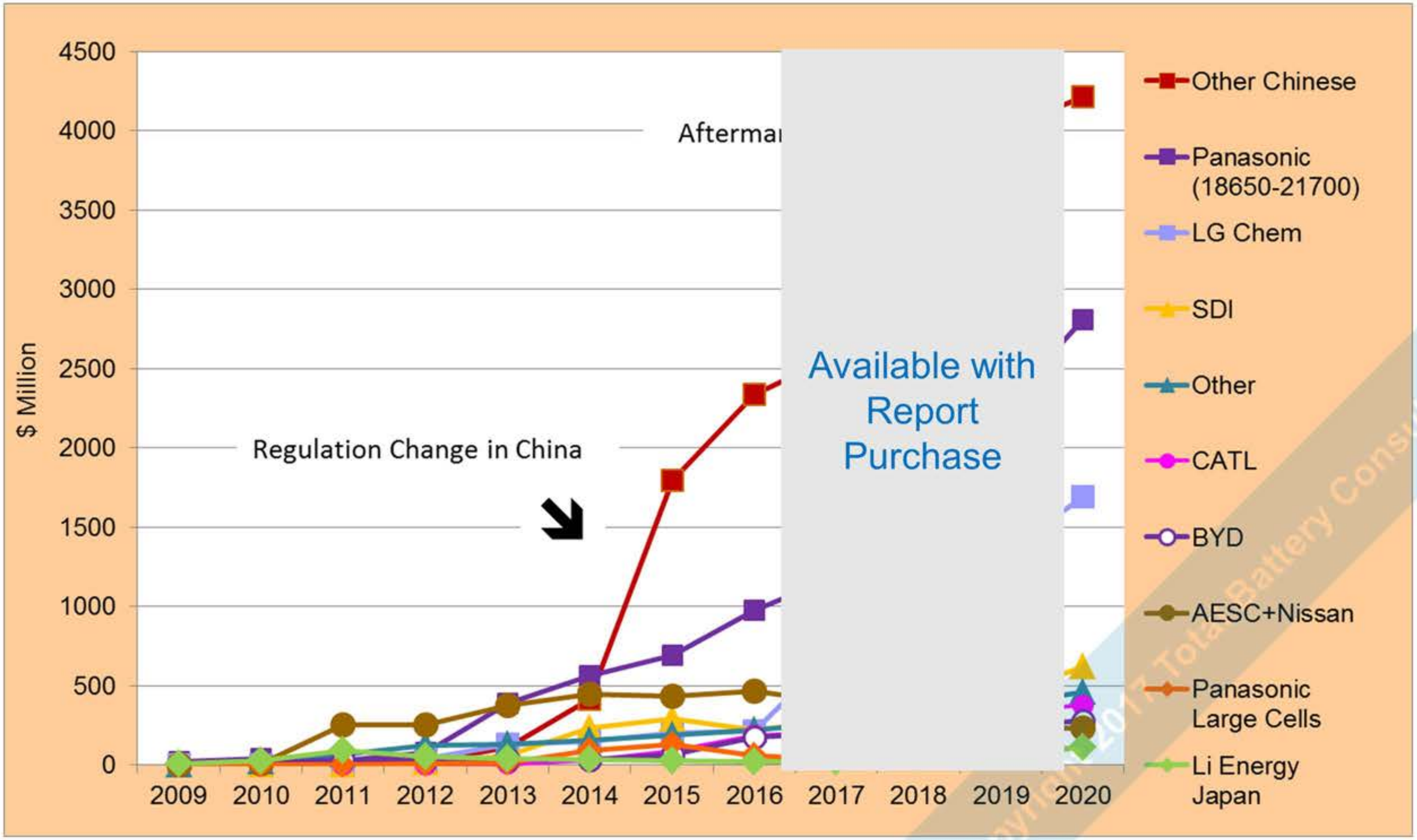
Tesla's Impact on the EV / Battery Industry

- Tesla's main contribution to date has been to push other automakers to increase driving range.
  - Partially due to Tesla, but also to modified CARB regulations and improvement in battery energy density, we are seeing major automakers developing EVs with ranges of 150-300 miles versus the 70-100 miles developed through 2015.
- Whether or not the cylindrical-cell approach has a lasting life, EV batteries with higher capacity, lower power/energy ratio, and lower cost per kWh are now viewed with renewed interest.
- Pre-orders of the Model 3 confuse the industry: is there really a large (and profitable) market for a mid-size entry luxury $40k EV? The industry will not know until the end of the decade, which complicates investment decisions by automakers and suppliers.
- The supply chain cannot ignore a company that became the largest user of Li-Ion batteries in the world overnight and is planning a 20X expansion in 5 years.
  - Some materials will be produced in the U.S.
  - **Volume expectations are up but cost targets for cells and materials are down.**

Panasonic is the leader thanks to Tesla.



Tesla's Model 3 Sales Development

- The effect of the Model 3 on the market may slow down orders of the Model S.
- Pilot production is starting in Q3 2017, and volume shipments (over 10,000 per month) are likely to start sometime in 2018. Apparently, Tesla skipped the Beta prototype validation step, which in most car companies takes 9-15 months. This might present the risk of fielding too many defective cars, which would have cost and image implications.
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- 2018 to 2020 will be the trial years. Will Tesla be able to offer a product not only attractive but also reliable, and one that will also generate profits?

Our Projection: the Most Likely Scenario…

- The Model 3 will ramp up production sometime in 2018 and will be priced (prior to government incentives) in the range of $40-55k.
- Annual sales, excluding in China, will be significant, perhaps 200k cars by 2020.
- If sales in China are significant, the total worldwide sales may exceed 200k by 2020, but Tesla will have to shift some production to China.
- The profit margin on car sales is likely to be (much) lower than industry standards but sales of components and credits will contribute to profit.
- **High cash-burn rate and losses are likely to increase in 2017 and 2018.**
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Tesla is heading for two major accomplishments that the U.S. and other western governments have failed to achieve:

- Bringing an attractive EV closer to the average car buyer
- Establishing a domestic Li-Ion battery industry

This should be viewed as a huge success in itself, but:

- Will it be profitable?
- Will materials suppliers join the project?
- Will it support the highly lucrative EV business projected by some analysts?

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