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BENCHMARK | WORLD TOUR 2015

The battery supply chain in a lithium-ion revolution

Vancouver, 1 October 2015

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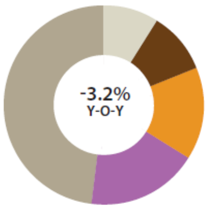
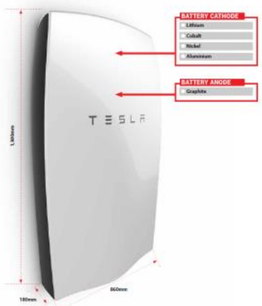
What is Benchmark?

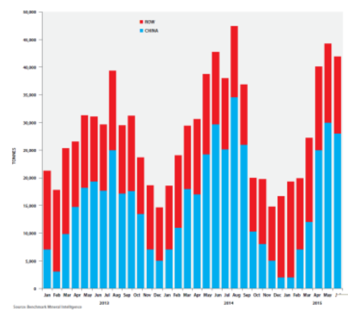
- Market focused publishing company
    - Supply, Demand, Prices
- Critical minerals and disruptive technology supply chains
- Specialising in the battery supply chain, mine to market
- Data collection: Market Prices and Price Mechanisms for niche minerals

9,500t

the estimated decrease in flake graphite production ytd







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Benchmark’s products

Subscriptions	• Membership (incl Quarterly Magazine) • Graphite | Data • Lithium |Data
Consultancy	• Market advisory • Forecasting: supply, demand, prices • Country reports
Events	• Free seminars – World Tour 2015 • Industry Conferences • Workshops

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World Tour 2015

Lithium-ion battery supply chain in 2015

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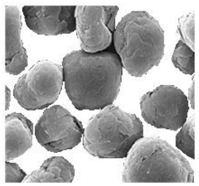
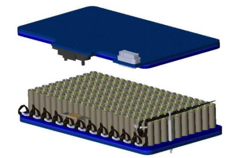
Lithium-ion supply chain basics





Upstream

Downstream

Raw Materials	Semi processed products	Batteries	Battery Packs	Mobile / EV / Utility
Lithium Graphite Cobalt	Anode Cathode Separators	Cells Various form factors (18650)	4-7Wh 7-10 kWh 40-85 kWh >500 kWh	Smartphone Home EVs Commercial

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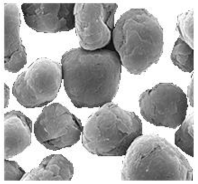

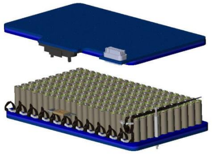

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Downstream | Mobile, EV, Commercial batteries

- **Market Growth: Not just about EVs anymore**

Product Line	Automotive	Residential	Commercial
Power/Energy	310 kW / 85 kWh	5 kW / 10 kWh	200 kW / 400 kWh+

Source: Tesla Motors

Downstream | Mobile, EV, Commercial batteries

Mobile Technology: More devices, bigger batteries

1995

Downstream | Mobile, EV, Commercial batteries

Mobile Technology: More devices, bigger batteries

1998

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Downstream | Mobile, EV, Commercial batteries

Mobile Technology: More devices, bigger batteries

2005

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Downstream | Mobile, EV, Commercial batteries

Mobile Technology: More devices, bigger batteries

2015

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Downstream | Mobile, EV, Commercial batteries

Mobile Technology: More devices, bigger batteries

Battery Size	5.4Wh	6.9Wh	11.1Wh
Graphite	9g	12g	19g
Year	2012	2014	2014

Source: Benchmark Mineral Intelligence

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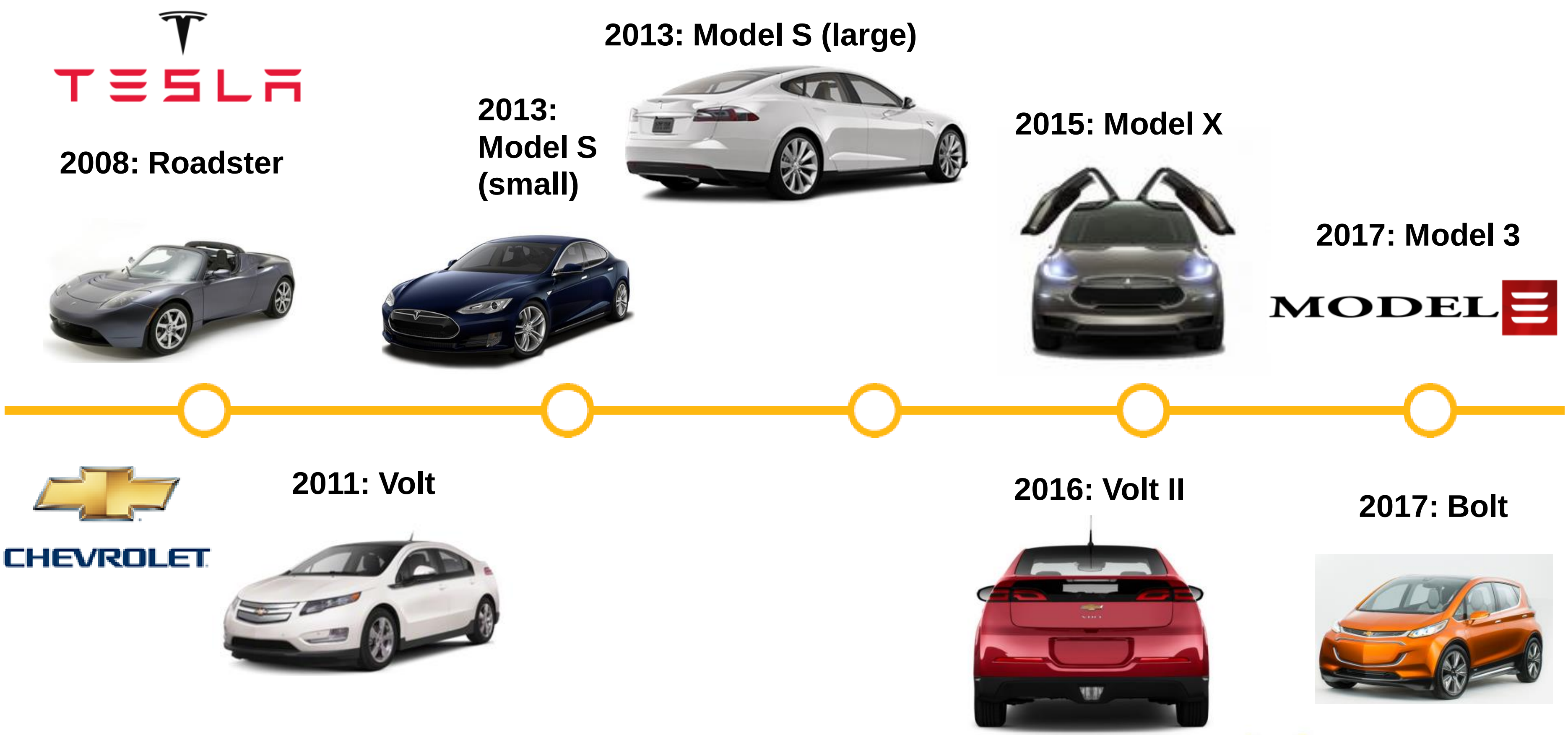
Downstream | Mobile, EV, Commercial batteries

EVs: From niche to mass market



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Downstream | Mobile, EV, Commercial batteries

EVs: From niche to mass market

More companies are entering the space in a serious way…

- **Apple**: Rumours developing EV technology
  - Bloomberg: 200+ team working on "Titan"
- Sony
- Tesla Model X / Chevrolet Bolt
- Nissan Leaf III
- Aston Martin
- Mercedes Benz
- Audi
- Toyota: Hydrogen competition
- Google: Self driving tech, EV?

THE WALL STREET JOURNAL.

Apple Gears Up to Challenge Tesla in Electric Cars

IPhone Maker Has 100s Working on Design of a Minivan Like Vehicle

THE INDEPENDENT

Dawn of the iCar? Apple rumoured to be secretly working on design for an electric people-carrier

theguardian

Google almost bought Tesla when it had just two weeks of cash left

Sony looks at adding cars to growth drive

By Kana Inagaki in Tokyo

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Downstream | Mobile, EV, Commercial batteries

Commercial / Utility: Take-off

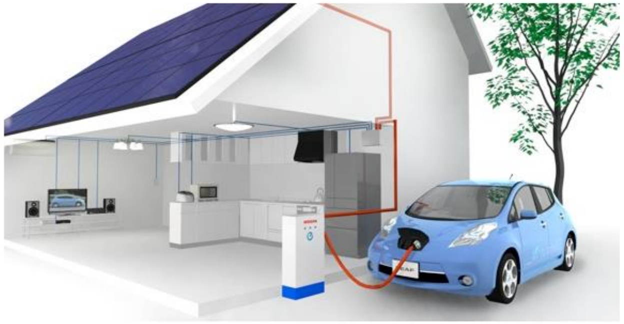
- New Utility storage devices being launched
- Auto manufacturers becoming battery producers
- Major commercial interest in back up and off-grid power

Home storage

Mercedes

Tesla

Nissan



Commercial storage

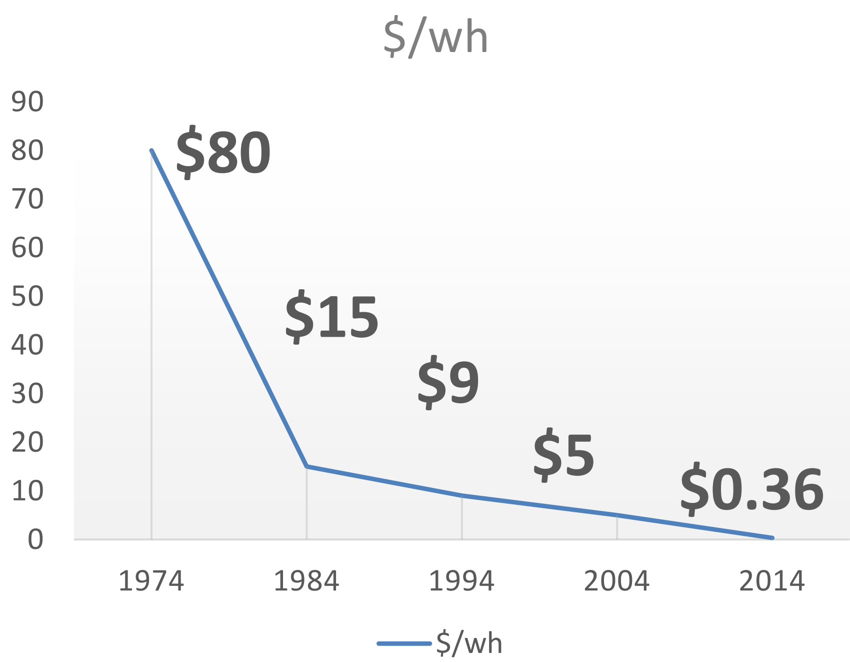
LG Chem / Panasonic / Samsung

Downstream | Mobile, EV, Commercial batteries

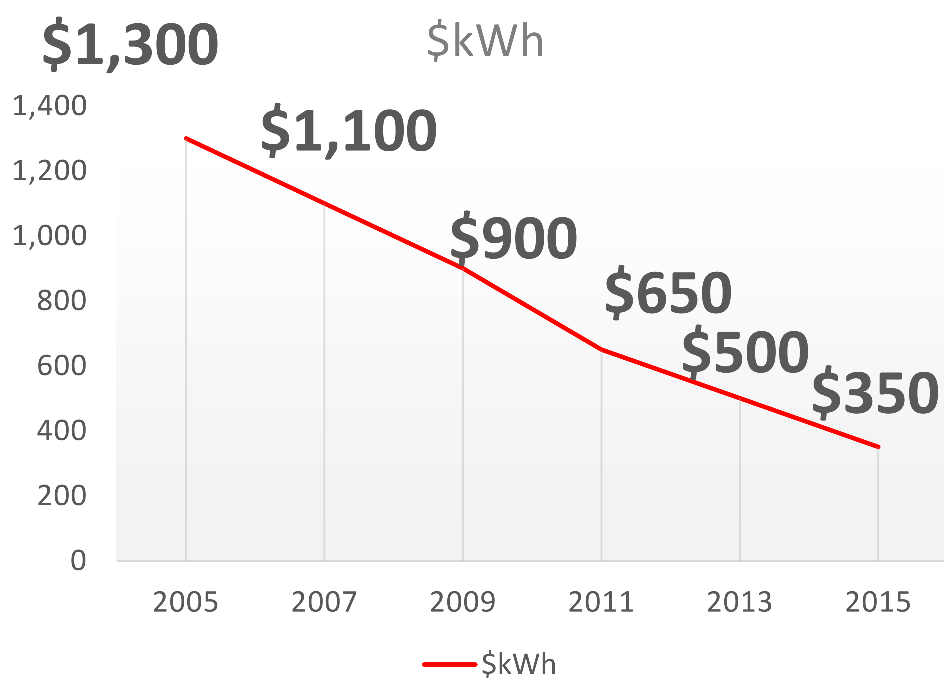
Commercial / Utility: Take-off

- Solar power storage offers greatest opportunity
- Technologies reaching converging point

Solar panel: cost of production



Lithium-ion battery: cost of production



Source: Bloomberg New Energy Finance (Solar), Benchmark (Batteries)

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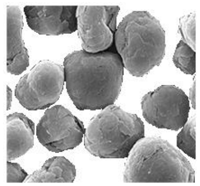
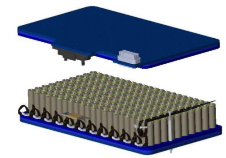
Lithium-ion supply chain basics





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Downstream | Batteries

Tesla's Gigafactory has sparked a battery arms race

Source: Reno Gazette (top); Steve Jurvetson (bottom)

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Downstream | Batteries | Megafactory highlights

Global 2013 capacity was 35GWh

Tesla / Panasonic	35GWh	$5bn	Nevada, USA	Lithium-ion	2016
LG Chem	7GWh* 1.6 GWh	$500m* $300m	Nanjing, China Michigan, US	Lithium-ion Lithium-ion	2016 Expansion
Foxconn	15GWh*	$810m*	Anhui, China	Lithium-ion	2016
BYD	20GWh		various, China	Lithium-ion	2020
Boston Power	10GWh		various, China	Lithium-ion	2020
Samsung SDI	1.5 GWh (combined)		Ulsan, South Korea Xi'an, China	Lithium-ion Lithium-ion	Expansion Expansion

Source: Benchmark Mineral Intelligence

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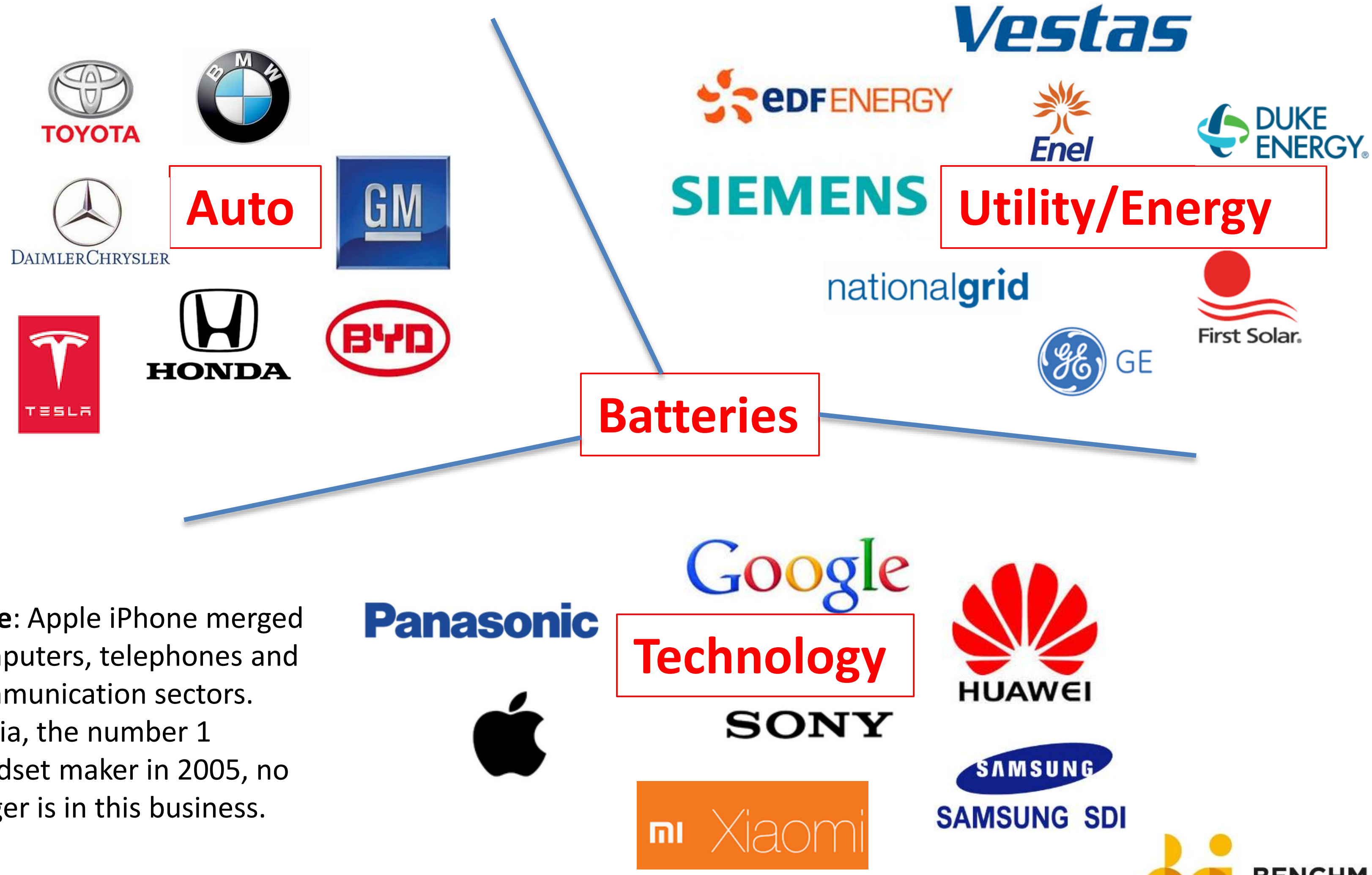
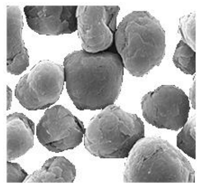
Downstream | Batteries

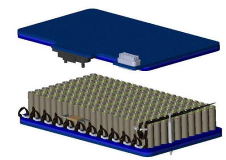
Downstream summary: Convergence of 3 multi-billion dollar industries



- **Note**: Apple iPhone merged computers, telephones and communication sectors.
- Nokia, the number 1 handset maker in 2005, no longer is in this business.

Lithium-ion supply chain basics





Upstream

Downstream

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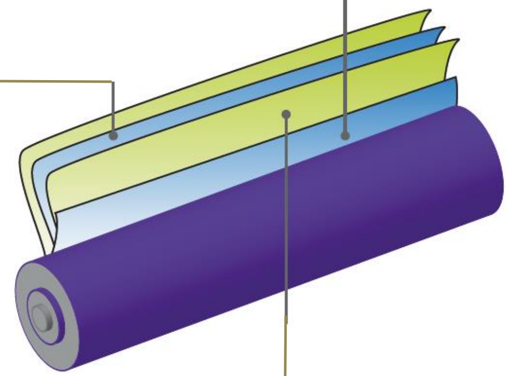
Upstream | Lithium-ion battery raw materials



Anode | **Separator** | **Cathode**

Carbon

- Natural flake (spherical)
- Synthetic
- Hard carbon
- Soft carbon
- MCMB

Polymer films

Lithium chemicals
Nickel
Cadmium
Phosphate
Cobalt
Manganese

And more

Source: Benchmark Mineral Intelligence

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Upstream| Lithium-ion chemistries

Lithium Cobalt Oxide LCO 1991 Mainstream chemistry being challenged

\+
> Higher energy density
> Well established

\-
> Longer to charge
> Average lifespan ~2 years

Nickel Cobalt Aluminium NCA 2000s Tesla / Panasonic chemistry

\+
> Good specific energy density
> Good power

\-
> Past safety issues
> Raw material costs

Nickel Manganese Cobalt NMC 2000s Emerging – LG Chem / 3M deal

\+
> Ability to tailor for energy or power
> Lower raw material cost
> LG Chem adopting / Volt

\-
> Less commercially widespread

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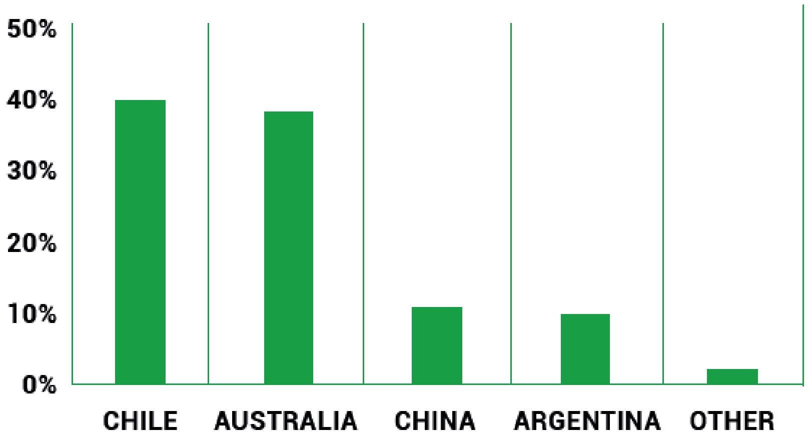
Upstream | Lithium



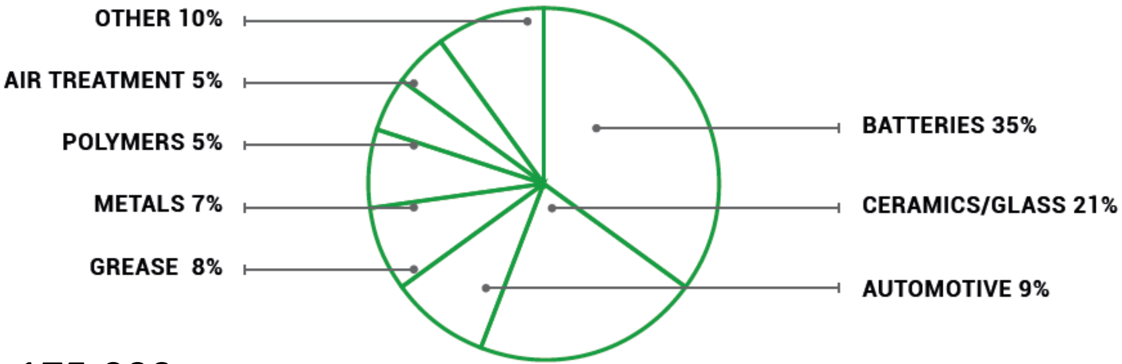
Supply

- Brine: Chile, Argentina, China
- Spodumene: Australia

Expected LCE supply in 2015: 150,000 tonnes

Demand

- Driven by batteries
- Overtook Glass / Ceramics in 2010



Expected LCE demand in 2015: 175,000 tonnes

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Upstream | Lithium | Supply

Supply:

Problems in the Atacama / Slow ramp ups

Chile

- Leading volume producer, Atacama licence issues
- SQM: CEO fired, lawsuit with CORFO (government) over lithium rights
- Atacama Flooding, March 2015

Argentina

- New producer: Orocobre slow ramp up

China

- Import dependant on raw material

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Upstream | Lithium | Demand

Demand:

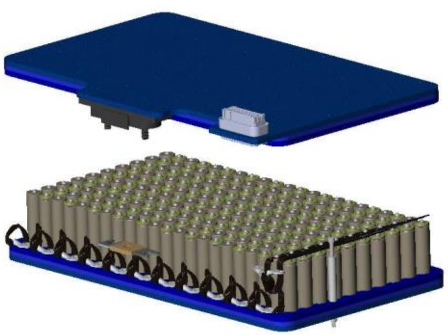
Battery demand increasing

Asia

- Orders for technical grade lithium carbonate and hydroxide up
- Increased battery output in China, Japan and South Korea
- EV ramp ups, strong smartphone sales in China

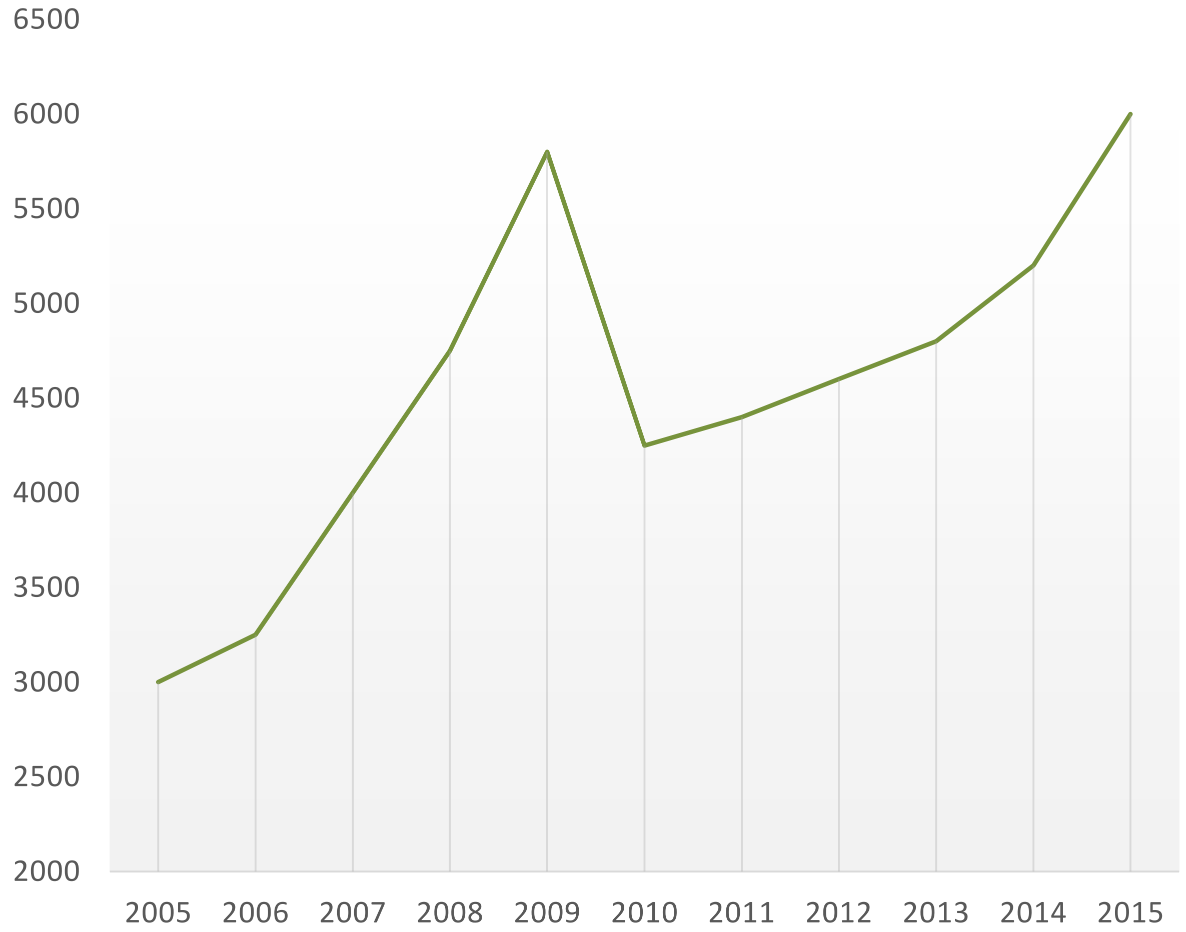
North America

- No buying yet to take place for Tesla’s Gigafactory
- Future lithium supply agreements only just announced (Bacanora)
- More from Tesla to come



Upstream | Lithium | Prices

Lithium Carbonate Price Trend: 2005-2015 ($/tonne)



In 2015:

> **Carbonate** prices up 10-15% on 2014 average

> **Hydroxide** up 20-25% on 2014 average

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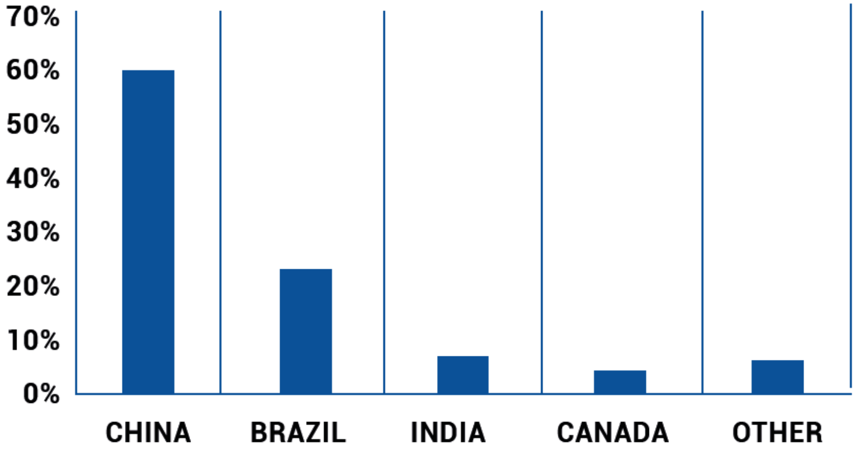
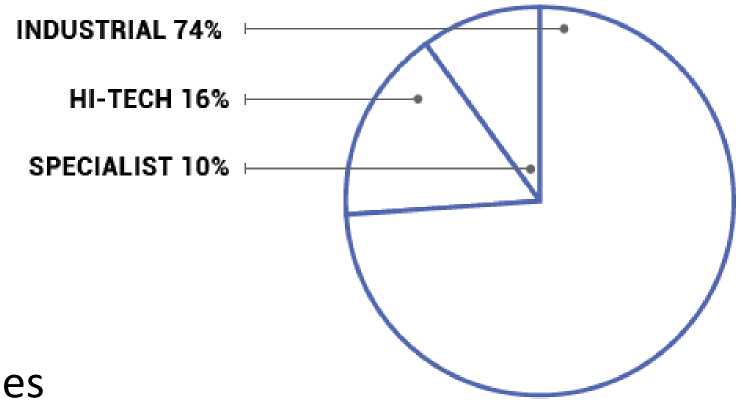
Upstream | Flake Graphite



Supply

- China leading producer but undergoing consolidation / modernisation
- Domestic demand low: closed many mines
- Average graphite mine size: 11,600 tpa

Expected flake supply in 2015: 400,000 tonnes



Demand

- Driven by steel
- Batteries / Foundry, second largest market

Expected flake demand in 2015: 375,000 tonnes

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Upstream | Flake Graphite | Supply

Supply:

China's consolidation / Domestic demand slump

China

- Consolidation underway last 2 years
- Est to impact 30% of capacity
- **Controls 95%** of World's battery grade graphite capacity
- Battery grade coating capacity shared between predominately China and Japan

Brazil

- Only volume producer outside of China
- No expected significant expansions in next 3-5 years

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Upstream | Flake Graphite | Demand

Demand:

Industrial markets in China significantly down

Battery markets: strong growth

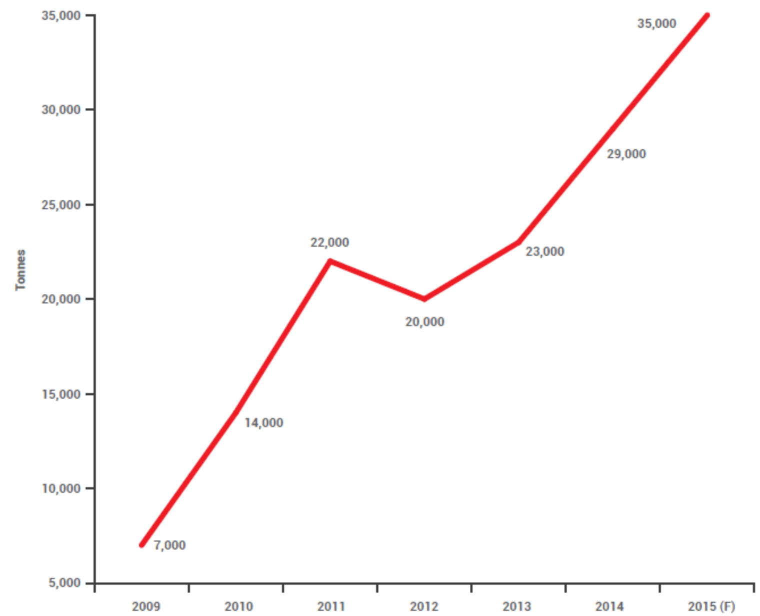
Steel

- Volume of grades driven by refractories and recarburizer in steel
- Forced price down

Batteries

- Converse situation in batteries
- Exports out of China: 27% CAGR over last 5 years

China Spherical Graphite Exports 2009-2015



IN NUMBERS

27%

COMPOUND ANNUAL GROWTH RATE OF CHINA'S BATTERY GRADE GRAPHITE EXPORTS

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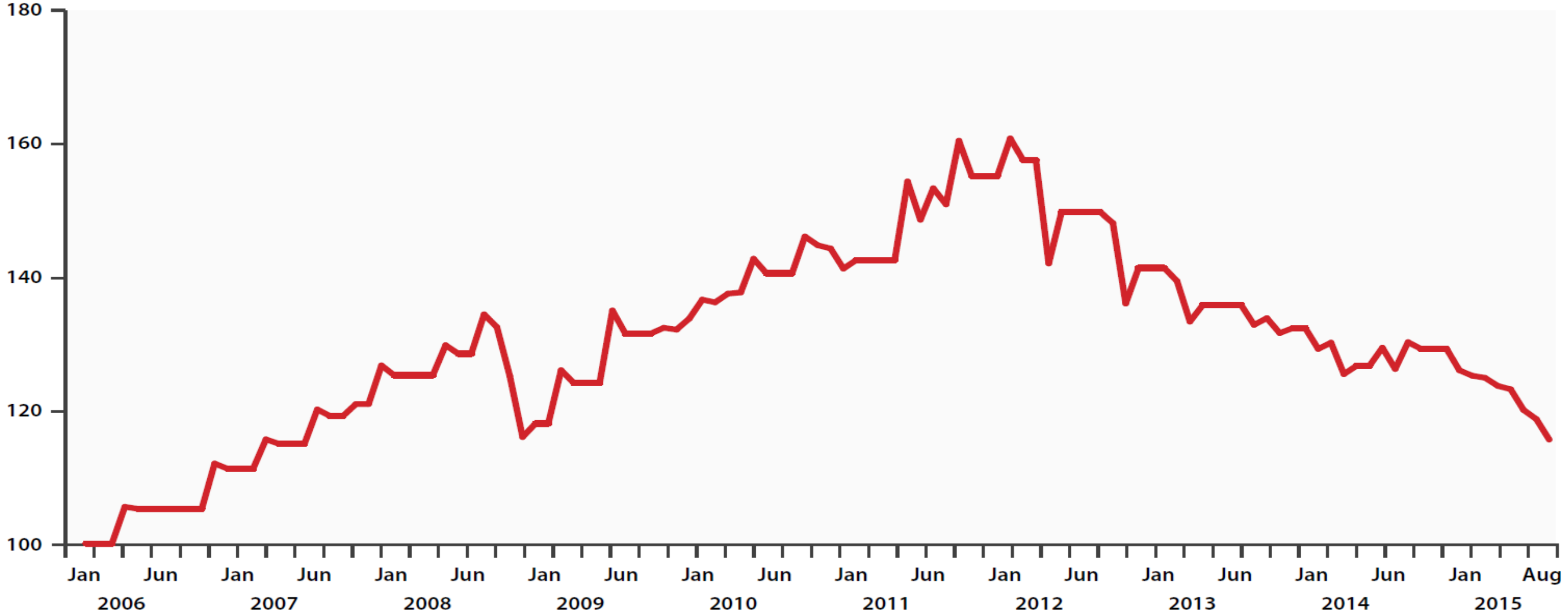
Upstream | Graphite | Prices

Benchmark Graphite Price Index:



Q3 2015 Traded Prices

- Medium Flake, 94-95% C, CIF Europe: $750-850/tonne
- Large Flake, 94-95%C, CIF Europe: $1,000-1,150/tonne
- Jumbo Flake, 94-95% C, CIF Europe, $1,500-1,600/tonne

- Battery grade graphite (spherical), uncoated: $3,000-3,5000/tonne
- Battery grade graphite (spherical), coated: $7,000-10,000/tonne

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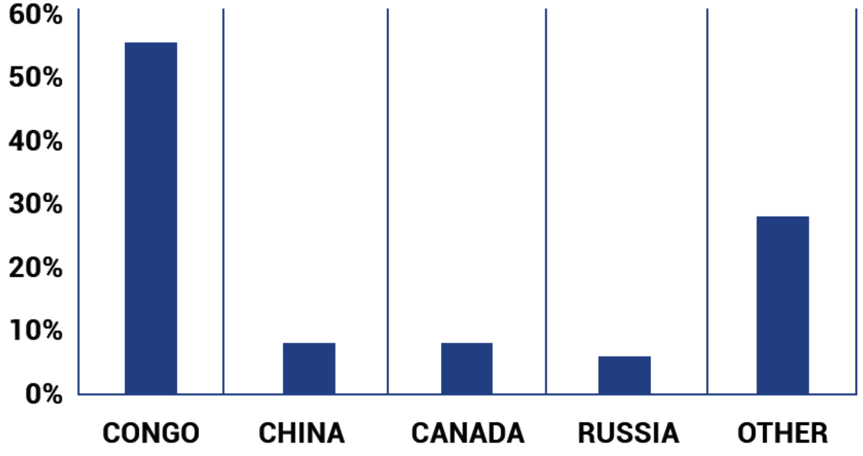
Upstream | Cobalt



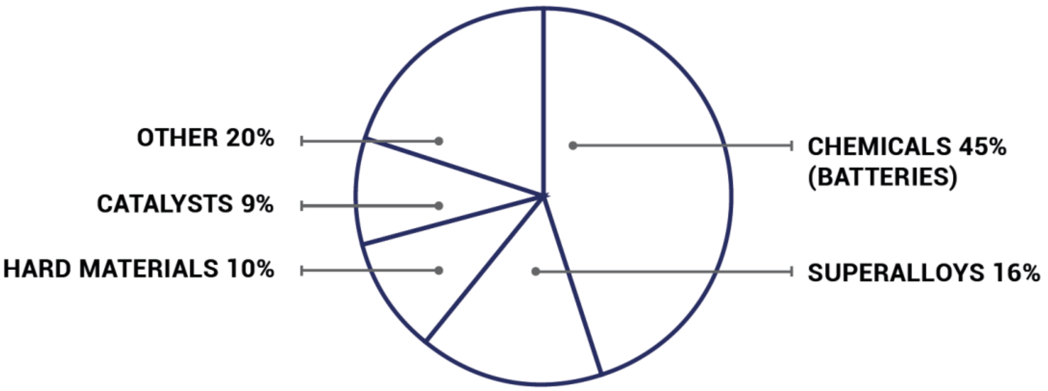
Supply

- DRC leading source of raw material
- China dominates refining capacity
- Almost 100% mined as a by-product

Expected cobalt supply in 2015: 87,000 tonnes
US import dependancy: 100%

Demand

- Driven by batteries
- Traditional metal demand falling



Expected cobalt demand in 2015: 86,000 tonnes

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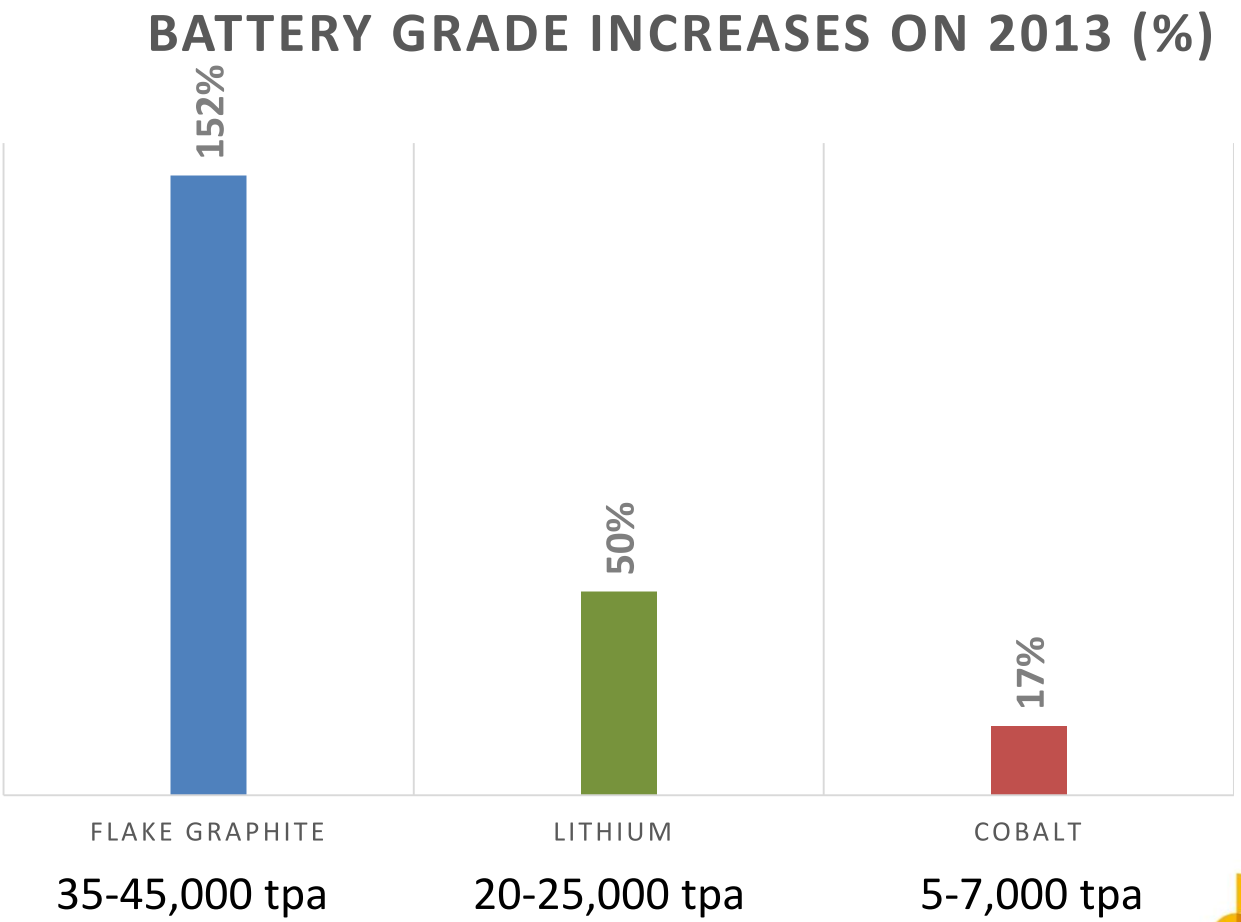
Final Thought

Raw materials case study: Tesla Gigafactory at capacity

Source: Benchmark Mineral Intelligence



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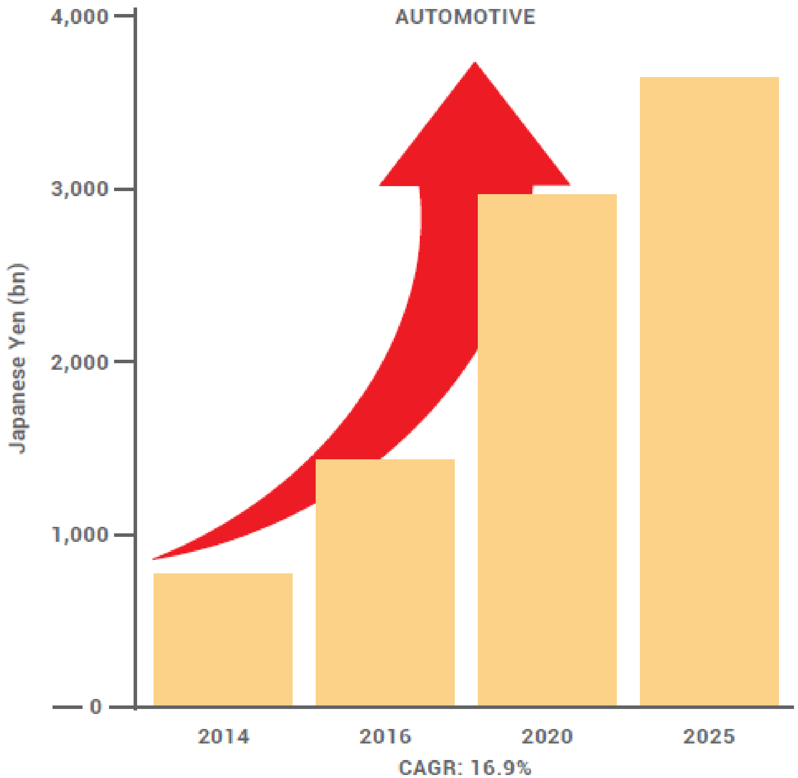
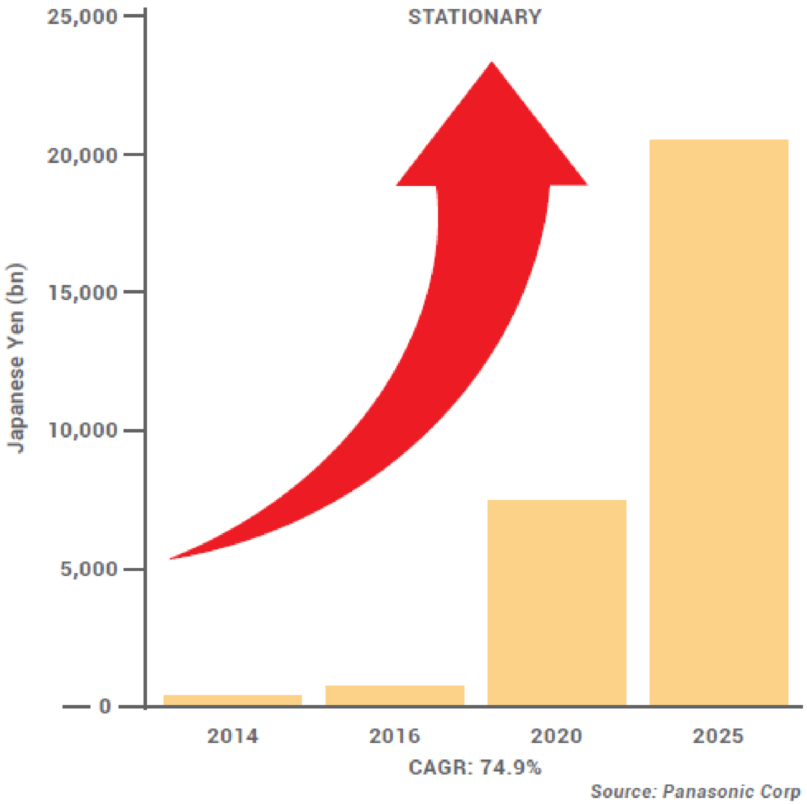
Final Thought

Panasonic's Forecast for lithium-ion battery growth: 2014-2025 (revenue)





CAGR: 16.9%

CAGR: 74.9%

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Final Thought

Timeline: Battery Commercialisation

1969-1990	Late-1990s	2006-2016	2017 onwards
I	II	III	IV
Watches Cars	Cell phones Power tools Personal music	Smartphones Tablets Laptops Hybrid cars	Full Electric vehicles Utility/Stationery Storage
Mercury Lead acid	NiMH/Lithium-ion	Lithium-ion / NiMH	Lithium-ion

1969 Late-1990s 2006 2007 2010

Source: Benchmark Mineral Intelligence

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