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Industry
Lithium 101

Date
9 May 2016

Global

M&M - Other Metals

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F.I.T.T. for investors

Welcome to the Lithium-ion Age

Global lithium S&D analysis highlights opportunity for high-quality assets

The emergence of the Electric Vehicle and Energy Storage markets is being driven by a global desire to reduce carbon emissions and break away from traditional infrastructure networks. This shift in energy use is supported by the improving economics of lithium-ion batteries. Global battery consumption is set to increase 5x over the next 10 years, placing pressure on the battery supply chain & lithium market. We expect global lithium demand will increase from 181kt Lithium Carbonate Equivalent (LCE) in 2015 to 535kt LCE by 2025. In this Lithium 101 report, we analyse key demand drivers and identify the lithium players best-positioned to capitalise on the emerging battery thematic.

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The emergence of the Electric Vehicle and Energy Storage markets is being driven by a global desire to reduce carbon emissions and break away from traditional infrastructure networks. This shift in energy use is supported by the improving economics of lithium-ion batteries. Global battery consumption is set to increase 5x over the next 10 years, placing pressure on the battery supply chain & lithium market. We expect global lithium demand will increase from 181kt Lithium Carbonate Equivalent (LCE) in 2015 to 535kt LCE by 2025. In this Lithium 101 report, we analyse key demand drivers and identify the lithium players best-positioned to capitalise on the emerging battery thematic.

Global lithium demand to triple over the next 10 years

The dramatic fall in lithium-ion costs over the last five years from US$900/kWh to US$225/kWh has improved the economics of Electric Vehicles and Energy Storage products as well as opening up new demand markets. Global battery consumption has increased 80% in two years to 70GWh in 2015, of which EV accounted for 35%. We expect global battery demand will reach 210GWh in 2018 across Electric Vehicles, Energy Storage & traditional markets. By 2025, global battery consumption should exceed 535GWh. This has major impacts on lithium. Global demand increased to 184kt LCE in 2015 (+18%), leading to a market deficit and rapid price increases. We expect lithium demand will reach 280kt LCE by 2018 (+18% 3-year CAGR) and 535kt LCE by 2025 (+11% CAGR).

Supply late to respond but wave of projects coming; prices are coming down

Global lithium production was 171kt LCE in 2015, with 83% of supply from four producers: Albemarle, SQM, FMC and Sichuan Tianqi. Supply has not responded fast enough to demand, and recent price hikes have incentivized new assets to enter the market. Orocobre (17.5ktpa), Mt. Marion (27ktpa), Mt. Cattlin (13ktpa), La Negra (20ktpa), Chinese restarts (17ktpa) and production creep should take supply to 280kt LCE by 2018, in line with demand. While the market will be in deficit in 2016, it should rebalance by mid-2017, which should see pricing normalize. Our lithium price forecasts are on page 9.

Best exposures to this thematic? Buy companies with Tier 1 strategic assets

Our view is that companies with Tier 1 assets generating strong margins and volume growth will outperform in this market. Albemarle (ALB.N, US$72/sh PT, Buy) is the market leader, with interests in the world's best brine and hard-rock projects and should double output over the next six years. Orocobre (ORE.AX, Buy A$3.90/sh PT) is ramping up its 17.5ktpa Olaroz brine project; we assume it expands to 35ktpa by 2022. Mineral Resources (MIN.AX, Buy A$8.00/sh PT) has a stake in the Mt. Marion hard-rock project, which is entering the market in 2H16; MIN will operate on behalf of its JV partners. One of those partners, Ganfeng Lithium (002460.SZ, Buy CNY78/sh PT) is well positioned as part-owner of Mt. Marion and #2 downstream processor in China. Longer term, Rio Tinto (RIO.AX, Buy A$56.50/sh PT) owns the world's largest undeveloped hard-rock deposit (not in our numbers). ASX-listed Syrah Resources (SYR.AX, Buy A$6/sh PT) also benefits from this thematic as the #1 global graphite play.

Valuation and sector risks

This report changes price targets and recommendations (see right column). Our PT's are set in line with DCF valuations. Key risks: adverse commodity & FX movements.

Key Changes

Company	Target Price	Rating
ORE.AX	2.70 to 3.90(AUD)	Hold to Buy
MIN.AX	6.70 to 8.00(AUD)	Hold to Buy
002460.SZ	– to 78.00(CNY)	NR to Buy

Source: Deutsche Bank

Companies Featured

Albemarle (ALB.N),USD68.63	Buy
Orocobre (ORE.AX),AUD3.50	Buy
Mineral Resources (MIN.AX),AUD7.34	Buy
Ganfeng Lithium (002460.SZ),CNY67.60	Buy
Rio Tinto (RIO.AX),AUD47.75	Buy
Tianqi Lithium (002466.SZ),CNY175.70	Hold
Tesla Motors (TSLA.OQ),USD211.53	Hold

Source: Deutsche Bank

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Executive Summary

The global economy is undergoing structural change. As we move towards becoming a globally connected society, self-sufficiency and mobility become greater priorities. Consumers are aware of their reliance on carbon fuels and seek to break away from traditional infrastructure networks. Policy makers and the private sector are preparing for the inevitable shift in how we use energy.

This is the dawn of the Lithium-ion Age

The commercialization of the lithium-ion battery in the 1990's powered a 20-year surge in the telecommunication and computing industries following the rapid development of light, powerful, rechargeable batteries. As we enter the second half of this decade, the emergence of the Electric Vehicle (EV) is a globally significant thematic based on the same battery technology. Governments are setting carbon emissions targets for the automotive industry whilst also subsidizing EV technology. Beyond traditional demand markets and the emergence of EV, another potential market is beginning to materialize. Battery energy storage on a grid-, industrial-, commercial- and consumer-scale is reaching commercial viability, and rapidly falling battery costs suggest that the Energy Storage sector could grow materially over the next 10 years.

What does this mean for the battery supply chain?

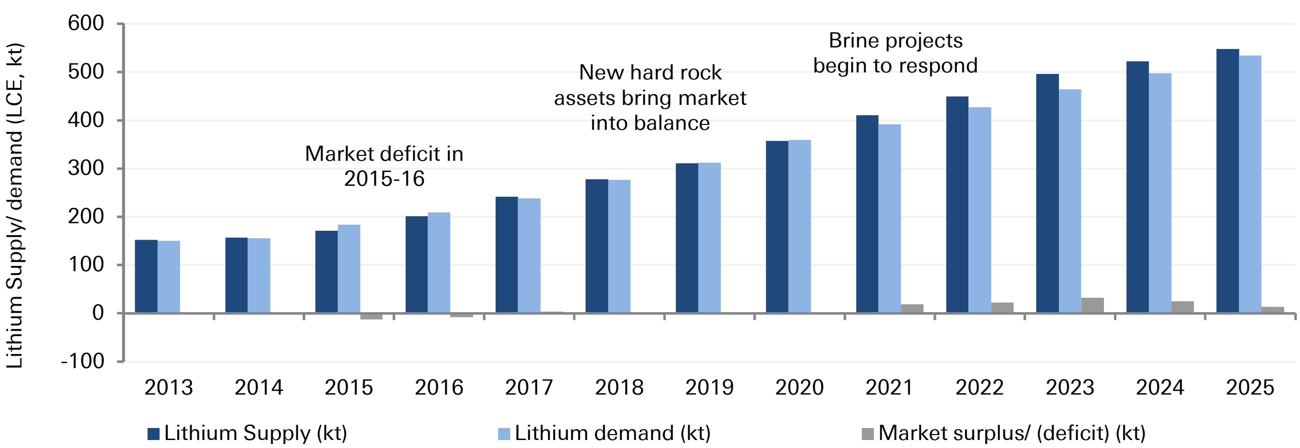
Significant investment is underway to increase global production capacity of lithium-ion batteries, from the EV car manufacturers through to existing producers of the key components of the battery cell. In this report, we focus on lithium, the critical element that drives the chemistry within a lithium-ion battery, to understand if lithium supply is a key risk to this growing thematic.

The global lithium market is measured in terms of 'lithium carbonate equivalent (LCE), given that lithium carbonate is the most commonly traded product in the market.

Global lithium supply needs to triple in 10 years

Global lithium demand was 184kt in 2015, with battery demand increasing 45% YoY and accounting for 40% of global lithium demand. Based on our analysis, global lithium demand will increase to 534kt by 2025, with batteries accounting for 70% of global demand. We have reviewed over 70 companies and 125 lithium projects to forecast how the supply market will respond.

Figure 1: Global Lithium Supply and demand balance

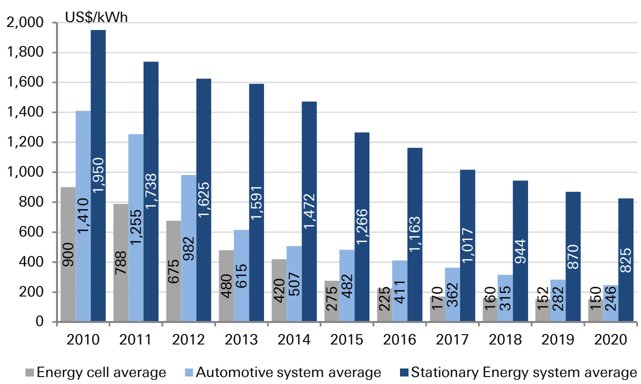


Source: Deutsche Bank, United States Geological Society, company data

Unprecedented demand growth over next 10 years

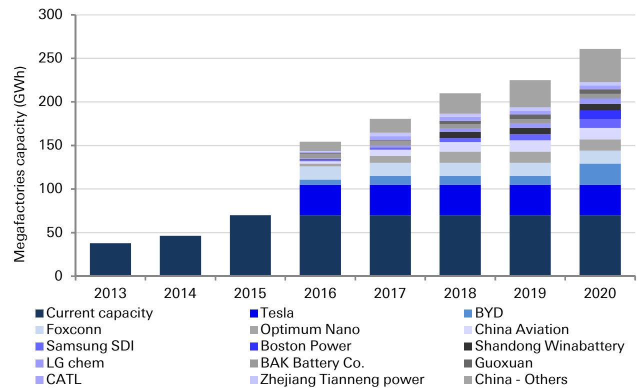
Lithium-ion battery costs are falling rapidly as global battery producers expand manufacturing facilities, unlocking economies-of-scale. Energy cell costs have fallen from US$900/kWh in 2010 to around US$225/kWh today. This cost reduction is opening up new demand applications for lithium-ion and making lithium-ion batteries superior to other battery technologies not just on power and performance but also on cost. We believe costs can fall to US$150/kWh by 2020 as multinational companies like Tesla, Panasonic, LG Chem, Foxconn and BYD further expand global battery manufacturing capacity.

Figure 2: Lithium-ion battery costs are falling



Source: Deutsche Bank; Cairn ERA

Figure 3: The battery supply chain is rapidly increasing



Source: Deutsche Bank, company data

The Electric Vehicle industry is the major demand market

Global investment in the battery supply chain and the need for cheaper batteries is being driven by the emergence of the Electric Vehicle. This growing market has been pioneered by Tesla in recent years, but the larger catalyst for global mass market uptake of EV technology is China, where government subsidies are in place for both passenger EV vehicles and commercial EV's (buses and small trucks). Hybrids & plug-in hybrids currently dominate global EV sales, with full-electric EV's accounting for only 0.6% of global auto sales in 2015. We expect EV sales to grow to over 16 million vehicles by 2025 with full-electric EV sales rising to 3.0 million vehicles (2.6% of global sales, 6x the 2015 market). This market share gain should lift lithium consumption in EV's from 25kt LCE in 2015 to 205kt LCE in 2025 (23% CAGR over the next 10 years).

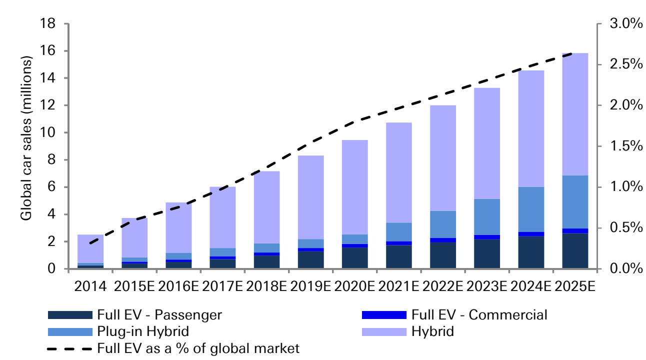
Tesla is now targeting 500,000 units of annual production by 2018, two years earlier than previously planned. On their 1Q16 call, management also suggested that they hope to sustain a 50% growth rate, which would imply over 1 million units by 2020.

Figure 4: DB global EV forecasts (m units)

	2015	2020	2025
Hybrid	2.9	6.9	9.0
Plug-in Hybrid	0.3	0.7	3.9
Full EV - Passenger	0.4	1.6	2.6
Full EV - Commercial	0.1	0.3	0.4
Subtotal	**3.7**	**9.5**	**16**
Diesel	18	19	20
Gasoline	67	73	76
Total	**89**	**102**	**112**
Hybrid as % of global market	3.2%	6.8%	8.0%
Plug-in Hybrid as % of global market	0.4%	0.7%	3.5%
Full EV as % of global market	0.6%	1.8%	2.6%
Full EV as % of Total EV	14.3%	19.4%	18.7%

Source: Deutsche Bank

Figure 5: DB global EV forecasts



Source: Deutsche Bank

Energy Storage an emerging market but still five years away

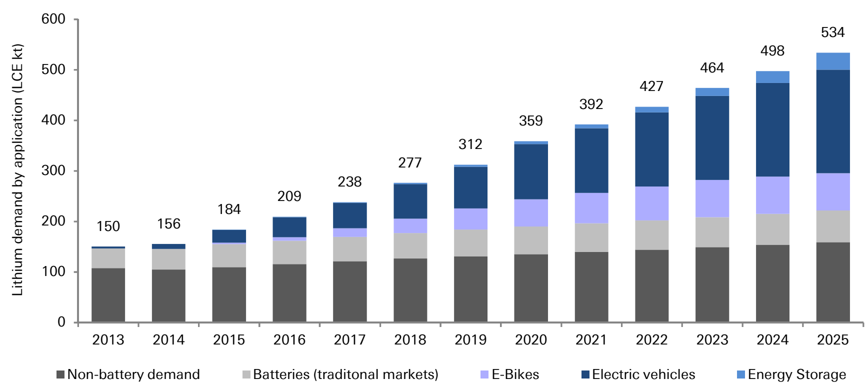
We believe the Energy Storage market is reaching an inflexion point. Driven by the declining costs of lithium-ion batteries, battery storage is now economically feasible for a number of Energy Storage applications. The impact on installed capacity has been immediate, with installed battery capacity in Energy Storage products doubling in two years, albeit off a low base.

We believe battery use in Energy Storage will grow to be a 50GWh per annum market by 2025 (46% CAGR over next 10 years). Lithium-ion batteries should be the leading technology, with superior performance and rapidly falling costs helping ensure it will be the battery of choice in Energy Storage. We believe lithium battery consumption will reach 48GWh (54% CAGR), accounting for 97% of battery use in Energy Storage. As a result, lithium demand should increase from virtually nothing in 2015 to 34kt LCE in 2025 (6% of 2025 demand).

Traditional lithium demand markets still supportive

While traditional markets (consumer electronics, glass, ceramics, greases, medical etc) are not seen to be major drivers of demand growth, we do expect these existing markets to grow at 3.6% p.a. over the next 10 years, taking lithium consumption in these markets from 155kt in 2015 to 222kt in 2025.

Figure 6: DB global lithium demand forecast



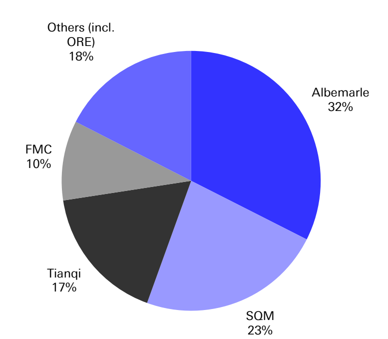
Source: Deutsche Bank, Inside EV

Market deficit driving global supply response

Lithium is produced from either brine-based deposits or from hard-rock mineral deposits. Lithium products derived from brine operations can be used directly in end-markets, but hard-rock lithium concentrates need to be further refined before they can be used in value-added applications like lithium-ion batteries.

The current lithium supply market is dominated by four major producers. Albemarle, SQM, FMC and Sichuan Tianqi accounted for 83% of global supply in 2015. An increase in lithium prices in the late 2000's led to a wave of investment in mine expansions for South America-based lithium brine assets and increasing conversion capacity in China for hard-rock lithium feedstocks. However, stagnant global growth met an oversupplied lithium market, leading to depressed lithium pricing from 2013 until mid-2015.

Figure 7: 2015 supply - by company



Source: Deutsche Bank, company data

Over the last 12 months, global lithium demand has surged, leaving a number of Chinese conversion plants searching for lithium feedstocks to be converted into value-added products. China currently has 115kt LCE installed capacity for hard-rock processing and only 55-60kt LCE of imports (mainly from the Greenbushes asset in Australia) and domestic production of 17kt LCE, leading to conversion plant utilization of 65% in 2015.

The capital-intensive brine operations, which account for 50% of global lithium supply, have been unable to respond quickly to market conditions and increase output. The subsequent supply shortage, particularly in China, has led to a significant surge in pricing; 1Q16 spot prices in China for battery-grade lithium carbonate and lithium hydroxide were 196% and 190% higher than six months ago, respectively (see Figure 9). The lithium market will remain in deficit for 2016, suggesting that these elevated prices can hold to the end of this year. It is this market backdrop that is now incentivizing new projects into the market.

New hard-rock projects entering into the market over the next 12 months

In 2015, around 45% of global lithium supply was produced in China through the processing of hard-rock lithium sources. Chinese installed capacity sits at 114kt LCE, suggesting a 65% utilisation rate in 2015 due mainly to lack of feedstock supply. Two new hard-rock projects, based on the lithium-bearing mineral spodumene, are set to commence production in the second half of 2016. The Mt. Marion project and the Mt. Cattlin project are both located in Western Australia, and have design capacity of 27ktpa (we assume increased output of 33ktpa) and 13ktpa, respectively. These two projects are set to lead to a 67% increase in spodumene concentrate imports into China within the next 12 months, lifting the average utilization rate of Chinese conversion plants to over 90%. We believe increased feedstock availability will alleviate the current supply crisis & pricing will fall as the market re-balances.

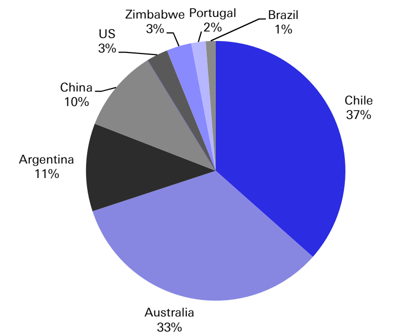
Orocobre the only new brine project currently entering the market

Orocobre (ORE.AX, Buy $3.70/sh PT) is currently ramping up the Olaroz brine project in Argentina, the first greenfields lithium brine operation in 20 years. Once at full capacity, Olaroz aims to produce 17.5ktpa LCE at sector-leading costs. Based on our demand analysis and the quality of the Olaroz resource, we believe an Phase II 17.5ktpa expansion will be incentivized into production, taking total Olaroz output to 35ktpa LCE by 2022 (see Page 105).

The Lithium majors are responding

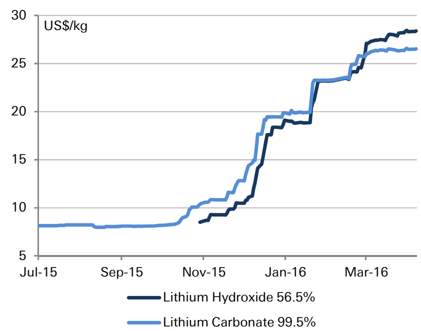
- Albemarle is the largest lithium producer in the world, controlling high-quality assets in both lithium brine and spodumene. ALB plans to spend US$600m over the next 6-7 years to increase lithium volumes, with plans to significantly expand its Chilean operations (from 25ktpa LCE to 70ktpa LCE), including its La Negra plant, and invest in downstream spodumene processing facilities outside of China.
- SQM is facing serious permitting issues in Chile and has sought volume growth outside of its home market, entering a joint venture with Lithium Americas to develop an Argentinean brine project into a 40ktpa LCE operation.
- FMC, the third major brine producer, operates the Salar de Hombre Muerto operation in Argentina. FMC has a well developed 'Special lithium products' business, but is yet to announce any major upstream expansion plans, despite controlling one of the highest-quality brine deposits outside of Chile.

Figure 8: 2015 supply - by country



Source: Deutsche Bank, company data

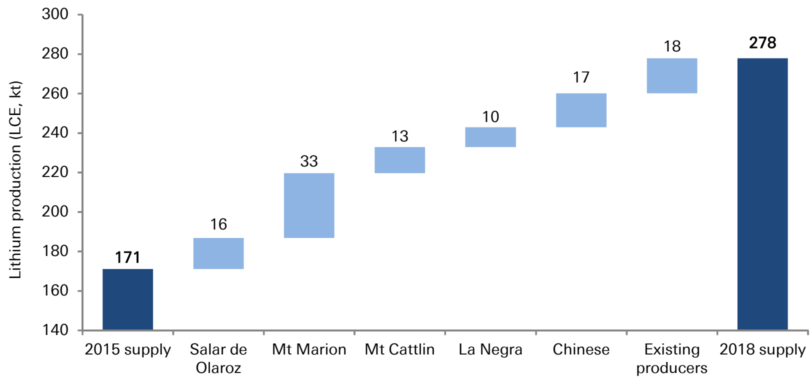
Figure 9: Chinese domestic battery-grade lithium prices (2015-present)



Source: Asianmetal

We believe increased feedstock availability in China from 2017 will alleviate the current supply crisis & pricing will fall as the market re-balances.

Figure 10: DB forecasts for lithium supply growth from 2015 to 2018

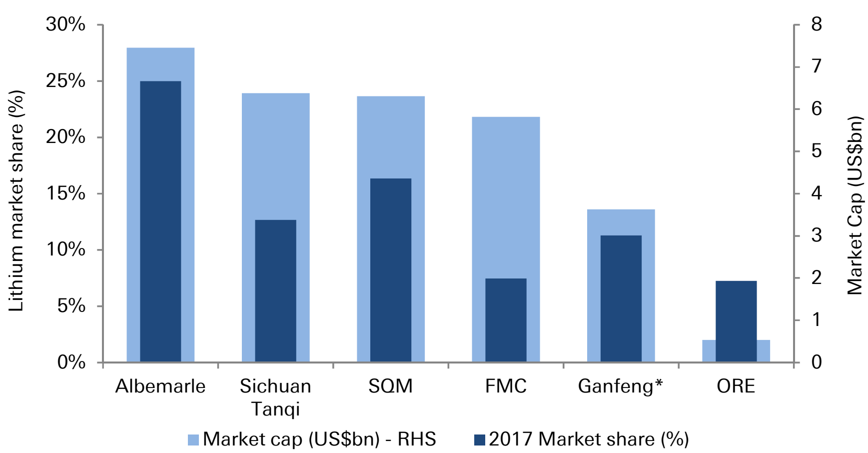


Source: Deutsche Bank

Lithium is not rare, just an underdeveloped market

The lithium supply market is relatively small compared to most other industrial commodities; however, it is not a fragmented market or lacking large market participants with the ability to deploy capital. The four largest global producers have a combined market capitalization of US$26bn, while the second-largest Chinese producer, Ganfeng, has a US$3.6bn market cap. Further, these five companies control 46% of global reserves.

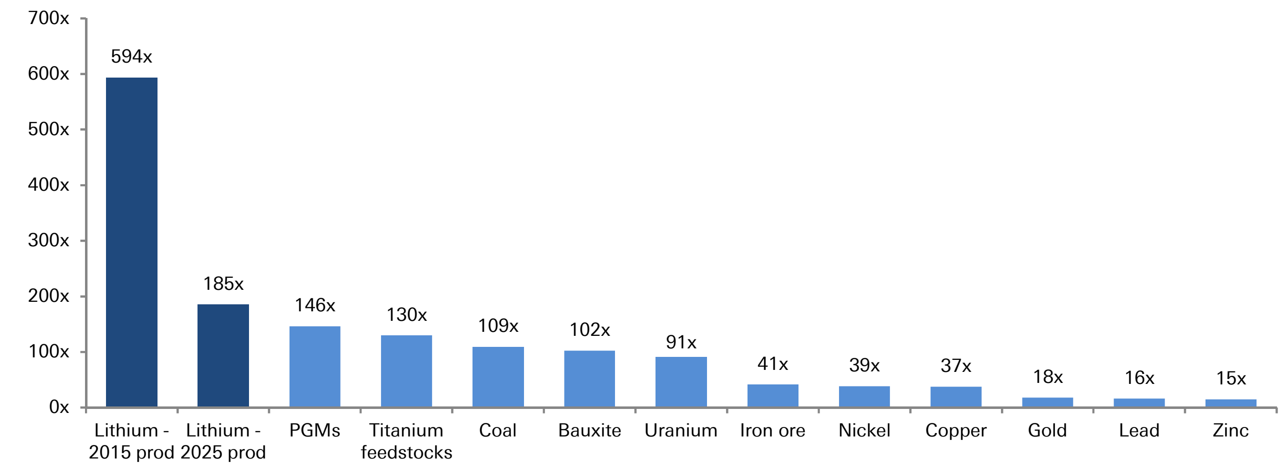
Figure 11: Market cap of major lithium producers vs. market share



*Source: Deutsche Bank, Bloomberg Finance LP *100% production from Mt. Marion is attributable to Ganfeng*

Global lithium output in 2015 was 171kt LCE, a fraction of global lithium reserves (102Mt LCE). Most major commodities generally have somewhere between 15 and 100 years of global reserves based on 2015 supply; however, global lithium reserves sit at 594 times 2015 global output. We forecast the lithium supply market to triple over the next 10 years, and even then lithium would still have 185 years of global reserves available.

Figure 12: Current lithium market vs. global reserves/reserves compared to other metal markets



Source: Deutsche Bank, United States Geological Society

Lithium price forecasts

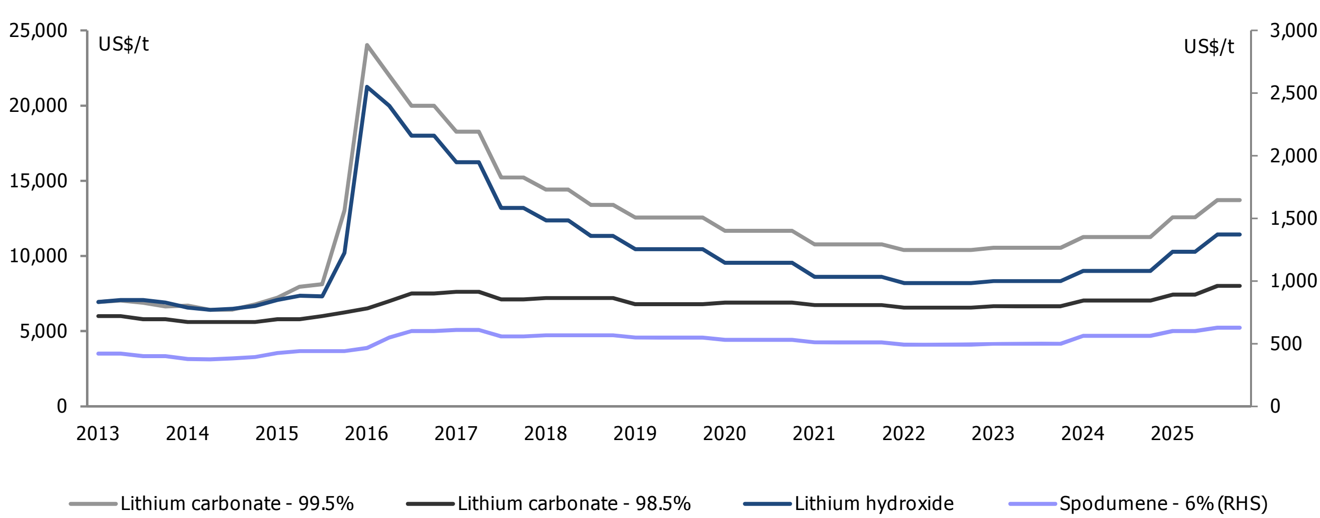
New supply is being incentivized into the market over the next 12 months (Mt. Marion and Mt. Cattlin) with another wave of spodumene assets potentially entering the market from 2018. While these projects require incentive pricing to enter the market over the next 2-3 years, we are of the view that long-term pricing will be driven by marginal cost.

We expect hard-rock supply to increase market share from 50% in 2015 to 57% by 2020, before South American brine expansions begin to enter the market and the market share split comes back to 50:50 by 2025.

Marginal cost set by brine projects in the long term

76% of global lithium reserves are brine-based deposits, and while they are more capital-intensive and slower to respond to market conditions, brine projects have inherently lower costs and greater economy of scale. As a result, we believe brines will reclaim market share after 2018 and spodumene pricing will be linked to the marginal cost of a brine asset producing lithium carbonate, not the other way round.

Figure 13: DB price forecasts for 99.5% & 98.5% lithium carbonate, lithium hydroxide and 6% spodumene concentrate



Source: Deutsche Bank, Asian Metal, company data

Figure 14: Lithium product nominal price forecasts (2016-2025)

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025 - (LT, Real)
Market surplus/(deficit)	**kt**	**2**	**2**	**-13**	**-8**	**3**	**1**	**-2**	**-2**	**19**	**22**	**33**	**25**	**14**
Lithium carbonate - 99.5%	US$/t	6,880	6,577	9,081	21,509	16,748	13,908	12,548	11,675	10,773	10,388	10,544	11,265	12,000
Lithium hydroxide	US$/t	6,996	6,535	7,985	19,315	14,718	11,848	10,457	9,552	8,618	8,201	8,324	9,012	10,000
Lithium carbonate - 98.5%	US$/t	5,900	5,600	5,963	7,125	7,359	7,212	6,797	6,899	6,733	6,561	6,659	7,041	7,000
Spodumene - 6% (RHS)	US$/t	410	383	436	554	584	567	549	531	512	492	499	563	550

Source: Deutsche Bank, Asian Metal, company data

Key equity exposures

Albemarle (ALB.N, Buy US$72/sh PT, 0.9x P/NPV); the global leader

Albemarle is the global leader in the lithium supply market. Following the acquisition of Rockwood in 2015, ALB operates the world's second-largest brine project on Salar de Atacama in Chile (25ktpa), the Silver Peak brine operation in the U.S. (6ktpa), global lithium processing facilities and holds a 49% equity interest in the world-class Greenbushes hard-rock operation in Western Australia (30ktpa ALB share). ALB plans to increase Chilean production to over 70ktpa within six years through a partnership with the Chilean Government. With two of the world's lowest-cost operations, a large resource base and a strong growth profile, we believe ALB is the best-positioned company in the market. However, ALB does own other business; we believe lithium is only c.20% of FY16E earnings.

Orocobre (ORE.AX, Buy A$3.90/sh PT, 0.9x P/NPV); the top pure-play exposure

Orocobre is currently ramping up production at its low-cost 17.5ktpa Olaroz brine project in Argentina. ORE owns 66.5% of Olaroz through a joint venture with Toyota Tsusho. The project has faced commissioning issues but has now reached 60% of nameplate capacity and expects to be at full run rates by September 2016. With cash costs expected to be below US$2,500/t LCE, the asset should be strongly free-cash flow positive once at full run rate. Our S&D analysis suggests the market will need an Olaroz Phase II expansion to push the asset to 35ktpa LCE, with the ramp-up commencing from 2019.

Mineral Resources (MIN.AX, Buy A$8.00/sh PT, 0.9x P/NPV); the innovators

MIN will earn-in to the Mt Marion Joint Venture up to a 43% interest. The project is currently under construction and should enter the market in 2H16, with a target production rate of 200ktpa 6% concentrate (27ktpa LCE). MIN is building the project and will operate on behalf of its two JV partners, ASX-listed Neometals and SZ-listed Ganfeng Lithium (also the offtake partner). MIN's ownership & contract at Mt. Marion is worth A$165m (A$0.88/sh); incorporating this asset into our MIN model has increased FY17E earnings by 68% to A$66m.

ASX-listed Syrah Resources (SYR.AX, Buy A$6.00/sh PT) also benefits from the emerging battery thematic as it is the #1 global graphite play and is set to produce battery-grade natural graphite (which is used in battery anodes) from 1Q 2017.

Ganfeng Lithium (002460.SZ, Buy CNY78/sh PT); the downstream player

Ganfeng Lithium has strong market positioning as part-owner of the Mt. Marion hard-rock asset (currently under construction) and #2 market share in the Chinese downstream market. A catalyst for the company has been entering the Mt. Marion JV, which once in production will make it one of only two vertically-integrated players with margin protection and growth potential.

Figure 15: Other listed companies with lithium exposure

ASX		TSX-V	NYSE	Other
Pilbara Minerals (PLS)	Dakota Minerals (DKO)	Nemaska Lithium (NMX)	FMC Corporation (FMC)	Sichuan Tianqi (002466)
Altura mining (AJM)	Lithium Australia (LIT)	Lithium Americas (LAC)	Sociedad Quimica y Minera de Chile (SQM)	POSCO (005490)
Galaxy Resources (GXY)	Ardiden (ADV)	Pure Energy Minerals (PE)		Eramet (ERA)
General Mining (GMM)	Liontown Resources (LTR)	Bacanora minerals (BCN)		
Neometals (NMT)		Lithium X Energy Corp. (LIX)		
Rio Tinto (RIO)				

Source: Deutsche Bank; Company data

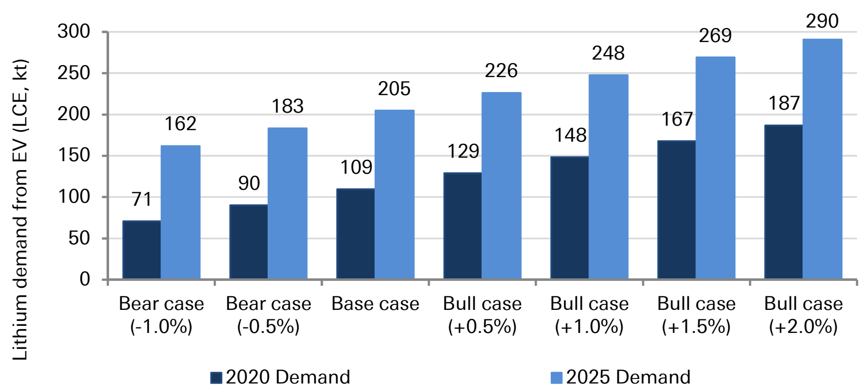
Risks to our forecasts

Demand risks

- **Slower take-up of Electric Vehicles:** Deutsche Bank forecasts global EV penetration (including hybrids and plug-in hybrids) to increase from 4% of 2015 global auto sales (of which full EV accounted for only 0.6%) to 14% market share in 2025, of which full EV makes up 2.6% of sales. While these market share forecasts do not appear aggressive, they suggest the full EV market will grow from 500,000 unit sales last year to 3.0m global sales within 10 years. This assumption leads to lithium consumption in EV's increasing over 6x to 205kt LCE in 2025E.

  In 2020 and 2025, we have assumed Full EV penetration rate of 1.8% and 2.6% of the global car market, respectively. If the EV penetration rate in 2025 is 1% less than our base case estimate (2.6%), 2025 lithium demand from EV's would equate to 162kt LCE, 21% short of our base case estimate (Figure 16). Conversely, if EV penetration is 2% higher than our 2.6% base case estimate, lithium demand from EV would increase to 290kt LCE by 2025 (41% above our base case).

Figure 16: LCE demand from EV at varying global EV penetration rates



Source: Deutsche Bank estimates

- **Energy storage not using lithium-ion:** The battery requirements for energy storage are vastly different to the EV market, where power-to-weight ratio is of greatest importance. In our forecasts, we assume lithium-ion has a clear dominance in the energy storage market, with an average of 92% market share over the next 10 years; there are competing technologies, but further progress would need to be made to make them commercially viable alternatives.

If lithium-ion market share in the Energy Storage market is only 50% in 2025, lithium demand from the Energy Storage market would be 17.5kt LCE, well below our 34kt LCE base case (6% of 2025 demand).

- **New battery technologies:** There are a number of new technologies currently in the research & development stage or concept stage, including hydrogen fuel cells and aluminium-air batteries. While these technologies show great potential, they have not reached economic viability and we believe are at least 10 years from commercialization. The falling lithium-ion manufacturing costs and the current investment in infrastructure provide lithium-ion batteries with considerable first-mover advantage. We discuss other battery technologies on pg. 22.

Supply risks

- **Expansion of Salar de Atacama:** The Salar de Atacama lithium deposit in Chile is the highest-grade brine deposit in the world and accounts for 36% of global reserves. Both SQM and ALB have operating assets on Salar de Atacama; SQM is operating at 40ktpa LCE and ALB is increasing from 25ktpa LCE currently to 45ktpa LCE over the next three years.

  Assuming that the world's largest reserve and highest-grade lithium brine deposit does not expand beyond 85ktpa LCE demand is a major risk to our supply forecasts. The Chilean government is not approving increases to SQM's extraction permits, although it has approved ALB's growth plans, which include partnerships with the government. There is a risk that all or part of the Salar de Atacama deposit ends up being controlled by a third party, either private or state-owned, which could push Salar de Atacama total output above our base case forecasts.

- **Technological breakthroughs:** A number of international mining and industrial companies, including South Korean conglomerate POSCO and the privately owned Energi Corporation, are developing new brine processing technologies. The major current economic constraint for brines is the cost to remove brine impurities, mainly magnesium, calcium, iron and potassium. Both POSCO and Energi have mineral rights over brine deposits in Argentina and are developing extraction methods that, instead of requiring evaporation ponds and large volumes of consumables to precipitate the impurities out of solution, employ a direct extraction method within a processing circuit to treat high-impurity brines. If these new processing technologies prove to be economically viable, the breakthrough could make a number of currently undeveloped brine deposits commercially viable.

Deutsche Bank lithium S&D forecasts

Figure 17: Lithium supply and demand summary (LCE)

Global Lithium Supply													
Country	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
Chile	59	63	63	64	65	75	85	100	110	110	110	110	110
% growth		*6%*	*0%*	*2%*	*2%*	*16%*	*13%*	*18%*	*10%*	*0%*	*0%*	*0%*	*0%*
Australia	32	41	57	69	97	112	130	159	181	186	196	206	206
% growth		*26%*	*40%*	*21%*	*40%*	*15%*	*16%*	*23%*	*14%*	*3%*	*5%*	*5%*	*0%*
Argentina	18	18	19	31	36	41	46	48	69	103	138	153	153
% growth		*0%*	*4%*	*63%*	*16%*	*14%*	*12%*	*5%*	*44%*	*49%*	*34%*	*11%*	*0%*
China	28	21	18	23	28	35	35	35	35	35	37	38	43
% growth		*-25%*	*-16%*	*29%*	*22%*	*25%*	*0%*	*0%*	*0%*	*0%*	*6%*	*3%*	*13%*
US	4.5	4.5	4.5	4.5	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
% growth		*0%*	*0%*	*0%*	*33%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*
Rest of World	10	10	10	10	10	10	10	10	10	10	10	10	30
% growth		*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*191%*
Total (kt)	**152**	**157**	**171**	**201**	**242**	**278**	**311**	**358**	**411**	**450**	**497**	**523**	**548**
% growth		*3%*	*9%*	*18%*	*20%*	*15%*	*12%*	*15%*	*15%*	*9%*	*10%*	*5%*	*5%*
Global Lithium Demand													
Market													
Electric Vehicles	3.8	10.0	25.1	39.7	50.4	68.7	82.4	109.4	128.0	146.9	166.0	185.5	204.8
% growth		*164%*	*152%*	*58%*	*27%*	*36%*	*20%*	*33%*	*17%*	*15%*	*13%*	*12%*	*10%*
Energy Storage	0.0	0.0	0.4	0.7	1.4	2.2	4.3	5.8	7.7	11.1	15.9	23.4	33.8
% growth		*0%*	*0%*	*62%*	*96%*	*57%*	*92%*	*36%*	*32%*	*45%*	*43%*	*47%*	*45%*
Batteries (traditional markets)	38.9	41.0	45.6	46.3	48.1	50.2	53.1	55.0	56.4	57.8	59.3	61.0	62.7
% growth		*5%*	*11%*	*1%*	*4%*	*4%*	*6%*	*4%*	*2%*	*3%*	*3%*	*3%*	*3%*
E-Bikes	0.0	0.0	2.9	7.1	16.9	28.6	41.7	53.6	60.3	67.1	73.8	73.8	73.8
% growth		*0%*	*0%*	*145%*	*136%*	*70%*	*45%*	*29%*	*13%*	*11%*	*10%*	*0%*	*0%*
Glass-Ceramics	50.3	44.0	42.6	44.0	45.7	47.3	49.1	50.9	52.8	54.7	56.8	58.9	61.0
% growth		*-13%*	*-3%*	*3%*	*4%*	*4%*	*4%*	*4%*	*4%*	*4%*	*4%*	*4%*	*4%*
Greases	14.4	16.8	19.0	19.6	20.3	21.0	21.7	22.5	23.2	23.9	24.7	25.5	26.3
% growth		*17%*	*13%*	*3%*	*3%*	*3%*	*3%*	*3%*	*3%*	*3%*	*3%*	*3%*	*3%*
Air Treatment	8.0	8.0	7.3	7.5	7.8	8.1	8.4	8.7	9.0	9.3	9.7	10.0	10.4
% growth		*0%*	*-9%*	*3%*	*4%*	*4%*	*4%*	*4%*	*4%*	*4%*	*4%*	*4%*	*4%*
Polymer	8.0	6.4	6.2	6.3	6.5	6.7	7.0	7.2	7.3	7.5	7.7	7.9	8.1
% growth		*-20%*	*-4%*	*3%*	*3%*	*3%*	*3%*	*3%*	*3%*	*2%*	*2%*	*2%*	*2%*
Medical	6.4	5.6	6.7	6.8	6.9	6.9	7.0	7.1	7.1	7.2	7.3	7.4	7.4
% growth		*-12%*	*20%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*
Primary Battery	2.8	3.2	2.9	3.0	3.1	3.3	3.4	3.5	3.6	3.8	3.9	4.1	4.2
% growth		*15%*	*-8%*	*3%*	*4%*	*4%*	*4%*	*4%*	*4%*	*4%*	*4%*	*4%*	*4%*
Aluminium	1.6	2.0	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5
% growth		*25%*	*26%*	*3%*	*3%*	*3%*	*3%*	*3%*	*3%*	*3%*	*3%*	*3%*	*3%*
Casting Powders	9.6	9.6	7.6	7.6	7.8	7.9	8.0	8.1	8.3	8.4	8.5	8.7	8.8
% growth		*0%*	*-21%*	*1%*	*2%*	*2%*	*2%*	*2%*	*2%*	*2%*	*2%*	*2%*	*2%*
Others	6.8	9.2	15.0	18.0	20.7	22.8	23.6	24.5	25.4	26.3	27.3	28.3	29.4
% growth		*36%*	*63%*	*20%*	*15%*	*10%*	*4%*	*4%*	*4%*	*4%*	*4%*	*4%*	*4%*
Total (kt)	**150**	**156**	**184**	**209**	**238**	**277**	**312**	**359**	**392**	**427**	**464**	**498**	**534**
% growth		*4%*	*18%*	*14%*	*14%*	*16%*	*13%*	*15%*	*9%*	*9%*	*9%*	*7%*	*7%*
Market Balance													
Market surplus (deficit)	**2**	**2**	**-13**	**-8**	**3**	**1**	**-2**	**-2**	**19**	**22**	**33**	**25**	**14**

Source: Deutsche Bank, industry data, company data

The Lithium-ion Age

The global economy is undergoing structural change. As we move towards becoming a globally connected society, self-sufficiency and mobility become greater priorities. Consumers are aware of their reliance on carbon fuels and seek to break away from traditional infrastructure networks, while not accepting any impact to quality of living. Policy makers and the private sector now consider the sustainability of natural resources and environmental impacts when making investment decisions and are preparing for the inevitable shift in how we use energy.

This is the dawn of the Lithium-ion Age

The rapid development of more powerful, rechargeable batteries led the mobile phone revolution of the late 1990's and early 2000's and the smartphone and tablet industry in the late 2000's. With minimal technological development, those same batteries are fuelling the emerging Electric Vehicle industry and, by the end of this decade, should enable Energy Storage to revolutionise power generation and distribution.

These industries are driving the shift towards a more mobile yet globally connected society. These new technologies need to compete with incumbent alternatives on cost, availability and consistency. Significant global investment in the battery supply chain is supporting this shift, with technological advancements, manufacturing efficiencies and the roll-out of infrastructural support networks already underway.

In this report

- We provide global lithium supply and demand forecasts over the next 10 years, determine market balance dynamics and present pricing forecasts for all major lithium products, both value-added products and feedstock materials.
- We review the development of the lithium-ion battery, identify why it is the leading battery technology and what threats are posed by competing technologies.
- We discuss the current lithium market and provide growth forecasts for i) the Electric Vehicle market, ii) the emerging Energy Storage market and iii) traditional demand applications.
- We analyse the battery supply chain from raw materials through to final cell manufacture and delivery to the consumer; highlighting margins and major global players throughout the supply chain.
- We present the current global lithium supply situation, discuss the geopolitical dynamics involved in opening up new supply and identify the major producers and projects that are best positioned to respond to significant demand growth.

The evolution of the battery

A battery consists of one or more electrochemical cells in which chemical energy is converted into electricity and used as power source. A battery has two terminals, a positive terminal (cathode) and a negative terminal (anode) which allows charged particles to pass from one terminal to the other, generating an electric current.

Batteries have been under development for over 2000 years; however, modern batteries as we use them today date back to 1859, when the first rechargeable battery was invented. The lead-acid battery was made of low-cost materials and could be used in a number of applications where a small amount of energy storage was required to support power generation from another source. Lead-acid batteries continue to be the most common batteries found in internal combustion vehicles today.

The next 100 years saw significant research into other battery technologies not only to compete with lead-acid batteries, but to also open up applications that were not being pursued at the time due to the low energy-to-weight ratio of lead-acid batteries. New battery technologies like zinc-carbon cells, nickel-iron cells and nickel-cadmium batteries were commercialized by the early 1900's.

The second half of the 20th century focused on further refinements to existing battery chemistries, with the common alkaline battery being commercialized in 1959 and the nickel-hydrogen and nickel-metal hydride (NiMH) batteries entering the market in 1989. These batteries were much more powerful than lead-acid and other existing technologies and could be used in more compact, lightweight applications.

The breakthrough of lithium-ion

Using lithium metal in batteries was first considered in 1912 though it took until the 1970's before significant research was invested in developing a lithium-based battery. Lithium is the metal with the greatest electrochemical potential (the amount of free energy per charged particle), which suggested it would have excellent energy-to-weight performance.

Early attempts to develop rechargeable lithium batteries used lithium metal as the anode, which allowed for very high energy densities. However, it was discovered in the 1980s that small dendrites, needle-like lithium metal particles, formed on the anode during discharge which upon growing would eventually penetrate the separator and cause an electrical short. The research community sought a non-metallic alternative for the anode which would allow for lithium to be used in the cathode and in the electrolyte solution. Since that time, carbon-based anodes have been the dominant anodes used in commercial applications, with graphite the most efficient form of carbon used.

The development of the lithium-cobalt-oxide cathode in the early 1980's, along with the discovery of graphite as an anode material, led Asahi Chemical to build the first lithium-ion cell in 1985. The technology was commercialised by Sony Corporation in 1991. Today there are over 80 different lithium-ion battery chemistries in production with unique performance metrics (energy density, power density, battery life) and costs.

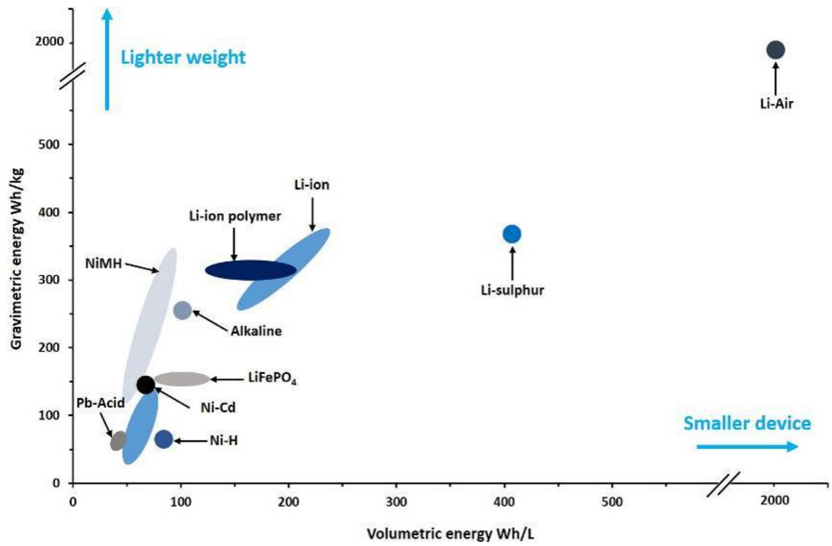
Lithium-ion is the leading technology

Why lithium?

Lithium is the lightest known metal, the least dense solid element with the greatest electrochemical potential, which leads to excellent energy-to-weight performance. It also has a very low melting point, which enables it to be used in metallurgical applications.

Lithium is highly reactive in pure form, with a single valence electron that is easily given up to bond with other molecules. It's very high electrochemical potential (its willingness to transfer electrons) makes it a powerful component of battery cells. A typical lithium-ion battery generates around 3 volts compared to 2.1 volts for lead-acid or 1.5 volts for zinc-carbon cells.

Figure 18: Lithium-based battery technologies have superior energy density



Source: CSIRO

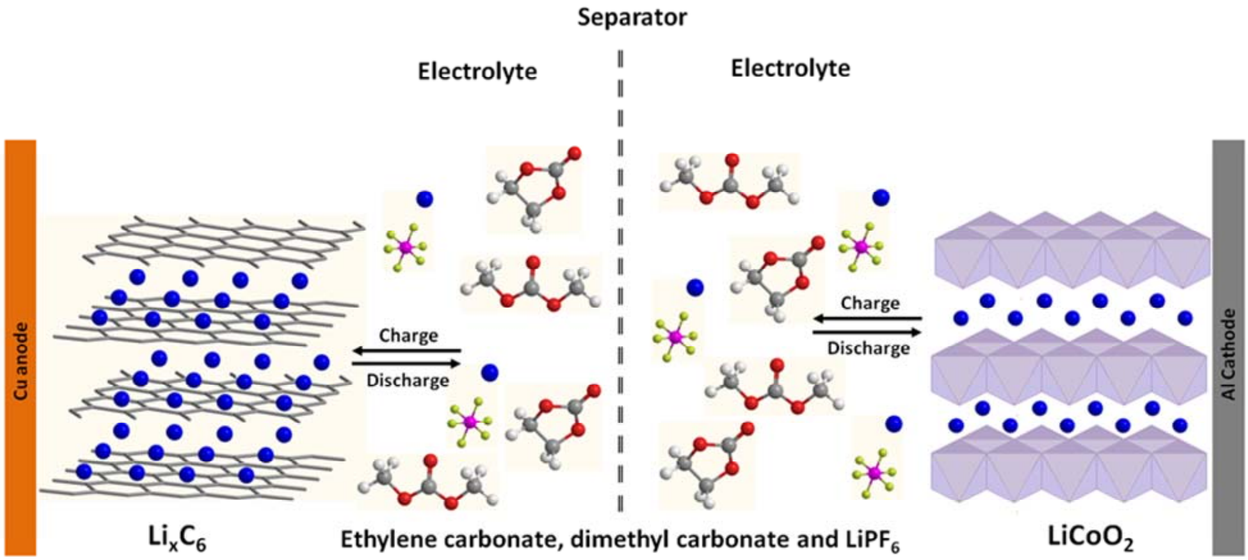
How the lithium ion cell works

Rechargeable battery cells use a negative electrode material (anode) and a positive electrode material (cathode) to convert chemical energy into electrical energy and vice-versa.

- The lithium-ion cell uses a lithium-based metal oxide as the cathode and normally a carbon-based material as the anode.
- Graphite is generally the anode material of choice because of accessibility, price and a molecular structure that allows for storage of a large amount of ions within the crystal lattice (charge capacity).
- Electrons pass between the anode and the cathode via a liquid solvent, the electrolyte, which also contains some lithium ions (the industry standard electrolyte is 1M $LiPF_6$ in solution).

As the battery is charged, lithium ions move through the electrolyte from the positive electrode (cathode) and attach to the negative electrode (anode). For example, if a graphite anode is being used, the lithium ions attach to the carbon lattice. When discharging, the lithium ions move back from the anode to the cathode, and this movement of electrons generates an electric current.

Figure 19: An example of lithium-ion cell using a lithium-cobalt oxide cathode and a graphite anode



Source: Bhatt and O'Mullane, Chemistry in Australia, June 2013

Current cathode material options

The active metal oxide used within the cathode of lithium-ion cells can vary depending on the application and battery properties required. The active material will make up 90-98% of the cathode weight (the rest being adhesive to 'paste' the active material to the cathode metal). The actual lithium content can be calculated based on the molecular weight of the lithium as a proportion to the molecular weight of the active material used.

Recharging times, discharge rates and stability are all factors that will be considered when selecting a cathode material. Lithium-cobalt oxide has held market dominance as it was the first technology commercialized, but its market share has been declining from 70% in 2008 (54% by 2009) as new technologies have been developed. Lithium is the only active material in the battery, so consequently increasing the battery's lithium content increases energy density. The challenge is that lithium is highly reactive, so current technologies require other materials to be included to ensure stability, increase safety, and maximize life expectancy. Nickel-cobalt-aluminium (NCA) and nickel-manganese-cobalt (NMC) cathode technologies are the two leading technologies being used in the Electric Vehicle industry.

Figure 20: Major lithium metal oxides used in cathodes

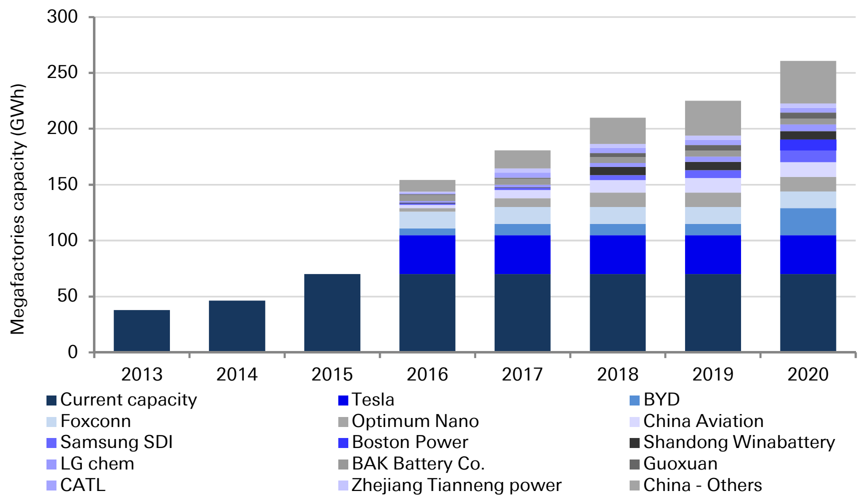
Acronym	Material components	Chemical formula	Uses	Characteristics
LCO	Lithium Cobalt Oxide	$Li_{1-x}CoO_2$	Mobile phones, laptops	Incumbent technology first introduced in 1991, high energy density but incurs longer charge times and shelf life of 1-3 years, can be dangerous if damaged.
LMO	Lithium Manganese Oxide	$Li_{1-x}MnO_4$	Power tools, medical instruments	Low internal cell resistance allows fast recharging and high-current discharging but 1/3 of LCO's energy capacity.
NCA	Nickel Cobalt Aluminium	$Li_{1-x}NiCoAlO_2$	**Electric powertrains for vehicles**, energy storage	High specific energy and long life span; safety and cost were historical concerns but these are now resolved; Tesla uses NCA.
NMC	Nickel Manganese Cobalt	$Li_{1-x}(NiMnCo)O_2$	**Electric powertrains for vehicles**, power tools	Can be tailored to high specific energy or high specific power; most Japanese and Korean producers sell NMC into EV market.
LFP	Lithium Iron Phosphate	$Li_{1-x}FePO_4$	**Electric powertrains for vehicles** , eBikes, garden lights etc.	LFP batteries offer a safe alternative due to thermal and chemical stability of the Fe-P-O bond compared to Co-O bond; the Chinese government is promoting LFP use in China over NCA/NMC.

Source: CSIRO presentation, DB Future Metals conference, 25/06/2013

Battery cost falling rapidly

Market expectations of falling battery costs are based on the construction of a number of large-scale lithium-ion battery manufacturing plants mainly in China (except the US-based 'Gigafactory'). These facilities should bring economy of scale to lithium-ion battery manufacturing, which should allow battery costs to reach US$100-200/kWh without any further technological advances.

Figure 21: Significant investment is underway on the battery supply chain



Source: Deutsche Bank; BMI

Small tweaks in chemistry unlocking cell efficiencies

In Electric Vehicles, battery cells are placed within modules which are then placed into larger packs that include electronic battery management systems, electrical connectors, switches, and thermal controls (heating and cooling). Typically, the pack level systems account for around 20% of the cost of the battery pack (i.e. battery cells/modules account for 80%). Slow but steady progress continues to be made in improving the energy density of batteries through reformulation of the materials used (typically taking non-active materials out), reducing the cost of materials, cell design, production speed, and production yield. This has resulted in increased energy density and reduced costs on both a cell level and battery pack level.

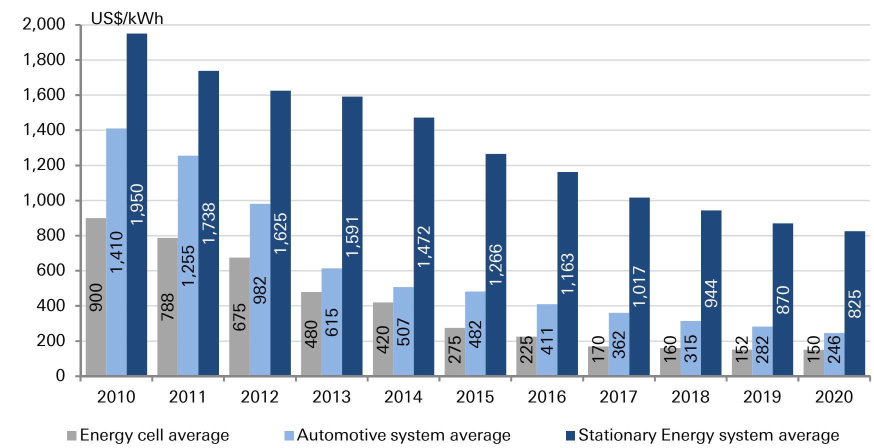
The first lithium ion cells produced by Sony Corporation in the 1990's had energy density levels of roughly 90Wh/kg and cost US$2,000/kWh. Today's Panasonic 18650 batteries used in Tesla Electric Vehicles have an energy density of approximately 150Wh/kg and they cost less than US$250/kWh. We expect this trend to continue.

Global majors entering the race for EV market share

Global car manufacturers, led by Tesla and GM, continue to enter supply agreements with lithium-ion battery producers ahead of expected increases in global EV sales. Tesla/Panasonic is currently setting the industry benchmark for battery pack costs. We estimate that Tesla is already below US$200/kWh for its cells and at around US$225/kWh for their entire battery pack including power electronics, thermal management, and an accrual for warranty.

We believe other automakers will likely reach Tesla's current benchmark for costs within the next 2-3 years, and we expect industry-wide costs to continue to track towards US$100-$150/kWh by 2020. Tesla's 'Gigafactory' (in partnership with Panasonic) will be operating by mid-2016 and will support Tesla's forecast of 500,000 vehicle sales and battery costs of US$100/kWh by 2020. General Motors (whose subsidiary Chevrolet is in partnership with LG Chem) released an investor presentation in October 2015 which forecast battery costs of US$145/kWh by 2017 and US$120/kWh by 2020.

Figure 22: Battery costs are falling, EV benefitting from economy-of-scale



Source: Cairn ERA Advisors

We believe Tesla's sector-leading battery costs are due to the company taking advantage of high volume, mature small-format 18650 battery manufacturing capacity in Japan, whereas Tesla's competitors focused on developing large format "automotive grade" batteries, which were lower scale and less mature in terms of supply chain. Other automakers also incorporated added materials into their battery cells making them less volatile (able to pass the battery crush test with no fire) and longer lasting, but at the expense of energy density.

We do not anticipate major automakers to follow Tesla's small format cylindrical cell design philosophy, largely because the major automakers do not feel comfortable with the complexity and long-term reliability of having 6000+ cells in each vehicle and 4 welded connections per cell. Nonetheless, now that major automakers are gaining more confidence with lithium battery technology, they are shifting towards more energetic materials, which will reduce the energy density gap to 15-20%. Interestingly, we have learned that Korean battery manufacturers are already pricing their large format Automotive Grade cells at roughly $200/kWh. This in itself is significant, given that the cost of these cells was approximately 100% higher in 2008/2009. In addition, the use of large format cells may actually benefit automakers due to lower complexity (fewer connections, simpler thermal balancing system, simpler electronics), which could enable them to achieve competitive costs even if they continue to pay a slight premium for their cells.

The three phases of technological improvements

Battery applications are moving towards greater power requirements and lower costs, meaning improvements in lithium-ion battery technology will be required to meet consumer demand. As industry seeks more powerful and less expensive batteries, step changes in technology are still being pursued Researchers are investigating alternatives for the anode material to increase charge capacity. ‘Game-changing’ technological advances that utilize more complex chemical reactions are longer-dated, but will generate step-changes in voltage and charge capacity. We have identified three key trends in R&D efforts to improve lithium-ion batteries.

Phase 1 - Advancements in electrolyte

The current market-leading lithium-ion cell for power is the 4.2V cell that uses the nickel-manganese-cobalt (NMC) group of cathodes. Further work is continuing to refine the cathode mix, but beyond 4.2V the limiting agent becomes the electrolyte solution (1M $LiPF_6$ solution currently used). Improving the electrolyte will allow the current lithium-ion configuration (lithium-based cathode and electrolyte and non-metallic anode) to extend beyond 4.2V.

Phase 2 - Change the anode material

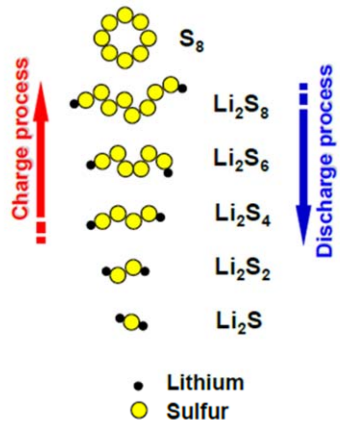
Shifting to either silicon or lithium metal anodes would significantly increase voltage and/or charge capacity. Silicon anodes would still use lithium-based cathodes, allowing the lithium ions to embed within the silicon lattice (currently the technological constraint due to the fragile structure of the silicon lattice). Shifting from graphite to a lithium metal anode would increase the energy density by about 10x, but these technological shifts remain unstable in the cell and are very longer-dated options (beyond 10 years and the scope of this report).

Phase 3 - Li-S and Li-air technologies

The major technological advancement is driven by more complex chemistry. There are intense research efforts underway around the globe on two major technologies, Li-S and Li-air, but both technologies are a long way from being market-ready.

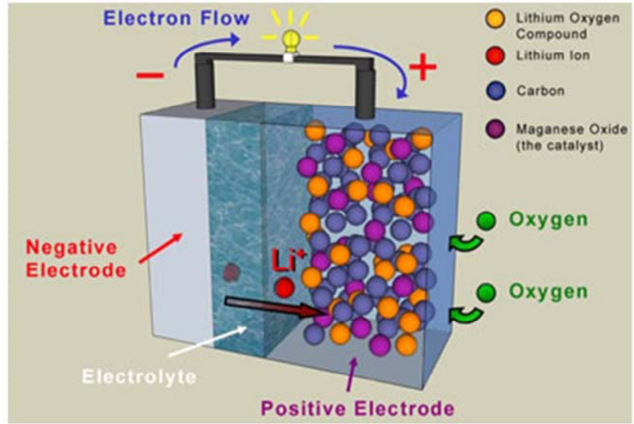
- **Li-S technology:** uses the multiple-step conversion of sulfur into lithium polysulphides (see Figure 23) instead of the transfer of lithium ions from cathode to anode. This process has a theoretical energy density of 1,675Wh/kg compared to 100-150Wh/kg currently achieved in lithium-ion batteries. This technology is largely a materials challenge, and has significant interest from the research community.
- **Li-air technology:** considered the ‘holy grail’ of lithium technology, the lithium-air battery has a very high theoretical energy density of 3,842Ah/kg (lithium-ion currently at 137Ah/kg), which is comparable with the energy density of petroleum fuel. Lithium is oxidized at the anode forming lithium ions and electrons. As electrons follow the external circuit to do electric work, lithium ions migrate across the electrolyte to reduce oxygen at the cathode.

Figure 23: Lithium-sulfur technology



Source: CSIRO presentation, DB Future Metals conference, 25/06/2013

Figure 24: Lithium-air technology



Source: CSIRO presentation, DB Future Metals conference, 25/06/2013

Sulfur is relatively abundant and can directly replace other materials used in existing battery plants. Conversely, the cost of Li-air is largely dependent on the eventual composition of the cathode catalyst layer (will need stabilizing additives, possibly rare earth elements or precious metals), and new infrastructure will be required to produce Li-air batteries in commercial quantities. The key issue for both technologies is keeping the active materials stable through multiple charge-and-discharge cycles (commercial devices are deemed to reach the end of life when 80% of the initial capacity is reached. For portable electronics applications this should occur around 300 cycles, for other applications it is around 1000 – 5000 cycles).

Metal consumption in batteries

Lithium consumption in lithium-ion batteries can vary depending on which cathode chemistry is being used in what application. For example, lithium accounts for 7% of the active material in a lithium-cobalt-oxide battery cell and only 3% of active material in a lithium-nickel-manganese-cobalt (NMC) battery cell. Exact cell chemistries and metal content is a well-held secret by battery producers, as their major Intellectual Property is their commercial cell chemistries. A summary of independent research estimates of lithium consumption on a g/kWh basis is shown in Figure 25. We note that consumption estimates are falling over time (industry shift away from LCO).

In our demand forecasts, we use a 0.7kg LCE/kWh assumption across EV and Energy Storage markets

Figure 25: Estimates of Li Metal/Carbonate amount consumed per kWh

Source	Tahil, 2010	Mediema et al. 2013	Kushnir et al. 2012	Grubber et al.	Speirs et al. 2014	**Group Average**
Li per kWh	320	178	200	114	190-280	**209**
Li carbonate per kWh	1703	949	1064	607	1011-2022	**1168**

Source: Lithium Process Chemistry', 2015 Changes, Swiaowska

Our industry analysis suggests that current battery producers are using as little as 0.6-0.7kg LCE/kWh (lithium consumption is particularly low in China, perhaps due to poor availability). Our forecasts incorporate a flat lithium assumption of **0.7kg LCE/kWh**, which we believe is conservative based on NCA and NMC technologies taking 100% market share outside of China and LFP being the dominant cell chemistry in China. We do not expect the lithium and cobalt-rich LCE chemistry to compete in the EV market due to the higher material costs and lower cell stability.

Competing battery technologies

Global R&D efforts are being focused on lithium-ion batteries as well as a number of other technologies. While lithium-ion is the leading technology being commercialized, individual demand applications that require specific battery requirements (power-to-weight ratio, charge capacity, cycle life, battery cost etc) could see other technologies increasing penetration. While the power-to-weight ratio of lithium-ion makes it a clear leader in EV, other battery technologies could be viable alternatives for applications like energy storage.

Vanadium flow batteries

Vanadium flow or vanadium redox batteries use vanadium ions, which can exist in solution in four separate states of oxidation, to store chemical potential energy. Vanadium flow batteries have very quick response time (how quickly a charge can be generated), but relatively low energy density. As a result, their best current application is in backup power within commercial applications or electrical grids. Vanadium flow batteries also have excellent lifespan (over 20 years) with minor maintenance required along the way. However, the key challenge for vanadium flow is price; current pricing is around US$800/kWh compared to lithium-ion which is US$250-300/kWh on a cell level or around US$500/kWh for an integrated lithium-ion battery energy storage system. Two years ago, the two technologies were at cost-parity, however the reduction in lithium-ion pricing has shifted that argument quickly towards lithium-ion.

Zinc-bromine batteries

A zinc-bromine flow battery stores zinc-bromide solution in two tanks with the solution pumped through a reactor stack and back to the tanks. During the charging cycle, metallic zinc is plated onto the negative electrode surfaces in the cell stacks, while bromide is converted into bromine on the positive electrode surface. On discharge, these reactions reverse and an electric current is created. Zinc-bromine flow battery failure rates are higher than lithium-ion due to the more complex reactions occurring on a molecular level. Adding to this issue, zinc-bromine batteries have a lower energy density than lithium-ion, leading to larger and more expensive battery installations.

Future technologies: Hydrogen fuel cells, Aluminium air

There are new technologies that have proven to work in small-scale, niche applications but are yet to be fully commercialized (not cost competitive).

- Aluminium-air batteries produce electricity from the reaction of oxygen with aluminium, producing a high energy density battery. However, anode costs are very high and aluminium-air is a non-rechargeable battery as the oxidation of aluminium metal is difficult to reverse.
- Hydrogen fuel cell technology uses hydrogen and oxygen to produce electricity, heat and water. Similar to batteries, fuel cells convert the energy produced by a chemical reaction into electric power, but a fuel cell does not lose charge and will continue to function as long as fuel (in the form of hydrogen) is supplied. The major issues with hydrogen fuel cell technology are economics and the safe storage of hydrogen, as an infrastructure and fuel storage network similar to petroleum would be required. Lithium-ion technology has another advantage in that it can utilize solar power to directly recharge Electric Vehicle batteries instead of refining a fuel (another economic consideration) and storing it across a network.

Figure 26: Battery energy densities

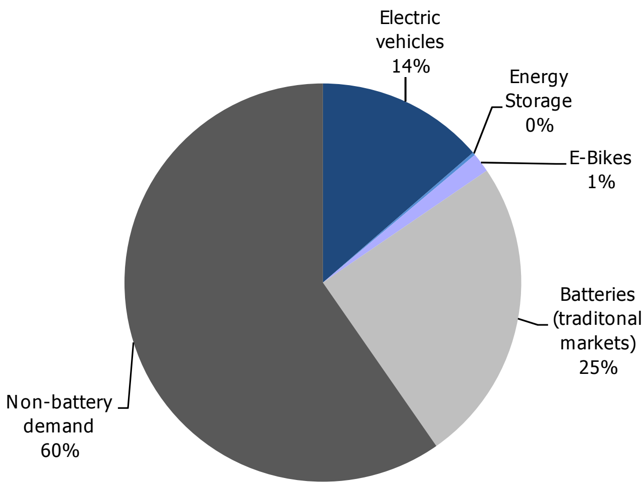
Lithium-ion batteries	
Lithium-cobalt-oxide (LCO)	203Wh/kg
Nickel-manganese-cobalt (NMC)	95-130Wh/kg
Lithium-manganese-oxide (LMO)	110-120Wh/kg
Lithium-iron-phosphate (LFP)	95-140/Wh/kg
Lead-acid battery	33-42Wh/kg
Vanadium-flow	10-20Wh/kg
Zinc bromine flow	34-54Wh/kg
Aluminium-air	1300Wh/kg
Hydrogen fuel cell	40MWh/kg

Source: Deutsche Bank, industry data

Global Demand

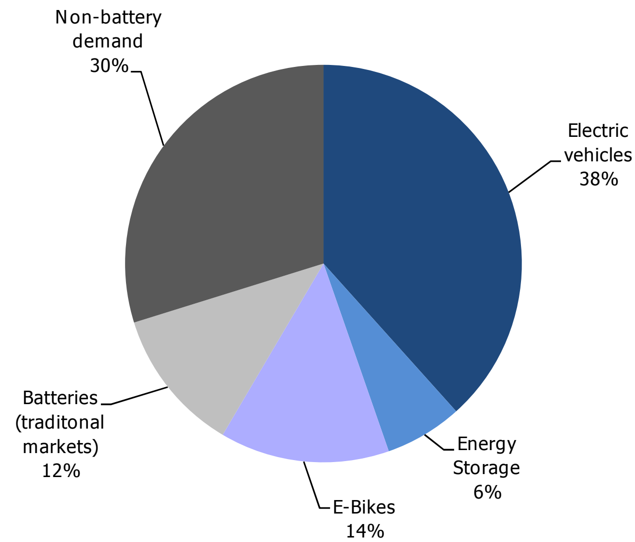
Global lithium demand was 184kt in 2015, with EV demand doubling YoY and accounting for 14% of global demand. Based on our industry analysis, global lithium demand will increase to 534kt by 2025, with batteries accounting for 45% of demand. In this section, we step through our global growth forecasts.

Figure 27: 2015 lithium demand by applications



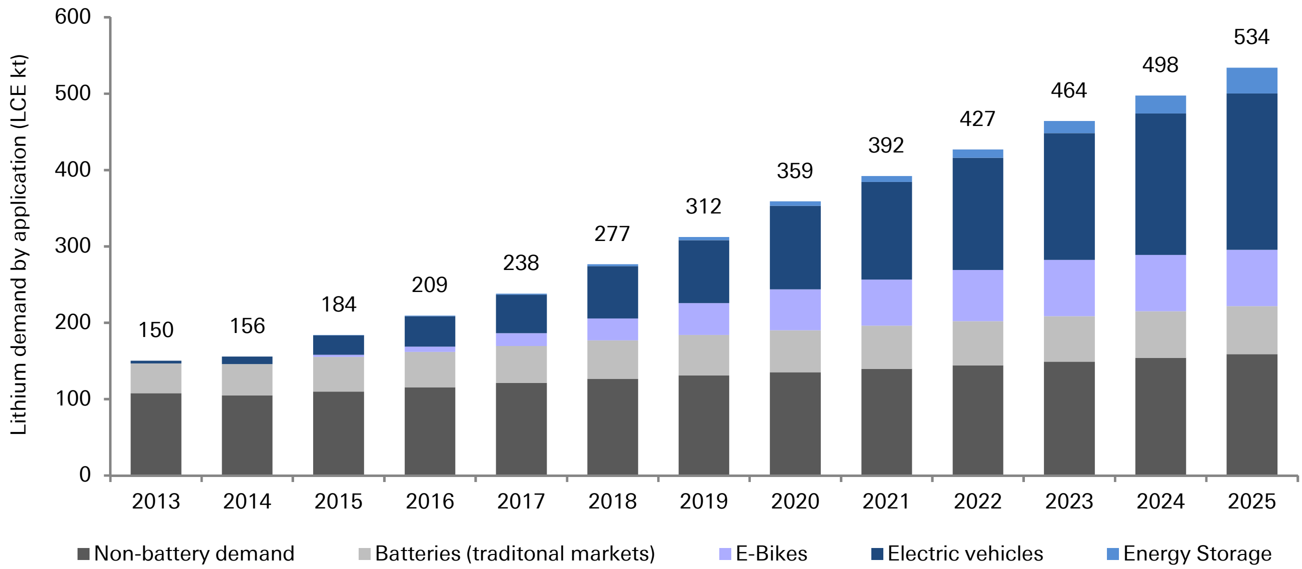
Source: Deutsche Bank; Industry data

Figure 28: 2025 lithium demand by applications



Source: Deutsche Bank; Industry data

Figure 29: Lithium demand by end applications (2013-25)



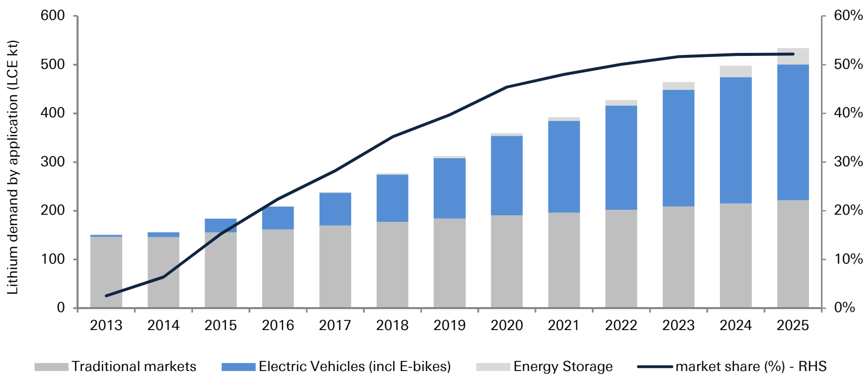
Source: Deutsche Bank; Industry data

Electric Vehicles

293GWh market, 38% of global lithium demand by 2025

Lithium is used in high-energy density rechargeable lithium-ion batteries which power the batteries in full-electric, plug-in hybrid and hybrid vehicles (EVs, PEV & HEVs). Due to the growth in EV technology, as well as concerns over increased CO_2 pollution and rising fuel costs from combustion engines, lithium has been put into widespread use in EV batteries. Lithium's combination of high electrochemical potential and low mass makes it ideal for EV battery use.

Figure 30: Electric Vehicle lithium demand vs. other demand markets



Source: Deutsche Bank, industry data

Global EV sales boosted by regulatory changes

Autos are entering a period of unrivalled technological and regulatory change Amongst the many challenges, fuel efficiency/CO_2 regulations in the U.S. and Europe are unprecedented. In the U.S. regulations will compel automakers to improve from 30 MPG (real world 24.9 MPG) to 38 MPG by 2020 (real world 32MPG) and 54.5 MPG by 2025 (real world 45 MPG). Europe will require that automakers improve from 42 MPG to 58 MPG by 2020. Though the 2025 targets for Europe may change, the currently contemplated target is 71-81MPG. DB's Global Auto Team has examined the implications for the automotive value chain, including the potential for significant impacts on vehicle demand, profitability, and the competitiveness of different automakers and suppliers. Our conclusion is that the next 5+ years will be characterized by significant regulatory cost inflation, largely driven by fuel economy mandates.

Figure 31: Comparison of Fuel Economy Regulations

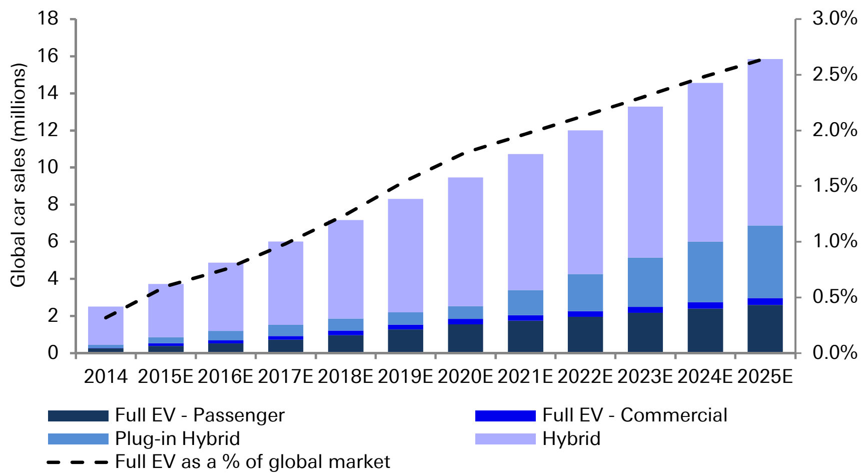
						MPG (CAFE Equivalent)		
Country/ Region	Metric	Test Cycle	2015 Target	2020 Target	2025 Target	2015 Target	2020 Target	2025 Target
US	Fuel Economy/ GHG	FTP + Highway	32.6 mpg / 283 g/mile	N/A	54.5 mpg / 157 g/mile		38.3 mpg	54.5 mpg*
EU	CO2	NEDC	130 g/km	95 g/km	N/A	54.2 mpg	58 mpg	71-81 mpg
China	Fuel Consumption	NEDC	7 L/100km	N/A	N/A	34.1 mpg	47 mpg	N/A
Japan	Fuel Economy	JC08	17 km/L	20.3 km/L	N/A	47 mpg	55 mpg	N/A
India	CO2	MIDC	135 g/km	N/A	N/A	46.5 mpg	N/A	N/A

Source: Deutsche Bank, HIS, * 54.5 MPG combined 2025 EPA target is based on 163 grams/mile CO2 emissions, partially achieved through reduced A/C system leakage

Technological change could lead to a paradigm shift

Technologies that improve the efficiency of conventional engines should experience extraordinary growth over the next five years. But the marginal cost of conventional internal combustion will increase significantly. At the same time the cost of electrification should continue to decline, and a key finding of our study is that Electrified Vehicles should reach cost parity with Internal Combustion vehicles by the early 2020s and with diesel powertrains within the next five years. This, we believe, will drive an inflection in demand for EVs—they won't be a niche market.

Figure 32: Deutsche Bank global EV sales estimates

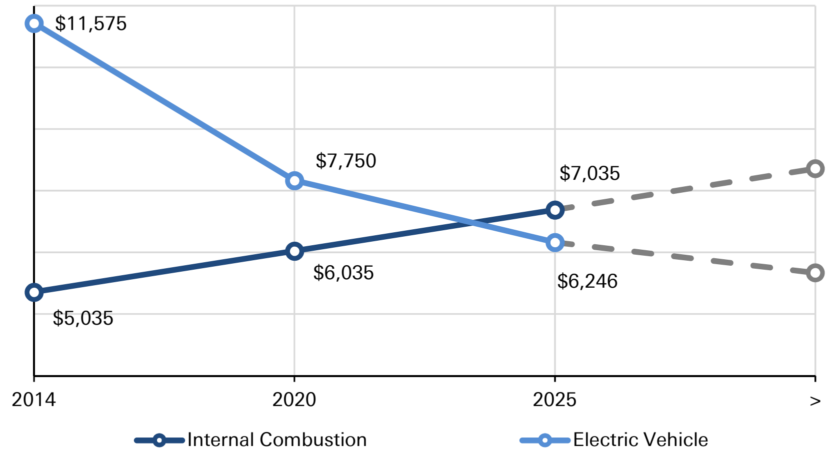


Source: Deutsche Bank estimates, IHS

We believe that battery pack cost targets in the US$150/kWh (currently US$225/kWh) area are realistic over the relatively short term, and costs could decline to US$100/kWh in fewer than 10 years. We believe that this reduction in costs will serve as a catalyst for significant expansion of volume, as it will enable electrified powertrains to reach cost parity (and in some cases lower cost) compared with more advanced internal combustion powertrains. We note that typical mass market engine/transmission/fuel/exhaust systems in the U.S. cost approximately $5,000 today, and higher-end engine/transmission combinations found in luxury vehicles, and in many European mass market models are already costing automakers >$5,500. Moreover, over the next 10 years these costs could increase by $2,000 in the U.S. and $2,600 in Europe.

A comparable 200-mile-range electric powertrain will incorporate a 47 kWh battery pack. At $100/kWh this could cost ~$5,000. After adding the electric motor and inverter, the entire powertrain could cost ~$6,100. As we approach this point, we believe that the appeal of Electric vehicles will increase significantly (other advantages include lower operating costs, improved performance, quietness, more efficient packaging and home refueling).

Figure 33:Comparison of Cost Trajectories of IC and Electric Powertrains



Source: Deutsche Bank; Argonne National Labs; Supplier estimates, Industry experts

In certain markets, including Europe, fully electric vehicles are viewed as achieving zero emissions (i.e. regulators ignore the emissions generated from producing the electricity). This policy is expected to stimulate significant growth in this market. Electrification is being introduced into vehicles to varying degrees. Below, we explain various technological options available.

Hybrid Electric Vehicles (HEVs)

- Micro Hybrid/Stop-start systems allow the vehicle's IC engine to turn off when idling, and instantly start when the vehicle is required to move. These types of vehicles offer minimal if any electric power to propel the vehicle, and the lowest level of regenerative braking. The cost of these systems is lowest, and they can be integrated into virtually any platform through the addition of a more robust battery (such as an AGM Lead Acid Battery, or Lithium-Ion), starter-generator, DC/DC converter, sensors, controls, and other components. Micro hybrids have already reached high installation rates in Europe (50-55%) and we believe they will be standard across all European product categories by 2020. We also expect 35% penetration in North America by 2020, compared with less than 3% today. We estimate that these vehicles can reduce CO_2/improve fuel efficiency by 3-7% for $250-$500 and only slightly increased weight (+0.5%). Over time, more advanced systems are expected (48V systems to replace current 12V systems), which can achieve incrementally larger improvements in fuel efficiency. These systems may also serve as a catalyst for changes in battery technology (lithium-ion could replace lead acid).

- Mild Hybrids have engine stop-start capability. In addition they include small electric motors and slightly upgraded batteries that are sufficient to provide some electric boost during acceleration, which is the least efficient phase of driving (Although IC engines achieve 15%- 18% efficiency overall, the acceleration phase is significantly less efficient. The electric powertrain is able to add value by playing a significant role during this phase). Mild hybridization also enables some engine downsizing. There are several versions of this technology, which affects the cost and benefit. Generally, fuel economy savings from mild hybrids are estimated in the 9-13% range.

- Full Hybrids provide all of the benefits of the prior systems, and their electric motors and batteries are large enough to provide some level of propulsion on electric power alone (i.e. for a small distance during acceleration). The concept is already well proven (e.g. Toyota's Prius). Full hybrids offer fuel efficiency gains ranging from 22% to 25% despite a ~ 8% increase in vehicle weight.

Plug in Hybrid Vehicles (PHEVs)

Plug-In Hybrids are similar to full hybrids, but they are able to propel the vehicle for extended distance (i.e. 10-50 miles) solely on electric power, as their batteries are larger and can be charged via an external plug. Since the vast majority of consumers drive fewer than 40 miles per day (in Europe >50% drive under 40km/day), a significant portion of the energy consumed could come from electric power. For 2020 compliance we see PHEV's as an important technology as the incremental cost to switch to PHEV is comparably minimal (slightly larger battery etc.), and PHEVs carry a significantly larger regulatory CO_2 savings. Overall, PHEVs are expected to have the ability to deliver a ~60% improvement in fuel economy (versus non-hybrid vehicles).

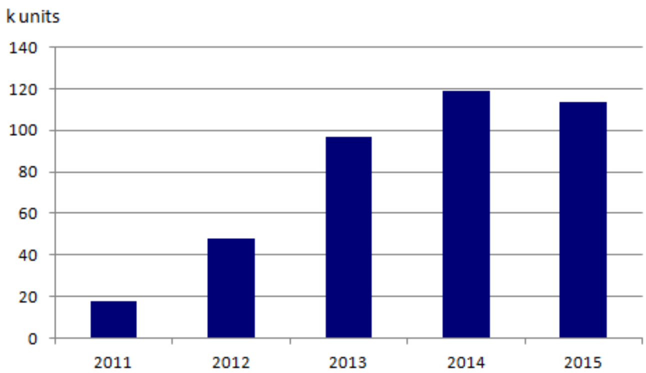
Full Electric Vehicles (EVs)

Full Electric Vehicles generate 100% of their propulsion from "zero emission" electric motors. Positives include: additional reliance on the electric grid for energy, which is inherently more efficient and less costly; electric motors are more reliable (as they contain 1 moving part, versus 400 in a typical ICE); BEVs are potentially more fun to drive (they can offer higher torque at low speeds). Drawbacks associated with this technology include range, cost, time to refuel/recharge, and size/weight. But many of these deficiencies are likely to moderate over the next 5-10 years. Indeed, based on our expectations for cost, we believe that fully electric powertrains will become cost competitive with conventional Internal Combustion powered vehicles by the early 2020s.

United States – the global IP leaders

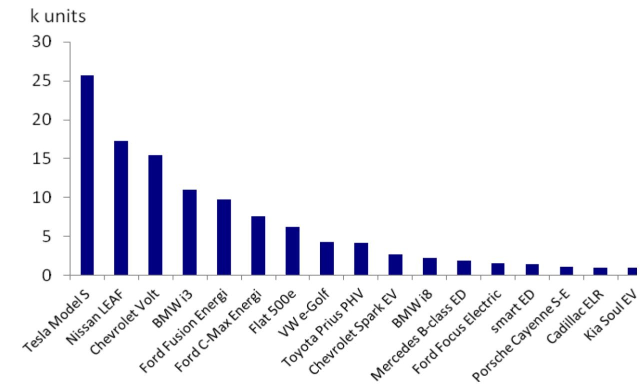
The U.S continues to be one of the most important EV leaders in the world, selling 117,000 units (EV and PEV combined) in 2015 and accumulating almost 400 k units on road by the end of 2015. US EV sales slightly dropped 4% YoY mainly due to low fuel prices in 2015. However, recent monthly sales trajectory data demonstrates that US EV sales have a healthy momentum. In December 2015, the U.S. sold 13,700 units in the month, a record breaking high, in spite of persistently low fuel prices. We expect U.S EV sales (across EV, PEV and HEV) will grow from 500,000 units in 2015 to 2.4m units in 2025 (17% CAGR over the next ten years).

Figure 34: US Full EV sales from 2011-2015



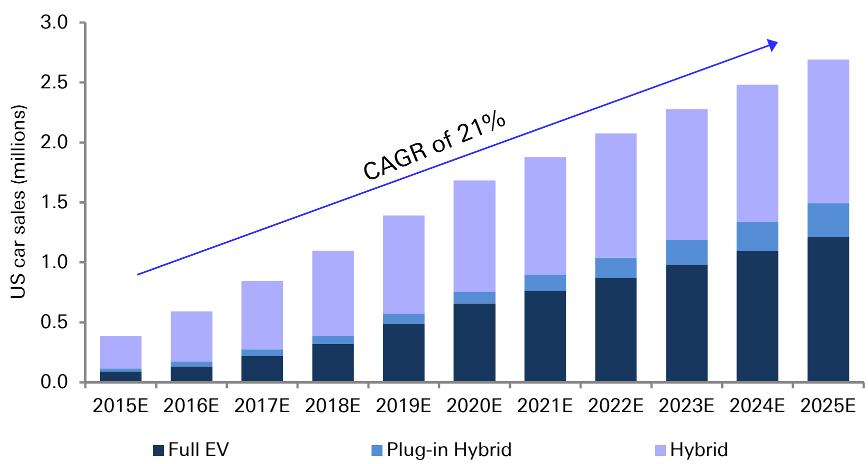
Source: Deutsche Bank, InsideEVs

Figure 35: US sales in 2015 breakdown by models



Source: Deutsche Bank, InsideEVs

Figure 36: US EV outlook from 2015-2025E



Source: Deutsche Bank, HIS, InsideEV

In the U.S, Tesla was the best seller in 2015, with total sales of 25,000 Model S units and 214 Model X units, representing 22% market share. Nissan Leaf, Chevrolet Volt and BMW i3 also shared great market position, by selling 17,000 units, 15,400 units and 11,000 units respectively.

Figure 37: : Nissan LEAF

Source: NISSAN

Figure 38: Chevrolet Volt

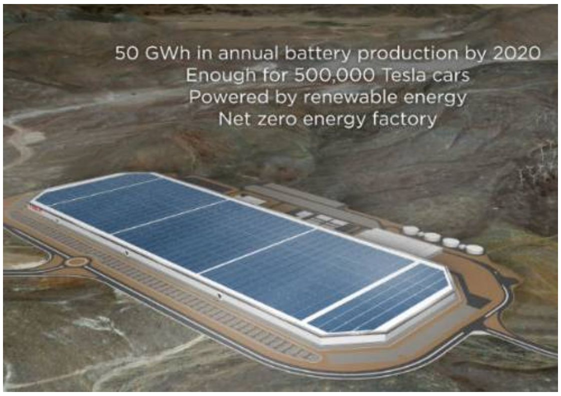
Source: Chevrolet

Figure 39: BMW i3

Source: BMW

The much bigger EV sales event is coming in 2017, with the release of Tesla's Model 3. Within a week of pre-orders opening, the Model 3 had received more than 325,000 pre-orders and the latest pre-order numbers disclosed by Tesla are over 400,000 units, which is equivalent to the number of total EV's sold in the U.S in the past five years. The first delivery is expected to occur by 2017 year end. To meet the needs of EV battery, Tesla is also building an unprecedentedly large battery factory with total capacity of 50GWh in Nevada in U.S to support 500,000 EV sales by 2020.

Figure 40: Tesla's 50GWh Gigafactory



Source: Tesla Motors

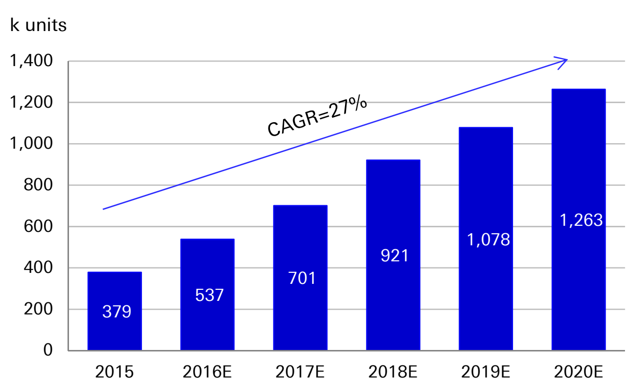
Figure 41: Tesla Model 3

Source: Tesla Motors

China – subsidies stimulating sales

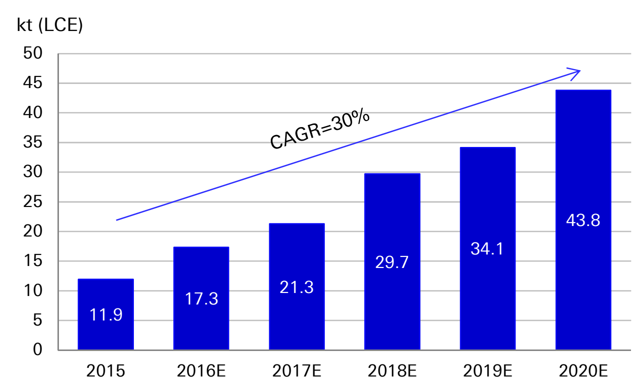
We expect China EV sales to post a CAGR of 27% in the coming five years, and will meet the government target of putting 5m EV units on the road by the end of 2020. With the rapid development of the electrical vehicle (EV) industry in China, we believe the demand for lithium in EV batteries will post a CAGR of 30% in the coming five years. In our view, this will lead to overall global lithium demand growth accelerating from a CAGR of 6.6% for the past decade to a CAGR of 14% in the coming five years (11% CAGR over 10 years). Our base-case scenario is that China EV sales will grow at 42%/30%/31% in 2016/2017/2018, respectively. Annual sales numbers should reach c.921,000 units in 2018 and c.1,263,000 units in 2020, compared with 87,000 units in 2014. That should translate into 42m kwh of demand for lithium batteries, which also translates into 30kt LCE (lithium carbonate equivalent) demand by the end of 2018E, or about 19% of global LCE as of the end of 2014.

Figure 42: China EV sales estimates



Source: Deutsche Bank estimates, MIIT

Figure 43: Lithium demand estimates - China EV battery



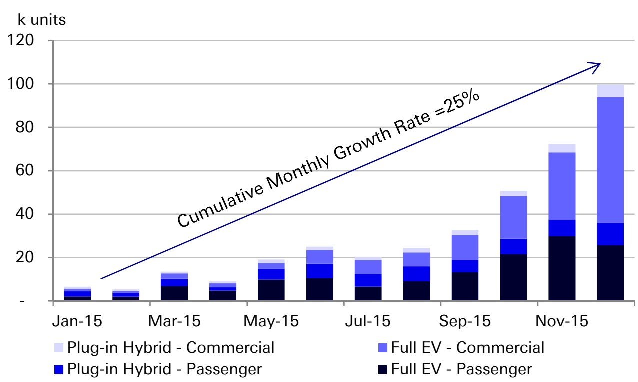
Source: Deutsche Bank estimates, MIIT

Strong China EV sales driven by government subsidies

Unlike EV sales in the U.S. and Europe, which are driven by regulatory changes, we believe China EV sales are and will continue to be driven by government subsidies and purchasing quotas on traditional vehicles in big cities. In 2015, China replaced the US to become the largest EV market in the world. It sold 379,000 units in 2015, representing a 332% YoY increase. Those strong sales included 88,144 PHEVs (plug-in hybrids) and 290,874 EVs (full electric vehicles). The breakdown for passenger EVs vs. commercial EVs is 206,377 units for passengers and 172,641 units for commercial (see Figure 44). HEVs (hybrid electric vehicles) are not taken into account in these statistics and government subsidies because the Chinese government wants to accelerate development of the EV industry and strategically does not focus on hybrids. In China, HEV is considered to be a New Energy vehicle but previous subsidies on HEVs were cancelled in the middle of 2013.

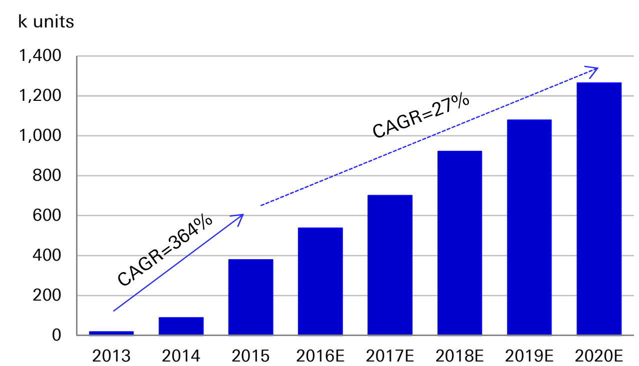
After several years' subsidy and government promotion, the sales of China EV started to accelerate in 2015. We expect that the growth of China EV sales will continue to be strong in the next few years as supportive government policies and quotas on traditional vehicle plates in big cities will continue to be favorable to EV sales. We forecast that annual EV sales in China will grow to c. 1.26m units by the end of 2020, with a CAGR of 27% in line with the Chinese government's target of putting 5m units on the road by the end of 2020.

Figure 44: Monthly China EV sales in 2015



Source: Deutsche Bank, MIIT

Figure 45: Estimated annual China EV sales



Source: Deutsche Bank estimates, MIIT

Forecast commercial EV will post a CAGR of 17% during 2015-2018

We believe the new subsidy will sustain strong demand growth in coming years. We forecast total commercial EV sales to post a CAGR of 17% in 2015-2018 (20%/15%/15% in the next three years respectively). Subsidies will be cut in 2019-2020 by 40% based on the 2016 amount, and that will likely trigger producers/operators who want to enjoy the subsidy to accelerate their adoption. We believe the next three years will be a high-growth period for commercial EV sales in China.

Government subsidy plays an important role

The Chinese central government started to promote EVs in 2009. The latest regulations (2016-2020 version) on the subsidies on sales remain material, ranging widely from RMB24k-RMB600k/unit. To further promote commercial EV buses, the Ministry of Finance announced in mid-2015 that it would give an operation subsidy for EV buses running in cities (see Figure 46).

Subsidies are important for both passenger EVs and commercial EVs but more critical for commercial EV sales. Aggregate subsidies for commercial buses could be as high as 60% of total ASP, while the subsidy for passenger cars is usually less than 40% of the final ASP (including both central government and local government subsidies; the ratio of central government subsidy to local government was typically 1:1 before 2016, but local government subsidy policies are still not yet decided.

Figure 46: Operation subsidy for EV buses

Thousand RMB/year	6m ≤L<8m	8m ≤L<10m	L ≥10m
BEV bus	40	60	80
PHEV bus	20	30	40

Source: Deutsche Bank, MOF

Compared to the simple and direct 2013-2015 version (see Figure 47), the latest commercial EV subsidy policy (2016-2020 version; see Figure 48) is much more complicated and favorable to commercial EV with better energy efficiency. The old version of the subsidy was given only according to the length of EV, which was considered to be correlated to battery capacity. However, in reality, the subsidy didn't encourage the adoption of batteries with higher performance.

Figure 47: 2013-2015* subsidy regulation on commercial EVs

Thousand RMB	6m ≤L<8m	8m ≤L <10m	L ≥10m
BEV	300	400	500
PHEV	-	-	250

Source: Deutsche Bank, MOF

For the new subsidy policy, we notice several key changes from the old one.

- First of all, the new policy is expanded to cover the whole country, while the old policy was applied for only around 90 cities.
- Secondly, the new policy is applicable to more varieties of commercial EVs, including commercial EVs with a length of less than six meters and EV trucks, but the absolute amount of the subsidy for previous existing varieties has been cut significantly.
- Thirdly, the policy introduces a new indicator for lithium battery performance termed as "Ekg," defined as "wh/(km·kg)" to quantify the energy needed to move the vehicle per kilogram per kilometer.
- Last but not least, the subsidy given is now divided into more than 170 different brackets based on 1) the type of EV, 2) Ekg, 3) driving range, and 4) the length of the EV.

To sum up, the new policy prioritizes battery capacity (the larger the better) and comprehensive EV efficiency (the higher the better). Comprehensive EV efficiency is highly reliant on lithium battery efficiency and efficiency improvements in either the mechanism system or electronic system.

We expect the new policy to be helpful and more efficient in terms of stimulating the quick development of the lithium battery industry. EV makers should be inclined to purchase larger capacity lithium batteries to obtain higher subsidies since lithium performance (energy density) is unlikely to be improved significantly in the short term. In the long term, as lithium battery size has a limit, improvement in lithium battery performance can be expected.

Figure 48: 2016-2020* subsidy regulation on commercial EVs**

Thousand RMB	Ekg (Wh/km·kg)	Standard auto（10m＜length of auto≤12m）*** Driving range (Use battery only) R 6≤R＜20	20≤R＜50	50≤R＜100	100≤R＜150	150≤R＜250	R≥250
BEV	Ekg<0.25	220	260	300	350	420	500
	0.25≤Ekg<0.35	200	240	280	320	380	460
	0.35≤Ekg<0.5	180	220	240	280	340	420
	0.5≤Ekg<0.6	160	180	200	250	300	360
	0.6≤Ekg<0.7	120	140	160	200	240	300
PHEV	-	-	-	200	230	250	250

Source: Deutsche Bank, MOF
*subsidy in 2017-2018 will be cut by 20%, comparing to that in 2016 and 2019-2020 will be cut by 40%,comparing to that in 2016.
**For other commercial cars like truck and logistics cars, subsidy will be given at RMB1.8k/Kwh.
***For auto with length less than 6 meters, 6 to 8 meters, 8-10 meters , and 12 meters above, will give 0.2, 0.5, 0.8, and 1.2 times of subsidy of standard vehicle respectively

After factoring in the subsidies from both the central government and local government, the final sales price of a commercial EV in China is almost equivalent to that of a traditional commercial car. However, the system does not leave much time for EV manufacturers to increase efficiency and decrease cost, because the government subsidies in 2017-2018 and 2019-2020 will be cut by 20% and 40%, respectively, compared to those in 2016. In order to maintain the competitiveness of commercial EVs against traditional commercial vehicles, EV manufacturers are guided by the government to cut costs as soon as possible.

Passenger EV sales should be strong due to favorable policies

We believe the new subsidy will boost demand in 2016. We forecast total passenger EV sales will post a CAGR of 46% in 2016-2018 (60%/40%/40% in the coming three years respectively) under favorable subsidy policies and restrictive quota policies on traditional vehicles in big cities. Considering the government subsidy will be further cut by 40% in 2019-2020 based on subsidy amount in 2016, we also think the next three years will be a golden period for passenger EV sales in China.

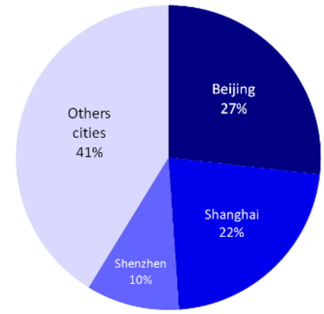
Similar to the subsidy on commercial EVs, the subsidy on passenger EVs is also material to sales. Under the new regulation, the subsidy was cut by c.RMB5,000-10,000 for each unit, compared to the 2013-2015 version. In addition, the government raised the subsidy threshold on the requirement for EV driving range. Originally, the requirement was 80km and the new requirement is raised to 100km. The purpose is to promote improvements in battery capacity and performance. Nevertheless, the new 2016-2020 version of the subsidy remains meaningful, ranging from RMB25k/unit to RMB55k/unit (see Figure 50). Combined with the local government subsidy, the total subsidy could reach RMB50k-100k/unit, assuming the subsidy ratio for the central government and local government remains at 1:1 as it has been before 2016.

Figure 50: Central government subsidy regulation on passenger vehicles

k RMB	Driving range (Use battery only) R			
2013-2015 version	80≤R<150	150≤R<250	R≥250	R≥50
BEV	35	50	60	-
PHEV	-	-	-	35
2016-2020 version	100≤R<150	150≤R<250	R≥250	R≥50
BEV	25	45	55	-
PHEV	-	-	-	30

Source: Deutsche Bank, MOF

Figure 49: EV sales breakdown by city *(First 11 months of 2015.)*



Source: Deutsche Bank estimates; China Vehicle Administrative Offices

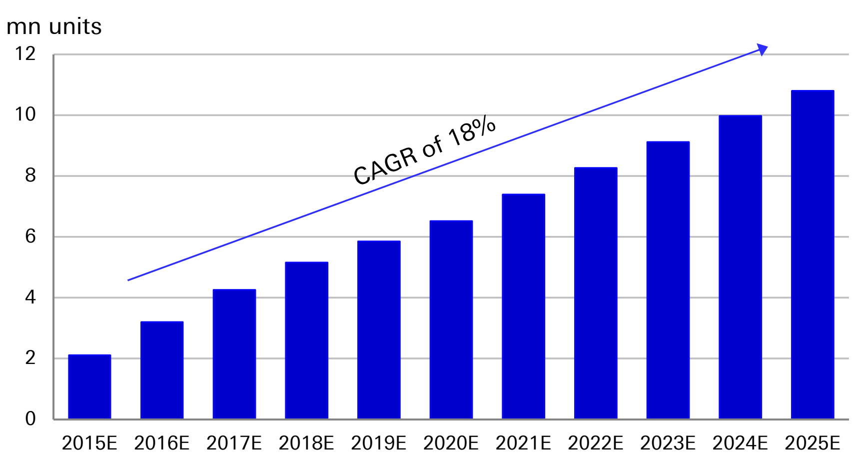
Restrictive policies on traditional vehicles keep boosting EV sales in big cities

Passenger EV sales occur mainly in big cities. EV sales in Shanghai, Beijing and Shenzhen cities accounted for 60% of total passenger EV sales in China in 2015. We remain optimistic on demand as we believe the strong growth of EVs is deeply affected by restrictive quota policies on traditional vehicles in these big cities and odd-even rationing policy prospectively going forward. The likely sustainability of these restrictive policies will drive strong passenger EV sales in the future, in our view.

The rest of the world

We expect EV sales in the rest of world will grow from current 1.8m units to 10.6m units, with a CAGR of 15% in the next decade. The major driver should be Japan and Europe, especially northern European countries. Market penetration rate in Northern European countries (13% for Norway and 5% for Netherlands in 2014), leads the world.

Figure 51: EV sales outlook in the rest of the world from 2015-2025E



Source: Deutsche Bank

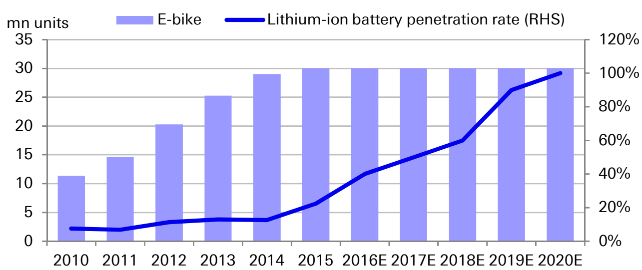
E-bikes

74GWh market, 14% of global lithium demand by 2025

E-bicycle: penetration rate climbs while battery costs fall

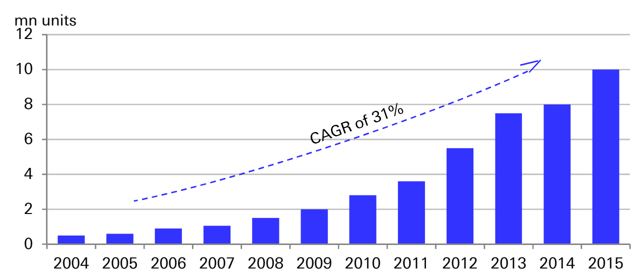
China is the world's largest producer and consumer of electrical-bicycles. It sold 30m E-bikes in 2015 and has accumulated 200m E-bikes on the road already. The E-bike market is a lead-acid dominated market, but as lithium-ion costs continue to drop, penetration of lithium-ion batteries has been steadily climbing in the past several years, though it remained at a relatively low 22% in 2015. We believe the overall sales volume may not grow further but remain steady in the next several years at 22m units (deducting 8m tricycle annual sales); however, lithium-ion demand should continue grow as it gains market share from lead-acid. We expect the penetration rate will climb from 22% to 100% by the end of 2020. The typical e-bicycle battery size is 1kWh. Therefore, annual battery demand from this market is forecast to reach 20GWh in 2020.

Figure 52: Sales of E-bike from 2010-2020E



Source: Deutsche Bank estimates, EVtank, NBS, GIIB

Figure 53: Sales of E-tricycle in the past 10 years



Source: Deutsche Bank, Evtimes

E-tricycle: strong lithium demand driven by overall sales growth

Sales of E-tricycles in China started to take off in 2004, growing at31% CAGR over the past decade. In 2015, China sold more than 8m units driven by demand from both agriculture transportation in rural area and logistics transportation (mainly online shopping) in urban areas. Unlike E-bicycles, the E-tricycle is equipped with much large batteries. The right side Figure 54 demonstrates that typical battery size for E-tricycles could be as large as 12kWh, close to the battery size for a PHEV. This market is also dominated by lead-acid batteries, but we expect lead-acid replacement will happen similar to E-bicycles in the coming years. Because of the much larger battery size and our forecast of 80% penetration rate by 2025, we expect the total demand for E-tricycles is likely to be as large as 54GWh within 10 years.

Figure 54: Typical tricycle battery size

Module	#. Module	Total battery size (kwh)
48V20A	4	4
48V35A	4	7
60V20A	5	6
60V35A	5	11
60V40A	5	12

Source: Deutsche Bank; industry experts

Figure 55: E-bike

Source: aimatch

Figure 56: Tricycle in rural area

Source: Zhengmin

Figure 57: EMS's tricycle in cities

Source: Deutsche Bank

Energy Storage

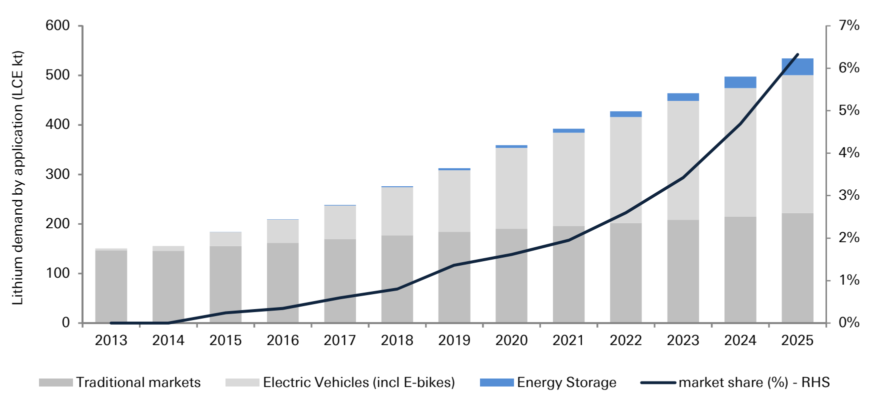
50GWh market, 6% of global lithium demand by 2025

Energy storage is not a new idea. It has been actively developed for well over 100 years. By 2015, total global capacity of energy storage installations had reached 190GWh. Until now, this market has been dominated by pumped-hydro energy storage, which accounted for 94% total market share in 2015.

We believe the energy storage market is reaching an inflexion point. Driven by the declining costs of lithium-ion batteries, battery storage is now economically feasible for many energy storage applications. The impact on installed capacity has been immediate, with installed energy storage capacity doubling in two years. The U.S. is the largest market (350MWh in 2015) and is growing quickly; it accounts for 30% of global installations (1.1GWh in 2015).

We believe battery use in global energy storage will grow to be a 50GWh per annum market by 2025 (46% CAGR over next 10 years). Lithium-ion batteries should be the leading technology, with superior performance and rapidly falling costs helping ensure it is the battery of choice in energy Storage. We believe lithium battery consumption will reach 48GWh (54% CAGR), equivalent to 97% of total battery use in energy storage. As a result, lithium carbonate demand should increase from virtually nothing in 2015 to 34kt LCE in 2025.

Figure 58: Energy Storage lithium demand vs. other demand markets



Source: Deutsche Bank estimates, industry data, company data

Figure 59: Global Energy Storage and lithium demand forecasts

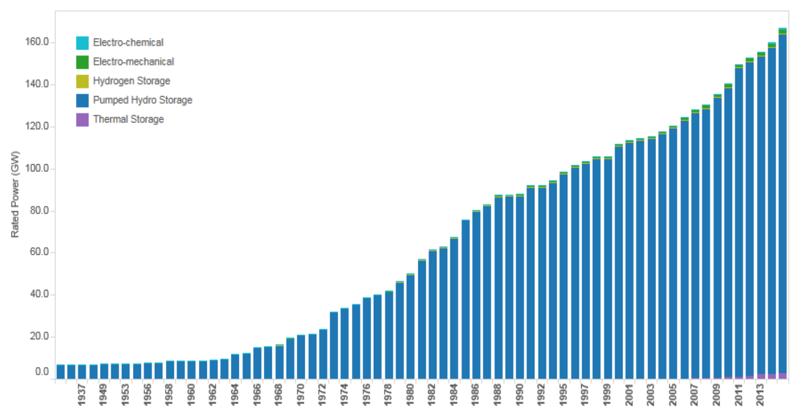
	2015	2016E	2017E	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E	2015	2016E
Installed battery power (MWh)	403	450	1,126	1,510	2,495	3,580	6,415	8,540	11,180	16,100	22,960	34,085	49,985
Li-ion battery power (MWh)	0	0	636	1,029	2,021	3,163	6,084	8,290	10,930	15,850	22,710	33,363	48,270
Li-ion market share (%) (RHS)	0%	0%	56%	68%	81%	88%	95%	97%	98%	98%	99%	98%	97%
LCE consumed (kt)	**0.0**	**0.0**	**0.4**	**0.7**	**1.4**	**2.2**	**4.3**	**5.8**	**7.7**	**11.1**	**15.9**	**23.4**	**33.8**
% growth				62%	96%	57%	92%	36%	32%	45%	43%	47%	45%

Source: Deutsche Bank estimates, Cairn ERA

The global energy storage market is dominated by pumped-hydro energy storage (94% market share in 2015), a method of storing energy in the form of gravitational potential energy. Low-cost, off-peak electric power (usually hydro-power) is used to pump water from a lower elevation reservoir to a higher elevation. Because of the pumping efficiency losses, the overall energy efficiency of pumped-hydro energy storage is 70-80%. Further increases in pumped-hydro are limited because of the unique site locations required, needing both a variable topographical environment and access to water.

There have been very few examples of installed battery storage (see 'Electro-chemical' in Figure 60) until recent years. By the end of 2015, global installed battery storage remained below 1GWh, less than 1% of the global energy storage market.

Figure 60: Global energy storage installations 1930-2015



Source: Deutsche Bank, Global Energy Storage Database

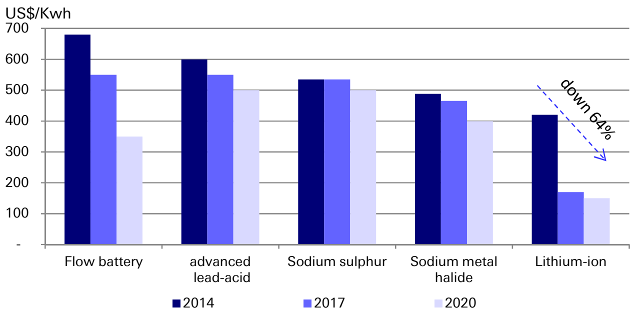
Battery costs falling but other challenges remain

Major battery types that are applicable to energy storage applications include lithium-ion, lead-acid, sodium sulphur, sodium metal halide, and flow batteries. We forecast the cost of all major battery types will continue to decrease in the coming years, however lithium-ion batteries have seen industry-leading cost reductions (US$900/kWh in 2010 down to US$225/kWh in 2016) and are forecast to see costs fall further; we estimate cell-level costs of US$150/kWh by 2020.

Lithium-ion battery systems require an integrated battery management system (BMS), which regulates the electric current being produced by each lithium-ion cell within the pack to ensure heat build-up does not occur, preventing battery failure. Energy Storage products have not fully realised the same economies of scale as seen in Electric Vehicle battery packs. We believe this is because current battery pack producers have not vertically integrated with the battery producers (unlike the EV companies) and purchase a lot of the casing and electronic items at commercial prices.

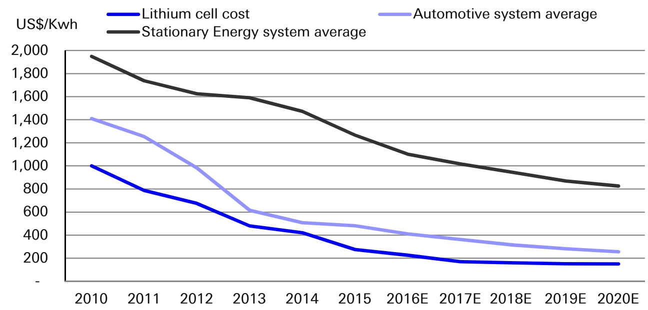
To put this into context, lithium-ion cell level costs in 2016 are ~US$225/kWh; an Electric vehicle battery pack cost is ~US$410/kWh while an energy storage product using lithium-ion batteries will cost over US$1,000/kWh. Energy storage pack costs have halved over the last five years and we believe they will fall to US$825/kWh by 2020, however they do and should continue to lag costs in the EV market, which has first-mover advantage.

Figure 61 battery cell cost comparisons



Source: Navigant Research, Cairn ERA, Deutsche Bank

Figure 62: Lithium-ion cell & battery pack cost forecasts



Source: Deutsche Bank, Cairn ERA

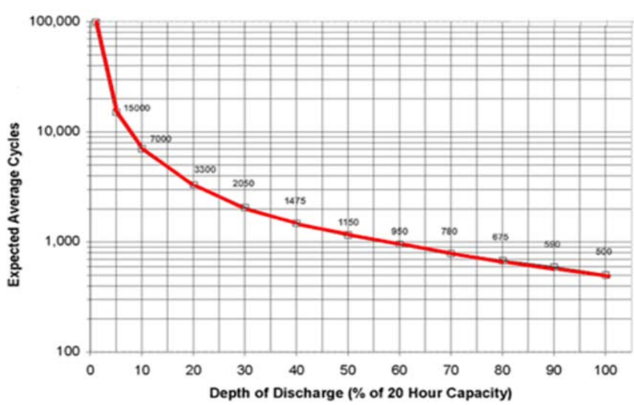
Battery technologies still need to improve

Batteries have not been able to penetrate the Energy Storage market because of historical performance issues across major battery technologies. Lead-acid batteries are considered 'too dirty' with very lower power-to-weight ratios, nickel-metal hydride (NiMH) batteries are too expensive and lithium-ion has previously been considered 'too fragile'. The key issues for lithium-ion has been temperature management, depth of discharge and cycle life, though falling battery costs are making these issues less restrictive to commercial roll-out.

- Depth of discharge, DoD, refers to the % of full charge capacity that can be safely used. DoD is negatively-correlated to cycle life (Figure 63).
- Cycle life is the amount of charge/discharge cycles a battery can perform before losing performance. A battery would be considered to be expired once it can only perform 60-80% of its full charge capacity.

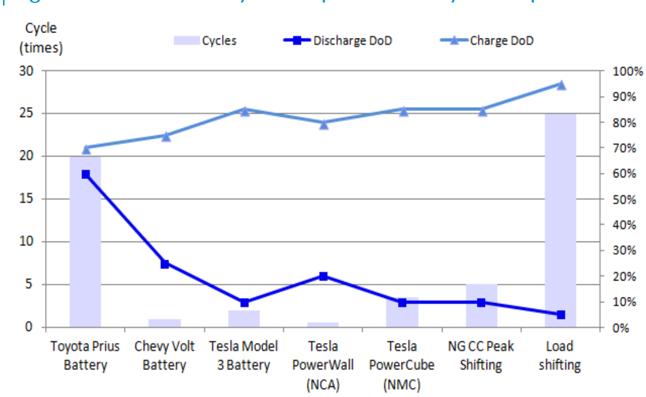
Most lithium-ion battery applications, including electric vehicles and consumer electronics, do not require significant increases in cycle life and/or depth of discharge. In contrast, a number of energy storage applications (particularly residential installations) require deeper charge/discharge levels and increases in cycle life. For this reason, residential applications are not likely to be a major market for batteries in the next 10 years, but we have identified five key energy storage applications where batteries should capture market share.

Figure 63: Depth of discharge vs. cycle life of a battery



Source: Electropaedia

Figure 64: Case study: DoD profiles & cycle requirements

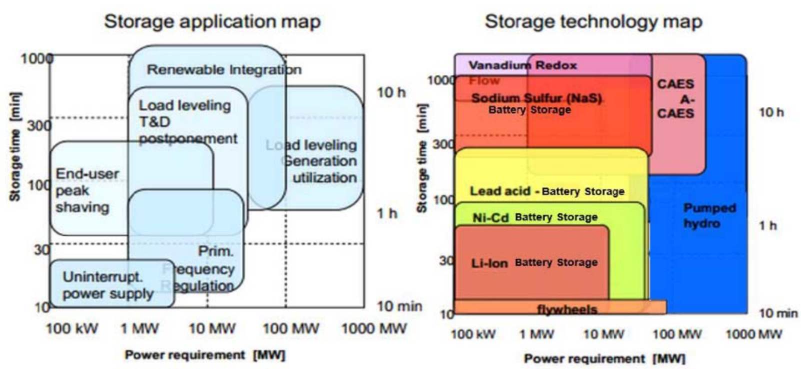


Source: Cairn ERA

Five major Energy Storage applications

Battery applications in Energy Storage are diverse, with different commercial models based on different application requirements: charge capacity, depth of discharge, durability, safety, cycle times, grid/utility requirements, space limitations, ambient environment and obviously cost.

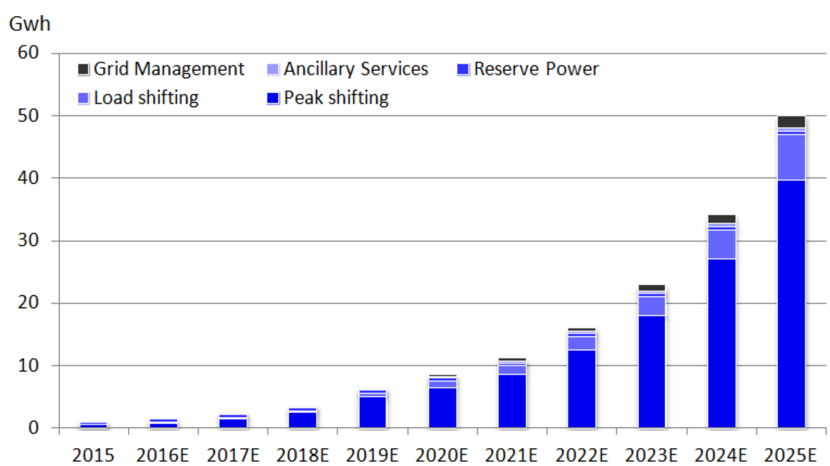
Figure 65: Energy storage applications and technology map



Source: ECOFYS

There are over 25 identified battery applications within Energy storage, of which we believe five are viable markets based on current and future expectations of battery costs and performance. These five demand markets are i) Load Shifting, ii) Peak Shifting, iii) Grid Management, iv) Ancillary Services and v) Reserve Power. These five major applications should create market demand for battery storage of 1.5GWh in 2016, 8GWh in 2020 and 50GWh in 2025 (46% CAGR over the next 10 years). Peak shifting is forecast to be the most important market, with expectations of it growing to 40GWh by 2025.

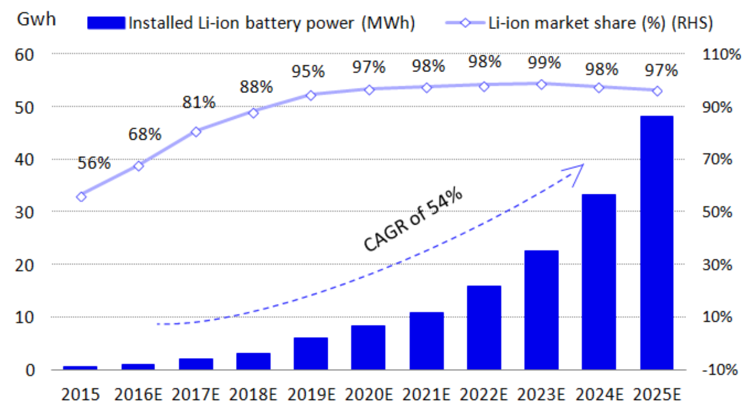
Figure 66: Battery demand for five major Energy Storage applications



Source: Deutsche Bank, Cairn ERA,

Based on battery performance and costs (including replacement and maintenance costs), Lithium-ion technology is expected to dominate four of the five major demand applications; the outlier is Reserve Power, where lead-acid is the incumbent technology and will likely retain some market share over time. We forecast global market share of lithium-ion batteries in the five major demand applications will climb from 56% in 2015 to above 95% from 2019.

Figure 67: Lithium-ion battery demand and market share forecasts



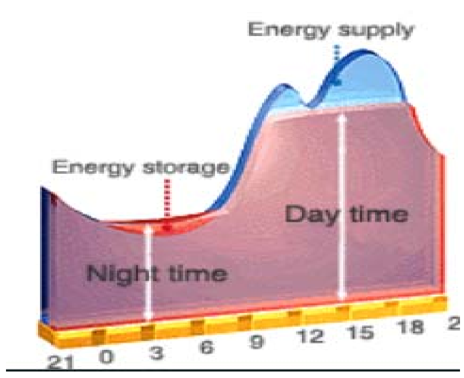
Source: Deutsche Bank, Cairn ERA,

Peak shifting

The largest opportunity for batteries, forecast to be a 40GWh market by 2025

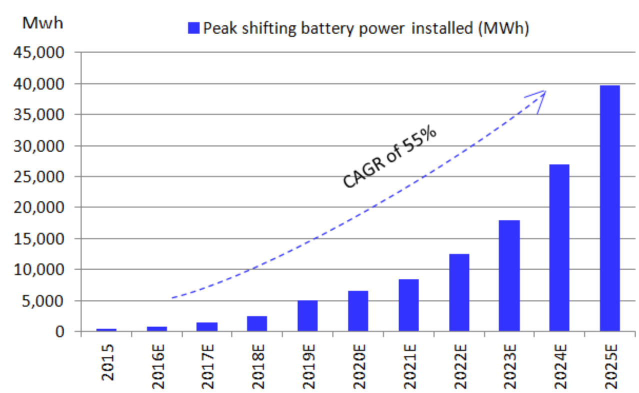
Peak shifting is one of the most common ideas in energy storage, based on moving electric power from low-demand hours to periods of peak demand. Non-peak electricity generation can charge batteries either within the grid or behind the meter for discharge during peak demand with a typical duration of cycle of 30 minutes to 2 hours. In California, combining a solar-panel system with a commercial-scale battery installation (500kWh) can deliver a 20% ROI with state subsidies (12% ROI without). This is a growing market with a number of new entrants offering industrial and consumer-level integrated installations (PV and batteries). We expect Peak Shifting will grow from 500MWh in 2015 to 40GWh in 2025 (55% CAGR), driving a US$3.9bn battery market, which Lithium-ion should dominate due to its superior cell performance and costs

Figure 68: The idea of peak-shifting



Source: NAS

Figure 69: Peak-shifting capacity outlook



Source: Deutsche Bank, Cairn ERA

Figure 70: Battery capacity and lithium demand forecast for peak-shifting application

	2015	2016E	2017E	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E
Peak shifting battery power installed (MWh)	500	800	1,500	2,500	5,000	6,500	8,500	12,500	18,000	27,000	39,700
Li-ion market share (%)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
% growth of lithium-ion battery demand		60%	88%	67%	100%	30%	31%	47%	44%	50%	47%

Source: Deutsche Bank estimates, Cairn ERA,

Load shifting

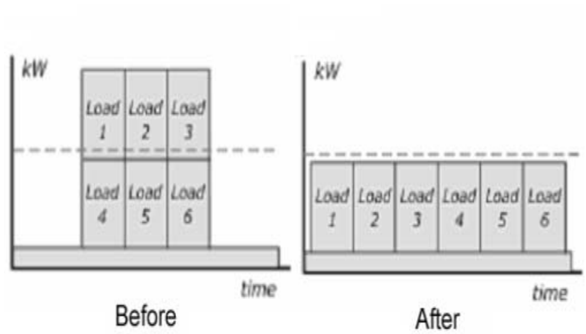
A growing market that could reach 7.3GWh in 2025

The concept of load shifting is based on moving large blocks of generation from nighttime to daytime periods. This application would require a much longer duration of cycle hours, typically 2-12 hours (how long the batteries can sustainably discharge power). Current load-shifting is being done by pumped-hydro/nuclear systems. In order to promote battery storage, battery costs need to decrease significantly to around US$120/kWh, which is why this market will likely not grow until the end of this decade.

Among battery technologies, lithium-ion batteries are the most applicable in the short/medium term; however, this is a demand market that is gaining attention from developers of 'flow-style' batteries, like vanadium-redox and zinc-bromide flow batteries. These technologies are much more expensive than lithium-ion, and in-field testing has proven cell failures are common; however, further technological developments could make them viable alternatives to lithium-ion. We account for this risk by reducing lithium-ion market share from 2024E.

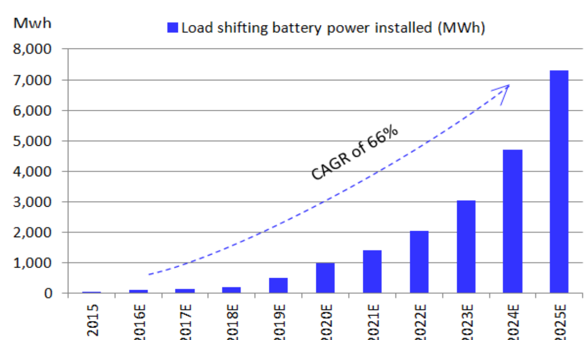
We forecast that load shifting will increase battery consumption from a very small 46MWh in 2015 to 7.3GWh in 2025 (66% CAGR). Due to the lower battery cost requirements, this market should reach around US$1.2bn by 2025.

Figure 71: The idea of load-shifting



Source Cairn ERA,

Figure 72: Load-shifting capacity outlook



Source: Deutsche Bank, Schneider

Figure 73: Battery capacity and lithium demand forecast for load shifting application

	2015	2016E	2017E	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E
Load shifting battery power installed (MWh)	46	100	150	200	500	980	1400	2050	3050	4700	7300
Li-ion market share (%)	100%	100%	100%	100%	100%	100%	100%	100%	100%	90%	80%
% growth of lithium-ion battery demand		117%	50%	33%	150%	96%	43%	46%	49%	39%	38%

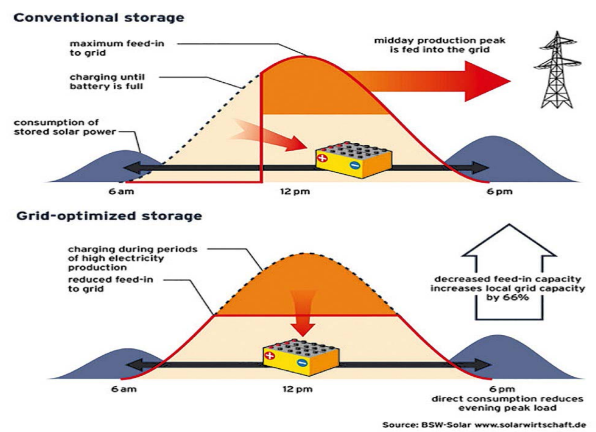
Source: Deutsche Bank, Cairn ERA

Grid Management

A late-blooming market, currently at pilot-project stage

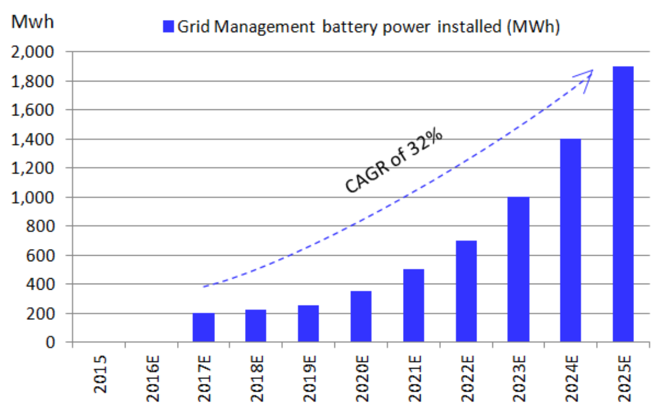
Grid management is a concept where utilities providers use energy storage to help distribute grid services smartly, reliably and resiliently. Most of the grid management projects being progressed at the moment are still pilot projects. Grid management applications need to be responsive, with cycle durations of 15-60 minutes to manage voltage levels, harmonics management etc. A well-designed battery management system is required to ensure the system can economically distribute storage energy at the right time. We expect grid management applications will increase from 2018, with the timing lag mainly due to the early-stage of investments in the sector. Total capacity should increase from 200MWh in 2017 to 1.9GWh in 2025 (32% CAGR over 8 years). The total value for the battery demand should reach US$500m by 2025.

Figure 74: The concept of grid management



Source: Deutsche Bank, Cairn ERA

Figure 75: Grid-management capacity outlook



Source: Deutsche Bank, Cairn ERA

Figure 76: Battery capacity and lithium demand forecast for grid management application

	2015	2016E	2017E	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E
Grid management battery power installed (MWh))	0	0	200	220	250	350	500	700	1000	1400	1900
Li-ion market share (%)			100%	100%	100%	100%	100%	100%	100%	100%	100%
% growth of lithium-ion battery demand				10%	14%	40%	43%	40%	43%	40%	36%

Source: Deutsche Bank, Cairn ERA

Reserve power

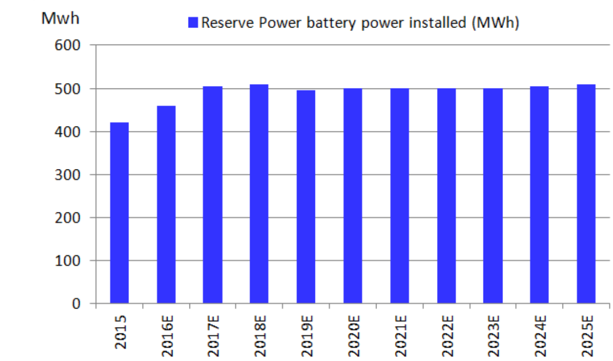
Mature market with an incumbent technology, only 2% growth expected

Reserve Power is used to provide emergency reserve power when grid power goes down, with a typical duration of cycle of 5-30 minutes. Reserve power is a stable, mature market growing at CAGR of 2% in the next decade. However, lithium-ion batteries are competing with lead-acid batteries which is the incumbent battery technology used in this market. Lithium-ion has inherent advantages in terms of smaller size, which is essential to projects that have limited space. Lead-acid batteries are cheaper, but their Depth of Discharge is shallow compared to lithium-ion, so cost advantage vs. performance is less clear. We expect lithium-ion batteries can increase market share to around 50% by 2025, from 10% in 2015. The total value of this battery market should reach US$2.7bn in 2025.

Figure 77: BYD's energy storage modular system

Source: BYD

Figure 78: Reserve power capacity outlook



Source: Deutsche Bank, Cairn ERA

Figure 79: Battery capacity and lithium demand forecast for reserve power application

	2015	2016E	2017E	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E
Reserve power battery power installed (MWh))	420	460	505	510	495	500	500	500	500	505	510
Li-ion market share (%)	10%	15%	20%	30%	40%	50%	50%	50%	50%	50%	50%
% growth of lithium-ion battery demand		64%	46%	51%	29%	26%	0%	0%	0%	1%	1%

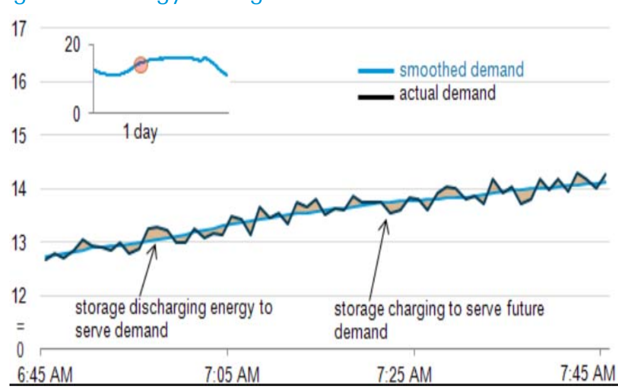
Source: Deutsche Bank, Cairn ERA

Ancillary services

Smallest market, but still 0.6GWh demand in 2025

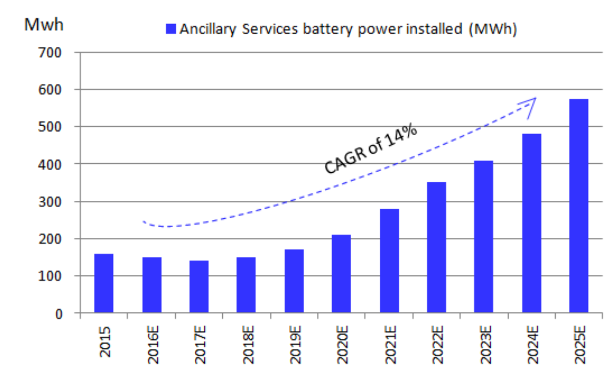
Ancillary Services is defined as merchant energy provisions being provided to assist with electricity services like spinning reserve, frequency regulation and system restart ancillary services, used to help restart the system post blackout situations. Ancillary Services should grow from 160MWh in 2015 to 575MWh in 2025 (14% CAGR). Total market value should reach US$750m.

Figure 80:Energy Storage smoothes demand in variations



Source: Deutsche Bank, EIA

Figure 81: Ancillary service capacity outlook



Source: Deutsche Bank, Cairn ERA

Figure 82: Battery capacity and lithium demand forecast for ancillary service power application

	2015	2016E	2017E	2018E	2019E	2020E	2021E	2022E	2023E	2024E	2025E
Ancillary service battery power installed (MWh))	160	150	140	150	170	210	280	350	410	480	575
Li-ion market share (%)	30%	40%	50%	60%	80%	100%	100%	100%	100%	100%	100%
% growth of lithium-ion battery demand		25%	17%	29%	51%	54%	33%	25%	17%	17%	20%

Source: Deutsche Bank, Cairn ERA

Government policies supporting Energy Storage

United States

The U.S is the leading market for energy storage. Most of its energy storage projects have been installed within the major competitive wholesale electricity markets, including PJM (PJM interconnection), ERCOT (Electric Reliability Council of Texas), and CAISO (California independent system operator). PJM, ERCOT and CAISO are all regional transmission organisations. PJM has the most energy storage capacity installed for utilities (mostly third party-owned) while California is providing strong incentives to install Energy Storage products, both residential and non-residential.

Major Energy Storage policies are issued by the Federal Energy Regulatory Commission (FERC), which passed Order 890 in 2007, allowing non-generators to provide Ancillary Services. This was followed by FERC Order 755, which set up ‘pay for performance’ and frequency regulation, helping to create storage revenue based on speed and accuracy. In addition, battery storage was also well supported by the 2009 federal stimulus package, the American Recovery and Reinvestment Act (ARRA). Five demonstration project categories were set as 1) Battery storage for utility load-shifting or wind farm diurnal operations and ramping control; 2) Ancillary Services, frequency regulation; 3) Distributed Energy storage for grid support; 4) Compressed air energy storage; and 5) Promising energy storage technologies. It is estimated that ARRA funds provided about US$100m for battery storage projects and brought another US$122m in private funds toward battery storage technologies.

California has a very ambitious official target for energy storage, announced in 2010, which targets energy storage of 1.33GWh by 2020. California’s major subsidies were given through its SGIP, Self-Generation Incentive Program, which regulates a $1.62/w incentive rate for advanced energy storage projects up to 1MW capacity. The state of New York is also actively developing battery storage; its incentive program provides $2.1/w subsidy for projects constructed before June 1 2016. Looking forward, it is likely that the US will continue to lead energy storage globally due to its supportive policy packages, more mature technologies and increasing capacity (economies of scale) to help further reduce battery costs.

China

As one of the world’s largest energy consumers, China has great potential to adopt Energy Storage. Though China had several trial projects started as early as 2011, supportive official government policies have not been announced due to disagreements on technology solutions. The most important document is the draft report *“Promoting battery storage to providing Ancillary service during the peak time in Three Northern area”,* which was disclosed by the National Energy Administration in March 2016. The draft report shows plans to allow electricity sellers’ energy storage facilities (above 10MW) to buy electricity from grid and sell electricity to downstream users with no restrictions on battery size and power. It allows energy storage facilities, being able to discharge/charge longer than four hours, to sell electricity on grid. We treat these facilities the same as a small thermal plant to attend peak-load-dispatching operations. We believe the official final report will likely give legitimacy to energy storage projects. As energy storage in its current form does need policy support, this report will significantly accelerate the energy storage process in China since 2016.

Figure 83: Current Energy Storage products available for residential markets

Company	Tesla	Panasonic	BYD	Kokam	Samsung SDI	Iron Edison
Product Name	Powerwall	Li-ion Storage Battery System	DESS	KHESS	All-in-one ESS	Iron Edison Battery
Storage Capacity	6.4 kWh	8.0 kWh	>=8 kWh	5.38-15.54kWh	3.6 - 5.5 kWh	9.36 - 52 kWh
Voltage	350 - 450 V	250 V	52 V (DC)	51.8 V (DC)	230 V	52 V (DC)
Weight	100 kg	159 kg	75 Lg		95 kg (3.6 kWh)	118 - 710 kg
Price	US$3,000					US$9,919 - 35,760
						

Company	LG Chem	Saft Groupe	Juice Box	Simpliphi	Orison	Schneider Electric
Product Name	RESU 6.4 EX	Intension Home	Energy Storage System	PHI2.6/PHI3.4	Orison Panel/ Tower	Ecoblade
Storage Capacity	6.4 kWh	4 - 10 kWh	8.6 kWh	2.6 / 3.4 kWh	2.2 kWh	5 kWh (per blade)
Voltage	51.8 V (DC)	48 V (DC)	50 V (DC)	48 V (DC)	120 V	
Weight	60 kg	85 kg (4 kWh)	127 kg	26.1 / 34.8 kg	17 kg/ 18 kg	25 kg
Price	EUR 4,087					US$500/kWh
						

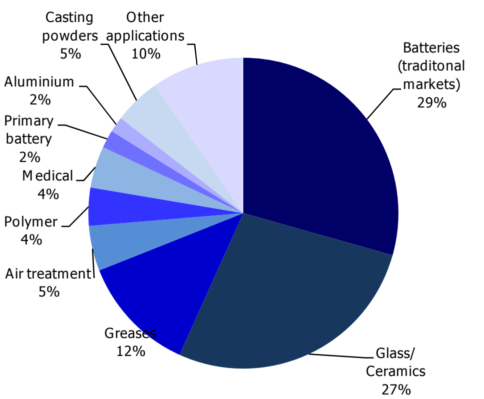
Source: Deutsche Bank; company data

Traditional markets

Lithium is used in a variety of existing industries, including glass and ceramics, industrial greases, air treatment, medical applications, primary batteries, aluminium smelting, casting powders and many more. It is these industries that have driven global lithium demand over the last 100 years, and these applications provide a foundation of demand that supports DB's overall demand outlook for lithium.

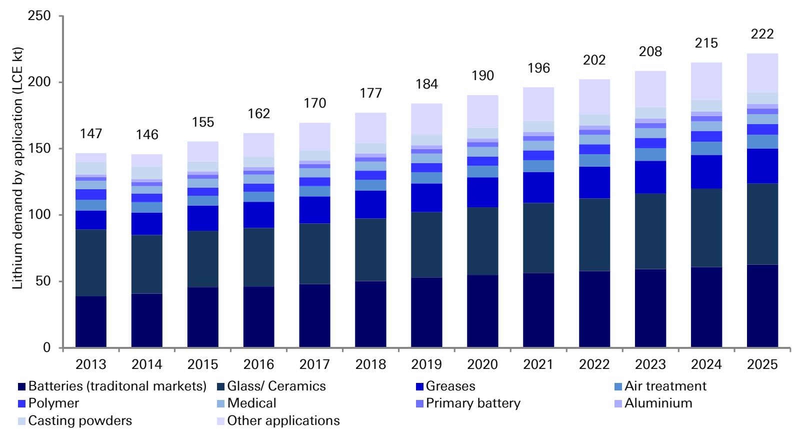
We consider the emergence of lithium-ion batteries in computers, mobile phones and other consumer electronics as an existing, albeit rapidly growing, demand market. As a result, we include this non-EV, non-Energy Storage lithium-ion battery demand in our 'traditional market' demand analysis.

Figure 84: Traditional markets - 2015



Source: Deutsche Bank; Industry data

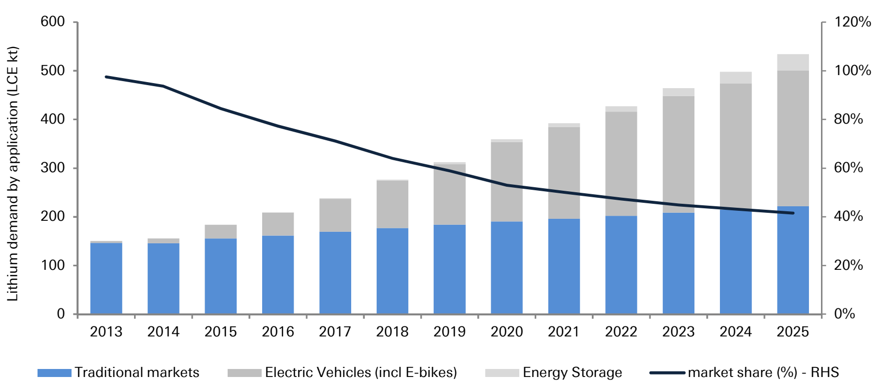
Figure 85: Traditional demand markets (2013-2025)



Source: Deutsche Bank; Industry data

While traditional markets are not seen to be the major drivers of lithium demand growth, we do expect these existing markets to grow at average of 3.6% per annum over the next 10 years, taking lithium consumption in these markets from 155kt in 2015 to 222kt in 2025.

Figure 86: Traditional market lithium demand vs. other demand markets



Source: Deutsche Bank, industry data, company data

Batteries

Lithium-ion batteries are used in a number of applications including consumer electronics and telecommunication devices. The light-weight nature of lithium-ion batteries along with rechargeability and high energy density makes them a good fit for portable electronics. Since being commercialized in 1991 by Sony Corporation, batteries have been the main use of lithium globally since 2005 and the lithium-ion battery market has grown into a US$15bn market in 2015.

Major demand markets for batteries in 2015 were Electric Vehicles (25%), cell phones (19%) and portable PC's (16%). Importantly, lithium-ion battery costs are coming down, as shown in Figure 87. Battery costs across all demand markets reduced 12% YoY in 2014 and a further 5% YoY to US$273/kWh in 2015. The EV industry consumes batteries with higher energy density which leads to a c.50% higher battery price in that market over traditional battery markets.

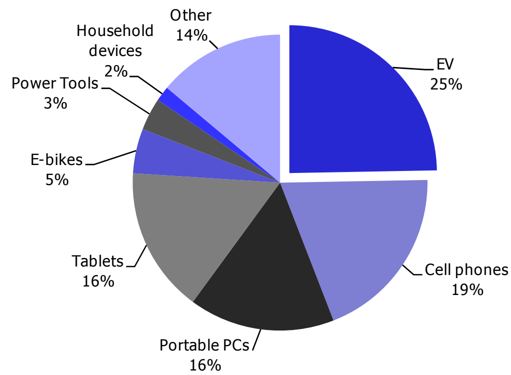
Figure 87: Global expenditure on batteries is growing while battery costs are falling

	GWh			US$bn			US$/Kwh		
	2013	2014	2015E	2013	2014	2015E	2013	2014	2015E
EV	**5.35**	**9.28**	**13.77**	**2.80**	**3.84**	**5.47**	**523**	**414**	**397**
Cell phones	**8.47**	**9.56**	**10.80**	**3.14**	**3.17**	**3.31**	**371**	**332**	**306**
Portable PCs	**9.71**	**8.98**	**8.91**	**2.10**	**1.85**	**1.76**	**216**	**206**	**198**
Other applications	**14.22**	**18.45**	**22.24**	**4.32**	**4.44**	**4.65**	**304**	**241**	**209**
Tablets	4.49	7.21	8.88	1.51	1.46	1.45	336	202	163
Power Tools	1.56	1.82	1.97	0.62	0.69	0.72	397	379	365
Camcorders	0.45	0.45	0.45	0.13	0.12	0.11	289	267	244
Digital Camera	0.96	0.45	0.40	0.22	0.14	0.12	229	311	300
Video Games	0.66	0.30	0.30	0.11	0.10	0.10	167	333	333
MP3	0.30	0.30	0.25	0.11	0.10	0.08	367	333	320
Toys	0.30	0.50	0.61	0	0	0			
Household devices	0.71	0.81	0.91	0	0	0			
E-bikes	1192	2.32	2.72	0.79	0.94	1.10	411	405	404
Other	2.87	4.29	5.75	0.83	0.89	0.97	289	207	169
Total	**37.75**	**46.27**	**55.72**	**12.36**	**13.30**	**15.19**	**327**	**287**	**273**
YoY price decline (total market)							-	-12%	-5%
YoY price decline (EV batteries)							-	-21%	-4%
Price premium for EV batteries							1.60x	1.44x	1.46x
Cell phones									
% of battery market	22%	21%	19%	25%	24%	22%			
CAGR growth	-	13%	13%	-	1%	4%			
Portable PC's									
% of battery market	26%	19%	16%	17%	14%	12%			
CAGR growth	-	-8%	-1%	-	-12%	-5%			
Electric Vehicles									
% of battery market	14%	20%	25%	23%	29%	36%			
CAGR growth	-	73%	48%	-	37%	42%			
Other markets									
% of battery market	38%	40%	40%	35%	33%	31%			
CAGR growth	-	30%	21%	-	3%	5%			

Source: Avicenne Energy, note that 2015 data are estimates made by Avicenne Energy, we believe the final 2015 number was c.70GWh (driven by surprising EV demand in China)

To forecast demand growth from traditional battery markets, we have removed Electric Vehicles from this market analysis. The traditional battery market (excluding EV) consumed 46kt LCE in 2015, roughly 25% of global demand. We expect this demand market to increase to 63kt LCE by 2025.

Figure 88: Pie chart of 2015 battery demand



Source: Avicenne Energy, Deutsche Bank

Figure 89: Consumer electronics is a major demand market

Source: iStockphoto

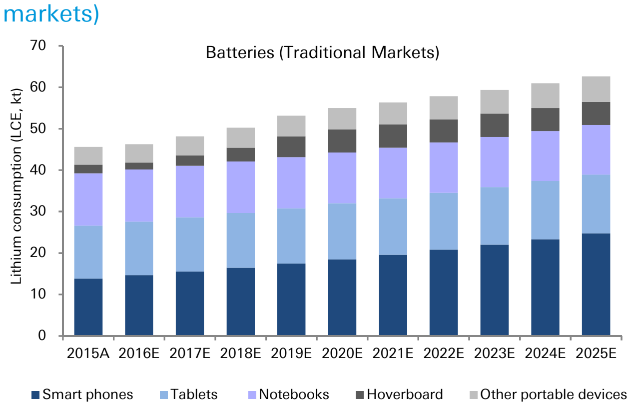
To forecast demand growth for lithium consumption in lithium-ion batteries from traditional battery markets, we have used global smart phone, tablet and notebook growth assumptions sourced from International Data Corporation, an independent market analysis firm. We use DB growth forecast for e-Boards, an emerging product market. For all other applications, we have assumed global growth in line with Deutsche Bank's global GDP forecasts.

Figure 90: Market growth estimates used for batteries (traditional markets)

	Implied market growth	Source	2016	2017	2018	2019	2020	Average
Smart phones	Global smartphone production	IDC	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%
Tablets	Global tablets production	IDC	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
Notebooks	Global notebook production	IDC	-0.5%	-0.5%	-0.5%	-0.5%	-0.5%	-0.5%
e-Boards	Global e-Board production	Deutsche Bank	-20.0%	45.8%	37.1%	50.0%	11.1%	24.8%
Other devices	Global GDP forecasts	Deutsche Bank	3.1%	3.7%	3.7%	3.7%	3.7%	3.6%

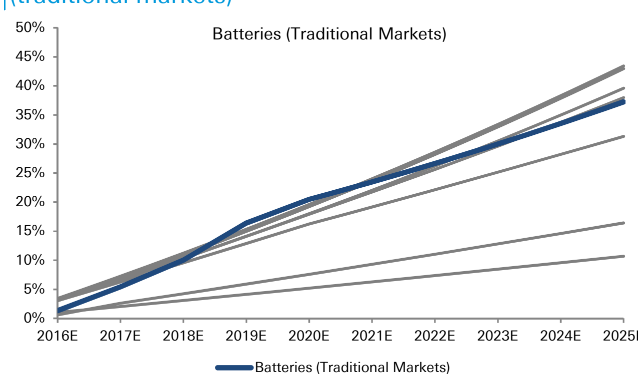
Source: Deutsche Bank estimates; International Data Corporation

Figure 91: Lithium demand for batteries (traditional markets)



Source: Deutsche Bank; Industry data

Figure 92: Cumulative demand growth for batteries (traditional markets)



Source: Deutsche Bank; Industry data

Glass and Ceramics

Lithium is used extensively in the glass and ceramics industry to improve melt viscosity and temperature. Lithium in the form of spodumene, petalite or other lithium oxides can be added to glass melts to decrease melting temperature (usually by as much as 25°C), which in turn reduces energy use by 5-10%, lowers emissions and increases the operating life of the refractory materials that line the hot sections of the production facilities. The addition of lithium also produces a strong glass or ceramic product with low thermal expansion, qualities that are very important in kitchenware, glass cooking surfaces and car windshields where thermal environments can change quickly. Lithium is also used to add colour or improve glazed finishing in glass and ceramic products.

Figure 93: Lithium is used in hardened glass…

Source: iStockphoto

Figure 94: …as well as in ceramics and glazes

Source: iStockphoto

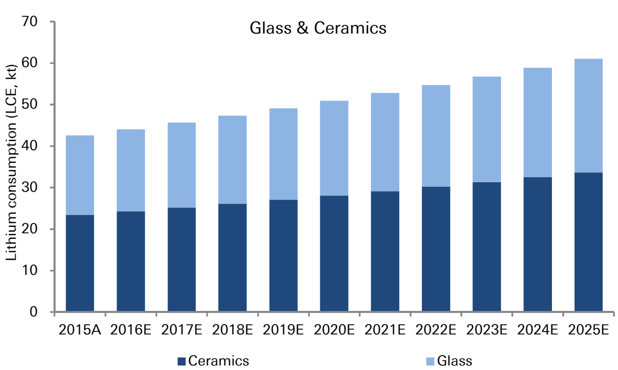
Outside of batteries, glass and ceramics is the largest demand market for lithium, making up 25% of global demand in 2015. To forecast demand growth for lithium from glass and ceramics, we use the following assumptions:

Figure 95: Market growth estimates used for glass and ceramics

	Implied market growth	Source	2016	2017	2018	2019	2020	Average
Ceramics	Global ceramics growth	Deutsche Bank	3.7%	3.7%	3.7%	3.7%	3.7%	3.7%
Glass	Global GDP forecasts	Deutsche Bank	3.1%	3.7%	3.7%	3.7%	3.7%	3.6%

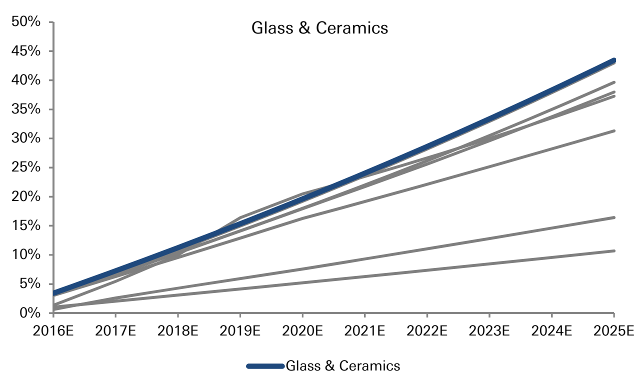
Source: Deutsche Bank estimates

Figure 96: Lithium demand for glass and ceramics



Source: Deutsche Bank; Industry data

Figure 97: Cum. demand growth for glass and ceramics



Source: Deutsche Bank; Industry data

Greases

Lithium is an additive to many types of grease used in industrial applications including the automotive, manufacturing and agricultural industries. Lithium greases represent around 70% of global grease production used in technical applications; they are very stable, excellent lubricators and will not break down when exposed to high operating temperatures. As a result, lithium grease is used in sealed mechanical systems like gearboxes and hydraulic systems.

Figure 98: 70% of global grease production is lithium based

Source: iStockphoto

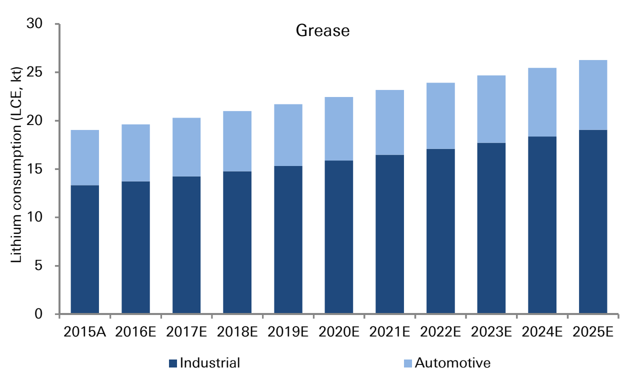
Greases are the third-largest demand market for lithium, making up 11.3% of global lithium demand in 2015. Lithium hydroxide is mixed with fatty acids to produce 'lithium soap', a thickening agent that is usually accounts for 3-20% of the grease product. As a result, around 0.2-0.3% of the final grease product is lithium. To forecast demand growth for lithium from global grease production, we have used the following growth assumptions:

Figure 99: Market growth estimates used for greases

	Implied market growth	Source	2016	2017	2018	2019	2020	Average
Industrial	Global GDP forecasts	Deutsche Bank	3.1%	3.7%	3.7%	3.7%	3.7%	3.6%
Automotive	Global car production	Deutsche Bank	3.0%	2.9%	2.8%	2.8%	2.7%	2.8%

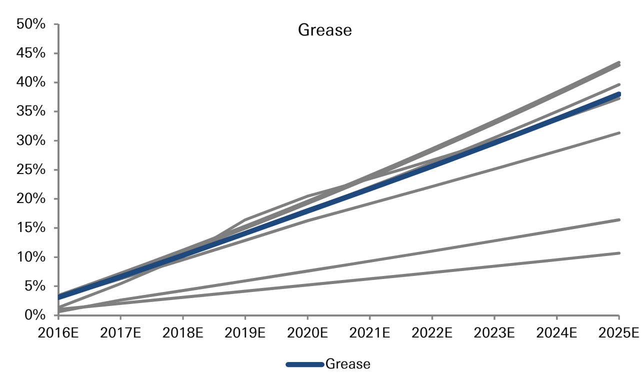
Source: Deutsche Bank estimates

Figure 100: Lithium demand for lithium greases



Source: Deutsche Bank; Industry data

Figure 101: Cumulative demand growth for greases



Source: Deutsche Bank; Industry data

Casting powders

Lithium is an additive in mold flux powders used in the continuing casting process in the global steel industry. The method of continuous casting (where a 'semi-finished' steel billet or slab is produced and further rolling is required to get to the final product) accounts for 90% of global steel production, so the use of mold flux powders to improve cast quality control is important.

Figure 102: Lithium is used in the continuous casting process

Source: iStockphoto

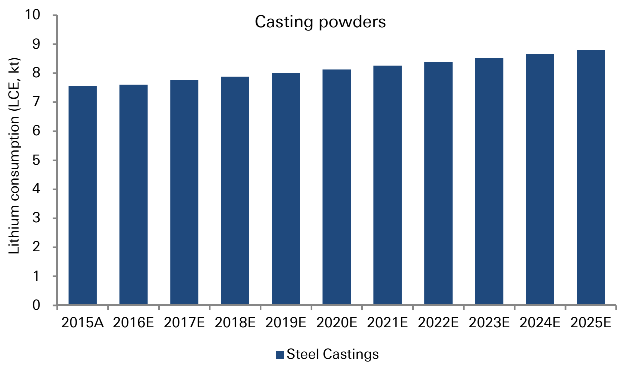
Casting powders are the fourth-largest demand market for lithium, making up 4.5% of global lithium demand in 2015. Adding up to 5% lithium (in either carbonate or mineral form) reduces mold viscosity and lowers the temperature that steel crystallization begins, delivering operating efficiencies. To forecast demand growth from casting powders, we use the following assumptions:

Figure 103: Market growth estimates used for casting powders

	Implied market growth	Source	2016	2017	2018	2019	2020	Average
Steel Castings	Global Steel supply	Deutsche Bank	0.6%	2.0%	1.6%	1.6%	1.6%	1.5%

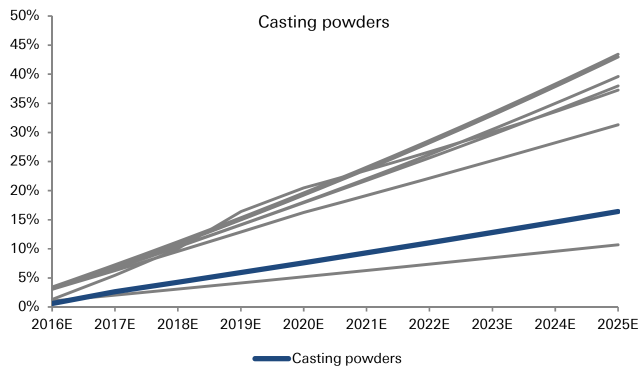
Source: Deutsche Bank estimates

Figure 104: Lithium demand for casting powder



Source: Deutsche Bank; Industry data

Figure 105: Cumulative demand growth for casting powder

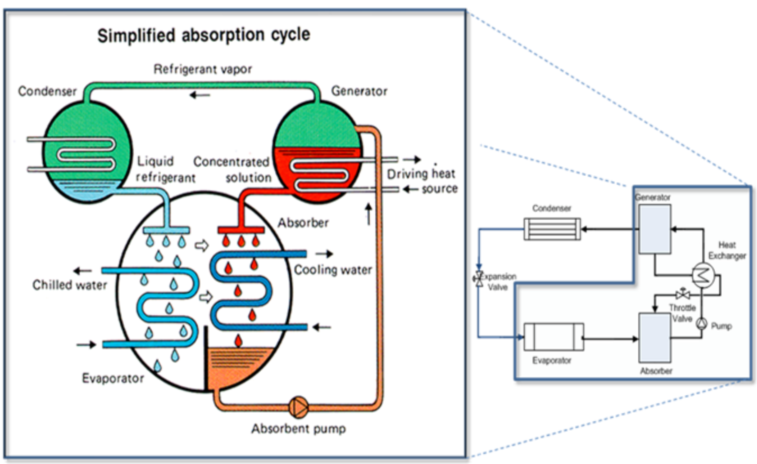


Source: Deutsche Bank; Industry data

Air treatment

Lithium is used in industrial refrigeration, humidity control and drying systems. Lithium bromide solutions act as a coolant in air conditioning systems, where moisture from moist warm air is absorbed by the lithium bromide. The diluted solution then passes through a heat exchanger where the water is vaporized, condensed and collected, allowing the lithium bromide solution to be re-used. Lithium is also used in air drying systems (lithium bromide/chloride) and in CO_2 scrubbers in closed environments (mining, space and submarine applications).

Figure 106: Absorption cycle in air conditioning (lithium bromide in red)



Source: Renewal Energy

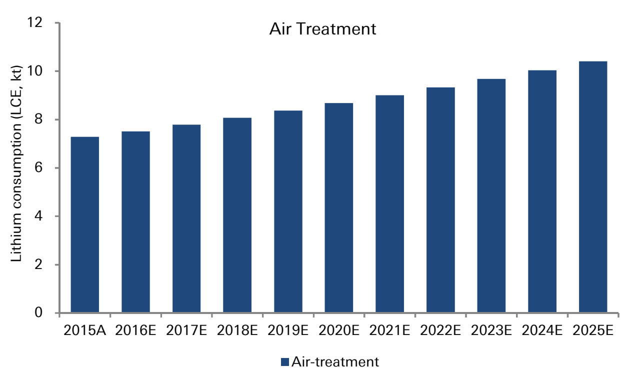
Air treatment is the fifth-largest demand market for lithium, making up 4.3% of global lithium demand in 2015. To forecast demand growth for lithium from air treatment, we have used the following growth assumptions:

Figure 107: Market growth estimates used for air treatment

	Implied market growth	Source	2016	2017	2018	2019	2020	Average
Air-treatment	Global GDP forecasts	Deutsche Bank	3.1%	3.7%	3.7%	3.7%	3.7%	3.6%

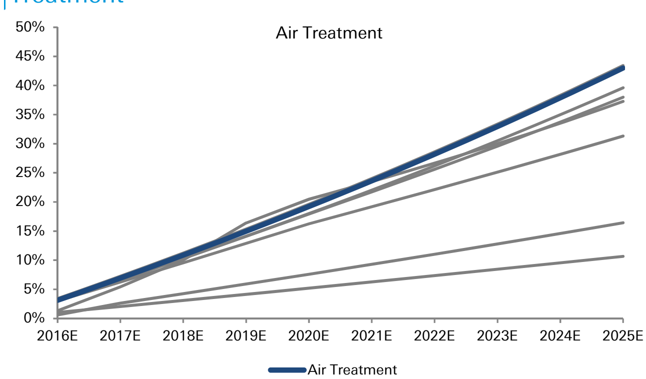
Source: Deutsche Bank estimates

Figure 108: Lithium demand for Air Treatment



Source: Deutsche Bank; Industry data

Figure 109: Cumulative demand growth for Air Treatment

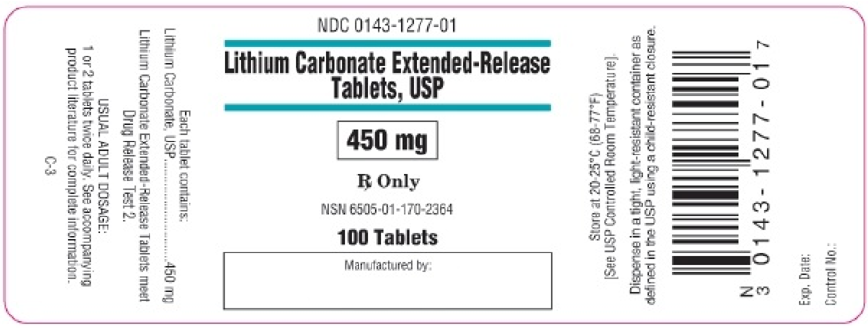


Source: Deutsche Bank; Industry data

Medical

Lithium-based compounds are used in the medical industry to treat certain psychiatric disorders, including bipolar disorders, depression and other nervous problems (90% of lithium use). Lithium acts as an antidepressant and a mood stabilizer, helping with the management of these conditions. Lithium is also used as a catalyst in other drugs used to treat weight reduction, AIDS and cancer treatment (10% of lithium use).

Figure 110: Lithium carbonate tablets prescribed for manic-depressive illness



Source: West Ward Pharmaceutical Corporation

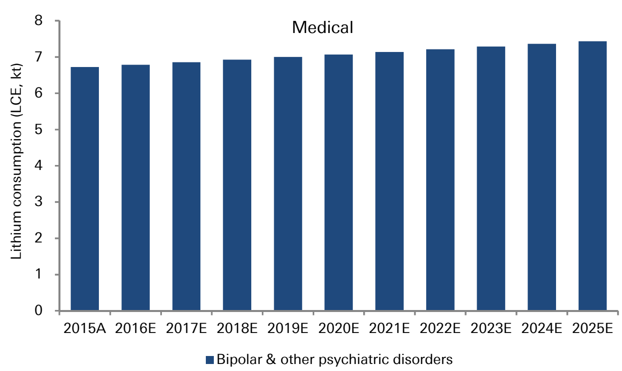
Medical applications are the sixth-largest demand market for lithium, making up 4.0% of global lithium demand in 2015. As the lithium is being ingested, purity is important and lithium is used in the form of high-purity lithium carbonate. To forecast demand growth for lithium from medical applications, we have used the following growth assumptions:

Figure 111: Market growth estimates used for medical applications

	Implied market growth	Source	2016	2017	2018	2019	2020	Average
Bipolar & other psychiatric disorders	Global population growth	United Nations	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%

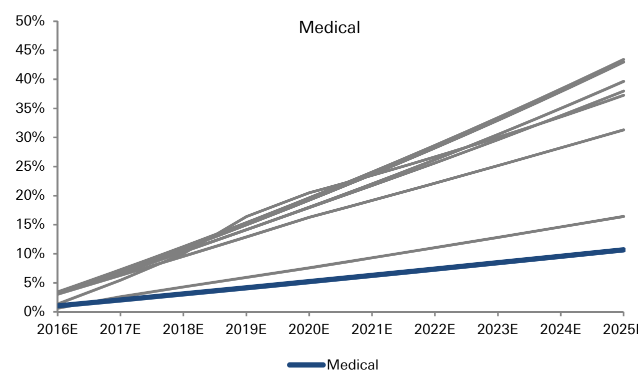
Source: United Nations

Figure 112: Lithium demand for Pharma/Medical



Source: Deutsche Bank; Industry data

Figure 113: Cumulative demand growth for Pharma



Source: Deutsche Bank; Industry data

Polymers

Lithium in the form of butyllithium is used as a catalyst for the production of a number of synthetic rubber products. The most common products are styrene-butadiene and polybutadiene which are used in the car tyre manufacturing industry (70% of global demand). Synthetic rubbers are also used in plastics, kitchenware, golf balls (polybutadiene core) and other applications.

Figure 114: Tyres are the most common application for synthetic rubbers

Source: iStockphoto

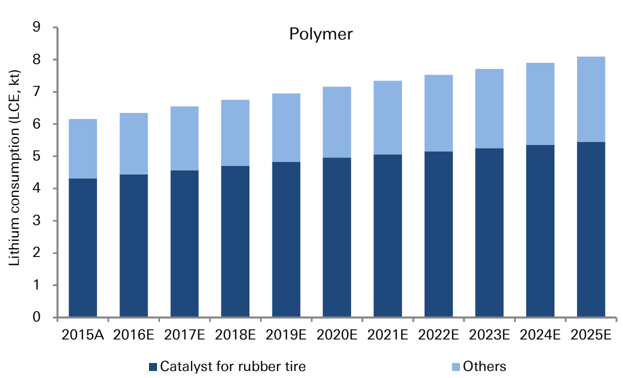
Polymers are the seventh-largest demand market for lithium, making up 3.7% of global lithium demand in 2015. To forecast demand growth for lithium from polymers, we have used the following growth assumptions:

Figure 115: Market growth estimates used for polymers

	Implied market growth	Source	2016	2017	2018	2019	2020	Average
Catalyst for rubber tire	Global car production	Deutsche Bank	3.0%	2.9%	2.8%	2.8%	2.7%	2.0%
Others	Global GDP forecasts	Deutsche Bank	3.1%	3.7%	3.7%	3.7%	3.7%	3.6%

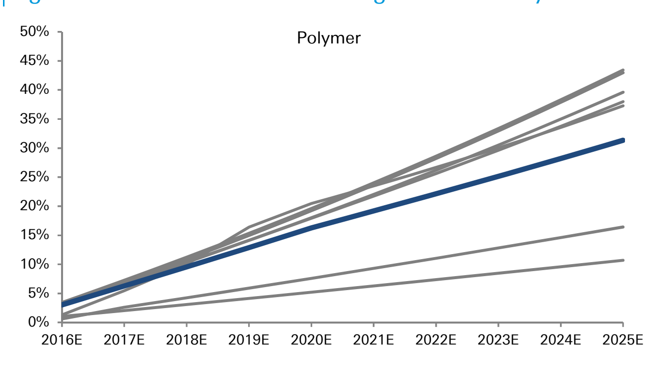
Source: Deutsche Bank estimates

Figure 116: Lithium demand for Polymers



Source: Deutsche Bank; Industry data

Figure 117: Cumulative demand growth for Polymers



Source: Deutsche Bank; Industry data

Primary batteries

Lithium is used in disposable, non-rechargeable primary batteries. Primary lithium batteries are more expensive than disposable alternatives like alkaline batteries, but are superior in terms of operational life, size, stability and durability. These qualities enable primary lithium batteries to be used in various applications including heart pacemakers, medical implants, defibrillators, watches, calculators, car keys and smoke alarms.

Figure 118: Primary batteries are used in a large number of applications

Source: iStockphoto

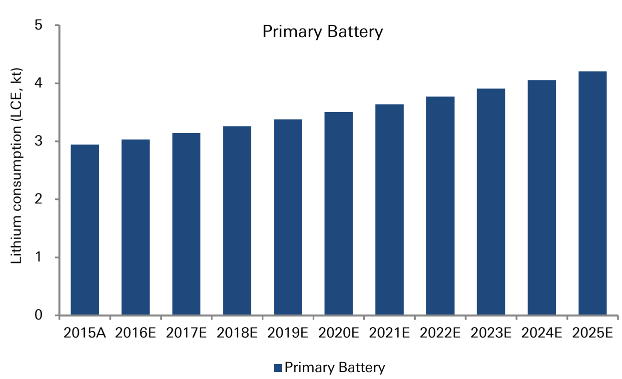
Primary batteries is the eighth-largest demand market for lithium, making up 1.8% of global lithium demand in 2015. To forecast demand growth for lithium from primary batteries, we use the following growth assumptions:

Figure 119: Market growth estimates used for primary batteries

	Implied market growth	Source	2016	2017	2018	2019	2020	Average
Primary Battery	Global GDP forecasts	Deutsche Bank	3.1%	3.7%	3.7%	3.7%	3.7%	3.6%

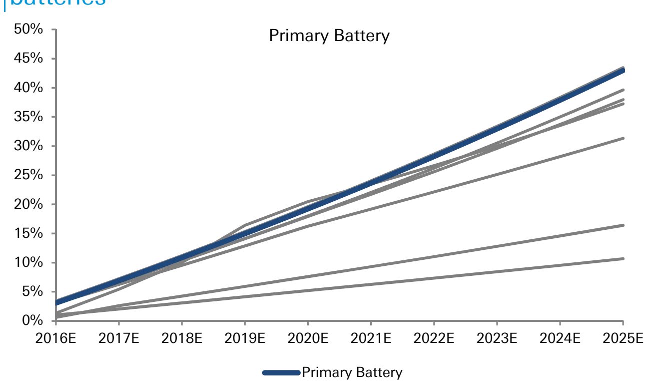
Source: Deutsche Bank estimates

Figure 120: Lithium demand for Primary batteries



Source: Deutsche Bank; Industry data

Figure 121: Cumulative demand growth for Primary batteries



Source: Deutsche Bank; Industry data

Aluminium

Aluminium smelting

Aluminium is produced by electrolysis of molten alumina (Al_2O_3) using the Hall-Heroult process. Due to the high melting temperature of alumina (2,072°C), the process is energy intensive and additives are added to the cryolite bath (NaF_2) to reduce the melting point and improve melt viscosity. Lithium carbonate or lithium bromide can be added to the cell to form lithium fluoride; 2-3% of lithium fluoride in the melt can lower the process temperature by 12-18°C, reduce electricity consumption by 2-4%, improve carbon cathode degradation by 1-2% and reduce flour emissions.

Figure 122: Aluminium smelting cells (or pots) at Rio Tinto's Kitimat smelter in Canada

Source: Rio Tinto

Only around 15% of global aluminium output is produced from smelters that utilize lithium additives, and these plants are mainly in the U.S. and Canada. On average, around 300g of lithium (equivalent to 1.5kg of lithium carbonate) is used to produce 1 tonne of aluminium.

As global aluminium smelting capacity is shifting towards Asia, mainly China, and away from traditional markets like the US and Europe, lithium demand growth from aluminium smelting is lagging growth in global aluminium output. As the Chinese aluminium industry matures, it is likely the cost, efficiency and environmental gains created by lithium additives will become more attractive and lithium consumption could greater align with the trend of global aluminium production growth.

Aluminium alloys

An emerging growth market for lithium is aluminium alloys, used in industries like aeronautics where light-weight, high-strength materials are a necessity. Aluminium-lithium alloys have been used in industry since the 1970's; however, new Al-Cu-Li alloys that have been developed over the last 10 years are expected to replace composite materials in many aeronautical applications.

Al-Cu-Li alloys produced by Alcoa and Constellium are already used in the production of Airbus line of planes, Bombardier aircraft and the latest F-15 and Eurofighter jetfighters. As an example, every Airbus A350 requires around 40 tonnes of Al-Cu-Li alloys which consumes 400kg of lithium, equivalent to two tonnes of lithium carbonate. While not a major demand market at the moment, aluminium alloys could experience strong growth over the next 10 years.

Figure 123: Each Airbus A350 consumes around 400kg lithium

Source: iStockphoto

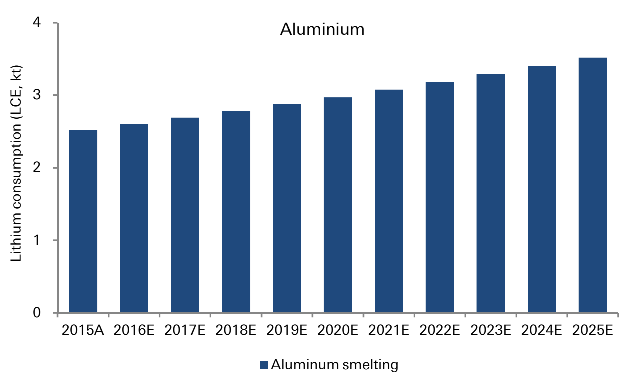
Aluminium is the ninth-largest demand market for lithium, making up 1.5% of global lithium demand in 2015. To forecast demand growth for lithium from aluminium smelting and aluminium alloys, we have used the following growth assumptions:

Figure 124: Market growth estimates used for aluminium

	Implied market growth	Source	2016	2017	2018	2019	2020	Average
Aluminum smelting	Global Aluminum supply	Deutsche Bank	3.4%	3.4%	3.4%	3.4%	3.4%	3.4%

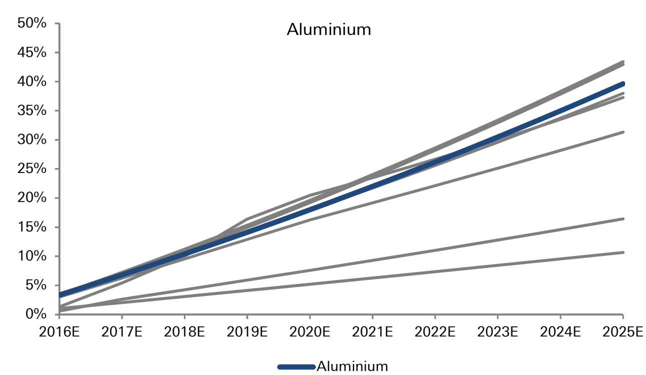
Source: Deutsche Bank estimates

Figure 125: Lithium demand for Aluminium



Source: Deutsche Bank; Industry data

Figure 126: Cumulative demand growth for Aluminium



Source: Deutsche Bank; Industry data

Other applications

Lithium and other lithium based compounds are used in small quantities in a number of different industries. These applications include:

- **Electronics:** Lithium niobate and tantalite are used to produce surface wave filters in mobile telecommunications and consumer electronics
- **Nuclear:** The Li-6 isotope can be used to produce tritium, a potential future energy source in nuclear fusion.
- **Textiles:** Lithium acetate and lithium hydroxide are used as additives in textile and polymer dying.
- **Cement:** lithium compounds are used as an additive to accelerate the cement hardening process
- **Fireworks:** Lithium nitrate is used in fireworks to generate the red colour.
- **Water treatment:** Lithium hypochlorite is used in swimming pool cleaning products.

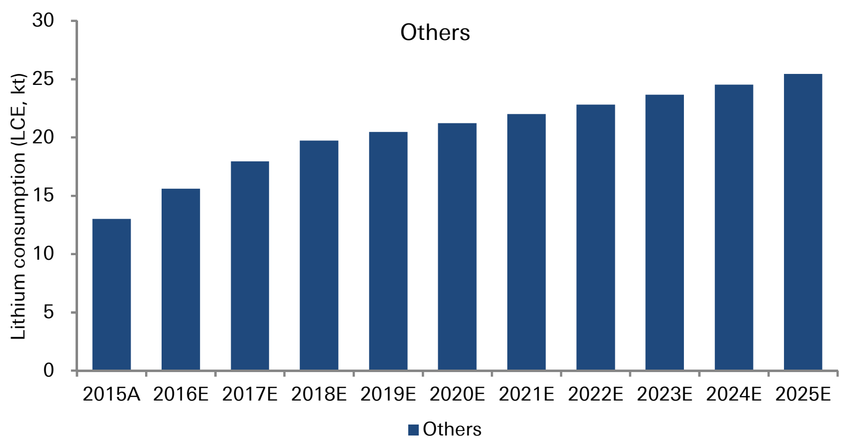
Other applications accounted for c.6.3% of global lithium demand in 2015. To forecast demand growth across these applications, we have assumed lithium consumption will grow in line with DB's official global GPD growth.

Figure 127: Market growth estimates used for other applications

	Implied market growth	Source	2016	2017	2018	2019	2020	Average
Others	Global GDP forecasts	Deutsche Bank	3.1%	3.7%	3.7%	3.7%	3.7%	3.6%

Source: Deutsche Bank estimates

Figure 128: Lithium demand for Other applications



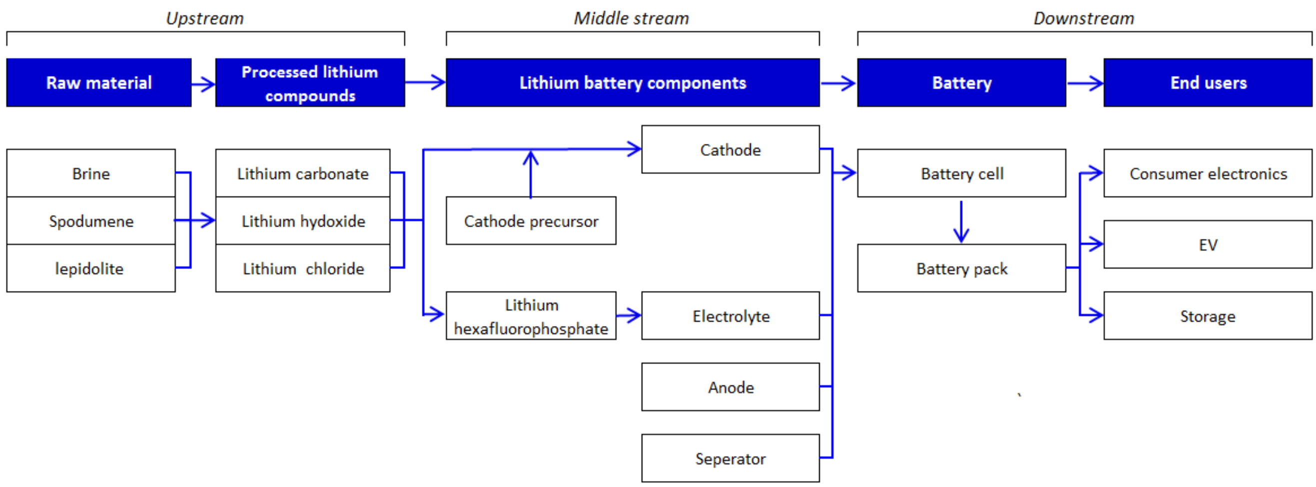
Source: Deutsche Bank; Industry data

Battery Supply Chain

We break down the lithium battery supply chain into upstream, middle stream, and downstream components. Upstream players provide lithium compounds used for cathode and electrolyte manufacturing. Middle-stream players produce components of lithium batteries, including cathode, electrolyte, anode and separator, while downstream battery producers focus on assembly and packing.

Despite having a simple industry supply chain structure, the whole industry chain is considered long and fragmented, as many niche players focus only on one key activity, such as Ganfeng (mainly lithium compounds processing) and Do-Fluoride (mainly lithium hexafluorophosphate manufacturing). There have been several M&A deals amongst competitors in single sections of the supply chain in the past several years; however, very few cases of vertical integration have occurred.

Figure 129: Industry chain of lithium batteries



Source: Deutsche Bank

So far, East Asian countries dominate the middle stream and downstream of the lithium battery supply chain. Except for upstream companies, for which the location of resources is highly relevant, most middle-stream and downstream players are Chinese, Korean, and Japanese companies. Given significant investments in 2015 by these three countries and rapid development of China's EV market, we believe the market share of East Asian countries will increase further in the coming years, and the Chinese EV market will be the main battlefield.

Upstream: market deficit driving higher prices

The current lithium supply market of 171kt LCE (DBe 2015) is already being outpaced by demand, which we believe reached 184kt LCE last year (inventory wind-down bridged the supply gap). As a result, pricing for raw, semi-processed and refined lithium products increased significantly in 2015 and early 2016.

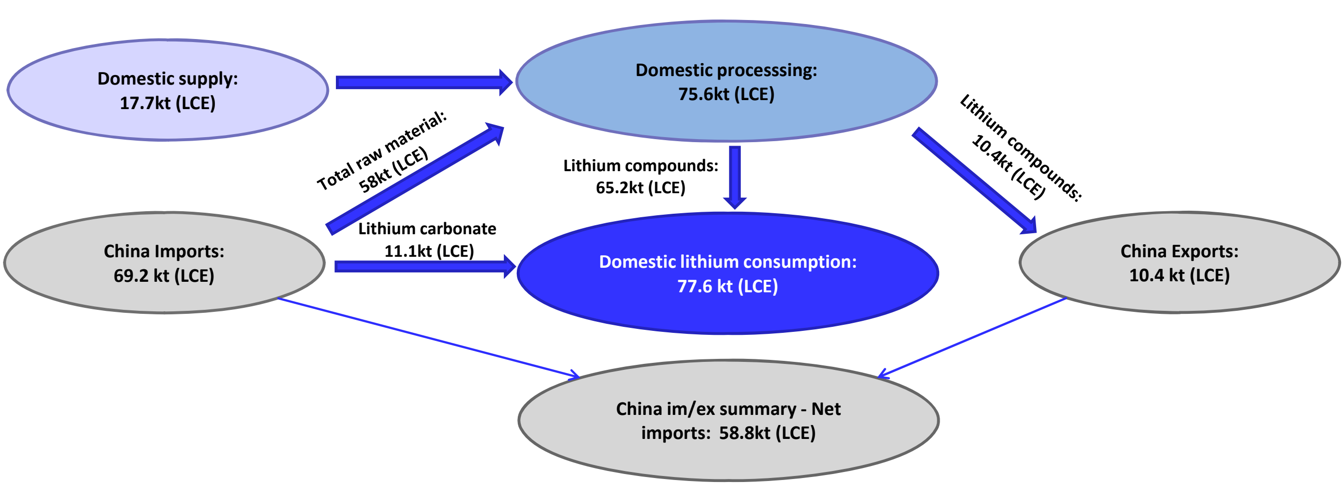
Brine operations in South America account for 50% of current supply, while spodumene makes up the remaining 50%. The Greenbushes mine in Australia (jointly-owned by Albemarle and Tianqi) is the world's largest spodumene operation and accounts for almost 35% of global lithium supply.

Brine operations have lower operating costs but are more capital intensive and incur significant lead times to production (technical and geographical challenges). ORE's Olaroz brine project in Argentina is the only major greenfields or brownfields brine project underway at the moment and we believe it will begin producing meaningful volumes by mid-2016.

- In the short/medium term, we believe further supply responses will likely come from low-grade spodumene projects in Australia and lepidolite in China, Jiangxi province being incentivized into the market. Downstream spodumene processing facilities, currently based in China, will also need to expand to allow for greater capacity.
- Longer term, the brine deposits that are already in operation have ample lithium resources to support significant brownfields expansions. While these will not enter the market in the next two years, we believe that taking a 10-year view, there will be a substantial response from the incumbent major brine producers, as well as greenfields brine projects, to market conditions.

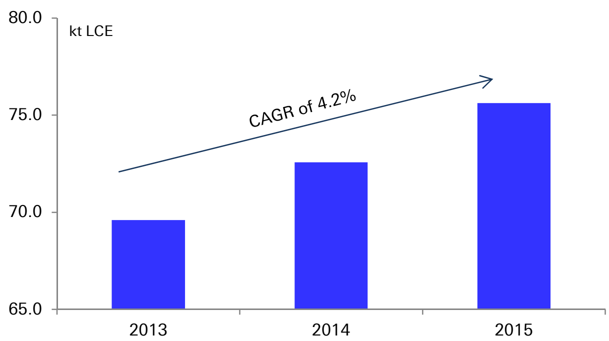
China is home to majority of the world's lithium refining facilities. As a result, it holds a critical place in the battery supply chain and is also the world's largest importer and consumer of lithium (see below).

Figure 130: China lithium market inflow/outflow in 2015



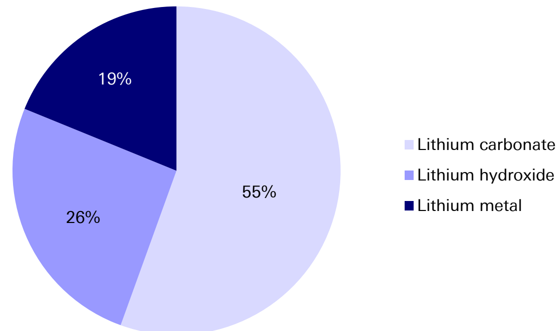
Source: Deutsche Bank estimates, GIIB, China lithium association, China Customs, In the past three years, total output of lithium products made by Chinese processors has not grown quickly (only 4.2% CAGR), mainly due to feedstock supply issues. Total output of China lithium products in 2015 was 76kt LCE, of which 55% was lithium carbonate, 26% was lithium hydroxide (LCE adjusted) and 19% were other lithium products (LCE adjusted).

Figure 131: Total production of China lithium products from 2013 to 2015



Source: Deutsche Bank, industry data

Figure 132: Total China lithium production breakdown by products (LCE adjusted.)

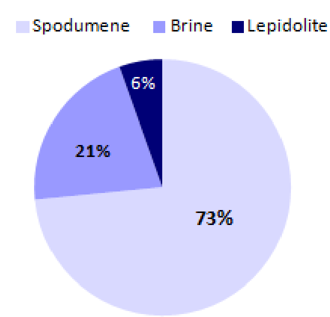


Source: Deutsche Bank, industry data

There are three different types of lithium processors in China. Firstly, brine-based manufacturers account for around 20% of total nominal capacity. These producers usually own the development rights to salt lake deposits in Qinghai and their own processing capacities. Many projects were installed over the last five years but were idled due to varying reasons like technology issues, high costs or harsh operating environment; many of these assets are still struggling to ramp up to full capacity with technology difficulties unlikely to be resolved quickly. We estimate nominal utilization rates could be as low as only 27% for Chinese brine-based assets. A typical production cost for a 10ktpa facility is around US$3,000-4,000/t if it was being operated at full capacity.

The second type is spodumene processing, which represents around 75% of total nominal capacity in China. These processors use both domestic and imported spodumene. Many processors had to stop production in 2015 when domestic resources began depleting and imported spodumene was in short supply. We estimate average utilization rates of local spodumene based manufacturers were at only 50%. Typical costs of spodumene-based producers were around US$4,500-5,000/t LCE when spodumene pricing was US$420/t (it has since lifted to over US$500/t). The biggest cost is spodumene concentrate, which accounts for 60-70% of the total. The other major variable costs are sodium carbonate, sulfuric acid and electricity.

Figure 133: Market share of processors in China.



Source: Deutsche Bank estimated, China Lithium Associations

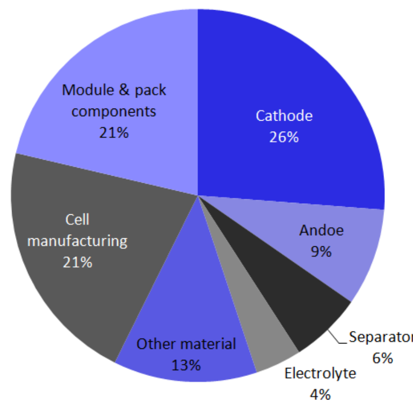
Last but not least are the lepidolite processors, which are the marginal players in China, with average production costs of US$7,000-8,000/t LCE. These producers were not able to survive by only producing lithium compounds from lepidolite in the past. A comprehensive development and sales of other high-value byproducts like rubidium and cesium is the key. However, market demand for rubidium and cesium is very limited. With lithium carbonate prices currently above US$20,000/t LCE, lepidolite-based producers can also deliver strong returns by selling only lithium carbonate and not other byproducts.

As China lacks raw material for its domestic market, lithium feedstock imports are material for China. China imported 69kt LCE in 2015. The majority of imports are spodumene concentrates from Australia, mainly the Greenbushes operation jointly owned by Sichuan Tianqi and Albemarle, which accounted for 78% of total imports in China in 2015 while other imports are brine and some industry grade lithium carbonate and hydroxide. China's domestic battery market consumed around 78kt LCE in 2015 after adjusting for 10kt LCE exports (probably battery grade lithium hydroxide).

Middle stream: eager for technology breakthroughs

The middle stream refers to the manufacturing of the four key components of batteries: cathodes, anodes, separators, and electrolytes. Cathodes, anodes, electrolytes, and separators account for roughly 26%, 9%, 6%, and 4% of the total manufacture cost of a lithium battery, respectively. As our report is mainly focused on lithium, we discuss only cathodes and electrolytes, in which lithium is involved as a critical element. To significantly improve the performance of the lithium battery, technology breakthroughs are anticipated in all four components. Although many promising solutions are being researched for each of the components, the competition remains intensive.

Figure 134: Lithium battery manufacture cost breakdown

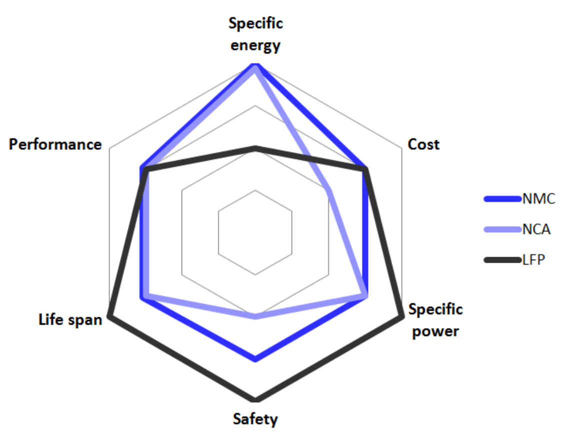


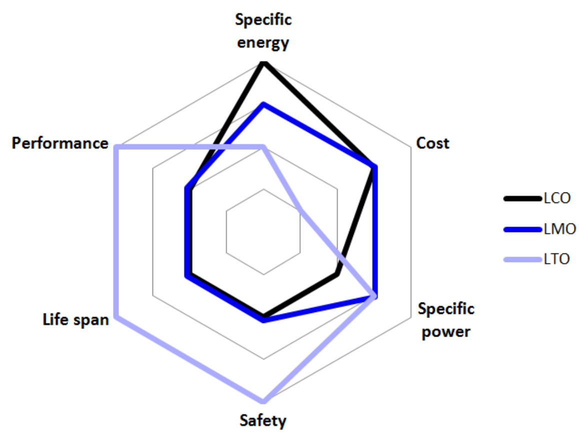
Source: Argonne National Labs, Supplier Estimates, Industry Experts, Deutsche Bank

Cathode: NMC/NMA is the trend for EV battery, but LFP is not yet abandoned

The cathode is the key to improving battery performance, including production cost, life span, energy density and safety. There are a number of options for cathode manufacturers, including NMC (Lithium Nickel Manganese Cobalt Oxide, $LiNiMnCoO_2$), NCA (Lithium Nickel cobalt Aluminum Oxide, $LiNiCoAlO_2$), LFP (Lithium Iron Phosphate $LiFePO_4$), LCO (Lithium cobalt Oxide, $LiCoO_2$), LMO (Lithium Manganese Oxide, $LiMn_2O_4$) and LTO (Lithium Titanate, $Li_4Ti_5O_{12}$), etc. Unfortunately, none of the cathodes available right now can claim to be the optimal product as certain applications prefer particular chemistries. Figure 135 compares the major characteristics of lithium batteries using different types of cathodes. Nevertheless, lithium is the common element regardless of technology choice.

Figure 135: Characteristic comparisons of different types of lithium batteries





Source: Deutsche Bank, Cadex Electronics, Battery university

Different types of lithium batteries are suitable for different types of usage based on the natural chemical characteristics resulting from varying cathodes. For the EV battery, the key considerations are safety and energy density (kWh/kg). Therefore, the current mainstream solutions are 1) ternary material series, NMC/NCA, which have higher energy density, but concerns on safety remain. The risks of fire hazard are higher; and 2) LFP, which is safer, but energy density is relatively low, and there has been slow progress on performance improvements. In China, most commercial EVs use LFP, as manufacturers put safety as the first priority, while passenger EV producers prefer to use NMC/NCA, as driving distance matters. A typical user of NCA is Tesla, while a typical user of LFP is BYD.

In China, we believe LFP will not yet be given up, especially after several recent accidents involving explosions. The rise of the importance of safety has been swift. The CAAM (China Association of Automobile Manufacturers) recently submitted a suggestion to the MIIT (Ministry of Industry of Information and Technology), asking that it should not allow passenger EVs to install ternary material lithium batteries due to safety considerations. The policy risk may be significant to NMC/NCA cathode producers (which are mainly Japanese and Korean companies) but has a limited impact on our forecast of lithium demand. In our forecasts, only 12% of commercial EVs will use NMC/NCA in 2015-2018. We believe the cathode technology debate will continue without any clear conclusion for a while. The risks of technical breakthrough, intensive competition, government policy interference, and lack of clear industry standards will continue to affect the cathode manufacturing sector.

Electrolyte: current technical solution is steady

Electrolytes are made of lithium salt compounds (lithium hexafluorophosphate, $LiPF_6$) which have a relatively high barrier of entry, and solvents, which are easier to produce. Based on using different electrolyte solvents, lithium batteries can be divided into two basic types: liquefied lithium ion battery (LIB) and polymer lithium ion battery (PLB). PLB's electrolyte could be either gel or solid. However, lithium hexafluorophosphate is effectively a necessity in all popular solutions that have been developed so far. Research on electrolytes is still underway to improve battery performance, such as enhancing low-temperature conductivity and reducing the viscosity of the electrolyte, improving cycle life, and increasing safety features, especially for larger-sized batteries. Significant efforts have been made to try additives, new solvents, and a mixture of current popular solvents.

Anode – currently low profit and waiting for graphene to take off

For rechargeable lithium batteries, the anode is the negative pole during discharge and positive pole during charge, helping to release the electrons into the circuit. In terms of anode production, barriers to entry are reasonably low and the profitability of anode producers is usually low as well. The material typically used in anodes is either natural or synthetic graphite. Graphite is the incumbent product, is readily available and not a major cost input for batteries. There are strict quality controls on the graphite products used in batteries as they affect cell performance.

Separator – Japanese producers still dominate

The battery separator is used to separate the cathode from the anode. A separator is usually made out of nylon, polypropylene (PE) and polyethylene (PP). The quality of separator decides the ion-transportation capability and will have a direct influence on battery performance. For EV batteries, some unique characteristics are essential, such as 1) higher shut-down temperature and melting point for safety purposes; 2) high puncture resistance; 3) homogenous pore size and distribution. The production know-how requirement is high. Japanese companies play a big role in this area.

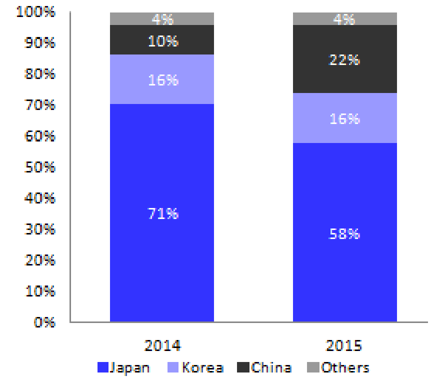
Downstream: potential industry vertical integrators

Major lithium battery manufacturers are generally traditional electrical appliance producers; the biggest ones are Panasonic (36% market share), BYD (11% market share), PEVE (10% market share, a joint venture of Panasonic and Toyota), AESC (8% market share, a joint venture of NEC and Nissan), LG Chemical (8%), and Samsung SDI (5%) in 2015.

Japan, Korea, and China dominate the lithium battery market, with a 96% market share in terms of battery capacity shipments. Among these three countries, Japanese companies have the largest market share on their leading technology, while Korean and Chinese companies are catching up quickly. China has successfully enlarged its market share from 14% in 2014 to 26% in 2015, benefiting from booming demand of EV sales in China.

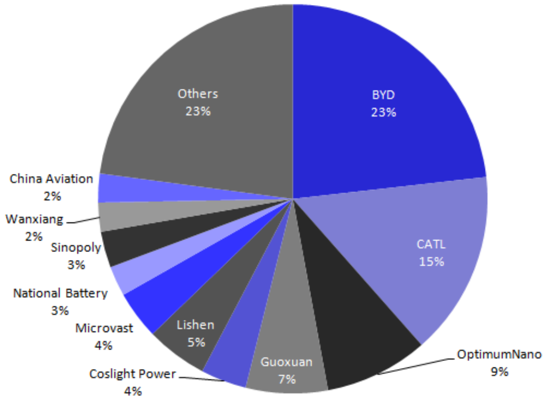
China replaced the U.S. as the largest EV market in the world in 2015, making China the main battlefield, attracting more investment to catch up with the strong battery demand. Chinese battery capacity shouldl increase from c.56 GWh in 2015 to 212 GWh in 2020, with a CAGR of 31%, based on companies' latest announcements. The increase will primarily cater to the overwhelming demand from the EV market. While local battery suppliers are aggressively expanding their capacities, global battery majors, Panasonic, LG and Samsung have all announced capacity expansion plans in China in coming years. LG's new factory in Nanjing can provide batteries for 50,000 EV units in 2016 and plans to expand to support 200,000 EV units by the end of 2020. Samsung SDI's Xi'an factory's capacity in 2015 supported 40,000 EV units and may further expand to supply 350,000 EV units by the end of 2020. Following its major competitors, Panasonic also announced its intent to invest US$412mn to build a new lithium battery factory with a capacity to supply 200,000 EV units every year in Dalian city in the future.

Figure 136: Lithium battery market share by country



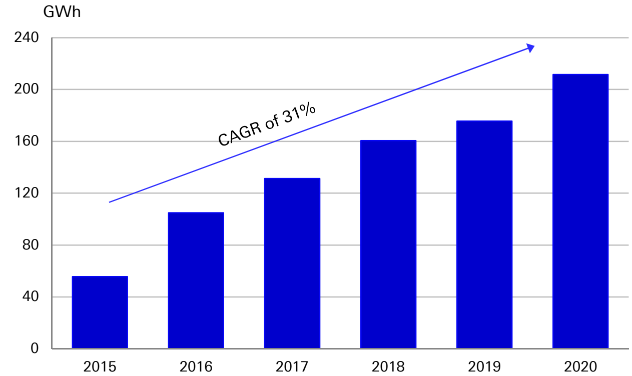
Source: Deutsche Bank estimated, SNE research

Figure 137: China battery manufacturing (2015)



Source: Deutsche Bank, GIIB

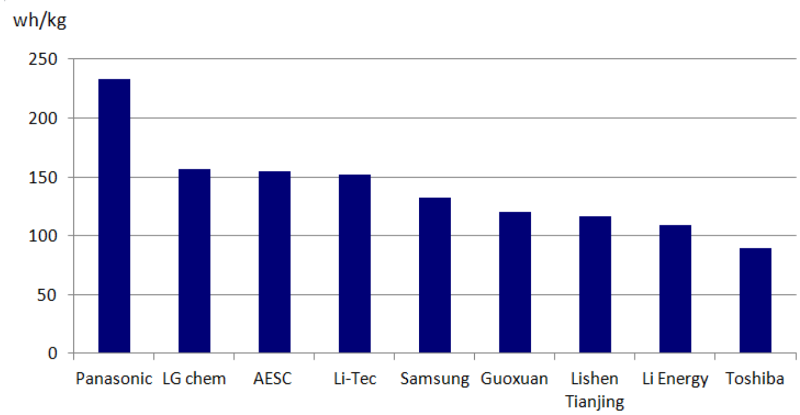
Figure 138: China battery manufacturing capacity



Source: Deutsche Bank estimated, GIIB

We should note that, compared to small-sized lithium batteries, batteries for EVs have higher quality requirements, especially consistency of the battery cell and pack. Because of the short-board effect in the battery module, even just one low-quality battery cell will significantly hurt the final performance of the whole lithium battery module. Lithium-ion batteries are sold by USD per kWh, which means if battery cells are developed with higher energy density, this could lead to higher selling prices with no impact to raw material cost; this would be supportive for downstream margins.

Figure 139: Energy density variations in different manufacturers



Source: Deutsche Bank, total battery consulting, company data.

Quality control starts in the raw material production stage, especially in cathode manufacturing. Therefore, major battery manufacturers have meaningful in-house cathode capacity. With the increasing requirement for consistency, battery manufacturers may start to enlarge their in-house capacity and squeeze the market share of other independent cathode producers. On the other hand, downstream EV is also likely to purchase high-performance batteries for more comprehensive EV performance, which can enjoy a higher government subsidy. As such, we believe battery manufacturers have a strong motivation to be the major industry integrator for quality control purposes, starting with cathodes.

Figure 140: Major Companies across the supply chain of lithium industry

RAW MATERIALS	BATTERY COMPONENTS	CELLS	APPLICATIONS
LITHIUM (Li2O, LiOH, Li2O3)	ANODE	CELL CONSTRUCTION	EVs/PHEVs/HEVs
Soquimich	Altair Nanotechnologies	Panasonic	Tesla
FMC Corp	ConocoPhilip	LG Chem	Ford
Orocobre	Hitachi Chemical	Foxconn	GM
Albemarle	Kureha	Boston Power	BYD
Bacanora Minerals	Nippon Carbon	Sansumg SDI	Daimler
Pure Energy Minerals	Pyrotek	Tesla	Honda
Jiangxi Ganfeng	Superior Graphite	BYD	Nissan
Tianqi Group	LG Chem	Continental	Toyoto
Galaxy		Johnson Controls	Volkswagen
Neometals	CATHODE	GM	Geely Automobile
Pilbara Minerals	Umicore	Lishen	Chevrolet
	Nichia Chemical	LithChem	Aston Martin
GRAPHITE/SYNTHETIC GRAPHITE	Sumitomo	Maxwell	Mercedes Benz
Syrah Resources	L&F	NEC	Audi
China - various	Shanshan	Sanyo	Zoyte Auto
Brazil	3M	Toshiba	BAIC Motor Corp
Triton Minerals	BASF		SAIC Motor Corp
Mason Graphite	Bamo-Tech		Chongqing Changan Auto
Graphite One	Easpring	BATTERY PACKS	
Energiser/Malagasy	Nippon denko	A123	STATIONARY STORAGE
Talga Resources	Toda Kogyo	AC Propulsion	Tesla
	Formosa	All Cell Technologies	LG Chem
COBALT COMPOUNDS	King-ray	Boston Power	Samsung
Tanaka Corporation		BYD	AES
Kansai Catalyst	SEPARATORS (FOILS)	Coda	BYD
Santoku	Applied Materials	LG Chem	Saft Groupe
Glencore	Asahi Kasei	Continental	Coda Energy
	Celgard	XALT energy	Stem
NICKEL COMPOUNDS	DuPont	Electrovaya	Green Charge Networks
Tanaka Corporation	Entek	EnerDel	Sonnen-Batterie
Kansai Catalyst	Evonik Industries	OptimumNano	Vestas
Sumitomo	SK Energy	Guoxuan	EDF Energy
WSA	Toray Tonen	China Aviation	Enel
	Cangzhou Mingzhu	Sinopoly	Duke Energy
MANGANESE COMPOUNDS		CATL	National Grid
Mitsui	ELECTRODES	GM	First Solar
Sumitomo	Cheil Industries	GSYuasa	GE
S32	LithChem	Hitachi	Siemans
	Mitsubishi Chemical	Johnson Controls-saft	
ALUMINUM	Mitsui Chemical	Lishen	ELECTRONICS/CONSUMER PRODUCTS
Alcoa	Novolyte Technologies	NEC	Sony
	Panex	Panasonic	Google
	Shenzhen Capchem	Sanyo	Huawei
	Do-Fluoride Chemicals	Samsung SDI	Samsung SDI
	Tianci Materials	Tesla	Xiaomi
	ShanShan		Apple
	Shinestar		Panasonic
	Tomiyama Yakuhin		

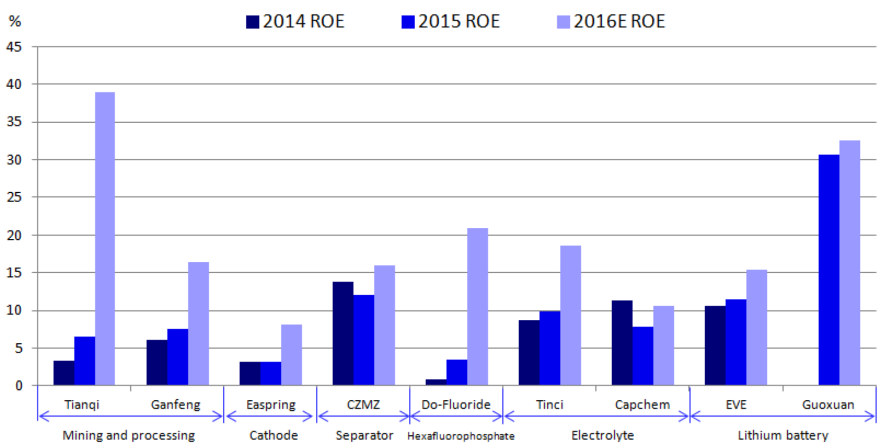
Source: Deutsche Bank

Margins in the supply chain

There are several segments in the EV/battery supply chain, and we believe that upstream might eventually be the most attractive place to be. We expect upstream players to benefit from increases in both selling price and volume, which should drive their top line and bottom line to climb significantly in coming years. For mid-stream segments such as cathodes, anode, electrolytes and separators, the entry barriers are not necessarily high, and players might be facing risks of picking the right technology. For downstream companies such as EV/battery producers, reducing ASP is critical to ensuring that sales volume takes off. As such, upstream lithium might be the best place to be along the supply chain because of common usage, limited resources, and a tight supply market for the next three years.

The following chart presents Return-On-Equity (RoE) results for Chinese lithium industry companies for 2014 and 2015 as well as RoE forecasts for 2016 (using Bloomberg consensus data). All subsectors in the battery supply chain have an improving RoE outlook in 2016 than 2014/2015. It is evident that profitability of upstream and downstream players is on average higher than that of middle stream players.

Figure 141: Chinese lithium industry companies' Return-On-Equity (RoE)



Source: Deutsche Bank, Bloomberg Finance LP

Based on our forecast of high growth in the EV and lithium battery industries, the slow ramp-up of new lithium supply, and the oligopolistic nature of lithium supply, we expect lithium producers to enjoy great profitability in the coming years. We forecast the battery-grade lithium carbonate price to remain high above US$15,000/t LCE as the deficit of lithium is likely to continue, at least in the next 12-18 months. Our cost sensitivity analysis leads us to conclude that the high price of lithium will not deter EV/lithium battery penetration from growing quickly, because total cost of lithium material as a % of the total battery is only 5-7%. Furthermore, EV manufacturers cannot find suitable replacements for lithium batteries. However, mid-stream players such as cathode producers might face a margin squeeze.

Capacity expansion capability decides future bottleneck

High profitability at the supply chain bottleneck will naturally encourage investments in capacity expansion, which poses a threat to profitability for those areas with low barriers to entry. After a comprehensive analysis of capital requirements, production know-how, and access to raw materials, we believe lithium compound refining has the highest entry barriers, followed by hexafluorophosphate and battery manufacturers. We believe the subsectors with higher entry barriers and high market centralization will continue to benefit from higher profitability in the coming years.

Figure 142: Entry barrier analysis of lithium industry supply chain

	Hard rock minerals Salt lake brines	Lithium compounds	Cathode	Hexafluorophosphate	Electrolyte	Lithium Batteries
Market centralization rate*						
Top 4 players' market share	86%	75%	42%	62%	50%	65%
Top 10 players' market share			67%	99%	85%	90%
Entry barrier	High	Medium	Low	Medium	Low	Medium
Capital requirement	High	Low	Low	Low	Low	Medium
Production know-how	Medium	Medium	Low	High	Low	Medium
Clear industry standard	Yes	No	No	Yes	Yes	Yes
Access to raw material	Easy	Hard	Medium	Easy	Medium	Easy

Source: Deutsche Bank estimates, Navigant,GGIB industry experts

Figure 143 summarizes all the capacity expansion plan announcements to date. It demonstrates that hexafluorophosphate should have strong capacity growth in 2016 and 2017, attracted by the current high profitability. We believe more investment plans in all industry subsectors will be announced in 2016. For most capacity expansions, it takes around one year to build a factory, if this is not postponed by others factors like government environmental compliance. After that, the ramp-up of the new factories alone can take around six to eight months. As shown in Figure 144 the shortage of supply in most subsectors should be greatly resolved, except in lithium raw material/compounds.

Figure 143: YoY capacity increases through the supply chain

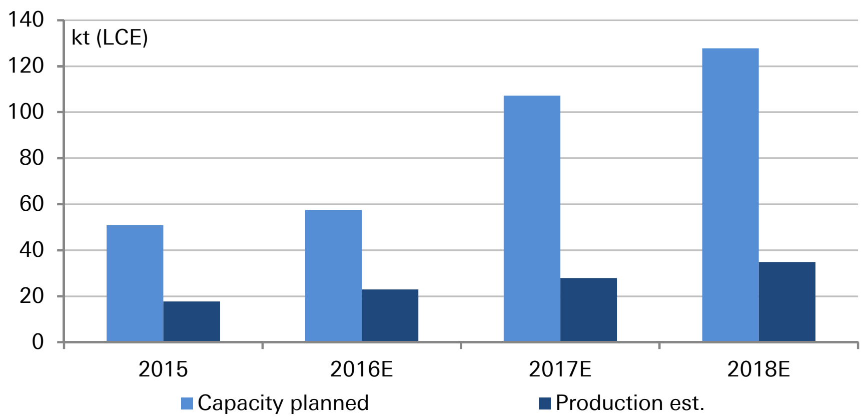
YoY growth rate	2015E	2016E	2017E	2018E
Lithium battery demand (GWh)	*45%*	*27%*	*25%*	*28%*
Lithium compounds	9%	18%	20%	15%
Cathode	27%	38%	20%	15%
Hexafluorophosphate	24%	56%	33%	5%
Electrolyte	4%	15%	7%	0%
Battery capacity	62%	89%	25%	22%

Source: Deutsche Bank estimates, Avicenna energy, GIIB, Chyxx.

In terms of project expansion plan, major potential expansion projects are in salt lakes in Qinghai, spodumene mines in Sichuan province and lepidolite mines in Jiangxi province. Although the plans look aggressive enough to increase some supply, we maintain the view that the ramp-ups and expansion of domestic mines won't turn around the tight supply situation of lithium. Historical experience has also demonstrated that various challenges will keep arising during the development of either domestic salt lake brine or hard-rock mines. It is highly possible that output of new projects constructed may not reach the designed level or the project actually fails.

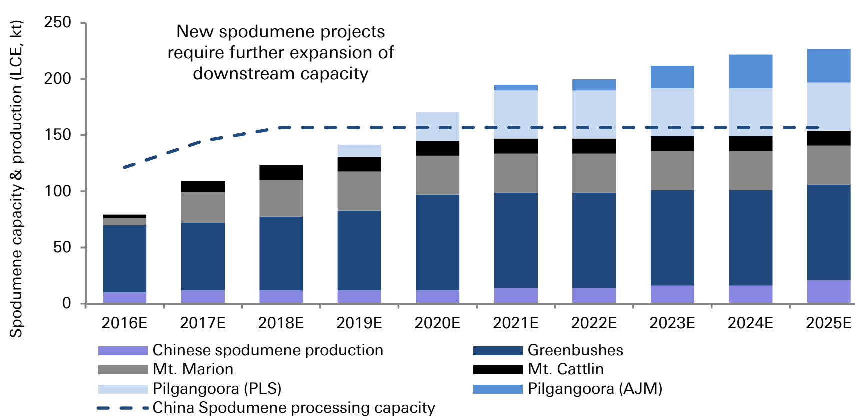
We believe in mining part including all brine, spodumene and lepidolite, total supply would increase from 17.7kt LCE in 2015 to 35kt in 2018, mainly from spodumene in Sichuan and also lepidolite in Jiangxi province. We believe brine in Qinghai is likely to suffer from technical and environmental challenges. In terms of processing capacity, Chinese processors are continuing to build new capacities, driven by larger companies like Tianqi and Ganfeng. Total nameplate capacity of processing may increase from an estimated 163kt in 2015 to 272kt in 2018 (across all lithium products).

Figure 144: Expansion and production forecast for Chinese raw material



Source: Deutsche Bank estimates, industry data

Figure 145: China spodumene processing capacity v/s future production



Source: Deutsche Bank estimates

Risks to our forecasts

Shift in cathode technology

- The active metal oxide used within the cathode of lithium-ion cells can vary depending on the application and battery properties required. Lithium Cobalt Oxide (LCO) has been the incumbent technology since it was first introduced in 1991. It has a high energy density but incurs longer charge times, a shelf life of 1-3 years and can be dangerous if damaged.
- Tesla Motors currently uses the Nickel Cobalt Aluminium (NCA) technology. NCA has a high specific energy and power density and also a long life span, but safety and cost have historically been concerns. Tesla's cell management systems and economy of scale can alleviate both of these issues.
- We believe that over the medium term, a further shift towards Nickel Manganese Cobalt (NMC) is likely. NMC has lower material costs (less cobalt in particular) and can be tailored to high specific energy or high specific power.
- There is potential for new technologies to be developed, but we are comfortable that lithium metal (the most constant consumption across the current competing technologies) will remain in the active material chemistry going forward.

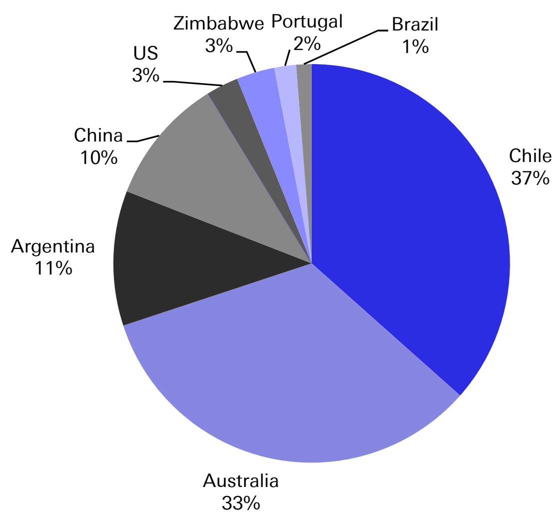
Other factors create upside and downside for lithium demand

- A larger-capacity battery pack tends to be required for an EV to drive for a long distance when the battery is the sole source of power. Current capacities of batteries used by Chinese EVs are relatively small. Comparing to the Tesla S model, which uses battery capacity of 85/90kWh, many typical Chinese passenger EV models have battery capacities only ranging from 20kWh to 30kWh. Increasing the number of battery cells is the most direct and simplest way of increasing the capacity of a battery pack.
- There is also significant room for Chinese lithium battery producers to improve energy density. It is estimated that Tesla uses lithium battery packs with energy density as high as 233Wh/kg, while typical Chinese companies can only produce battery packs with energy density at c.100-120wh/kg or 130-150wh/kg for LFP lithium battery or MNC/NCA lithium battery, respectively. If improvement in energy density comes, demand for lithium could be weaker than expected under the base-case scenario for EV sales.
- We believe the net impact of these two factors in the coming years may not be significant. As such, we believe our forecast on demand for lithium is based on fair assumptions.

Global Supply

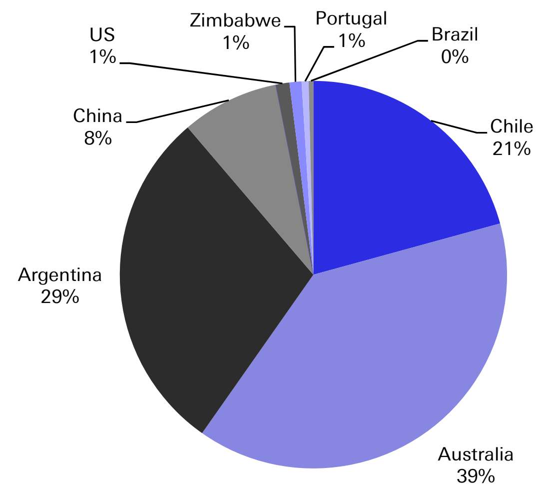
Global supply of lithium minerals has been historically dominated by hard-rock mineral sources, however development of large-scale lithium brine operations in South America commenced in the early 1980's. Global lithium supply has increased at a 7% CAGR growth rate from 1995 to 2015 to meet increased demand from mobile phones and other electronics. Today, global lithium supply is around 171kt LCE, split roughly 50:50 between hard-rock and brines.

Figure 146: 2015 lithium supply by country



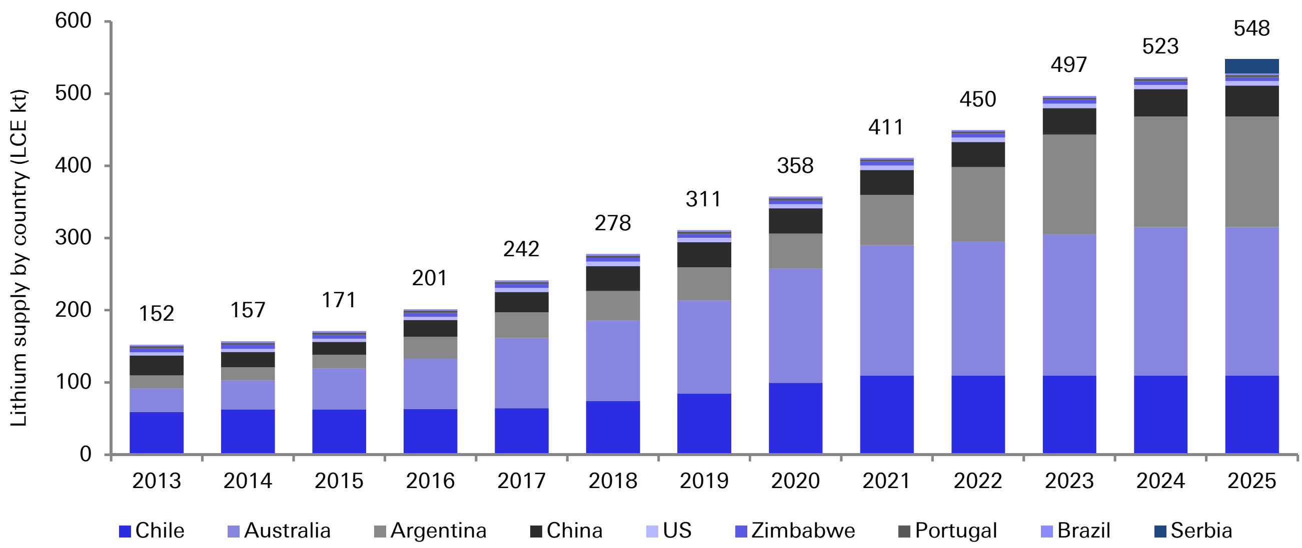
Source: Deutsche Bank; USGS; Company data

Figure 147: 2025 lithium supply by country



Source: Deutsche Bank; USGS; Company data

Figure 148: Lithium supply by country (2013-25)

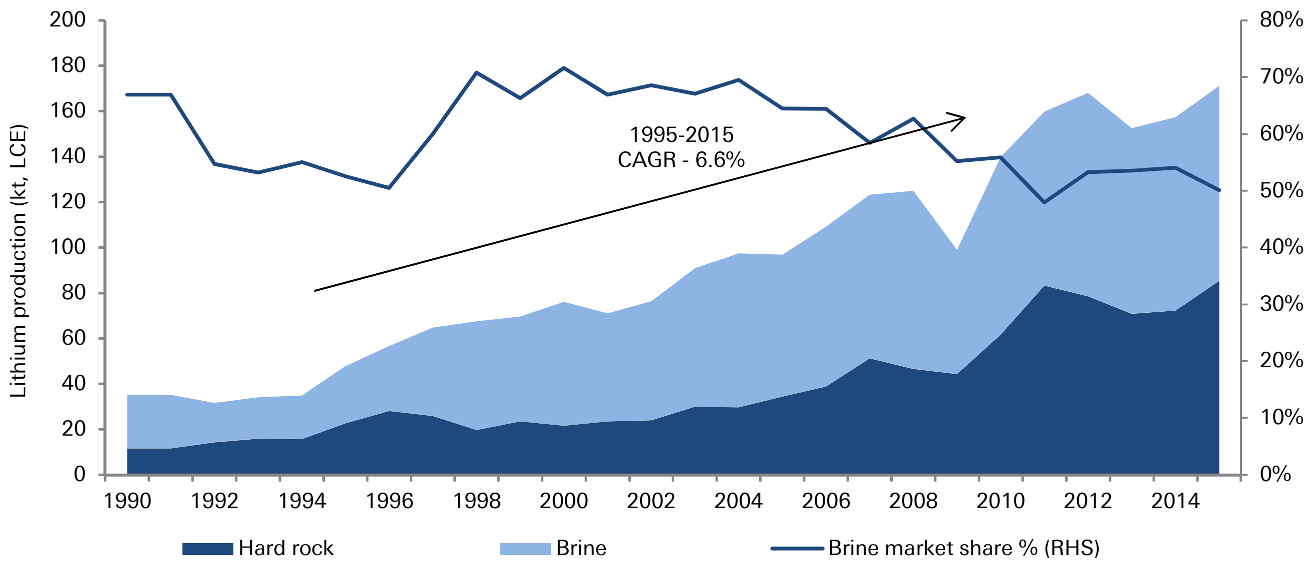


Source: Deutsche Bank; USGS; Company data

The current supply situation

The global supply market for lithium products is around 171kt of lithium carbonate equivalent (LCE), with close to 83% of global supply being sourced from four major producers – Albermarle, SQM, FMC and Sichuan Tianqi. We believe demand outpaced supply in 2015 by around 13kt LCE, leading to a significant increase in prices for high-grade lithium products over the last 6-12 months. However, there are a number of new operations entering the global market this year. We expect supply to increase by 18% this year to reach 201kt LCE, however this will still not meet global demand (DBe 209kt LCE).

Figure 149: Historical global lithium output – presented on a lithium carbonate equivalent basis



Source: USGS, Roskill

Capital intensity vs. operating margin

Lithium brine operations account for around 50% of global lithium supply, with hard-rock operations accounting for the remaining 50%. Lithium brine deposits generally have better economics as lithium is already isolated and in solution within the deposit, negating the requirement for drilling, blasting, crushing and physical separation. Brine operations also utilise solar evaporation to concentrate the brine within a series of ponds prior to purification. The downside of brine operations is that they are more capital intensive than hard-rock operations, incur significant lead times to meaningful production (technical and geographical challenges), require economies-of-scale and have a long resonance time influenced by evaporation rates.

ORE's Olaroz lithium brine project in Argentina is the first greenfields brine operation to be developed in 20 years. The 17.5ktpa LCE project had a final capital cost of US$280m to construct (US$16,000/t LCE capital intensity). It has taken five years for the Company to take the project from Definitive Feasibility Study stage to commercial production and the asset has been plagued by commissioning and design issues. However, once at full operating rates, ORE management expects operating costs to be below US$2,500/t LCE.

As global lithium demand increases over coming years, hard-rock operations will be able to respond to market conditions much faster than their brine counterparts. The Greenbushes mine in Australia (jointly-owned by Albemarle and Tianqi) is the world's largest spodumene operation and accounts for almost 40% of global lithium supply. New operations are also coming to market, with Mt. Marion and Mt. Caittlin currently being commissioned.

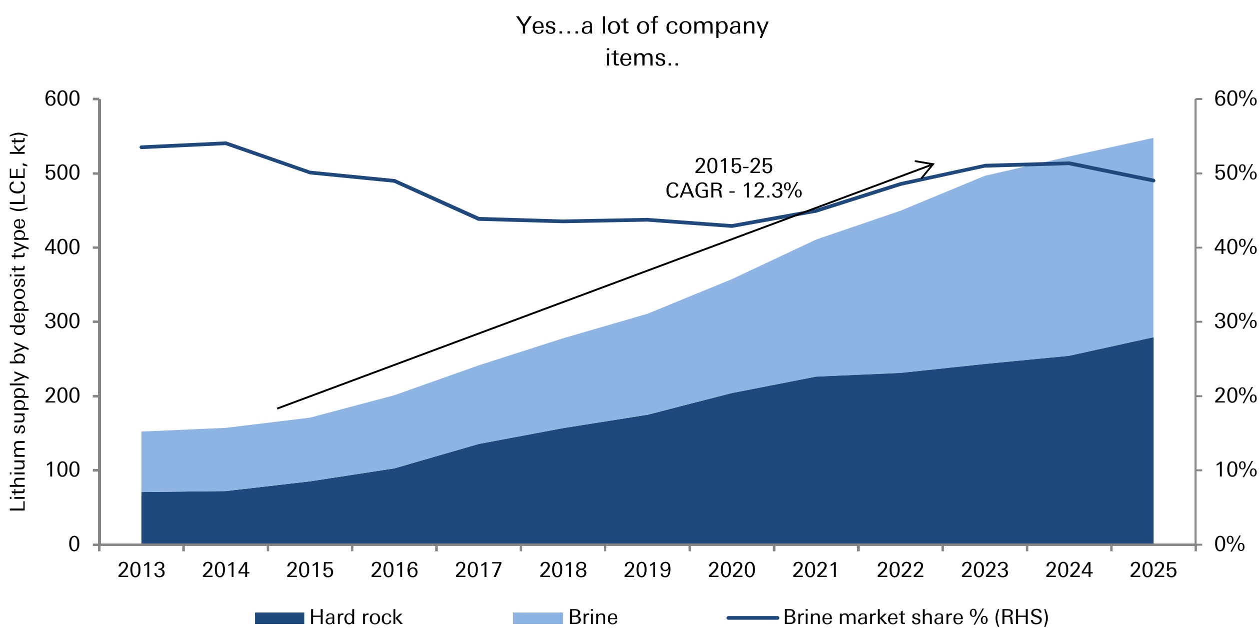
As a comparison, the Mt. Marion project (owned by a JV between Mineral Resources, Neometals and Jianxi Ganfeng) is being built for A$50m and will produce 200kt of 6% Li_2O spodumene concentrate, equivalent to 27kt LCE (US$1,400/t LCE) and will have a 12 month construction and ramp-up time frame. However, lithium concentrates are an intermediate product and need to undergo further refining into lithium carbonate or hydroxide before they can be used in batteries. We believe the capital intensity to build a lithium conversion plant is around US$10,000-12,000/t LCE outside of China and possibly as low as US$6,000/t LCE inside China for larger facilities. When including the downstream plants, hard-rock and brine sources are closer in capital intensity.

Figure 150: Comparison of salt lake brine and hard-rock minerals

	Salt Lake Brines	Hard Rock Minerals
Resource approachable	Abundant but low recoveries	Very few high-grade mines
High-technology required	Yes	No
Scalable	Yes	Yes
Processing time	Long	Short
Weather dependent	Yes	No
Capital intensity	High	Low
Operating costs	Low	High
As % of global lithium supply	50%	50%

Source: Deutsche Bank estimates

Figure 151: Global lithium output (2013-25) – presented on a lithium carbonate equivalent basis



Source: Deutsche Bank estimates

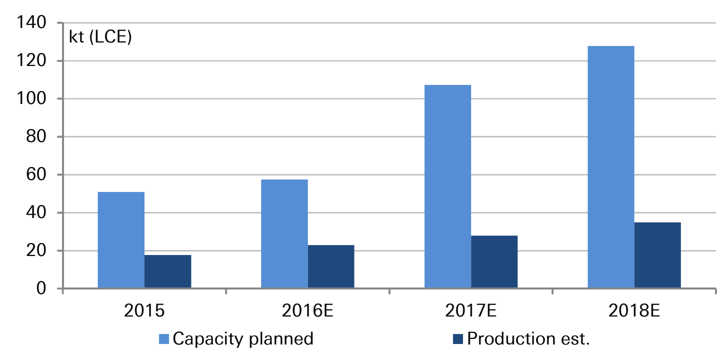
China lithium resources plentiful but hard to release

China has substantial lithium resources in the forms of brine, spodumene and lepidolite. China has salt lakes in Qinghai province, spodumene resources in mainly Xinjiang and Sichuan province and lepidolite in Jiangxi province. We estimate Chinese producers supplied 17.7kt LCE in 2015, among which, brine, spodumene and lepidolite contributed 30%, 50% and 20%, respectively.

We believe domestic supply will respond to increase lithium prices since the second half of 2015 by increasing capacity. However, we do not expect that Chinese producers will deliver expansions as suggested by the individual companies as technical difficulties are unlikely to be resolved quickly.

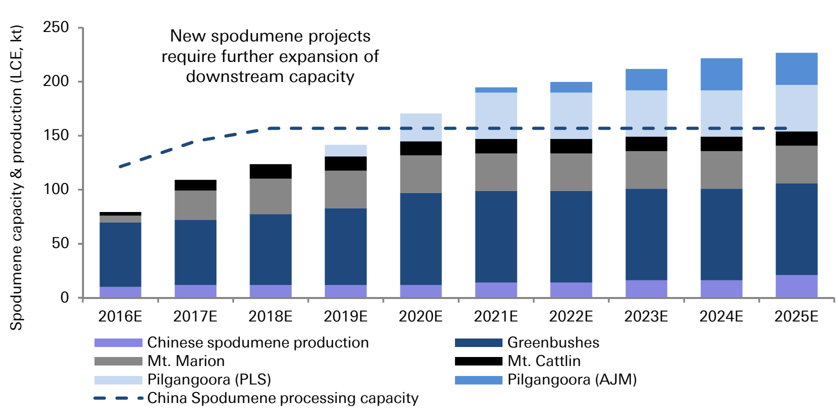
- For Chinese brine assets, immature technologies and harsh operating environments makes capacity ramp-up difficult.
- For spodumene producers, there are some low-grade, higher cost resources in Sichaun that are facing community issues which will affect expansion potential.
- For lepidolite producers, higher costs and limited usage of by-products may influence lepidolite processors' decisions on committing to aggressive expansion plans.

Figure 152: Expansion and production forecast for Chinese raw material



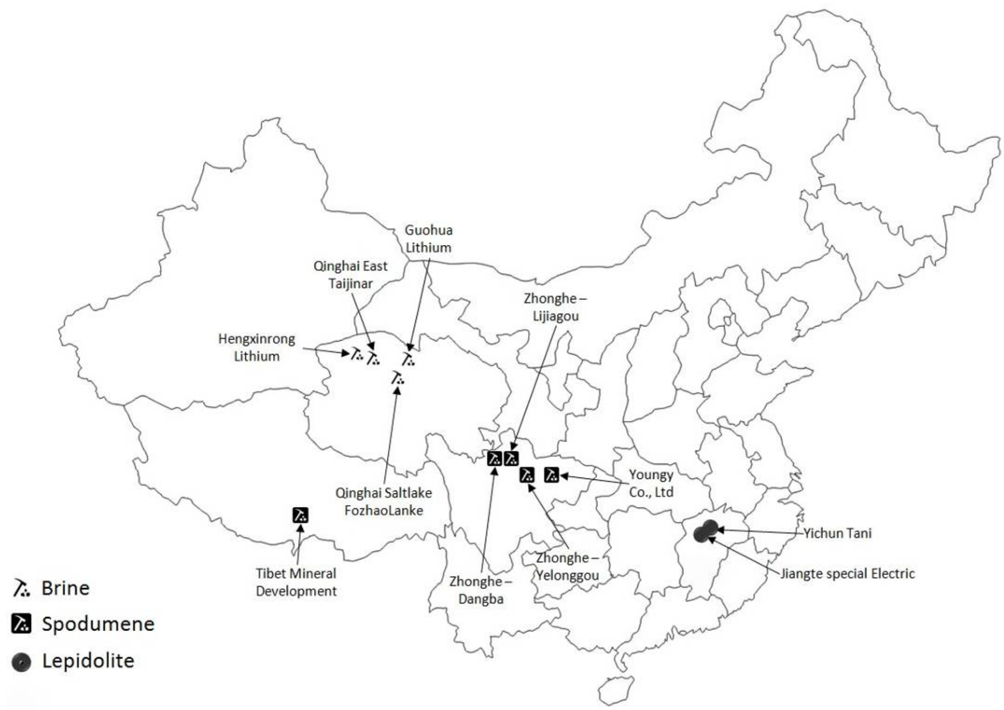
Source: Deutsche Bank estimated

Figure 153: China spodumene processing capacity v/s future production



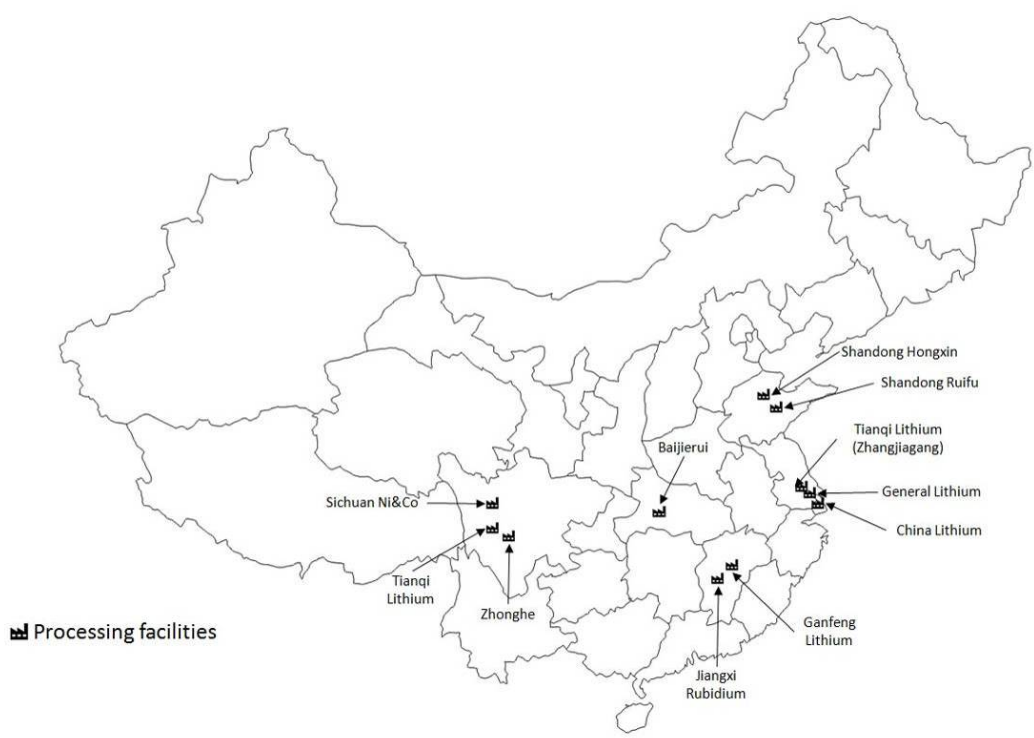
Source: Deutsche Bank estimates

Figure 154: Chinese lithium feedstock operations and major development projects



Source: Deutsche Bank

Figure 155: Chinese downstream lithium processing facilities in China



Source: Deutsche Bank

Figure 156: Summary of mine nameplate capacity outlook (capacity reported in LCE)

Companies' English Name	Companies' Chinese name	Assets' English name	Assets' Chinese name	Resource type	2015	2016E	2017E	2018E
					Capacity (LCE)			
China Minmetals Salt Lake	五矿盐湖	Yiliping Salt Lake	一里坪盐湖	Brine	10	10	10	10
Qinghai Saltlake Fozhao Lake Lithium	青海盐湖佛照蓝科锂业(盐湖股份)	Qarhan Salt Lake	察尔汗盐湖	Brine	10	10	40	40
Qinghai East Taijinar Lithium Resources	青海东台吉乃尔锂资源 (西部矿业)	East Taigener Salt Lake	东台吉乃尔盐湖	Brine	10	10	10	10
Qinghai Hengxinrong Lithium	青海恒信融锂业 (斯尔太/中信国安)	West Taigener Salt Lake	西台吉乃尔盐湖	Brine	2	2	18	18
Citic Guoan Information	青海中信国安	West Taigener Salt Lake	西台吉乃尔盐湖	Brine	0	0	0	0
Guohua Lithium	国华锂业	Da Chaidam Salt Lake	大柴旦盐湖	Brine	0.9	0.9	0.9	0.9
Tibet Urban Development	西藏城投	Jiezechaka & Longmucuo	结则茶卡&龙木措	Brine	0	0	0	0
Tibet Mineral Development	西藏矿业	Baiyin Zabuye	白银扎布耶	Spodumene mine	3	3	3	3
ZhongHe	众合股份				2.5	6	8	8
Maerkang	马尔康金鑫矿业 (100%)	Dangba	党坝乡锂辉石矿	Spodumene mine	2.5	6	8	8
Dexin	阿坝州德鑫矿业 (100%)	Lijiagou	李家沟锂辉石矿	Spodumene mine	1	1	1	1
Huamin	四川华闽 (100%)	Yelonggou	业隆沟锂多金属探矿及太阳河口锂多金属探矿权	Spodumene mine	0	0	0	0
Tianqi Lithium	天齐锂业	Yajiang Cuola	雅江县措拉锂辉石	Spodumene mine	0	0	0	0
Sichuan Ni&Co Guorun New Materials	尼科国润	Maerkang	马尔康锂辉石矿	Spodumene mine	0	0	0	0
Youngy Co., Ltd	融捷股份	Kangding Jiajika	康定呷基卡锂辉石矿	Spodumene mine	9.4	9.4	9.4	21.9
Jiangxi Special Electric	江特电机				2.2	4.0	5.7	6.3
Jiangxi Special Mining	江特矿业(100%)	Yifeng Shiziling	宜丰县狮子岭锂瓷石矿	Lepidolite mine	0.0	1.8	3.5	3.5
Xinfang	新坊钽铌 (51%)	Xinfang	新坊钽铌	Lepidolite mine	1.3	1.3	1.3	1.3
Juyuan	巨源矿业 (51%)	Hejiaping	何家坪高岭土矿	Lepidolite mine	0.6	0.6	0.6	0.6
Taichang	泰昌矿业 (100%)	Xuankuangchang	选矿厂 40 万吨	Lepidolite mine	0.3	0.3	0.3	0.8
Ganfeng Lithium	赣峰锂业	Heyuan	河源锂辉石矿/广昌县头坡里坑锂辉石	Spodumene mine	0.0	1.3	1.3	8.8
Yichun Tani	宜春钽铌矿 411	411 Formanite	411 钽铌矿	Lepidolite mine	1.0	1.0	1.0	1.0
Total company forecast					**52.0**	**58.5**	**108.2**	**128.8**
DB production estimate					**17.7**	**22.9**	**28.9**	**35.9**

Source: Deutsche Bank

Figure 157: Summary of processing nameplate capacity outlook (capacity reported in LCE)

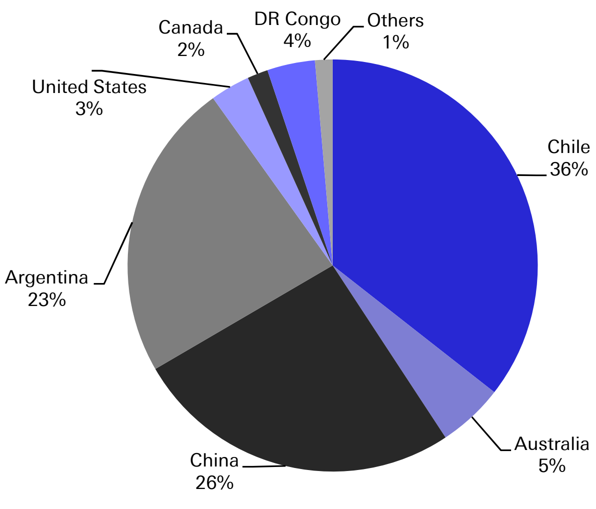
Companies' English Name	Companies' Chinese name	Assets' English name	Assets' Chinese name	Resource type	2015	2016E	2017E	2018E
					Capacity			
China Minmetals Salt Lake	五矿盐湖	Yiliping Salt Lake	一里坪盐湖	Brine	10	10	10	10
Qinghai Saltlake Fozhao Lake Lithium	青海盐湖佛照蓝科锂业(盐湖股份)	Qarhan Salt Lake	察尔汗盐湖	Brine	10	10	40	40
Qinghai East Taijinar Lithium Resources	青海东台吉乃尔锂资源 (西部矿业)	East Taigener Salt Lake	东台吉乃尔盐湖	Brine	10	10	10	10
Qinghai Hengxinrong Lithium	青海恒信融锂业 (斯尔太/中信国安)	West Taigener Salt Lake	西台吉乃尔盐湖	Brine	2	2	18	18
Citic Guoan Information	青海中信国安	West Taigener Salt Lake	西台吉乃尔盐湖	Brine	0	0	0	0
Guohua Lithium	国华锂业	Da Chaidam Salt Lake	大柴旦盐湖	Brine	0.87	0.87	0.87	0.87
Tibet Mineral Development	西藏矿业	Baiyin Zabuye	白银扎布耶	Spodumene	3	3	3	3
ZhongHe	众合股份							
Sichuan Guoli	四川国锂(100%)							
Hengding	恒鼎锂盐			Spodumene processing	6	6	6	6
Sichuan Xingcheng	四川兴晟 (100%)			Spodumene processing	6	6	6	6
Tianqi Lithium	天齐锂业							
Shehong base	射洪基地			Spodumene processing	16	16	16	38
Zhangjiagang base	张家港基地			Spodumene processing	17	17	17	17
Sichuan Ni&Co Guorun New Materials	尼科国润			Spodumene processing	8	8	8	8
Youngy Co., Ltd	融捷股份							
Sichuan Luxiang	四川路翔锂业			Spodumene processing	0	0	10	22
Jiangxi Special Electric	江特电机							
Jiangxi Special mining	江特矿业(100%)							
Jiangxi Yinli New Energy	宜春银锂 (99%)			Lepidolite processing	1.5	1.5	4	8
Ganfeng Lithium	赣峰锂业			Brine processing	7	7	7	7
				Spodumene processing	23	30	30	30
Jiangxi Hzong	江西合纵			Lepidolite processing	1	1	10	10
Jiangxi Rubidium	江西东鹏			Lepidolite processing	6	6	10.88	10.88
Shandong Ruifu Lithium	山东瑞福锂业			Spodumene processing	5	5	5	5
Shandong Hongxin	山东宏鑫锂业			Spodumene processing	6	6	6	6
Baijierui Advanced Materials	湖北百吉瑞			Spodumene processing	3.42	3.42	10.88	10.88
General Lithium, Palith	海门容汇通用锂业有限公司			Spodumene processing	6	6	12	12
China Lithium	上海中锂实业有限公司			spodumene processing	8	8	8	8
Xinjiang Xinjing Lithium Development	新疆昊鑫锂盐开发有限公司			Spodumene processing	7	7	7	7
Brine capacity					**40**	**40**	**86**	**86**
Spodumene capacity					**114**	**121**	**145**	**179**
Lepidolite capacity					**8.5**	**8.5**	**25**	**29**
Total processing capacity					**163**	**170**	**256**	**294**

Source: Deutsche Bank estimates

Global resources/reserves

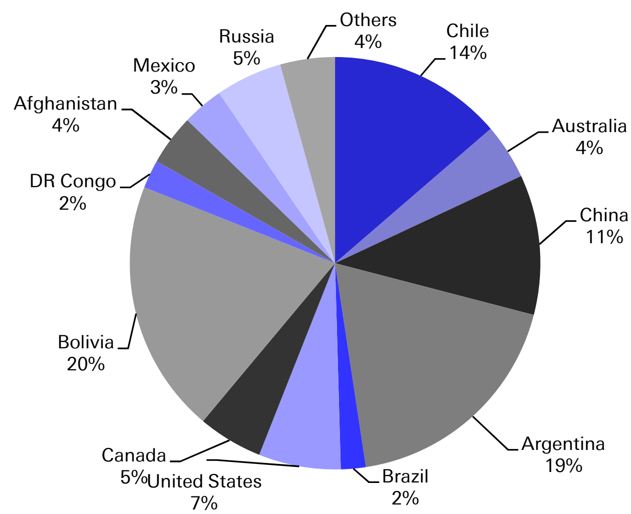
Two-thirds of the world's lithium reserves are found in Chile (the world's largest lithium producer), Bolivia and Argentina, in what is known as the 'Lithium Triangle'. Bolivia has a number of large lithium salar deposits that have high Mg:Li ratios, making processing and lithium extraction uneconomic.

Figure 158: Global lithium reserves – 102Mt LCE



Source: Deutsche Bank; USGS; Company data

Figure 159: Global lithium reserves – 273Mt LCE



Source: Deutsche Bank; USGS; Company data

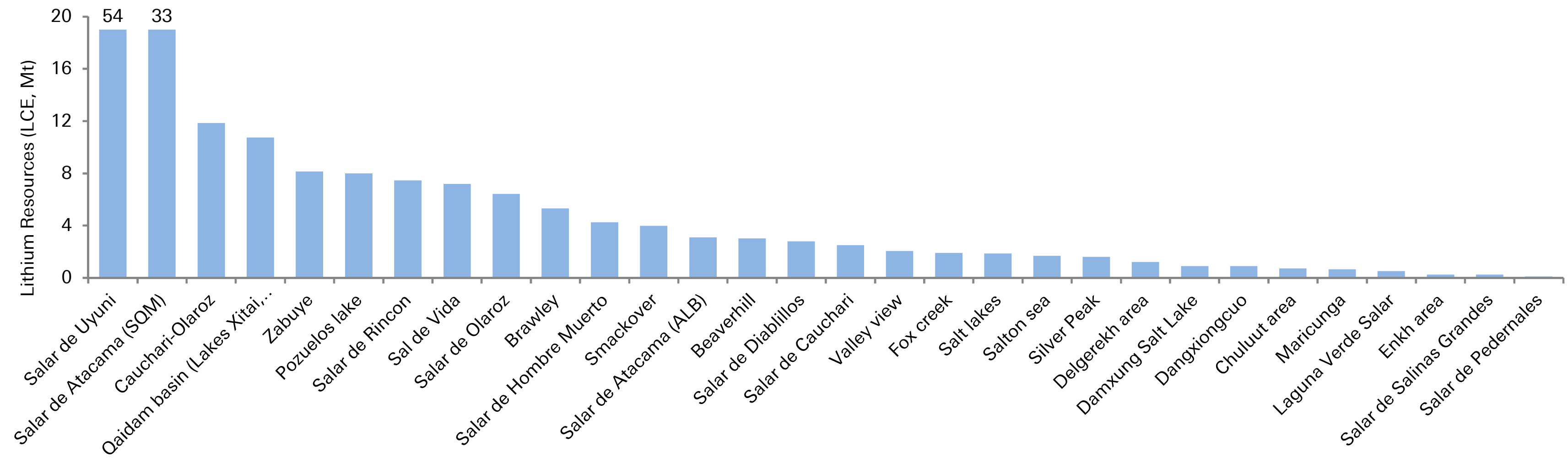
Lithium brine operations are found within the 'Lithium Triangle', the United States and China while hard-rock lithium deposits are generally mined in Australia, China, Brazil and some African countries.

Figure 160: 2015 production, reserves and resources by country –

	Production (2015)		Reserves		Resources	
	Kt	%age of Global	Mt	%age of Global	Mt	%age of Global
Argentina	19	11%	24	23%	51	19%
Australia	57	33%	5.3	5.2%	12	4.3%
Bolivia	0.0	0.0%	0.0	0.0%	54	20%
Brazil	2.1	1.2%	0.5	0.5%	5.3	2.0%
Canada	0.0	0.0%	1.7	1.6%	14	5.1%
Chile	63	37%	36	36%	37	14%
China	18	10%	26	26%	30	11%
DR Congo	0.0	0.0%	3.8	3.8%	6.1	2.2%
Mexico	0.0	0.0%	0.0	0.0%	8.9	3.2%
Portugal	3.0	1.8%	0.0	0.0%	0.1	0.0%
Russia	0.0	0.0%	0.0	0.0%	14	5.2%
Serbia	0.0	0.0%	0.0	0.0%	5.6	2.0%
Zimbabwe	5.3	3.1%	0.8	0.8%	1.7	0.6%
United States	4.5	2.6%	3.2	3.1%	18	6.5%
Others	0.0	0.0%	0.1	0.1%	15	5.6%
World total	**171**	**100%**	**102**	**100%**	**273**	**100%**

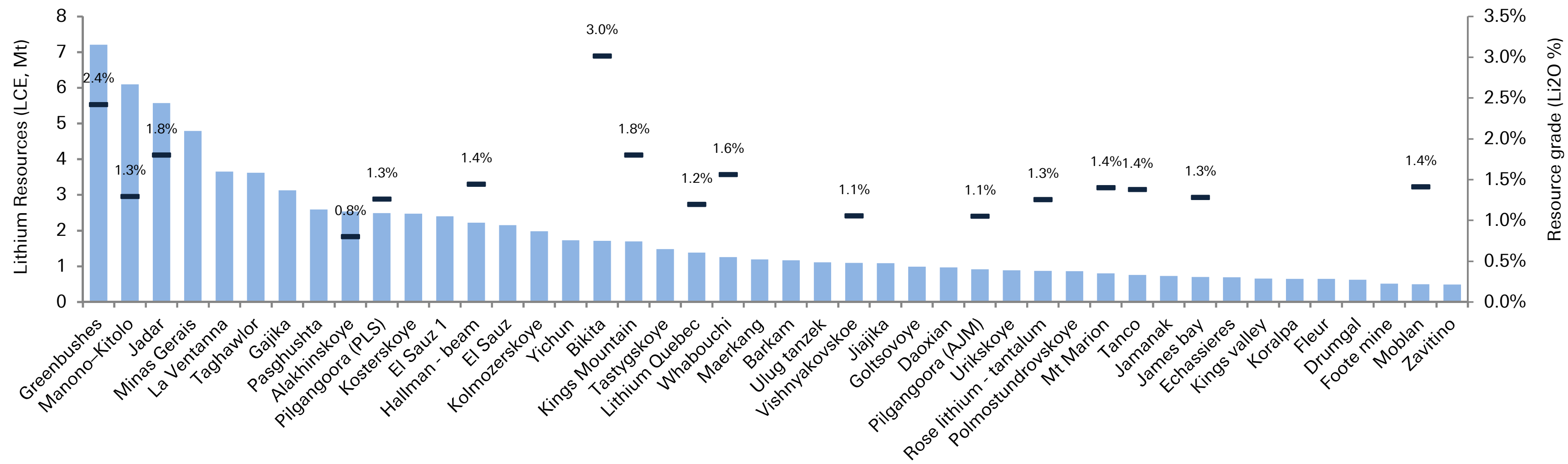
Source: Deutsche Bank, USGS

Figure 161: Lithium resources of global brine deposits



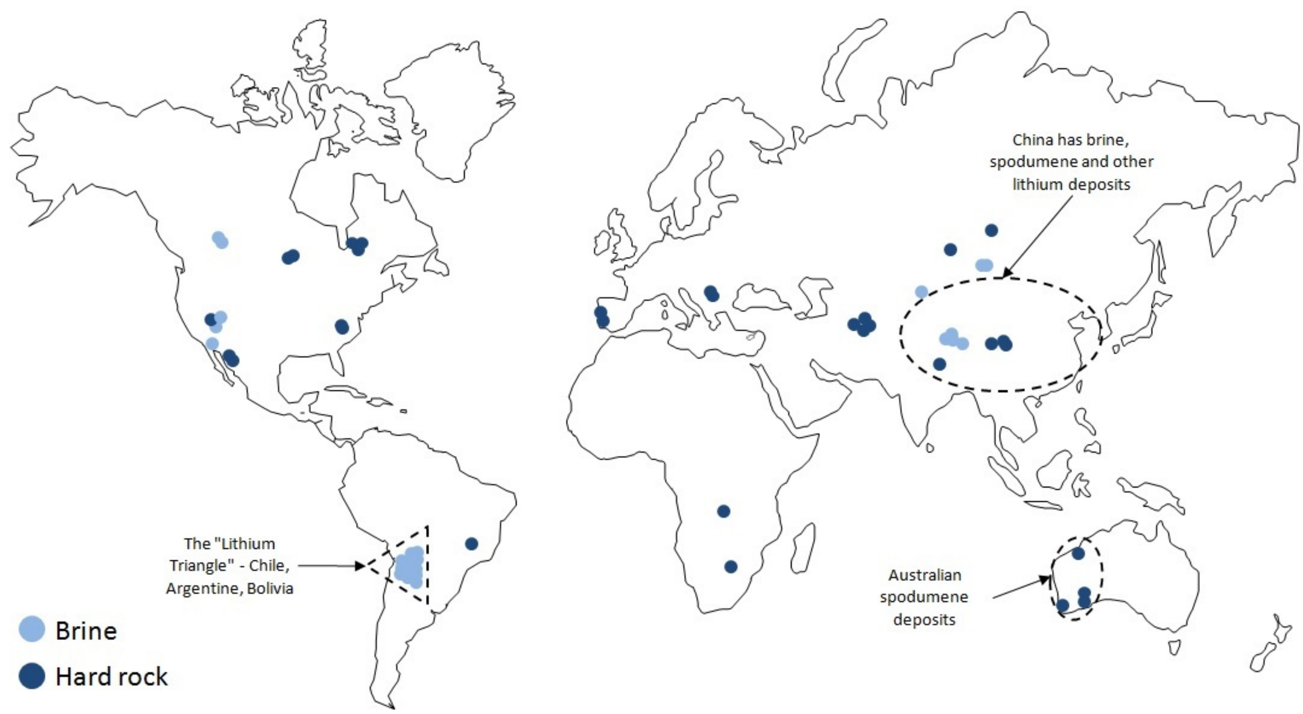
Source: Deutsche Bank, industry data, company data

Figure 162: Lithium resources of global hard-rock deposits



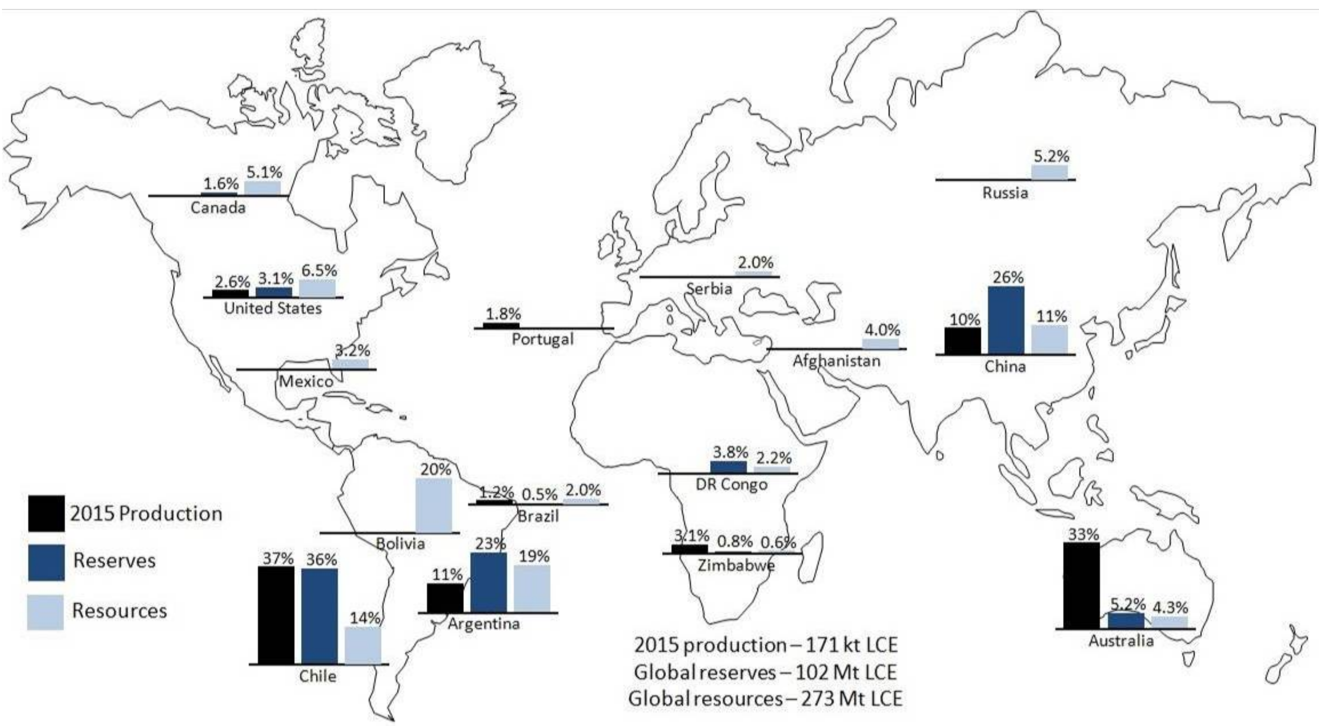
Source: Deutsche Bank, industry data, company data

Figure 163: Lithium deposits around the world (by deposit type)



Source: Deutsche Bank; Company data; USGS

Figure 164: Global lithium production (2015), reserves and resources (by country)



Source: Deutsche Bank; Company data; USGS

Lithium geology

Brine deposits

Brine resources are mainly found in South American countries – Chile, Argentina and Bolivia (in an area known as the "Lithium Triangle"). There are brine deposits found in the United States and in China, however these are lower quality deposits. Brine-based operations have historically produced large quantities of potash as a bi-product which has helped with project economics during periods of low lithium pricing.

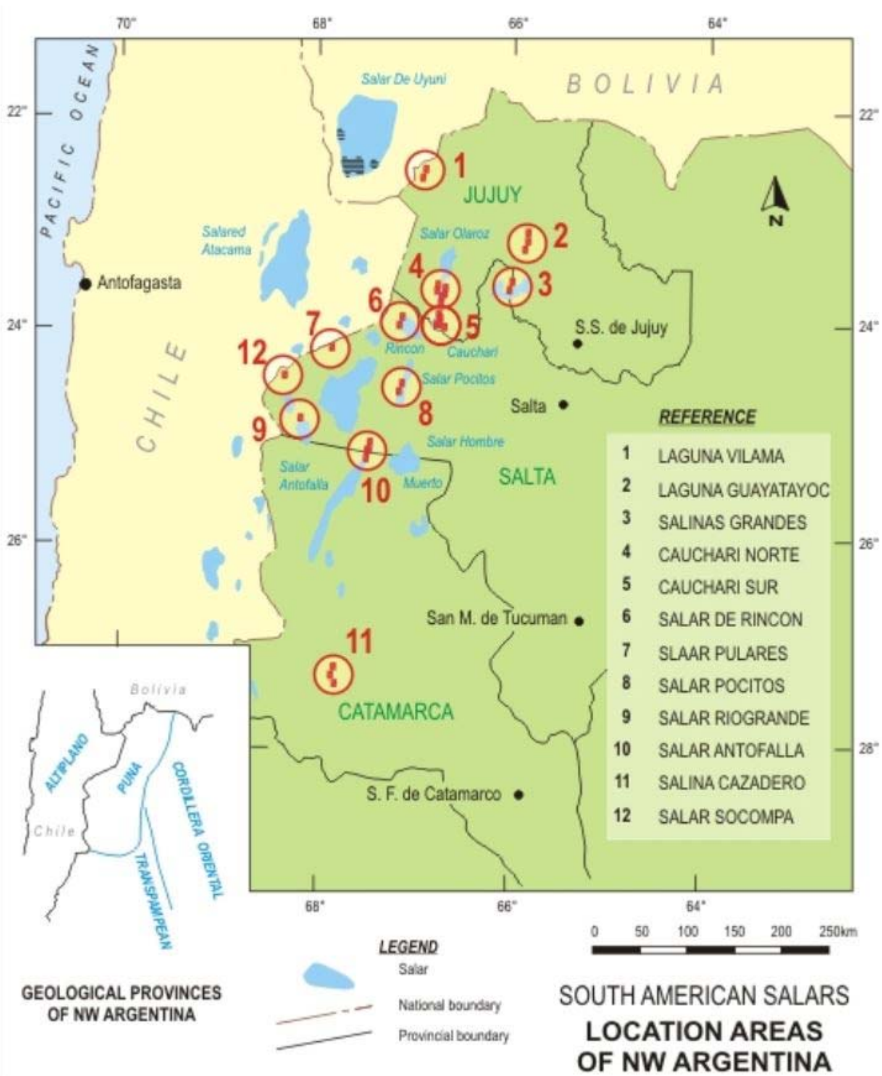
The major brine-based projects in the world are SQM's Salar de Atacama/Salar del Carmen operations in Chile, FMC's Salar del Hombre Muerto in Argentina, Albemarle's Salar de Atacama asset in Chile and its Silver Peak operations in the United States and Orocobre's Salar de Olaroz Lithium Project in Argentina.

Figure 165: Major brine deposits

Asset name	Owner
Argentina	
Salar de Hombre Muerto	FMC
Salar de Olaroz	Orocobre, TTC, JEMSE
Cauchari-Olaroz	Lithium Americas, SQM
Salar de Rincon	Enirgi group
Sal de Vida	Galaxy resources
Chile	
Salar de Atacama	Albemarle
Salar de Atacama	SQM
China	
Zabuye	Tibet mineral
Qaidam basin	Qinghai Salt Lake

Source: Deutsche Bank; company data

Figure 166: Brine deposits located in the "Lithium Triangle"



Source: Orocobre

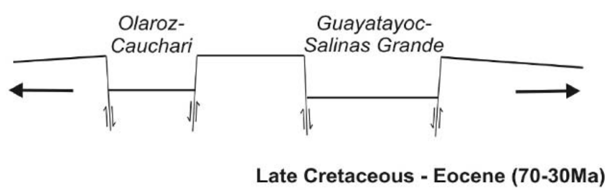
There are some inherent challenges in brine processing; there are different technologies used around the world which have a big influence on operating costs. Other major challenges that the companies face are 1) high Mg/Li ratio, 2) weather, and 3) lack of infrastructure, among others. For example, Bolivia is still unable to develop its brine deposits economically because of the high Mg/Li ratio, despite Salar de Uyuni being the world's largest lithium resource.

South American salar deposits formed along with the Andes mountain range, which sits along the western coast of South America and forms most of the border between Argentina and Chile. The Andes belt formed 150 million years ago through uplifting, faulting and folding events associated with two major tectonic plates being pushed against each other, forming a subduction zone.

From c.70 million years ago, tectonic activity increased to the west of what is now referred to as the Puna basins. This led to extensional tectonic forces, and N-S trending fault lines creating "block" formations (Figure 167). The depressed crustal blocks are known as 'grabens' and the highland areas are commonly referred to as 'horsts'.

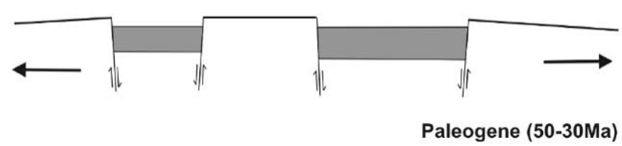
The rapid change in topography accelerated erosional forces and the Puna basins filled with coarse-grained continental sediment over a relatively short space of time (Figure 168).

Figure 167: Initial extension creates basin formations



Source: Orocobre Olaroz Lithium project NI43-101 technical report, 2011

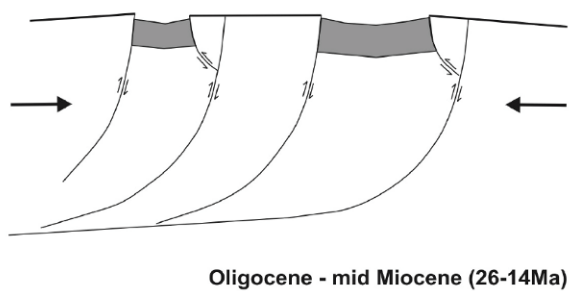
Figure 168: Basin infill by coarse gravels over time



Source: Orocobre Olaroz Lithium project NI43-101 technical report, 2011

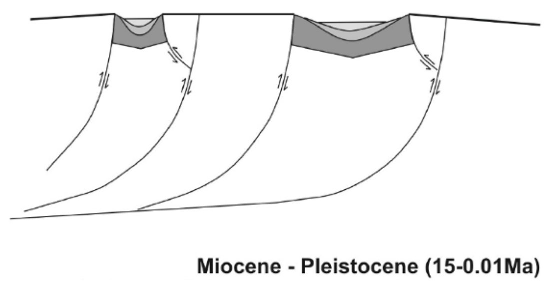
- A change in tectonic activity occurred 25 million years ago, with compressional forces and reverse faulting driving an uplift in the mountain ranges, isolating the Puna basins and creating secondary depressions (Figure 169).
- With major ranges bounding the Puna region to the east and west, these watersheds acted as internal drainages in the area, increasing sedimentation and initiating a second phase of basal fill (Figure 170).

Figure 169: Compression warps basin sediment



Source: Orocobre Olaroz Lithium project NI43-101 technical report, 2011

Figure 170: Two-stage basin infill; salar deposits form



Source: Orocobre Olaroz Lithium project NI43-101 technical report, 2011

In the last 5 million years, the Puna region saw a reduction in tectonic activity and a fluctuating climate regime of alternating periods of dry and severe wet conditions. The frequent aridity and a limited amount of sediment relocation (due to the accommodation space of the basins being filled), restricted erosion despite the water run-off continuing to move freely.

Surface and underground water movement allowed dissolved solids to concentrate in the low-lying basins and the relatively-young sediment beds. With evaporation the only outlet, these fluids became mineral rich, leading to the lithium-potassium-boron rich brine deposits seen today.

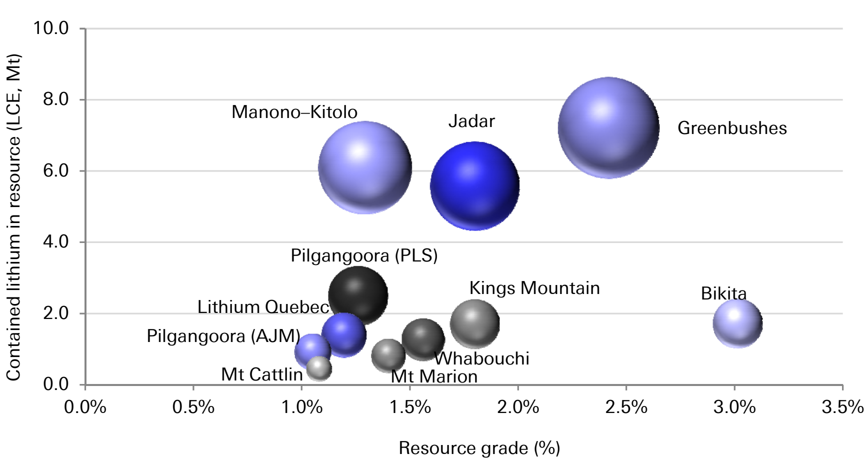
Being fluid deposits, there are some unique aspects to the mineral resource reported at these salar projects;

- The mineral-rich brine has a higher density than groundwater (1.2 vs. 1), and as a result sits at the base of the salar basin.
- Grade variability of the brine is relatively low, and extraction from the different pumping wells reduces in-situ variability.
- As pumping extracts the lithium brine, fresh water from the margins will fill the void left by the brine.
- The brine and water do not mix favourably, however some dilution is possible on the periphery of the resource as it is depleted.
- Although there is a seasonal skew in evaporation rates, the large size of the evaporation and concentrating ponds used at these assets ensure relatively steady production rates throughout the year.

Spodumene

Hard-rock spodumene deposits are found within pegmatite intrusions around the world. Pegmatites are an intrusive igneous rock composed of large (>2.5cm) crystals; they are very hard ores that require significant crushing and grinding. Pegmatite-based lithium deposits are mined in Australia, China, Brazil, Portugal and Zimbabwe. The largest hard-rock project in the world is the Greenbushes asset owned by Sichuan Tianqi (51%) and Albemarle (49%).

Figure 172: Comparison of major Spodumene mines



*Bubble size represent contained lithium in lithium carbonate equivalent terms
Source: Deutsche Bank, industry data, company data

Figure 171: Major spodumene mines

Asset name	Owner
Australia	
Greenbushes	Albemarle; Sichuan Tianqi
Mt Cattlin	Galaxy resources
Mt Marion	Neometals; Mineral resources; Ganfeng
Pilgangoora (AJM)	Altura mining
Pilgangoora (PLS)	Pilbara minerals
Canada	
Whabouchi	Nemaska Lithium
Lithium Quebec	Canada lithium corp
DR Congo	
Manono–Kitolo	
Serbia	
Jadar	Rio tinto
USA	
Kings Mountain	Albemarle
Zimbabwe	
Bikita	Bikita minerals inc.

Source: Deutsche Bank; company data

Spodumene ores are crushed grinded and liberated into a 6% Li_2O concentrate that can be used in industrial markets or converted downstream into battery-grade products. High-grade (7.5% Li_2O), low-iron (less than 0.1% Fe_2O_3) spodumene concentrates are known as technical grade concentrate and can be directly used by downstream "technical markets" users, including glass, ceramics, fiberglass and continuous casting without further processing into lithium carbonate.

Other mineral deposits

Lithium is also found in economic levels in petalite (extracted at the Bikita mine in Zimbabwe), lepidolite (a number of mines in China) and hectorite (deposits identified the United States, Mexico and Morocco).

With the recent lithium feedstock shortage in China, a number of low-grade, high cost deposits have been restarted to sell to downstream processors. We believe non-spodumene hard-rock supply will be 5-10ktpa LCE in 2016 and do not foresee other minerals gaining significant market share as most current exploration is focussed on spodumene deposits.

Figure 173: Spodumene ore

Source: Pilbara Minerals

Figure 174: Spodumene outcropping at surface

Source: Galaxy Resources (James Bay project, Canada)

Figure 175: Lepidolite – another pegmatite-based mineral

Source: New World Encyclopedia

Figure 176: Hectorite – a lithium-clay mineral

Source: Western Lithium

Politics of lithium supply

Chile

The Chilean Government created the Chilean Nuclear Energy Commission (CCHEN) in 1965 and declared lithium as a "material of nuclear interest", meaning lithium extraction could not occur without CCHEN approval. In 1979 the government reserved all lithium interests except previously existing rights.

- In 1975, Foote Minerals and CORFO (Chile's government-owned industrial development agency) created Sociedad Chilena del Litio (SCL) for the development of the Salar de Atacama brine resource. SCL started production at Salar de Atacama in 1984. The company was sold to Cyprus, then Chemetall, then Rockwood over the following decades. Albemarle acquired the business in early 2015 following its acquisition of Rockwood.
- In 1986, CORFO, Amax and Molymet formed Minsal S.A., a company created to also extract minerals from the Salar de Atacama brines. Ownership was transferred to SQM in 1993 and the operations were producing lithium carbonate by 1996.

Both Albemarle and SQM has sought to increase lithium output in recent years, however increases to their production quotas were not being approved. SQM is currently in arbitration with the Chilean government about lithium rights and permits. ALB recently announced an MoU with the government to allow ALB to increase from 25ktpa to 70ktpa, through the commissioning of a second lithium carbonate plant (La Negra) and a third operation (in conjunction with the government) which should be in operation by 2021. Both CORFO and Codelco have lithium brine tenements which could be developed over time.

Argentina

November 2015 elections in Argentina resulted in the centre-right PRO political party assuming power following 12 years of government controlled by the centre-left FPV party. Within the first two months, the new administration relinquished control of US dollars in-country, allowing the peso to free-float which led to a 40% devaluation of the peso in late 2015/early 2016. This helps local lithium producers by lowering USD reported costs as well as freeing up borrowing capacity on debt facilities that are secured against US dollars. A 5% export duty on value-added lithium carbonate has also been removed and import restrictions have been loosened which should help procurement of consumables and equipment.

Bolivia

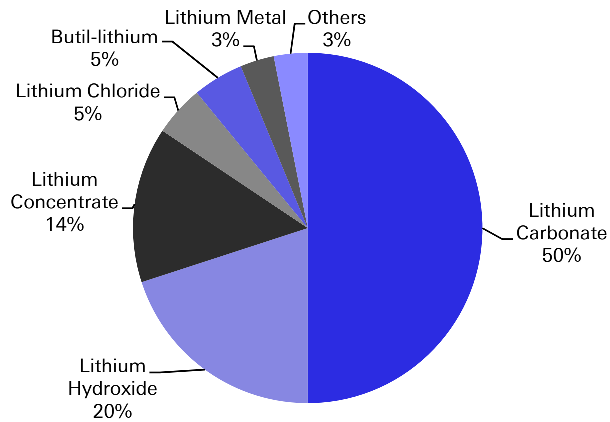
Bolivia hosts the world's largest lithium brine resource, Salar de Uyuni (54Mt LCE), however the deposit has a magnesium:lithium ratio of 19:1, making it uneconomic up until now. The Bolivian government has stated that it intends to start lithium production at Salar de Uyuni from late 2018. The design contract has been awarded to German industrial salts firm K-Utec, with construction of a 50ktpa lithium carbonate plant planned to be finished by April 2018. The government has invested US$250m into its US$900m lithium program since 2008, including a pilot plant at Uyuni in 2014. We do not include Salar de Uyuni in our global supply & demand analysis and will review the progress of the Uyuni project. A development of Uyuni would require a significant production of potash which may help lithium production economics (as a by-product credit) but may increase technical and market risk.

Lithium products

The two most common lithium products used in batteries are high-grade lithium carbonate and lithium hydroxide.

Lithium is sold in a number of forms. Lithium carbonate (Li_2CO_3) is the largest lithium product market based on volumes sold, accounting for 90kt LCE, or around 50%, of global lithium sales in 2015. The second major lithium product is lithium hydroxide (LiOH) which makes up 20% of product sales, followed by technical grade lithium concentrate (Li_2O), which is used in glass and ceramics and accounts for 14% of global lithium sales. A number of other lithium compounds (lithium chloride, butyl-lithium etc.) are used in industrial markets and make up around 13% of global supply.

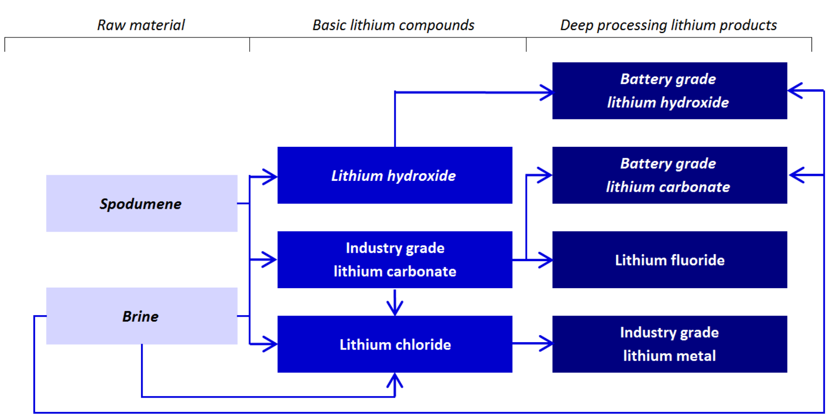
Figure 177: 2015 global lithium product market – split by product



Source: Deutsche Bank, industry data

The major lithium products are industry-grade lithium carbonate, industry-grade lithium hydroxide, and lithium chloride from either a salt lake brine deposit or a lithium concentrate from a hard rock mineral deposit. Further processing is needed to produce value-added lithium products like battery-grade lithium carbonate/hydroxide, lithium metals and lithium fluoride.

Figure 178: Lithium product processing paths



Source: Deutsche Bank, Company data

How to compare different lithium products

The most common unit of measurement when referring to the size of the lithium market is "Lithium Carbonate Equivalent" or "LCE". The size of the lithium market in 2015 was 184kt LCE, however some industry participants refer to the size of the lithium market on contained metal terms (around 34kt in 2015). While the market is measured on an 'end-product' basis, there are multiple paths to end-markets. Around 50% of lithium feedstock supply is from lithium brines (lithium in solution), 45% is from hard-rock spodumene ores, while other lithium minerals account for 5-10%. The conversion factors to translate volumes to an LCE basis are shown below.

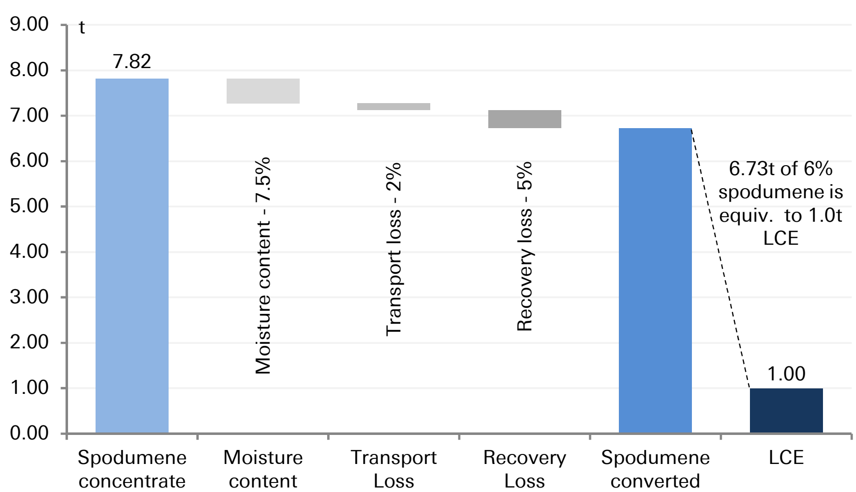
Figure 179: Lithium compound conversion factors

	Formula	Li	Li_2O	Li_2CO_3
Lithium metal	Li	1.000	2.152	5.322
Lithium carbonate	Li_2CO_3	0.188	0.404	1.000
Lithium oxide	Li_2O	0.465	1.000	2.473
Lithium hydroxide	LiOH	0.290	0.624	1.542
Spodumene	$LiAlSi_2O_6$	0.037	0.080	0.199
Petalite	$LiAlSi_4O_{10}$	0.023	0.049	0.121
Lepidolite	$KLi_2AlSi_3O_{10}(OH,F)_2$	0.019	0.041	0.102
Lithium chloride	LiCl	0.164	0.352	0.871
Lithium bromide	LiBr	0.080	0.172	0.425
Butyllithium	C_4H_9Li	0.108	0.233	0.577

Source: Deutsche Bank, industry data

Figure 180 shows the basic calculation to convert one tonne of 6% spodumene concentrate to an LCE unit. Beyond the imperial conversion, the industry standard is to include some conversion and transport losses in the calculation.

Figure 180: Converting spodumene to Lithium Carbonate Equivalent



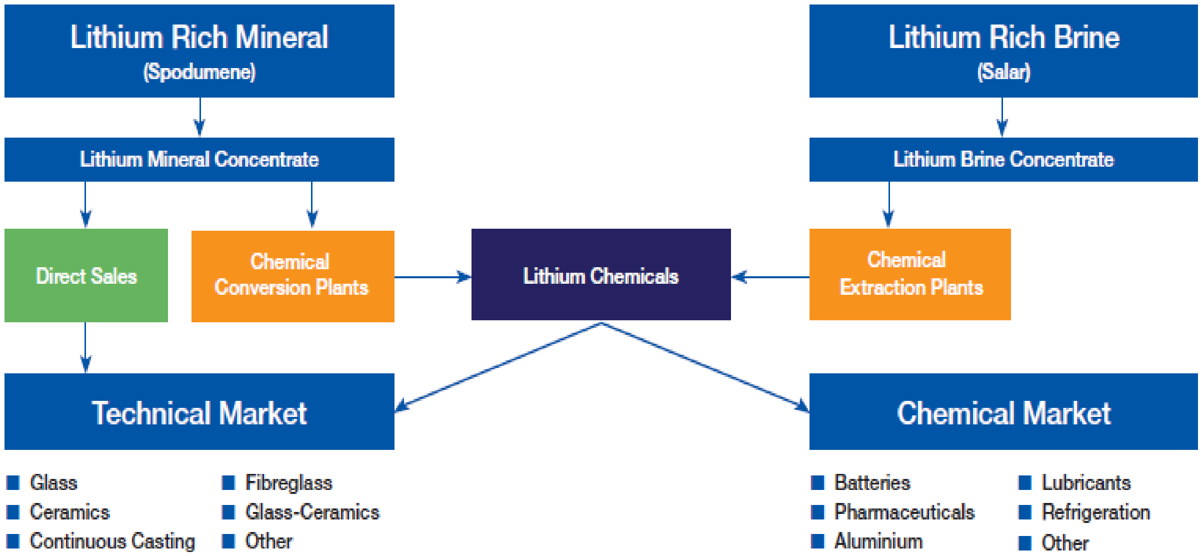
Source: Deutsche Bank, industry data

Lithium carbonate is a common basic lithium compound product and is widely accepted by downstream users. Lithium hydroxide has been increasing its share of middle-stream usage since 2015 due to the increasing popularity of the NMC/NCA battery chemistries.

Lithium compound products can vary in terms of purity based on the requirements of various end-applications. Industry-grade lithium carbonate generally has a purity rate of 98.5-99% LCE, while battery-grade lithium carbonate has a rate of above 99.5% LCE. Higher-purity compound products realise a price premium to reflect higher production costs, process technology IP and value-in-use. Concentrations of other impurities (magnesium, calcium, iron, phosphorous etc.) can also affect pricing. Some companies operating high-quality brine operations can produce battery-grade lithium compounds directly from their brine processing plants.

Brine-based and hard-rock mineral-based lithium operations have both advantages and disadvantages. In simple terms, hard-rock mineral operations have higher operating costs but lower capital costs and can respond more quickly to market conditions. Also, hard-rock mining operations are generally less affected by external factors like weather (impacts evaporation).

Figure 181:Lithium source, type and end users



Source:, Talison Lithium

Brine processing

Brine-based operations extract lithium brine from a salar (salt-lake) deposit via a series of pumping wells. The brine is stored in a large pond system over a 9-12 month period where lime is added (to precipitate impurities); evaporation occurs and the brine is concentrated for processing. Processing plant configurations can vary by asset; a standardized flow sheet is shown below.

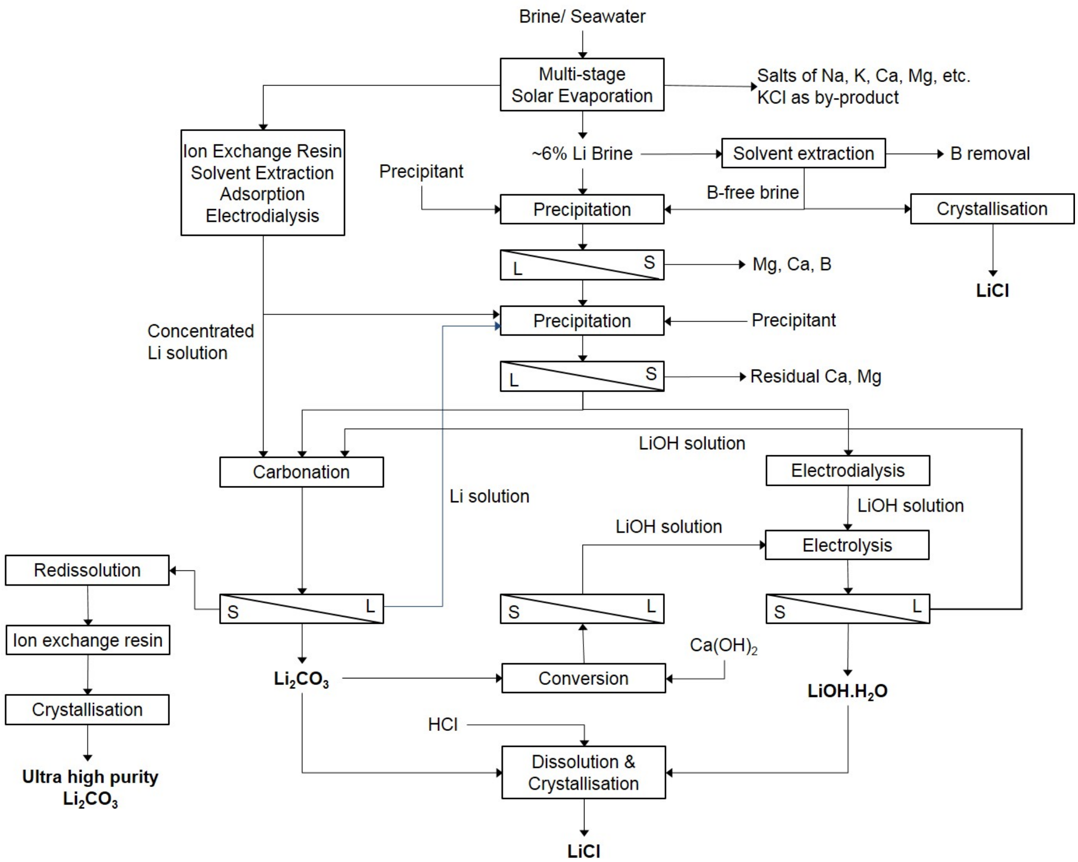
Figure 182: ALB's Salar de Atacama operation

Source: Albemarle

Figure 183: ORE's Olaroz pond system (being filled)

Source: Orocobre

Figure 184: Process flow diagram of a typical brine processing operation



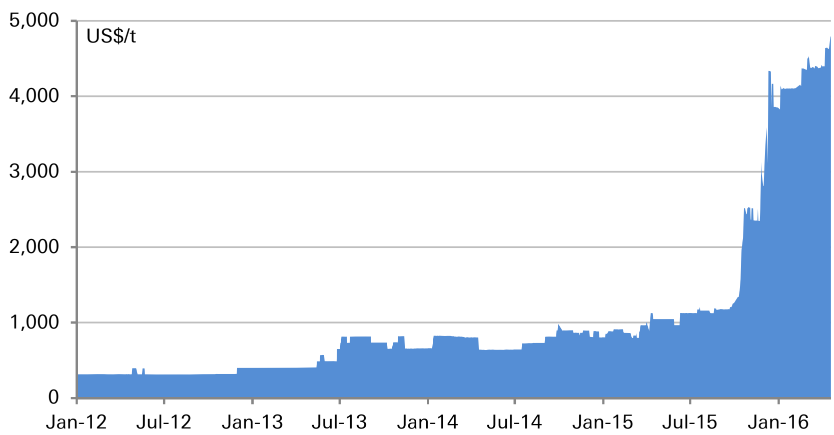
Source: 'Lithium Process Chemistry', 2015 Changes, Swiaowska

Industry grade lithium carbonate to battery grade lithium carbonate

Historically, most high-grade (+99.5% LCE) lithium carbonate products have been produced through purification of hard-rock lithium concentrate, a market dominated by China. Downstream processing of industry-grade (98-99% LCE) lithium carbonate into a higher-quality battery-grade lithium carbonate has not been a major supply route; this is mainly due to the cost of further refining exceeding the price premium between the two carbonate products.

In recent years, the battery-grade lithium carbonate price has traded at a c.US$500-800/t premium to industry-grade carbonate, below the estimated US$1,000-1,200/t LCE conversion costs incurred to upgrade the carbonate product. It is important to note that the battery-grade price premium has widened considerably over the last 6-12 months as battery-grade lithium products have been in strong demand in China. While this price premium remains, this new supply route will be a viable option for downstream lithium processors to capture the margin. ORE has confirmed it has sold lower-quality lithium carbonate to Chinese customers at above-market prices; this carbonate is likely being refined in China and sold into battery-grade markets.

Figure 185: Price premium of industry-grade LC over battery-grade LC



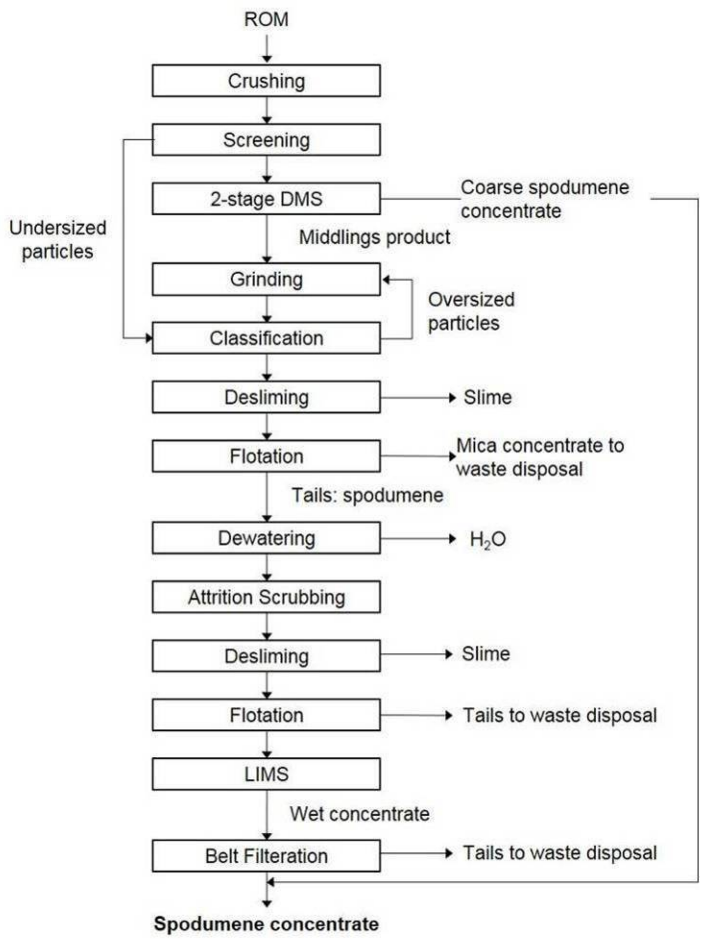
Source: Deutsche Bank; Wind

Spodumene processing

The processing route for hard-rock lithium ores follows a more conventional mining and processing approach, similar to many other hard-rock mining operations. Ore is mined via conventional drill and blast methods, then excavated and trucked to a central processing facility. The ore undergoes multiple stages of crushing to reduce the particle size down to below 6mm.

Lithium-bearing minerals like spodumene can be liberated from gangue minerals via dense media separation using either spirals and/or cyclones to separate particles based on density. Based on the individual deposits, some ores need to be further processed to liberate the lithium from other minerals, like micaceous minerals, which can be entrained with lithium in the crystal structure. To do this, floation is used, floating the lithium-bearing minerals and suppressing the gangue minerals. Further magnetic separation can be used to remove magnetite. The wet concentrate is filtered and prepared for transportation as a 6% Li_2O concentrate.

Figure 186: Process flow diagram to produce lithium concentrate



Source: 'Lithium Process Chemistry', 2015 Chagnes, Swiaowska

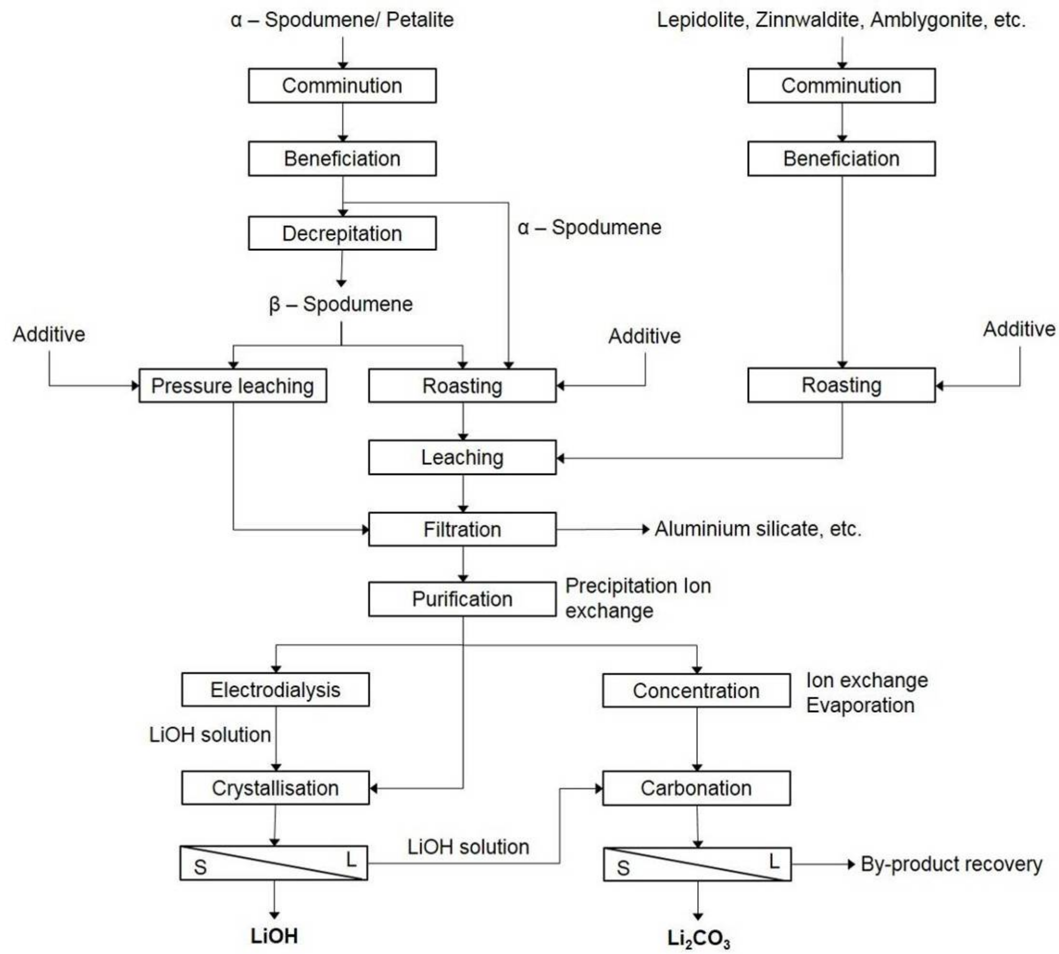
Downstream lithium concentrate processing

Intermediate lithium concentrates need to be further refined into higher purity lithium products before they can be used in the battery supply chain. The lithium concentrates are transported to conversion plants, most of which are located in China. These conversion plants are normally configured to accept one type of concentrate and designed for a specific particle size (coarse-grained of fine grained concentrates), however spodumene conversion plants have been known to be reconfigured to process lepidolite concentrates.

Lithium concentrates undergo communition to further reduce particle size and are then decrepitated and/or roasted using various acids and then leaching to produce lithium sulfate or chloride in solution. The lithium fluids are then purified using hydroxide precipitation to remove impurities like aluminium, iron, calcium etc. Ion exchange is the next step in the purification process before a battery grade (99.5%) lithium carbonate is produced by carbonation at 80-100°C using sodium carbonate (Na_2CO_3). To reach higher levels of purity, the lithium carbonate can be redissolved into water using CO_2 (to form lithium bicarbonate liquor) and is then passed through another phase of ion exchange to remove impurities trapped in the lithium carbonate precipitate. Following the second stage of ion exchange a 99.9% lithium carbonate is produced, which is used in high-end applications incl. medical applications and batteries.

These conversion plants can also produce lithium hydroxide, by taking the post-ion exchange product and undergoing electrodialysis to produce a lithium hydroxide solution and crystallisation to form a high-purity lithium hydroxide product. The volume of lithium hydroxide and lithium carbonate products can be varied to meet market conditions.

Figure 187: Process flow diagram for a typical spodumene conversion plant



Source: Lithium Process Chemistry', 2015 Chagnes, Swiaowska

We believe the capital intensity to build a lithium conversion plant is around US$10,000-12,000/t LCE outside of China and possibly as low as US$6,000/t LCE inside China for larger facilities. Based on power, labour and chemicals consumed in the purification process, we expect the operating costs for conversion plants in China would likely be lower than outside China as well.

Figure 188 shows DB estimates for conversion costs to produce a tonne of battery-grade lithium carbonate from a 6% Li_2O spodumene concentrate. We believe the conversion costs are US$5,241/t, however US$3,680/t of those costs are attributable to the spodumene concentrate consumed. We note that the two largest Chinese lithium processing companies, Sichuan Tianqi and Jiangxi Ganfeng will be vertically integrated with their own spodumene operations from the second half of 2016.

Figure 188: Lithium Carbonate conversion costs

	Units	Unit price	US$/t LCE
Spodumene	8 t	US$460/t	3,680
Sodium carbonate	1.6 t	US$219/t	350
Sulfuric acid	2.4 t	US$50/t	120
Others			71
Materials			**4,221**
Electricity	2,400 KWh	US$0.09/KWh	207
Coal	3 t	US$24/t	72
D&A			354
Labour			175
Others			212
Other costs			**1,020**
Total COGS			**5,241**
Conversion costs (excl. spodumene)			**1,561**

Source: Deutsche Bank, industry data

Figure 189: China's downstream lithium conversion facilities (capacity reported in LCE)

Companies' Name	Assets' name	Resource	Capacity			
			2016	2017	2018	2018
China Minmetals Salt Lake	Yiliping Salt Lake	Brine	10	10	10	10
Qinghai Saltlake Fozhao Lake Lithium	Qarhan Salt Lake	Brine	10	10	40	40
Qinghai East Taijinar Lithium Resources	East Taigener Salt Lake	Brine	10	10	10	10
Qinghai Hengxinrong Lithium	West Taigener Salt Lake	Brine	2	2	18	18
Citic Guoan Information	West Taigener Salt Lake	Brine	0	0	0	0
Guohua Lithium	Da Chaidam Salt Lake	Brine	0.87	0.87	0.87	0.87
Tibet Mineral Development	Baiyin Zabuye	Spodumene	3	3	3	3
ZhongHe						
Sichuan Guoli						
Hengding		Spodumene processing	6	6	6	6
Sichuan Xingcheng		Spodumene processing	6	6	6	6
Tianqi Lithium						
Shehong base		Spodumene processing	16	16	16	16
Zhangjiagang base		Spodumene processing	17	17	17	17
Sichuan Ni&Co Guorun New Materials Co.,Ltd	Maerkang	Spodumene processing	8	8	8	8
Youngy Co., Ltd						
Sichuan Luxiang		Spodumene processing	0	0	10	22
Jiangxi Special Electric						
Jiangxi Special mining	Yifeng Shiziling					
Jiangxi Yinli New Energy		Lepidolite processing	1.5	1.5	4	8
Ganfeng Lithium		Brine processing	7	7	7	7
		Spodumene processing	23	30	30	30
Jiangxi Hzong		Lepidolite processing	1	1	10	10
Jiangxi Rubidium		Lepidolite processing	6	6	11	11
Shandong Ruifu Lithium		Spodumene processing	5	5	5	5
Shandong Hongxin		Spodumene processing	6	6	6	6
Baijierui Advanced Materials		Spodumene processing	3.4	3.4	11	11
General Lithium, Palith		Spodumene processing	6	6	12	12
China Lithium		spodumene processing	8	8	8	8
Xinjiang Xinjing Lithium Development		Spodumene processing	7	7	7	7
Total			**163**	**170**	**256**	**272**

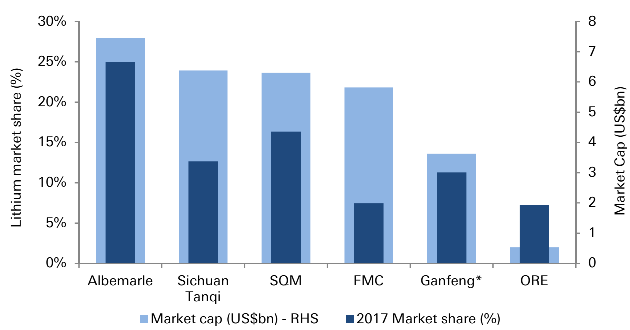
Source: Deutsche Bank; Company data; Industry data

Current producers

The lithium supply market was 171kt LCE in 2015. The four largest global producers (ALB, SQM, FMC and Sichuan Tianqi) have a combined market capitalization of US$26bn and accounted for 83% of global output in 2015. Further the second largest Chinese producer, Ganfeng, has a US$3.6bn market cap and will be vertically-integrated once the Mt. Marion asset ramps up in the second half of 2016. These five companies control 45% of global reserves.

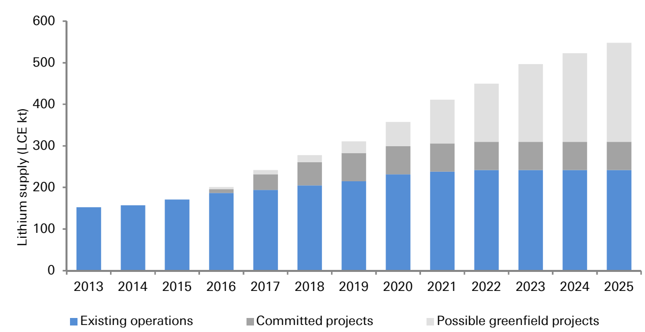
We expect global output from current producing assets can expand from 171kt LCE in 2015 to 215kt LCE in 2019, with most of this expansion coming from Orocobre Phase II (commissioning), ALB's La Negra plant in 2018 and a third operation from 2021/22, along with increasing output from Chinese producers.

Figure 190: Market cap of major lithium producers



Source: Deutsche Bank, *100% production from Mt. Marion is attributable to Ganfeng

Figure 191: Lithium supply - current producers (2013-25)



Source: Deutsche Bank

Figure 192: Production from current producers (2013-25)

	Company	Deposit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Australia															
Greenbushes	Albe/ Tianqi	Spod.	32	41	57	60	60	65	71	85	85	85	85	85	85
Argentina															
Hombre Muerto	FMC	Brine	18	18	17	17	18	23	23	23	23	23	23	23	23
Salar de Olaroz	Orocobre	Brine	0.0	0.0	1.7	14	18	18	18	18	18	18	18	18	18
Olaroz Phase II	Orocobre	Brine	0.0	0.0	0.0	0.0	0.0	0.0	5.0	7.5	14	18	18	18	18
Chile															
Salar de Atacama	Albemarle	Brine	23	23	23	24	25	25	25	25	25	25	25	25	25
Salar de Atacama	SQM	Brine	36	40	40	40	40	40	40	40	40	40	40	40	40
China															
Chinese producers		Both	28	21	18	18	18	18	18	18	18	18	18	18	18
United States															
Silver Peak	Albemarle	Brine	4.5	4.5	4.5	4.5	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Zimbabwe															
Bikita Mine	Bikita Minerals	Spod	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
Portugal															
Various		Spod	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Brazil															
Various	Companhia Brasileira	Spod	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Total			**152**	**157**	**171**	**187**	**194**	**205**	**215**	**232**	**238**	**242**	**242**	**242**	**242**

Source: Deutsche Bank, company data

Albemarle

Albemarle is a US based specialty chemicals company which develops, manufactures and markets technologically advanced and high value added products, including lithium and lithium compounds, bromine and derivatives, catalysts and surface treatment chemicals. The company is listed on the NYSE (ALB.N). In January 2015, Albemarle acquired Rockwood Lithium and became a leading integrated and low cost global producer of lithium and lithium compounds. It is headquartered in Baton Rouge, Louisiana.

Through its Rockwood acquisition, Albemarle became a leading lithium company

Figure 193: ALB's Salar de Atacama operation in Chile

Source: Albemarle

Figure 194: ALB's Silver Peak operation in Nevada, U.S.

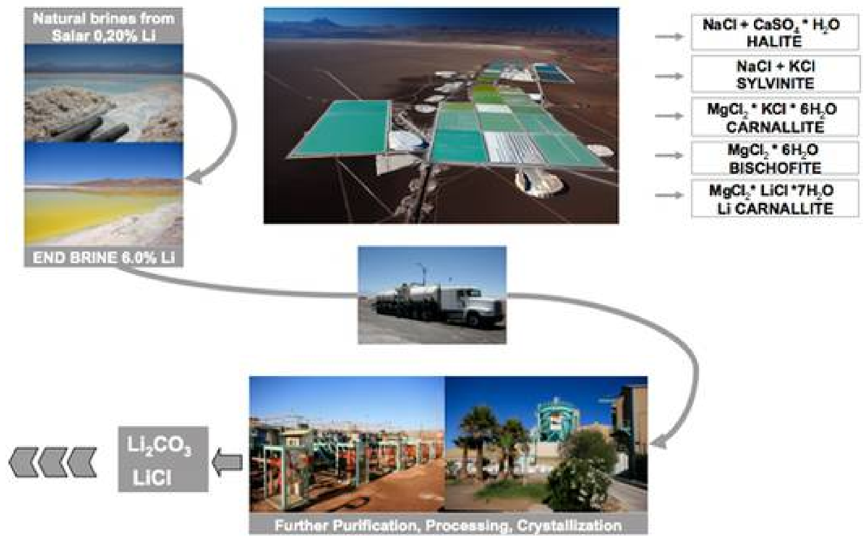
Source: Albemarle

Lithium assets

Albemarle's subsidiary Rockwood Lithium operated two resource bases: Salar de Atacama (Chile) and Clayton Valley near Silver Peak, Nevada (US). The company has a contract in place with the Chilean government for material extracted from the Salar de Atacama with current production of 24ktpa. Lithium carbonate production capacity at Silver Peak is 6ktpa. Additionally, the company holds a 49% stake in the Greenbushes spodumene mine in Western Australia where the company uses tolling partners in China to process spodumene. The Greenbushes production is currently 55-60ktpa (100%) Further, the company owns the Kings Mountain mine in the US (not currently operating).

At Salar de Atacama in Chile, lithium contained in the brine is pumped out of the Salar, impurities are removed and evaporation occurs. During the evaporation process, the lithium concentration is increased from 2,000 ppm to 6% in the final brine which is then transported to Rockwood Lithium's plant for further purification and processing to form lithium carbonate and other products explained below.

Figure 195: Lithium production process in Chile



Source: Company data

Lithium products

Albemarle produces a number of products including the following:

Albemarle produces a number of different products

- Lithium Carbonate (Li_2CO_3): Used in Li-ion batteries, glass ceramics, cement and aluminum.
- Lithium Hydroxide (LiOH): Used in Li-ion battery, grease, CO2 absorption and mining.
- Lithium Metal: Used in Lithium Primary batteries, pharmaceuticals and aerospace.
- Organo-lithium: Applications in elastomers, pharmaceuticals, agrochemicals and electronic materials.

Operational performance and outlook

Albemarle expects 10% plus EBITDA growth and targets 50% of growth in Li demand.

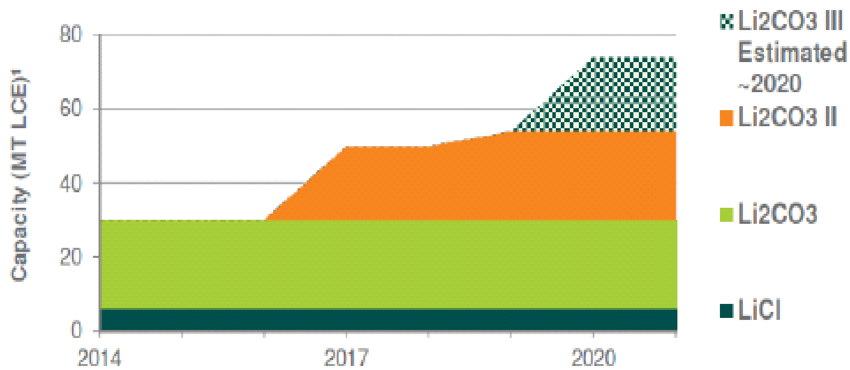
- In 2015, lithium revenues were US$509m (14% of overall revenues) with an EBITDA margin of 42%.
- Albemarle expects +10% EBITDA growth on volume and price in battery-grade products.
- Currently 75% of the business is in non-battery grade applications where pricing gains have been more modest.
- The company plans to capture ~50% of growth in lithium demand.
- Key Lithium customers include Panasonic Corp., Syngenta AG, Umicore SA, Samsung SDI Co. Ltd., Royal DSM NV.

Expansion plans

- Albemarle has a brine pumping permit in Chile that allows capacity of over 75ktpa of lithium carbonate.
- The Company also has a Memorandum of Understanding with the Chilean government that increases the expected life of secured reserves in Chile from 15 years to 27 years.

- In Chile, Albemarle plans to expand production from the current rate of 24ktpa to 75ktpa by around 2020/21 with the addition of two processing facilities (US$220m for first facility and < US$200m for second facility) at La Negra (~two hours from the Atacama salar). This still relies on additional negotiations with the Chilean government.

Figure 196: Albemarle's expansion plans in Chile



Source: Company data

Albemarle looking to enter downstream market

After its Chile expansion plans, Albemarle is exploring the option of bringing online a lithium processing plant in 2022-23 at a cost of US$300m. This processing plant would consume spodumene concentrate coming from the Greenbushes operation in Western Australia, in which ALB has a 49% interest. ALB believes its proposed spodumene processing plant would be the most technologically advanced mineral conversion plant ever built, with capacity as high as 50kt LCE, producing a number of battery grade lithium derivatives – including both lithium carbonate and lithium hydroxide

Figure 197: Engineering design of ALB's proposed spodumene process plant

Source: Albemarle 2015 Lithium Day investor presentation

Sociedad Quimica y Minera (SQM)

Sociedad Quimica y Minera (SQM) is a Chile based chemical producer operating in both the fertilizer and specialty chemicals sectors. SQM has a primary listing on the Santiago stock exchange and a secondary listing on NYSE (SQM.N). The company is headquartered in Santiago, Chile. The company has a run rate of 35-40ktpa LCE and a reserve base of 6.2Mt LCE (with an average recovery of 28-40% typically).

Lithium assets

SQM extracts brine from the Salar de Atacama (SDA) located in Chile. Both potassium chloride (KCl) and lithium are removed from the salar. The deposit is recognized as the largest and highest grade brine system globally. Lithium is produced as a by-product of potassium chloride manufacturing and is processed at the Salar del Carmen plant near Antofagasta. The brine has high evaporation rates (~3700mm per year) which increases the speed of extraction.

Figure 198: SQM asset map in Chile

Source: Company data

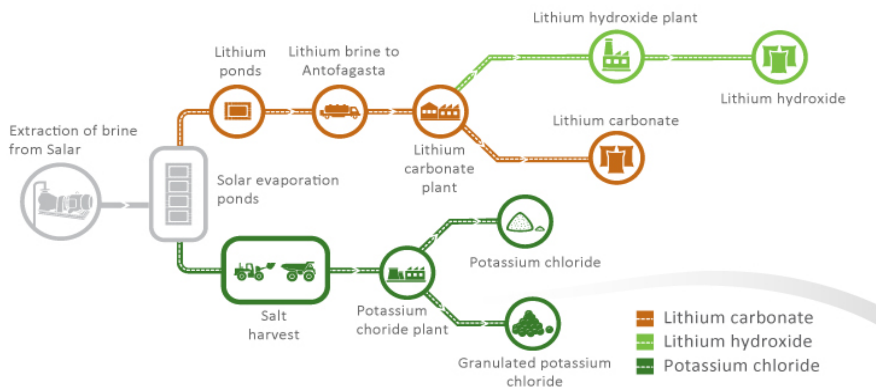
Figure 199: SQM's Salar de Atacama operation

Source: Company data

Operational performance and outlook

- In 2015, SQM represented 23% of the lithium production market with sales of 39kt LCE (40kt LCE in 2014 and 36kt LCE in 2013). This resulted in revenues of US$223m (13% of company total) and contributed 21% to SQM's gross profit for the year.
- The company produces a mix of lithium carbonate (majority of production, used in batteries, ceramic, glass, primary aluminum, chemicals, steel extrusion, pharmaceuticals, and lithium derivatives), Lithium hydroxide (6ktpa, used in the lubricating grease industry, dyes and battery market) and lithium chloride (used in lithium derivatives industry).
- The operating plant has an overall capacity of 48ktpa theoretically. Between 1993 and 2030, SQM has a LCE limit of 959kt and at the end of 2015 was ~55% through this absolute production quota.

Figure 200: SQM's Lithium production process flowsheet



Source: Company data

Expansion plans

SQM recently signed a JV with LAC to progress the Cauchari-Olaroz lithium project in Argentina

- SQM expanded the capacity of the Salar de Carmen plant to the current capacity of 48kt LCE (20% increase) in 2011 but has been operating below this level to spread the total quota allocated to 2030.
- In March 2016, SQM announced a JV with Lithium Americas Corporation (LAC.TSX) to progress the Cauchari-Olaroz lithium project in Argentina.
- The JV requires a US$25m investment from SQM in return for a 50% share of the deposit. The project is currently at the initial economic feasibility stage.
- The deal diversifies potential production outside of Chile into Argentina and also diversifies the operating system.
- An updated feasibility study will now be completed with a possible staged approach with 20ktpa expanded to 40ktpa over time.
- SQM will implement its technical knowledge from the Atacama salar to reduce construction and start-up risks.

Food Machinery Corporation (FMC)

FMC is a US-based specialty chemical company operating with segments in crop protection chemicals, health ingredients and lithium based specialty chemicals. FMC is listed on the NYSE stock exchange (FMC.N). The company is headquartered in Philadelphia.

Lithium assets

FMC operates the Salar del Hombre Muerto (SHM) in Argentina, to extract lithium. The brine has low impurities (Mg/Li ratio of ~1.37) which assist in reducing operating costs, an average grade of 692ppm and a current reserve life of 75 years.

Figure 201: FMC asset map in Argentina

Source: FMC

Figure 202: Salar del Hombre Muerto operations

Source: FMC

FMC manufactures lithium products in two phases. The SHM brine is first used to extract Li_2CO_3 and LiCl in FMC's plant based in Salta, Argentina. These products are then shipped to FMC's other manufacturing plants which are located near the key end product markets in North America; Asia (China and India) and Europe (UK).

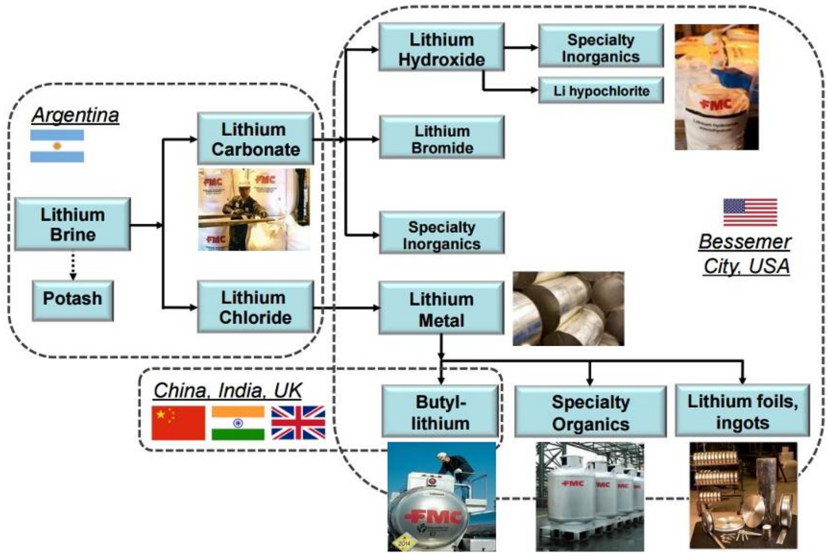
Lithium products

FMC produces specialty grade lithium products which include the following:

FMC produces specialty grade Li products, Specialty Li products account for 72% of FMC's Li revenues.

- Butyllithium (C_4H_9Li): This product is used as a polymerization initiator and has application in tyres and synthetic rubber. FMC is the leading producer of this specialty lithium product.
- Lithium hydroxide (LiOH): Used as a raw material in the lubricating grease industry, as well as dyes and batteries.
- High purity metal (Li): Used in aerospace and rechargeable batteries.
- Lithium carbonate (Li_2CO_3): Applications in a variety of industries, however FMC mainly uses this product as the feed for LiOH. Production capacity for Li_2CO_3 is 23ktpa.
- Lithium chloride (LiCl): Primarily used in the Lithium, derivatives industry.

Figure 203: FMC Lithium products

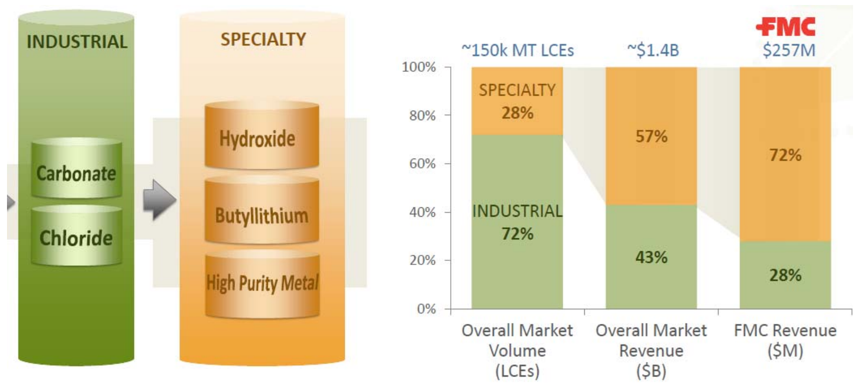


Source: FMC

Operational performance and outlook

- FMC produced 18kt LCE of Lithium products in 2015. Lithium revenues were US$238m (-7.4% YoY, 7% of overall company).
- The company expects its operating profit from its lithium division to be in the range of US$33-43m in 2016 with higher pricing. This implies a growth of US$15m (at the midpoint of guidance range) compared with US$23m in 2015.

Figure 204: Specialty Lithium dominates FMC Lithium sales



Source: Company data

Expansion plans

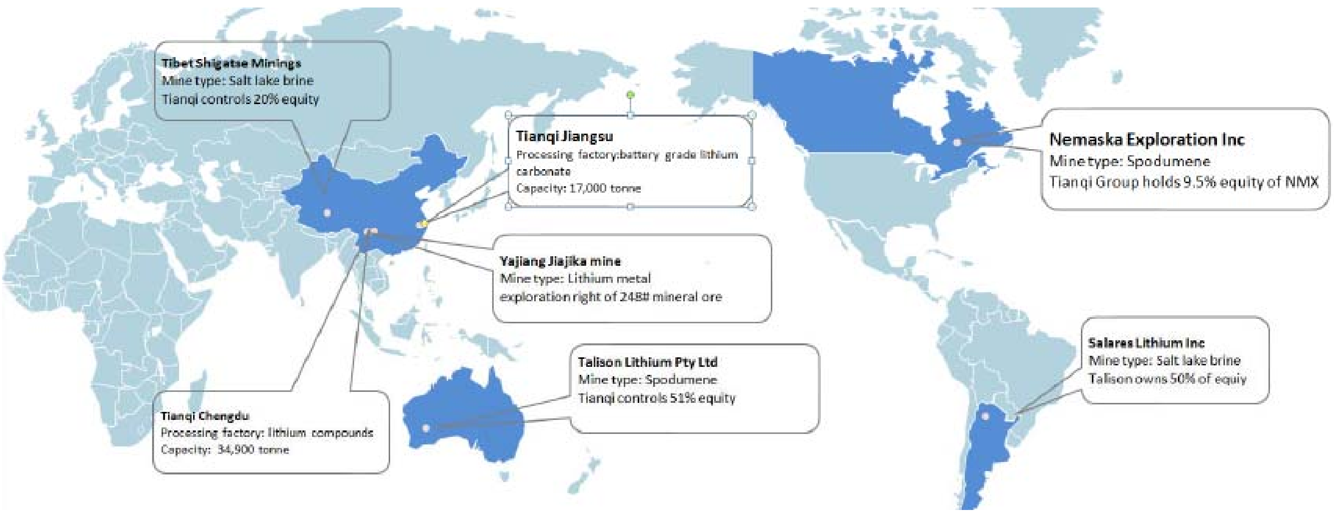
- FMC expanded the capacity of its processing plant in Argentina by 30% to 23ktpa. At this stage the company does not have further expansions planned that we are aware of.

Tianqi Lithium

Global spodumene leader

Founded in 1995 and after acquiring Talison in 2013, Sichuan Tianqi has become one of top four largest lithium mining and producers in the world, controlling c. 18% of the world market share. Tianqi's primary operations are 1) mining spodumene concentrates in Australia and 2) processing spodumene concentrates to lithium chemical compounds in its China factories.

Figure 205: Tianqi's assets in China.



Source: Deutsche Bank, company data

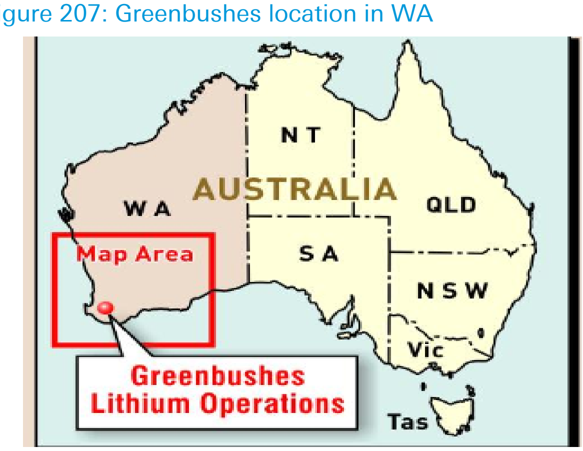
Talison – spodumene mine in Australia

Talison, the Greenbushes project is the most important asset for Tianqi, and is owned via a joint venture between Albemarle (49%) and Tianqi (51%). The Greenbushes deposit comprises a rare-metal zoned pegmatite with smaller pegmatite dykes and footwall pods. Its Lithium Zone is enriched in spodumene. By strategically acquiring Talison, Tianqi successfully integrated the upstream and been transformed from a pure lithium processor into an international lithium company with a large amount of high-quality resources.

Figure 206: The Greenbushes mine

Source: Sichuan Tianqi

Figure 207: Greenbushes location in WA



Source: Deutsche Bank, Talison

Figure 208: Greenbushes Lithium mineral resources as at 30 September, 2012

Category	Tonnage (Mt)	Li2O (%)	LCE (Mt)
Measured	0.6	3.2	0.04
Indicated	117.9	2.4	7.1
Inferred	2.1	2	0.1
Total resources	**120.6**	**2.4**	**7.2**

Source: Greenbushes technical report, December 2012

Figure 209: Greenbushes Lithium ore reserves as at 30 September, 2012

Category	Tonnage (Mt)	Li2O (%)	LCE (Mt)
Proven	0.6	3.2	0.04
Probable	61	2.8	4.2
Total reserves	**61.6**	**2.8**	**4.3**

Source: Greenbushes technical report, December 2012

The lithium technical grade processing plant is expected to process 61.5Mt of ore to produce 22.2Mt of lithium products over the life of mine of 24 years. Total capacity of Talison is 750ktpa spodumene concentrates its current utilization rate is c. 60%. As the market is short of spodumene concentrate, Talison is about to mainly support to major shareholders, Tianqi and Albemarle in 2016 and going forward. The mining costs vary between c.A$12/t and c.A$28/t of ore, depending on the waste to ore strip ratio, over the LOM.

China processing base -- the biggest processor in China

Tianqi is the largest lithium processing manufacturer in China, operating two processing plants in China and planning a new processing plant. The acquisition of Zhangjiagang processing factory in 2014, from Galaxy Resources quickly doubled its capacity of lithium compounds processing to 34.8ktpa. And in March, 2015, Tianqi announced it will develop another production line for lithium hydroxide in the next 2-4 years.

Figure 210: Tianqi lithium's capacity breakdown by products

Battery/Industry grade lithium carbonate	27.5ktpa
Lithium hydroxide	5ktpa
Lithium chloride	1.5ktpa
Lithium metal	0.2ktpa
New lithium hydroxide in the pipeline	20ktpa

Source: Deutsche Bank estimates, Company data

For Tianqi, we believe the visibility of its organic earnings growth will be high in light of 1) high ASP of lithium compounds and expected increase in ASP of spodumene concentrates, and 2) flexibility to increasing volume of both spodumene concentrates in Talison, from current low utilization rate of only 60% only and lithium compounds in Zhangjiagang factory. The factory was acquired in 2015 and is now ready to ramp up.

Lithium's outlook in coming years looks very similar to iron ore's boom story in the past decade. For Tianqi, we believe the visibility of its organic earnings growth will be high in light of 1) high ASP of lithium compounds and expected increase in ASP of spodumene concentrates, and 2) flexibility to increase volume of both spodumene concentrates in Talison, from current low utilization rate of only 60% only and lithium compounds in Zhangjiagang factory.

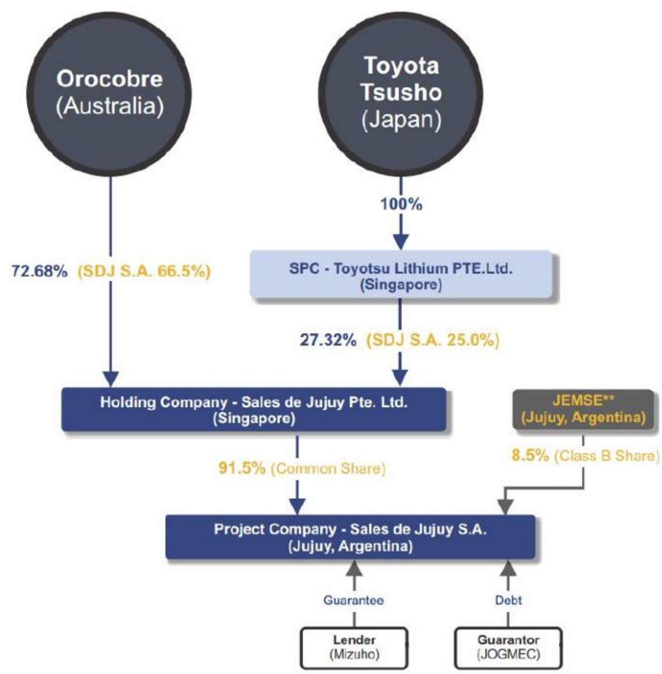
Orocobre

Orocobre is developing the world's first greenfields lithium brine operation in 20 years. With construction now complete, Olaroz commissioning is underway with expected ramp-up to 17.5ktpa nameplate capacity by September 2016. Once at full operating rates, Olaroz will represent around 10% of global lithium supply in 2016. The Olaroz resource of 6.4Mt LCE is one of the largest in the world and only 15% of this resource will be recovered based on a 25-year, 17.5ktpa LCE operation. As the only global pure-play exposure to a producing lithium brine operation, ORE is well positioned in the market with increasing volumes, industry-leading cost targets and expansion potential.

Figure 211: Location of the Olaroz project

Source: Orocobre

Figure 212: Olaroz ownership structure



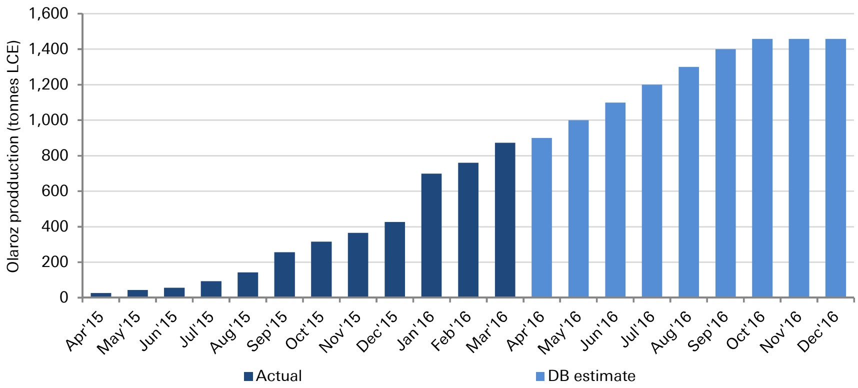
Source: Orocobre

Commissioning issues appear to be resolved

ORE announced that final commissioning was complete at Olaroz in February 2015 and that the asset was entering a commercial production ramp-up phase. Nameplate capacity of 17.5ktpa was expected to be achieved by the end of 2015. Over the following 12 months, the asset was plagued with commissioning issues, mainly focussed on operating temperatures, due to boilers and heat exchangers not operating to design due to the operating environment (high elevation). These challenges meant the liothium carbonate was not efficiently dissolving in the purification circuit, leading to some solid primary lithium carbonate being sent through the tailings stream.

ORE set a target of 650t/month for January as the "operating cash flow" breakeven point, which was achieved. The company now expects full operating rates will be achieved in September; we remain slightly conservative and assume this is achieved in the December quarter.

Figure 213: ORE production ramp up



Source: Deutsche Bank; Orocobre

ORE looking at options to produce lithium hydroxide at Olaroz

ORE has entered an MoU with Batemen Advanced Technologies to build a lithium hydroxide pilot plant to test the viability of using Olaroz lithium to produce high-quality lithium hydroxide (LiOH) products. There is a precedent for lithium hydroxide plants associated with brine operations, with SQM producing LiOH in Antofagasta using lithium sourced from its Salar de Atacama brine operations in Chile.

A lithium hydroxide development is not in our current numbers

Figure 214: The Olaroz processing plant and pond system (bottom right) and the Olaroz wellfield and salar

Source: Orocobre

Olaroz Phase II expansion

We value an Olaroz Phase II expansion at A$217m, or A$1.03/sh.

ORE is planning to begin an engineering study on a Phase II expansion of its Olaroz project this quarter. The company hopes to have the engineering study completed by September, which we believe suggests ORE could be in a position to make an investment decision by the end of this year. ORE estimates the capital cost to double Olaroz capacity to 35ktpa LCE would be 60% of the headline Phase I capital cost of US$229m, which equates to around US$140m.

Global lithium S&D analysis suggests the market needs Olaroz Phase II

Our recent global lithium report forecasts lithum demand to increase from 181kt LCE in 2015 to over 530kt LCE in 2025 (11% CAGR for 10 years). While hard-rock operations will respond to market demand in the next 3-5 years, we are of the view that the lower-cost brine operations will expand over time. Olaroz has a very large resource (6.4Mt LCE at 690mg/L) and will have first-mover advantage over greenfileds brine projects due to the befeits of developing a brownfields expansion (faster permitting, existing labour, lower procurement costs, established relationships with government, technical know-how after Phase I commissioning issues and engineering solutions).

Olaroz Phase II could enter the market in 2019

We believe the lithium market will require Olaroz Phase II by the end of this decade. We assume Olaroz Phase II is approved in 2017, first capital is spent in March 2018 and allow two years for construction. As a comparison, it took ORE three years (Nov 2012 – Nov 2015) to complete development of Olaroz Phase I, however within that period, physical construction of the processing plant only took 6 months. We use a US$180m capital cost assumption, 30% above ORE's capital estimate. We assume Phase II commissioning commences in late 2019 and allow a 24 month commissioning period (full run rate achieved in 2022), consistent with the ramp-up delivery seen thus far from Phase II. We note that ORE currently has excess lithium in its pond system, equivalent to 39kt LCE; this inventory build-up could be used to accelerate Phase II commissioning.

Funding options available, capital requirements depend on timing

The Olaroz JV has an existing US$192m debt facility with Mizuho which was fully drawn to help fund Oloarz Phse I construction; we believe US$177m remains outstanding. If ORE chooses to accelerate Olaroz Phase II development (ahead of our forecasts), debt funding would be required and we think a re-financing with Mizuho is most likely. Based on our Pahe I output a nd cash flow assumptions, the Olaroz JV could self-fund the development of Phase II if capital spending commenced from 1Q 2018 onwards.

Olaroz Phase II highly accretive, adds over $1/sh to our Group NPV

We value a 17.5ktpa Olaroz Phase II expansion at A$217m, or A$1.03/sh, assuming capital costs of US$180m and operating costs in line with Phase I guidance (sub US$2,500/t LCE).

Other Chinese producers

China has substantial lithium resources in the forms of brine, spodumene and lepidolite. China has salt lakes in Qinghai province, spodumene resources in mainly Xinjiang and Sichuan province and lepidolite in Jiangxi province. We estimated that China domestic market supplied 17.7kt LCE in 2015, among which, brine, spodumene and lepidolite contributed 30%, 50% and 20%, respectively.

We believe domestic supply will respond to increase lithium prices since the second half of 2015 by increasing capacity. However, we do not expect that Chinese producers will deliver expansions as suggested by the individual companies as technical difficulties are unlikely to be resolved quickly in the short term.

- For Chinese brine assets, immature technologies and harsh operating environments makes capacity ramp-up difficult.
- For spodumene producers, there are some low-grade, higher cost resources in Sichaun that are facing community issues which will affect expansion potential.
- For lepidolite producers, higher costs and limited usage of by-products may influence lepidolite processors' decisions on committing to aggressive expansion plans.

Figure 215: Summary of China mine production (2015-20)

Company name	Asset name	Resource Type	2015	2016E	2017E	2018E	2019E	2020E
China Minmetals Salt Lake	Yiliping Salt Lake	Brine	0.0	0.0	0.0	0.0	0.0	0.0
Qinghai Saltlake Fozhao Lake Lithium	Qarhan Salt Lake	Brine	3.0	3.0	5.0	8.0	8.0	8.0
Qinghai East Taijinar Lithium Resources	East Taigener Salt Lake	Brine	3.0	3.0	3.0	3.0	3.0	3.0
Qinghai Hengxinrong Lithium	West Taigener Salt Lake	Brine	2.0	2.0	2.0	5.0	5.0	5.0
Citic Guoan Information	West Taigener Salt Lake	Brine	0.0	0.0	0.0	0.0	0.0	0.0
Guohua Lithium	Da Chaidam Salt Lake	Brine	0.9	0.9	0.9	0.9	0.9	0.9
Tibet Urban Development	Jiezechaka & Longmucuo	Brine	0.0	0.0	0.0	0.0	0.0	0.0
Tibet Mineral Development	Baiyin Zabuye	Spodumene	3.0	3.0	3.0	3.0	3.0	3.0
ZhongHe			2.5	6.0	8.0	8.0	8.0	8.0
Maerkang	Dangba	Spodumene	2.5	6.0	8.0	8.0		
Dexin	Lijiagou	Spodumene	0.0	0.0	1.0	1.0		
Huamin	Yelonggou	Spodumene	0.0	0.0	0.0	0.0	0.0	0.0
Tianqi Lithium	Yajiang Cuola	Spodumene	0.0	0.0	0.0	0.0	0.0	0.0
Sichuan Ni&Co Guorun New Materials Co.,Ltd	Maerkang	Spodumene	0.0	0.0	0.0	0.0	0.0	0.0
Youngy Co., Ltd	Kangding Jiajika	Spodumene	0.1	1.0	1.0	1.0	1.0	1.0
Jiangxi Special Electric			2.2	3.0	4.0	5.0	5.0	5.0
Jiangxi Special Mining	Yifeng Shiziling	Lepidolite	0.0					
Xinfang	Xinfang	Lepidolite	1.3					
Juyuan	Hejiaping	Lepidolite	0.6					
Taichang	Xuankuangchang	Lepidolite	0.3					
Ganfeng Lithium	Heyuan	Spodumene	0.0	0.0	0.0	0.0	0.0	0.0
Yichun Tani	411 Formanite	Lepidolite	1.0	1.0	1.0	1.0	1.0	1.0
Total			**17.7**	**22.9**	**27.9**	**34.9**	**34.9**	**34.9**

Source: Deutsche Bank, industry and company data

Other producers

Zimbabwe – Bikita Minerals

The Bikita deposit is a large complex of Li-Sn-Cs rich pegmatites, located 64km north-east of Masvingo, Zimbabwe. The deposit occurs within the Victoria Greenstone Belt over a distance of 3-5km, and hosts the world's largest known cesium-petalite and beryl resource; it is also estimated to contain up to 168kt LCE at an average concentration of 4% Li2O. The Bikita pegmatite area is separated into four distinct sectors -- Al Hayat, Bikita, Southern and Nigel. The Al Hayat sector hosts the largest zone of petalite, and has very large crystals of low-level of iron (0.03% Fe2O3). The Bikita sector, which was originally dominated with lepidolite (most of which have been mined so far), also hosts spodumene, petalite and amblygonite. Given the deposit produces its lithium products from petalite with very low levels of impurities (notably iron), its products are typically used in high-temperature ceramics and glassware. Bikita is currently producing at around 4.5kt LCE. Bikita Minerals controls nearly all of the country's lithium mining and announced expansion plans in 2014.

Democratic Republic of Congo – Manono-Kitolo

The Manono-Kitolo mine is one of the world's largest pegmatite hosted deposit of cassiterite, columbo-tantalite and lithium. The pegmatite is exposed over 14 kilometres, open to the northeast and southwest. Historically, 180kt of cassiterite (tin oxide) were mined during the Belgian colonial era. The mineralogy of the deposit is unique due to the high tonnages of spodumene (which contains up to 2% Li_2O) and columbo-tantalite (which accounts for 5% of the tin concentrate).

Portugal - Sociedade Mineira de Pegmatites

Sociedade Mineira de Pegmatites extracts lithium from the lepidolite-rich, aplite-pegmatite veins in the Guarda district of Portugal. In 2009, the company produced 1.8kt LCE in the form of lithium concentrates, most of which are used in the ceramics and glass industries. Portugal occupies an important position in the lithium akret as it is closer to a number of technical grade concentrate markets, however we are not aware of any expansion plans.

Brazil

Two companies produce lithium minerals in Brazil while a third company is developing a new project;

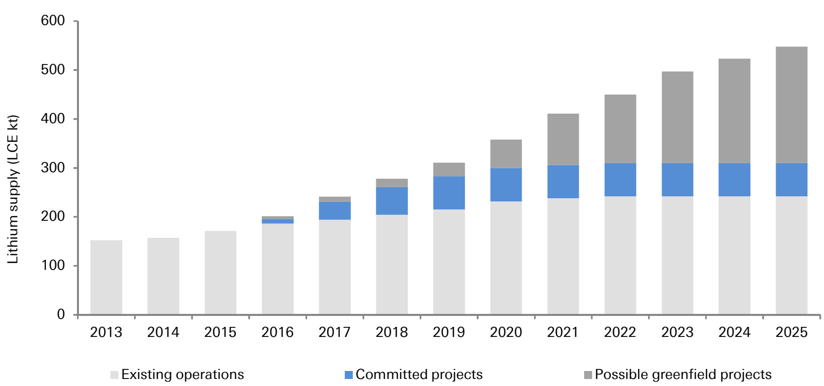
- Companhia Brasileira de Litio produces spodumene concentrates from the underground Cachoeira Mine in Araçuaí. This material is used as feedstock for lithium carbonate and lithium hydroxide production at a plant in Aguas Vermelhas in Minas Gerais. In 2006, CBL produced 8.5kt of lithium concentrates at an average concentration of 5.09% Li_2O; today, CBL has the capacity to produce up to 2kt LCE.
- Arqueana de Minérios e Metals Ltda. produces a mixture of spodumene, petalite, and lepidolite concentrates at several mines in Araçuaí and Itinga. In Brazil, lithium compounds and minerals are used in greases and lubricants, primary aluminum production, ceramics and batteries.
- Companhia Industrial Fluminense (CIF) is developing a pegmaitie source at Mibra with a tantalite grade of 300g/t which also contains a lithium resource of 21Mt grading 1.0% Li_2O.

Committed projects

There are three major lithium projects that have been committed to and are expected to enter production within the next 24 months.

- The Mt. Marion spodumene project is a joint venture between Mineral Resources, Neometals and Jianxi Ganfeng. The operation is currently under construction (A$50m capital budget) and will commence commissioning in June/July. The plant will produce 200ktps a 6% Li2O spodumene concentrate, equivalent to 27kt LCE. There is also scope for another 80ktpa (10kt LCE) from a flotation circuit (we include this in our base case).
- The Mt. Cattlin spodumene project is an existing operation owned by Galaxy Resources that has been on care & maintenance since 2013,. General Mining is earning into Mt. Cattlin up to 50% (for A$25m) and is the operator. The restarted operation is expected to produce 100ktpa Li2O spodumene concentrate, equivalent to 13kt LCE.
- Albemarle recently received approvals to increase its Chilean lithium production by bringing online its second lithium carbonate plant in La Negra, Chile. The plant, known as La Negra, is already built however it will likely take 18-24 months for ALB's Salar de Atacama operation to increase extraction rates to 45kt LCE.

Figure 216: Lithium supply from committed projects



Source: Deutsche Bank

Figure 217: Production from committed projects (2013-25)

	Company	Deposit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Australia															
Mt Marion	MIN/NMT/Ganfeng	Spodumene	0.0	0.0	0.0	6.1	27	33	35	35	35	35	35	35	35
Mt Cattlin	GXY/GMM	Spodumene	0.0	0.0	0.0	3.3	10	13	13	13	13	13	13	13	13
Chile															
La Negra	Albemarle	Brine	0.0	0.0	0.0	0.0	0.0	10	20	20	20	20	20	20	20
Total			**0.0**	**0.0**	**0.0**	**9.4**	**37**	**56**	**68**	**68**	**68**	**68**	**68**	**68**	**68**

Source: Deutsche Bank; company data

Mt. Marion

Ownership: Ganfeng (43%), Mineral Resources (43%), Neometals (13%)

The Mt. Marion lithium project is a greenfields project being developed through a joint venture between ASX-listed Neometals (NMT.AX, not covered), Mineral Resources (MIN.AX, $8.50/sh PT) and Jiangxi Ganfeng Lithium Co. Ltd (Insert ticker details), who is also the major offtake partner. NMT granted MIN and Ganfeng options pursuant to which they can elect to increase their respective shareholdings by acquiring shares from NMT at an agreed price. If these options are fully exercised, the effective ownership will be NMT (13.8%), MIN (43.1%) and Jiangxi Ganfeng Lithium Co. Ltd (43.1%).

The project is located 40km south west of Kalgoorlie, Western Australia with construction currently underway. Annual production is planned to be 200ktpa of 6% Li2O chemical grade spodumene concentrate (equivalent to 27kt lithium carbonate equivalent), however the JV partners are also considering a further 80ktpa of 4% Li2O spodumene concentrate recovered via flotation.

Figure 218: Mt. Marion location Map

Source: Neometals investor presentation, February 2016

Geology and Reserves & Resources

The Mt Marion lithium deposit was originally discovered by WMC in the 1960's who commenced metallurgical testing of the ore for commercial purposes. The mineralisation is hosted within a number of sub-parallel, NE-NW trending pegmatite intrusive bodies which dip 10- 30° to the west. Individual pegmatites vary in strike length from 300 m to 700 m. The pegmatites intrude the mafic volcanic host rocks of the surrounding greenstone belt. The lithium occurs as 10-30 cm long spodumene crystals within medium grained pegmatites.

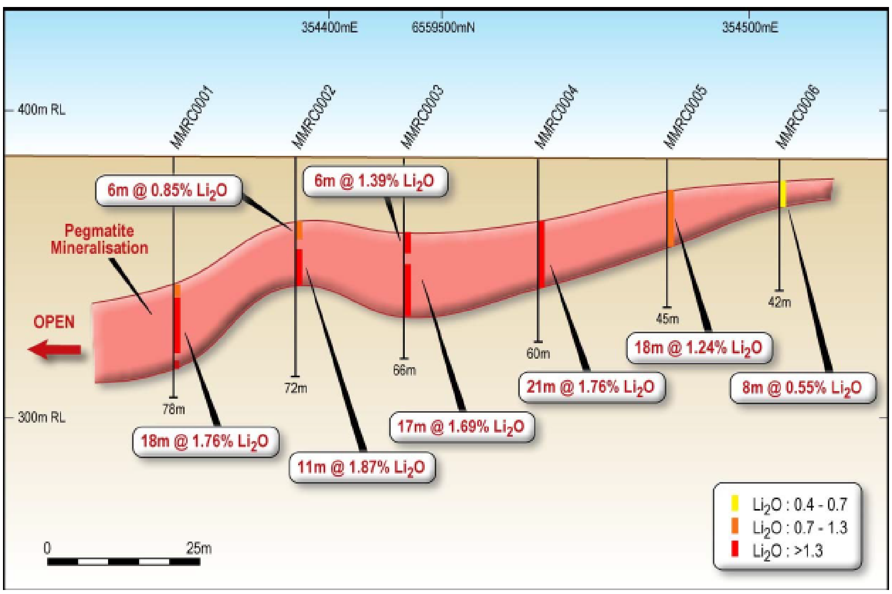
Figure 219: Mt Marion mineral resources as of September 2015

Category	Tonnes (Mt)	Li2O (%)	Fe2O3 (%)
Indicated resource	10.05	1.45	1.33
Inferred resource	13.19	1.34	1.5
Total resource	**23.24**	**1.39**	**1.43**

Source: Neometals investor presentation, February 2016

A Mt Marion resource expansion drill program commenced in late 2015 in which up to 335 reverse circulation holes and 30 diamond holes will be drilled. The program aims to extend the mine life through the extension of, and infill drilling of, existing deposits as well as the definition of new resources from outcropping pegmatite prospects. The program is expected to be completed in June 2016, with an upgraded Mineral Resource Estimate and Ore Reserve planned to be completed in the June and September quarters respectively.

Figure 220: Mt. Marion drill results, December 2015



Source: Company announcement, January 2016

Mining and Processing

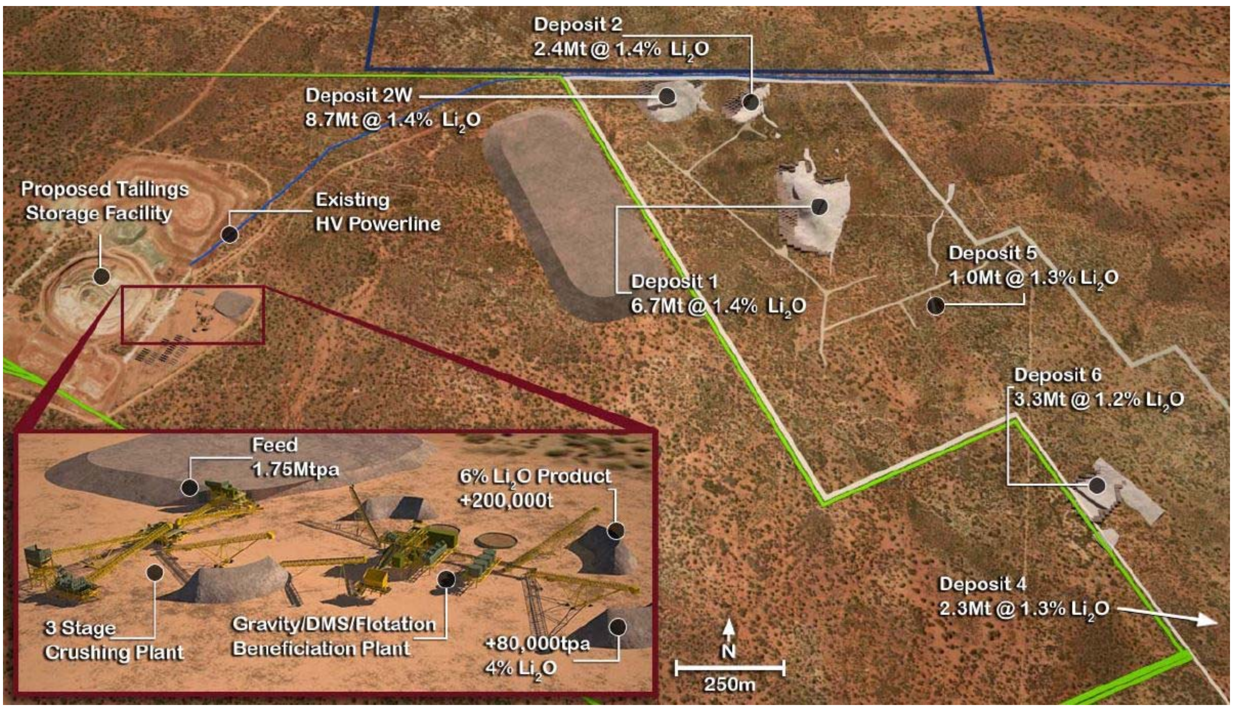
The Mt. Marion project will be a standard open-cut mining operation, employing traditional drill & blasting techniques and conventional load & haul methods using a small fleet of trucks and one or two small excavators. Life-of-mine strip ratios are expected to be 3:1. The pegmatite ore is harder than many other commercial ores, which is likely to lead to higher mining costs than similar-sized operations elsewhere in WA.

The processing plant is designed to have a nameplate capacity of 1.75Mtpa, however we note the primary crusher is oversized (we believe closer to 6Mtpa) which will be beneficial if further expansions are pursued. The theoretical yield of the processing plant design based on Mt. Marion ore is 15-16%, however the nameplate production rate of 200ktpa of 6% Li2O spodumene concentrate is conservatively based on a 11% yield.

The processing plant is expected to have 3-stage crushing to produce a -6mm product, which liberates most of the spodumene, with all material then being passed to the Heavy Media Separation (HMS) circuit. The different specific gravities between spodumene and the gangue minerals allow separation to occur within cyclones; no magnetic separation is required. Tantalum can be recovered from the spirals, in association with the proposed addition of a flotation plant to recover the 4% Li2O concentrate (we believe around 27ktpa), however it is not clear if this will be extracted for commercial sale.

The JV partners have announced they will consider a second processing stream, with fines rejects material from the HMS circuit being fed into a flotation circuit to recover an extra 80ktpa of 6% Li2O spodumene concentrate. Tailings from the processing plant is planned to be deposited in an expired gold open pit nearby, known as the 'Ghost Crab' pit.

Figure 221: Mt. Marion planned site layout



Source: Company data

Capital and operating costs

Initial project capital is estimated at A$50m, with the construction being conducted by MIN under a build/own/operate model. MIN will levy a monthly capital recovery charge in addition to operating costs based on quantity processed, to operate the asset on behalf of the JV. Product will be trucked to Kwinana during the early stages of ramp-up, however will transition to Esperance as volumes increase.

Offtake

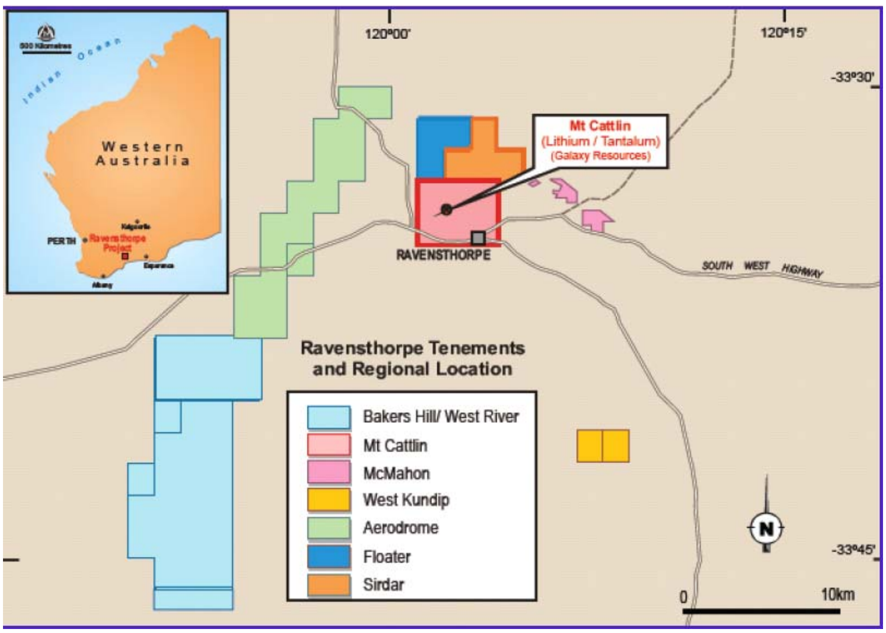
Ganfeng will purchase 100% of spodumene production from the Mt. Marion lithium project for the life of the mine ("LOM") at market prices on a CIF basis, subject to an agreed pricing floor. After the first three years of production, MIN and NMT can exercise options to collectively purchase up to 51% of the spodumene concentrate from the JV, with Ganfeng retaining offtake rights for the remaining 49% of output.

Mt. Cattlin

Ownership: General Mining (50%), Galaxy Resources (50%)

The Mt Cattlin project is a JV between General Mining (GMM) and Galaxy Resources (GXY) located 2 km north of the town of Ravensthorpe in WA. In September 2015, GMM and GXY entered into an agreement whereby GMM will earn-in up to 50% by outlaying a total A$25m capital (A$7m of which will be spent on capital to restart the operation). The mine was placed on care and maintenance in 2012 due to poor recoveries and a subdued lithium market. GMM has now restarted mining operations with plant commissioning expected to commence this quarter.

Figure 222: Mt Cattlin location



Source: Company data

Asset history

Galaxy Resources built the Mt. Cattlin lithium-tantalite operation in 2010, spending over A$100m in capital expenditure for project construction. GXY made its first shipment of 6,500t spodumene concentrate to China in March 2011 to its then-owned downstream processing plant. GXY sold tantalite concentrate to Global Advanced Metals (GAM) under a long term agreement. In July 2012, operations at Mt Cattlin were halted due to poor market conditions, lower-than-expected spodumene recoveries and the fact GXY had a year's supply of spodumene feedstock stockpiled in China.

Geology and Reserves & Resources

The Mount Cattlin Project lies within the Ravensthorpe Terrane, with host rocks comprising both the Annabelle Volcanics to the west, and the Manyutup Tonalite to the east. The contact between these rock types extends through the Project area, with spodumene-bearing pegmatites presenting as a series of sub-horizontal dykes, hosted by the surrounding volcanic and intrusive rocks.

Figure 223: Mt Cattlin mineral resources as at July 2012

Category	Tonnes (Mt)	Li2O (%)	Li2O (Kt)
Measured	2.54	1.2	31
Probable	9.53	1.06	101
Inferred	4.34	1.07	47
Total resource	**16.42**	**1.08**	**178**

Source: Galaxy Resources Roadshow presentation, January 2016

Figure 224: Mt Cattlin mineral reserves as at September 2010

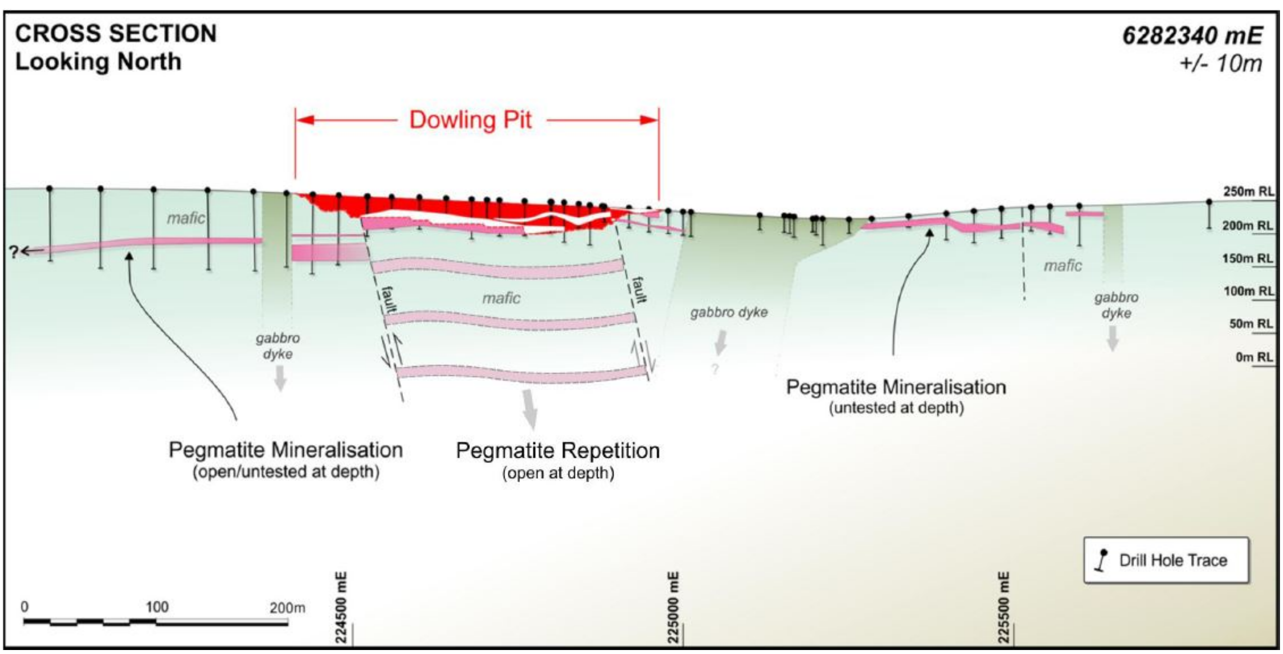
Category	Tonnes (Mt)	Li2O (%)	Ta2O5 (ppm)
Proved	2.43	1.11	141
Probable	7.54	1.02	152
Total reserves	**9.97**	**1.04**	**149**

Source: Galaxy Resources

Mining and processing

The Mt Cattlin mining operations include open-pit mining of what is a relatively flat lying pegmatite ore body. Mining is carried out using excavator and truck operations and conventional drill and blast techniques. Contract mining is used for grade control drilling and earthmoving operations (drilling, blasting, load, haul and ancillary work) for the open-cut mining operation. The Life of mine for Mt Cattlin is projected to be17 years at 800ktpa.

Figure 225: Cross section of the Dowling pit and the flat-lying pegmatite dykes at Mt. Cattlin



Source: General Mining investor presentation

The Mt. Caittlin processing plant consists of a four-stage crushing circuit designed to have a 1Mtpa front-end capacity through the primary crusher. The crushing plant provides feed to a fine ore bin and this fine ore bin feeds the concentrator on a continual basis. The concentrator consists of classification screens prior to three-stage Heavy Media Separation (HMS) cyclones. Coarse waste HMS plant float material is collected in a surge bin and then trucked to either the waste dump or to expired mining areas as back-fill. Cyclone underflow is collected, dried and stored as 6% spodumene concentrate in preparation for transportation to the Esperance port. The HMS pre-screen undersize (-0.5mm) is treated by gravity suspension (spiral classifiers) to recover tantalite and residual spodumene. The final spodumene concentrate is stacked on a pad near the plant, drained and prepared for trucking to port. The processing plant has a design capacity of 137ktpa 6% Li_2O spodumene concentrate; however LOM average production is expected to be 111.5ktpa as head grades decline over time.

Figure 226: Mt. Cattlin ROM and processing plant

Source: General Mining investor presentation

Mt. Cattlin ramp-up

Production has commenced at Mt. Caittlin, with both mining and processing operations underway. A five-week processing campaign will build product stockpiles from residual plant feed ahead of crusher and HMS circuit commissioning later in the June quarter. Given the quantities of ore already mined and available for processing, the immediate focus at restart is on the processing plant, including commissioning of the primary and secondary feed preparation circuits, thickener, fine and coarse circuit screens, mica removal screens, tantalum spirals and tables, fines reflux classifiers and filter belt.

Figure 227: Mining activities at Mt. Caittlin have recommenced

Source: Galaxy Resources Roadshow presentation, January 2016

La Negra (Albermarle)

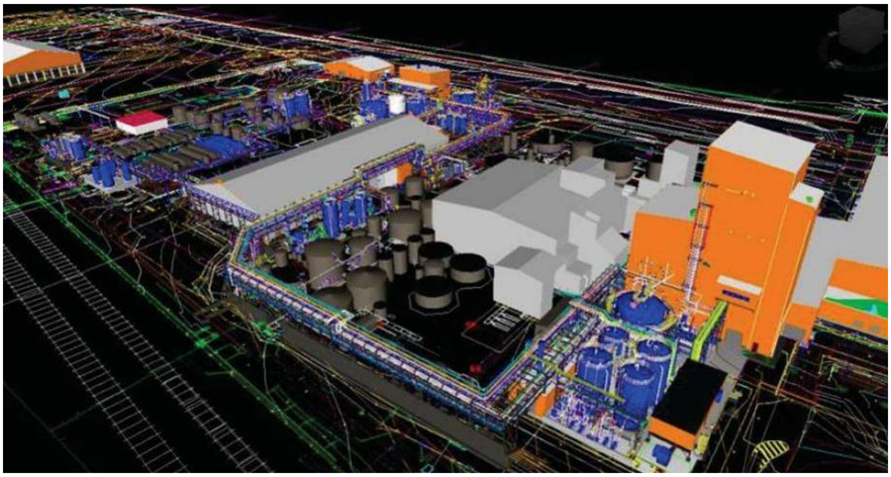
U.S.-listed Albemarle has announced that it has been granted approval to increase lithium brine extraction rates at its Salar de Atacama facilities in Chile. The Company has also signed a Memorandum of Understanding (MoU) with the Chilean government providing Albemarle with a lithium quota sufficient to support extraction rates of 70ktpa lithium carbonate for a 27 year period. To achieve this increase from its current 25ktpa operating rate, we expect Albemarle will lift output at its two existing processing facilities to 45ktpa (possibly within the next 24 months, in our view) and then construct a third operation under the MoU (potentially a 3-5 year construction period).

La Negra expansion to deliver volume growth within the next two years

ALB currently pumps lithium brine from Salar de Atacama, removes impurities within concentration ponds, then allows the brine to be concentrated via evaporation. The lithium concentration is increased from 2,000ppm to 6% in the final brine which is then transported to ALB's existing processing plant located in La Negra, a small industrial complex 22km east of Antofagasta, Chile. This plant further purifies the brine to produce industry-grade lithium carbonate and other products.

ALB has already developed a second processing plant at La Negra, known simply as a 'La Negra' plant, which is completed however has not been permitted to operate until recently. This plant is designed to produce 20ktpa battery-grade lithium carbonate which will be sold directly to battery customers, improving ALB's product mix and realised pricing. ALB believes this plant will be the produce the lowest-cost, highest quality battery grade material in the industry.

Figure 228: Detailed engineering design for La Negra processing plant



Source: Albemarle 2015 Lithium Day investor presentation

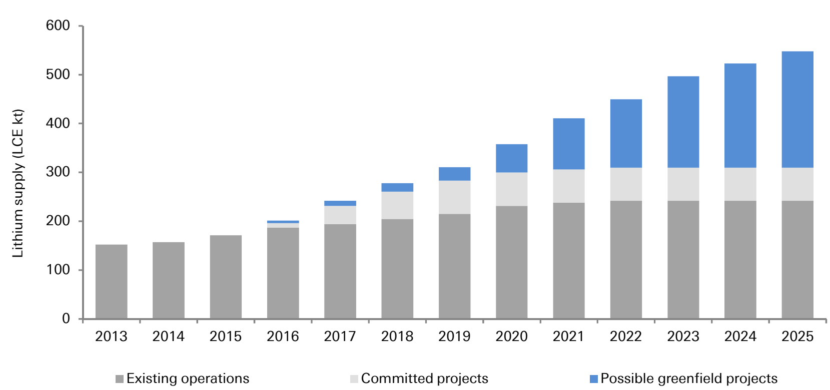
Now that ALB has the permits to expand production rates in Chile, the company needs to increase brine extraction rates at Salar de Atacama to service the increased processing capcity. We believe this may cause a lag in the ramp-up of La Negra, but it should be operating at full run rates by 2018.

Next wave of projects

A number of lithium projects have been progressed over the years but found to have higher capital intensity and/or higher operating costs than existing operations, requiring higher lithium prices to generate acceptable returns on investment. The recent price increase for battery-grade lithium products is bringing these projects back into focus as well as incentivizing companies to explore and develop new lithium targets.

The following section provides a summary of lithium development projects that we believe are next to come to market. While not an exhaustive list, these assets are those which we believe are the most de-risked (through feasibility studies) and closest to an investment decision by companies that have sufficient access to capital to develop these assets. Our supply forecasts remain conservative compared to a number of individual company targets to allow for potential delays in project development, construction and delivery.

Figure 229: Lithium supply from next wave of projects



Source: Deutsche Bank

Figure 230: Production from possible greenfield projects

	Company	Deposit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Australia															
Pilgangoora	Pilbara Minerals	Spod	0.0	0.0	0.0	0.0	0.0	0.0	11	26	43	43	43	43	43
Pilgangoora	Altura Mining	Spod	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	10.0	20.0	30.0	30.0
Argentina															
Salar del Rincón	Energi Group	Brine	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10	25	40	50	50
Cauchari-Olaroz	SQM/ LAC	Brine	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5	10	20	20	20
Sal de Vida	Galaxy	Brine	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10	20	25	25
China															
Chinese producers	Various	Both			0.0	5.2	10.2	17	17	17	17	17	19	20	25
Chile															
Asset 3*	Albemarle	Brine	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15	25	25	25	25	25
Serbia															
Jadar	Rio Tinto	Spod	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20
Total			**0.0**	**0.0**	**0.0**	**5.2**	**10**	**17**	**28**	**58**	**105**	**140**	**187**	**213**	**238**

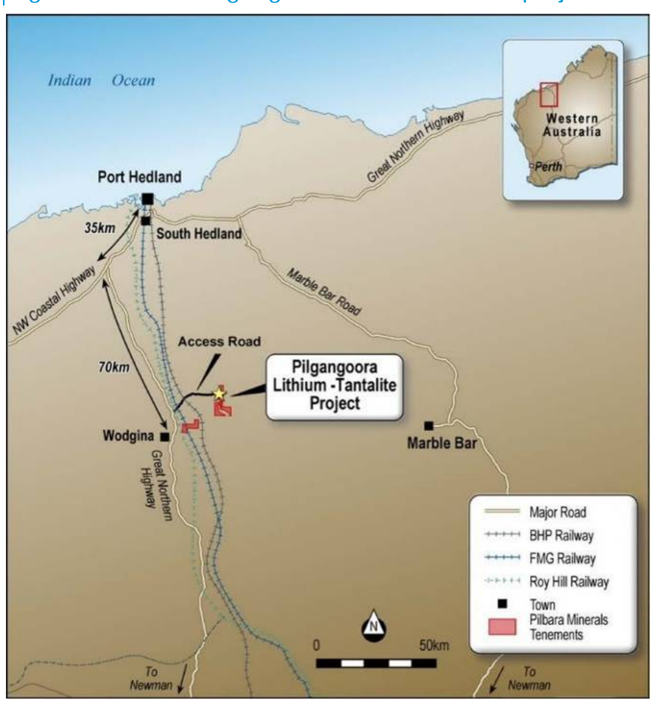
*Source: Deutsche Bank; Company data *ALB has announced it will develop a third asset in Chile to increase Chilean production to 70ktpa*

Pilgangoora (Pilbara Minerals)

The Pilgangoora lithium-tantalite project is 100% owned by Pilbara Minerals (PLS.AX, not covered). It is located 120km south of Port Hedland in the Pilbara region of WA. PLS acquired the Pilgangoora lithium project from Global Advanced Metals (GAM) in July 2014 and through subsequent drilling programs, the Company has grown the resource base from 8.6Mt @ 1.01% Li_2O to 80Mt @ 1.26% Li_2O. A maiden reserve of 29.5Mt at 1.31% Li_2O and 134ppm Ta_2O_5 was reported along with a Pilgangoora Pre-Feasibility Study in March 2016.

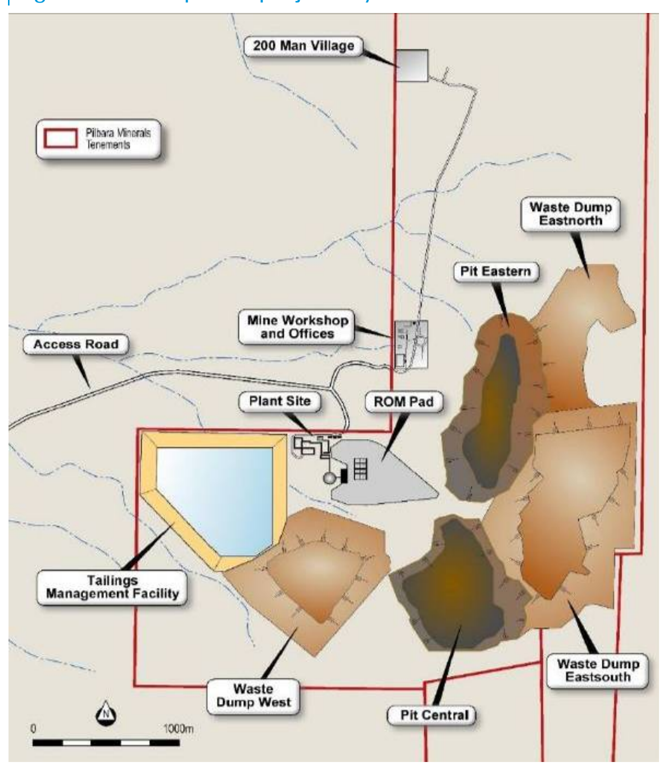
The Pilgangoora Pre-Feasibility Study estimated the project to have an NPV of A$407m and 44% IRR based on a spodumene price assumption of US$430/t, with current output expectations of around 330ktpa of 6% spodumene concentrate, equivalent to 43ktpa Lithium Carbonate Equivalent (LCE). In early April, PLS completed a "heavily oversubscribed" A$85m share placement and A$15m Share Purchase Plan (SPP) to raise a total of A$100m capital for development of Pilgangoora. PLS expects to have a Definitive Feasibility Study completed by August 2016.

Figure 231: PLS' Pilgangoora lithium-tantalite project



Source: Pilgangoora Pre-Feasibility Report, Pilbara Minerals

Figure 232: Proposed project layout



Source: Pilgangoora Pre-Feasibility Report, Pilbara Minerals

Geology

The Pilgangoora tenements are located within the Archean North Pilbara Craton, a granitoid-greenstone terrane, composed of a series of granitoid-gneiss domes bordered by valley-shaped greenstone belts composed of mafic-volcanic dominated supracrustal sequences. The prospective pegmatites are intruded into amphibolite rocks and ultramafic and mafic schists from the Warrawoona group close to the contact of a granitoid body. The pegmatite system extends over 7km, with mineralization occurring in multiple, stacked north-south trending pegmatites that can reach lengths up to 1.2km. These pegmatite dykes and veins range from 5-50m thick with a 30-70° dip to the east. PLS has interpreted the dykes as thickening with depth. The pegmatites are comprised of albite, quartz, spodumene, muscovite and K-feldspar.

Figure 233: Pilgangoora lithium-tantalite project resources as at Jan 2016

Category	Tonnage (Mt)	Li2O (%)	Li2O (Kt)
Indicated	35.7	1.31	469.4
Inferred	44.5	1.21	538.6
Total resource	**80.2**	**1.26**	**1008**

Source: Pilgangoora Pre-Feasibility Report, Pilbara minerals

Figure 234: Pilgangoora lithium-tantalite project reserves as at Feb 2016

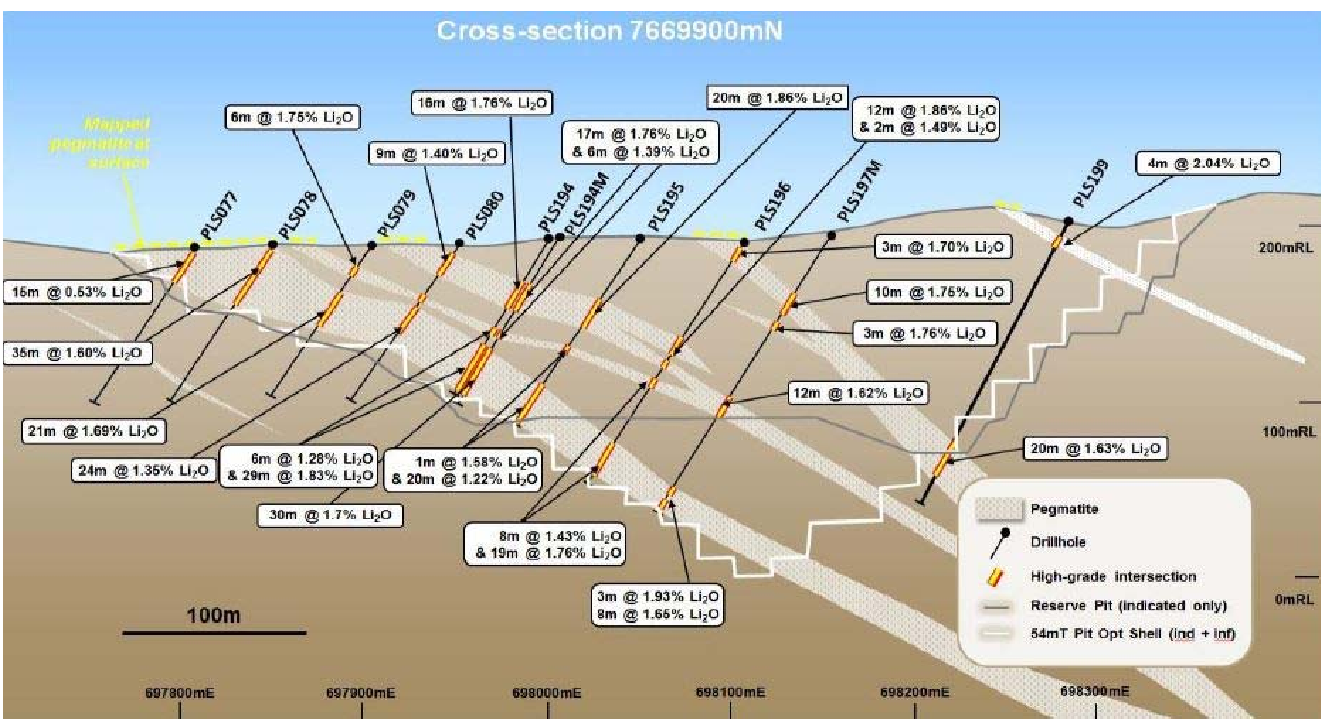
Category	Tonnage (Mt)	Li2O (%)	Li2O (Kt)
Probable reserve	29.5	1.31	298
Total reserves	**29.5**	**1.31**	**273**

Source: Pilgangoora Pre-Feasibility Report, Pilbara minerals

Mining

The Pilgangoora PFS suggests a 2Mtpa open-pit mining operation with a 15 year mine life and an estimated LOM strip ratio of 3.47:1. The PFS Study is based on contractor mining scenario, however the DFS will consider both owner mining and contracted mining. PLS describes the Pilgangoora ground as both hard and abrasive. Due to the hardness of the pegmatite ores, PFS mining costs were estimated at A$6.80/t for ore and a more industry-standard A$3.35/t for waste, mainly due to drilling and blasting costs.

Figure 235: Cross section of Pilgangoora reserve pit shell showing pegmatite ore zones



Source: Pilgangoora Pre-Feasibility Report, Pilbara Minerals

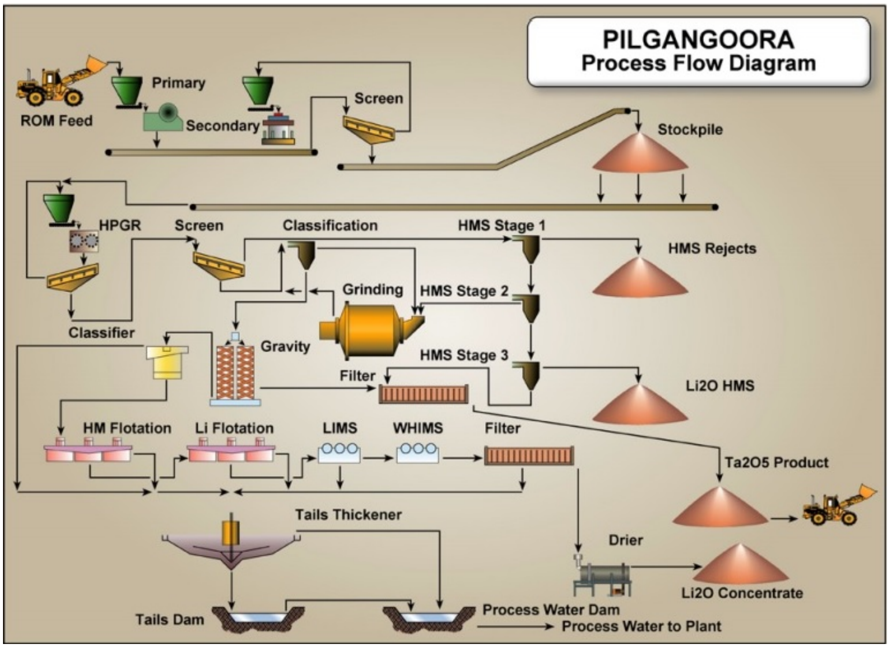
Processing

The proposed Pilgangoora processing plant is designed to process 2Mt of ore feed each year. The nominal capacity of the concentrator is 250tph of ore at an average utilization rate of 91%. Annual production is estimated at 330kt (6% Li_2O) spodumene concentrate and 274 klbs of tantalite.

The flow sheet has been designed to target three distinct product streams:

- Chemical grade spodumene at 6% Li_2O, medium iron content
- Technical grade spodumene at 6.5% Li_2O, low iron content
- Tantalite concentrate at 4-5% Ta_2O_5.

Figure 236: Pilgangoora process flow diagram



Source: Pilgangoora Pre-Feasibility Report, Pilbara minerals

The concentrator has substantial crushing and grinding infrastructure including three-stage crushing, a High-Pressure Grind Roll (HPGR) mill and a regrind circuit for oversize material. A tantalite conctentrate product is recovered via gravity separation. Coarse-grained material is sent to three-stage dense media separation, where the very coarse material is rejected (mainly barren silicates). A HMS concentrate is produced with has a coarse-grind size and 6% grade (roughly 100-140kt of concentrate).

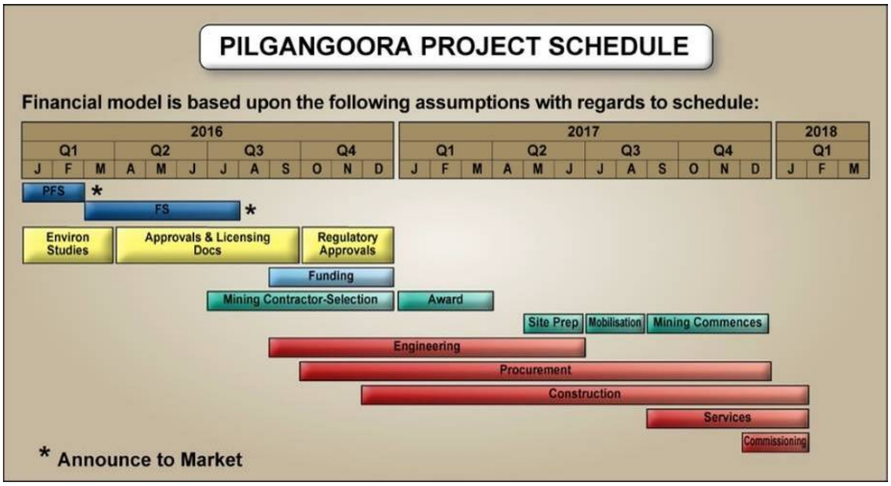
Coarser material from the gravity circuit reports to gravity underflow and has entrained lithium associated with mica and requires flotation. Post flotation, magnetic separation is used (LIMS and WHIMS) is used to remove magnetite to leave a fine-grained, high grade 6.5% Li_2O, low iron content concentrate (190kt of concentrate) suitable for technical markets (non-battery).

Capital and operating costs

Initial capex for Pilgangoora is estimated to be A$184m (± 25%) including A$22m contingency. The LOM average costs of production is expected to be A$273/t concentrate, post bi-product credits from tantalite concentrate sales.

After recently raising A$100m, PLS has already partially covered the capital requirement for construction of Pilgangoora.

Figure 237: Pilgangoora project schedule



Source: Pilgangoora Pre-Feasibility Report, Pilbara minerals

Offtake

PLS has engaged with potential customers and signed Memorandums of Understanding (MoU's) with key users/agents for spodumene concentrates in China, Korea/Japan, North America and Europe. In total, PLS has eight non-binding MoU's in place; four with technical customers and four with parties involved with battery supply chain.

Figure 238: Pilgangoora – Key parameters summary - PFS report

Life of Mine (LOM)	Years	15
LOM Ore Mined	Mt	29.5
LOM Waste Mined	Mt	102.4
LOM Strip Ratio	(waste:ore)	3.5
Plant Feed Rate	Mtpa	2.0
Average Lithium Head Grade	%	1.31
Average Lithium Recovery	%	76.7
Average Spodumene Concentrate Production	ktpa	330
Average Tantalite Production	k lbs pa	274
Average Roskill Forecast Chemical Grade Price	US$/t FOB Real	456
Tantalite Forecast Price	US$/lb FOB Real	60
Forecast FX Rate	AUD:USD	0.75
Initial Capital Cost (including 15% contingency)	A$M	184
Average LOM Operating Cost (Real$)	A$/t product	339
Average LOM Operating Cost (after Tantalite Credit)	A$/t product	273
Average Annual EBITDA (Real$)	A$M	103
NPV (10% Discount Rate, Post Tax)	A$M	407
IRR	%	44.4
Payback	Years	2.2

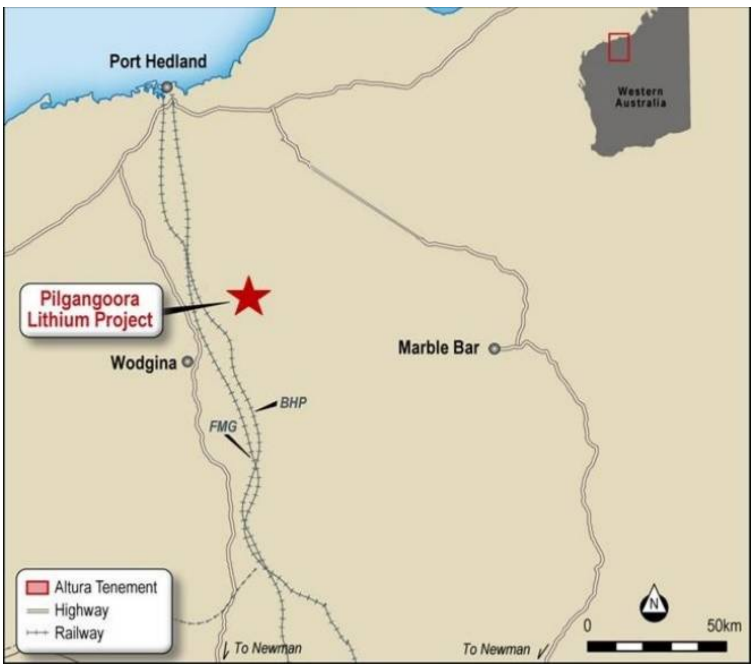
Source: Pilbara Minerals, Pilgangoora pre-feasibility study Report – March 2016

Pilgangoora (Altura Mining)

Altura Mining is developing its 100%-owned Pilgangoora lithium project in Western Australia, AJM's project tenements are 120km south of Port Hedland in the Pilbara region and neighbours PLS' Pilgangoora project. AJM acquired the tenements in 2001 and commenced lithium exploration in 2009.

AJM recently released the results of a Pilgangoora Feasibility Study, which assumed a mine life of 14 years based on the current reserve estimate. The annual average output is estimated at 215kt 6% Li2O spodumene concentrate. Initial capex for the project is estimated at A$129m with average C1 cash costs projected at A$298/t concentrate. The project is estimated to have an NPV of A$382m using a 10% discount rate, and an IRR of 59.5%.

Figure 239: Altura Mining's Pilgangoora project location



Source: Pilgangoora Feasibility Report, Altura mining

Geology and Reserves & Resources

Lithium mineralisation is contained within pegmatite dykes that have intruded amphibolites rocks within the broader Pilgangoora region. The pegmatites cover a strike of about 1.6km in a zone about 300 metres wide. The dykes range in thickness from 5-40m. A regional pattern of zonation away from a nearby granite/greenstone contact has been observed with a simple quartz–microcline–muscovite pegmatite assemblage near the contact and changing to an albite-spodumene-muscovite at a distance of c.2km from the contact.

Figure 240: Pilgangoora mineral resources as at February 2016

Category	Cut-off Li2O (%)	Tonnes (Mt)	Li2O (%)	Li2O (Kt)
Indicated resource	0.4	26.7	1.05	280
Inferred resource	0.4	9.0	1.02	92
Total resource	**0.4**	**35.7**	**1.05**	**372**

Source: AJM Pilgangoora Feasibility Report

Figure 241: Pilgangoora ore reserves as at April 2016

Category	Cut-off Li2O (%)	Tonnes (Mt)	Li2O (%)	Li2O (Kt)
Probable reserves	0.4	18.4	1.07	198
Total reserves	**0.4**	**18.4**	**1.07**	**198**

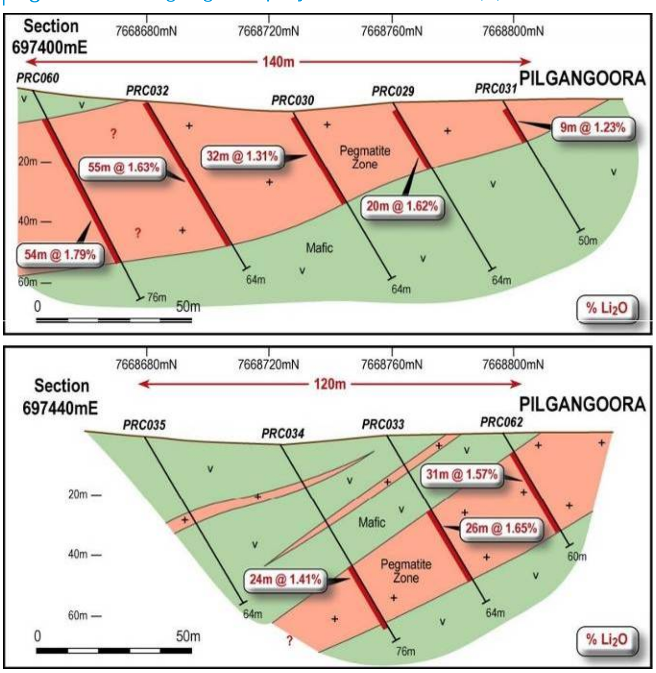
Source: AJM Pilgangoora Feasibility Report

AJM has commenced a further evaluation program to better understand the deposits on its tenement package; the company's aim with this program is to convert more Indicated & Inferred resource into reserve.

Mining and processing

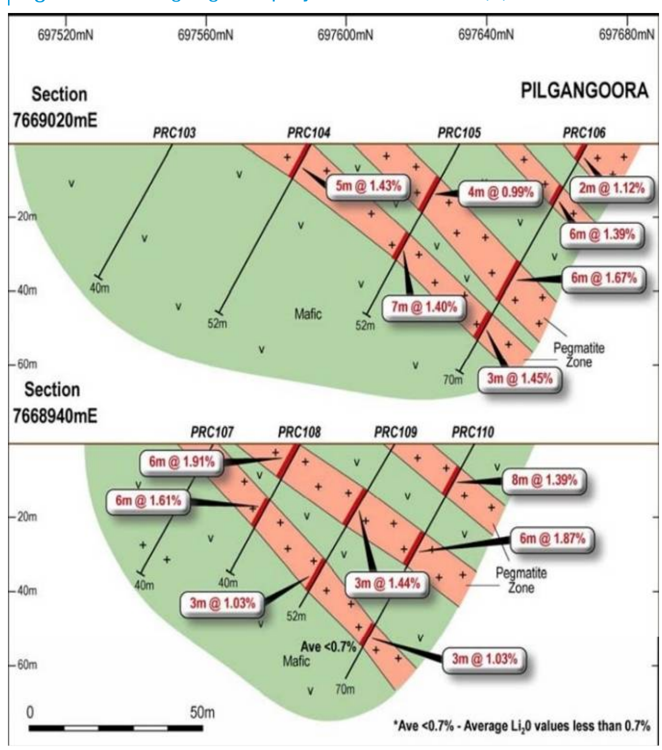
AJM plans to develop an open-pit mining operation at the Pilgangoora project, utilising conventional bulk mining methods (hydraulic excavators, dump trucks and drill & blast) delivering ore either directly to the primary crusher or to a ROM stockpile. Mining is expected to extract 18.5Mt of ore over the 14 year life-of-mine at a strip ratio of 2.7:1. The pit design suggests a final pit length of approx. 1.5km, width of 185-500m, and depth ranging between 46 and 199m depending on natural topography.

Figure 242: Pilgangoora project cross section (1)



Source: AJM investor presentation

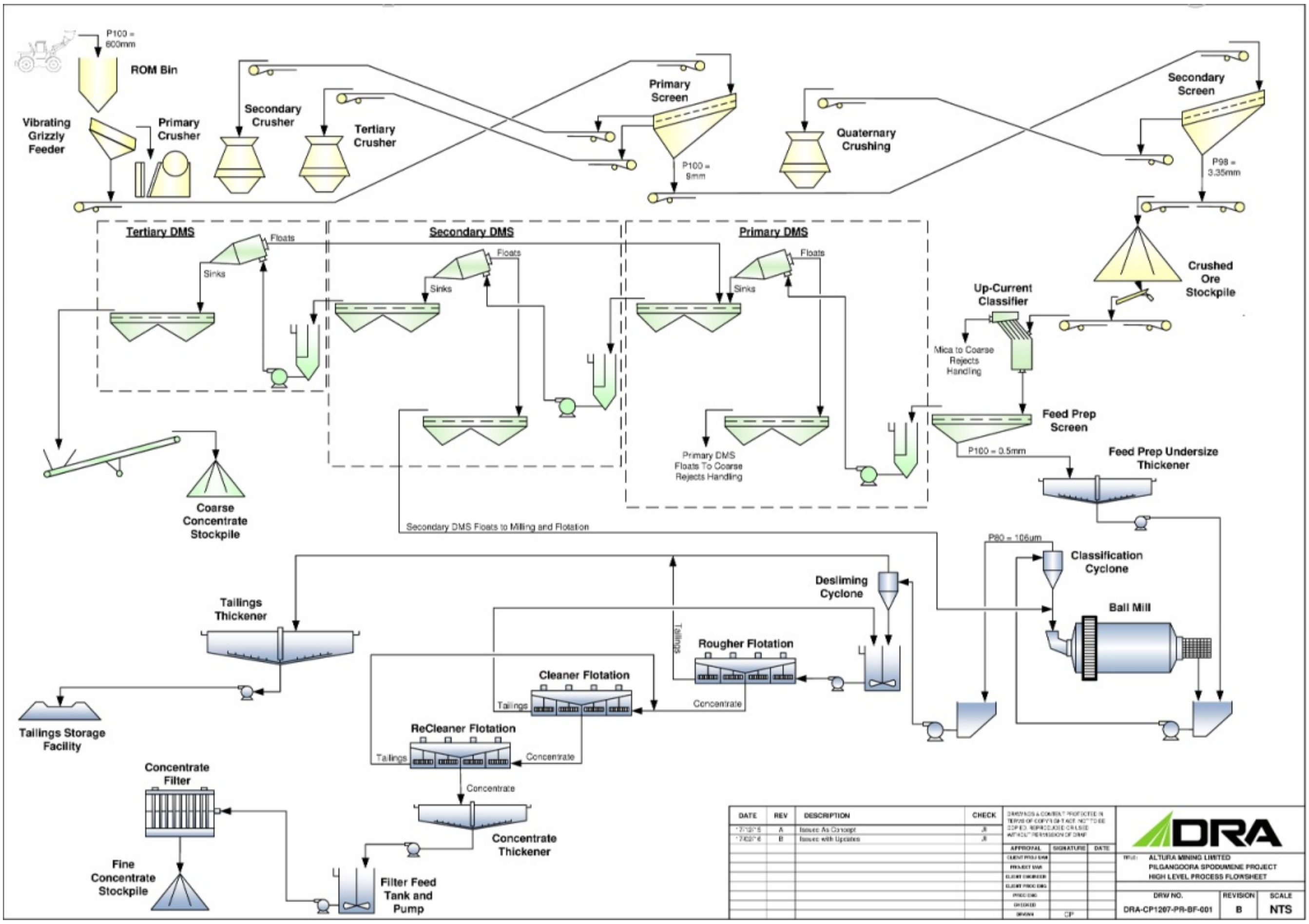
Figure 243: Pilgangoora project cross section (2)



Source: AJM investor presentation

The process plant has been designed to process 1.4Mtpa of Pilgangoora lithium ore, beneficiating ROM Ore to a 6.5% lithium concentrate. The plant creates both a coarse and fine concentrate, utlising four stage crushing circuit and three stages of Dense Media Separation to produce coarse (+0.5mm) spodumene concentrate, then a second fine concentrate is recovered via flotation.A tailings storage facility (TSF) is required to accommodate fine tailings from the process plant and to facilitate recovery of process water. The mine will produce 420kt of fines tailings per annum over 14 years.

Figure 244: Altura Mining – Pilgangoora process flow diagram



Source: AlturaMining – Pilgangoora Feasibility Study

Figure 245: Pilgangoora – Feasibility study - Key parameters summary

Average Annual Ore Feed to Plant	Mtpa	1.4
Total Ore Mined	Mt	18.47
Annual Spodumene Concentrate Production (steady state, years 1-11 @ 6% Li2O)	tonnes	215,000
Life of Mine (LOM)	years	14
Total Spodumene Concentrate Produced	Mt	2.74
LOM Strip Ratio	waste:ore	2.7:1
Spodumene Concentrate Market Price	US$	494
Capital Cost Estimate	A$M	129.3
Total Net Revenue	A$M	1,562
Project EBITDA	A$M	774
Total C1 Cash Cost	A$M	690
Total Cash Cost FOB/ tonne product	A$	297.9
Net Present Value (NPV)	A$M	382
Internal Rate of Return (IRR)	%	59.5
Discount Rate	%	10
Project payback period	years	1.7
Exchange Rate	AUD:USD	0.75

Source: Altura Mining – Pilgangooga Feasibility Study Report – April 2016

Salar del Rincon (Enirgi)

Salar del Rincon is 100% owned by ADY Resources Ltd, a wholly owned subsidiary of Enirgi Group Corporation ("Enirgi"). Enirgi is a private company wholly owned by the Sentient Group ("Sentient"). The project is located on the northern periphery of Salar del Rincon, Salta Province, in the northwestern region of Argentina. Enirgi Innovation, which is a division of Enirgi Group, has developed a proprietary lithium extraction process in cooperation with the Australian Nuclear Science and Technology Organisation ("ANSTO") to directly extract lithium from raw brine. This process does not require evaporation pond infrastructure and reduces logistical inputs with only two external reagents required; natural gas (a 40km pipeline will be constructed) and lime (ADY owns a limestone deposit 10km from Rincon).

Salar del Rincon PFS completed last October, DFS due this quarter

Following a series of drilling campaigns and brine aquifer tests beginning in 2010 and a three year period of detailed engineering studies, Enirgi completed a PFS summarized in an independent 43-101 Technical Report authored by SRK Consulting together with Schlumberger and ANSTO in October 2015. Enirgi's 43-101 compliant DFS is expected to be delivered in Q2 2016. At the time of writing of the PFS, the proposed Salar del Rincon plant had a 50kt LCE nameplate capacity.

Asset ownership history

Admiralty Resources NL acquired the mining lease applications for Salar de Rincon from a private partnership in 2001. Within months, ADY released a preliminary scoping study on potassium chloride and lithium chloride extraction from the Salar. In 2007, ADY announced a de-merger creating a separate entity, Rincon Lithium Ltd, which was subsequently acquired by private-equity firm Sentient in 2008. Sentient founded Enirgi Group in 2012 and vended-in Rincon Lithium, which was re-named ADY Resources. ADY operates under the Enirgi Chemicals Division.

Figure 246: Energi's lithium carbonate demonstration plant built with cooperation from ANSTO in Sydney, Australia

Source: Enirgi Corporation

Salar de Rincon demonstration plant (new proprietary process)

Enirgi Group constructed a lithium carbonate demonstration plant in Sydney Australia in 2014 and demonstrated that its extraction technology could economically extract lithium brine from unconcentrated brine at commercial scale. The plant operated for 12 days with brine from Salar del Rincon and demonstrated continuous manufacturing of high-purity lithium carbonate while precipitating out major impurities to very low concentrations. The resulting slurry was filtered on a vacuum filter to remove moisture to produce a filter cake. The demonstration plant has since been decommissioned and its modular parts have been shipped to the Salar del Rincon for reconstruction, commissioning and testing at site.

Figure 247: Rincon demonstration plant vacuum filter

Source: Enirgi Corporation

Figure 248: Lithium carbonate filter cake

Source: Enirgi Corporation

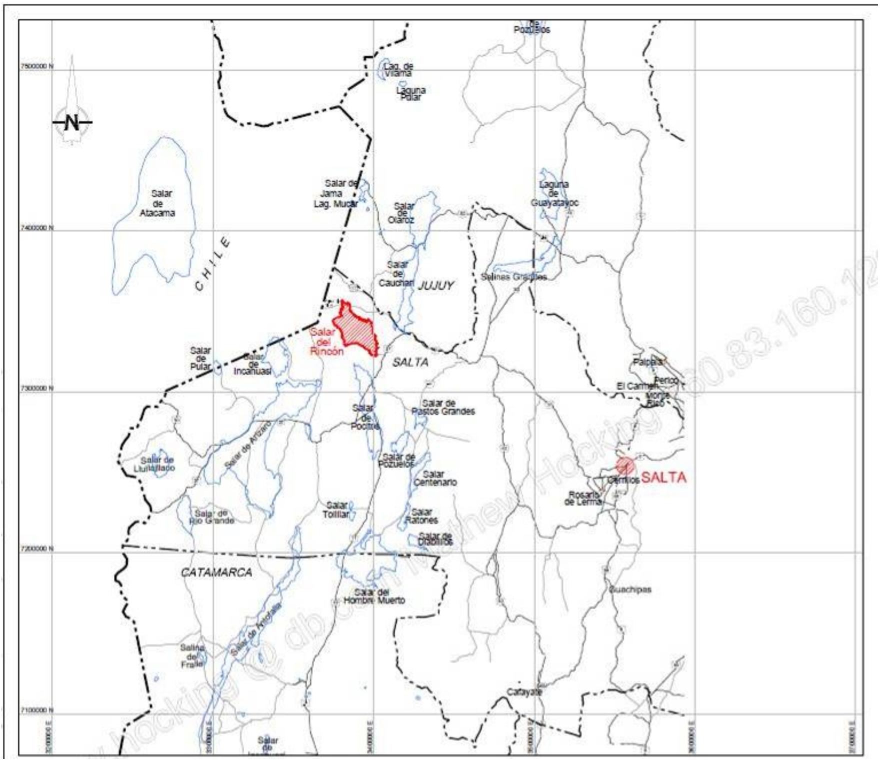
Regional and local geology

The Puna Region of northwestern Argentina is part of a technically elevated plateau that covers a portion of Peru, Bolivia, Chile and Argentina. This plateau has a baseline elevation of 3,800m to 4,000m. The exposed rock units within this portion of the Puna range from Pre-Cambrian to present-day formations with a number of missing sections and complex structures resulting from series of major tectonic events.

Volcanic activity typical of extensional terrains plays a large role in the ultimate concentration of the elements (Li, B, K, etc.) that are ultimately contained in both the brines, clays and silts of the Miocene basins of the Puna region. One prominent theory is that these elements are conveyed to these closed basins by the heated waters that leached them from the volcanic units.

Salar del Rincon is a structurally derived, closed drainage basin filled with clastic sedimentary material and evaporates. Unconsolidated clastic sediments have accumulated along with important amounts of saline minerals. These saline minerals have accumulated for millions of years, during which time the basins remained closed and the climate was conducive to high evaporation. The climate has not always been as dry during this period, which has led to the dissolution and re-deposition of the Salar components (slats and brine) through time. The current environment is estimated to have been in place for over 5 million years, giving a long period of accumulation to present concentrations.

Figure 249: Salar del Rincon is located to the south of ORE's Olaroz project

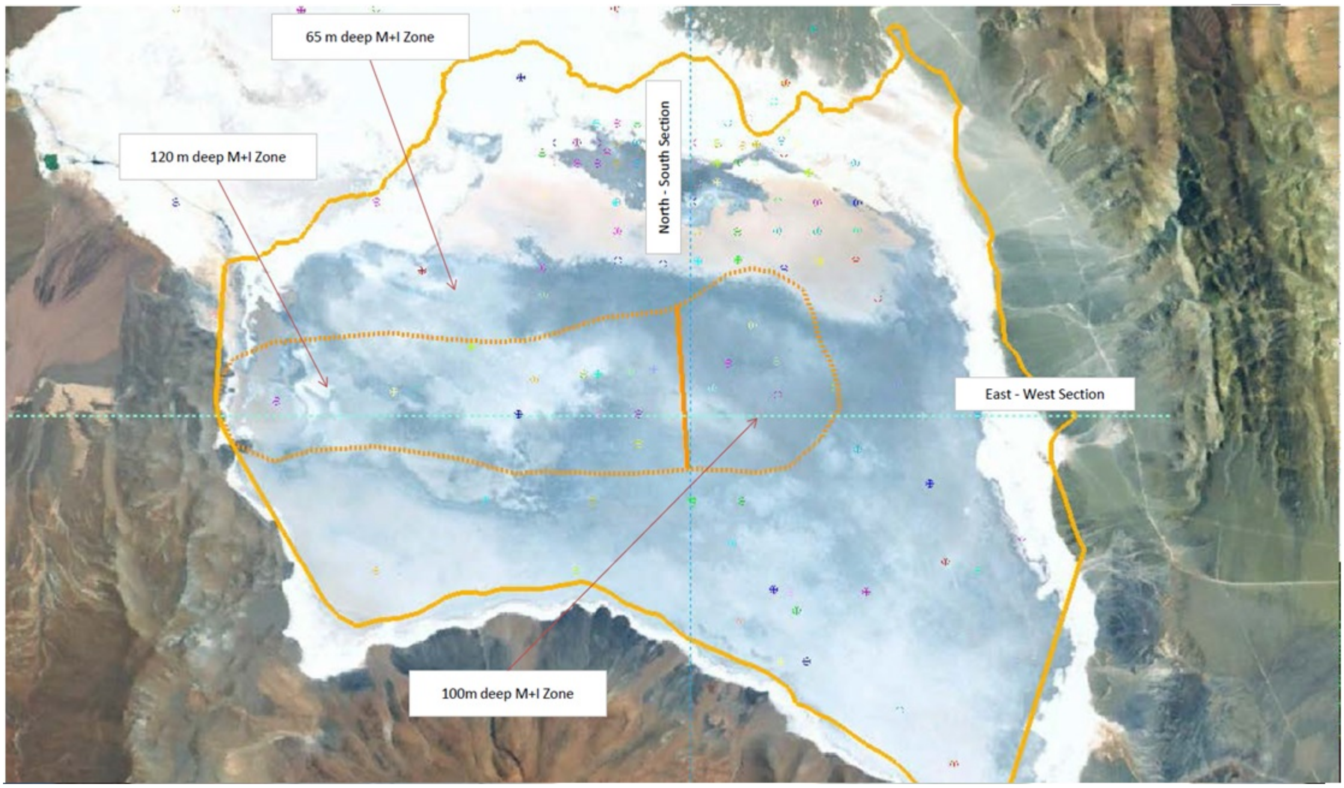


Source: Enirgi Corporation

Mineral resource estimate

At the time of writing of the PFS, initial estimates of Salar del Rincon noted a recoverable Measured & Indicated resource of approximately 3.6Mt LCE and a recoverable inferred resource of 4.3Mt LCE for a total recoverable resource of 7.9Mt LCE. Based on these estimates, this makes the Rincon the world's seventh largest brine-based resource according to our industry analysis.

Figure 250: The Salar del Rincon resource



Source: Enirgi Corporation

Historic production

There is no recorded production of lithium or potassium from Salar del Rincon prior to 2011, however some borates and salt production has occurred. A pilot plant using a conventional brine process (incl. evaporation ponds) operated at Rincon from April 2012 until Dec 2014. The pilot plant produced 1.2kt LCE industrial-grade LCE, 31t technical grade LCE and 59t of battery-grade LCE.

Capital costs

Capex for the Salar del Rincon Lithium project is estimated to be in the range of approximately US$600m - $700m.

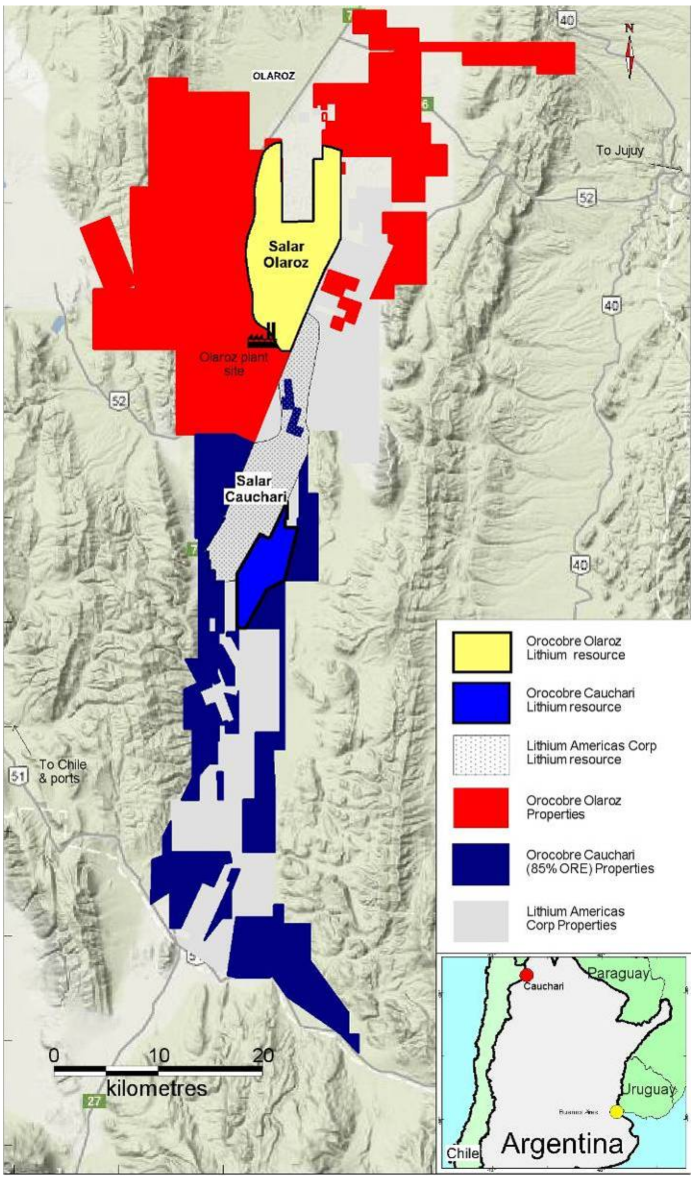
Operating costs

Estimated production costs (to Port) are in the range of US$1,300 - $1,600/t LCE and total estimated cash operating costs are in the range of US$1,800 - $2,000/t LCE. The DFS, which will include updated capex and opex costs for the 50ktpa Salar del Rincon lithium project, is expected to be completed in Q2 2016. A key cost component is natural gas along with royalties and site administration costs.

Cauchari-Olaroz (SQM and Lithium Americas)

SQM and Lithium Americas (TSX.LAC, not covered) have entered a 50/50 joint venture to develop the Cauchari-Olaroz project in Argentina. SQM committed US$25m to acquire its stake in the project. Feasibility studies will commence immediately on a 40ktpa lithium carbonate operation, roughly the same output at SQM's 2015 production of 38kt from Salar de Atacama in Chile. Timing of the studies and potential construction and ramp-up has not been disclosed.

Figure 251: Lithium Americas tenements border ORE's Olaroz project



Source: Orocobre

The Cauchari-Olaroz project borders ORE's Olaroz lithium project. Lithium Americas released a DFS on the project in 2012 targeting 20ktpa which, based on lower lithium carbonate prices, generated a US$404m NPV and annual cash flows of US$117m, however the project stalled due to lack of funding.

Sal de Vida (Galaxy Resources)

Galaxy Resources acquired the Salar de Vida project in July 2012 through the merger with Lithium One Inc. Salar de Vida is situated in the north-western region of Argentina, adjacent to FMC Lithium's El Fenix lithium operation in the Salar del Hombre Muerto, which has been in operation for the last 15 years. In April 2013, Galaxy Resources released a Definitive Feasibility Study (DFS) on Sal de Vida, estimating a project NPV of US$380m using at 10% discount rate.

Galaxy has undergone a major corporate restructure over the last 24 months, divesting downstream assets, repaying debt and bringing in a joint venture partner to operate their Mt. Cattlin spodumene operation. The focus of the management team is now Sal de Vida. The first target for GXY is re-budgeting the 2013 Sal de Vida PFS for the current cost environment and weaker Argentinean peso. Considering the cost deflation seen in the mining industry over recent years along with weaker FX, it is likely the re-budgeted Sal de Vida PFS will come in below the 2013 capital estimate of US$368m (incl. US$33.5m contingency).

Figure 252: Sal de Vida location

Source: Salar de Vida DFS report, April 2013

Project summary

The Sal de Vida DFS suggested a project that would produce 25ktpa of lithium carbonate and 95ktpa of potash products, over a 40 year mine life. The project would encompass two wellfields (Southwest and East) based on brine quality, extent of the brine aquifer, and the ability to pump the brine aquifer at sufficient quantities and rates to support filling and maintaining levels of the evaporation ponds. A total of 24 well field pumps will provide a continuous flow of brine to the liming and evaporation ponds. In summer months when temperatures are highest and rainfall low, evaporation rates can double. In these periods, additional wells will be brought online to increase the flow of brine to the evaporation ponds. Well pumping rates and lime plant throughput can be operated at 40% above the average to take advantage of high evaporation rates.

Geology and Reserves & Resources

Sal de Vida has a reported reserve of 1.4Mt LCE, equivalent to 40 years of operation. The deposit hosts a larger resource of 7.2Mt LCE (at 753mg/L) which suggests recoverable lithium could exceed current reserve estimates.

Figure 253: Salar de Vida – Mineral Resource Estimate

	Brine Volume (m3)	Avg. Li (mg/L)	In situ Li (tonnes)	LCE (tonnes)
Measured	7.2 x 108	787	565,000	3,005,000
Indicated	2.6 x 108	768	197,000	1,048,000
Inferred	8.3 x 108	718	597,000	3,180,000
Total	**18.1 x 108**	**753**	**1,359,000**	**7,233,000**

Source: Salar de Vida DFS report, April 2013

Figure 254: Salar de Vida – Reserve Estimate

	Time Period (Years)	In situ Li (tonnes)	LCE (tonnes)
Proven	1-6	34,000	181,000
Probable	7-40	180,000	958,000
Total	**40 years total**	**214,000**	**1,139,000**

Source: Salar de Vida DFS report, April 2013

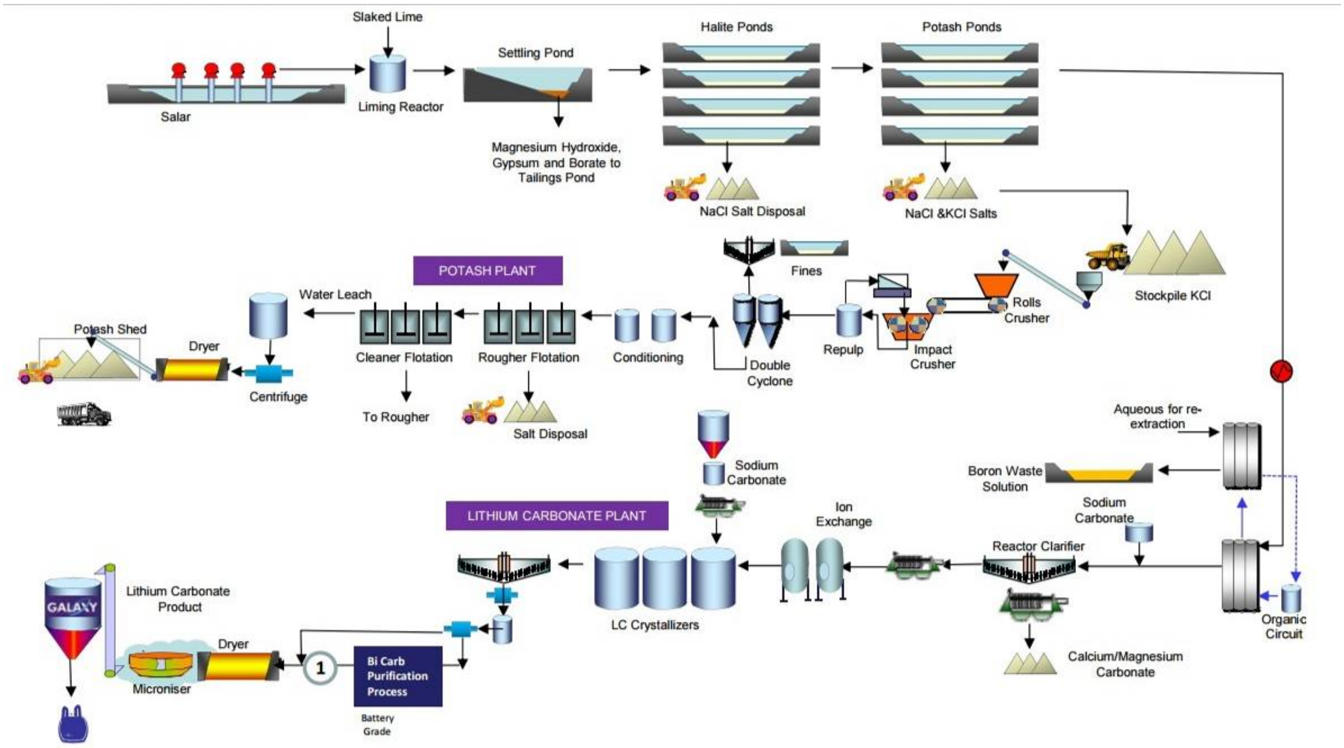
Processing flow sheet

- **Evaporation ponds:** Extracted brine from the well fields will be pumped to the liming ponds for magnesium removal as the first step of the purification process. Magnesium is precipitated as magnesium hydroxide $Mg(OH)_2$ after reacting with lime. Brine is pumped into the lime settling pond where magnesium hydroxide solids settle to the pond floor and brine overflows into a pumping well.
- **Halite ponds**: The function of the halite ponds is to concentrate limed brine to its potassium chloride saturation limit through evaporation and remove the sodium chloride (NaCl). The lined halite ponds consist of five strings (four operating, one in harvest) with a total surface area of 7.7km^2. The crystallised salts rich in sodium chloride accumulate at the bottom of the ponds and are recovered by harvesting.
- **Muriate ponds**: From the last halite pond the brine is transferred into the muriate (KCl) ponds where it is concentrated to 2% lithium. At the same time, potassium chloride (KCl) crystallizes along with the halite, gypsum and borate. The muriate ponds consist of five strings (four operating, one in harvest) with a total surface area of 1.5km^2, which are each connected to one of the halite pond strings. Muriate salts, rich in potassium chloride and sodium chloride, accumulate at the bottom of the ponds as they crystallise and are harvested as the raw material feed for the potassium chloride process plant. Ponds will be harvested sequentially in 18 month cycles. Concentrated brine is pumped into a surge pond, and then to the lithium carbonate plant.
- **Potash plant:** 95ktpa of agricultural-grade potash is expected to be produced from 500ktpa of muriate being harvested from the muriate ponds. The harvested muriate contains around 71% NaCl and 25% KCl. The potash plant is designed to extract and purify the potash (KCl) to 97% grade which is suitable as a fertiliser for the agricultural industry. The process involves the crushing, milling, conditioning, flotation, centrifugation, drying and packaging.
- **Lithium carbonate plant** - The lithium carbonate plant is designed to produce 25ktpa of battery grade (99.5%) lithium carbonate. Brine is supplied from the muriate ponds with a minimum 2%(w/w) lithium content. The plant consists of several process stages; boron removal (solvent extraction), calcium and magnesium removal, lithium carbonate precipitation, purification, dewatering and drying, micronizing, and bagging.
- Brine is pumped into the lithium carbonate plant, heated and pH adjusted before the solvent extraction (boron removal) process. The solvent extraction circuit consists of three extraction stages, where the process brine is mixed with organic extractant and five stripping stages where the organic extractant, loaded with boron, is exposed to an aqueous stripping solution, which then releases boron (reduces boron concentration to 50ppm). The low boron-calcium-magnesium brine concentrate is pumped to the primary ion exchange feed tank where further calcium, magnesium and boron contaminants are removed using ion exchange technology.
- Brine is then pumped into the lithium carbonate plant, and reacted with soda ash (sodium carbonate) to precipitate calcium and magnesium as carbonates. The brine is pumped through a press filter

and a polish filter to remove the precipitated solids. Once the brine has been purified by precipitation, solvent extraction and ion exchange it passes through a series of heat exchangers to raise its temperature. The brine is then reacted with soda ash (Na_2CO_3) solution in draft tube crystallisers, precipitating lithium carbonate (Li_2CO_3). The reactor product is pumped to the crystalliser thickener, then the final lithium carbonate is extracted via a bank of centrifuges.

- Galaxy developed and patented its purification technology in 2010 and has successfully proven the technology at its Jiangsu Plant in China. Purification involves digestion, ion exchange and recrystallisation. During digestion, the solid Li_2CO_3 crystals are digested in cold process liquor in the presence of CO_2 which reacts to form lithium bicarbonate ($LiHCO_3$), which has a much greater solubility than lithium carbonate. The resulting liquor is filtered and passed through an ion exchange unit to remove excess entrained contaminants. The final pure liquor is steam-heated and pure lithium carbonate crystals precipitate out of solution. The product is pumped to the crystalliser thickener where the lithium carbonate is extracted via a bank of centrifuges and dried.

Figure 255: Salar de Vida – Process Flow Diagram



Source: Deutsche Bank

Capital and operating costs

The Sal de Vida DFS capital estimate was US$368m (incl. US$33.5m contingency), while estimated average operating costs were US$2,200/t LCE (after potash bi-product credits). Over 40% of operating costs comprises of which 42% comprises reagent costs such as soda ash, lime and various process reagents. The other major contributors to costs include labour (15%), transport costs (16%) and power generation (7%).

Nemaska Lithium

Nemaska Lithium Inc. is a Canadian lithium company located in Quebec, Canada and listed on the TSX Venture exchange (NMX.V). It is engaged in the exploration and development of hard rock lithium and processing of spodumene into lithium compounds. The company plans to supply lithium hydroxide and lithium carbonate to the emerging battery-grade lithium market.

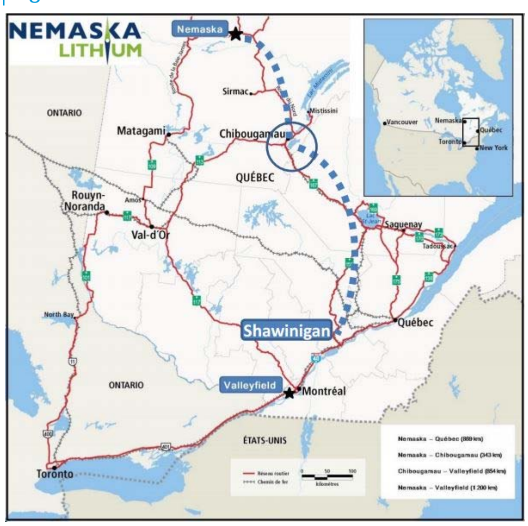
Whabouchi

The Whabouchi spodumene project is located in Eeyou Istchee James Bay region, 300km north of Chibougamau and is 100% owned by NMX. The company has released a Feasibility Study on Whabouchi, scoping a 20-year operation with planned production of 213ktpa spodumene concentrate that will then be converted onsite into 27.5ktpa lithium hydroxide and 3.2ktpa of lithium carbonate. Project capital was estimated at US$439m (including contingency), and NMX forecast a Whabouchi NPV of US$1.5bn using an 8% discount rate.

DMS mill purchased to commence bulk sampling

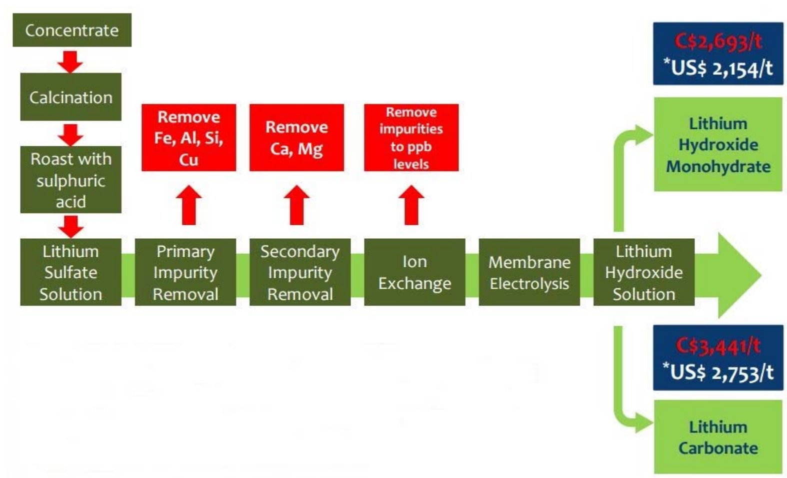
NMX recently announced that it had bought a portable DMS mill which will be located in the mine site. The mill has a capacity of 10t/hour and will be used to produce 6% Li_2O spodumene concentrate which NMX intends to further refine in its proposed Phase 1 demonstration plant in Shawinigan, Quebec.

Figure 256: Location of Whabouchi mine



Source: Nemaska Lithium, Corporate Presentation (April 2016)

Figure 257: Nemaska Lithium – process flow diagram



Source: Nemaska Lithium, Corporate Presentation (April 2016)

Figure 258: Whabouchi mineral reserves and resources

Category	Tonnage (Mt)	Li2O (%)
Open Pit	20	1.53
Underground	7.3	1.28
Total Reserves	**27.3**	**1.46**
Total Resources	32.7	1.56

Source: Nemaska Lithium, Corporate presentation (April 2016)

POSCO (Argentina)

POSCO announced in February 2016 that the company had held a groundbreaking ceremony for its lithium plant at Pozuelos salt lake in Argentina. The company has announced that this plant will produce '2.5kt of high-purity lithium'; we interpret this as 2.5ktpa of +99% lithium carbonate, signaling that this plant is likely a large-scale demonstration plant to test POSCO's proprietary lithium extraction technology before the company makes a final investment decision on a larger operation.

POSCO's independent technology is touted as dramatically reducing the time taken to extract lithium, which usually is more than a year, through chemical reactions. The new technology was developed with support from the energy resource technology development project led by the Ministry of Trade, Industry and Energy in 2010, and does not require a large area of salt farms compared to the conventional evaporation and extraction method, and is less influenced by climate changes (weather/ evaporation rates).

Figure 259: POSCO is developing a proprietary lithium extraction method

Source: POSCO, Lithium Americas

POSCO's commitment to development of a lithium project remains at pilot-plant stage. While this could change very quickly, we have not included any output from the Pozuelos salt lake in Argentina in our global supply and demand analysis. We do note that new processing technologies do present a significant potential risk to global supply, project economics and industry structure.

Jadar (Rio Tinto)

The Jadar project is a world-class, pre-feasibility stage lithium-borate project, discovered by Rio Tinto in 2004. The project is located in the Jadar basin 140km from Belgrade in Serbia. In 2007, the company geologists discovered a new mineral, unique to Serbia, named Jadarite at the project, which contains both borate and lithium. Serbia is the only known source of Jadarite in the world.

As of mid-February 2016, Rio Tinto had invested c.US$70m in exploration and pre-feasibility studies, including technical, social, environmental and economic studies. The company has further committed to invest US$20m through 2017 to complete the pre-feasibility studies and obtain a resource/reserve certificate from the Serbian government. Studies are currently focused on determining the optimum-sized operation that complements its borate mining operations in California (U.S.). Once developed, Rio Tinto forecasts the Jadar project could supply over 10% of the world's lithium demand.

The Jadar project has excellent access to road, rail and river transportation, as well as electricity, gas and telecommunications infrastructure. This will help in smooth development of the project. Rio Tinto expects that bringing Jadar from its current development phase to first production will take about six years.

Figure 260: The Jadar resource is an underground deposit in the Jadar basin, situated underneath the town of Jadar

Source: Rio Tinto Jadar factsheet, September 2011

Jadar Resource

The lower zone of the project currently hosts an inferred resource (JORC Compliant) of 125Mt at an average Li_2O concentration of 1.8% and 18Mt of borates (B_2O_3). Additionally Upper and Middle zone has inferred resource (AMEC NI 43-101 compliant) of 80 Mt containing 1.5% Li_2O

Figure 261: Jadar Resource (Inferred)

	Tonnage (Mt)	Li2O%	LCE	
Lower Jadarite	**125.3**	**1.80%**	**5.58**	**JORC Compliant**
Upper Jadarite	46	1.50%	1.71	NI 43-101 Compliant
Middle Jadarite	34	1.50%	1.26	NI 43-101 Compliant
Total	**80**	**1.50%**	**2.97**	**NI 43-101 Compliant**

Source: Rio TInto

Figure 262: Jadar mineralisation sits in flat lying lenses that are split into upper, middle and lower zones

Source: Rio Tinto Jadar factsheet, September 2011

Project economics influenced by both lithium and borates

Once the Jadar project is developed, it will further strengthen Rio Tinto's market leadership in borates. Rio Tinto is currently the global leader in borate production and supplies about one-third of the world's demand for refined borates through its open-pit mine at the Mojave Desert in Boron, California. The company has a worldwide network of refineries, shipping facilities, research centers and sales/distribution facilities, including refineries and shipping facilities in the U.S. and France, a research laboratory in China, and shipping and distribution facilities in the Netherlands, Spain and Malaysia

Global borates consumption is expected to remain strong with healthy demand from the ceramics, agriculture and borosilicate glass sectors in Asia (particularly in China). According to Roskill, the global borates (B_2O_3) demand is expected to reach 2.2Mt in 2018 compared to 1.5Mt in 2009.

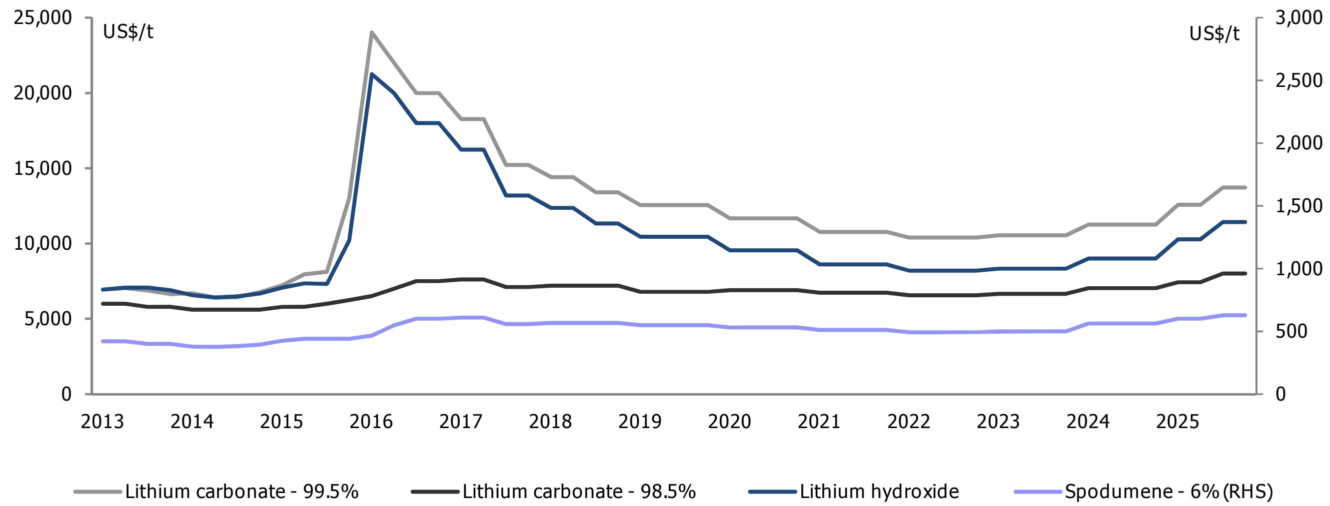
Lithium price forecasts

New supply is being incentivized into the market over the next 12 months (Mt. Marion and Mt. Cattlin) with another wave of spodumene being developed for potential market entry from FY18. While these projects require incentive pricing to enter the market over the next 2-3 years, we are of the view that long term pricing will be driven by marginal cost.

Marginal cost longer term set by brine projects

76% of global lithium reserves are brine-based deposits, and while they are more capital intensive and slower to respond to market conditions, brine projects have inherently lower costs and greater economy of scale. As a result, we believe brines will reclaim market share after 2018 and spodumene pricing will be linked to the marginal cost of a brine asset producing lithium carbonate, not the other way round.

Figure 263: DB price forecasts for 99.5% & 98.5% lithium carbonate, lithium hydroxide and 6% spodumene concentrate



Source: Deutsche Bank;

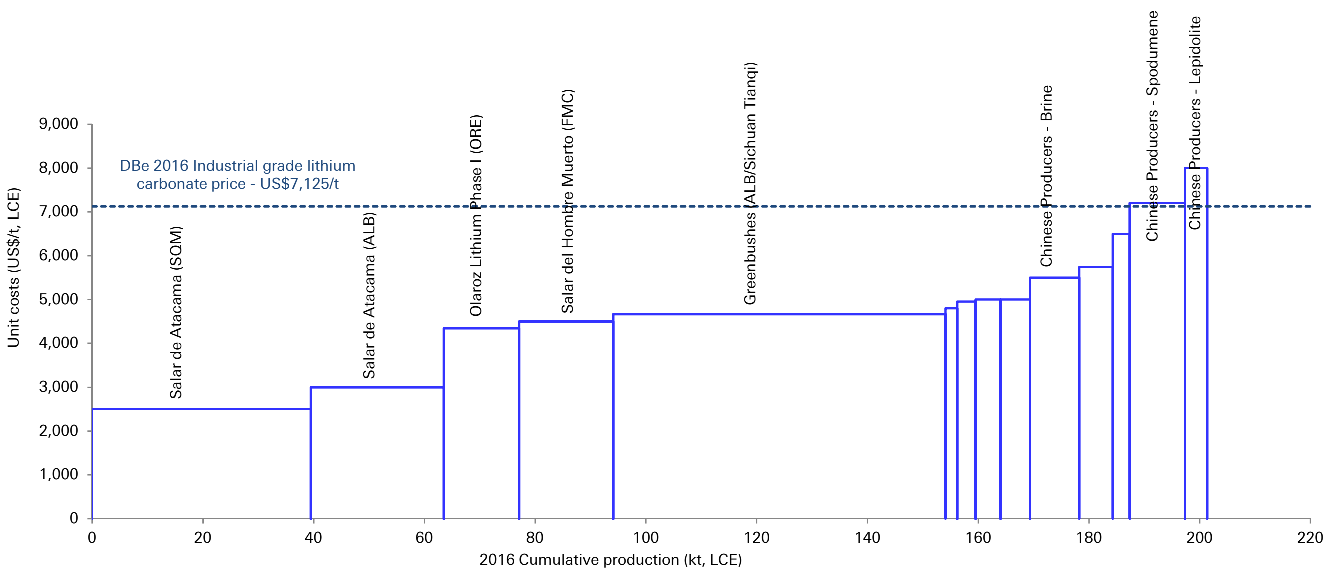
Figure 264: Lithium products price forecasts (2016-25)

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025 - (LT, Real)
Market surplus/(deficit)	**kt**	**2**	**2**	**-13**	**-8**	**3**	**1**	**-2**	**-2**	**19**	**22**	**33**	**25**	**14**
Lithium carbonate - 99.5%	US$/t	6,880	6,577	9,081	21,509	16,748	13,908	12,548	11,675	10,773	10,388	10,544	11,265	12,000
Lithium hydroxide	US$/t	6,996	6,535	7,985	19,315	14,718	11,848	10,457	9,552	8,618	8,201	8,324	9,012	10,000
Lithium carbonate - 98.5%	US$/t	5,900	5,600	5,963	7,125	7,359	7,212	6,797	6,899	6,733	6,561	6,659	7,041	7,000
Spodumene - 6% (RHS)	US$/t	410	383	436	554	584	567	549	531	512	492	499	563	550

Source: Deutsche Bank

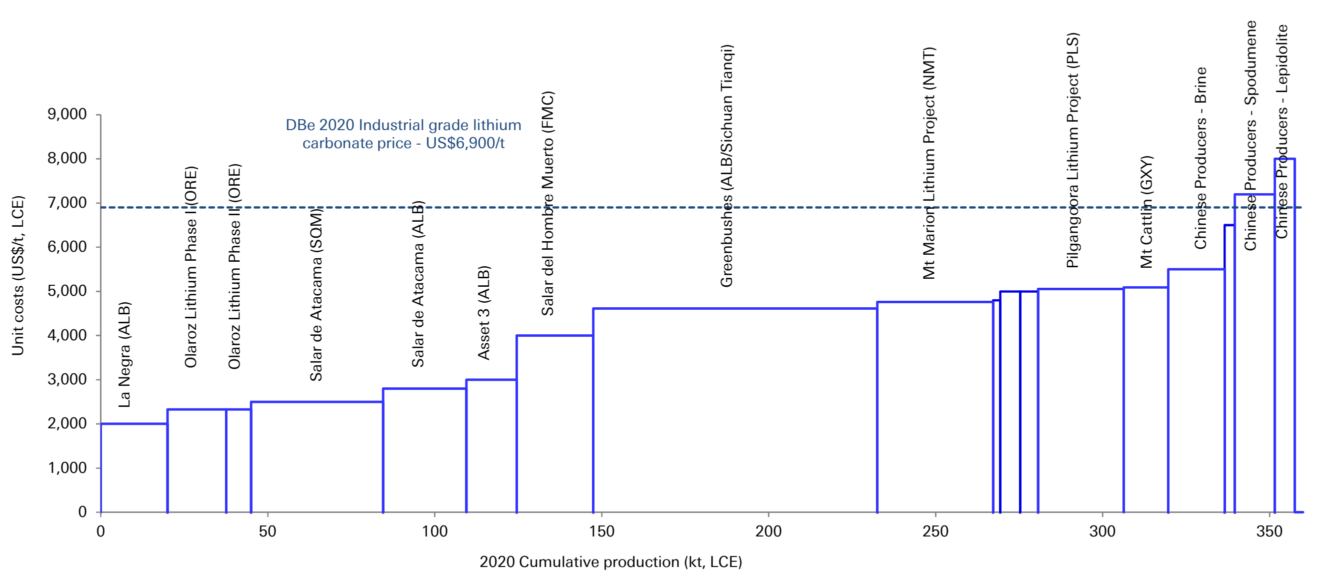
Lithium global cost curve

Figure 265: 2016 cost curve (LCE)



Source: Deutsche Bank

Figure 266: 2025 cost curve (LCE)



Source: Deutsche Bank

Lithium S&D

Figure 267: Lithium supply and demand summary (LCE)

Global Lithium Supply	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Chile	59	63	63	64	65	75	85	100	110	110	110	110	110
% growth		*6%*	*0%*	*2%*	*2%*	*16%*	*13%*	*18%*	*10%*	*0%*	*0%*	*0%*	*0%*
Australia	32	41	57	69	97	112	130	159	181	186	196	206	206
% growth		*26%*	*40%*	*21%*	*40%*	*15%*	*16%*	*23%*	*14%*	*3%*	*5%*	*5%*	*0%*
Argentina	18	18	19	31	36	41	46	48	69	103	138	153	153
% growth		*0%*	*4%*	*63%*	*16%*	*14%*	*12%*	*5%*	*44%*	*49%*	*34%*	*11%*	*0%*
China	28	21	18	23	28	35	35	35	35	35	37	38	43
% growth		*-25%*	*-16%*	*29%*	*22%*	*25%*	*0%*	*0%*	*0%*	*0%*	*6%*	*3%*	*13%*
US	4.5	4.5	4.5	4.5	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
% growth		*0%*	*0%*	*0%*	*33%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*
Rest of World	10	10	10	10	10	10	10	10	10	10	10	10	30
% growth		*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*191%*
Total (kt)	**152**	**157**	**171**	**201**	**242**	**278**	**311**	**358**	**411**	**450**	**497**	**523**	**548**
% growth		*3%*	*9%*	*18%*	*20%*	*15%*	*12%*	*15%*	*15%*	*9%*	*10%*	*5%*	*5%*
Global Lithium Demand													
Electric Vehicles	3.8	10.0	25.1	39.7	50.4	68.7	82.4	109.4	128.0	146.9	166.0	185.5	204.8
% growth		*164%*	*152%*	*58%*	*27%*	*36%*	*20%*	*33%*	*17%*	*15%*	*13%*	*12%*	*10%*
Energy Storage	0.0	0.0	0.4	0.7	1.4	2.2	4.3	5.8	7.7	11.1	15.9	23.4	33.8
% growth		*0%*	*0%*	*62%*	*96%*	*57%*	*92%*	*36%*	*32%*	*45%*	*43%*	*47%*	*45%*
Batteries (traditional markets)	38.9	41.0	45.6	46.3	48.1	50.2	53.1	55.0	56.4	57.8	59.3	61.0	62.7
% growth		*5%*	*11%*	*1%*	*4%*	*4%*	*6%*	*4%*	*2%*	*3%*	*3%*	*3%*	*3%*
E-Bikes	0.0	0.0	2.9	7.1	16.9	28.6	41.7	53.6	60.3	67.1	73.8	73.8	73.8
% growth		*0%*	*0%*	*145%*	*136%*	*70%*	*45%*	*29%*	*13%*	*11%*	*10%*	*0%*	*0%*
Glass-Ceramics	50.3	44.0	42.6	44.0	45.7	47.3	49.1	50.9	52.8	54.7	56.8	58.9	61.0
% growth		*-13%*	*-3%*	*3%*	*4%*	*4%*	*4%*	*4%*	*4%*	*4%*	*4%*	*4%*	*4%*
Greases	14.4	16.8	19.0	19.6	20.3	21.0	21.7	22.5	23.2	23.9	24.7	25.5	26.3
% growth		*17%*	*13%*	*3%*	*3%*	*3%*	*3%*	*3%*	*3%*	*3%*	*3%*	*3%*	*3%*
Air Treatment	8.0	8.0	7.3	7.5	7.8	8.1	8.4	8.7	9.0	9.3	9.7	10.0	10.4
% growth		*0%*	*-9%*	*3%*	*4%*	*4%*	*4%*	*4%*	*4%*	*4%*	*4%*	*4%*	*4%*
Polymer	8.0	6.4	6.2	6.3	6.5	6.7	7.0	7.2	7.3	7.5	7.7	7.9	8.1
% growth		*-20%*	*-4%*	*3%*	*3%*	*3%*	*3%*	*3%*	*3%*	*2%*	*2%*	*2%*	*2%*
Medical	6.4	5.6	6.7	6.8	6.9	6.9	7.0	7.1	7.1	7.2	7.3	7.4	7.4
% growth		*-12%*	*20%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*	*1%*
Primary Battery	2.8	3.2	2.9	3.0	3.1	3.3	3.4	3.5	3.6	3.8	3.9	4.1	4.2
% growth		*15%*	*-8%*	*3%*	*4%*	*4%*	*4%*	*4%*	*4%*	*4%*	*4%*	*4%*	*4%*
Aluminium	1.6	2.0	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5
% growth		*25%*	*26%*	*3%*	*3%*	*3%*	*3%*	*3%*	*3%*	*3%*	*3%*	*3%*	*3%*
Casting Powders	9.6	9.6	7.6	7.6	7.8	7.9	8.0	8.1	8.3	8.4	8.5	8.7	8.8
% growth		*0%*	*-21%*	*1%*	*2%*	*2%*	*2%*	*2%*	*2%*	*2%*	*2%*	*2%*	*2%*
Others	6.8	9.2	15.0	18.0	20.7	22.8	23.6	24.5	25.4	26.3	27.3	28.3	29.4
% growth		*36%*	*63%*	*20%*	*15%*	*10%*	*4%*	*4%*	*4%*	*4%*	*4%*	*4%*	*4%*
Total (kt)	**150**	**156**	**184**	**209**	**238**	**277**	**312**	**359**	**392**	**427**	**464**	**498**	**534**
% growth		*4%*	*18%*	*14%*	*14%*	*16%*	*13%*	*15%*	*9%*	*9%*	*9%*	*7%*	*7%*
Market Balance													
Market surplus (deficit)	**2**	**2**	**-13**	**-8**	**3**	**1**	**-2**	**-2**	**19**	**22**	**33**	**25**	**14**

Source: Deutsche Bank

DB covered companies

Tesla Motors

Tesla is a US based company active in the automobile and energy storage sectors. The company is listed on the NYSE stock exchange (TSLA,N). The Palo Alto headquartered company is an innovation leader in the field of energy storage application (hybrid cars, power banks) and is also likely to become one of the largest end consumers of lithium.

Company overview

- TSLA appears well on its way to proving the inherent advantages of Electric Vehicles, evidenced by several unbiased third parties concluding that TSLA's first mass-produced vehicle is the best car ever tested. TSLA has already largely eliminated the range issue; with the next step to close the cost gap while generating strong gross margins.
- Tesla is in process of building a facility for manufacturing lithium batteries. The facility is known as the Gigafactory and is located in Nevada, US. The facility is targeted to produce 50GWh of lithium-ion batteries by 2020. The company anticipates lithium-ion battery costs declining below US$100/kWh within the next 10 years.
- Tesla has announced plans to leverage their scale and battery systems knowhow in Stationary Energy Storage. This market is in its infancy (1.2 GWh added in the US in 2014) however it will likely increase dramatically (14.3 GWh by 2020). The global opportunity is likely >2x this level.

Tesla shooting for much steeper growth

Tesla now targets 500,000 units of annual production by 2018, 2 years earlier than previously planned. On their call management also suggested that they hope to sustain a 50% growth rate, which would imply 1+ million units by 2020. Investors are well aware of Tesla’s propensity for aggressive projections. That said, there is no question that this represents a significant development (our prior bull case assumption was for 500k units in 2020). The company plans to raise capital and ramp up capital spending (by 50%) to support of this plan. And while there are plenty of execution risk associated with this unprecedented growth plan (e.g. TSLA has not yet finalized design and engineering specs, which implies a very tight timetable for supplier contracting, part development, and validation), the company emphasized that they’re adopting a conservative strategy w/r/t design and engineering risk.

Lithium requirements

- Tesla currently has no upstream lithium assets and currently plans to source its lithium needs from external sources.
- Tesla has signed conditional agreement for supply of LiOH with early stage lithium developers, Baconara Minerals and Pure Energy Minerals.

Model updated:05 May 2016

Running the numbers

North America

United States

Autos & Auto Parts

Tesla Motors

Reuters: TSLA.OQ Bloomberg: TSLA UN

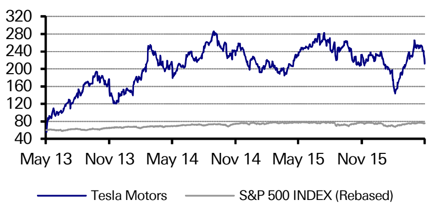
Hold

Price (5 May 16)	USD 211.53
Target Price	USD 290.00
52 Week range	USD 143.67 - 282.26
Market Cap (m)	USDm 28,929
	EURm 25,382

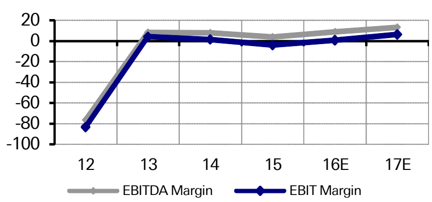
Company Profile

Tesla Motors designs, manufactures, and sells electric vehicles and EV powertrain components. Founded in 2003, the company introduced the first widely available highway-capable electrick vehicle in 2008. They plan to produce a higher-volume product (Model S) in 2012.

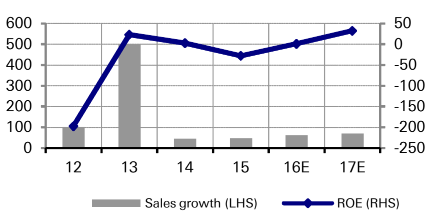
Price Performance



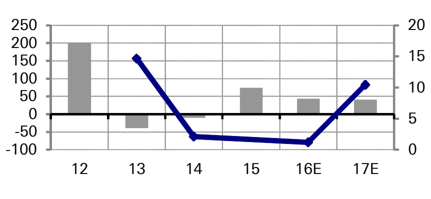
Margin Trends



Growth & Profitability



Solvency



Rod Lache
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Fiscal year end 31-Dec	2012	2013	2014	2015	2016E	2017E
Financial Summary						
DB EPS (USD)	-3.20	0.78	0.14	-2.30	0.06	4.81
Reported EPS (USD)	-2.91	0.68	0.14	-2.02	0.06	4.81
DPS (USD)	0.00	0.00	0.00	0.00	0.00	0.00
BVPS (USD)	1.16	5.59	7.79	8.82	15.34	19.56
Valuation Metrics						
Price/Sales (x)	8.1	5.0	7.7	5.6	3.4	2.0
P/E (DB) (x)	nm	134.5	nm	nm	nm	44.0
P/E (Reported) (x)	nm	153.2	nm	nm	nm	44.0
P/BV (x)	29.2	26.9	28.6	27.2	13.8	10.8
FCF yield (%)	nm	nm	nm	nm	nm	nm
Dividend yield (%)	0.0	0.0	0.0	0.0	0.0	0.0
EV/Sales	8.7	4.9	7.7	5.7	3.5	2.1
EV/EBITDA	nm	59.2	97.5	142.1	38.9	15.5
EV/EBIT	nm	121.7	528.5	nm	490.9	32.8
Income Statement (USDm)						
Sales	413	2,478	3,599	5,292	8,544	14,626
EBITDA	-315	206	284	213	767	1,945
EBIT	-344	100	52	-209	61	918
Pre-tax profit	-344	93	30	-282	29	830
Net income	-344	90	20	-295	10	798
Cash Flow (USDm)						
Cash flow from operations	-246	245	-57	-524	663	1,168
Net Capex	-239	-264	-970	-1,635	-2,250	-2,250
Free cash flow	-485	-19	-1,027	-2,159	-1,587	-1,082
Equity raised/(bought back)	246	510	100	857	1,000	0
Dividends paid	0	0	0	0	0	0
Net inc/(dec) in borrowings	0	0	0	0	0	0
Other investing/financing cash flows	172	-535	-281	-247	0	0
Net cash flow	-67	-43	-1,208	-1,550	-587	-1,082
Change in working capital	*64*	*125*	*-257*	*-493*	*-53*	*-657*
Balance Sheet (USDm)						
Cash and cash equivalents	202	846	1,906	1,197	2,610	2,328
Property, plant & equipment	581	1,124	2,614	5,217	7,623	9,646
Goodwill	0	0	0	0	0	0
Other assets	331	447	1,330	1,678	3,187	5,166
Total assets	1,114	2,417	5,849	8,092	13,420	17,140
Debt	452	586	1,807	2,040	3,520	3,520
Other liabilities	537	1,164	3,073	4,921	7,801	10,724
Total liabilities	989	1,750	4,879	6,961	11,322	14,244
Total shareholders' equity	125	667	970	1,131	2,098	2,896
Net debt	*250*	*-260*	*-99*	*843*	*911*	*1,193*
Key Company Metrics						
Sales growth (%)	102.3	499.5	45.2	47.0	61.5	71.2
DB EPS growth (%)	-44.6	na	-81.7	na	na	7,462.9
Payout ratio (%)	nm	0.0	0.0	nm	0.0	0.0
EBITDA Margin (%)	-76.3	8.3	7.9	4.0	9.0	13.3
EBIT Margin (%)	-83.3	4.0	1.5	-4.0	0.7	6.3
ROE (%)	-197.4	22.8	2.5	-28.1	0.6	32.0
Net debt/equity (%)	200.8	-38.9	-10.2	74.6	43.4	41.2
Net interest cover (x)	nm	14.7	2.1	nm	1.2	10.4
DuPont Analysis						
EBIT margin (%)	-83.3	4.0	1.5	-4.0	0.7	6.3
x Asset turnover (x)	0.5	1.4	0.9	0.8	0.8	1.0
x Financial cost ratio (x)	1.0	0.9	0.5	1.1	0.2	0.9
x Tax and other effects (x)	1.0	1.0	0.7	1.2	1.0	1.0
= ROA (post tax) (%)	-37.7	5.1	0.5	-4.2	0.1	5.2
x Financial leverage (x)	5.2	4.5	5.0	6.6	6.7	6.1
= ROE (%)	-197.4	22.8	2.5	-28.1	0.6	32.0
annual growth (%)	*-99.6*	*na*	*-89.2*	*na*	*na*	*5,146.2*
x NTA/share (avg) (x)	1.5	3.0	5.8	7.2	10.4	15.1
= Reported EPS	-2.91	0.68	0.14	-2.02	0.06	4.81
annual growth (%)	*-43.4*	*na*	*-79.2*	*na*	*na*	*7,462.9*

Source: Company data, Deutsche Bank estimates

TESLA Investment Thesis

Outlook

TSLA appears well on its way to proving the inherent advantages of Electric Vehicles, evidenced by several unbiased third parties concluding that TSLA's first mass-produced vehicle is the best car they've ever tested. Not to mentioned the 400k+ reservations for TSLA's Model 3. Now is targeting a steeper growth trajectory (500k in 2018, 1MM in 2020), and targeting battery pack costs of $150/kWh by late 2018-2020 (vs. <$200/kWh today). The company anticipates costs declining below $100/kWh within the next 10 years. Tesla will also leverage their battery scale to build their Tesla Energy business as the Stationary Energy Storage market grows(1.2 GWh added in the US in 2014, and maybe 14.3 GWh by 2020). But Investors were provided few details on the assumptions of the business plan to achieve the faster ramp in volumes (we assume 355k units in 2018 (vs. Tesla's goal of 500k) and 755k units in 2020). And Tesla has not yet shown strong execution on their volume ramps. Hold on Valuation & uncertainty re. key business plan assumptions.

Valuation

Our target is based on 20x our 2020 EPS estimate of ~$23 discounted back 12%/yr, and supported by our DCF model that incorporates 755k units of production by late-decade and an 11.6% EBIT margin. Other key assumptions of the DCF are 7.5% terminal growth (above industry global auto growth in the low to mid single digits), 5.2% Capex/sales, tax rate of 20%, and WACC of 12.0%.

Risks

Key upside/downside risks include ASPs (i.e. mix of higher end vs. lower end vehicles), the company's ability to achieve expectations for cost reduction, achievement of aggressive ramp-up targets for the company's Gigafactory and production facilities, currency, growth expectations, and competition.

Albemarle

Albemarle is a US based specialty chemicals company which develops, manufactures and markets technologically advanced and high value added products, including lithium and lithium compounds, bromine and derivatives, catalysts and surface treatment chemicals. The company is listed on the NYSE (ALB.N). In January 2015, Albemarle acquired Rockwood Lithium and became a leading integrated and low cost global producer of lithium and lithium compounds. It is headquartered in Baton Rouge, Louisiana.

Lithium assets

Albemarle's subsidiary Rockwood Lithium operated two resource bases: Salar de Atacama (Chile) and Clayton Valley near Silver Peak, Nevada (US). The company has a contract in place with the Chilean government for material extracted from the Salar de Atacama with current production of 24ktpa. Lithium carbonate production capacity at Silver Peak is 6ktpa. Additionally, the company holds a 49% stake in the Greenbushes spodumene mine in Western Australia where the company uses tolling partners in China to process spodumene. The Greenbushes production is currently 55-60ktpa (100%) Further, the company owns the Kings Mountain mine in the US (not currently operating).

Lithium products

Albemarle produces a number of products including the following:

- Lithium Carbonate (Li_2CO_3): Used in Li-ion batteries, glass ceramics, cement and aluminum.
- Lithium Hydroxide (LiOH): Used in Li-ion battery, grease, CO2 absorption and mining.
- Lithium Metal: Used in Lithium Primary batteries, pharmaceuticals and aerospace.
- Organo-lithium: Applications in elastomers, pharmaceuticals, agrochemicals and electronic materials.

Operational performance and outlook

- In 2015, lithium revenues were US$509m (14% of overall revenues) with an EBITDA margin of 42%.
- Albemarle expects +10% EBITDA growth on volume and price in battery-grade products.
- Currently 75% of the business is in non-battery grade applications where pricing gains have been more modest.
- The company plans to capture ~50% of growth in lithium demand.
- Key Lithium customers include Panasonic Corp., Syngenta AG, Umicore SA, Samsung SDI Co. Ltd., Royal DSM NV.

Model updated:01 April 2016

Running the numbers

North America

United States

Chemicals / Specialty

Albemarle

Reuters: ALB.N Bloomberg: ALB UN

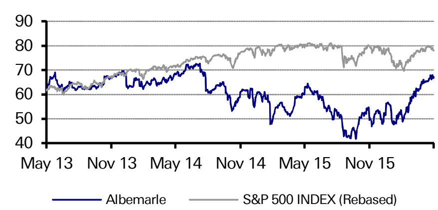
Buy

Price (5 May 16)	USD 67.10
Target Price	USD 72.00
52 Week range	USD 41.78 - 67.90
Market Cap (m)	USDm 7,556
	EURm 6,629

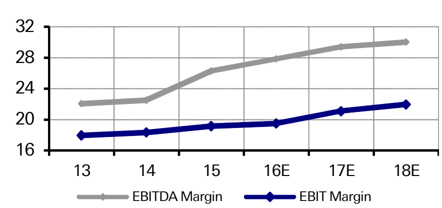
Company Profile

Baton Rouge, Louisiana-based Albemarle Corp. is a leading global developer, manufacturer and marketer of highly engineered specialty chemicals. The company has three operating business segments: Polymer Additives (flame retardants and stabilizers/curatives), Catalysts (refinery and polyolefin) and Fine Chemicals (performance chemicals and fine chemistry services). Albemarle's chemicals are additives to, or intermediates for plastics, polymers and elastomers, cleaning products, agricultural compounds, pharmaceuticals, photographic chemicals, drilling compounds, and biocides.

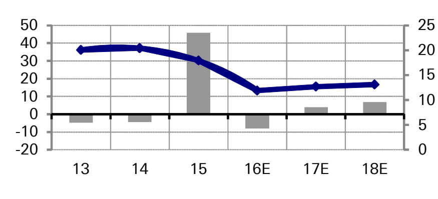
Price Performance



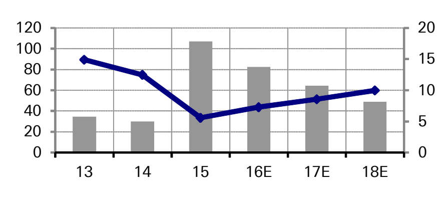
Margin Trends



Growth & Profitability



Solvency



David Begleiter
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Fiscal year end 31-Dec	2013	2014	2015	2016E	2017E	2018E
Financial Summary						
DB EPS (USD)	4.07	4.17	3.93	3.75	4.35	4.90
Reported EPS (USD)	4.07	4.17	3.93	3.75	4.35	4.90
DPS (USD)	1.05	1.26	1.28	1.17	1.26	1.36
BVPS (USD)	20.67	18.82	30.49	32.78	35.80	39.19
Valuation Metrics						
Price/Sales (x)	2.1	2.0	1.6	2.3	2.2	2.0
P/E (DB) (x)	15.7	15.4	13.6	17.9	15.4	13.7
P/E (Reported) (x)	15.7	15.4	13.6	17.9	15.4	13.7
P/BV (x)	3.1	3.2	1.8	2.0	1.9	1.7
FCF yield (%)	3.4	5.4	2.1	6.0	7.6	7.4
Dividend yield (%)	1.6	2.0	2.4	1.7	1.9	2.0
EV/Sales	2.3	2.2	2.6	3.2	2.9	2.6
EV/EBITDA	10.4	9.8	10.0	11.3	9.9	8.7
EV/EBIT	12.8	12.0	13.8	16.2	13.8	11.9
Income Statement (USDm)						
Sales	2,616	2,502	3,651	3,357	3,487	3,723
EBITDA	577	563	959	935	1,025	1,117
EBIT	470	459	699	654	735	817
Pre-tax profit	438	422	573	564	649	735
Net income	343	330	438	422	491	556
Cash Flow (USDm)						
Cash flow from operations	338	387	352	689	818	842
Net Capex	-155	-111	-228	-235	-244	-279
Free cash flow	183	277	125	454	573	563
Equity raised/(bought back)	-582	-150	0	0	0	0
Dividends paid	-88	-100	-143	-132	-143	-154
Net inc/(dec) in borrowings	380	1,876	-322	-588	-448	-427
Other investing/financing cash flows	16	24	-2,099	0	0	0
Net cash flow	-92	1,927	-2,438	-266	-17	-18
Change in working capital	*-31*	*57*	*-42*	*-1*	*-25*	*-54*
Balance Sheet (USDm)						
Cash and cash equivalents	477	2,490	214	214	214	214
Property, plant & equipment	1,357	1,232	2,485	2,127	2,014	1,924
Goodwill	284	287	4,627	4,627	4,627	4,627
Other assets	1,466	1,214	2,290	2,366	2,456	2,589
Total assets	3,585	5,223	9,615	9,333	9,311	9,355
Debt	1,079	2,934	3,852	3,264	2,816	2,388
Other liabilities	763	800	2,362	2,378	2,456	2,524
Total liabilities	1,842	3,734	6,214	5,642	5,271	4,912
Total shareholders' equity	1,743	1,489	3,401	3,691	4,040	4,442
Net debt	*602*	*444*	*3,638*	*3,050*	*2,602*	*2,175*
Key Company Metrics						
Sales growth (%)	-4.7	-4.4	45.9	-8.0	3.9	6.8
DB EPS growth (%)	-16.1	2.6	-5.9	-4.6	16.2	12.6
Payout ratio (%)	25.7	30.2	32.5	31.3	29.0	27.7
EBITDA Margin (%)	22.1	22.5	26.3	27.8	29.4	30.0
EBIT Margin (%)	18.0	18.3	19.1	19.5	21.1	22.0
ROE (%)	20.1	20.4	17.9	11.9	12.7	13.1
Net debt/equity (%)	34.5	29.9	107.0	82.6	64.4	49.0
Net interest cover (x)	14.9	12.5	5.6	7.3	8.5	10.0
DuPont Analysis						
EBIT margin (%)	18.0	18.3	19.1	19.5	21.1	22.0
x Asset turnover (x)	0.8	0.6	0.5	0.4	0.4	0.4
x Financial cost ratio (x)	0.9	0.9	0.8	0.9	0.9	0.9
x Tax and other effects (x)	0.8	0.8	0.8	0.7	0.8	0.8
= ROA (post tax) (%)	10.1	7.5	5.9	4.5	5.3	6.0
x Financial leverage (x)	2.0	2.7	3.0	2.7	2.4	2.2
= ROE (%)	20.1	20.4	17.9	11.9	12.7	13.1
annual growth (%)	*-22.8*	*1.9*	*-12.3*	*-33.6*	*6.8*	*3.1*
x NTA/share (avg) (x)	20.3	20.4	21.9	31.5	34.3	37.4
= Reported EPS	4.07	4.17	3.93	3.75	4.35	4.90
annual growth (%)	*-16.1*	*2.6*	*-5.9*	*-4.6*	*16.2*	*12.6*

Source: Company data, Deutsche Bank estimates

ALB Investment Thesis

Outlook

The key concern exiting Q2 was the weakness in Albemarle's HPC business which management expects to persist through year-end (Refinery Solutions EBITDA -20% for '15E) owing to i) delayed change-outs, ii) cost-cutting by refinery customers, iii) weaker product mix driven by fewer first fills and iv) increased competition from Euro-based competitors. In contrast, FCC volumes rose on higher gasoline demand and new business. Other positives in Q2 included strong EBITDA growth in bromine (38%); lithium (28%, driven by battery-grade products; and PCS (9%, driven by curatives). For the remainder of '15, these trends are expected to continue as a 30% bromine and bromine derivatives price increase continues to gain traction, battery-grade lithium demand (and pricing) remains strong, PCS continues to benefit from higher polyolefin and curative demand and Surface Treatment is seeing improvement in auto, aero, coil and aluminum finishing demand. With valuation an attractive at 9.7x '16E EBITDA, Buy.

Valuation

Our price target is based on Albemarle trading at 10.9x 2016E EBITDA and 15x 2016E EPS in 12 months, roughly in line with the average specialty chemicals multiple. We believe this is appropriate given Albemarle's improved earnings growth prospects, notably in lithium and bromine. Our methodology is supported by our ROIC forecasts of 17% in 2015E and 2016E, and the close correlation we have found (R2>75%) between chemical sector valuations and ROIC.

Risks

Key risks include price erosion in elemental bromine and brominated flame retardants, a downturn in consumer electronics demand (a key end market for brominated flame retardants) escalating rare earths prices and an inability to pass thru higher rare earths and other metals prices in fluid catalytic cracking and hydroprocessing catalysts.

Orocobre

The market needs more from Olaroz; upgrade to Buy

We have updated our ORE valuation for our latest lithium price forecasts and included an Olaroz Phase II expansion for the first time. Global lithium demand is set to grow from 181kt lithium carbonate equivalent (LCE) in 2015 to over 530kt LCE by 2025. To meet this demand, hard-rock assets will enter the market in the short term, but the economics for expansions of existing brine assets are compelling. Olaroz hosts a very large, high-quality resource that can comfortably support an Olaroz expansion which the lithium market needs. Our PT has lifted 44% to $3.90/sh; upgrade to Buy.

Battery thematic driving demand growth, brine operators will respond

We forecast lithium consumption, driven by Electric Vehicles and Energy storage, will increase at 11% CAGR for the next 10 years. While the short term deficit is being met with new hard-rock supply, we expect brine operators to respond. 76% of global lithium reserves are brine-based deposits. Olaroz has one of the world’s largest resources (6.4Mt LCE), is high-grade (690mg/L) and low impurity (2.4:1 Mg/Li ratio). Brine quality and extraction rates to date have been excellent, supporting our view that the deposit can support an expansion to 35ktpa and possibly beyond. ORE will begin an engineering study on Olaroz Phase II this quarter and hopes to complete by September, which we believe suggests an investment decision could be made by the end of this year.

Phase II could enter the market by late 2019

We value a 17.5ktpa Olaroz Phase II expansion at A$217m, or A$1.03/sh, assuming capital costs of US$180m, 30% above ORE’s current US$140m estimate, and operating costs in line with Phase I guidance (sub-US$2,500/t LCE). We assume Olaroz Phase II is approved in 2017, first capital is spent in March 2018 and we allow two years for construction. As a comparison, it took ORE three years (Nov 2012 – Nov 2015) to complete development of Olaroz Phase I, however within that period, physical construction of the processing plant only took 6 months. We assume Phase II commissioning commences in late 2019 and allow a 24 month commissioning period (full run rate achieved in 2022), consistent with the ramp-up seen thus far from Phase I. ORE currently has excess lithium (39kt LCE) in its pond system, which could be used to accelerate Phase II commissioning. We present NPV sensitivities on Page 5.

$3.90/sh PT (previously $2.70/sh); Olaroz is a high-quality, strategic asset; Buy

Our PT is set at 1x P/NPV, which has lifted $1.03/sh by adding Olaroz Phase II and our latest price forecasts. Downside risks: slower ramp-up, lower prices.

Model updated:04 May 2016

Running the numbers

Australasia

Australia

M&M - Other Metals

Orocobre

Reuters: ORE.AX   Bloomberg: ORE AU

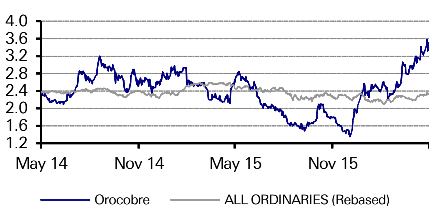
Buy

Price (6 May 16)	AUD 3.50
Target Price	AUD 3.90
52 Week range	AUD 1.35 - 3.58
Market Cap (m)	AUDm 611
	USDm 456

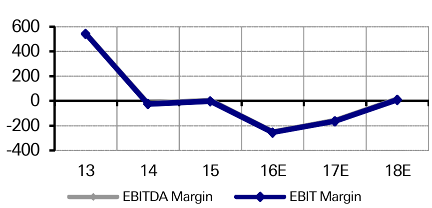
Company Profile

Orocobre Limited (Orocobre) is a mineral exploration company. The Company's exploration focus is on lithium, potash and salar minerals in Argentina. The Olaroz Project, located in the Puna region of Jujuy Province of northern Argentina, is the Company's flagship project.

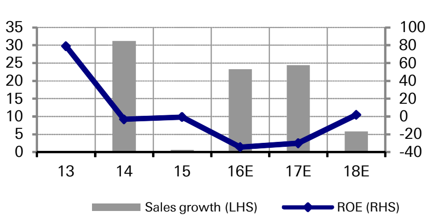
Price Performance



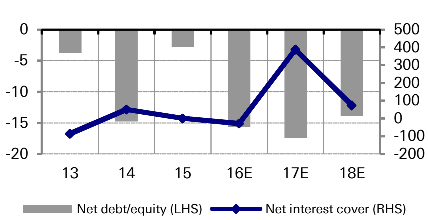
Margin Trends



Growth & Profitability



Solvency



Mathew Hocking
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Fiscal year end 30-Jun	2013	2014	2015	2016E	2017E	2018E
Financial Summary						
DB EPS (AUD)	0.84	-0.04	-0.01	-0.43	-0.28	0.01
Reported EPS (AUD)	0.84	-0.04	-0.01	-0.43	-0.28	0.01
DPS (AUD)	0.00	0.00	0.00	0.00	0.00	0.00
BVPS (AUD)	1.56	1.22	1.40	1.07	0.81	0.83
Valuation Metrics						
Price/Sales (x)	10.4	12.0	15.3	21.3	17.1	16.2
P/E (DB) (x)	1.9	nm	nm	nm	nm	239.5
P/E (Reported) (x)	1.9	nm	nm	nm	nm	239.5
P/BV (x)	0.9	1.9	1.5	3.3	4.3	4.2
FCF yield (%)	nm	nm	nm	nm	nm	nm
Dividend yield (%)	0.0	0.0	0.0	0.0	0.0	0.0
EV/Sales	9.8	11.3	14.6	20.5	16.2	15.4
EV/EBITDA	1.8	-58.9	312.0	-8.2	-10.2	105.3
EV/EBIT	1.8	-45.3	-626.6	-8.0	-9.8	187.1
Income Statement (AUDm)						
Sales	18	23	23	29	36	38
EBITDA	96	-4	1	-72	-56	6
EBIT	96	-6	-1	-73	-59	3
Pre-tax profit	97	-6	-2	-76	-59	3
Net income	96	-5	-1	-74	-59	3
Cash Flow (AUDm)						
Cash flow from operations	-1	0	-9	-15	-4	-3
Net Capex	-2	-7	-2	-2	-1	-1
Free cash flow	-3	-6	-12	-17	-5	-4
Equity raised/(bought back)	24	28	46	116	2	0
Dividends paid	0	0	0	0	0	0
Net inc/(dec) in borrowings	4	0	-1	5	0	0
Other investing/financing cash flows	-22	-5	-50	-72	0	0
Net cash flow	-6	17	-19	30	-6	-5
Change in working capital	*35*	*0*	*12*	*44*	*0*	*0*
Balance Sheet (AUDm)						
Cash and cash equivalents	11	26	9	39	34	28
Property, plant & equipment	9	13	17	18	17	15
Goodwill	0	0	0	0	0	0
Other assets	195	148	225	207	219	231
Total assets	214	187	252	264	269	275
Debt	4	3	4	4	4	4
Other liabilities	27	25	36	37	97	97
Total liabilities	30	28	40	42	101	101
Total shareholders' equity	184	160	212	222	168	173
Net debt	*-7*	*-24*	*-6*	*-35*	*-29*	*-24*
Key Company Metrics						
Sales growth (%)	nm	31.2	0.6	23.3	24.4	5.8
DB EPS growth (%)	na	na	82.6	-5,658.2	34.5	na
Payout ratio (%)	0.0	nm	nm	nm	nm	0.0
EBITDA Margin (%)	546.1	-19.2	4.7	-251.3	-157.9	14.6
EBIT Margin (%)	542.0	-25.0	-2.3	-255.2	-164.5	8.2
ROE (%)	78.9	-3.2	-0.5	-34.3	-30.1	1.8
Net debt/equity (%)	-3.8	-14.8	-2.8	-15.7	-17.4	-13.9
Net interest cover (x)	-86.2	50.0	-0.4	-28.8	386.8	72.8
DuPont Analysis						
EBIT margin (%)	542.0	-25.0	-2.3	-255.2	-164.5	8.2
x Asset turnover (x)	0.1	0.1	0.1	0.1	0.1	0.1
x Financial cost ratio (x)	1.0	1.0	3.7	1.0	1.0	1.0
x Tax and other effects (x)	1.0	1.0	0.5	1.0	1.0	1.0
= ROA (post tax) (%)	68.6	-2.7	-0.5	-28.9	-22.0	1.1
x Financial leverage (x)	1.1	1.2	1.2	1.2	1.4	1.6
= ROE (%)	78.9	-3.2	-0.5	-34.3	-30.1	1.8
annual growth (%)	*na*	*na*	*82.8*	*-6,178.6*	*12.4*	*na*
x NTA/share (avg) (x)	1.1	1.3	1.4	1.2	0.9	0.8
= Reported EPS	0.84	-0.04	-0.01	-0.43	-0.28	0.01
annual growth (%)	*na*	*na*	*82.6*	*-5,658.2*	*34.5*	*na*

Source: Company data, Deutsche Bank estimates

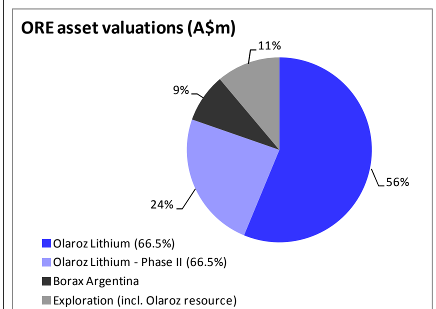
OROCOBRE OPERATIONAL AND FINANCIAL SUMMARY DATA

	2014A	2015A	2016F	2017F	2018F	2019F	2020F	2021F	2022F (LT)
AUDUSD	0.92	0.84	0.72	0.68	0.66	0.68	0.71	0.73	0.75
USDARS	6.82	8.61	12.21	16.06	16.79	17.20	17.26	17.26	17.26
Argentina inflation rate (%)	31.9%	33.0%	31.6%	25.1%	9.8%	-	-	-	-
Lithium Carbonate - 98.5%, US$/t	5,700	5,700	6,438	7,500	7,000	6,750	6,500	6,375	6,125
Lithium Carbonate - 99.5%, US$/t	6,660	7,094	16,796	19,000	14,500	12,500	11,500	10,500	9,750
Lithium Hydroxide, US$/t	6,738	6,894	14,697	17,000	12,500	10,500	9,500	8,500	7,750
Potash KCl, US$/t	350	375	400	400	400	400	400	400	400
Borates (mixed), US$/t	538	548	589	606	625	625	638	650	650
PRODUCTION (100%)									
Olaroz Lithium									
Lithium Carbonate (kt)	0.0	0.1	6.9	17.0	17.5	17.5	17.5	17.5	17.5
Potash (kt)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Olaroz Lithium - Phase II									
Lithium Carbonate (kt)	0.0	0.0	0.0	0.0	0.0	0.0	5.0	10.0	17.5
Potash (kt)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Borax Argentina (100%)									
Borates (kt)	40.1	44.4	38.2	40.0	40.0	40.0	40.0	40.0	40.0
Total Lithium Carbonate (kt)	**0.0**	**0.1**	**6.9**	**17.0**	**17.5**	**17.5**	**22.5**	**27.5**	**35.0**
SALES (100%)									
Olaroz Lithium									
Lithium Carbonate (kt)	0.0	0.0	6.4	17.7	17.5	17.5	17.5	17.5	17.5
Potash (kt)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Olaroz Lithium - Phase II									
Lithium Carbonate (kt)	0.0	0.0	0.0	0.0	0.0	0.0	5.0	10.0	17.5
Potash (kt)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Borax Argentina									
Borates (kt)	40.1	44.4	38.2	40.0	40.0	40.0	40.0	40.0	40.0
Total Lithium Carbonate (kt)	**0.0**	**0.0**	**6.4**	**17.7**	**17.5**	**17.5**	**22.5**	**27.5**	**35.0**
COSTS (US$/t)									
Olaroz Lithium (excl. royalty)	0	0	1,863	2,529	2,604	2,321	2,318	2,318	2,318
Olaroz Lithium (incl. royalty)	0	0	1,871	2,540	2,615	2,332	2,328	2,328	2,328
Olaroz Lithium (AISC)	0	0	6,384	3,538	3,587	3,132	3,014	2,941	2,871
Borax Argentina (excl. royalty)	534	550	630	528	518	487	486	486	486
Borax Argentina (incl. royalty)	534	550	638	544	534	501	501	501	501
CAPEX (US$m) - 100%									
Olaroz Lithium - Development	110	80	3	0	0	0	0	0	0
Olaroz Lithium - Maintenance	0	0	25	8	8	5	5	5	5
Olaroz Lithium - Phase II - Developme	0	0	0	0	40	70	50	20	0
Olaroz Lithium - Phase II - Maintenanc	0	0	0	0	0	0	2	5	5
Borax Argentina - Development	5	0	0	0	0	0	0	0	0
Borax Argentina - Maintenance	1	1	1	1	1	1	1	1	1
Exploration	0	0	2	2	2	2	2	2	2
Total	**117**	**81**	**31**	**11**	**51**	**78**	**60**	**33**	**13**
FINANCIAL METRICS									
Revenue (A$m)	28	39	32	37	48	52	42	81	92
EBITDA (A$m)	-4	1	-72	-56	6	13	-39	43	55
EBIT (A$m)	-6	-1	-73	-59	3	11	-41	41	53
NPAT (A$m)	-5	-1	-74	-59	3	10	-42	40	52
Cashflow from operations (A$m)	0	-9	-15	-4	-3	4	5	5	5
Cashflow from investing (A$m)	-9	-4	-26	-3	-3	-3	-3	28	38
Free cash flow (A$m)	-8	-13	-40	-7	-6	1	2	33	43
FCF yield (%)	-1.1%	-1.8%	-5.4%	-1.0%	-0.7%	0.1%	0.2%	4.4%	5.7%

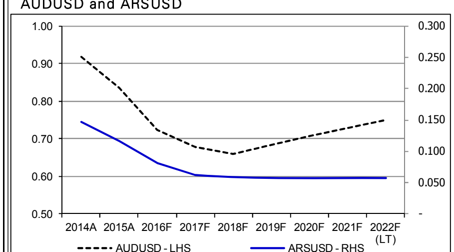
SENSITIVITY (to 10% move)	NPV
Lithium Carbonate	15.6%
Borates	3.7%
AUDUSD	-8.0%
USDARS	2.7%

NPV (FY17)	A$m	A$ps	(%)
Olaroz Lithium (66.5%)	506	2.41	62%
Olaroz Net Debt (66.5%)	(97)	(0.46)	-12%
Olaroz Lithium - Phase II (66.5%)	217	1.03	27%
Borax Argentina	77	0.37	9%
Exploration (incl. Olaroz resource)	100	0.48	12%
Corporate	(75)	(0.36)	-9%
Gross Asset Value	**727**	**3.46**	**89%**
Net Debt	89	0.43	11%
Valuation	**817**	**3.88**	**100%**

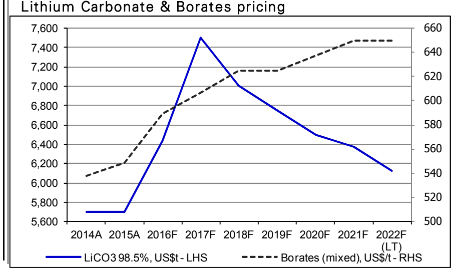
Discount rate (real) 9% **Shares** 210M



AUDUSD and ARSUSD



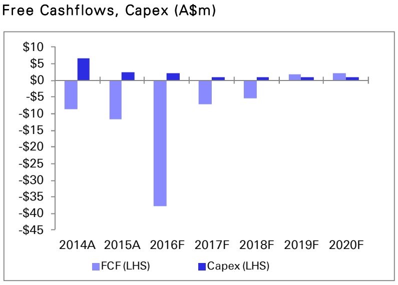
Lithium Carbonate & Borates pricing



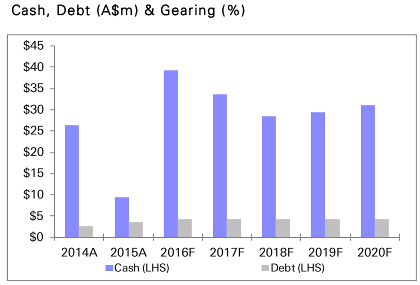
RESERVES & RESOURCES

Resources	Li (mg/l)	$LiCO_3$ (kt)	Potassium (mg/l)	Potash (kt)	Boron (mg/l)	Boron (kt)
Olaroz Lithium	690	6437	5730	19291	1050	1850
Salinas Grandes	795	239	9547	1031	283	12
Cauchari	383	470	3683	1621	533	123

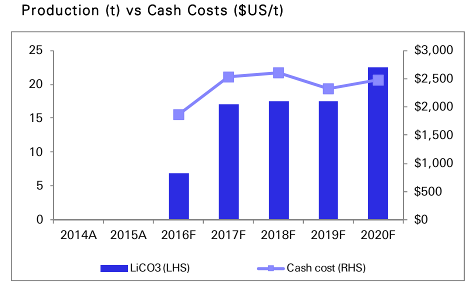
Free Cashflows, Capex (A$m)



Cash, Debt (A$m) & Gearing (%)



Production (t) vs Cash Costs ($US/t)



Source: Deutsche bank, Company data

ORE Investment Thesis

Outlook

Orocobre (ORE) is an ASX- and TSX-listed mining company with mineral assets in Argentina. ORE has a 66.5% equity interest in the Olaroz lithium project. The operation should achieve 17.5ktpa nameplate capacity by the end of 2016 in our view. We model a 25-year mine life, but note that this only exploits c.10-15% of the known resource at Olaroz. Further plant expansions are anticipated, with a 17.5ktpa Phase II expansion currently in study-stage; based on our global lithium supply and demand analysis, we include an expansion in our numbers. ORE also operates the Borax Argentina business which produces c.40ktpa of boron-based products and mineral concentrates. The stock is trading below our DCF based valuation, we therefore rate it a Buy.

Valuation

Our price target is set broadly in line with our DCF valuation. The DCF is based on a long-term real lithium carbonate price of US$7,000/t, US$650/t for borates products, AUDUSD 0.75 and USDARS of 17.3. We discount the life-of-mine cash flow from ORE's Olaroz lithium project (66.5% equity basis) and the Borax Argentina business using a nominal discount rate of 10%, in line with other mining companies in our coverage universe. We also ascribe a small nominal valuation to exploration which includes other nearby projects such as Salinas Grandes and Cauchari.

Risks

Downside risks specific to ORE include lower plant throughput than expected and/or lower recoveries through the Olaroz plant. Macro risks include adverse movements in the lithium carbonate and borates prices and FX movements in the Australian dollar and Argentinean Peso. There is also risk associated with the high inflation rate in Argentina.

Mineral Resources

Lithium supercharge; upgrade to Buy

We now include MIN's interest in the Mt Marion lithium project in our valuation. Global lithium demand is set to triple over the next decade. The Mt Marion project will produce c. 27ktpa of Lithium Carbonate Equivalent (LCE), or 10% of global supply in 2017. MIN is building and operating the mine for its JV partners under its highly successful Build Own Operate model. It also holds an equity stake (30% increasing to 43%). We value MIN's economic interest at A$1.10/sh. This has increased our MIN NPV 17% to A$7.87/sh and we upgrade to BUY on valuation (0.9xNPV, +10% FCF yield).

First lithium production in 2H16

Our supply/demand analysis shows the lithium market is currently in deficit. Lithium prices are at record highs with spodumene prices (6% LiO2) currently around US$550/t CIF to China. We forecast an increase to US$600/t in early 2017. New feedstock supply is entering the market however Mt Marion is the first cab off the rank. The project is currently under construction and should ship its first cargo of spodumene during 2H16. Mt Marion is being designed to produce an initial 200ktpa of 6% spodumene but will likely be expanded to 280ktpa, and has the potential to produce in excess of 300ktpa. MIN is building the project and will operate the mine on behalf of its two JV partners, ASX-listed Neometals (ASX: NMT) and SZ-listed Jiangxi Ganfeng (also the off-take partner). We value MIN’s eventual 43% economic stake of Mt. Marion at around A$210m (A$1.10/sh). This includes its contractor margin (we assume 15%) and the US$20m (A$25m) payment to NMT increase its stake to 43%.

Lithium enhances crushing and iron ore earnings

Mt Marion will generate around A$40m of EBITDA per annum for MIN on our forecast US$550-600/t spodumene price and US$330/t unit costs. The project represents c. 10% of group EBITDA and 15% of group NPV. We have lifted our MIN earnings by around 50% or A$30m per annum. Furthermore, there is upside risk to earnings from iron ore. We forecast FY17 EBITDA of A$236m (A$166m mining services, A$70m iron ore lithium), based on US$43/dmt Fe and A68c AUD, however at spot (US$60/dmt, 75c AUD), EBITDA would increase 74% to A$410m. The stock is already on an attractive 5x EV/EBITDA.

Valuation and risks

Our A$8.00/sh PT is set broadly in-line with our A$7.87/sh NPV (assumes LT US$57/t real Fe, US$550/t spodumene, 75c AUDUSD). Downside risks include weaker Fe prices, crushing margins and stronger FX (see page 9).

Model updated:05 May 2016

Running the numbers

Australasia

Australia

M&M - Other Metals

Mineral Resources

Reuters: MIN.AX Bloomberg: MIN AU

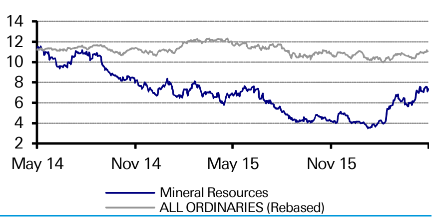
Buy

Price (6 May 16)	AUD 7.34
Target Price	AUD 8.00
52 Week range	AUD 3.49 - 7.63
Market Cap (m)	AUDm 1,373
	USDm 1,025

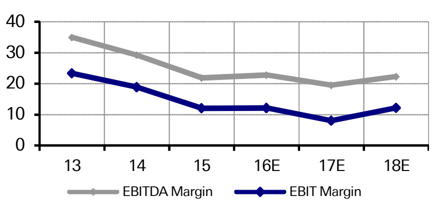
Company Profile

Mineral Resources Ltd builds and operates crushing and screening circuits for the Australian mining industry and produces and ships iron ore. MIN has c. 85Mtpa of installed crushing capacity and ships around 10Mt of iron ore per annum.

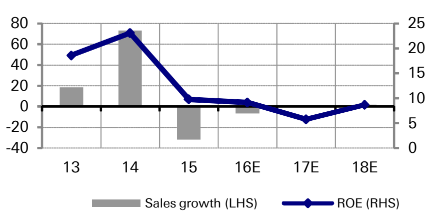
Price Performance



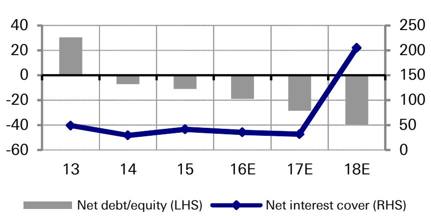
Margin Trends



Growth & Profitability



Solvency



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Fiscal year end 30-Jun	2013	2014	2015	2016E	2017E	2018E
Financial Summary						
DB EPS (AUD)	0.97	1.33	0.58	0.54	0.35	0.56
Reported EPS (AUD)	0.97	1.23	0.07	0.54	0.35	0.56
DPS (AUD)	0.48	0.62	0.23	0.14	0.11	0.14
BVPS (AUD)	5.36	5.97	5.68	5.91	6.16	6.60
Valuation Metrics						
Price/Sales (x)	1.5	1.1	1.2	1.1	1.1	1.1
P/E (DB) (x)	9.0	8.2	13.9	13.6	20.8	13.1
P/E (Reported) (x)	9.0	8.9	122.8	13.7	20.8	13.1
P/BV (x)	1.5	1.6	1.2	1.2	1.2	1.1
FCF yield (%)	nm	35.3	nm	11.0	12.4	13.9
Dividend yield (%)	5.5	5.7	2.8	1.8	1.5	1.9
EV/Sales	1.7	1.1	1.1	1.0	0.9	0.8
EV/EBITDA	4.8	3.9	5.0	4.4	4.7	3.5
EV/EBIT	7.2	6.1	9.1	8.3	11.5	6.5
Income Statement (AUDm)						
Sales	1,097	1,899	1,299	1,215	1,217	1,242
EBITDA	383	554	283	276	236	276
EBIT	256	357	156	147	98	151
Pre-tax profit	251	327	152	142	95	150
Net income	180	231	12	100	66	105
Cash Flow (AUDm)						
Cash flow from operations	329	567	52	298	265	230
Net Capex	-401	155	-111	-146	-95	-39
Free cash flow	-72	721	-59	152	170	191
Equity raised/(bought back)	1	0	0	0	0	0
Dividends paid	-80	-110	-64	-43	-19	-23
Net inc/(dec) in borrowings	151	-242	-34	26	0	0
Other investing/financing cash flows	-2	-209	168	-6	-25	0
Net cash flow	-18	149	3	122	119	161
Change in working capital	*-23*	*143*	*-121*	*35*	*0*	*0*
Balance Sheet (AUDm)						
Cash and cash equivalents	58	206	210	332	451	612
Property, plant & equipment	1,007	661	672	641	538	452
Goodwill	0	0	0	0	0	0
Other assets	740	991	710	678	710	717
Total assets	1,804	1,858	1,592	1,651	1,699	1,781
Debt	368	126	92	117	117	117
Other liabilities	419	593	418	410	410	410
Total liabilities	787	719	509	527	527	527
Total shareholders' equity	1,018	1,139	1,082	1,124	1,172	1,254
Net debt	*310*	*-81*	*-118*	*-215*	*-334*	*-494*
Key Company Metrics						
Sales growth (%)	18.5	73.1	-31.6	-6.4	0.2	2.0
DB EPS growth (%)	-26.3	37.6	-56.3	-7.1	-34.4	58.8
Payout ratio (%)	49.7	50.4	343.1	25.2	30.1	25.0
EBITDA Margin (%)	34.9	29.2	21.8	22.7	19.4	22.2
EBIT Margin (%)	23.3	18.8	12.0	12.1	8.0	12.1
ROE (%)	18.6	23.1	9.8	9.1	5.8	8.7
Net debt/equity (%)	30.5	-7.1	-10.9	-19.1	-28.5	-39.4
Net interest cover (x)	49.2	29.7	41.6	35.7	32.0	204.9
DuPont Analysis						
EBIT margin (%)	23.3	18.8	12.0	12.1	8.0	12.1
x Asset turnover (x)	0.7	1.0	0.8	0.7	0.7	0.7
x Financial cost ratio (x)	1.0	1.0	1.0	1.0	1.0	1.0
x Tax and other effects (x)	0.7	0.7	0.1	0.7	0.7	0.7
= ROA (post tax) (%)	11.1	12.6	0.7	6.2	3.9	6.0
x Financial leverage (x)	1.7	1.7	1.6	1.5	1.5	1.4
= ROE (%)	18.6	21.4	1.1	9.1	5.8	8.7
annual growth (%)	*-40.8*	*15.2*	*-94.8*	*722.6*	*-36.6*	*50.4*
x NTA/share (avg) (x)	5.2	5.8	5.9	5.9	6.1	6.5
= Reported EPS	0.97	1.23	0.07	0.54	0.35	0.56
annual growth (%)	*-26.3*	*27.5*	*-94.7*	*717.6*	*-34.0*	*58.8*

Source: Company data, Deutsche Bank estimates

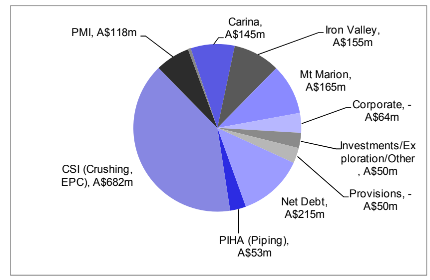
MIN OPERATIONAL AND FINANCIAL SUMMARY DATA

COMMODITY & CURRENCY		2014A	2015A	2016F	2017F	2018F	2019F	2020F	2021F	2022F
AUDUSD		0.92	0.84	0.72	0.68	0.66	0.68	0.71	0.73	0.75
Fines ore (Asia CIF) - CY	**US$/dmt**	**97**	**56**	**44**	**46**	**49**	**51**	**52**	**54**	**56**
Fines ore (Asia CIF) - FY	**US$/dmt**	**121**	**72**	**48**	**43**	**48**	**51**	**54**	**57**	**61**
Average moisture content	%	6.9%	6.2%	5.8%	5.9%	5.9%	5.9%	5.9%	5.9%	0.0%
Discount for impurities	%	12%	15%	11%	8%	8%	9%	9%	9%	0%
Average product grade	% Fe	57.5%	58.7%	59.2%	58.9%	58.1%	58.1%	58.1%	58.1%	0.0%
Price realisation to Index	**%**	**83%**	**91%**	**97%**	**94%**	**91%**	**91%**	**90%**	**91%**	**91%**
Realised price	**US$/dmt**	**101**	**65**	**47**	**40**	**44**	**46**	**49**	**52**	**55**
Realised price	**A$/wmt**	**103**	**73**	**61**	**56**	**62**	**63**	**65**	**67**	**0**
Lithium (Spodumene 6% Li2O)	**US$/t CFR**	**389**	**410**	**474**	**605**	**562**	**558**	**540**	**521**	**502**
KEY FINANCIAL METRICS										
Underlying Earnings	**A$m**	**249**	**109**	**101**	**66**	**105**	**168**	**247**	**236**	**179**
EPS	Ac/sh	133	58	54	35	56	90	132	126	96
EPS Change	%	38%	-56%	-7%	-34%	59%	60%	47%	-4%	-24%
DPS	Ac/sh	62	23	14	11	14	23	33	32	24
Payout ratio	%	47%	39%	25%	30%	25%	25%	25%	25%	25%
CASH FLOW										
Operating Cash Flow	A$m	567	52	298	265	230	225	294	278	206
Capex (incl. exploration) and divestments	A$m	138	-118	-153	-102	-46	-42	-43	-37	-27
Free Cash Flow - before dividends	**A$m**	**705**	**-66**	**144**	**163**	**184**	**183**	**251**	**240**	**180**
Dividends	A$m	-110	-64	-43	-19	-23	-26	-42	-62	-59
Acquistions	A$m	-198	-7	0	-25	0	0	0	0	0
Free Cash Flow - before debt	**A$m**	**397**	**42**	**101**	**119**	**161**	**157**	**209**	**179**	**121**
Free Cash Flow yield	%	**34%**	**-5%**	**11%**	**12%**	**14%**	**14%**	**19%**	**18%**	**14%**
Dividend yield		**9%**	**3%**	**2%**	**2%**	**2%**	**3%**	**5%**	**4%**	**3%**
P/FCF		1.9	-20.2	9.2	8.1	7.2	7.2	5.3	5.5	7.4
BALANCE SHEET AND RETURNS										
Net Debt	A$m	-81	-118	-215	-334	-494	-651	-860	-1039	-1160
Gearing (ND/E)	**%**	**-7%**	**-11%**	**-19%**	**-28%**	**-39%**	**-47%**	**-54%**	**-59%**	**-61%**
ROE	%	23%	10%	9%	6%	9%	13%	16%	14%	10%
ROA	**%**	**22%**	**10%**	**11%**	**8%**	**13%**	**22%**	**33%**	**31%**	**23%**
IRON ORE PRODUCTION (wet)										
Carina	Mt	4.6	5.1	5.2	5.2	5.2	5.0	5.0	5.0	-
Phils Creek	Mt	4.3	1.7	-	-	-	-	-	-	-
Iron Valley	Mt	-	4.1	7.1	6.8	6.8	6.0	6.0	6.0	6.0
Spinifex Ridge	Mt	1.5	0.4	-	-	-	-	-	-	-
Total	**Mt**	**10.9**	**11.3**	**12.3**	**12.0**	**12.0**	**11.0**	**11.0**	**11.0**	**6.0**
Sales	**Mt**	**10.4**	**10.3**	**11.8**	**12.0**	**12.0**	**11.0**	**11.0**	**11.0**	**6.0**
Guidance				**12.0**						
Manganese production and sales	**kt**	**30**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Lithium (Mt Marion Spodumene) - 100%	**kt**	**-**	**-**	**-**	**143**	**218**	**278**	**278**	**278**	**278**
Lithium (Mt Marion LCE) - 100%	**kt**	**-**	**-**	**-**	**20**	**29**	**35**	**35**	**35**	**35**
CRUSHING VOLUMES (wet)										
Gold Crushing	**Mt**	**15**	**15**	**13**	**12**	**12**	**12**	**12**	**12**	**12**
The Fe Majors	**Mt**	**45**	**54**	**62**	**62**	**62**	**62**	**62**	**42**	**32**
Christmas Creek	Mt	14	0	0	0	0	0	0	0	0
Wodgina	Mt	8	7	5	5	0	0	0	0	0
Carina	Mt	5	5	5	5	5	5	5	5	0
Iron Valley	Mt	0	4	7	7	7	6	6	6	6
TOTAL CRUSHING	**Mt**	**92**	**87**	**93**	**91**	**86**	**85**	**85**	**65**	**50**
Guidance				**94**						
DIVISIONAL FINANCIALS										
Mining Services and Processing	A$m	256	234	167	174	151	168	267	224	195
Mining	A$m	193	52	101	70	133	136	137	155	86
Central	A$m	86	-3	8	-8	-8	-8	-8	-8	-8
Group EBITDA	**A$m**	**536**	**283**	**275**	**236**	**276**	**296**	**396**	**371**	**272**
Guidance				**250-290**						
Mining Services and Processing	A$m	152	162	96	92	74	143	241	204	179
Mining	A$m	104	-1	44	15	86	106	117	135	75
Central	A$m	-10	-9	-5	-9	-9	-9	-10	-10	-10
Other	A$m	93	4	11	0	0	0	0	0	0
Group EBIT	**A$m**	**339**	**156**	**146**	**98**	**151**	**239**	**349**	**329**	**244**
% mining assets of EBITDA	**%**	**36%**	**18%**	**37%**	**30%**	**48%**	**46%**	**35%**	**42%**	**31%**
% mining assets of EBIT	**%**	**31%**	**0%**	**30%**	**15%**	**57%**	**44%**	**34%**	**41%**	**31%**
IRON ORE CASH COSTS										
Carina	A$/wmt	57	36	26	28	31	33	34	34	10
Phils Creek	A$/wmt	75	51	-	-	-	-	-	-	-
Iron Valley	A$/wmt	-	43	38	36	36	36	36	37	37
Spinifex Ridge	A$/wmt	66	61	-	-	-	-	-	-	-
Average C1 unit costs	**A$/wmt**	**66**	**42**	**33**	**32**	**34**	**34**	**35**	**36**	**37**
Carina	A$/wmt	88	61	50	48	53	55	56	53	-
Phils Creek	A$/wmt	97	79	-	-	-	-	-	-	-
Iron Valley	A$/wmt	-	54	51	54	55	55	56	57	59
Spinifex Ridge	A$/wmt	73	75	-	-	-	-	-	-	-
All-in costs	**A$/wmt**	**84**	**62**	**51**	**51**	**54**	**55**	**56**	**55**	**59**
Margin	**A$/wmt**	**19**	**11**	**10**	**4**	**8**	**8**	**9**	**11**	**-59**
CAPEX & EXPLORATION										
Services and processing	A$m	59	40	85	15	0	0	0	0	0
Mining assets / operations	A$m	80	50	35	46	0	0	0	0	0
Total growth capex	**A$m**	**139**	**90**	**120**	**61**	**0**	**0**	**0**	**0**	**0**
Sustaining capex	A$m	29	36	35	34	37	40	41	35	24
Total capex	**A$m**	**167**	**125**	**155**	**95**	**39**	**42**	**43**	**37**	**27**
Exploration expense	A$m	11	7	7	7	7	0	0	0	0
Guidance				**140-150**						
EBITDA Margin	**%**	**29%**	**22%**	**23%**	**19%**	**22%**	**23%**	**30%**	**30%**	**31%**
EBIT Margin	**%**	**19%**	**12%**	**12%**	**8%**	**12%**	**18%**	**26%**	**26%**	**28%**

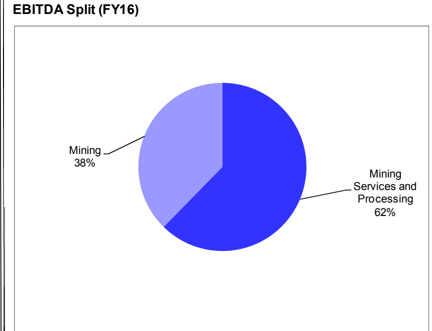
NPV (FY16)	A$m	A$ps	(%)
PIHA (Piping)	53	0.28	4%
CSI (Crushing, EPC)	682	3.65	46%
PMI (Mining, haulage, camps)	113	0.61	8%
Manganese	9	0.05	1%
Mining Services and Processing	**857**	**4.58**	**58%**
Carina	145	0.77	10%
Iron Valley	155	0.83	11%
Mt Marion	165	0.88	11%
Mining	**464**	**2.48**	**32%**
Corporate	-64	-0.34	-4%
Investments/Exploration/Other	50	0.27	3%
Provisions	-50	-0.27	-3%
Net Debt	215	1.15	15%
Total	**1,472**	**7.87**	**100%**

WACC Nominal	10.0%
Shares on issue (m)	187.0

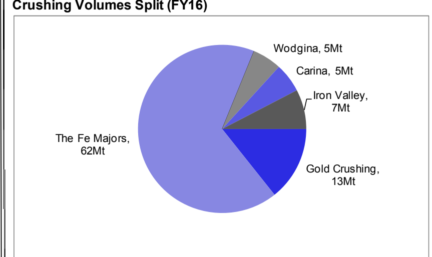
NPV Split (FY16)



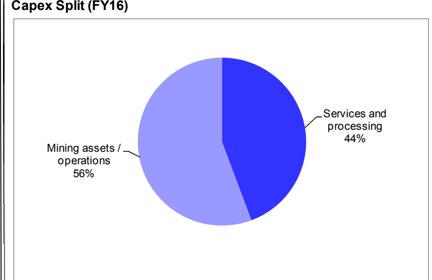
EBITDA Split (FY16)



Crushing Volumes Split (FY16)



Capex Split (FY16)



Source: Deutsche Bank, company data

MIN Investment Thesis

Outlook

Mineral Resources (MIN) has built a high margin 90-95Mtpa annuity style crushing business and a 10Mtpa iron ore export business in a short space of time. Key customers are the Australian iron ore majors who are growing volumes through brownfield expansions. The company's key skill is building and operating 5-20Mtpa mobile and fixed wet and dry iron ore crushing plants for mines in the Pilbara cheaply and quickly, leveraging off extensive in-house fixed plant inventory and construction workshops. MIN is well placed to win and fund further mobile and EPC crushing plants and even mining acquisitions with over A$400m in available debt facilities. The plans to build a light rail for its Iron Valley mine (not in our base case valuation) and MIN's involvement in the Mt Marion lithium project demonstrates management's approach to investing counter-cyclically. With strong FCF (yield of over 10%), a strong balance sheet, robust margins and numerous growth opportunities, we rate MIN a BUY on valuation.

Valuation

Our price target is set broadly in line with our DCF-derived NPV. We use DCF analysis over the life of the mining and crushing projects using a nominal WACC of 10% and assume a long run iron ore price of US$57/t (real), long run spodumene price of US$550/t (real) and AUDUSD of 0.75. We assume 90-95Mtpa of crushing volumes until FY20, then dropping to 50-60Mt from FY21, and sliding volumes to contract completion in FY30 (DBe).

Risks

Downside risks to our estimates include the loss of crushing volumes if mining companies terminate contracts, a stronger AUD, weaker iron ore price, and technical risks associated with the light rail and or Mt. Marion lithium project.

Model updated:29 April 2016

Running the numbers

Australasia

Australia

M&M - Diversified Resources

Rio Tinto

Reuters: RIO.AX Bloomberg: RIO AU

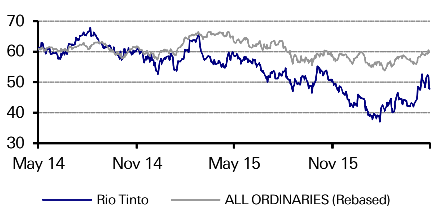
Buy

Price (6 May 16)	AUD 47.75
Target Price	AUD 56.50
52 Week range	AUD 37.03 - 59.25
Market Cap (m)	AUDm 86,192
	USDm 64,377

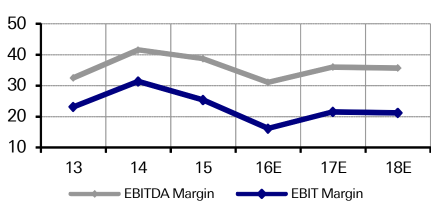
Company Profile

Rio Tinto is a global diversified mining company with interests in aluminum, borax, coal, copper, diamonds, gold, iron ore, titanium dioxide feedstock, uranium and zinc. Rio Tinto's key mining operations are located in Australia, New Zealand, South Africa, South America, the United States, Europe, and Canada. Rio Tinto's management structure is based primarily on six principal global products businesses Aluminium, Diamonds, Copper, Energy (coal and uranium), Industrial Minerals, and Iron Ore supported by worldwide exploration and technology groups.

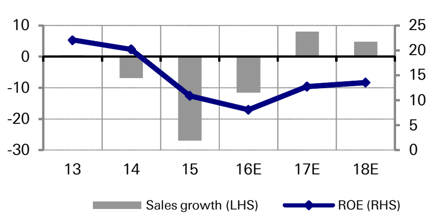
Price Performance



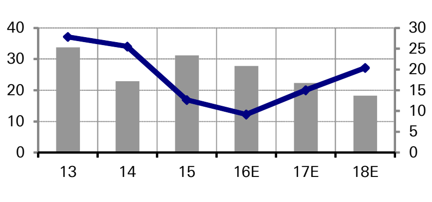
Margin Trends



Growth & Profitability



Solvency



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Fiscal year end 31-Dec	2013	2014	2015	2016E	2017E	2018E
Financial Summary						
DB EPS (USD)	5.50	5.02	2.50	1.63	2.48	2.62
Reported EPS (USD)	1.97	3.52	-0.48	1.63	2.48	2.62
DPS (USD)	1.92	2.15	2.15	1.10	1.24	1.31
BVPS (USD)	24.78	24.95	20.69	19.54	19.44	19.25
Valuation Metrics						
Price/Sales (x)	2.1	2.2	2.1	2.1	1.9	1.8
P/E (DB) (x)	10.7	11.1	16.1	21.9	14.4	13.6
P/E (Reported) (x)	29.8	15.9	nm	21.9	14.4	13.6
P/BV (x)	2.7	2.1	1.6	1.8	1.8	1.9
FCF yield (%)	3.8	7.5	3.4	7.4	7.0	6.7
Dividend yield (%)	3.3	3.8	5.3	3.1	3.5	3.7
EV/Sales	2.7	2.7	2.7	2.7	2.5	2.3
EV/EBITDA	8.2	6.4	7.0	8.8	6.8	6.4
EV/EBIT	11.6	8.5	10.7	16.9	11.4	10.8
Income Statement (USDm)						
Sales	51,171	47,664	34,829	30,807	33,265	34,876
EBITDA	16,613	19,775	13,460	9,547	11,963	12,426
EBIT	11,822	14,915	8,815	4,957	7,151	7,384
Pre-tax profit	3,505	9,552	-726	4,065	6,323	6,671
Net income	3,665	6,527	-866	2,934	4,478	4,729
Cash Flow (USDm)						
Cash flow from operations	15,078	14,286	7,089	8,297	9,341	9,979
Net Capex	-10,946	-6,503	-4,600	-3,503	-4,807	-5,667
Free cash flow	4,132	7,783	2,489	4,794	4,533	4,312
Equity raised/(bought back)	0	0	-2,028	0	0	0
Dividends paid	-3,322	-3,710	-4,076	-2,662	-2,215	-2,524
Net inc/(dec) in borrowings	2,122	-3,034	-1,681	-2,683	-1,740	-2,059
Other investing/financing cash flows	202	1,168	2,239	0	0	0
Net cash flow	2,914	2,191	-5,340	-551	578	-271
Change in working capital	*207*	*1,468*	*1,219*	*200*	*-455*	*299*
Balance Sheet (USDm)						
Cash and cash equivalents	10,216	12,423	9,366	8,815	9,393	9,122
Property, plant & equipment	70,827	68,693	61,057	59,970	59,965	60,589
Goodwill	1,349	1,228	892	892	892	892
Other assets	28,633	25,483	20,249	19,718	19,979	19,802
Total assets	111,025	107,827	91,564	89,396	90,229	90,405
Debt	28,271	24,918	23,149	20,466	18,726	16,667
Other liabilities	29,425	28,315	24,373	26,940	29,749	32,388
Total liabilities	57,696	53,233	47,522	47,406	48,475	49,055
Total shareholders' equity	53,502	54,594	44,128	41,990	41,754	41,350
Net debt	*18,055*	*12,495*	*13,783*	*11,651*	*9,333*	*7,545*
Key Company Metrics						
Sales growth (%)	0.4	-6.9	-26.9	-11.5	8.0	4.8
DB EPS growth (%)	9.8	-8.7	-50.2	-35.0	52.7	5.6
Payout ratio (%)	97.0	61.1	nm	67.7	50.0	50.0
EBITDA Margin (%)	32.5	41.5	38.6	31.0	36.0	35.6
EBIT Margin (%)	23.1	31.3	25.3	16.1	21.5	21.2
ROE (%)	22.0	20.2	10.9	8.1	12.7	13.5
Net debt/equity (%)	33.7	22.9	31.2	27.7	22.4	18.2
Net interest cover (x)	27.8	25.5	12.6	9.1	15.0	20.3
DuPont Analysis						
EBIT margin (%)	23.1	31.3	25.3	16.1	21.5	21.2
x Asset turnover (x)	0.4	0.4	0.3	0.3	0.4	0.4
x Financial cost ratio (x)	1.0	1.0	0.9	0.9	0.9	1.0
x Tax and other effects (x)	0.3	0.5	-0.1	0.7	0.7	0.7
= ROA (post tax) (%)	3.2	6.0	-0.9	3.2	5.0	5.2
x Financial leverage (x)	2.5	2.4	2.4	2.5	2.6	2.6
= ROE (%)	7.9	14.2	-2.1	8.1	12.7	13.5
annual growth (%)	*na*	*79.2*	*na*	*na*	*57.5*	*6.4*
x NTA/share (avg) (x)	25.0	24.9	23.0	20.1	19.5	19.3
= Reported EPS	1.97	3.52	-0.48	1.63	2.48	2.62
annual growth (%)	*na*	*78.5*	*na*	*na*	*52.7*	*5.6*

Source: Company data, Deutsche Bank estimates

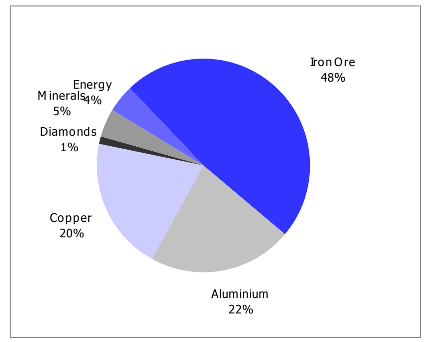
RIO TINTO OPERATIONAL AND FINANCIAL SUMMARY

FX/COMMODITIES (Nominal)	CY14A	CY15A	CY16F	CY17F	CY18F	CY19F	CY20F	CY21F
AUDUSD	**0.90**	**0.75**	**0.71**	**0.66**	**0.67**	**0.70**	**0.72**	**0.74**
Iron ore - lump (US$/t) - CIF	106	63	50	52	55	59	63	66
Iron ore - fines (US$/t) - CIF	**97**	**56**	**44**	**46**	**49**	**52**	**56**	**59**
Aluminium (US$/lb)	**0.86**	**0.76**	**0.70**	**0.72**	**0.77**	**0.82**	**0.87**	**0.91**
Bauxite (US$/t) - CIF	47	47	50	51	52	52	60	61
Copper (US$/lb)	**3.11**	**2.50**	**2.10**	**2.14**	**2.37**	**2.60**	**2.82**	**3.05**
Thermal Coal (US$/t) - contract	**85**	**71**	**60**	**54**	**54**	**56**	**57**	**59**
Coking Coal (US$/t)	126	102	84	88	98	108	118	129
Uranium (US$/lb) - term	49	53	44	59	65	67	68	66
Rutile (US$/t)	**794**	**733**	**770**	**833**	**853**	**866**	**879**	**892**
Zircon (US$/t)	**1,050**	**964**	**912**	**979**	**993**	**1,154**	**1,172**	**1,189**
Gold (US$/oz)	1,267	1,161	1,195	1,231	1,275	1,317	1,359	1,400
KEY FINANCIAL METRICS								
Underlying Earnings (US$M)	**9,305**	**4,540**	**2,934**	**4,478**	**4,729**	**5,413**	**6,293**	**7,675**
EPS (USc)	503	250	163	248	262	300	349	425
EPS Change (%)	-9%	-50%	-35%	53%	6%	14%	16%	22%
DPS (USc)	215	215	110	124	131	150	174	213
Payout ratio (%)	43%	86%	68%	50%	50%	50%	50%	50%
CASH FLOW								
Operating Cash Flow (US$M)	14,286	7,089	8,297	9,341	9,979	10,660	11,907	13,932
Capex (US$M)	(8,162)	(4,685)	(4,244)	(4,865)	(5,667)	(5,391)	(4,086)	(3,428)
Aquisitions and Divestments (US$M)	1,659	85	741	58	-	-	-	-
FCF (US$M) - before dividends	**7,783**	**2,489**	**4,794**	**4,533**	**4,312**	**5,269**	**7,822**	**10,504**
Dividend (US$M)	(3,710)	(4,076)	(2,662)	(2,215)	(2,524)	(2,535)	(2,927)	(3,492)
FCF (US$M) - pre debt and buybacks	**4,073**	**(1,587)**	**2,132**	**2,318**	**1,788**	**2,733**	**4,895**	**7,012**
FCF yield (%)	**11.7%**	**3.8%**	**7.4%**	**7.0%**	**6.7%**	**8.1%**	**12.1%**	**16.2%**
BALANCE SHEET AND RETURNS								
Net Debt (US$M)	12,495	13,783	11,651	9,333	7,545	4,812	(83)	(7,095)
Gearing (ND/ND+E - %)	**22%**	**25%**	**22%**	**18%**	**15%**	**9%**	**0%**	**-14%**
ROE (%)	20%	11%	8%	13%	14%	15%	16%	18%
ROA (%)	**15%**	**10%**	**6%**	**9%**	**9%**	**11%**	**12%**	**15%**
PRODUCTION								
Copper - refined (kt)	295	213	258	293	284	252	252	252
Copper - mined (kt)	**603**	**504**	**579**	**644**	**562**	**583**	**578**	**781**
Iron ore (Mt) - attributable	227	257	275	287	302	303	310	310
Iron ore (Mt) - Pilbara (100%) - prodn	**281**	**310**	**332**	**345**	**360**	**361**	**368**	**368**
Iron ore (Mt) - Pilbara (100%) - sales	**288**	**319**	**331**	**345**	**360**	**361**	**368**	**368**
Iron ore (Mt) - Global (100%) production	295	328	351	364	379	380	387	387
Iron ore (Mt) - Global (100%) shipments	**303**	**337**	**349**	**364**	**379**	**380**	**387**	**387**
Coal - Hard and Semi soft coking (Mt)	11	12	12	13	13	13	13	13
Coal - Thermal (Mt)	21	19	16	16	16	13	13	13
Bauxite (Mt)	**41**	**43**	**45**	**45**	**45**	**50**	**55**	**55**
Alumina (Mt)	8.1	7.8	8.0	8.2	8.3	8.3	8.4	8.4
Aluminium (Mt)	**3.4**	**3.3**	**3.6**	**3.6**	**3.6**	**3.6**	**3.6**	**3.6**
Uranium (kt)	1.9	2.2	2.7	2.0	2.0	2.0	2.0	0.8
Diamonds (Mcts)	14	17	21	21	21	21	21	21
Gold (koz)	486	376	355	708	334	422	284	623
Titanium dioxide feedstock (kt)	1,442	1,089	1,041	1,500	1,700	1,700	1,700	1,700
Copper Eq Production (Mt)	**5.8**	**5.8**	**6.1**	**6.6**	**6.5**	**6.4**	**6.5**	**6.8**
Copper Eq CAGR (%)			**6.0%**	**6.5%**	**4.1%**	**2.7%**	**2.4%**	**2.6%**
CONSOLIDATED CAPEX (US$M)								
Growth								
Aluminium	1,528	1,058	295	665	665	285	0	0
Copper	839	465	1,155	1,678	1,895	1,422	500	400
Diamonds	42	25	200	190	0	0	0	0
Minerals	85	40	0	0	0	0	0	0
Energy	37	0	0	0	0	0	0	0
Iron Ore	2,106	550	600	200	800	1,000	800	0
Total Growth Capex	**4,637**	**2,137**	**2,250**	**2,733**	**3,360**	**2,707**	**1,300**	**400**
Sustaining Capex	**3,134**	**2,474**	**1,994**	**2,132**	**2,254**	**2,684**	**2,786**	**2,818**
Total Capex	**7,416**	**4,611**	**4,244**	**4,865**	**5,614**	**5,391**	**4,086**	**3,218**
Guidance		5,000	4,000	5,000	5,500			
EBITDA (US$M)								
Aluminium	2,930	2,742	2,873	3,213	3,336	3,329	3,824	4,040
Copper	2,336	1,495	955	1,639	1,208	2,035	2,034	3,582
Diamonds	315	293	439	440	440	436	453	355
Minerals	829	539	509	706	615	583	572	694
Energy	251	474	240	495	631	863	979	1,064
Iron Ore	14,244	7,872	6,093	7,134	7,866	7,870	8,486	8,991
Others (includes associates and JVs)	-1,240	-794	-642	-682	-682	-692	-701	-711
Total	**19,665**	**12,621**	**10,466**	**12,944**	**13,415**	**14,424**	**15,647**	**18,014**

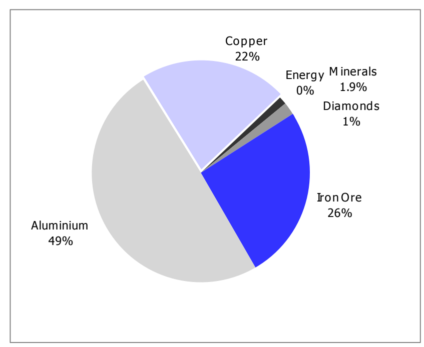
Source: Company data, DB estimates

NPV (CY16)	US$M	US$/sh	AUD/Sh
Aluminium	23,285	12.90	17.20
Copper	21,466	11.89	15.86
Diamonds	1,220	0.68	0.90
Minerals	4,573	2.53	3.38
Energy	4,461	2.47	3.30
Iron Ore	51,210	28.37	37.83
Investments	0	0.00	0.00
Corporate (HO, pensions, rehab)	(17,005)	(9.42)	(12.56)
Net Debt	(12,676)	(7.02)	(9.36)
TOTAL	**76,534**	**42.40**	**56.53**
WACC (nominal)	9.3%	Shares	1,805M

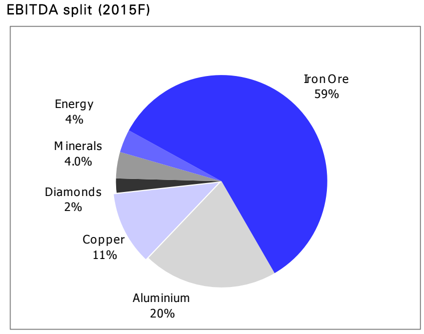
Valuation (2016)



Growth capex split (2015F)



EBITDA split (2015F)



RIO Investment Thesis

Outlook

Rio Tinto has a very high-quality suite of assets that are generally low operating cost, long life, expandable, and mostly offer above-average returns and operating margins. Rio is pushing ahead with a clear strategy which we expect to remain broadly the same under the new CEO in mid 2016. Rio has a simple strategy of lifting growth and returns; 1. Maximising cash flow through cost cutting and capex reductions (mostly structural) and brownfields expansions (Pilbara, bauxite, aluminium, grade rebound from the large copper assets). 2. Optimising the portfolio (asset sales). 3. Growing the business (counter-cyclical greenfield projects). They have reduced costs by over US$6b since the cost out drive commenced in 2012. The aluminium division is now outperforming peers and the market's expectations. The new strategy is a dramatic (positive) change for Rio Tinto and management are delivering on their promises. We expect the stock to re-rate in 2016 as commodity markets rebalance. We believe Rio Tinto is undervalued on most metrics (P/E multiples, DCF valuation), and we rate the stock a Buy, trading at a discount to our NPV.

Valuation

We value Rio Tinto using discounted cash flow analysis of each of its assets. Our Price Target is set broadly in-line with our valuation using life of mine cashflows (9.3% WACC), as the rapidly improving balance sheet re-opens significant growth opportunities.

Risks

Key risks to our view include movements in iron ore, copper, coal and aluminium prices away from those that we currently forecast. Earnings for the group are strongly biased to iron ore and copper (c. 75% of operating earnings) therefore production levels, prices for those commodities are an important consideration. Specifically, for the aluminium division risks include reduced Chinese demand for bauxite, alumina and aluminium, delays to expansion projects and weakness in prices.

Sichuan Tianqi

An industry leader, controlling one-fifth of world lithium supply

Founded in 1995 and after acquiring Talison in 2013, Sichuan Tianqi has become one of the largest lithium compound producers in the world, controlling c. 18% of the world market share. Tianqi's primary operations are 1) mining spodumene concentrates in Australia, and 2) processing spodumene concentrates to lithium chemical compounds in its China factories.

For Tianqi, we believe the visibility of its organic earnings growth will be high in light of 1) high ASP of lithium compounds and expected increase in ASP of spodumene concentrates, and 2) flexibility to increasing volume of both spodumene concentrates in Talison, from current low utilization rate of only 60% only and lithium compounds in Zhangjiagang factory. The factory was acquired in 2015 and is now ready to ramp up.

Model updated:08 May 2016

Running the numbers

Asia

China

Metals & Mining

Tianqi Lithium

Reuters: 002466.SZ | Bloomberg: 002466 CH

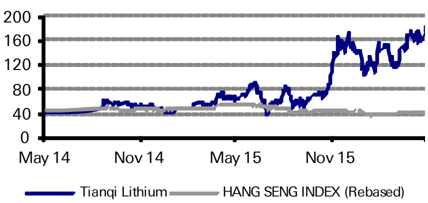
Hold

Price (6 May 16)	CNY 175.70
Target Price	CNY 162.20
52 Week range	CNY 37.80 - 182.56
Market Cap (m)	CNYm 45,464
	USDm 6,991

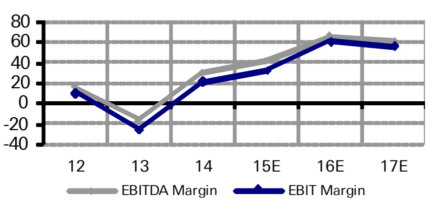
Company Profile

Sichuan Tianqi Lithium Industries, Inc. develops, manufactures and sells lithium products. The Company's products include industrial lithium carbonate, battery lithium carbonate, lithium chloride, and lithium hydroxide.

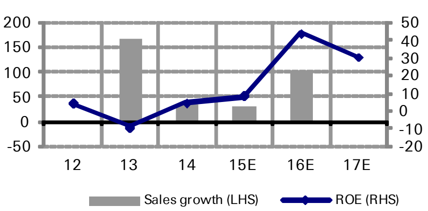
Price Performance



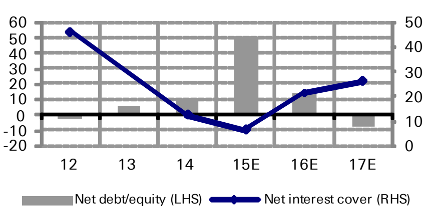
Margin Trends



Growth & Profitability



Solvency



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Fiscal year end 31-Dec	2012	2013	2014	2015E	2016E	2017E
Financial Summary						
DB EPS (CNY)	0.28	-1.30	0.54	0.96	6.24	5.68
Reported EPS (CNY)	0.28	-1.30	0.54	0.96	6.24	5.68
DPS (CNY)	0.10	0.00	0.00	0.00	1.56	1.42
BVPS (CNY)	6.9	21.0	11.4	11.9	16.5	20.8
Weighted average shares (m)	147	147	240	259	259	259
Average market cap (CNYm)	4,342	5,194	11,295	45,464	45,464	45,464
Enterprise value (CNYm)	3,932	6,896	12,742	47,622	46,498	45,308
Valuation Metrics						
P/E (DB) (x)	104.0	nm	86.7	183.4	28.2	30.9
P/E (Reported) (x)	104.0	nm	86.7	183.4	28.2	30.9
P/BV (x)	4.67	1.44	3.53	14.80	10.62	8.45
FCF Yield (%)	nm	2.0	1.9	0.4	3.7	3.8
Dividend Yield (%)	0.3	0.0	0.0	0.0	0.9	0.8
EV/Sales (x)	9.9	6.5	9.0	25.5	12.2	12.1
EV/EBITDA (x)	63.1	nm	29.4	61.0	18.5	19.5
EV/EBIT (x)	91.1	nm	40.8	77.6	20.1	21.4
Income Statement (CNYm)						
Sales revenue	397	1,068	1,422	1,867	3,796	3,760
Gross profit	103	274	578	1,036	2,927	2,734
EBITDA	62	-175	434	781	2,518	2,323
Depreciation	19	96	122	167	204	201
Amortisation	0	0	0	0	0	0
EBIT	43	-271	312	614	2,314	2,121
Net interest income(expense)	-1	-42	-25	-95	-108	-81
Associates/affiliates	0	0	0	0	0	0
Exceptionals/extraordinaries	-1	17	3	-10	-7	-7
Other pre-tax income/(expense)	8	12	37	4	1	1
Profit before tax	49	-283	328	513	2,200	2,034
Income tax expense	7	11	46	87	440	407
Minorities	0	-103	151	178	145	158
Other post-tax income/(expense)	0	0	0	0	0	0
Net profit	42	-191	130	248	1,615	1,470
DB adjustments (including dilution)	0	0	0	0	0	0
DB Net profit	42	-191	130	248	1,615	1,470
Cash Flow (CNYm)						
Cash flow from operations	-44	223	302	660	1,850	1,876
Net Capex	-186	-121	-85	-460	-170	-160
Free cash flow	-230	101	217	199	1,680	1,716
Equity raised/(bought back)	0	3,672	3,037	84	0	0
Dividends paid	-20	-87	-58	-329	-404	-367
Net inc/(dec) in borrowings	447	41	-108	1,061	-50	-50
Other investing/financing cash flows	-23	-3,590	-3,324	-905	0	0
Net cash flow	174	138	-235	111	1,227	1,298
Change in working capital	*-112*	*443*	*-249*	*-74*	*-114*	*47*
Balance Sheet (CNYm)						
Cash and other liquid assets	500	682	437	576	1,802	3,101
Tangible fixed assets	202	1,075	1,026	1,568	1,540	1,515
Goodwill/intangible assets	132	2,975	2,774	2,669	2,659	2,643
Associates/investments	387	587	847	929	921	921
Other assets	348	1,346	1,046	1,782	1,847	1,788
Total assets	1,569	6,666	6,130	7,524	8,771	9,968
Interest bearing debt	477	952	944	2,663	2,613	2,563
Other liabilities	81	607	440	781	732	720
Total liabilities	557	1,559	1,384	3,444	3,345	3,283
Shareholders' equity	1,011	3,088	2,958	3,072	4,281	5,383
Minorities	0	2,019	1,787	1,000	1,145	1,302
Total shareholders' equity	1,011	5,107	4,745	4,072	5,426	6,686
Net debt	*-23*	*269*	*507*	*2,087*	*810*	*-538*
Key Company Metrics						
Sales growth (%)	-1.5	169.2	33.1	31.3	103.3	-1.0
DB EPS growth (%)	3.7	na	na	76.5	551.4	-9.0
EBITDA Margin (%)	15.7	-16.4	30.5	41.8	66.3	61.8
EBIT Margin (%)	10.9	-25.4	22.0	32.9	61.0	56.4
Payout ratio (%)	35.2	nm	0.0	0.1	25.0	25.0
ROE (%)	4.2	-9.3	4.3	8.2	43.9	30.4
Capex/sales (%)	46.8	11.6	6.0	24.7	4.5	4.3
Capex/depreciation (x)	9.7	1.3	0.7	2.8	0.8	0.8
Net debt/equity (%)	-2.3	5.3	10.7	51.3	14.9	-8.0
Net interest cover (x)	46.5	nm	12.7	6.5	21.4	26.2

Source: Company data, Deutsche Bank estimates

Tianqi Investment Thesis

Outlook

Sichuan Tianqi is one of the largest lithium compound producers in the world, controlling c. 18% of the world market share. We believe ASP of lithium carbonate in 2016 will have another 126% YoY increase and remain high at RMB120,000/t, until at least 2018.

Strong EV sales in China and the slow rampup of new lithium supply should allow the tight supply of lithium to continue. Meanwhile, the top four suppliers of lithium control almost 86% of the supply. Lithium's outlook in coming years looks very similar to iron ore's boom story in the past decade.

For Tianqi, we believe the visibility of its organic earnings growth will be high in light of 1) high ASP of lithium compounds and expected increase in ASP of spodumene concentrates, and 2) flexibility to increase volume of both spodumene concentrates in Talison, from current low utilization rate of only 60% only and lithium compounds in Zhangjiagang factory.

While we have seen the lithium carbonate price weaken, we believe the supply/demand situation has not been significantly changed yet. We retain a Hold rating given valuation.

Valuation

We derive our target price of RMB162.2 from a DCF model, with WACC of 8.5%. We adopt 10.8% as the cost of equity to reflect a risk-free rate of 3.9%, a market risk premium of 5.6% and beta of 1.24. Using a terminal growth rate of 3%, in line with long term industry growth.

Risks

Major downside risks: 1) Slower-than-expected demand from EV or other downstream industries. 2) Quicker-than-expected increase in lithium raw material supply, especially if there is a technology breakthrough in downstream salt lake brine extraction. And 3) Slower-than-expected utilization rate ramp-up in either the Greenbushes mine or the Zhangjiagang factory.

Major upside risks: 1) slower-than-expected supply increase and 2) stronger-than-expected demand from EV or other downstream industries.

Ganfeng Lithium

Initiating coverage on Ganfeng with Buy

Ganfeng Lithium is one of the largest lithium compounds processors in China, with total capacity of c.30ktpa LCE in 2016E. Ganfeng is directly benefiting from higher ASP of lithium compounds, driven by booming EV sales and lead-acid battery replacement. Through purchasing shares of Process Minerals International, Ganfeng will become to be the largest shareholder (43.1%) of the Mt Marion project which will solve the problems of an uncertain raw material supply in the long term. With a target price of RMB78, we initiate coverage on Ganfeng Lithium with a Buy.

Tripled demand in the next decade

We forecast that Global lithium demand will triple over the next 10 years, driven by electrical vehicles, energy storage and traditional markets. By 2025, global battery consumption will exceed 535GWh. This has a major impact on lithium. Turning to the supply side, the response from primary producers has not been fast enough to match demand. Recent price hikes however have encouraged owners to develop new assets to enter the market but even with this increase we believe the market will not start to re-balance until mid-2017.

Price of lithium compounds expected to remain high

We believe that, after a 40% YoY hike in 2015, the price of lithium carbonate will have another 143% YoY increase in 2016 and remain high at RMB120,000/t, (exl VAT) and RMB100,000/t and 2017. As a lithium mining producer and compound processor, Ganfeng will benefit both from owning the raw material as well as the processing technology as demand rises to fill its new capacity and spodumene concentrates from Mt Marion.

Raw material supply shortage in the short term, no big concern in the long run

Ganfeng has significantly expanded processing capacity but was constrained due to short of raw material supply. However, through an exclusive sales agreement with RIM, Ganfeng will remove this bottleneck beginning from 3Q16. As the largest shareholder of Mt Marion, we believe Ganfeng is likely to secure raw material supply from in the long term to satisfy its capacity expansion plan.

Valuation and risks

With resilient lithium prices and strong shipment growth in the coming years, we forecast Ganfeng's 2016/2017E NPAT to grow 655% YoY and 41% YoY, respectively. We derive our target price from a DCF model, with WACC of 8.6%. We adopt 10.1% as the cost of equity to reflect a risk-free rate of 3.9%, a market risk premium of 5.6% and beta of 1.11. Using a terminal growth rate of 3% in line with industry growth, Our TP of RMB78, implies 17% upside potential and 2016/17E P/Es of 30x/22x. Major risks: slower-than-expected demand pickup from EV, slower than expected ramp up of Mt Marion project.

Model updated:06 May 2016

Running the numbers

Asia

China

Metals & Mining

Ganfeng Lithium

Reuters: 002460.SZ Bloomberg: 002460 CS

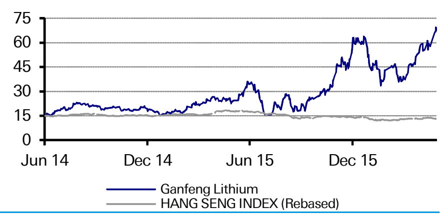
Buy

Price (6 May 16)	CNY 67.60
Target Price	CNY 78.00
52 Week range	CNY 15.88 - 69.31
Market Cap (m)	CNYm 25,208
	USDm 3,876

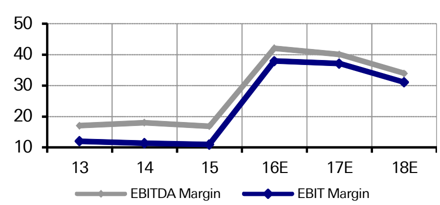
Company Profile

Jiangxi Ganfeng Lithium Co., Ltd. researches and produces lithium products and operates import, export and manufacturing businesses for its own products. The Company's products include lithium metal, lithium aluminum hydride, lithium fluoride, lithium chloride, and other chemical products of lithium.

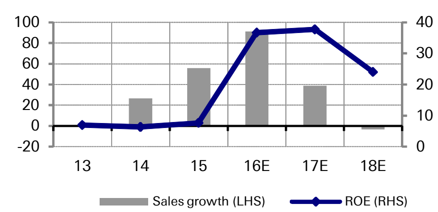
Price Performance



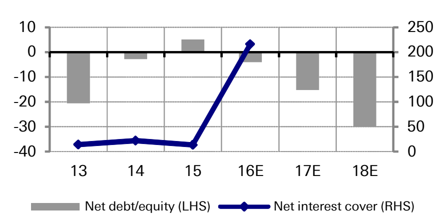
Margin Trends



Growth & Profitability



Solvency



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Fiscal year end 31-Dec	2013	2014	2015	2016E	2017E	2018E
Financial Summary						
DB EPS (CNY)	0.42	0.24	0.34	2.20	3.10	2.53
Reported EPS (CNY)	0.42	0.24	0.34	2.20	3.10	2.53
DPS (CNY)	0.21	0.10	0.14	0.27	0.54	0.40
BVPS (CNY)	7.4	3.9	5.0	6.9	9.5	11.6
Weighted average shares (m)	178	357	373	373	373	373
Average market cap (CNYm)	1,940	6,319	10,622	25,208	25,208	25,208
Enterprise value (CNYm)	1,660	6,273	10,523	24,729	24,242	23,439
Valuation Metrics						
P/E (DB) (x)	26.2	73.7	84.9	30.8	21.8	26.7
P/E (Reported) (x)	26.2	73.7	84.9	30.8	21.8	26.7
P/BV (x)	1.58	3.87	12.47	9.75	7.12	5.82
FCF Yield (%)	nm	nm	2.2	2.0	2.7	3.8
Dividend Yield (%)	1.9	0.6	0.5	0.4	0.8	0.6
EV/Sales (x)	2.4	7.2	7.8	9.6	6.7	6.7
EV/EBITDA (x)	14.2	40.0	46.1	22.7	16.8	19.9
EV/EBIT (x)	20.1	63.4	71.0	25.2	18.2	21.7
Income Statement (CNYm)						
Sales revenue	686	869	1,354	2,588	3,594	3,479
Gross profit	158	183	289	1,136	1,502	1,263
EBITDA	117	157	228	1,088	1,439	1,178
Depreciation	34	58	80	108	108	98
Amortisation	0	0	0	0	0	0
EBIT	83	99	148	980	1,331	1,080
Net interest income(expense)	-6	-4	-11	-5	0	9
Associates/affiliates	0	0	0	0	51	39
Exceptionals/extraordinaries	0	0	0	0	0	0
Other pre-tax income/(expense)	9	7	13	17	17	17
Profit before tax	86	101	150	993	1,399	1,145
Income tax expense	17	17	25	174	245	201
Minorities	-5	-1	0	0	0	0
Other post-tax income/(expense)	0	0	0	0	0	0
Net profit	74	86	125	819	1,154	944
DB adjustments (including dilution)	0	0	0	0	0	0
DB Net profit	74	86	125	819	1,154	944
Cash Flow (CNYm)						
Cash flow from operations	64	11	366	608	797	1,063
Net Capex	-251	-149	-131	-110	-110	-110
Free cash flow	-187	-138	235	498	687	953
Equity raised/(bought back)	486	0	120	0	0	0
Dividends paid	-37	-36	-52	-100	-200	-150
Net inc/(dec) in borrowings	207	60	-73	0	0	0
Other investing/financing cash flows	-6	-58	-431	-178	-51	-39
Net cash flow	463	-171	-201	220	436	764
Change in working capital	*-67*	*-145*	*109*	*-319*	*-465*	*21*
Balance Sheet (CNYm)						
Cash and other liquid assets	545	374	181	383	819	1,583
Tangible fixed assets	569	657	734	716	698	690
Goodwill/intangible assets	105	106	467	487	507	527
Associates/investments	9	8	196	374	425	464
Other assets	568	809	950	1,368	1,979	1,988
Total assets	1,796	1,954	2,528	3,327	4,427	5,252
Interest bearing debt	274	334	278	278	278	278
Other liabilities	208	232	367	465	611	642
Total liabilities	482	567	644	743	889	919
Shareholders' equity	1,314	1,387	1,883	2,584	3,539	4,333
Minorities	0	1	1	0	0	0
Total shareholders' equity	1,313	1,388	1,883	2,584	3,539	4,333
Net debt	*-271*	*-39*	*97*	*-105*	*-541*	*-1,305*
Key Company Metrics						
Sales growth (%)	nm	26.7	55.7	91.1	38.9	-3.2
DB EPS growth (%)	na	-42.2	39.6	554.4	40.9	-18.2
EBITDA Margin (%)	17.0	18.0	16.9	42.1	40.1	33.9
EBIT Margin (%)	12.0	11.4	10.9	37.9	37.0	31.0
Payout ratio (%)	50.0	41.6	41.2	12.2	17.3	15.9
ROE (%)	7.0	6.3	7.7	36.7	37.7	24.0
Capex/sales (%)	36.6	17.3	9.7	4.3	3.1	3.2
Capex/depreciation (x)	7.3	2.6	1.6	1.0	1.0	1.1
Net debt/equity (%)	-20.6	-2.8	5.1	-4.1	-15.3	-30.1
Net interest cover (x)	14.4	22.3	13.6	216.0	nm	nm

Source: Company data, Deutsche Bank estimates

Ganfeng Investment Thesis

Outlook

Securing long term raw material supplies has been a critical strategic step for Ganfeng – previously it was very exposed to swings in availability of volume, as well as moves in the market price of lithium. It already has the processing capacity in place to meet the surge in demand from the EV battery manufacturers. With vertical integration now complete and as the Mt. Marion asset ramps up in the 2H16, Ganfeng will be one of the top five players globally. Along with Albemarle, Tianqi, SQM and FMC, these five companies control 45% of global reserves.

Ganfeng has enlarged its lithium processing capacity to 30ktpa in 2016E/2017E, representing c.15% global market share. We expect sales volume will improve from c.18ktpa in 2015 to 27ktpa in 2017. Pricing of battery grade lithium carbonate, the benchmark price of lithium products, should remain at a high level (RMB120,000-83,000/t) due to unbalanced demand/supply until at least 2018 as strong EV sales and lead-acid battery replacement, and slow ramp-ups of new lithium supply will likely continue to tighten global supply in the next three years. The impact will be a surge in earnings to RMB819mn and RMB1177mn, up more than five folds this year and 44% in 2017.

The shares have performed very strongly along with the move in the commodity price over the past 6 months and as the Mt Marion deal has moved ahead, Ganfeng has been a stand out stock in the past quarter. Our DCF of the enhanced business generates a valuation of Rmb 78 indicating further upside.

Valuation

We derive our target price from a DCF model, with WACC of 8.6%. We adopt 10.1% as the cost of equity to reflect a risk-free rate of 3.9%, a market risk premium of 5.6% and beta of 1.11. Using a terminal growth rate of 3%, we set our target price at RMB78, implying 17% upside potential from current levels. Our target price implies 2016/17E P/Es of 36x/25x.

Risks

We highlight the following downside risks: 1) slower-than-expected demand from EV or other downstream industries: 2) a quicker-than-expected increase in lithium raw material supply, especially if there is a technology breakthrough in upstream salt lake brine extraction; 3) a slower-than-expected ramp-up at the Mt. Marion project and Jiangxi Lithium in the middle of 2016 and 4) larger than expected shortage of supply after 2019.

Appendix

Supporting data

Figure 268: List of lithium deposits

Deposit name	Ownership	Deposit type	Reserves Mt	Reserves Li%	Reserves Li2O %	Reserves Li (Mt)	Reserves LCE (Mt)	Resources Mt	Resources Li%	Resources Li2O%	Resources Li (Mt)	Resources LCE (Mt)
Drumgal		Pegmatite									0.1	0.6
Jamanak		Pegmatite									0.1	0.7
Pasghushta		Pegmatite									0.5	2.6
Pasghushta lower		Pegmatite									0.1	0.3
Paskhi		Pegmatite									0.1	0.3
Salt lakes		Brine									0.4	1.9
Taghawlor		Pegmatite									0.7	3.6
Tsamgal		Pegmatite									0.1	0.5
Yaryhgul		Pegmatite									0.1	0.3
Afghanistan - Total											**2.0**	**10.8**
Hombre Muerto	FMC	Brine				0.8	4.5				0.8	4.3
Salar de Olaroz	Orocobre, TTC, JEMSE	Brine									1.2	6.4
Cauchari-Olaroz	Lithium Americas, SQM	Brine				0.5	2.7				2.2	11.8
Salar de Cauchari	Orocobre; Western lithium	Brine									0.5	2.5
Salar de Rincon	ADY Resources (Enirgi group)	Brine				1.4	7.5				1.4	7.5
Salinas Grandes	Orocobre	Brine									0.04	0.24
Sal de Vida	Galaxy resources	Brine				0.2	1.1				1.4	7.2
Mariana lithium	GFL, ILC	Brine										
Salar de Diablillos	Rodinia lithium inc.	Brine									0.5	2.8
Pozuelos lake	Lithea Inc.	Brine				1.5	8.0				1.5	8.0
Centenario-Ratones	ERAMET	Brine										
Argentina - Total						**4.5**	**23.8**				**9.5**	**50.7**
Greenbushes	Albemarle;, Sichuan Tianqi	Pegmatite	61.6	1.3%	2.8%	0.8	4.3	120.6	1.1%	2.4%	1.4	7.2
Mt Cattlin	Galaxy resources	Pegmatite	10.0	0.5%	1.0%	0.05	0.3	16.4	0.5%	1.1%	0.1	0.4
Mt Marion	Neometals; MIN; Ganfeng;	Pegmatite	1.5	0.8%	1.6%	0.01	0.1	23.2	0.7%	1.4%	0.2	0.8
Pilgangoora (AJM)	Altura mining	Pegmatite						35.7	0.5%	1.1%	0.2	0.9
Pilgangoora (PLS)	Pilbara minerals	Pegmatite	29.5	0.6%	1.3%	0.1	0.7	80.2	0.6%	1.3%	0.5	2.5
East kirup	Red river resources ltd.	Pegmatite										
Australia - Total						**1.0**	**5.3**				**2.2**	**11.9**
Koralpa	Global Strategic Metals NL	Pegmatite									0.1	0.6
Austria - Total											**0.1**	**0.6**
Salar de Uyuni	Comibol, POSCO, KORES	Brine									10.2	54.3
Bolivia - Total											**10.2**	**54.3**
Cachoeira		Petalite									0.02	0.1
Aracuai	Companhia Brasileria de litio	Pegmatite									0.01	0.1
Itinga	Arqueana de minerios	Pegmatite										
Volte Grande	Advanced metallurgical group	Pegmatite						19.4	0.4%		0.1	0.4
Minas Gerais		Spodumene				0.1	0.5				0.9	4.8
Brazil - Total						**0.1**	**0.5**				**1.0**	**5.3**

Source: Deutsche Bank; Company data; Industry data

Figure 268: List of lithium deposits (Cont'd)

			Reserves					Resources				
Deposit name	Ownership	Deposit type	Mt	Li%	Li2O %	Li (Mt)	LCE (Mt)	Mt	Li%	Li2O%	Li (Mt)	LCE (Mt)
James Bay	Galaxy resources	Pegmatite						22.2	0.6%	1.3%	0.1	0.7
Buckton Zone	DNI Metals Inc.	Black shales									0.01	0.03
Rose lithium – tant.	CE corp	Pegmatite						37.2	0.4%	1.3%	0.2	0.9
Whabouchi	Nemaska Lithium	Pegmatite	27.3	0.7%	1.5%	0.2	1.0	32.7	0.7%	1.6%	0.2	1.3
Pakeagama Lake	Houston lake mining	Pegmatite						7.4	0.4%	1.9%	0.03	0.2
Mavis-Fairservice	International lithium	Pegmatite										
Lithium Quebec	Canada lithium corp	Pegmatite	17.1	0.4%	0.9%	0.1	0.4	47.0	0.6%	1.2%	0.3	1.4
Authier	Glen eagle resources	Pegmatite						7.7	0.4%	1.0%	0.03	0.2
Moblan	Zhongjin Lingnan	Pegmatite						14.3	0.7%	1.4%	0.1	0.5
Root Lake	Landore Resources limited	Pegmatite						2.3	0.6%	1.3%	0.01	0.1
Valley view	Lithium Exploration Group	Brine									0.4	2.0
Godslith	First Lithium Resources	Pegmatite									0.05	0.3
Separation rapids	Avalon rare metals inc.	Pegmatite	7.8	0.7%	1.4%	0.1	0.3	11.6	0.6%	1.3%	0.1	0.4
Georgia lake	Ultra lithium inc.	Pegmatite						9.5	0.5%	1.0%	0.05	0.2
Fox creek	Channel resources ltd.	Brine									0.4	1.9
Beaverhill	Ameri lithium	Brine									0.6	3.0
Violet/ Thompson	Rodinia lithium inc.	Pegmatite									0.03	0.1
Tanco	Cabot corporation	Pegmatite						22.3	0.6%	1.4%	0.14	0.8
Canada - Total						**0.3**	**1.7**				**2.6**	**13.9**
Salar de Atacama	Albemarle	Brine				0.6	3.1				0.6	3.1
Zoro 1	Force minerals corporation	Pegmatite						1.7		0.9%	0.01	0.04
Laguna Verde Salar	First Potash corporation	Brine									0.1	0.5
Salar de Pedernales	CODELCO	Brine									0.02	0.1
Salar de Atacama	SQM	Brine				6.2	33.0				6.2	33.0
Salares 7	Albemarle and Talison	Brine										
Salar del Carmen	SQM	Brine										
Maricunga	Cocina and Litio property	Brine									0.1	0.7
Chile - Total						**6.8**	**36.1**				**7.0**	**37.4**
Altai		Pegmatite										
Zabuye	Tibet mineral development co	Brine				0.9	4.5				1.5	8.1
Dangxiongcuo	Beijing Mianping Salt Lake	Brine				1.4	7.2				0.2	0.9
Qaidam basin (Lakes Xitai, Dongtai)	Qinghai Salt Lake Industry Group Co Ltd	Brine				0.9	5.0				2.0	10.8
Damxung Salt Lake		Brine				0.2	0.9				0.2	0.9
Jiajika	Sterling group ventures inc.	Pegmatite	80.5	0.6%	1.3%	0.5	2.55				0.2	1.1
Maerkang	Sichuan Sheng co ltd	Pegmatite				0.2	1.2				0.2	1.2
Gajika	CITIC Guoan & Tech. Co.	Spodumene				0.5	2.6				0.6	3.1
Barkam		Pegmatite				0.2	1.2				0.2	1.2
Nanping		Pegmatite										
Yichun	Jiangxi Special Electric Motor	Pegmatite									0.3	1.7
Daoxian	Sterling group ventures inc.	Pegmatite				0.2	1.2				0.2	1.0
China - Total						**4.9**	**26.3**				**5.6**	**30.0**
Manono–Kitolo		Pegmatite	120	0.6%	1.3%	0.7	3.83				1.1	6.1
DR Congo - Total						**0.7**	**3.83**				**1.1**	**6.1**

Source: Deutsche Bank; Company data; Industry data

Figure 268: List of lithium deposits (Cont'd)

Deposit name	Ownership	Deposit type	Reserves Mt	Reserves Li%	Reserves Li_2O %	Reserves Li (Mt)	Reserves LCE (Mt)	Resources Mt	Resources Li%	Resources Li_2O%	Resources Li (Mt)	Resources LCE (Mt)
Lantta	Keliber	Pegmatite	1.0	0.5%	1.0%	0.004	0.02	1.3	0.5%	1.1%	0.01	0.03
Outovesi	Keliber	Pegmatite	0.3	0.5%	1.2%	0.002	0.01	0.3	0.7%	1.5%	0.002	0.01
Syvajarvi	Keliber	Pegmatite	1.4	0.5%	1.1%	0.01	0.04	1.7	0.6%	1.2%	0.01	0.05
Rapassari	Keliber	Pegmatite						0.9	0.6%	1.3%	0.01	0.03
Leviakangas	Keliber	Pegmatite						0.5	0.5%	1.0%	0.002	0.01
Emmes	Keliber	Pegmatite						0.8	0.7%	1.4%	0.01	0.03
Janislampi	Keliber	Pegmatite										
Finland - Total						**0.01**	**0.1**				**0.03**	**0.2**
Echassieres	Imerys	Greisen/Aplite									0.1	0.7
Treguennec		Greisen/Aplite									0.03	0.2
Total - France											**0.16**	**0.86**
Avalonia lithium	55% GFL, 45% ILC	Pegmatite										
Blackstairs	Ganfeng; International lithium	Pegmatite									0.004	0.02
Total - Ireland											**0.004**	**0.02**
La Ventanna	Bacanora minerals	Hectorite and Polylithionite						276			0.7	3.7
El Sauz	Bacanora minerals	Hectorite and Polylithionite						247			0.4	2.2
El Sauz 1	Bacanora minerals	Hectorite and Polylithionite						150			0.5	2.4
Fleur	Bacanora minerals	Hectorite and Polylithionite						47			0.1	0.6
Total - Mexico											**1.7**	**8.9**
Enkh area	Tsagaan Shonkhor	Brine									0.05	0.2
Delgerekh area	Tsagaan Shonkhor	Brine									0.2	1.2
Chuluut area	Tsagaan Shonkhor	Brine									0.1	0.7
Total - Mongolia											**0.4**	**2.2**
Karibib	Black fire minerals	Pegmatite						1.1	1.4%	3.0%	0.02	0.1
Total - Namibia											**0.02**	**0.1**
Fregeneda Almendra		Pegmatite										
Barroso - Alvao		Pegmatite									0.01	0.05
Alijo-Veral		Aplite-pegmatite	1.2									
Adagoi		Aplite-pegmatite	0.4									
Total - Portugal			**1.6**								**0.01**	**0.05**

Source: Deutsche Bank; Company data; Industry data

Figure 268: List of lithium deposits (Cont'd)

Deposit name	Ownership	Deposit type	Reserves					Resources				
			Mt	Li%	Li2O %	Li (Mt)	LCE (Mt)	Mt	Li%	Li2O%	Li (Mt)	LCE (Mt)
Alakha		Peraluminous granite bodies										
Vishnyakovskoe		Pegmatite						42	0.5%	1.1%	0.21	1.10
Alakhinskoye		Pegmatite						128	0.4%	0.8%	0.5	2.5
Kolmozerskoye		Pegmatite									0.4	2.0
Polmostundrovskoye		Pegmatite									0.2	0.9
Belorechenskoye		Pegmatite									0.1	0.4
Zavitino	Transbaikalia (ZabGOK JSC)	Pegmatite									0.1	0.5
Kosterskoye		Pegmatite									0.5	2.5
Tastygskoye		Pegmatite									0.3	1.5
Ulug tanzek		Pegmatite									0.2	1.1
Urikskoye		Pegmatite									0.2	0.9
Goltsovoye		Pegmatite									0.2	1.0
Zavitskoye		Pegmatite										
Total - Russia											**2.7**	**14.3**
Balkans	Ultra lithium inc. (95%)	Jadarite										
Balkans	Pan global resources	Jadarite										
Jadar	Rio tinto	Jadarite						125	0.8%	1.8%	1.0	5.6
Total - Serbia											**1.0**	**5.6**
Doade-presqueiras	Iberian Minerals	Pegmatite						4.2		0.8%	0.02	0.1
Silver Peak	Albemarle, CFC	Brine									0.3	1.6
Kings valley	Western lithium	Hectorite Clay	27.1	0.4%	0.9%	0.1	0.6				0.1	0.7
Salton sea	Rockwood Holdings Inc.	Brine									0.3	1.7
Foote mine	Rockwood Holdings Inc.	Pegmatite				0.2	1.1				0.1	0.5
Kings Mountain	Albemarle	Pegmatite								1.80%	0.3	1.7
Clayton Valley South	Pure energy minerals	Brine										
South Big Smokey	Ultra lithium inc.	Brine										
Brawley	Simbol Materials	Brine (Geothermal)									1.0	5.3
Smackover		Brine									0.8	4.0
Hallman - beam	FMC Lithium	Pegmatite			0.6	0.3	1.5	62.3	0.7%	1.4%	0.4	2.2
Total - USA						**0.6**	**3.2**				**3.3**	**17.7**
Naukinskoe	Republic of Uzbekistan	Pegmatite									0.002	0.01
Shavazsai	Republic of Uzbekistan	Pegmatite									0.1	0.4
Total - Uzbekistan											**0.1**	**0.4**
Kamativi	ZMDC	Pegmatite										
Bikita	Bikita minerals inc.	Pegmatite	10.8	1.4%		0.2	0.8	23	1.4%	3.0%	0.3	1.7
Total - Zimbabwe						**0.2**	**0.8**				**0.3**	**1.7**
Total - Global						**19**	**102**				**51**	**273**

Source: Deutsche Bank; Company data; Industry data

Companies mentioned

Figure 269: Companies mentioned list

Company	Ticker	Exchange	Target price	Recommendation
DB Covered				
3M	MMM	NYSE	US$175/sh	Hold
Albemarle Corporation	ALB	NYSE	US$72/sh	Buy
Alcoa Inc.	AA	NYSE	US$13/sh	Buy
Apple Inc.	AAPL	NASDAQ	US$105/sh	Hold
Applied materials Inc.	AMAT	NASDAQ	US$24/sh	Buy
BAIC Motor Corp Ltd.	1958	HK	HK$7.3/sh	Buy
BASF SE	BAS	FF	EUR85/sh	Buy
Bayerische Motoren Werke AG (BMW)	BMW	FF	EUR110/sh	Hold
BYD Company	1211	HK	HK$47/sh	Hold
Cabot Corporation	CBT	NYSE	US$44/sh	Hold
Cadillac	GM	NYSE	US$34/sh	Hold
China Minmetals Rare Earth Co. Ltd.	000831	SZ	CNY6/sh	Sell
Chevrolet	GM	NYSE	US$34/sh	Hold
ConocoPhillips	COP	NYSE	US$62/sh	Buy
Constellium	CSTM	NYSE	US$12/sh	Buy
Continental AG	CON	FF	EUR230/sh	Buy
Daimler AG	DAI	FF	EUR95/sh	Buy
Duke Energy corp	DUK	NYSE	US$80/sh	Hold
DuPont	DD	NYSE	US$80/sh	Buy
EDF energy	EDF	Euronext	EUR7/sh	Sell
Energizer Resources Inc.	EGZ	T	US$49/sh	Buy
Evonik industries	EVK	FF	EUR29/sh	Hold
Fiat Chrysler Automobiles	FCA	MI	EUR8/sh	Hold
First Solar Inc.	FSLR	NASDAQ	US$80/sh	Buy
Foote Minerals	ALB	NYSE	US$72/sh	Buy
Ford Motor company	F	NYSE	US$16/sh	Hold
Formosa Plastics Corporation	1301	TW	TW$83/sh	Hold
Foxconn Technology Group	2354	TW	TW$102/sh	Hold
Geely Automobile Holdings Ltd.	0175	HK	HK$3.7/sh	Hold
General Electric	GE	NYSE	US$28/sh	Hold
General Motors Company	GM	NYSE	US$34/sh	Hold
Google	GOOG	NASDAQ	US$1100/sh	Buy
Hitachi Chemical Co. Ltd.	4217	TO	JPY2000/sh	Hold
Honda Motor Co. Ltd.	7267	TO	JPY3450/sh	Hold
Jiangxi Ganfeng Lithium Co. Ltd.	002460	SZ	CNY78/sh	Buy
Johnson Controls Inc.	JCI	NYSE	US$47/sh	Hold
Kia Motors Corp	000270	SE	KRW54000/sh	Hold
LG Chem Ltd.	051910	SE	KRW390000/sh	Buy
LG Electronics Inc.	066570	SE	KRW78000/sh	Buy
Mercedes benz	DAI	FF	EUR95/sh	Buy
Mineral Resources Ltd.	MIN	AU	AU$6.7/sh	Hold
Mitsui & Co. Ltd.	8031	TO	JPY1060/sh	Hold
National Grid plc	NG	LN	GBP900/sh	Hold
Nissan Motor Co. Ltd.	7201	TO	JPY1300/sh	Hold
Orocobre Ltd.	ORE	AU	AU$2.7/sh	Hold

Source: Deutsche Bank

Figure 269: Companies mentioned list (Cont'd)

Company	Ticker	Exchange	Target price	Recommendation
DB Covered				
Panasonic Corporation	6752	TO	JPY1400/sh	Buy
Porsche automobil Holding SE	PAH3	FF	EUR56/sh	Hold
POSCO	005490	SE	KRW245000/sh	Hold
Rio Tinto Limited	RIO	AU	AU$56.5/sh	Buy
Rockwood Holdings Inc	ALB	NYSE	US$72/sh	Buy
Royal DSM N.V	DSM	Euronext	EUR50/sh	Hold
SAIC Motor Corporation Limited	600104	SH	CNY23.8/sh	Buy
Samsung Electronics Co. Ltd.	005930	SE	KRW1650000/sh	Buy
Samsung SDI Co. Ltd.	006400	SE	KRW113000/sh	Hold
Schneider Electric SE	SU	Euronext	EUR65/sh	Buy
Sichuan Tianqi Lithium Industries Inc.	002466	SZ	CNY162.2/sh	Hold
Siemens AG	SIE	FF	EUR100/sh	Hold
Sony corporation	6758	TO	JPY3500/sh	Hold
South32 Ltd.	S32	AU	AU$1.7/sh	Hold
Syngenta AG	SYNN	EB	CHF430/sh	Buy
Syrah Resources Ltd.	SYR	AU	AU$6/sh	Buy
Tesla Motors Inc.	TSLA	NASDAQ	US$290/sh	Hold
Toyota Motor Corporation	7203	TO	JPY7850/sh	Buy
Umicore N.V	UMI	Euronext	EUR32/sh	Sell
Volkswagen Group	VOW	FF	EUR135/sh	Hold
Western Areas Ltd.	WSA	AU	AU$2/sh	Sell
Listed but not covered by Deutsche Bank				
Advanced Metallurgical Group N.V	AMG	Euronext		
AES Corporation	AES	NYSE		
Altair Nanotechnologies	ALTI	NASDAQ		
Altura mining	AJM	AU		
AmeriLithium Corp.	PTTN	US OTC		
Asahi Kaisei Corporation	3407	TO		
Audi AG	NSU	FF		
Avalon Advanced Materials Inc.	AVL	T		
Bacanora minerals	BCN	V		
Beijing Easpring Material Technology Co. Ltd.	300073	SZ		
Canada Lithium Corp.	CLQ	T		
Cangzhou Mingzhu Plastic Co. Ltd.	002108	SZ		
Central Glass Co. Ltd.	4044	TO		
Chongqing Changan Automobile Co. Ltd	000625	SZ		
Citic Guoan Information Industry Co. Ltd.	000839	SZ		
Critical Elements Corp.	CRE	V		
DNI Metals Inc.	DNI	V		
Do - Fluoride Chemicals Co. Ltd.	002407	SZ		
Electrovaya Inc.	EFL	T		
Enel	ENEL	MI		
Eramet	ERA	Euronext		
Eve Energy Co. Ltd.	300014	SZ		
FMC Corporation	FMC	NYSE		
Foosung Co. Ltd.	093370	SE		
Force Minerals Corp.	FORC	US OTC		

Source: Deutsche Bank

Figure 269: Companies mentioned list (Cont'd)

Company	Ticker	Exchange	Target price	Recommendation
DB Covered				
Galaxy Resources Limited	GXY	AU		
General Mining Corp Ltd.	GMM	AU		
Glencore Plc	GLEN	LN		
Glen Eagle Resources Inc.	GER	V		
Graphite One Resources Inc.	GPH	V		
GS Yuasa Corporation	6674	TO		
Guangzhou Tinci Materials Technology Co. Ltd.	002709	SZ		
Hebei Jinniu Chemical Industry Co Ltd.	600722	SH		
Hitachi Ltd.	6501	TO		
Houston Lake Mining Inc.	HLM	V		
Hunan Corun New Energy Co. Ltd.	600478	SH		
Iberian Minerals Ltd.	IML	V		
Imerys S.A	NK	Euronext		
International Lithium Corp.	ILC	V		
Jiangsu Guotai International Group Guomao Co. Ltd.	002091	SZ		
Jiangsu Jiujiujiu Technology Co. Ltd.	002411	SZ		
Jiangxi Special Electric Motor Co. Ltd.	002176	SZ		
Jinhui Holdings Co. Ltd.	0137	HK		
Kanto Denka Kogyo Co. Ltd.	4047	TO		
Kingray New Materials Science & Technology Co. Ltd.	600390	SH		
Kureha Corporation	4023	TO		
L&F Material Co. Ltd.	066970	KQ		
Laqndore Resources Ltd.	LND	LN		
Li3 Energy Inc.	LIEG	US OTC		
Lithium Americas corp	LAC	T		
Lithium Exploration Group	LEXG	US OTC		
Mason Graphite	LLG	V		
Maxwell Technologies	MXWL	NASDAQ		
Mitsubishi Chemical Corporation	4188	TO		
Mitsui Chemicals Inc.	4183	TO		
NEC Corporation	6701	TO		
Nemaska Lithium Inc	NMX	V		
Neometals Ltd.	NMT	AU		
Ningbo Shanshan Co. Ltd.	600884	SH		
Nippon Carbon Co. Ltd.	5302	TO		
Nippon Denko Co. Ltd.	5563	TO		
Novolyte technologies inc.	BAS	FF		
Pan Global Resources Inc.	PGZ	V		
Pilbara Minerals Ltd.	PLS	AU		
Primearth EV Energy Co. Ltd.	7203	TO		
Pure Energy Minerals Ltd.	PE	V		
Qinghai Salt Lake Industry Co. Ltd.	000792	SZ		
Red River Resources Limited	RVR	AU		
Rodinia Lithium Inc.	RM	V		

Source: Deutsche Bank

Figure 269: Companies mentioned list (Cont'd)

Company	Ticker	Exchange	Target price	Recommendation
DB Covered				
Saft Groupe S.A	SAFT	Euronext		
Sanyo Electric Co. Ltd.	6764	TO		
Shandong Shida Shenghua Chemical Group Co. Ltd.	603026	SH		
Shenzhen Capchem Technology Co. Ltd.	300037	SZ		
Shenzhen Zhongjin Lingnan Nonfemet Company	000060	SZ		
SK energy	034730	SE		
Sociedad Quimica y Minera de Chile	SQM	NYSE		
Stella Chemifa Corp	4109	TO		
Sterling Group Ventures Inc.	SGGV	US OTC		
Sumitomo Corporation	8053	TO		
Talga Resources Ltd.	TLG	AU		
Tanaka Chemical Corporation	4080	TO		
Tibet Mineral Development Co. Ltd.	000762	SZ		
Tibet Urban Development and Investment Co. Ltd.	600773	SH		
Toda Kogyo Corp	4100	TO		
Toshiba Corporation	6502	TO		
Toyota Tsusho Corporation	8015	TO		
Triton Minerals Ltd.	TON	AU		
Ube Industries Ltd.	4208	TO		
Ultra Lithium Inc.	ULI	T		
United Science and Technology co. Ltd.	000925	SZ		
Vestas Wind Systems A/S	VWS	KO		
Wanxiang Qianchao Co. Ltd.	000559	SZ		
Western Lithium Corporation	LAC	T		
Western Mining Corporation	BHP	AU		
Youngy Co. Ltd	002192	SZ		
Zhonghe Co. Ltd.	002070	SZ		
Private companies				
A123 systems				
AC Propulsion Inc.				
ADY Resources Limited				
AGC Seimi Chemical Co. Ltd.				
AllCell Technologies				
ANSTO minerals				
Arqueana de Minérios e Metals Ltd				
Aston Martin Lagonda Limited				
Automotive Energy Supply Corporation				
Bateman Advanced Technologies Ltd				
Beijing Mianping Salt Lake Research Institute				
Bikita minerals ltd				
Black Fire Minerals Ltd.				
Boston power Inc				

Source: Deutsche Bank

Figure 269: Companies mentioned list (Cont'd)

Company	Ticker	Exchange	Target price	Recommendation
DB Covered				
Celgard				
Channel Resources Ltd.				
China Lithium				
Cheil industries				
China Aviation Lithium Battery Co. Ltd.				
CODA energy				
Codelco				
Companhia Brasileira de Litio				
Companhia Industrial Fluminense Mineracao S.A				
Contemporary Amperex Technology Co. Ltd. (CATL)				
Corporacion Minera de Bolivia				
Cyprus Amax Minerals Company				
EnerDel Inc.				
Energi Group				
Entek				
First Lithium Resources Inc.				
First Potash Corp.				
General Lithium (Haimen) Corporation				
Global Adavanced Metals				
Global Strategic Metals Limited				
Green charge networks				
Guohua Lithium				
Guoxuan High-Tech Co. Ltd.				
Harbin Coslight Power Company Limited				
Huawei Technologies Co. Ltd.				
Hubei Baijierui Advanced Materials corporation				
International Data Corporation				
Iron Edison				
Jiangxi Hzong				
Jiangxi Rubidium				
JEMSE (Jujuy Energia y Mineria Sociedad del Estado)				
Johnson Controls - Saft Advanced Power Solutions				
JuiceBox Energy				
K-Utech				
Kansai Catalyst Co. Ltd.				
Keliber Oy				
Kokam Co. Ltd.				
Korea Resources Corporation				
Li Energy				
Li-Tec Battery GmbH				
Linyi Gelon LIB Co. Ltd.				
Lithchem Energy				
Lithea Inc.				
Microvast Inc.				
Minsal S.A				
Molibdenos y Metales S.A (Molymet)				
Morita Chemical Industries Co. Ltd.				

Source: Deutsche Bank

Figure 269: Companies mentioned list (Cont'd)

Company	Ticker	Exchange	Target price	Recommendation
DB Covered				
Nichia Corporation				
Nihon Chemical Co. Ltd.				
Orison Co. Ltd.				
Panex Etec Co. Ltd.				
Phostech Lithium Inc.				
Pyrotek				
Qinghai East Taijinar Lithium Resources				
Qinghai Hengxinrong Lithium Technology Co. Ltd.				
Qinghai Lithium Industry Co. Ltd.				
Qinghai Saltlake Fozhao Lake Lithium Industry Co. Ltd.				
Rincon Lithium Ltd.				
Sales de Jujuy Pte. Ltd.				
Sales de Jujuy S.A.				
Santoku Corporation				
Shandong Hongxin Chemicals Co. Ltd.				
Shandong Ruifu				
Shenzhen OptimumNano Energy Co. Ltd.				
Shinestar Group Co. Ltd.				
Sichuan Ni&Co Guorun New Materials Co. Ltd.				
Sichuan Sheng Ni Kei Guorun Xin cai Liao Co. Ltd.				
Simbol Materials LLC				
Simpliphi Power				
Sinopoly Battery Limited				
Sociedad Chilena del Litio Limitada				
Sonnen				
Stem Inc.				
Superior graphite				
Talison Lithium				
Tianjin Bamo Technology Company limited				
Tianjin Lishen Battery Co. Ltd.				
Tomiyama Pure Chemical Industries Ltd.				
Tomiyama Yakuhin Kogyo K.K				
Toray Tonen Speciality Separator				
Toyotsu Lithium Pte. Ltd.				
Transbaikalia				
Tsagaan Shonkhor Holding LLC				
Turnkey Group				
Winfield Holdings Pty. Ltd.				
XALT energy				
Xiaomi Inc.				
Xinjiang Xinjing Lithium Development				
Yichun Tani				
Zimbabwe Mining Development Corporation				
Zoyte Auto				

Source: Deutsche Bank

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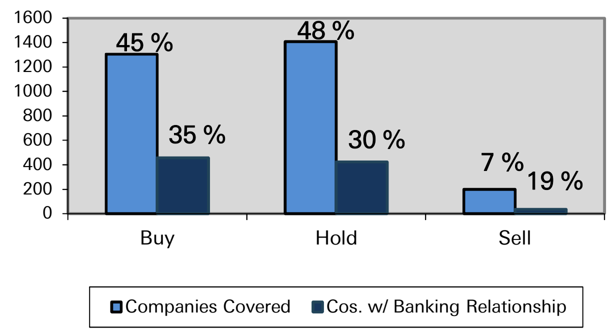

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