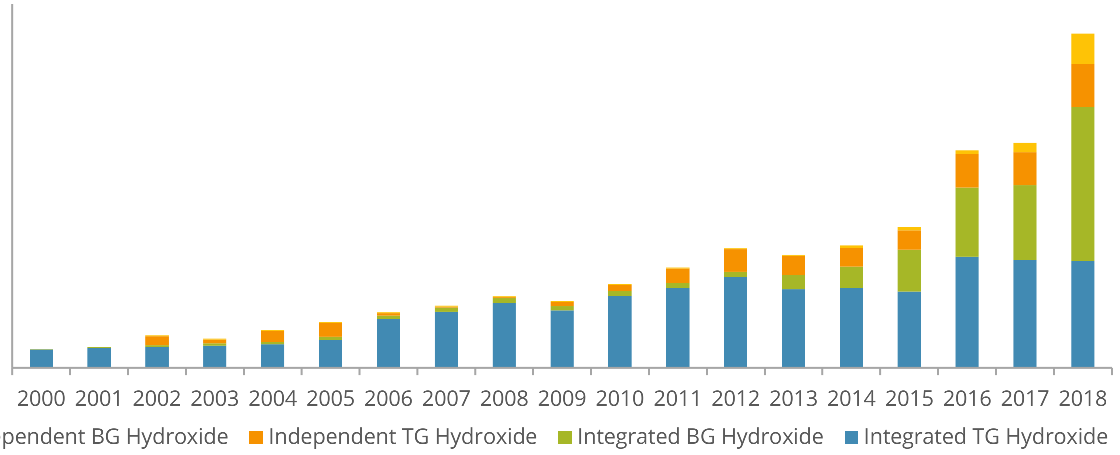
Figure 34: Lithium hydroxide production by product and integration, 2000-2018 (LCE t)



Source: Roskill

Over the past eighteen years lithium hydroxide production has been dominated by established integrated companies. But independent supply was boosted in 2018, especially battery-grade hydroxide, as Shandong Ruifu brought online a hydroxide circuit at Feichen City and Youngdream Li-ion ramped up production at its plant in Quzhou. This had no material impact on integrated production market share only decreasing it to around %, a decrease of only %. Integrated operator product composition is also changing from industrial/technical-grade toward battery-grade products. Battery-grade hydroxide comprised % (0t LCE) of integrated production in 2018, up from % t LCE) in 2010.

Table 18: Lithium hydroxide by company and product, 2014-2018 (LCE t)

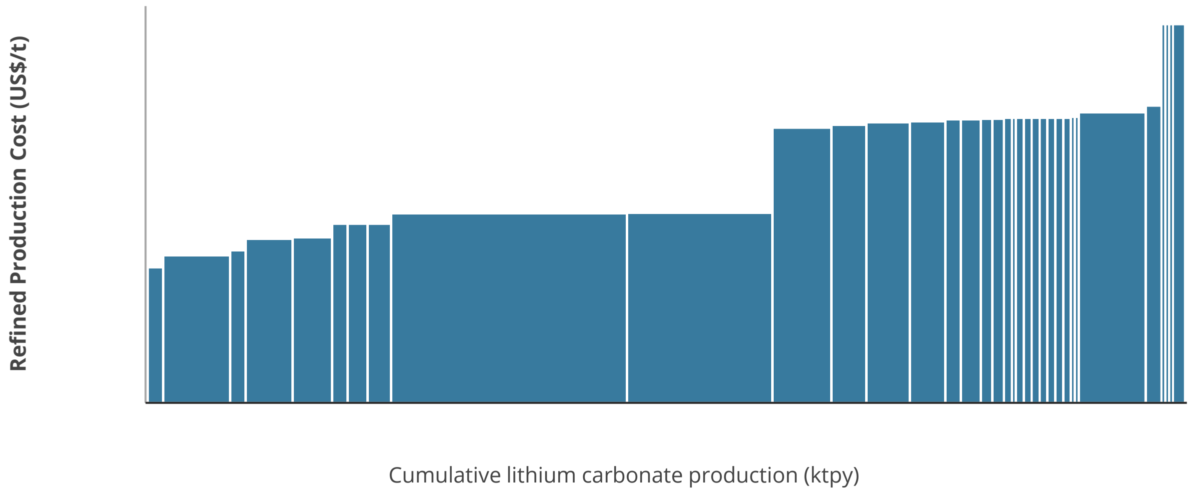
	2014	2015	2016	2017	2018
Technical-grade					
Albemarle					
SQM					
Livent					
Tianqi Lithium					
Ganfeng Lithium					
Yahua Group					
Others (China)					
Others (ROW)					
Sub-total	*18,858*	*18,373*	*27,836*	*27,060*	*28,812*
Battery-grade					
Albemarle					0
SQM					
Livent					
Tianqi Lithium					
Ganfeng Lithium					
Yahua Group					
Others (China)					
Others (ROW)					
Sub-total					
Total					

Source: Roskill

4.1 Lithium carbonate costs

The brine producers enjoy the lowest lithium carbonate production costs because of their low-cost brine-based extraction methods with refined production cost of between US$ /t. In comparison, mineral conversion plant costs range between US$ - /t, depending on the cost of their feedstock (often linked to the level of vertical integration), age of the plant and production volumes being key determinants of their overall refined production cost. Chinese converters with vertical integration have the advantage of having access to lower cost feedstock, whereas those reliant on third-party mineral feedstock have the highest costs. It should be noted that the cost differential between the brine and mineral conversion operations has narrowed considerably between 2018 and 2019, following the higher royalties for brine operations in South America and a reduction in spodumene feedstock costs. Furthermore, the marked reduction in arm's length spodumene cost has helped narrow the refined production cost between the various mineral converters in China.

Figure 38: Lithium carbonate cost curve in 2019



Source: *Roskill Lithium Cost Model Service*

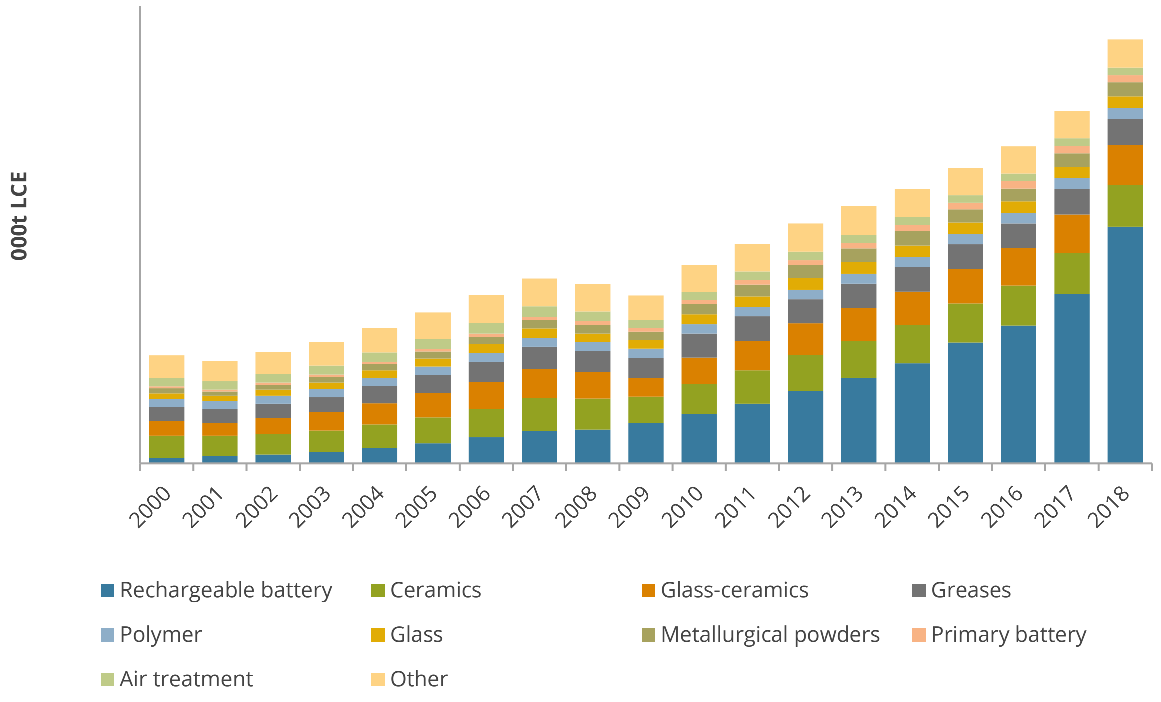
Note: *Battery and technical grades; Includes direct carbonate production from raw materials (brine and minerals); SQM & Albemarle costs assume potash cost share methodology; Spodumene concentrate costs of US$ /t for inter-company (Tianqi Lithium & Albemarle), US$750/t for related-party (Ganfeng) and US$ /t for arms-length (other facilities) in line with our chemical-grade spodumene concentrate forecast prices for 2019). As a result, it should be noted that production costs presented here for Tianqi Lithium, Albemarle (China) and Ganfeng Lithium are inflated by the fact that a portion of the profit margin is incorporated within the spodumene feedstock cost which is sourced from their subsidiary mining companies.*

Refined production cost *includes all direct and indirect operating costs related directly to the physical activity of producing a refined lithium compound, including feedstock costs (either from internal sources measured using the all-in sustaining cost of production (site operating plus other costs, as defined above), refining, on-site general and administrative costs and selling expenses. It does not include costs associated with corporate-level administrative expenses.*

4.2 Lithium hydroxide costs

Comparable to the lithium carbonate sector, the brine producers enjoy the lowest lithium hydroxide-monohydrate production costs because of their access to low-cost brine-based feedstock with refined production costs of between US$ - /t. The costs of Chinese converters, producing lithium hydroxide from mineral concentrate, range between US$ - /t. The high cost portion of the cost curve relates to those operations in China converting lithium carbonate into hydroxide; it should be noted that the cost of these operations is

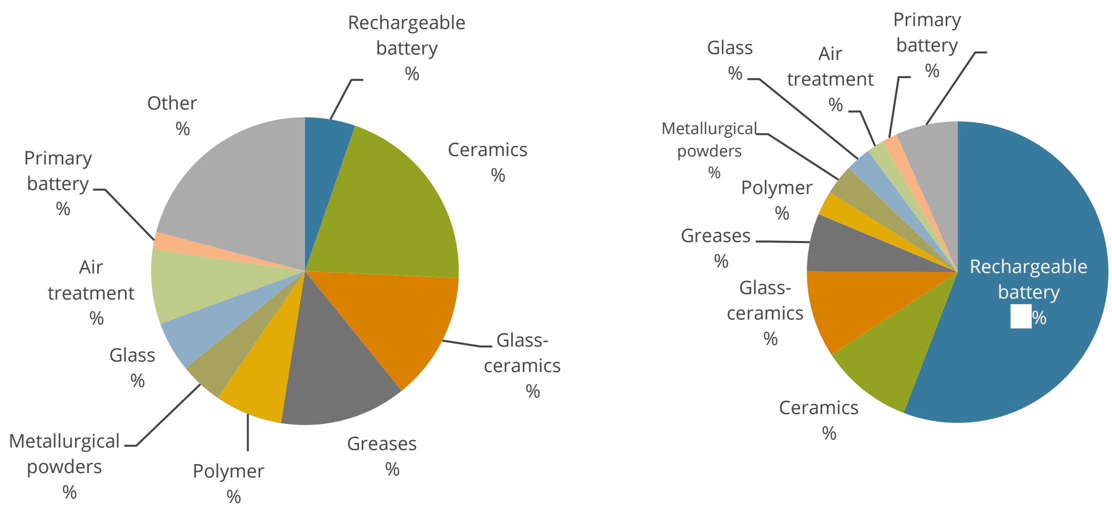
Figure 48: World: Consumption of lithium by first use, 2000-2018 (000t LCE)



Source: Roskill estimates

The rechargeable battery sector accounted for %, of lithium consumption in 2018, up from % in 2017 (Figure 49). The rechargeable battery sector became the largest lithium consumer in 2006, and in 2015 accounted for over three times the volume consumed by the next largest sector, ceramics.

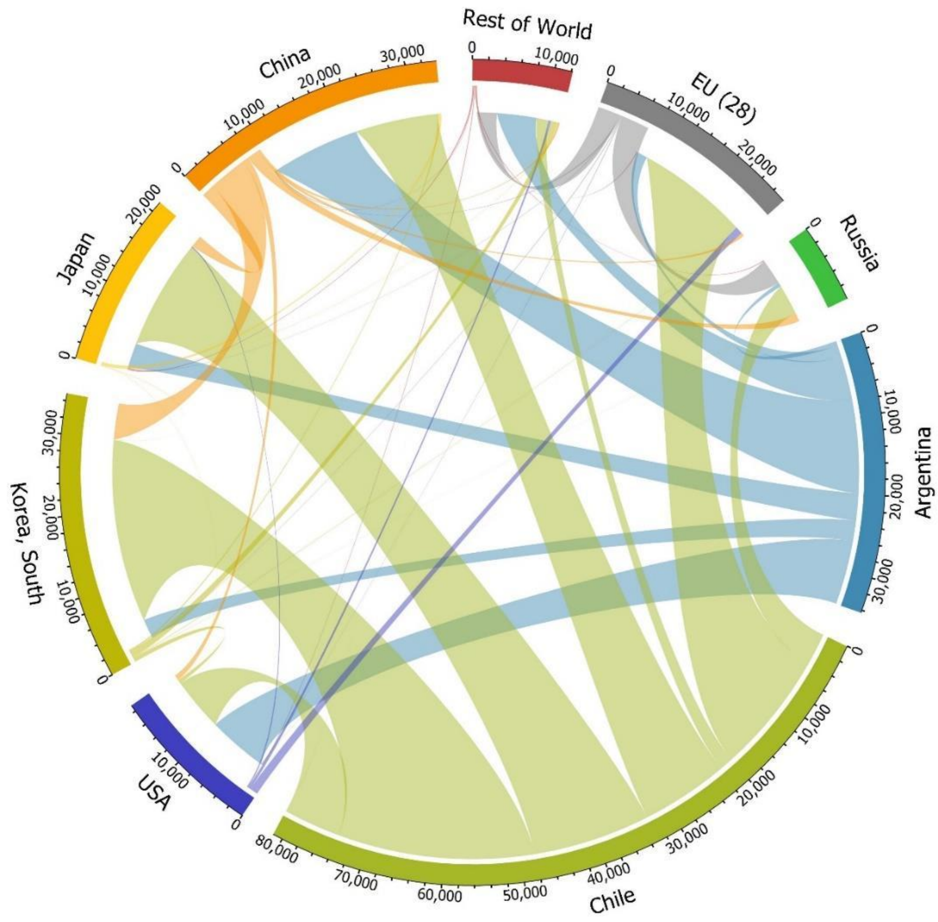
Figure 49: World: Consumption of lithium by first use, 2000 and 2018 (t LCE)



Source: Roskill estimates

Within the battery industry, the largest consumer of lithium is the automotive industry followed by the portable electronics industry. In 2016, lithium consumption by automotive powertrain batteries surpassed the lithium consumption by the portable electronics industry. In 2018,

Figure 55: Export of lithium carbonate by producing country and destination, 2018 (t)



Source: Roskill

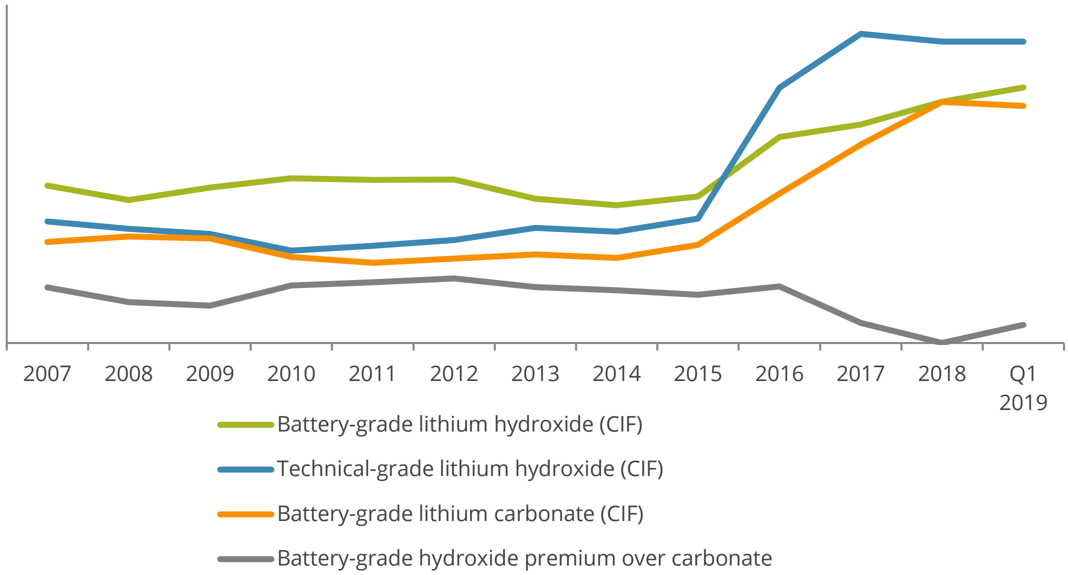
Imports of lithium carbonate are dominated by the flow of material into China, Japan, South Korea and the USA, which combined represent % of recorded imports in 2018. South Korea was the largest importer of lithium carbonate in 2018, with reported imports totalling kt Li_2CO_3, an increase of % compared to the previous year. South Korea is heavily reliant upon imports of lithium carbonate to supply its domestic lithium-ion battery industry.

Chinese imports of lithium carbonate fell to kt in 2018, compared to kt in 2017, representing a decrease of %. The decrease in Chinese imports likely represents a combination of greater domestic production of lithium carbonate from mineral concentrates reducing the requirement for imports and an increasing switch to lithium hydroxide feedstocks at cathode manufacturers targeting higher nickel cathode materials. Imported lithium carbonate, however, remains a key raw material not only for the Chinese battery industry, but also for conversion to hydroxide, e.g. by Livent, and for use in ceramics, glass and metallurgical applications.

Lithium carbonate imports by Japan reached a new high of kt Li_2CO_3 in 2018, increasing % compared to 2017. Similar to South Korea, Japan is highly dependent upon imports of

Battery-grade lithium hydroxide carried a large premium on a CIF contract basis until 2017 when long-term battery-grade contracts limited the price upside verses technical-grade, however in the Chinese spot market the premium has been just over US$ /t since 2016. Battery-grade lithium hydroxide also carries a premium over battery-grade carbonate, ranging between US$ - /t in 2007-2016, but in 2017 this sunk to US$1,200/t for the same reasons as described above for the premium over technical-grade hydroxide. It continued falling in 2018 to almost zero but returned to around US$ /t in Q1 2019.

Figure 66: Average annual contract prices for battery-grade lithium hydroxide and battery-grade lithium carbonate, 2007-2019 Q1 (US$/t CIF)



Source: Battery-grade lithium hydroxide CIF = Weighted average of Japan, Korea and Taiwan imports; Technical-grade lithium hydroxide = see above; battery-grade Lithium carbonate CIF = see above

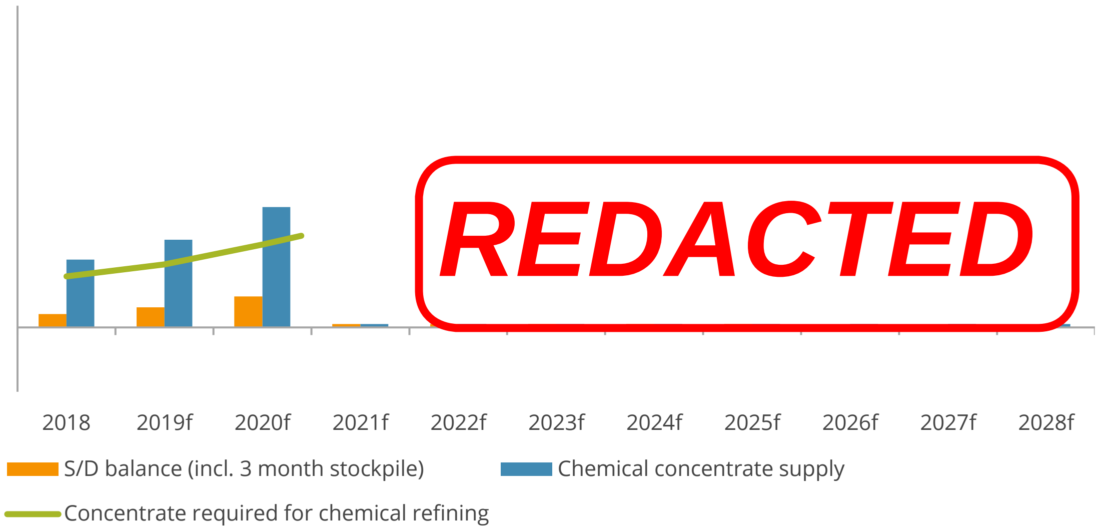
Table 37: Comparison of battery-grade and technical-grade lithium hydroxide average annual contract and spot prices, 2010-2019 Q1 (US$/t CIF)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019 Q1
Spot China (Asian Metal):										
Technical-grade										
Battery-grade										
Premium										
CIF Contract (Roskill):										
Technical-grade										
Battery-grade										
Premium										
CIF Contract (Fastmarkets):										
Technical-grade										
Battery-grade										
Premium										

Source: Roskill (contract); Asian Metal (spot)
Note: DDP Spot China ex. VAT

Existing planned expansions and potential new capacity are expected to weigh heavily on market balance throughout the forecast period, greatly outpacing that of lead demand (and consumption). Therefore, creating an oversupply of lithium raw materials. Roskill has adjusted its capacity forecast to incorporate these factors; nevertheless, Roskill still sees oversupply in the market in the near-term. This does not, however, account for existing producer reaction or responsiveness to prevailing demand climates, which is difficult quantify.

Figure 76: Forecast chemical grade concentrate market balance, 2018-2028 (LCE t)



Source: Roskill forecasts

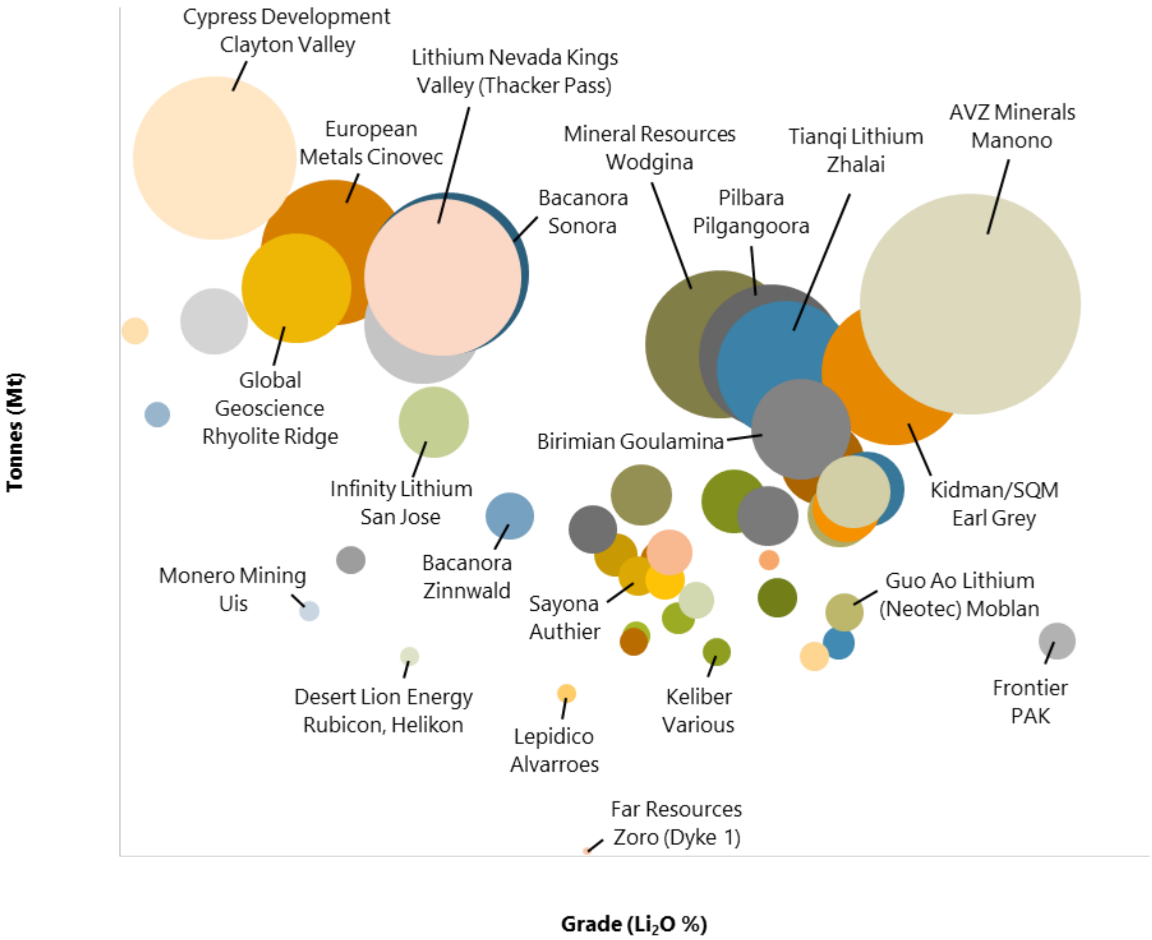
Roskill considers a proactive approach by miners in managing oversupply of lithium mineral concentrates. Therefore, existing players will directly dictate the opportunity/necessity for new market entrants in the **short-medium term**. As a result, access to capital markets for developers will be further hampered with soft prices likely to impact feasibility study economics. Roskill considers potential exemptions to this being the development of integrated mine-to-refinery operations that purely serve 'captive needs', rather than 'market needs'. Even so, there are few projects of this type that are likely to be commissioned before the mid-2020's.

Evidence of producer responsiveness has already begun to play out with Pilbara Minerals curbing production in Q2 2019 and Galaxy Resources delaying shipments until future quarters of this year. These moves come off the back of delays in construction/commissioning of conversion plants in China, which includes respective offtake partner companies.

8.4.2 Refined lithium supply

Following a flurry of new mine supply in conjunction with a rapid response from existing lithium compound producers, supply of refined lithium products remains plentiful in 2019. Roskill forecasts a continuation of this trend and its run on affects for refined lithium markets in the **short-term**. A function of the current supply environment has been lacklustre demand from battery precursor manufacturers as a result of global EV adoption rates being below expectations. The ramping-up of newly constructed refineries, processing both brine and mineral concentrates, is likely to exacerbate the status quo until the early .

Figure 92: Mineral resource estimates for lithium mineral & clay deposits (excluding Talison Greenbushes), 2019 (Mt vs. Li_2O %)



Source: *Company data, Roskill*
Notes: *Bubble size represents lithium contained in mineral resources in terms of LCE*
Talison Lithium - Greenbushes operation is excluded for scale purposes, 120.6Mt, 5.93% LCE, bubble size similar to Kidman/SQM Earl Grey project

Lithium brine and clay mineral resources are generally larger than those of lithium mineral deposits, typically containing - Mt LCE, though the grade of lithium brines is much lower at between %- % Li. Lithium clay resources reside in the space between lithium brine and mineral deposits in terms of their resource estimate, both in terms of grade and bulk size. The lithium content of clay mineral resources is more comparable to lithium brine deposits, however, at - Mt LCE.

Table 64: Reported lithium mineral resources and reserves of advanced projects, 2019

			Reserves			Resources	
		Gross (Mt/Mm^3)	Li_2O (%) Li (mg/l)	LCE (Mt)	Gross (Mt/Mm^3)	Li_2O (%) Li (mg/l)	LCE (Mt)
Argentina							
Albemarle	Antofalla						
LAC/Ganfeng	Cauchari						
Galaxy Lithium	Sal de Vida						
Enirgi	Salar del Rincon						
Eramet	Centenario-Ratones						
International Lithium	Mariana						
Neo Lithium	Q3						
Lithium X	Sal de Los Angeles						
Millenial Lithium	Pastos Grandes						
Advantage Lithium	Cauchari						
LSC Lithium	Pozuelos						
LSC Lithium	Rio Grande						
Australia							
Kidman/SQM	Earl Grey						
Core Exploration	Grants (Finniss)						
Austria							
European Lithium	Wolfsberg						
Brazil							
Sigma Resources	Minas Gerais						
Canada							
Nemaska	Whabouchi						
Critical Elements	Rose						
Sayona	Authier						
Rock Tech	Georgia Lake						
Galaxy Resources	James Bay						
Avalon	Separation Rapids						
Guo Ao Lithium (Neotec)	Moblan						
Ardiden	Seymour Lake						
Frontier	PAK						
Chile							
Minera Salar Blanco	Maricunga						
China							
Pulead	Xitai						
Pulead	Dongtai						
Qinghai Salt Lake	Chaerhan						
Yahua Lithium	Lijiagou						
Tianqi Lithium	Cuola						
Tibet Zhabuye	Zhabuye						
Czech Republic							
European Metals	Cinovec						
Finland							
Keliber	Various						
Germany							
Bacanora	Zinnwald						
Lithium Australia	Sadisdorf						

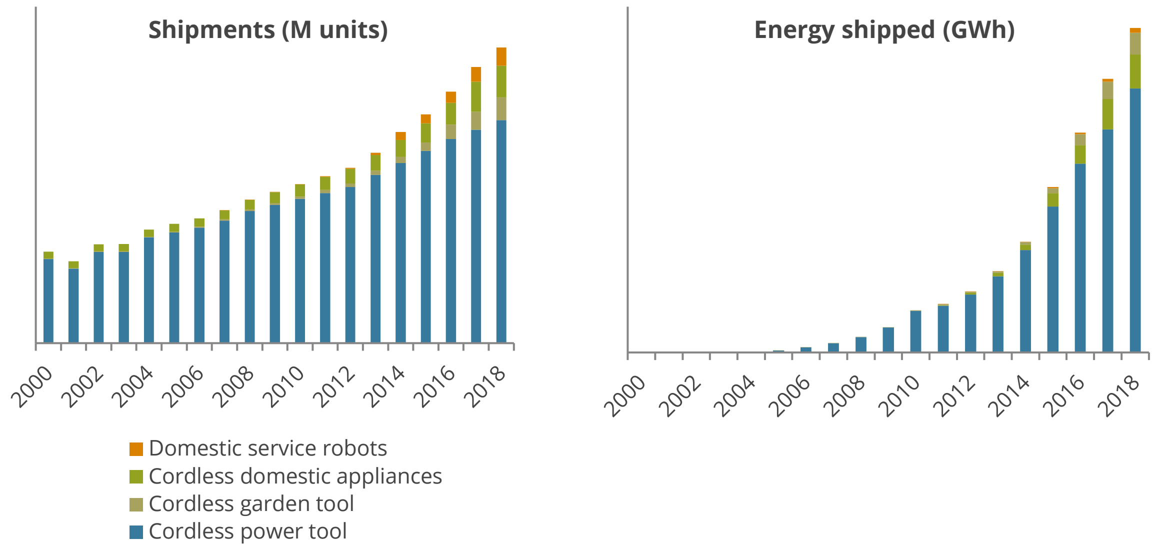
Table continues...

11.1.3.2 Power devices

Power applications is a category that comprises several types of products that operate under power-demanding conditions and high discharge-rates. They range from power tools such as drills, to domestic service robots such as robotic vacuum cleaners. For this report, power applications have been divided into four sub-categories: cordless power tools, cordless garden tools, cordless domestic appliances and domestic service robots.

Globally, the power Li-ion battery market had a size of GWh in 2018, of which GWh can be attributed to Li-ion technology. In recent years, the growth in Li-ion batteries for power applications has been mostly attributed to the cordless power tools, with GWh of Li-ion batteries shipped in 2018 compared to only GWh a decade ago. Cordless domestic appliances, followed by garden tools and domestic service robots were the second, third, and fourth drivers of growth in Li-ion batteries.

Figure 116: Trends in shipment of portable electronics, 2000-2018 (M units and GWh capacity)



Source: *Roskill*

Table 139: World: Li-ion battery consumption in power devices and motive power, 2018

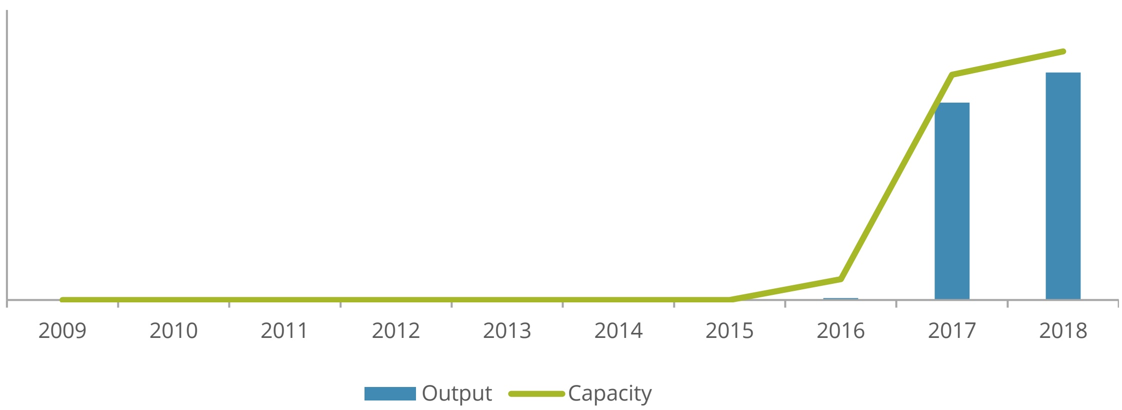
Device	Shipments (M units)	Cells (No. per unit)	Cell capacity (Wh)	Li-ion battery (GWh)[1]
Power tools				
Garden tools				
Cordless domestic appliance				
Domestic service robots				
Total				

Source: *Roskill*

Li-ion batteries have been growing their market share in the **power tool** and **garden tools** market, from close to zero in 2004 to % in 2018, and the main competition is from NiMH and

Spodumene concentrate production started at the Mt. Marion operation in December 2016, with first shipments of concentrates taking place in Q1 2017. The operation has the capacity to produce t of % and % Li_2O mineral concentrates, containing approximately t LCE, with production capacity being achieved in H2-2017. Production in 2018 totalled t mineral concentrates, containing t LCE, with the majority of production being % Li_2O concentrates. An upgrade to processing equipment at the Mt. Marion plant is currently being commissioned with the aim of increasing all production to % Li_2O mineral concentrate.

Figure 213: Mineral Resources: Mt. Marion production, 2009-2018 (t LCE)



Source: Roskill estimates

Mineral resources at the Mt. Marion operation were updated in October 2018 to total Mt grading % Li_2O, containing Mt LCE.

Table 269: Mineral Resources: Mt. Marion mineral resource, December 2017

	Tonnes (Mt)	Grade (Li_2O %)	Contained LCE (kt)
Indicated			
Inferred			
Total			

Source: Company information

Ganfeng Lithium signed a take or pay off-take agreement for 100% of % Li_2O spodumene concentrates, and for tpy - % Li_2O spodumene concentrates produced at Mt. Marion for the life-of-mine. In July 2017, Mineral Resources revised its off-take agreement with Ganfeng Lithium, with mineral concentrate prices now being linked to lithium carbonate and hydroxide prices.

12.33 Nemaska Lithium

Nemaska Lithium owns the Whabouchi project in the James Bay region of Quebec, Canada. The Whabouchi project is an integrated lithium operation which consists of the Whabouchi mine, producing lithium concentrates, and the Shawinigan electrochemical plant, producing lithium carbonate and hydroxide. Nemaska Lithium began small scale production from the Whabouchi mine and the Shawinigan plant in Q1 2017 to demonstrate its ability to produce battery grade lithium carbonate and hydroxide. Production was reported to total t of mineral