LITHIUM USES AND MARKETS

Roskill has previously highlighted that lithium end-use can generally be divided into two broad market categories: chemical and technical application markets.

CHEMICAL APPLICATION MARKETS

The following chemical applications use various common lithium chemicals, including lithium carbonate, lithium bromide, lithium chloride, butyl lithium and lithium hydroxide:

- Batteries: The two main lithium battery types are:
  – Primary (non-rechargeable): including coin or cylindrical batteries used in calculators and digital cameras. The lithium battery has a higher energy density compared to alkaline batteries as well as a low weight and long shelf and operating life; and
  – Secondary (rechargeable): the main applications are powering cell phones, laptops and other hand held electronic equipment. As with the primary battery, the lithium secondary battery has a higher energy density and lighter weight compared to NiCd and NiMH batteries.

- Lubricants: According to Roskill, lithium greases dominate the lubrication market. Lithium provides the thickener in the grease ensuring lubrication properties are maintained over a broad range of temperatures.

- Aluminium Smelting: The addition of lithium during aluminium smelting reduces the bath temperature which reduces power consumption, increases the bath electrical conductivity and reduces fluorine emissions.

- Air Treatment: A number of lithium-based chemicals are used in air treatment. This includes lithium bromide as an absorption medium for industrial refrigeration systems and lithium chloride for humidity control and drying systems.

- Pharmaceuticals: Lithium is used in the treatment for bipolar disorder as well as in other pharmaceutical products.

- Other Chemical Applications: Lithium chemicals are also used in a range of other applications including:– butyl lithium as a catalyst for polymerisation of synthetic rubbers; – aluminium-lithium alloys; – lithium niobate and tantalate in electronics; – concrete additive; – water treatment; and – specialty inorganics.

Technical Application Markets

The technical application markets are dominated by low iron lithium concentrate products to meet the highly specialised requirements of end users. Lithium utilised in these scenarios is highly beneficiated and usually of very fine grain size.

- Glass/Ceramics: There are three distinct markets for lithium in glass/ceramics:
  - Glass: including container glass, flat glass, pharmaceutical glass, specialty glass and fiberglass. These glass products may be designed for durability or corrosion resistance or for use at high temperatures where thermal shock resistance is important. The addition of lithium increases the glass melt rate, lowers the viscosity and the melt temperature providing higher output, energy savings and moulding benefits.

    Major producers of technical glass products are located in Germany, France, Japan and the United States of America;

  - Ceramics: including ceramic bodies, frits, glazes and heatproof ceramic cookware. Lithium lowers firing temperatures and thermal expansion, and increases the strength of ceramic bodies. The addition of lithium to glazes improves viscosity for coating, as well as improving the glazes' colour and lustre. The major ceramic production centres include China, Italy, Spain and Mexico; and

  - Specialty Applications: including induction cook tops and cookware. Lithium's extremely low co-efficient of thermal expansion makes these products resistant to thermal shock and imparts mechanical strength and lowers thermal conductivity.

- Metallurgical: Lithium is used in mould fluxes for steel casting. The addition of lithium in the continuous casting mould fluxes assists the melting and fluidity of the flux, which in turn improves the viscosity and flow of the continuous casting.

Lithium is also used in the production of iron castings such as engine blocks where it reduces the effect of veining, thereby reducing the number of defective casts. Producers of continuous casting steel are located around the world, including in the United States of America, China and Europe.

LITHIUM – SUPPLY & DEMAND

Demand for Lithium is currently entrenched in the following applications as shown graphically below in Figure 1:

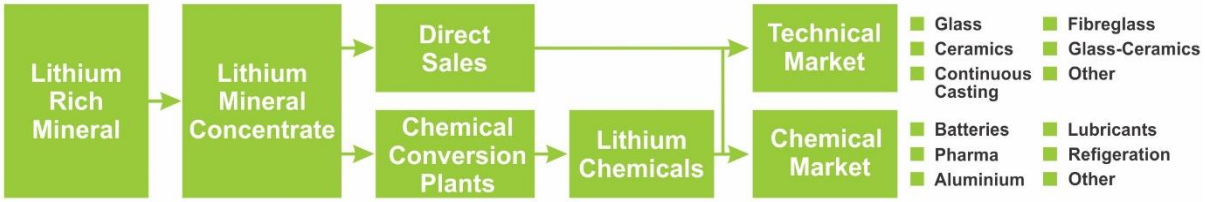

Figure 1: Lithium applications

- **Batteries** – Batteries are possibly the best known lithium application of all. It is where the future lays for lithium demand. Batteries have essentially three main components: cathode, anode and electrolyte. When the cathode and anode are connected via a wire, for example, electrons flow from the anode through the wire to the cathode, creating an electrical current.

  Currently, there are an estimated 80 different lithium-ion battery chemistries in production, with these varying chemistries all exhibiting different characteristics, such as capacity and voltage. More are being developed each year. Lithium is typically found in the cathode of the battery, commonly in the form of lithium cobalt oxide, while the electrolyte is commonly in the form of a lithium salt, such as LiPF6, LiBF4 or LiCLO4. The anode material is commonly carbon-based, with graphite being the most popular.

  Overall, a lithium ion battery's output is around 3.6 volts, which is more than twice as much as its alkaline competitor.

The lithium content of various batteries is shown in Table 1 below.

CHEMISTRY	TYPE	LITHIUM CONTENT PER CELL (G)
Primary batteries		
Lithium manganese-dioxide (Li-MnO_2)	Button/coin	0.05–0.10
	Cylindrical	0.60–4.00
Lithium iron disulfide (Li-FeS_2)	Cylindrical	1.35
Lithium thionyl chloride (Li-$SOCl_2$)	Cylindrical	0.60–2.75
Lithium sulfur dioxide (Li-SO_2)	Cylindrical	2.10
Secondary batteries		
Lithium cobalt dioxide ion (Li-CoO_2)	Cylindrical	0.35–0.65
	Prismatic	2.46
Lithium ion industrial battery pack (Li-ion)	Prismatic	16.00–26.00
Lithium cobalt dioxide polymer (Li-poly)	Prismatic	0.30–3.10

Table 1: Lithium content on various batteries

- Lubricant Grease– An estimated US$4 billion market, in which lithium-based greases make up 75%. Lithium-based greases generally have good stability, high temperature characteristics and water-resistance properties.

- Glass– Lithium typically sourced from the mineral spodumene reduces the viscosity and thermal expansion of glass and, therefore, leads to increased melting efficiencies and/or larger effective furnace capacities. The end result is a substantial energy saving for the glass manufacturers.

- Ceramics – Lithium is used in the ceramics industry to produce glazes. The glazes improve a ceramic piece's shock absorption and stain resistance, protecting the piece against damage. Lithium carbonate is typically used for this application.

- Health Products – Lithium, in small amounts (around 0.170 mg/L), is prescribed to those with bipolar disorders or individuals with depression who don't respond to anti-depressants.

Mr. Brian Leni is a professional engineer and the founder of *Junior Stock Review*. He publishes research on investment ideas and financial product reviews, specific to the junior resource sector. The following is an extract of his work.

"The worldwide rechargeable battery market is dominated by lithium ion batteries (51%) followed by NiMH (22%), NiCd (17%), and lithium polymer (10%). Lithium batteries reduce the weight by half and volume by 20% to 50% compared to the same capacity NiCd and NiMH. Lithium ion batteries also provide three times the voltage of NiCd and NiMH; thus, it helps reduce the dimension of electronic devices and allows partial charging.

In 2011, the major applications of lithium batteries are in portable personal computers (41%) and mobile phones (24%), and the remaining 35% are others like tablets (6%), power tools (5%), e-bikes (5%), automobiles (5%), digital cameras and camcorders (5%), toys and video games (2%), household devices (2%), MP3 players (1%), and other electronic devices (4%). Only in 2009, the units of lithium secondary cells increased from 500 million to 3100 million, which contains 4140 tonnes of lithium.

The demand for lithium batteries is still expected to increase from the portable electronics and automotive industries. As China is recognized as a major base of production for lithium batteries, major automobile and established battery manufacturers have taken different actions to secure low-cost supply of lithium. Such actions include purchasing a part of lithium-producing companies, diversifying lithium sources, establishing partnerships to build battery plants for hybrid and electric-drive vehicles, and beginning mass production of Li ion batteries.

Table I Lithium content in primary and secondary batteries

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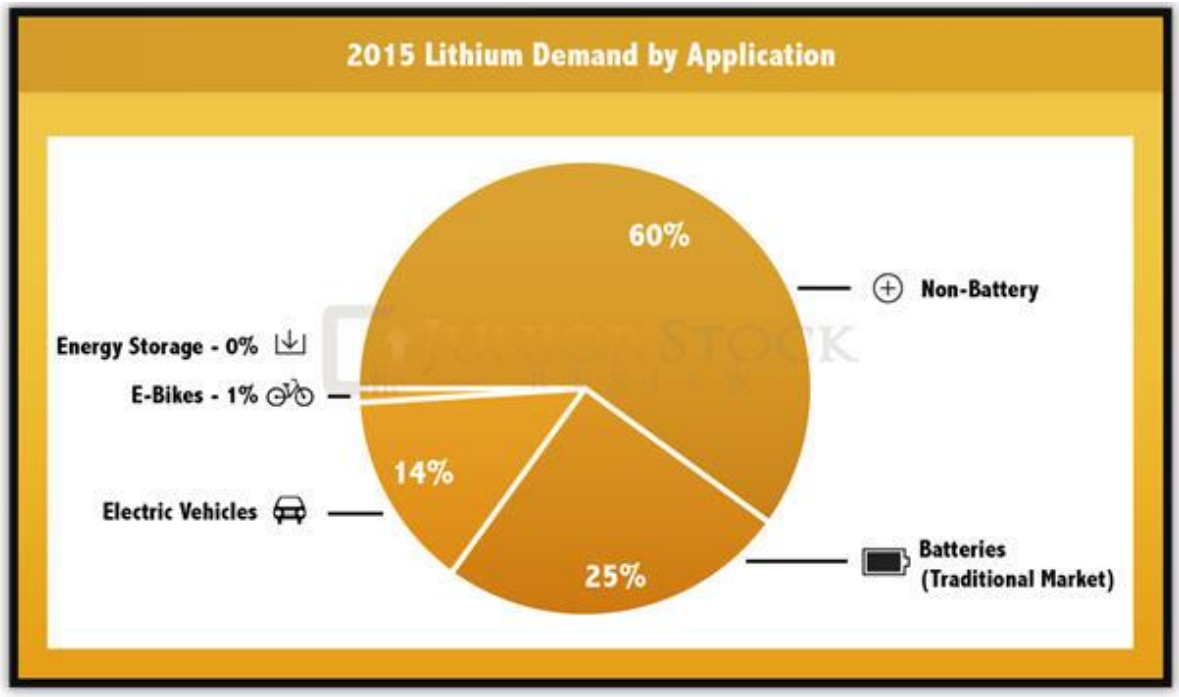
Batteries

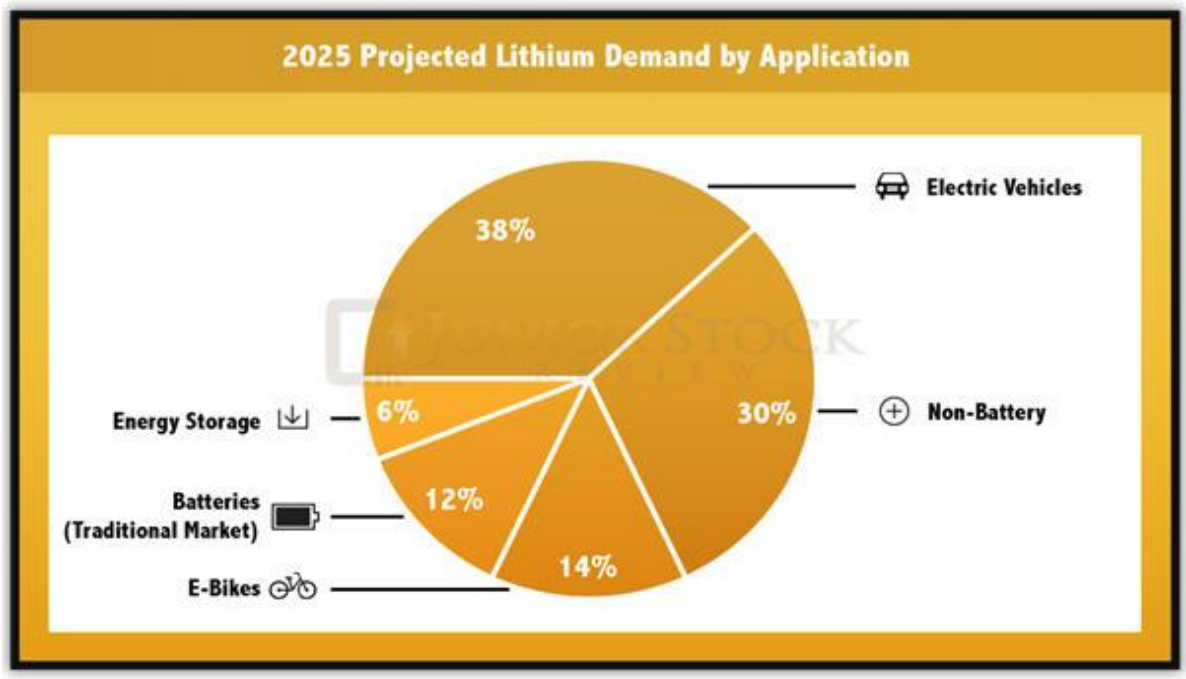
Why is lithium used in batteries? Simply, with current technology, lithium provides the best combination of energy density (weight to power ratio) and price.

What does the current (2015) lithium demand by application look like?



Source: Deutsche Bank Markets Research – Lithium 101 – *pg.23*

Projected demand for 2025 is much different, not only in overall demand tonnage, but the percentages each application encompasses. The future is expected to be bright for batteries in the non-traditional markets; electric cars, e-bikes, and energy storage.



Source: Deutsche Bank Markets Research – Lithium 101 – *pg.23*

Lithium Present and Future Market Demand

Source: Deutsche Bank Markets Research – Lithium 101 – pg.23

The interesting thing about this projected demand curve is that it is linear. The reason I think that's interesting is that most things in life don't follow a linear path, especially those things that are rapidly changing, such as the lithium market. Now, the opposite could be true, the demand could be flat or declining in the future, but I tend to think that the future for lithium will be exponential.

For those who don't know what an exponential function looks like, think of a hockey stick turned upwards with the blade in the air. Basically, it looks linear for a while, constant growth, and then boom – to the moon it goes.

Why do I think this? Mainly because of the politicized nature of green energy. Whether it's the 450 Scenario or some other push to reduce carbon emissions, governments across the world are allocating more and more policy and CASH to the cause. The final inflection point could be massive and it could happen before 2025, in my opinion.

Emissions Perspective

The USA 450 Scenario calls for long-term concentrations of local greenhouse gases to be at 450 ppm CO2 equivalent by 2040. To put that into perspective, we globally emitted 32,381 Mt of CO2 in 2014 (International Energy Agency, 2016 Key World Energy Statistics, 45). Under the 450 Scenario, that number reduces dramatically to 18,777 Mt of CO2.

Using the United States as an example, Statista states that there were around 260 million registered vehicles in the United States in 2014. The U.S. Energy Information Administration (EIA) estimates that U.S. fossil fuel consumption for transportation in 2015 resulted in a combined 1,545 million tonnes of CO2, which is 29% of the total CO2 emissions by the country.

Emissions per vehicle = 1,545,000,000 / 260,000,000 = 6 tonnes/vehicle

Therefore, estimated carbon emissions per U.S. vehicle is around 6 tonnes per year. If the United States wishes to comply with the goals of the 450 Scenario, to drop transportation emissions to 26%, in-line with the rest of the world, they will need a reduction of 3% (29% to 26%) (International Energy Agency, 2016 Key World Energy Statistics, 46).

The following calculation shows that a reduction of this magnitude would affect approximately 7.7 million vehicles.

3% of 1,545,000,000 = 46,350,000 tonnes of CO2

46,350,000t / 6 t/vehicle = 7,725,000 vehicles

NOTE: *This calculation should not be taken as exact, there are assumptions that have been made. The calculation is only to gain some perspective on the potential impact of the 450 Scenario.*

Insideevs.com reports that there were 116,099 full electric vehicles sold in the United States in 2015, and 441,179 worldwide. If you linearly distribute the number of vehicles affected by the 450 Scenario on a 23-year time horizon (2017 to 2040), 7,725,000 / 23 = 335,870 vehicles per year would need to be sold, or almost 3 times the number of current sales per year.

This is provided that car demand in the United States stays where it is. If there is growth in the number of people who want to drive, this electric vehicle number would need to increase.

How does this equate to lithium demand? Well, it isn't an easy calculation as there are a lot of assumptions, but I did find an estimate of 47 lbs (0.021 t) of lithium per Tesla Model S (sedan). If 335,870 Tesla Model S were sold in the United States in a given year, this would translate into 335,870 x 0.021 t of 7,053 t of lithium, or 37,544 t of lithium carbonate (conversion from Li to LiCO3 – 1 : 5.323) (from 37,544t of LiCO3 to 188,659t of Spodumene using a conversion of 1:5.025)

To summarise this example:

- *Calculation only represents a 3% decrease in American transportation carbon emissions.*
- *A 3% improvement in emissions will affect the equivalent of 7.7 million vehicles.*
- *If these 7.7 million vehicles were replaced by fully electric vehicles over the next 23 years (450 scenario deadline is 2040), that would equate to 335,870 cars sold each year. In my opinion, it is highly unlikely that it will be linearly distributed.*
- *Using 2015 data from insideevs.com, world demand is roughly 4 times that of the United States, thus, if the world kept pace, it would equal around 1.3 million vehicles per year.*
- *In terms of lithium carbonate, 1.3 million electric vehicles could mean 150,176 t in worldwide demand.*

I believe this 3% improvement scenario for vehicles per year is conservative. In reality, I think demand in the next 5 years could easily be twice as much. Deutsche Bank believes demand will hit 2.4 million in global electric vehicles sold in 2025. They estimate total demand in terms of lithium carbonate equivalent to be 534 kt, of which batteries would make up 45%.

The following table gives you a quick conversion factor for some common lithium compounds.

Lithium Volume Conversion Table

To Convert...	To Li	To LiOH	To LiOH-H_2O	To Li_2O	To Li_2CO_3	To $LiAlSi_2O_6$
Lithium (Li)	1	3.448	6.061	2.153	5.323	26.455
Lithium Hydroxide (LiOH)	0.29	1	1.751	0.624	1.543	7.77
Lithium Hydroxide Monohydrate (LiOH-H_2O)	0.165	0.571	1	0.356	0.88	4.435
Lithium Oxide/Lithia (Li_2O)	0.464	1.603	2.809	1	2.473	12.5
Lithium Carbonate (Li_2CO_3)	0.188	0.648	1.136	0.404	1	5.025
Spodumene ($LiAlSi_2O_6$)	0.038	0.129	0.225	0.08	0.199	1

Source: London Stock Exchange

***FYI**– A quick example: If you're given a resource in terms of %Spodumene, 5%, and you want to convert it to %Lithium, simply multiply the 5% by the lithium conversion factor 0.038, which equals 0.19%.*

I believe it's undeniable that lithium will play a major role in powering our clean air future. The trend is your friend and in this case it is only the beginning of what appears to be a major turning point in the way we live our day to day lives."

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