

LITHIUM DEMAND, SUPPLY AND PRICE FORECASTS – Who do we throw out of the boat?

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What is Stormcrow?

- We are a consultancy
 - Our specialty is the study of opaque commodity markets
 - Even more specifically, we study the supply, demand and future pricing of critical materials
- We are a registered securities dealer
 - Not because we chase public deals, we are too small to make that work
 - Because many of our larger clients eventually ask the question “So what do we do?”
 - Being a securities dealer makes it easier for us to get paid!
- Today, we are here to give you what we hope you will agree is an unbiased look at lithium
 - A hot topic, but too much sizzle and not enough steak is never good
 - We have no junior company to pitch, no deposit to sell
 - Our work has been conservative, and largely correct, in the past

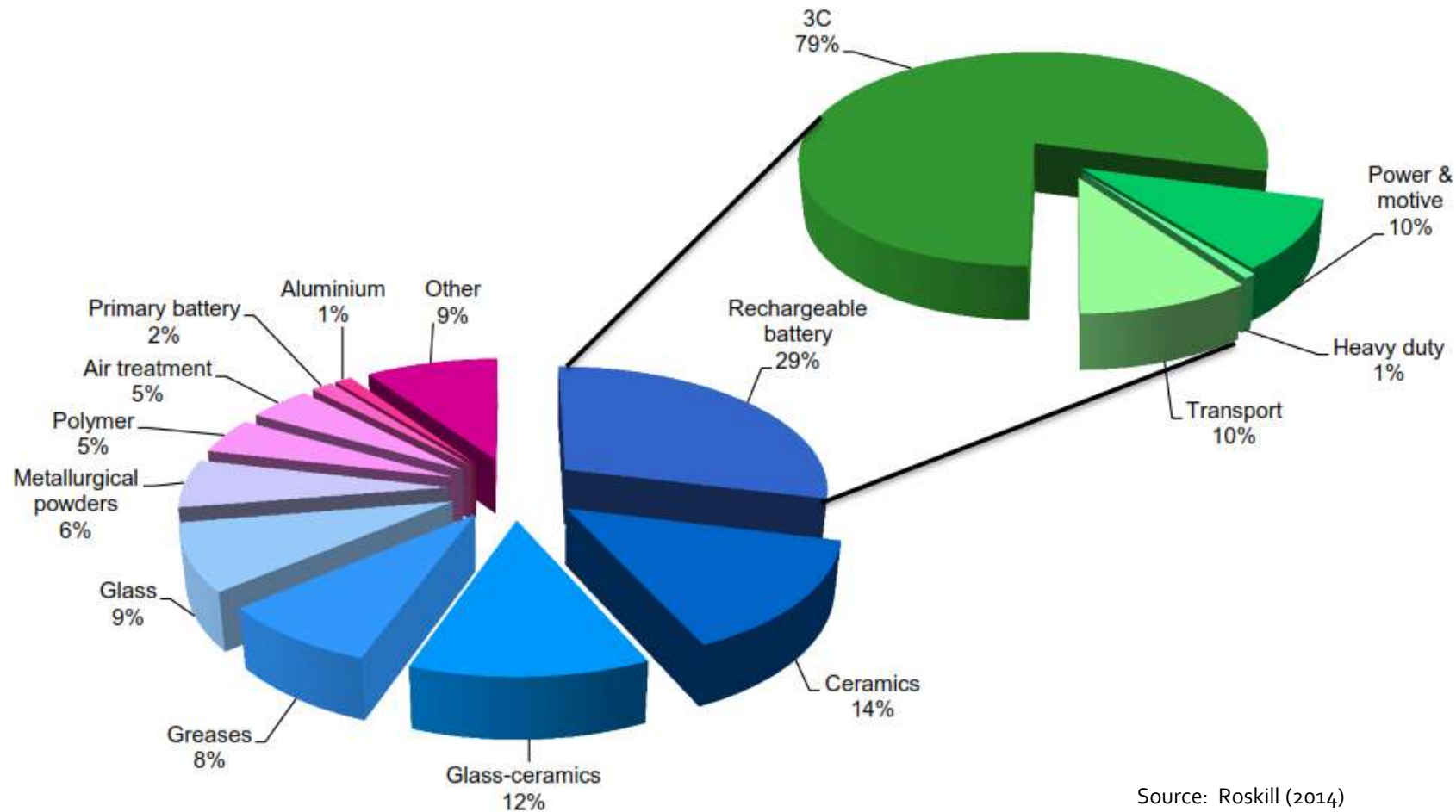
What We Will Do...

- Concentrate on lithium
 - Commodity of the year in 2016, without doubt
 - What many are unaware of is that lithium spot prices have been headed sideways and down for at least six months, already
- Discuss demand
 - Easy to project all the growth anyone could want, but will it arrive?
 - We believe we take a more realistic stance than many
- Discuss supply
 - Lithium is not that rare
 - Many projects can produce lithium by 2025, assuming capital to build a mine is available
- Discuss price projections
 - Our models are based on historical spot pricing, there are obvious patterns
- Conclusions
 - Are there reasons to remain excited, or is this a bubble that will pop and vanish?

Lithium

- As the amount of battery energy storage increases, with lithium batteries being as important in portable applications as they are, so does lithium use
 - This should probably be interpreted as belaboring the obvious...
 - There are some important details at the edges; some lithium cathodes use more or less Li per kWh of energy storage
 - Which cathode compounds are used alters the amount of Li used, but also very directly impacts how much of some other common or rare metals will be used
- We must bear in mind that Li demand is a LOT more than just batteries

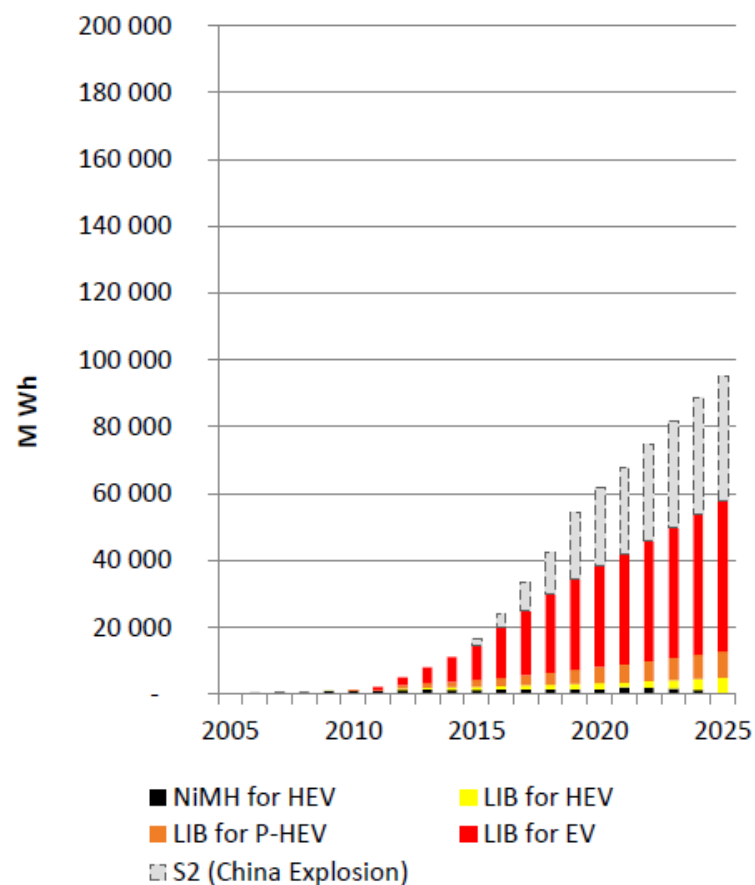
Lithium – More than Batteries...



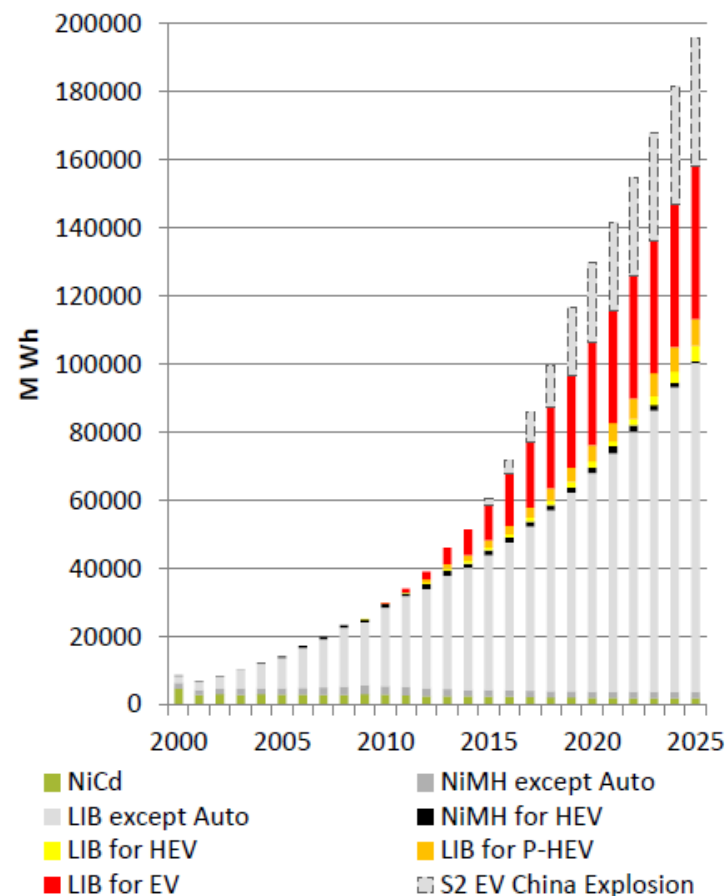
Source: Roskill (2014)

... but Batteries Really Matter

EV, HEV & P-HEV Battery needs (MWh)
CAGR 2014-2025: +16% / S2: +22%



Total battery demand (MWh)
CAGR 2014-2025: +11% / S2: +13%

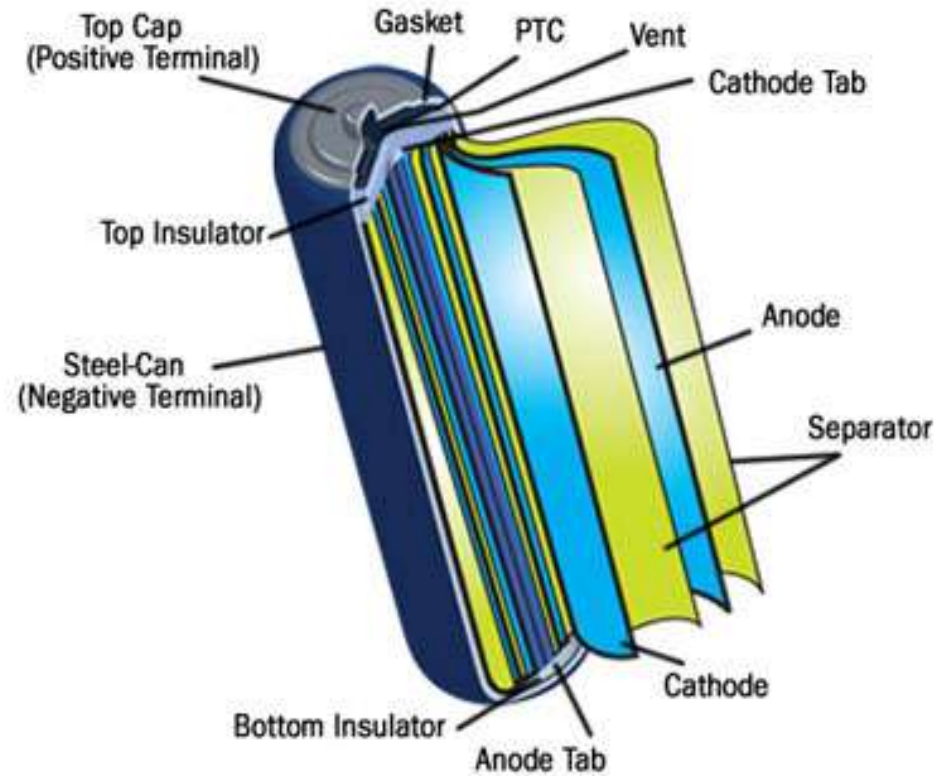


Source: Avicenne (2015)

What is a Battery?

- This is a lithium 18650 cell...

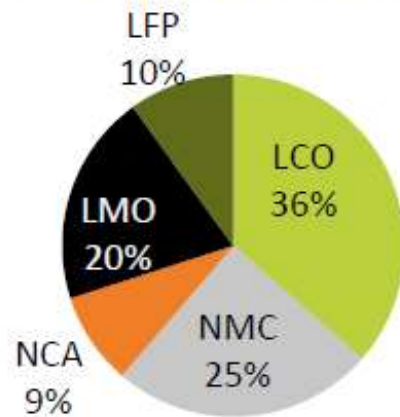
Cylindrical lithium-ion battery



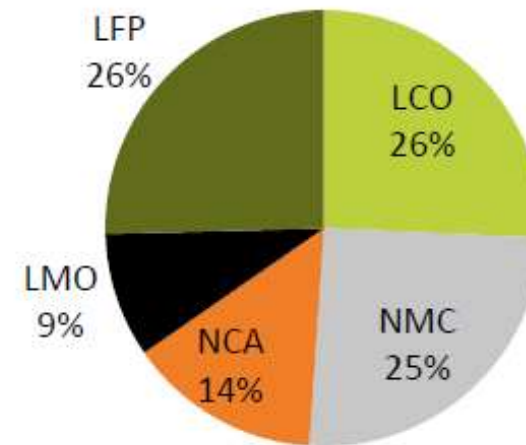
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Different Cathodes, Different Demands

Cathode active materials in
2014: > 100 000 Tons



Cathode active materials in
2025: > 300 000 Tons



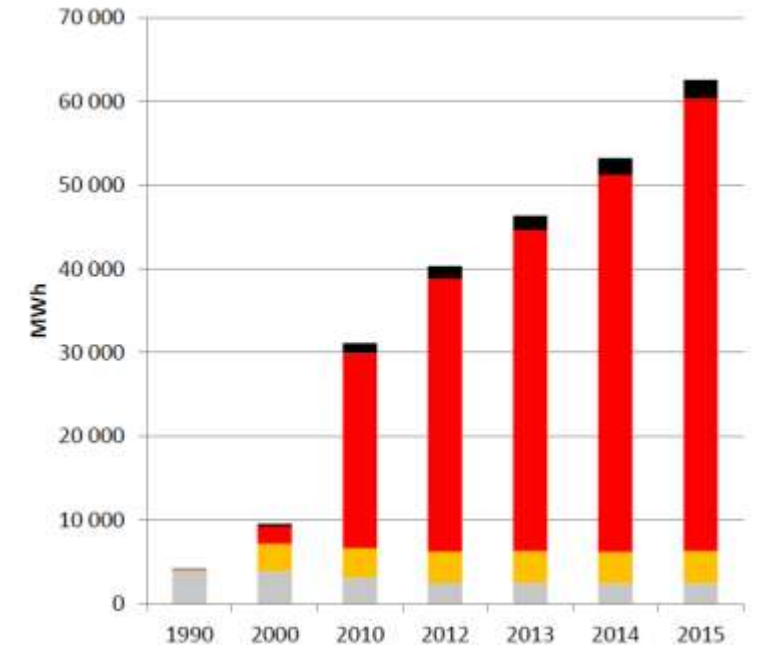
Source: Avicenne (2015)

Deeper Into the Cathode

- This is where chemistry comes in
- Cathodes are conductive surfaces coated with particles
 - In this case, those particles are lithium chemicals
 - Different lithium chemicals give different voltages, power and energy densities
- We commonly discuss six different lithium battery cathode chemicals:
 - LiCoO_2 – old and a little scary
 - $\text{LiNi}_x\text{Al}_y\text{Co}_{1-x-y}\text{O}_2$ (NAC) – Tesla's preferred material
 - $\text{LiNi}_x\text{Mn}_y\text{Co}_{1-x-y}\text{O}_2$ (NMC) – GM's preferred stuff
 - LiMnO_4 (spinel) – safe, but boring, used by GM and others
 - LiFePO_4 (iron phosphate) – lots of power, not much energy, used in China and in power tools
 - $\text{Li}_4\text{Ti}_5\text{O}_{12}$ (lithium titanate) – stable but expensive, really an anode

Let's Make Something Very Clear...

- Batteries are not integrated circuits
 - In electronics, we have Moore's "Law"
 - There is no such thing pertaining to batteries, this is more like making chairs than "chips"
- The cost of making batteries does not just decrease
 - Yes, there can be a reasonable scale effect, but making batteries is already nearly fully automated
 - Ultimately, the cost of a battery is defined by its raw materials
- Scale is already baked in
 - A Tesla 18650 NAC cell holds 12.2 Wh of energy
 - 2016 global production of lithium batteries was equivalent of 5.3 BILLION cells (Tesla used about 0.7 billion of those)



Source: Avicenne (2015)

As We Saw, Batteries are More than Just Lithium

- Demand for a number of other materials will grow with additional battery use
- Specifically, cobalt and natural graphite are very interesting, too

Year	LCE (t) All	Co (t) Battery	Natural Cg (t) Battery	Mn (t) Battery	Ni (t) Battery	Al (t) Battery
2015	193,750	53,043	55,194	34,546	15,934	200
2020	304,767	89,316	103,081	51,670	32,881	463
2025	399,760	120,660	156,312	58,871	54,595	838

Source: Stormcrow (2016)

Historical Lithium Consumption

- The available end-use data from Roskill overlapping this period gives us the following
- The results are:

Year	Total Consumption (t LCE)	Battery Consumption (t LCE)	Other (t LCE)
2008	120,968	20,026	100,942
2009	101,613	24,346	77,267
2010	125,726	29,058	96,668
2011	138,306	32,984	105,322
2012	151,048	39,463	111,585
2013	165,484	50,262	115,222
2014	182,903	64,398	118,505
2015	194,000	65,108	128,892
2016	212,719	77,821	134,897

Source: Roskill

Historical Lithium Pricing Data

- Available historical spot pricing for common lithium chemicals: is shown below
 - Yes, a lot of lithium chemicals are sold by contract
 - Some would argue that spot prices don't matter, but they obviously don't trade anything
 - Spot prices, at minimum, show us the direction of the market

Year	Tech Li ₂ CO ₃	Batt Li ₂ CO ₃	Tech LiOH
2008	\$ 5.37	\$ -	\$ -
2009	\$ 4.10	\$ -	\$ -
2010	\$ 3.97	\$ -	\$ -
2011	\$ 3.91	\$ 4.51	\$ -
2012	\$ 4.80	\$ 5.05	\$ 6.48
2013	\$ 4.84	\$ 5.29	\$ 6.99
2014	\$ 4.46	\$ 5.06	\$ 6.54
2015	\$ 7.64	\$ 9.14	\$ 8.02
2016	\$ 18.83	\$ 22.17	\$ 23.37

Source: Asian Metal

Projected Lithium Demand

- The following is projected latent demand through 2025
- Batteries play an increasingly important role
 - With respect to batteries, we are going to use a modified version of Avicenne's base scenario, without the "Chinese battery explosion" and without grid storage
- Don't forget ceramics and ceramic-glass, these maintain reasonable growth due to increases in consumer discretionary spending

	2017	2021	2025
Rechargeable Batteries	93,294	153,303	212,820
Ceramics	30,367	39,657	51,788
Glass-Ceramics	26,029	33,992	44,390
Greases	14,970	16,849	18,964
Glass	16,841	18,955	21,334
Metallurgical Powders	13,015	16,996	22,195
Polymer	9,539	10,947	12,624
Air Treatment	9,539	10,947	12,624
Non-rechargeable Batteries	3,670	4,051	4,450
Aluminum	680	279	91
Other	16,841	18,955	21,334
Total	234,788	324,930	422,614

Source: Stormcrow (2017)

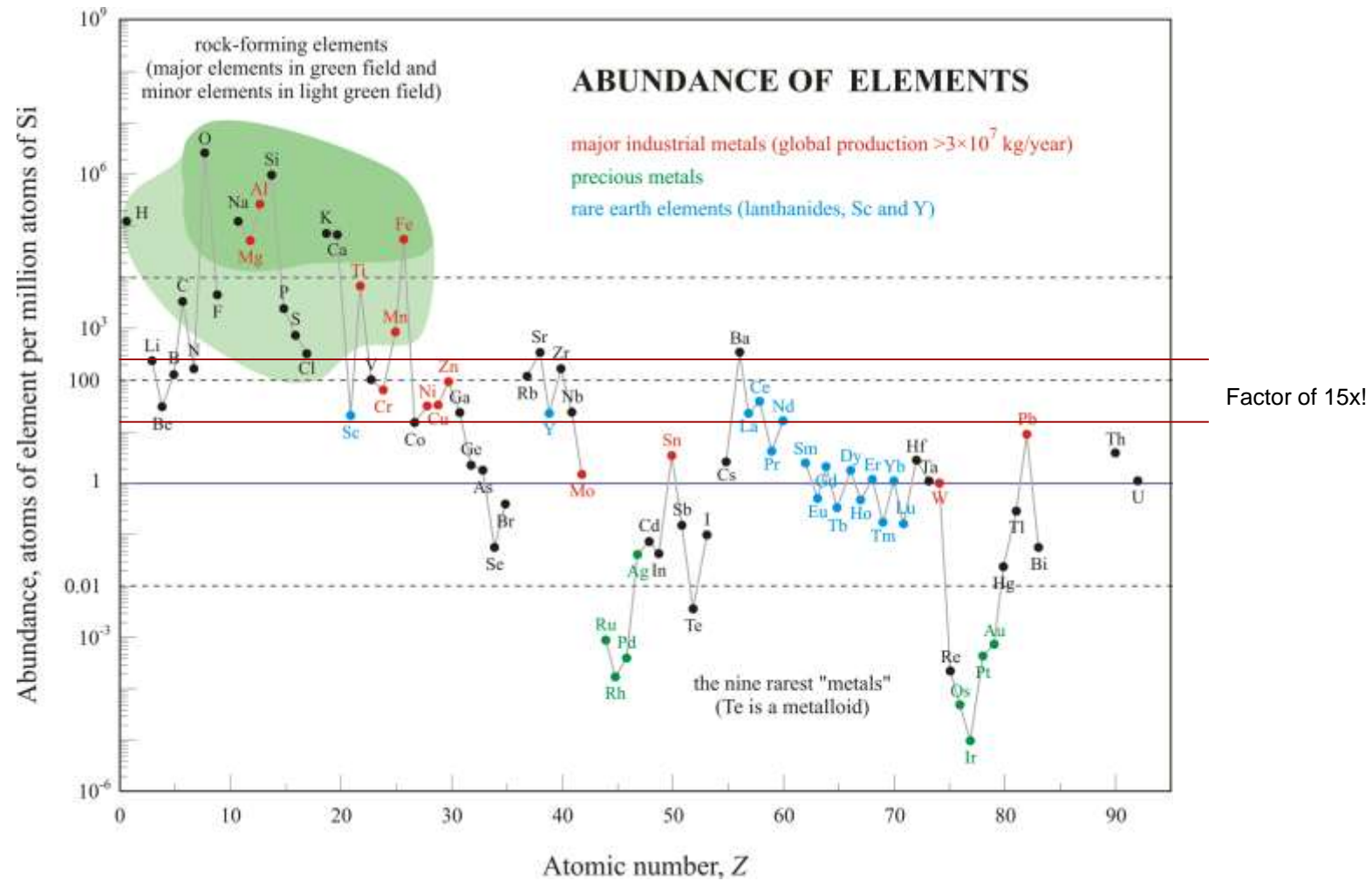
Projected Lithium Supply – Our Most Pessimistic Projections

- Lithium is not uncommon
- Money to build new mines is harder to come by
- Still, if a given project insists it can happen, who are we to cut others out?

Producer	2017	2021	2025
SQM	48,000	65,000	80,000
Greenbushes	75,000	130,000	130,000
Rest of China	22,000	50,000	50,000
Orocobre	13,000	35,000	35,000
FMC Lithium	22,000	22,000	22,000
Rockwood Brine	50,000	70,000	80,000
Lithium Americas/SQM		25,000	50,000
Nemaska		38,000	43,000
Galaxy Resources (Arg)		15,000	20,000
Galaxy Resources (Aus)	15,000	20,000	20,000
Neometal/MIN/Ganfeng (Aus)	25,000	58,000	58,000
POSCO (salar or alt brine)		30,000	40,000
Frontier Lithium		3,000	3,000
Pilbara Minerals		20,000	20,000
Eramet		15,000	15,000
Enirgi		20,000	20,000
New Chilean (Li3 et al)		15,000	20,000
Total (t LCE)	270,000	631,000	706,000

Source: Stormcrow (2017)

Pricing Rationale via Fundamental Scarcity



Projecting Prices

- We develop a model, based on historical pricing
- There are some obvious issues with this approach...
 - First, the models are necessarily extrapolating, which is risky
 - But we don't have a choice, we've never seen these projected levels of demand or supply before
 - Second, these models are mathematical
 - Others might say that, having worked in the space, they "know" or "feel" what the market is doing
 - Probably nonsense, we saw people get whip-sawed by the rare earths crisis in 2011, and by the uranium price run in 2007
 - Again, we have never seen these levels of demand from these particular markets before, so precognitively "knowing" what this suggests is impossible
- Our models are multivariate, generally incorporate a relevant demand level and a supply/demand gap

Projected Prices

- Based on individual models for the four major lithium chemical products
 - Both carbonate and hydroxide in both technical and battery grade
- These are spot prices
 - As such, we completely allow that contract and spot prices may differ significantly for a period of time
 - Look at recent uranium spot price behavior
- Our projected prices for a few select years are:

Pessimistic Supply Model

Year	2017	2021	2025
Tech Grade CO ₃	\$ 13.23	\$ 5.85	\$ 5.48
Batt Grade CO ₃	\$ 13.33	\$ 6.64	\$ 6.22
Tech Grade OH	\$ 15.50	\$ 7.74	\$ 7.25
Batt Grade OH	\$ 16.60	\$ 8.29	\$ 7.76

Optimistic Supply Model

Year	2017	2021	2025
Tech Grade CO ₃	\$ 13.23	\$ 6.15	\$ 9.82
Batt Grade CO ₃	\$ 13.33	\$ 6.77	\$ 10.25
Tech Grade OH	\$ 15.50	\$ 7.85	\$ 11.22
Batt Grade OH	\$ 16.60	\$ 8.41	\$ 12.02

Conclusions

- Demand will continue to grow
 - Latest subsidy decreases in China may slow EV growth there
 - Frankly, pure battery EVs were never the correct path forward, anyway
- Supply can (easily?) keep pace
 - Let's see how generous the capital markets remain
 - Current producers will invest, and are investing, in additional capacity
 - So will companies such as POSCO, Eramet, Enirgi/Sentient, as well as others
- Result should be prices reverting back toward historical norms
 - There won't be a collapse, *à la* rare earths
 - Costs of > US\$4,000/t to make battery-grade chemicals, scarcity premiums for battery grades and robust demand should mean prices are never below cost for long
 - But these days of US\$15,000/t spot prices will probably be remembered fondly



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