Raw material needs by the Li-ion battery industry

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Contents

1. Background

Li-ion batteries are powering most of our portable electronics including cellphones, tablets and laptop computers. Battery (BEV) and Plug-in Hybrid Electric Vehicles (PHEV) as well as grid connected stationary energy storage are expected to drive fast growth of Li-battery demand (Frost & Sullivan, 2014) (Lux Research, 2015).

As battery industry is already using a large share of global lithium and cobalt (and flake graphite) production there are concerns about future availability of these raw materials. Lithium and cobalt reserves, production, battery use and recycling rate are summarized in Table 1.

Table 1. *Production, reserves, share of battery use and recycling rate of lithium and cobalt in 2015 (Jaskula, 2016) (CDI, 2016) (UNEP, 2011).*

	Lithium	Cobalt
Annual production (Ton/a)	32.500	99.000
Useful reserves (million tons)	14	7.1
Global resources (million tons)	34	120
Share of battery use (%)	35	42
Main reserves	Chile, Argentina, Bolivia China, Australia	Democratic Republic of Congo
Recycling rate (%)	< 1	68

2. Li battery production and use in 2015-2016

The global production capacity of lithium batteries in 2015 was 52 GWh and 24 GWh was under construction, totaling 76 GWh, Table 2 (Chung;Elgqvist;& Santhanagopalan, 2015). In addition, 48 GWh of new capacity was announced, including the 35 GWh Tesla Gigafactory. Half of the production capacity is in China, and 88 % in China, Japan and Korea together. These countries are dominating the portable electronics sector. The US and European capacities are mostly dedicated to the automotive sector.

Table 2. Li-ion battery production in 2015 (Chung;Elgqvist;& Santhanagopalan, 2015).

Country	Fully comis-sioned	Partially comis-sioned	Under Construc-tion	Announ-ced	Total	Share	Auto-motive	Share of auto-motive
	MWh	MWh	MWh	MWh	MWh		MWh	
China	16704	3576	18730	12847	39010	0,51	11240	0,29
Japan	10778	0	1200	0	11978	0,16	5750	0,48
Korea	16059	0	0	0	16059	0,21	4600	0,29
USA	3770	0	1200	35000	4970	0,07	4600	0,93
EU	1798	0	0	0	1798	0,02	1300	0,72
Rest of the world	2440	0	0	564	2440	0,03	0	0,00
Total	**51549**	**3576**	**21130**	**48411**	**76255**	**1,00**	**27490**	**0,36**

A rough estimate of the Li-battery use in portable electronics can be made from global sales of cellphones, tablets and laptops, Table 3. The portable electronic use accounted for 55 % of the total production capacity and 85 % of the non-automotive production capacity.

Table 3. An estimate of Li battery use in portable electronics (Statista, 2017)

Device	Global sales 2016	Average battery size	Total battery capacity
	Million	Wh	GWh
Cellphone	1400	10	14
Tablet	180	30	5,4
Laptop computer	150	50	7,5
Total	**1730**	**16**	**26,9**

The BEV and PHEV use of Li batteries in 2016 was estimated from the sales statistics (EV Volumes, 2017) and battery capacities of the most popular models (EV Obsession, 2017) accounting for 80 % of the BEV and 70 % of the PHEV sales volumes, respectively, Table 4. It is more difficult to get exact information about the bus market. However, according to recent news 94.000 full electric and 23.000 plug-in electric buses were sold in China in 2015 (CleanTechnica, 2016). If these values are confirmed, it would indicate that the battery market for eBUSes is as big as the one for EVs

Table 4. An estimate of the BEV and HEV use of lithium batteries (EV Volumes, 2017) (CleanTechnica, 2016).

Vehicle type	Global sales 2016	Average battery size	Total battery capacity
	Thousand	kWh	GWh
BEV	472	45	21,2
PHEV	302	13	3,9
Total	**774**	**33**	**25,2**
eBUS (China 2015)	94	230	21,6

Utilization of the automotive Li-ion battery production capacity in 2014 was 22 % only (Chung;Elgqvist;& Santhanagopalan, 2015). However, it appears that it has reached 90 % in 2016 and the expansion of the capacity is well justified.

Less than 1 GWh of stationary Li-batteries were assembled in 2016 (IRENA, 2017).

3. Raw material production and use in 2015-2016

Lithium, cobalt and graphite need of different lithium-ion chemistries are estimated in Table 5 and prices in Figure 1. The most cobalt intensive LCO is still predominantly used for consumer electronics. All other chemistries are used in electric vehicle applications. Tesla is favoring the NCA chemistry, Nissan NMO and the Chinese manufacturers LiPF, respectively. However, there are indications that the Chinese would gradually shift from LiPF to NMC due to its higher performance (Lima, 2016).

Table 5. Critical raw material need of different Li-ion battery chemistries (Petersen, 2016).

Chemistry	Li need	Co need	Graphite need
	kg/kWh	kg/kWh	kg/kWh
Lithium cobalt oxide (LCO)	0,16	1,44	1
Nickel manganese cobalt oxide (NMC)	0,16	0,36	1
Nickel cobalt aluminum oxide (NCA)	0,16	0,22	1
Nickel manganese oxide (NMO)	0,16	0	1
Lithium iron phosphate (LiPF)	0,16	0	1

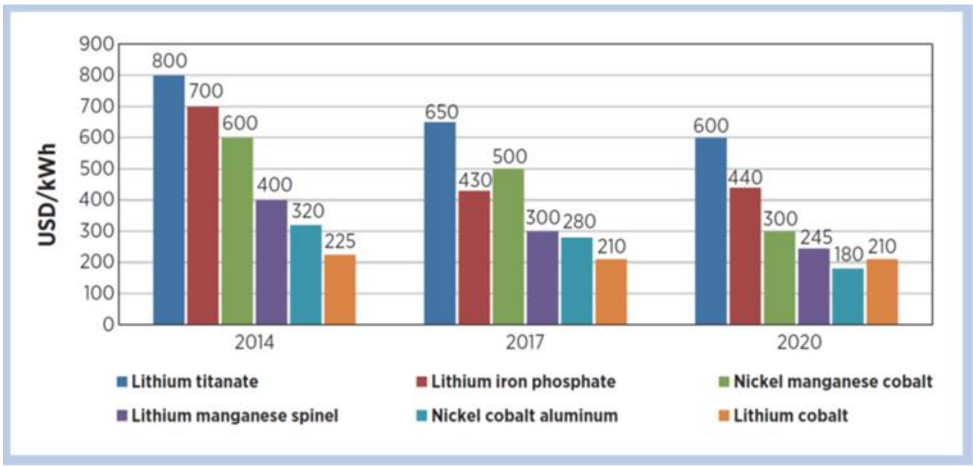


Figure 1. Price estimates for different Li-ion battery chemistries (Jaffe & Adamsson, 2014).

In the following, the raw materials use is estimated by the following assumptions, Table 6:

- LCO chemistry is used for portable electronics.
- LCA chemistry is used for BEV and PHEV outside China. This is believed to be a good average between the NMC, NCA and NMO chemistries.
- LiPF chemistry is used in China.

Table 6. Critical raw material needs for Li-batteries 2016.

	Lithium	**Cobalt**	**Graphite&Carbon**
Global production (Tons)	32.500	99.000	380.000
Battery use (Tons)	11.400	41.600	133.000
Consumer Electronics (CE) (Tons / % of battery use)	4.300 38%	38.700 93%	26.900 20%
BEV+PHEV (Tons / % of battery use)	4.000 35%	2.300 5%	25.200 19%
eBUS in China (Tons / % of battery use)	3.500 30%	0	21.600 16%
CE+BEV+PHEV+eBUS (Tons / % of battery use)	11.800 104%	41.000 99%	73.700 55%

The assumption made are overestimating the lithium and cobalt needs and underestimating graphite need. The main reasons are probably too large average battery sizes in the consumer electronics and eBuses. Anyhow, the analysis is accurate enough to estimate the growth in raw material needs based on growth estimates in different applications.

4. Market estimates for lithium battery applications and their raw material needs

4.1. Electric vehicles

The electric vehicle battery market is expected to double from 30 to 60 GWh and from 10 to 20 B$ between 2016 to 2020, Figure 2 (Frost & Sullivan, 2014) (Lux Research, 2015). This would mean global sales of about 2 Million EVs in 2020 which is well below the Chinese plans of producing 5 million EVs in 2020 (IEA, 2016). According to IEA and UN Paris Declaration, 10 million eVs on 2020 and 100 million eVs in 2030 would be needed in different low carbon scenarios, Figure 3 (IEA, 2016). This corresponds to an annual production of at least 10 million EVs in 2020s. The raw material needs for the annual production of 2, 5 and 10 million EVs are estimated in Table 7 assuming 50 kWh average battery size and today´s technology.

Table 7. Raw material needs for EV batteries. Assuming 50% share for NMC, NCA and another 50% for LMO and LiPF. 75 GWh were produced in 2016.

Global EV production	Battery needs	Lithium	Cobalt	Graphite&Carbon
EVs / year	GWh (times 2016 production)	Ton (times 2016 production)	Ton (times 2016 production)	Ton (times 2016 production)
2 million	**100 1,33x**	**16.000 0,50x**	**11.000 0,11x**	**100.000 0,26x**
5 million	250 3,33x	40.000 1,3x	27.500 0,28x	250.000 0,66x
10 million	**500 6,66x**	**80.000 2,5x**	**55.000 0,56x**	**500.000 1,32x**

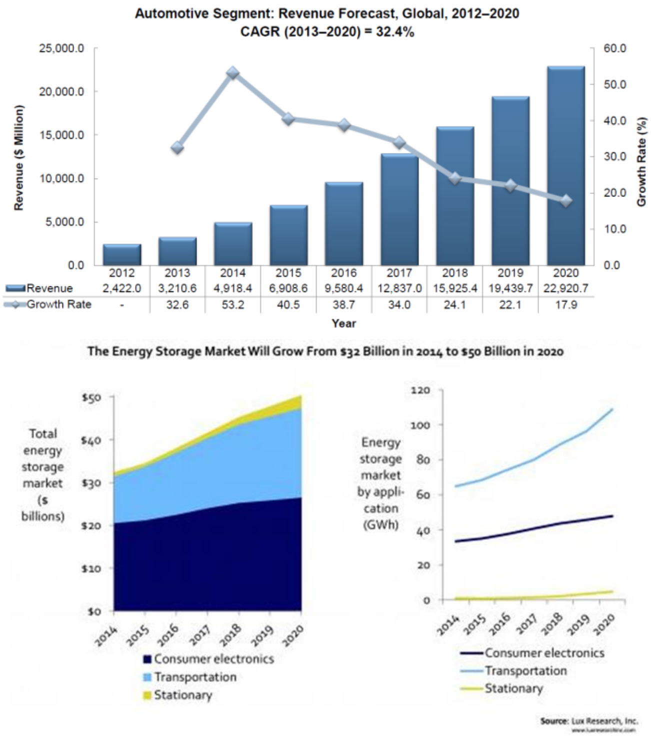


Figure 2. Market forecasts for lithium battery applications (Frost & Sullivan, 2014) (Lux Research, 2015).

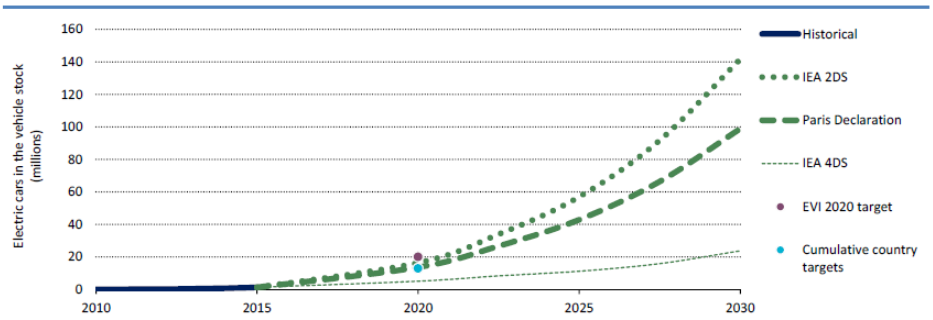


Figure 3. EV deployment scenarios for low carbon future (IEA, 2016).

4.2. Consumer electronics

The consumer electronics segment is expected to grow from 30 to 40-45 GWh/year by 2020 (Frost & Sullivan, 2014) (Lux Research, 2015). The raw material needs for this are estimated in Table 8.

Table 8. Raw material need for consumer electronic batteries in 2020.

Demand grow between 2016 to 2020	**Battery needs**	**Lithium**	**Cobalt**	**Graphite&Carbon**
%	GWh (times 2016 production)	Ton (times 2016 production)	Ton (times 2016 production)	Ton (times 2016 production)
33	**40 0,53x**	**6.400 0,20x**	**57.600 0,58x**	**40.000 0,11x**
50	**45 0,60x**	**7.200 0,23x**	**64.800 0,65x**	**45.000 0,12x**

4.3. Stationary energy storage

The stationary Li battery for renewable energy and grid scale storage is expected to reach 5-20 GWh by 2020, 40 GWh by 2025 and 100 GWh by 2030 (Frost & Sullivan, 2014) (Lux Research, 2015) (IRENA, 2017). As very high cycle life is expected in this market segment, NMC and LiPF are the preferred chemistries for this application. The raw material needs expecting 50/50 share between the two chemistries are estimated in Table 9.

Table 9. Raw material needs for stationary lithium batteries.

Year	**Battery needs**	**Lithium**	**Cobalt**	**Graphite&Carbon**
	GWh (times 2015 production)	Ton (times 2015 production)	Ton (times 2015 production)	Ton (times 2015 production)
2020	5 0,07x	800	900	5.000
2020	**10 0,13x**	**1.600**	**1.800**	**10.000**
2020	20 0,27x	3.200 0,10x	3.600	20.000
2025	40 0,53x	6.400 0,20x	7.200	40.000 0,11x
2030	**100 1,33x**	**16.000 0,50x**	**18.000 0,18x**	**100.000 0,26x**

4.4. Estimate summary

The probable raw material needs in 2020 have been shown in green in Tables 7 to 9, and the high end need by 2025 in red. These values are summed up in Tables 10 and 11. Non-battery uses of the raw materials are expected to remain stable at 2015 volumes.

Table 10. Probable raw material need for lithium batteries in 2020.

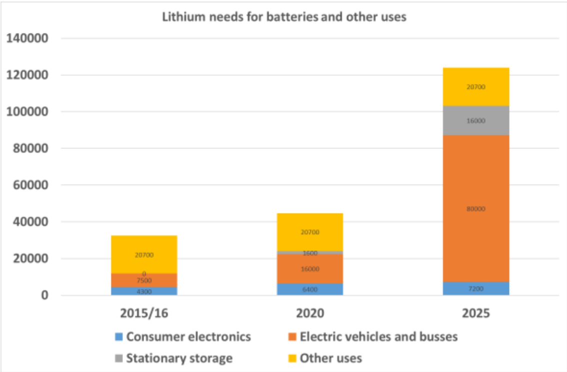
Year	Battery needs	Lithium	Cobalt	Graphite&Carbon
	GWh (times 2015 production)	Ton (times 2015 production)	Ton (times 2015 production)	Ton (times 2015 production)
Electric vehicles and buses	100 1,33x	16.000 0,5x	11.000 0,11x	100.000 0,26x
Consumer electronics	40 0,53x	6.400 0,20x	57.600 0,58x	40.000 0,11x
Stationary	10 0,13x	1.600 0,05x	1.800 0,02	10.000 0.03
Li battery total	**150 2,0x**	**24.000 0,75x**	**70.400 0,71x**	**150.000 0,40x**
Other uses		20.700	58.000	306.000
Total needs		**44.700 1,37x**	**128.400 1,30x**	**456.000 1,20x**

The need for lithium batteries is expected to doubly from the 2016 production by 2020. This would mean that the share of battery use of lithium and cobalt would increase to above 70 % of global production if no new mines were opened. The effect on graphite use would be less dramatic. The need for cobalt depends strongly on chemistry. Tesla is favoring the cobalt containing NCA and NMC chemistries for automotive and stationary applications, and the Chinese are favoring LiFP but could be shifting to NMC for automotive applications. However, the main use of cobalt will remain in portable electronics. At least 30 % increase in global Li and Co production would be needed to support the growth of the battery industry without harming the other end uses.

Table 11. Raw materials needs for lithium batteries in 2025.

Year	Battery needs	Lithium	Cobalt	Graphite&Carbon
	GWh (times 2015 production)	Ton (times 2015 production)	Ton (times 2015 production)	Ton (times 2015 production)
Electric vehicles and buses	500 6,67x	80.000 2,5x	55.000 0,56x	500.000 1,32x
Consumer electronics	45 0,60x	7.200 0,23x	64.800 0,65x	45.000 0,12x
Stationary	100 1,33x	16.000 0,50x	18.000 0,18x	100.000 0,26x
Li battery total	**645 8,6x**	**103.200 3,23x**	**137.800 1,39x**	**645.000 1,70x**
Other uses		20.700	58.000	306.000
Total needs		**123.900 3,81x**	**195.800 1,98x**	**951.000 2,50x**

The main growth beyond 2020 is expected from the automotive sector. If the BEV, PHEV and electric bus production targets are met, the demand for lithium batteries can increase by a factor of 8 to 10. This means that the global lithium production should be increased by a factor of four and the cobalt and graphite production doubled, at least, by 2025. This is challenging especially for cobalt, as cobalt is a byproduct of copper and nickel and there are no dedicated cobalt mines. Tables 10 and 11 are finally summarized in Figure 4.



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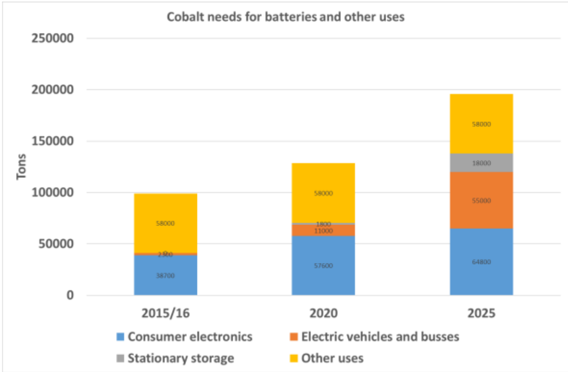

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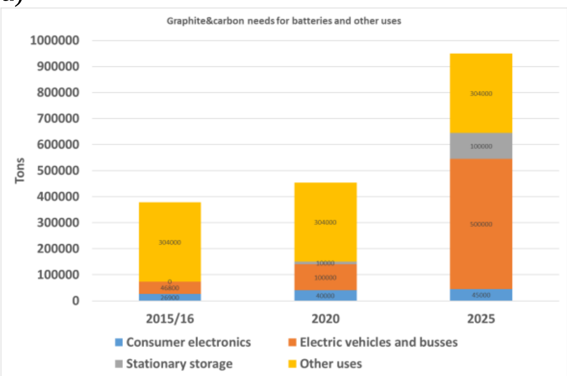

c)

Figure 4. Raw materials estimates for a) lithium, b) cobalt and c) carbon&graphite.

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