Critical Raw Materials for Electric Vehicles

Bert Witkamp – Operating Agent Task 40

2030: EV, Battery deployments and key mineral requirements

29th April 2022 - webinar

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Electric Vehicle transition scenarios

EV penetration 2030 likely to be (much) higher than forecasted in 2020

Task 40 CRM4EV scenarios cover this possible development

Assumptions on BEV developments

BEV are lower in purchase cost than conventional cars around 2025, combined with lower fuel and maintenance cost.

Battery sizes are increasing for several reasons, however in mature BEV markets battery sizes will be less important and could (should) decrease.

Commercial vehicles will show a rapid uptake within a few years. BEV Heavy Duty Trucks are or will be soon financially attractive, including long distance applications.

BEVs and batteries continue to improve energy efficiency, requiring smaller batteries.

2021 Analyses

Global (electric) vehicle markets 2020 - 2030 (sales in millions)

	2020 market	2030 market					
			CRM4EV	CRM4EV	CRM4EV	IEA STEPS	IEA SDS
Vehicle category		kWh per	BEV LCV 30% YoY	BEV LCV 40% YoY	BEV LCV 50% YoY		
	vehicle sales	vehicle	vehicle sales	vehicle sales	vehicle sales	vehicle sales	vehicle sales
Light Duty Vehicles (LDV)							
Passenger Cars (PC)	83		100	100	100	130	114
Light Commercial Vehicles (LCV)	8		10	10	10	18	17
LDV motorisat *ICE*	85		64	36	0	123	86
BEV	1.6	65	36	69	110	17	33
PHEV	0.6	15	10	5	0	8	12
Hybrid	3.5	2					
Heavy / Medium Duty Vehicles							
HDV/MDV (total)			5.4	5.4	5.4	12.3	13.9
Buses	0.5		0.6	0.6	0.6	1.1	1.2
Trucks	4.2		4.8	4.8	4.8	11.2	12.7
e-Buses	0.1	300	0.4	0.5	0.6	0.5	1.1
e-Trucks		500	0.8	1.2	2.4	0.2	0.5
PHEV e-Trucks						0.1	0.5
Vocational	0.5	300	0.1	0.1	0.3		

- 2020: sources OICA, (US light trucks are in PC); EV data source Valuad); 2030 estimates CRM4EV (sources BNEF, own estimates) and IEA scenarios; CRM4EV scenarios YoY BEV growth rates 2020 - 2030: 30%, 40%, 50%

2021 – 2022 YTD growth rates will lead to near 100% penetration by 2030

2022 Analyses

Global (electric) vehicle market 2020 and 2030 scenarios (sales in millions): 2022 update							
	2020 market	2030 market					
Vehicle category	vehicle sales	kWh per vehicle	CRM4EV BEV LCV 30% YoY vehicle sales	CRM4EV BEV LCV 40% YoY vehicle sales	CRM4EV BEV LCV 50% YoY vehicle sales	IEA STEPS vehicle sales	IEA SDS vehicle sales
Light Duty Vehicles (LDV)							
Passenger Cars (PC)	83		100	100	100	130	114
Light Commercial Vehicles (LC	8		10	10	10	18	17
LDV motorisa *ICE*	85		55	10	0	123	86
BEV	1.6	65	50	100	110	17	33
PHEV	0.6	15	5	0	0	8	12
Hybrid	3.5	2					
Heavy / Medium Duty Vehicle							
HDV/MDV (total)			5.4	5.4	5.4	12.3	13.9
Buses	0.5		0.6	0.6	0.6	1.1	1.2
Trucks	4.2		4.8	4.8	4.8	11.2	12.7
e-Buses	0.1	300	0.4	0.5	0.6	0.5	1.1
e-Trucks		500	0.8	1.2	2.4	0.2	0.5
PHEV e-Trucks						0.1	0.5
Vocational	0.5	300	0.1	0.1	0.3		

- 2020: sources OICA, (US light trucks are in PC); EV data source Valuad); 2030 estimates CRM4EV (sources BNEF, own estimates) and IEA scenarios; CRM4EV scenarios YoY BEV growth rates 2022 - 2030: 30%, 40%, 50%

Battery and mineral demand scenarios

CRM4EV scenarios and external global scenarios

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Assumptions on batteries technology developments for EVs:

If in 2020 a Tesla Model 3 standard range can be equipped with LFP batteries, why would not most LDVs use LFP batteries in a few years from now?

2022-Q1: 50% of Tesla cars produced use LFP batteries!

- **Battery chemistry development (into commercial applications) has proven to be much faster than forecasted:**
  - Towards high nickel chemistries
  - Towards high LFP storage density
  - High manganese chemistries
  - Battery life time improvements, equal to and exceeding vehicle lifetimes
  - Fast charging performance
  - Cost reduction through scale, manufacturing process developments and chemistries
- **Expected medium term (5 years):**
  - **Solid state batteries**
  - **Sodium (anode) based batteries (CATL announcement)**
- **The acceleration in battery development by industry and research institutes is continuing: we are just in the beginning of the transition!!**

?

- **Mineral availabilities will not impact the long term supply of batteries for EVs (2030+), at whatever speed and scale this takes place, towards a full electrification of land transport by 2035**

!

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CRM4EV and external EV/battery/mineral scenarios

- **CRM4EV scenarios developed:**
  - Cover the external scenarios, both in growth rate as well as battery chemistry mixes: CRM4EV “High NiCo Li-ion demand” scenario at 30% YoY growth
  - Cover higher EV growth rates, in line with current trends and OEM/country ambitions (40% and 50%)
  - **Cover the current trends in battery chemistries for commercial applications (LFP, high-Mn) as well as probable/logical developments: 90% LFP scenarios**
  - Cover a higher penetration of electrification for heavy duty vehicles

- **External scenarios: GGB (Global Battery Alliance), IEA, BNEF**
  - **Assume a strong domination of high nickel battery chemistries (2030 horizon)**; this concluded from the scenario details, provided and CRM4EV analysis
  - **Assume an EV growth leading to a 30% penetration by 2030 (BEV cars)** and limited penetration of eletric heavy duty vehicles; this is well below historic and current growth rates and below leading OEMs and country ambitions
  - For the 2019 GBA (WEF) “target” and the 2021 IEA SDS scenarios, around 1.5 million tons of nickel per year will be required by 2030; 260-290 kton cobalt and 380 kton lithium (metal!)

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Summary of scenarios for battery (GWh) and key minerals demands (kton) for EVs

Summary of 2030 scenarios CRM4EV baseline 2021 EV sales IEA SDS 2021 - GBA 2020		Units	30% growth CRM4EV	40% growth CRM4EV	50% growth CRM4EV	GBA base	GBA target	EV30@30 midpoint	IEA STEPS	IEA SDS	BNEF	Road transport 100% electric "COP 21"
Batteries GWh												
	For transport	GWh	4277	7770	8905	2332	3389	2651	1490	2980	1322	10230
	Total for EV, ESS & CE	GWh	4567	8060	9195	2622	3679	2941	1687	3305	1612	10520
	Li-ion for transport	%	*94*	*96*	*97*	*89*	*92*	*90*	*88*	*90*	*82*	*97*
Mineral demand (CRM4EV modelling & scenario data)												
Nickel	High nickel	kton	2168	3910	4400	1003	1398	1365	767	1463	706	4924
	Ni demand external scenarios	kton				1061	1584		657	1584		
	50% LFP / High Ni / High Mn	kton	754	1300	1401							1487
	90% LFP / 10% High Ni	kton	232	355	409							484
Cobalt	High nickel	kton	352	639	719	191	274	220	129	251	111	805
	Co demand external scenarios	kton				214	290		109	263		
	50% LFP / High Ni / High Mn	kton	210	383	411							427
	90% LFP / 10% High Ni	kton	53	90	102							116
Lithium	All CRM4EV Li-ion scenarios	kton	516	911	1039	243	330	332	177	346	182	1189
	Li demand external scenarios	kton				164	378		164	378		

- Current public global scenarios compared to CRM4EV scenarios and the COP21 (100% zero emission transport by 2050)
- Mineral requirements are based CRM4EV modelling or taken from the different scenarios (underligned data)

Key mineral demands in current chemistry (“high nickel”)

Scenario: Additional availability of nickel for EVs:

1 to 1.2 million tons by 2030

Forecasts & scenarios for (B)EV

(IEA, GBA-WEF, EV30@30, BNEF; most consultancies)

The 2020 / 2021 "consensus" view for 2030

- **30% penetration (BEV cars), or 30 million BEV cars sold**
- **High nickel batteries the dominating technology for EVs**
- 2,500 - 3,500 GWh Li-ion battery demand for transport with mineral requirements of 1.5 million tons of nickel, 260-290 kton cobalt and 380 kton lithium (metal!)
- **High risk of shortages of (perceived) critical minerals**
  - For batteries: nickel, cobalt, lithium,….
  - For e-motors: rare earth elements (for permanent magnets)
  - Supply, price and environmental risks

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Current forecasts & scenarios for (B)EV 2030

Nickel already outstripping potential supply?! (excluding deep sea & excessive Indonesia supply)

2030 view: history repeating itself?

- **Underestimating BEV growth (again!)?**
  - 30% BEV (cars) penetration in 2030 = 23% year-on-year growth (2021 and beyond) **or 3 to 4 times lower than actual growth rate**
  - Very low penetration forecasted for other (heavy duty) vehicles
- **To meet demand of certain critical minerals, significant impacts and risks will occur** (supply, environmental, social, cost, geopolitical)
- **Any "faster than anticipated" BEV growth will exponentially aggravate the iompacts of the supply chain**

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Nickel demand (kton): CRM4EV scenarios "High NiCo Li-ion battery demand" 2030 for EV

0.565 Scenario: / Application area:	Weighted Average Ni content in application kgNi/kWh	30% growth CRM4EV	40% growth CRM4EV	50% growth CRM4EV	GBA base	GBA target	EV30@30 midpoint	IEA STEPS	IEA SDS	BNEF	Road transport 100% electric "COP 21"
Light Duty Vehicles											
LDV BEV	0.51	1753	3414	3636	812	1172	1025	641	1302	455	3636
LDV PHEV	0.51	76	38	0	81	117	86	56	92	58	0
Heavy Duty Vehicles											
HDV/MDV	0.40										
e-Buses	0.40	50	59	65	0	0	99	0	0	45	71
e-Trucks	0.40	154	237	475	0	0	46	0	0	16	949
Vocational	0.40	6	12	36	0	0	0	0	0	0	59
2/3 Wheelers	0.40	40	40	40	40	40	40	0	0	0	59
Other transport	0.40	20	40	79	0	0	0	0	0	61	79
Transport total		2098	3840	4330	933	1328	1295	697	1393	636	4854
ESS - stationary storage	0.00	0	0	0	0	0	0	0	0	0	0
Consumer electronics	0.57	70	70	70	70	70	70	70	70	70	70
Total kton		2168	3910	4400	1003	1398	1365	767	1463	706	4924
% NiCo batteries used for LDV		84	88	83	89	92	81	91	95	73	74
% NiCo batteries used for transport		97	98	98	93	95	95	91	95	90	99

Global scenarios (continu to) assume high penetration of "high nickel" battery chemistries.

This domination is especially strong for the use in passenger cars. Which in turn dominate the total battery demand.

Leading to (very) high nickel demands at relatively modest EV growth (2030).

Key mineral demand in different CRM4EV battery chemistry scenarios

The need for a drastic shift away from high nickel chemistries

Nickel demand (kton): CRM4EV scenarios "High LFP and High Mn Li-ion battery demand 2030" for EV

0.335 Scenario: / Application area:	Weighted Average Ni content in application	30% growth CRM4EV	40% growth CRM4EV	50% growth CRM4EV	GBA base	GBA target	EV30@30 midpoint	IEA STEPS	IEA SDS	BNEF	Road transport 100% electric "COP 21"
Light Duty Vehicles	kgNi/kWh										
LDV BEV	**0.17**	**553**	**1078**	**1198**	**267**	**386**	**338**	**211**	**429**	**150**	**1198**
LDV PHEV	0.17	42	21	0	45	65	48	31	51	32	0
Heavy Duty Vehicles											
HDV/MDV	0.03										
e-Buses	0.03	7	8	9	0	0	14	0	0	6	10
e-Trucks	0.03	22	34	68	0	0	7	0	0	2	136
Vocational	0.03	1	2	5	0	0	0	0	0	0	8
2/3 Wheelers	0.17	28	28	28	28	28	28	0	0	0	42
Other transport	0.07	6	11	23	0	0	0	0	0	18	23
Transport total		**660**	**1183**	**1331**	**341**	**479**	**434**	**242**	**480**	**209**	**1417**
ESS - stationary storage	0.00	0	0	0	0	0	0	0	0	0	0
Consumer electronics	0.57	70	70	70	70	70	70	70	70	70	70
Total kton		**730**	**1253**	**1401**	**411**	**549**	**504**	**312**	**550**	**279**	**1487**
% NiCo batteries used for LDV		82	88	86	76	82	76	78	87	65	81
% NiCo batteries used for transport		90	94	95	83	87	86	78	87	75	95

High LFP + High Mn *

(Chemistries used for cars are 50% zero Ni + mix of Ni-based chemistries)

This scenario is challenging if current high growth rates continue

*Similar to what (for example) VW is forecasting as chemistry mix.

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Nickel demand (kton): CRM4EV scenarios "90% LFP / 10% High Ni battery demand 2030" for EV

0.335 Scenario: / Application area:	30% growth CRM4EV	40% growth CRM4EV	50% growth CRM4EV	GBA base	GBA target	EV30@30 midpoint	IEA STEPS	IEA SDS	BNEF	Road transport 100% electric "COP 21"
Light Duty Vehicles										
LDV BEV	115	225	240	812	1172	1025	641	1302	455	240
LDV PHEV	8	4	0	81	117	86	56	92	58	0
Heavy Duty Vehicles										
HDV/MDV										
e-Buses	7	8	9	0	0	99	0	0	45	10
e-Trucks	22	34	68	0	0	46	0	0	16	136
Vocational	1	2	5	0	0	0	0	0	0	8
2/3 Wheelers	6	6	6	40	40	40	0	0	0	8
Other transport	3	6	11	0	0	0	0	0	61	11
Transport total	162	285	339	933	1328	1295	697	1393	636	414
ESS - stationary storage	0	0	0	0	0	0	0	0	0	0
Consumer electronics	70	70	70	70	70	70	70	70	70	70
Total kton	232	355	409	1003	1398	1365	767	1463	706	484
% NiCo batteries used for LDV	53	65	59	89	92	81	91	95	73	50
% NiCo batteries used for transport	70	80	83	93	95	95	91	95	90	86

90% LFP

(or other zero Ni/Li chemistries)

EV growth limited "only" by lithium availability

Observations from scenarios

- **Difference in the CRM4EV 30, 40, 50% scenarios is mainly a matter of timing with a BEV (car) dominance occuring somewhere in the time frame 2030 – 2035.**
  - Which fits with leading government and EU ambitions as well as the COP21 ambition
- **External scenarios (e.g. Global Battery Alliance, IEA) assume around 30% growth but all apply "high nickel" chemistries as the dominant chemistry by 2030.**
  - Leading to nickel and cobalt requirements equal to the 50% "LFP+high Mn" CRM4EV scenario
  - Foresee an actual slowdown in growth after 2025 (data not shown)
  - OEM forecast (much) more optimistic
- **External scenarios forecast (very) low BEV penetration for commercial (heavy duty) vehicles which does not seem to be in line with analyses showing a lower overall cost for BEV HDV in many applications well before 2030.**

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Global experience & insights in EV and battery development and market dynamics

EV future: critical mineral use per EV has to be reduced FAST

CRM4EV 2030 view

BEV (car) penetration, 50 – 70 million / year
Battery demand 5,000 GWh or much higher

- **LFP likely to become the chemistry of choice within a few years**
  - Lower cost, longer lifetime, lower footprint, zero Ni & Co
  - > 75% LFP needed to avoid major supply issues
- **Solid state batteries likely to become relevant faster** and more significantly than projected currently, 20 – 40% by 2030?
  - Lower weight, higher storage density, less materials, more stable
- **The potential of sodium (Na) to replace lithium partially / substantially / mainly will become clear in this decade and commercial application will start in a few years**
- **Geopolitical risks have become very real and very high: mineral independence is KEY, especially for Europe, Japan, Korea,…**

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Assumptions on key mineral availabilities and potential supply issues

Will there be enough lithium available OR will there be an alternative chemistry not requiring lithium soon enough?

- **Nickel**: availability for EV batteries by 2030 could be (as a max) 1.2 million ton per year (analyst view), very large shift to ZERO nickel chemistries required
- **Cobalt**: does not seem to an issue, large potential from (new nickel) Indonesian sources and scale-up potential DRC, shift to ZERO Ni/Co chemistries
- **Lithium**: very large resources available which will be further extended, no structural shortage expected but possible short term supply shortages (USGS: lithium reserves 2019 of 14 million ton, resources 62 million ton; 2021: 21 million ton reserves and resources of 86 million ton).
- **Graphite**: large potential for additional mining, also graphite is made through chemical processes so no structural shortage expected, with the development of silicon-graphite, the graphite content will be reduced and solid state batteries do not use graphite as anode material.
- *The geological availability is not an issue, bringing new supply to stream within such short timescales may be an issue. Conversion capacity as well as environmental & social local conditions are other important considerations. Secondary supplies will grow in importance but remain limited.*

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New developments will provide a solid basis for a sustainable and rapid transition to electrified transport

Please attend the remaining presentations and the concluding remarks!

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Rare earth elements for Electric Vehicles
PGM savings from BEV deployment

29th April 2022 - webinar