Solutions to cobalt supply chain problems for transitioning to a BEVs only future #21

First published May 2023

The value of cobalt in BEVs is relatively low

1. **Low cost of cobalt in typical BEV**

- Cobalt currently cost 34.18 USD per kg but only 6.2 kg of it is needed to make a typical BEV with a nickel rich battery so total cost is a low 211.3 USD
- However, cobalt price is volatile sometimes it cost nearly 3X as much and then it will be 600 USD for cobalt
- Also Tesla is known for having ½ the amount of cobalt in its batteries so if price 3X that would mean 1200 USD
- Already today most cobalt is used for making batteries 56%
- Cobalt for batteries could rise to over 90% of global use because the demand for batteries rise 30 to 40% each year
- **Fact is cobalt is a very good material for making battery cathodes (the + electrode in Li-ion batteries) that have high energy density and high thermal stability and thus long life of battery**

Price of raw materials needed to make battery electric vehicles

Material type	One average BEV in kg per vehicle	Price in USD per kg	Price USD of needed material in BEV	Date of price info
Graphite (Li-ion cells 19% 83kWh)	58.73	2.28	133.97	1-May-22
Nickel battery cells 20% 83kWh	61.82	25.42	1,571.57	20-Apr-23
Lithium carbonate or equivalent	44.23	28.01	1,239.23	17-Apr-23
Lithium battery cells 2.7% 83kWh	8.35	148.48	1,239.23	17-Apr-23
Copper (battery, motor, wires)	91.00	9.02	820.82	25-Mar-23
Manganese (batteries, steel alloy)	10.00	4.73	47.30	25-Mar-23
Magnesium (VW Beetle)	20.00	3.90	78.00	15-Apr-23
Zinc (rust protection battery etc)	17.50	2.85	49.82	15-Apr-23
Cobalt in battery cells 2%, 83kWh	6.18	34.18	211.31	26-Apr-23
Rare earth (fx **Nd**, Pr, Dy, Tb)	0.90	103.33	92.99	25-Mar-23
Aluminium (vehicle GM Volt))	169.00	2.35	396.81	25-Mar-23
Crude steel (98% Fe/Iron)	900.00	0.59	535.04	25-Mar-23
Plastics textile & other	250.00	4.00	1,000.00	25-Mar-23
Total vehicle weight	**1,629.37**	**Total cost**	**6,176.87**	

Sources: Follow link below video to download spreadsheet containing clickable sources

Consumption of cobalt in 2020

Application	Percentage
Batteries	56.45%
Nickel-based alloys	13.20%
Tool materials	7.90%
Pigments	6.45%
Catalysts	4.90%
Magnets	4.10%
Soap & dryers	1.95%
Others	5.05%
Total	100.00%

Source/attribution: https://www.statista.com/statistics/1143399/global-cobalt-consumption-distribution-by-application/

Source/attribution: https://tradingeconomics.com/commodity/cobalt

Very high supply chain risk for cobalt in BEVs

2. **Supply chain risks are currently very high for cobalt** as 76.3% is mined in high risk countries and these countries also got 58.6% of the known cobalt reserves

- Supply from these countries could disappear at any time without much warning ahead
- Making 100 million BEVs annually using the current Tesla battery chemistry will require 618,000 tons of cobalt per year or 325% of global production of cobalt in 2022
- Also, using all known reserves of cobalt to make BEVs with a Tesla battery would yield **1.35 billion BEVs** (=8,345,000*1000/6.18)

Raw materials needed to make 100 million BEVs per year if no innovation

Material type	One average BEV in kg per vehicle	100M BEVs in tons	Global production in tons	Data year	In % of current global production
Graphite battery cells 19% 83kWh	58.73	5,873,280	3,034,000	2021	193.58%
Nickel battery cells 20% 83kWh	61.82	6,182,400	3,300,000	2022	187.35%
Lithium carbonate or equivalent	44.23	4,423,490	540,000	2021	819.16%
Lithium battery cells 2.7% 83kWh	8.35	834,624	130,000	2022	642.02%
Copper (battery, motor, wires)	91.00	9,100,000	21,200,000	2021	42.92%
Manganese (batteries, steel alloy)	10.00	1,000,000	20,090,000	2022	4.98%
Magnesium (VW Beetle)	20.00	2,000,000	1,022,000	2022	195.69%
Zinc (rust protection battery etc)	17.50	1,750,000	13,080,000	2021	13.38%
Cobalt in battery cells 2%, 83kWh	6.18	618,240	190,000	2022	325.39%
Rare earth (fx **Nd**, Pr, Dy, Tb)	0.90	90,000	300,000	2019	30.00%
Aluminium (vehicle GM Volt))	169.00	16,900,000	68,000,000	2022	24.85%
Crude steel (98% Fe/Iron)	900.00	90,000,000	1,951,000,000	2021	4.61%
Plastics textile & other	250.00	25,000,000	-	-	-
Total vehicle weight	**1,629.37**				

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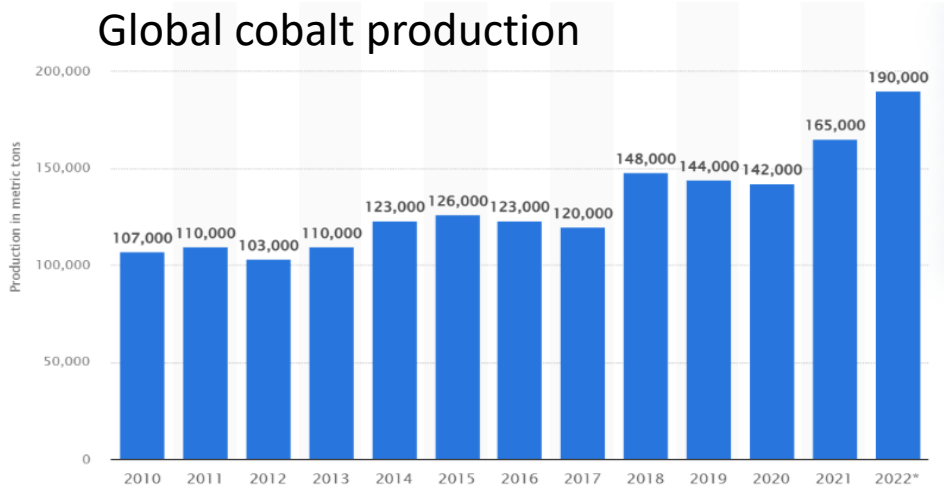
Cobalt mine production and reserves in tons in 2022

Country	Production	% of total	Reserves	% of total
DR Congo	130,000	68.42%	4,000,000	47.93%
Indonesia	10,000	5.26%	600,000	7.19%
Russia	8,900	4.68%	250,000	3.00%
Australia	5,900	3.11%	1,500,000	17.97%
Canada	3,900	2.05%	220,000	2.64%
Cuba	3,800	2.00%	500,000	5.99%
Philippines	3,800	2.00%	260,000	3.12%
Madagascar	3,000	1.58%	100,000	1.20%
Papua New Guinea	3,000	1.58%	47,000	0.56%
Turkey	2,700	1.42%	36,000	0.43%
Morocco	2,300	1.21%	13,000	0.16%
China	2,200	1.16%	140,000	1.68%
United States	800	0.42%	69,000	0.83%
Other countries	9,700	5.11%	610,000	7.31%
World total	**190,000**	100.00%	**8,345,000**	100.00%
Risky countries	**144,900**	76.26%	**4,890,000**	58.60%

Sources: Follow link below video to download spreadsheet containing clickable sources



Source/attribution: https://www.statista.com/statistics/339759/global-cobalt-mine-production/

Options for dealing with cobalt supply chain risk

- Three options/strategies for dealing with the serious supply chain risks for cobalt

1. **Do not use battery chemistries that require any cobalt**

- E.g., Tesla are currently switching to cobalt free lithium-ion chemistries in particular the LFP batteries at >160Wh/kg for storage and mid-range BEVs and nickel rich Li-ion batteries at >245Wh/kg for long range BEVs
- Future cobalt free Na-ion batteries at 160 Wh/kg may also become possible for storage

2. **Second strategy is to continue making battery cells with cobalt but acquire an emergency stock of cobalt to deal with sudden supply cut**

- The stock of cobalt should be large enough to keep existing production going at full speed for as long as it would be expected to make a full switch to cobalt free battery chemistries, e.g. 2yr

3. **Third strategy is to wait for miners from risk free countries** to start mining cobalt and other elements from deep sea Polymetallic nodules

- Problem is it will require many years (10+) to develop such a new supply chain for cobalt, cobber, nickel and other elements
- Higher commodity prices could get this going much faster

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Magnesium (VW Beetle)	20.00	2,000,000	1,022,000	2022	195.69%
Zinc (rust protection battery etc)	17.50	1,750,000	13,080,000	2021	13.38%
Cobalt in battery cells 2%, 83kWh	6.18	618,240	190,000	2022	325.39%
Rare earth (fx **Nd**, Pr, Dy, Tb)	0.90	90,000	300,000	2019	30.00%
Aluminium (vehicle GM Volt))	169.00	16,900,000	68,000,000	2022	24.85%
Crude steel (98% Fe/Iron)	900.00	90,000,000	1,951,000,000	2021	4.61%
Plastics textile & other	250.00	25,000,000	-	-	-
Total vehicle weight	**1,629.37**				

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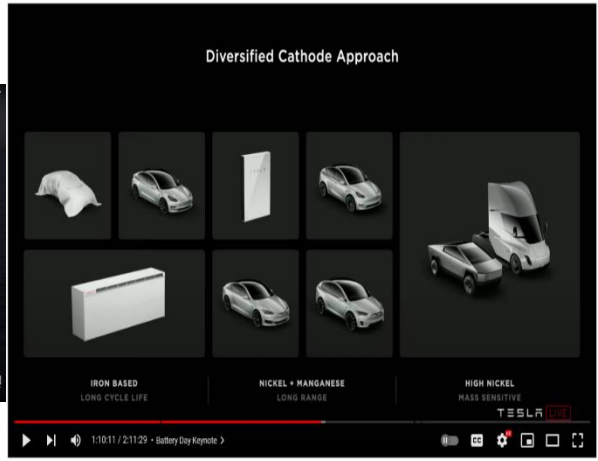
Source/attribution:
https://www.youtube.com/watch?v=Lwq1j3nOODA

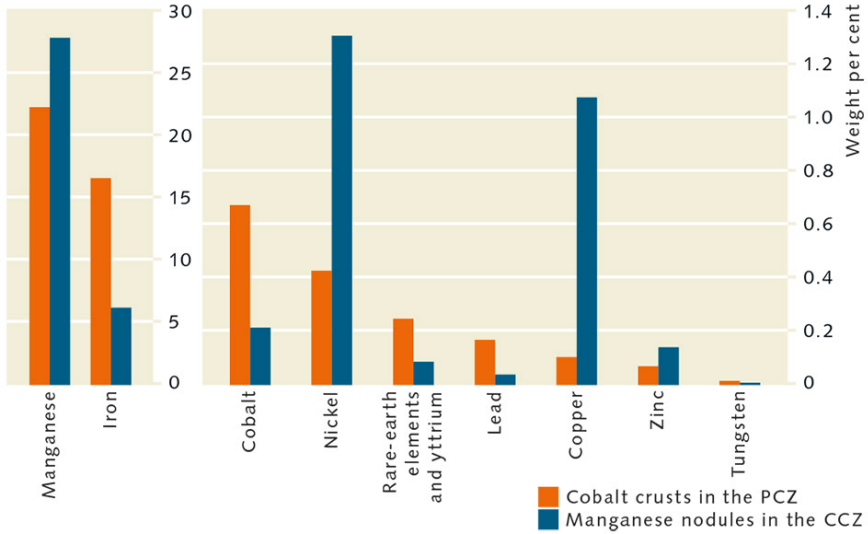


Tesla Battery Day
Streamed Sep 22, 2020:
https://www.youtube.com/watch?v=l6T9xIeZTds&t=4628s

Deep sea mining potential: Beware source is 2014

3. **Continued: Third strategy is to wait for miners from risk free countries** to start mining cobalt and other elements from deep sea Polymetallic nodules

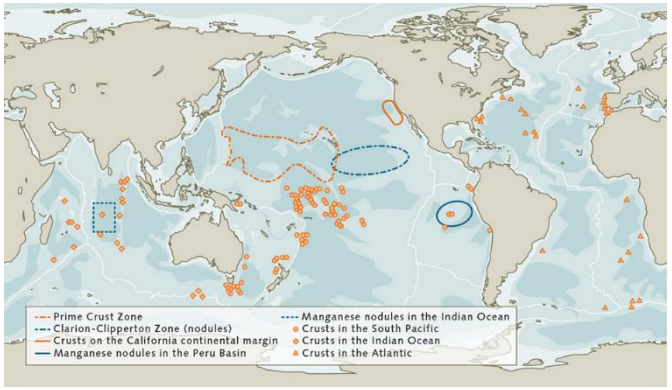
- Cobalt reserves in cobalt crusts plus manganese nodules is 94 million tons or **11.3** (=94/8.3) **times as much as land based reserves in 2022**
- **Enough for 15.2 billion BEVs** (=94Mt/6.18kg)
- Deep see mining could end all supply chain worries for cobalt
- IMO environmental worries about deep sea mining are academic



Metal contents in millions of tonnes

Elements	Cobalt crusts in the Prime Crust Zone (PCZ)	Global reserves on land (economically minable deposits today)	Global reserves and resources on land (economically minable as well as sub-economic deposits)	Manganese nodules in the Clarion-Clipperton Zone
Manganese (Mn)	1714	630	5200	5992
Copper (Cu)	7.4	690	1000+	226
Titanium (Ti)	88	414	899	67
Rare earth oxides	16	110	150	15
Nickel (Ni)	32	80	150	274
Vanadium (V)	4.8	14	38	9.4
Molybdenum (Mo)	3.5	10	19	12
Lithium (Li)	0.02	13	14	2,8
Cobalt (Co)	50	7.5	13	44
Tungsten (W)	0.67	3.1	6.3	1.3
Niobium (Nb)	0.4	3	3	0.46
Arsenic (As)	2.9	1	1.6	1.4
Thorium (Th)	0.09	1.2	1.2	0.32
Bismuth (Bi)	0.32	0.3	0.7	0.18
Yttrium (Y)	1.7	0.5	0.5	2
Platinum group	0.004	0.07	0.08	0.003
Tellurium (Te)	0.45	0.02	0.05	0.08
Thallium (Tl)	1.2	0.0004	0.0007	4.2

Cobalt reserves on land in 2022 are 8.3 million tons, enough for 1.35B BEVs, see slide 3



Source/attribution: https://worldoceanreview.com/en/wor-3/mineral-resources/cobalt-crusts/?ssp=1&darkschemeovr=1&setlang=en-XL&safesearch=moderate

How hard is it to scale cobalt production

- **Question:** How hard is it to make 618,000 tons of cobalt annually or enough for making 100 million BEVs with batteries that are using cobalt?
- It is very doable as we will need to mine the equivalent of 309 million tons of typical cobalt ore at 0.2%
- 309 million tons only represent 7.9% (=309/3902) of the iron ore mined in 2021
- Also note cobalt is a tiny mining industry only 6.5 billion USD and therefore it is also easier to scale
- However, problem with cobalt still is that 76% of the supply is from countries who are unreliable
- We need deep sea mining to get going to ultimately solve the supply chain risks for cobalt
- **BEV batteries can be fully recycled** so eventually much less mining is needed for cobalt

Scale of global raw materials industry by size in tons and USD sales

Material type	Production and mining in tons	Data year	In % of iron ore	Price USD/kg	Date of price info	Global sales million USD	Materials tons for 100M BEVs
Graphite (Li-ion cells 19% 83kWh)	3,034,000	2021	0.08%	2.28	1-May-22	6,921	5,873,280
of which is mined graphite	1,034,000	2021	-	-	-	2,359	-
of which is synthesized graphite	2,000,000	2021	-	-	-	4,562	-
Nickel in battery cells 20% 83kWh	3,300,000	2022	-	25.42	20-Apr-23	83,886	6,182,400
Nickel ore at 1.2%	275,000,000	2022	7.05%	-	-	-	515,200,000
Lithium carbonate or equivalent	540,000	2021		28.01	17-Apr-23	15,128	4,423,490
Lithium battery cells 2.7% 83kWh	130,000	2022		148.48	17-Apr-23	19,302	834,624
Lithium ore at 0.7%	18,571,429	2022	0.48%	-	-	-	119,232,000
Copper (battery, motor, wires)	21,200,000	2021	-	9.02	25-Mar-23	191,224	9,100,000
Copper ore at 0.6%	3,533,333,333	2021	90.55%	-	-	-	1,516,666,667
Manganese (batteries, steel 1%)	20,090,000	2022		4.73	25-Mar-23	95,021	1,000,000
Manganese ore at 30%	66,966,667	2022	1.72%	-	-	-	3,333,333
Magnesium Mg	1,022,000	2022		3.90	15-Apr-23	3,986	2,000,000
Magnesium ore at 3.86%	26,450,000	2022	0.68%				51,761,252
Zinc (rust protection battery etc)	13,080,000	2021		2.85	15-Apr-23	37,239	1,750,000
Zinc ore at 5%	261,600,000	2021	6.70%				35,000,000
Cobalt in battery cells 2%, 83kWh	190,000	2022	-	34.18	26-Apr-23	6,494	618,240
Cobalt ore at 0.2%	95,000,000	2022	2.43%				309,120,000
Rare earth (fx **Nd**, Pr, Dy, Tb)	300,000	2019	-	103.33	25-Mar-23	30,998	90,000
Aluminium (vehicle GM Volt))	68,000,000	2022	-	2.35	25-Mar-23	159,664	16,900,000
Aluminium ore Bauxite at 18%	380,000,000	2022	9.74%	-	-	-	94,441,176
Crude steel (98% Fe/Iron)	1,951,000,000	2021		0.59	25-Mar-23	1,159,858	90,000,000
Iron ore needed at 50%	3,902,000,000	2021	100.00%	0.12	4-Apr-23	481,897	180,000,000
Coal (price is Newcastle Europe)	7,700,000,000	2021	197.33%	0.20	6-Apr-23	1,524,600	0
Oil (price is WTI US crude)	4,200,000,000	2021	107.64%	0.56	6-Apr-23	2,343,180	0
Gas (price is UK natural gas)	3,872,074,514	2021	99.23%	0.49	6-Apr-23	1,914,013	0

Sources: Follow link below video to download spreadsheet containing clickable sources

Value of different sources of mining ore

Ore type	Nickel	Lithium	Cobalt	Copper	Manganese	Iron	USD/ton	Nickel	Lithium	Cobalt	Copper	Manganese	Iron
Price USD/kg	25.42	148.48	34.18	9.02	4.73	0.59	-	USD/Ton	USD/Ton	USD/Ton	USD/Ton	USD/Ton	USD/Ton
Tesla bat. cell	20.00%	2.70%	2.00%	8.00%	0.00%	0.00%	10,498	5,084	4,009	684	722	0	0
Typical ore	1.20%	0.70%	0.20%	0.60%	30.00%	50.00%	3,183	305	1,039	68	54	1,419	297
Deep sea Co	0.40%	0.00%	0.67%	0.10%	22.00%	17.00%	1,481	102	0	229	9	1,041	101
Deep sea Ma	1.30%	0.00%	0.20%	1.10%	27.00%	6.00%	1,811	330	0	68	99	1,277	36

Sources: Follow link below video to download spreadsheet containing clickable sources

309 million tons of deep sea Mg nodules

✓ **As a thought experiment what would happen if we mined 309 million tons of manganese nodules per year?**

1. First note that land based cobalt ore and these nodules both contain 0.2% cobalt so 309 million tons contain 618,000 tons of cobalt or enough for making 100 million BEVs
2. The supply chain risks for cobalt would be completely solved
3. We would also get 83 million tons of manganese or 4 times more than current global production and enough to make 8,3 billion BEVs. But nearly all manganese is used for making steel
4. We would also get 4 million tons of nickel enough to make 65 million BEVs with a nickel rich battery
5. Also importantly we will get 3.4 million tons of copper or enough for making 37 million BEVs using 91 kg of copper each
6. If large scale deep see mining happened the price of manganese would plummet and surface mining would end
7. So realistically we will likely need the price of nickel, cobalt and copper to double before deep sea mining becomes economic

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Sources: Follow link below video to download spreadsheet containing clickable sources

Mining 309 million tons of manganese nodules

Element	Ore/nodule quality	Tons mined	Need for 1 BEV in kg	# of BEVs in millions	Current USD/kg	Value mined billion USD	Future USD/kg	Future val. billion USD
Cobalt	0.20%	618,240	6.18	100.00	34.18	21.13	68.36	42.26
Manganese	27.00%	83,462,400	10.00	8,346.24	4.73	394.76	0.95	78.95
Nickel	1.30%	4,018,560	61.82	65.00	25.42	102.15	50.84	204.30
Copper	1.10%	3,400,320	91.00	37.37	9.02	30.67	18.04	61.34
Iron/steel	6.00%	18,547,200	900.00	20.61	0.59	11.03	0.59	11.03
Other stuff	64.40%	199,073,280	-	-				
Total	**100.00%**	**309,120,000**	-	-		**559.74**		**397.89**
USD per ton of ore						**1,811**		**1,287**

Sources: Follow link below video to download spreadsheet containing clickable sources

8. The global off-shore oil/gas companies like Exxon and BP should be the ones that start investing the 10s of billions of USD it takes to get deep sea mining started
9. Exxon and BP have the capital and the specialized engineers that could develop the needed equipment for deep sea mining

Sources/attribution for previous slides

- Cobalt has two innate properties that make it ideal for battery applications: thermal stability and high energy density: https://science.howstuffworks.com/environmental/earth/geology/cobalt.htm
- Global demand for batteries grow by 30 to 40% each year see HMexperience video #6: https://www.youtube.com/watch?v=5ABraHH0FTo
- At Tesla Battery Day - Tesla use zero cobalt for their next generation high nickel lithium ion batteries (timestamp 1:09:40): https://www.youtube.com/watch?v=l6T9xIeZTds&t=4628s
- High nickel Tesla 2170 and 4680 battery cells have respectively 269 and 244 Wh/kg: https://www.notebookcheck.net/Tesla-4680-vs-2170-battery-cell-test-reveals-lower-energy-density-in-the-Texas-made-Model-Y.669162.0.html
- LiFePO4 by CATL at minimum 160 Wh/kg: https://cleantechnica.com/2020/02/18/how-catl-lithium-iron-phosphate-batteries-could-be-leading-to-100-kwh-tesla-model-3/
- Na-ion (sodium-ion) at minimum 160 Wh/kg by CATL: https://cnevpost.com/2023/04/16/chery-to-be-1st-to-adopt-catl-sodium-ion-batteries/