Batteries - In debt cost and scalability analysis #22

First published May 2023

Battery cost breakdown: Current prices 2023

1. **Table shows *raw material cost at cell level* in USD for a 83kWh battery** (Tesla LR Model Y) for each kind of raw material used
2. Table cover **most applied types of battery chemistries** used for BEVs and energy storage
3. **Sodium-ion battery** is included in table because although not yet in mass production it has potential as it does not use lithium, cobalt, nickel or copper
4. **Na-ion** use very expensive synthetic Hard carbon and also has low energy density so **still more expensive per kWh than its alternatives**
5. **LMFP battery is likely to lead use for BEVs and grid storage in coming years**
6. **LMFP has** 1) **lowest cost** per kWh and 2) **acceptable 210Wh/kg** energy density & 3) **few supply chain issues**

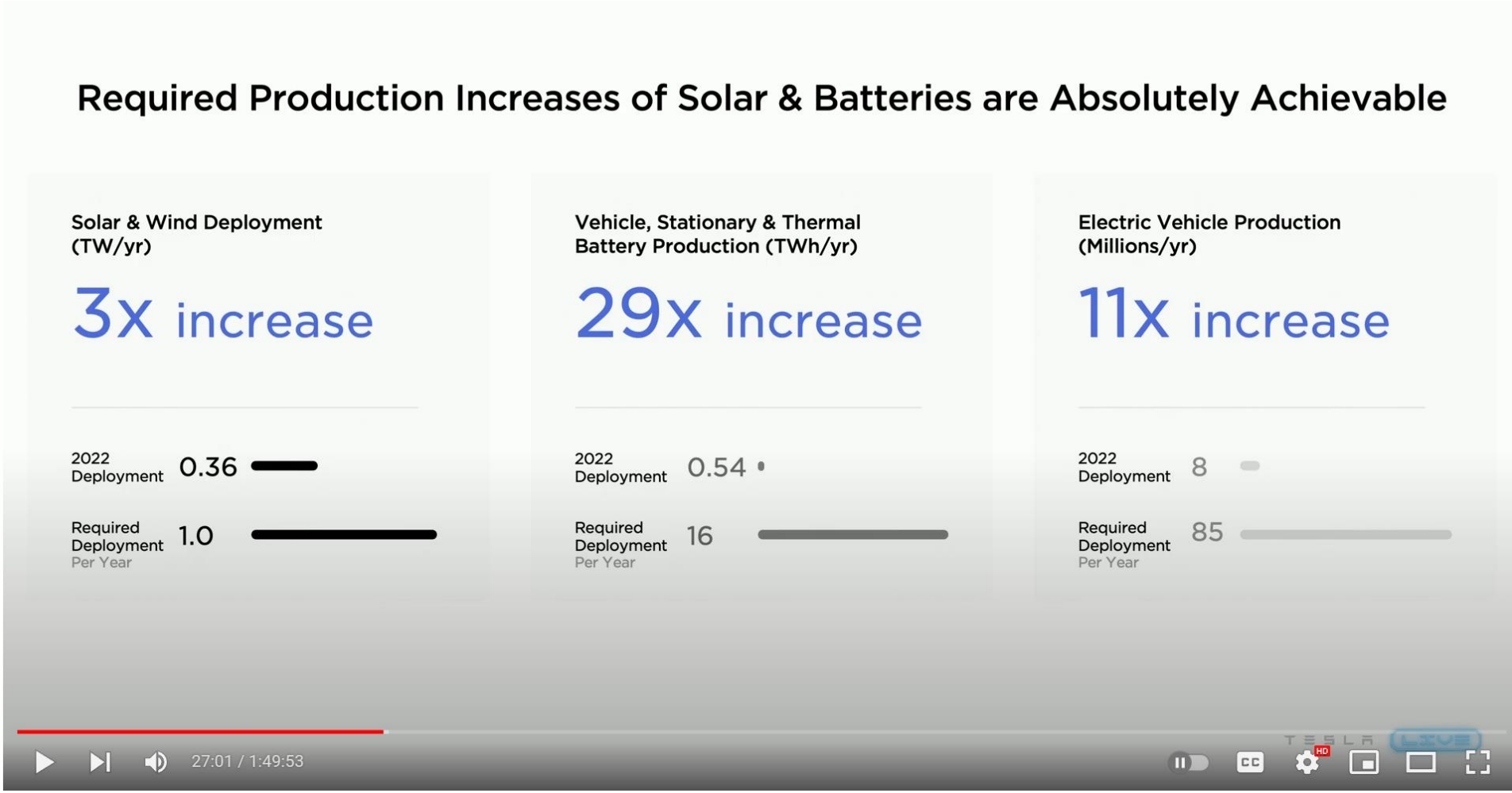
Cost breakdown analysis in USD for different battery chemistries

Raw materials used for 83.15 kWh battery (TLR Model Y)	Price USD/kg Current prices 2023	Price change from current	Li-ion, NMC811 Nickel 80% Manganese 10% Cobalt 10%	Li-ion, NMC523 Nickel 50% Manganese 20% Cobalt 30%	Li-ion, LFP Lithium iron phosphate LiFePO4	Li-ion, LMFP Lithium, Mn iron phosphate LiMnFePO4	Li-ion, Tesla NCA variant nickel, cobalt aluminium	Na-ion Sodium-ion CATL, BYD
Lithium carbonate Li2CO3	$32.33	1.00	$1,187.42	$1,662.39	$1,424.91	$1,085.64	$1,430.21	$0.00
Sodium carbonate Na2CO3	$0.36	1.00	$0.00	$0.00	$0.00	$0.00	$0.00	$11.51
Cobalt Co	$34.93	1.00	$242.04	$532.48	$0.00	$0.00	$215.94	$0.00
Nickel Ni	$24.45	1.00	$1,321.30	$948.63	$0.00	$0.00	$1,511.35	$0.00
Manganese Mn	$4.62	1.00	$32.01	$102.42	$0.00	$99.98	$0.00	$120.02
Graphite C, for Li-ion	$9.50	1.00	$592.44	$697.77	$868.92	$662.03	$583.59	$0.00
Hard carbon C, for Na-ion	$30.00	1.00	$0.00	$0.00	$0.00	$0.00	$0.00	$3,118.13
Iron Fe	$0.52	1.00	$0.00	$0.00	$29.69	$11.31	$0.00	$59.75
Aluminium Al	$2.35	1.00	$97.62	$113.89	$143.17	$109.08	$98.34	$262.96
Copper Cu	$8.23	1.00	$228.10	$228.10	$296.53	$225.93	$203.51	$0.00
Steel Fe 98%, Ma 1%	$0.52	1.00	$14.48	$14.48	$18.83	$14.35	$12.40	$20.85
Plastics/other C,H,O, N, P, F			-	-	-	-	-	-
Total cell raw material cost			**$3,715.41**	**$4,300.16**	**$2,782.05**	**$2,208.33**	**$4,055.34**	**$3,593.22**
Cell raw material cost /kWh	Sources		$44.68	$51.72	$33.46	$26.56	$48.77	$43.21
Cell production cost /kWh	https://www	1.00	$50.00	$50.00	$50.00	$50.00	$50.00	$50.00
Battery packaging cost/kWh	https://abou	1.00	$29.35	$33.21	$50.44	$38.43	$30.00	$50.44
Total battery pack cost/kWh			**$124.03**	**$134.93**	**$133.90**	**$114.99**	**$128.77**	**$143.65**
Total cost of 83kWh battery	https://www.findmy		**$10,312.99**	**$11,219.06**	**$11,133.43**	**$9,561.16**	**$10,707.34**	**$11,944.60**
Battery cells weight in kg			302.4	342.2	519.7	396.0	309.1	519.7
Est battery pack weight in kg	71.45% increase		518.4	586.7	891.0	678.9	530.0	891.0
Wh/kg (cells)			275.00	243.00	160.00	210.00	269.00	160.00
Percentage Wh/kg relative to LMFP battery			130.95%	115.71%	76.19%	100.00%	128.10%	76.19%
Wh/l (cells)			-	-	350.00	450.00	750.00	260.00
Percentage Wh/l relative to LMFP battery					77.78%	100.00%	166.67%	57.78%

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

7. **Best strategy for auto makers** is to design their BEVs to be great (270 mile range and >150kW charging) using a LMFP battery
8. **A premium version of same BEV** could be sold with nickel rich battery with 28% to 31% more range while keeping the total weight of vehicle the same so structural integrity stay the same and vehicles can be produced the same way with no need for additional crash testing

Scaling global battery industry : How much?



Source: https://www.youtube.com/watch?v=bZNL_8bUz6A&t=1655s

Sustainable economy halves energy consumption

Source: https://www.youtube.com/watch?v=bZNL_8bUz6A&t=1655s

Sustainable economy also reduces needed mining

Source: https://www.youtube.com/watch?v=bZNL_8bUz6A&t=1655s

Sustainable economy: Total requerments

Batteries recycled every
15 years =240TWh/16TWh

Solar/wind recycled every
30 years =30TW/1TW

World GDP
96.5 trillion USD

Source: https://www.youtube.com/watch?v=bZNL_8bUz6A&t=1655s

Scalability analysis: Raw material reserves

Billions of 83kWh battery packs that can be made using all global reserves of particular raw material

Raw material used in battery	Global reserves million tons in 2022	Price USD/kg Current prices 2023	Billion USD value of global reserves	Li-ion, NMC811 Nickel 80% Manganese 10% Cobalt 10%	Li-ion, NMC523 Nickel 50% Manganese 20% Cobalt 30%	Li-ion, LFP Lithium iron phosphate LiFePO4	Li-ion, LMFP Lithium, Mn iron phosphate LiMnFePO4	Li-ion, Tesla NCA variant nickel, cobalt aluminium	Na-ion Sodium-ion CATL, BYD
Lithium carbonate Li2CO3	131.73	$32.33	$4,259.30	3.587	2.562	2.989	3.923	2.978	NA
Sodium carbonate Na2CO3	25,000.00	$0.36	$8,918.28	NA	NA	NA	NA	NA	774.651
Cobalt Co	8.35	$34.93	$291.49	1.204	0.547	NA	NA	1.350	NA
Nickel Ni	102.07	$24.45	$2,495.31	1.889	2.630	NA	NA	1.651	NA
Manganese Mn	1,718.00	$4.62	$7,935.49	247.937	77.480	NA	79.370	NA	66.117
Graphite C, for Li-ion	330.00	$9.50	$3,135.00	5.292	4.493	3.608	4.735	5.372	NA
Hard carbon C, for Na-ion	NA-syntetic	$30.00	NA	NA	NA	NA	NA	NA	NA-syntetic
Iron Fe + Steel	99,000.00	$0.52	$51,736.40	3,571.858	3,571.858	1,066.226	2,016.372	4,171.174	641.879
Aluminium Al	5,547.37	$2.35	$13,025.22	133.430	114.369	90.975	119.405	132.446	49.533
Copper Cu	870.00	$8.23	$7,159.89	31.389	31.389	24.145	31.691	35.182	NA
Cost of 83kWh battery pack				**$10,312.99**	**$11,219.06**	**$11,133.43**	**$9,561.16**	**$10,707.34**	**$11,944.60**
Total battery pack cost/kWh				**$124.03**	**$134.93**	**$133.90**	**$114.99**	**$128.77**	**$143.65**
Wh/kg (cells)				**275.00**	**243.00**	**160.00**	**210.00**	**269.00**	**160.00**
Wh/l (cells)				**-**	**-**	**350.00**	**450.00**	**750.00**	**260.00**

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

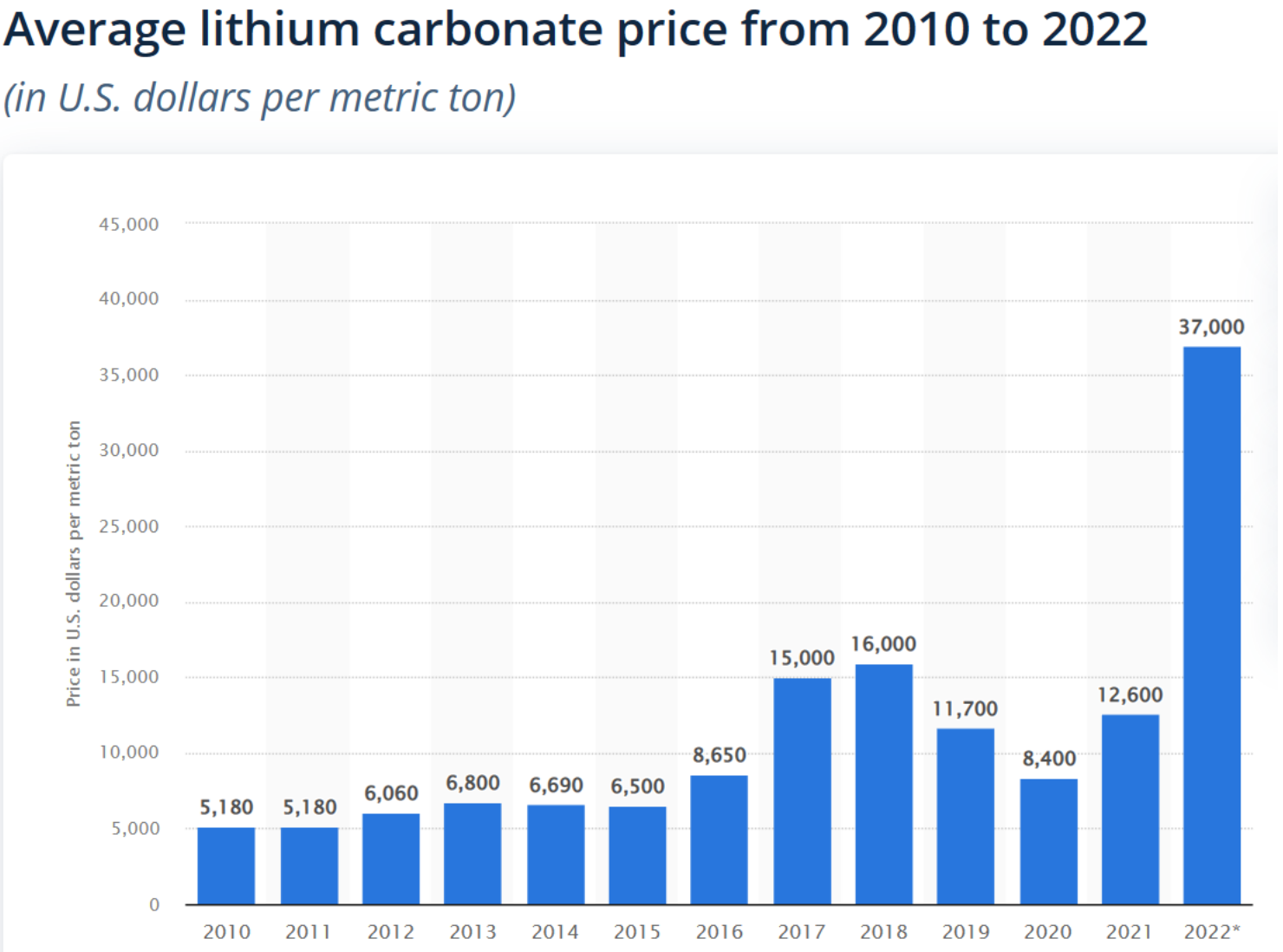
1. **Table shows** global economically minable reserves of raw materials and how many billion 83kWh battery packs these reserves could make
2. **The LMFP battery again is the winner among good energy density batteries** as we can make at least 3.9 billion battery packs with lithium being the limiting factor
3. **Nickel is worse than it looks at 1.6 billion 83kWh packs** (Tesla variant) because 69% of all nickel mined currently is used for making stainless steel and demand for stainless steel is growing
4. **Sodium-ion has zero supply chain issues** but battery is still most costly and low energy density
5. **Making 16TWh of LMFP batteries per year would cost 2 trillion USD at 115 USD/kWh** but should also be enough to end use of all fossil fuels that cost 4.7 trillion USD per year

Battery packs to TWh

Billion 83kWh packs	In terms of TWh	Billion USD Li-ion, LMFP
0.1	8.32	$956.12
0.2	**16.63**	**$1,912.23**
0.4	33.26	$3,824.47
2.0	166.30	$19,122.33
2.9	240.00	$27,596.87
World 2021 current GDP		**$96,530.00**
Coal (C,H) annual sales		$1,247.40
Oil (C, H) annual sales		$2,201.20
Gas (C, H) annual sales		$1,274.41
Sum global fossil fuel sales		**$4,723.01**

Sources: Follow link below video

Long-term Li-carbonate prices



Source: https://www.statista.com/statistics/606350/battery-grade-lithium-carbonate-price/

Cost of making Li-carbonate is 30.000RMB/4260 USD/ton: https://cnevpost.com/2023/04/03/lithium-carbonate-likely-to-fall-below-rmb-100000-says-chairman-of-farasis/

Nearly 4X more lithium resources

Lithium production (2020), reserves and resources in tons

Country	Production	% of total	Reserves	% of total	Resources	% of total
Argentina	6,200	7.46%	1,900,000	7.64%	19,300,000	21.11%
Australia	40,000	48.15%	4,700,000	18.91%	6,400,000	7.00%
Austria	-	-	-	-	50,000	0.05%
Bolivia	-	-	-	-	21,000,000	22.97%
Brazil	1,900	2.29%	95,000	0.38%	470,000	0.51%
Canada	0	0.00%	530,000	2.13%	2,900,000	3.17%
Chile	18,000	21.67%	9,200,000	37.01%	9,600,000	10.50%
China	14,000	16.85%	1,500,000	6.04%	5,100,000	5.58%
Czech Republic	-	-		-	1,300,000	1.42%
DR Congo	-	-	-	-	3,000,000	3.28%
Finland	-	-	-	-	50,000	0.05%
Germany	-	-	-	-	2,700,000	2.95%
Ghana	-	-	-	-	90,000	0.10%
India	-	-	5,900,000	23.74%	5,900,000	6.45%
Kazakhstan	-	-	-	-	50,000	0.05%
Mali	-	-	-	-	700,000	0.77%
Mexico	-	-	-	-	1,700,000	1.86%
Namibia	-	-	-	-	50,000	0.05%
Peru	-	-	-	-	880,000	0.96%
Portugal	900	1.08%	60,000	0.24%	270,000	0.30%
Serbia	-	-	-	-	1,200,000	1.31%
Spain	-	-	-	-	300,000	0.33%
United States	870	1.05%	750,000	3.02%	7,900,000	8.64%
Zimbabwe	1,200	1.44%	220,000	0.89%	500,000	0.55%
World total (by Li metal)	**83,070**	100.00%	**24,855,000**	100.00%	**91,410,000**	100.00%
World total (Li-carbo. equivalent)	**440,271**		**131,731,500**		**484,473,000**	
Risky countries (by Li metal)	**15,200**	18.30%	**1,720,000**	6.92%	**29,600,000**	32.38%

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

Scalability analysis: 8.3TWh per year

Percentage of current global production to make 100 million 83kWh batteries or 8.3TWh of battery cells

Raw material used in battery	Annual global production in million tons in 2022	Price USD/kg Current prices 2023	Billion USD value of global production	Li-ion, NMC811 Nickel 80% Manganese 10% Cobalt 10%	Li-ion, NMC523 Nickel 50% Manganese 20% Cobalt 30%	Li-ion, LFP Lithium iron phosphate LiFePO4	Li-ion, LMFP Lithium, Mn iron phosphate LiMnFePO4	Li-ion, Tesla NCA variant nickel, cobalt aluminium	Na-ion Sodium-ion CATL, BYD
Lithium carbonate Li2CO3	0.6890	$32.33	$22.28	533.01%	746.22%	639.62%	487.33%	641.99%	0.00%
Sodium carbonate Na2CO3	58.0000	$0.36	$20.69	0.00%	0.00%	0.00%	0.00%	0.00%	5.56%
Cobalt Co	0.1900	$34.93	$6.64	364.69%	802.32%	0.00%	0.00%	325.38%	0.00%
Nickel Ni	3.3000	$24.45	$80.68	163.78%	117.59%	0.00%	0.00%	187.34%	0.00%
Manganese Mn	20.0900	$4.62	$92.80	3.45%	11.04%	0.00%	10.77%	0.00%	12.93%
Graphite C, for Li-ion	3.5000	$9.50	$33.25	178.18%	209.85%	261.33%	199.11%	175.51%	0.00%
Hard carbon C, for Na-ion	0.0200	$30.00	$0.60	0.00%	0.00%	0.00%	0.00%	0.00%	51968.75%
Iron Fe + Steel	1,951.0000	$0.52	$1,019.57	0.14%	0.14%	0.48%	0.25%	0.12%	0.79%
Aluminium Al	68.0000	$2.35	$159.66	6.11%	7.13%	8.97%	6.83%	6.16%	16.47%
Copper Cu	21.8400	$8.23	$179.74	12.69%	12.69%	16.50%	12.57%	11.32%	0.00%
Cost of 83kWh battery pack				**$10,312.99**	**$11,219.06**	**$11,133.43**	**$9,561.16**	**$10,707.34**	**$11,944.60**
Total battery pack cost/kWh				**$124.03**	**$134.93**	**$133.90**	**$114.99**	**$128.77**	**$143.65**
Wh/kg (cells)	**8.315 TWh**			**275.00**	**243.00**	**160.00**	**210.00**	**269.00**	**160.00**
Wh/l (cells)				**-**	**-**	**350.00**	**450.00**	**750.00**	**260.00**

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

1. **Table shows** global production in million tons of particular battery raw materials and its sales value in global commodity markets
2. Tabel also shows the percentage of global production it would take to make 100 million 83kWh battery packs or 8.3TWh
3. **Note 8.3TWh is only half of needed** to go 100% fossil free
4. **Small industries like lithium, cobalt and hard carbon (<23 billion USD)** are easier to scale than large industries like copper and nickel (>81 billion USD)
5. **Again the winner for scalability is the LMFP** battery that require the least increase in lithium production to happen 487% assuming all of it was used for making batteries

Battery cost breakdown: Current prices 2023

Cost breakdown analysis in USD for different battery chemistries

Raw materials used for 83.15 kWh battery (TLR Model Y)	Price USD/kg Current prices 2023	Price change from current	Li-ion, NMC811 Nickel 80% Manganese 10% Cobalt 10%	Li-ion, NMC523 Nickel 50% Manganese 20% Cobalt 30%	Li-ion, LFP Lithium iron phosphate LiFePO4	Li-ion, LMFP Lithium, Mn iron phosphate LiMnFePO4	Li-ion, Tesla NCA variant nickel, cobalt aluminium	Na-ion Sodium-ion CATL, BYD
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Manganese Mn	$4.62	1.00	$32.01	$102.42	$0.00	$99.98	$0.00	$120.02
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Iron Fe	$0.52	1.00	$0.00	$0.00	$29.69	$11.31	$0.00	$59.75
Aluminium Al	$2.35	1.00	$97.62	$113.89	$143.17	$109.08	$98.34	$262.96
Copper Cu	$8.23	1.00	$228.10	$228.10	$296.53	$225.93	$203.51	$0.00
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Plastics/other C,H,O, N, P, F			-	-	-	-	-	-
Total cell raw material cost			**$3,715.41**	**$4,300.16**	**$2,782.05**	**$2,208.33**	**$4,055.34**	**$3,593.22**
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Cell production cost /kWh	https://www	1.00	$50.00	$50.00	$50.00	$50.00	$50.00	$50.00
Battery packaging cost/kWh	https://abou	1.00	$29.35	$33.21	$50.44	$38.43	$30.00	$50.44
Total battery pack cost/kWh			**$124.03**	**$134.93**	**$133.90**	**$114.99**	**$128.77**	**$143.65**
Total cost of 83kWh battery	https://www.findmye		**$10,312.99**	**$11,219.06**	**$11,133.43**	**$9,561.16**	**$10,707.34**	**$11,944.60**
Battery cells weight in kg			302.4	342.2	519.7	396.0	309.1	519.7
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Wh/kg (cells)			275.00	243.00	160.00	210.00	269.00	160.00
Percentage Wh/kg relative to LMFP battery			130.95%	115.71%	76.19%	100.00%	128.10%	76.19%
Wh/l (cells)			-	-	350.00	450.00	750.00	260.00
Percentage Wh/l relative to LMFP battery					77.78%	100.00%	166.67%	57.78%

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Battery cost breakdown: Prices 2027-2032?

Cost breakdown analysis in USD for different battery chemistries

Raw materials used for 83.15 kWh battery (TLR Model Y)	Price USD/kg Likely prices 2027-2032?	Price change from current	Li-ion, NMC811 Nickel 80% Manganese 10% Cobalt 10%	Li-ion, NMC523 Nickel 50% Manganese 20% Cobalt 30%	Li-ion, LFP Lithium iron phosphate LiFePO4	Li-ion, LMFP Lithium, Mn iron phosphate LiMnFePO4	Li-ion, Tesla NCA variant nickel, cobalt aluminium	Na-ion Sodium-ion CATL, BYD
Lithium carbonate Li2CO3	$12.93	0.40	$474.97	$664.96	$569.96	$434.26	$572.08	$0.00
Sodium carbonate Na2CO3	$0.36	1.00	$0.00	$0.00	$0.00	$0.00	$0.00	$11.51
Cobalt Co	$69.86	2.00	$484.07	$1,064.96	$0.00	$0.00	$431.89	$0.00
Nickel Ni	$48.89	2.00	$2,642.60	$1,897.25	$0.00	$0.00	$3,022.70	$0.00
Manganese Mn	$4.62	1.00	$32.01	$102.42	$0.00	$99.98	$0.00	$120.02
Graphite C, for Li-ion	$11.40	1.20	$710.93	$837.32	$1,042.70	$794.44	$700.30	$0.00
Hard carbon C, for Na-ion	$15.00	0.50	$0.00	$0.00	$0.00	$0.00	$0.00	$1,559.06
Iron Fe	$0.52	1.00	$0.00	$0.00	$29.69	$11.31	$0.00	$59.75
Aluminium Al	$2.35	1.00	$97.62	$113.89	$143.17	$109.08	$98.34	$262.96
Copper Cu	$12.34	1.50	$342.15	$342.15	$444.80	$338.89	$305.27	$0.00
Steel Fe 98%, Ma 1%	$0.52	1.00	$14.48	$14.48	$18.83	$14.35	$12.40	$20.85
Plastics/other C,H,O, N, P, F			-	-	-	-	-	-
Total cell raw material cost			**$4,798.83**	**$5,037.43**	**$2,249.16**	**$1,802.31**	**$5,142.99**	**$2,034.16**
Cell raw material cost /kWh	Sources		$57.71	$60.58	$27.05	$21.68	$61.85	$24.46
Cell production cost /kWh	https://www	0.70	$35.00	$35.00	$35.00	$35.00	$35.00	$35.00
Battery packaging cost/kWh	https://abou	0.70	$20.54	$23.25	$35.31	$26.90	$21.00	$35.31
Total battery pack cost/kWh			**$113.25**	**$118.83**	**$97.36**	**$83.58**	**$117.85**	**$94.77**
Total cost of 83kWh battery	https://www.findmye		**$9,417.14**	**$9,880.66**	**$8,095.12**	**$6,949.30**	**$9,799.39**	**$7,880.12**
Battery cells weight in kg			302.4	342.2	519.7	396.0	309.1	519.7
Est battery pack weight in kg	71.45% increase		518.4	586.7	891.0	678.9	530.0	891.0
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Battery cost breakdown: Prices from 2033?

Cost breakdown analysis in USD for different battery chemistries

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Lithium carbonate Li2CO3	$4.85	0.15	$178.11	$249.36	$213.74	$162.85	$214.53	$0.00
Sodium carbonate Na2CO3	$0.36	1.00	$0.00	$0.00	$0.00	$0.00	$0.00	$11.51
Cobalt Co	$69.86	2.00	$484.07	$1,064.96	$0.00	$0.00	$431.89	$0.00
Nickel Ni	$48.89	2.00	$2,642.60	$1,897.25	$0.00	$0.00	$3,022.70	$0.00
Manganese Mn	$3.70	0.80	$25.60	$81.94	$0.00	$79.98	$0.00	$96.02
Graphite C, for Li-ion	$7.60	0.80	$473.96	$558.21	$695.13	$529.63	$466.87	$0.00
Hard carbon C, for Na-ion	$9.90	0.33	$0.00	$0.00	$0.00	$0.00	$0.00	$1,028.98
Iron Fe	$0.42	0.80	$0.00	$0.00	$23.75	$9.05	$0.00	$47.80
Aluminium Al	$1.88	0.80	$78.09	$91.11	$114.54	$87.27	$78.68	$210.37
Copper Cu	$8.23	1.00	$228.10	$228.10	$296.53	$225.93	$203.51	$0.00
Steel Fe 98%, Ma 1%	$0.42	0.80	$11.59	$11.59	$15.06	$11.48	$9.92	$16.68
Plastics/other C,H,O, N, P, F			-	-	-	-	-	-
Total cell raw material cost			**$4,122.13**	**$4,182.52**	**$1,358.76**	**$1,106.18**	**$4,428.10**	**$1,411.36**
Cell raw material cost /kWh	Sources		$49.57	$50.30	$16.34	$13.30	$53.25	$16.97
Cell production cost /kWh	https://www	0.50	$25.00	$25.00	$25.00	$25.00	$25.00	$25.00
Battery packaging cost/kWh	https://abou	0.50	$14.67	$16.60	$25.22	$19.21	$15.00	$25.22
Total battery pack cost/kWh			**$89.25**	**$91.91**	**$66.56**	**$57.52**	**$93.25**	**$67.19**
Total cost of 83kWh battery	https://www.findmye		**$7,420.91**	**$7,641.97**	**$5,534.45**	**$4,782.60**	**$7,754.10**	**$5,587.05**
Battery cells weight in kg			302.4	342.2	519.7	396.0	309.1	519.7
Est battery pack weight in kg	71.45% increase		518.4	586.7	891.0	678.9	530.0	891.0
Wh/kg (cells)			275.00	243.00	160.00	210.00	269.00	160.00
Percentage Wh/kg relative to LMFP battery			130.95%	115.71%	76.19%	100.00%	128.10%	76.19%
Wh/l (cells)			-	-	350.00	450.00	750.00	260.00
Percentage Wh/l relative to LMFP battery					77.78%	100.00%	166.67%	57.78%

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

Battery growth towards a sustainable economy

Global battery & lithium production for fully sustainable economy at 16TWh annually and 240TWh cumulatively using LMFP

Year	Battery production in TWh per year	Change in TWh	Cumulated TWh max15Y	Battery growth	Price USD/kWh LMFP pack level	Battery sales billion USD	Needed lithium carbonate tons	Li-carbonate cumulated tons	Li-carbo. in % of 2022 production	Cum. Li-carbo. in % of 2022 reserve	Price USD/kg Li carbonate	Cost in B. USD of Li carbonate
2022	0.540		0.540		$115	$62	218,057	218,057	31.65%	0.17%	$32.33	7.05
2023	0.810	0.270	1.350	50.00%	$115	$93	327,086	545,143	47.47%	0.41%	$32.33	10.58
2024	1.215	0.405	2.565	50.00%	$115	$140	490,629	1,035,771	71.21%	0.79%	$32.33	15.86
2025	1.823	0.608	4.388	50.00%	$115	$210	735,943	1,771,714	106.81%	1.34%	$32.33	23.80
2026	2.734	0.911	7.121	50.00%	$115	$314	1,103,914	2,875,629	160.22%	2.18%	$32.33	35.69
2027	4.101	1.367	11.222	50.00%	$84	$344	1,655,871	4,531,500	240.33%	3.44%	$12.93	21.42
2028	6.151	2.050	17.373	50.00%	$84	$517	2,483,807	7,015,307	360.49%	5.33%	$12.93	32.12
2029	8.611	2.460	25.984	40.00%	$84	$723	3,477,330	10,492,637	504.69%	7.97%	$12.93	44.97
2030	11.195	2.583	37.179	30.00%	$84	$940	4,520,529	15,013,166	656.10%	11.40%	$12.93	58.47
2031	13.881	2.687	51.060	24.00%	$84	$1,166	5,605,456	20,618,622	813.56%	15.65%	$12.93	72.50
2032	**16.102**	2.221	67.163	16.00%	$84	$1,353	6,502,329	27,120,951	943.73%	20.59%	$12.93	84.10
2033	16.586	0.483	83.748	3.00%	$58	$962	6,697,399	33,818,350	972.05%	25.67%	$4.85	32.48
2034	17.083	0.498	100.831	3.00%	$58	$991	6,898,321	40,716,671	1001.21%	30.91%	$4.85	33.46
2035	17.596	0.512	118.427	3.00%	$58	$1,021	7,105,270	47,821,941	1031.24%	36.30%	$4.85	34.46
2036	18.123	0.528	136.550	3.00%	$58	$1,051	7,318,428	55,140,369	1062.18%	41.86%	$4.85	35.49
2037	18.667	0.544	154.678	3.00%	$58	$1,083	7,537,981	62,460,294	1094.05%	47.41%	$4.85	36.56
2038	19.227	0.560	173.095	3.00%	$58	$1,115	7,764,121	69,897,329	1126.87%	53.06%	$4.85	37.66
2039	19.804	0.577	191.684	3.00%	$58	$1,149	7,997,044	77,403,744	1160.67%	58.76%	$4.85	38.79
2040	20.398	0.594	210.259	3.00%	$58	$1,183	8,236,956	84,904,757	1195.49%	64.45%	$4.85	39.95
2041	21.010	0.612	228.536	3.00%	$58	$1,219	8,484,064	92,284,907	1231.36%	70.06%	$4.85	41.15
2042	21.640	0.630	**246.075**	3.00%	$58	$1,255	8,738,586	99,367,622	1268.30%	75.43%	$4.85	42.38

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

Sources/attribution for previous slides

- Tesla shareholder annual meeting 2023: Source: https://www.youtube.com/watch?v=bZNL_8bUz6A&t=1655s
- 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/
- LMPF battery with 240 Wh/kg to enter mass production in 2024: https://cnevpost.com/2023/05/19/gotion-unveils-new-battery-lmfp-chemistry-range-1000-km/
- Report on battery startups with silicon anode technology with up to 500Wh/kg: https://spectrum.ieee.org/silicon-anode-battery
- The actual cost of lithium carbonate per ton is around RMB 30,000 or 4260 USD/ton: https://cnevpost.com/2023/04/03/lithium-carbonate-likely-to-fall-below-rmb-100000-says-chairman-of-farasis/
- In May 2023 Elon Musk thinks we are 3 to 6 years away from creating AGI in a large data center (so 2026 to 2029) Timestamp: 58:30: https://www.youtube.com/watch?v=PDy7s1SDDn4&t=11s
- Ray Kurtzweil has predicted decades back that AGI will happen first in a large datacenter in 2029 and we will reach the AI singularity in 2045 when intelligence will be millions of times better than human intelligence and everything becomes unpredictable. Timestamp 0 and 3:20: https://www.youtube.com/watch?v=ykY69lSpDdo&t=4s
- 70% material loss for purification of natural graphite into battery grade graphite: https://www.nature.com/articles/s41467-020-20380-0