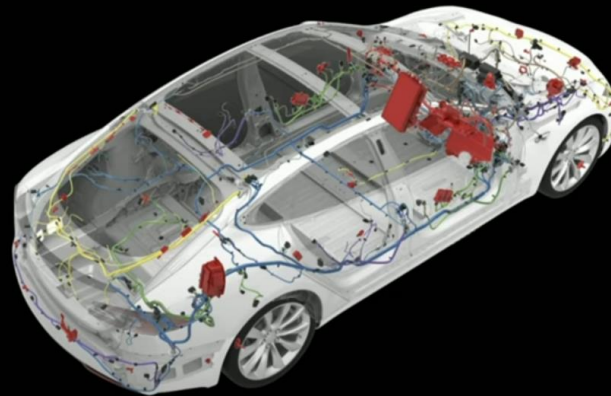
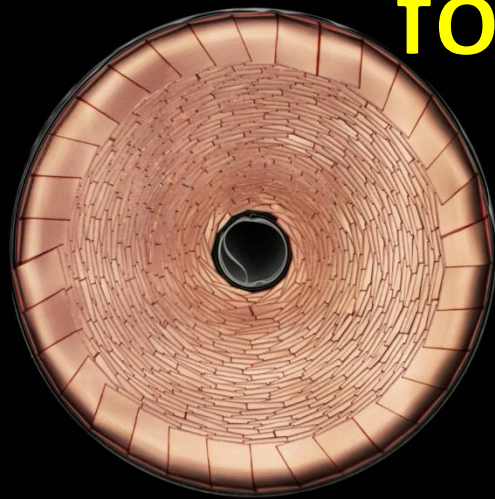


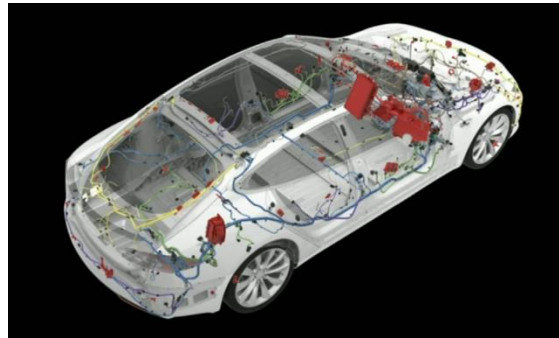
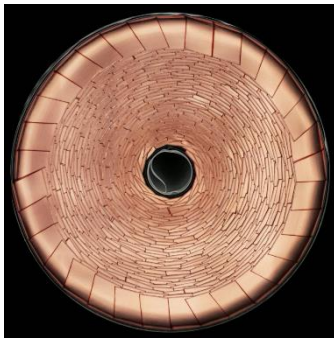
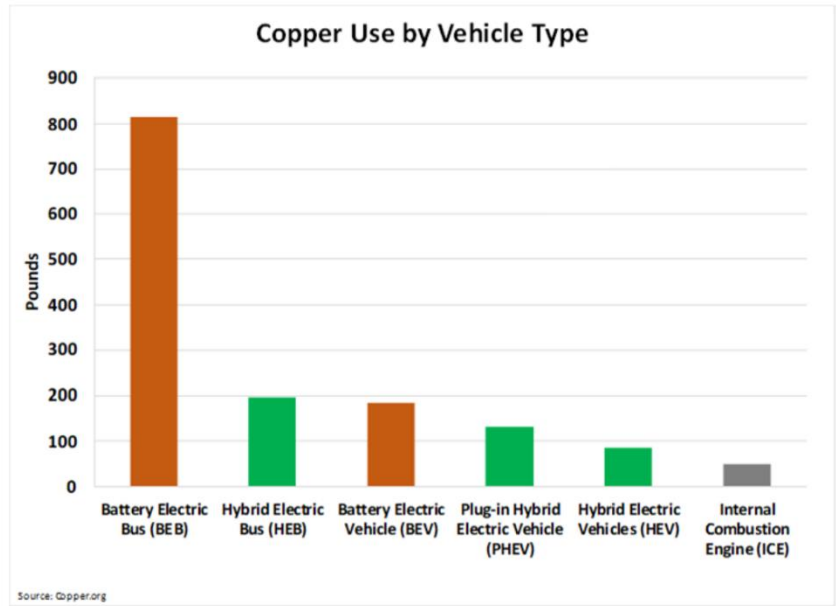
# How Tesla's next generation vehicles may nearly cut the need for copper in half #18



First published March 2023

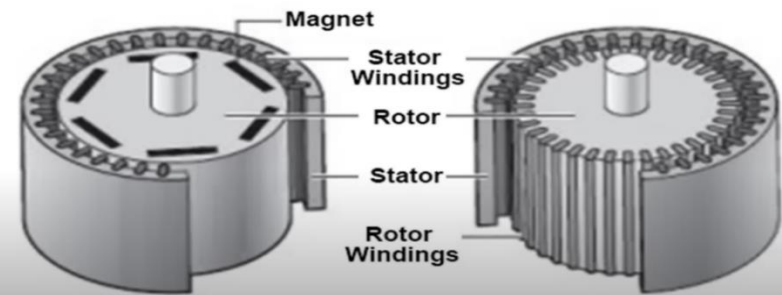
# How much copper in a typical BEV?

- ✓ I found 3 sources that are credible and that agree an average BEV in 2022 has about 90kg of copper in it
- ✓ That copper is distributed on 1) wire harness, 2) batterie and 3) electric motors
- 1. **The wire harness** of an ICE is about the same as a BEV so **23 kg of copper**, see graph
- 2. Also a **BEV battery pack** is about 8% copper and weight 530 kg (Model Y) so battery pack contain about **42 kg copper**
- 3. The remaining copper for **the PM motor** of an average single motor BEV will use **25 kg=90-23-42**
- **Two motors is likely 50 kg** and if induction is used for one motor and permanent magnet for other needed copper may be 65kg (25 + 25 + 15 rotor). In this case total copper use for all wheel drive BEV is 130 kg



Permanent Magnet

Induction



Source and attribution: <https://cambridgehouse.com/news/8707/how-evs-will-forever-change-the-copper-landscape#:~:text=Average%20ICEs%20contain%2018%2D49%20pounds%20of%20copper>

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# Why worry about copper use in BEVs?

- ✓ We need to worry about copper in BEVs because:
  1. **Copper is expensive.** 91 kg of copper cost 820 USD at current prices
  2. **Supply chain risk** issues may arise in a world that need to make 100 million BEVs per year, 43% of current production
    - If we do not expand production of copper its price will go up
  3. **Copper is a large part of vehicle weight 5.44%** and a reduction will save weight that will make vehicle more efficient
    - Also all weight reduction has a **multiplier effect significantly larger than 1** as not as much material needed for structural integrity
    - Also weight savings increase efficiency that in turn reduce size of battery pack => more weight savings

**Price of raw materials needed to make 1 fully electric vehicle if no innovation**

Material type	One average BEV in kg per vehicle	Tesla 20M BEVs in tons	Price in USD per kg	Price USD of needed material in BEV	Date of price info
Graphite (99.95% pure anode)	100.000	2,000,000	1.50	150.00	25-Mar-23
Nickel (tesla battery 78kWh)	45.000	900,000	23.30	1,048.50	25-Mar-23
Lithium carbonate or equivalent	63.000	1,260,000	40.26	2,536.30	25-Mar-23
<b>Copper (battery, motor, wires)</b>	<b>91.000</b>	<b>1,820,000</b>	<b>9.02</b>	<b>820.82</b>	<b>25-Mar-23</b>
Manganese (batteries)	1.041	20,811	4.73	4.92	25-Mar-23
Cobalt (batteries)	3.416	68,315	34.18	116.75	25-Mar-23
Rare earth (fx Nd, Pr, Dy, Tb)	0.900	18,000	103.38	93.04	25-Mar-23
Aluminum (vehicle GM Volt))	169.000	3,380,000	2.35	396.81	25-Mar-23
Crude steel (98% Fe/Iron)	1,000.000	20,000,000	0.59	594.78	25-Mar-23
Other textile and plastic	200.000	4,000,000	4.00	800.00	25-Mar-23
<b>Total vehicle weight</b>	<b>1,673.356</b>		<b>Total cost</b>	<b>6,561.92</b>	

**Raw materials needed to make 100 million fully electric vehicles per year if no innovation**

Material type	One average BEV in kg per vehicle	Tesla 20M BEVs in tons	Global 100M BEVs in tons	Global production in tons	Data year	In % of current global production
Graphite (99.95% pure anode)	100.000	2,000,000	10,000,000	3,300,000	2021	303.03%
Nickel (tesla battery 78kWh)	45.000	900,000	4,500,000	2,460,000	2019	182.93%
Lithium carbonate or equivalent	63.000	1,260,000	6,300,000	540,000	2021	1166.67%
<b>Copper (battery, motor, wires)</b>	<b>91.000</b>	<b>1,820,000</b>	<b>9,100,000</b>	<b>21,200,000</b>	<b>2021</b>	<b>42.92%</b>
Manganese (batteries)	1.041	20,811	104,055	19,000,000	2019	0.55%
Cobalt (batteries)	3.416	68,315	341,575	122,000	2019	279.98%
Rare earth (fx Nd, Pr, Dy, Tb)	0.900	18,000	90,000	300,000	2019	30.00%
Aluminum (vehicle GM Volt))	169.000	3,380,000	16,900,000	64,000,000	2019	26.41%
Crude steel (98% Fe/Iron)	1,000.000	20,000,000	100,000,000	1,951,000,000	2021	5.13%
Other textile and plastic	200.000	4,000,000				
<b>Total vehicle weight</b>	<b>1,673.356</b>					

Source and attribution: My own tables. For sources for data points follow link below video and download excel spreadsheet

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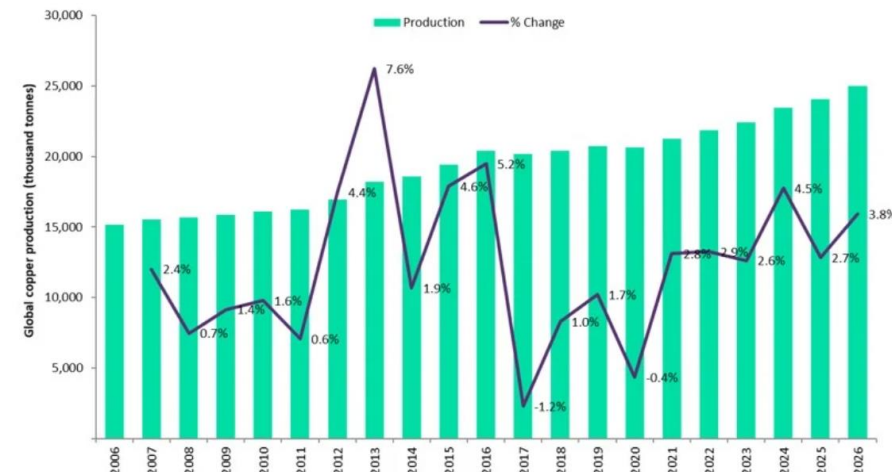
# Supply chain risks & copper price

- ✓ **Supply chain risk of copper is low** because production is spread on many countries and China and Russia only makes 12% combined
- ✓ Copper can be recycled. In fact, another 8.7 million tons is produced from scrap in addition to the 21 million tons that are mined
- ✓ Copper is regarded an early predictor of economic growth cycles
- ✓ I 2005 price increased from about 1 USD per lbs to about 3.5 USD and is unlikely to fall again
- ✓ IMO copper is more likely to go further up \$1 or \$2 in coming years
- ✓ We need more copper not just for BEVs but also charging infrastructure and wind turbines and solar power

Rank	Country	2021E Copper Production (Million tonnes)	Share
#1	Chile	5.6	27%
#2	Peru	2.2	10%
#3	China	1.8	8%
#4	DRC	1.8	8%
#5	United States	1.2	6%
#6	Australia	0.9	4%
#7	Russia	0.8	4%
#8	Zambia	0.8	4%
#9	Indonesia	0.8	4%
#10	Mexico	0.7	3%
#11	Canada	0.6	3%
#12	Kazakhstan	0.5	2%
#13	Poland	0.4	2%
	Other countries	2.8	13%
	World total	21.0	100%



Global copper production (thousand tonnes), 2006–2026

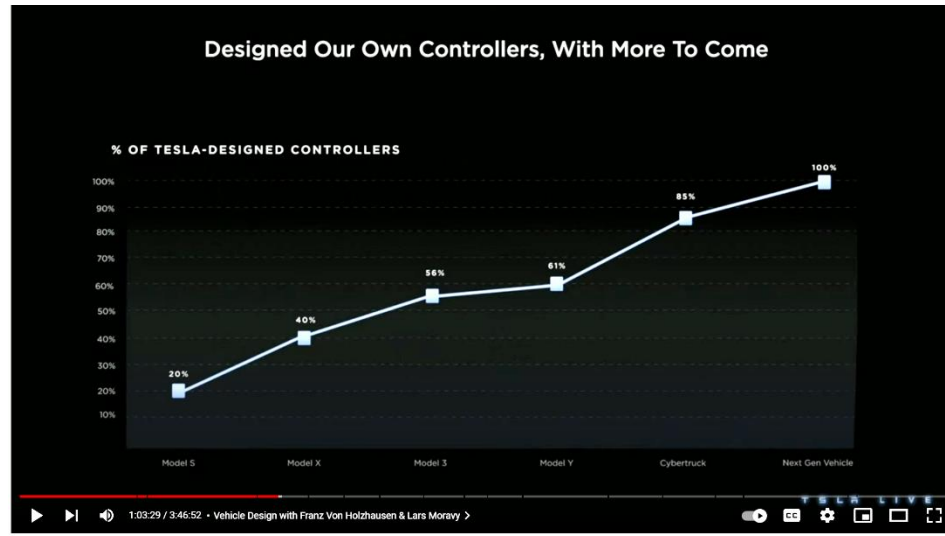
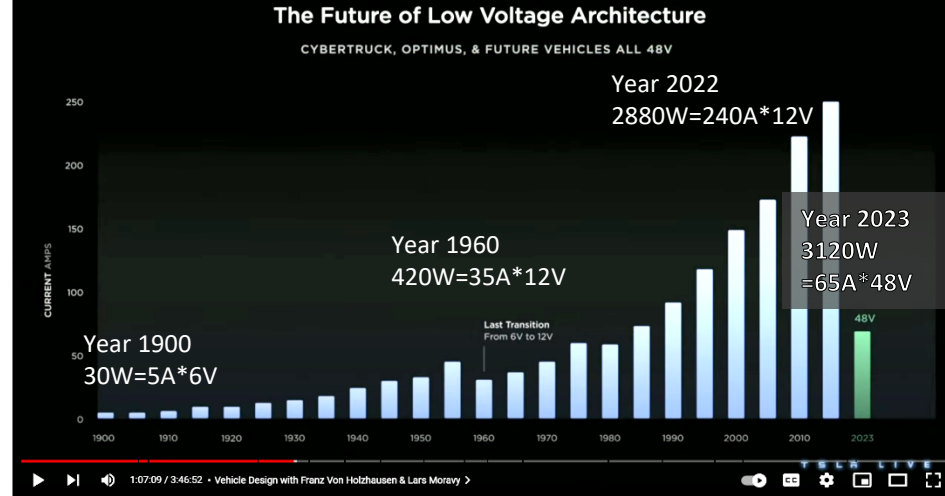


Source and attribution: <https://www.mining-technology.com/comment/global-copper-output-grow/>



# Copper reduction: Wire harness

- ✓ At Investor Day 2023 Tesla announced they will replace the 12V system with an 48V system that also integrates data communication on the same wire harness
- ✓ The shift could decrease need for copper in wire harness by 75% because  $48V/12V=4$  if done 100%
- ✓ So from **23kg of copper in average BEV to 5.75kg!**
- ✓ The slide (right) suggest it will happen in 2023
- ✓ If 48V begins in 2023, it is most likely limited to Cybertruck that will begin sales in 2023
- ✓ I speculate Cybertruck will be running 48V on 85% of units that have Tesla controllers and remaining 15% will 1) either still need 12V and old com bus or 2) Tesla has build an adapter that converts from 48V to 12V and also converts communication or 3) Tesla supplier can deliver electric unit that is 48V
- ✓ Tesla's next gen vehicle (the one they build in Mexico) should be first 100% 48V power and communication wire harness where all controllers are build and programmed in-house

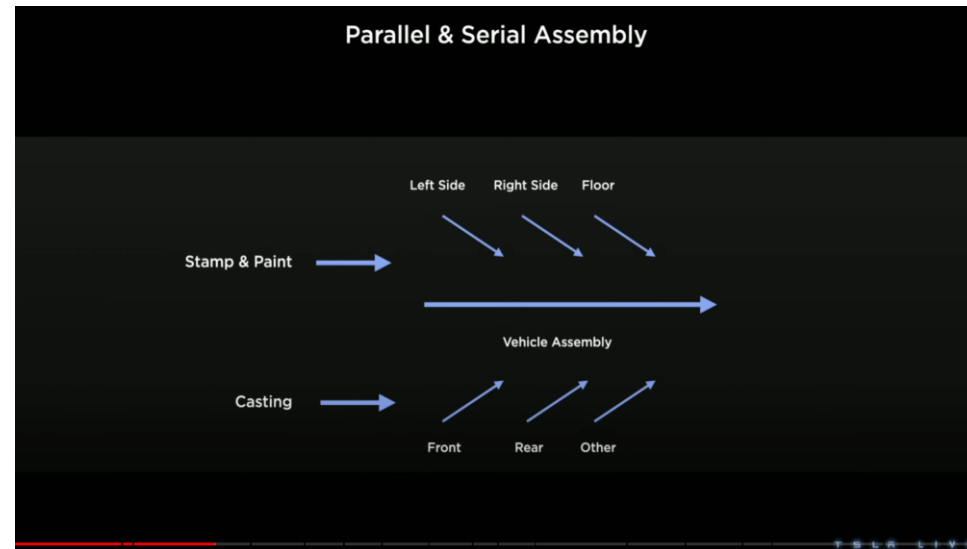
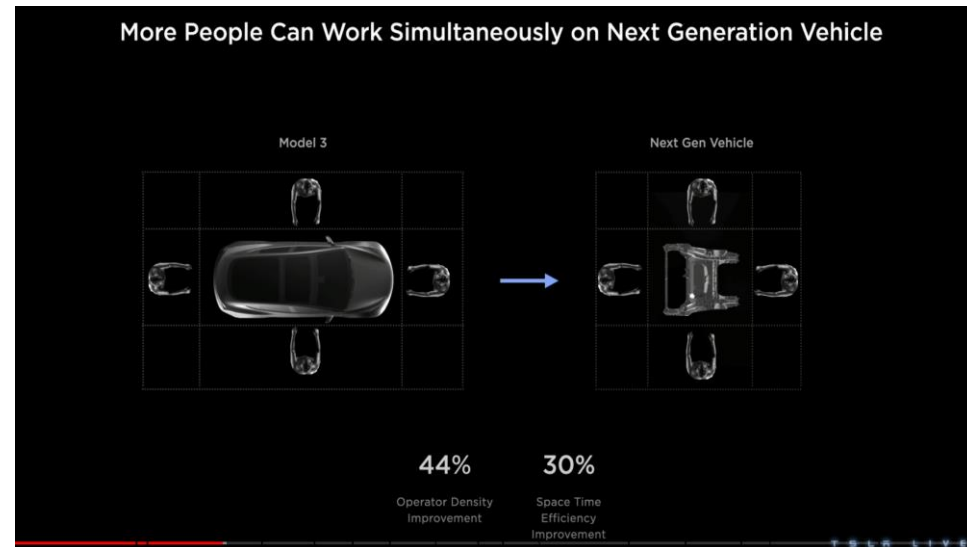


Source and attribution: <https://www.youtube.com/watch?v=Hl1zEzVUV7w&t=2982s>



# Copper reduction: Wire harness with aluminum

- ✓ IMO Tesla could make further copper reduction possible by also replacing some but not all copper wires with aluminum wires
- ✓ Two reasons this substitution is possible:
  1. **The much thinner wires that 48V enables will make aluminum wires more flexible** thus making them more likely to be able to replace copper
  2. **The other reason** is that Tesla's next generation assembling system also presented at Investor Day 2023 will allow **much better access to install the wire harness** thus **further decreasing the need for flexible copper wires**
- ✓ Best way to understand this is to see how Tesla presented the current way of making vehicles (invented by Henry Ford in 1920 but still used by everyone), see top video
- ✓ And also see how Tesla will assemble their next generation vehicle, see bottom video
- ✓ **So 48V could cut copper in wire harness from 23 kg to 5.75 kg and new assembling method IMO could make further cuts to perhaps 3 kg**

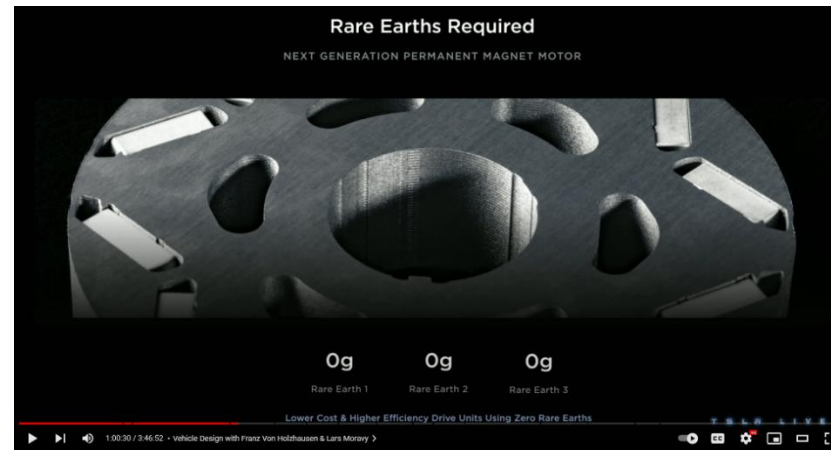
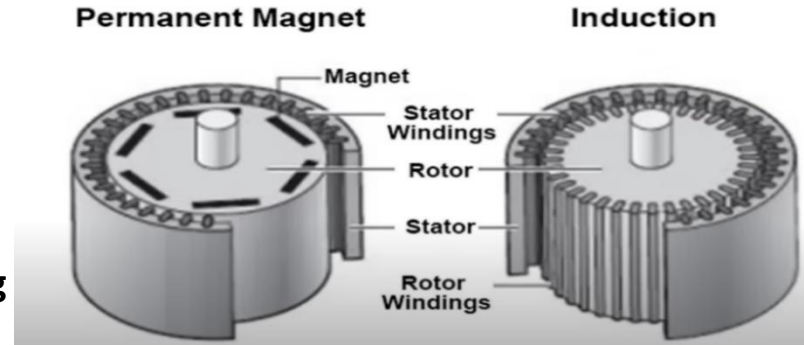


Source and attribution: <https://www.youtube.com/watch?v=Hl1zEzVUV7w&t=2982s>



# Copper reduction: Motors

- ✓ Tesla's current AWD M3 and MY likely use 65 kg of copper in their two electric motors of which 25 kg is for the permanent magnet motor and 40 kg is for the induction motor that likely needs 15 kg more copper for its rotor
- ✓ However, Tesla **could replace the induction motor** with another permanent magnet motor and **thus save the 15 kg of copper likely used in rotor**
- ✓ At Investor Day 2023 Tesla announced they have developed a more efficient permanent magnet motor that only cost 1000 USD and no rare earth
- ✓ This is a big deal because cost seems to have been cut 50% from Tesla's current M3 208kW motor and no rare earth elements implies that huge supply chain risks have been eliminated
- ✓ I made a video specifically about that #17
- ✓ IMO it is obvious that Tesla will use that new permanent magnet motor to replace their induction motors because it only cost 1000 USD and no longer use rare earth elements
- ✓ The only argument for keeping the induction motor is to have higher efficiency at high power use but I think it will be marginal and not enough to save the induction motor



Source and attribution: <https://www.youtube.com/watch?v=Hl1zEzVUV7w&t=2982s>

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# Copper reduction: Wire harness motors & batteries

- ✓ No mention of 900V motors at Investor Day 2023 but Tesla will make the switch for sure (or 800V to 1200V)
- ✓ Tesla going from 400V to 900V could reduce copper in its motors by 56% =  $(1 - 400/900)$
- ✓ 900V charging power could also reduce charging time by a lot and enable fast charging for large vehicles
- ✓ Copper use in batteries will not change much because copper is an efficient current and thermal conductor

## ✓ Conclusions:

1. IMO copper is not a potential show stopper for BEV transition
2. Copper also has no supply chain risks as supply is spread globally

Raw materials needed to make 100 million fully electric vehicles per year if no innovation

Material type	One average BEV in kg per vehicle	Tesla 20M BEVs in tons	Global 100M BEVs in tons	Global production in tons	Data year	In % of current global production
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Crude steel (98% Fe/iron)	1,000.000	20,000,000	100,000,000	1,951,000,000	2021	5.13%
Other textile and plastic	200.000	4,000,000				
<b>Total vehicle weight</b>	<b>1,673.356</b>					

Copper use in typical battery electric vehicle current and next generation

Where copper is used (new technology applied)	Rear wheel drive vehicles (one motor)		All wheel drive vehicles (two motors)	
	Current Model 3/Y like BEV	Next gen Model 3/Y like BEV	Current Model 3/Y like BEV	Next gen Model 3/Y like BEV
Wire harness copper in kg	23	3	23	3
Wire harness tech	12V copper wires	48V, partial aluminium wires	12V copper wires	48V, partial aluminium wires
Rear motor copper in kg	25	11	25	11
Rear motor tech	400V permanent magnet	900V PM no rare earth	400V permanent magnet	900V PM no rare earth
Front motor copper in kg	-	-	40	11
Front motor tech	-	-	400V induction motor	900V PM no rare earth
Battery pack copper in kg	42	42	42	42
<b>Total copper use in kg</b>	<b>90</b>	<b>56</b>	<b>130</b>	<b>67</b>
<b>Reduction in percentage</b>		<b>37.65%</b>		<b>48.29%</b>





# Sources/attribution for previous slides

- **Tesla 2023 Investor Day, Powertrain technologies 52:40:** <https://www.youtube.com/watch?v=Hl1zEzVUV7w&t=2982s>
- **Global copper production 2006 to 2026:** <https://www.mining-technology.com/comment/global-copper-output-grow/>
- **All the mines Tesla needs to build 20 million cars a year:** <https://www.mining.com/all-the-mines-tesla-needs-to-build-20-million-cars-a-year/>
- **90 kg of copper in a BEV:** <https://www.mining.com/all-the-mines-tesla-needs-to-build-20-million-cars-a-year/> and <https://www.grandviewresearch.com/industry-analysis/copper-electric-vehicle-market-report> and <https://cambridgehouse.com/news/8707/how-evs-will-forever-change-the-copper-landscape#:~:text=Average%20ICEs%20contain%2018%2D49%20pounds%20of%20copper.>
- **A battery contain 8% copper:** <https://cambridgehouse.com/news/8707/how-evs-will-forever-change-the-copper-landscape#:~:text=Average%20ICEs%20contain%2018%2D49%20pounds%20of%20copper>
- **Weight of battery pack in Tesla Model Y is 530 kg:** <https://www.uetechologies.com/how-much-does-a-tesla-battery-weigh/>
- **Largest producers of copper globally:** <https://www.visualcapitalist.com/visualizing-the-worlds-largest-copper-producers/>
- **8.7 million tons of copper is produced each year from scrap/recycling 2018:** [https://copperalliance.org/resource/copper-recycling/#:~:text=Currently%2C%20a%20total%20of%20around,production%20and%20downstream%20manufacturing%20processes\).](https://copperalliance.org/resource/copper-recycling/#:~:text=Currently%2C%20a%20total%20of%20around,production%20and%20downstream%20manufacturing%20processes).)
- **208 kW (279 hp) for Tesla Model 3 rear end motor:** [https://en.wikipedia.org/wiki/Tesla\\_Model\\_3#Specifications\\_table](https://en.wikipedia.org/wiki/Tesla_Model_3#Specifications_table)
- **78.1 kWh in a Tesla model Y battery pack:** <https://ev-database.org/car/1619/Tesla-Model-Y-Long-Range-Dual-Motor>
- **Porsche Taycan, Audi e-tron GT, only the Lucid Air, Hyundai Ioniq 5, and the Kia EV6 use the 800-volt architecture:** <https://www.autoevolution.com/news/if-800-volt-architecture-is-the-holy-grail-of-evs-why-do-so-few-carmakers-use-it-186005.html>
- **“How many volts does a Tesla battery have?”, it’s 350V for the Model 3 and Model X, 375V for the Model S and 400V for the Model Y:** <https://www.carsguide.com.au/ev/advice/400v-vs-800v-whats-the-difference-electric-car-battery-voltage-explained-88101>

