Inconvenient truth about Li-ion battery (LIB) electric cars

Prof. Dr. inz. Robert A. Varin
Professor Emeritus of Materials Science&Engineering, Department of Mechanical&Mechatronics Engineering, University of Waterloo

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Reasons for implementing electric cars:

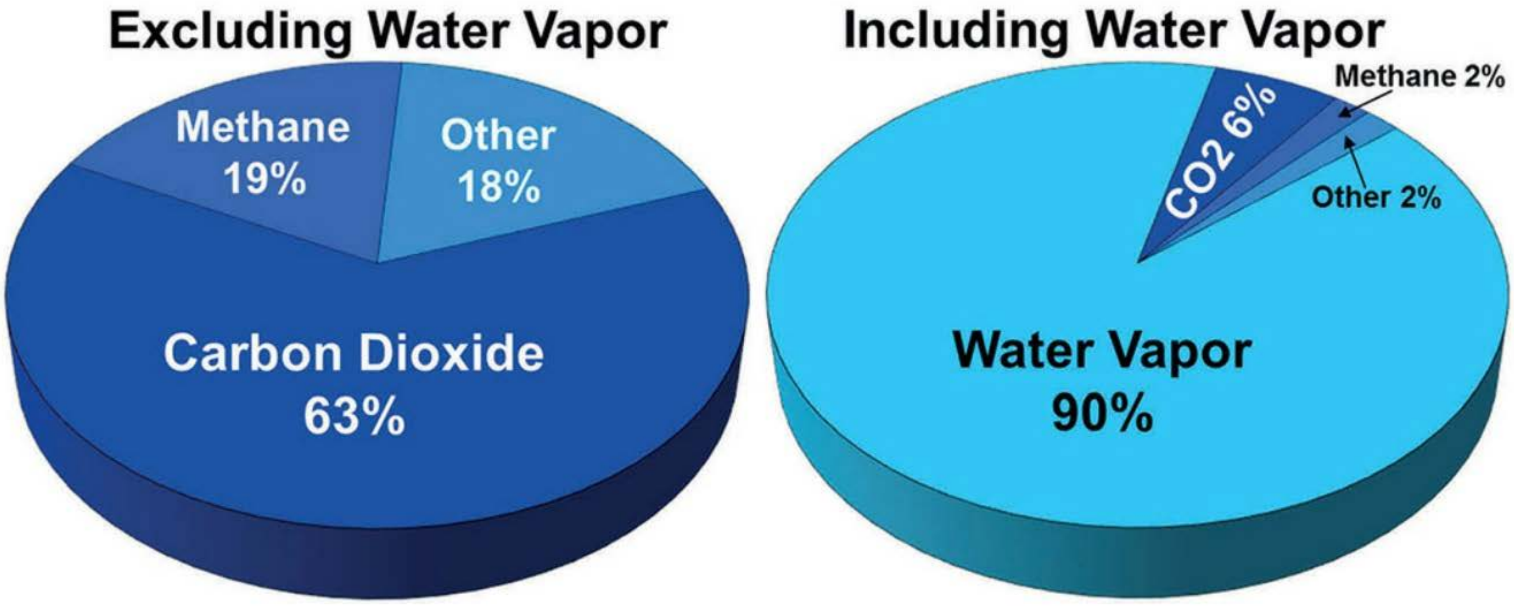
(i) Primary: elimination of so-called "greenhouse gas" CO_2, that supposedly increases Earth temperature and leads to "climate change" (whatever it means! -there is no agreeable scientific evidence how much increment in temperature is due to CO_2) (I presented it on Nov.4/2019).

(ii) Secondary: reduction of obnoxious exhaust gases (NO_x etc.) that may cause some respiratory problems.

(iii) A number of jurisdiction like European Union, California etc legislated stopping production of IC gasoline engine cars by 2030-2035.

Reminder from my presentation on Nov. 4/2019 - 1

CO_2 is not the primary greenhouse gas

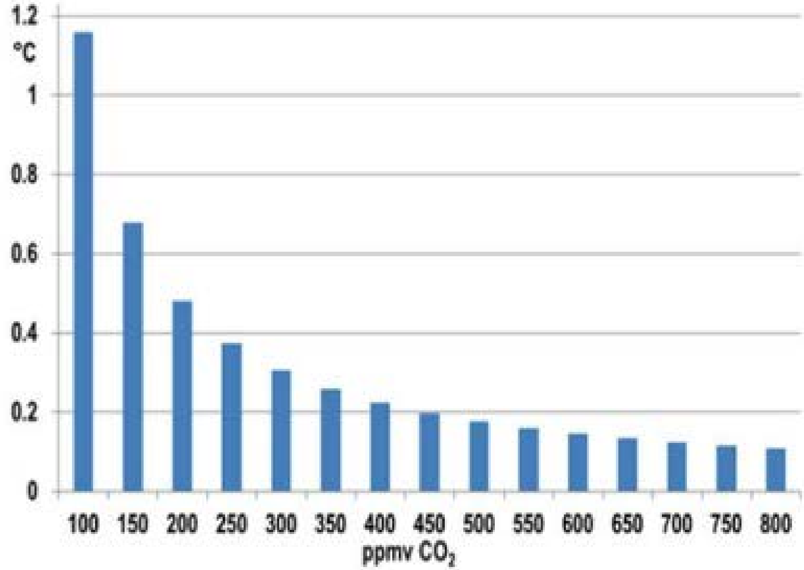


(GHG Data source: CDIAC 2016, water vapor effect: Robinson 2012)

Reminder from my presentation on Nov. 4/2019 - 2

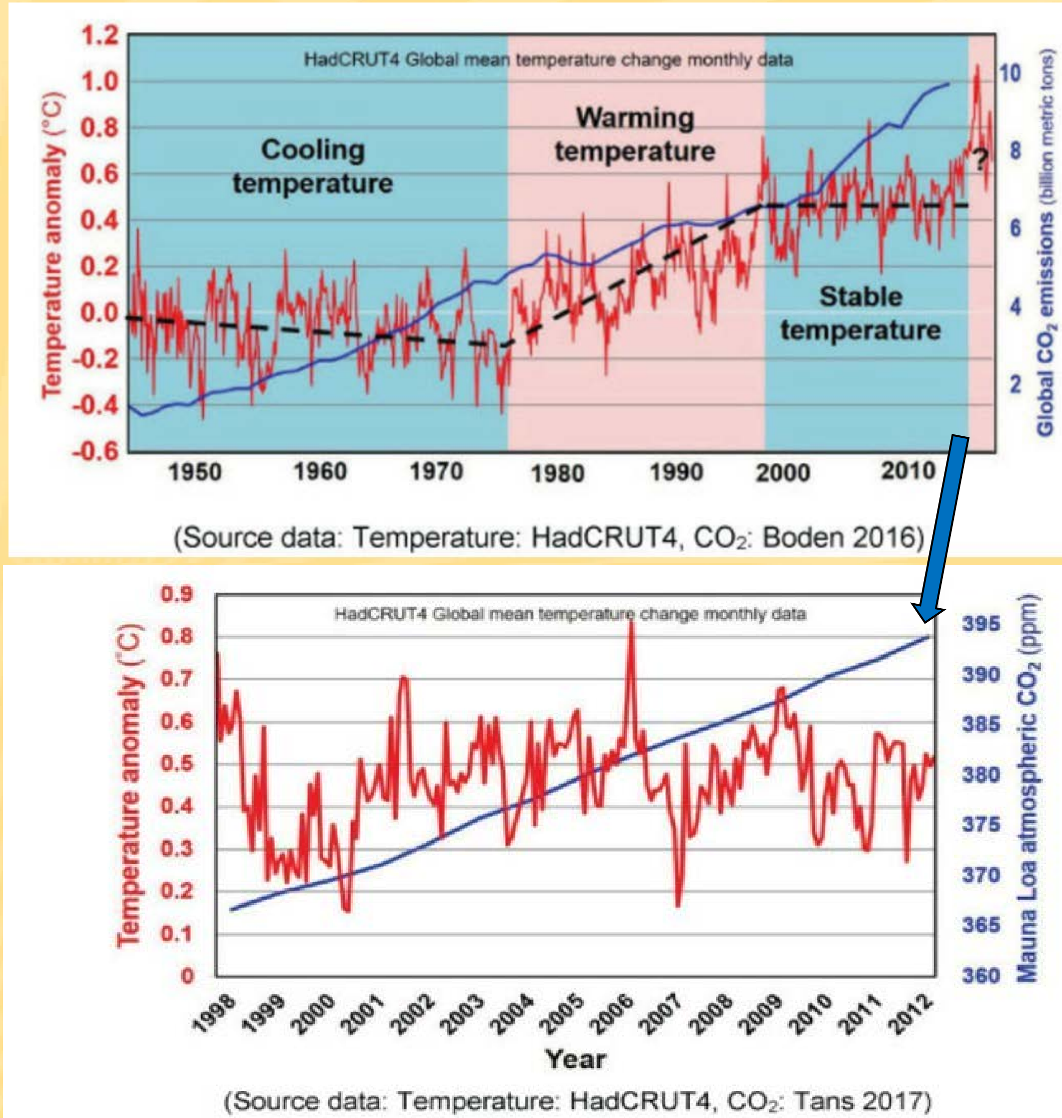
The warming effect of CO_2 declines as it concentration increases

Figure I-3: Less global warming for each additional 50 parts-per-million-by-volume of CO2 concentration



(Graph calculated using IPCC's formula $\Delta T_0 = \frac{5.35}{3.2} \ln \frac{C}{C_0}$;AR3, Ch. 6.1. Courtesy Monckton 2017)

Reminder from my presentation on Nov. 4/2019 - 3



Reminder from my presentation on Nov. 4/2019 - 4

Climate Apocalypse Myths-forest fires and tornadoes

Figure II-10: Global burned area by decade

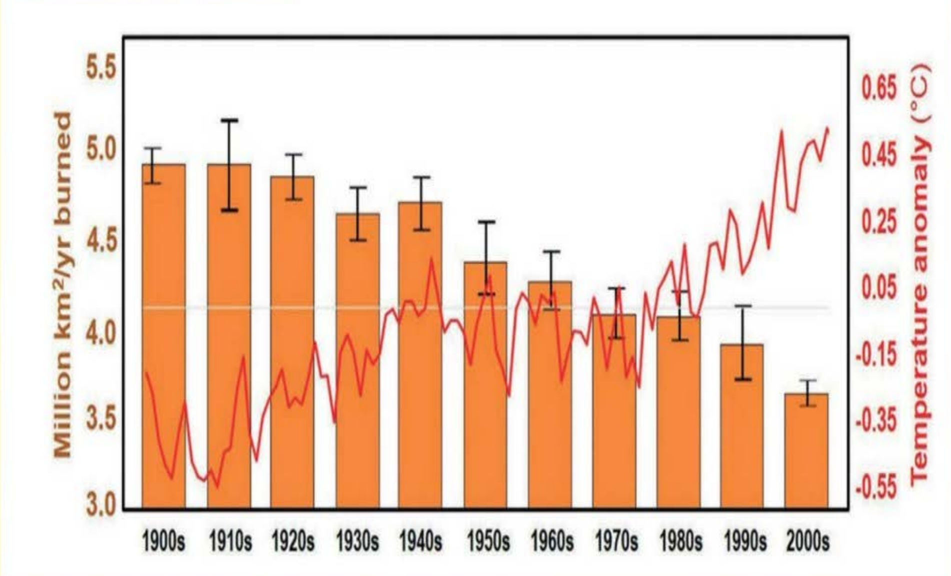
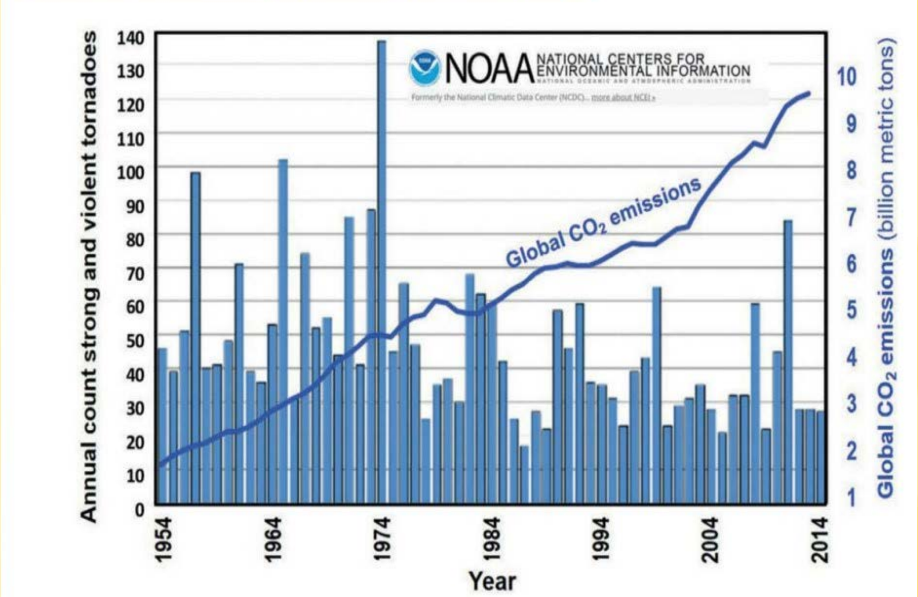
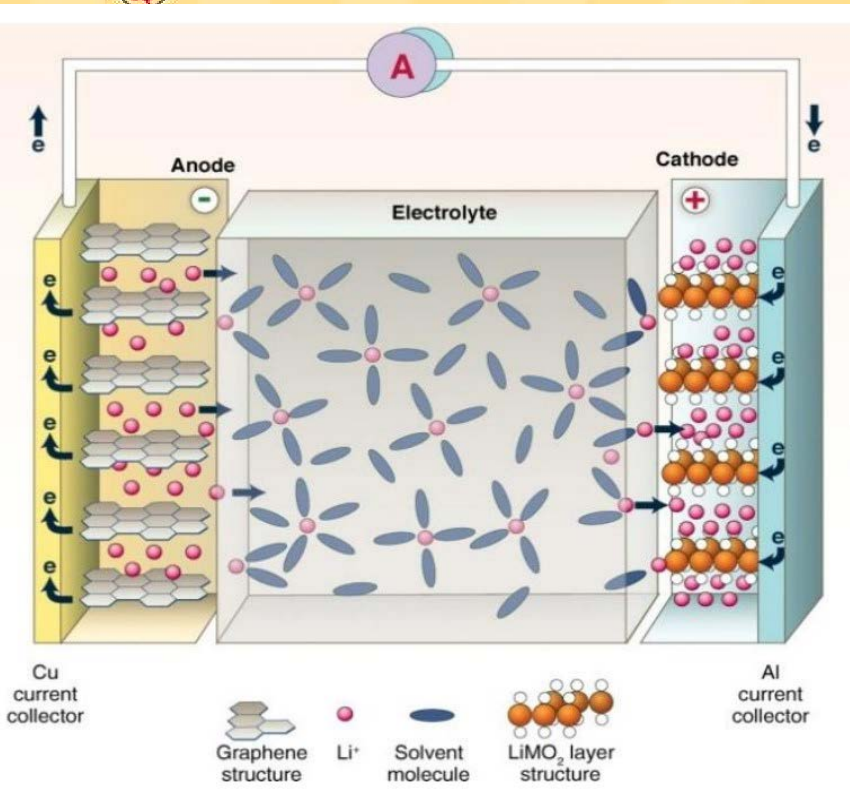


Figure II-27: Severe tornadoes (F 3+) are less frequent than 50 years ago.



How does a Li-ion battery work?



Xiaochao Wu-PhD Thesis, RWTH Aachen University, 2019

Anode: Li intercalated graphite (C_6)
Cathode: $LiCoO_2$

Electrolyte is flammable!
(lithium hexafluorophosphate (LiPF6))

Anode reaction discharging (charging): Li_xC_6 >< C_6+xLi^+
Cathode reaction discharging: $Li_{1-x}CoO_2$ + xLi^+ + xe^- >< $LiCoO_2$ + HEAT! (charging is opposite)

Practical energy densities of various cathode materials - summary

(https://www.fluxpower.com/blog/what-is-the-energy-density-of-a-lithium-ion-battery#:~:text=High%20Energy%2C%20High%20Risk%3A%20Lithium,150%2D200%20Wh%2Fkg).

Li-ion battery type	Energy density (Wh/kg)	Pros	Cons
Lithium Cobalt Oxide (LCO)	150-200	**High energy density**	**Volatile and expensive (used for Ev's)**
Lithium **Nickel Manganese Cobalt Oxide** (NMC)	150-200	**High energy density**	Safer than LCO but **still relatively unstable and expensive (used for EV's)**
Lithium **Iron Phosphate** (**LFP**)	90-160	Medium-high energy density	Stable, long lasting (**forklifts**)
Lithium **Titanate** (**LTO**)	50-80	Long life, stable	Low energy density, more expensive

Co can be substituted by Fe, Ni and Mn but the energy density is LOWER.

Tesla battery cell chemistry

https://insideevs.com/news/587455/batteries-tesla-using-electric-cars/#:~:text=Battery%20cell%20chemistry,%2Dcobalt%2Daluminum%20(NCA)

The three main cathode types in Tesla EVs:

- **Li-nickel-cobalt-aluminum oxide (NCA)(energy density 250-300 Wh/kg)**
- **Li-nickel-manganese-cobalt (NMC)**
- **Li-iron phosphate (LFP)**

The two first - NCA and NCM - have a high energy density, which predisposes them to use in long-range versions of Tesla cars. (Remember energy density=driving range!)

The LFP is a less energy-dense type. It does not contain any nickel or cobalt, which makes it less expensive. It's a perfect fit for entry-level models.

Availability of important chemical elements

All cathodes contain Li (lithium) and those with the highest energy densities also contain Co (cobalt).
How much Li reserves in the world (https://www.nsenergybusiness.com/features/six-largest-lithium-reserves-world):

1. ***Argentina - 17 mln tons***
2. ***Chile - 9 mln tons***
3. ***US – 6.8 mln tons***
4. ***Australia – 6.3 mln tons***
5. ***China – 4.5 mln tons***

Total 5 countries– about 44 mln tons; total in Earth about 88 mln tons (but a large quantity inaccessible for mining) (https://www.popularmechanics.com/science/energy/a42417327/lithium-supply-batteries-electric-vehicles/

Li mining is very detrimental to the environment!

As electric cars are built, will Li run out?

(https://www.motorbiscuit.com/will-lithium-run-out/)

Forbes estimated that if 50% cars in 2030 would be EV's then 2,700GWh/year would be needed. (https://www.forbes.com/sites/danrunkevicius/2020/12/07/as-tesla-booms-lithium-is-running-out/?sh=25da0ee71a44)

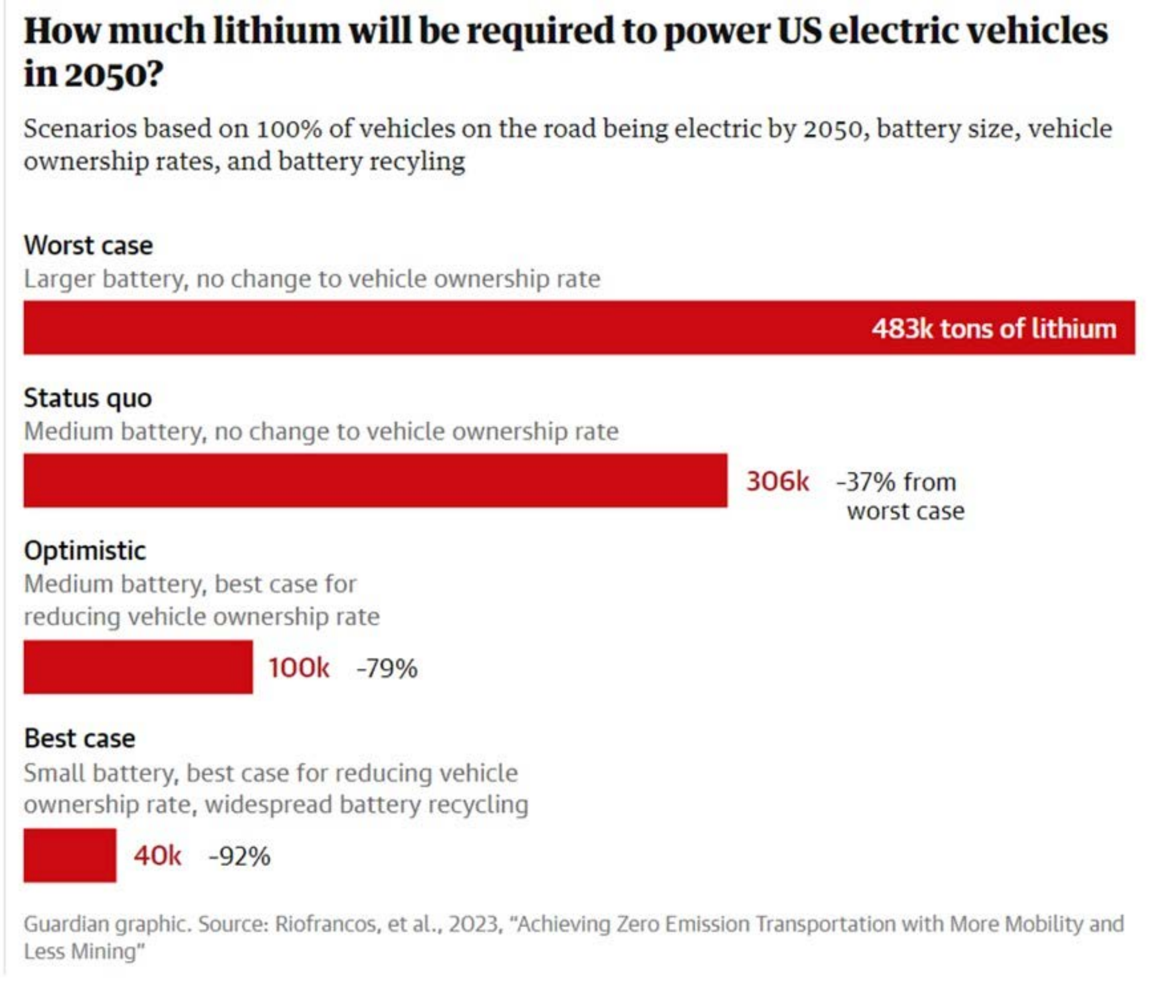
Now, let's do some math: a typical lithium ion battery can store 150 watts per kilogram. Convert 2,700GWh to watts, then divide that by 150 to get the total kilograms of lithium needed. The answer? 18 billion kilograms, or 20 million tons. Now, take those numbers with a grain of salt, that's just some paper-napkin math. Some batteries may make more watts per kilogram, and some may make less. But here's where things start to get dicey: The approximate amount of Li reserves is about 44 million tons. Even doubling this amount with improved mining of Li means we'll run out eventually, but we're not sure when. Some say it could be as soon as 2040, assuming electric cars demand 20 million tons of lithium by then.

How about Li prices that would skyrocket with increasing demand? The EV prices could go through the roof!

EVs will keep using lithium until it's run dry. Then what?

How to reduce Li consumption: the US example

https://www.theguardian.com/us-news/2023/jan/24/us-electric-vehicles-lithium-consequences-research



The largest reduction will come from changing the way we get around towns and cities – fewer cars, more walking, cycling and public transit made possible by denser cities – followed by downsizing vehicles and recycling batteries.

Ditto: NO CAR OWNERSHIP!

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US attempts to get more Li

ENERGY.GOV

Office of
ENERGY EFFICIENCY & RENEWABLE ENERGY

EERE News

September 18, 2023

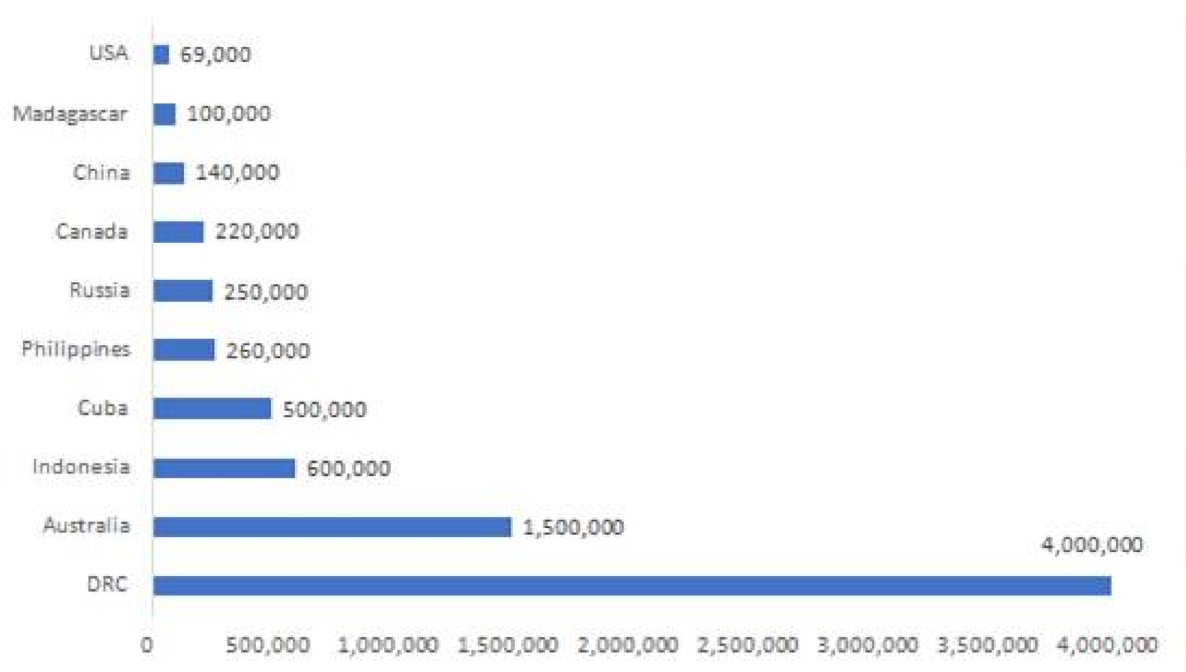
DOE Awards $2 Million for Innovations to Source Domestic Lithium from Geothermal Brines

Solutions Will Advance Cost-Effective Methods for the United States to Secure an Abundant Domestic Lithium Resource

The U.S. Department of Energy (DOE) today announced the winners of its first-ever **American-Made Geothermal Lithium Extraction Prize**. Three teams will split a total of $2 million for prototyped innovations to directly extract lithium from the hot water used to produce geothermal energy, known as geothermal brines. Lithium is a crucial element in the clean energy supply chain, but the United States currently imports about 99% of its lithium supply. Work under the prize helps support access to cost-effective, domestic sources of this critical mineral for batteries for stationary storage and electric vehicles—crucial to meet the Biden-Harris Administration's goals of 50% electric vehicle adoption by 2030 and a net-zero emissions economy by 2050. Advancing geothermal lithium extraction will also help ensure American leadership in the clean energy future and create U.S. jobs and a strong

What about Co?

According to the U.S. Geological Survey (USGS), the total global mine cobalt reserves amounted to 8,300,000 tonnes in 2022, which is 9% higher than 7,600,000 tonnes reported in 2021 (https://www.kitco.com/news/2023-02-07/The-world-s-largest-cobalt-reserves-by-country-in-2022.html).



The largest reserves are in the Democratic Republic of Congo (DRC) - they use child labor to extract cobalt.

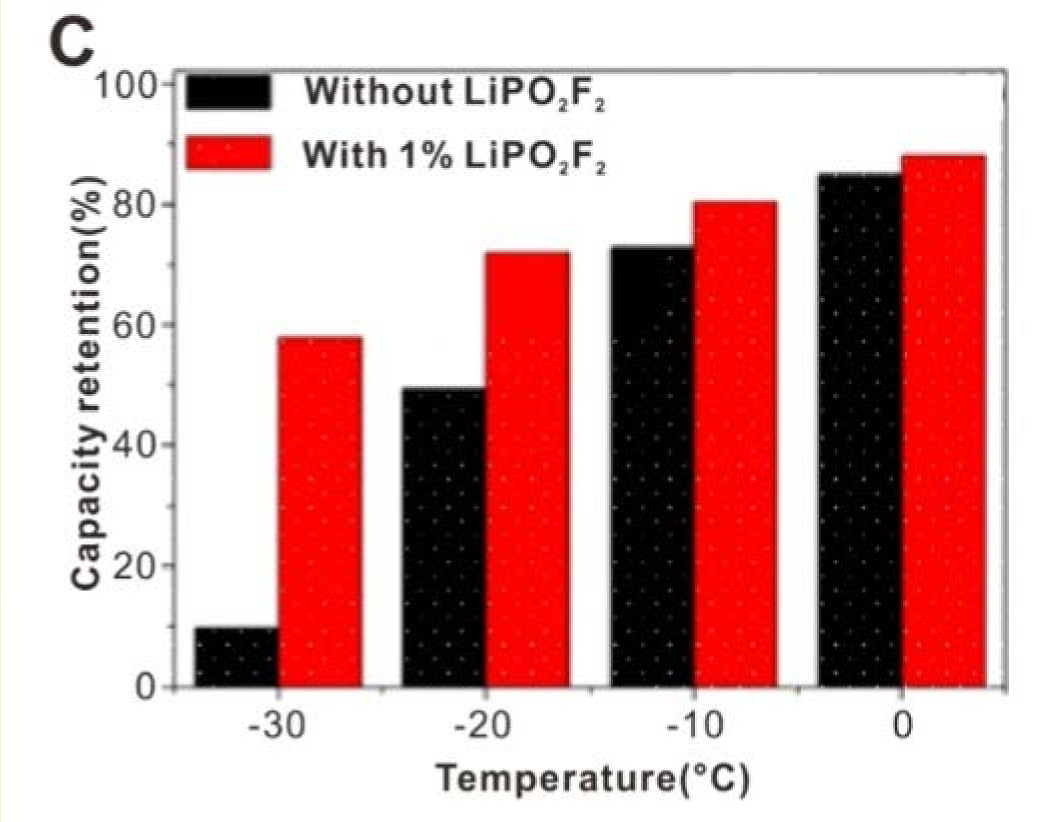
How long would Co reserves last?

Co mining in DRC

Forced child labor at a cobalt mine in the Democratic Republic of the Congo. Credit: Minding Hearts.

The effects of low temperature on Li-ion cathodes

Ma et al, Progress in Natural Science: Materials International 28(2018)653-666.

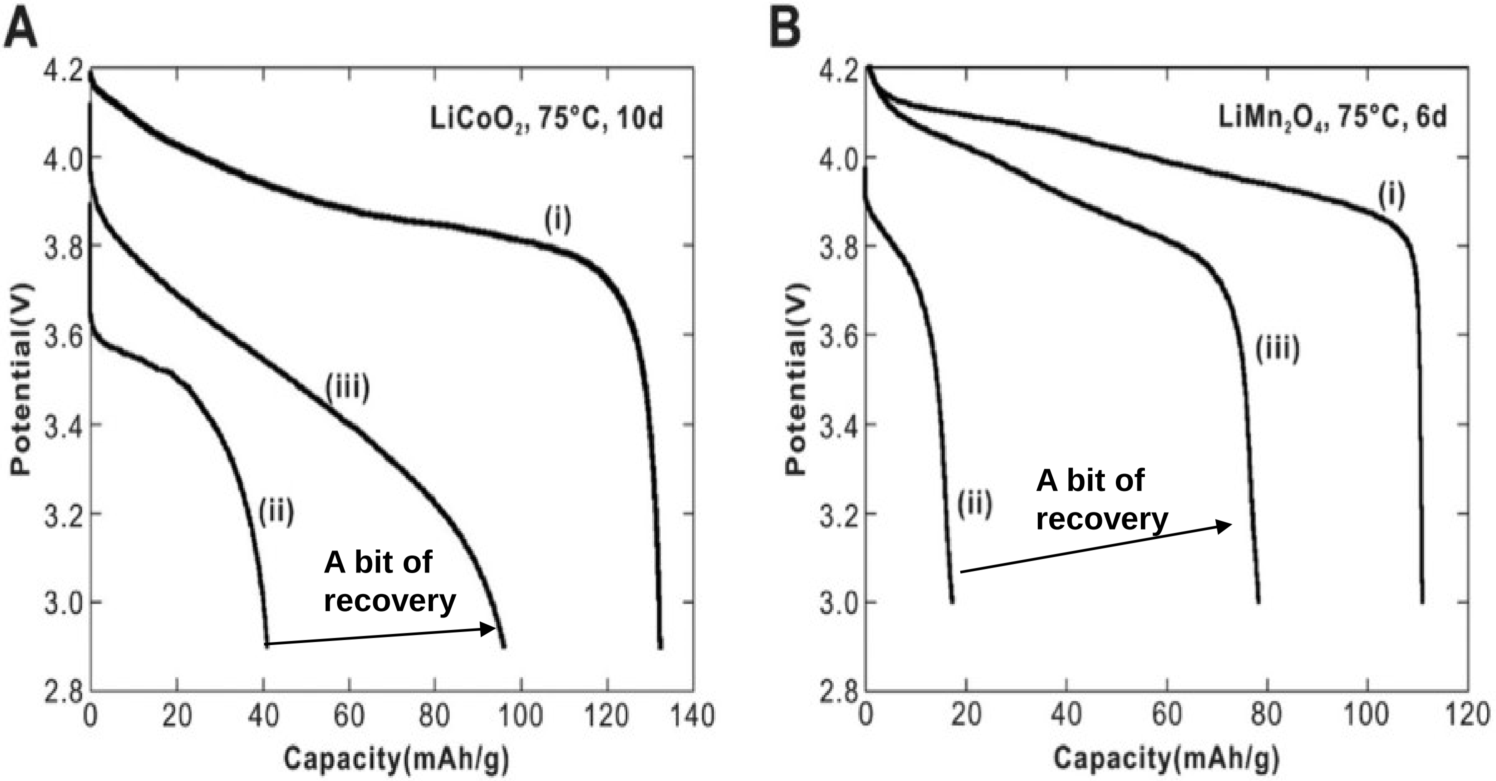


Low temperature effect: (C) The effect of using $LiPO_2F_2$ as the additive to the electrolyte on the capacity retention at different temperatures.

Every additive complicates battery in production and increases its cost!

The effects of high temperature on Li-ion cathodes

High temperature on cathodes: (i) Discharge curves of batteries with (A) $LiCoO_2$ and (B) $LiMn_2O_4$ cathodes before and after aging at 75°C for 10 days and 6 days, respectively, (i) after the 5th cycle before aging, (ii) after the 1st cycle after aging, (iii) after the 5th cycle after aging (Gabrisch et al. Electrochimica Acta 52 (2006) 1499–1506)



Useful life of a EV Li-ion battery

Two important factors:

(i) **The average decline in energy storage is 2.3% per year.** (https://electrek.co/2019/12/14/8-lessons-about-ev-battery-health-from-6300-electric-cars/)

(ii) **When an electric car battery's performance drops to 70% or less, it must be removed from an EV** (https://www.nationalgrid.com/stories/journey-to-net-zero-stories/what-happens-old-electric-car-batteries)

(iii) **Ditto: the useful life of an EV battery is approx. 30%/2.3%/year=13 years (plus minus). In practical terms, the battery life is within 8-10 years.**

What to do with still useful batteries (about 70% or less capacity)?

(i) Use in other capacities e.g. back up power

(ii) Recycle - battery recycling market is in its infancy

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Price of EV's (history)

In the U.S., the first successful electric car made its debut around 1890 thanks to William Morrison, a chemist who lived in Des Moines, Iowa. By 1900, electric cars were at their heyday, accounting for around a third of all vehicles on the road. During the next 10 years, they continued to show strong sales.

It was Henry Ford's mass-produced Model T that dealt a blow to the electric car. Introduced in 1908, the Model T made gasoline-powered cars widely available and affordable. By 1912, the gasoline car cost only $650, while an electric roadster sold for $1,750. That same year, Charles Kettering introduced the electric starter, eliminating the need for the hand crank and giving rise to more gasoline-powered vehicle sales.

(https://www.energy.gov/articles/history-electric-car#:~:text=Here%20in%20the%20U.S.%2C%20the,lived%20in%20Des%20Moines%2C%20Iowa).

Prices of EV's in C$ (Autotrader 2023)

2023 Tesla Model Y Long Range AWD | 3,801 km | Georgetown |$70,950+TAXES & LICENSING

2022 Tesla Model 3 Base 17,115 km | North York | $49,021+TAXES & LICENSING

2018 Tesla Model 3 Long Range RWD | 62,150 km | Georgetown | $37,950+TAXES & LICENSING

2023 Kia Niro EV Limited, 25 km | Mississauga $56,824+TAXES & LICENSING

2020 Kia Niro EV SX Touring EV 85,825 km | Guelph |$35,995+TAXES & LICENSING

Gasoline:

2024 Toyota Camry SE Auto 0 km | London $36,089+TAXES & LICENSING

2024 Toyota Camry Hybrid SE, 50 km | Bolton $38,612+TAXES & LICENSING

2023 Nissan Murano Platinum TOP OF THE LINE 3.5l, 14,091 km | Waterloo |$47,950+TAXES &LICENSING

Cheapest new EV’s in Canada

- https://www.cargurus.ca/Cars/articles/cheapest-electric-cars-canada

- **Chevrolet Bolt EV and Bolt EUV: $38,548/$40,548**
- **Nissan Leaf $40,248**
- **Mazda MX-30: $42,150** **+HST**
- **Kia Soul EV: $42,995**
- **Volkswagen ID.4: $43,995**
- **Hyundai Kona Electric: $44,399**

Driving range of Tesla EV cars

https://insideevs.com/reviews/344001/compare-evs/ - from July 7/2022

2022 Tesla Model 3 Long Range 19" AWD - 358 miles (576 km)
2022 Tesla Model S Long Range 19" AWD - 405 miles (652 km)
2022 Tesla Model 3 19" RWD- 267 miles (430 km)

For comparison:
2014 Toyota Camry 2.5L FWD 70 liters gasoline tank:
city: 10l/100km; on full tank: 700 km
highway: 6.5l/100km; on full tank: 1077 km

How much grid electricity for millions of LIB EV's? Renewables energy to rescue?

Dr. Douglas Pollock (https://wattsupwiththat.com/2023/01/11/the-final-nail-in-the-coffin-of-renewable-energy/)

H - **the mean hourly demand** met by a given electricity grid, in MWh/h

R- **the mean capacity factor** of renewables for electricity generation (**<1**)

C-the minimum installed capacity of renewables that would be **required to meet the hourly demand H** (MWh/h)

$$C=H/R \text{ (MWh/h)}$$

N-the minimum installed capacity of renewables required to generate the fraction **f** of total grid generation

$$N = fC = fH/R$$

The renewables fraction **f**, of course, reaches its maximum f_{max} when

$$N=H$$

So for $f=f_{max}$ $\quad N=f_{max}H/R=H$

$f_{max}H/R = H$ /:H then

$f_{max}/R = 1$ which means that

$$f_{max} = R$$

The maximum possible fraction of total grid generation contributable by renewables turns out to be equal to the average fraction of capacity of those renewables that is realistically achievable under real-world conditions.

Since the average fraction of capacity R of wind energy is a depressingly low 25-30%, regardless of number of wind generating towers their contribution will never exceed 25-30% of total electricity demand on the grid.

Will common sense prevail? GM and other manufacturers are gradually backing out of the EV's market

https://qz.com/gm-is-slowing-ev-production-amid-labor-strikes-and-evo-1850954588

GM is slowing EV production amid labor strikes and "evolving" demand

The automaker says it will save $1.5 billion next year by punting production to 2025; **By** **Grete Suarez;** Published **Oct. 24/2023**

https://www.youtube.com/watch?v=Hkg4suMd5kM#:~:text=in%20a%20stunning%20announcement%20that,focus%20to%20hydrogen%20fuel%20cell.

General Motors CEO Mary Bara has declared that the auto giant will cease production of electric vehicles. and shift its focus to hydrogen fuel cell; Oct. 26/2023

https://www.businessinsider.com/auto-executives-coming-clean-evs-arent-working-2023-10

Auto execs are coming clean: EVs aren't working

Alexa St. John and Nora Naughton Oct 26, 2023, 12:43 PM EDT

Tesla joins GM, Ford in slowing EV factory ramp as demand fears spread

https://www.msn.com/en-ca/money/topstories/tesla-joins-gm-ford-in-slowing-ev-factory-ramp-as-demand-fears-spread/ar-AA1ivZZj?rc=1&ocid=winp1taskbar&cvid=0503277689bc4c10f452d11133a80565&ei=9

Tesla on Wednesday joined General Motors and Ford in being cautious about expanding electric vehicle (EV) production capacity, citing economic uncertainties and underscoring fears of a slowdown in demand.

Tesla CEO Elon Musk said he was worried that higher borrowing costs would prevent potential customers from affording its vehicles despite substantial price cuts, and that he would wait for clarity on the economy before ramping up its planned factory in Mexico.

Musk's comments came after warning bells from other automakers and EV startups. It sent shares of Tesla down 8% Thursday as well as shares of other EV makers.

GM said on Tuesday it would delay production by a year of Chevrolet Silverado and GMC Sierra electric pickup trucks at a plant in Michigan, citing flattening demand for EVs.

Summary

1. Only batteries containing Co have a high energy density which translates to a longer driving range for LIB cars.
2. Li and Co shortages – for how long would they last?
3. Mining of Li and Co is terrible for the environment.
4. Battery capacity decreases with both low as well as high temperature.
5. LIB EV cars are more expensive than their IC engine counterparts. Due to a price factor, Tesla may cut off production.
6. Driving ranges of LIB cars are inferior to their IC counterparts.
7. The electrical grid would barely withstand hundreds of millions of EV's after 2030-35.
8. Due to EV's drawbacks car manufacturers start reconsidering EV's as viable options.

New battery type to the rescue? Sulfur/selenium battery from NASA

NASA's incredible new solid-state battery pushes the boundaries of energy storage: 'This could revolutionize air travel' 'SABER battery' (October 26/2023)

(https://finance.yahoo.com/news/nasa-incredible-solid-state-battery-130000645.html#:~:text=NASA's%20sulfur%20selenium%20battery%20discharges,lithium%2Dion%20batteries%20can%20withstand.)

Claimed energy density up to 500Wh/kg!

Non-flammable! But very, very COSTLY!

Thank you very much for your attention!