Critical Raw Materials for Electric Vehicles

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Task 40 CRM4EV: outlook @2030 & recommendations

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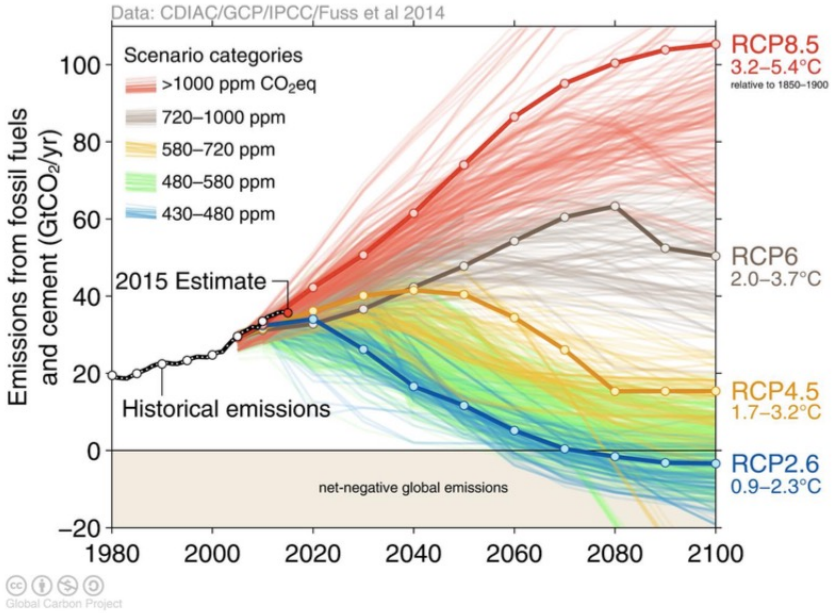
The COP21 commitment: what we need to do



Over 1000 scenarios from the IPCC Fifth Assessment Report are shown
Source: Fuss et al 2014; CDIAC; Global Carbon Budget 2015

1.5 C implies:

- *Emissions peak in 2020*
- *Zero carbon in 2070*
- *Developed countries zero carbon in 2060*

➢ **Near 100% ZERO CARBON ROAD TRANSPORT IN DEVELOPED COUNTRIES BY 2050**

➢ **Latest insights:**

Climate change is accelerating

➢ **From 2035 only ZEV road vehicles sold**

The battery revolution has just started!

@2030/2035, BEVs will:

Require very limited or no critical minerals

High performance: very long lifetimes, lower cost, higher density, more stable

Lower impacts & risks : environmental and social impacts, geoplitical risks

LFP batteries: energy storage density high enough for most BEV and improving

LFP & Tesla: 60 kWh pack @ 125 Wh/kg density at pack level; 75 kWh @ 160 Wh/kg (announced)
BYD Blade: 150 Wh/kg pack level
Gotion: 180 Wh/kg (estimated) pack level 2021, further improvements announced

- According to company CEO Li Zhen, Volkswagen's Chinese battery partner Gotion High-Tech has achieved industrialisation of the battery cell with LFP chemistry presented at the beginning of 2021, which offers an energy density of 210 Wh/kg. The company is also working on a semi-solid-state battery that is expected to reach 360 Wh/kg.
- Li confirmed this during his appearance at the China EV100 Forum 2022. In addition, Gotion plans to bring LFP cells with an energy density of 230 Wh/kg to series production by the end of this year.
- The energy densities mentioned, with 210 Wh/kg, are the energy density at cell level, not the gravimetric energy density in the ready-to-install battery pack. There is no confirmed statement from Gotion on this value. The portal *InsideEVs* estimated at the time that it could rise "to about 180 Wh/kg".
- By comparison, CATL's LFP cells, which are installed in the Tesla Model 3 and Model Y in Shanghai, reportedly come to 125 Wh/kg at pack level. CATL itself also presented the third generation of its cell-to-pack technology at the China EV100 Forum, which is said to enable 160 Wh/kg at pack level. Based on Tesla's 60 kWh pack, this 28 per cent improvement could enable a 76 kWh pack in a mid-size sedan – with LFP cells.
- In addition to LFP cells, Gotion High-Tech is also working on semi-solid-state batteries, such a cell should reach 360 Wh/kg. Volkswagen has been the largest shareholder in Gotion since June 2020.
- Compared to NMC cells, these cells have a lower energy density; but this is no longer the only criterion for a good battery. Chinese manufacturers such as BYD with the 800-volt platform 3.0 and the large-volume, so-called "blade" cells (English: sword) are showing the way. BYD's Blade battery. These are known to be LFP cells, which initially had 140 Wh/kg, but in the current long-range version of the BYD Yuan Plus already reach 150 Wh/kg.

Sodium based batteries

Elimination of last potentially critical mineral?
+ other laternatives for lithium around the corner?!

SODIUM-ION BATTERIES

Sodium-ion batteries are an emerging rechargeable battery technology

Inexpensive

- Secure supply and a predictable price
- No copper current collector
- No cobalt
- BoM 70% of LFP / NMC

Sustainable

- Sodium is abundant and ubiquitous
- No Lithium
- No copper current collector
- No cobalt related ethical or environmental issues
- No toxic lead

Safe

- Can be transported or stored in their low energy state at 0V
- Excellent safety testing results

Scalable

- Same operation principle and format as lithium-ion batteries
- Diverse chemistries are possible
- Are manufactured using existing plants

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- Lower and less fluctuating cost
- Geopolitical supply risks (very) low
- Much more R&D needed: policy priority!
- Other Li-free alternatives exist!
- Sodium-ion batteries
- Scientists in Japan are working on new types of batteries that don't need lithium like your smartphone battery. These new batteries will use sodium and they'll be up to seven times more efficient than conventional batteries.

Solid state batteries:
- longer range
- lower cost
- higher energy density
- ultra fast charging

- Nissan: The new all-solid-state battery will seek to replace the lithium-ion battery by 2028. It will also be about half the size of current battery models and achieve a **full charge in a mere 15 minutes,** cost of $75 per kWh in 2028 and $65 per kWh thereafter.
- When Nissan announced it was prototyping all solid-state batteries, the news held an ambitious timeline to start pilot producing ASSBs in 2024 and power a series EV in 2028.
- Solid-state batteries are the next barrier to break. Volkswagen and Mercedes, now Honda and first Toyota, have been hailing it as the holy grail. VW first pilot plants in 2025 or 2026.
- Volkswagen trusts in QuantumScape; Prologium just unveiled an actual battery powering Gogoro's LEVs, while Toyota is now thinking to team up with Panasonic to share the burden of investment.

BEV efficiency 2x as high

- Mercedes-Benz aims to produce electric cars consuming as little as 10 kilowatt hours of energy per 100 km (62 miles)
- Mercedes unveiled its Vision EQXX prototype, boasting a 1,000 km-range with a battery half the volume of its flagship EQS model, in January 2022. The car spent 8.7 kilowatt hours of energy per 100 km on its 11-and-a-half hour drive to France, Mercedes-Benz said, about twice as efficient as Mercedes models on the market and Tesla's longest-range car on offer, the Model S 60.
- On EV battery size: "There'll be a further increase for some time before a fall, which will happen once charging infrastructure is as available as petrol stations".

Very long life times of batteries:

1.5 million?
3.5 million ?
5 million ?
kilometers

- With “special additives”, the batteries (***announced by Tesla in 2020 as 1 million miles***) should be able to withstand 10,000 cycles. Assuming a relatively conservative 350 kilometer range per cycle (i.e., a full charge from 0 to 100 percent), this would be 3.5 million kilometers. Whether 3.2 or **3.5 million kilometers**: the one million miles or 1.6 million kilometers announced in September 2019 seem to be clearly surpassed.
- If the cells were treated more carefully, i.e. if the complete charge stroke from 0 to 100 percent were not used, the cells **should even last 15,000 cycles**, according to Dahn.
- **Batteries with high number of cycles:**
  - Vehicle-to-Grid: EV as part of grid when not in use, including for grid energy storage
  - No recycling of batteries required (for dozens of years), second use in new EVs or other applications
  - (Very) high cycle applications (ferries, aircraft,…)

IBM's battery is sourced from sea water and out-performs lithium-ion ????!!!!

Just 1 example of potential developments!!

- IBM Research points out that these advantages will make its new battery technology suitable for electric vehicles, and it is working with Mercedes-Benz amongst others to develop this technology into a viable commercial battery.
- Using three new and different proprietary materials, which have never before been recorded as being combined in a battery, IBM Research has discovered a chemistry for a new battery which does not use heavy metals or other substances with sourcing concerns.
- **Lower cost:** The active cathode materials tend to cost less because they are free of cobalt, nickel, and other heavy metals. These materials are typically very resource-intensive to source, and also have raised concerns over their sustainability.
- **Faster charging:** Less than five minutes required to reach an 80 percent state of charge (SOC), without compromising specific discharge capacity.
- **High power density**: More than 10,000 W/L. (exceeding the power level that lithium-ion battery technology can achieve).
- **High energy density**: More than 800 Wh/L, comparable to the state-of-art lithium-ion battery.
- **Excellent energy efficiency:** More than 90 percent (calculated from the ratio of the energy to discharge the battery over the energy to charge the battery).
- **Low flammability of electrolytes**

The future of batteries and EVs @2030 –2035 but probably earlier then we think !!

A typical BEV car may have a 30 kWh battery pack which lasts several decades

- Batteries: no use of critical minerals, low cost, low environmental and social impacts, no geopolitical risks, “eternal” lifetime, many applications.
- Electric motors: not using any rare earth elements
- EVs: (virtually) all new vehicles are electric, when not in use part of the electricity grid, battery sizes used are half or less than those used today with much more efficient vehicles, faster charging, battery swapping, denser charging network and higher confidence of EV drivers.

A fantasy ☺ ! ??

In 2015 Electric Vehicles were clearly a fantasy and not a serious proposal….

We need a mindset change from policymakers and leaders

Look ahead, not in the rear-view mirror….

Align ambitions and strategy to how EVs and batteries performance will become in @2030

Focus policies and R&D on the FUTURE battery and EV technologies *not those of the past…*