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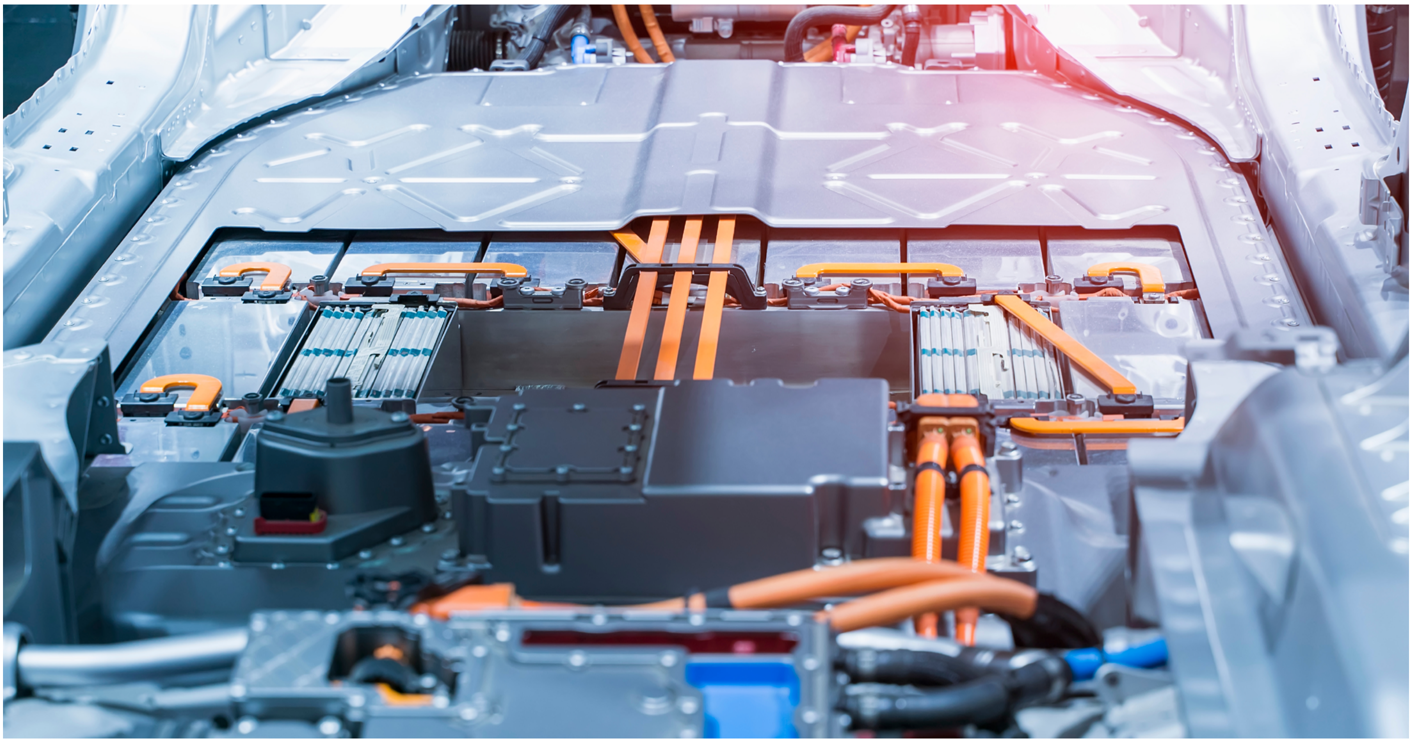


Fueling the future of mobility
Battery metals will not be for everybody

How to get the most from EV battery metals in terms of decarbonation, in a context of an anticipated very tight supply / demand balance?

Introduction

The global pandemic, starting 2020, demonstrated that the established status quo of global trade, especially in raw resources, as well as cross-continental supply chains are more susceptible to disruption than thought before. This has been further exacerbated by the conflict in Ukraine, which extended consequences on global trade strained production and supply of crucial goods – such as grain, gas as well as metals for the modern industry.

Furthermore, the progressive transition towards green mobility will require sizeable amounts of special metals. For instance, NCM (Nickel – Cobalt – Manganese) batteries use 20+ different key materials across 6 main modules: Cathode, Anode, Battery System, Module periphery, Cell housing, Electrolyte separators and other components. Among all those materials, Lithium (2.1% in weight), Cobalt (6.1%), Nickel (6.1%), Manganese (5.7%) and Graphite (16.1%) appear most critical ones for an NCM111 battery[1,2].

In 2021, nearly 10% of light duty vehicles sold globally were EVs (however, four times the market share of 2019), amounting a total of 6.6M units (of which 4.4M EV, and the rest PHEV), and bringing the global fleet to 16.5M units (BEV of PHEV). As far as the heavy-duty market is concerned, in 2021, the global electric bus stock was 670 000 (4% of total) and electric heavy-duty truck stock was 66 000 (0.1% of total)[3].

Going forward, by 2030, as penetration will increase, according to the IEA "Stated Policies Scenario", the global EV fleet across all road transport modes (excluding two/three-wheelers) will expand rapidly up to 200 million vehicles: an average annual growth of over 30%, reaching an approx. 7% global penetration rate[4].

Therefore, EV batteries sector is expected to capture a more and more significant share of metals demand by 2030. The expected uptake in EV adoption will be reflected in the EV share of metals demand. 50+% of the lithium extracted in 2021 (as lithium carbonate equivalent) was used in EVs and storage[5]; this proportion should reach 80+% in 2030 following typical EV penetration rates scenarios[6]. Similar patterns are expected for Cobalt (34% i in2021[7]), Nickel (4% of Class I and Sulphate in 2021[8]) and natural Graphite (18% in 2019[9]).

Figure 1: Key components of a typical NCM111 battery
Lithium, Cobalt, Nickel, Manganese and Graphite are critical metals for battery production, being key components of the Anode and the Cathode

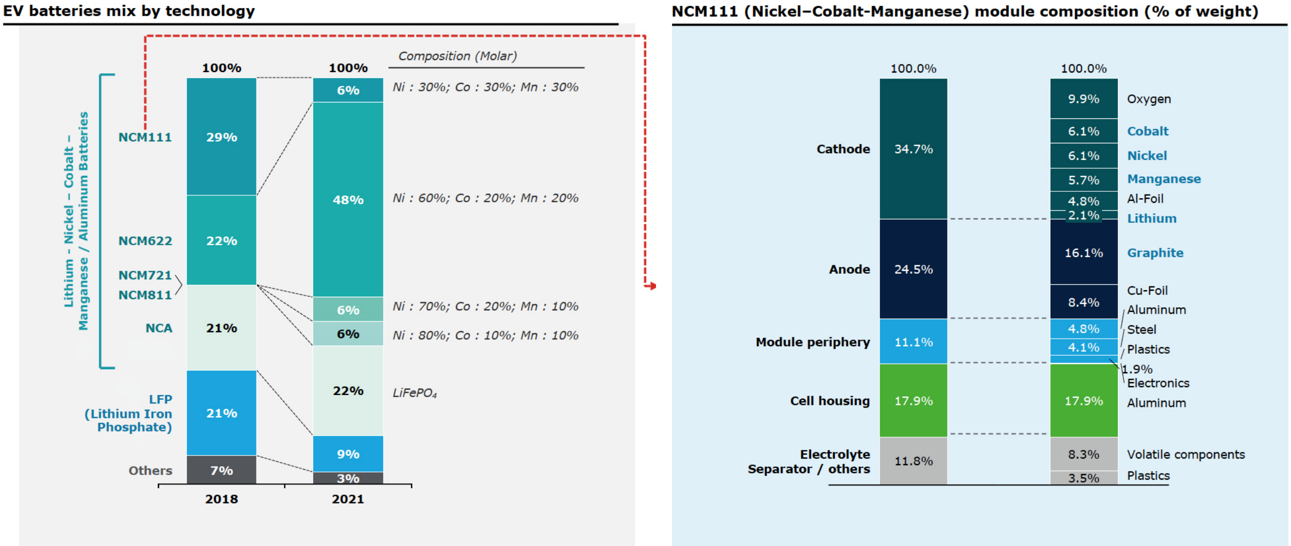
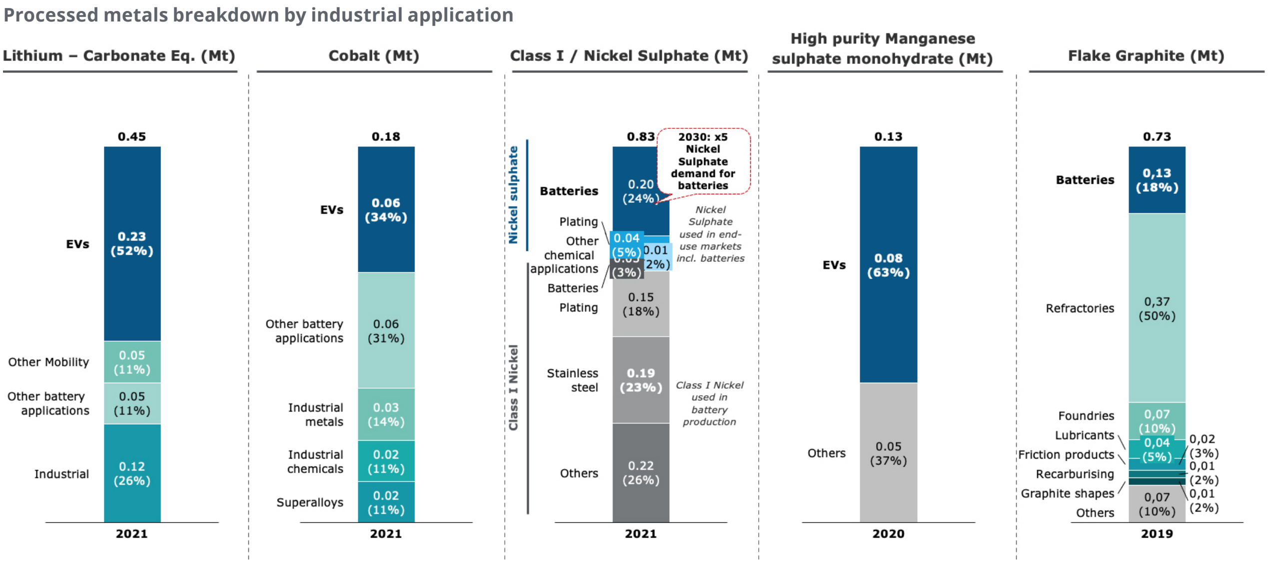


Figure 2: EV battery metals demand by application (2021)
Share of use by application for critical EV battery metals



Sources: Benchmark Mineral Intelligence; USGS; IEA; Monitor Deloitte Analysis

In this document, we will try to bring elements to discuss a major strategic issue in the field of EV battery metals for car manufacturers aiming at having a maximal impact on climate transition. Indeed, as the EV battery metals supply demand balance is expected to be tight in the future:

- How to get the most of them in terms on decarbonation?
- Which segments should be targeted in priority (Passenger vs. Heavy Duty vehicles? City vs. Sedan personal cars?)
- What is the advantage in terms of metal consumption to deploy EV in countries with a decarbonated power grid (e.g., France or Nordics) vs. other countries (e.g., USA, Germany, or even China)?

Supply/demand balance of ev batteries metals at mining and processing value chains stages will be a key constraint for the penetration of electric vehicles by 2030, calling for alternative strategies

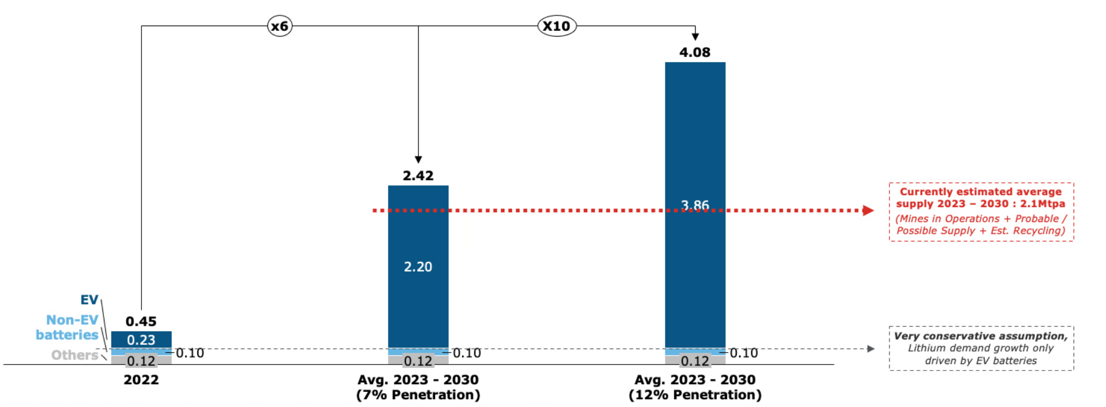
It is expected that supply demand balance of EV battery metals will become challenging as of 2030. For instance, without a major technological leap, and as most of currently existing battery technologies involve Lithium (NCM, LFP, …) at rather close proportions, enabling a 7% EV penetration globally would require multiplying in average by at least 6 the production levels of 2022 over the 2023-2030 period. Given typical time frames for developing new mining projects (usually 15 to 20 years are necessary between first geological surveys and run-rate operations), it will be hardly possible to match the demand with existing "in the pipe" assets (incl. potential ones) and current Lithium recycling levels.

The prospects on Cobalt raise even more questions. Under a stable technological mix (majority of NCM622 batteries, with a sizeable share of NCM811, NCM721 and NCM111), almost 25-40% of currently known cobalt reserves[10] should be used to fulfill the EV batteries sector growth only (ignoring other sector's needs) by 2030.

Figure 3: Lithium Supply/Demand projection (at current technological conditions)
Lithium supply demand projection over the 2023 – 2030 period

- **Without major technology shifts (i.e., Lithium based batteries still being most of the market), achieving a 7% EV penetration globally could be possible yet challenging**
- **Higher penetration scenarios would require a (not much probable) major leap in supply development**

EV demand projection for battery critical metals *(based on IEA Scenarios 7 and 12% penetration*)* **(Mt of Lithium Carbonate Equivalent, 2022 - 2030)**

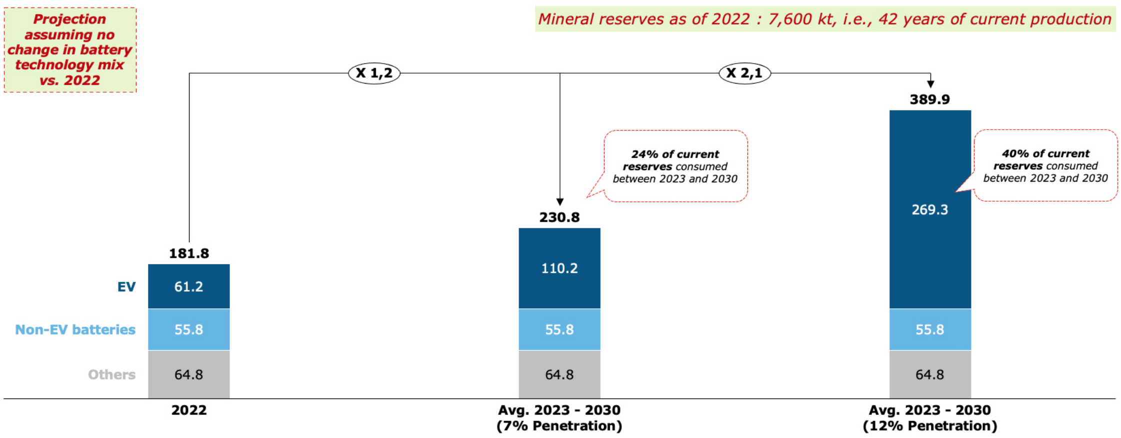


**Stated Polices Scenario and Sustainable Development Scenario. We also took 7% penetration assumption for heavy duty trucks*

Figure 4: Cobalt demand projection vs. identified reserves (at current technological conditions)
Cobalt demand projection over the 2023 – 2030 period

- **Without major technology shifts (i.e., Lithium based batteries still being most of the market), achieving even 7% EV penetration would strongly impact current reserves**
- **Cobalt substitution mechanisms (LFP, LNO, LMO batteries, …) must be implemented to cope with those limitations**

EV demand projection for Cobalt vs. identified reserves *(based on IEA Scenarios 7 and 12% penetration*)* **(kt, 2022 - 2030)**



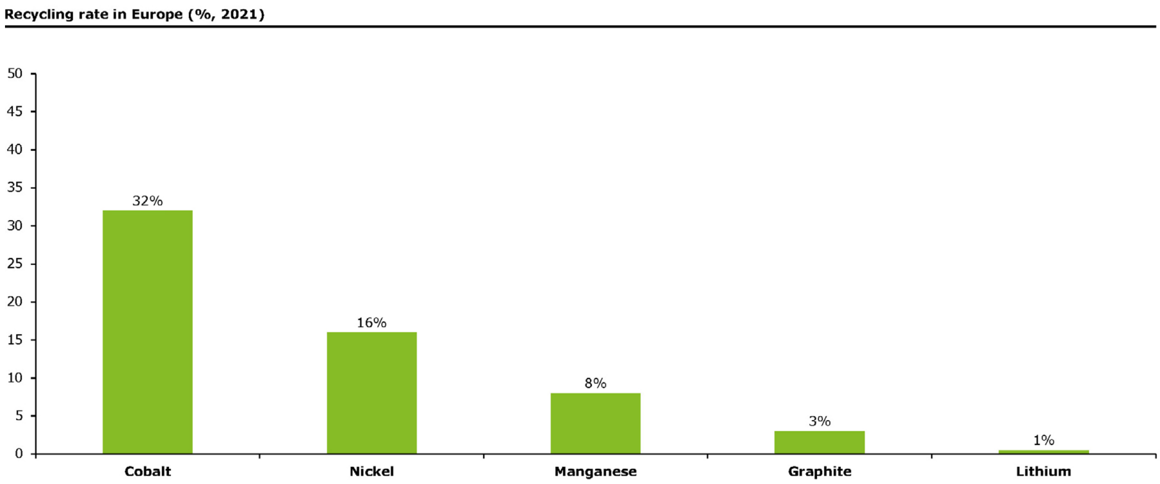
A full range of measures must be deployed to mitigate a supply demand balance that will hinder the road to a decarbonized mobility future

To avoid unsustainable cobalt prices, alternative measures should therefore be therefore explored by battery and EV manufacturers:

- **Batteries technology has a major role to play in rationing critical metals.** EV manufacturers like GM, for example, are working to limit Cobalt use in favor of other materials. On the NCM type batteries, cobalt rich NCM111 batteries (33% of Cobalt in cathode composition) are being progressively phased-out and substituted by NCM622 and NCM811[11]. Tesla announced that it would be transitioning to LFP (lithium iron phosphate) to avoid Cobalt altogether. LFP batteries are of lower density (90 – 160 g / Wh vs. 150 – 240 g / Wh power density), but better durability[12] (2000 + charging cycles vs. 1000 – 2000 charging cycles) than NCM ones. Therefore, this technology is to be privileged for small battery size vehicles (city cars, small urban LCVs…). Other Cobalt-free battery compositions are also expected to become significant on the market such as LMO (Li / Mn) or LNO (Li / Ni).
- **Recycling is an important step on the road to a decarbonized mobility future,** as well as a circular economic model that can free the EV industry from metals shortages and price fluctuations. If we remain dependent on cobalt, our renewable energy future could come to look eerily like the historic fossil fuel model: dependent on a few sources of production and damaging to the environment.
  - Recycling rates of critical battery metals vary significantly. In Europe, significant strides have been made regarding some metals' recycling rate – up to 32% for Cobalt and 16% for Nickel[13]. However, Manganese (8%)[14], Graphite (3%)[15] and Lithium (1%)[16] still have very low recycling rates. Improvement of the recycling branches for each metal will be key to meeting the rising demand fueled by EVs, and they will have to be specific to battery type (NCM vs. LFP).
  - As of 2030, sizeable amounts of EV batteries will be available for recycling, as 1.2 million tons of lithium-ion batteries will have reached end-of-life[17], feeding the industry with a however modest 125 kt of Li, 35 kt of Co and 86 kt of Ni. It is estimated that once EV penetration will be close to 70-80%, recycling could cover 40-60% of total supply, and reaching 80% about 8 to 10 years after full transition to EV globally[18].
  - A variant of recycling to relieve tensions on critical metals is also the development of the re - use of EV batteries. Renault launched a pioneering project in its Flins car manufacturing plant, which is now dedicated to giving a second life to EV batteries (e.g., storage)[19].

Tesla announced that it would be transitioning to LFP (lithium iron phosphate) to avoid Cobalt altogether…

Figure 5: Recycling rates of EV battery metals in Europe
Some EV battery metals have a decent recycling rate of up to 32% (e.g., Cobalt), while others barely have 1% (such as lithium)



Notes: 1. Only for high purity manganese required for batteries - i.e., HPEMM: High Purity Electrolytic Manganese Metal and HPMSM: High Purity Manganese Sulphate Monohydrate
Sources: S&P Global Intelligence; IEA; IFRI; Monitor Deloitte Analysis

- **Focusing scarce material on the right vehicle segments is critical to take the most from every ton of metal that is being extracted.** This implies that EV adoption should be more encouraged in the vehicle segments that have the most significant impact on well to wheel GHG emissions reduction.
  - **The quantity of metal used to prevent the emission of one ton of GHG** varies according to EV category. The electrification of heavy-duty vehicles is more impactful (from a GHG reduction perspective) compared to passenger cars. For example, each ton of CO_2 avoided requires almost twice less cobalt for a semi-truck (0.12-0.44 kg Co / t CO_2 avoided) than in a personal car (0.24-0.64 kg Co / t CO_2 depending on the segment and country). Indeed, trucks compensate huge batteries (e.g., 600kWh – 1000 kWh, weighting 3.6 to 6t on a Tesla Semi) by a high utilization rate (typically 50,000 km p.a. over 15 years). However, the electrification of heavy-duty trucks will require the deployment of a competitive charging infrastructure at the European level (incl. megawatt charging systems deployed along TEN-T corridors in Europe).
  - **On the passenger cars segment, city cars** (embedded with smaller size batteries, e.g., ~ 40kWh) have some advantage over sedans, which come at par only if they run more than 16,000 km / year. Electrification efforts should be therefore targeted in these segments (incl. also small LCVs), and any measures such as car-sharing enabling an increase of the distance covered by each city car will be profitable. More generally, avoiding overkilling the battery size, and fitting it well to each segment needs will be a major challenge to manage future supply demand.
  - **Even if looking like evidence, electrification should also be privileged in countries with the most decarbonated electric power grid** (i.e., with a GHG emissions intensity < 100 g CO_2 / kWh e.g., France, the Nordics, to a lower extent Canada, Iberia, or Brazil[20]). With the same driving parameters (distance / year, ...) the same vehicle type emits two times more CO_2 over a lifecycle in USA or Germany than in France (and 3 times more in China)[21,22].

Figure 6: Decarbonation impact of cobalt used in EV batteries by vehicle segment
Using critical materials in e-trucks will have a bigger impact on CO_2 reduction compared to personal cars

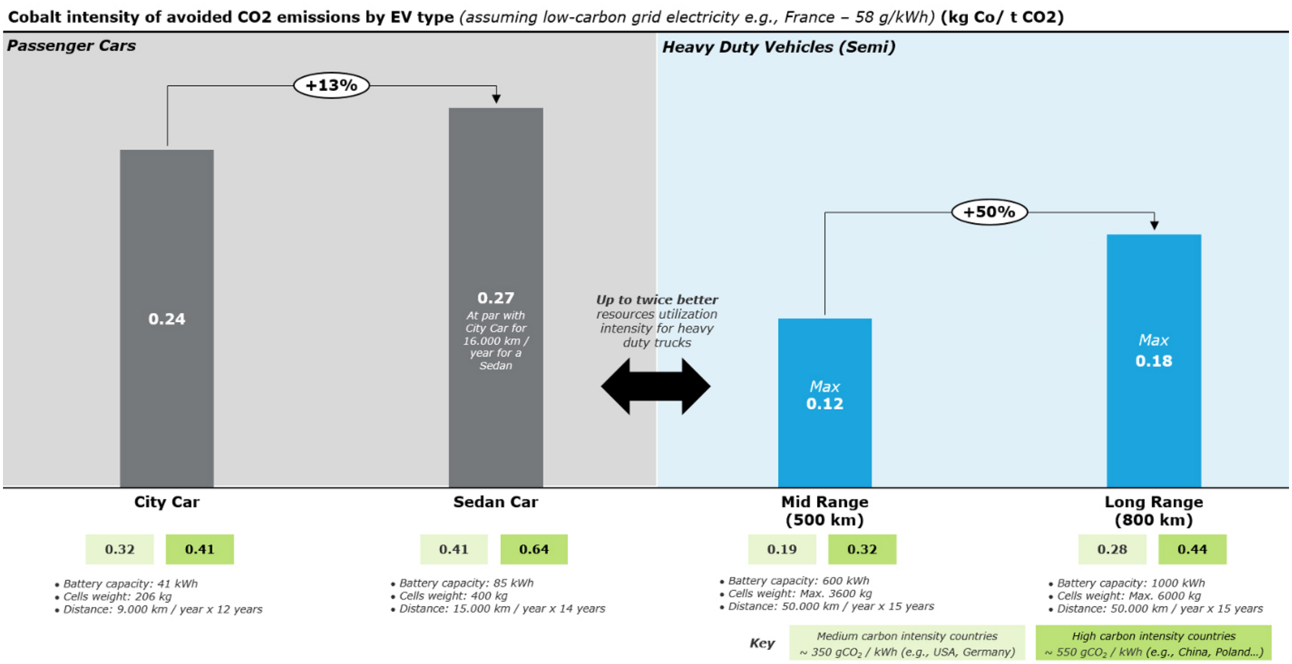
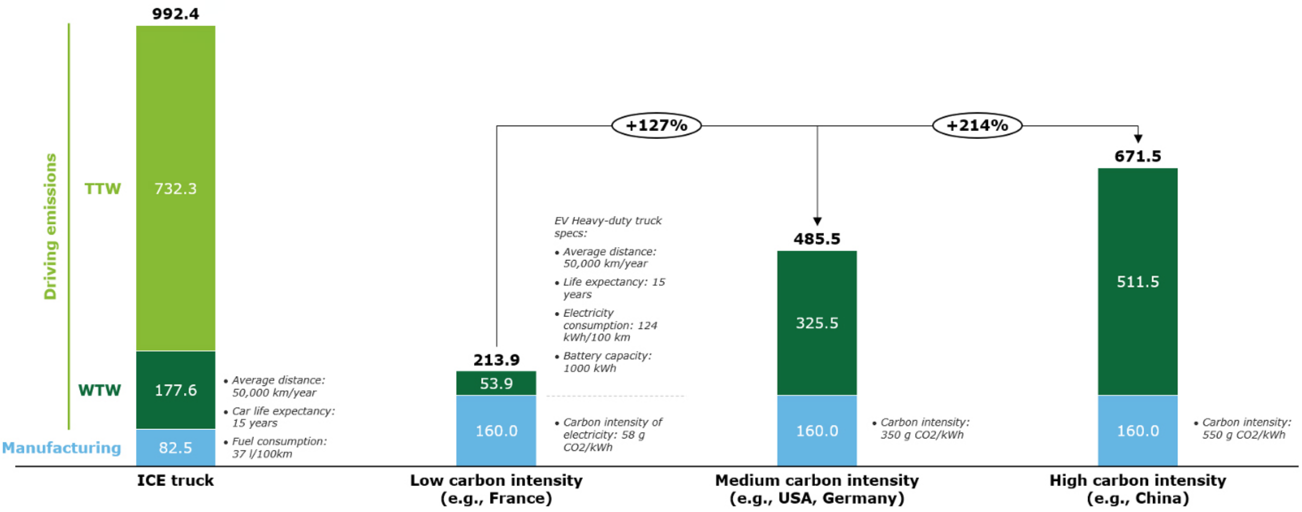


Figure 7: Decarbonation impact of cobalt used in EV batteries by vehicle segment
EV driving emissions strongly depends on the country energy mix

CO_2 emissions of an ICE and electric heavy-duty truck for three different energy mixes (t, 2022)



Source: Monitor Deloitte Analysis

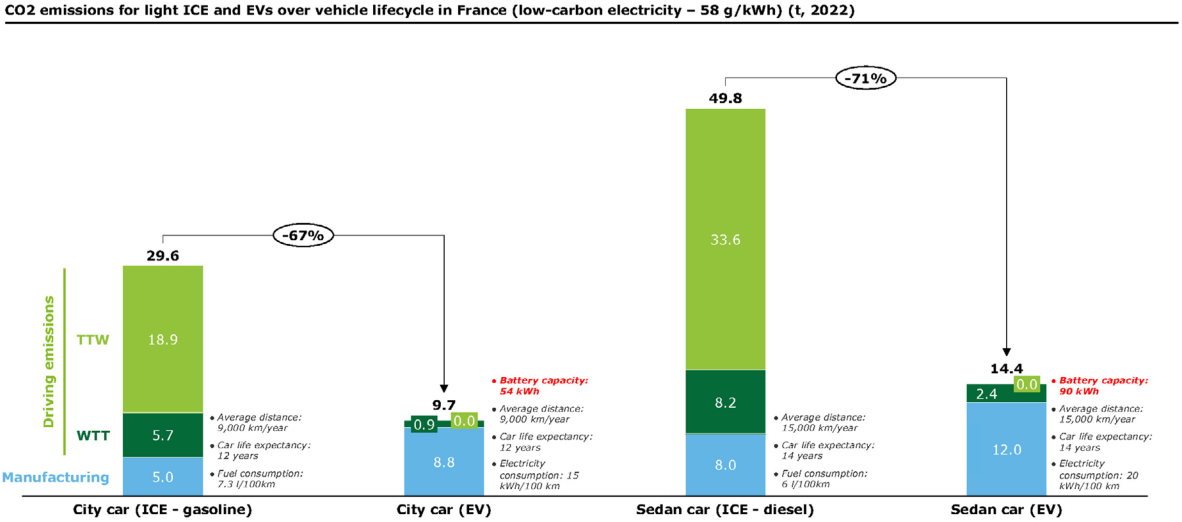
Conclusion

To cope with EV battery metals scarcity, in a context of very stretched supply demand balance, and take the most from available metals to have the best impact on the road to a greener mobility environment, car manufacturers should deploy the following action plan:

- **Drive battery technologies towards a lower utilization of the most critical metals** (e.g., Cobalt), and align battery technologies with car segments (e.g., LFP for city cars and small LCVs)
- **Develop recycling** (and re-use of batteries) branches, in priority for NCM batteries, then for LFP as critical volumes of feedstock will be available on the market
- **Focus on the right priorities for mobility electrification** (trucks, city cars / small LCVs), and contribute to the development of the right enablers (fast charging infrastructure for trucks along TEN T corridors, car sharing platforms for city cars, ...)

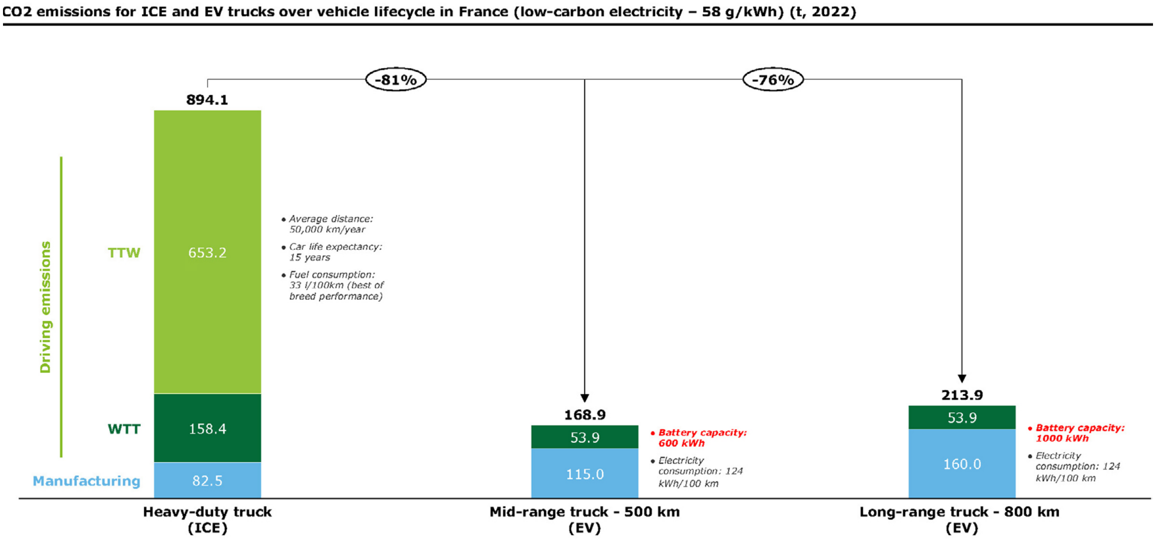
Appendix

Figure 8: GHG emissions (WtW) for ICE an EV passenger cars
GHG emissions (WtW) for ICE and EV passenger cars (City vs. Sedan cars)



Source: Monitor Deloitte Analysis

Figure 9: GHG emissions (WtW) for ICE an EV heavy duty vehicles
GHG emissions (well-to-wheel) of ICE and EV heavy-duty vehicles



Source: Monitor Deloitte Analysis

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Glossary

EV: Electric Vehicle

GHG: Green House Gas

LCV: Light Commercial Vehicle

LFP: Lithium Ferro Phosphate (Batterie)

LMO: Lithium-Ion Manganese Oxide (Batteries)

LNO: Lithium-Ion Nickel Oxide (Batteries)

NMC: Nickel Cobalt Manganese (Batteries)

PHEV: Plug-in hybrid electric vehicle

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