Afghanistan nickel-cobalt-aluminum batteries nca

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Electric vehicles (EVs) generally have a reduced climate impact compared to internal combustion engine vehicles1. Together with technological progress and governmental subsidies, this advantage led to a massive increase in the demand for EVs2. The global fleet of light-duty EVs grew from a few thousand just a decade ago to 7.5 million vehicles in 20193. Yet, the global average market penetration of EVs is still just around 1.5% in 2019 and future growth is expected to dwarf past growth in absolute numbers3.

Lithium-ion batteries (LIBs) are currently the dominant technology for EVs2. Typical automotive LIBs contain lithium (Li), cobalt (Co), and nickel (Ni) in the cathode, graphite in the anode, as well as aluminum and copper in other cell and pack components. Commonly used LIB cathode chemistries are lithium nickel cobalt manganese oxide (NCM), lithium nickel cobalt aluminum oxide (NCA), or lithium iron phosphate (LFP), although battery technology is currently evolving fast and new and improved chemistries can be expected in the future2,4.

Due to the fast growth of the EV market, concerns over the sustainable supply of battery materials have been voiced. These include supply risks due to high geopolitical concentrations of cobalt5,6 and social and environmental impacts associated with mining7,8, as well as the availability of cobalt and lithium reserves9 and the required rapid upscaling of supply chains to meet expected demand5.

a NCX scenario. b LFP scenario. c Li-S/Air scenario. See Supplementary Fig. 4 for the Sustainable Development scenario. See Supplementary Fig. 5 for battery sales in units. LFP lithium iron phosphate battery, NCM lithium nickel cobalt manganese battery, Numbers in NCM111, NCM523, NCM622, NCM811, and NCM955 denote ratios of nickel, cobalt, and manganese. NCA lithium nickel cobalt aluminum battery, Graphite (Si) graphite anode with some fraction of silicon, Li-S lithium-sulphur battery, Li-Air lithium-air battery, TWh 109 kWh.

a Primary material demand. b materials in end-of-life batteries. See Supplementary Fig. 7 for other materials. STEP scenario the Stated Policies scenario, SD scenario Sustainable Development scenario, Mt million tons.

Figure 4 shows the cumulative demand from 2020-2050. It ranges from 7.3-18.3 Mt for Li, 3.5-16.8 Mt for Co, and 18.1-88.9 Mt for Ni across fleet and battery chemistry scenarios (numbers for all materials are reported in Supplementary Table 5). The cumulative demand is twice as high in the SD scenario, and 2-2.5

times higher for Ni and Co in the NCX compared to the LFP and Li-S/Air scenarios. Consequently, there is a factor of 4-5 between the cumulative Ni and Co demands in the SD-NCX and the STEP-LFP or STEP-Li-S/Air scenarios.

Gray error bars represent a sensitivity analysis for battery capacity considering two extreme cases (if all EVs were PHEVs with small 10 kWh batteries or if all EVs were large SUVs with 110 kWh batteries, e.g., Tesla"s Model S Long Range Plus37, see annual results in Supplementary Fig. 10). See Supplementary Fig. 11 for other materials. The black line represents known reserves32. STEP scenario the Stated Policies scenario, SD scenario Sustainable Development scenario, Mt million tons.

In reality not all materials go through all processing steps. For example, pyrometallurgical recycling (smelting) still requires hydrometallurgical processing (leaching) before cathode materials can be produced, while direct recycling is designed to recover cathode materials directly. In pyro- and hydrometallurgical recycling the recovery of Li may not be economical and in pyrometallurgical recycling graphite is incinerated and Al not recovered from the slag (see also methods).

Hydrometallurgical recycling is used for NCX and LFP batteries and mechanical recovery of Li metal for Li-S and Li-Air batteries. Gray dots show how second-use, which postpones the time of recycling, reduces the closed-loop recycling potentials and thus the availability of secondary materials in the coming decades. See Supplementary Table 8 for other materials.

If a significant share of batteries experience a second-use, the recovery of that material will be delayed in time and thus the CLRP will be substantially lower for the decades to come (shown by the dashed lines in Fig. 6). The CLRP of other materials follow similar patterns (see Supplementary Table 8).