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How Batteries Make "Real" Contributions to Sustainability?

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Abstract Rechargeable battery technologies, particularly lithium-ion batteries (LIBs) are playing a dominant role in various application including electric vehicles, portable electronics and medical tools, as highly efficient power sources. LIBs are usually regarded as clean energy technologies, since they realize the conversion between chemical energy and electric energy in a "green" manner without greenhouse gas emission. On the one hand, many transition metal elements (e.g., Ni, Co, Mn) are utilized in electrode materials, which have significant environmental impact. Moreover, a variety of chemicals (e.g., precursors for electrode materials, organic solvents for electrolyte, etc.) are consumed during battery fabrication, which makes them not "green" and exacerbates the environmental deterioration. On the other hand, the uneven distribution of lithium and relevant transition metals reserves globally leads to the high cost of LIBs, while the highly active nature of lithium and the use of volatile organic electrolyte brings huge safety issues. Both high cost and safety concerns make LIBs not only challenging in electric vehicle application as a power battery technology, but also impracticable at all for large-scale electric energy storage as storage battery technology. In order for batteries to make real and essential contributions to sustainability, two possible solutions are as follows: (i) realizing recycling and upcycling of batteries, particularly LIBs, to create close-loop of essential materials towards circular economy; and (ii) developing next-generation alternative battery technologies to LIBs with much lower cost and higher reliability. In the first solution, research focus has been concentrated on the recycling of LIBs electrode (particularly cathode) by regenerating or upgrading the electrode materials. Moreover, upcycling primary batteries into rechargeable batteries has also been studied. In the second solution, rechargeable aqueous batteries, particularly zinc-ion batteries have been investigated. Both anode and cathode materials have been explored, while electrolyte has been engineered. In addition, practical feasibility has also been studied by investigating ultrahigh-loading electrode, ultrafast-charging and discharging operations, and extreme temperature adaptability.

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Lithium-Ion Batteries, Aqueous Zinc-Ion Batteries, Battery Recycling and Upcycling, Electrode Regeneration

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