

ABSTRACT:

New Technologies and Materials in the Center of the Energy Transition

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The energy sector currently claims one-tenth of all global patents, mainly in the field of clean and low-carbon energy technologies, especially in the field of energy storage (1/2 of all patents in clean, carbon-free energy), highlighting the central role of science and R&D. The new technologies rely heavily on mineral raw materials. Therefore, materials science and new materials such as nanomaterials are crucial for the necessary advances, e.g. to account for material availability, performance improvements, durability, etc. For example, Li-ion batteries with nickel-manganese-cobalt chemistry contain critical elements, while Li-FePO₄ mitigates this problem and ultimately leads to Na-ion chemistry providing a global material solution. The energy transition is based on clean electrification, sustainable molecules for fuels and chemicals, CO₂ capture for defossilization, and circular supply chains, which are also the focus of energy material development. Advanced materials need to be linked to advanced manufacturing to enable scaling up, e.g., additive manufacturing, 3D printing, etc. Artificial intelligence opens up new avenues, not only for material development, but also for integrating new energy technologies into energy systems. Environmental aspects deserve more attention, e.g. integrating Life Cycle Assessments (LCA) more closely into material and technology development, and incorporating circular economy into supply chains. As the transition to clean energy is driven by the rapid adoption of variable renewable power generation, energy storage is becoming an important technology to balance future electricity supply and demand. 90% of electricity storage capacity is based on traditional pumped hydropower systems, while 90% of all new capacity comes from Li-ion batteries for short-term storage. However, these additions are not enough to cover future storage demand, especially for long-term use, which will be one of the key technological challenges of the energy transition and also affects materials. A wide range of next-generation storage technologies are being developed, such as air-based, Zn and redox flow batteries, hybrid and multi-technology approaches (e.g. battery/fuel cell, electric/thermal).