THE DAWNLIT REVIEW
Volume-1, Issue-1, February-July 2026
https://journal.iggc.org.in/

Sodium-Ion batteries: History, working principle, prospects and challenges for Large Scale Energy Storage

Miyon Moyong[1], Pebam Munindro Singh[2], Arumugan Murugan[3]

[1]Assistant Professor

[2]Associate Professor
[1&2]Department of Chemistry, Indira Gandhi Government College
Tezu, Arunachal Pradesh

[3]Assistant Professor
[3]Department of Chemistry, NERIST, Itanagar, Arunachal Pradesh

Date of submission: 31/05/2026 Date of acceptance : 21/07/2026

Abstract

Energy is an indispensable factor that decides the status of the nation in 21st century. Available natural resources have not been able to back up the rapid advancement of technology. The existing scenario demands the integration of Electrochemical Energy Storage system (EESs), capacitors and super capacitors, pumped hydro energy storage, thermal energy storage etc. EESs provide higher efficiency because of its higher energy density. The Sodium Ion Batteries (SIBs) is one of them. SIBs are an emerging, promising, viable and superior alternative than most widely used Lithium Ion Batteries (LIBs) due to their easy availability and lower cost, more sustainable and environmental friendly. In this paper the history of SIBs, their chemistry and advantages over LIBs, the prospects and the future directions are elaborated. It will serve as an eye opener to all about the dynamics of energy crisis, storage knowledge and a review paper for researchers in the field of energy.

Keywords: Energy, Electrochemical Energy Storage system, Sodium Ion Batteries, Lithium Ion Batteries.

[1]Corresponding Author

Introduction: The Early History and re-emergence of SIBs.

The foundation of economic progress and global super power in 21st century is energy. It is playing a vital role in growth of industrial productivity, technology innovation, digital infrastructure and development of humanity. The need to shift to sustainable energy source is one of the most sought-after goal today with countries across globe investing heavily on this area of research. Renewable energy sources and its utilization are therefore either implemented or under the process of implementation. However, most of these resources are season dependent, therefore a bridge to close the available gap between demand and supply is utilizing energy storage devices. Various devices that can store energy are batteries or otherwise also known as Electrochemical Energy Storage system (EESs), capacitors and super capacitors, pumped hydro energy storage, thermal energy storage etc. EES provides higher efficiency because of its higher energy density(Tedla etal., 2025). In the modern landscape of technology, batteries are a primary source of energy, over expanding different ranges of applications. Batteries can be classified into three categories as primary batteries that are not rechargeable, commonly found in flashlights, remote controls etc, mostly comprising of Lithium, alkaline and zinc-carbon, low cost, easy availability and sufficient energy density for applications that do not require high power. Secondary batteries constitute rechargeable battery type used extensively in EVs, laptops, grid systems, smart devices that is commonly made up of lead-acid, Nickel-cadmium, and Li-ion batteries (LIBs). They are ideally used for applications that requires repeated usage and supports the transitioning from non-renewable to renewable energy sources by helping in storing the production of excess energy. Under the third category we have speciality batteries that are designed for applications with unique demands and characteristics specific performance. These category of battery finds its applications in extreme conditions of temperature, or where ever the durability and energy density are very critical such as medical devices and aerospace. However, these are extremely expensive and therefore are less widely used diminishing their application to niche market. There is also a fourth category which is otherwise also known as emerging battery technology which is focused on cutting-edge development to surpass current technology in scalability, sustainability and performance. Solid-state batteries, sodium-ion batteries, flow batteries and lithium-sulphur batteries are included under this criterion. These batteries aim to address the limitations of existing battery types such as sustainability, safety and cost (Phogat etal.,2025). The development in this area has made it possible for improvement in devices with greater energy storage capacities, innovations in electronic devices, renewable energy systems, electric vehicles (EVs) etc. In the present era, because of the widespread adoption of smart devices, there is an increased demand for an environmentally sustainable batteries which will be very efficient and reliable towards achieving the global goal towards cleaner energy systems. The development of battery took place in the early 19th century with the invention of voltaic pile by Alessandro Volta, that consisted of alternating layers of copper and zinc, separated by cardboard soaked in saltwater which acts as a bridge to transport the ions generated and thus generating electricity via chemical reaction, which is a classic example of Galvanic or Voltaic cell. These early voltaic cells would use a wide variety of different metal combinations giving varied voltage with different metal combinations. Daniel cell was developed in 1836 by John Frederic Daniell with a steady yield of Electro Motive Force (EMF) providing a more reliable and steady current. This cell comprises of a Zn rod as anode submerged in $ZnSO_4$ solution and a copper rod submerged in $CuSO_4$ for cathode with the electrons following from Zn anode to Cu cathode through an external circuit facilitating the flow of electrons. French physicist Gaston Planté in 1859, invented lead-acid battery revolutionizing the capabilities of power storage capacity and providing a solution of reloadable battery. This battery though affordable with regards to manufacturing as well as being consumer friendly had certain limitations like lowered life cycle, longer charging times and lowered energy density. This invention was later followed by the development of Dry Cell, utilising a paste electrolyte and discarded liquid electrolytes building the foundation of Morden day portable batteries. During the oil crises in the 1970s, an English chemist M. Stanley Whittingham developed the first rechargeable lithium-ion battery with TiS2 cathode but the metallic Li anode led to short circuits and explosion risk causing serious safety hazard issues. In the 1985, Japanese chemist Akira Yoshino was able to replace the metallic anode with petroleum coke and embedded unstable Li ions in carbon to create a safer, more functional and practical Lithium Ion Batteries (LIBs), later commercialized by Sony in 1991. These batteries were equipped with better cycle life and energy density, lower self-discharge rates. They have ever since dominated various applications field from electric vehicle to laptops to handheld smart devices to hearing aids, becoming indispensable and essential in every day routine. Their significance covers almost every sector and in particular the transportation sector, which can provide us a solution to the existing modern-day crises of greenhouse gas emission, that is a major contributor to rising global temperature in disrupting natural cycles and resulting in extreme weather condition, rising sea levels, habitat loss, damaging biodiversity and hampering the health of human across nations. LIBs have a remarkable fleet in their ability to continuously find new applications. The demand for an increased electric vehicle is expected to reach 50-200 million by 2028 to meet the objective of cleaner energy policies towards a climate neutral globe(Phogat et al.,2025).

LIBs operate through the movement of Li+ ions between anode and cathode during the process of charging and discharging. With robust cycle life (500-1500 cycles), higher energy density and a longer shelf life, they are undisputedly a popular choice. Li batteries are also able to retain a higher percentage of their capacity over numerous cycles, proving to be an ideal choice for many portable devices, renewable energy storage devices and EVs (Phogatet al.,2025). Although there isn't any apparent limitation in performance for LIB technology, difficulties with sourcing of raw material such as $Li2CO_3$ and cobaltite has arisen. Challenges have also been faced with issues of safety concerns, thermal runaway and corrosion, dendrite growth etc. Along with the increase in number of battery installations, the growth of battery packs has increased, it has become difficult to mine this resource to match the global demand. It is reported that the Li_2CO_3 is scarce and unevenly distributed across the globe which inherently leads to shortage in global supply risk and overexploitation of the resource. With South Africa being the primary source of global production of Lithium, there also lies the risk of overexploitation of human labour and their rights. The other vital constituents of LIBs are cobalt and graphite which have been classified as critical raw material under European Union (EU), putting greater pressure over an already congested value chain, thus resulting in a greater price fluctuation(Chayambuka et al., 2020). Therefore, the need to find an alternative source beyond lithium technology is necessary and hence we require robust research to overcome this overreliance on a single scarce resource.

The Sodium ion batteries (SIBs) share its conceptual origin with LIBs but was deprioritized due to the earlier dominance of the latter in commercial arena. However, the cost-effectives, abundant availability and lower environmental consequences(Phogat et al., 2025)of sodium has led it towards the direction as a viable solution and possible promising alternative. SIBs share a similar cell configuration and working mechanism(Cui et al.,2025)with that of LiBs. Both of these battery type employs a carbonate-based electrolytes and carbonaceous anodes. However the SIBs constitute a more cost effective and environmentally friendly cathode chemistry with an abundantly found affordable raw source with lower cost Fe, Mn and Zn, which are the other constituent of SIBs(Cui et al.,2025). One of the most critical cell components that can significantly lower the expenditure cost is the selection of cathode components (Roshtami et al., 2024). It is also observed that Na ion exhibits minimal reactivity with Aluminium (Al) metal affirming that it is serving as a sole metal source for SIBs within their typical operational constraints(Rostami et al., 2024). Such activities help in reclaiming of the resources that could otherwise be discarded. The existing material and battery manufacturing facilities for LIBs can also be utilised for the production of SIBs. This technology has been gaining considerable attention and rapid industrialization with China pioneering in the field(Li et al., 2026). The first battery storage system was installed a during the early years of 2019 and SIB car was introduced in the later months of 2023 in China with a limited global production of less than 1% in comparison to that of LIBs(Lombardo et al., 2026). SIBs also exhibit a better performance in lower temperature than that of LIBs with the most recent inventory that can retain approximately 90% of nominal capacity at lower temperature of -40°C and operating at temperature as high as 70°C. These batteries have highlighted ways to reduce reliance on critical minerals and diversify the supply chain of batteries. However, most of the existing manufacturing capacities are located in China, accounting for more than 95% of 2030 capacity (Lombardo et al., 2026), reinforcing the risk of supply chain but the geographical diversified components of SIBs offer a potential advantage in upstream supply chain resilience.

Scaling and Electro-chemistry of SIBs.

A battery is made up three core components viz. anode, cathode and the electrolyte. Li batteries usually have Li along with other elements such as Cobalt, Nickel, in cathodes and graphite in anode, often listed under critical minerals. Sodium ion batteries include varieties of different cathode types with different chemical compositions and a hard carbon in anode. The electrochemical mechanism thrives due to movements of Na^+ ion between the anode which serves as reductant and the cathode that is acting as the oxidant. During the process of charging, these ions are extracted from the cathode and transferred to anode via an electrolyte which is often infused with a separator. The process however isn't thermodynamically feasible and therefore the circuit requires an external power supply to drive the forward reaction. The discharging process or the reverse process, however is thermodynamically feasible and hence occurs favourably. For a battery to perform efficiently, the electrochemical potential should lie in the stable range of electrolyte. This stability window is defined as the energy gap between the Lowest Unoccupied Molecular Orbital (LUMO) and Highest Occupied Molecular Orbital (HUMO) of the electrolyte. If the anodic potential rises above LUMO level, the electrolyte might undergo decomposition, to prevent this, a thin protective layer called the Solid Electrolyte Interface (SEI) is formed on the surface of anode restricting excessive electron flow and thereby reducing the electrolyte(Mashfy et al., 2026). Careful materials selection for cathode, anode and electrolytes are imperative to attain an optimal electrochemical performance with longer cycle life(Tedla et al., 2025). Most experimented types of cathode chemistry available for SIBs are Prussian blue analogues (PBAs), layered oxides (LO) and Poly Anion compounds (PACs). PBAs are metal cyanides with general formula $Na_xM_y[M'(CN)_6]._zH_2O$, where M and M' stands for a transition metal atom, x, y and z represents the stoichiometric ratio of sodium, transition metal and water respectively. They have a mesh-like structure with their physical and chemical properties depending on the metal present in the salt. They have an elevated ion mobility because of their open structured architect. The PBAs have a prolonged cycle life, non-toxic, high theoretical capacity and thus have been gaining momentum in China and the US. A major setback of this material is it is highly sensitive to aqua and the content of aqua in lattice, though its presence also stabilises the structure of PBAs, but if present excessively a decreased in overall capacity and lowering of energy density is observed and therefore the need to have a vigilant control over humidity and water content across the plant to maintain a high quality performance(Mashfy et al., 2026).

LOs and PACs on the other hand have gained attention of EU and India. The structure of LOs is similar to a Nickel Manganese Cathode (NMC) cathode whereas that of PACs are analogous to lithium iron phosphate (LFP) cathode active materials (CAM). The choice of the cathode is very helpful in determining the suitability of end term application, cost, availability of raw material and its manufacturing. LOs constitute sodium embedded metal oxides often extracted from carbonates, oxides, hydroxides, phosphates, silicates, represented generally as Na_2MO_2 where MO_6 sheets are repeatedly layered with Na^+ sandwiched in between these layers. LOs remain unaffected by humidity making the process less costly. Stability of a cycle, specific capacities, average operating voltage can be altered by incorporation of metal components. Therefore processes such as substitution of metal and doping are incorporated to enhance the battery performance. PACs are one of the most promising categories of cathode materials commonly utilizing sodium vanadium fluorophosphate (NVPF) formulated as $Na_3V_2(PO_4)$. These are characterised by their polyanionic group (PO_4^3-, SO_4^2- and SiO_2^{4-}). These groups form covalent bond with transition metals such as Vanadium (V) to enhance structural stability during the process of intercalation and deintercalation of Na^+ ions. Generally expressed as $Na_xM_y(XO_4)_n$, where XO4 represents polyanionic group, M stands for the transition metal, either single or multiple(s). The connection of $(XO4)^{n-}$ to M allows the movements of ions to be quick and maintains the stability of redox potential the metal. The stronger covalent bond between X and O creates a weak ionic interaction with M and O as a result of which the gap between antibonding orbital are widens increasing the redox potential also referred to as "inductive effect" in PACs. The stronger X-O bond is responsible for an improved oxygen stability within the structure and increases its safety. The phosphate group induces higher redox potential to the redox couple(Rostami et al.,2024). Synthesis of Sodium Vanadium Fluorophosphate (NVPF) involves the treatment of V_2O^5 with phosphate source and H_2 gas(Dey et al., 2026). Compounds similar to PACs are also manufactured by fertiliser industry. Although the prevalent chemistry is relying on Vanadium the emerging variants are free of critical minerals. China has a leverage over the overlapping supply chain between fertilizer and LFP industry and has capitalized and dominated the LIB industry globally. The active anode material in SIBs mostly consists of hard carbon that can be easily manufactured from waste streams originating from different industries including agricultural waste, biomass, petrochemicals and polymers etc. Selection of a suitable active anode material is crucial as the ionic radii of sodium is larger. Graphite used in LIBs are not suitable for SIBs because of the small interlayer spacing which doesn't allow the percolation of Na+ ion, reducing intercalation and resulting it lower energy density. A challenging feature observed with the choice of hard carbon for active anode material is that it decreases the lifecycle and demands higher research and optimization to emphasise them in SIBs. Other possible alternate for anode material is metal alloy anode mostly based on Tin (Sn) and Antimony (Sb),also comes with significant issues but shows lower redox potential, larger theoretical capacity, and a faster charging capability (Kumar & Kundu, 2024). Introduction of a polymer hybrid solid electrolyte to develop the SIBs without conventional liquid electrolyte also offers an attractive solution to avoid any unwanted consequences of leakage risk, dendrite overgrowth with an enhanced safety feature.

Electrolytes is another crucial element in SIB performance and are expected to exhibit wider electrochemical window, higher thermal resistance and an excellent ionic conductivity. Different types of electrolytes such as organic, ionic, aqueous, solid-state electrolytes and hybrid systems have been formulated. Organic electrolytes which are carbon based for example ethylene carbonate and propylene carbonate (EC:PC+$NaPF_6$), and ether based a mixture of Diethylene glycol dimethyl ether and Sodium bis (trifluoromethanesulfonyl)imide or (DEGDME+NaTFSI) have shown to offer higher conductivity in the range of 8-12 and 5-8mScm-1 respectively with expansive voltage window up to 4.5V but has safety and risk concerns as these are flammable often with toxic byproducts such as CO^2 and HF, exhibits dendrite risk(Dey et al., 2026). Aqueous electrolytes have certain advantages of being non-flammable, cheaper with excellent safety coverage. Theirlimitations being narrower voltage windows, corrosion in alkaline medium and water reduction issues. Polymeric electrolytes offer greater flexibility, mechanical strength, sustainable and are thermally stable but have been found to exhibit lower Na+ conductivity(Mashfy et al., 2026).

Technology advancement in SIB will undoubtedly play an essential role to support high power propulsion, vehicle batteries, ground power, short range drones. Recent development showcases a promising future for SIBs in low speed EVs with several Chinese manufactures demonstrating this potential with electric 2/3 wheels vehicle. EV manufacture JAC motors which is backed by Volkwagen, has launched Yiwei 3, a 5 door electric hatchback that features a 25kWh SIB pack and offers a range of 230 km. Similar to this, Farasis Energy,Chinese battery manufacturer has also launched its LO based SIB powered EV in 2024 claiming a range of 251 km suitable for daily commute. Thus, concluding that SIBs can offer an economic advantage for small and medium sized battery packs whereas LIBs are still preferred for long range EVs(Sandri et al., 2026).

Prospects, Challenges and the future of SIBs

SIBs has significant upper hand with respect to the price of energy storage unit when compared to LIBs due to its widespread availability around the globe. Na makes up 2.6% of the earth's crust and is the sixth most common element found on the earth crust. The processing and extraction of Na is also less damaging to the environment reducing ecological footprints often associated with refining operations and mining. Even though the larger size of Na+ ion results in lower energy density, these can always offer comparable or greater power density owing to faster mobility of ions in certain material, making them in particular quite appealing for applications that requires rapid energy burst while still offering an adequate energy storage capacity. Energy density is a crucial property which defines the amount of energy a battery can store relative to its volume and weight. It is typically express in Watt-hrs/Kg. A higher density point towards a system that can store greater energy with respect to its size and volume, delivering more energy for its given size, and an essential parameter to judge the viability of batteries for varied applications (Phogat et al.,2025). Lithium batteries with slower discharge rate and exceptional longer shelf life lasting somewhere between typical rangesof 10-15 years are known to show better performance which adds to their appeal for long term storage. Hybrid energy system like mild hybrid electric vehicle, supercapacitors paired with batteries, medical devices are few examples of some devices that utilises this technology. The cost of storing energy per kilowatt-hour is also competitive for large scale grid storageapplications and integration ofrenewable energy even they show lower density than LIBs. SIBs have an economic advantage to serve as one of the most viable alternative to solutions of energy storage prioritizing affordability, sustainability and greater energy density. SIBs boast a promising lifecycle with an expected range of 500-2000 cycles and charging time in the ranges of 3-6hrs while still in developmental stage. For similar battery capacity,they can be charged and discharged 4-10 times than the conventional LIBs. SIBs also do not exhibit any sodium plating at the rate of charging 2C or higher leading to faster charging of EVs and batteries for higher power applications. These batteries can also be produced on existing LIB manufacturing lines since the mechanism and the chemistry i.e. similar structure, stacking geometry and battery form factors are similar thereby making the transition process an easy one and an accelerated development however with this also comes the issues of cross contamination(Phogat et al., 2026). The hard carbon SIB anodes also requires a temperature of 700-1300°C which is significantly lower than that of graphite (2800-3000°C) removing the barrier of requiring a special furnace and thereby decreasing the capital expenditure and energy inputs. It is a common observation that batteries get heated up during operation and many a times numerous unfortunate incidents have been reported. This often occurs when electrolytes in batteries are exposed to a spark at 36-45°C also known as flash point. It is to be noted that the flash point of SIBs is 100°C making it safer even during operation that could exceed 50°C, a plus point for tropical countries where the summer temperature very easily crosses 40-50°C. The higher ion mobility of sodium in sub-zero conditions also makes them a good alternate for high altitude areas and applications in defence sector. Thus, one can infer that SIBs can operate at ambient temperature as low as -40°C to as high as 50°C without any concern of safety hazard or risk of fire. Though SIBs offer lower energy density than LIBs but these are expected to be improved as research progresses. Even though they have not been fully and widely commercial, they are being studied and developed where it is critical to achieve sustainability and cost-effectiveness such as grid energy storage systems. SIBs with their simpler chemical composition aligns well with the Circular Economy Action Plan(CEAP),2020 which targets climate neutrality by 2050. The plan includes recycling, use of less toxic chemistry, minimize waste production and improving resource efficiency. The absence of toxic materials and easy composition are an ideal candidate for recycling(Jang et al., 2026).

The development of SIBs faces several difficult challenges that requires to be addressed for achieving commercial viability. Challenges such as slower diffusion kinetics due to larger size of Na^+ ions, higher atomic weight, stress on the host material during cycling resulting in lower energy density and a decreased lifetime cycle, reversible intercalation of the ions etc offers significant challenges for material selection as well as battery design. Enhancement of electrochemical performance relies on various strategies to improve electrode stability, ionic conductivity, and overall efficiency. Processes such as doping, substitution of elements will serve to structural stability by incorporation of foreign particle into the electrode materials. In order to safeguard against corrosion and degradations, measures such as coating of the electrode surface, use of additives to optimize of electrolytes, incorporation of nano materials to increase surface area etc will help to increase the pathways for ion diffusion(Tedla et al., 2025). Identification andoptimization of suitable electrode material is still under process for achieving an enhanced electrochemical performance. Monitoring advances in LIB performance is also necessary to understand the niche and maximize the performance to bridge the disparity of SIBs. Driven by the essential need for a cost-effective energy storage solutions and sustainability, the future of SIBs looks quitepromising and bright globally. Scalability of SIBs renders them as a perfect candidate towards integration with renewable energy enhancing their role towards a cleaner and sustainable energy landscape globally.

Conclusion

SIBs are emerging as a promising and viable alternative to LIBs due to their easy availability and lower cost, more sustainable and environmentally friendly. With similar operation system as that of LIBs, they utilise Na ions to store and release energy. Even if they have a lower life cycle, lower energy density but they also come with an attractive potential for a large scale storage system and a future contender in battery market owing to their scalability, lower cost and reproducibility. SIBs provide leverage over abundant available sodium resource, reduces reliance on critical minerals and cuts off CO^2 emission by up to 30%. Though SIBs lag behind in performance as compared to a LIBs for now, they are for sure providing a balance between cost and energy density emerging as a robust solution towards achieving a cost-effective large-scale solution for various energy storage devices and applications.

References:

Chayambuka, K., Mulder, G., Danilov, D. L., &Notten, P. H. (2020). From li-ion batteries toward Na-ion chemistries: challenges and opportunities. Advanced energy materials, 10(38), 2001310.

Cui, Z., Liu, C., &Manthiram, A. (2025). A perspective on pathways toward commercial sodium-ion batteries. Advanced Materials, 37(46), 2420463.

Dey, S., Phogat, P., & Wan, M. (2026). Policy-driven strategies for advancing sodium-ion battery adoption in India. Next Energy, 11, 100573.

Jang, H., Youn, B., Han, Y., & Lee, D. (2026). Bridging the gap from basic principles to advanced applications in sodium-ion batteries. Journal of Energy Storage, 142, 119547.

Kumar, K., & Kundu, R. (2024). Empowering energy storage technology: recent breakthroughs and advancement in sodium-ion batteries. ACS Applied Energy Materials, 7(9), 3523-3539.

Li, Q., Ulissi, U., Liang, Z., Chen, X., Guo, B., Zhang, X., & Ouyang, C. (2026). Progress and Prospect of Industrialization of Sodium-Ion Battery in China. Advanced Energy Materials, 16(2), e04877.

Lombardo T, Modeller T, Paoli L.(2026) ,Sodium- ion battery momentum grows, but challenges remain, IEA, (https://www.iea.org/commentaries/sodium-ion-battery-momentum-grows-but-challenges-remain).

Mashfy, M. M., Alvy, T. A., Hossain, N., Haque, M. A., Mohsin, F. T., Sharmin, T., & Nasim, M. (2026). Sodium ion batteries: A sustainable alternative to lithium-ion batteries with an overview of market trends, recycling, and battery chemistry. Next Energy, 10, 100478.

Phogat, P., Dey, S., & Wan, M. (2025). Comprehensive review of sodium-ion batteries: principles, materials, performance, challenges, and future perspectives. Materials Science and Engineering: B, 312, 117870.

Phogat, P., Dey, S., & Wan, M. (2025). India's role in advancing sodium-ion battery technology: a bibliometric study. Ionics, 31(8), 7693-7707.

Phogat, P., Dey, S., & Wan, M. (2025). Powering the sustainable future: a review of emerging battery technologies and their environmental impact. RSC Sustainability, 3(8), 3266-3306.

Rostami, H., Valio, J., Suominen, P., Tynjälä, P., & Lassi, U. (2024). Advancements in cathode technology, recycling strategies, and market dynamics: A comprehensive review of sodium ion batteries. Chemical Engineering Journal, 495, 153471.

Sandri, C., Di Rienzo, R., Deiaco, A., Morelli, M., Cristofoli, G., Cazzanti, S., ... &Saletti, R. (2026). Sodium-ion batteries: A review of modeling, safety, and state estimation techniques. Journal of Energy Storage, 163, 122120.

Tedla, T. S., Hlongwa, N. W., Nkambule, T. T. I., & Kebede, M. A. (2025). Advancements in sodium-ion batteries technology: A comprehensive review of recent development on materials, mechanisms, applications, and prospects for energy storage. Energy Reports, 14, 3175-3203.