She Sells Sea Cells: Exploring the Potential of Sodium-Based Batteries

A thought piece by OPEXA

Executive Summary

As the world transitions to cleaner energy systems, the limitations of lithium-ion batteries are becoming increasingly clear. Lithium is scarce, geopolitically concentrated, and environmentally intensive to extract. Sodium, by contrast, is abundant, accessible, and extractable from seawater. This paper explores how sodium-based batteries—especially those derived from marine and biomass sources—could reshape energy storage in the UK and beyond.

The Case for Sodium

Sodium is 400 times more abundant than lithium and widely distributed across the globe. In the UK, our extensive coastline and existing desalination infrastructure offer a unique opportunity to explore sodium extraction from seawater. Unlike lithium, sodium does not require rare metals or complex mining operations. It can be harvested through processes such as solar evaporation, electrodialysis, and emerging bioadsorption techniques.

How Sodium Batteries Work

Sodium-ion batteries operate similarly to lithium-ion systems. Sodium ions shuttle between the anode and cathode during charge and discharge cycles. Common materials include:

- **Anode**: Hard carbon, often derived from biomass such as coconut shells or seaweed.
- **Cathode**: Sodium-based compounds like $NaFePO_4$ (sodium iron phosphate) or layered oxides (are a class of materials commonly used as **cathodes** in sodium-ion and lithium-ion batteries. Their structure consists of alternating layers of metal oxides and alkali ions (like sodium or lithium), which allows ions to move in and out during charge and discharge cycles.)
- **Electrolyte**: Organic solvents or emerging solid-state formats.

These components can increasingly be sourced from recycled or renewable feedstocks, reducing environmental impact and improving circularity.

Sourcing Components Sustainably

Anodes: Biomass-Derived Hard Carbon

- Feedstocks include coconut shells, seaweed, sugarcane bagasse, wood pulp, and agricultural waste.
- In the UK, forestry byproducts and marine biomass offer scalable sources.
- These materials are low-cost, renewable, and compatible with sodium-ion chemistry.

Cathodes: Recycled and Bio-Templated Materials

- Iron and manganese can be recovered from steelmaking slag or spent batteries.
- Phosphate may be reclaimed from fertiliser runoff or wastewater treatment.
- Bio-templating uses natural scaffolds—such as cellulose or diatomaceous earth (naturally occurring, soft, siliceous sedimentary rock made up of the fossilised remains of **diatoms** — microscopic algae with intricate, glass-like cell walls composed of silica.) —to guide crystal formation, improving performance and reducing synthesis temperatures.

Electrolytes: Renewable and Recyclable Options

- Biopolymer electrolytes can be made from lignin (paper industry waste), chitosan (shellfish processing), and cellulose (agricultural residues).
- Organic solvents like ethylene carbonate can be recovered and purified from spent batteries.
- These approaches align with UK circular economy goals and biomass availability.

Bioadsorption and Saltwater Loop Innovation

Two emerging concepts offer promise for sustainable sodium recovery:

- **Bioadsorption** uses natural materials—such as algae, cellulose, or shellfish waste—to bind and extract sodium ions from seawater. This method is low-energy, eco-friendly, and potentially scalable in coastal regions.
- **Saltwater Battery Loop** refers to systems where sodium is extracted during battery charging and reused during discharge. This closed-loop approach could pair effectively with offshore wind farms, offering grid-scale storage without reliance on solar input.

Bio-Templating: Nature-Inspired Synthesis

Bio-templating is a sustainable method that uses biological structures to guide the formation of battery materials. For example, plant fibres or fossilised algae can shape the morphology of cathodes (means **engineering the cathode's physical form** to improve how the battery works — and bio-templating offers a sustainable way to do that), enhancing ion diffusion and reducing energy input. Templates such as dextran, cellulose, and chitosan are already being trialled in academic labs, with promising results.

Benefits include:

- Enhanced charge rates and capacity retention
- Lower synthesis temperatures

- Use of renewable UK feedstocks

Strategic Fit for the UK

The UK's coastal geography, biomass availability, and policy alignment with circular economy principles make it an ideal testbed for sodium-based energy systems. Potential deployment zones include the Humber, Teesside, and Forth Estuary, where desalination, offshore wind, and industrial infrastructure intersect.

OPEXA's Position

OPEXA promotes this concept as a strategic thought piece. We're not experts in battery chemistry, but we believe the convergence of marine extraction, biomass innovation, and circular design deserves serious attention. We invite researchers, policymakers, and industry leaders to challenge, refine, and build upon these ideas.

Questions for further exploration:

- Could the UK become a global leader in seawater-derived energy systems?
- How might bioadsorption and bio-templating reshape material science in energy storage?
- What role should public-private coalitions play in piloting sodium-based technologies?
- Can circular chemistry become a competitive advantage for UK infrastructure?
- How might regional biomass and waste streams be mapped to battery innovation?