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## SUSTAINABLE ENERGY STORAGE THROUGH BIOMASS-DERIVED CARBON: A NEW PARADIGM?

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The urgent demand for clean energy storage aligns with the EU's Green Deal and Net-Zero Industry Act (EC, 2024), driving innovation beyond conventional lithium-ion technologies. Although widely adopted, lithium-ion systems depend on critical minerals, entail complex recycling, and pose fire risks. Emerging carbon-based energy storage cells address these challenges by utilizing agricultural biomass-derived porous carbon, water, and halide salts (Interesting Engineering, 2025).

Operating through ion sorption mechanisms, these cells store charge via physical adsorption into renewable carbon electrodes. Aqueous electrolytes ensure non-flammability and environmental safety. Recent developments have demonstrated cycle lives exceeding 6,000–10,000 cycles and durable system operation over 25 years with energy densities up to 434 Wh/kg reported in metal-free dual-carbon systems (Zishuai Zhang et al. 2022).

Patents and scientific studies confirm that metal-free carbon electrodes combined with saltwater electrolytes enable safe, scalable, and recyclable storage. New designs even eliminate metal current collectors, allowing batteries made entirely from renewable, non-toxic materials (Naresh, R., et al., 2019). This advances the vision of truly circular energy storage, independent from mining constraints and toxic substances.

Aligned with Industry 5.0 principles (EC, 2023), these carbon-based cells represent a critical innovation for resilient, sustainable grids and energy autonomy. This paper discusses their architecture, lifecycle performance, and role in advancing Europe's clean energy goals through fully renewable, low-impact storage technologies.

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