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Pairing hemp battery production with the byproduct of recycling plastic—low-grade carbon—could enhance San Diego's investment case for hemp batteries by creating a circular economy, further reducing environmental impact and leveraging local resources. Assuming hemp batteries have received equivalent investment to lithium-ion (making them equally production-ready), let's explore how this synergy strengthens the case for hemp over lithium-ion in San Diego, focusing on renewability, fire safety, and the innovative use of plastic recycling byproducts.

Plastic Recycling Byproduct: Low-Grade Carbon

- Process: Plastic recycling, particularly through pyrolysis or chemical recycling, breaks down plastics into oils, gases, and low-grade carbon (e.g., carbon black or amorphous carbon). This carbon is often a low-value byproduct, used in fillers or burned, but it can be repurposed for battery electrodes.
- Application to Hemp Batteries: Low-grade carbon from plastic waste could supplement or replace hemp-derived carbon (e.g., B4C, nanosheets) in battery anodes or supercapacitors. Research shows carbon-based electrodes from waste plastics can achieve high capacitance (e.g., 100-200 F/g in supercapacitors), comparable to hemp-derived carbon's performance (12 Wh/kg in lab tests). Combining hemp and plastic-derived carbon could optimize costs and performance.
- Local Opportunity: San Diego generates significant plastic waste (California produces ~5 million tons annually). Recycling facilities could supply low-grade carbon, reducing landfill use and supporting the city's zero-waste goals by 2040.

Hemp Batteries with Plastic Byproduct vs. Lithium-Ion

- Renewability and Sustainability:
  - Hemp Batteries: Hemp is a renewable crop, grown in 3-4 months, and California's hemp industry (legal since 2018) supports local sourcing. Using low-grade carbon from plastic recycling further reduces reliance on mined materials, creating a closed-loop system. Recycling hemp batteries is simpler (only lithium recovery), and plastic-derived carbon minimizes waste. This aligns with San Diego's 100% clean energy goal by 2035 and zero-waste initiatives.
  - Lithium-Ion: Relies on non-renewable lithium and cobalt, with mining causing environmental damage (15,000 gallons of water per ton of lithium) and ethical issues (cobalt mining in the Congo). Recycling is complex, recovering only 50-60% of materials, and cannot incorporate plastic byproducts as directly as hemp batteries.
- Fire Safety:
  - Hemp Batteries: Lithium-sulfur (Li-S) hemp batteries form a passive layer when damaged, preventing thermal runaway and reducing fire risk. This is critical in San Diego's wildfire-prone climate (e.g., Cedar Fire, 2003). Plastic-derived carbon electrodes are stable, unlikely to increase flammability, and may enhance

safety by reducing metallic oxides.
    - Lithium-Ion: Prone to thermal runaway, causing intense fires and toxic fumes (e.g., 40 large-scale fires globally). Even with advanced safety systems, risks persist in San Diego's dry, seismic environment, where earthquakes could trigger fires.
- Performance:
    - Hemp Batteries: With equal investment, hemp Li-S batteries achieve 550 mAh/g capacity (vs. 200-300 mAh/g for lithium-ion) and supercapacitors reach 12 Wh/kg, potentially 200+ Wh/kg with optimization. Plastic-derived carbon could enhance electrode conductivity, maintaining or boosting performance for grid storage (e.g., supporting SDG&E's renewable integration).
    - Lithium-Ion: Offers 100-265 Wh/kg, proven for grid and EV use (e.g., SDG&E's 30 MW Top Gun facility). Plastic byproducts are less applicable, as lithium-ion anodes typically use mined graphite.
- Cost:
    - Hemp Batteries: With equivalent investment, costs could match lithium-ion (~$100/kWh). Using low-grade carbon from plastic waste reduces raw material costs, as it's a cheap byproduct. Local hemp and plastic recycling in San Diego lower supply chain expenses.
    - Lithium-Ion: Costs are optimized (~$100/kWh), but reliance on finite lithium and cobalt risks price volatility. Plastic byproducts are less viable, limiting cost savings.
- Local Fit:
    - Hemp Batteries: Integrating plastic-derived carbon leverages San Diego's waste management infrastructure, creating jobs and reducing landfill use. Hemp cultivation and UC San Diego's R&D can drive a local battery industry, enhancing economic and environmental benefits. Lower fire risk is ideal for wildfire-prone areas.
    - Lithium-Ion: Proven but less sustainable, with higher fire risks and no direct use for plastic byproducts. Global supply chains offer less local economic impact.

San Diego Investment Case

Hemp batteries, paired with plastic recycling byproducts, make more sense than lithium-ion for San Diego under the assumption of equal development. Key advantages:

- Fire Safety: Hemp batteries' low flammability addresses San Diego's wildfire risks, unlike lithium-ion's thermal runaway hazards.
- Sustainability: Hemp's renewability and plastic-derived carbon create a circular economy, aligning with zero-waste and clean energy goals. Lithium-ion's non-renewable materials conflict with these priorities.
- Economic Benefits: Local hemp cultivation and plastic recycling (e.g., via pyrolysis plants in California) reduce costs and create jobs, unlike lithium-ion's reliance on global mining.
- Performance: Hemp batteries match or exceed lithium-ion in capacity and could

integrate plastic-derived carbon without compromising efficiency, meeting grid demands.

Implementation:

- Pilot Projects: Deploy hemp batteries with plastic-derived carbon in low-risk grid storage sites (e.g., rural San Diego County), testing performance and fire safety.
- Recycling Infrastructure: Partner with local waste management (e.g., EDCO) to supply low-grade carbon from plastic recycling, scaling pyrolysis facilities.
- R&D Support: Fund UC San Diego and cleantech startups to optimize hemp-plastic battery designs, leveraging California's hemp industry.
- Phased Transition: Use lithium-ion for existing infrastructure while scaling hemp batteries, ensuring grid reliability during rollout.

Caveats:

- Even with equal investment, integrating plastic-derived carbon into hemp batteries may require fine-tuning for consistency and performance.
- Regulatory approval for hemp-plastic batteries must be fast-tracked, feasible with San Diego's cleantech influence.
- Lithium-ion's proven reliability could justify a small backup role (e.g., 10-20% of storage) during hemp battery scale-up.

Conclusion

Investing in hemp batteries with plastic recycling byproducts is the smarter choice for San Diego, assuming equal development to lithium-ion. Hemp's renewability, paired with low-grade carbon from plastic waste, maximizes sustainability and economic benefits while minimizing wildfire risks. Lithium-ion's non-renewable materials, fire hazards, and limited use of plastic byproducts make it less suitable. By leveraging local hemp and recycling infrastructure, San Diego can lead in safe, green energy storage, aligning with its environmental and safety goals.