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A Resilient, Waste-Driven Alternative to Chlor-Alkali for California Industry

Additional submitted attachment is included below.

Electric Program Investment Charge 2026–2030 (EPIC 5) Research Concept Proposal Form

The California Energy Commission (CEC) is currently soliciting research concept ideas and other input for the Electric Program Investment Charge 2026–2030 (EPIC 5) Investment Plan. For those who would like to submit an idea for consideration, please complete this form and submit it to the CEC by **August 8, 2025**. More information about EPIC 5 is available below.

To submit the form, please visit the e-commenting link: https://efiling.energy.ca.gov/EComment/ECommentSelectProceeding.aspx and select the Docket **25-EPIC-01**. Enter your contact information and then use the "choose file" button at the bottom of the page to upload and submit the completed form. Thank you in advance for your input.

1. Please provide the name, email, and phone number of the best person to contact should the CEC have additional questions regarding the research concept:

Name: Bilen Akuzum
Email: bilen@aepnus.com
Phone: +1-215-760-4080

2. Please provide the name of the contact person's organization or affiliation:

Organization: Aepnus Technology Inc.
Title: Co-founder & CTO

3. Please provide a brief description of the proposed concept that you would like the CEC to consider as part of the EPIC 5 Investment Plan. What is the purpose of the concept, and what would it seek to do? Why are EPIC funds needed to support the concept?

Aepnus Technology proposes to scale and deploy a novel electrochemical process—the **Sulfate-Alkali™ Process**—to address critical challenges in California's industrial chemical supply chain. This technology **converts sodium sulfate waste**, a pervasive industrial byproduct, into **high-purity caustic soda (NaOH)** and either **sulfuric acid (H_2SO_4)** or **ammonium sulfate** fertilizer, all without producing chlorine. The platform provides a **clean, chlorine-free alternative** to the traditional chlor-alkali process and unlocks circular chemical production using industrial waste as a feedstock.

The core purpose of this concept is to **establish localized, sustainable, and resilient chemical manufacturing in California** that supports clean energy and battery manufacturing, while addressing a growing environmental burden: sodium sulfate waste. Caustic soda and sulfuric acid are essential reagents in the state's battery, semiconductor, wastewater treatment, and general manufacturing industries, yet **California lacks meaningful local production capacity** for either reagent. Caustic soda, in particular, is predominantly produced in the Gulf Coast (e.g., Texas and Louisiana), where chlor-alkali plants operate at large scale due to co-location with chlorine-consuming industries such as PVC production. This model does **not translate well to California**, where:

- **Few chlorine-consuming industries** exist, making traditional chlor-alkali projects uneconomical or environmentally risky
- **Transportation of caustic soda** from Texas to California is expensive, carbon-intensive, and vulnerable to disruption
- **Sodium sulfate waste** from lithium-ion battery, cathode, and chemical production is accumulating rapidly without viable disposal options

Aepnus' technology provides a California-fit alternative: it enables **on-site or near-site electrochemical upcycling** of sodium sulfate waste into high-value reagents **without chlorine production**, significantly lowering environmental risks and logistics costs. The Sulfate-Alkali™ Process:

- Reduces energy consumption by ~40% vs. legacy chlor-alkali electrolysis
- Avoids hazardous chlorine handling and storage
- Cuts GHG emissions by reducing the need to truck in reagents from out of state
- Turns an expensive waste liability into a source of local revenue and supply security

EPIC funds are essential to validate and scale this technology in California, where industrial users and regulators alike are urgently seeking safer, cleaner alternatives to legacy chemical supply chains. Specifically, funding will support:

- System engineering for California waste streams (e.g., sodium sulfate from battery recycling, cathode production)
- Pilot deployment at an industrial site in-state
- Techno-economic analysis under California utility and policy conditions
- Validation of emissions and waste diversion metrics in alignment with EPIC priorities

This concept directly aligns with California's clean energy goals by providing a **novel electrochemical solution that decarbonizes industrial processes**, enhances supply chain resilience, and enables circular manufacturing — outcomes that are not currently achievable through conventional chemical production pathways. Aepnus' platform transforms a cost and environmental liability into a clean, locally available asset, making it a strong candidate for EPIC 5 support.

4. In accordance with Senate Bill 96[i], please describe how the proposed concept will "lead to technological advancement and breakthroughs to overcome barriers that prevent the achievement of the state's statutory energy goals." For example, what technical and/or market barriers or customer pain points would the proposed concept address that would lead to increased adoption of clean energy technology or innovation? Where possible, please provide specific cost and performance targets that need to be met for increased industry and consumer acceptance. For scientific analysis and tools, provide more information on what data and information gaps the proposed concept would help fill, and which specific parties or end users would benefit from the results, and for what purpose(s)?

The proposed concept—the development and California deployment of Aepnus Technology's **Sulfate-Alkali Process**—represents a **breakthrough in electrochemical manufacturing** that directly addresses multiple technical and market barriers limiting the state's progress toward its statutory energy and climate goals.

Technological Breakthrough
The Sulfate-Alkali Process is a **first-of-its-kind platform** that uses **sodium sulfate**, a widespread industrial waste stream, as the feedstock to generate **caustic soda (NaOH)**, **sulfuric acid (H_2SO_4), and Ammonium Sulfate** — critical reagents in California's clean energy economy. Unlike the conventional chlor-alkali process, Aepnus' system:

- **Does not produce chlorine**, eliminating a hazardous byproduct that creates permitting, safety, and storage challenges in California
- **Consumes significantly less energy** (target: **<1,400 kWh per metric ton** of NaOH, ~40% lower than standard membrane electrolysis)
- **Uses abundant, non-precious materials** (no iridium), allowing for scalable, domestic manufacturing
- **Recycles hydrogen in situ** to lower OPEX and enhance energy utilization (>98% H_2 recycling target)
- Is **modular and site-adaptable**, suitable for distributed deployment across industrial zones, brownfields, or co-located with battery recycling or manufacturing plants

This represents a **fundamentally different and cleaner paradigm** for producing essential chemicals—advancing California's transition to electrified, zero-carbon industry.

Barriers Overcome by This Concept

1. Supply Chain Dependence & Geographic Mismatch

- **Barrier**: California relies almost entirely on caustic soda and sulfuric acid imports from the Gulf Coast, despite being one of the largest consumers. The state lacks the chlorine-consuming infrastructure to support traditional chlor-alkali plants.
- **Breakthrough**: Aepnus decouples caustic soda production from chlorine, enabling **in-state production tailored to California's industrial profile**.

2. Waste Accumulation and Disposal Costs

- **Barrier**: Sodium sulfate, a byproduct of battery manufacturing, cathode processing, and detergent production, is currently **landfilled or stockpiled** at high cost (~$30–$150/ton), creating economic and environmental liabilities.
- **Breakthrough**: Aepnus **upcycles sodium sulfate** into usable commodities, eliminating waste and creating new revenue streams from previously discarded material.

3. Energy and Emissions Intensity

- **Barrier**: Traditional reagent supply chains are fossil-fuel intensive—both in production and in transportation over long distances.
- **Breakthrough**: The Sulfate-Alkali Process is designed to run on **electricity (ideally renewable)**, and cuts energy usage per ton of output. Local production eliminates long-haul trucking and associated GHG emissions.

Data & Scientific Gaps Addressed

The proposed pilot would also generate critical data to guide broader deployment across California:

- **TEA/LCA data** comparing Sulfate-Alkali Process to imported chemical supply chains
- **Real-world validation** of reagent quality for use in battery recycling, wastewater treatment, and semiconductor manufacturing
- **Hydrogen utilization analytics** that inform integration with California's hydrogen hubs and electrolyzer roadmap
- **Permitting and siting learnings** for electrochemical systems in industrial zones

Beneficiaries and End Users

The proposed research will benefit a wide range of California stakeholders:

- **Battery and materials manufacturers**: Gain access to clean, local reagents while eliminating waste costs

- **Wastewater treatment plants and municipalities**: Benefit from reliable, low-carbon chemical inputs
- **Clean energy developers**: Gain a platform for integrating industrial loads with distributed energy resources and renewable energy.
- **Environmental regulators and planners**: Receive validated data to inform policies supporting circular and electrified industry
- **Local communities**: Experience reduced emissions, waste, and hazardous materials risks.

This research and demonstration effort will provide California with a validated, scalable platform to **replace legacy chemical infrastructure** with a **clean, circular, and electrified alternative**—perfectly aligned with the vision of Senate Bill 96.

5. Please describe the anticipated outcomes if this research concept is successful, either fully or partially. For example, to what extent would the research reduce technology or ratepayer costs and/or increase performance to improve the overall value proposition of the technology? What is the potential of the innovation at scale? How will the innovation lead to ratepayer benefits in alignment with EPIC's guiding principles to improve safety,[ii] reliability,[iii] affordability,[iv] environmental sustainability,[v] and equity?[vi]

If successfully demonstrated and scaled in California, the proposed Sulfate-Alkali Process would offer transformational benefits for the state's industrial decarbonization, chemical resilience, and circular economy infrastructure. This project would provide quantifiable gains in **cost reduction, waste elimination, emissions avoidance, and regional self-sufficiency**—all aligned with the statutory goals of EPIC 5 and California's broader climate and equity policies.

Technology Performance and Cost Outcomes
Successful deployment would yield the following outcomes:

- **Energy Efficiency**: Demonstrated energy consumption of **<1,400 kWh per metric ton of caustic soda**—a ~40% reduction compared to legacy chlor-alkali electrolysis systems.
- **Hydrogen Recovery**: >98% hydrogen recycling rates within the system, minimizing feedstock losses and operating costs.
- **Reagent Quality**: Production of **>99% pure NaOH and H_2SO_4**, compatible with critical industrial applications such as battery recycling and wastewater treatment.
- **Capital and Operating Cost Savings**:
    - 20–35% lower operating costs than relying on imported reagents from the Gulf Coast

    - Up to **$833 per ton of sodium sulfate processed** in combined avoided waste disposal and reagent value
- **System ROI for Industrial Users**: Payback periods of 2–4 years with IRRs above 20%, improving investability for private-sector partners.

Impact at Scale

If commercialized across California’s battery, chemicals, semiconductor, and municipal sectors, the Sulfate-Alkali Process could:

- **Divert 100,000–150,000 tons/year of sodium sulfate waste** per large industrial facility
- Displace **tens of thousands of tons per year of imported caustic soda and sulfuric acid**
- **Avoid 15,000–25,000 tCO_2e/year per site** from reduced long-haul reagent transport and legacy process emissions
- Support **distributed, modular deployment** at dozens of sites across California's industrial and recycling corridors

These outcomes enable the state to move away from a **centralized, fossil-fueled, chlorine-dependent chemical model** toward a **resilient, electrified, and waste-negative paradigm**.

Alignment with EPIC’s Guiding Principles

Principle	Anticipated Impact
Safety	Eliminates chlorine production and storage risks, reducing hazard potential
Reliability	Creates local, distributed reagent supply, reducing dependence on external markets
Affordability	Lowers chemical and waste disposal costs for ratepayer-funded industrial services
Environmental Sustainability	Diverts industrial waste from landfills and reduces chemical transport emissions
Equity	Reduces pollutant exposure near industrial communities and improves siting flexibility

For example, wastewater treatment plants and lithium-ion battery facilities—many of which are co-located with or near disadvantaged communities—stand to benefit from cleaner onsite chemical access and reduced waste truck traffic.

6. Describe what quantitative or qualitative metrics or indicators would be used to evaluate the impacts of the proposed research concept.

Quantitative Metrics

Category	Metric	Target / Evaluation Criteria
Energy Efficiency	Energy consumption per ton of NaOH produced	**<1,400 kWh/ton** (40% better than industry norm)
Hydrogen Recycling	% of hydrogen internally recovered and reused	**>98%**
Product Purity	Purity levels of NaOH and H_2SO_4 outputs	**>99%** to meet industrial specs
Waste Reduction	Tons of sodium sulfate diverted from landfill	**100,000–150,000 tons/year** per large facility
Emissions Reduction	Avoided GHG emissions from transport & legacy production	**15,000–25,000 tCO_2e/year** per site
Cost Impact	Reduction in reagent and disposal costs	**20–35%** savings over imported chemicals
Economic Performance	Payback period, IRR	**2–4 years**, IRR **>20%**
System Uptime	Hours of continuous operation without failure	**1,000+ hours** durability at pilot scale

These quantitative metrics will be captured through direct system monitoring, reagent testing, third-party TEA/LCA assessments, and host site feedback.

Qualitative Metrics

Domain	Indicator
Technology Acceptance	Willingness of host facilities and customers to expand adoption post-pilot
Safety & Permitting	Community and regulatory response to chlorine-free operation
Workforce & Skills Impact	Ease of operator training, safety procedures, and maintenance transition
Siting Flexibility	Number of viable deployment sites unlocked by non-chlorine model
Circular Economy Enablement	Degree to which sodium sulfate is converted into usable products on-site
Community Impact	Stakeholder feedback on noise, emissions, trucking reductions, etc.

These qualitative outcomes can be assessed through surveys, stakeholder interviews, environmental impact evaluations, and community engagement sessions.

7. Please provide references to any information provided in the form that supports the research concept's merits. This can include references to cost targets, technical potential, market barriers, equity benefits, etc.

Market & Technical References

- **IHS Markit Chemical Economics Handbook: Chlorine and Sodium Hydroxide (2021)**
  Documents the heavy concentration of chlor-alkali production in the U.S. Gulf Coast and the lack of production on the West Coast, highlighting the **logistical and economic disadvantage California faces** in sourcing caustic soda.
- **IHS Markit Sodium Sulfate Market Report (2023)**
  Confirms that sodium sulfate is a **growing industrial waste stream** from several established industries, with **limited reuse pathways** and increasing disposal costs.
- **Morgan Stanley: North America Commodity Chemicals Outlook (2024)**
  Highlights strategic value in companies focused on **low-cost, energy-efficient, feedstock-flexible chemical production**, underscoring market momentum toward decarbonized commodity chemicals.
- **US Chemicals & Agriculture Market Report (2023)**
  Reinforces the need for **domestic, circular production of fertilizer precursors** like ammonium sulfate and sulfuric acid, especially in regions like California with constrained logistics.

Technology & Investment Validation

- Clean Energy Ventures. *"Aepnus raises $8M to electrify chemical manufacturing"*
  ➤ https://cleanenergyventures.com/clean-energy-venture-capital/aepnus-8-million-to-electrify-chemical-manufacturing/
  Overview of Aepnus' $8 million seed round and its mission to decarbonize industrial chemicals using **electrochemical innovation and waste valorization**.
- Clean Energy Ventures. *"Why We Invested in Aepnus"*
  ➤ https://cleanenergyventures.com/clean-energy-venture-capital/why-we-invested/why-we-invested-aepnus/
  Explains the firm's investment thesis, citing Aepnus' unique ability to enable **localized, chlorine-free caustic soda production** using industrial waste.

News Coverage on Sodium Sulfate & Circular Chemistry

- **TechCrunch**. *"Aepnus wants to create a circular economy for key battery manufacturing materials"* (June 2024)
  ➤ https://techcrunch.com/2024/06/13/aepnus-wants-to-create-a-circular-

economy-for-key-battery-manufacturing-materials/
Highlights Aepnus' innovation in **recycling sodium sulfate waste from cathode production** into usable chemicals—directly relevant to California's growing battery manufacturing sector.

- **Latitude Media**. *"Can this start-up solve the battery supply chain's waste problem?"*
  ➤ https://www.latitudemedia.com/news/can-this-start-up-solve-the-battery-supply-chains-waste-problem/
  Explores the broader challenge of **circularity in the battery sector**, focusing on sodium sulfate as a major unresolved bottleneck.
- **Chemical & Engineering News (ACS)**. *"Battery industry's sodium sulfate waste mounts"*
  ➤ https://cen.acs.org/energy/battery-industrys-sodium-sulfate-waste/102/i21
  Reports that sodium sulfate disposal is now a **limiting factor for lithium-ion battery and cathode manufacturers**, with mounting regulatory and cost pressures.
- **Worley**. *"Cathode manufacturing solutions for sodium sulfate"*
  ➤ https://www.worley.com/en/insights/our-thinking/resources/cathode-manufacturing-solutions-for-sodium-sulphate
  Describes growing awareness in the cathode manufacturing space regarding **sodium sulfate accumulation**, and the lack of recycling options—validating the need for technologies like Aepnus.

8. The EPIC 5 Investment Plan must support at least one of five Strategic Goals:[vii]
   a. Transportation Electrification
   b. Distributed Energy Resource Integration
   c. Building Decarbonization
   d. Achieving 100 Percent Net-Zero Carbon Emissions and the Coordinated Role of Gas
   e. Climate Adaptation

   Please describe in as much detail as possible how your proposed concept would support these goals.

The proposed concept—the deployment of Aepnus Technology's Sulfate-Alkali Process—supports **three out of five** of the EPIC 5 Strategic Goals, with particularly strong alignment to **Goal D (Achieving 100% Net-Zero Carbon Emissions and the Coordinated Role of Gas)** and **Goal E (Climate Adaptation)**. The technology also contributes to the success of **Goal B** by enabling decentralized clean chemical production and decarbonized building and industrial operations.

Achieving 100% Net-Zero Carbon Emissions and the Coordinated Role of Gas

The Sulfate-Alkali Process directly supports the transition to **net-zero carbon emissions** in California by:

- **Electrifying chemical production**: Aepnus replaces fossil-intensive chemical supply chains (such as those producing caustic soda in Texas and transporting it by truck or rail) with **clean, electricity-driven electrolysis**.
- **Enabling zero-emissions industrial inputs**: The reagents produced—caustic soda and sulfuric acid—are foundational to **battery recycling**, **critical mineral refining**, and **wastewater treatment**, all of which are core to California's decarbonization strategy.
- **Decoupling from fossil-based hydrogen**: The process internally recycles hydrogen with >90% efficiency, reducing the need for external hydrogen supply or natural gas-based input.
- **Providing a clean alternative to chlorine-based systems**: By avoiding chlorine, Aepnus' system allows clean reagent production **without the hazards and emissions of chlor-alkali facilities**, which are rarely feasible or safe to build in California.

Climate Adaptation

Aepnus enhances California's **climate resilience** by transforming **industrial waste into valuable feedstock**, reducing pollution and dependency on fragile, out-of-state chemical supply chains:

- **Waste valorization**: The system converts **sodium sulfate**, a waste byproduct from battery manufacturing and cathode production, into marketable reagents—eliminating tens of thousands of tons of landfill-bound material per site.
- **Pollution avoidance**: By avoiding chlorine production, the technology reduces the risk of hazardous chemical releases, particularly important in **environmentally burdened communities**.
- **Infrastructure resilience**: On-site chemical production reduces reliance on long-haul deliveries that are increasingly vulnerable to wildfires, floods, and other climate-exacerbated disruptions.

Building Decarbonization

The system indirectly supports building decarbonization by supplying **clean, local chemical inputs** to sectors that intersect with the built environment, such as:

- **Municipal water and wastewater treatment**
- **Industrial heat processing and neutralization**

- **Chemical use in HVAC systems, cleaning, and maintenance**
  By offering a **non-fossil, on-demand chemical source**, Aepnus helps decarbonize the chemical layer of building operations.

Strategic Summary

Aepnus' concept is a **cross-cutting clean manufacturing innovation** that:

- Electrifies an essential industrial process
- Eliminates an environmental waste liability
- Reduces GHGs and supply risk
- Improves climate and community resilience

It supports California's transition to a **safe, reliable, affordable, and equitable clean energy economy**, and is therefore a strong candidate for EPIC 5 inclusion under multiple strategic goals.

About EPIC

The CEC is one of four EPIC administrators, funding research, development, and demonstrations of clean energy technologies and approaches that will benefit electricity ratepayers of California's three largest investor-owned electric utilities.

EPIC is funded by California utility customers under the auspices of the California Public Utilities Commission.

To learn more about EPIC, visit: https://www.energy.ca.gov/programs-and-topics/programs/electric-program-investment-charge-epic-program

EPIC 5 documents and event notices will be posted to: https://www.energy.ca.gov/proceeding/electric-program-investment-charge-2026-2030-investment-plan-epic-5

Subscribe to the EPIC mailing list to stay informed about future opportunities to inform the development of EPIC 5: https://public.govdelivery.com/accounts/CNRA/signup/31897

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i See section (a) (1) of Public Resources Code 25711.5 at: https://leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?lawCode=PRC&sectionNum=25711.5.

ii EPIC innovations should improve the safety of operation of California's electric system in the face of climate change, wildfire, and emerging challenges.

iii EPIC innovations should increase the reliability of California's electric system while continuing to decarbonize California's electric power supply.

iv EPIC innovations should fund electric sector technologies and approaches that lower California electric rates and ratepayer costs and help enable the equitable adoption of clean energy technologies.

v EPIC innovations should continue to reduce greenhouse house gas emissions, criteria pollutant emissions, and the overall environmental impacts of California's electric system, including land and water use.

vi EPIC innovations should increasingly support, benefit, and engage disadvantaged vulnerable California communities (DVC). (D.20-08-046, Ordering Paragraph 1.) DVCs consist of communities in the 25 percent highest scoring census tracts according to the most recent version of the California Communities Environmental Health Screening Tool (CalEnviroScreen), as well as all California tribal lands, census tracts with median household incomes less than 60 percent of state median income, and census tracts that score in the highest 5 percent of Pollution Burden within CalEnviroScreen, but do not receive an overall CalEnviroScreen score due to unreliable public health and socioeconomic data.

vii In 2024 the CPUC adopted five Strategic Goals to guide development of the EPIC 5 Investment Plan. A description of the goals can be seen in Appendix A of CPUC Decision 24-03-007 available at: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M527/K228/527228647.PDF