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Re Public Comment on Electric Program Investment Charge 2026â€“2030 Investment Plan (EPIC 5)

Additional submitted attachment is included below.

VYCARB

Public Comment to CEC on EPIC 5

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June 18, 2026

California Energy Commission
715 P Street
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Re: Public Comment on Electric Program Investment Charge 2026–2030 Investment Plan (EPIC 5)

Dear CEC and EPIC team,

Thank you for the opportunity to provide feedback on the Electric Program Investment Charge 2026–2030 Investment Plan (EPIC 5). We are writing to indicate our support for the allocation of resources towards Getting to 100% Net Zero Carbon and the Coordinated Role of Gas, particularly on Cost-Effective Industrial Decarbonization. In addition, we are writing to share an alternative pathway for permanent carbon capture and storage that would be a valuable complement to CEC and EPIC's efforts to accomplish these objectives.

Vycarb is a U.S.-based carbon capture and storage company that converts point-source CO_2 into permanently stored bicarbonate in natural waters, using a containerized, sensor-controlled reactor system. Our approach is rooted in established ocean chemistry, has been demonstrated in pilots including an active installation at the Brooklyn Navy Yard, and is independently verifiable under existing registry methodologies (e.g., Isometric's Dissolved Inorganic Carbon Storage protocol).

Our pathway aligns directly with EPIC's focus area on Cost-Effective Industrial Decarbonization and First-of-a-Kind Deployment Support for Difficult-to-Decarbonize Sectors, serving as a permanent storage option for point-source industrial CO_2 that conventional geologic CCS cannot economically reach.

The attached comment summarizes (a) the structural limitations of geologic storage that necessitate an alternative pathway, (b) the underlying science of bicarbonate as a permanent carbon reservoir, and (c) Vycarb's technology and pilot validation. Given the challenges and limitations of the traditional carbon capture, transportation, and geologic storage value chain, we see Vycarb's water-based CCS solution as an additive alternative approach to enable decarbonization of California's CO_2-emitting facilities, and consideration of the technology in California legislation can significantly accelerate the state's climate objectives. We welcome the opportunity to meet with CEC and EPIC staff to discuss further.

Respectfully submitted,

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PUBLIC COMMENT

Water Bicarbonate-Based Permanent Carbon Storage

Public Comment on Electric Program Investment Charge 2026–2030 Investment Plan (EPIC 5)

Submitted by Vycarb, Inc. | June 18, 2026

1. Executive Summary

California has an opportunity to implement permanent carbon storage pathways that extend the reach of CCUS beyond geologic injection. A growing body of peer-reviewed science indicates that geologic storage alone is unlikely to meet net-zero scenarios, and that the majority of California's industrial CO_2 sources fall below the volume thresholds at which geologic CCS is economically viable.

Vycarb supports EPIC's focus area on Cost-Effective Industrial Decarbonization and First-of-a-Kind Deployment Support for Difficult-to-Decarbonize Sectors, where the inclusion of bicarbonate-based permanent carbon storage in natural waters as a recognized pathway for industrial decarbonization. Bicarbonate storage is the natural chemistry that governs the ocean's carbon reservoir; current registry methodologies certify ≥1,000-year permanence as a conservative floor, with literature supporting residence times on the order of 100,000 years (e.g., Berner, Lasaga, Garrels, 1983; Renforth & Henderson, 2017). The chemistry is mature, measurable, and amenable to modular, sensor-controlled deployment at the scale of individual facilities — making it a strong fit for California's distributed industrial emissions, from biogas (landfill, agriculture, RNG) to materials (cement, petrochemicals) to energy (power generation, natural gas).

2. About Vycarb

2.1 Technology

Vycarb has developed a first-of-its-kind system that converts CO_2 from a wide range of point sources — direct or captured streams from industrial facilities such as bioenergy plants, cement plants, anaerobic digesters, wastewater treatment plants, and landfills — and runs it through a water-based reactor where it interacts with crushed alkaline minerals containing calcium and magnesium to neutralize the CO_2 as dissolved HCO_3 (bicarbonate). Importantly, the system can permanently store even low-purity CO_2, eliminating the need to purify, compress, or transport CO_2 to faraway geological reservoirs. This enables distributed, on-site storage that integrates into existing infrastructure.

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The system consists of a series of reactors containing flowing water and crushed alkaline minerals. CO_2 is injected into the reactor, where it dissolves and reacts with the mineral. Vycarb's sensors track dissolved CO_2, bicarbonate, carbonate, and pH in real time, and measure exactly how much carbon is stored. The treated water is then returned to the natural water body, where the carbon remains locked away in dissolved form for millennia. This continuous, in-line verification also ensures alkalinity additions stay within ecologically safe bounds.

By measuring the specific carbon molecules — bicarbonate and carbonate — directly and in real time, rather than relying on proxies or atmospheric-flux modeling, Vycarb's MRV approach is materially more conservative and traceable than enhanced rock weathering (ERW) or open-ocean alkalinity enhancement (OAE), in which the source, transport, and ultimate atmospheric uptake of CO_2 are often modeled rather than measured.

2.2 Differentiation in the CCS landscape

- **Source traceability:** direct input of measurable CO_2 streams that would be otherwise vented into the atmosphere provides additionality and traceability relative to vented baselines — a structural advantage over OAE/ERW, which depend on long-term absorption of atmospheric CO_2 compliant only for voluntary carbon markets rather than direct industrial decarbonization.
- **Geographic flexibility:** the relevant siting constraints are water bodies, not subsurface injection wells, opening a substantially wider deployment map than geologic CCS. Vycarb's technology uniquely can use a wide range of mineral feedstock, leveraging existing supply chains and mineral transportation (truck, rail, ship) to supply for large and distributed facilities.
- **Modularity:** containerized, sensor-controlled reactors deploy at the scale of an individual facility, making the pathway accessible to small- and mid-volume California emitters.
- **Low-purity CO_2 tolerance: Vycarb's technology entirely bypasses many of the most energy and capital-intensive steps of the traditional CCS value chain by enabling the permanent storage of even low purity CO2 directly. While contaminant gases are scrubbed prior to injection to the Vycarb system, this uses existing commercial equipment with no technology risk and lower cost and energy than existing carbon capture, providing a faster, cheaper, and simpler solution.**

2.3 Validation, pilots, and partners

Since its founding, Vycarb has progressed from lab validation to field deployment across three real-world pilots in coastal New York. These include an active installation at the Brooklyn Navy Yard, where CO_2 is being captured and stored in New York's East River. Vycarb has demonstrated commercial adoption by early buyers including Stripe and Milkywire, and was selected as a semifinalist in the U.S. Department of Energy's carbon dioxide removal purchase program.

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In 2025, Vycarb has raised >$7.5M from corporate emitters seeking decarbonization solutions like Shell, Mitsui O.S.K. Lines, Idemitsu Americas, and Rio Tinto, highlighting the strong commercial interest in Vycarb's technology and rapid adoption potential with appropriate policy support. The company will soon announce additional partnerships to advance projects across multiple continents.

3. Recommendations for EPIC's Inclusion of Water-Based CCS in Industrial Decarbonization

We respectfully offer the following input on the key considerations for water-based CCS — permanence, monitoring, reporting, verification, and quantification:

Permanence

- Adopt the ≥1,000-year durability floor that is consistent with peer-reviewed estimates of ocean alkalinity residence times on the order of 10^4–10^5 years. This is already standardized by Isometric and Puro.Earth for dissolved-inorganic-carbon storage in Voluntary Carbon Markets.
- Distinguish in-reactor, measured bicarbonate storage (Vycarb pathway) from other marine Carbon Dioxide Removal approaches for permanence accounting and regulatory compliance, because the former captures and stores point-source CO_2 emissions and produces a measured bicarbonate stream prior to discharge.

Monitoring, Reporting & Verification (MRV)

- Require continuous, in-line measurement of dissolved CO_2, bicarbonate, carbonate, and pH at the reactor outlet — direct molecular MRV rather than modeled assumptions, given the high variability in water chemistry controlling carbon storage efficiency and ecosystem safety.
- Require independent downstream ecosystem monitoring (e.g., receiving-water pH, alkalinity, trace-metal panels) by a qualified third party, on a cadence appropriate to the receiving water body.
- Require pre-deployment elemental analysis of mineral feedstock with publicly disclosed acceptance criteria for trace metals.

Quantification

- Quantify net storage on the basis of measured bicarbonate added to discharged water, net of any reactor-stage CO_2 degassing and lifecycle emissions from feedstock supply, energy, and transport.
- Require a project-level lifecycle assessment consistent with existing LCA practice (e.g., CARB's LCFS CI methodology) to ensure net-removal claims are conservative.

Integration with the existing regulatory structure

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- Recognize bicarbonate-based storage as eligible permanent storage for compliance and crediting frameworks that today are scoped only to geologic injection — including for biogenic CO_2 from regulated facilities (WWTPs, landfills, anaerobic digesters, bioenergy) and other industrial CO_2 sources (materials, power, fuels).
- Coordinate with existing State Water Resources Control Board and Regional Water Board permitting pathways so that discharge-side permitting can be handled within established water-quality structures, as Vycarb has already demonstrated in New York.

4. The Problem: Limitations of Conventional Geologic Storage

4.1 Structural barriers exclude most California CO_2 sources

Carbon capture and storage is critical to meeting global and California climate targets, but incumbent geologic solutions are constrained by barriers that make them inaccessible for the vast majority of industrial emitters:

- **High CAPEX and operating costs —** particularly disproportionate at small and mid-scale, given the carbon capture systems and associated energy required to regenerate solvents or sorbents, CO2 transportation infrastructure, and geologic injection equipment.
- **Geographic dependence —** geologic CCS requires proximity to specific subsurface formations; most California industrial sources are not so located, requiring extensive CO_2 pipeline networks that face considerable cost, local community concerns, and risk.
- **Minimum volume thresholds —** conventional CCS economics generally require a commitment of CO_2 streams >1 Mtpa; a significant portion of California's industrial CO_2 sources are too small and too distributed to consolidate for dedicated geologic storage projects.
- **High energy intensity —** purification, compression, and long-haul transport costs require significant energy, adding complex project considerations to source additional power and maintain net neutrality.
- **Decades-long monitoring obligations —** subsurface MRV requirements impose persistent liability on host facilities.
- **Complex, long permitting timelines —** Class VI well permitting and pipeline siting routinely take years.
- **Hazard risk and community opposition** - CO_2 transportation may pose hazards for residents in nearby communities, leading to potential community opposition.

These barriers exclude the majority of industrial CO_2 sources in California from carbon capture and storage using geologic solutions — particularly facilities emitting less than 1 million tonnes per year, and those without proximate geologic storage or pipeline access. **EPIC's support for CCS innovations beyond**

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traditional geologic storage will unlock decarbonization for more of the state's addressable industrial CO_2 beyond those with existing CO_2 infrastructure.

4.2 The geological-capacity question

A September 2025 study published in Nature challenged a foundational assumption of global CCS strategy by showing that geological formations do not have sufficient accessible capacity to absorb the CO_2 volumes required by net-zero scenarios. The study warns against overreliance on geologic storage as the primary carbon-removal pathway and suggests investors and policymakers balance their portfolios and policy prescriptions with alternative approaches.

The implications extend beyond any single project: much of the capital flowing into CCS infrastructure today assumes geological capacity that does not exist at the required scale, in the required locations, on the required timelines. Vycarb's approach bypasses geological constraints entirely — CO_2 is stored permanently as dissolved bicarbonate in water, a mechanism that scales with access to water bodies and coastal facilities rather than to specific subsurface formations. (See coverage and interview with Vycarb's CEO in Forbes; September 12, 2025).

5. The Solution: Bicarbonate as Permanent Carbon Storage

5.1 The science

Vycarb's technology is rooted in chemical oceanography and climate science. When CO_2 dissolves in water it forms carbonic acid ($CO_2 + H_2O \rightarrow H_2CO_3$). In the presence of alkaline elements (Ca^{2+}, Mg^{2+}) released from dissolving minerals, that carbonic acid is converted to bicarbonate (HCO_3^-) and a small fraction of carbonate (CO_3^{2-}) through a charge-balance, pH-mediated reaction (the Bjerrum equilibria). The core reaction is:

$$CaCO_3 + CO_2 + H_2O \rightarrow 2HCO_3^- + Ca^{2+}$$

Bicarbonate and carbonate together constitute the largest permanent (>1,000-year) carbon reservoir on Earth's surface — over 36 trillion tonnes of carbon. Bicarbonate alone makes up ~91.7% of ocean dissolved inorganic carbon; carbonate is another ~5.2%; dissolved CO_2 gas is <2%. In effect, we are converting CO_2 gas into the same stable dissolved carbon molecules the ocean naturally produces.

Storing humanity's historical anthropogenic CO_2 emissions (~1.5 trillion tonnes) as bicarbonate would represent only a ~5% addition to the existing ocean DIC pool of ~37 trillion tonnes — an enormous amount of geochemical headroom relative to the climate problem.

5.2 Permanence

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The actual ocean residence time for bicarbonate alkalinity is on the order of tens of thousands of years (e.g., Berner, Lasaga, Garrels, 1983; Cross et al., 2023), and the broader literature (e.g., Renforth & Henderson, 2017) treats ocean bicarbonate storage as effectively permanent for all practical climate purposes. Emerging methodologies held in the Voluntary Carbon Market like Isometric's Dissolved Inorganic Carbon Storage module and Puro.Earth's Direct Air Capture and Ocean Storage module certify permanence at ≥1,000 years as a conservative floor. That is the registry-grade durability threshold for issuing high-quality removal credits — not the scientific ceiling. The fundamental chemistry has been understood for decades; the practical question is whether it can be executed at cost, at scale, and with verifiable measurement — which is the problem Vycarb solves.

5.3 Safety, ecology, and permitting

Vycarb's reactor and process are designed so that water leaving the system falls within the receiving ecosystem's existing chemical envelope:

- Typical ocean water runs ~400 mg/L calcium, ~140 mg/L bicarbonate, pH ~8.3.
- Our process adds calcium on the order of ~150 mg/L — well within natural variation.
- Water initially leaves the reactor slightly acidic (pH 6.5–7.0) by design; the final discharge comes into equilibrium around pH 8.0–8.5. This actually buffers against local acidification, benefitting marine ecosystems.
- We deliberately operate below carbonate saturation thresholds to avoid runaway precipitation, which prevents water-column clouding and secondary CO_2 release.
- Mineral feedstock is elementally analyzed before deployment; any feedstock with concerning trace metals is excluded
- Downstream ecosystem monitoring is handled by independent partners compliant with applicable regulatory monitoring requirements.
- Water discharge is governed by existing water discharge regulatory frameworks like the National Pollution Discharge Environmental System (NPDES), given its draw and release of waters at industrial facilities with controlled discharge chemistry.

Vycarb's Brooklyn Navy Yard pilot was permitted by the New York State department of Environmental Conservation — meaning the technology has already cleared environmental review in one of the most scrutinized urban estuaries in the United States.

6. Conclusion

California's leadership in climate policy depends on a portfolio of decarbonization and carbon-management options that is wide enough to absorb the state's real emissions profile. Supporting

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industrial decarbonization with bicarbonate-based permanent storage would meaningfully expand the state's portfolio of solutions, in a way that is grounded in established ocean chemistry, supported by registry-grade permanence standards, and demonstrably permittable in the United States today.

Vycarb would welcome the opportunity to meet with CEC and EPC staff to dive deeper on the science, MRV approach, pilot data, and protocol-development considerations in greater detail. We are also happy to make our team and external technical advisors available to support workshops, technical sessions, or written follow-up as helpful.

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About the author

Dr. Garrett Boudinot is the founder and CEO of Vycarb, a technology company developing a novel water-based approach for carbon capture and storage. He received a PhD in organic geochemistry from the University of Colorado Boulder, developing analytical tools to trace carbon cycling in marine ecosystems, led a carbon-management research program at Cornell University, and was an Activate Entrepreneurial Fellow. He has served as a Community Science Fellow with the American Geophysical Union, a member of the New York State Climate Impacts Assessment, and a Science Advisor for the ClimateMusic Project.