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25-EPIC-01 Research Idea - Disinfection

See attached file

Additional submitted attachment is included below.

CALIFORNIA ENERGY COMMISSION

CALIFORNIA NATURAL RESOURCES AGENCY

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: Onder Caliskaner
   Email: onder@cwatertech.com
   Phone: (530) 219-0567

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

   Organization: Caliskaner Water Technologies Inc.
   Address: 2733 Brookshire Cir., Woodland, CA, 95776

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?***

   The state of CA has established ambitious recycled water goals to ensure long-term water resilience in the face of persistent drought, population growth, and increasing demand for non-potable and potable reuse applications[1]. Disinfection represents a critical step achieving these goals, as it directly affects public health and safety, reliability, and regulatory compliance of recycled water that is intended for direct and indirect potable reuse.

However, conventional disinfection technologies -such as chlorination, ozonation, and high-dose UV systems- are often misaligned with California's broader decarbonization and energy reduction mandates [2–4] to their high energy intensity and chemical consumption and operational costs [5]. These approaches may also exhibit operational limitations under variable loading or water quality conditions, posing risks to continuous compliance with Title 22 requirements or do not adequately address the safety and reliability requirements for sustained recycled water production [6].

Recently, innovative emerging disinfection technologies offer promising pathways to reduce energy demand and greenhouse gas emissions [7,8]. However, their market adoption remains minimal in California due to industry conservatism, perceived technological risk, and the absence of full-scale, long-duration performance validation under real-world conditions [3,4]. EPIC funds are essential to overcome these barriers by enabling pilot-to-full-scale demonstrations of clean energy-aligned disinfection technologies within operating wastewater treatment plants. Such demonstrations will lower the risk of investment, support regulatory acceptance, and accelerate commercial adoption across municipal utilities[9]. This initiative directly supports California's water-energy-climate nexus by enhancing recycled water reliability, reducing operational costs, and achieving measurable reductions in energy use and GHG emissions—advancing the equity, affordability, and sustainability principles embedded in the Electric Program Investment Charge (EPIC) and SB 96 framework[10].

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)?**

California's long-term energy, climate, and water resilience strategies are increasingly dependent on the large-scale expansion of water recycling. However, this expansion is constrained by the persistent reliance on conventional disinfection technologies that, while compliant, present notable limitations in terms of energy intensity, operational complexity, lifecycle emissions, and safety.

Over 90% of recycled water disinfection systems in the state are based on mature but rigid methodologies that offer limited flexibility to adapt to site-specific needs, energy optimization, or low-emission operation. These systems frequently require high energy input, utilize hazardous or carbon-intensive chemicals, and lack real-time responsiveness, placing both technical and economic burdens on utilities, particularly in small or disadvantaged communities.

This concept proposes to address these systemic barriers by supporting the demonstration and validation of energy-aligned disinfection approaches that are specifically developed to operate within California's regulatory, climatic, and infrastructural context. By shifting the paradigm from "compliance-first" to "compliance-plus-efficiency," the project aims to enable utilities to adopt disinfection systems that meet statutory health requirements while also contributing to the state's clean energy transition.

The concept responds to multiple points simultaneously:

Technical Barriers: The absence of scalable, low-energy disinfection strategies that can consistently meet California Title 22 pathogen removal standards across variable flow and loading conditions.
Market Barriers: Gap exists between technology providers (manufacturers), utilities, and design engineer – limited demonstration and study in actual utilities to support research and development on emerging technologies with direct comparison with conventional technologies.
Economic Barriers: Rising costs of operation and maintenance (O&M), energy, and chemicals, especially for utilities in rural or decentralized systems where economies of scale are limited.
Regulatory Barriers: Limited field-validated data on emerging disinfection systems constrain regulatory acceptance and slows permitting processes.
Environmental Barriers: Current practices contribute to avoidable GHG emissions and toxic byproduct generation, both of which are increasingly at odds with California's environmental justice and climate policies.

To address these gaps, the research will:

- Generate high-resolution O&M and performance data under real-world conditions,
- Provide comparative benchmarks of energy consumption, GHG emissions, and lifecycle cost across reuse scenarios,
- Establish performance-based frameworks to support regulatory pathways for alternative disinfection designs,
- Enable knowledge transfer to utilities, regulators, and underserved communities via scalable guidance and validated demonstration.

Ultimately, this concept represents a critical step toward integrating the water reuse and clean energy agendas of California. By de-risking the deployment of innovative disinfection methods and aligning system design with GHG reduction and energy efficiency priorities, the project supports the intent of **SB 96** to overcome market and technology barriers that prevent equitable and cost-effective access to next-generation clean technologies [10].

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 successful, this research concept will demonstrate a clear pathway for integrating disinfection solutions that reduce energy consumption, lower emissions, and enhance safety in recycled water production. The outcomes are expected to directly support California's transition to low-carbon water infrastructure while improving the financial and operational viability of water reuse projects. These outcomes will enhance affordability, reliability, and environmental performance across a wide range of facilities—from decentralized systems to large-scale recycling plants. By closing the gap between compliance and sustainability, the project ensures that disinfection is no longer a limiting factor in the equitable expansion of recycled water statewide.

This research will align well with the following EPIC's principles:

Safety: Collect long-term performance data in order to optimize the design criteria with technology providers and ensure the emerging technologies can consistently meet Title 22 standard for discharge and reuse. Improve public and operator safety by eliminating hazardous chemical use.

Reliability: Generate asset management database with field and O&M record from long-term (i.e., 1-2 years) day-to-day operation of demonstration-scale to full-scale pilot and optimize the design criteria with technology providers.

Affordability: Reduce disinfection-related O&M expenditure by at least 15%, lowering the financial burden on ratepayers.

Environmental Sustainability: Cut disinfection-related processes' GHG emissions by 20%, contributing to California's net-zero goals.

Equity: Decrease disinfection-related capital expenditures by approximately 20%, enabling broader adoption by small and mid-sized utilities.

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

The proposed concept will be evaluated using clear, outcome-driven performance metrics that reflect EPIC principles and SB 96 priorities.

Quantitative Metrics

- Energy intensity of disinfection (kWh/m^3): ≥ 25% reduction
- GHG emissions (kg CO_2e/m^3): ≥ 20% reduction
- Operational cost savings (% OPEX): ≥ 15% reduction
- Disinfection performance (log reduction values): Meets or exceeds Title 22 standards

Qualitative Metrics

- Operator and public safety: Elimination of hazardous chemical handling
- System reliability: Stable performance under variable loading
- Regulatory readiness: Alignment with existing Title 22 and future potable reuse pathways
- Adoption potential: Stakeholder feedback and integration ease for utilities of varying size

These metrics will be tracked through field data, utility reporting, third-party validation, and stakeholder engagement to ensure both technical success and market relevance.

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.

The proposed research concept is supported by a robust body of regulatory, technical, and environmental literature emphasizing the need for cleaner and more energy-efficient disinfection practices in water reuse systems. While disinfection processes are critical to ensuring water quality and public health, they are also among the most energy- and emission-intensive components of treatment trains. [11,12]

Importantly, the impacts of disinfection extend beyond energy and GHG emissions. Chemical-based processes, particularly chlorination, generate disinfection by-products (DBPs) that can have toxicological effects on aquatic ecosystems and public health[13]. The formation and variability of DBPs such as trihalomethanes differ significantly across methods and conditions, complicating environmental performance assessments. [14,15]

LCA-based evaluations have further confirmed that UV disinfection generally performs better from an energy perspective but must still be assessed holistically in terms of full life cycle impacts and emissions. [9] As concerns grow over climate change and pathogen resilience, sustainable disinfection strategies are increasingly emphasized in global policy agendas. [16,17] As concerns grow over climate change and pathogen resilience, sustainable disinfection strategies are increasingly emphasized in global policy agendas. Notably, the convergence of scientific findings and regulatory priorities underscores an urgent need to critically examine the real-world performance of emerging disinfection technologies under California-specific conditions.

State and federal agencies—including the California Energy Commission (CEC), the State Water Resources Control Board (SWRCB), and the U.S. Environmental Protection Agency (EPA)—have underscored the urgency of adopting low-carbon, cost-effective, and health-conscious disinfection solutions. However, field-validated data and comparative benchmarks remain limited. This proposal seeks to fill that gap by enabling evidence-based regulatory alignment and accelerating equitable access to clean disinfection technologies.

The following references correspond to the in-text citations above and provide the scientific, regulatory, and technical foundation for the proposed research:

1. State Water Resources Control Board, C. *STATE WATER RESOURCES CONTROL BOARD RESOLUTION NO. 2018-0057 ADOPTION OF AN AMENDMENT TO THE POLICY FOR WATER QUALITY CONTROL FOR RECYCLED WATER AND THE STAFF REPORT WITH SUBSTITUTE ENVIRONMENTAL DOCUMENTATION WHEREAS*. (2018).
2. Newsom, G. *Demonstrating Innovative Water Leakage Reduction Strategies Correlating Continuous Acoustic Monitoring, Satellite Imagery, and Flow Sensitive Pressure Reducing Valve System*. www.amwater.com (2021).
3. Bill Text - SB-32 California Global Warming Solutions Act of 2006: emissions limit. https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB32 (2016).
4. Newsom, G. *2021 SB 100 Joint Agency Report Achieving 100 Percent Clean Electricity in California: An Initial Assessment*. (2021).
5. Demir, M. Z. *et al.* Comparative Life Cycle Assessment of Four Municipal Water Disinfection Methods. *Sustainability* **16**, 6104 (2024).
6. State Water Resources Control Board. *Title 22 Code of Regulations*.
7. Cai, Y. *et al.* Plasma-Assisted Rotating Disk Reactor Toward Disinfection of Aquatic Microorganisms. *Ind Eng Chem Res* **58**, 13977–13986 (2019).
8. Zheng, C. *et al.* Water Disinfection by Pulsed Atmospheric Air Plasma Along Water Surface. *Aiche Journal* **59**, 1458–1467 (2012).
9. Moura, I. E. M. O. de & Silva, E. A. d. Eco-efficiency Improvement Strategies for Disinfectants. *Environ Prog Sustain Energy* **43**, (2024).
10. SB 96 Senate Bill - CHAPTERED. http://www.leginfo.ca.gov/pub/13-14/bill/sen/sb_0051-0100/sb_96_bill_20130926_chaptered.html (2013).
11. Ulucan-Altuntas, K. *et al.* Iron–Copper Bimetallic Nanoparticle for the Removal of Disinfection by-Products: Optimization, Kinetic Study, and Life Cycle Assessment. *Water Air Soil Pollut* **233**, (2022).
12. Remy, C., Miehe, U., Lesjean, B. & Bartholomäus, C. Comparing Environmental Impacts of Tertiary Wastewater Treatment Technologies for Advanced Phosphorus Removal and Disinfection With Life Cycle Assessment. *Water Science & Technology* **69**, 1742–1750 (2014).
13. Cui, H. *et al.* Toxicity of 17 Disinfection by-Products to Different Trophic Levels of Aquatic Organisms: Ecological Risks and Mechanisms. *Environ Sci Technol* **55**, 10534–10541 (2021).
14. Ng, T., Li, B., Chow, A. & Wong, P. K. Formation of Disinfection by-Products From Bacterial Disinfection. 235–250 (2015) doi:10.1021/bk-2015-1190.ch013.

15. Collivignarelli, M. C., Abbà, A., Benigna, I., Sorlini, S. & Torretta, V. Overview of the Main Disinfection Processes for Wastewater and Drinking Water Treatment Plants. *Sustainability* **10**, 86 (2017).
16. Malheiro, J. *et al.* Surface Wiping Test to Study Biocide - Cinnamaldehyde Combination to Improve Efficiency in Surface Disinfection. *Int J Mol Sci* **21**, 7852 (2020).
17. Chen, W., Yang, H., Peng, C. & Wu, T. Resolving the "Health vs Environment" Dilemma With Sustainable Disinfection During the COVID-19 Pandemic. *Environmental Science and Pollution Research* **30**, 24737–24741 (2023).

Together, these references underscore the opportunity and necessity for EPIC-funded investment in validated, next-generation disinfection technologies—particularly those that reduce energy intensity, eliminate hazardous chemicals, and ensure equitable access to safe water reuse.

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.

(e) Climate Adaptation

California faces increasing hydrologic variability, prolonged droughts, and rising water demand—especially in urban and agricultural regions. Expanding water reuse is a cornerstone of the state's climate adaptation strategy, as reflected in the SWRCB Recycled Water Policy and California's Water Resilience Portfolio. However, achieving large-scale, reliable reuse is contingent upon the availability of safe, cost-effective, and energy-efficient disinfection systems.

By validating alternative disinfection solutions that eliminate chemical dependency and perform reliably under variable conditions, this project directly supports climate adaptation by:

- Increasing the resilience of recycled water systems to climate extremes,
- Enabling broader geographic implementation of reuse (e.g., decentralized and inland regions),

- Reducing dependence on imported potable water sources and overstressed groundwater basins.

(d) Achieving 100 Percent Net-Zero Carbon Emissions and the Coordinated Role of Gas

Disinfection is among the most energy-intensive steps in advanced wastewater treatment. Legacy systems contribute significantly to facility-level energy demand and Scope 1/2 GHG emissions. Without intervention, expanding reuse infrastructure may inadvertently increase the sector's carbon footprint—conflicting with California's net-zero commitments.

This concept addresses that risk by enabling disinfection strategies that:

- Reduce energy demand by ≥25% compared to conventional systems,
- Eliminate or minimize reliance on carbon-intensive chemicals (e.g., chlorine-based oxidants),
- Improve process efficiency and compatibility with low-carbon energy sources.

Together, these outcomes contribute to sector-wide decarbonization and support SB 100, SB 32, and the broader statewide carbon neutrality targets for 2045. [3,4]

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