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Monitoring the acoustic and physical oceanographic environments near floating offshore wind farms with underwater gliders

Additional submitted attachment is included below.

Electric Program Investment Charge 2026–2030 (EPIC 5)

Research Concept Proposal Form

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:

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

(a) Scripps Institution of Oceanography (SIO)
University of California, San Diego

(b) National Renewable Energy Laboratory (NREL)
Golden, Colorado

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?

Monitoring the acoustic and physical oceanographic environments near floating offshore wind farms with underwater gliders

Purpose

Robust and informative marine environmental monitoring will be needed for the state of California to meet its ambitious offshore wind (OSW) development goals. Key aspects of the marine environment relevant to regulators and OSW developers- marine mammal occurrence and physical oceanographic features- cannot be meaningfully understood in the context of individual lease areas. A regional monitoring approach, which is not the responsibility of any single developer, is best suited to understanding site conditions and detecting potential changes associated with OSW development. Underwater gliders are uniquely suited to collect acoustic and oceanographic data at the spatial and temporal scales required for a robust monitoring program. Our principal interest is to demonstrate a monitoring approach to (a) understand the distribution of marine mammals near OSW sites and detect any changes before and after site development and (b) measure any changes to the wind-driven coastal upwelling cell before and after OSW development amidst considerable variability due to tides, eddies, seasons, and longer period processes (such as El Nino).

California's offshore waters support at least 30 cetacean species that use the habitat in different ways and vocalize at different frequencies. Species groups of particular concern include baleen whales, which are considered low-frequency (LF) cetaceans, sperm whales, which are considered mid-frequency (MF) cetaceans, and harbor porpoise and beaked whales, which are considered high-frequency (HF) cetaceans. Their distributions are patchy and responsive to oceanographic features. Baleen whale acoustic signals can be detected over tens of kilometers. Toothed whale high-frequency acoustics can be difficult to detect beyond 1 to 3 km, depending on species. Hence, we will repeatedly cross these various preferred habitats with the combined sensor suite on the HARP Spray gliders (Figure 1).

The coastal upwelling cell is driven by alongshore winds, which push surface waters offshore (Figure 1b). This water is replaced by upward motion of deeper, nutrient rich waters, which support a rich ecosystem and fisheries. Sustained glider measurements can measure this coastal upwelling circulation (Johnston and Rudnick, in prep., 2025).

OSW development is expected to alter the wind forcing and upwelling based on numerical modelling but these effects have not yet been quantified in a rigorous way that represents the air/sea interactions of a realistic wind energy area development (Figure 1b; Raghukumar et al., 2023).

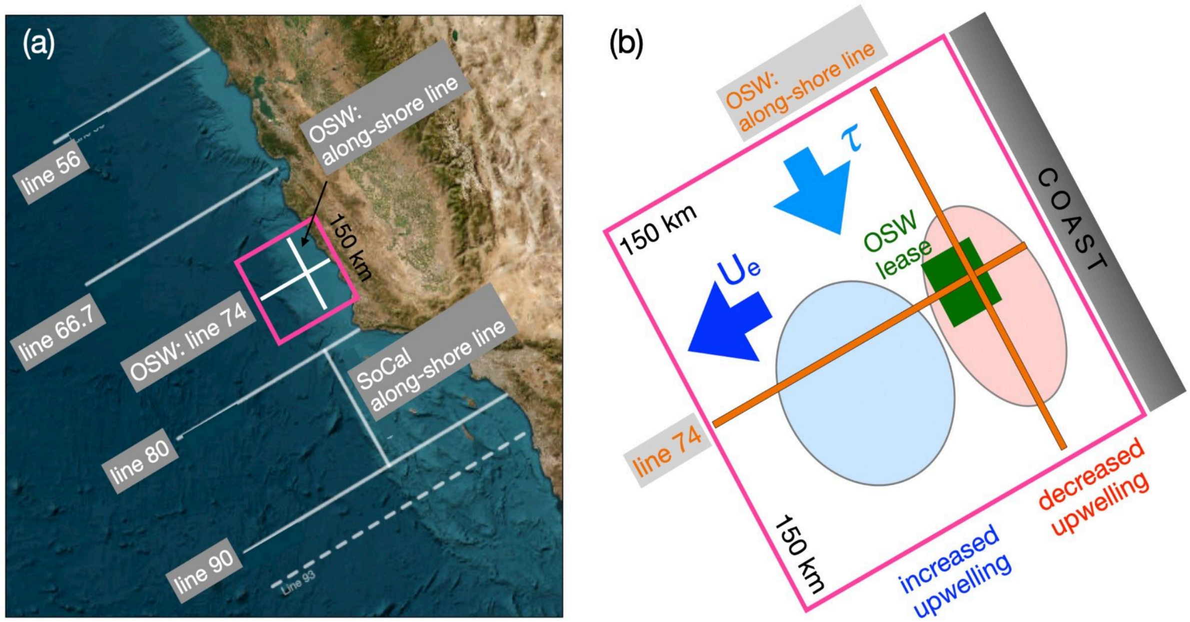

Figure 1. (a) Existing across-shore California Underwater Glider Network lines 56, 66.7, 80, and 90, and SoCal along-shore line (gray lines) have been sampled in some cases for over 20 years. New glider lines across the OSW energy area near Morro Bay (pink box) are line 74 and the OSW along-shore line (white lines). (b) A schematic of the sampling plan in the OSW area near Morro Bay shows the new 150-km long across-shore line 74 and the new 150-km long OSW along-shore line. Thick arrows show the dominant alongshore wind stress (τ, light blue) and offshore Ekman transport (Ue, dark blue). Regions of increased/decreased upwelling offshore/inshore (blue/red) of the OSW lease (green) are sketched roughly based on Raghukumar et al. [2023].

Objective

For two decades, Spray gliders and bottom-mounted high-frequency acoustic recording packages (HARPs), developed separately by SIO, have been used to collect oceanographic and acoustic data in California waters, including near the Morro Bay Wind Energy Area (Figure 1). We propose to (a) incorporate HARPs into the Spray gliders (Figure 2), (b) test prototype systems in California waters, (c) collect and analyze data, (d) compare findings with moored HARP data simultaneously collected within the lease areas, and (e) identify ways in which these data inputs could be used to fulfill applicable environmental monitoring requirements. Two specific objectives of our demonstration monitoring program are to (a) measure the distribution of marine mammals and (b) detect changes in the upwelling cell.

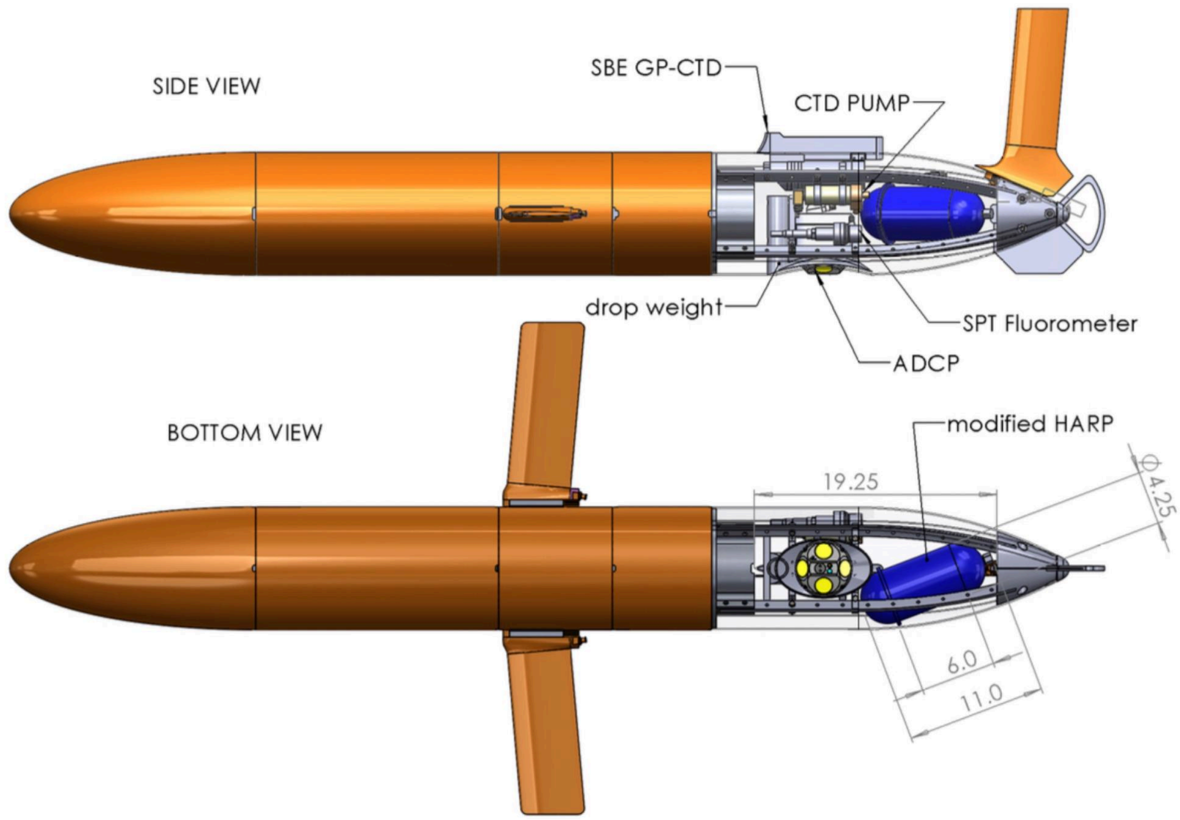

Figure 2. Spray2 glider payload bay arrangement with ADCP, CTD, fluorometer, and modified HARP.

Funding

EPIC funds are essential for such a demonstration project. Regional monitoring of the acoustic and physical oceanographic environment extends beyond each individual lease area. Regulatory agencies require OSW developers to have knowledge of multiyear environmental data in their lease areas, but these data are most valuable in a regional context and are not specific to a particular lease area or developer. *During informal discussions with our team, developers have indicated concerns about the practicality of any one developer shouldering responsibility for broad-scale regional monitoring beyond their lease area, as well as a reluctance to unintentionally set regulatory expectations for neighboring lessees by doing so.* Existing passive acoustic monitoring (PAM) glider systems and monitoring study designs are not robust enough to capture priority marine mammal species occurrences with respect to evolving physical oceanographic features.

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)?

Mitigating environmental impacts from OSW

California has a target to decarbonize its energy sectors by 2045. This is an enormous challenge that will require the rapid development and deployment of a range of new and existing renewable energy technologies including floating offshore wind. In response to SB 525, California has targeted 25 GW of offshore wind as part of the diverse renewable energy mix that will be required to maintain grid stability and reliability under all weather conditions. California is also committed to avoiding or mitigating environmental impacts from offshore wind as much as possible. These could potentially include direct interactions and consequential impacts to protected species, such as marine mammals, but also changes in the physical oceanography and hydrodynamics altering broader ecosystem services due to the introduction of in-water structures.

Each of the five existing offshore wind lease holders risk expensive delays due to uncertainties in complying with the requirements of a variety of federal and state regulatory processes. These and other regulations require developers to demonstrate monitoring and mitigation strategies to avoid and/or minimize potential environmental impacts. As noted above, regional environmental characterization requires understanding a wider area than an individual OSW lease area.

Although less than 2% of a typical project cost is devoted to site characterization, the industry will spend over $3 billion to characterize the site conditions prior to project approval. The proposed glider development plan has the potential to substantially reduce the $3 billion of industry expenditures by streamlining data monitoring and reducing uncertainty regarding environmental impacts in and around lease areas. More importantly perhaps, the efficiency gained in the data monitoring process may shorten development timelines, further lowering costs.

Understanding the acoustic and physical oceanographic environment

This demonstration project will advance the state of the art for collecting and analyzing acoustic data to better understand the distribution and seasonal presence of endangered, vulnerable and protected marine mammal species (baleen whales, beaked whales, sperm whales) in and around lease areas. We will collect and analyze oceanographic data that influence the habitat and prey availability for these species and help address questions about potential changes in oceanography and hydrodynamics that may result from the presence of OSW in-water structures.

The coastal upwelling cell is of particular physical and ecological importance. Alongshore winds produce offshore flow near the surface (Figure 1b). Near the coast, the water that moved offshore is replaced by nutrient-rich water from below. This upwelling cell forms the basis for a rich ecosystem and productive fisheries. An open question is how much upwelling is affected by OSW development (e.g., Raghukumar et al., 2023). Sustained glider measurements can measure this coastal upwelling cell amidst considerable variability due to eddies, tides, seasonal cycles, and El Nino variability (Johnston and Rudnick, in prep., 2025).

A state-of-the-art approach to acoustic and physical oceanographic monitoring

We will combine the proven technologies of Spray underwater gliders with HARPs to obtain continuous monitoring of the Morro Bay OSW area. A demonstration project will cover many months during two field seasons. A more robust program would provide continuous coverage across years. This technical advancement will help both increase regulatory/permitting certainty and decrease OSW project costs. The cost savings can be passed on to ratepayers. Understanding the acoustic and physical oceanographic environment will help OSW developers with their operations. A successful demonstration project will pave the way for similar, longer duration work either by OSW lessees, environmental consultancies, and/or oceanographic research institutions.

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, reliability, affordability, environmental sustainability, and equity?

Outcomes

The main goal is to demonstrate a state-of-the-art environmental monitoring technology that is needed for site characterization of OSW lease areas. This advance will increase regulatory/permitting certainty and lower OSW project costs. Furthermore, understanding the acoustic and physical oceanographic environment will help OSW developers with their operations.

Due to the bathymetry and water depths in which floating OSW is planned on the west coast, glider PAM systems proposed for use in this region will need to sample frequencies at a minimum of 200 kHz to detect deep-diving species such as beaked whales. These whales are not currently a priority species group in shallow-water east coast lease areas, and current technology is therefore not optimized for environmental monitoring in California waters. PAM gliders currently used on the east coast specialize in recording low frequency sounds, such as those produced by North Atlantic right whales (Baumgartner et al. 2020).

For this demonstration project, Spray2 gliders equipped with HARPs will be uniquely suited to environmental monitoring in California waters for the following reasons: (a) we can record low, middle, and high frequency acoustic signals for priority species on the west coast; (b) our team has a long history of PAM and oceanographic data collection in and near the Morro Bay area, which will put our findings into context, and (c) the in-depth regional knowledge of our California-based investigators, including at SIO and NREL.

Reducing costs

See also response to Question 4 in describing reduced costs under the heading "Mitigating environmental impacts from OSW."

Replicating our method at scale

This project will demonstrate the capability of Spray2 gliders equipped with HARPs. This capability could be of commercial interest. MRV Systems holds the license for Spray2, which is currently available but without HARPs. On the east coast, the use of gliders for environmental monitoring in conjunction with OSW development is becoming increasingly common and is largely performed by environmental consultants and oceanographic research organizations.

Improving reliability, affordability, and environmental sustainability

We anticipate the main benefit of acoustic and physical OSW site characterization is gaining greater permitting/regulatory certainty. Delays and uncertainty related to these issues may increase costs, affect reliability, and alter how the public perceives the reliability/sustainability of OSW. More importantly perhaps, the efficiency gained in the monitoring process may shorten development timelines, further lowering costs.

Spray2 gliders equipped with HARPs are state-of-the-art and cost effective tools for environmental monitoring. Gliders are autonomous and operate continuously regardless of sea state. The reliability of Spray is documented at 97% coverage on three across-shore lines in the California Underwater Glider Network (Rudnick et al., 2016).

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

Success metrics

The main metric of coverage in the California Underwater Glider Network is maintaining one glider on a continuously-covered line. This evaluation of the reliability of Spray documented 97% coverage on three across-shore lines in the California Underwater Glider Network (Figure 3; Rudnick et al., 2016).

The main metric of demonstrating our method of acoustic monitoring will be comparison with an existing bottom-mounted HARP in the Morro Bay area. The key point is that we will be able to document ecological niches and local habitat preferences of the species in the area by covering a larger spatial extent than what is accessible to a stationary system.

The main metric of demonstrating our physical oceanographic monitoring will be comparing and contrasting results from the Morro Bay across-shore line with adjacent lines in the California Underwater Glider Network near Monterey Bay (line 66.7; Figure 3) and Point Conception (line 80; Figure 3). Lines 66.7 and 80 have been covered continuously for almost 20 years, the oceanographic variability has been documented, and a climatology has been produced (Rudnick et al, 2017). A specific metric/goal for the Morro Bay area is to detect any changes in the coastal upwelling cell.

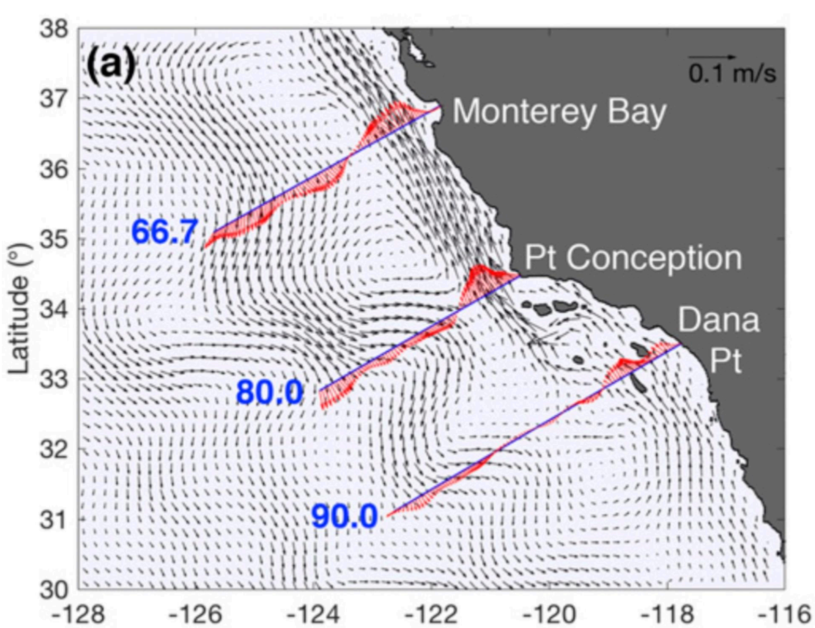

Figure 3. Time- and depth-mean velocity from gliders (red vectors) and the California State Estimate (a data assimilating model; black vectors) from 2007-2013 and 0-500 m in depth. The northward California Undercurrent extends 100-200 km offshore (Zaba et al., 2018).

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.

Technical merit

A Spray2 glider has an endurance of 120+ days. One glider covers 3,600+ km and provides ~1,000 profiles to 500 m. The horizontal spacing between profiles is about 3 km and data are averaged into 10-m bins in the vertical. The gliders are equipped with a Seabird CTD to measure temperature, salinity, and depth; a Nortek 1 MHz AD2CP to measure currents; a Seapoint fluorometer to measure chlorophyll fluorescence; and a HARP to record acoustics from marine mammals and other sound sources. Therefore, sustained glider operations can provide the wide spatial and temporal coverage, while also obtaining high resolution in the horizontal and vertical (Figure 3). This type of sampling is needed to distinguish natural variability on a range of scales from any changes associated with OSW sites. Gliders have accommodated dissolved oxygen, pH, and nitrate sen. sors.

The HARP module stands out from other PAM systems by having the following features:
• Broadband (up to 320 kHz) continuous recording needed to effectively detect high frequency, short-duration acoustic encounters of beaked whales, harbor porpoises, and other toothed whales, while also covering low frequency baleen whale calls and other acoustic sources.
• Multichannel needed to determine 3D habitat use patterns of deep divers, to understand potential for interactions with subsurface infrastructure, and measure behavioral changes post-installation.
• Onboard data processing in development needed to relay occurrences in near real time or to guide autonomous fine-scale surveys to better understand where and why marine mammal species may aggregate offshore (e.g. Walker et al 2025).
• Over 30 years of HARP development and >1,000 deployments conducted to date have resulted in a reliable low-power system for long deployments (typically 12 months), fully-calibrated to support quantitative analyses (e.g., density estimation) and cross-platform comparisons (e.g., with moored systems).
• Data can be compared with >100 cumulative recording years of HARP data collected along the U.S. west coast since 2007 (>400 years globally).
• SIO maintains an extensive library of marine mammal vocalizations, making automated multi-species classification with artificial intelligence possible.
• Deep diving capability of Spray reaches more favorable depths for acoustic recording compared to ASVs like the Wave Glider.

As a test case and to compare glider data with bottom-moored HARP data concurrently collected through other funding sources, we propose to deploy two neural net-based detector-classifiers, optimized for either baleen whale or toothed whale signals, specifically searching for blue and fin whale calls, and various delphinids and beaked whale echolocation clicks. Output of this process results in signal-level labels that can be converted to call counts per hour, day, or week as a proxy for animal density. Additionally, ambient noise measurements will be generated to describe baseline noise conditions over the monitoring period.

References

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8. The EPIC 5 Investment Plan must support at least one of five Strategic Goals:

- *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 most relevant gap was identified (Strategic Goal d) as a “lack of independent studies on the appropriate, cost-effective roles and lifecycle costs and impacts of emerging technologies, including floating OSW, … in achieving carbon neutrality.” Our project directly addresses such impacts by demonstrating advanced technology and techniques for monitoring the acoustic and physical oceanographic environment around OSW areas. This demonstration project paves the way for longer term, independent studies by environmental consultancies or other oceanographic research institutions.