

## **NSF Engine: MOCEAN: Accelerating a Just Energy Transition While Nurturing Healthy Oceans and New Blue Economies Through Innovative Nature-Inclusive Offshore Wind Farms**

### **Overview**

Coastal states have made significant commitments to source increasing portions of their electricity supply from offshore wind energy (OWE) to achieve their climate goals, but development and deployment of OWE farms is hampered by challenges including conflicts with other ocean industries and decision-making processes governed by short time-horizon market forces. The Engine will encourage cooperation among three industries—OWE, Sustainable Seafood, and Blue Technology—through co-creation of Nature-Inclusive Design (*NID*) policies and technologies (e.g. *NID* scour protection, marine sensors, submersibles, and eDNA) and coordinated shepherding of these innovations from the lower Technology Readiness Levels all the way to commercialization. United through the Engine, OWE developers, marine scientists, engineers, fishers, policymakers, entrepreneurs, and historically underserved coastal communities, will be empowered to support the development of cross-state policy supportive of *NID*, high-quality jobs—including to underserved populations—that leverage the skills of the existing local workforce, and to co-create a brighter and more equitable future through a *New Blue Economy*.

### **Intellectual Merit**

This proposed NSF Engine will catalyze significant advancements at the intersections between different science and technology fields and develop system-of-system models in engineering, economics, and education—advancements which otherwise would remain out-of-reach. Advancements in science will range from the micro to the macro scales including marine biology, impacts of stressors on habitats, effects of materials and coating selection on marine growth, and changes in local and regional ecosystems. Advancements in technologies will include new sensing systems (e.g. eDNA, acoustic, & image-based), new inspection equipment & techniques, new coating systems, more durable materials, intelligent nature-inclusive scour protection, productive artificial reefs, and future-proof OWE turbine foundations. Advancements in engineering models will account for important factors insufficiently considered in practice such as impacts of cathodic protection on design life and the environment. Advancements in policy will include the creation of models that quantify the benefits of *NID* in OWE to local labor, the environment, and new jobs in fisheries to be used in the decision-making process for offshore wind development. Advancements in education will include the development of methods of engagement, support, and learning that lead to much greater participation of students and workers from underserved communities in the *New Blue Economy*. The Engine will engage key ecosystem actors in a Use-Inspired Research Design loop that supports the co-creation of new technologies, relevant policies, workforce development systems, cross-industry collaboration, novel products, and interdisciplinary research and thereby ensures that advancements serve all communities in a just and timely way.

### **Broader Impacts**

Broader Impacts include: 1.) Improved ocean health through deployment of *NID* features in OWE farms; 2.) A seafood economy better adapted to the changing ocean through co-created nature-inclusive solutions, including sustainable fishing techniques and restorative aquaculture; 3.) A globally-competitive US OWE industry thanks to new technologies brought to market through collaboration with existing BlueTech communities within the RoS and increased social license of OWE through *NID*; 4.) Inclusive economic growth in underserved coastal communities with historical ties to the existing blue economy and models for catalysis of such growth throughout and outside of the RoS; 5.) STEM workforce entry and retention systems co-created with and serving diverse communities through the *New Blue Economy*.

**Overarching Challenge(s):** A Just Transition to Clean Energy, Sustainable Seafood, Healthy Oceans

**Keywords:** Energy technology, advanced materials, advanced manufacturing, biotechnology, marine biology

**Industry Sectors:** 2211 (Electric Power Generation, Transmission and Distribution), 1141 (Fishing), 3345 (Navigational, Measuring, Electromedical, and Control Instruments Manufacturing)



quality jobs, and commercial spin-off impacts for the RoS, especially for focal communities in the RoS—like New Bedford MA, Bridgeport CT, Cape May NJ, and Hampton Roads VA—with high fractions of Justice 40 populations [10].

The Engine's Core Partners will connect the Engine to their networks. Most of these organizations have been working within or with the aforementioned three industry sectors and alongside local communities for several years—and in some cases, decades. All of the organizations listed below (by field of primary contribution) have already been engaged in detailed discussions with Team MOCEAN about the Engine. The number of Core Partners will grow as the Engine matures.

**OWE developers and associated supply chain coalitions, energy** [Avangrid, Dominion Energy, Oceantic, Orsted, Boskalis]: Represent commercial interests/needs of developers and supply chain; provide engagement of heavy industry and technology leaders in support of the Engine's efforts; advance joint-industry projects.

**Fisheries, OWE, and conservation coalitions** [Responsible Offshore Science Alliance (ROSA), Regional Wildlife Science Collaborative (RWSC), New Bedford Ocean Cluster (NBOC)]: Utilize existing fisheries, research, and E-NGO/research/public agency networks to inform Engine priorities.

**BlueTech and community-based accelerators** [SeaAhead, Entrepreneurship for All (EforAll), and the Massachusetts Technical Collaborative (MassTech)]: Design research-to-commercialization translational programs; start-up/entrepreneurship support; programs and outreach to ensure full participation of under-represented individuals and groups.

**Marine Science, Fisheries, Restorative Aquaculture, and Associated Technologies** [Woods Hole Oceanographic Institution (WHOI), Marine Biological Laboratory (MBL), Hampton University (Hampton), Rutgers University (Rutgers), The New England Aquarium (NEAq), UMass-Dartmouth (UMD), UMass Boston (UMB), Gloucester Marine Genomics Institute (GMGI), University of Delaware]: Globally leading community in this area that provides R&D expertise & facilities that advance the global state-of-the-art.

**Engineering** [Tufts University (Tufts), University of Rhode Island (URI), Florida Institute of Technology (FIT), Rutgers University (Rutgers)]: Design and evaluate physical infrastructure—such as foundations, scour projection, and cable protection systems—including considerations of durability, strength, and demands.

**Workforce Development** [National Offshore Wind Training Institute (NOWI) at Bristol Community College in New Bedford (BCC), GMGI, UMB, Hampton, NEAq]: Assume key responsibilities for training programs, curriculum development, and the professional development of those from under-represented and underserved communities.

**Design and Development of Ocean Renewable Energy Innovation Center** [Massachusetts Clean Energy Center (MassCEC), City of New Bedford, NBOC]: Collaborator in design of new innovation center.

### **Broader Impacts**

At the heart of this regional Innovation Ecosystem are collaborations aimed at optimizing economic, equity, and environmental needs. By including partners from industry, government, higher education, and local communities, the Engine will: 1) Accelerate a nature-inclusive energy transition by collaborating with coastal communities to advance environmental stewardship and emerging technologies to co-create innovations; 2) Support diverse communities entering the STEM workforce by partnering with Historically Black Colleges and Universities (Hampton U) and Minority Serving Institutions (UMass Boston), and organizations committed to entrepreneurial equity (EforAll); and 3) Steward investments into innovation, research, policy, and technological advancements, supporting equitable economic growth in underserved coastal communities. As it develops the New Blue Economy in the RoS, the Engine will enhance understanding of place-based, justice-oriented science and renewable energy technology applicable to other regions.

## II. Technology Innovation Plans

The MOCEAN Engine will benefit local communities, the ocean, and the nation by facilitating innovation in *NID* across all Technology Readiness Levels (TRLs) and all stages of bringing technology to practice (identification, development, validation, certification, and adoption). The Engine will enable synergies across sectors of the *New Blue Economy* to increase economic development, drive new entrepreneurial activities, and find opportunities for large-scale commercialization of innovations via industry partnerships. The Engine will maximize the ability of the underwater infrastructure in OWE farms to support ecosystem services, including biodiversity, fisheries habitat creation, carbon capture, and co-location of related enterprises like restorative seaweed farming.

Innovation at the intersection of OWE, Sustainable Seafood, and BlueTech faces several R&D translation challenges, stemming from the key unknowns in the 8 areas introduced below. The references cited are to work by Engine Core Partners who have started to address these key questions.

- **Measuring Success:** How should the impacts of nature-inclusive design of OWE systems be measured and how does that translate to the overall health of the ocean and local fisheries? What are the key metrics and species of interest? How do local/medium/large effects scale? [11, 12, 13]
- **Data Collection:** What data are needed to better understand species distribution and ocean health? What new sensors and data collection techniques are needed to lower costs and increase the quality of data? Who within coastal communities is best prepared to use this equipment to collect these data? [14, 15, 16, 17, 18, 19, 20]
- **Data Sharing and Transparency:** What coordination is needed across both public and private data streams to utilize the data-rich resources within the Engine's ecosystem? How can data be collected efficiently for use by both the broader research and BlueTech sectors? [21]
- **Validation and Testbeds:** What testing do regulators and industry leaders need to adopt new *NID* technologies? What testbeds are needed to support this work, and how can existing testing facilities be leveraged for this purpose? [22]
- **Identifying *NID* Opportunities and Co-located Industries:** What are the requirements for species-specific *NID* opportunities and restorative aquaculture? Which of the current U.S. lease areas have promising conditions to pilot these co-located technologies? What needs do the OWE and/or Sustainable Seafood industries have that BlueTech entrepreneurs and researchers could help to meet, and what paths to higher TRLs are needed to make them attractive to investors? [23, 24, 25]
- **Digital Products and Services:** How can existing data be best leveraged into commercial products that support modeling of the environmental effects of OWE farms for all phases of development, predict locations of key seafood species for fisheries, and identify keystone species for measuring ocean health? [26 27]
- **Co-Creation with Local Communities:** How can underserved coastal communities be sustainably integrated into the *New Blue Economy* innovation ecosystem? How can their skills and knowledge be used? What does this mean for definitions of Innovation, Equity, Economy, and Sustainability? [28, 29, 30, 31, 32]
- **Policy Innovations:** How can public policy support *NID* principles and the *New Blue Economy*? What changes are needed in regulations to incentivize innovation and enable innovative ideas to be piloted in publicly managed offshore areas to identify and address technical issues early in the validation process? What processes effectively get those regulations in place? [33, 34, 35]

The Engine will investigate these themes primarily through two mechanisms—*Working Groups* and *Use-Inspired Convergent Research Projects (Projects)*—in a coordinated feedback loop. The technical *Working Groups* will include representatives from across the innovation ecosystem, including marine scientists, OWE developers, engineers, conservationists, BlueTech innovators, and policymakers. These *Working Groups* will be organized into cross-cutting themes, such as Nature Inclusive OWE Farms; Measuring Ocean Health; Developing the New Blue Economy; and Education, Outreach, and Training. The groups will meet to frame and develop assessment metrics for multi-disciplinary, cross-sector *Projects* to which members will contribute. The *Working Groups* will leverage our understanding of current knowledge gaps to inform key areas for further investigation, recommend regional goals and targets for biodiversity/habitat enhancement, and identify the technology innovation needed to support the design of

*NID* engineering features, strategies for prosperous co-existence, and marine science data acquisition, monitoring, and assessment. The *Projects* will feed information back to the *Working Groups* which then inform the development of technology testbed frameworks and policy recommendations to support/incentivize *NID* applications. This bidirectional feedback loop will anchor learning and innovation in the needs of the ecosystem and will be at the core of the Engine's technical and scientific research work, generating the deeptech innovations lower on the TRL ladder.

The Engine will also have activities focused on bringing higher TRL technologies up the ladder. The Engine will collaborate with local community members, researchers, innovators, and entrepreneurs to identify key opportunities for innovations, exchanging knowledge within *Communities of Practice* (CoP). The CoP model was selected because of its success in the North Sea in balancing OWE, Sustainable Seafood, and environmental stewardship [36]. This model ensures that the Engine's *Projects* are place-based in the local community and that the Engine will benefit from critical information related to practical aspects of the existing blue economy. The Engine's link to these CoPs will help identify opportunities for new small business creation, supported by Core Partner EforAll, that may not require fundamental research to increase the TRL. The Engine may also identify local needs leading to a new *Project* for the core research loop described earlier. Using pathways for both venture-funded startups and bootstrapped small businesses, the Engine will expand economic impact in the coastal regions and nurture a thriving and growing innovation ecosystem.

Project evaluation will include lifecycle/economic analysis, supported by Tripp-Umbach, a leading economic and social impact assessment firm, and will include a focus on opportunities for equitable access to new jobs. Policymakers/regulators of the three impacted industries will be engaged as Partners alongside industry actors early on and throughout to reveal opportunities and barriers to the application of *technology innovation* and explore opportunities for *policy innovation* of mutual benefit to the industries and local communities involved while meeting the statutory goals and requirements of regulators. The *Projects* will bring together concepts and ideas from the Working Groups to run larger-scale pilots *in situ* in the RoS, moving innovative ideas closer to commercialization and real impact. These *Projects* engage and are co-created with local communities, and span technology as well as programs for workforce development, education, and outreach.

Over the past year, Team MOCEAN has convened more than 100 meetings, including several in-person planning workshops with various ecosystem actors, including those from local coastal communities, industry organizations, and state and local governments. They have also initiated and are extending pilot projects. The project examples below demonstrate the type of multi-phase activities and collaborations needed to make real progress, and which are the types of projects that the Engine would support:

Pilot 1: Designing structures to support marine growth in different environments. In 2023-24, MOCEAN team members (Tufts, WHOI, FIT), with funding from the Bureau of Ocean and Energy Management and the Massachusetts Clean Energy Center, studied the impact of various structural coatings on marine growth and durability in marine environments with various water chemistries [37]. WHOI's philanthropic funding is sustaining the project's next phase, which includes examining the effects of nutrient-infused coatings on coral and seaweed growth. A larger project, expected to begin in late 2024, will analyze the benefits and effectiveness of these materials in field sites and potentially in U.S. OWE farms. The Engine will support the next phase of this work: to develop intelligent, nature-inclusive scour protection to promote ideal benthic habitats, involving local fish and aquaculture members, and creating new companies, jobs, innovative sensing technologies, and big data tools for ocean ecosystem understanding.

Pilot 2: Measuring on a regional scale the changing marine and atmospheric conditions and their impact on fish movement. After a pilot study, several Core Partners from Massachusetts (MA) and New Jersey (NJ) alongside others have planned a major new Project expected to launch in late 2024. This project will have more than 100 GPS-tracked fishing vessels equipped with sensors to track temperature, dissolved oxygen, and conductivity at different water depths. In combination with fish catch logs, the resulting data will advance understanding of fish species movement to inform fishing practices. The Engine will support the use of this fleet of fishing vessels for the collection of more comprehensive information about the condition and changing condition of the ocean. This project is an example of the type of community-led

innovation (in this case by local fisher partners) that brings scientists together with local communities equipped with lived experiences and front-line insights and knowledge to co-create new innovative and advanced ways to grow businesses and improve regional economies.

Pilot 3: Develop new approaches to OWE impact mitigation that support local fisheries. Through the work of Core Partners Rutgers and ROSA, the MOCEAN Team is currently leading efforts to mitigate the effects of OWE on the surf clam industry. Researchers, OWE developers, and local surf clam fishers in Cape May, NJ are co-developing a nature-inclusive solution where juvenile surf clams are deployed on new fishing grounds outside the wind farm. In July 2024, the MOCEAN Team's Type-1 NSF grant supported an in-person workshop on this topic with about 40 participants from across these groups to identify key data gaps and enable steps to realize this *NID* solution. This example illustrates Team MOCEAN's capacity to convene all relevant ecosystem actors—including local community members—to co-create technology innovation plans that serve all interested parties while supporting the transition to the co-existence of OWE and Sustainable Seafood.

These pilots illustrate how the partners and stakeholders in the RoS are prepared and committed to advancing *NID*, and some of what is needed to develop the fundamental science and technological tools for the co-thriving of the Engine's three industry sectors (OWE, Sustainable Seafood, and BlueTech). Pilot 1 utilizes some of the most advanced marine science institutions in the country. Pilot 2 shows the creative thinking that states are using to bring together communities to collect data. Pilot 3 shows that universities are already working closely with local coastal communities on nature-inclusive solutions. The demand for research and science around OWE and the environment is currently high, and it will increase dramatically as the OWE industry grows tenfold in the next decade in the RoS. The Engine is needed now to establish goals that serve all needs, to co-create innovative technological solutions, to advance basic science and engineering, to advance regulations and policies, and to build communities focused on creating a just future. Without such actions, OWE and opposition forces may develop in ways that stifle the energy transition in the Mid-to-North Atlantic and fail to deliver the full economic development potential.

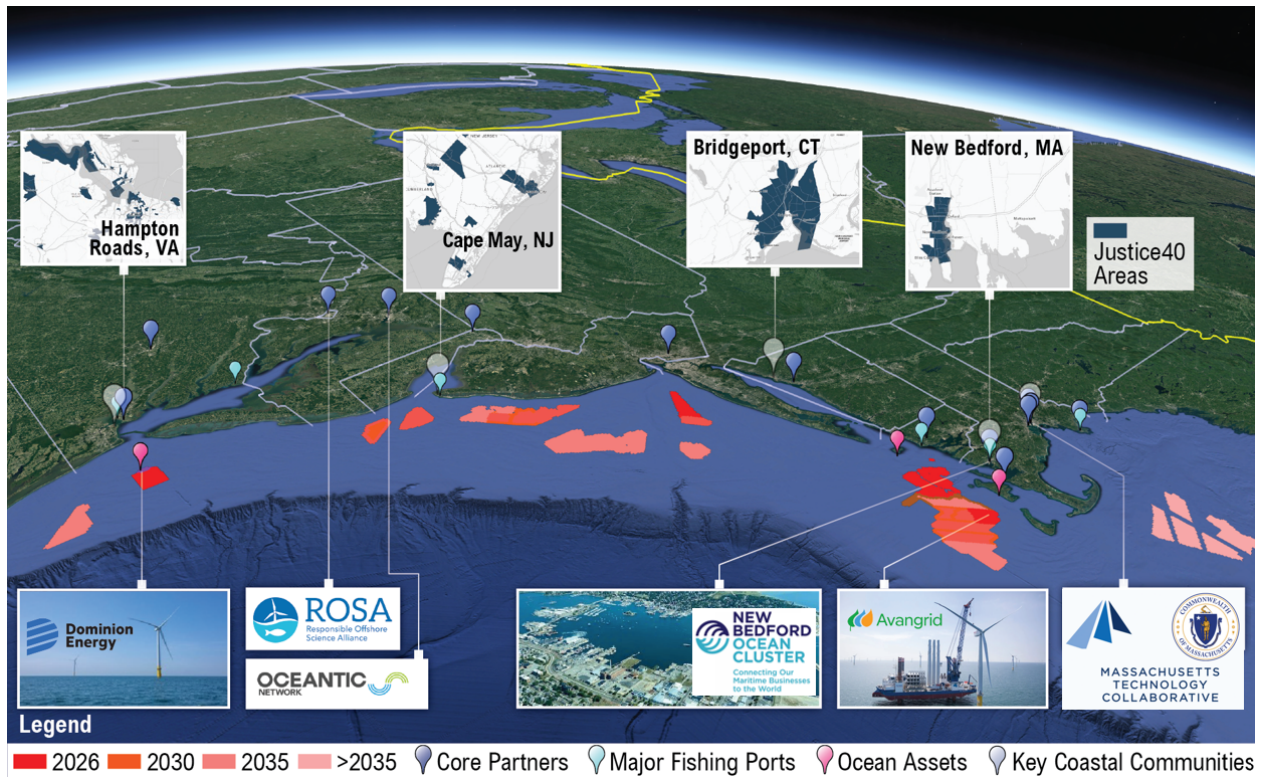
### III. Region of Service

The ocean is one of the greatest untapped resources for the nation's economic development [38, 39]. The MOCEAN Engine is designed to advance a sustainable ocean-based economy—the *New Blue Economy*—which encompasses technologies for *NID* of OWE farms, Sustainable Seafood, and BlueTech, and also impacts other industries including blue carbon, shipping, environmental conservation, big data, and artificial intelligence. The Engine's RoS—visualized in Figure 2 from the perspective of the Atlantic Ocean—is naturally defined as the place where OWE, ecological, and seafood production opportunities coincide, i.e., as the *New Blue Economy's* core economic activity zone. The RoS consists of the coastal-ocean ecosystem and neighboring states along the East Coast—from Massachusetts (MA) to Virginia (VA)—which are developing their OWE industry. The red-colored portions of the figure represent OWE areas that are under development or to-be-auctioned in the next ten years. The legend shows the year that each OWE project is expected to begin operations. The figure also identifies selected Core Partners, including a regional organization for supporting OWE and commercial fishing collaboration (ROSA), the largest national OWE industry organization (Oceantic), the New Bedford Ocean Cluster, and the State of Massachusetts—which has committed \$20M of contingent co-funding (see Part IV and Existing and New Resources Document).

The potential for measurable economic change in the RoS, through innovation at the interface of OWE, Sustainable Seafood, and BlueTech, is immense. Recent OWE industry growth within the U.S. includes \$36B in infrastructure investments [40], and the annual cost of building OWE farms will grow to \$25B/year by 2030 (90% in the RoS) [41]. OWE farms are particularly well suited to electrify the mid-to-north Atlantic because of the strength of winds, size of market, cost of electricity from other sources, and because transmission permitting challenges are a barrier to providing commercial-scale electricity from more distant sources [39]. For these reasons, and based on the expected demand for electricity for a clean energy transition, the OWE industry in the RoS could grow to \$50-\$100B/year for the construction and operation of OWE farms by 2050. The Engine will help to magnify OWE's positive economic impact on

the RoS through technological innovations and integrated partnerships with the ultimate goal of restoring ocean health, creating a more resilient and equitable innovation ecosystem that promotes OWE development in harmony with the needs of local communities, and helping to win public acceptance and accelerate beneficial public policy around OWE [42].

The RoS is integrated through strong cultural and economic ties within the fishing industry [43]; commercial fisheries operating out of New England and Mid-Atlantic ports generate \$2B/year in landings revenues, or about 40% of the national total. The seafood industry in this region is estimated to directly or indirectly support nearly 350K jobs with total sales impacts of over \$45B/year [44]. Commercial fisheries are at risk due to the combined negative impacts of a changing climate and historic human use [45]. The Engine will create a space for experts in marine ecosystems and habitats, commercial fisheries, and the OWE industry to increase community-based economic activity via co-creation of robust future fisheries.



**Figure 2.** Map of the Engine’s Region of Service (RoS)

The Engine’s region is defined by the extent of the OWE and commercial fishing industries—the industries that provide the primary fuel for the Engine. Consistent with the objectives of the NSF Engines program and the Justice40 initiative [10], the economic and workforce development benefits of this Engine focus on disadvantaged and stressed communities. The Engine will act locally, leveraging its existing partnerships and relationships. A prime example of this place-based justice-oriented economic development is New Bedford, MA which is a microcosm of the challenges and the opportunities for catalyzing economic growth through synergies across industries including OWE. Like many similarly situated American cities, New Bedford has lost thousands of manufacturing jobs over the past half century [46]. With most of the city’s population living in “Justice 40” census tracts (19% living below the poverty line), it is precisely the type of place that has been prioritized for capital investment by federal programs. With the nation’s first OWE port [47, 48] and highest-value fishing port [49], it hosts the conflicts for the shared use of the oceans as well as the people who can co-create the technology innovations needed for the co-thriving of these industries. The Engine’s partners in New Bedford include the New Bedford Ocean Cluster (NBOC), Avangrid, EforAll, the School of Marine Science and Technology, and the National Offshore Wind Institute (training facility). New Bedford will also be the home

of the new Ocean Renewable Energy Innovation Center where most of the \$20M co-funding for the Engine will be located as a shared-use resource for the public and private sectors. What the Engine learns and accomplishes in New Bedford can be a model replicated and adapted for other communities, including Hampton Roads VA, Cape May NJ, and Bridgeport CT as shown in Figure 2. Approximately 1 million people live across the four key coastal communities highlighted in Figure 2, and about 30M people live across the RoS that can contribute to and benefit from the proposed Engine.

#### IV. Strategy to Address Ecosystem Gaps

The innovation strategy of the MOCEAN Engine is grounded by a Use-Inspired Research agenda built on the deep relationships among our Core Partners and the pilot Use-Inspired Convergent Research Projects already underway (see Section II. pilot Projects). This approach will identify knowledge gaps and key questions; recommend regional goals and targets for biodiversity/habitat enhancement; and facilitate technology innovation needed to support the design of nature-inclusive engineering features, fisheries co-existence strategies, and marine science data acquisition, monitoring, and assessment. A continuous feedback loop between the Technical Working Groups and community-rooted Use-Inspired Research Projects will in turn inform the development of technology test bed frameworks and policy recommendations to support/incentivize the application of *NID*.

The Engine’s approach to innovation has four elements: **1.)** Research questions will be jointly developed by technical experts and community-based actors via the Engine Working Groups; **2.)** Projects will co-create with local communities and partners to enable a continual feedback loop that anchors learning and innovation in user needs; **3.)** Project evaluation will include lifecycle/economic analysis and identify opportunities for equitable job creation; **4.)** Policymakers/regulators of the impacted industries (in this case OWE, fisheries, and ocean health) will be engaged as partners alongside industry actors and community actors to reveal barriers to the application of *technology innovation* and explore opportunities for the *policy innovation* needed to promote mutual benefits while meeting the statutory goals and requirements of regulators.

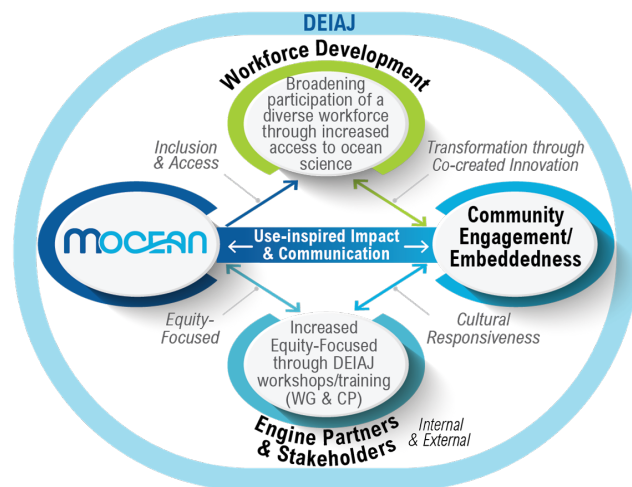


Figure 3. DEIAJ Model

The Engine will advance equity, inclusion, and access in nature-inclusive OWE through community embeddedness and an integrated research-practice collaborative through its Diversity, Equity, Inclusion, Accessibility, and Justice Team, which will be guided by three key processes of the DEIAJ Model (see Fig. 3): (i) Advance economic and workforce development by accelerating access and inclusion to OWE, fisheries and aquaculture, and BlueTech; (ii) Implement equity-focused education, outreach, and training activities that increase access to OWE, ocean science, and STEM broadly; and (iii) Center the voices of communities of color in the Engine’s OWE initiatives through culturally responsive practices.

The Engine will follow these processes to address gaps in each driver of ecosystem change:

**1. Cross-sector Partnerships and Stakeholder Alignment.** Key gaps: (i) Existing relationships are structured by the regulatory processes governing OWE development—processes that focus on avoiding, minimizing, and mitigating environmental and socio-economic impacts as opposed to developing win-for-all solutions such as those possible through *NID*; (ii) Existing distrust between sectors needs to be ameliorated. Solution: Team MOCEAN will continue to build, strengthen, and leverage the relationships within the innovation ecosystem to create a new space for constructive conversation around *NID*. For example, partnerships with key regional convening organizations—including ROSA, RWSC, and Oceanic—will drive the Working Group model described in Section II. The Engine will also leverage its



strong ties to the New Bedford Ocean Cluster and its Act-Local program to facilitate new connections within a critical local community.

**2. Use-inspired Research and Development (R&D).** Key gaps: (i) Current ecosystem data and experiences are often siloed between different community groups, companies, states, and industries, limiting regional co-learning that would benefit everyone; and (ii) *NID* of OWE farms requires testbeds and frameworks to pilot and ultimately certify innovative technologies so that they can be accepted by regulators and industry. Solution: As described in Section II, by bringing the key ecosystem actors, including members of local communities, into the Working Groups, Use-Inspired Research Projects, and CoPs, the Engine will ensure that R&D work is explicitly tied to each community's challenges and needs. By fostering a holistic and incremental approach to the development and testing of solutions within the coastal communities, the Engine will develop a playbook for the innovation ecosystem that can be adapted across the RoS to support the development of additional place-based use-inspired research projects. For data, the Engine emphasizes availability and transparency in all of our work, but recognizes it may take some time to develop the processes and trust for other industries to share. The Engine's Working Groups and strong ties to industry partners will allow the Engine to learn from their expertise even as the Engine works towards increasing data-sharing capabilities and practices.

**3. Translation of Innovation to Practice.** Key gap: Societal and environmental benefits of OWE farms—including the potential to strengthen the marine ecosystem, increase fishing stocks, and grow a *New Blue Economy*—are undervalued. Current policy on OWE focuses on the lowest sticker price of electricity at the exclusion of environmental effects and sustainability (e.g. most OWE farms are designed to last only 25 years whereas we should be constructing durable infrastructure as we do for hydroelectric dams). Solution: Policies need to advance to serve the best interests of society by valuing the full benefits of *NID* to communities and the environment; just changes in policies would drive the market at scale. Engagement of the OWE industry, commercial fisheries, coastal communities, policymakers, and BlueTech innovators in the Engine will support the development of policies that advance responsible OWE project development with broad-based benefits, as has been realized to some extent in other nations [5]. To advance *NID* technology and services, the Engine will combine existing local research with resources from OWE developers interested in the RoS to gather the evidence of benefits needed to support the necessary advancements in policy. Although it is not well incentivized by public policy, many OWE developers have internal net-positive environmental impact goals that will help further create a market for *NID* features. For multi-use concepts around Sustainable Seafood, the Engine will leverage existing expertise in the local seafood industry through intentional collaboration with existing CoPs in coastal communities where members know the important challenges. These can be developed into new ideas for products and services to be incubated and selectively fed into advanced deep-tech accelerators such as SeaAhead or small business accelerators such as EforAll. Through close collaboration with regulators, the Engine will also facilitate the validation and approval of these technologies so they can be implemented into policies and regulations that further support just and clean economic growth through *NID* innovation.

**4. Workforce Development.** Key gap: OWE and *NID* are both new to the RoS, and we have not yet fully defined the workforce and innovation needs driven by technological advancements in the marine space (i.e., data acquisition technology, robotics, digitalization, data science). Solution: The Engine will work to quantify and address those needs. For example, the Engine will work with our workforce development partners to offer low-barrier, authentic educational and training experiences for early career workers and career-shifters to allow them to “taste” the opportunities within OWE (e.g., micro-credentials & workshops). The Engine will also create multiple career pathways by using our strong network of academic and industry partners. The Engine will develop the comprehensive and supportive network needed to attract and retain diverse individuals in high-quality jobs and to achieve the collective impact that cannot be realized by creating individual pipelines. The Engine will also catalyze future *NID* innovations by training K-12 learners in entrepreneurial and interdisciplinary thinking. The Engine will map new industry needs to job opportunities created by advances in blue technology and develop community-based credentialing programs, learning from successful models like the biotechnology academy of Core Partner GMGI. Specific working groups will be dedicated to these key initiatives.

**5. Inclusive Engagement.** Key gap: There currently is no mechanism to hear the unique voice of each coastal community and to co-develop and translate best-practices across communities. Solution: The Engine will embed its innovation ecosystem within historically underserved coastal communities (e.g., Justice40 communities) that are on the front line of climate change and leverage their assets and expertise to co-create and deploy innovations. To effectively listen to the communities we serve, the DEIAJ Team will hold quarterly convenings with community members and groups committed to including People of Color in conversations about clean energy. Community members are culturally embedded in their communities and uniquely understand the issues plaguing those within communities, yet they are often not engaged in the planning and development of innovation and technological advancements. As is stated in Disability Justice principles, “nothing about us without us” [50]. So, no innovation and policy should be created without the full and direct participation of those who will be affected. Engine Partners and other ecosystem actors will participate in bi-annual equity-focused trainings to strengthen the Engine’s culturally responsive and community-engaged practices.

**6. Strategic Regional Investment and Demonstrable Sources of Sustainable Capital.** Key gap: Significant capital and large joint public-private investments are needed to disrupt market-driven forces, which are not delivering a just or sustainable energy transition. Solution: Justifying such a disruption requires vision, evidence, and a broad-based community of experts and stakeholders to drive this change. The Engine builds upon a strong foundation of globally-leading expertise and research assets in marine science and fisheries. In particular, the Buzzards Bay area is home to Core Partners WHOI, Marine Biological Lab (MBL), and SMAST (at UMass-Dartmouth), and the nation’s highest-by-value fishing port (the Port of New Bedford) and where there are well-organized local communities (NBOC, NOAA-Fisheries, DMF). The Engine also benefits from several ongoing OWE-, fisheries-, and publicly-funded projects by these and other Core Partners. The Synergistic Activities documents of Key Personnel present the Broader Impacts of some of these projects. Upon this foundation, the Engine is pleased to have an investment of \$20M (contingent on NSF Engines award) from the state of Massachusetts to acquire equipment and create capabilities that augment, leverage, and complement existing resources. As documented in the Spreadsheet of Existing and New Resources, these new resources will be located in the Ocean Renewable Energy Innovation Center being developed in New Bedford, and in nearby ocean field site locations. Existing resource commitments of \$15M are presented in this spreadsheet showing resources that are anticipated to be needed for the first set of Use-Inspired R&D Projects and other activities that are expected to begin in Year 1 of the Engine. Significant co-funding commitments are expected from other public and private sector support with a full proposal (if invited). As the Engine builds momentum, there are millions of dollars set aside by OWE developers for community benefit agreements that can potentially be leveraged as the Engine gains trust and capacity.

**7. Governance and Management.** Key gap: No organization currently has the infrastructure and resources for cooperation across state and industry boundaries to advance opportunities for mutual benefit and data sharing and research frameworks focused on regulatory decision making. Solution: The Engine will leverage local programs throughout the RoS, regional and national Partners that convene different industries, and Team MOCEAN’s own breadth of expertise, resources, and direct relationships to ensure that champions from across all relevant local communities, industries, governmental bodies, areas of expertise, and advocacy organizations have a vital role in play in the Engine and are recognized and supported in their efforts. The Engine governance and management will take place over four levels. As introduced in Part II, *Working Groups* of actors from various parts of the innovation ecosystem identify critical questions and needed technological innovations, help secure resources for launching new initiatives, learn from and inform ongoing Projects, and set goals for future Projects and continuing Projects. *Project leads* are responsible for conducting multidisciplinary and multi-objective Projects that advance science, engineering, technologies, policy, and societal objectives through Use-Inspired R&D Projects; they are supported by the Leadership Team, DEIAJ Team, Working Groups, and Communities of Practice. A *Leadership Team* is responsible for the overall Engine and the integration of efforts, and the *DEIAJ Team and Partners from the three Industry Sectors* (OWE, Sustainable Seafood, and BlueTech) will ensure that their respective communities contribute to and benefit from Engine activities. As mentioned in Section II, the Engine will contract a leading economic and social impact assessment firm, Tripp-Umbach, to measure its impacts in the RoS.

## V. Key Partners and Stakeholders in the Region of Service

The committed Core Partners of the Engine were introduced (and named) in Part I. These partners represent several types of organizations and communities, including: (i) the OWE, fishing, and BlueTech industries; (ii) universities, colleges, and research institutions; (iii) environmental and other organizations focused on protecting interests and co-existence; and (iv) organizations that support and advance innovation and economic development, including members of impacted coastal communities. The individuals involved in the Engine from these and other Partner organizations and communities include scientists, engineers, educators, conservationists, industry leaders, policymakers, innovators, entrepreneurs, community leaders, and others who are committed to jointly creating a just energy transition through advancing the design and valuing of nature-inclusive multi-purpose OWE farms. Please refer to Part I for the types of contributions that they will make to the Engine.

One group that Part I did not properly introduce was the Engine's DEIAJ team and their role in ensuring and driving inclusive engagement. The Engine uses a distributed model for integrating DEIAJ objectives and activities across the Engine, where the champions are from Hampton University (Historically Black College and University), the University of Massachusetts Boston (Minority Serving Institution), Bristol Community College's workforce training institution, Entrepreneurship for All, and others from across the Engine that are committed to advancing justice initiatives at their organizations and in Engine activities. This includes engagement from K-12, underserved populations, and the public, as illustrated through their initiatives and publications [52, 53, 54, 55, 56]. These individuals will constitute the Engine's DEIAJ leadership, which will help to ensure that the Engine channels benefits to under-served communities and untapped populations traditionally underrepresented in STEM through workforce development.

Part II further illustrates the commitment of these individuals and organizations through their work on pilot and upcoming projects and also by the areas of their work as presented across the eight identified R&D transition challenge areas. The geography of these groups is displayed in Figure 2 (in Part III), and the groups' responsibilities across the seven drivers of ecosystem change are presented in Part IV.

Team MOCEAN will grow as the Engine develops its innovation ecosystem and learns through its *Use-Inspired Convergent Research Projects* and *Working Group* activities. Engine-developed infrastructure will attract additional investment in *NID*, future fisheries, and related workforce development across the RoS; members of the broader RoS will see the value that the Engine can provide in the form of knowledge sharing and the ability to leverage existing resources for innovative projects. Concurrently, the Engine will leverage its existing relationships—direct and indirect—to include more of the ecosystem's actors. The Engine will engage types of organizations currently not represented (e.g., local conservancy organizations) that are key to the co-design work—including to translation efforts—and use existing Partners to identify other communities and subsectors (e.g. within fisheries) who would be key to such efforts, leveraging the interests of the prospective communities to engage them in the collaborative work.

All individuals mentioned above—including those on and beyond the Leadership Team—will be invited to integrate their expertise and activities through participation in the Working Groups (introduced in Section II) and Communities of Practice, as well as scheduled conferences, workshops, meetings, and listening sessions organized by the Engine to promote cross-sector communication. The Engine will also share resources more broadly through its website [57] and through community meetings and engagement activities.

The strong and deep connections among the Engine's Core Partners and between the Partners and the RoS enable the Engine to quickly develop and strategically maintain an inclusive and interdependent innovation ecosystem, accelerating the RoS toward clean energy through OWE, sustainable oceans and fisheries, and a skilled local workforce which can take advantage of jobs created through a new, high-tech *New Blue Economy*.

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