Overview

NSF Engines: Type-2: MOCEAN: Accelerating a Just Energy Transition While Nurturing Healthy Oceans and New Blue Economies Through Innovative Nature-Inclusive Offshore Wind Farms

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Purpose and Vision

The U.S. offshore wind energy resource is enormous, and the cost to generate electricity from offshore wind energy farms is now very affordable. Coastal states have made significant commitments to have increasing portions of their electricity supply come from offshore wind energy to help them achieve their climate goals. Unfortunately, however, the development and deployment of offshore wind farms is hampered by many challenges. These include conflicts in the shared-use of the ocean with fisheries, the lack of a regional industrial development strategy, and unprepared workforces for the breadth of excellent employment opportunities. In addition, current dispersed policies and decision-making processes will not deliver a just energy transition. The MOCEAN Innovation Engine will serve the coastal region from Massachusetts to Virginia by bringing together communities, policy makers, offshore wind developers, marine scientists, engineers, and entrepreneurs to co-create innovative ways not only to deploy nature-inclusive designs that protect and enhance existing marine ecosystems and reduce conflicts, but also to ideate and incubate new technologies and new employment opportunities that specifically target low-income and historically disadvantaged communities.

Intellectual Merit

This proposed NSF Engine will make significant advancements in science and technology, as well as improve engineering, economic, and educational models. The advancements in science will range from the micro-to-macro scale, and these will include the formation of marine organisms; marine biology; impact of stressors on habitats; the effect of different materials and coatings on marine growths; local ecosystems, as well as regional ecosystems that includes habitat migration due to the changing ocean environment. The advancements in technologies will also be broad and will include new sensing systems (e.g. eDNA, acoustic, image-based), new types of inspection equipment, coating systems, more durable materials, intelligent nature-inclusive scour protection, productive artificial reefs, and future-proof foundations. The advancements in engineering models will account for important factors that are presently ignored or insufficiently considered in practice, including the effects of soil-foundation structure interactions on design, and the impact of cathodic protection on design life and the environment. For economics, the advancements will quantify the benefit of local labor, environmental impact, and new jobs in fisheries to create models that can be used in the decision-making process for the design and operation of offshore wind farms. In education, advancements will create new methods of engagement, support, and learning that lead to much greater participation of students and workers from marginalized communities in the New Blue Economy. The composition of the MOCEAN team was designed to make intellectual progress at the intersections between different fields, and to create system-of-system models.

Broader Impacts:

The MOCEAN team is committed to bringing together currently disconnected researchers, economic development efforts, innovation, community groups, and others to co-create an offshore wind energy deployment strategy that foster new blue tech industries and enables underserved coastal communities to grow and thrive beyond their traditional economies. This strategy will also establish the nation as the global leader in sustainable offshore wind farm development. The broader impacts of this include: (i) Ensuring a just energy transition; (ii) Creating a continuously learning and innovating ecosystem that advances technologies for economic and ecological benefit; (iii) Integrating diverse fields to achieve community-centered research and policy objectives; (iv) Creating a better-informed citizenry and empowered decision makers; (v) Fostering collaboration across institutions, governments, and financial investment institutions, and (vi) Mobilizing deep outreach programs to motivate young people to enter STEM fields and to create entry points for broad stakeholder participation in the energy transition. All MOCEAN activities and programs integrate diversity, inclusion, equity, accessibility and justice principles with intentionality, including within the leadership team, STEM education and training, and communities across the region to enhance economic development.

Keywords: Climate, Offshore, Wind, Ecojustice, Fisheries

LOI ID L23-000114

Concept Outline ID INQ-22-00192

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Project Description

a. Overview, Vision, and Rationale

Overall Purpose and Vision. The United States has recognized that Offshore Wind (OW) energy can support the essential transition to a low-carbon energy economy. Based on federal and state contracts and commitments, approximately 30 GW of offshore wind farms are expected to be constructed in the region of the Engine (see Figure 1) by 2033 at a total cost of about $100B, based on projections given in the most recent Department of Energy OW Market Report [1]. Using an average expected turbine size of 15 MW, about 2000 turbines are needed to create 30 GW of capacity. Yearly development expectation through 2031 and the expected number of turbines and development cost per year are found in Figure 1. The color key in this table is used to identify the location of developments for each year; for example, the "red" colored region is the Vineyard Wind project that is located 15 miles south of Martha's Vineyard. To date, the US only has seven 6-MW OW turbines (42 MW), while the globally installed capacity is 56 GW [1], with 25 GW developed by China and the rest by Europe.

The U.S. currently lacks the expertise, experience, workforce, vessels, ports, and supply chain to develop its own offshore wind resource at scale and is largely reliant on European industry [2].

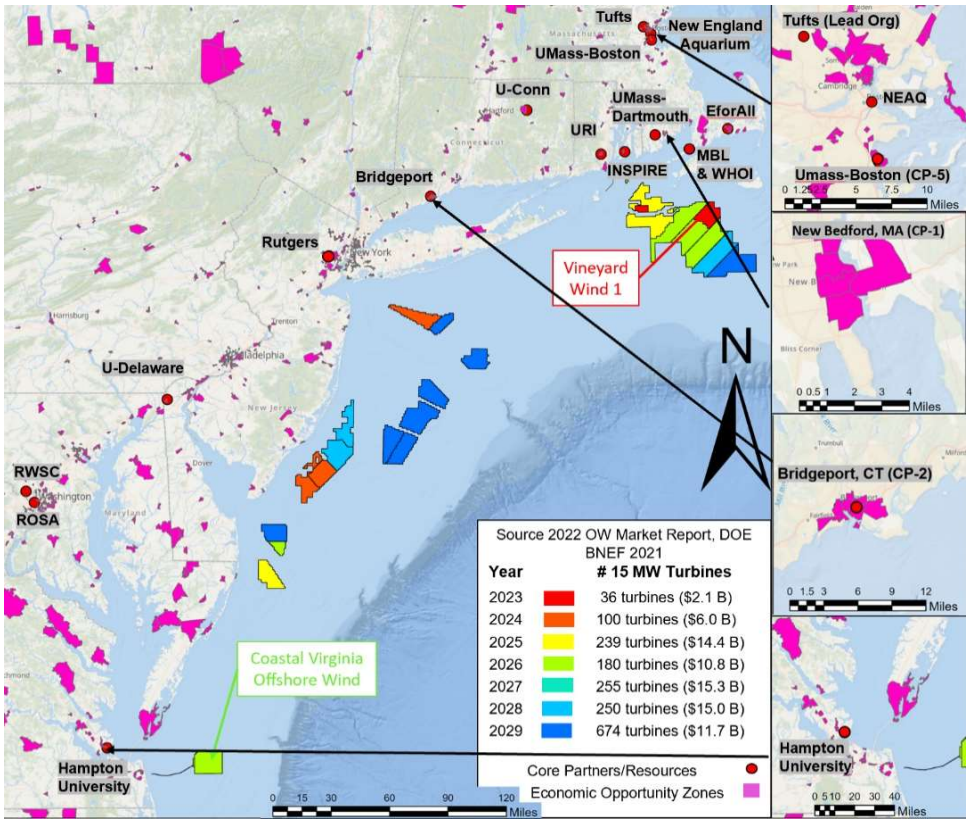


Figure 1: Wind Farms, Engine Partners, and EDA Opportunity Zones

U.S. offshore wind lease areas are also located in waters used extensively by the fishing industry, leading to lawsuits and delays over the past 20 years [3]. The problem of co-location of OW and fishing can be resolved by "Nature-Inclusive" OW farms designed to support healthy oceans and thriving fisheries. If this can be done, then large-scale development of the vast OW resource will be possible while growing a new blue economy around our oceans. For example, a Danish offshore wind development has tested broodstock structures and intentional seeding to replenish an oyster population that has decreased due to fishing and disease [4].

The design, deployment, and operation of nature-inclusive offshore wind farms present an opportunity for the U.S. to become global leaders in responsible offshore wind energy development. MOCEAN will bring together the coastal communities, policy makers, developers, marine scientists, engineers and entrepreneurs to create an innovation ecosystem centered around Nature Inclusive Design (NID) that can consider the complexity of such an enterprise. The goal includes maximizing the benefits to low-income and underserved communities, to society writ large, and to healthy oceans.

Region Definition and Fit for Engine.

MOCEAN's Region of Service & Fuel for Engine: The region is defined by the area from which the fuel for the Engine is derived. The 2,236,767 total acres [5] off the East Coast of the US that is being permitted for OW development is connected to land areas and communities through a variety of connections. This region includes about $100 Billion to be spent by the industry in the deployment of offshore wind farms between Boston MA and Hampton VA (contiguous region) over the life of the NSF-supported Engine. One way to look at MOCEAN's goal is that this $100 Billion is used in ways that advance science, engineering, technologies, evidence-based decision making, and policy to maximize what is in the best long-term interests of society and the environment that cross state borders and include historically marginalized communities and populations; industry and public policy cannot do this on its own.

The Fuel also includes the federal, state, and private support for the development of the physical infrastructure, human capacities, and financial structures across this region needed for optimizing offshore wind energy. Examples of public investments have shown that historically underrepresented communities (EDA Opportunities Zones) along the coastlines between MA and VA can and will be centers for offshore wind development [6–8]." As conveyed in this proposal, several of MOCEAN's activities are centered in the EDA zones where state and investor interest plan to turn these regions into innovation and industry hubs for offshore wind energy. This proposal outlines the necessary and critical role that an NSF Engine can have in aligning these public and private investments for the good of society.

MOCEAN's Core Partners: Figure 1 presents the location of core-partner organizations (see grey background blocks) that have key personnel listed in Table 1 in section (b). As MOCEAN lead, Tufts University has convened a regional collaboration in the Region of Service (Region), starting with convergent projects (section c) throughout the region that have been developed based on local priorities, including AI/ML models for local fisheries (NJ), local job development (CT), novel technologies for NID features in offshore wind farms (MA), and a new pathway for an HBCU to become directly involved in OW (VA). Figure 1 shows that although many of the initial partners are located around New England, there are also critical partners in NJ, DE, and VA. This initial lean towards New England states is a function of the timeline for OW deployment. Figure 1 shows that the first large-scale offshore wind farms (e.g., Vineyard Wind 1) will be built in close proximity to MA/RI. New Bedford, MA, an EDA Opportunity Zone that hosts one of MOCEAN's initial projects, is the first offshore wind port built in the US. The flexible structure of MOCEAN will allow the engine to "follow the work" and MOCEAN will mature throughout the region alongside industry. The core partners in states such as NJ, DE, and VA will act as "stations" and help engine activities propagate throughout their local areas in addition to their other roles in MOCEAN (see section c).

Timeliness of MOCEAN: Because the U.S. is at the nascent stages of OW development when the future of the industry can still be effectively shaped, now is the time to launch MOCEAN. There is already investment occurring related to offshore wind organized at a state-by-state level. For example, in NJ the research monitoring initiative receives funding from OW developers to research the impacts of OW farms on the environment [9]. The Massachusetts Clean Energy Center (MassCEC) has also funded research related to OW [10]. While these efforts are great starts, they are limited because they are largely driven by state policy instead of a regional perspective. In the absence of MOCEAN, underserved communities and local and state governments will not have a united voice backed by data to directly address the conflicts and potentially competing priorities between existing coastal industries and OW developers. To fully leverage the opportunity of OW development, the vision needs to be regional and not solely rely on a state-by-state approach. Now is the time to build this regional community before the policy, supply chain, and business opportunities in the Region are fully set.

Maturity Phase of the Region's Ecosystem: Currently, MOCEAN's region is in the nascent phase with regards to offshore wind and the new blue economy. While the federal government and individual states are investing significantly in offshore wind, and developers are leasing areas for deployment, these benefits have not yet translated to sustainable economic development in these communities. However, many stakeholders do see OW as a potential driver for new, higher-paying jobs [11]. OCEAN is bringing OW developers, local communities, marine scientists, researchers, engineers, and entrepreneurs to co-

create new innovative products, services, and businesses that will inspire and lift underserved communities and set in “MOCEAN” a brighter, cleaner future for the region. MOCEAN’s will succeed by amplifying existing resources/relationships in the region rather than building a new system from scratch.

Challenges, Gaps, & Status Quo. Offshore wind development in the region has momentum, but several challenges and gaps remain. These include conflicts with ocean users, communication barriers, availability of metrics to inform policy, sparse resources for a marine construction industry along the Atlantic coast, and data availability related to the status and function of the marine ecosystem.

Challenge 1 Conflicts Between Ocean Users: High-profile conflicts, mistrust, and competing priorities among the fishing, aquaculture, and some coastal communities and the OW industry regarding the shared use of the oceans has contributed to the U.S.’s lack of OW progress compared to Europe and China [3]. Significant progress has been made in mediating these conflicts through policy. However, gaps in fundamental science and ocean modeling must be filled to be able to predict the impact of these OW farms on the marine environment. These models will help remove some of the uncertainty that can contribute to the tension around ocean-use conflicts and spur innovation in mitigation and adaptation.

Challenge 2 Communication Barriers: Because OW pulls together a diverse array of stakeholders, many barriers in communication exist. In addition to the previously discussed state barriers, OW must contend with different ocean habitats, fisheries, scientific disciplines, and life experiences. MOCEAN will cross these barriers and serve as a trusted convener of researchers in engineering and marine science, the OW industry, co-located marine industries, government, and communities to support the data development, technologies, and models to fully realize the opportunity of OW development beyond climate change mitigation. This approach will allow people with different experiences to find the innovative solutions needed to build a new blue economy connected to and accelerated by OW development.

Gap 1 Limitations of LCoE: The current economic model Levelized Cost of Energy (LCoE) used for OW policy, farm design, and operation narrowly focuses on the cost of the system and leaves out additional impacts. A deeper understanding of the aggregate impacts in understandable and common metrics will be critical to streamline the allocation and permitting processes while maximizing benefits [12]. Two main policies that affect offshore wind use LCoE: federal leasing policy and state policy related to purchasing power. These two policies set market conditions for OW development and associated downstream and upstream economic activity, while simultaneously determining the environmental and social impacts in marine systems and coastal communities. The Engine will create and calibrate a Societal Cost of Energy (SCoE) model to incorporate these additional factors affecting the long-term interests of society, including appropriate design life parameters for underwater infrastructure of different types of deployments designed to provide enhance underwater ecosystems. This new SCoE tool will assist policymakers and stakeholders when considering the comprehensive costs and benefits of the emerging OW industry.

Gap 2 No Offshore Construction Industry in Region: Currently, the MOCEAN region lacks a heavy marine industry. For example, while the North Sea had a large offshore oil and gas industry that their OW industry was able to leverage when OW was first developed, our region does not have offshore oil and gas resources that can be adapted to make large OW products (e.g., foundations), provide OW services (e.g., inspection services), or train a workforce (e.g., welders to manufacture jackets). Instead, the nascent OW industry will need a combination of large investments that build supply chains from scratch and leverage existing assets in the region, such as ports like New Bedford or carpenters skilled in concrete work in CT. OW development in the region is almost a blank slate and there will be opportunity for new U.S. companies to join a new blue economy.

Gap 3 Availability of Data: The importance of data unites all these challenges and gaps for nature-inclusive OW development. Despite many significant and successful data collection and sharing initiatives, the advancement of basic science, models, and technologies for offshore wind energy are still hampered by a lack of data and associated metadata [13–15]. While some posit that the unjustified reluctance of Developers and Original Equipment Manufacturers (OEMs) to share data is the main barrier to broad-based learning and advancement, this is not the case. Industry may be wisely reluctant in many cases to limit access to proprietary data, and the level of data and metadata needed to advance existing and new models is often well beyond that which is normally collected by Developers and OEMs. A core

vision of the MOCEAN engine is to fill this critical gap by creating a system where data and industry experience can be shared and discussed frankly to inform future research and innovative ideas that will help all ocean users.

Current state of practice and Engine vision: The U.S. is at the nascent stages of a full-scale deployment of OW and many gaps must be filled, and challenges overcome. The current practice in OW development is a project-by-project framework that is not optimized to consider the challenges and opportunities associated with the anticipated scale of development over time. The MOCEAN Regional Innovation Engine will fill this gap in systems-level thinking by creating collaborative communities-of-interest that can address cumulative impacts from a regional perspective.

Innovation Sector & Jobs in the Region. The opportunities for innovation sector jobs can be broken up into three broad categories. First, there are opportunities directly related to providing NID products or services to OW farms (e.g., sensors and environmental monitoring techniques). Second, there are opportunities for products and services related to helping existing ocean users adapt to an ocean being changed by external forces such as climate change and OW development (e.g., AI/ML probabilistic models to map ocean ecologies and species; gear adaptations for fishing safely within windfarms). Once fundamental models are established through use-inspired research and opportunities are identified through the MOCEAN ecosystem of partners, the third opportunity is the end goal of MOCEAN: To identify potential for multi-use zones that maximize the utility of the OW infrastructure as has been investigated in Europe [16].

New Businesses: To turn these opportunities into new businesses, the engine has partnered with experts in entrepreneurship that will be described in more detail in section cii: SeaAhead, EforAll, and the New Bedford Ocean Cluster (NBOC). The initial focus will be on New Bedford, where MOCEAN has existing connections with NBOC and local government officials. New Bedford is key to early engine activities because it is a major hub for the first US commercial OW farm, Vineyard Wind 1. As the OW industry moves further down the coast with different projects MOCEAN will use the same framework described in section (cii) and established and practiced in New Bedford (MA) to establish additional innovation hubs in the region, in Bridgeport (CT), Hampton (VA) where MOCEAN has established strong roots.

Workforce Development: For the U.S. to develop its own offshore wind energy resources, new educational programs, training institutes, and support for existing workers and professionals are needed. The design, deployment, and operation of NID OW farms will require the creation of significant workforce development and retraining pathways facilitated by curricula and programs developed by the MOCEAN engine. The need is enormous. Using data presented in the 2022 Department of Energy U.S. Offshore Wind Workforce Assessment [2] and other assessments [17], it is estimated that about 77,000 offshore wind jobs will be created to develop 30 GW of offshore wind (the amount in the Engine's region by 2033).

Corporate Footprint: The current corporate footprint can be characterized as European firms establishing offices between Massachusetts and New Jersey, and many U.S. companies are unprepared to compete for very-high dollar value contracts, with a few exceptions such as Dominion wind in VA. Through outreach and engaging with entrants new to the field, MOCEAN can help U.S. companies with relevant experience (e.g., oil and gas work in the Gulf of Mexico) see opportunity in OW. MOCEAN's focus on NID will also engage companies that may not have direct experience in the energy sector but are experts in ecosystem services or ecological modeling and contribution to OW farm development in the region.

b. Proposing Team and Organizational Structure

Organizational Structure. Figure 2 presents the personnel, teams, and boards that will manage and oversee MOCEAN. The Green Boxes denote positions and entities that will be in-place as soon as possible into the operation of the Engine, which will be immediate for some but not all. In accordance with the BAA, the full-time CEO and their team will be in position within the first 6 months of operation. The PI and other key personnel will share responsibility for the immediate launch of all activities and operations until the needed hires are in place. They will also establish the Governance and Advisory Boards. The CEO is supported by a full-time Operations Manager and Financial Manager as shown to the right of the CEO. There are 3 Director positions in addition to the CEO. The Technical Director is responsible for supporting and overseeing the operation of the Working Groups (WGs) and Convergent Projects (CPs).

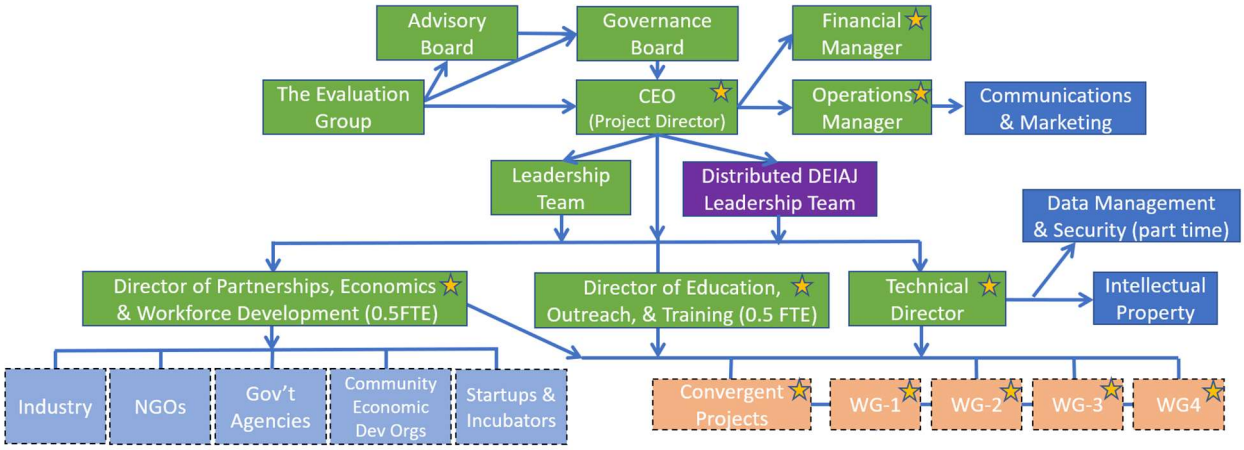


Figure 2: Overall Organization Structure

These Working Groups (WGs) and Convergent Projects (CPs) are shown in orange, and they are introduced in Figure 3 and described in sections (c). There are two half-time Director positions, one in Education, Outreach, and Training who will also support the CPs and WGs. The other is in Partnerships, Economics, & Workforce Development who will make connections between the broader community (see light blue boxes below this position) and the CPs and WGs. To embed a culture of DEIAJ across MOCEAN, a Distributed DEIAJ Leadership Team (see purple box) has been established of existing leaders in this field who are from the Lead Organization and Core Partners. They are introduced in section (d.i). The Leadership Team consists of the CEO, 3 members of the DEIAJ Team, and the lead of each CP and WG. Table 1 identifies their names in bold. The blue boxes denote positions in the future. The full composition of the Working Groups will be established at the onset of the Engine.

Relevant Activities and Roles. The work of the Engine is done in three categories of activities: Working Groups (WGs), Convergent Projects (CPs), and Engine Infrastructure (EIs) as shown in Figure 3, and they are described in greater detail in sections (c). Figure 3 shows the four Working Groups (WGs) established to support the development and translation of use-inspired research in the following areas: Nature-Inclusive Engineering (WG-1), Ocean Science (WG-2), New Blue Economy (WG-3), and Education, Outreach, and Training (WG-4). These WGs are the primary activities to engage the broader public and private sectors, and communities. The WGs will identify and debate "the big questions" and determine the most effective ways to address these questions, who needs to be involved in this work, and what Engine (and non-Engine) assets and external collaborations are best suited to address these questions. WG-3 and WG-4 will also be key resources for the MOCEAN activities related to turning innovation into practice and workforce development as described in section (c.ii) and (c.iii).

In the first two years of the engine, five CPs will be distributed across the region in places where new economic development opportunities are greatly needed. The CPs are designed to address specific community-identified needs and to lead to technologies or other products that can be translated and scaled. These CPs are only initial projects for the nascent stage of the engine and the initial five CPs may be expanded and new CPs added as the engine matures with more external funding and as new ideas are developed in the WGs. As one example, CP-1 will be focused on New Bedford MA, which is an Economic Development Administration (EDA) Opportunity Zone (low-income distressed community), where there is significant interest and commitment from all levels of government, from the Mayor's office through federal Congress members to develop this area as an innovation hub for offshore wind energy. The New Bedford Ocean Cluster (NBOC), a development organization, will be a member of MOCEAN WG-3 focusing on building the new blue economy.

The red numbers in Figure 3 identify the funding over years 1 and 2 of the Engine in the WGs & CPs.

Cross-cutting elements, denoted as Engine Infrastructure (EI-1 to EI-5), are the responsibility of the Lead Organization with support from core partners and from industry, governing entities, coastal communities, and others. The EIs are the glue that binds the WGs to the CPs and makes the engine structure flexible, since new WGs or CPs can be added without a dramatic change to the core engine organization structure. As the engine grows, additional project coordinators may be hired to link WGs to CPs.

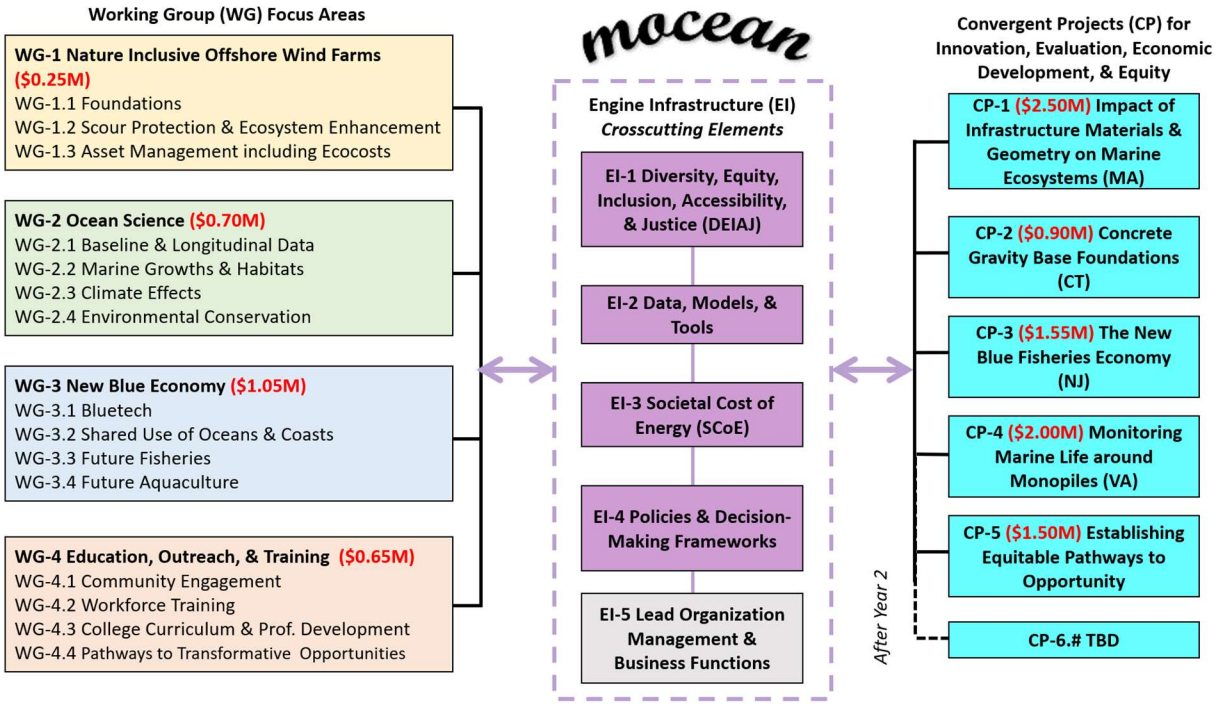


Figure 3. Engine Activity Structure

EI-1 Diversity, Equity, Inclusion, Accessibility, & Justice (DEIAJ): In order to instill a culture of DEIAJ across the Engine, a distributed leadership model is used. The personnel are presented in section (d.i) and the DIEAJ management plan is presented in (d.iii). In this proposal, the team and activities will be defined using DEIAJ, whereas the impacted communities will be defined using DEIA.

EI-2 Data, Models, and Tools: EI-2 is the cross-cutting theme in the Engine that is concerned with advancing data collection and analysis methods, beginning with existing datasets and new data collected through CP-1, CP-3, and CP-4. As discussed in section a, data availability is a key gap to be filled.

EI-3 Societal Cost of Energy (SCoE): EI-3 is the Societal Cost of Energy (SCoE) model (see section (a)). The SCoE model will be created and calibrated in the Engine to consider relevant factors that are in the long-term interests of society and measure them in common and comparable terms that reflect values and preferences of stakeholders, providing the scientific basis for next generation allocation procedures.

EI-4 Policies and Decision-Making Frameworks: Through EI-4, MOCEAN will work with Federal and State regulatory bodies and design making groups, industry, and others to support the improvement of policies and decision-making frameworks. The MOCEAN team has close working relationships with many of these key groups and organizations. For instance, the lead organization, Tufts University, has done research projects for BOEM and DOE WETO and has written several reports related to offshore wind foundations.

EI-5 Lead Organization Management & Business Functions: Described in Figure 2.

Governance Board. The Governance board, shown in Figure 2, will oversee the entire MOCEAN engine. The composition of this board will include the CEO, 3 total representatives WGs & CPs, at least two members of the DEIAJ leadership team, and representatives from the communities engaged in the convergent projects. The Governance Board will be responsible for ensuring that milestones are met by WGs, CPs and EI units, and that the data management and sharing plan is implemented to integrate new partners and projects. The Board will also identify gaps in expertise or sectors, approve WGs plans for new CPs, and approve any changes in staffing, structure, or financial oversight. The Governance Board will meet at least quarterly, with additional meetings on an as-needed basis based on challenges identified. The CEO will be hired by and will report to the Governance Board.

Plans for Advisory Boards. Advisory Board members will be drawn from the members of the groups and communities identified in section (c.iv), including one or more persons from industry, responsible bodies, educators, community representatives from across the region, and the research community.

MOCEAN will seek to ensure that the Advisory Board members deeply understand the challenges and opportunities the Engine faces, as well as the specific economic and workforce development needs of our region. Importantly, to ensure that DEIAJ goals are met, members of the advisory board will have expertise in advancing DEIA within STEM workforce development, private and academic organizations, and/or economic development. The Advisory Board will meet at least twice per year to review progress toward milestones and recommend changes to the Governance Board and Leadership Team.

Core-Partners and Roles. Table 1 lists all organizations to be funded in the first two years of the Engine, and the specific persons to receive funding. This does not include graduate students, post-doctoral researchers, and other staff who will only be hired once the grant is awarded. The third column in the table uses keywords to identify the core competence and/or role that that organization has in the Engine, including specific Engine activities, WGs, CPs, and EI units. The Leadership Team is built from CPs leads and WGs convenors (bold text in Table 1), as well as DEIA leads, the CEO, and other key positions. Letters of collaboration and biosketches more fully describe roles and qualifications.

Table 1: Committed Engine Organizations and Key Personnel

Organization	**Personnel**	**Relevance and Role**
Consultant; employed at Bristol Community College	Yashwant Sinha	Workforce; Lead WG-4.2; Contribute to CP-5
Entrepreneurship for All	Jeremiah Hernandez, **Meralis Hood**	DEIA; co-convene WG3
Inspire Environmental	Annie Murphy, Drew Carey, Kersey Sturdivant, Lianne Jacobson, Samuel Sturdivant	Co-lead CP-4
Florida Institute of Tech.	Geoffrey Swain	Lead WG-1.3; Contribute to CP-1
Hampton University	**Deidre Gibson**, Joseph Reustle, **Jeanette Davis**	Co-lead CP-4; Contribute to E-1
Marine Biological Lab.	Loretta Roberson, Ketil Jakobsen, Javier Lloret, Minta Teichberg	Artificial Reefs; Lead WG-1.2; Contribute to CP-1
New England Aquarium	Michelle Cho, Jessica Redfern	Lead WG-2.4 and WG-4.1; Contribute to CP-1, CP-3, CP-5, & EI-1
Outer Harbor Consulting	Fara Courtney	WG-3, WG-4, EI-2
Regional Wildlife Science Collaborative; (in-kind)	Emily Shumchenia	Lead WG-3.2; Contribute EI-2
Responsible Offshore Science Alliance	**Michael Pol**	Lead WG-3.2; Convene WG-2; Contribute to WG-3.2, WG-3.3, & EI-2
Rutgers University	**Josh Kohut**, Aziz Ezzat Ahmed, Daphne Munroe, Douglas Zemeckis, Wade Trappe, Amy Mandelbaum, Jason Morson	New Blue Economy; Lead CP-3; Contribute to WG-3.3
SeaAhead	**Mark Huang**, Alissa Petersen	Lead WG-3.1; Co-convene WG-3; Contribute to CP-1 & CP-4
Tufts University	**Daniel Kuchma**, Eric Hines, Kevin Oye, Chris Swan, **Grace Marie Festin Caldara**, Merredith Portsmore	Lead organization; Foundations, Innovation, SCoE, DEIA, Evaluation
Univ. of Connecticut	Michael Whitney, Kaylan Randolph, James O'Donnel, Catherine Matassa, Samantha Siedlecki	Contribute to CP-3
Univ. of Delaware	Matt Oliver, Cristina Archer, Yun Li	Contribute to CP-3
Univ. of Mass.-Boston	**Robert Chen, Kerrie Wilkins-Yel,** Elizabeth Sweet, Susan Crandall	Lead WG-4.3, WG-4.4, & CP-5; Contribute WG-4.2 and EI-1
Univ. of Mass.-Dartmouth	Kevin Stokesbury, Gavin Fay, Changsheng Chen, Robert Griffin, Geoffrey Cowles, Pingguo He	Contribute to WG-3.3, EI-3, & CP-1
Univ. of Rhode Island	Aaron Bradshaw, Chris Baxter	Contribute WG-3.3 & CP-2
Woods Hole Oceanographic Institution	**Colleen Hansel**	Lead WG-2.2, WG-2.3, & CP-1

Lead Organization. Tufts was selected by the MOCEAN team to be Lead Organization to launch this Engine for several reasons: (i) the breadth and depth of relationships with the burgeoning U.S. OW industry, researchers, stakeholders, states, and affected communities as well as global leaders in research and the offshore wind community in Europe, and in K-Gray STEM education research and programs; (ii) track record of grants and publications in offshore wind energy including the white paper "*Research Convergence in United Stages Offshore Wind Energy Research: A Multidisciplinary Framework for Innovation*"; (iii) national convenor of more than a dozen workshops on the topics of this proposal including a 2016 Interagency Workshop that brought together leaders from agencies including NSF, DoE, DoI, NOAA, NASA, NCCOS, with representatives from the burgeoning U.S. industry and international research communities, as well as an online workshop with more than 100 participants on the Nature Inclusive Design of Offshore Wind Structures [18]. Tufts has the experience, staff, and processes needed to manage the contractual and budget elements of the Engine, including compliance and audit requirements for federally funded grants.

Core Management Functions: Personnel and Qualifications: The management plan is presented in Section (d) of the project description. A high-level introduction to the management functions and staffing over the Nascent Period of the Engine (first 2 years) is as follows:

Contacts and Budgets Administration Functions: Fiscal management of the project will be provided by the Tufts Post-Award Office, which has previous experience in the management of large, complex federal grants, including satisfying all compliance and auditing requirements. The Tufts School of Engineering will establish and manage subcontracts and payments where primary support will be provided by a Senior Research Administrator to be hired. Until that time, Dianne Deschenes, CRA, will provide support with oversight from School and University administration.

DEIA Management Functions: As presented in Section (d.iii) "Culture of Diversity, Equity, Inclusion, and Accessibility," the Engine will have a distributed approach to embedding DEIAJ across all activities. The Lead Organization will have responsibilities for most convening activities, identifying and sharing best practices, and ensuring that the data needed to evaluate the effectiveness of programs and initiatives are shared and incorporated into all activities. These responsibilities will be shared between three current full-time staff and their assistants.

Other Management Functions: Prior to the hiring of the CEO and two other full-time staff (Manager of Operations, and a Coordinator of Working Groups and Projects), other MOCEAN management functions will be performed by existing personnel at Tufts (PI and others), with contributions from core partners to ensure an integrated approach across the region. The highest priority is hiring the CEO, who will lead the recruitment of the other two full-time staff. Tufts is well prepared to meet NSF's expectations for the Lead Organization, as reflected in the Evaluation Plan in section (d) that also presents the establishment of a new non-profit that continually grows over the duration of the NSF-supported Engine with funding from the state, industry, philanthropists, venture capitalists, and others.

Risk Mitigation and Conflict Resolution. Based on the integration of team members, the strength of Tufts as a convener across sectors, and the stage of the U.S. offshore wind industry, the MOCEAN team does not anticipate significant challenges in achieving its goals. However, to mitigate risks across all activities and infrastructure, we have a robust evaluation plan (see section (d.v)) designed to identify challenges early and a nimble approach to instituting changes across the Engine. The contracted external evaluator "The Evaluation Group" will be evaluating progress and potential concerns early, including having a direct line for "confidential conversations" for anyone engaged in the engine with an ethical or other concern so that these concerns are addressed early and before they escalate. MOCEAN leadership will appoint an expert in mediation and team facilitation to elevate and find solutions to conflicts that are not so easily resolved. If these efforts fail, conflict resolution and directional changes will be coordinated by a committee composed of the Tufts Dean of Engineering, Vice Provost for Research, and Provost, along with high-level representatives of any partnering institutions. An additional role of "The Evaluation Group" to mitigate risk is to assess when the transition of the Lead Organization to a new non-profit would best serve the Engine in achieving its goals and objectives.

New Non-Profit MOCEAN. A new non-profit named MOCEAN will be created at the start of the NSF Engine that will be the entity that receives and manages funds from industry, economic development organizations, philanthropists, and other sources. This structure will provide flexibility for the overall operation of the MOCEAN Engine, particularly for activities that are outside the scope of the Federal award. At some point before and up to the end of the 10 years of NSF support, Lead Organization responsibilities and staff (where appropriate) will transition to the new Non-Profit. When this occurs will depend on the "The Evaluation Groups" assessment of Tufts as the Lead Organizations, and ultimately decided upon by the Governance Board in consultation with NSF.

c. Strategic and Implementation Plans

As previously described, there are many communication barriers in OW development across different states, energy markets, geographic boundaries, community needs, and scientific disciplines. The MOCEAN engine will bring together people across sectors and life experiences with the overall objective of leveraging nature-inclusive OW farms to build a strong new blue economy around a healthy ocean. As Figure 4 demonstrates, the MOCEAN engine serves as a "rock tumbler," bringing together working groups and convergent projects within a robust, region-wide infrastructure to deliver joint industry projects and design guidance documents, policy recommendations, business ideas, outreach programs, curricula for workforce development, new technologies, and other positive disruptions for the ocean and society. The documents and programs that MOCEAN produces then feed back into the tumbler via community feedback and new research questions. The main benefit of the MOCEAN rock tumbler is flexibility. As the engine develops, new ideas will be added to build upon previous work and transfer knowledge and impacts across the region.

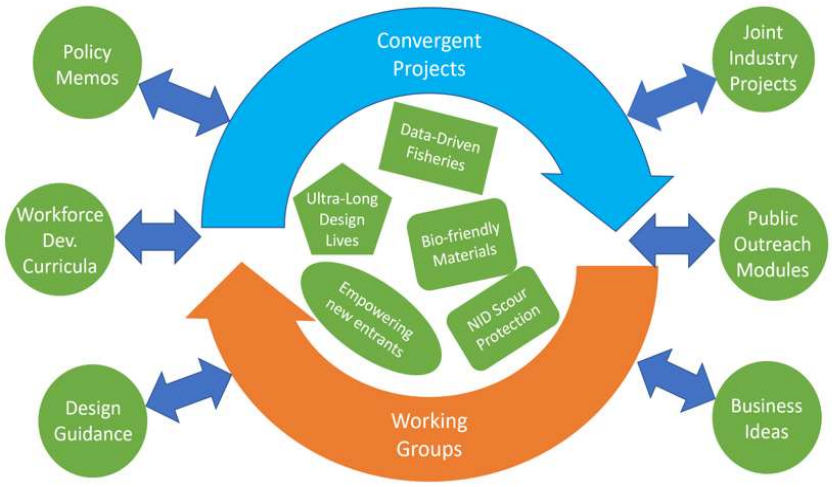


Figure 4. The MOCEAN Engine "Rock Tumbler"

To cover the first two "nascent phase" years, the MOCEAN team has seeded the rock tumbler with five multi-disciplinary, cross-partner Convergent Projects (CPs) to demonstrate and refine the operation of the Engine while generating new knowledge and opportunities. WGs will be updated on the progress of the CPs to disseminate interim results and integrate CP findings into all MOCEAN activities. While some of these CPs may warrant on-going work, all will deliver significant tangible products within the nascent phase. The close links in the Engine between the CPs, WGs, and experts in entrepreneurship (e.g., SeaAhead, EforAll & New Bedford Ocean Cluster) will support novel concepts through the full development cycle from proof-of-concept to commercialization.

Figure 5 shows the projected lifespan of the engine through all phases. In the nascent phase, the focus of the engine will be on establishing the systems, culture, and engine infrastructure and to develop marketing strategies across the region to expand MOCEAN's capacity. In the emergent phase, the engine will be fully operational, with a focus on new and continuing CPs, large-scale joint industry projects, incubation of likely projects for small-business development, and expansion of education, outreach, and training programs needed to achieve MOCEAN's mission. The addition of new CPs and focuses of the engine will be guided by MOCEAN's strategic goals listed in Table 2. In the growth phase, the engine will move towards self-sufficiency by piloting new industry membership groups and maintaining a community of regional businesses and entrepreneurs. Finally, as the engine reaches the end of the NSF funding period it will develop a form similar to the Carbon Trust Offshore Wind Accelerator [19] in Europe.

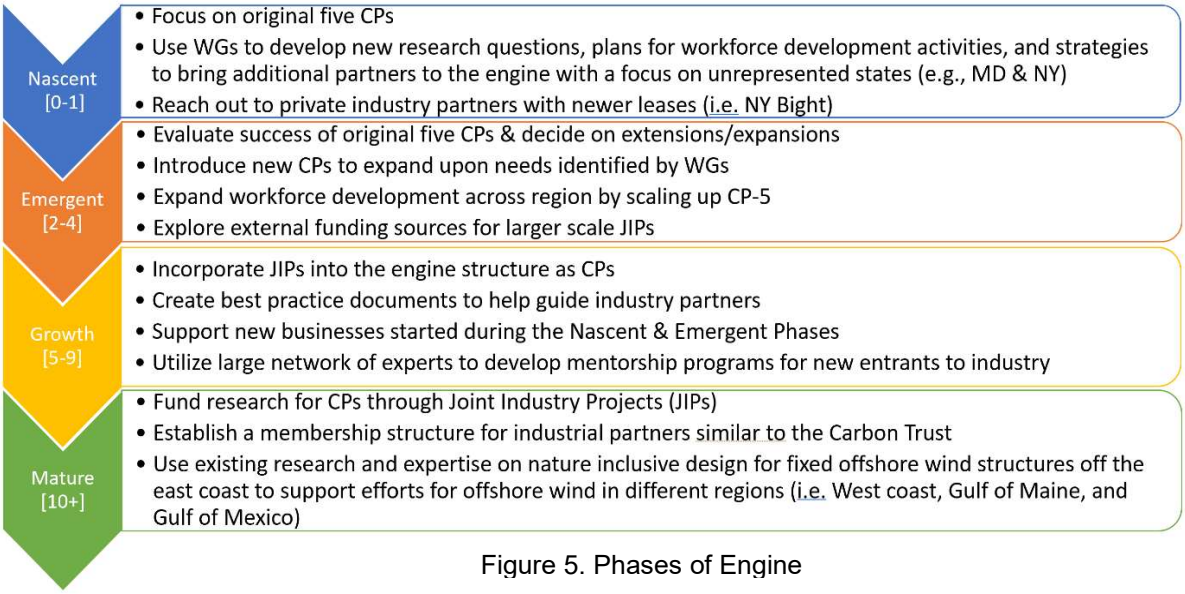


Figure 5. Phases of Engine

Table 2. Overall Strategic Goals of the MOCEAN Engine

Goal	Goal Description	Key Word
SG-1	SG1 - Advance fundamental understanding of interactions between structures (incl. materials, textures, and coatings) in different marine environments	Engineering
SG-2	SG2 - Advance knowledge of the marine environment by collating existing data, collecting new data, and testing new monitoring strategies and technologies	Science
SG-3	SG3 – Assess full impact of design decisions and the use of new technologies to create a calibrated SCoE framework that supports informed decision making	Policy
SG-4	SG4 - Build data driven models to support nature inclusive design of OW farms	Practice
SG-5	SG5 - Target underserved coastal communities when selecting locations for convergent projects and innovation hubs to stimulate economic development	Economic Dev.
SG-6	SG6 - Develop curricula and program to create a new blue economy workforce that delivers a just energy transition and improves ocean health	Education
SG-7	SG-7 - Ensure all partner organizations create inclusive, safe environments to mentor and support young STEM professionals from historically marginalized communities	Workforce
SG-8	SG8 - Create innovation hubs that can expand into a burgeoning bluetech, start-up community focused on leveraging new OW infrastructure for new businesses	Economic Dev.

Strategy and Implementation Plans for Economic Development and Justice. MOCEAN's workplan has been designed to drive economic development and justice for MOCEAN's region of service, and to establish approaches that can be replicated across the nation. As described in section (d.v), Evaluation Plan, MOCEAN's metrics for economic development include raising incomes of low-income communities, particularly low-income DEIA communities. This will be accomplished by broadening the spectrum of new improved employment opportunities and by maximizing supplemental benefits of development.

To address the challenge of creating a cohesive regional innovation ecosystem that includes multiple states and that benefits the communities in the region that are most in need, MOCEAN recognizes the development potential created by targeting EDA Opportunity Zones in combination with the expected $100B investment over the next 10 years to build out the offshore wind farms in the region of the engine. These EDA Opportunity Zones were established through the income tax act of 2018 [20] that established incentives for the investment of unrealized capital gains (>$2 trillion) in these zones. These zones are selected by state Governors to be up to one-quarter of all Qualified Census Tract (QCT) areas, which are areas in which at least 50% of households have an income of less than 60% of the area median gross income or a poverty rate of at least 25%. Governors' flexibility through this tax act allowed them to select

areas that have the characteristics needed for significant new economic opportunities. MOCEAN's economic development strategy (EDS) will leverage this framework to target investment.

EDS 1 - Development Focused on Specific EDA Opportunity Zones: For local EDA Opportunity Zones, MOCEAN's approach is to leverage existing support mechanisms and investment potential needed for large-scale job creation while building upon the skills and assets of that community in order to serve those in that community most in need of opportunity. For example, this strategy is used in CP-1 and CP-2.

EDS 2 - Future Fisheries: MOCEAN will create new approaches and tools for existing fishing and aquaculture communities to not just adapt to the impact of climate change and OW farms, but to thrive in the shared use of the ocean. These approaches are developed and evaluated in CP-3 and CP-4.

EDS 3 – Ensure DEIA Approach to Job Creation: MOCEAN's approach of embedding DEIA approaches across all activities will ensure that job creation is implemented in ways that target underserved communities to deliver a just energy transition for the nation.

Use-Inspired Research Strategic Plan and Implementation. Five initial convergent projects (CPs) that promote use-inspired research and development, translate innovation into practice, and develop a regional workforce for nature-inclusive OW will be the catalyst for creating an ecosystem of partners and stakeholders to advance, grow, and sustain regional innovation (see Table 3). As described above, MOCEAN's leadership and working groups will use the results of these projects over the first two years of the engine to initiate new CPs and innovations across the life of the engine. Each CP is designed to have key deliverables that tie into the strategic goals of the engine and these deliverables are presented in tables 4, 5, 6, and 7.

Table 3: Summary of Initial Convergent Projects

#	Title	Key Partners	Region Focus	Key WGs
CP-1	Impact of Infrastructure Materials and Geometry on Marine Ecosystems	MBL, WHOI, FIT, UMD, ROSA, RWSC	New Bedford, MA	WG-1.1, WG-1.2, WG-2.2, WG-3.4, WG-4.1, WG-4.3
CP-2	Nature Inclusive Concrete Gravity Base Foundations (GBFs) for Offshore Wind Turbines	Tufts, URI, (SeaTower, State of CT, Carpenters Local Union 326)	Bridgeport, CT	WG-1.1, WG-1.3, WG-2.3, WG-3.2, WG-4.2, WG-4.4
CP-3	The New Blue Fisheries Economy	Rutgers, U Conn, U Delaware	NJ fishing sector	WG-1.3, WG-2.1, WG-2.3, WG-2.4, WG-3.3, WG-4.1
CP-4	Monitoring of Marine Life around Monopiles	Hampton University, INSPIRE Environmental, Sea Ahead, NOAA, Dominion Energy	Hampton, VA - (CVOW) Research Turbines	WG-1.1, WG-1.2, WG-2.2, WG-2.3, WG-3.1, WG-3.2, WG-4.2, WG-4.3
CP-5	Establishing Equitable Pathways to Opportunity	U Mass Boston, New England Aquarium	New Bedford MA and Salem MA	WG-4 (all)

CP-1: Impact of Infrastructure Materials and Geometry on Marine Ecosystems

Background and Motivation: Nature-inclusive design (NID) strategies to increase biodiversity and marine life associated with a range of manufactured structures put in the ocean are gaining momentum [21]. NID features include the materials and geometry of structures as well as added ecosystem enhancement, including oyster farms, co-located aquaculture, seaweed, kelp farms, and many others [22–25]. Abundant evidence demonstrates that, similarly, OW structures, including monopiles and concrete scour protection, can serve as biological hotspots in the coastal environment if intentionally designed with protecting marine ecology in mind [26]. These NID structures can support dense and diverse benthic organisms (e.g., mussels) that attract fish and higher trophic levels. However, use-inspired research is needed to optimize OW farm design to enhance this biodiversity by providing substrates that accelerate and sustain biological recruitment and establish benthic communities.

Project Description [Lead Colleen Hansel (WHOI)]: CP-1's goal is to determine the NID features needed to optimize biodiversity and provide ecosystem services. These features include assessing chemistry of

materials, seeding with bio-stimulants and/or key species, and creating geometries ideal for habitat development. Specifically, this project will investigate the impacts of material selection and geometric design on the biological colonization that occurs on small-scale specimens. The long-term goal will be to use this information to design NID-specific features to support fisheries, create habitats with net positive ecological effects, and provide a foundation for parallel ecosystem services (e.g., integrated aquaculture).

CP-1 Economic Development: New Bedford, MA, will pilot MOCEAN's first Innovation Hub in support of CP-1. Only 70 miles from Boston, the per capita income of New Bedford is $27.5K/year, 43% below the state average, and 18.7% of the people live in poverty, 80% higher than the state average. It is a good starting location because close to $1B has been invested to development the New Bedford port region for OW deployment; and Mayor Jon Mitchell envisions transforming New Bedford from a city of "strong shoulders" to one that adds "strong brains." In addition to the Mayor, MOCEAN's partners with strong local connections include the New Bedford Ocean Cluster (NBOC), a local non-profit with the mission of "ensuring New Bedford achieves its full potential as a leading maritime center" [27]; UMass-Dartmouth, which has a long history of working locally at the intersection of marine science and the fisheries; and SeaAhead with direct experience accelerating blue tech startups through their BlueSwell Accelerator. Finally, EforAll has operated in New Bedford since 2015 and has deep relationships in the local community, launching multiple startups, the majority of which are led by women and people of color. These four key partners will co-convene WG-3 and lead the Innovation Hub development. MOCEAN will co-create a multi-year strategy for staged investment to yield new economic opportunities for low-income and underserved communities by leveraging these relationships with local industry, government, community leaders, investors, and the research community in WG-1.2 and CP-1.

MOCEAN's pilot in New Bedford will create a playbook to foster innovation hubs in other regions. For example, SeaAhead has experience extending operations to other regions (e.g., Gulf of Maine and Gulf of Mexico), and EforAll has operations in 13 cities across 5 states. These partners will allow MOCEAN to extend the Innovation Hub model piloted in New Bedford across the region to other communities in need.

CP-1 Deliverables: The specific deliverables for CP-1 are presented in Table 3. All the projects cut across multiple strategic goals, but CP-1 is particularly focused on fundamental research (SG1), new sensors (SG2), and economic development by starting new bluetech businesses in New Bedford (SG8 & SG5).

Table 3: CP-1 Deliverables Relationship to MOCEAN Strategic Goals

SG & Section #	Goal Description
SG1 & i	Test materials, geometries, and deployment approaches with small scale specimens
SG1 & ii	Construct and test NID features increasing in complexity to enhance recruitment & biodiversity
SG1 & i	Quantify the impact of NID modifications on biodiversity, ecosystem structure and function, environmental parameters, and structural integrity
SG2 & ii	Test new biogeochemical sensors, camera systems, and audio sensors to monitor benthic communities, ecosystem function, and organism health
SG2 & i	Perform discrete sampling to further characterize ecosystem bio-geochemistry and identify future sensing needs for monitoring and models
SG1 & ii	Use the detailed knowledge on the impact of structural features on the environment to build models and features that can be installed in an OW farm to support aquaculture
SG8, SG5 & ii	Launch and graduate at least 2 cohorts from Innovation Hub in New Bedford

CP-2: Nature-Inclusive Concrete Gravity Base Foundations (GBFs) for Offshore Wind Turbines

Background and Motivation: Currently, approximately 75% of offshore wind turbines are supported on monopile foundations, which are large diameter (up to 10 m), and 100 m long steel tubes weighing up to 1000 tons, driven 30 or more meters into the seabed [28]. Concrete GBFs offer advantages over the use of steel monopiles (or jackets), including: (i) greater durability, enabling operational lives of 100 years or more; (ii) quieter installations via float and sink approaches, avoiding loud pile driving that can negatively affect marine life; (iii) lower cost associated with building foundations that can support larger turbines in the future; (iv) stable cost of concrete relative to volatile cost of steel that is very sensitive to global

demand; (v) ability to adjust material composition and surface textures to strengthen and control specific types of marine growths and habitats; and (vi.) between 10 and 30 times the number of local construction jobs in comparison to steel monopiles [28]. Despite these advantages, nearly all U.S. projects thus far are using steel monopiles, the standard for first generation offshore wind turbines deployed primarily in Europe. Some may use steel jackets, but none have committed to using concrete GBFs. Yet there may be significant Life-Cycle Eco-Cost benefits to GBFs over steel monopiles.

Project Description [Project Lead: Eric Hines (Tufts University)]: While CP-1's work will focus on designing monopiles to be as nature-inclusive as possible, CP-2 will focus on nature-inclusive design of concrete GBFs, building upon completed work to create a design tool for the design of monopiles that did not consider nature-inclusive design. CP-2's expected outcomes are a cost/benefit comparison between concrete GBFs and steel monopiles, and, with local communities, industry, and state government agencies, policies and incentives needed for concrete GBFs to be competitive. This work will include use-inspired geotechnical and structural engineering, workforce assessment, economic analysis, and environmental assessment.

CP-2 Economic Development: Concrete gravity base foundations are much more likely to be fabricated near their offshore wind farm than are steel monopile or steel jackets. Until now, all steel monopiles have come from overseas. The construction of concrete GBFs is also much more labor intensive. Therefore, it is in a state's best interest to encourage developers to use concrete GBF in the wind farm projects that are providing electricity to their states. MOCEAN members Kuchma and Hines have worked extensively on GBFs for the past 8 years with many innovators and developers. Kuchma also chairs a technical committee of the American Concrete Institute on support structures for wind turbines. Partnering with local labor and concrete industry players, Kuchma and Hines published the report "*Low-Carbon, Nature-Inclusive Concrete Gravity-Based Foundations for Offshore Wind Turbines*" [28], which informed the workplan for CP-2, along with discussions with Connecticut State Legislators who are driving the state to make major investments in public/private partnerships to support the coastal facilities and labor training needed to manufacture concrete GBFs. Bridgeport (CT) will be the EDA Opportunity Zone of focus. The use of Concrete GBFs over steel structures creates an economic development opportunity of up to $20B over the 10-years of the Engine and perhaps 10 times that amount by 2050.

CP-2 Deliverables: The specific deliverables for CP-2 are presented in Table 4. CP-2 is particularly focused on developing examples of concrete GBFs (SG1), identifying policy barriers around longer design lives (SG3), and outreach to local k-12 schools (SG6).

Table 4: CP-2 Deliverables Relationship to MOCEAN Strategic Goals

SG & Section #	Goal Description
SG1 & i	Complete engineering design of concrete GBFs and steel monopiles for different turbine classes (a 15, 20, and 25 MW turbine) for three different case study sites
SG1 & ii	Compare the costs and benefits of concrete GBFs verses steel monopiles
SG3 & ii	Identify policy barriers around longer lease lengths for offshore wind farms
SG6 & iii	Partner with local k-12 schools to teach students about marine concrete.

CP-3: The New Blue Fisheries Economy

Background and Motivation: The OW industry has begun to recognize that developing at a large scale in U.S. East Coast waters will require wind farms to provide net-positive benefits to the environment, including commercial fisheries and associated communities [16,29,30]. The *New Blue Economy* is centered on the use of new, large datasets and models integrated with innovative research to inform policy and decision making that will ensure a sustainable response to the climate crisis and optimize related economic development opportunities. The effort under this convergent project will leverage the publicly available, validated, data assimilative ocean model Doppio, developed and maintained at Rutgers University [31]. This model assimilates over 200 available mapped and *in situ* observations to improve its representation of the Mid Atlantic Bight and Gulf of Maine and can be used to physically model the ocean.

Project Description [Lead: Josh Kohut (Rutgers University)]: Using pre-existing ecological/fisheries data and co-existent oceanographic/atmospheric models, we will co-develop with stakeholders and industry partners dynamic fisheries habitat projections that support the transition to a New Blue Fisheries economy. The project will use artificial intelligence/machine learning frameworks to integrate existing, well resolved, data assimilative physical models with expanding ecological/fisheries datasets to build dynamic ecological projections at different spatial scales in and around planned and existing OW facilities. The ecological projections will support fisheries-specific product development responding to the needs of the fisheries community during and after the transition to a co-existence with OW.

CP-3 Economic Development: CP-3 will develop and evaluate economic innovation to help fisheries transition to a future that thrives sustainably with offshore wind. Commercial and recreational fishing have been critical to the ocean-based economy for centuries. On local and regional scales, these economies rely on sustained commercial and recreational fishing. Linked supply chain industries like vessel construction and service, bait, fuel, and equipment along with downstream restaurant and wholesale markets extend the impact of these local fisheries communities to a global scale. In 2019, commercial and recreational fishing supported over 1.8 million American jobs. They contributed over $255 billion in sales and added an estimated $117 billion into the U.S. economy [32].

We will co-develop with stakeholders and industry partners dynamic fisheries habitat projections to support the fisheries-based economy and the introduction of a new data-based economy. The co-management of human fishing and OW activities, from decisions made on an individual ship to a room full of regulators, needs to be informed by a broad-scale habitat ecology reflecting the dynamic realities of the ocean. Through this CP, we will show how these data-informed dynamic models can ensure the continuation of a fisheries-based economy and simultaneously support the introduction of a new blue economy that delivers the products to support sustained co-existence of future fisheries and OW.

This approach will serve the fishing and regulatory sector with various forms of dynamic habitat classification in ways that serve multiple clients' needs. Through community-based co-development conducted through this engine (e.g., see (c.ii) WG3), the economic benefit of these products can be more rapidly developed and delivered, enhancing existing fisheries in the coastal communities and possibly incubating and co-creating new businesses.

CP-3 Deliverables: The specific deliverables for CP-3 are presented in Table 5. All the projects are designed to be convergent and cut across multiple strategic goals, but CP-3 is particularly focused on collecting and coordinating data (SG2) and building models to inform new blue economy fisheries (SG5).

Table 5: CP-3 Deliverables Relationship to MOCEAN Strategic Goals

SG & Section #	Goal Description
SG2 & i	To the highest resolution possible, identify spatial patterns of species abundance, individual size frequency, biomass, and growth by collating publicly available data sets
SG2 & i	Integrate the publicly available, validated, data assimilative ocean model developed and maintained at Rutgers University called Doppio
SG5 & i	Develop novel AI/ML methodologies to map species-specific habitat suitability by fusing coincident, heterogeneous fisheries and environmental data with a data assimilative oceanographic model.
SG5 & ii	Use ecologically aware data science and optimization models to support future fisheries to co-existence with OW throughout the region.
SG5 & i	Develop a shellfish habitat assessment tool to incorporate a dynamic habitat model and find suitable locations to maximize survival of juvenile shellfish for future shellfish enhancement.
SG5 & i	Perform initial development of a thermal finfish habitat mapping tool. Initiate the development of dynamic pelagic habitat projections focused on the pelagic squid that include the influence of OW facilities through the integration of realistic treatment of turbine-generated turbulence

CP-4: Monitoring of Marine Life around Monopiles

Background and Motivation: As described in CP-1, the introduction of novel structures associated with

the development of offshore wind can facilitate epibenthic growth through the water column, which can lead to potentially large shifts in the flow of energy through the marine food web. By serving as artificial reefs, offshore wind monopile foundations attract epibenthic organisms as well as mobile fish and invertebrates, many of which may be commercially valuable species [33–35]. This colonization also alters the ecosystem function of the benthic environment surrounding the structures by supplying organic matter to the sediments. The epibenthic community, both the species composition and abundances (biomass), will largely influence the magnitude of effects of these structures on the larger ecosystem. However, the biotic and abiotic factors that control the epibenthic community structure and biomass on monopiles are not well understood. Further, the type and resolution at which data collected to monitor benthic shifts associated with offshore wind structures are not well defined.

Project Description [Project Lead: Deidre Gibson (Hampton University)]: This project aims to assess biotic and abiotic factors that influence benthic community structure and function on the monopile foundations and surrounding seafloor at the Costal Virginia Offshore Wind (CVOW) research turbines in Virginia. The project will also explore various approaches for monitoring shifts in benthic community structure and function, including non-invasive emerging technologies such as eDNA and visual data (e.g., photogrammetry). Established best practices for monitoring benthic changes are critical within the regulatory and compliance framework for permitting offshore wind projects in the US. This project will also take advantage of the opportunity for field work to develop internship programs that expose undergraduate marine science students to various scientific career paths. Access to CVOW will be facilitated by INSPIRE Environmental.

CP-4 Economic Development: By examining the effect of offshore wind foundations and scour protection on marine ecosystems and habitats, CP-4 will provide evidence for the potential of these structures to increase the biomass of fishing stocks for similar conditions and influence the fisheries economies. If the data suggest a significant increase, then this will not only provide economic benefits to the fisheries community but will also increase the acceptance of OW energy development. We will also establish a baseline for comparison of valuable biomass benefits for a particular design case, which is relevant for comparison to structures specifically selected and designed to be nature inclusive. Based on lessons learned, we will establish a process for similar investigations in other regions and study the benefits of each technology for making these assessments. This work will increase the economic benefits to fisheries community by using data-driven techniques to quantify the impact on fisheries of OW. Further, student researchers on this project will be from Hampton University, creating new employment opportunities aligned with the DEIAJ objectives of the Engine (section (d.iii)).

CP-4 Deliverables: The specific deliverables for CP-4 are presented in Table 6. All the projects cut across multiple strategic goals, but CP-4 is particularly focused on researching the benthic community (SG1), collecting data from CVOW research turbines (SG2), and developing internships to bring historically underrepresented professionals into the marine science discipline (SG6 & SG7).

Table 6 CP-4 Deliverables Relationship to MOCEAN Strategic Goals

SG & Section #	Goal Description
SG1 & i	Study the abiotic and biotic factors that influence benthic community structure and function on the monopile foundations and nearby seafloor
SG2 & ii	Explore emerging technologies (e.g., eDNA, stero imagery, and in-situ sensors) to monitor shifts effectively and efficiently in benthic community structure and function associated with the monopile foundations to inform guidance on monitoring requirements
SG6 & iii	Develop internship opportunities for undergraduate marine science students and training workshops for host organizations in order expose undergraduate students to various scientific career paths
SG7 & iv	Develop training workshops for companies and organizations that will host early-career and student interns to foster effective mentorship and a welcoming environment to optimize professional development opportunities during the internship.

Convergent Project 5 (CP-5): Establishing Equitable Pathways to Opportunity

Background and Motivation: A very large, multi-sector, sustainable, and equitable workforce is needed to develop nature-inclusive offshore wind farms. To date, ocean careers have not been filled with people from all demographics, and the rapid development of this new OW workforce provides the opportunity to apply what we have learned about diversifying STEM and engaging historically marginalized communities. Meeting these future workers where they are in their communities, schools, and everyday lives, listening to their needs and desires, and providing low barriers to multiple pathways towards high paying jobs have all proven to be effective. In MOCEAN, our approach to fulfilling this demand is to engage with diverse and inclusive communities and to develop outreach programs with social equity as a core value.

Project Description [Lead: Robert Chen (UMass-Boston)]: We will apply our vast experience with public engagement, working with youth, and engaging diverse communities to create models of equitable strategies that engage people with nature-inclusive offshore wind. We will ground and develop these activities with our coastal community partners and heavily populated EDA Opportunities Zones in the greater Boston region. The outreach and curriculum/module development coordinated by UMass-Boston will focus on Ocean Science while engineering activities will be led by the Tufts Center for Engineering Education and Outreach (CEEO). Initial target regions include Boston, Chelsea, Everett, Lynn, New Bedford, and Salem. After development and proof testing in local schools and communities, we will expand these models across the region in Years 3-10 using our core partners as “stations” to help adapt the models to local needs. All MOCEAN activities will recognize the cultural wealth of individuals and communities, provide support and opportunity to advance towards careers in nature-inclusive OW, and use practices that have been effective for a variety of equitable workforce training ecosystems; see section (c.iii) and (d.iii) for more information about workforce development and DIEAJ implementation.

CP-5 Economic Development: MOCEAN is aimed at developing interests and pathways for underserved low-income communities and those from historically underserved groups across all employment opportunities. Massachusetts is well positioned to develop and demonstrate effective approaches and assess their efficacy through testing in traditional public schools and vocational schools (there are 38 vocational schools in MA). These are essential to achieve equitable distribution of the economic benefits described in the other CPs. As CP-5 matures beyond the nascent phase of the engine and offshore wind industry these resources developed by the CP-5 team will be adapted to fit new communities in the region.

CP-5 Deliverables: The specific deliverables for CP-5 are presented in Table 7. All the projects are designed to be convergent and cut across multiple strategic goals, but CP-5 is particularly focused on SG5, SG6, and SG8 as new methods of outreach and workforce development are developed.

Table 7: CP-5 Deliverables Relationship to MOCEAN Strategic Goals

SG & Section #	Goal Description
SG5 & iv	Develop effective public engagement tools, including high quality, adaptive hands-on educational activities; youth-lead community needs assessments in two future offshore wind port communities; and marketing materials to attract people to become interested in nature-inclusive offshore wind.
SG6 & iv	Use outreach strategies through the New England Aquarium, potentially including use of exhibits, interactive websites and social media tools to expose a broad cross section of the public to the benefits and opportunities in nature-inclusive OW with specific emphasis on future OW ports.
SG5 & iii	Co-develop with community partners three effective, hands-on educational activities that can be used in teacher professional development workshops, K-16 classrooms, and science fairs, and disseminate them through the NEOSEC network.
SG7 & iv	Engage two future offshore wind port communities: New Bedford, MA and Salem, MA, to conduct youth-led needs assessment, project job growth, and map educational and training programs and share the results with community and government leaders.
SG6 & iv	Form a Community Advisory Council to the New England Aquarium with representatives from New Bedford and Salem including the above engaged youth, teachers, and informal educators, and community organizations so that we can listen carefully to community needs.

Figure 6 provides a visual description of elements of each of the CPs, as well as the primary relationships between these CPs and the WGs, and also the CPs and the four primary strategic elements. With these as identified relationships, the broader characteristics of these strategies apply to these CPs specifically, the WGs in general, and as guiding strategies for future CPs.

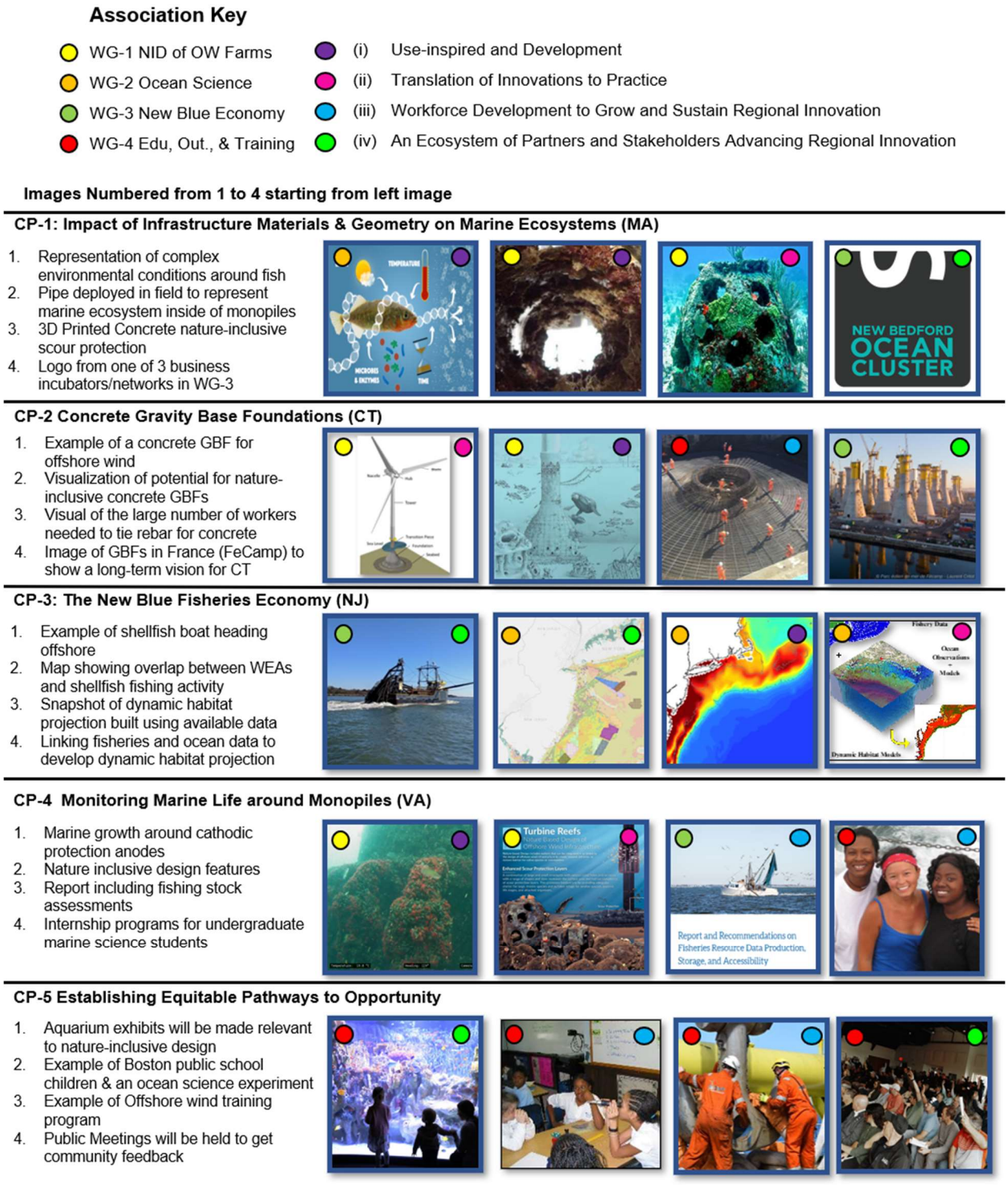


Figure 6: Convergent Project Visualizations and Interrelationship with WGs and Strategic Elements

c.i. Use Inspired Research. To ensure the cross-region collaboration essential for MOCEAN's long-term success, the MOCEAN engine will create a platform for collaborative, use-inspired research that anticipates the *regional offshore wind build-out*. Strategic goals 1 and 3 are the guiding stars for this research. While MOCEAN takes significant inspiration from similar work ongoing in the EU to support nature-inclusive design of offshore wind farms, any nature-inclusive design framework for U.S. OW farms must consider the different environmental conditions, regulations, industrial, and community contexts. This includes an understanding of the fundamental biology and chemistry occurring at an offshore wind farm (SG1), as well as clear knowledge about the ocean as it existed before OW development (SG2).

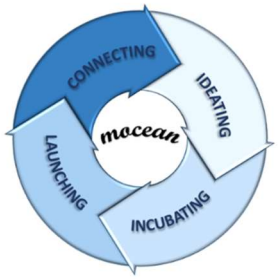
Establishing a strong understanding of the fundamental interactions between structures and the environment at a micro and macro scale will drive solutions to three important social, environmental, and economic challenges. First, the fundamental knowledge and models gained in these projects will inform work to ensure that the emerging OW sector creates synergies rather than conflicts with important marine food production sectors, specifically wild-harvest fisheries and aquaculture. Second, these projects aim to support overall ocean health by enhancing biodiversity. Third, relationships and structures will be created that integrate engineering and marine sciences to revitalize the region's maritime sector and associated infrastructure through innovation. Finally, the use inspired research agenda will be integrated with other engine activities to develop innovative, equitable pathways to opportunity. For example, NID features that are generated as a part of work done in CP-1 can be further developed and supported by entrepreneurial experts in WG-1 and WG-3 as a part of translating innovation into practice.

The heart of the engine is a mutualistic relationship where convergent projects provide information to regional partners and stakeholders in the working groups and in return, the working groups convene the stakeholders, industry, and public sectors that are needed to plan more ambitious projects including joint-industry projects. As these opportunities are identified by the core research loop they are further developed into practice in section (c.ii). Corresponding measures and metrics for success of MOCEAN's use-inspired research are stated in section (d.v) Evaluation Plan.

c. ii. Translation of Innovations to Practice. Various stakeholders currently operating in the OW industry, the marine sciences, and the fisheries and coastal communities, all do their best to optimize their use of the ocean. Yet to implement solutions that optimize not only clean power generation but also responsible stewardship of our oceans and growth of our fisheries through new blue tech innovations, the gaps among all who share the ocean must be closed. The WGs of the MOCEAN Engine will close the gaps with the goal of driving innovation to commercialization, thus seeding new opportunities across the region. For example, WG-3, co-convened by MOCEAN partners SeaAhead and EforAll, can bring stakeholders, industry, the public sector, and venture funds together to develop a manufacturing hub in New Bedford (EDA Opportunity Zone) for nature-inclusive and intelligent scour protection that builds from what is learned and developed in CP-1.The strategies developed in New Bedford and other examples will, with input from the Evaluation Plan, result in a flexible framework that can increase innovation across the region while creating opportunities for higher-paying jobs across skill levels.

MOCEAN's Innovation Ecosystem design is a 4-phase cycle as new innovations build on previous ones, creating a continuous, ever-expanding series of innovations (see Figure 7). Each cycle can also be viewed as a funnel, with a great number of connections and ideas ideated, from which a handful are incubated to a level that attracts investment, resulting in the most promising being launched.

Figure 7.
MOCEAN Innovation Ecosystem



In the ***Connecting phase***, MOCEAN will bring together stakeholders from diverse backgrounds in person in the coastal communities using working groups as facilitators to ensure that diverse perspectives are in the room and heard. These connection meetings will be grouped into areas of interest, such as fisheries, construction services, or environmental protection, with a goal of keeping the number of people to a size that fosters open dialogue. The outcomes from these connecting meetings will be small groups of self-identifying individuals to take on a specific challenge that is currently not well-addressed and to advance to the ideating phase.

In the ***Ideating phase***, groups that meet during the connecting phase and correspond to the domain areas identified in WG3 will develop possible areas for innovation. They will leverage design thinking and strategic doing, which have been used successfully in economic development contexts, to keep the focus on identifying innovations that directly benefit the local coastal community [36]. Entrepreneurs and community members will be invited to these ideation workshops. The outcome of this phase will be teams that then move on to the Incubating Phase.

In the ***Incubating phase***, to build community, MOCEAN will create cohorts of teams twice per year that meet weekly to share progress and advice. Frameworks such as the Business Model Canvas or Lean Canvas will guide each cohort. MOCEAN will help each team identify industry mentors to work with them to maximize chances of commercialization. The outcome of this phase will be a demonstration day at the end of each fall and spring session, where each cohort will share lessons learned, scalable solutions, and investible financial proposals to the local community, investors, and industry stakeholders.

In the ***Launch Phase***, new startup teams will seek seed funding from external sources and be encouraged to apply to advanced industry accelerators such as SeaAhead and TechStars, as well as for MOCEAN seed grants that will be co-funded with outside sponsors. The MOCEAN Advisory Board will appoint a subcommittee that includes members from industry, community, and venture advisors to select these awards. Teams may also apply to other potential funders, such as state or federal government agencies, to maximize impact on existing products, services, policies, and regulations.

As described in section (d.v) Evaluation Plan, MOCEAN will track and measure its progress and impact with metrics such as attendance at initial Connection and Ideation Phase events, the number of teams formed during Ideation, the number of teams graduating from the Incubation Phase, the number of teams funded and launched as ventures, and the impact of the teams on the local community and the region.

c.iii. Workforce development to grow and sustain regional innovation. Many more jobs will be created through nature inclusive design that provides new opportunities for fisheries and aquaculture communities. To meet this demand, a sustainable, healthy, equitable workforce needs to be intentionally developed. Youth, emerging adults, and career-changers will be exposed to, engaged with, and educated for the many diverse careers needed to support this aspect of the new blue economy. Diverse careers include construction, technician, electrician, marine scientist, sensor developer, computer science, engineer, designer, aquaculture farmer, fisheries manager, marine mammal observer, and myriad other jobs related to a shift to nature-inclusive offshore wind as a source of clean energy. In fact, we expect career entrepreneurship, where students define their own innovative new careers based on their interests and the evolving needs of the transdisciplinary industry at the cross-sections of STEM & policy, blue & white collars, and traditional & innovative.

To meet this goal, MOCEAN will provide a variety of options. For example, low-barrier, authentic educational and training experiences will be created for early career and career-shifters to “taste” the opportunities within offshore wind (e.g., micro-credentials & workshops). Multiple career pathways will be created using our network of academic and industry partners. We 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 MOCEAN Education, Outreach & Training Strategies in WG-4 will drive the key strategic initiatives as now introduced.

WG-4.1-Equitable Practices: Education, training, and outreach activities will include best practices in DEIAJ areas, including student-centered approaches (Fig 9, see also EI 5.1). In the first two years, methods for this work will be developed and tested by engaging two future OW port cities, New Bedford and Salem. These methods will be expanded throughout the region in Years 3-5. MOCEAN will continually celebrate the cultural wealth of individuals from diverse backgrounds [37] to ensure that we engage all the possible contributors to the workforce. Multiple educational pathways lower barriers common in “pipeline” models (e.g. fear of heights, Calculus I) and allow easy entry and promotion through a variety of nature-inclusive offshore wind careers.

WG-4.2- Experiential Learning: Authentic, experiential learning is effective at engaging and educating students, that then can lead to employment. Specifically, we will (1) Develop an internship model where the company pays the direct stipend to the intern, while MOCEAN provides wraparound services including a pre-internship expectation workshop, a host training workshop to ensure a supportive environment within each company, monthly cohort-building meetings to provide a sense of belonging among interns that may be individually placed, and an end of internship celebration to allow reflection and exposure to multiple pathways; and (2) Integrate on-line and in-class education with immersive training at CP sites in MA, CT, NJ, and VA within the first two years and to additional sites as new CPs are developed. Hands-on training can lead to micro-credentials that can be integrated into broader training programs and can be used as an initial, accessible, powerful exposure to offshore wind work. Low-barrier experiential learning (e.g., a weekend) will be integrated with on-line learning (e.g., asynchronous on-line or evening); these stackable credentials could lead directly to jobs or to certificate or degree programs.

WG-4.3-Educational Pathways: Many students have been underrepresented in ocean science, engineering, and the offshore workforce because of multiple barriers in education and career tracks. Forming a supportive cohort or community of students facing the same barriers, working with people in power to better consider implicit bias and cultural wealth in their educational and hiring practices, and coordinating a network of multiple pathways are known to be effective practices to support a robust, sustainable, and equitable workforce. To this end, we will:

- Map existing educational and training programs in Massachusetts that are relevant to nature-inclusive OW and identify gaps among existing programs to expand opportunities across the region of service.
- Co-generate training programs among academic and corporate partners
- Evaluate OW industry demand for a skilled workforce on an ongoing basis, identify suitable partners who can contribute to offshore work, propose recommendations for efficient and safe working conditions, publish results of innovative work that will assist in developing a highly skilled and productive workforce, and aid decision-makers by supplying data-driven factsheets.

We will also work with all partners to coordinate and leverage existing programs in this area including NEOSEC, STEM Ambassadors, REU experiences, PATHS network, Mass CEC projects, OW Center activity, and others developing OW training resources [38].

c. iv. Ecosystem of Partners and Stakeholders Advancing Regional Innovation. Currently, the very little coordination between OW projects in each state and adjacent coastal community limits the benefits of the industry and associated use-inspired research on economic and workforce benefit, all OW projects and coastal communities share the same goal: To ensure effective initial OW deployment to set a precedent for the future. This goal includes modeling government policies, workforce development programs, and innovation incubation practices that results in the optimal deployment of low-carbon energy generation while protecting and enhancing coastal ecosystems and marine ecologies and fisheries. This regional engine can develop and share research and best practices widely while co-creating the new blue economy with offshore wind developers, academic institutions, community members, and governments. Furthermore, with its regional focus, MOCEAN will have the critical mass and scale to attract and grow funding beyond the initial Engine deployment.

As described earlier, Working and Convergent Project groups will convene organizations and people from across the region. Working groups will be charged with developing priority research questions and governments, MOCEAN can accelerate and enable the United States to be the global leader in OW and the New Blue Technology Economy. Furthermore, with its regional focus, MOCEAN will have the critical mass and scale to attract and grow funding beyond the initial Engine deployment. Figure 8 illustrates MOCEAN's role as the hub of groups and communities that need to work together to create and preserve "Healthy Oceans" and to "Grow the Blue Economy" through "Nature Inclusive Offshore Wind Farms."

With these structures, MOCEAN will create an attractive ecosystem for incubating new innovations and will attract entrepreneurs and technologists from within and outside the region of service, as well as strategic investments from industry, venture capital groups, and government agencies. Spinning up the innovation hubs across the region's coastal communities will be key to the long-term growth in the region,

as with each innovation launched, new jobs will be created, which also create new educational opportunities for local K-16 organizations. We anticipate that as the engine matures, additional partners from a range of sectors will be added, depending on WG- and CP-identified needs.

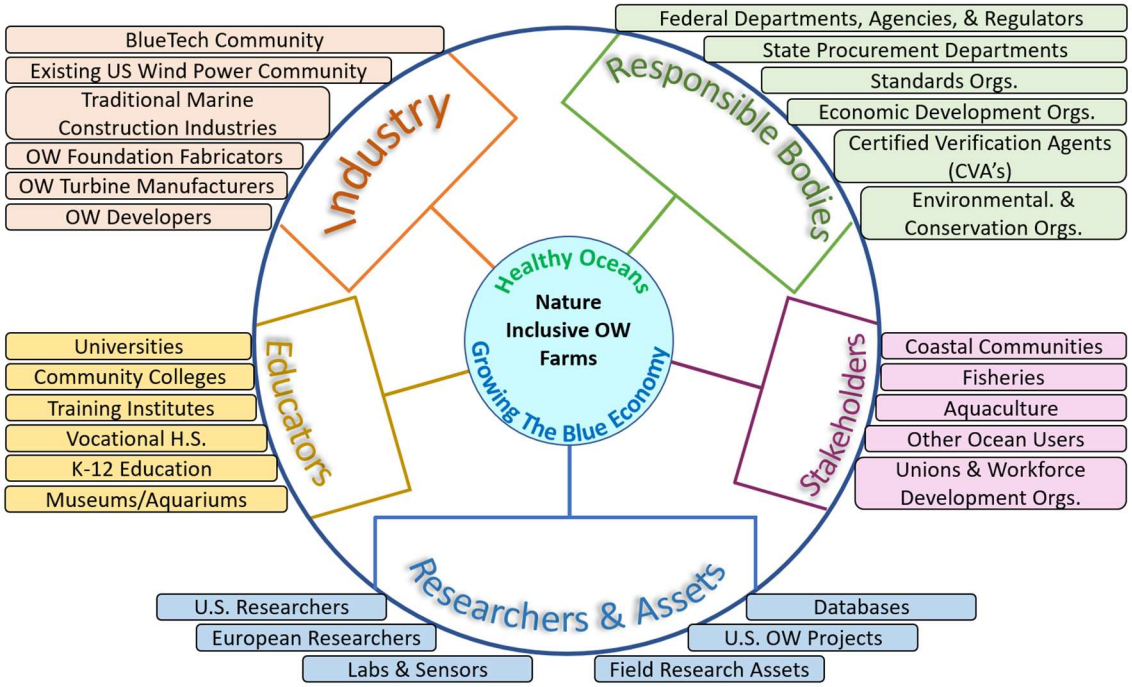


Figure 8. Communities Coming Together on Offshore Wind

MOCEAN's regional focus gives it leverage with state and federal policy makers to ensure data driven decisions when developing policies that foster both responsible carbon free energy deployment as well as marine ecology and economic growth. Individual coastal communities may lack the clout to affect policies that directly impact their local communities, but as MOCEAN partners, they will gain the power of larger, region-focused community that can advocate for policies and regulations that fairly benefit all coastal communities, helping them grow and expand their roles in the new blue economy. Regional MOCEAN partners already working the intersection of offshore wind and the oceans, such as ROSA (Responsible Offshore Science Alliance) and RWSC (Regional Wildlife Science Collaborative), will allow MOCEAN to leverage and amplify their work and partnerships to ensure a data-driven understanding of OW's impact on marine ecologies and fisheries that will result in clean energy, a healthy ocean, and a thriving region.

d. Management Plan

d.i. Leadership Team. The leadership team will consist of the principal investigator from each of the five Convergent Projects (CPs), the lead for each of the four Working Groups (WGs), the CEO, and the chair of the Governance Board. If not already represented in the above, at least three members of the leadership team will be from the distributed DEIAJ team.

Rational for Structure: As presented in Figure 3 (Engine Structure), the CPs and WGs are the fabric of MOCEAN that support the four elements of the strategic and implementation plan. This composition ensures that: (i) WGs and others can use findings from the CPs to advance the goals of the overall engine; (ii) CPs can get advice and support from WGs, such as identifying gaps in expertise that could be engaged in the CPs to advance their objectives; (iii) WGs can postulate questions for current CPs to consider and can plan CPs for years 3-10; and (iv) all can identify Engine Infrastructure (EI) services needed to support the CPs, WGs, and overall objectives of MOCEAN.

Composition of the Leadership Team: Appropriate qualifications of the leadership team are ensured in part by the structure of the activities that were presented in Figure 2 (Overall Organizational Structure). This structure ensures that that leadership team includes participation from an array of WG disciplines and the breadth of the first five CPs. Strong participation from the distributed DEIAJ team will help steer all MOCEAN activities. As the Engine matures and additional full-time staff are added, the leadership team will likewise evolve. However, as CPs and WGs change, we will ensure continuity and institutional knowledge by a six-month "overlap" period, wherein new leadership is mentored by the previous member in that position. Additionally, should the CEO or other leadership positions leave the program at any point during the initial ten-year funding period, the Governance Board, with input from the Advisory Board, will appoint an interim member who has the appropriate expertise to fill the role until a new hire is made.

Personnel, Qualifications, and Responsibilities: The leads for the CPs and WGs are shown in section (b) and their qualifications are presented in their biosketches. As presented in section (b), the position for CEO, program manager, and WG/CP coordinator will be filled as soon as possible after the Engine award is made. The ideal CEO will be a mid-career leader from the offshore wind energy community with the experience and expertise to manage a large, complex project. While the Governance Board will conduct a broad search, we anticipate that the most qualified candidate will have worked in the European offshore wind industry, given that there are 7000 offshore wind turbines in the North Sea and only 7 in U.S. waters. A suitable CEO could come from one of many public/private research organizations in Europe (e.g., Fraunhofer-IWES in Germany, TNO/Deltares/Marin in The Netherlands, ORE-Catapult or a Supergen in the UK) who have all managed similarly large research/economic- development projects that have been supported by the European Union, country-specific economic development organizations, and joint-industry projects. The MOCEAN team is well connected with European academic, research, and industry leaders, many of whom provided significant input into the development of the underlying principles of MOCEAN through many online meetings and through a workshop held by the Tufts University in May of 2022, another workshop held by the L.O. in January of 2023, as well as delegation visits.

A strong and distributed approach to DEIAJ is needed due to the scale of the economic and workforce development, and the need to ensure underserved communities take leading roles in the innovation ecosystem. This approach will include leaders from across the region and allow MOCEAN to develop strategies that meet broad regional needs, while adapting activities for individual communities. The members and responsibilities of our DEIAJ team are presented in Table 8.

Table 8: Names, Qualifications, and Roles for the Distributed DEIAJ Team

Name	**Qualifications**	**Role**
Grace Caldara	Director of the Center for STEM Diversity at Tufts University	Support the STEM Ambassador program, Support relationships with local high schools, & Co-supervise/mentor the post-doctoral associate with Portsmore & Kuchma
Chris Swan	Dean of Undergraduate Education in the School of Engineering at Tufts University	Coordinate DEIAJ efforts at Tufts including development and oversight of Tufts internship and research programs for STEM students historically marginalized in the discipline.
Jeanette Davis	Adjunct Research Professor at Hampton University	Develop internship opportunities to expose undergraduates to scientific careers & Support mentorship in safe and inclusive environments through a series of workshops and trainings for both students and host organizations
Meralis Hood	CEO of EforAll	Support the DEIAJ outreach and engagement activities in New Bedford associate with CP-1, CP-5, and WG-4.
Jeremiah Hernandez	Director of Strategic Initiatives for EforAll	Support the DEIAJ outreach and engagement activities with CP-1, CP-5, and WG-4.
Kathayoon Khalil	Associate VP of Conservation Learning at New England Aquarium	Focus on youth development work & outreach as a part of CP-5
Kerrie Wilkins-Yel	Asst. Prof. of Psychology at the UMass-Boston; Director of RISSE Consulting llc	Serve as the UMB liaison to the Engine's DEIA team and a UMB Co-PI co-leading WG-4 and CP-5.
Merredith Portsmore	Research Associate Professor and Director of the Center for Engineering Education and Outreach at Tufts University	Support the development of engineering activities, Support relationships with pre-college STEM organizations, Support implementing CP-5 work at Tufts, Co-supervise/Co-mentor the post-doctoral associate with Caldara & Kuchma.

d.ii. Culture of Innovation. MOCEAN has been intentionally designed to bring together all necessary disciplines, skills, perspectives, and capabilities to achieve its overall objective to leverage the US investment in offshore wind energy to catalyze innovation that ensures that the offshore wind industry leads to healthier oceans, sustainable fishery and aquaculture economies, and multiple on-ramps to high quality jobs in currently underserved communities. Within the current MOCEAN team, partners bring skills related to structural engineering, AI/ML approaches, marine science, education, DEIAJ principles, innovation, entrepreneurship, economic development, and others. As MOCEAN matures, new disciplines will be needed to build on previous work and to fill gaps as yet unidentified. Based on evidence brought and the diversity of the Governance Board and Leadership team, MOCEAN has established processes for bringing new partners and capitalizing on new opportunities, as described in section c.iv.

Furthermore, MOCEAN's approach to innovation must be convergent. To achieve our goals, we must not only include many disciplines, but we must also integrate those disciplines in novel ways to answer questions that – because of the fragmented nature of offshore wind research and development to date – have not been addressed. We anticipate that new fields will be created as a result of MOCEAN's work, to further inspire linking use-inspired research with entrepreneurship and commercialization. These fields may be driven by universities or may be part of trainings instituted by vocational high schools or community colleges to provide workers with skills they need to fully participate in the new blue economy.

d.iii. Culture of Diversity, Equity, Inclusion, and Accessibility. An ethos of DEIAJ is at the core of all the Engine's processes, practices, and activities. These efforts will be led by the **MOCEAN DEIAJ Collaborative**, which includes the team introduced in Table 8. Two key strengths underscore the integrated MOCEAN DEIAJ Collaborative: 1) the Engine will be able to leverage the wealth of expertise across our distributed team, and 2) MOCEAN will be uniquely positioned to adopt and expand the well-established DEIAJ initiatives currently in existence across partner institutions. With these strengths, the Engine is uniquely poised to focus primarily on implementation of DEIAJ efforts within the first two years. The overarching aim of the MOCEAN DEIAJ Collaborative is to advance equity, inclusion, and access in nature-inclusive offshore wind energy through community embeddedness and an integrated research-practice collaborative. The achievement of this aim will be guided by three objectives steeped in the MOCEAN DEIAJ Model (see Figure 9).

DEIAJ 1 - Advance economic and workforce development by accelerating access and inclusion to offshore wind energy: As described earlier, the Engine will play a significant role in advancing economic and workforce development in the Atlantic coast offshore wind industry, particularly among communities that have been historically underserved. These efforts will be led by a strategic partnership with Entrepreneurship for All (EforAll), one of the five core partners in the MOCEAN DEIAJ Collaborative. EforAll is a non-profit entrepreneurship training organization that focuses on helping underrepresented individuals successfully start businesses. This nationwide organization has launched programs in five states, including Massachusetts, where they are in eight underserved communities, including coastal communities such as New Bedford. Since its founding in 2013, EforAll has launched 1,100 startups, which collectively have created 1,734 local jobs and over $54M in revenues. More importantly, over 76% of EforAll businesses are women owned, 70% are BIPOC owned, and 33% are owned by immigrants. As part of the partnership with EforAll, the Engine will engage community leaders in free, asset-based, entrepreneurial training in offshore wind and the new blue economy. Specifically, the Engine aims to support 3-4 new entrepreneurial ventures per year.

DEIAJ 2 - Implement equity-focused education, outreach, and training activities that increase access to offshore wind, ocean science, and STEM broadly: Through an integrated, research-practice DEIAJ collaborative, the Engine will offer two robust equity-focused education, outreach, and training activities in addition to those proposed by WG-4 and CP-5.

Paid Internships Opportunities. The Engine will establish two paid internship sites for historically underserved students. Drs. Chris Swan and Merredith Portsmore will coordinate the development and oversight of internship opportunities at Tufts University. Internships will focus on offshore wind industries and will include MOCEAN Engine partners leading Working Group activities (e.g., SeaAhead and Woods Hole Oceanographic Institution). Dr. Jeanette Davis will work in conjunction with CP-4 to develop internship programs at Hampton University, a Historically Black College and University (HBCU), to

expose undergraduate marine science students to scientific career paths. To optimize the professional development experiences that diverse students have at their internship sites, Dr. Davis will offer mentoring workshops to host organizations that center inclusion and belonging practices. With these activities, the Engine will increase access to science careers and uniquely address structural barriers that often deter retention in STEM. A total of 15 students across Tufts and Hampton will be offered internships in Year 1 and 20 in year 2.

Outreach to High Schools through STEM Ambassadors Program. The Engine will offer tailored programming to high school students in the region. Initially, this outreach will be at three high schools and at the New England Aquarium. Through a partnership with the Tufts Center for STEM Diversity, Ambassadors will lead engaging presentations with high school students that showcase cutting-edge technologies and real-world applications. The STEM Ambassadors program is a part of the nationwide Engineering Ambassadors program and is designed to offer science communication outreach opportunities to students from racially/ethnically minoritized backgrounds. Ambassadors currently conduct presentations at several high-schools in the region. High school students who are interested in deepening their engagement with ocean science will have the opportunity to participate in the New England Aquarium youth activities such as the Summer Teen Internship program or the ClimaTeen program. Over the next two years, the Center for STEM Diversity will add six paid Ambassadors that will offer tailored presentations to the three high schools. Through the 10-year funding period, Dr. Caldera will work with partnering institutions to become Engineering Ambassadors members or, if their institutions are currently members, will involve programs with MOCEAN activities. Tufts STEM Ambassadors will share best practices/lessons learned as the program expands across the region.

<u>DEIAJ 3 – Center the voices of communities of color in the Engine's offshore wind initiatives through culturally responsive practices</u>: A key component of the MOCEAN Engine is to conduct use-inspired research that is informed by the community and, in turn, enriches the community. To effectively listen to the communities we serve, the MOCEAN DEIAJ Collaborative will hold quarterly convenings with community members and organizations committed to including People of Color in conversations about clean energy (e.g., Browning the Green Space and All in 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 new STEM processes. As is stated in Disability Justice principles, "nothing without us about us" [39]. So, no innovation and policy can be created without the full and direct participation of those who will be affected. To support the Engine's commitment to centering the community, particularly those who are historically underserved, the members of the MOCEAN DEIAJ Collaborative will be centrally engaged in the Engine's Infrastructure and decision-making processes. Additionally, Engine stakeholders and partners will participate in bi-annual virtual and in-person equity-focused trainings led by Dr. Kerrie Wilkins-Yel, Executive Director of Radical Investment in Strategic Solutions towards Equity Consulting LLC and member of the UMass-Boston Faculty. These trainings will contribute to strengthening the Engine's culturally responsive and community engaged practices.

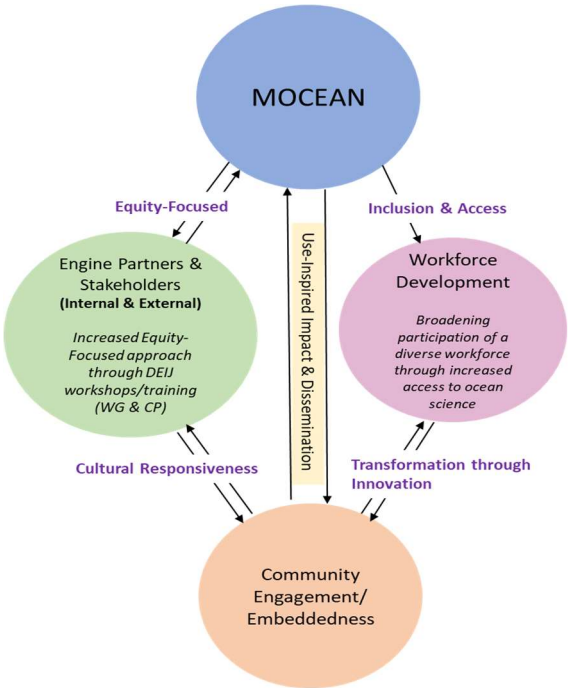


Figure 9: MOCEAN DEIAJ Model

iv. Partnerships

Trusted partnerships. The relationships with core partners and broader community that are needed for MOCEAN to achieve its objectives has been under development for more than a decade, with hundreds of strong relationships built among the core-partners of MOCEAN and the groups presented in Figure 8 (Communities Coming Together on Offshore Wind). In addition to joint grant proposals with MOCEAN members, the LO led the creation of a state-supported Massachusetts Research Partnership in offshore wind energy that the LO and their Massachusetts partners grew to become the national Partnership in Offshore Wind Energy Research (POWER-US). More than a dozen MRP/POWER-US workshops have been conducted with a summary of findings and a vision for research being published in the 2018 publication "Reaching Convergence in United States Offshore Wind Energy Research: A Multidisciplinary Framework for Innovation." The lead organization has led several sessions at conferences on topics central to this proposal, had more than 100 industry representatives and international delegates come to Tufts campus for meetings with Tufts MOCEAN key personnel, and the LO conducted many online international workshops including two on nature-inclusive design of offshore wind farms in the past 9 months; more than 600 different people have attended these workshops from more than 15 countries [18]. These experiences built the foundation for the trust developed between both existing collaborators and those relationships newly formed through the development of the MOCEAN proposal, and all components of the proposal were co-developed by the partnering institutions. Core partners also bring their own close and trusted relationships with groups identified in Figure 8. For example, the MOCEAN core partner Regional Wildlife Science Collaborative has built strong caucuses between the fisheries and offshore wind industry communities, so they are prepared to take on several topics central to the MOCEAN's success.

Rights and responsibilities of core and contributing partners: As described throughout this proposal, the roles and responsibilities of all partners are well defined and will be overseen by the Governance Board and Advisory Board. Additionally, all MOCEAN partners will have access to shared resources (see Resources attachment), as well as the ability to propose new projects, working groups, and partners, and to leverage MOCEAN infrastructure to accomplish MOCEAN's goals.

Security of shared resources: MOCEAN leadership recognizes the need for strong data security, particularly around potential areas of national security, such as energy. The lead organization will work with existing Tufts University research data resources to ensure that all data are stored securely and that only appropriately credentialed individuals can access sensitive data. Additionally, for other shared resources, organizations contributing resources will be responsible for developing guidelines for access.

Licensing and royalty agreements: In line with best practices, the organization leading the effort to develop new technologies will follow their organization's policies for licensing and royalties. Should there be disputes regarding new technologies or other intellectual property developed as a part of this Engine, Tufts Office of the Vice Provost for Research will be responsible for resolving them, in collaboration with other participating organizations.

D.v Evaluation Plan

MOCEAN's external evaluator, The Evaluation Group, will use a mixed-methods, utilization-focused evaluation approach that combines multiple quantitative and qualitative data sources from multiple reporters for triangulation, thereby significantly enhancing the validity and reliability of the evaluation and ensuring that results are useful for continuous quality improvement [40,41]. The evaluation will focus on the impact of both individual aspects of the program, as well as the combined impacts toward MOCEAN's overall goal of co-creating innovative, nature-inclusive offshore wind infrastructure with local coastal communities, offshore wind developers, marine scientists, engineers, and entrepreneurs to protect and enhance existing marine ecologies and industries and to incubate new industries and new employment opportunities for communities impacted by offshore wind. The MOCEAN Theory of Change (see Figure 10) guides the short-, medium-, and long-term metrics and changes throughout the program to ensure that the team's ambitious goals will be met, specifically in the areas of **a) diversity, equity, inclusion, accessibility, and justice; b) leadership and organizational structure; c) use-inspired research; d) education, outreach, and training;** and **e) economic impact**.

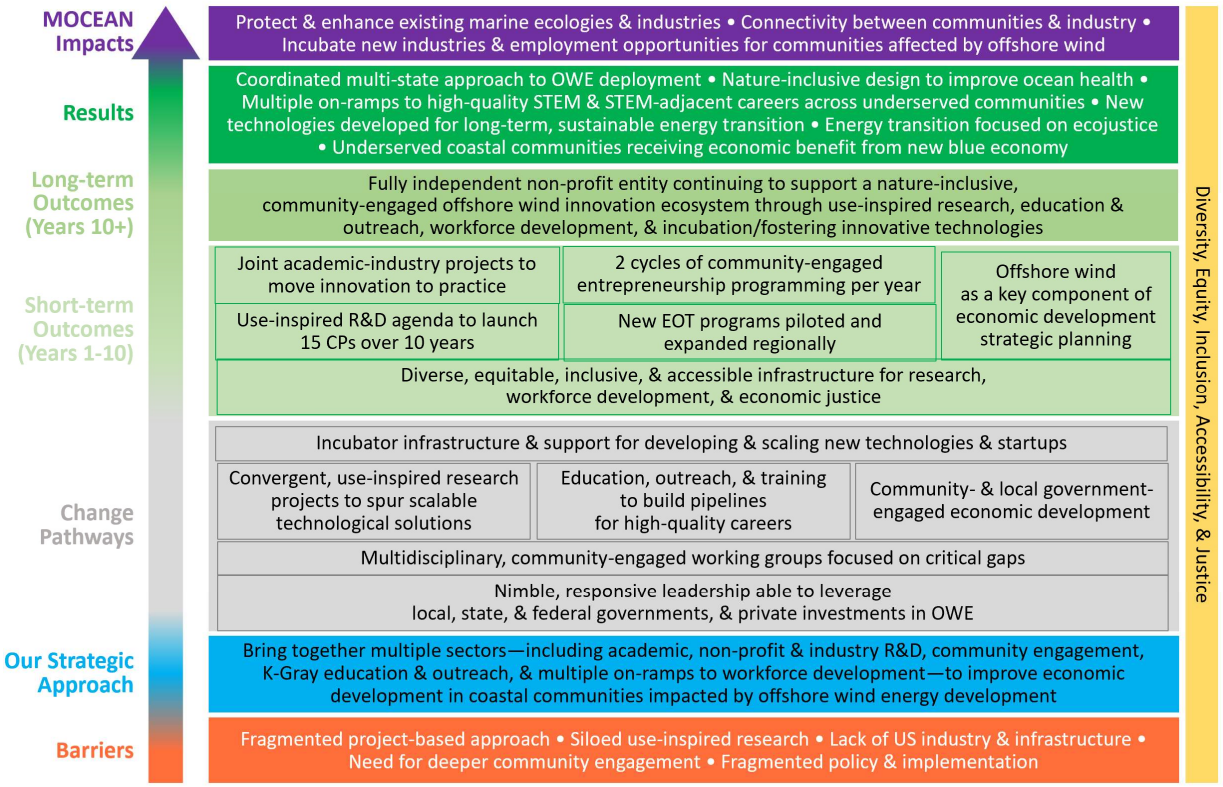


Figure 10 MOCEAN Theory of Change

Evaluation approach: The Evaluation Group (TEG) will serve as our independent evaluator. TEG has over 30 years of experience conducting large-scale evaluations funded by NSF and the Department of Education. With a commitment to utilization-focused evaluation, TEG has expertise in creating project-specific, quantitatively based instruments, which include surveys, checklists, and observational protocols and qualitatively based data collection techniques such as key informant interviews, focus groups, and group interviews. In the first six months of the MOCEAN program, baseline data will be collected for each of the major categories according to the metrics and in line with the Theory of Change to allow MOCEAN leadership to determine change over time and to assess the strengths and weaknesses of the project.

With the Advisory Board, the Governance Board will determine changes that need to be made to address weaknesses, to ensure appropriate and timely progress toward project goals, and to determine gaps. Following the first six months, and upon hiring of the MOCEAN CEO, the evaluation team will initiate assessment of individual aspects of the program and report results to the Governance Board on a quarterly basis. At least annually, results will be presented to the Advisory Board or more often if the Governance Board, CEO, and/or NSF staff determine that significant changes need to be made.

Additionally, the MOCEAN project director and CEO will be responsible for presenting baseline data, progress toward goals, and challenges to internal Tufts administration, including the Tufts University Dean of the School of Engineering, the Tufts Vice Provost for Research, the Tufts Vice President for Finance, and/or their delegates on a quarterly basis to ensure oversight of the project beyond the leadership and governance structure described in this proposal.

Principles of DEIAJ will be evaluated within and across each of the four major components below. In fact, to address MOCEAN's overall goal of ecojustice through nature-inclusive offshore wind energy, DEIAJ is the most crucial component of each activity and component, and, thus, should TEG find that the MOCEAN team is not meeting DEIAJ metrics, the results will immediately be brought to the Governance Board, the Advisory Board, and the leadership team to develop strategies to address any concerns.

In the first six months, the evaluation team will gather DEIAJ baseline data [42,43], including:

- *Compositional diversity* of the core leadership team, WGs, CPs, and targeted communities within the region's initial projects, including demographic data on race and ethnicity, gender/gender identity, level of education, socioeconomic status, disability status, and other relevant data
- *Equity* of resources, access, and ability to achieve individual and team goals.
- *Culture of inclusion*, including the extent to which all members of the MOCEAN team and targeted communities feel a sense of belonging and ownership within the MOCEAN structure, that their voices are valued, and that they have the ability to create positive change
- *Accessibility,* including accessibility of digital resources, spaces where activities are conducted, and ability to be involved to the extent that the individual wishes for all activities
- *Justice,* including economic and ecological justice for communities impacted by the offshore wind energy, specifically including fishery and aquaculture communities

These metrics will be tracked throughout the other components, as described below in Table 9, with the following short-, medium-, and long-term milestones.

Table 9: DEIAJ Metrics and Milestones

	Years 1-2	**Years 3-7**	**Years 8-10**
Compositional diversity	MOCEAN team at all levels meets or exceeds diversity of communities served; participants in EOT programs, projects, and small businesses launched meet or communities served		
Equity	Initial WGs and CPs have resources needed to accomplish goals	New CPs, incubator projects, educational programs, and other activities have the needed resources	
Culture of inclusion	MOCEAN team members experience a culture of inclusion	Target communities, education and outreach audiences, and stakeholder groups experience a culture of inclusion	
Accessibility	All digital resources, spaces, and ability to engage with MOCEAN are accessible; Education, outreach, and training programs have on-ramps to achieve individual and community goals		
Justice	Strategic plans center the needs of community members & stakeholders	R&D and education & outreach programs provide economic impact to underserved communities	

Leadership and organizational structure. Leadership and organizational structure evaluation will be assessed for both the Tufts-led aspects of the MOCEAN, as well as for the nascent regional non-profit that will be created as a part of the Engine's long-term goals. The organizational structure must be *flexible* to address the rapidly evolving state of the practice in nature-inclusive offshore wind development and deployment, must be *diverse and inclusive* to ensure a 'seat at the table' for community members and other stakeholders who may feel that the current state of the offshore wind industry does not take into account their needs, *accessible* to all stakeholders and members of the team, *effective* in ensuring that milestones are addressed, strategic goals are achieved, and opportunities are capitalized upon, and *trustworthy* to bring together the wide range of stakeholders, industries, governments, and researchers in good-faith efforts to bridge gaps and chart a path forward to address MOCEAN's research and development, environmental, and eco-justice goals. The leadership and organizational structure milestones are as follows:

- Years 1 and 2: Develop formal strategic plan and partnership agreements; hire CEO and additional leadership positions; launch Working Groups and five initial Convergent Projects; launch MOCEAN regional non-profit; begin fundraising from government and industry sources.
- Years 3-7: Launch additional Convergent Projects in new communities within the region of service; fundraise sufficient funds to fully staff nonprofit and launch parallel activities in support of MOCEAN's goals
- Years 8-10: Fully transition activities from lead institution to MOCEAN regional nonprofit; by the end of Year 10, nonprofit is a fully independent entity with robust fundraising to sustain and support its research, education, and workforce development mission

Use-inspired research. Use-inspired research metrics will be concrete measurements of the outcomes of CPs, the number of new projects launched, products incubated and spun off into small business, and the impact of the research on the state of art in OW. Use-inspired research milestones are as follows:

- Years 1-2: At least one new product or service disseminated from each CP, including at least three hands-on outreach projects developed and disseminated.
- Years 3-7: Six new convergent projects co-developed by community, academic, and industry partners; continuous project to incubator pipeline; broad dissemination of results to relevant stakeholder groups, including communities, industry, and academia
- Years 8-10: Enhanced biodiversity around offshore wind farms; MOCEAN-launched technologies, services, and EOT products launched throughout the region of service; adoption of MOCEAN-developed best practices and approaches adopted by offshore wind industry and R&D fields

Education, outreach, and training. Education, outreach and training (EOT) metrics are based on the number and impact of programs, as well as the extent to which programs meet the needs of professionals at all levels (multiple onramps), industry, and other stakeholder groups. EOT metrics are as follows:

- Years 1-2: Develop public engagement programming with the New England Aquarium to raise awareness of nature-inclusive offshore wind energy; develop at least 3 hands-on projects with CPs, conduct a youth needs assessment in New Bedford and Salem, MA; begin needs assessment mapping of additional communities; co-launch internship programs with industry
- Years 3-7: Continue needs assessment mapping to other communities hosting CPs; launch additional hands-on projects in collaboration with CPs; fully developed and robust internship program throughout the region of service, for participants at diverse educational levels; launch and disseminate public engagement programming across the region; develop and launch at least 5 training programs that span the region
- Years 8-10: Expand needs assessment mapping across the entire region of service; co-developed training programs fully sustainable in collaboration with government, industry, and academic partners; workforce development meets the needs of communities and industry

Economic Development. Economic development metrics will be measured in collaboration with state and local governments and will assess concrete outcomes regarding job creation, new industries launched, and sufficient workforce to support the new opportunities created through MOCEAN. Economic development milestones are as follows:

- Years 1-2: Establish baseline economic development status and needs in collaboration with state and local government; establish workforce development needs in collaboration with industry.
- Years 3-7: Launch workforce development programs in line with state and local needs; launch at least 1 new venture in each community with a CP in Years 1-2; continue to launch ventures in new communities based on CPs launched in Years 3-7
- Years 8-10: Established innovation ecosystem in underserved communities throughout the region of service, including appropriate numbers and training of workforce for new and existing industry, high-quality jobs created, and successful companies launched within the BlueTech space

MOCEAN Evaluation Plan: TEG will analyze quantitative data using descriptive statistics (i.e., means, standard deviations, frequencies, and percentages) and parametric and non-parametric inferential statistics (i.e., chi square, t-tests, ANOVA, MANOVA, OLS), and effect sizes will be computed and reported for any subgroups (i.e., school, community, gender, minority, economically disadvantaged). Qualitative data will be coded and analyzed thematically to gain a richer and deeper understanding of stakeholder reactions. A detailed plan of data collection is found in Table 10.

vi. Long-term Sustainability Plan

Throughout its operation, MOCEAN will seek co-funding from the public and private sectors. Several states are already creating funds to fund research on environmental and social impacts. For example, the states of NJ and NY are charging fees to wind developers that will fund environmental effects monitoring for offshore wind farms. As another example, the Governor of Massachusetts, Maura Healey, announced her aspiration to boldly develop the climate technology sector, paralleling the way the state developed the life science sector, which included over $1B in state tax incentives and grants. The developers of offshore wind farms are mainly oil & gas companies that have historically supported joint research in Europe through programs like The Rich North Sea and the Carbon Trust Offshore Wind Accelerator [19,44]

Table 10: Evaluation Plan

Activities/ Metrics	Data	Measurements	Targeted Population	Timing
Leadership & Organizational Structure				
Diversity meets or exceeds that of communities served	Demographics	Surveys	Leadership at all levels: core leads, WGs, CPs	1st 6 months; then yearly
All team members, community stakeholder groups, perceive that MOCEAN has a culture of inclusion	Qualitative indicators of inclusive excellence	Survey; focus groups	Team members on WGs, CPs, and stakeholder groups	1st 6 months; annually thereafter
Strategic plan accepted by all team members	Quantitative indicators of understanding of and agreement with strategic plan	Surveys; focus groups	Team members on WGs, CPs, and stakeholder groups	1st 6 months; then every 2 years
Confidence in team's leadership and capacity	Qualitative attitudes on leadership and MOCEAN program climate; quantitative gap analysis of expertise and resources	Surveys; focus groups	Team members on WGs, CPs, and stakeholder groups	1st 6 months; then every 2 years
Ability of team to raise external funds	Quantitative financial analysis of external funds	Grant and donation reports	CEO and financial leadership	Yearly
# new partners added address new goals	# and type of partnering orgs.	Subcontract data; surveys of WG and CP leads; progress reports	WG and CP leadership; financial leadership	Yearly
Ability to flexibly address new science, tech., & educational directions	# and type of new projects launched; # and type of new products in practice	Reports from leaders; outcome analysis of projects	CEO and financial leadership; WG and CP leadership	Yearly
Use-Inspired Research				
CPs launched and completed	Number and type of projects launched; outcomes from projects; impact of projects on field and communities	Reports from CP leaders; publications & presentations; citations	MOCEAN leadership and CP members	Every Quarter
New technical and educational/outreach products into practice	# and type of products incubated; number and type of products scaled	Tracking of products; patents and license agreements; #spin-offs	MOCEAN, new company, and CP leadership	Yearly
Diversity of new ventures incubated and launched	Demographic data on leadership and membership of new ventures	Surveys	Venture leadership and staff	Yearly
Culture of inclusion in ventures incubated and launched	Qualitative inclusive excellence and climate data	Surveys; focus groups	Venture leadership and staff	Yearly
Venture funding attained by new companies	Amount of funding attained	Reports from spin-off companies	New company leadership	Yearly
Education, Outreach, and Training				
Youth needs assessment in communities	# and quality of summer programs; # and quality of presentations to communities	Pre- and post-test for programs; effectiveness surveys for presentations	Participants in summer programs; audiences	Per program
Public engagement	# and demographics reached via website, social media, exhibits	Website and social media engagement analysis; surveys	Public engaged in programs	Per program
Internship model	Number interns, number cohorts, leveraged company funds for stipends; inclusive culture	Reports from EOT WG; pre- and post-surveys for interns	Interns participating in program; companies participating in program	Yearly
Hands-on training in CPs	# of events/participants; hands-on training into broad programs	Reports from EOT WG; effectiveness surveys of CP membership; pre- and post-survey of participants	CP team members; participants	Per program
Mapping education & training program gaps	Gap analysis	Surveys and publicly available data	Educational, outreach, & community organizations; stakeholder groups	Yearly
Co-generated training programs	Number and quality of training programs	# of participants; demographics of participants; pre- and post-surveys of	Participants	Per program
Workforce assessment	Workforce needs and gaps	Surveys; government and industry reports	Government and community stakeholders; industry	Yearly
Economic Impact				
# & type of jobs created within existing industry	Quantitative analysis; salaries; recruitment and retention	Government & industry reports	Government & industry within region of service	Yearly
New companies launched within region	# and impact of companies, including # and demographics of employees, amount of profit	Surveys	launched companies	Yearly
"Spillover" impacts	Average salary, level of home-ownership, & other eco. indicators	Eco. indicators of region of service communities	Local and state Eco. Develop. Agencies	Every 2 years

More than a trillion dollars could be invested to development offshore wind farms by 2050 as now explained. If 10% of the needed 2050 electricity demand nationally (assuming high electrification) were to come from offshore wind farms, then about 300 GW of deployment would be needed by 2050. Depending on the percentage of U.S. offshore wind farms and components that are built in the U.S., and scaling from expectations for the first 30 GW of development, a workforce of 500,000 or more would be needed to build and operate the nation's offshore wind farms by 2050. If nature-inclusive design proves to be as beneficial as the MOCEAN team believes is possible, then many tens of thousands or more new jobs for future fisheries and aquaculture would be expected.

Ensuring a scalable and sustainable MOCEAN beyond the initial NSF Engine grant will be a key outcome of the initial funding period. During the 10-year NSF Engine grant, MOCEAN will establish a new regional non-profit that can complement and then continue its mission. As a regional non-profit building on lessons learned from partners who serve the MOCEAN region (e.g. ROSA & RWSC) and the Massachusetts Life Sciences Center that have spurred economic development through innovation, MOCEAN will be able to speak with one voice on behalf of all the coastal communities affected by wind energy deployment while soliciting both public and private funding to expand its mission into other regions and more broadly (e.g. floating offshore wind structures, hydrogen, energy storage).

Independent to the sustainability plan, it may be that new technologies and circumstances change the landscape significantly during the 10-years of operation. MOCEAN will work with its communities and others, and with the Governance Board and NSF, to adapt to the new opportunities and form new partnerships as best serves MOCEAN's mission.

Broader Impacts

The US has a massive offshore wind energy resource that could be developed to power a fully electrified nation many times over, and federal, state, and private interests have aligned to begin to develop this resource. However, we are not on track to use this immense investment off our coasts to advance the critical priorities of healthy oceans and a just energy transition. The MOCEAN team contends that industry cannot be expected to achieve this goal without a collaborative public-private platform to fully address all these societal priorities while meeting legitimate business needs. Responsible bodies and public decision makers lack the evidence as well as the broad-based and well-informed understanding to create and continually improve the policies, incentives, and public investments that are needed to best serve the nation. The MOCEAN team's commitment is to take on this critical responsibility by bringing together currently disconnected research, economic development, innovation, and community groups, and many others to co-create an offshore wind energy deployment strategy that fosters new blue tech industries and enables underserved coastal communities to grow and thrive beyond their traditional economies. This will also establish the nation as a global leader in responsible OW farm development.

If MOCEAN can deliver what is intended for the 10-years of NSF support, and beyond through a sustained mission, then there will be no upper bound to the level of offshore wind energy that can be harvested because putting heavy infrastructure under the water will be proven as acceptable as planting forests. Considering the scale of this opportunity, the broader impacts are substantial:

- Achieve massive CO2e reductions while ensuring a just energy transition
- Create a continuously learning and innovating blue economy ecosystem that advances technologies
- Integrate the fields of marine biology, engineering, economics, and policy
- Create the scale-of-investment (>$1T) needed to elevate underserved communities
- Create a better-informed citizenry and empowered decision makers.
- Foster collaboration across research institutions, industry, states, and decision makers to develop and implement system-level approaches and to adopt best practices
- Mobilize deep outreach programs to motivate young people to study science and engineering
- Create multiple entry points for broad stakeholder participation in the energy transition, equalizing and diversifying access to new economy jobs across the skill spectrum.