Macroalgae Research Inspiring Novel Energy Resources (MARINER)

The projects that comprise ARPA-E's Macroalgae Research Inspiring Novel Energy Resources (MARINER) program seek to develop the critical tools to allow the United States to grow into a world leader in the production of marine biomass. Presently, macroalgae, or seaweed, is primarily used directly as food for human consumption, but there is a growing opportunity for the production of seaweed for use as fuel, chemical feedstock, and animal feed.

MARINER project teams will develop technologies capable of providing economically viable, renewable biomass for energy applications that does not compete for valuable dry land. These projects are divided into five categories, each part of a suite of technologies necessary to reduce capital and operating costs and enable significantly larger farm sizes and areas of deployment. MARINER teams and their partners cover a wide array of technical disciplines and geographical zones, offering a comprehensive, portfolio approach to advancing this early-stage technology area.

- Category I: Design & Experimental Deployment of Integrated Cultivation and Harvesting Systems
- Category II: Design & Experimental Deployment of Advanced Component Technologies
- Category III: Design & Testing of Computational Modeling Tools
- Category IV: Design & Testing of Aquatic Monitoring Tools
- Category V: Research & Development of Advanced Breeding and Genetic Tools

PROJECT DESCRIPTIONS

Catalina Sea Ranch – San Pedro, CA

Design of Large Scale Macroalgae Systems (Category I) – *$449,772*

The Catalina Sea Ranch team will design an advanced cultivation system for giant kelp (*Macrocystis*) to reduce operational and capital costs for large-scale seaweed farms. In collaboration with its commercial partners, the team's direct seeding method, which deposits young plants onto specially designed substrates, will save money and time during the hatchery and deployment phase. Additionally, the team's mechanical partial harvest technology, which allows the same plant to be cut multiple times, is expected to further reduce seeding costs by 75% compared to the state of the art.

Fearless Fund – Washington, DC

Ocean Energy from Macroalgae (OEM): Ranching Sargassum (Category I) – $500,000

The Fearless Fund team will develop a new system to enable large-scale seaweed "ranching" using remote sensing and imaging technologies to monitor free-floating, low-impact *Sargassum* cultivation designed to mimic naturally occurring seaweed mats found in nature. Free-floating farms decouple biomass production from costly, capital-intensive infrastructure and present opportunities to scale production in the Gulf of Mexico and Caribbean Sea. Working along the Texas/Louisiana coastline, the team will use satellite technology and computational modeling to seed, monitor, and harvest *Sargassum* biomass over a three-month cultivation cycle. By leveraging the wealth of data generated from a suite of sensors, the team seeks to achieve large-scale farming without the need for capital-intensive infrastructure.

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Kampachi Farms, LLC – Kailua-Kona, HI

Blue Fields: Single Point Mooring Array for High-Yield Macroalgae Culture (Category I) – $500,000

The Kampachi Farms team will develop technologies for the delivery of deep seawater nutrients to a novel macroalgae production farm design suitable for deployment in tropical and subtropical deep ocean environments. The nutrient delivery system will be powered by ocean-current-driven pumps, and the innovative single-point mooring array growth system will harness currents for optimal nutrient dispersal. Finally, the team seeks to demonstrate a prototype harvester that could be adapted to renewable power sources. All subsystems are intended to be deployed in Hawaii's offshore environment to validate field performance.

Marine Biological Laboratory – Woods Hole, MA

Development of Techniques for Tropical Seaweed Cultivation (Category I) – $500,000

The Marine Biological Laboratory team will focus on the development of a cultivation system for the tropical seaweed *Eucheuma isiforme* for the production of biomass for conversion to biofuels. *Eucheuma* is a commercially valuable species of "red" macroalgae that has been difficult to propagate in a cost-effective manner. The team seeks to develop a new farming system to mechanize seeding and harvesting processes to reduce labor intensity and enable deployment in offshore areas. The team's test site in the waters around Puerto Rico aims to demonstrate cost-effective production in underutilized areas of the Gulf of Mexico and tropical areas of the U.S. exclusive economic zone, where year-round production is possible.

Pacific Northwest National Laboratory – Richland, WA

Nautical Offshore Macroalgal Autonomous Device (NOMAD) (Category I) – $500,000

The Pacific Northwest National Laboratory team at the Marine Sciences Laboratory in Sequim, Washington, will develop a free-floating, carbon fiber seaweed longline to be released far offshore and collected after a six-month, 1,500km path along nutrient-rich ocean currents. The floating cultivation system, called NOMAD, does not require capital for anchors or moorings and will operate without direct human intervention. The recycled carbon fiber line will be equipped with GPS buoys to track position, while other sensors will be used to estimate harvest readiness in real time. Fully automated, high-speed seeding and harvesting machines will be designed and deployed to minimize labor costs. The team will use state-of-the-art hydrodynamic modeling for device design and placement.

Trophic, LLC – Albany, CA

Continuous, High-Yield Kelp Production (Category I) – $500,000

The Trophic team will develop a suite of technologies to significantly increase the capital efficiency of seaweed farms to reduce production costs. Specifically, Trophic's approach will use renewable energy to passively lift nutrients from deep ocean water to crops at the ocean surface, mimicking the natural upwelling that occurs in the world's most productive marine ecosystems. The system will also employ a self-diving buoy system to help protect the farm from wave motion and an adjustable system to optimize exposure to sunlight and increase productivity. In tandem with new harvesting technologies, the team expects to design a cultivation system that can produce seaweed at a cost meeting the MARINER target.

University of Southern Mississippi – Hattiesburg, MS

AdjustaDepth – Adjustable Depth Seaweed Growth System (Category I) – $500,000

The University of Southern Mississippi team will develop a novel and robust seaweed growth system capable of precise positioning for maximizing productivity and avoidance of surface hazards such as weather or marine traffic. The system is anticipated to be suitable for diverse "attached-growth" seaweeds and scalable across multiple temperate climate regions. The USM project team will also investigate the potential to integrate drone technology to develop a glider-based version of its system, capable of returning to its home port for harvesting when not roaming thousands of miles offshore.

University of Southern Mississippi – Hattiesburg, MS

SeaweedPaddock Pelagic Sargassum Ranching (Category I) – $500,000

The University of Southern Mississippi team will develop a semi-autonomous enclosure to contain fields of free-floating *Sargassum* mats. Wave-powered tugs, operated remotely onshore by a single person, will move the enclosure to ensure maximum exposure to nutrients. The system is designed to never return to shore, while the pilot can relocate the enclosure to avoid storms and ships—or move it into “dead zones” where excessive nutrients can be taken up by the seaweed, improving ocean health.

University of Alaska Fairbanks – Fairbanks, AK

Development of Scalable Coastal & Offshore Macroalgal Farming (Category I) – $500,000

The University of Alaska Fairbanks team will develop replicable scale model farms capable of the cost-effective production of sugar kelp, a type of seaweed. The UAF project aims to reduce capital cost using purpose-built designs while simplifying installation and production to lower operational expenses. The team seeks to integrate the entire farming process, including seed production, outplanting, grow-out, harvest, and re-seeding. A particular emphasis will be on the development of cost-effective harvesting methods based on technologies applied in the commercial fishing industry. Test deployments for the integrated system are planned for locations in Alaska and New England.

C.A. Goudey and Associates – Newburyport, MA

Autonomous Tow Vessels for Offshore Macroalgae Farming (Category II) – $406,549

The C.A. Goudey and Associates team will develop an autonomous tow vessel to enable deployment of large-scale seaweed farming systems. This “drone tug” will operate energy-efficiently—at low speeds—to conduct critical farming tasks, such as relocating marine infrastructure and biomass transport to processing locations. Because the vessel is capable of piloting itself and therefore requires no crew, the drone tug presents an opportunity to efficiently scale up farming systems while moving them farther offshore, where human access would be significantly more challenging and costly.

Makai Ocean Engineering, Inc. – Honolulu, HI

Modeling the Performance and Impact of Macroalgae Farming (Category III) – $995,978

The Makai Ocean Engineering team will develop a modeling tool to simulate the biology, nutrient flux, and structural performance of offshore seaweed farming systems. This work will result in a hydromechanical model that can simulate forces on offshore seaweed structures due to waves and currents. In addition, the team will develop tools to assess the flow and dispersion of nutrient-rich waters pumped to a farm site from the deep ocean. Several scenarios will be modeled for varying wave sizes, water depths, and currents. The model’s output will be used to determine the proper size for offshore components and to create cost estimates based on these components for a wide range of locations and farm designs.

Pacific Northwest National Laboratory – Richland, WA

Multi-resolution, Multi-scale Modeling for Scalable Macroalgae Production (Category III) – $2,025,986

The Pacific Northwest National Laboratory team will develop a set of integrated modeling tools capable of simulating multiple factors simultaneously. The team will use the best available regional and global modeling products to understand macroalgae farm structure-hydrodynamics interactions, load response calculations, and nutrient flux to provide consistent and accurate simulations of seaweed growth and biomass yields. The effort will perform a hydrodynamic load analysis for different farm designs across different regions of U.S. coastal and open waters, which is expected to reduce the risk and cost of farm deployment.

University of California, Irvine – Irvine, CA

MacroAlgae Cultivation MODeling System (MACMODS) (Category III) – $1,815,529

The University of California, Irvine team will develop a modeling system capable of capturing the complex interplay between ocean currents, surface waves, turbulence, farm canopy architecture, nutrient and light fields, and biological processes. UC Irvine's modeling system will integrate an open-source regional ocean model with a fine-scale, high resolution hydrodynamic model, allowing the team to evaluate different farm designs to maximize yield while minimizing cost and environmental impact. The model is anticipated to provide critical information to enable seaweed producers to develop efficient structural components, cultivation techniques, and operational parameters for optimized overall performance and yields.

University of New England – Biddeford, ME

Validated, Finite Element Modeling Tool for Hydrodynamic Loading and Structural Analysis of Ocean-Deployed Farms (Category III) – $1,321,039

The University of New England team will develop and validate a fine-tuned 3D modeling tool to simulate the hydrodynamic-induced mechanical stress of seaweed cultivation systems in high fidelity. The team will focus on predictive modeling to determine the structural performance of new and existing farm designs, complemented by a field plan to validate the model at multiple scales in the Gulf of Maine. The team's model will be capable of simulating hectare-sized farms at resolutions of less than one meter, accelerating the engineering, testing, permitting, and operation of new seaweed farming systems.

University of California, Santa Barbara – Santa Barbara, CA

Scalable Aquaculture Monitoring System (SAMS) (Category IV) – $2,003,894

The University of California, Santa Barbara team will develop a system-level solution to continuously monitor all stages of seaweed biomass production and integrate data into real-time, actionable intelligence for farm operators. Specifically, the technology will reduce logistical requirements and cost through integration of autonomous aerial and submarine drones and permanent sensors. UCSB's system provides a scalable capability to continuously assess physiological condition and production, as well as the environmental factors influencing the health and yield of the farm.

Woods Hole Oceanographic Institution – Woods Hole, MA

Integrated Monitoring of Macroalgae Farms Using Acoustics and UUV Sensing (Category IV) – $2,063,170

The Woods Hole Oceanographic Institution team will develop an autonomous underwater observation system for monitoring large-scale seaweed farms for extended periods without human intervention. The team will outfit an unmanned underwater vehicle (UUV) with acoustic, optical, and environmental sensors to monitor macroalgae growth and health, equipment status, and water column properties, such as nutrient content. A particular focus of the project is to collect and interpret acoustic (sonar) data of the macroalgae. A docking station for vehicle recharge and data telemetry makes long-term operation possible.

University of Wisconsin-Milwaukee – Milwaukee, WI

Genome-wide Association Studies for Breeding M. Pyrifera (Category V) – $2,820,128

The University of Wisconsin-Milwaukee team will develop a breeding program focused on determining the ideal genetic traits for farmed seaweed at scale. The team will use a combination of genome sequencing, optical mapping, and capture sequencing to create a genotyped strain collection—enabling the selection of the best performing farming traits from 50,000 possible crosses. The team will produce a specific set of genetic markers for traits controlling biomass growth rate, and low nutrient as well as temperature tolerance. This information will serve as a valuable tool for breeders to guide effective plant selection.

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Woods Hole Oceanographic Institution – Woods Hole, MA

Integrated Seaweed Hatchery and Selective Breeding Technologies for Scalable Offshore Seaweed Farming (Category V) – $3,704,276

The Woods Hole Oceanographic Institution team will develop a selective breeding program for *Saccharina*, one of the most commercially important kelp varieties, with the goal of obtaining improved cost effectiveness of seaweed production. The breeding program will build a germplasm library associated with plants that produce a 20% to 30% improvement over plants currently in the field. By using a combination of phenotyping, genome-wide studies, and genome prediction methods, the team expects to accelerate the production of improved plants while decreasing the need for costly field evaluations. The project will conduct sampling and testing at field sites in New England and Alaska.