Affordable, Scalable Biomass Feedstock Grown in the Open Ocean

Marine BioEnergy, Inc.

ARPA-E 2021 Energy Innovation Summit

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U.S. Energy Use

- U.S. per-capita energy use ~10kW continuous (24/7/365 average)
  - ~⅓ as liquid transportation fuels
  - ~⅓ to make electricity
  - ~⅓ for heating
- Fossil fuels need to be replaced and currently supply 80% of U.S. energy.

https://www.pexels.com/search/Los%20Angeles%20Night%20Time/

Energy as a Finite Resource

- Renewable energy yields are low density (1-10 W/m^2 average year-round)
- Land surface is only ~29% of Earth's surface

→ Either we can have endless land-use and fresh-water debates, or we can farm a modest fraction of the open ocean.

Carbon-Neutral Fuel from the Ocean

- The open ocean does not currently support much photosynthesis-based life because sunlight is at the surface and nutrients are below the thermocline (~150 m).
- Kelp is only found near shore where nutrients and sunlight are both available in shallow water.

Marine BioEnergy Solution

- Our patented solution is to grow kelp in the open ocean:
  - Surface the kelp during the day to absorb sunlight
  - Submerge the kelp at night to absorb nutrients
- This can be done inexpensively using environmentally-powered underwater drones.

The Kelp Advantage

- Kelp does not compete with food production for land area and will not harm environmentally-sensitive areas, such as deserts or marine reserves.
- Kelp does not use any fresh water, pesticides, or artificial fertilizers, instead using abundant nutrients in deeper water.
- The harvest is non-destructive so farms could be productive for years.

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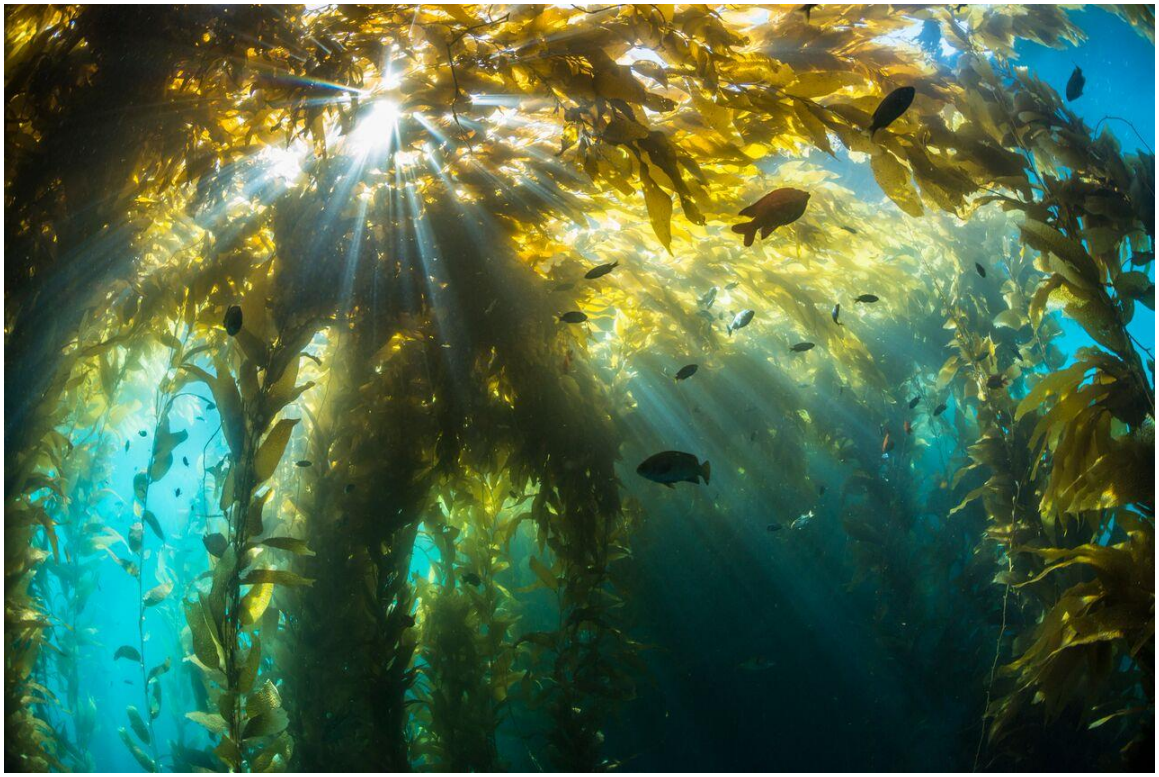
The Kelp Advantage

- Kelp is relatively easy to process into drop-in fuels because it has no lignin and little cellulose.
- Kelp is one of the fastest-growing plants at ~ 1 - 2 feet per day, with average photosynthetic efficiency much higher than terrestrial plant production.



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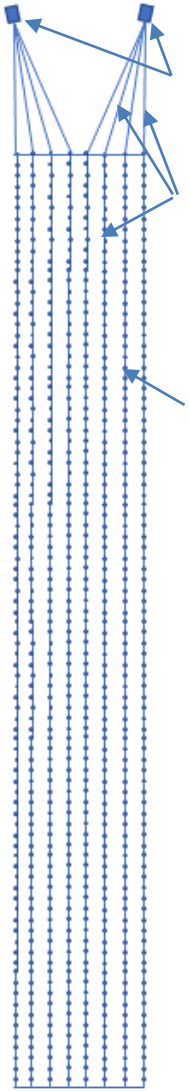
Marine BioEnergy Farm Concept



- 2 Drones towing farm
- Lines distribute towing force
- Lines have floats every ~12 m and have kelp planted on lines
- All lines are pressurized and maintain tension and float separation

Overhead view of farm

- Inexpensive solar-powered underwater drones tow the farm.
- Buoyancy-control floats are attached to lines to surface and submerge on command.
- Farms rendezvous with harvesters 3 to 4 times per year.

ARPA-E Project

Marine BioEnergy was awarded $2.1 million in funding from ARPA-E to demonstrate that kelp can be successfully grown in the ocean through depth cycling.

The main focus was to show that at least one kelp species thrives in the open-ocean when exposed to sunlight at the surface in the daytime and submerged at night to nutrients at depth.

Depth-Cycling Experiment Begins

Kelp are outplanted (~9” length)

See kelp collection video on this virtual web site.

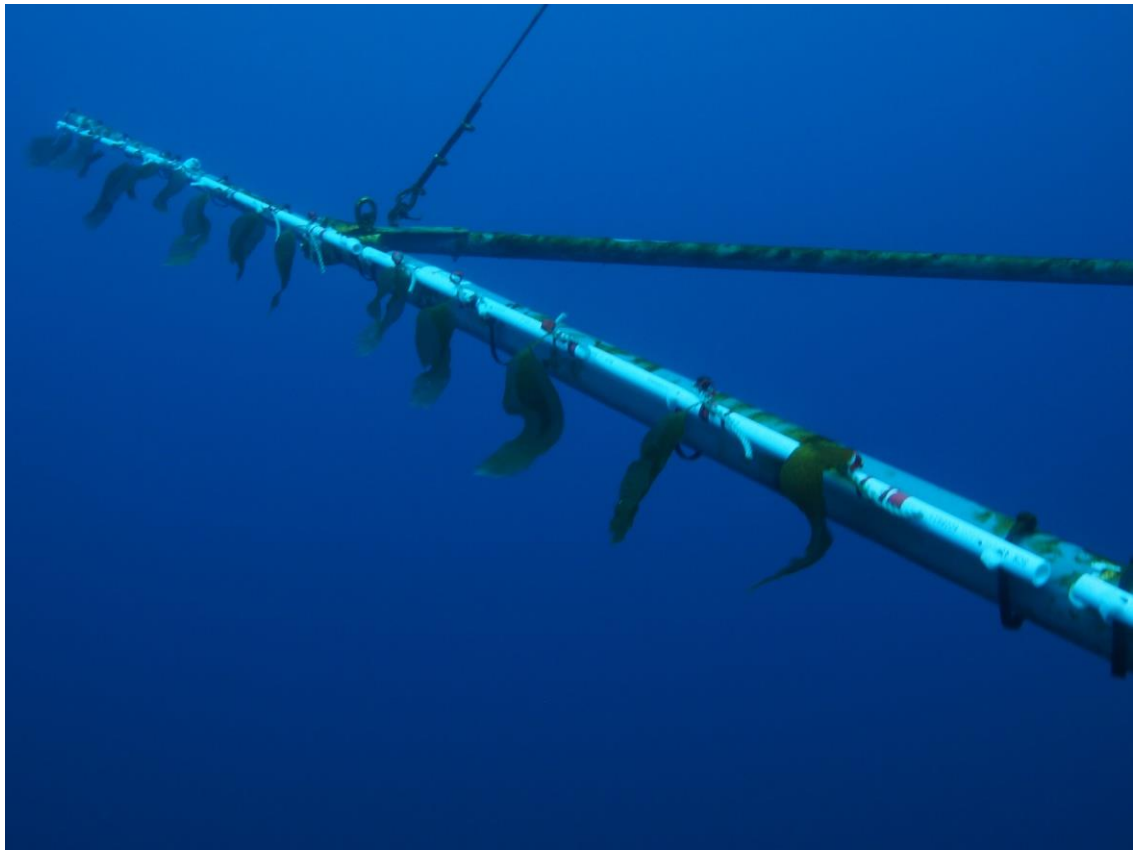


Photo: David Ginsburg

Depth-Cycling Success

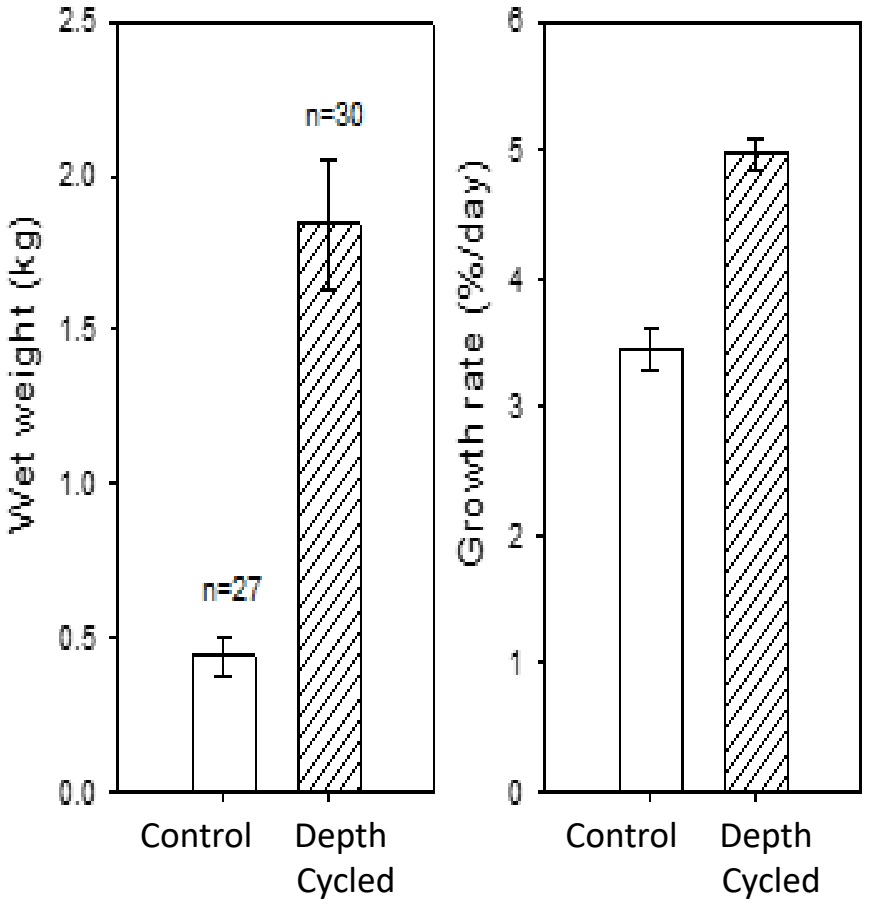
Week 8, Intermediate Results

See short video on this virtual web site.

Photo: Maurice Roper

Foundational Experiment

- In deep water off Catalina Island, ~30 kelp were depth-cycled nightly to ~80 meters for ~100 days.
- Depth-cycled kelp showed significantly higher biomass production compared to control kelp at nearby local kelp bed.



Depth-cycled kelp produced almost 4 times as much biomass as controls.

How Much Kelp Do We Need?

To deliver ~10% of U.S. transportation fuel, we need an area under cultivation of approximately 220,000 square kilometers, which is about the same area as the State of Utah.

The Pacific Ocean is ~155 million square kilometers, 705 times the size of Utah.

First Customers

- CR&R is digesting biomass to biogas(green waste and food waste, and soon kelp). The biogas is first used to fuel their waste disposal fleet, replacing diesel. The balance is available to the regional gas pipeline, including to fuel the spinning generators for the grid.
- Primary Ocean will be processing the kelp for their kelp organic bio-stimulant product.

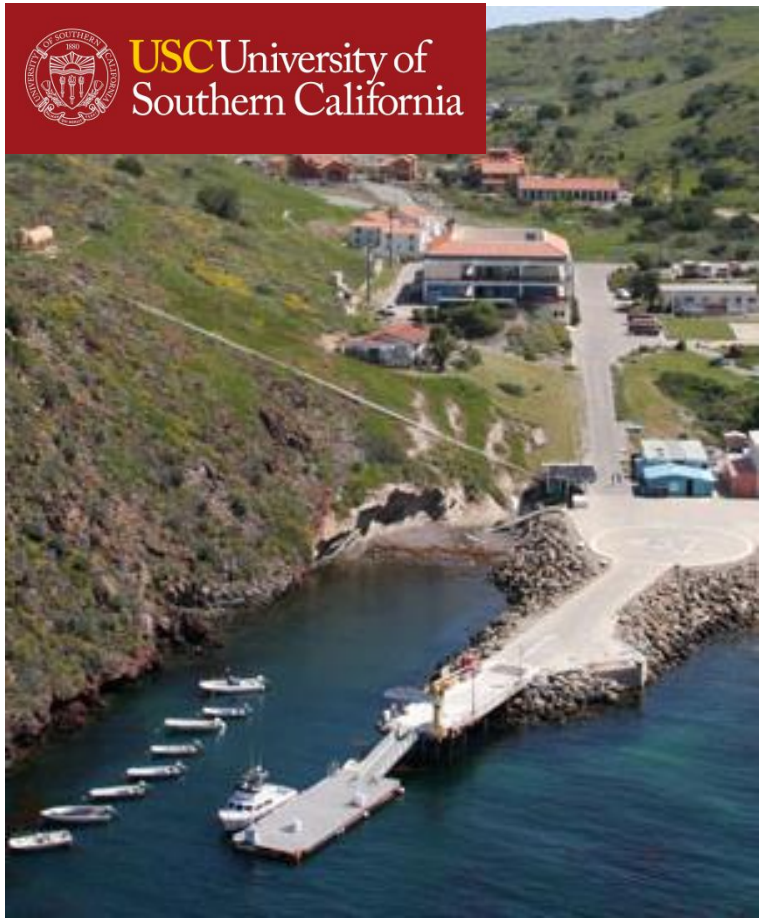
Management Team

- Brian Wilcox: co-founder of Marine BioEnergy, and inventor of the patents. Retired after ~38 years at NASA's Jet Propulsion Laboratory, proposed and led >$100 million in robotics technology development projects. 1 of 40 JPL Fellows, named "for extraordinary technical and institutional contributions".
- Cindy Wilcox, co-founder of Marine BioEnergy, served two terms as elected school board member in high-ranking district, improved student outcomes and maintained solvency during Great Recession.
- Professional management will be brought-in for transition to production.

Biology Team

We are collaborating with the University of Southern California, Wrigley Institute for Environmental Studies on Catalina Island for the kelp depth cycling test.

USC Wrigley Institute, early kelp tests



USC Wrigley Institute
Catalina Island

Engineering Team:

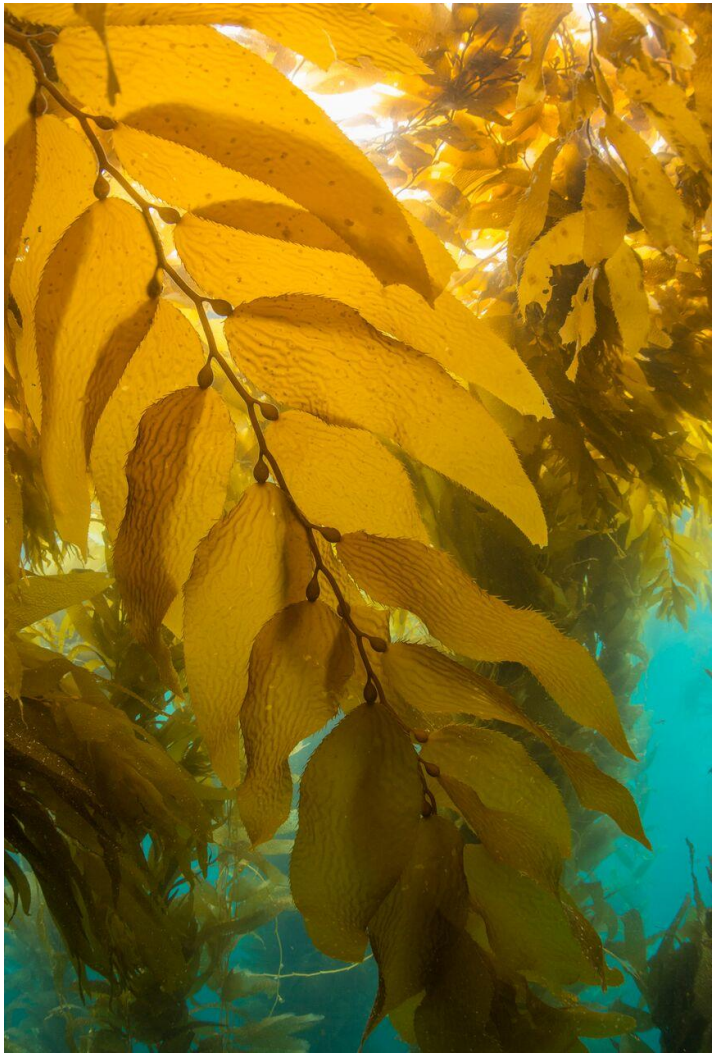
- Kelson Marine for modeling open-ocean farm dynamics
- Glosten for design package of drone submarines
- ZSquared for propulsion system design

Next Steps

- Marine BioEnergy is designing farm elements now.
- We will ocean test the sub-assemblies and then build a “first farm”.

Improving Kelp Yield

- Marine Biologist Mike Neushul & team cultivated 722 *Macrocystis* (aka Giant Kelp) for 4 years near Santa Barbara, CA, 1978-1982.
- They discovered that the highest yield kelps consistently produced **3 times as much biomass** when compared to the average kelps.
- Genetics teams at USC and University of Wisconsin Milwaukee are developing robust sterile hybrids for ocean farming.



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Future Growth

- Harvest kelp to produce liquid transportation fuels.
- Harvest kelp to replace natural gas with renewable methane in the pipelines to maintain spinning generators as the backbone of electrical grid.
- License drone submarines to other companies/countries. Marine BioEnergy has received multiple licensing requests to date.
- Manage “ocean farm traffic control system” for harvesting and collision, hazard and storm avoidance.

→ Eventually own some farms and license most farms, operate harvesters and farm traffic control system, and transition to a platform company.

In Summary

Patented approach to deploy farms in the open ocean that will surface the kelp during the day to absorb sunlight and submerge the kelp at night to absorb nutrients.

Abundant biomass will be used to make carbon-neutral fuels that are competitive with liquid fossil fuels.

Easy to scale to meet growing demand.

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Please see other videos and slide decks at the Marine BioEnergy Innovation Summit booth, or see www.marinebiomass.com

Thank you!

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Kelp photos by Phillip Colla, Oceanlight.com