From the Sea to the Pump: Is Kelp a Viable Biofuel?

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Brown kelp macroalgae — the strange, foul-smelling seaweed so often found washed up on the Pacific Northwest's volcanic sand beaches — could ultimately offer an almost unlimited global supply of commercial-quality ethanol or biomethane.

Or so says Paal Bakken, founder and CEO of Seaweed Energy Solutions (SES), based in Trondheim, Norway.

Although in the U.S. the idea of macroalgae for energy production is often either confused with microalgae cultivation or dismissed by environmentalists who mistakenly believe "farmed" macroalgae will somehow deplete existing wild seaweed populations, Europe seems to be casting a less jaundiced eye toward cultivated kelp's renewable possibilities.

"We are convinced there is a potential for seaweed as biomass for ethanol and biomethane," said Bakken. "We have done cultivation technology development since 2008 and are now scaling up to 100,000 tons of [seaweed] production from about 170 hectares off the coast of Denmark."

Bakken says Sugar Kelp (laminaria saccharina) can produce about 50 liters of ethanol and 20 cubic meters of biomethane per wet ton. Although SES has produced both ethanol and biomethane gas during testing, it has yet to commercially market any such bioenergy.

While more than 70 percent of earth's surface is dominated by oceans, they currently only produce a paltry two percent of the globe's food, feed and biomaterials. In fact, the world only averages a million dry metric tons of seaweed biomass annually, mostly from seaweed crops off the coasts of Asia. However, with cultivation improvements by some estimates annual global seaweed production could be ramped up to 3.5 billion dry metric tons. But at this point, Bakken is simply interested in seeing his own project to fruition.

Bakken says in addition to nearly $20 million already on hand via private investors and project supports from both the European Union and Norwegian government, SES still needs to raise another $10 million to completely fund the company's next phase of development.

Our long-term goal is seaweed cultivation for energy purposes, says Bakken. But demand for sustainable seaweed-based fish and animal feed and bulk chemical will be important in bridging the gap to full energy production.

However, Bakken hopes that by 2020 SES will be solely focused on producing bioenergy from seaweed.

Meanwhile, although research groups in the U.K, The Netherlands, and Ireland are actively pursuing their own seaweed-based bioenergy projects, private start-ups solely devoted to the idea are hardly plentiful.

Another one of the few such companies is The Bio Architecture Lab (BAL), a five-year old, privately held company headquartered in Berkeley, California, that has spent much of its time pursuing macroalgae production off the coast of Chile. The company garnered headlines early last year when its work on extracting sugars from seaweed feedstock were highlighted in a scientific article that made the cover of *Science* magazine.

BAL CEO Ric Lucien was unavailable for interview regarding the latest status of such efforts, but did provide *Renewable Energy World* with the following statement:

"BAL continues to develop its core intellectual property around unlocking the potential of brown seaweed to be a scalable and sustainable source of sugars for biofuels and other industrial products," said Lucien. However, Lucien didn't offer a timetable for doing so.

While Bakken also remains optimistic about the "potential to unlock" seaweed's bioenergy prowess, he readily admits that his company's prime focus at the moment is scaling up macroalgae production to commercially acceptable levels. In Europe, that means offshore production of the brown kelp from the top of Norway to southern Portugal.

"The biggest problem is that you need to produce huge quantities at low cost," said Bakken. "In China, they harvest seaweed in a very labor intensive way, but we are looking at making that process more efficient. To [start producing] bioenergy, you need at least 2 million tons of wet weight seaweed."

SES has a patent on its seaweed carrier, a "large sail-shaped structure" on which to cultivate large numbers of closely spaced macroalgae plants in the ocean itself. With a seaweed breeding facility in Norway, SES is currently conducting cultivation tests off the coasts of Norway, Denmark and Portugal.

As Bakken explains, with conventional seaweed cultivation, the plants are ready for harvest six to seven months after its spores (attached to ropes) are put out to grow at sea. These spores, in turn, typically spawn three- to four-meter long plants that normally grow from the surface down to depths of a few meters. And unlike terrestrial crops, which are sensitive to the vagaries of the weather, seaweed is generally unperturbed by normal wind, waves and current.

Even so, seaweed still needs waters rich in dissolved nutrients like nitrogen, phosphorus and carbon dioxide that are typically found near coastal areas and in deep ocean water. As a result, macroalgae cultivation for biofuel is going to depend greatly upon geographic location and the development of mariculture facilities says Brandon Yoza, a microbiologist with the Hawaii Natural Energy Institute.

"You're not going to grow macroalgae in paradisiacal waters around Hawaii," said Michael Cooney, a chemical engineer at the Hawaii Natural Energy Institute. "When you have crystal clear waters, you have nutrient-deficient waters. That's why you can see through it."

Bakken, on the other hand, says that in addition to providing a viable source of bioenergy, seaweed can also be used as a natural ocean filtration system to clean up overly nutrient-rich (read polluted) waters. Seaweed increases biodiversity and oxygen levels, says Bakken, noting ocean pollution is now a huge issue in coastal Europe where he says wild seaweed resources are dying out.

Because the kelp plant is potentially exposed to sunlight filtering beneath the water's surface, Bakken also notes that seaweed's photosynthetic efficiency is higher than that for sugar cane.

But despite seaweed's high marks for the efficient photosynthetic use of incoming solar insolation, Yoza says terrestrial biofuel crops like sugar cane or corn still have significantly higher yields per area. Thus, he notes that profitability from macroalgae is going to depend on a very efficient development process.

Because seaweed is mostly made up of water and salt, Cooney thinks harvesting it efficiently enough to make it viable as a bioenergy alternative will be a major challenge.

"When you harvest the kelp, you have to expend energy to harvest it," said Cooney. "It's 60 to 70 percent water; there's a huge dewatering effort that has to occur. Then you have to get rid of the salt. That takes energy."

That's one reason why Yoza says that macroalgae needs to finally be recognized as a distinct biomass resource.

"It's often [lumped] with terrestrial sources or confused with microalgae," said Yoza. "Its composition, lifecycle and growth environment is different enough that distinct metrics and evaluation need to be developed. Then [its] research can be better focused."

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