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Algae Project Scale and Risk

Water, light, site infrastructure and risk are key considerations for algae projects

BY MARK J. HANSON

Many algae project developers face the question of how to approach "commercial-scale." Commercial-scale has not been defined for algae biofuel facilities, but guidance from other biofuel models is available. Ethanol production facilities started commercial-scale production at 12 to 18 MMgy with local financing in the mid-1980s. With a proven track record, commercial facilities were designed at 40 MMgy in 2000, and since 2005 are customarily built on a 100 MMgy model to achieve economies of scale. The brief history of commercial biodiesel production since 2006 has focused on commercial scale of 20 to 30 MMgy.

Twenty to 30 MMgy of algae oil can be a daunting proposition for open pond algae systems, requiring 6,000 acres of ponds producing high rates of algae oil, 5,000 gallons per acre. For algae biofuel facilities, scale will be a factor in considering whether the oil will be further processed to biodiesel or marketed as biocrude to a refinery. Some suggest commercial-scale marketing of algae oil as biocrude to petroleum refineries is about 100 MMgy. Biocrude can be marketed to existing biodiesel plants, but opportunities present today may be subject to compatibility with other feedstocks, availability and pricing of others including waste oil with little market value, and a risk that the biodiesel facility will stay in business with that algae oil capacity available. If a facility is designed to refine algae oil to biodiesel, scale is much less of a factor because biodiesel can be marketed in smaller quantities.

Commercial scale also focuses on economies of scale for production, harvesting, extraction, refining to biodiesel, product inventory and storage, and personnel costs. Algae production is not a manufacturing system or land-based plant cropping system, but rather a dynamic plant growth system requiring monitoring and management similar to live animal production instead of land crop production. Larger scale requires attentive monitoring and management to detect growth rates, nutrient uptake and environment changes, as well as diseases, viruses and predators. As a result, the cost of technical personnel, monitoring, harvesting, extraction and refining equipment needs to be spread over an appropriate production base. If the scale is too small, the project risks high overhead costs that affect profitability.

Water. While many projects focus on sunlight as the critical factor for algae production, water availability is probably more important. Location, system design and size determine what the water needs will be. Permits, regulations and competing uses will determine the availability. Water needs for a 100-acre open pond system in a region with high solar radiation and little rainfall include evaporation and water lost through algae harvesting. In the high solar, arid areas of the U.S., evaporation can be 60 to 80 inches of open surface water annually. The impact of evaporation is not just removal of water, but also concentration of minerals and salts. A 100-acre open pond in a high solar, arid area would require about 160 million gallons of additional water per year to maintain the same water levels. At a production rate of 5,000 gallons of algae oil per acre per year (high), this 100-acre, 500,000 gallon algae oil production system requires about 320 gallons of water for each gallon of algae oil produced.

Open systems also have the risk of too much water through precipitation and local flooding. While catastrophic events may be rare, rainfall in open systems can dilute and change the chemistry of nutrient-laden water optimal for algae growth. Algae production entrepreneurs such as Phyco Biosciences have reduced the effects described above on open systems by lining and covering trench systems in Arizona. Those systems reduce the risk of evaporative water loss and concentration of minerals and salts.

In closed systems, there is still water loss from harvesting and a need to make up water as necessary to supply micronutrients taken up by the algae, which are removed from the system. At any time the algae nutrient uptake (including micronutrients essential to cell structure and growth) exceeds the nutrient replacement rate, the system is at risk of reducing productivity. In natural systems such as lakes, the water and nutrient replenishment is constant, varied, and dynamic. A lake has multiple, complex systems from the air-water interface to the water-sediment interface coupled with variable mixing regimes to supply and change algae production dynamics. Designed systems insulate the water from many of the external variables to achieve stability with the goal of predictability, but still face the water chemistry dynamics necessary to optimize photosynthesis and algae production that will occur in variable cycles, typically at nonlinear rates.

Light. Many algae production designs focus on optimal sunlight as the primary factor for siting a facility. While some systems such as Solazyme's focus on dark algae growth through sugar-supplied energy, most focus on light energy for algae photosynthesis to produce growth and oil. Algae need a certain amount of light at opportune times to grow well. Solar energy generally exceeds the amount of light needed for photosynthesis at the water surface and attenuates rapidly in the first four to six inches of depth and, as algae grow, they self shade the light source so mixing is utilized to bring more algae into appropriate light to promote growth.

Nationally, the areas of the country with the most sunlight receive no more than nine to 10 hours of variable intensity sunlight per day, annually averaged. The variation throughout the country from summer to winter may be as much as 25 to 50 percent. The daily and annual variation can result in production variability, unless the available sunlight is underutilized by the algae production system.

Sunlight photosynthesis systems have an inexpensive source of energy, but it is variable and will be diminished by clouds, weather and atmospheric events. In winter months, reduced production and corresponding algae oil supply may cause demand and pricing variations.

In the best locations sunlight photosynthesis systems are without light over half the time and subject to technological risks of better artificial lighting that efficiently produce more algae per volume of water by optimizing the strength, wavelength and duration of light and dark periods 24 hours a day, without daily and seasonal variability. The artificial systems may even collect and store solar energy to release light efficiently over a longer period. The 20- to 25-year levelized costs of algae oil production of sunlight systems and artificial light systems should be considered in the design process.

Site Infrastructure. Most algae production facilities have a considerable investment in site infrastructure. The amount of capital invested in a unique application is an additional risk factor for project developers, investors and financiers. The amount of permanent infrastructure—concrete, buildings—reduces flexibility of a project to adapt to changing technologies and different operations. Permanent infrastructure is also at risk if water availability or quality changes, reducing algae production and project viability at a particular location. Pond system infrastructure is permanent and cannot be relocated. Photo bioreactor systems have significant capital investment, but can be relocated with varying costs.

Rewards of Risk Assessment. In the rapidly developing algae industry, risks are being considered for open pond, photo bioreactor and hybrid systems. The design and siting of systems incorporate varying amounts of risk and risk tolerance. Projects should be designed with risk factors considered on the front end to develop a sustainable, financeable algae production system. One can imagine an open pond system near the equator, adjacent to the ocean to minimize water and sunlight risks; or one that is mobile, scalable to a particular size by adding or subtracting interconnected modules, utilizing artificial light to optimize algae production on a 24-hour basis, extracting oil for biodiesel production that can, in turn, be used as a backup fuel, using algae biomass as a fuel or feed product, contained in a manner to minimize water usage.

Alberta, Canada-based Symbiotic Envirotek Inc. developed a system of isolatable modules that are insulated, portable and scalable to form a biofield of the desired size with microalgae yields forecasted to be four times of first-generation photobioreactors, with a smaller ecofootprint. To optimize such a closed, mobile system it must be closely monitored for water usage, nutrient availability and control. Mobility would allow different uses for varying periods of time and additional financing mechanisms. If modules are considered equipment, financing could be enhanced by accelerated depreciation and equipment lease and financing.

OriginOil developed advanced harvesting and extraction technology used in open systems in Australia, which can be applied to other systems. OpenAlgae also developed a harvesting, dewatering and extraction system using a lysing technology. Mcgyan Biodiesel LLC developed a catalyst technology to convert oils to biodiesel, which can include algae oil separately or with other oils in a cost-efficient modular system. The National Algae Association has taken a project approach with engineering and financing groups and is developing a 100-acre closed system (photobioreactors) designed to avoid or minimize risk.

New venture financing will frequently accept higher risk profiles, but in the technological algae development boom, adaptability to new technologies will also be a key factor. Each project will need to address risks involving light (energy), water quality and quantity, operations, including qualified personnel; and technological risks and obsolescence. The projects that analyze and address these in designs and systems will likely be rewarded with project financing and sustainability.

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