Project Summary

Title: *Decision-Model Supported Algal Cultivation Process Enhancement*
Applicant: Arizona State University
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Current decision-support models (TEA, LCA, and growth/productivity) for large-scale algae cultivation systems lack critically important quantitative, culture-failure risk data. At very large scales, semi-continuous versus full-batch cultivation strategies present very different risk profiles from pathogen-, grazer-, and competitor-induced culture failures. These uncertainties constitute a critical knowledge gap that must be closed to guide major investments in commercial algal biofuel systems and enable systems for crop insurance. For example, at very large scales, small open raceway ponds (ORPs) for seed-culture production are often assumed to manage capital costs, however this strategy amplifies the economic risk of culture failures, which can result in very long scale-up recovery time. Mitigation of this risk requires both significant operational knowledge and CAPEX/OPEX investment in crop protection and pest-management strategies as a necessary hedge against failures. Alternatively, larger investment in intensified, photobioreactor (PBR) seed-inoculum scale-up capacity, coupled with complete batch-mode ORP harvests, can manage cultivation failure risk by minimizing algal seed-culture exposure. The precise advantages of either approach is difficult to disambiguate, as cultivation risks are likely to show significant strain-, location-, and seasonal-dependencies. Thus, we propose the development and integration of four key strategies which quantify cultivation risks and their economic and sustainability impacts for different seed-train/cultivation strategies—including seasonal crop rotation—providing a robust framework for data-driven decision-support models. Variability and sensitivity analysis through Monte Carlo modeling will be used to understand the risks associated with culture failures and the sustainability impact of avoidance and mitigation strategies. This integrated framework will promote rapid advancement of strategies to generate large-scale best-practices, leading to improved biomass productivity and robustness, plus lowering the costs of algal biofuels and bioproducts.

We will quantify the economic and technical risks associated with different cultivation strategies and crop protection approaches through an integrated program of indoor lab studies, cultivation optimization and simulation, multi-scale "omics," and robust outdoor cultivation campaigns—all informed by >5 years of outdoor cultivation data generated under the AzCATI led ATP^3 consortium and our ongoing work. This will produce a more integrated and realistic assessment of risks, the current state of technology, and pathways to BETO's target of \$3.00 GGE^{-1} and trajectory to \$2.50 GGE^{-1}. Additionally, through the development and deployment of a suite of novel real-time sensors for nutrient and water quality monitoring, we will gain better process control though novel insights, plus the ability to optimize productivity, robustness, and biomass quality of our selected high-performance strains. Finally, robust TEA, LCA, and biomass productivity modeling will be utilized to: a) assess progress towards performance targets; b) identify critical research and development priorities; and c) evaluate the impact of sub-system technologies at a systems level, allowing for more rapid advancement of those strategies that generate scalable best practices.