Advancing microalgae biotechnologies for sustainable food, fuels and chemicals.

Jennifer Yarnold, Ben Hankamer University of Queensland.

Background: By 2050, global projections indicate we will require 50% more food, 50% more fuel, 40% more freshwater and 80% less carbon emissions to sustain a population of approximately 9.6 billion people.

Microalgae have the potential to help address these challenges. These small, green photosynthetic cells use sunlight for energy to capture carbon dioxide from the air and turn it into 'biomass' that is rich in proteins, nutrients and oils, including Omega-3 oils. These organics can be used for a variety of products – from sustainable biofuels and bioplastics to nutrient-rich animal and fish feeds and human health supplements.

As available land and freshwater becomes ever more scarce, a distinct advantage of microalgae production systems is that they can be located along coastlines or on arid lands not suitable for agriculture and forests and be grown in saltwater or wastewater, utilising recycled nutrients such as nitrogen and phosphorous.

To date, global scale up of commercial microalgae technologies has been slow due to a lack of cost competitiveness with traditional biomass feedstocks used for food and fuels. A key factor to bring down these costs is to increase the growth rate of microalgae to produce more biomass.

Study Rationale: This project sought to investigate how different species of microalgae respond to dynamic changes in ***light*** and ***temperature*** – two key variables that significantly affect growth – and to develop predictive models to determine favourable conditions and design parameters that could guide the design of microalgae production systems that would increase productivity and feasibility.

Study Approach and Aims: In Part I, a robotic high-throughput screening method was developed to simulate the dynamic light regimes that algae cells are exposed to when they mix through dense cultures in outdoor photobioreactors change over day and night cycles. The high throughput screening method employed a multifactorial design to test a range of light variables on two commercial algae species. In part II the findings of part I were used to guide the design of a novel pilot-scale photobioreactor system with unique light distribution qualities to test the conditions in a real world outdoor scenario. In part III, the light and temperature model was developed and combined into a wider techno-economic and life cycle analysis (TELCA) platform. The TELCA assessed the feasibility of microalgae biodiesel production in twelve global locations.

Key Results: In part I, it was found that individual microalgae species respond differently to light fluctuations and that biomass production could be enhanced by changing the parameters of: culture cell density and culture depth to suit local sunlight conditions. These results were used to build a predictive model which enabled productivity estimates over a number of different design scenarios and in different locations.

In part II, experiments to investigate the productivity of a local strain of microalgae showed improved growth rates and improved light distribution in a novel photobioreactor designed to optimise light utilisation.

In part III, a global model-analysis revealed the commercial potential of microalgae-based biodiesel under optimal technology and policy settings in 12 different global locations – using real solar radiation and temperature data and unique variables according to country (e.g. tax rates, etc.). Model-predictions found that microalgae biodiesel could be produced under cost competitive conditions in a number of global locations. The best locations for productivity were those with high solar irradiation and temperature, however, the policy settings, labour rates and capital costs in different jurisdictions had a significant effect on the economic viability.

Conclusion: A key conclusion from this study identified that with model-guided settings, sustainable microalgae biodiesel could be a feasible commercial reality with the support of government and investment.

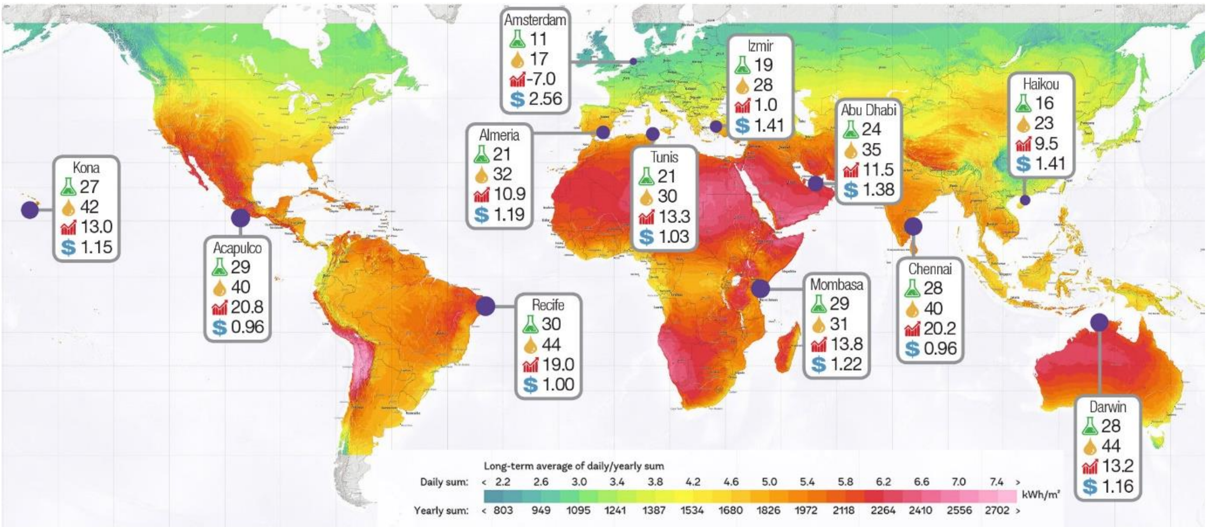

Figure 1. Modelled analysis of microalgae renewable biodiesel production systems at 12 international locations. Biomass productivity (green flask, $g.m^{-2}.d^{-1}$) and biodiesel production (yellow oil drop, $kL.ha^{-1}.y^{-1}$). **Scenario 1 (for profit model):** shows Internal Rate of Return (red graph, %) at a minimum diesel selling price (MDSP) of $US2 L^{-1}. **Scenario 2 (public utility model):** shows MDSP (blue dollar sign, US$ L^{-1}). Global irradiance map (background).