The Oil Drum
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Book Review: Green Algae Strategy

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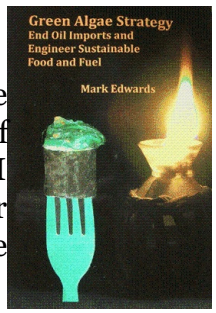
Introduction



I love to read. I particularly enjoy books about energy, sustainability, and the environment. One of the benefits of reviewing books is that I end up getting a lot of free books on these topics. One thing about getting free books, though, is that I have to be careful that it doesn't impact my objectivity. After all, the publisher or author was nice enough to send me this free book. How do I then approach the matter if I sharply disagree with some aspects of the book?

I am on record as being very skeptical about the ability of algal biodiesel to scale up and contribute significantly toward liquid energy supplies. Mark Edwards, a Professor of Strategic Marketing and Sustainability at Arizona State University recently saw one of my essays, and said that while he agreed with my points that many algal producers have been overly optimistic, he also felt like I had glossed over algae's potential. He offered to send me a copy of his book Green Algae Strategy: End Oil Imports And Engineer Sustainable Food And Fuel.

The first thing I thought when I saw that title is "*Either Mark Edwards is dead wrong, or I am dead wrong*." But I believe it is important to read and understand a wide range of viewpoints, because I just might change my mind. Maybe I am dead wrong. This book won the 2009 IPPY award for the best science book, so there are definitely those who think Mark makes a good case.

Mark Edwards writes that he has three goals:

1. Create Green Independence for America and the world

2. Halt and reverse climate change

3. End American and world hunger

While I can certainly get behind those goals, the devil is always in the details. And I think in the details we are going to run into some very challenging problems. Of course this is something I wouldn't mind being dead wrong about. In fact, a few years ago I was very optimistic about the possibility of algae to produce large amounts of fuel without utilizing large amounts of good crop land. The prospects for algal fuel certainly sounded too good to be true. But a series of articles and discussions since then has swung me increasingly to the belief that the stories were too good to be true.

My Slide Toward Skepticism

First I read an essay here at TOD called Has the Algae Cavalry Arrived? The essay was mostly based on work done by Krassen Dimitrov, who had gone back to first principles of incoming solar insolation to argue that GreenFuel Technologies was exaggerating their claims. While Dimitrov's work has been criticized, he does raise a number of important issues. Primarily for me was the issue of just how much renewable diesel could be made from a square meter of area, contrasted with what the overall costs might be. Dimitrov concluded that you could make at best about a gallon of algal oil per square meter per year. However, costs were estimated to be over $100 per square meter. That sounded like a pretty serious, but potentially surmountable problem. (Important to note that in Green Algae Strategy, Mark Edwards also argues that GreenFuel made "some serious mistakes in executing strategy", and led the industry in "hope and hype").

Then came a post from John Benemann: Algal Biodiesel: Fact or Fiction? John has been heavily involved in algae studies for many years. In fact, he was the Principal Investigator and main author of the U.S. DOE Aquatic Species Program Close-Out Report. He certainly has some credentials on the topic of algae, and he weighed in to say that the essay described in the previous paragraph was generally correct. John's position is that the present status of algal biodiesel is nowhere near commercialization, but in 10-15 years commercialization may not be out of the question. But it is far from a sure thing, and it certainly won't happen soon. (See also John's recent position paper on the subject: Opportunites and Challenges in Algae Biofuels Production).

Meanwhile, more question marks emerged. De Beers Fuel, having made some pretty far-fetched claims about their ability to deliver algal biodiesel, as well as having sold 27 franchises for algal biodiesel production, turned out to be a scam and collapsed. GreenFuel Technologies finally decided their future was bleak, and they closed down.

Information about the true costs started to become publicly available. While it has long been known that algal biodiesel is currently very expensive to produce, the actual price was only vaguely quantified. Krassen Dimitrov had suggested costs of around $20/gal. The government in British Columbia commissioned a study to look at the prospects, as well as the estimated costs of production. They estimated that the net cost of production per liter for photobioreactors (PBRs) was $24.60 ($93.23 US dollars/gallon), for open raceways it was $14.44 per liter, and for fermentors was $2.58 per liter. (There are some other issues with using fermentation that I won't get into here). The report also stated that the much-touted carbon sequestration benefits of algae were illusory:

> What about the value of sequestered carbon in algae-based biofuels? In short, there isn't any. Atmospheric carbon is only sequestered for a short time until it's burned in an engine. Under existing biofuels mandates in most industrialized countries, there will be no opportunity to sell carbon offsets unless fuel production is additional, or beyond such mandates.

Finally, Bryan Wilson, a co-founder of Solix Biofuels, went on record and stated that they could indeed make biofuel from algae, but the cost to do this was $33/gallon.

That preamble is meant to establish that there was quite a lot behind my slide from algae optimist to algae skeptic. But I was looking forward to seeing whether Mark Edwards could push me back toward the optimist camp with his book.

The Book's Strengths

Let me talk first about what I feel are the book's strengths. Edwards clearly lays out the challenges we face over our dependence on fossil fuels. He takes on current U.S. biofuel policy in a credible way. He is sufficiently skeptical about the near term prospects for cellulosic ethanol, and is harsh in his assessment of corn ethanol (even more so than I have been). He cites familiar names such as Lester Brown, delves deeply into the challenges of water and soil depletion, and discusses the issue of NPK (nitrogen, phosphorous, and potassium) availability in the future.

On the overall topic of algae, the book is incredibly informative. I had no idea that algae played such an important role in food, medicines, and consumer products (e.g., Aquafresh toothpaste). Edwards discusses many different varieties of algae, and characterizes them according to lipid, protein, or carbohydrate production.

Edwards makes a good case for *why* it would be a great idea to have algae-based fuels. He emphasizes that the co-products in many cases can improve the overall economics of the process. He lays out all the possible benefits of procuring our fuel from specific waterways as opposed to trading topsoil and fossil aquifers for fuel.

I can say with certainty that this book will come in handy for me in the future as a reference book. (More details at a later date, but I am likely to do some work on algae myself in the not-too-distant future). But what I won't use this book for is as a "How To" guide. And that's a good segue into the problems I had with the book.

The Book's Weaknesses

At times it felt as if this book was written by two people. There was Mark Edwards, the cellulosic ethanol skeptic, accurately reporting on some of the potential problems with commercialization of cellulosic ethanol. Then there was Mark Edwards, the algal biofuel optimist, uncritically presenting seemingly far-fetched claims from any number of would be algae producers.

There was even Mark Edwards the algal fuel skeptic, but I just couldn't reconcile that person's views with those of Mark Edwards the optimist. On one hand, Professor Edwards notes that the current estimated costs for algal biodiesel are over $20/gallon. He said that over 75% of the companies who had algal aspirations in the 80's and 90's no longer exist. He wrote that the algal fuel industry as a whole has produced less than 100 barrels of product. Then he turns around and writes that within three years the industry will be producing hundreds of millions of gallons. (Based on the 2008 publication date, I guess we can expect a gusher of production next year).

I had a number of specific criticisms as I read the book. First, it was presented throughout the book that algae can be used to produce food and fuel, all while sequestering carbon. I don't agree with that. Certainly algae take up carbon dioxide and convert it into biomass as they grow. However, unless that biomass is stored away without being consumed, there is no real carbon sequestration. Imagine two different scenarios. In the first scenario, the carbon dioxide from a coal-fired power plant is bubbled through tubes filled with algae. The algae will consume that CO_2, preventing the immediate escape into the atmosphere. But what happens if fuel is produced from the algae? The carbon dioxide ends up getting released into the atmosphere. What you can say is that the release was delayed, and (depending on the energy inputs into producing the fuel) potentially more fuel was produced for a given emission of CO_2. However, that isn't carbon sequestration.

Second case, algae are grown utilizing atmospheric CO_2. During the growth phase carbon dioxide is indeed removed from the atmosphere. Take that algae and bury it deep in the earth, and carbon is sequestered. Turn it into fuel, and the CO_2 taken up during the growth-phase is

released back into the atmosphere. This is potentially a greenhouse gas (GHG) neutral process, but there is little potential for sequestration if the goal is to use the algae for fuel. However, this carbon sequestration meme is mentioned many times in the book (and many themes in the book were unnecessarily repetitive).

He blames the lack of progress for algae on lack of funding, which is blamed on corn ethanol. This, he argues, was the politically favorable biofuel that sucked up all the R&D funding (and subsidies). He later writes "If corn ethanol makes sense, the market will reward it without taxpayer monies or protectionist tariffs." Can't we say the same about algal fuel? If the potential is so great, money should flood in from investors looking to get in early on a huge growth opportunity.

I don't recall that the issue of energy return was ever covered in the book. If the energy inputs into the process are too high - as Bryan Wilson of Solix Biofuels recently suggested - then you have a potentially serious issue. How can algae be harvested and processed with minimal energy inputs? One of John Benemann's comments from his position paper was "At present there are no low-cost harvesting technologies available." Why? It takes a lot of energy to extract the algae from the water, relative to the BTU content of the algae you are extracting.

I felt that there was some confusion around the usage of specific terminology. For instance, on Page 6 Professor Edwards wrote that oil pressed directly from algae can be used directly in a diesel engine, and this is called green diesel. While plant oils can be used straight in a diesel engine, this product is called straight vegetable oil, or SVO. (Note: Do not attempt to use SVO in a vehicle unless you understand the caveats!) Further, there is a difference between green diesel and biodiesel, but this terminology is used interchangeably in the book. (See my Renewable Diesel Primer for an explanation of the differences between green diesel and biodiesel.) Another misuse of terminology comes on Page 15, where ethanol is called a hydrocarbon.

But those aren't the biggies for me. The title of the book indicates that it is a strategy book, but I see it more as a series of facts, connected to goals. What is missing is the "how to", which would be the strategy part. Yet difficult technology challenges were addressed casually. There are numerous instances where there is a presumption that technology will solve a particular problem. The word "might" is used an awful lot in the book. But when you casually dismiss technical challenges, you can effectively argue that the most implausible scenarios are inevitable. Let me give you an example.

Bananas are a very healthy food, and in the U.S. we depend on imports from tropical countries for our banana supplies. Just imagine if we could grow bananas in the Midwest. The soil is fertile. There would be additional options for farmers to make money. New jobs could be created in the domestic banana supply chain. So let's say I write a book about my Midwest Banana Strategy. I talk at length about the benefits of bananas, and the benefits of growing them in the Midwest. These are facts. I then tie them to my goals: To commercially grow them in the Midwest. The only problem is that unless I am willing to invest in heated greenhouses - at very great expense - my banana goal is going to come to naught. So presently Midwestern bananas are a pipe dream. But if I invoke the wonders of biotech - "there will be a solution that will enable cold-tolerant bananas" - then problem "solved." And that's how I felt many problems were dealt with in the book.

There are a series of independent facts, and then we have a black box, and then we have commercial algal biofuel. Solutions are presented as inevitable ("when this happens") instead of possible ("if this happens"). Sometimes I had flashbacks to The Singularity Is Near, in which author Ray Kurzweil employed this tactic throughout to argue that the near future is so fantastic we can't even imagine it. It is certainly true that a lot of companies are working on algae. But I

would argue that Professor Edwards falls prey to the Vinod Khosla fallacy on cellulosic ethanol: *This is simply too important and there are too many companies working on this to fail.*

If I hand wave away the challenging problems and presume technology will solve them, then who needs algae for fuel? Hydrogen is waiting to solve all of our problems. Recall all that hydrogen economy business that was all the rage a few years ago? Despite numerous potential benefits, there are multiple very challenging technical issues that keep a hydrogen economy at bay - and will continue to do so for the foreseeable future. But I could still write a book called Hydrogen Economy Strategy if I am willing to brush away those technical issues as temporary.

While there were a number of claims that I thought were presented uncritically, there were also some claims that I found to be very odd. Some examples:

Page 13: As a criticism of using food crops for fuel, he states that massive planting of corn leads to high humidity because the leaves transpire water. This leads to thunderstorms and potentially tornadoes.

That large areas planted in corn can increase the risk of tornadoes is something I have never heard before.

Page 105: Algal biodiesel **is** carbon neutral because the power needed for producing and processing the algae **can** come from the methane produced by anaerobic digestion...

That sentence is inaccurate. It is only carbon neutral if the power **does** come from digestion, not that it **can**. Based on the above, we could also say that corn ethanol is carbon neutral, because the power for processing can come from methane produced from digestion.

Page 150: When writing that algal fuel mimics fossil fuels without fossilization, he writes "Skipping the fossilization step not only saves 200 million years of pressure and heat, but lowers production costs significantly."

I can't really comprehend this one. The reason biofuels have trouble competing with fossil fuels is because nature already did the heavy lifting for the fossil fuels. Nature provided all that heat and pressure for free. Humans have to provide the heat and pressure to process biofuels - at a price. So I would come to the opposite conclusion: Skipping 200 million years of pressure and heat increases production costs significantly.

Page 179: He cites a claim by Aurora Biofuels that their process creates biodiesel with yields 125 times higher and 50% cheaper than current methods.

I am going to presume that this was supposed to read 125% higher and not 125 times higher.

Page 204: "When someone invents a carbon capture filter for vehicle exhaust pipes, there will be a nearly limitless supply of low-cost CO2 for growing algae."

I don't even know what to say about that one. It gets back to the issue of energy return. Anything you do here (e.g., compressing the spent CO2 from the vehicle) is going to take energy (and add weight to the vehicle) which is a penalty against the overall energy return of the process.

Conclusion

Let me say that I agree with the goals of Professor Mark Edwards, and that I think his heart is in the right place. I agree that we should spend research dollars on an algal biofuel program. I agree

with him that economical algal biofuel could provide substantial benefits. (A good portion of the book was devoted to algae as food, and I didn't really address that at all in this review). Where I disagree sharply is that solving the technical challenges is inevitable. This is primarily where I found fault with the book.

On the other hand, the book was very informative on the topic of algae. I learned a lot I didn't know. But at the end of the book, my skepticism had not been swayed because I did not see a real pathway to get from where we are today to vast quantities of commercial algal biofuel. The book failed to make the case that the technical challenges will be solved.

No doubt Professor Edwards will disagree with some of this review. But I am a strong proponent of allowing people to answer criticisms. I therefore extend an open invitation to Professor Edwards. If he wishes to dispute or address any of the points I have raised, I will happily publish his comments.