

The "Down and Dirty" Guides to Making Biodiesel at Home

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Making Algae **Biodiesel**

At Home

By David Sieg



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2010 Edition

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About the Authors



David Sieg, teacher/consultant/biofuels entrepreneur/writer and author of the Series “Down and Dirty Guides to...” Covering all aspects of biodiesel, biofuels, and alternative energy. He is also the Managing Director of International Biofuel Solutions, LTD. Thailand and President of Information Specialists, Corp., USA He lives in Des Moines, Iowa USA with his wife, Tram and Son, Lennon.

These guides were written with the intent of providing “Down and Dirty” realistic, no BS, info on all aspects of the algae process. If you liked this EBook, we’d like to hear about it.

If you didn’t like it, **WE’D REALLY LIKE TO HEAR ABOUT IT.** Your comments will help make future editions of this eBook even better. Don’t hesitate to sound off.

Send all comments, complaints, criticisms, and compliments to dsieg@making-biodiesel-books.com

Other Books in the “Down and Dirty” Biodiesel Series TM:

- [Making Algae Biodiesel at Home](#) TM (New 2010 Edition coming Dec. 2009)
- [Making Algae Photo Bioreactors at Home](#) TM (out in Nov. 2009)
- [Growing Algae at Home](#) (out in Feb. 2010)
- [The Encyclopedia of Making Biodiesel at home](#)
- [Biodiesel Recipes](#)
- [Biodiesel Processors](#)
- [Washing and Quality Testing Biodiesel](#)

Dedication:

To Damien. Thanks for showing me the way back home.

Acknowledgments

No work of this size and scope can be made without the input, and help of many people. Any work, by any author is a collaboration. In this respect, this work is no different. I like to thank the following people.

Countless (and nameless) Vietnamese and Thai students contributed to this work in one way or another. (I'm also a teacher) They deserve credit. I'm sorry I can't list you all by name. You know who you are, and you have my profound thanks. While your grades may not have reflected it (LOL) I couldn't have done it without you. I owe you so much more than you know. I can honestly say I learned more from each one of you, than you probably did from me. It was my honor, and I, who benefited from knowing you. Thank YOU.

Countless, and by request nameless, people in the open source community. People who strongly believe knowledge should be shared with everyone, not hoarded for the benefit of a few. People who silently, without thanks or fanfare, put their money where their mouth is. My hat is off to you. I feel humbled by the selfless contributions you made to me. "Thanks" is such an inadequate word when compared against the 1000's of hours of patience, endless questions and the constant bothering I put you through.

With this work, I'm trying to "pay it forward" because of you. I hope it pleases you.

A big round of applause also goes to my customers, who also took the time to write to me, share their thoughts and input on this work. I keep updating it, usually every month, based on the feedback I get from you. You've also helped me to keep going. Your thoughts and comments have improved this work immeasurably. Keep them coming!

Last but not least, my wife Tram, and my son Lennon. Who gave me the respect, privacy, and didn't complain when I was working 16-20 hours a day for years at a time, on projects they didn't understand, and truthfully, could care less about. Instead they gave me encouragement not to give up during long years of trials and tribulations that contributed to this work.

Again, a simple "thanks" seems so inadequate.

Introduction

OK, I'm not going to BS you. Making biodiesel from algae is a whole different ballgame.

First off, let's get one thing clear; I'm not an "expert" on algae biodiesel. No one is. I'm not even sure there is such a thing. There are no textbooks to study, no college courses or degrees. In this field there is mostly interested tinker's sharing their knowledge, or huge companies, hoarding their commercial secrets. Mostly I'm a writer and teacher with major bent towards alternative energy.

If you're used to my other books where I have taken a step-by-step approach, this eBook is a radical departure. I've tried to outline this process as simply as possible. Some places it worked, in other places, I have been accused of technical gibberish. I'm sorry for that. It's a constant work in progress. But there is a reason why some things are difficult.

It's because SOME THINGS ARE DIFFICULT.

Trial and error in your personal situation is needed, and almost guaranteed. There is no "one-size-fits-all" in algae biodiesel. They are based on methods which have worked, but the variables involved in this undertaking, are too many, and too complex to cover in a short report such as this for all people, everywhere. I've tried my best though.

Is this difficult? Well, for those of you who think it's as easy as scraping the pond-scum off the bird bath and turning into heating oil, yeah, you're in for a surprise. If you're looking to click on a link inside this eBook and get all the algal oil you'll ever need flowing from your computer, you're going to be disappointed.

You're dealing with different processes here. These processes involve living organisms. When you introduce life into the equation, the capacity for variation increases dramatically. This is not a "static" process, like making biodiesel. (Mix A + B = biodiesel) It's a dynamic process, which means it changes all the time, in every situation, because introducing a life form into the process, forces that change.

On the other hand, creating biodiesel from algal oil is much easier in other ways. The trick is getting enough of it. It's a clean oil, not waste oil. No begging for waste oil, no filtering, no dewatering, no titrating, none of the hassles involved in using waste oil.

Some of the very best minds on the planet at Exxon-Mobil, at Chevron, even the US Department of Defense, are trying to work out viable method of mass producing oil from algae. They have billions of dollars to spend. They have unlimited resources. I have to admit, I don't belong in that class of individual, either financially, or intellectually.

But I do believe it's possible to create enough algal oil on a small scale to dramatically have an impact of your own personal energy needs. You can create enough to power your house, or small business.

This work is meant as an overview of the entire algae biodiesel process. It's not perfect. It scratches the surface of the subject, and is meant as a starting point, not an ending. You're literally going into the biodiesel wilderness where most fear to tread.

This work, however, is meant to get you started in the right direction. You will want, and need to branch out on your own from there as your personal situation dictates. All situations are different. I generally work and make biodiesel in Southeast Asia. The problems we encounter here are totally different than say, Portland Maine, USA, or Dundee, Scotland. Temperature, humidity, salinity, type of algal strain, and many other factors come into play.

Your aim in Making Algae Biodiesel at Home can and should be to create an abundant, never-ending energy source that can be made, and used economically, giving back into the life-cycle, as you take something away from it, in a complete, never-ending, biological circle. Nothing wasted, everything used.

Above all, don't get discouraged. I know I'm supposed to be all "you-can-do-it" in the introduction. But it's also important to be realistic about this project. Trial and error are inevitable, and truthfully, necessary. If you don't have the patience of Edison, don't try this at home, folks.

One final note: This eBook is intended for home-biodieselers. Not a commercial enterprise. Yes, I have included a number of commercial and large scale applications in here, but that is to get your brain working and see what other people have done are doing, where the big money is going. These are ideas to enlarge your own algal oil production. This work is not intended as a way to set up your own algae biodiesel enterprise and retire as the next J. Paul Getty.

The energy mess we are in now is going to be solved, I think, in large part by back-yard tinker's, small-scale production and home-grown solutions. In short... you. Don't count on the government to help you. There are too many vested interests in the industrial-complex that profit by keeping you "energy-slaves." Their one and only passion is keeping you tied to the gas pump. Believe it.

I personally respect every single one of you, more than you know, for having the courage, and the forward thinking, to even envision this goal. Let alone take steps towards it. Most people can't even do that. You are already a minority, and heroes in my eyes.

Also keep me updated on your progress...I mean that. I like hearing from you. You guys, my steady customers, have been an inspiration to me. I can't thank you enough for your encouragement, and also for the kick in the ass when I needed it.

All the best, and the absolute best of luck to you and your families. Keep in touch with me.

David Sieg

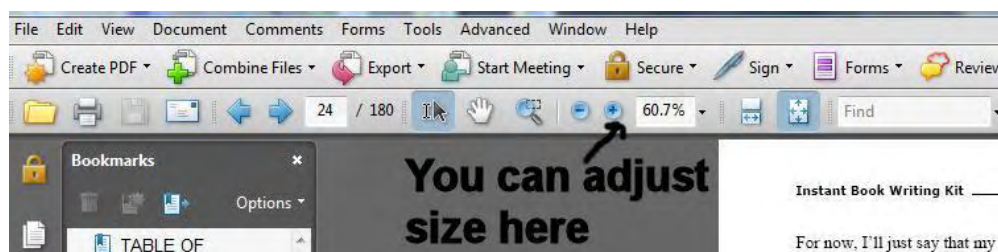
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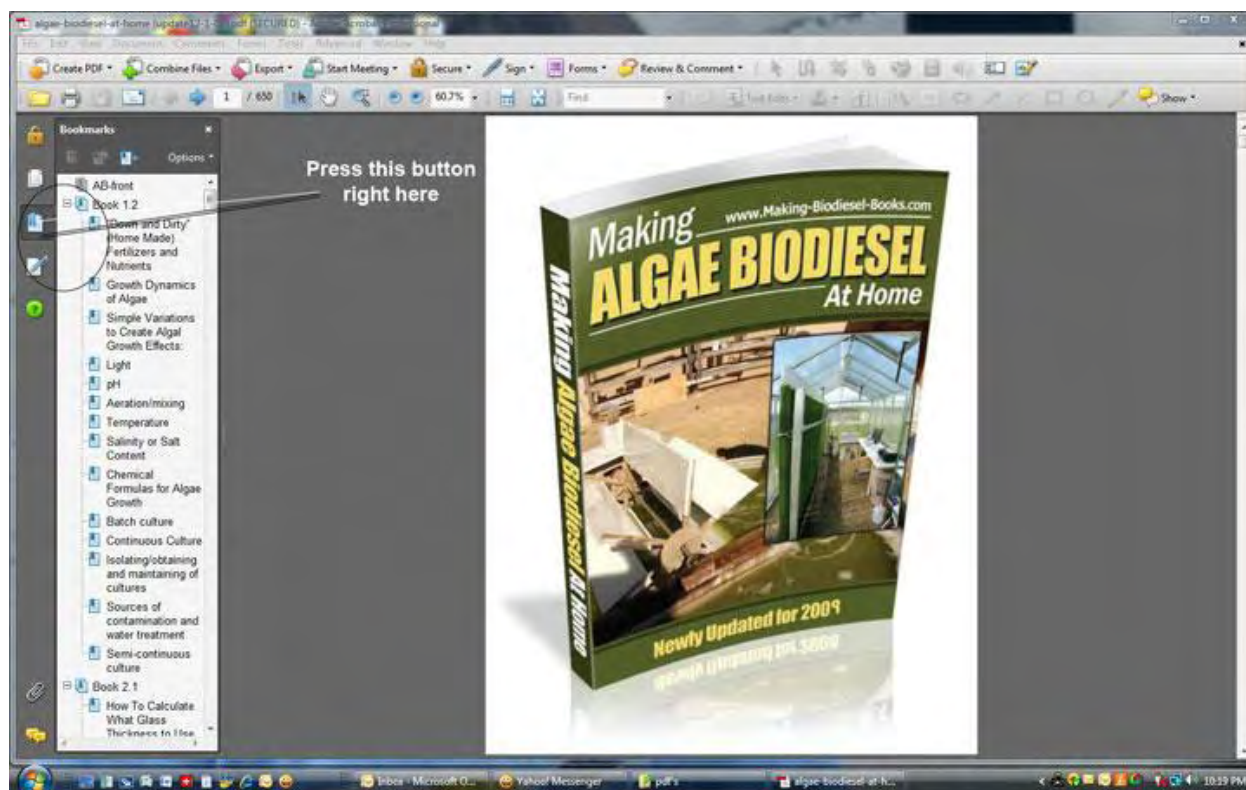
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How to Use this eBook...Part I

Adobe eBooks are extremely easy to use. For example, unlike a regular book, you can adjust the size of the font to any size you want. This is very helpful for vision impaired readers.

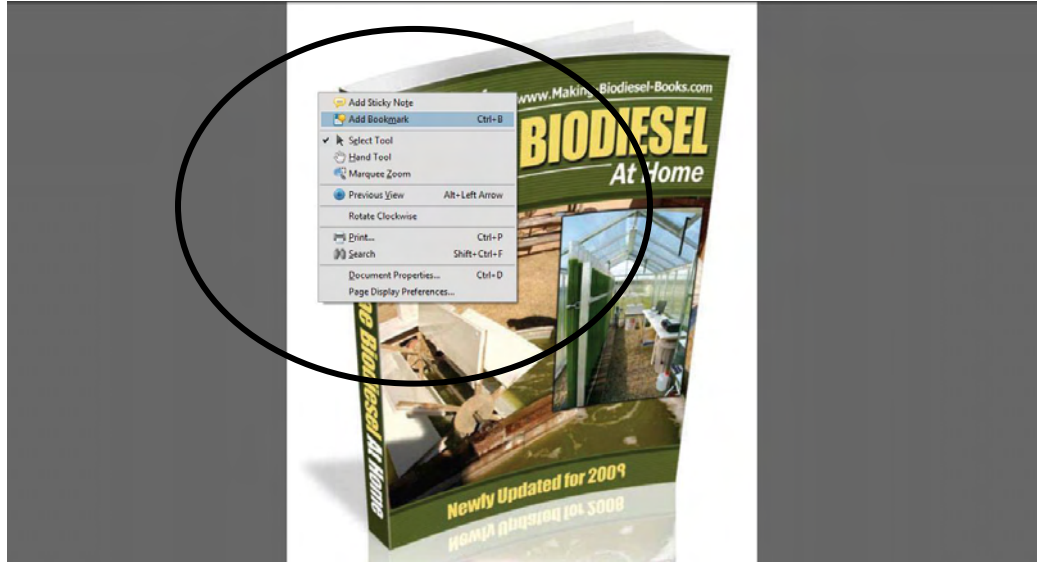


You can also go to any section of the book, easily and quickly. Press the button indicated and you'll find a full Table of Contents.



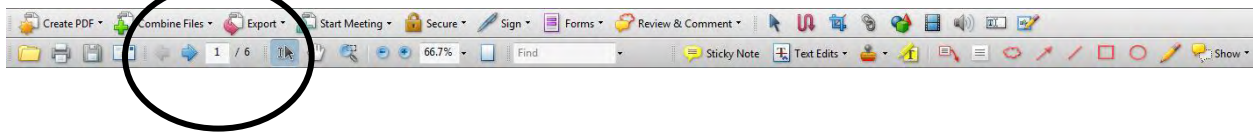
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Simply "right click" your mouse and a menu will appear. Click "add bookmark" and your page choice will be added to the menu on the left.



You'll need to click on the "untitled" section and add a name for your bookmark.

You can also jump to any page, easily and quickly by typing the page number in right here:



This is a very quick overview of some of the features of Adobe reader. There are many more and you can **find out many more by reading the "help"** section on the top tool bar.

How to Use This Book...Part II

This book is set up to be as easy, or as difficult, as you want it to be. It is set up to give you as little detail as needed to get the job done, to giving as much detail as you could possibly want.

It starts with a basic flowchart overview so that in a glance you can see the various stages and processes necessary.

The **"Quick Start Guide"** is available to give you the essential necessary details when **you need them. It provides "What" to do.**

The **"Down and Dirty" Guides** will provide most of the detail you need to actually accomplish the task, presented in an easy-to-understand, bulleted format, without a lot of details to bog you down. It provides **"How" to do** information.

After that, come relevant details you may need, or want, for any given procedure. It goes into more depth and provides a better understanding of the **"why" you do certain actions and can also be used for trouble shooting.**

The "Technical Data" Section is provided for an in-depth understanding of the subject, and various different ways, and means of accomplishing your goal.

FIRST...

Read through the entire book. At least once. If the Technical Details sections get to be a little much, then skip it.

NEXT...

Read the section you need to begin. Then read the "Down and Dirty" Guide for that section. Try to visualize the actions you're about to take.

· Gather the material needed for each section before you begin.

TAKE ACTION...

There is not much more to it than that. This can be as easy, or as difficult as you want to make it. My advice? Make it as easy as possible. If something doesn't work, try again.

Above all, make notes of everything you do. Note amounts, times, and durations, keep careful track of what DOESN'T work, as well as what does. It is your notes which will prove more invaluable than even this ebook.

Above all, don't give up. Trial and error and inevitable. Visualize your goal, and keep moving forward.

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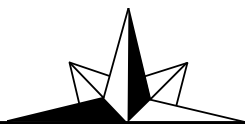
Book One

Cultivating Algae

For Biodiesel

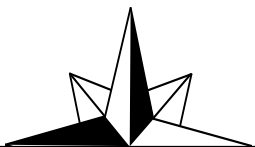


At Home



**“There is no other resource that
comes even close in magnitude
to the potential for making oil,”**

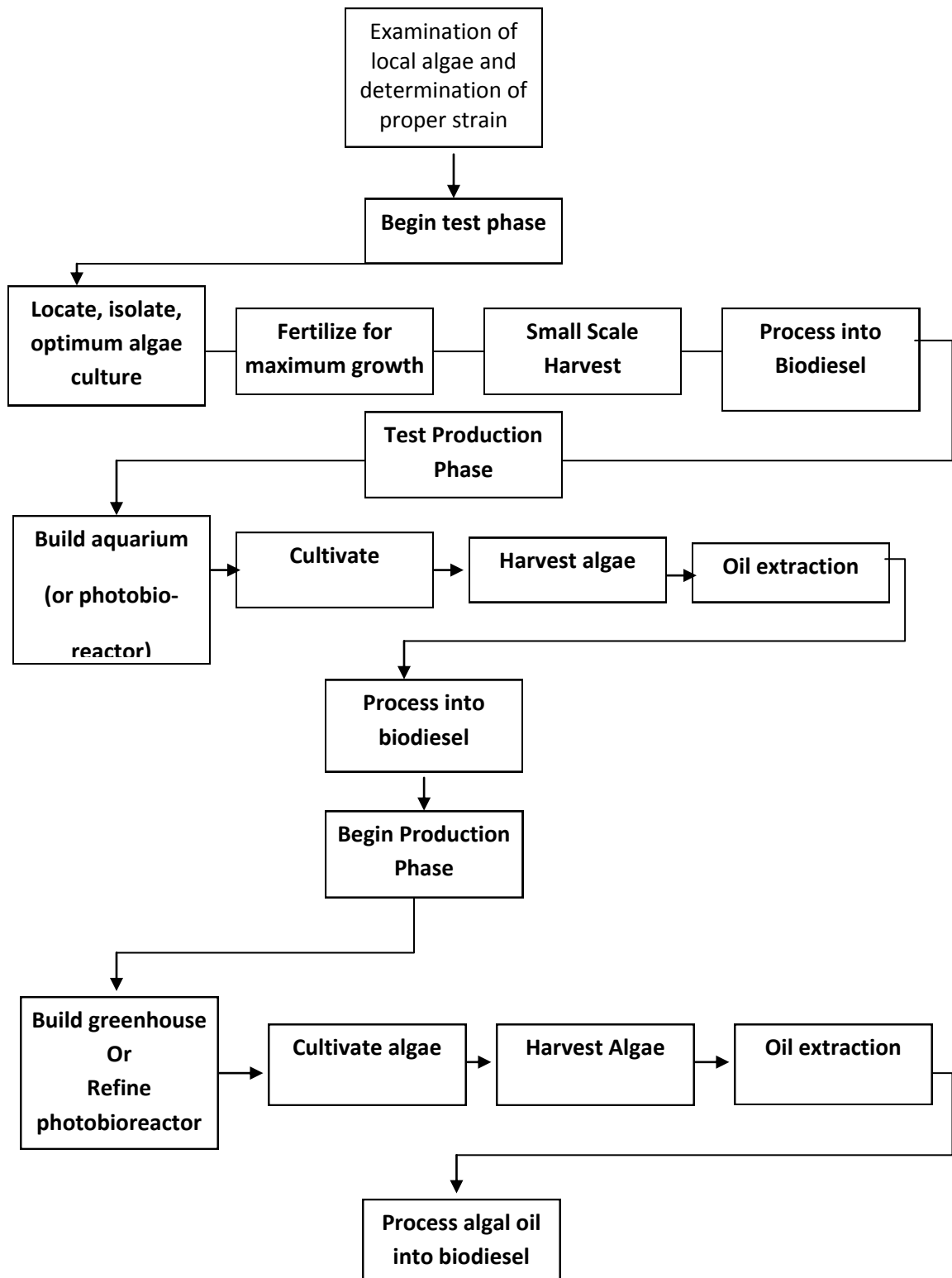
**John Sheehan, energy analyst
with the National Renewable
Energy Laboratory (NREL) in
Golden, Colo.,**



**“If we were to replace all of the
diesel that we use in the United
States” with an algae derivative,...
we could do it on an area of land
that’s about one-half of 1 percent of
the current farm land that we use
now.”**

...Douglas Henston Solix CEO

Flow chart of The Entire Algae to Biodiesel Process



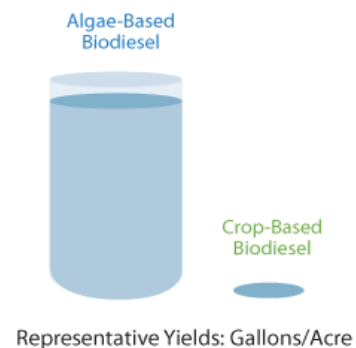
Algae Overview

WITH THE INCREASING INTEREST in biodiesel as an alternative to petro-diesel, many people are now looking at the possibility of growing micro-algae as a solution to the problem of peak oil. Micro-algae is, by a factor of 8 to 25 for palm oil. and a factor of 40 to 120 for rapeseed, the highest potential energy yield temperate vegetable oil crop.

Michael Briggs at the Univ. of N. Hampshire Biodiesel group estimates that using open, outdoor, racetrack ponds, only 15,000 square miles could produce enough algae to meet all of the USA's ground transportation needs. Transportation accounts for 67% of US oil consumption according to the *Atlantic Monthly*, July/August 2005. We'll say more about the 15,000 square mile number below. If all of this land were in one rectangular piece, it would be 120 miles by 125 miles—about 1/7th of the area of the state of Colorado.

Gallons of Oil per Acre per Year

Corn	18
Soybeans	48
Safflower	83
Sunflower	102
Rapeseed	127
Oil Palm	635
Micro Algae	5000-15000



The National Renewable Energy Laboratory

During the oil crisis of the 1970s, Congress funded the National Renewable Energy Laboratory (NREL) within the Department of Energy to investigate alternative fuels and energy sources. Between 1978 and 1996, the Aquatic Species Program (ASP) focused on the production of biodiesel from high lipid-content algae growing in outdoor ponds and using CO₂ from coal-fired power plants to increase the rate of algae growth and reduce carbon emissions. Prior to this

program, very little work had been done to understand the growth process and metabolic composition of algae. As a result of the ASP there are now some 300 species, mostly diatoms and green algae, in a collection stored at the Marine Bio products Engineering Center that is available to researchers interested in developing algae as an energy source.

Some results listed in the Close Out Report of the ASP are:

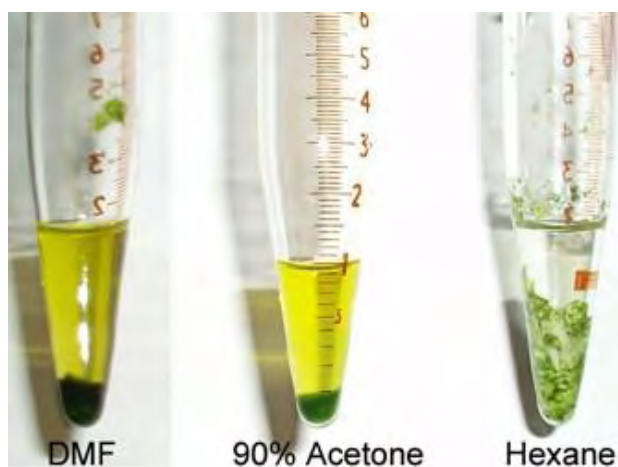
- Under optimum growing conditions micro-algae will produce up to 4 lbs./sq. ft./year or 15,000 gallons of oil/acre/year. Micro-algae are the fastest growing photosynthesizing organisms. They can complete an entire growing cycle every few days.
- One quad (1015 BTU or 7.5 billion gal.) of biodiesel could be produced on 200,000 ha of desert land (equivalent to 772 sq. mi., roughly 500,000 acres). (To produce one quad from a rapeseed crop would require 58 million acres or 90,000 sq. mi.)
- The outdoor race-track pond production system is the only economically feasible approach given the cost of petroleum in 1996. (One of the problems with growing algae in any kind of pond is that only in the top 1/4" or so of the water does the algae receive enough solar radiation. So the ability of a pond to grow algae is limited by its surface area, not by its volume.)
- Algae contains fat, carbohydrates, and protein. Some of the micro-algae contain up to 60% fat. Once the fat is 'harvested'— some 70% can be harvested by pressing—what remains becomes a good animal feed or can be processed to produce ethanol.
- The desert test location in New Mexico had sufficient sunlight, but low nighttime temperatures limited the ability to achieve consistently high productivity.
- There were problems getting lab-cultured algae to grow in the outside pond environment.
- No tests were carried out on mechanisms and procedures for harvesting the algae nor on the extraction of oils from the algae.

Algae to Biodiesel: A Pilot Project

To create a prototype of alga diesel, *Scenedesmus Obliquus* was grown in two one-liter flasks of water and WC Media, a combination of phosphates and other nutrients that are required to grow the specific strain of algae. The alga was stored in a climate-controlled, sterile growth chamber for approximately one week.

Once enough alga was grown, it was separated from the water and remaining nutrients. The separation was done through a process of micro-filtration through a filter with holes 8 microns wide. The algae was then blotted dry with a paper towel to ensure that there was as little water as possible still remaining with the algae.

To begin the extraction process, the algae and filter was placed in a test tube. Three different chemicals were tested to see which one would extract the most algae: 90% acetone, hexane,



and dimethyl formamide (DMF). Each test tube sat for approximately 5 minutes until some reaction could be seen between the algae and the chemicals. The final results can be seen in Figure 1. To quicken the process and to separate the unnecessary materials (i.e. cell walls, filter particles) from the necessary ones (i.e. the oils), the tubes were placed in a centrifuge and spun for approximately 5 more minutes. Following the centrifuge, the three tubes were placed in a well-ventilated area to evaporate the

remaining solvent from the oils.

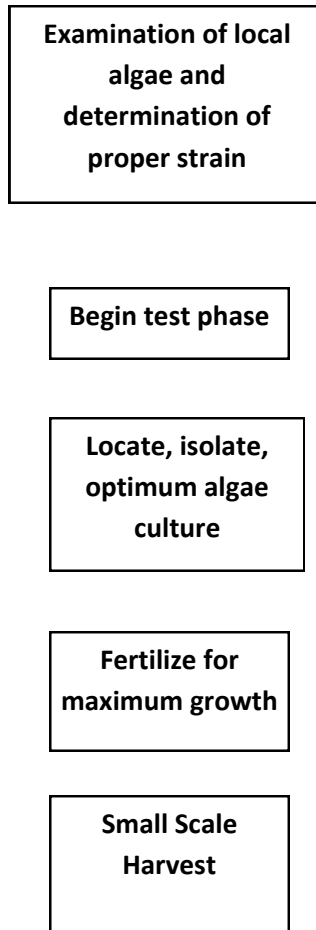
The hexane did not separate any cells and did not, in fact, look like there was any reaction among the chemical and the algae. The DMF never fully evaporated during the time of study, making it an unlikely source for extracting oils in a quick manner. The 90% acetone had the best results, showing a small film of oil. Such process would have to be done on a larger scale to create enough oil to convert into biodiesel.

However, had there been enough oils from the algae, the process to convert those oils into a diesel would not be a hard process. For the prototype, a simple vegetable oil was used so that there was enough oil. Four grams of Sodium Hydroxide (NaOH) and 250mL of methanol were

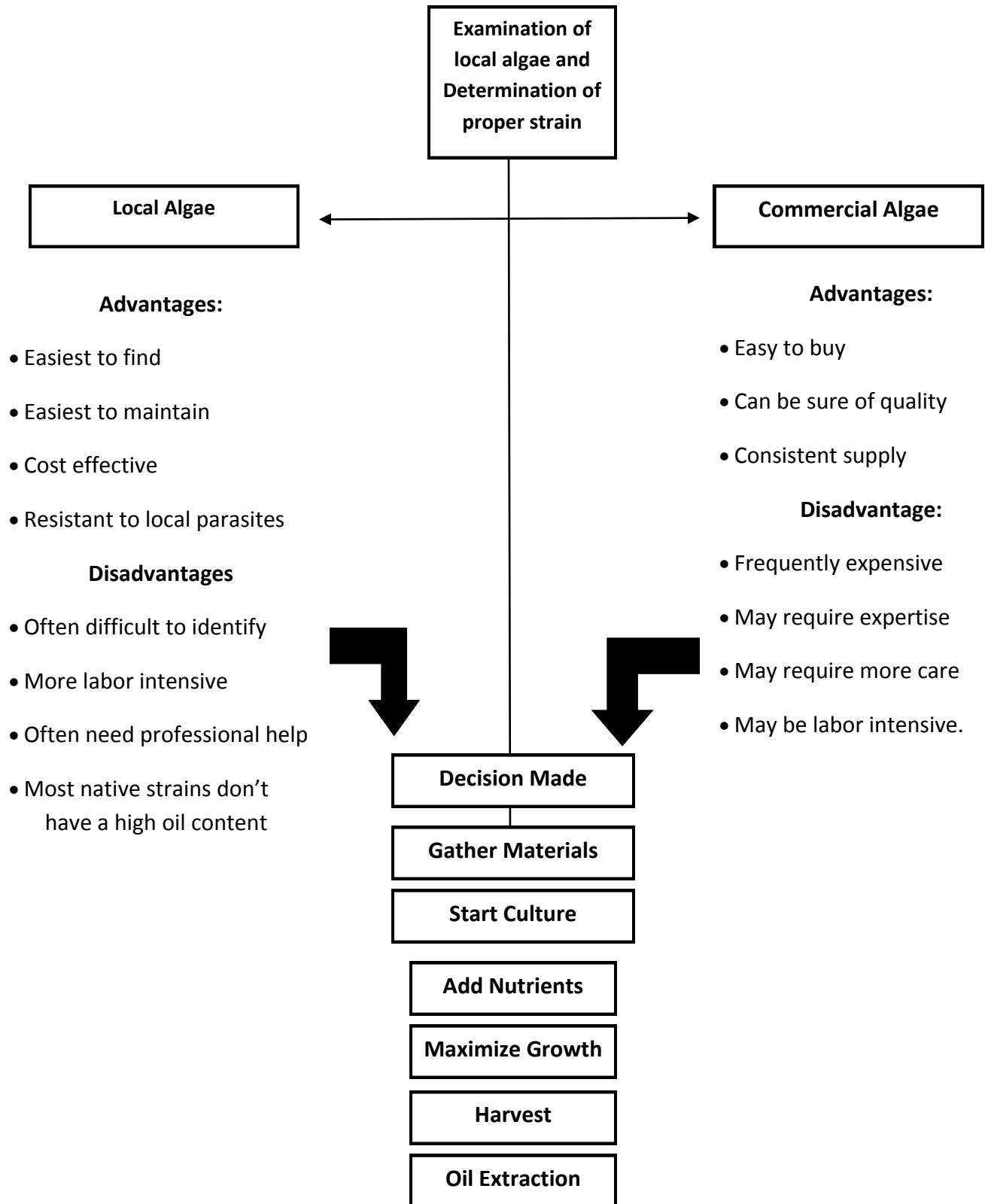
shaken together in a name brand plastic soda bottle for approximately one minute. The vegetable oil was heated to 60°C and combined into the NaOH and Methanol mixture, than shaken for 6 more minutes. This process created a large amount of bubbling between the chemicals and the oils. Following the 6 minutes of shaking, a solid orange juice type substance resulted. This substance would settle for approximately 8 hours, where following that time there would be an obvious separation of the diesel and waste, which sinks to the bottom.

The prototype was done under a batch process, which would not be the best way to produce the diesel on a large scale especially given the labor-intensive process that we used. **However, it proves that creating biodiesel fuel from algae is possible.**

Flow chart of The Algae Cultivation Process



Quick Start Guide Cultivation



A “Down and Dirty” Overview of the Process

Phase One: Examination of local algae:

An examination of local algae is done for a number of reasons.

- What works best naturally for your environment, ultimately will eliminate problems with invasive algae down the road during the aquarium and/or open pond stage.
- Easy to procure.
- Easy to resupply
- Local algae strains reduce costs
- Local algal strains are more resistant to contamination

If you're lucky, a local strain will also have high lipid (oil) content. This is the ultimate goal.

- You can also short-cut this process by going to your local university micro-biology Dept. and seeing which algal strains are native to your area. If a high yielding strain is available, start there.
- If not, try to identify a strain yourself.
- If this proves impossible, simply start with ANY algae from your area.
- If possible, and you can identify more than one species, take as many different strains as possible for testing and comparing.

Buying an Algal Strain

If a local strain is not available or unacceptable, then your choices are to buy the strain you want. With a bought strain you can be sure of

- Quality
- That it is the correct strain
- It should be healthy to begin with
- You can be sure of a supply

However the disadvantages are:

- Depending on the strain, they can be expensive
- They may not be able to resist local contamination
- Extra care must be taken, i.e. More labor intensive

Phase II

If local...

- Procure a small sample
 - This can be easily done. Simply go down to local bog/marsh, etc, and scoop some up, along with some water, and put into a glass jar.
 - Keep the algae in a sunlit location during the day.
 - If you're going to keep it for any amount of time, add nutrients daily.

If strain is commercial variety

- Contact a local culture collection about the particular strain you're thinking of using.
- Explain why you want the algae, and if they have any suggestions
- Ask about it's "lipid" (Oil) value.
- Ask if they know of a strain in their collection with a higher lipid value.
- Ask about nutrients
- Ask about any special growing needs or techniques.

While buying an algal strain can be much more expensive, the time you save, and the expertise you gain by not "re-inventing the wheel" can be well worth the exchange.

Phase III....Start Culture

In any wide mouth glass container, take a small amount of algae out of your supply. (See Making an Algal Incubator)

- Add a small amount of water, just enough so that the algal culture “floats.”
- Let the algae sit in the sun light as much as possible.
- Then adding nothing else, watch the culture for a few days
- Does it grow, or does it die?
 - If it grows (doubles in size) with no interaction from you, stop. You’ve completed this section.
 - If it dies, try again.
 - Vary the amount of sunlight
 - Vary the amount of algae
 - Vary the water supply

The point of this exercise is...

- To get an algal specimen to grow without any outside help. If it does...
 - This is a strong species
 - This is a species which hopefully will excel with nutrient manipulation.
 - If it has a high lipid content, you’re well on your way to a successful project.

Phase IV...Add Nutrients

At this point you have a strong species of algae with a high lipid content. You know..

- With a minimum of fuss and bother it will grow
- You'll have an idea of how fast it will double it's mass
- You'll know the correct amount of sunlight
- You'll know the correct amount of water necessary

Next you'll want to add nutrients to see the various effects. The hope here is that they will enhance growth, and/or speed up the growth process.

- Start with fish nitrates (feces) if available.
- Try plant food at your local aquarium shop
- Try dried animal manure, ground into a powder
- Try "Miracle Grow" or a commercial variety of plant food.

Try using very small amounts of each in the beginning. Simply sprinkle over the specimen or mix into the water.

After you tried ONE thing. Stop. Watch what happens. (A few days)

- In some case, your specimen will die. If so, start again. And now you know not use that particular nutrient.
- If nothing happens, add another nutrient
 - Vary the amount of the nutrient
 - Vary the amount of sunlight
 - Vary the amount of water

What you WANT to happen is that the growth of the algae is accelerated

- If the algae was doubling in size every 3 days, and now it's doubling every 1.5 days, stop.
- You've identified key nutrients and/or conditions to enhance growth

Phase V...Maximize Growth

In this phase, the goal is to maximize all aspects of the algal growth. By now you should know...

- What algal strain is best for your environment
- That your algal strain will grow with little or no help from you
- The “doubling rate” of your algal strain
- The amount of sunlight necessary.
- The amount of nutrients necessary for growth
- The kind of nutrients your algal species prefers
- The “doubling rate” with nutrients.

Now it's time to start maximizing the growth rate.

- To do this, you'll use all the information you've learned from before.
- Now, vary the amounts of sunlight.
 - Add a Glowlux light or florescent light.
 - Try 6 hours of light, try 12 hours.
- Vary the amount of nutrients. Add more. Add less.
- Mix the nutrients with other nutrients.
 - Try adding nitrates with plant food.
 - Try any combination of the above.

The purpose of this phase is to get as much growth from your algal species without killing it. As before, only try one difference at a time. Watch the results. Then try again.

If you do terminate the algal growth, go back to what has worked, and proceed from there.

Phase VI....Harvest

By this time, you'll know...

- What algal strain is best for your environment
- That your algal strain will grow with little or no help from you
- The “doubling rate” of your algal strain
- The amount of sunlight necessary.
- The amount of nutrients necessary for growth
- The kind of nutrients your algal species prefers
- The “doubling rate” with nutrients.
- How to maximize the growth rate
- Which combinations of nutrients and sunlight are best.
- How much algae you can reasonably expect to grow within a given time period.

Now it's time to harvest your algae and dry it.

This step is easily accomplished.

Wait until the algae culture starts the “declining relative growth” phase. (More on this later) But basically when it stops with the steep upward growth climb. At this point, remove half the algae.

Depending on the size of the algae culture I'm working with, you may want to take it all, or take less than half..

- If you want to keep experimenting, leave some of the successful culture behind.

On a small, flat mesh screen, spread the algae out, put it into the sun and let it dry.

Let it dry in the sun until it changes color, and all water has evaporated. Depending on your location, this could be a day, or three.

If you're the impatient type, use a hair blower, keeping it at least 1 foot (1/3 meter) away from the algae.

Phase VII...Oil Extraction

By this time, you'll know...

- What algal strain is best for your environment
- That your algal strain will grow with little or no help from you
- The “doubling rate” of your algal strain
- The amount of sunlight necessary.
- The amount of nutrients necessary for growth
- The kind of nutrients your algal species prefers
- The “doubling rate” with nutrients.
- How to maximize the growth rate
- Which combinations of nutrients and sunlight are best.
- How much algae you can reasonably expect to grow within a given time period.
- If your algal strain will survive half extraction
- The ratio of “wet weight algae” to “dry weight algae”

Now you're ready to try and extract algal oil

What you'll need.

- A handful of dried algae.
- A garlic press
- Fold the algae upon itself, and pack it into the garlic press. You don't need a lot, just keep folding as much algae into the press as you can.
- When the garlic press is full, simply slide the plunger over the algae, and press with all your might. You may need to fold more algae into the press, if so, put more in.
- Sometimes, the oil, being vicious, may take awhile to work it's way out.
- Keep pressing.

If even one drop of all comes from the press. You've succeeded.

In reality, you should have more than that. But even one drop is a success.

At this point you need to try and identify factors which encouraged the algal oil growth.

If no oil comes out, then possibly...

- The local strain your using has a low lipid content. (Try another strain)
- You may need more algae for experimentation. (Get more algae, get a bigger press)
- You may want to try buying a established high lipid strain.
- More experimentation may be needed in the maximizing stage

At this point you can extrapolate how much algae you'll need to produce, in order to satisfy your energy requirements. For example (Purely hypothetical...don't follow this as a guideline)

- If you were able to produce 10 pounds of (wet) algae
- When dried, this was reduced to 1 pound of dry algae
 - AND 1 one pound of dry algae was able to expel 8 ounces (50% of dry weight) of algal oil, then...
 - You need 8 pounds of dry algae to produce 1 gallon of algal oil.
 - If you use 300 gallons of fuel per month
 - You'll need to produce 2,400 pounds of dry algal mass per month

Once again, these numbers are purely hypothetical. You may find, you'll need much less algae...or much more. The whole point is to determine whether this is indeed possible and/or feasible, for you to do on a theoretical basis. It will also give you an idea about

- Future land requirements needed.
- Costs involved in building large scale
- Costs involved in nutrients
- Necessary size of open-pond, or photobioreactor

If all the factors are a go, and you indeed have been able to expel oil, consider it a major success.

If you can't get the numbers to work, then at this point you know NOT to go any further with this project. Your options then are...

- Go back to step one.
- Identify another algal strain, rinse and repeat...
- Employ professionals to help

Now it's time to look at choosing the correct algae oil strain, and where to buy it...

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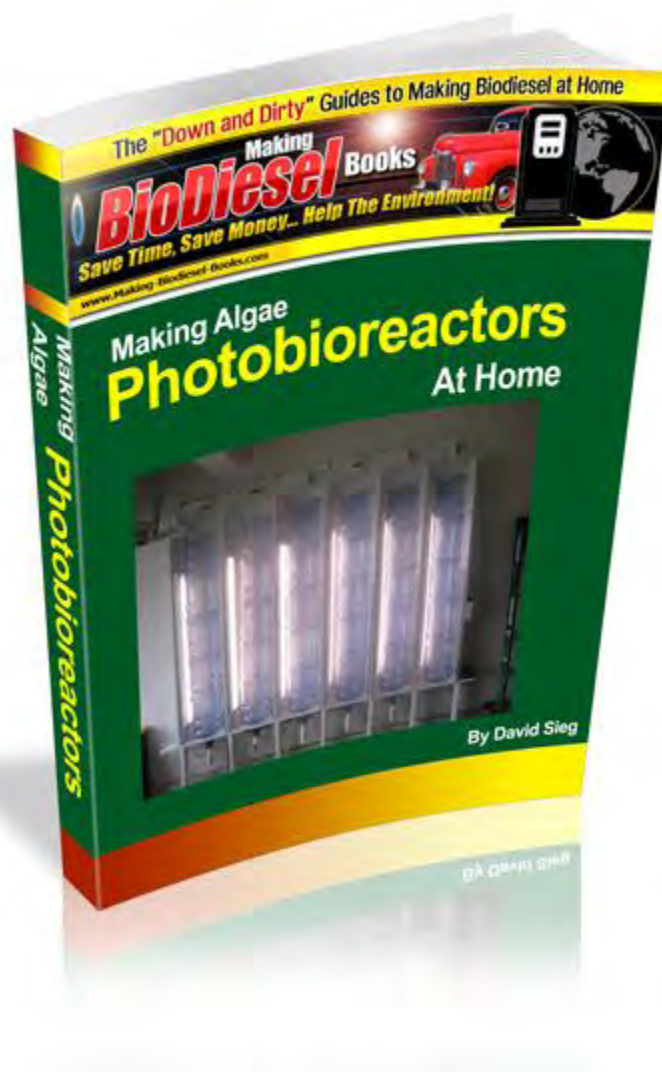
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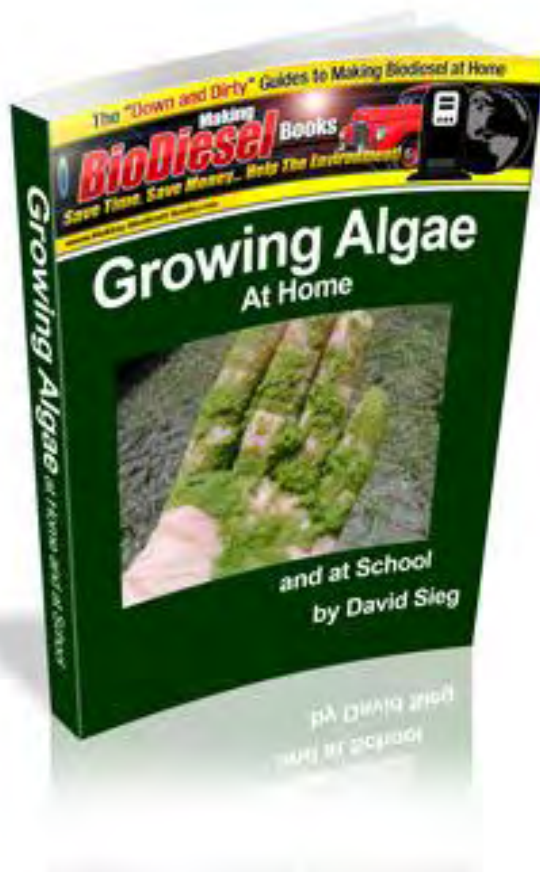
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