An Algae Bioreactor from Recycled Water Bottles

by mfischer on February 1, 2009

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**intro:**  An Algae Bioreactor from Recycled Water Bottles

In this instructable, we describe how to build a photo-bioreactor that uses algae to convert carbon dioxide and sunlight into energy. The energy that is produced is in the form of algae biomass. The photo-bioreactor is built from plastic recycled water bottles. By designing the apparatus to be compartmentalized, we are able to do many experiments in parallel.

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By using algae as a biofuel, we can increase the world's supply of oil while at the same time we decrease the amount of atmospheric carbon dioxide used during its production. The resulting product is a sustainable biofuel whose carbon footprint is neutral inasmuch as the CO2 produced on consumption is essentially balanced by the CO2 used in its production. In this instructable, we first make the carbon dioxide delivery system, then mount the water bottles on a rack, and then inoculate the bottles with algae. After letting the algae grow for a week, we extract the biomass.
**step 1: Make Carbon Dioxide Delivery System**
To make the carbon dioxide delivery system, connect an eight port sprinkler system manifold to a one inch long PVC pipe. To get good seals, use Teflon tape to tape the threads before attaching the pieces together. Next, attach the one inch pipe to a T-connector. Block off one end of the T-connector and attach the other end to a foot long PVC pipe.

![Image of carbon dioxide delivery system](http://www.instructables.com/id/An_Algae_Bioreactor_from_Recycled_Water_Bottles/)

**step 2: Attach Tubing to Manifold**
For each manifold, cut eight-pieces of flexible tubing and connect each piece to a port of the manifold. The manifold that I am using has a dial on each port to control the rate of flow. Make sure all the ports that you use are open and allow approximately the same amount of carbon dioxide to flow through the port.

![Image of tubing attached to manifold](http://www.instructables.com/id/An_Algae_Bioreactor_from_Recycled_Water_Bottles/)

**step 3: Mount Carbon Dioxide System**
Mount the air system to a metal rack using zip ties. Attach the air system to a tank of carbon dioxide.

![Image of carbon dioxide system mounted on rack](http://www.instructables.com/id/An_Algae_Bioreactor_from_Recycled_Water_Bottles/)
step 4: Mount Water Bottles
Hot glue the water bottles to the metal rack.
**step 5: Make Algae Media**

We next make the medium to grow the algae. Although there are many possible mediums, a standard garden store fertilizer contains all the nitrogen and nutrients that the algae need.
**step 6: Media Inoculation**

A good source of algae is pond algae, if available. If not, there are a large number of online vendors that sell batches of algae. To inoculate the culture, measure out a fixed amount of algae and add it to the growth medium.
**step 7: Growth and Harvesting**

After several days of sunlight and CO2 exposure, the algae are much denser. A French press is then used to extract the algae from the solution. The biomass of the dried algae can then be used as a fuel. As a by-product of this process, a large amount of atmospheric CO2 is sequestered.

By: Michael Fischer, Stanford University, mfsicher @t stanford.edu
Maverchick says:
Mar 19, 2009. 2:36 PM  REPLY
Don't get me wrong, I think this is a really cool idea!! -but if you glue the water bottles to the wire racks, then how do you empty them? Do you have to invert the whole stand?

yokozuna says:
May 16, 2009. 10:45 AM  REPLY
read step seven.

Maverchick says:
May 28, 2009. 8:14 PM  REPLY
I understand how to get the algae out of the solution, what I was asking was how do you get the solution out of the bottle.

xhmko says:
Apr 26, 2009. 11:24 AM  REPLY
Hot melt glue is quite easy to break cleanly
Can algae be grown in slowly moving water? If so, perhaps algae could be pumped from bottle to bottle and then through a central collection device that would skim off some algae, add fertilizer, and then pump an algae inoculation and new fertilizer back into the system...

I realize that I need to stop hypothesizing about a new feature on this site and just build it!

I've been working on an idea like this, with polycarbonate (like the used in windows), but I chose the wrong algae.

Yes, it can be grown in slowly moving water. In fact, watch this video:

I think this guy is on to something big. Have you built anything similar? Would love to see it.

Is it normal that I can't see the video?

Could I logically bury the algae in the ground so that it would fertilize my garden?

In Maui they are harvesting sea algae from the beaches to improve them for swimming and using the algae to fertilize local farms.

Yes

Hello
Is algae oil suitable to be used as cooking oil? Does it have any strange taste or odor? What color is the oil?

Yes algae oil can be used for cooking.
I have no clue as to flavor but I have seen a video of a man eating a brownie made with it and another of researchers drinking it straight.

Now that's a very cool thing that everyone should have at home! 5 stars!

The air bubbles maximize the surface area for the algae to absorb the carbon dioxide.

Hm. Just a thought:
If you burn the algae and use the CO2 to feed the next ones? Than you'll get energy out it without adding CO2 to the atmosphere.

But anyhow. I am very interested in how to make fuel from the algae. Can you make long burning briquettes from it? Or how do you get the oil from it and how do you use it to make energy?

Quite, quite interesting...
Could you give an example of what it could be used to fuel?

Theoretically you could, but it would take waaayy longer. Algae needs a smaller environment (and maximum sunlight exposure) to be effective in those quantities.
mizupan says:
In a closed loop system there is no way for it to get co2 from the atmosphere. If it is an open system it will get co2 from the air - and probably enough to grow algae - algae in a pond has no problem growing. However, if you want to accelerate the growth of algae - adding additional co2 will increase the speed with which it will grow and increase your harvest cycles.

Mar 7, 2009. 6:17 PM

REPLY

tallfuzzyone says:
quick question, when you introduce the CO2, how do you keep the bottles from exploding under pressure? is there some sort of venting system? when does the excess oxygen go when its released? and what pressure source did the co2 come from? and last but not least, after the crushing/extraction process, can you re-introduce the crushed algae to a medium again and heal, or do they all die when you remove the oil? if you can re-introduce post-extracted algae, it would be like having a green squishy dog that produces gas for your car whenever you "hug"(really harsh painful hug through a strainer) it! :D

Mar 7, 2009. 6:17 PM

REPLY

frollard says:
The bottles are not sealed.

April 22, 2009. 11:38 PM

REPLY

catboo22 says:
I was wondering if anybody has actually made fuel using this method? If so please tell me your results.

April 15, 2009. 5:48 PM

REPLY

GBlaze42 says:
What is the type of water you are using? is it distilled? normal tap water could be a problem.

February 5, 2009. 8:51 AM

REPLY

ap66218 says:
distilled is always a safe bet with any experiment, but tap water that has sat out overnight can be used too, for that gives time for the chlorine in the water to dissipate.

April 1, 2009. 1:44 PM

REPLY

amateur6 says:
I love it! But... "The biomass of the dried algae can then be used as a fuel." Isn't that a little "Step 2 -- then a miracle occurs"-ish? I guess I was hoping for a little more, teased by the word "bioreactor".

February 3, 2009. 5:31 AM

REPLY

Mother Natures Son says:
Actually, burning it would probably release less CO2 than just letting it decay--I'm not certain, mind, but it seems like some carbon would remain sequestered in the ashes. Yes? No?

February 19, 2009. 11:44 AM

REPLY

kingalex1 says:
you are correct.... ashes are mostly carbon i believe...

February 23, 2009. 11:34 AM

REPLY

A good name says:
The one thing you have to understand is that there's a limited amount of matter in the earth and basically matter just goes through phases. For instance, a body will eventually decay into soil.

March 7, 2009. 10:01 PM

REPLY

PKM says:
I think the mention of sequestering is confusing the issue slightly. Sequestration only works when atmospheric carbon is fixed by plants and then stays in the ecosystem as plant or animal matter, as opposed to carbon-neutral fuels.

February 3, 2009. 5:31 AM

REPLY

If you plant a tree, it sucks some carbon out of the air to grow, and when it dies the carbon it contains (in theory) stays in the ecosystem as it is consumed by fungi, woodlice, other plants etc. for them to grow. By doing this we are (again in theory) balancing the carbon that is coming out of the ground and into the air by mining fossil fuels.

The alternative use for plants is "carbon-neutral" fuel. Burning the algae biomass will release CO2, but that carbon came out of the air in the first place so the balance isn't changed overall. Using carbon-neutral fuel is never going to decrease the percentage of CO2 in the air, but it doesn't contribute as much as digging stuff out of the ground to burn.

As for using the biomass for fuel, I was under the impression that the algae sludge was basically crushed and separated - the algae contain vegetable oil, which you can skim off and use for making biodiesel or whatever, and the rest is a watery goop full of plant matter and so on that would ideally go back into the reactor to fertilise the next batch. The ideal sort of algae would be one that readily separates into pure hydrocarbons and pure fertiliser.
no algae can instantly separate into hydrocarbons or fertilizer, while some algae might contain hydrocarbons they are in such a small amount that they cant really be utilized, what you can do though is grow the algae under such ideal conditions that when the cells die they release a fair amount of oil into the water, if you can havest this before the rest of the algea consumes it you have an economican way of reteiving oil.

According to the guy with a lab coat and a bunch of microscopes linked in the video by aurora above says algae biomass is up to 50% hydrocarbon lipids.

I think you misunderstand me- I wasn't saying the Instructable was wrong, just that there existed possible confusion because of the combination of the sentences

*The biomass of the dried algae can then be used as a fuel. As a by-product of this process, a large amount of atmospheric CO2 is sequestered.*

As I understand it, sequestration involves absorbing atmospheric CO2 and storing it, carbon neutral fuels involve creating fuels from atmospheric CO2 so the net contribution is zero. I was just trying to clarify a possible misconception that the same atmospheric carbon won't be both sequestered and go into fuel. My point was just that any carbon sequestered reduces the oil yield, because there is no "something for nothing"- see Caladus’ comment, the algae will either sequester or be a carbon-neutral fuel, depending on how it is used, but not both simultaneously: A minor point really.

And of course you're not wrong to point out my error, but I don't see what the problem is- I can't find a concrete difference in the definition of plant oil and vegetable oil, other than that through received usage there may be an assumption that "vegetable oil" means edible crop oils (olive, corn, rape etc).

The intro to the Wikipedia article (http://en.wikipedia.org/wiki/Plant_oil or http://en.wikipedia.org/wiki/Vegetable_oil) says "Vegetable fats and oils are lipid materials derived from plants", so if we include photosynthetic algae under a broad definition of "plant" I don't see the problem. If you can give me a more precise definition then I might be able to correct the error.

Oh come on, you'll jump on a broad definition to save your hide between veggie and algae oils but you can't rap your mind around the idea that not all the carbon used in making the algae, is used to make the oil. I don't care of you pump the CO2 into the ground and it sits there until the sun goes red and eats the earth. The only true "forever sequestration" happens in a black hole. So they say anyway, I question that one. However we are not on that subject.

Not all the CO2 that the algae takes in gets converted to oil, some is sequestered. He used the term correctly. Everyone else I have ever talked with calls algae oil not veggie oil. Your the only one I seen do that. If you wanted to say plant oil you should of said so. At least you didn't call it corn oil.

I'm not going to sit here and debate this with you any longer. If you want to pull out the definition of sequestered also from Wikipedia it says "CO2 sequestration, the storage of carbon dioxide in a solid material through biological or physical processes " see http://en.wikipedia.org/wiki/Sequestration That is what he did isn't it? I didn't see it say anything about it having to be forever, or in a 100% fashion. He did what he said he did. The only one confused by the usage of the word is you, or so it seems to me.

So in every sense of the word he used it correctly, as I said it's pointless to debate this with you. Case closed. Try not to just look up terms to cover what you think is right. If you feel a need to debate something, other then to just post, look up what your about to step into just as much as you do to cover your self, after. Save the rest of us the stress please. Have a nice day. I'm not responding to you again, there just is no need for it. Your wrong.
PKM says:
The only one confused by the usage of the word is you, or so it seems to me.
So in every sense of the word he used it correctly

Again, if you read my last post closely you will see I never said he used it incorrectly. I was just trying to prevent a possible misconception that people who are unfamiliar with the subject might have had, that you seem to think I am also making. I never said the Instructable was wrong - so I don't see what the argument is about.

Everyone else I have ever talked with calls algae oil not veggie oil. Your the only one I seen do that. If you wanted to say plant oil you should of said so.

Arguing by numbers doesn't make it correct - look at all the people who say "I could care less" or "irregardless", both widespread but nonsensical phrases that mean the opposite of what the speaker intends.

I did want to say plant oil and as far as I can tell, "vegetable oil" and "plant oil" being interchangeable terms for plant-derived lipids, I did. Again, if there is a concrete difference in the definitions of the terms "vegetable oil" and "plant oil" then please point it out to me, I couldn't find one. I refrained from using "algae oil" because it's a tautology - obviously algae produce algae oil, but if you are not familiar with algae oil already it doesn't tell you anything. I used "vegetable oil" because it's a descriptive term that more people are familiar with, and as far as I can tell is scientifically accurate. Fail to see the problem.

servant74 says:
From the commercial stuff I have been reading on using algae, personally it sounds like squeezing out the lipids (veggie oil equivalent) and burying the remaining algae 'carcass' would get some of the oil out and allow sequestering quite a bit of CO2.

If you do something else with the 'carcass' material, like use it as animal feed, or break it down into sugars to ferment into something else then the CO2 comes back out into the environment.

Sequestration is nice, but the continued or re-use of the material makes the process carbon neutral over some period of time.

To bring down the CO2 levels in the atmosphere, sequestration of some form is needed, if that is the goal. If a higher level of energy independence is the goal, using this technique anyway, the sequestration may need to be moderated. ... It seems noting we do is done in isolation, and the formulas will always balance out in the end.

I do appreciate the instructable. Who is up for the 'squeeze lipids/oil out of algae' one? :)

siedentopf says:
That's true. Any Bio-fuel we produce will in the end be only neutral, as long as we use them as hold over's and go between then we'll come out ahead. If it takes 2 pounds of CO2 to make one pound of algae, then there has to be a reaction that releases O2 into the air. After all between one molecule of CO2 and H2O there is 75% is O2 in those masses. Assuming one CO2 and one H2O combine to make the hydrocarbons of the algae.

Also since it takes 2 pounds CO2 for one pound of algae, and since we only get 40% of the algae mass as usable oils, some 1.6 pounds remains as carcasses. If I did this right it means that for every one ton of oil we sequester some 5 tons of CO2. Now if we intelligently use that to cut back on other less green (no pun intended) feeds, the effect goes even higher.

What I would like to see is any bio fuel we produce be used as a transition fuel until we get everything running on renewable energy. Now that would be a big "score twice". As long as we keep using what nature sequestered from carbon compounds in the air, we're only biting the big bullet.

With any such system, as long as you don't burn the algae, you get a nice time delay to change the cars and get things worked out.

ggdancer says:
you could always process the carcasses into biochar and then bury that which would sequester the carbon for 100's (if not thousands) of years. being carbon neutral is great but we really need to start being carbon negative to remove significant carbon from the atmosphere.

siedentopf says:
Any amount of carbon taken from the air and buried back into the ground as algae carcasses would be a negative step regardless of the amount of fuel made from it and burned. Since all the carbon had to come from the air to start with.

We can't stop the demand for fuel, and can't change all that energy demand to renewable over night. It's still a very good in between method, but then so is a garden and planting trees. The only problem with trees and a garden, is they will not get everyone to work and back. I'd hate to see a fire department that would have to fire up the old steam engine before proceeding to a 911. We still need the fuel, until we get renewable sources and better battery technological, and as far as the air goes, it's a good step to reducing carbon.

Alpha2904 says:
Oh i have nothing to say i just wanted to make the comment ladder 1 step larger :) Global Warming does exsist and do humans cause a MAJOR effect on global warming by 50% or more? If so back it up with proof
oilsRus says:
These “carcasses” may have significant amounts of carbohydrates and or cellulose that can be converted to ethanol and still leave a feed or fertilizer component.

Feb 9, 2009. 10:11 PM

dedsetmad says:
A pleasure to read that which is writ by someone who has an idea of what they are talking about.........

Feb 5, 2009. 3:16 PM

omnibot says:
I can see how this would come in handy in outer space. Are the algae edible?

Mar 6, 2009. 4:15 AM

chuckr44 says:
I believe the power/electricity used to create all the plastic parts, and bottle the CO2, created more CO2 than your system could ever use up. I could be wrong. Therefore I posit that your system has a net increase in CO2.

Feb 11, 2009. 8:19 AM

Dungeonbrownies says:
the power has already been spent on production of the materials, this is simply recycling, so you're right, but it can't hurt? (maybe? i guess?)

Feb 28, 2009. 11:42 PM

chuckr44 says:
However this would be a great system to create free-floating algae to feed daphnia or plankton. Which would then be used to feed tropical fish.

Feb 11, 2009. 8:20 AM

chuckr44 says:
Ah. If you already had all the parts that would be good. However if you bought many of the parts, you are simply encouraging industry to create more parts, thus expending more energy and putting more carbon into the atmosphere.

Mar 2, 2009. 7:26 AM

temp says:
but you are also creating more jobs for people. Plus you can go to a recycling place and collect the bottles you need it a matter of minutes. You can scavenge some pvc pipe that was going in the trash/ and you can use any shelf system you want. The most you could be buying is the eight split sprinkler things and maybe a few other odds and ends.

Mar 3, 2009. 4:56 PM

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