**Growing Algae for Fuel**

**Objectives**

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| * To understand the difficulty and rewards of growing algae for fuel * Understand photosynthesis * Determine the factors that improve algae growth |

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| **Skill Level:** Middle School and High School | **Prep time:** 15 minutes **Class time:** Several weeks for growth  5 minutes daily to mix the algae  15 minutes for algae separation |

**Materials**

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| * Algae sample (Provided or collected from local pond).   **NOTE: Make sure the algae sample does not get hot prior to use as it will kill the sample. Samples can be stored in a refrigerator for up to 4 months before use.**   * Deionized, spring, or well water * 1 gallon container(s). Clear water containers work best, but milk jugs will also work. * ½ cup of hydrogen peroxide per jug (3% concentration) * Pipettes * Miracle Grow * Open cell foam * Scissors * Permanent marker * Coffee filters * Mobile app (free): LuxMeter (for iPhone) or MobiLux: Light Meter (for Android) * [Growing Algae for Fuel Activity Sheet](https://docs.google.com/file/d/0B0FEoHyeIyePdW51eFhkN2w3TW8/edit) |

[**Next Generation Science Standards**](http://www.nextgenscience.org/next-generation-science-standards)

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| **Disciplinary Core Idea:** MS-PS1: Matter and Its Interactions  **Performance Expectations:** MS-PS1-3: Gather and make sense of information to describe that synthetic materials come from natural resources and impact society  HS-PS3-3: Design, build, and refine a device that works within given constraints to convert one form of energy into  another form of energy.\* | |
| **Practices**  Asking questions / defining problems  Developing / using models  Planning / carrying out investigations  Analyzing / interpreting data  Math / computational thinking  Constructing explanations / design solutions  Engaging in argument from evidence  Obtaining / evaluate / communicate | **Crosscutting Concepts**  Patterns  Cause and effect: Mechanism / explanation  Scale, proportion, and quantity  Systems and system models  Energy / matter: Flows, cycles, conservation  Structure and function  Stability and change |

**Background Information**

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| Algal growth is currently being researched as a method of producing biofuel. Algae is a great bio-resource because it can grow just about anywhere and it does not compete with crop space and resources that other crops need (like corn or soybeans). Unlike first generation biofuels (that can also be used as food), algae does not use fresh water or farmable land – something that is in short supply on the planet. In addition, algae have the potential of generating from 100 to 1,000 times the fuel from the same acre of land (Corn yields 18 gallons of oil per acre compared to a potential of 5000 for algae). While second generation biofuels (such as poplar, wood slash, switchgrass) do not use farmable land, they are not able to produce the quantity of oil that algae can yield. Unfortunately, there are still many problems to overcome therefore algae are not yet ready for production. One of the two largest problems to solve is how to separate the algae from the water and how to keep pests out of the growth ponds. Johnathan Trent and his team at NASA are researching this fuel with a project called OMEGA. His TED Talk can be seen here: <https://www.ted.com/talks/jonathan_trent_energy_from_floating_algae_pods>  In this activity students get to explore the research themselves. Fertilizer will be used as the students “waste water” made of nitrogen (N), phosphorus (P), and potassium (K) that will help the algae grow. N-P-K is known as algae’s macronutirients, the nutrients algae need the most of in order to survive. The other chemicals noted on the fertilizer label are called the micronutrients. Macro and micronutrients are not the only nutrients needed to survive. Algae have optimal light exposure and a temperature range to perform at. Growing algae at its instructed ranges will yield the best growth. Almost all algae produce some oil as part of their natural growth. Dried algae can range from 5% to over 75% oil content. Once oil is made by algae there are several ways to extract the oil. One of the easiest ways, and the way it will be done in this activity, is by gravity filtration, which is allowing the algae/water solution to drop through filter paper. The oil extracted is referred to as “green crude” and is not really a fuel until it undergoes transesterification, which includes adding chemicals like alcohol to create biodiesel and glycerol.  Algae Farm. [Ref](http://www.our-energy.com/biofuel_production_from_algae.html)  As the video explains, algae have some advantages over other biofuels. It grows naturally with little to no effort. Algae can be found in almost any water source (lake, pond, river, etc.). Algae also feed on waste materials; it cleans the water to help it grow. Since algae naturally grow in water, there is no competition for field space on land. This way there is more room for poplar trees, corn, switchgrass and other biofuels. Although algae can produce high quantities of oil per acre, it is also diluted with millions of gallons of water per acre. Extracting the algae from the water becomes difficult with such a small quantity of algae per water volume. When these and other hurdles (like expensive equipment) have been cleared, algae may turn out be one of the best and highest producing biofuel feedstocks. Many researchers and startup companies are attempting to resolve these problems and create a green oil boom. |

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| **Engage** |
| Students should be interested in learning about an alternative fuel that grows naturally. Students should be curious to know how this fuel and separation process compares to those they are familiar with such as corn. They will also learn about how difficult the process of getting the useable oil from algae can be. The minimal amounts of oil they get shows how difficult separation is and will show students the grand scale this would need to occur at if gasoline became obsolete. |

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| **Explore** |
| **Experiment Questions**:   * Where is it best to grow the algae? Under what conditions? * Will the algae eventually die? Why or why not? * Does the color tell you anything about the health of the algae? * How does your container compare to the natural habitat of the algae? * What variables are playing into the health of your algae? * How might you grow algae commercially?   **Growth Procedure:**   1. Start by finding a container that is at least 1 gallon in size. Clear water containers as shown below work best. 2. Sterilize that container with ½ cup of 3% hydrogen peroxide mixed with ½ gallon water. Do not use tap water because it will kill the algae. Cap and shake the container for a good rinse. Be sure to rinse with deionized water at least 3 times after the peroxide to remove any remaining solution. 3. Fill the container with half a gallon of water. 4. Add Miracle Grow according to the measurement on the fertilizer’s box. 5. Shake well until all fertilizer is dissolved. 6. Shake algal sample well. Add at least 2 milliliters of algal sample to the container. More than 2 is acceptable, but must contain at least 2 milliliters. 7. Replace the container cap with foam one. This can be made or bought. Make sure the foam is open cell foam, which is easily compressible and allows for air transfer. Shake again making sure that algae is well mixed. 8. Set container in an area that receives at least 10 hours a day of light if not more. This can include a north-facing windowsill or a florescent light that can be on continuously (incandescent light generate too much heat). It is recommended that the sample sit under light with intensity between 2000 and 4000 Lux. Light intensity can be measured with either one of the following free smartphone apps: LuxMeter (for iPhone) or MobiLux: Light Meter (for Android). It can be helpful to start the algae growing about 18 inches away from a florescent light. This will ensure the algae have a constant light source to get them started. 9. Make sure the temperature of this area is also ideal for algal growth. The temperature needs to stay between 65 and 72 degrees Fahrenheit for ideal algae growth. 10. A video break down of our procedure is located [here.](https://www.youtube.com/watch?v=W0qcQu5MQZE&feature=youtu.be) 11. Carefully shake the algae daily as shown in the video. This will increase growth by exposing all the algae to light. 12. The liquid should begin to turn noticeably green within 3 or 4 days. 13. Have the students measure the amount of algae in the solution as often as possible. The results can be plotted on a graph. This can be done using the smartphone app (LuxMeter or MobiLux) as follows.     1. Place the cell phone camera against the algae container and measure the light intensity coming through the liquid.     2. Without moving the cell phone, place an identical container with fertilizer at the correct concentration in front of the camera lens as a control. This will measure the light that the nutrient solution absorbs without algae.     3. Divide the light intensity (algae) by light intensity (control)     4. The result is a measure of the amount of algae that are growing in solution. A fully colonized solution will show more than a 50% drop in light intensity.   **Separation Procedure:**   1. Cut off the top of a 2L bottle so a coffee filter will rest against the neck. 2. Place two coffee filters in the bottle top 3. Place the bottle top in a drain 4. Slowly pour the algae solution into the coffee filter until the filter is full. Wait until the water drains out. 5. Repeat adding algae water until all the water had been filtered out. 6. The remaining green slime is algae that contains oil (11% for the provided sample of Selenastrum). |

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| **Explain** |
| * What factors do you think are most important to growing algae? * What are some of the challenges of growing algae for a biofuel feedstock? * Why do you think that open ponds are often used for biofuel algae growth instead of indoor bioreactors? |

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| **Elaborate (Engineer)** |
| * Students should feel free to conduct their own algal experiment or concept experiment. * They should explore what would happen if tap water replaced the deionized water. * They also should think about how this relates to the real world and where algae get its macro and micronutrients. * Feel free to put an air pump in an additional sample and compare to another without an air pump. Again, feel free to have students adjust any variables. * Students can attempt to extract the oil from the algae by following the process outlined in this [activity](http://www.education.com/science-fair/article/oil-producing-algae/). * Have the students design a way to grow algae commercially (not using ponds). Their designs should include the following requirements:   + Maximum light contact with all algae   + Takes up minimum space   + A way to circulate the algae they get equal sunlight   + A way to add and remove algae from the system.   + Photos in Growing Algae for Fuel: Activity Sheet show some of current ways companies are growing algae. |

**Resources**

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| **Additional Resources:**   * [Third generation biofuels](http://biofuel.org.uk/third-generation-biofuels.html) * [Algae to green crude company](http://www.sapphireenergy.com/) * [How algae biodiesel works](http://science.howstuffworks.com/environmental/green-science/algae-biodiesel.htm)   **Resources Used:**   * [Carolina Optimal Growth Instructions](http://www.carolina.com/algae/ankistrodesmus-living/151955.pr?question) * [Isolation Media Video](https://www.youtube.com/watch?v=avrpX2jlGbU) * [Getting Started Video](https://www.youtube.com/watch?v=NAYnZbsIhY8) * [Algal Supplies](https://www.youtube.com/watch?v=iWyZlo1FWBg) |