Biofuel Production

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6-12/Chemistry-Biology

For the Teacher

The projects in this section are written in a manner that can be incorporated into a science class's curriculum in two ways. In the Project Ideas area, the questions are about general area and not specific scientific problems to be worked out. First, it can be done as long term semester project depending on how in depth and how much time the teacher would want to put into the project. Secondly the teacher writes them with the purpose of so that the project could be accomplished

With 60% of our petroleum supplies being imported into our country, there is a huge need to develop alternative fuel supplies for our future energy demands. The projects show ways of developing alternatives to petroleum fuels. The projects could also lead to more projects studying the impacts on the environment of using these types of fuels in the future. A great connection for more information on any of these projects would be the National Renewable Energy Labs in Golden, Colorado. The base web-site is www.nrel.gov. On the next two pages you will find the National Science Standards by the National Academy of Sciences that apply to this part of the book.

National Science Education Standards by the National Academy of Sciences

Science Content Standards: 5-8

Science of Inquiry
– **Content Standard A**
"Science of Inquiry"
"Abilities necessary to do scientific inquiry"

Physical Science
– **Content Standard B**
"Properties and Changes of Properties in Matter"
"Transfer of Energy"

Science and Technology
– **Content Standard E**
"Abilities of Technological Design"
"Understandings about Science and Technology"

Science in Personal and Social Perspective
– **Content Standard F**
"Populations, Resources, and Environments"
"Risks and Benefits"
"Science and Technology in Society"

History and Nature of Science
– **Content Standard G**
"Science as a Human Endeavor"
"Nature of Scientific Knowledge"

Science Content Standards: 9-12

Science of Inquiry
– **Content Standard A**
"Science of Inquiry"
"Abilities necessary to do scientific inquiry"

Physical Science

– **Content Standard B**
"Structure and Properties of Matter"
"Chemical Reactions"
"Conservation of Energy and Increase in Disorder"
"Interactions of Energy and Matter"

Life Science
– **Content Standard C**
"Matter, Energy, and Organization in Living Systems"

Earth and Space Science
– **Content Standard D**
"Energy in the Earth System"

Science and Technology
– **Content Standard E**
"Abilities of Technological Design"
"Understandings about Science and Technology"

Science in Personal and Social Perspective
– **Content Standard F**
"Personal and Community Health"
"Natural Resources"
"Environmental Quality"
"Natural and Human-induced Hazards"
"Science and Technology in Local, National, and Global Challenges"

History and Nature of Science
– **Content Standard G**
"Science as a Human Endeavor"
"Nature of Scientific Knowledge"

Technology Description

The traditional use of biomass is combustion in stoves or boilers for heat. Biomass is a term that refers to anything that is or was living at sometime. This is a significant source of energy for U.S. industries and homes. Yet biomass can also be converted to "biofuels" – liquid and gaseous fuels such as ethanol, methanol, gasoline, diesel fuel and methane. Making ethanol from corn is a major U.S. industry, producing nearly 1 billion gallons each year. The processes for converting biomass to fuels include a broad range of thermal, chemical and biological processes.

Combustion processes heat the biomass in the presence of unlimited oxygen. The products of the reaction are additional heat, ash, and smoke.

Gasification heats the biomass to higher temperatures of 600^0 – 1000^0 C in an environment of limited oxygen. The biomass begins to char and gives off a gaseous product that is a mixture of carbon monoxide, hydrogen, and methane. The mixture of gases, known as "syngas," can be burned directly in industrial processes, or it can be cleaned up and used as a substitute for natural gas. The syngas can also be converted to methanol, which can be used as a pure fuel or in blends with gasoline.

Pyrolysis heats the biomass to temperatures of 300^0 – 500^0 C. in the absence of air. The biomass "melts" and vaporizes, producing petroleum-like oil called "biocrude." This biocrude can be converted to gasoline or other chemicals or materials.

Anaerobic digestion is a biological process that uses bacteria in the absence of oxygen to convert biomass to a mixture of methane and carbon dioxide called "biogas." Liquid and solid wastes are particularly amendable to this process, which is already providing energy in many locations around the world. Like syngas, biogas can be used directly or converted to other fuels.

Fermentation is another biological process that uses yeast to convert the sugars in biomass to ethanol. This is the same process that has been used for thousands of years to make wine and beer. Some forms of biomass are made up of simple sugars that can be used directly, for example, sugar cane and sugar beets. Others are made up of carbohydrates –chains of sugar molecules- that must first be broken down (hydrolysis) using enzymes. Starch crops such as corn and woody crops such as trees and grasses both fall into this category. Like methanol, ethanol can be used as a pure fuel or in gasoline blends.

Oil extraction can be used with a variety of plants that produce oils directly. Peanut, rapeseed, and some species of aquatic algae are examples of these plants. The oils can be chemically upgraded to diesel fuel and burned in engines. Some of these plants are already grown as crops in several regions of the country. And micro-algae could be grown in saline water in the Southwest, using large quantities of carbon dioxide as a nutrient.

Bio-diesel is being produced from various types and conditions of vegetable oil in Europe and in the States. Bio-diesel is being made in considerable quantities at home-sites for use in diesel engines as a substitute or an additive to mix with petroleum-diesel fuels. The main advantage in using bio-diesel is that it produces no by-products containing sulfur.

The technologies for producing biofuels are at various stages of commercial development. Most are already providing limited amounts of energy today and greater amounts in times of tight supply such as the oil embargo of the 1970's or the World Wars. But the efficiencies and economics of all the processes stand to benefit from ongoing research. It was predicted in the 1980's that we would be producing large amounts of our liquid and gaseous fuels economically from biomass, but there is still a lot of work to done in the research fields to make biofuels economically feasible.

Good sources of information about biofuels in general are readily available via the Internet. Any good search engine will attain 1000's of possible websites to be looked at with a good healthy perspective. A few websites that might be a good start for further research could be as follows.

www.ethanolrfa.org/index

www.ott.doe.gov/biofuels

www.bioenergy.oml.gov

www.nal.usda.gov

This is just a partial listing of many and various websites that can again be obtained by using most search engines on the Internet.

Project Ideas

1 What can be controlled to increase the efficiency of ethanol production?

Variables: Sugar source (grain crops, fruits, cellulose), temperature, type of yeast

Specific Resources: Most life science, biology or chemistry textbooks and lab manuals give numerous setups on fermentation equipment.

Hints: Use the rate or total volume of CO_2 production as an indicator of the production of ethanol. A gas chromatography unit can determine exact quantities of ethanol.

Other Ideas: Advanced students could investigate the optimum temperature for fermentation, develop prototypes for efficient production of ethanol, investigate aerobic and anaerobic conditions, and investigate methods of quantifying ethanol production.

2 What kinds of biomass have the most heat energy in a given quantity?

Variables: Types of Biomass (i.e. plant species, grasses, wood, etc.), heat loss (depending of the efficiency of the calorimeter)

Special Equipment: Balance, calorimeter, thermometer, burner set-up.

Specific Resources: Many biology manuals will give instructions for making a calorimeter or a commercial unit may be purchased from Fisher Scientific for about $250 (not necessary). www.fishersci.com

Special Safety and Environmental Concerns: Work in well-ventilated areas. Be extremely careful of burns because a lot of heat energy can be generated and released.

Hints: Conduct preliminary tests to determine the best amount of biomass to test. The amount of water used in the calorimeter is important to keep consistent.

Other Ideas: More advanced students could decrease the margin of error by using a bomb calorimeter. Check with a local university for access to this equipment. Extraction of hydrocarbons (oils) from various kinds of plants could be investigated, especially those containing latex, e.g., milkweeds. Their heat energy could be compared in a search for the best source. Determine usable heat energy that could be produced on an acre of land if certain crops, e.g., castor beans, sunflowers, corn, and milkweed. This would require one to know the caloric value (Energy/unit mass) and the amount of biomass produced per unit area.

3 What type of "Biomass" will produce the greatest quantity of "biogases" by heating?

Variables: Biomass sources, moisture content, heating source/temperature.

Special Equipment: Heating container, heat source, gas collection apparatus.

Special Safety and Environmental Concerns: Provide adequate ventilation. Be careful in the way that the biomass is heated. The major gas produced is methane, which is explosive when mixed with air. Take care to avoid burns.

Hints: The amount of gas produced can be quantified using a water displacement method. An alternate method is to burn the methane produced as it leaves the heating vessel via a small glass tube. The burn time gives an indication of amount of gas produced. Extra care should be taken if using this method.

Other Ideas: Advanced students could determine if this method is energy efficient since the biomass source has to be heated. Various sources such as corncobs, old tires and sludge straw could be tested. The material remaining is charcoal. Is there any energy value remaining? If so, what is the total amount of available energy in a given amount of biomass using the destructive distillation process?

4 What conditions provide the maximum yield of charcoal from biomass?

Variables: Types of biomass, temperature, heating rate, pressure, gaseous environment, catalysts.

Special Equipment: Heating device, containment vessel, thermocouples, sources of gases.

Special Safety and Environmental Concerns: Heated pressurized vessels require special precautions and supervision.

Hints: Begin simply by heating something like cellulose in a test tube sealed to permit the escape of gases.

Other Ideas: Advanced students could possibly design their own heating vessels and also could devise ways to heat in the presence of other gases and in the absence of most atmospheric gases.

5 What conditions will produce the most efficient breakdown of paper into sugars?

Variables: Time of reaction, temperature, enzymes, type of paper, the amount of paper, the amount of water.

Specific Equipment: Cellulase, available from Fisher Scientific for $10-$20 (www.fishersci.com), Benedict's solution for testing for glucose or some other method to test for glucose. Benedict's solution can also be obtained from Fisher Scientific for $5.

Specific Resources: Biological and/or chemical laboratory manuals for sugar test procedures.

Special Safety and Environmental Concerns: Use of goggles while testing for the presence of sugar and while handling the enzymes.

Hints: Make the pulp using a high-speed blender. Make varying concentrations by adding different amounts of the dried pulp to water. Cover the container containing the pulp and enzymes because the fermentation is anaerobic.

Other Ideas: Advanced students could design an experiment that would allow for the hydrolysis and fermentation to ethanol. Factors to consider are pH, sterilization of the media and paper, filter, the cellulose solutions. The mixtures of yeast and cellulose could be varied to identify the most efficient culture. A gas chromatograph could be used to quantify the amount of ethanol produced. (Local labs or colleges could provide a gas chromatograph)

6 What conditions and/or biomass are best for producing methane?

Variables: types of biomass (plants, animal dung, food waste), moisture content, time, aerobic or anaerobic conditions, temperature and air pressure.

Special Equipment: Biogas generator, heat source such as a hot plate, and a gas collection apparatus.

Special Safety and Environmental Concerns: Methane the main component of biogas is explosive when mixed with air. Extreme care should be taken when attempting to generate large quantities of biogas.

Hints: Fill the jar with biomass and make sure it is well squashed down to remove as much air as possible. The biomass must be moist (add water if needed). Use equal masses of the different types of biomass.

Other Ideas: Compare the efficiency of producing methane from crop wastes, e.g., corncobs and corn silage to predict what the best crop source would be.

7 What conditions would produce the most efficient conversion of algae to a useful fuel?

Variables: Type of algae, amount of light, type of light, salinity of water, concentration of nutrients (carbon dioxide, nitrogen, phosphorus)

Special Equipment: Laboratory glassware, microscope, algae cultures from Fisher Scientific for $7.40 per algae culture, WWW.Fishersci.com

Specific Resources: *Fuels from Micro-algae,* 1989, SP-320-3396, Golden, Colorado: SERF

Special Safety and Environmental Concerns: None

Hints: Grow micro-algae in flasks exposed to a specific type of light. Examine samples of cells under microscope. Hydrocarbon oil, called lipids, will be visible as yellowish droplets.

Other Ideas: Advanced students could quantify the amount of lipids using a staining technique known as "Nile Red." The procedure requires specialized equipment, probably available at local colleges or universities. The "nile red" is available through source like Fisher Scientific but is very expensive to purchase.

8 What is the most efficient way to produce biodiesel?

Variables: new vegetable oil, used vegetable oil, types of oils, stir times, rate of stirring, amounts of sodium hydroxide and ethanol, temperature of mixture during the mixing process.

Special Equipment: liquid volume measuring devices, thermometer, mixing container, mixing device, mass measuring devices, pH measuring device

Special Safety and Environmental Concerns: materials produced are flammable, Sodium hydroxide is corrosive and poisonous, Sodium methoxide is extremely corrosive and poisonous, ethanol is flammable and poisonous, electrical safety issues, disposal of waste products

Hints: Web-sites showing the directions for making biodiesel-

http://journeytoforever.org/biodiesel_make.html ,
http://www.nrel.gov/education/, Stirring is a major key in bio-diesel production.

Appendix A

SCIENCE FAIR JUDGING GUIDELINES

Science Project Evaluation Criteria

Judging is conducted using a 100-point scale with points assigned to creative ability, scientific thought or engineering goals (II a and b respectively), thoroughness, skill, and clarity. Team projects have a slightly different balance of points that includes points for teamwork. A chart of these point values is located at the end of these criteria. Following is a list of questions for each criterion that can assist you in interviewing the students and aid in your evaluation of the student's project.

I. Creative Ability (Individual – 30, Team – 25)

1. Does the project show creative ability and originality in the questions asked? the approach to solving the problem? the analysis of the data? the interpretation of the data? the use of equipment? the construction or design of new equipment?

2. Creative research should support an investigation and help answer a question in an original way. The assembly of a kit would not be creative unless an unusual approach was taken. Collections should not be considered creative unless they are used to support an investigation and to help answer a question in an original way.

3. A creative contribution promotes an efficient and reliable way to solve a problem. When judging, make sure to distinguish between gadgeteering and genuine creativity.

II.a. Scientific Thought (Individual – 30, Team – 25)

1. Is the problem stated clearly and unambiguously?

2. Was the problem sufficiently limited to allow plausible attack? One characteristic of good scientists is the ability to identify important problems capable of solutions. Neither working on a difficult problem without getting anywhere nor solving an extremely simple problem is a substantial contribution.

3. Was there a procedural plan for obtaining a solution?

4. Are the variables clearly recognized and defined?

5. If controls were necessary, did the student recognize their need and were they correctly used?

6. Are there adequate data to support the conclusions?

7. Does the student recognize the data's limitations?

8. Does the student understand the project's ties to related research?

9. Does the student have an idea of what further research is warranted?

10. Did the student cite scientific literature, or only popular literature (i.e.: local newspapers, Reader's Digest)?

II.b. Engineering Goals (Individual – 30, Team – 25)

1. Does the project have a clear objective?

2. Is the objective relevant to the potential user's needs?

3. Is the solution workable? Unworkable solutions might seem interesting, but are not practical. acceptable to the potential user? Solutions that will be rejected or ignored are not valuable. economically feasible? A solution so expensive it cannot be used is not valuable.

4. Could the solution be utilized successfully in design or construction of some end product?

5. Does the solution represent a significant improvement over previous alternatives?

6. Has the solution been tested for performance under the conditions of use? (Testing might prove difficult, but should be considered.)

III. Thoroughness (Individual – 15, Team – 12)

1. Was the purpose carried out to completion within the scope of the original intent?

2. How completely was the problem covered?

3. Are the conclusions based on a single experiment or replication?

4. How complete are the project notes?

5. Is the student aware of other approaches or theories concerning the project?

6. How much time did the student spend on the project?

7. Is the student familiar with the scientific literature in the studied field?

IV. Skill (Individual – 15, Team – 12)

1. Does the student have the required laboratory, computation, observational and design skills to obtain supporting data?

2. Where was the project done (i.e.: home, school, laboratory, university laboratory)? Did the student receive assistance from parents, teachers, scientists, or engineers?

3. Was the project carried out under adult supervision, or did the student work largely alone?

4. Where did the equipment come from? Did the student build it independently? Was it obtained on loan? Was it part of a laboratory where the student worked?

V. Clarity (Individual – 10, Team – 10)

1. How clearly can the student discuss the project and explain the project's purpose, procedure, and conclusions? Make allowances for nervousness. Watch out for memorized speeches that reflect little understanding of principles.

2. Does the written material reflect the student's understanding of the research? (Take outside help into account.)

3. Are the important phases of the project presented in an orderly manner?

4. How clearly are the data presented?

5. How clearly are the results presented?

6. How well does the project display explain itself?

7. Is the presentation done in a forthright manner, without cute tricks or gadgets?

8. Did the student do all the exhibit work or did someone help?

VI. Teamwork (Team Projects only - 16)

1. Are the tasks and contributions of each team member clearly outlined? How did you delegate responsibilities between each of the team members?

2. Did you designate one person to be the team leader? If so, what were his/her responsibilities? Do you feel that a team leader is a necessary component for a team project? Why or why not?

3. Was each team member fully involved with the project, and is each member familiar with all aspects? How did you approach other team members to make sure the work got done?

4. Did you find it difficult finding the time to work together? What actions did you take to assure that you met as often as necessary to complete the project?

5. Does the final work reflect the coordinated efforts of all team members?

Evaluation Criteria	Individual Projects	Team Projects
Creative Ability	30 points	25 points
Scientific Thought/Engineering Goals	30 points	25 points
Thoroughness	15 points	12 points
Skill	15 points	12 points
Clarity	10 points	10 points
Teamwork	- - - - -	16 points
TOTAL POSSIBLE SCORE	100 points	100 points