U.S. DEPARTMENT OF
ENERGY | Energy Efficiency & Renewable Energy

ENERGY EDUCATION AND WORKFORCE DEVELOPMENT

Green Fuel

Grades: 9-12

Topic: Solar

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Owner: ACTS

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EDUCATIONAL MODULE Summer 2007

The Green Fuel Project

The Solar/Biodiesel Facility

Matthew Brown

July 2007

TITLE: The BTU or Bust Project

AUTHOR: Matthew A. Brown

GRADE LEVEL/SUBJECT: 11^{th} – 12^{th} Science & Technology Education

CURRICULUM STANDARDS: (from the National Science Education Content Standards)

Science as Inquiry Standard A:

Use appropriate tools and techniques to gather, analyze, and interpret data; Develop descriptions, explanations, predictions, and models using evidence; Think critically and logically to make the relationships between evidence and explanations.

Physical Science Standard B:

Transfer of energy – energy is a property of many substances and is associated with heat, light, and electricity. Energy is transferred in many ways.

Science and Technology Standard E:

Identify a problem or design an opportunity - Students should be able to identify new problems or needs and to change and improve current technological designs.

Propose designs and choose between alternative solutions - Students should demonstrate thoughtful planning for a piece of technology or technique. Students should be introduced to the roles of models and simulations in these processes.

Implement a proposed solution - A variety of skills can be needed in proposing a solution depending on the type of technology that is involved. The construction of artifacts can require the skills of cutting, shaping, treating, and joining common materials--such as wood, metal, plastics, and textiles. Solutions can also be implemented using computer software.

Evaluate the solution and its consequences - Students should test any solution against the needs and criteria it was designed to meet. At this stage, new criteria not originally considered may be reviewed. Communicate the problem, process, and solution - Students should present their results to students, teachers, and others in a variety of ways, such as orally, in writing, and in other forms--including models, diagrams, and demonstrations.

OVERVIEW:

This activity allows students the opportunity to explore different methods for collecting solar energy and using that energy for heating, creating electricity and applying that energy to an industrial process. Experimenting with different types of materials will also allow them to understand how the properties of different materials can drastically affect the outcome of their experiment. Students will be creating a parabolic trough that will heat one pound of water to as high of a temperature as can be achieved without damaging the water storage container.

PURPOSE:

To increase the students awareness of different types of solar energy capture

To apply knowledge of energy use and efficiency to real life situations

To compare different building materials and techniques to achieve the most efficient outcome

LEARNING OBJECTIVES:

Students should be able to discuss what factors enhance or hinder their attempts at gathering the suns energy.

VOCABULARY:

Energy	climate	passive solar
energy efficiency	energy transference	shading
Parabolic Trough	Laws of Thermodynamics	solar gain
Entropy	BTU, solar mass	

RESOURCES AND MATERIALS:

Resources:
BTU or Bust design brief handouts, computers for a web research of parabolic troughs, etc.

Materials: *An 18" piece of 1-1/2" PVC pipe with a 45 degree angle at one end(thermometer end), capped at both ends (a hole needs to be drilled in the cap on the 45 degree angle so that the thermometer can be inserted to record temperatures), Have a variety of reflective materials, cardboard, wood scraps, etc.*

Tools:
Safety Glasses, assorted methods for fastening (wood glue, hot glue, screws, nails), hammers, screw drivers, utility knives (safety version, self-retracting), tape measures, 12"-18" thermometers (one for each team), for final testing use Vernier lab pro or something comparable instead of thermometers if available, computers for research.

PREPATORY ACTIVITIES AND PREREQUISITE KNOWLEDGE:

Students should understand the Laws of Thermodynamics and how this affects building materials.

Energy exists in many forms, such as heat, light, chemical energy, and electrical energy. Energy is the ability to bring about change or to do work. Thermodynamics is the study of energy.

First Law of Thermodynamics: Energy can be changed from one form to another, but it cannot be created or destroyed. The total amount of energy and matter in the Universe remains constant, merely changing from one form to another. The First Law of Thermodynamics (Conservation) states that energy is always conserved, it cannot be created or destroyed. In essence, energy can be converted from one form into another.

The Second Law of Thermodynamics states that "in all energy exchanges, if no energy enters or leaves the system, the potential energy of the state will always be less than that of the initial state." This is also commonly referred to as entropy. A watch spring-driven watch will run until the potential energy in the spring is converted, and not again until energy is reapplied to the spring to rewind it. A car that has run out of gas will not run again until you walk 10 miles to a gas station and refuel the car. Once the potential energy locked in carbohydrates is converted into kinetic energy (energy in use or motion), the organism will get no more until energy is input again. In the process of energy transfer, some energy will dissipate as heat. Entropy is a measure of disorder: cells are NOT disordered and so have low entropy. The flow of energy maintains order and life. Entropy wins when organisms cease to take in energy and die.

Students should also have an understanding of positioning so the home can make the most of the south facing wall.

ACTIVITY TIME PERIOD:

This activity will take 10, 45 minute class periods or 5 block class periods.

BTU or Bust *Building a Parabolic Trough Solar Water Heater*

This module is designed for a 45 minute class period. For a block schedule just combine two days.

TEACHER SCHEDULE:

DAY ONE

1. PowerPoint presentation on Laws of Thermodynamics and passive solar
2. Handout on solar energy.
3. Break students into groups of two to four. *Alternative: Sometimes it works better to wait until they have their individual design ideas before you break them into groups.* Hand out the design brief. Have students put their name on the front cover and all the names of the members of their team on the instructor test data sheet. Assign due dates and have the students fill them into the appropriate spaces. Carefully go through the requirements, specifications and restrictions. Students do not write on the grading rubric on the last page (teacher does). Make sure that everyone understands that deviating from or misinterpreting these requirements **will** affect their final grade.

DAY TWO

1. PowerPoint on the different methods for collecting solar energy.
   Active vs. Passive
   Solar Thermal vs. Solar Electric (PV)
   How does a solar cell work?
2. Students should then begin to answer the research questions in Part 1.
3. Students can begin working on their individual designs for Part 2.
4. Students should come to the next class with the first page of Part 2 completed. (Design 1 & 2)

DAY THREE

1. Students meet in their groups to discuss the final design. Each student should bring two unique designs to the table. *Alternative: Now break them into groups of 2 - 4*
2. Once the team has decided on a final design each member must add this to their design brief.

Check point 1 - No group may progress beyond this point without this step being signed off by the instructor.

DAY FOUR

1. Each student will then begin writing construction steps and safety procedures for Part 3. Each student will create their own steps and the team will decide which ones will be combined to use for the construction of the final structure.
2. The team should pick the instruction that they wish to use and justify.

Check point 2 - No group may progress beyond this point without this step being signed off by the instructor.

3. Team members begin organizing materials and tools to begin constructing their device next class

DAY FIVE - EIGHT

1. Teams begin the construction phase, completing their design brief as appropriate.
2. Teams begin testing their structure and making changes as necessary. Parts 5 & 6.
3. Teams prepare for final testing.

TESTING: **The hole in the PVC tube can be sealed by the team with a material that won't permanently affect the thermometer or the tube. The thermometer must be able to be read from the outside of the device. All devices should start at tap temperature inside the classroom and an initially recorded temperature, before going outside.**

DAY NINE

1. Teams meet before first hour to setup their device.
2. One member takes readings each hour for eight hours. 8:00-3:00 (Student must get record sheet from instructor each hour) (If the school has electronic data recorders, the students can program them to take readings automatically.)
3. Teams collect their device after the last class of the day and record instructor's results.
4. During class time students should be completing unfinished sections of the design brief.
5. Design brief is due next class period. Each team will prepare 3-5 minute presentation on their device and the results of their testing.

DAY TEN

1. Teams present their device and results (If still testing, initial results and predicted results).
2. Students turn in the design briefs.

DAY ELEVEN

1. Intro to Photovoltaic Solar Cells
    a. Harvesting the suns energy to create electricity and heat
2. Video on how a solar cell works
    a. Bohrs Model
    b. Doping: The Critical Role of Impurities
    c. P-N Junctions
3. Types of Solar PV Panels
    a. Silicon Wafers
    b. Thin Film Technology
    c. III-V Solar Concentrators
    d. Future Technologies
        i. Dye Sensitized
        ii. Organics

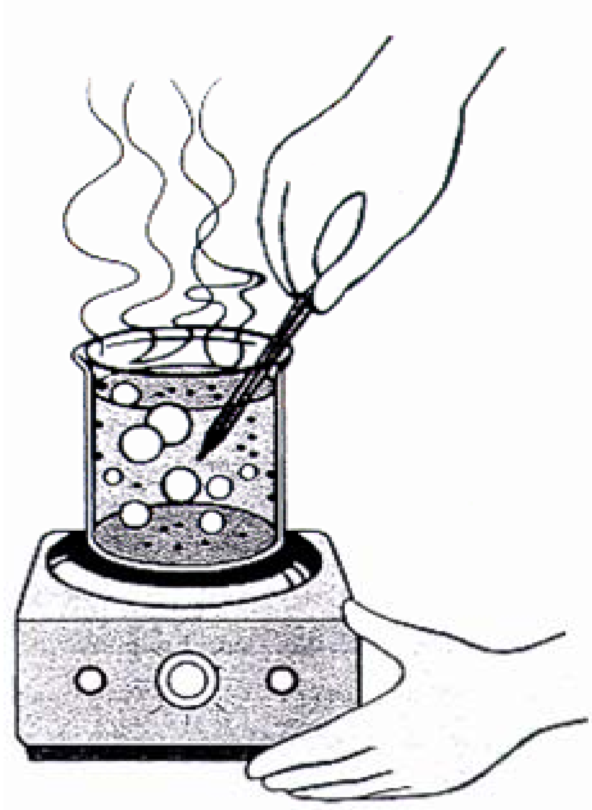
iii. Quantum Dots

DAY TWELVE

1. Estimating Solar Systems
2. Solar Installations
    a. Grid-tied vs. off-grid systems
3. Hybrid Systems
    a. Solar & Wind
    b. Solar, Wind and Hydrogen
    c. Solar & Biodiesel
        i. Biodiesel processor powered by PV
        ii. Proceed to lesson on biodiesel and use on site PV/Biodiesel facility as example. Students operate biodiesel facility to produce large quantities of ASTM grade biodiesel

BTU or Bust

Solar Heating Project



Technology Education

Statement of the Problem

To create a parabolic trough solar thermal device able to heat one pound of water to as high a temperature as possible without damaging the container

IDEAS * DEVELOPING * BUILDING * TESTING
EVALUATING * REDESIGN/REBUILD/RETEST
to
SUCCESS

NAME:____

DATE STARTED:__________________________ DATE DUE:______________________

OVERALL ACTIVITY GRADE:___________

Requirements

1. You will work in teams of two and complete a solar heating device and complete your own design brief.
2. This activity will be completed in two weeks. The device is due________________ for the instructors final test.

3. Your completed brief is due in class _________________.

4. You must conduct and record as many preliminary tests as necessary, then chart and graph the results.

5. Redesign, modify, and retest your design solution until it has achieved the greatest Btu value possible.

6. Complete all work asked for and answer all questions in the brief packet.

7. Write your name, etc. on the Assessment Rubric.

8. Review the Assessment Rubric to know all grade requirements and be sure they were satisfied.

Specifications

1. The tube container will hold one pound of water which is equivalent to 454.5 mL or just under 2 cups (1.92).

2. The 1 1/2" PVC pipe is 18" long capped at both ends The overall length is 20", the overall diameter is 2 1/4" and will be supplied by the instructor

3. Your device must be able to support the water filled container above.

4. You may use any safe materials in the construction of the device.

5. The instructor's final test readings will be taken every minute for a period of 20 minutes (20 data sets).

Restrictions

1. The cylinder **can not** be completely covered or sealed while inside your device.

2. The cylinder **can not** be damaged by excessive heat during any phase of testing.

3. The cylinder **can not** be permanently changed in any way.

PART ONE : Research (idea development)

List the steps you will take to get the information, etc. that will lead you to your final design solution (rough outline). Include what you expect to find out with each step and where you will find it. Indicate what you will do and what your partner will do to solve the problem (team strategy).

1

2

3

4

5

PART ONE cont'd: Research Questions

Answer the following questions concerning the information you will need to gather leading toward the solution of this design problem.

1. *What factors will you use to manipulate the heat energy?*

2. *What will cause the water to heat up inside the container? How can it be controlled?*

3. *List the criteria you will use to determine the possible materials for your container.*

4. *Should one material or several be used? How will they be combined if several are used?*

5. *How will you test the performance of the material/s identified?*

6. *Were you able to achieve the temperatures that you predicted? Why or why not?*

PART TWO : Ideas & Visual design Possibilities

After rough sketching (visual brainstorming) as many possible design solutions as you can think of on scrap paper, place your BEST 2possible solutions, neatly drawn with measurements, below. Compare your solutions with your teammate's, then agree on the team's final design choice.

You can take the best parts of what you see (four possibilities), then add up all the ideas to make the final design.

Design #1

Materials Used: ____

Design #2

Materials Used: ____

PART TWO cont'd: Final Solution Sketch

This sketch with dimensions, should show the size shape, and any other important information associated with your team's finished device. Consider drawing a front, top, and side views with perhaps a section and/or isometric view, to show the necessary detail.

PART FOUR : RESOURCE USAGE

These are the ***SEVEN RESOURCES of TECHNOLOGY****. How have you used these resources to complete your project?*

PEOPLE

Name	*Briefly describe how each helped you*

TOOLS & MACHINES

Tools used	*Briefly explain how each extended your abilities*

INFORMATION

Where did you find and/or how did you acquire information needed to reach your goals?

Place/Event	*Briefly describe the information you acquired*

ENERGY

The energy form	*Application - What did the energy source drive?*
Mechanical	
(potential, kinetic)	
Thermal	
Radiant (Solar)	
Electrical	
Chemical	
Nuclear	

MATERIALS and CAPITAL($)

Materials Used	*Quantity*	*Unit Price*	*Total $ Amount*

Total $ Spent: _______________

THE TIME RESOURCE

Describe when and how you used your time to complete this activity

Date	**TIME SPENT**	**NATURE OF ACTIVITY**

PART FIVE : Design Data Collection Log

In the boxes below, describe and/or sketch each change or modification you make on your heating device. It takes many changes for a good functional design to evolve into a success. By showing and evaluating each change in your design, you will have a permanent record that will lead you to your goal more quickly.

#1 (describe and/or sketch)	*From the 1st one tried, explain why you changed the design or material.*
Material Changes:	

#2 (describe and/or sketch)	*better same worse* *(circle one)*
Material Changes:	(Explain your choice)

#3 (describe and/or sketch)	*better same worse* *(circle one)*
Material Changes:	(Explain your choice)

#4 (describe and/or sketch)	*better same worse* *(circle one)*
Material Changes:	(Explain your choice)

PART SIX : Preliminary Testing

THERMOMETER TESTING PRIOR TO INSTRUCTOR'S TEST

Record the data taken from up to 4 team tests prior to the instructor's final test.

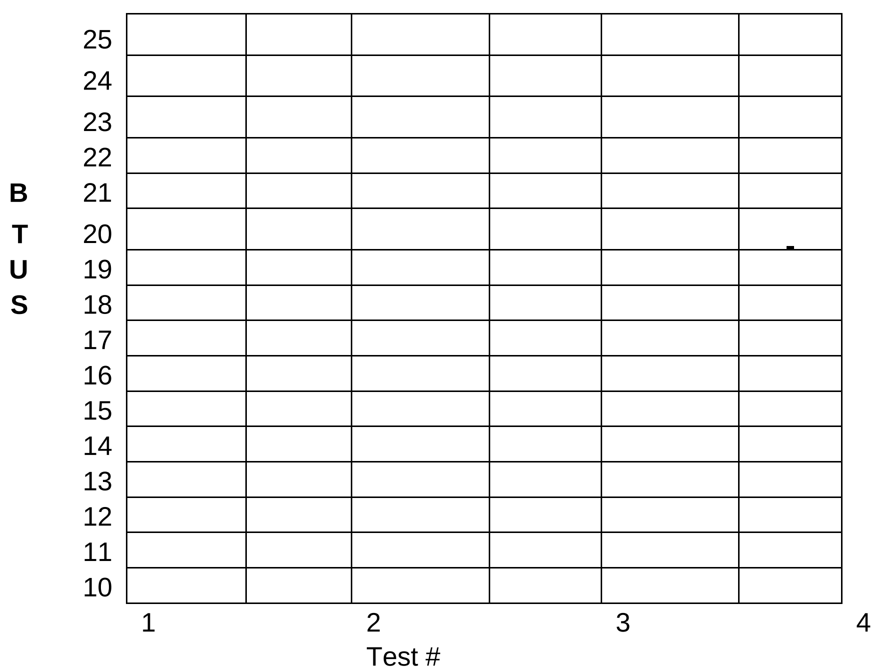
Test #	Start Temp.	Temp After 5 min.	Temp After 10 min.	Temp After 15 min.	Temp After 20 min.	Temp After 30 min	Temp After 35 min.	Temp After 40 min.	Temp After 50 min	Temp After 55 min.
1										
2										
3										
4										

BTU Achieved in: **Test #1** ________ **Test #2** ________ **Test #3** __________ **Test #4** [ ]

(Circle the test that has the ***highest rise in BTU)***

Calculation Space

1 BTU = (lb. Of water) x (deg. F change)



Graphing Test Results

To get a visual picture of your device's performance and help you choose the best possible design solution, use the graph to the left. Plot the Btu reached in all the preliminary tests you conduct. You fill in the best numerical Btu range along the left side of the graph to show the greatest detail possible.

(bar or line type)

PART SEVEN : Activity & Student Assessment

Describe a problem that you had to solve during the design and/or construction of your solar device solution.

What is the best feature of your final design solution (most imaginative)?

Did your solar heating device perform the way you thought it would during the final test? Why or why not?

Describe your feelings about the performance of your team's container in the instructors final test.

If you had a 2nd chance to solve the problem, would you change anything? Explain why you would not make any changes or describe how you would change the container and why.

PART SEVEN cont'd: Student Assessment

Did you understand what you had to do? Yes - No - With Help (Circle one). Explain how:

Which of these describes the amount of research you did? Sufficient - Not Enough - Enough to Get By *(Circle one)*
Explain your answer:

Did the use of a design brief guide you to do a better job and learn more? Yes - No - To some degree (Circle one)
Explain your answer:

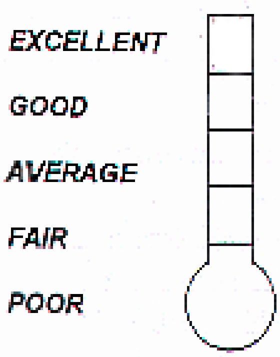
Was the activity challenging? OK - Very Hard - Too Easy (Circle one) Explain in what way:

Was the activity interesting? Yes - No - Could be Better (Circle one) Explain why:

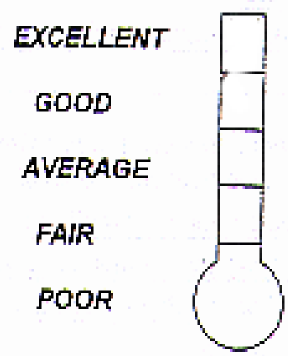
Was this activity relevant to the course? Yes - No - OK (Circle one) Explain why or why not:

Rate your effort on the following graphs

Research



The Design Brief



Describe something new that you learned from this activity beyond the building of an insulated container or keeping. something cold longer. ***The more information you can provide the better - be specific!***

What is the grade you expect to get for the work you did?

PART SEVEN cont'd: Team Assessment

Rate your team members based on their participation and performance. This is your opportunity to give feedback on the performance and participation of each individual member of your team. This is not a time to express personal feelings or dislikes. Circle the number that best represents their effort. Rate yourself first.

Using this assessment inappropriately will cost YOU points!

1. Team Member:____

Rating:		Lowest				Highest
	Performance	1	2	3	4	5
	Participation	1	2	3	4	5

2. Team Member:____

Rating:		Lowest				Highest
	Performance	1	2	3	4	5
	Participation	1	2	3	4	5

3. Team Member:____

Rating:		Lowest				Highest
	Performance	1	2	3	4	5
	Participation	1	2	3	4	5

4. Team Member:____

Rating:		Lowest				Highest
	Performance	1	2	3	4	5
	Participation	1	2	3	4	5

5. Team Member:____

Rating:		Lowest				Highest
	Performance	1	2	3	4	5
	Participation	1	2	3	4	5

Activity Notes

Use this space for any necessary notes

<u>"Btu or Bust" Assessment Rubric</u>

***Student:*____ *Period:*____________________**

Assessment Scale:

6 = Exceptional - Your work shows brilliance and extreme high quality.
5 = Accomplished - Your work fulfills all of the objectives of this portion of the activity.
4 = Acceptable - Your work is minimally acceptable or needs minor revisions.
3 - 2 = Minimum - Your work is either incomplete or requires major revisions.
1 = Not Addressed - Your work did not address or include what was asked for in the rubric.
0 = Not Turned In - Some portion of the activity was not turned in leaving nothing to score.

Points are awarded to each of the sub-categories (left margin), then their average is put as the total of the main category (right margin). The average of all the main categories will become the overall grade for the activity.

Design -

________ Originality of design (not copied)
________ Originality in how materials were used
________ Was able to determine the criteria and constraints and make tradeoffs to determine the best solution
________ A logical strategy was outlined to obtain ideas and information for a solution
________ Questions and answers to research were insightful, clear, detailed and complete

Construction -

________ Overall work performed showed neatness and quality
________ Container constructed matched the final sketch
________ Demonstrated a degree of measuring skill with the sketch and final construction
________ Safety precautions were documented for using hand tools and machines
________ The cylinder was held and supported by the finished device

Test & Evaluation

________ The cylinder was not damaged during the final testing procedure
________ The highest level attained for the instructor's final test
________ Safety precautions were documented and followed
________ Student preliminary tests were used to optimize the final solution
________ Students could make connections between their work and the real world

Design Brief -

________ Part One: Extent of research performed (people & information utilized)
________ Part Two: Quality of sketches were clear, detailed and complete
________ Part Three: Quality of step by step construction procedures were clear, accurate and complete
________ Part Four: Resource pages were clear, detailed and accurate - particularly the time resource log
________ Part Five: The data Collection log was clear, accurate and complete
________ Part Six: Preliminary Testing was recorded and graphed neatly, accuratly and completely
________ Part Seven: Activity, Student and Team Assessments: Neat, complete and insightful

Team Work -

________ Acted as a responsible member of the team during work and testing
________ Acted efficiently during work and testing sessions (time)

________ Activity Total Average (24 criteria)

Grade Legend

A+ = Above 5.00	**B+ = 4.25 to 4.49**	**C+ = 3.75 to 3.99**	**D+ = 3.25 to 3.49**	**F = 0 to 2.99**
A = 4.50 to 5.00	**B = 4.00 to 4.24**	**C = 3.50 to 3.74**	**D = 3.0 to 3.24**	

Instuctor Comments: On reverse side