

**Geothermal Systems in Sustainable Buildings Lesson Plan**

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## **Objectives**

- The student will be able to understand the meaning of sustainability
- The student will be able to identify new technology used in sustainable buildings
- The student will be able to explain how geothermal systems work
- The student will be able to analyze data when given multiple graphs
- The student will be able to make a connection between the advancements being made to buildings and how it benefits our environment

## **Grade Level: 6**

### **Next Generation Science Standards:**

#### Engineering Design

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

## Lesson Overview

### **Engage:**

“What are some ways buildings are heated and cooled? What kind of energy is used?” Students will be asked both questions and will write down their ideas. After students have had time to think about the questions, the entire class will share and discuss thoughts. Possible answers for the first question are HVAC (Heating, Ventilation, and Air Conditioning), Geothermal Systems, and Solar Panels. Possible answers for the second question are fossil fuels, natural gas, heat from the ground, and the sun’s solar rays.

### **Explore 1: Ground Temperature vs. Air Temperature Activity**

Students will be shown two graphs and a contoured map; one graph will display the annual air temperature of Grand Rapids, MI and the second graph will show soil temperature variations with depth. The contoured map will show ground temperature for the U.S. (Answers provided in PowerPoint)

### **Explore 2: Temperature Variations at Various Heights Activity**

Students will be shown three graphs, each giving information about temperature, time, and height for Blandford School. The students will analyze the graph and observe the trend for the temperature at varying heights. (Answers provided in PowerPoint)

### **Explore 3: Model of Geothermal System**

Students will participate in a hands-on activity about a simple geothermal system model. This model shows students how liquid is heated from the ground and flushed into a building, which ultimately transfers heat between the two areas. Students will also answer questions about the model. (Answers provided in PowerPoint)

### **Explain: Review Explore Activities**

Students will form small groups and discuss all three of the explore activities they've just completed. They will review their answers to the various questions and try to explain the importance and purpose of each activity. After students have collaborated, the teacher will review the activities with the entire class via PowerPoint presentation. Students will also be given brief information about LEED and how it pertains to Blandford.

### **Elaborate 1: Advantages and Disadvantages of using Geothermal Systems**

\* Students will need computers for this activity \* Students will work in small groups and fill out a chart with both the advantages and disadvantages of using a geothermal system. Students will explore a few websites online to gather their information. (Answers provided following the worksheet below)

### **Elaborate 2: LEED Standards WebQuest**

\*Students will need computers for this activity\* Students will individually look at the U.S. Green Building Council website and answer some guiding questions. (Answers provided following the worksheet below)

### **Elaborate 3: Video Clip**

Students will watch a short video clip on how geothermal systems work. They will take notes on this video. The video comes from the U.S. Department of Energy website:  
<http://energy.gov/energysaver/articles/geothermal-heat-pumps>  
(Answers provided following the worksheet below)

### **Elaborate 4: Geothermal System Diagram for Blandford**

Students will observe the diagram of Blandford's geothermal system. Then they will list the steps of how the geothermal system operates for Blandford. (Answers provided following the worksheet below)

**Evaluate 1: Summative Assessment**

Students will be given a quiz containing eight questions pertaining to geothermal systems. (Answers provided following the quiz below)

**Evaluate 2: What Would You Choose?**

Based on all of the information the students have learned from the lesson, students will explain whether or not they'd use a geothermal system if they owned a school building. Students will have to use evidence, five points, to support their reasoning.

Name: \_\_\_\_\_

## Explore 1: Ground Temperature vs. Air Temperature Activity

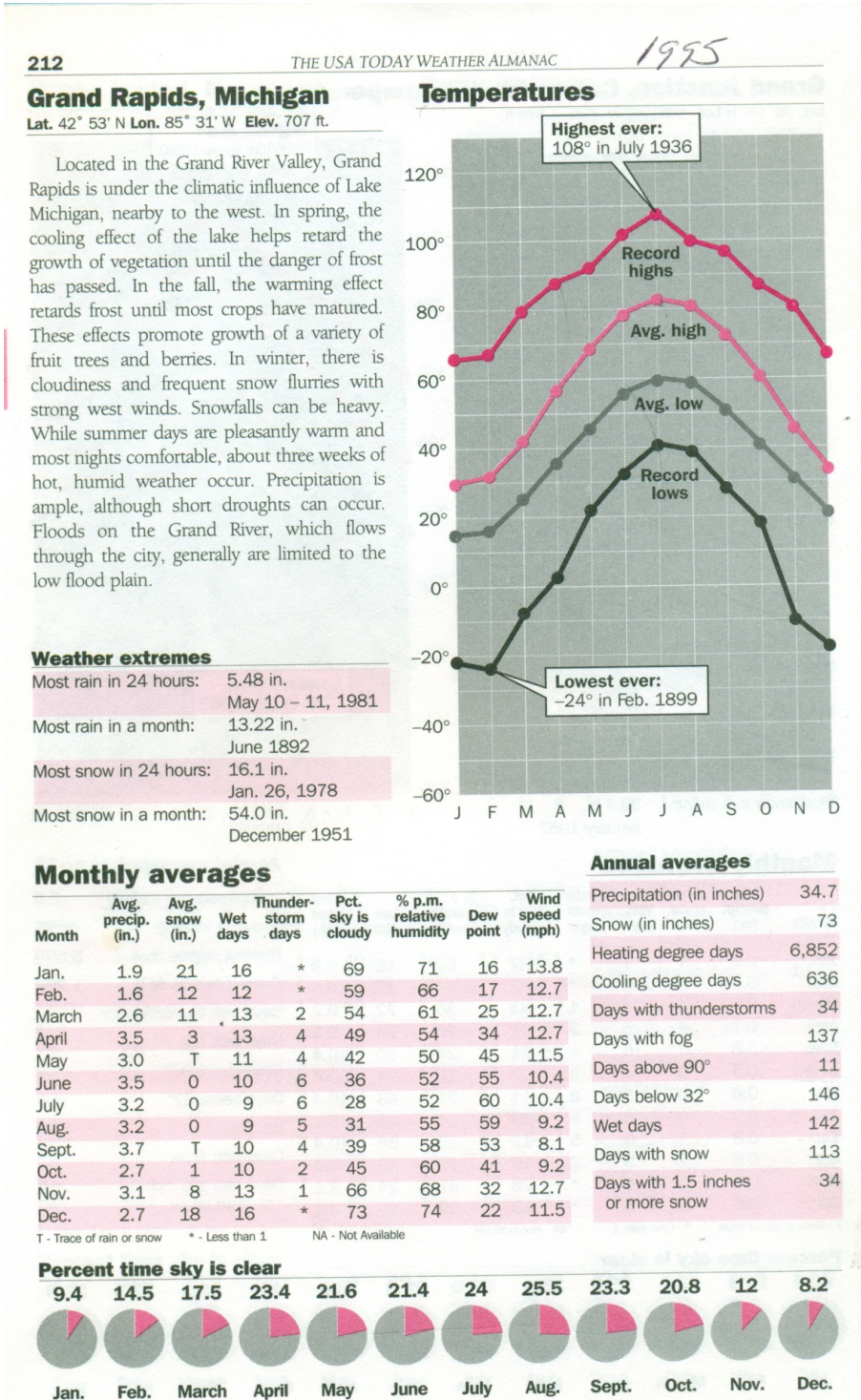


Figure 1. Weather Information for Grand Rapids, MI.

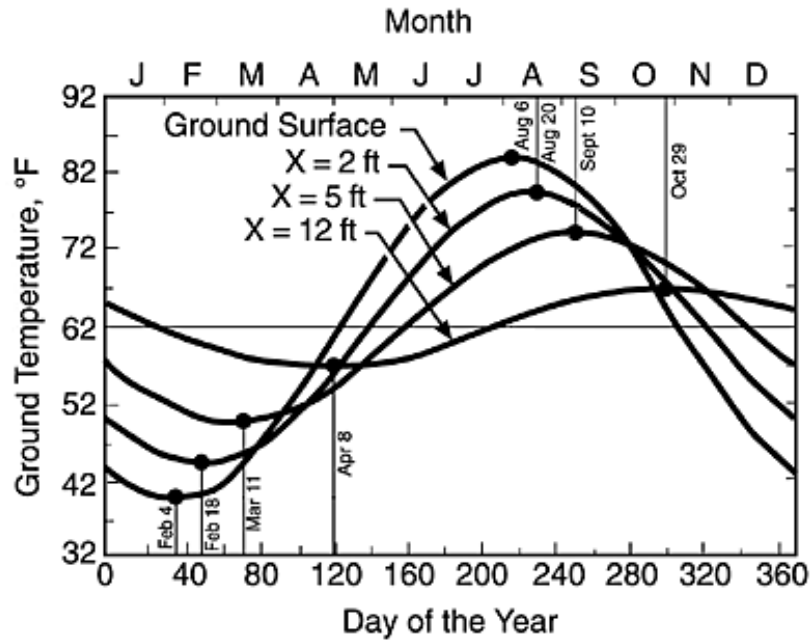


Figure 2. Seasonal soil temperature change as a function of depth below ground surface for an average moist soil.

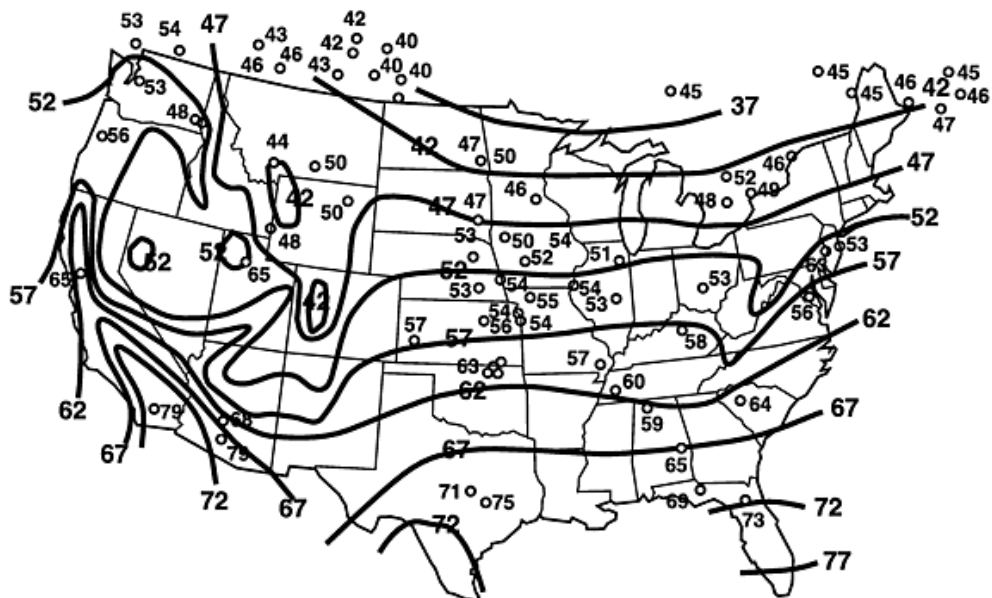


Figure 3. Mean annual earth temperature observations at individual stations, superimposed on well-water temperature contours.

Questions:

1. Looking at the average temperatures for the Grand Rapids area in Figure 1, what are the average low and high temperatures during the months of July and January?

2. Using Figure 2, what happens to the ground temperature as you increase depth during the summer months (List the specific temperature for 12ft)? What about the winter months (List the specific temperature for 12ft)?

3. Looking at this contoured map (Figure 3), what is the estimated mean annual ground temperature for Grand Rapids?

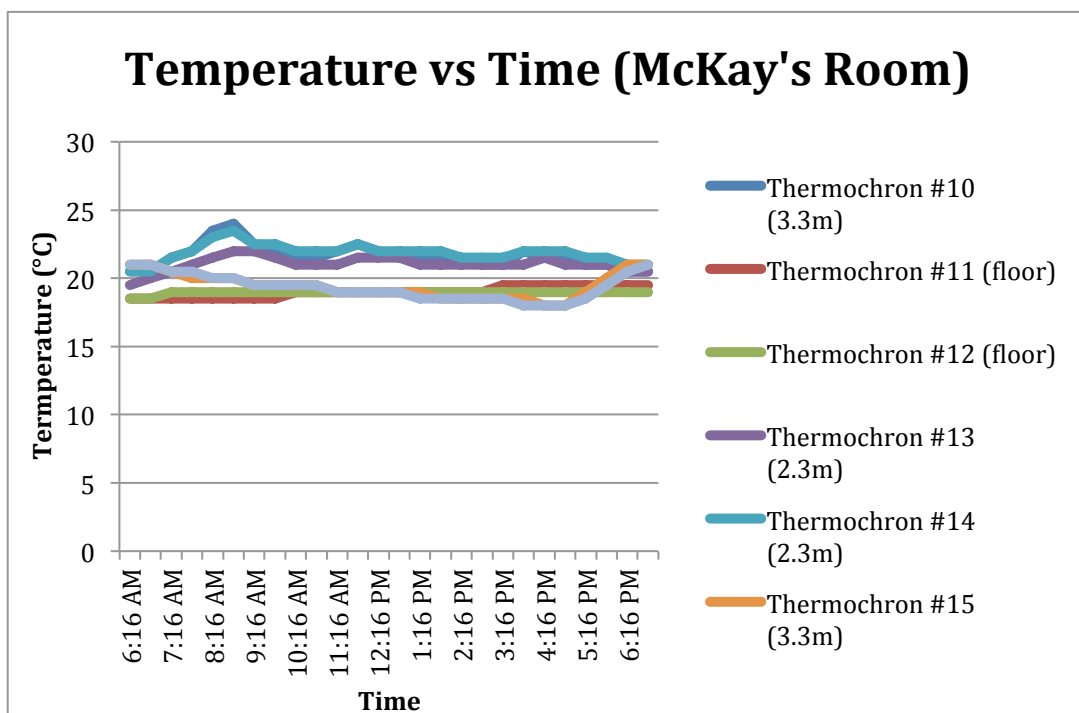
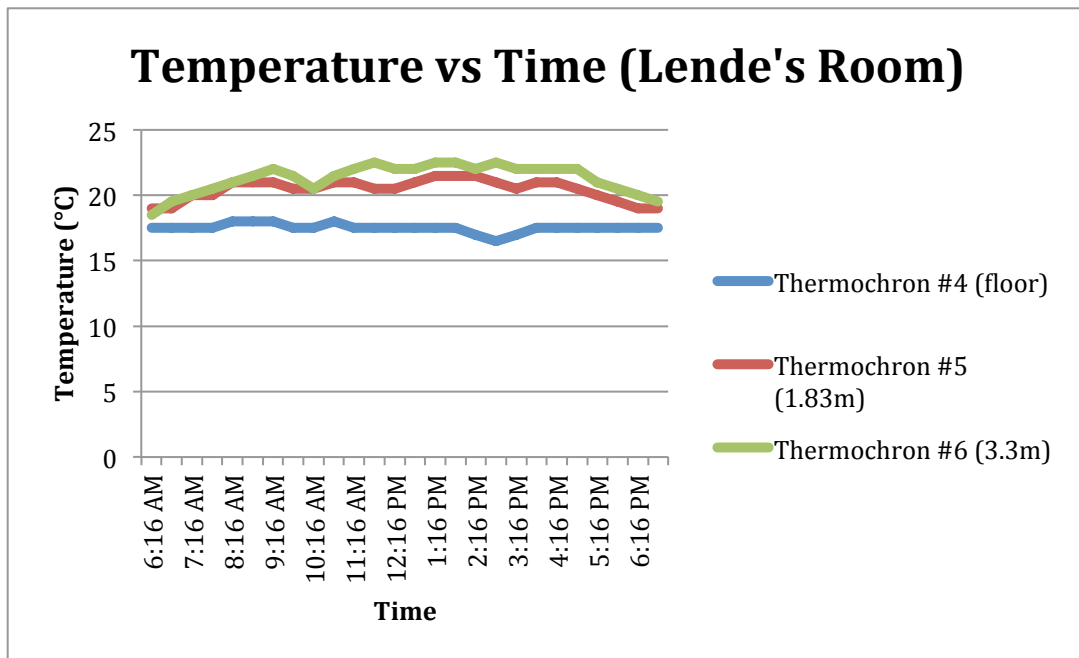
4. After looking at both air and ground temperatures during summer and winter, how do they vary in relation to each other during the year?

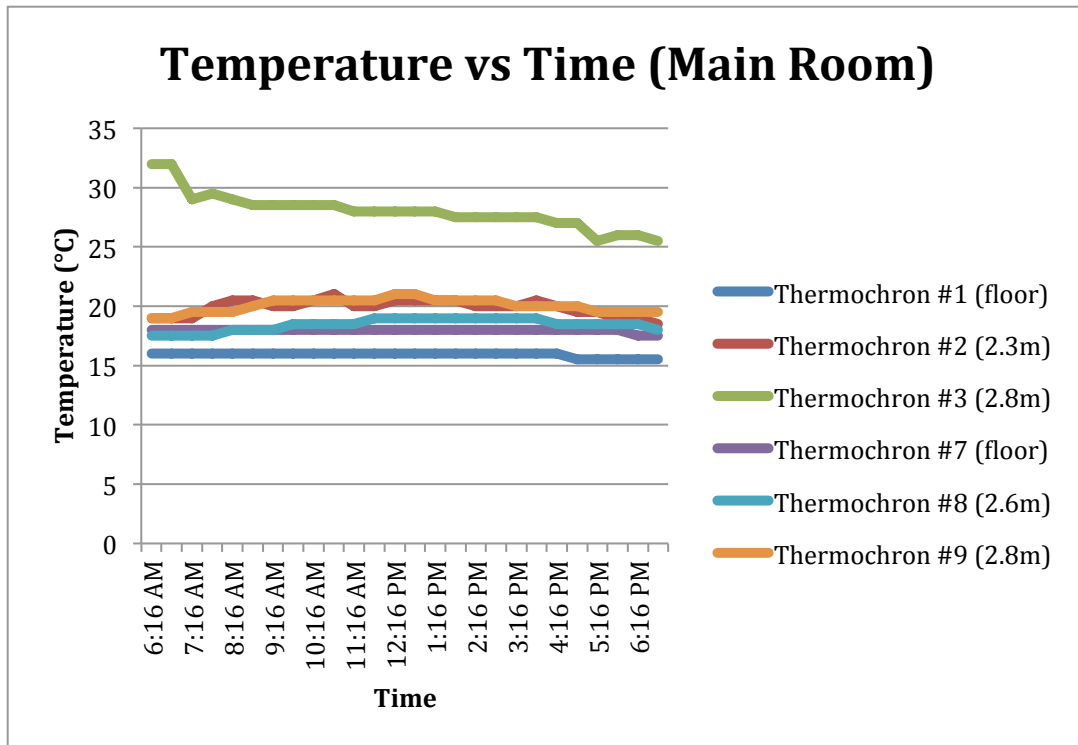


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### Explore 2: Temperature Variations at Various Heights Activity

These graphs were made using data right from Blandford! Thermochrons were used to measure temperature throughout the day at different heights in the school. For each graph, data was taken during a Monday from 6am-6pm. The numbers in parentheses in the key give the heights for each thermochron.





Questions:

1. For each graph, what height has the highest trend of temperature? Lowest trend?
2. Sometimes in data there are outliers. In which graph and what thermochron seems like the outlier in this data set? Why do you think this happened?
3. Since there is a geothermal heating system in Blandford, rooms are heated from the floor. What is the overall pattern for temperature distribution?

### **Explore 3: Model of Geothermal System (This information is for the teacher)**

#### Materials:

- Two pieces of clear vinyl tube (10 feet long)
- Three PVC pipe connectors that fit the vinyl tubes
- Six stoppers that fit into the PVC pipe
- Four thermometers
- Two cardboard boxes to fit the coiled tubes
- Paper or felt to cover the top of the boxes (one green and one tan)
- Hot water (enough to fill one entire piece of vinyl tube)
- Container to pour hot water into the tube
- Funnel

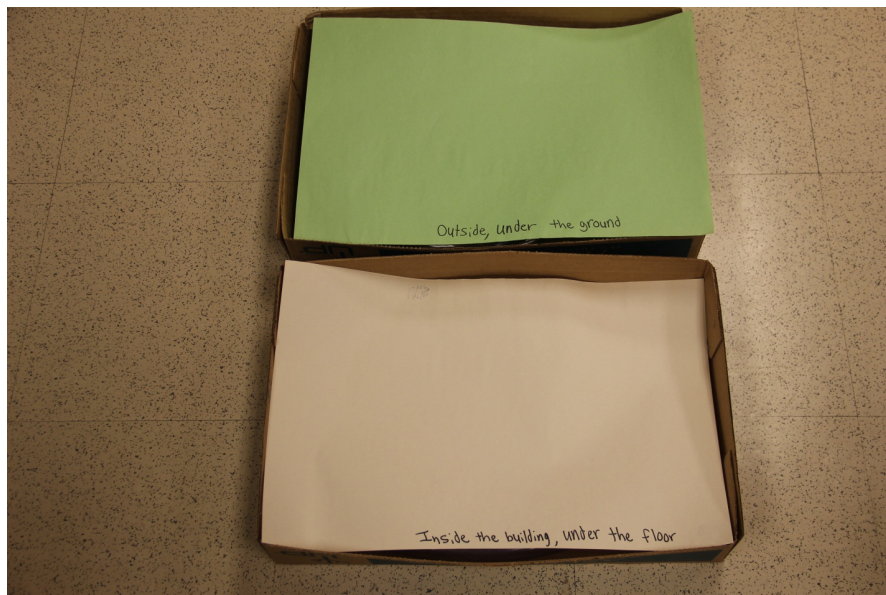
#### Procedure:

1. Fill one tube completely with hot water, put a thermometer inside the tube and have students measure the temperature of the water (it should be around 70°F)
2. Coil the tube and place it inside one of the boxes
3. Use another thermometer and have students take the temperature of the outside of the vinyl tube by placing the bulb in-between the coils
4. Coil the empty second piece of vinyl tube and place it in the other box
5. Put the green paper/felt over the box with the tube filled with water and place the tan paper/felt over the box with the empty tube
6. Explain to students that one box (with green paper) represents the ground outside with the geothermal system within it and the other box (tan paper) represents the floor of a building with the geothermal system under the floor
7. Remove both tubes and while using a funnel, transfer the hot water from one tube to the other (while doing this, explain to students that you're transferring water with the help of gravity instead of a motorized pump system that an actual geothermal system would use to move the water within the tubes)
8. Once you've successfully transferred the water, have students retake the temperature of the water within the tube and of the outside of the vinyl tube

9. After completing the following steps, make sure to explain how this is a simplified version of geothermal system



This is a picture of the set-up of the coiled tubes, which represents the loop within the geothermal system for the model.



This is a picture of the model once the colored paper is put over top of the coiled tubes. The green paper represents the grass and ground outside and the tan paper represents the floor in the building. The tubes are hidden in order to show students that the tubes are both underground and under the floor.

Name: \_\_\_\_\_

Questions pertaining to Geothermal System Model:

1. What were the four temperature readings?

Temperature of water inside first tube: \_\_\_\_\_°F

Temperature of the outside of the first tube: \_\_\_\_\_°F

Temperature of water inside second tube: \_\_\_\_\_°F

Temperature of the outside of the second tube: \_\_\_\_\_°F

2. What is a reasonable possibility for error in regards to the loss of heat during our experiment?

3. Describe the mechanism used to move the fluid (water) from tube to tube in our model.  
How is this different from an actual geothermal system?

4. If you had to make improvements on this model, what would you do? Why?

Name: \_\_\_\_\_

**Elaborate 1: Advantages and Disadvantages of using Geothermal Systems**

Visit these three websites and read about the advantages and disadvantages of using Geothermal Systems. After reading information on the websites, list five advantages and five disadvantages in the chart below.

<http://geothermalprosandcons.net>

<http://www.ecoheatsolutions.com/heatingsolutions/geothermalheat.html>

<http://www.geothermalgenius.org/benefits-of-geothermal/>

<b>Advantages of using Geothermal Systems</b>	<b>Disadvantages of using Geothermal Systems</b>

**Answers to “Advantages and Disadvantages of using Geothermal Systems”  
Worksheet**

Advantages:

- Uses thermal energy within the Earth
- Geothermal energy doesn't fluctuate in price
- Most green type of energy
- The government gives consumers money if they use geothermal systems in their homes
- In the long run, it saves customers money
- Extremely efficient
- Used to heat and cool buildings
- Source of renewable energy
- Clean operation
- Long life
- Low maintenance
- No noisy outdoor units
- Safe within the home (no chance of carbon-monoxide poisoning)

Disadvantages:

- Building electricity generation plants are very costly
- The Earth's crust has to be drilled frequently in order to receive the thermal energy
- Geothermal energy cannot be transported
- Maintenance of geothermal power plants is extensive and the plant itself is very dangerous
- Sites for geothermal energy are located at certain places where use is optimal
- For geothermal hvac systems, a substantial amount of area is needed for bores (area where hot water and steam are extracted)
- Expensive to install

- Not very helpful for retrofits (adding geothermal to older systems)
- One-third or more of heating energy still from electricity, which is costly
- Units must run at low output temperatures in order to be efficient
- The ground loop types in the lower water table are costly



Name: \_\_\_\_\_

### **Elaborate 2: LEED Standards WebQuest**

Visit the U.S. Green Building Council website. (<http://www.usgbc.org>) Follow the various steps and answer the questions below.

1. On the very top of the webpage, click “LEED”. Scroll down and read the information under the title, “Overview” (This title is on the left hand side of the webpage). Stop reading once you see the sentence “LEED v4 is the newest version...”

Answer the following questions:

o What does LEED stand for?

o Give a brief description of LEED

2. Scroll down until you reach the title, “Rating Systems” and read the information.

Click on the five rating systems and answer the following question:

o Name at least three specific projects that are rated by LEED (Examples are New Construction, Retail, Data Centers, etc.)

3. Continue on the webpage and scroll to the title, “Credits”.

o List and describe three credit categories.

Then click on “Explore The Credit Library”.

- o List two specific credits under each of your chosen categories.
  
- o In addition to listing the two credits for each category, write the possible points that could be earned with each credit.

4. Again, on the very top of the webpage, click “LEED”. Scroll down and find the “Levels of Certification” title.

- o What are the four levels of certification for LEED and how many points are needed for each?

5. Continue on the same page and find the title “Why LEED?”

Answer the following questions:

- o What does LEED try to accomplish for sustainability in buildings? (Under the title “Proven performance”)
  
- o What is the highest percentage of energy and water bill reduction for LEED-certified buildings? (Under the title Lifetime of returns”)

6. Go to the top of the webpage and hit “Directory” on the right hand side. Click on “Browse” under Projects. Then click on LEED BD+C: Schools on the left hand side of the webpage. Use the filter in the middle of the page and click on “Name”. This should bring up a down drop of options, click on “State”. Then, in the blank box to the right of the down drop, type in “Michigan” and then hit “Apply”. Choose any school and answer the following questions:

- o On the right hand side you’ll see a box labeled “LEED Facts”; this is a building’s scorecard. This gives you a break down of points earned for a particular building. What does the appearance of the scorecard remind you of? (Hint: Think of food)
  
- o For the school of your choice, what is the certification level based on the points earned?
  
- o Pick one category off of the building’s scorecard. List the category name and write down how many points that school has earned for that particular category.

7. Towards the top of the page, hit on the “Projects” Tab and in the search engine, type in Blandford School. Click on the link and answer the following question:

- o What does the scorecard say for Blandford?

## Answers to “LEED Standards” Worksheet

1.

- o Leadership in Energy & Environmental Design
- o LEED gives guidelines to owners and operators of buildings for designing, building, operating, and maintaining efficient and sustainable sites.

2.

- o New Construction, Core & Shell, Schools, Retail, Hospitality, Data Centers, Warehouse & Distribution Centers, Healthcare, Commercial Interiors, Existing Buildings, Plan, Built Project, Homes and Multifamily Lowrise, Multifamily Midrise

3.

- o The credit categories are Integrative Process, Location and transportation, Materials and Resources, Water efficiency, Energy and atmosphere, Sustainable sites, Indoor environmental quality, Innovation, and Regional priority credits. The descriptions are listed on the website; please visit the website and check for correct answers.
- o The specific credits will vary depending on the categories chosen; please visit the website and check for correct answers.
- o The possible points that could be earned with each credit will vary depending on the categories chosen; please visit the website and check for correct answers.

4.

- o Certified: 40-49 points, Silver: 50-59 points, Gold: 60-79 points, and Platinum: 80+ points

5.

- o LEED tries to accomplish energy efficiency, water efficiency, environmentally friendliness, cost savings, air quality improvements, better building materials, and tax rebates for buildings.
- o 40%

6.

- o Nutrition Labels for food
- o The certification level for the chosen school will vary; please visit the website and check for correct answers.
- o The category name and points earned for the particular category will vary; please visit the website and check for correct answers.

7.

- o Certification in progress

Name: \_\_\_\_\_

**Elaborate 3: Video Clip**

You'll watch a video from the U.S. Department of Energy website about geothermal systems. As you watch this video, list **five** facts you learned from the video.

1.

2.

3.

4.

5.

### **Answer to “Video Clip Worksheet**

Video Clip: After watching the video, quickly read the five facts given for each student and make sure the facts make sense and were from the video. This is more of a credit/no credit worksheet done to make sure students pay attention to the video.

Name: \_\_\_\_\_

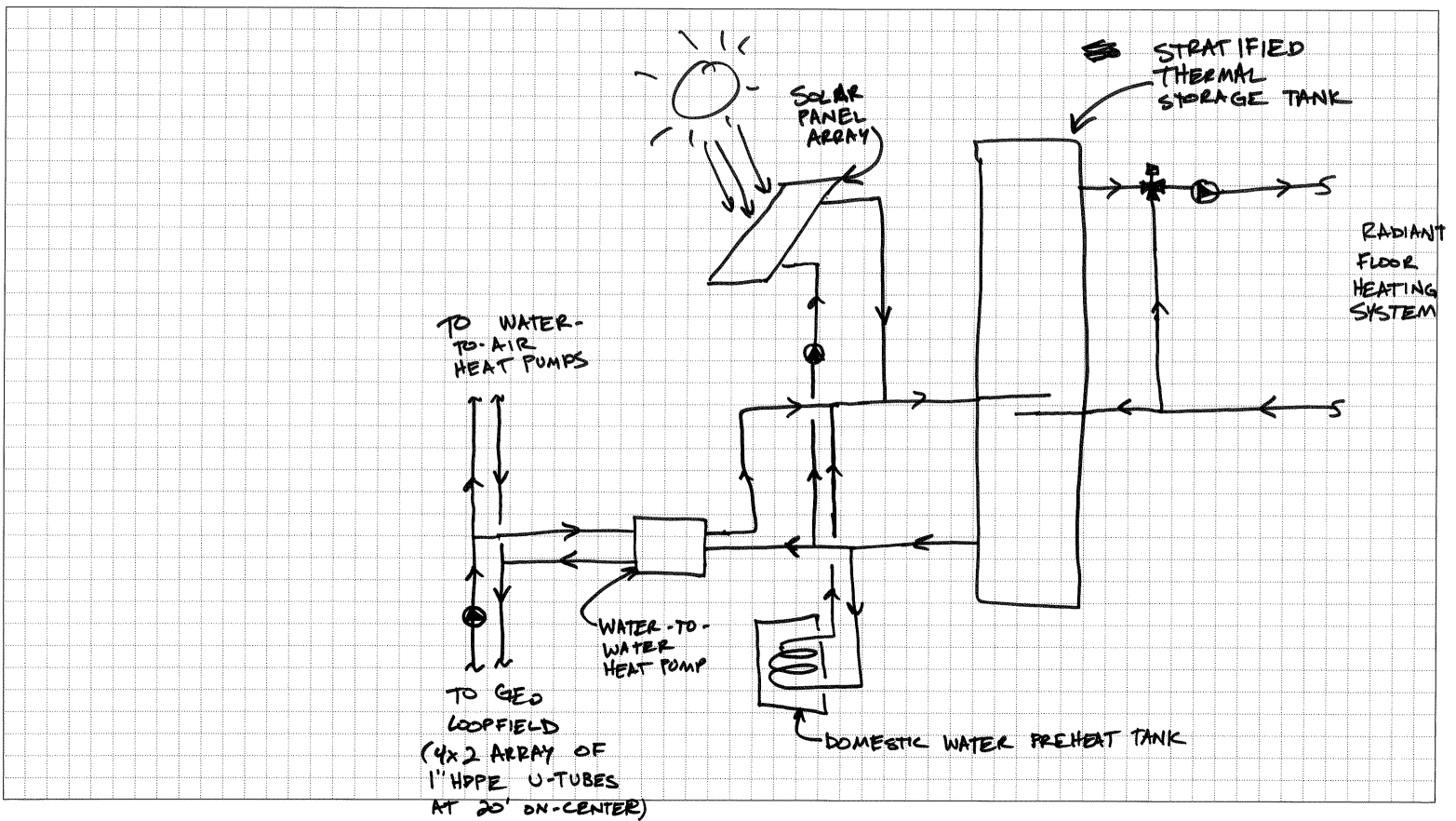
### Elaborate 4: Geothermal System Diagram

Observe this diagram of Blandford's Geothermal System and answer the following question:



1811 4 Mile Road, NE  
Grand Rapids, MI 49525 2442  
616 361 2664 VOICE  
616 361 1493 FAX  
www.progressiveae.com

PROJECT: \_\_\_\_\_  
SUBJECT: \_\_\_\_\_  
PROJECT NO. \_\_\_\_\_ PAGE \_\_\_\_\_ OF \_\_\_\_\_  
BY: \_\_\_\_\_ DATE: \_\_\_\_\_  
CHECKED: \_\_\_\_\_ DATE: \_\_\_\_\_



Imagine you are the engineer that designed this diagram. With your best efforts, follow the arrows and list the steps of how this geothermal system works starting from the bottom left description. Basically, you want to follow the cycle of this system by listing the descriptions given. (Continue to the next page)



1.

2.

3.

4.

5.

6.

7.

8.

9.

## **Answers to “Geothermal System Diagram” Worksheet**

Geothermal System Diagram: This is also can be a credit/no credit worksheet. The purpose of explaining the diagram is to have students describe the process of a geothermal system. The answer to this question would be:

1. Heat traveling by liquid through loop field array
2. Water-to-air heat pumps
3. Water-to-water heat pump
4. Solar panel array
5. Stratified thermal storage tank
6. Radiant floor heating system
7. Domestic water preheat tank
8. Water-to-water heat pump
9. Back to loop field array

Name: \_\_\_\_\_

### **Evaluate 1: Geothermal System Quiz**

1. Why is it beneficial to use geothermal energy (heat from the ground) instead of air from outside to heat and cool buildings?
  
  
  
  
  
  
  
  
  
  
2. When observing the temperature graphs at various heights in Blandford, what was the overall trend of temperature as you increased height? What does this data tell you about the movement of heat?
  
  
  
  
  
  
  
  
  
  
3. Briefly describe what a geothermal system is and how it works. Be sure to explain the process of the water/glycol liquid as it goes both inside and outside.

4. What does the abbreviation LEED stand for? What is the main goal of LEED?

5. List one advantage and one disadvantage for using geothermal systems.

6. Based on your answers from question five, would you use a geothermal system? Why or why not?

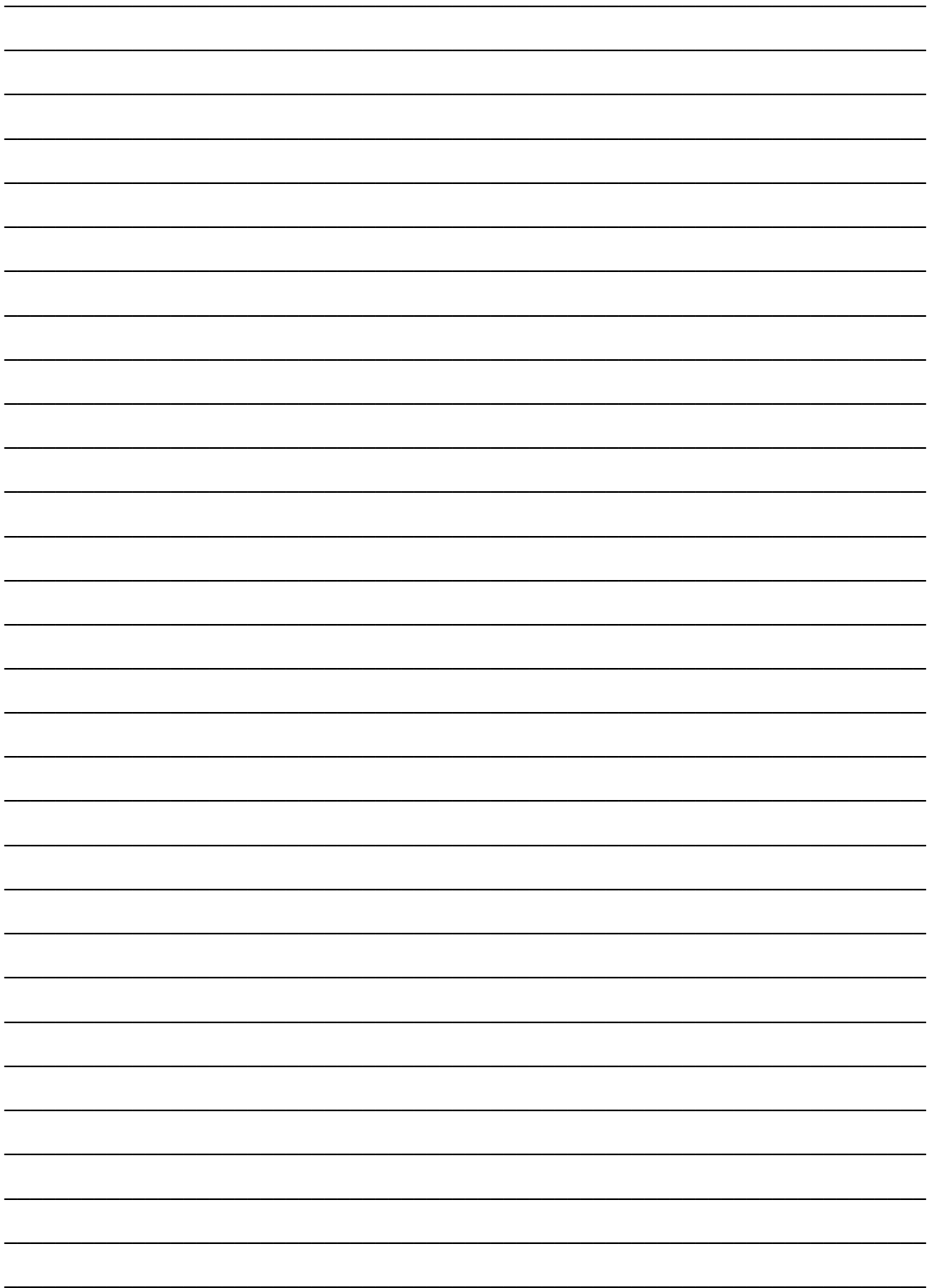
7. Explain how buildings are certified using LEED. List at least one category from which buildings earn points.

8. Did you enjoy this lesson plan about geothermal systems? Please be honest! How do you think this information will help you in the future?

### **Answers to “Geothermal System Quiz”**

1. By using a geothermal system, we’re using the heat from the ground, which is constant throughout the year. This is better than using air outside because it varies annually. This helps decrease the amount of energy we use and saves money.
2. As the height increased, the temperature increased as well. This data tells us that heat rises since the heat started from the floor.
3. A geothermal system uses heat from the ground to help heat the inside of buildings. The system uses a water/glycol mixture and sends it through pipes underground and outside to absorb heat from the Earth. Then it’s moved by a heat pump and used to help heat the inside of buildings using a regular heating/cooling system. Electricity is still used to heat the remaining air up to its required temperature.
4. Leadership for Energy & Environmental Design. The main goal of LEED is to certify and recognize buildings for the various ways of reducing energy (sustainability).
5. Answers will vary. Review answers to elaborate 1 worksheet.
6. Answers will vary. As long as they support their opinion, credit can be earned.
7. Buildings are certified using LEED by points earned from multiple categories. Categories will vary, review answers to elaborate 2 worksheet (aka the website)
8. Answers will vary. Use your best judgment and make sure students give a reasonable answer.







### **Answers to “What Would You Choose?”**

Answers will vary; at the very least, grading should be based on students having a clear position and stating five points of evidence within their essay. You, as the teacher, can create a rubric based on what criteria you want to have the students focus on.

## References

Blandford School

Progressive AE

Norman Christopher

USA Today Weather Almanac

Next Generation Science Standards

<http://www.nextgenscience.org/msets-ed-engineering-design>

GVSU Facilities Planning

[www.gvsu.edu/facilitiesplanning](http://www.gvsu.edu/facilitiesplanning)

Energy Resource Station Slides

[http://www.michigan.gov/documents/CIS\\_EO\\_KC-MAY06-Workshop\\_159640\\_7.pdf](http://www.michigan.gov/documents/CIS_EO_KC-MAY06-Workshop_159640_7.pdf)

Ground Temperature Graphs

<http://www.builditsolar.com/Projects/Cooling/EarthTemperatures.htm>

Advantages of using Geothermal Systems

<http://www.geothermalgenius.org/benefits-of-geothermal/>

Advantages and Disadvantages of using Geothermal Systems

<http://www.ecoheatsolutions.com/heatingsolutions/geothermalheat.html>

Advantages and Disadvantages of using Geothermal Systems

<http://geothermalprosandcons.net>

U.S. Green Building Council (LEED)

[www.usgbc.org](http://www.usgbc.org)

Video Clip

<http://energy.gov/energysaver/articles/geothermal-heat-pumps>

Factoid Picture about Trees

[http://www.envirotechgeothermal.com/geothermal\\_advantages.html](http://www.envirotechgeothermal.com/geothermal_advantages.html)