Solar Education for NY
SchoolPower...Naturally

Heat Pollution and Communities

SPN LESSON #45

TEACHER INFORMATION

LEARNING OUTCOME

After collecting and comparing data from their school and other schools' DAS systems, students are able to cite differences in waste heat amounts for contrasting environments.

LESSON OVERVIEW

In this lesson, students examine an issue, thermal pollution, in the broad context of environmental impact, and distinguish between opinions and claims as opposed to facts and data. A short reading provides students with an overview of the issue. The reading explains that whenever energy is transformed, heat is produced. This heat, known as waste heat, is seldom desirable. Many different strategies are used to dissipate waste heat, but few are environmentally neutral and many have some negative impact. Students come to realize that what seems like an environmentally sound solution may have negative repercussions; all technological changes result in both benefits and burdens.

Students are made aware of the thermal pollution issue on both personal and global levels. They are provided with the opportunity to collect data. Then, through analysis of this data, they find evidence to support the claim that thermal pollution is more of a problem in some locations than in others. Students learn why this is so and also develop understanding of the environmental ramifications of thermal pollution.

GRADE-LEVEL APPROPRIATENESS

This Level III Environmental Considerations lesson is intended for use with students in Living Environment classrooms in grades 9–10.

MATERIALS

Photocopies of the Student Handout section, including the temperature chart

SAFETY

There are no special precautions students need to be aware of for this lesson.

TEACHING THE LESSON

This lesson can be taught at any point during the school year. It is most appropriate when dealing with Key Idea 7 of the *Living Environment Core Curriculum*: Human decisions and activities have had a profound impact on the physical and living environment.

Put a few statements such as the following on the board or an overhead transparency:

- The freezing point of water is 0^{o}C. (F)

- It is healthier to take a cool shower than a hot shower. (O)
- The inside of a hot piece of pie is hotter than the outside. (F)
- During the summer months, cold foods are better for you than hot foods. (O)

Read through these statements and elicit from students which ones are facts and which are opinions. Ask students to describe the difference between a fact and an opinion. According to Slife (1998), a fact is information we take to be true because it is widely accepted, while an opinion is a judgment made by an individual who interprets data in the context of what makes personal sense.

You may want to have teams of students responsible for recording and sharing the photovoltaic panel data, or you may want to have students access the data via the computer network. You can provide them with the data recorded by other classes. Each class should select the other location from which it will record data. If all classes use the same location, then that data can also be shared. Be sure classes select locations that are geographically similar to the area in which they live. For example, if they live near a large body of water in the southern part of the state, they should not select a school located in the Adirondacks. Before they make a selection, ask students what factors (in addition to community size) they should consider in order to make the data comparison as accurate as possible.

ACCEPTABLE RESPONSES FOR DEVELOP YOUR UNDERSTANDING SECTION

1–4: Student answers will vary depending on location and time of year. Some general trends the data should exhibit are: as the day goes on, the temperature increases; the temperature in a more urban area will be warmer than in a rural area; ambient air temperature will be different than the module temperature.

5. How do the average temperatures for your community compare to those of the other community for which you obtained readings? On the basis of your data analysis, is it a fact or an opinion that the air temperature in cities is often several degrees higher than in the surrounding countryside? Use data from your chart to support your answer.

   Answers will vary. However, temperatures recorded in urban areas should be higher than those recorded in the country. If this conclusion is based on data collected by the students, the answer is a fact rather than an opinion. Students should reference specific examples from their data table to support their claims.

6. (a) Identify three specific sources of waste heat in your community.

   Answers will vary. Cars, home appliances, factories, landfills, etc. are all acceptable answers.

   (b) Explain how each of these sources produces waste heat.
   Answers will vary depending upon the sources students identify in 6(a).

7. Name one or more industries in your community that use a lot of water in their production process.
   Answers will vary depending on location.

8. (a) If a factory that has been warming the water in an area for many years had to shut down for repairs, what might happen to the plants and animals in that region of the river/lake?
   The plant and fish populations that thrive in warm water would probably not be able to survive an extreme temperature change. Species able to survive in cooler water would move back into that area. When the factory started operating again, the environment of these new inhabitants would be disrupted once again.

(b) Describe what would happen to both the aquatic and terrestrial plants and animals just outside the area where the heated water was being released.

The plants and animals just outside the warmed area would be impacted. Food chains would become unbalanced when specific species were eliminated or forced to move. There would be increased or decreased competition for specific resources. The communities of organisms would change as populations migrated or emigrated.

9. Decide if the following statement is a fact or an opinion: "Farmers are in favor of heat pollution because a longer growing season allows them to grow more crops and make more money." Use specific examples to support your answer.

   This statement is an opinion unless students are able to access and cite such sources as a survey of many farmers showing that they are in favor of heat pollution for these reasons. Students should be helped to see that a longer growing season does not necessarily allow farmers to make more money and grow more crops. For one thing, there may be less rain in spite of a longer growing season, and as a result the crops might die or the yield might be reduced. Also, the types of crops that can be grown might change and the new crops might have less value. On the other hand, crops requiring a longer growing season might grow successfully and actually have a higher monetary value.

10. What might happen if plants and other organisms are "tricked" into responding as if it were spring during January or February?

    Plant parts that start to grow when the temperature is temporarily higher may freeze when the temperature returns to normal, thereby affecting future growth or yield.

Activity Analysis

1. As the air becomes hotter on a summer day, people turn on their air conditioning units. In terms of waste heat, explain how this practice creates a feedback loop.

   As the air temperature increases, people turn on their air conditioning. By increasing the time or intensity of air conditioning use, more waste heat is produced. This heat increases the air temperature even more. People then use their air conditioning more or more intensely, and so on!

2. Select a heat pollution issue and take a proactive stand on a personal level. Name the issue and describe what action you could take to help remediate the problem.

   Answers will vary. Encourage students to take some personal action that results in using less energy, such as selecting more efficient appliances and energy sources. Perhaps they might become advocates for increasing the use of voltaic systems in the energy use mix. They might also produce informative videos, write letters, etc.

3. Is it a fact or an opinion that using photovoltaic panels to generate electricity reduces the amount of environmental disruption caused by waste heat from electric generating stations? Support your answer with evidence from this activity and/or from reliable sources you can reference.
   Students should respond that the use of photovoltaic panels to generate electricity does reduce heat pollution. They should be able to use data from their lab work and from online sources to support their answers.

4. Create a full-page newspaper or magazine advertisement that calls attention to the problem of waste heat. Use wildlife, agriculture, or industry as the focus.
   Student products will vary.

Extended Activities

Have students research the temperature requirements of a variety of aquatic organisms common to your area. This could be a quite open approach. For example, some could research only game fish species. Others could look for the temperature tolerances of any local fish varieties. Yet other students could investigate aquatic insects, other invertebrates, aquatic plants, algae, and bacteria. Students could then produce informational brochures, posters, or PowerPoint slide shows that would create an awareness of what happens when the water temperature goes up. Students should be helped to realize that some species will continue to thrive while others will be forced to migrate or die. Some species will not survive because warmer water holds less dissolved oxygen. Water polluting algal blooms are more likely to develop as the temperature goes up. Also, some pathogenic bacterial species flourish with increased water temperature.

Two good Web sites to get students started are:

- U.S. Environmental Protection Agency: Monitoring and Assessing Water Quality
  http://www.epa.gov/OWOW/monitoring/volunteer/stream/vms53.html
- The New York State Department of Environmental Conservation
  http://www.dec.state.ny.us/website/dfwmr/index.html

ADDITIONAL SUPPORT FOR TEACHERS

BACKGROUND INFORMATION

Heat is produced whenever energy is transformed from one form to another. The generation of this heat is seldom desirable, and it is difficult to avoid. Even though engineers and scientists have developed many techniques to dissipate the waste heat produced during industrial processes, few of these strategies are environmentally neutral, and many, in fact, have a severe impact. Students should come to realize that selecting the best method(s) requires an understanding of the advantages and disadvantages of each. They should also realize that trade-offs must be made—there is no easy solution to the problem.

A common student misconception about energy is that energy is "lost" during conversions when unusable forms result. For example, students might think that the heat generated by a light bulb is lost energy merely because it is not useful energy. Remind students that energy cannot be created or destroyed—only transformed from one form to another.

The photovoltaic panel monitor provides both the ambient air and panel surface temperatures. For the purpose of this investigation, students should record both temperatures.

REFERENCES FOR BACKGROUND INFORMATION

Allen, R. D. and Stroup, D. J. *Teaching Critical Thinking Skills in Biology.* National Association of Biology Teachers. Reston, VA, 1993.

Slife, B. *Taking Sides: Clashing Views on Controversial Psychological Issues.* 10th edition. Publishing Group, Inc. Guilford, CT, 1998.

LINKS TO MST LEARNING STANDARDS AND CORE CURRICULA

Standard 1—Analysis, Inquiry, and Design: Students will use mathematical analysis, scientific inquiry, and engineering design, as appropriate, to pose questions, seek answers, and develop solutions.

Science Key Idea 1: The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing and creative process.

S1.1: Elaborate on basic scientific and personal explanations of natural phenomena, and develop extended visual models and mathematical formulations to represent one's thinking.

S1.1a: Combine evidence that can be observed with what people already know about the world.

S1.1c: Understand that effective and ethical decision making involves both values and scientific knowledge.

S1.2: Hone ideas through reasoning, library research, and discussion with others, including experts.

S1.2a: Ask questions and locate, interpret, and process information from a variety of sources.

S1.2b: Make judgments about the reliability of a source and the relevance of information.

Key Idea 2: Beyond the use of reasoning and consensus, scientific inquiry involves the testing of proposed explanations involving the use of conventional techniques and procedures and usually requiring considerable ingenuity.

S2.1: Devise ways of making observations to test explanations.

Key Idea 3: The observations made while testing proposed explanations, when analyzed using conventional and invented methods, provide new insights into natural phenomena.

S3.1: Use various methods of representing and organizing observations (e.g., diagrams, tables, charts, graphs, equations, matrices) and insightfully interpret the organized data.

Standard 4

The Living Environment

Key Idea 1: Living things are both similar to and different from each other and from nonliving things.

1.1b: An ecosystem is shaped by the nonliving environment as well as its interacting species. The world contains a wide diversity of physical conditions, which creates a variety of environments.

1.1c: In all environments, organisms compete for vital resources. The linked and changing interactions of populations and the environment compose the total ecosystem.

1.1d: The interdependence of organisms in an established ecosystem often results in approximate stability over hundreds and thousands of years. For example, as one population increases, it is held in check by one or more environmental factors or another species.

1.1e: Ecosystems, like many other complex systems, tend to show cyclic changes around a state of approximate equilibrium.

1.1f: Every population is linked, directly or indirectly, with many others in an ecosystem. Disruptions in the numbers and types of species and environmental changes can upset ecosystem stability.

Key Idea 6: Plants and animals depend on each other and their physical environment.

6.1: Explain factors that limit the growth of individuals and populations.

6.1e: In any particular environment, the growth and survival of organisms depend on the physical conditions including light intensity, temperature range, mineral availability, soil/rock type, and relative acidity (pH).

6.3: Explain how living and nonliving environments change over time and respond to disturbances.

6.3a: The interrelationships and interdependencies of organisms affect the development of stable ecosystems.

6.3c: A stable ecosystem can be altered, either rapidly or slowly, through the activities of organisms (including humans), or through climatic changes or natural disasters. The altered ecosystem can usually recover through gradual changes back to a point of long-term stability.

Key Idea 7: Human decisions and activities have had a profound impact on the physical and living environment.

7.1b: Natural ecosystems provide an array of basic processes that affect humans. Those processes include but are not limited to: maintenance of the quality of the atmosphere, generation of soils, control of the water cycle, removal of wastes, energy flow, and recycling of nutrients. Humans are changing many of these basic processes and the changes may be detrimental.

7.1c: Human beings are part of the Earth's ecosystems. Human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems. Humans modify ecosystems as a result of population growth, consumption, and technology. Human destruction of habitats through direct harvesting, pollution, atmospheric changes, and other factors is threatening current global stability, and if not addressed, ecosystems may be irreversibly affected.

7.2: Explain the impact of technological development and growth in the human population on the living and nonliving environment.

7.2a: Human activities that degrade ecosystems result in the loss of diversity of the living and nonliving environment. For example, the influence of humans on other organisms occurs through land use and pollution. Land use decreases the space and resources available to other species, and pollution changes the chemical composition of air, soil, and water.

7.2c: Industrialization brings an increased demand for and use of energy and other resources including fossil and nuclear fuels. This usage can have positive and negative effects on humans and ecosystems.

7.3: Explain how individual choices and societal actions can contribute to improving the environment.

7.3a: Societies must decide on proposals which involve the introduction of new technologies. Individuals need to make decisions which will assess risks, costs, benefits, and trade-offs.

7.3b: The decisions of one generation both provide and limit the range of possibilities open to the next generation.

Standard 6—Interconnectedness: Common Themes: Students will understand the relationships and common themes that connect mathematics, science, and technology and apply the themes to these and other areas of learning.

Key Idea 1: Through systems thinking, people can recognize the commonalities that exist among all systems and how parts of a system interrelate and combine to perform specific functions.

- Explain how positive feedback and negative feedback have opposite effects on system outputs.
- Recognize that interrelationships exist within systems at all levels from a single cell to an ecosystem.

Key Idea 6: In order to arrive at the best solution that meets criteria within constraints, it is often necessary to make trade-offs.

Process Skills Based on Standard 4 (Laboratory Skills)

i. Follows safety rules in the laboratory.
xiii. Collects, organizes, and analyzes data, using a computer and/or other laboratory equipment.
xiv. Organizes data through the use of data tables and graphs.
xv. Analyzes results from observations/expressed data.
xvi. Formulates an appropriate conclusion or generalization from the results of an experiment.
xvii. Recognizes assumptions and limitations of the experiment.

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www.nyserda.org

Should you have questions about this activity or suggestions for improvement,
please contact Bill Peruzzi at billperuz@aol.com

(STUDENT HANDOUT SECTION FOLLOWS)

Name _____

Date _____

Thermal Pollution and Communities

When you turn on an electric light bulb, only about 5% of the electricity moving through the filament is transformed into light. Most of the electricity you are paying for is transformed into heat, and therefore is "wasted." Light bulbs are just a small source of the total amount of waste heat entering our communities. Just think of all of the appliances, vehicles, buildings, and factories that can and do generate waste heat. This heat has a serious negative impact on the environment. For this reason, waste heat is referred to as thermal or heat pollution.

Waste Heat and the City

The average air temperature in a city is generally several degrees higher than in the countryside a few miles away. This difference is partly due to the waste heat produced by just about everything that uses energy. Examples of energy users, and therefore waste heat producers, are cars, trucks, heating systems, refrigerators, and air conditioning units. Cities have more of these and therefore more waste heat. Even the water entering and leaving a sewerage system contains waste heat. Another source of waste heat is the solar energy absorbed by buildings, roads, parking lots, and sidewalks. The closely positioned buildings trap much of this heat and prevent it from escaping.

How might you determine whether the claim that city temperatures are higher than the surrounding countryside's is a fact or an opinion? What about the claim that solar energy is absorbed and that some is reradiated back out as heat? These claims seem logical, but research is necessary to substantiate them. There are several different ways to do this research. You could look through newspapers and find weather information for a nearby city or rural location. This search should give you accurate temperature data. Or, you could collect temperature data yourself, using scientifically accurate probes. You might want to ask friends who live in a different community whether they think city temperatures are higher, but their answers would only be opinions, so it would be better to ask friends to collect data and send it to you.

DEVELOP YOUR UNDERSTANDING

Procedures

1. Access the data display of the school's photovoltaic panel and record both the temperature of the panel (module temperature) and the temperature of the air surrounding the panel (ambient air temperature). Record the information on the temperature chart below. Do this for four consecutive days.

2. With your teacher's help, get temperature information from two other classes that meet at different times of the day. Record their temperature readings in the appropriate places on the temperature chart.

3. At the same time, check the panel and air temperature readings obtained by a school in a community that is different in size from your own. When selecting the community you will use in this investigation, it should be as similar to yours in every way possible but population size. Consider factors such as latitude, the presence of nearby bodies of water, and altitude. For example, if your school is located in the country on a river, obtain data from a school located in a city on a river and at the same latitude as yours. Record the location of the other school, the factors that are the same, the population of the community, and the temperature readings in the appropriate places on the temperature chart.

4. Calculate the average daily panel and air temperatures for both communities and record this information.

5. How do the average temperatures for your community compare to those of the other community? On the basis of your analysis of the data, is it a fact or an opinion that the air temperature in cities is typically several degrees higher than in the surrounding countryside? Use data from your chart to support your answer.

6. (a) Identify three specific sources of waste heat in your community.

   (b) Explain how each of these sources produces waste heat.

Heat Pollution and Industries

Imagine how much water it would take to fill your classroom or your school's gymnasium. Next, imagine a way to increase the temperature of that water by $5^{o}C$ in 5 seconds! This is what happens at an electric generating station where coal, oil, or natural gas is burned to produce electricity. About 60% of the chemical energy in the fossil fuels burned becomes waste heat. Other industries located along rivers and on lakes produce similar amounts of waste heat. Water is taken in from the environment, used during processing, and then released back into the environment at a temperature several degrees higher than it was when it went in.

7. Name one or more industries in your community that use a lot of water in the production process.

Heat Pollution and Wildlife

Heated water produced by electricity generation and industry is released back into the environment. This can cause problems for aquatic plants and animals because warm water is not able to hold as much oxygen as cooler water. Living organisms are adapted to survive in specific environmental conditions and any disruptions can be fatal. For example, lake trout need cold water to survive. If the temperature of the water increases, these trout cannot obtain enough oxygen and must swim to another area or die. When a new industry locates on a body of water, the plant and animal species living in that water are typically replaced by others that can survive higher temperatures and lower oxygen levels.

8. (a) If a factory that has been warming the water in an area for many years had to shut down for repairs, what might happen to the plants and animals in that region of the river/lake/ocean?

   (b) Describe what would happen to both the aquatic and terrestrial plants and animals just outside the area where the heated water was being released.

Heat Pollution and Agriculture

Crops are also affected by heat pollution. For example, waste heat in an area can lead to a longer growing season. Temperature changes also affect precipitation patterns. For example, some areas are experiencing decreased snowfall. Without snow cover, the soil heats up more quickly when the sun shines on it. During a warm, sunny spell in the winter, organisms might be "tricked" into responding as if it were spring. Decreased snowfall also means less water for groundwater systems, lakes, and reservoirs.

9. Decide if the following statement is a fact or an opinion: "Farmers are in favor of heat pollution because a longer growing season allows them to grow more crops and make more money." Use specific examples to support your answer.

10. What might happen if plants and other organisms are tricked into responding as if it were spring during January or February?

Activity Analysis

1. As the air becomes hotter on a summer day, people tend to adjust the settings of their air conditioning units. In terms of waste heat, explain how this practice creates a feedback loop.

2. Select a heat pollution issue and take a proactive stand on a personal level. Name the issue and describe what action you could take to help remediate the problem.

3. Is it a fact or an opinion that using photovoltaic panels to generate electricity reduces the amount of environmental disruption caused by waste heat from electric generating stations? Support your answer with evidence from this activity and/or from reliable sources you can reference.

4. Create a full-page newspaper or magazine advertisement that calls attention to the problem of waste heat. Use wildlife, agriculture, or industry as the focus.

Temperature Chart

Time/Date	Panel Temperature Home	Air Temperature Home	Panel Temperature _____	Air Temperature _____
Day 1 Time _____ Date ____				
Day 1 Time _____				
Day 1 Time _____				
Day 2 Time _____ Date ____				
Day 2 Time _____				
Day 2 Time _____				
Day 3 Time _____ Date ____				
Day 3 Time _____				
Day 3 Time _____				
Day 4 Time _____ Date ____				
Day 4 Time _____				
Day 4 Time _____				
Average Daily Temperature				