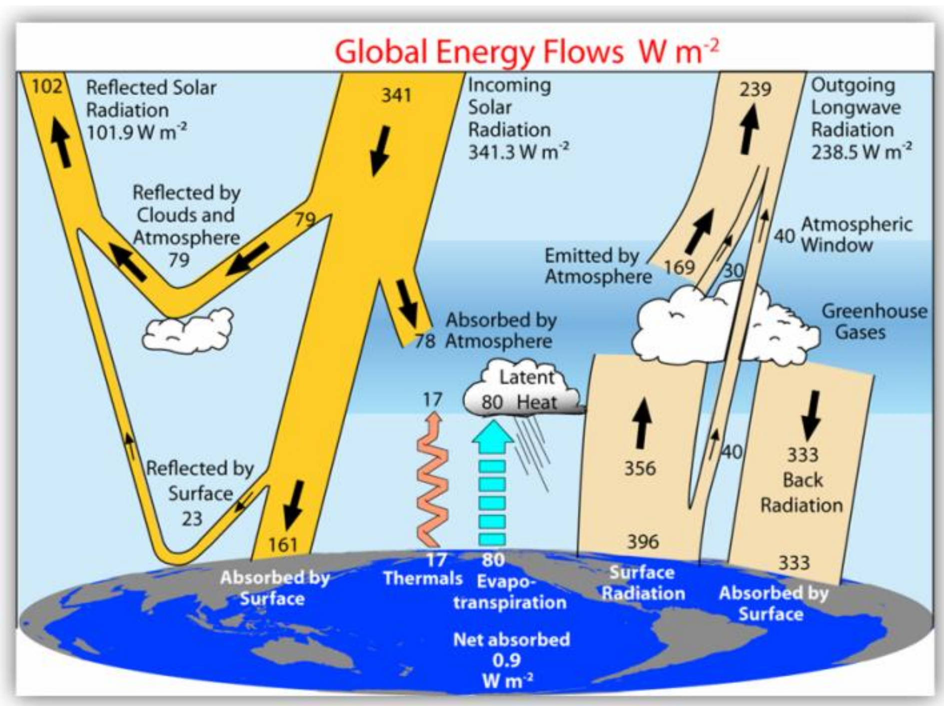
URBAN HEAT ISLAND MODULE

LESSON 5:

ENERGY FROM THE SUN



The global annual mean Earth's energy budget for 2000 to 2005 (W m^{-2}). The widths of the columns are proportional to the sizes of the energy flows. *Source:* *Trenberth et al (2009)*.

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The following lesson and associated materials are part of the Integrating Chemistry and Earth science (ICE) Urban Heat Island Module. The Module brings together important concepts from Earth science and chemistry to help students build an understanding of why urban areas have higher temperatures both during the day and at night, than their rural counterparts.

ICE Partners

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BALTIMORE CITY PUBLIC SCHOOLS
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ICE Integrating Chemistry & Earth Science

Lesson 5: Energy from the Sun (2 Days)

Driving Question: *What happens to radiation when it reaches the Earth?*

Summary: This lesson shifts the focus from the global level to the Solar. The objective of this lesson is for students to understand that hot objects (like the sun) emit shortwave (light) radiation that can travel through a vacuum and anything that is transparent. This radiation can either be reflected or absorbed by surfaces. The percentage of reflected radiation is the "albedo." Absorbed radiation will increase the temperature of the surface of the object. This heat energy is then released as long wave (infrared) radiation. **Teacher Note:** You have two scheduled days for this topic.

Activity Description:

Day I

- **Opening Activity:** Students will explore the effect of sunlight on surfaces by completing the *Energy from the Sun* activity.
  - Energy from the Sun: (weather permitting)
    - Give students a piece of paper and a magnifying glass (or other lens). You will also need black markers for students to share and stop watches.
    - Go outside somewhere with direct sunlight that is also shielded from the wind.
    - Directions/hints for students:
      - Make 2 circles. Leave one "white"(○) and fill one in solid "Black."(●)
      - Place your paper on the ground so you don't burn yourself.
      - Use the lens to focus light from the sun onto one of the spots on your paper.
      - Hold the lens so you have the smallest possible point of light.
      - Use a timer to see which circle burns fastest.
      - Discussion Question: Why would one catch fire faster than the other?
        - **Teacher Note:** The key point is that the "white" circle should take longer to burn because it is reflecting more of the solar energy than the "black" circle.
  - Energy from Hot Objects: (bad-weather option)
    - Plug in an incandescent light bulb and heat up various materials (a chunk of metal, a rock…).
    - Warn students that the objects are hot, and they will burn themselves if they touch them. Then allow students to take turns seeing if they can feel the heat without touching the objects or test them using the IR thermometers.
    - Discussion question: Why are the objects different temperatures if they have been sitting under the same light?
- **How much radiation does Baltimore get from the sun?** The teacher will lead a discussion on the amount of energy that Baltimore receives from the sun.

- Ask students, "Where does the sun get its energy from?"
  - Students should know that nuclear fusion of hydrogen atoms provides the sun with power
  - **Teacher Note: Accepted power output =** 3.846×10^{26} W.
- How much radiation from the sun reaches Earth's surface on average, per square meter?
  - Average value: 184 W/m^2.
  - **Teacher Notes**: The Value 184 W/m^2 can be found on the *Energy Flow Diagram* by adding the absorbed and reflected solar energy at the surface.
- Calculate the annual average power radiated by the sun to reach Baltimore City.
  - Students can look at this map to determine the average power radiated by the sun per square meter to reach the surface of Earth near Baltimore (180-200 W/m^2).
  - Students can look at the Wikipedia article on Baltimore to find the area of the land (210 km^2) and water (29 km^2).
    - Total Area: $210\ km^2 + 29\ km^2 = 239\ km^2 = 2.39 \times 10^8\ m^2$
    - Sample Calculation: $P_{Balt.} = (190\ W/m^2)(2.39 \times 10^8\ m^2) = 4.5 \times 10^{10}\ W$
  - Student Worksheet: *Energy in Baltimore*
- Students use the UHI Modeling Template to create a thermal model for Baltimore.
  - Models might include:
    - A general outline of a Baltimore-style cityscape.
    - Park or other urban-typical green areas.
    - Arrows with labels quantifying how much solar radiation is reaching Earth and Baltimore.
  - Student models should all be different.
  - See the Modeling Template – Teacher Instructions for additional information.
- Create a Generic Heat model, for the class, based on student input.
  - Discussion Prompt: What part of the system does the model show? Why are these parts shown? What parts of the system are not shown in the model? Why are these parts not shown?
  - Keep model up for further additions.

- **Homework:** Students may complete their model if they need more time.

Day II

- **Opening Activity:** Engage student's prior knowledge by using a review game.
  - Students review the concepts from yesterday using an interactive quiz type game, such as Kahoot, Quizlet Live, or Quizizz.

Where does that heat go?: Students will investigate the impact of color on the absorption and reflection of heat energy and its application to heating the city.

- Lab Activity: *Albedo Lab*
  - Special Material Preparation: You will need lamps and bulbs and construction paper (Black and White will show the most dramatic differences, but dark and light

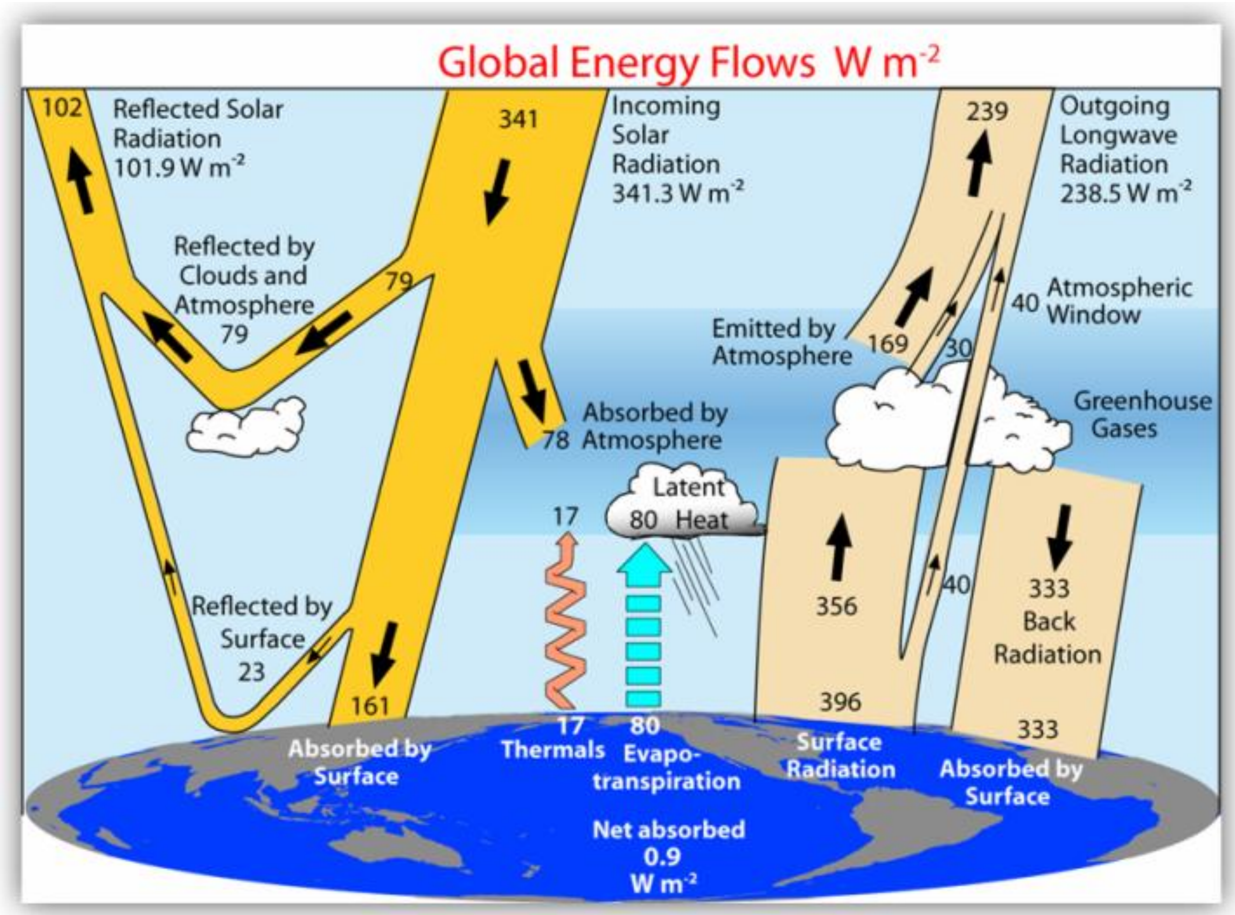
combinations in different colors will show interesting variations. It is suggested that each group have different colors combinations of "dark and light" to increase variation and discussion) along with the more traditional materials listed on the lab sheet.

- **Teacher Notes**: Topic Resources:
  - Global Albedo,
  - What is Albedo,
  - Surface Albedo

▪ Discussion Prompt: How does energy flow within the system?

- **Optional Albedo Lab Extension:** Students will extend their investigation by going outside.
  - Students go outside with the IR thermometers and investigate the effect of shade on pavement.
  - Materials needed:
    - IR thermometers
    - Carboard sheets
    - Stopwatch
- **Student Heat Models:** Students will update their Baltimore energy models based on the information from today's activity.
  - **Teacher Note:** In the past, students have had a hard time differentiating between reflected heat and heat radiated from buildings. It might be useful to discuss the differences and get students to create unique symbols to show the difference in their models.
- **Class Generic Heat Model:** Add to the class model, as appropriate, based on student input.
- **Homework:** Have students read the article: Dust linked to increased glacier melting, ocean productivity and then explain, in writing or through image diagrams, how the volcanic dust and sediment is able to increase the rate of melting of the glacier.

HEAT ENERGY FLOW DIAGRAM



https://www.skepticalscience.com/heatflow.html

The global annual mean Earth's energy budget for 2000-2005 (Wm-2). The widths of the columns are proportional to the sizes of the energy flows. From Trenberth et al (2009).

Integrating Chemistry & Earth Science

Energy in Baltimore

How much energy does the Sun give the city?

Your job is to calculate the total amount of solar radiation energy that reaches Baltimore in one year.

Information you need:

- Area of land in Baltimore MD.= 210 km^2
- Area of water in Baltimore MD = 29 km^2
- How much radiation from the sun reaches Earth's surface on average, per square meter?
  - Average value: 184 W/m^2

Calculate the total amount of energy. Show your work below.

Albedo Lab: Heating the Earth's Surface

Based on Heating Earth's Surfaces: Albedo

Introduction:

Think about this: On a hot summer day, do you find dark or light clothing the most comfortable to wear in the bright sunshine? Explain. Have you ever walked barefoot across dark pavement or sandy beach during a bright, hot summer day? What was the experience like? On a bright, hot summer day, if you had to walk barefoot down a dark sidewalk or along pavement lined with green grass, which surface would feel most comfortable to your feet? Why?

Objective:

Students will develop and test a hypothesis about how the reflection from surfaces of different colors affects temperature.

Materials:

- thermometers (2) (or Vernier temperature Probe with LabQuest)
- construction paper (dark and light)
- stopwatch
- lamp with heat bulb and stand
- large cups or other containers (2)
- foam lids/caps
- IR thermometer

Hypothesis: (How will temperature change in the containers with different colored surfaces?)

Procedures:

1. Place one thermometer through the lid of each cup, one covered with dark construction paper, the other covered with light. Make sure you can see the liquid in the thermometers.

2. Place the cups side by side on a flat surface, 10-15 centimeters in front of the bulb of the lamp, but don't turn on the lamp yet. (Make sure the distance to each cup is equal.)

3. Record the starting temperature of each cup in your data table at "0 minutes." Then use the IR thermometers to measure and record the surface temperature of the paper

4. Start the stopwatch and turn on the light simultaneously. Record the internal and surface temperature of each cup every minute for 10 minutes.

> → ***CAUTION: The bulb and shade may get very hot. Be careful, and avoid touching either during the experiment.***

5. At the 10 minutes mark, turn off the light and move it away from the cups (it will continue to generate heat even when turned off). Continue to record temperatures every minute for another 10 minutes.

6. Plot your data on the graph. Connect the points for the four sets of data, and label one "dark interior," one "dark surface, one "light interior" and the other "light surface." (Or use four different colors and complete the key.)

Data:

Time (Minutes)	**Dark**		**Light**	
	Interior Temperature (°C)	Surface Temperature (°C)	Interior Temperature (°C)	Surface Temperature (°C)
0				
1				
2				
3				
4				
5				
6				
7				
8				
9				
10 (Turn off light)				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

Graphing:

Create a line graph of your collected data. Include all proper labels, titles, and keys.

Key:

Analysis and Conclusion Questions :

1. Which portion of the test, by time, represents:
    - Day Time? _From ________min to _______min
    - Night Time? From _______min to _______min.
2. What is the total temperature change in each system?

- Dark interior:
    - Heated by ______________ degrees in 10 minutes.
    - Cooled by ________ degrees in 10 minutes.
- Dark Surface:
    - Heated by ______________ degrees in 10 minutes.
    - Cooled by ________ degrees in 10 minutes.
- Light Interior:
    - Heated by ______________ degrees in 10 minutes.
    - Cooled by ________ degrees in 10 minutes.
- Light Surface:
    - Heated by ______________ degrees in 10 minutes.
    - Cooled by ________ degrees in 10 minutes.

3. Did the temperatures in the interior of each cup change (rise/fall) at the same rate? Explain your observations.

4. Did the surface temperatures of each cup change (rise/fall) at the same rate? Explain your observations.

5. Compare your results to your hypothesis.

6. Based on the data, what would be the best color of roof to choose if you wanted to keep your house cooler in the summer? Why?

7. Based on your observations, which would keep a neighborhood "cooler" in the summer, a street made of asphalt or one made of cement? Why?

Albedo Investigation Extension- A sunny day in the real world

Materials:

- IR thermometers
- Stopwatch
- Cardboard

Procedures:

1. On a sunny day go outside and find a hot surface in the schoolyard (asphalt is best if available, cement or other surfaces will work as well.)
2. Record the temperature of your spot every 15 seconds for 2 minutes.
3. Use your piece of cardboard to shade your spot.
4. While shaded record the temperature of the spot every 15 seconds for 2 minutes.
5. Uncover the spot so that the sun is again shining on it.
6. Record the temperature of the spot for another 2 minutes.
7. Compare your results to another group that tested a different surface.

Data:

Time	Temperature(°C)	Sun/Shade
00:00		
00:15		
00:30		
00:45		
01:00		
01:15		
01:30		
01:45		
02:00		
02:15		
02:30		
02:45		
03:00		
03:15		
03:30		
03:45		
04:00		
04:15		
04:30		
04:45		
05:00		
05:15		
05:30		
05:45		
06:00		

Analysis:

Graph the data above.

Conclusion:

Using CER (Claim Evidence Reasoning) explain the causes of the changing temperatures you observed.