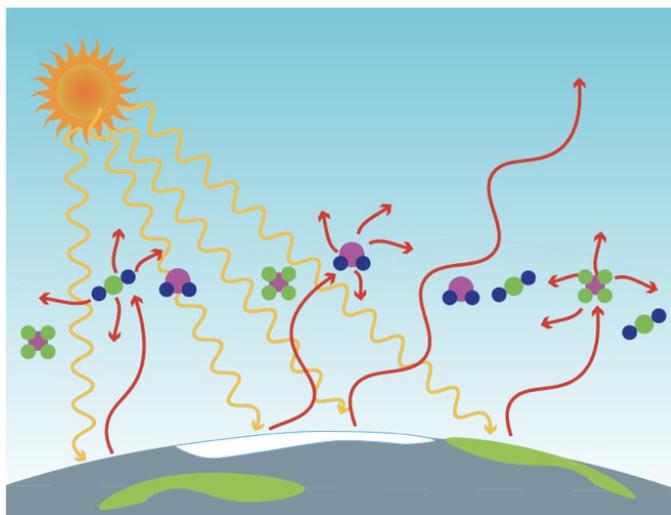


Greenhouse Effect

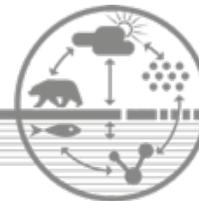
Setting the Stage

The greenhouse effect plays a large role in Earth's energy budget by absorbing and reemitting longwave energy emitted by Earth. Without any greenhouse gases, Earth would be inhabitable as temperatures would plummet. So we need some greenhouse gases to keep the Earth at a temperature that supports life on Earth. However, it is possible to have too much of a good thing. The burning of fossil fuels and subsequent increase in atmospheric CO₂ concentrations is causing global temperatures to rise at an alarming rate. In this lesson, students explore the relationship between shortwave/longwave energy and atmospheric gases through a simulation and predict how changes in greenhouse gas concentrations will affect global temperatures.

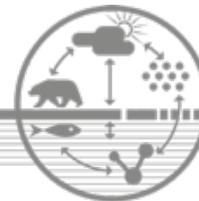


Lesson Overview

- *Part 1 – (15 minutes) Greenhouse Effect*
Students are introduced to the greenhouse effect through a warm-up prompt, Google Slide presentation, and class discussion.
- *Part 2 – (55 minutes) Molecules and Light PhET simulation*
Students explore the relationship between molecules found in Earth's atmosphere and infrared (longwave) and visible (shortwave) energy.
- *Part 3 – (10 minutes) Update Earth's energy budget model worksheet*
Students update their "Earth's energy budget model worksheet" to include greenhouse gases and the greenhouse effect.
- *Part 4 – (10 minutes) Update Summary Table*
Students reflect on their learning and how it helps them understand the unit driving question.



Instructional Overview	
Grade Level	Middle/High School
Instructional Time	90 minutes
Standards Alignment	<p>NGSS Disciplinary Core Ideas</p> <ul style="list-style-type: none"> • ESS2.D: Weather and Climate <p>NGSS Science and Engineering Practices:</p> <ul style="list-style-type: none"> • Analyzing and Interpreting Data <p>NGSS Crosscutting Concepts:</p> <ul style="list-style-type: none"> • Cause and Effect • Energy and Matter
Unit Driving Question	<ul style="list-style-type: none"> • Why might the Arctic be warming twice as fast as the rest of the world?
Driving Question(s) For This Lesson	<ul style="list-style-type: none"> • What characteristics define a greenhouse gas? • What is the greenhouse effect?
Learning Goals	<ul style="list-style-type: none"> • Identify and describe the relationship between shortwave/longwave energy and atmospheric gases • Describe the greenhouse effect using the following vocabulary terms: shortwave energy, longwave energy, greenhouse gases
Materials	<ul style="list-style-type: none"> <input type="checkbox"/> Greenhouse Effect PPT <input type="checkbox"/> Greenhouse Effect student worksheet (1 per student) <input type="checkbox"/> Answer Key <input type="checkbox"/> Greenhouse Effect animation <input type="checkbox"/> Computer/Ipad (1 per student) <input type="checkbox"/> Molecules and Light PhET simulation <input type="checkbox"/> “Our Shared Climate Future” video <input type="checkbox"/> “Earth’s energy budget model” worksheet (Students should have a copy of this worksheet as it was distributed and modified in the previous lesson) <ul style="list-style-type: none"> <input type="checkbox"/> Blank worksheet <input type="checkbox"/> Summary Table <input type="checkbox"/> Initial ideas public record Optional: <ul style="list-style-type: none"> <input type="checkbox"/> Homework/Exit Ticket
Material Preparation	<ul style="list-style-type: none"> <input type="checkbox"/> Cue and test web links (Molecules and Light PhET simulation) <input type="checkbox"/> Print student worksheets <input type="checkbox"/> Review presenter notes in the Greenhouse Effect PPT <input type="checkbox"/> Review Answer Key



	<input type="checkbox"/> Display summary table and initial ideas public record.
Vocabulary	<ul style="list-style-type: none"> • <u>Greenhouse effect</u> - Process by which gases in Earth's atmosphere absorb and reemit infrared radiation (heat) emitted by Earth, thereby warming Earth's surface. • <u>Greenhouse gas</u> - a gas/molecule that absorbs and reemits infrared radiation (heat) • <u>Molecule</u> - two or more atoms bonded together

Part 1 - Greenhouse Effect (15 minutes)

Refer to Part 1 slides included in the [Greenhouse Effect PPT](#). See PPT presenter notes for additional information.

1. Students complete warm up prompt.
2. Teacher facilitates a whole class discussion about the greenhouse effect.
 - a. Show [greenhouse effect animation](#)
3. Describe the composition of the atmosphere. Highlight the fact that atmospheric molecules/gases interact with longwave emitted by Earth and shortwave energy produced by the Sun in different ways.
4. Define the terms, greenhouse effect and greenhouse gas
 - a. Students record definitions onto their student worksheets and refer to them for Part 2

Note: Do NOT reveal which atmospheric molecules/gases are greenhouse gases. Students will determine this independently in Part 2.

Part 2 - Molecules and Light Simulation (35 minutes)

Refer to Part 2 slides included in the [Greenhouse Effect PPT](#). See PPT presenter notes for additional information.

1. Reiterate to students that their objective is to describe how different molecules found in Earth's atmosphere interact with energy of different wavelengths (infrared = longwave and visible = shortwave).
 - a. Students use a computer/ipad to open the [Molecules and Light simulation](#) and then follow the instructions on their worksheet to answer questions #3-8.
 - b. Students should STOP after completing Part 2 questions
2. Facilitate a whole class discussion about the simulation, reviewing questions #3-8 as a whole class.



3. Refer to the [Greenhouse Effect PPT](#) slides (#9-11) to describe the relationship between CO₂ and temperature with real data.
 - a. Refer to the PPT speaker notes for instructions and discussion prompts for each slide (#9-11).
4. Watch "[Our Shared Climate Future](#)" from **0-2:32** minutes to reinforce the relationship between CO₂ and temperature and humans' role in the world's increasing temperatures.

Part 3 - Update Earth's energy budget model worksheet (10 minutes)

Refer to Part 3 slides included in the [Greenhouse Effect PPT](#). See PPT presenter notes for additional information.

1. Guide students through updating their "[Earth's energy budget model worksheet](#)" to include greenhouse gases and the greenhouse effect concept. The teacher should update the class model under a document camera (see [Answer Key](#) for example). Students may want to use colored pencils to copy the whole class model onto their worksheet.

Teacher Note: Remind students that they will refer to and update the "[Earth's energy budget model worksheet](#)" with new information/concepts at the end of each class.

Part 4 - Update Summary Table (10 minutes)

Refer to Part 4 slides included in the [Greenhouse Effect PPT](#). See PPT presenter notes for additional information.

1. Students work in groups to reflect on their learning and how it relates back to the unit driving question, "Why might the Arctic be warming twice as fast as the rest of the world?"
2. Facilitate a discussion in which students come to a consensus about what they learned and how it helps them understand the unit driving question. Ideas/concepts agreed upon by the class should be included in the summary table (see [Answer Key](#)).
 - a. Students record new summary table entries onto their own summary tables.

Optional Extension: [Homework/Exit Ticket](#)

- Students provide a short explanation and create a sketch to describe the greenhouse effect using the following terms: greenhouse gases, CO₂, longwave radiation, shortwave radiation.

