## Greenhouse Effect Lab (Teacher Guide)

###

### Purpose

The purpose of this investigation is to get students to better understand the effect of changing the concentration of greenhouse gases in the atmosphere; specifically, how it causes an **increase in the temperature** on the Earth’s surface by **decreasing the amount of energy that can go out** of the atmosphere.

### When To Do This Investigation?

This is designed to be completed after students have been introduced to the greenhouse effect. It is helpful if students have an understanding of the differences between UV rays (light) coming from the sun and infrared rays (heat) that get radiated back from the Earth’s surface.

Many students have the common misconception that the greenhouse effect solely has a negative impact for people on Earth. The teacher may want to lead a post-lab discussion with students about the fact that there are “concentration” slider positions that result in a surface temperature below 0oC. In other words, without greenhouse gases, the Earth would be too cold for us to live.

### Materials

This investigation is done using a free virtual simulation on the [PhET](https://phet.colorado.edu/) website (produced by the University of Colorado Boulder) and a virtual timer. No hands-on materials are required.

### Results & Sources of Error

Remind students that simple written observations are all that is required for Table 2. No quantitative data is required for this section. This is an investigation where the data collected from the simulation is pretty consistent; therefore, it is recommended that the focus be on interpreting and analyzing the data.

**Safety Considerations**

There are no safety considerations for this investigation since it is purely virtual.

### Evaluation

There is a provided rubric for this investigation that teachers can use or modify as needed. Note that there are two tabs in the spreadsheet, including one with instructions for the teacher on how it works.

## Greenhouse Effect Lab (ANSWER KEY for Student Guide)

### Purpose

The purpose of this investigation is to determine the effect of changing the concentration of greenhouse gases in the atmosphere.

### Hypothesis

I predict that increasing the concentration of greenhouse gases in the atmosphere will

\_\_\_(answers will vary)\_\_\_\_\_\_\_\_ the **temperature on the Earth’s surface**.  *(increase, decrease, not change)*I predict that increasing the concentration of greenhouse gases in the atmosphere will cause:

* energy **into** the atmosphereto \_\_\_(answers will vary)\_\_\_\_\_\_ and
 *(increase, decrease, not change)*
* energy **out of** the atmosphereto\_\_\_\_(answers will vary)\_\_\_\_\_.
 *(increase, decrease, not change)*

### Materials

* [PhET Greenhouse Effect](https://phet.colorado.edu/en/simulations/greenhouse-effect) simulation
* [Online Timer](https://www.timeanddate.com/timer/)

### Procedure

**Part 1: Comparing the different time periods**

1. Select the Waves simulation in the *Greenhouse Effect* page.
2. Click on the Calendar icon in the Greenhouse Gas Concentration box on the right of the screen.
3. Choose the Ice Age time period.
4. Record the surface temperature **before the simulation starts** and record that in Table 1 of the Observations section under “Initial Temp oC”.
5. Set a timer for 60 seconds.
6. Click on Start Sunlight and start the timer as soon as you can after starting the simulation.
7. Observe the simulation as the timer is running.
8. Pause the simulation when the timer finishes.
9. Record the new surface temperature in Data Table 1 of the Observations section under “Final Temp oC”.
10. Reset the simulation settings using the orange circle icon. 
11. Choose the 1750 time period and repeat steps 4-10.
12. Choose the 1950 time period and repeat steps 4-10.
13. Choose the 2020 time period and repeat steps 4-10.

**Part 2: Observing the energy in and out**

1. Click on the checkbox next to Energy Balance.
2. Slide the Greenhouse Gas Concentration to None.
3. Click on Start Sunlight.
4. Observe the simulation and pay attention to the Energy Balance section in the top left corner.

|  |  |
| --- | --- |
| **In** | The amount of energy *coming into**the atmosphere* is represented by the arrow. |
| **Out** | The amount of energy *going out of**the atmosphere* is represented by the arrow. |
| **Net** | The difference between the energy in and the energy out if there is one. |

1. Pause the simulation as soon as the energy balance is stable *(meaning the Net arrow has disappeared).*
2. Record your observations in Table 2 of the Observations section below. Use words to describe what you see happening to the In, Out, and Net arrows over time. *Are they increasing or decreasing or staying the same? Is the change happening slowly or quickly?*
3. Reset the simulation settings using the orange circle icon. 
4. Slide the Greenhouse Gas Concentration to Lots and repeat steps 1-7.

### Observations

|  |
| --- |
| **Data Table 1:** |
| Greenhouse Gas Concentration | **Initial Temp. (°C)** | **Final Temp. (°C)** |
| Ice Age | -28.1 | 7.4 |
| 1750 | -28.1 | 13.5 |
| 1950 | -28.1 | 13.7 |
| 2020 | -28.1 | 14.8 |

|  |
| --- |
| **Data Table 2:** |
| Greenhouse Gas Concentration | **Energy Balance****IN** | **Energy Balance****OUT** | **Energy Balance****NET** |
| None | Constant | Zero then increases quickly | Constant then decreases quickly |
| Lots | Constant | Zero then increases slowly | Constant then decreases slowly |

### Analysis

1. What happens to the sunlight (yellow) waves over time? Do they only go in one direction or do they get reflected? Do clouds affect them at all?

|  |
| --- |
| * Constantly coming toward the Earth’s surface
* Can be reflected back to upwards by clouds, ice, or snow
 |

1. What happens to the infrared (red) waves over time? Do they only go in one direction or do they get reflected? Do clouds affect them at all?

|  |
| --- |
| * Radiating away from the Earth’s surface
* Some continue upwards into space
* Some are reflected back towards the Earth’s surface by greenhouse gases in the atmosphere
 |

1. Based on what you have seen, as greenhouse gases increase over time (from **Ice Age** to the year **2020**), what is the impact on the surface temperature of the Earth? Explain your answer.

|  |
| --- |
| The surface temperature increases as the greenhouse gases are increasing over time |

1. Does the concentration of greenhouse gases affect the flow of energy **coming in** or the energy **going out** or both?

|  |
| --- |
| The greenhouse gases only affect the energy going out of the Earth’s atmosphere, not going in. |

###

### Conclusions

According to the data that you collected, were your hypotheses correct?

|  |
| --- |
| Answers will vary, depending on what students hypothesized. Increasing the concentration of greenhouse gases in the atmosphere:* will **increase** the temperature on the Earth’s surface.
* will cause energy into the atmosphere to **not change**.
* will cause energy out of the atmosphere to **decrease**.
 |

What did you learn about the greenhouse effect through this investigation?

|  |
| --- |
| Answers will vary.  |