TØWNGREEN▸2025
Middle School Climate-Change Curriculum

Lesson 9

Carbon Cycles through Ecosystems

Unit Title: **Carbon Cycles through Ecosystems**	
Theme: **Ecosystems & Cycles**	Grade Level: **7**
# of sessions for the unit: **2**	Session #11: **Why does it matter which types of light bulbs we use?**
Date created: **Summer 2017**	Author: **B. Allia, C. McWilliams**

Unit Description

Focusing on systems and cycles, students use their understanding of climate-change and how carbon and thermal energy interact with Earth's land and atmosphere. Students practice skills such as argumentation and collecting and analyzing data. Students gain experience with the interactions of humans and Earth processes with ecosystem dynamics, and with developing solutions to complex climate-change issues. The lessons generally follow this order:

- Introduce unit and culminating event: climate-change's effect upon fauna
- analyze global temperature and carbon dioxide trends
- understand personal climate-change experiences, such as weather, matter and energy uses
- collect wetland and upland forest soil carbon-stores
- sample atmospheric carbon-store
- analyze land and atmospheric carbon-stores
- understand the carbon cycle, pre-human and human era
- describe personal experiences with solid forms of carbon changing into atmospheric carbon
- develop and present solutions to save a fauna from climate-change issues

Standard(s)

Based upon the 2016 MA Science & Technology/Engineering Curriculum Framework

MA LS2 Ecosystems: Interactions, Energy, and Dynamics

MA 7.MS-LS2-3 Develop a model to demonstrate how matter and energy are transferred among living and nonliving parts of an ecosystem and that both matter and energy are conserved through these processes

Unit Goals

1. Create an action plan to decrease carbon in the atmosphere, increase carbon stored by the land, and preserve natural carbon-stores in the ground
2. Build background knowledge of how carbon cycles within a local ecosystem
3. Understand relevant climate-change issues in order to make informed decisions
4. Identify authentic scientific processes, such as sampling, gathering, and analyzing land and atmospheric carbon-content data, in order to validate evidence regarding climate-change

Unit Objectives

Students will be able to

understand that:

1. Carbon cycles through the atmosphere and land
2. Human activities increases atmospheric carbon by burning fossil fuel
3. Atmospheric carbon is a "greenhouse gas"
4. Greenhouse gases increase global temperatures
5. Wetlands and uplands store different amounts of carbon above and below ground

and to:

1. Sample, collect, and analyze primary-source data
2. Collect and analyze secondary data as a means to validate causes of climate-change

Lesson Objectives

1. Students will identify what processes remove carbon from the atmosphere and which processes add carbon to the atmosphere
2. Students construct a model of carbon cycling through photosynthesis and respiration
3. Students identify processes that emit carbon to the atmosphere from consumers and decomposers
4. Students identify where in the photosynthesis cycle plants absorb carbon from the atmosphere
5. Students predict the climate-change effects of increasing levels of atmospheric carbon due to combustion of fossil fuels

Note any potential barriers to the lesson — consider variability

Student challenges

- Through 7th grade, students begin a process of moving from a more concrete to an abstract perspective. For some students, this presents a developmental challenge since the carbon cycle is not directly observable or experienced.

Student Mitigating Factors

- Students draw concept drawings to make the invisible carbon cycle more concrete.
- Students use tactile strategies to make the abstract carbon cycle more concrete.

Teacher challenges

- Student access to websites

Evaluation/Assessment

(directly linked to the goals, i.e., Formative/Ongoing Assessment or Summative/End of Lesson Assessment)

1. Lesson 1: Student's small-group presentations on human impact upon climate-change.
2. Actively Learn "Global Warming Grinnell Glacier" *www.activelylearn.com* (free subscription). Active Reading assignment with companion questions aligned to frameworks.
3. Actively Learn Climate-change" *www.activelylearn.com* (free subscription). Active Reading assignment with companion questions aligned to frameworks.
4. Climate Change 101 with Bill Nye, *National Geographic* *https://youtu.be/EtW2rrLHs08*. Students complete video graphic organizer that scaffolds video outline.

Vocabulary

- respiration
- photosynthesis
- decomposition
- emissions
- sink
- carbon atom
- atmospheric carbon
- particle
- fossil fuel
- greenhouse gas
- carbon dioxide
- methan gas

Differentiated Vocabulary Ideas

1. word wall
2. word splash
3. common prefixes and suffixes
4. content vocabulary roundtable
5. flashcards

NOTE: Consider the UDL Guidelines in selecting methods and materials to ensure that you provide options for engagement, representation, and action and expression.

Methods

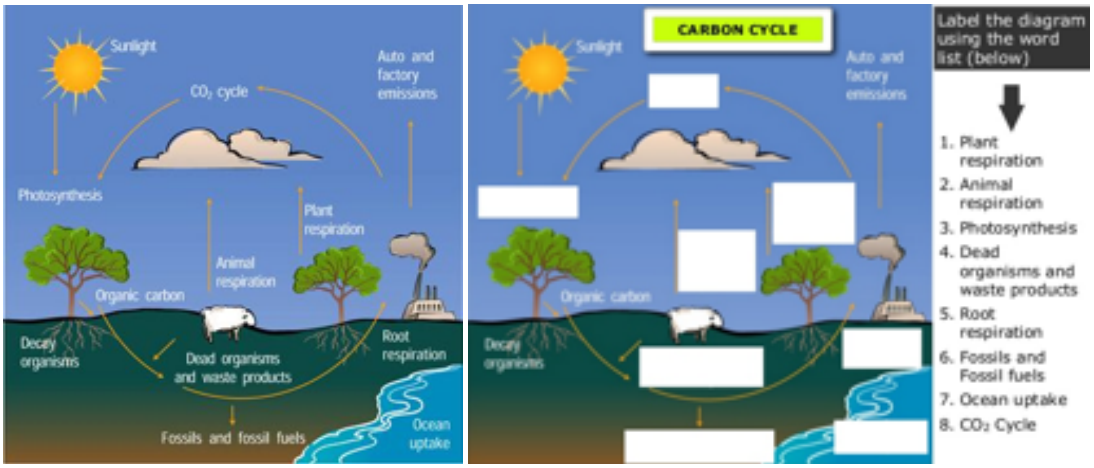
(e.g., Anticipatory Set, Introduce and Model New Knowledge, Provide Guided Practice, Provide Independent Practice)

June 15, 2016 *— The Earth passed another unfortunate milestone on May 23 when carbon dioxide surpassed 400 parts per million (ppm) at the South Pole for the frist time in 4 million years.*

Day 1 Hook:
http://www.noaa.gov/south-pole-last-place-on-earth-to-pass-global-warming-milestone

Opening hook, brief discussion: how did humans cause carbon dioxide levels to rise all the way on the South Pole, even though humans don't live at the South Pole? (14% increase)

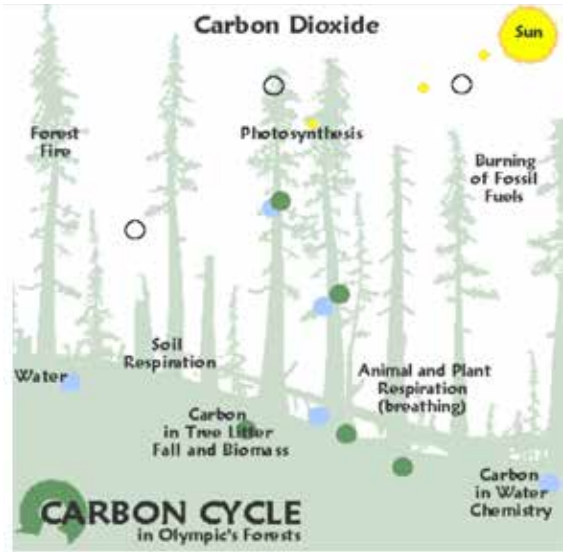
1. Class Discussion: Point out that the carbon cycle they have drawn in their science notebooks was in place for millions, possibly billions, of years.
   - **A.** Then along come humans. Then have students brainstorm how humans have affected the carbon dioxide cycle.
   - **B.** Ask how they could add this new information to their current cycle.
   - **C.** Add in a factory, cars, or other factors as humans dig up and burn fossil fuels and add carbon to the air.
   - **D.** Some students may add that humans have cut down many trees, so the amount of photosynthesis has decreased.
2. Students review carbon-cycle notes in their science notebooks/journals
   - **A.** Below are carbon-cycles and photosynthesis/respiration chemical formulas in their notebooks:

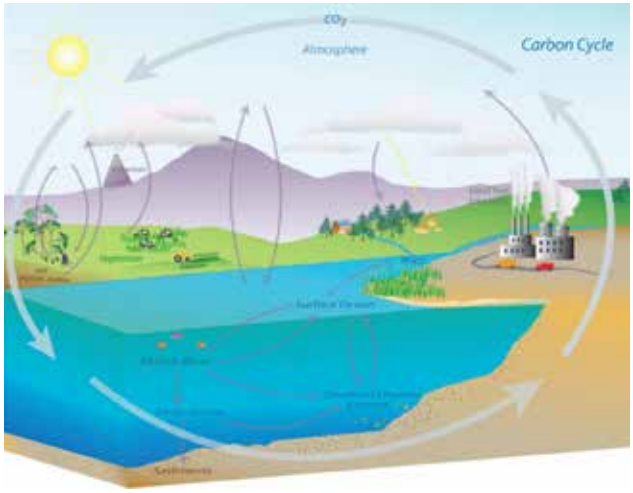


B. Through teacher question-answer session, review carbon cycle from previous lesson, to review the roles of:

1. Consumers emitting carbon dioxide
2. Decomposers emitting carbon dioxide
3. Chemical formula for consumer respiration
4. Photosynthesis absorbing carbon dioxide and formula for photosynthesis

C. Introduce human impact of burning fossil fuel upon the Earth's carbon cycle.

1. 



   https://www.google.com/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&uact=8&ved=0ahUKEwiN9_v9koXVAhXDbz4KHTwcASEQjRwIBw&url=http%3A%2F%2Fwww.res-bio.com%2Fcarbon-sequestration%2F&psig=AFQjCNHzYvulxgsRGs01lY1MitfT-T8bRQ&ust=1499997129979225
   Most of Earth's carbon is stored in rocks and sediments, while the rest is located in the ocean, in the atmosphere, and in living organisms. These are the reservoirs through which carbon cycles.

D. Students watch a 3-minute video from NOAA climate tracker at https://www.climate.gov/news-features/decision-makers-toolbox/tracking-carbon-dioxide-across-globe (scroll down to video clip), also found on https://youtu.be/nV6FDO_Pl5M.

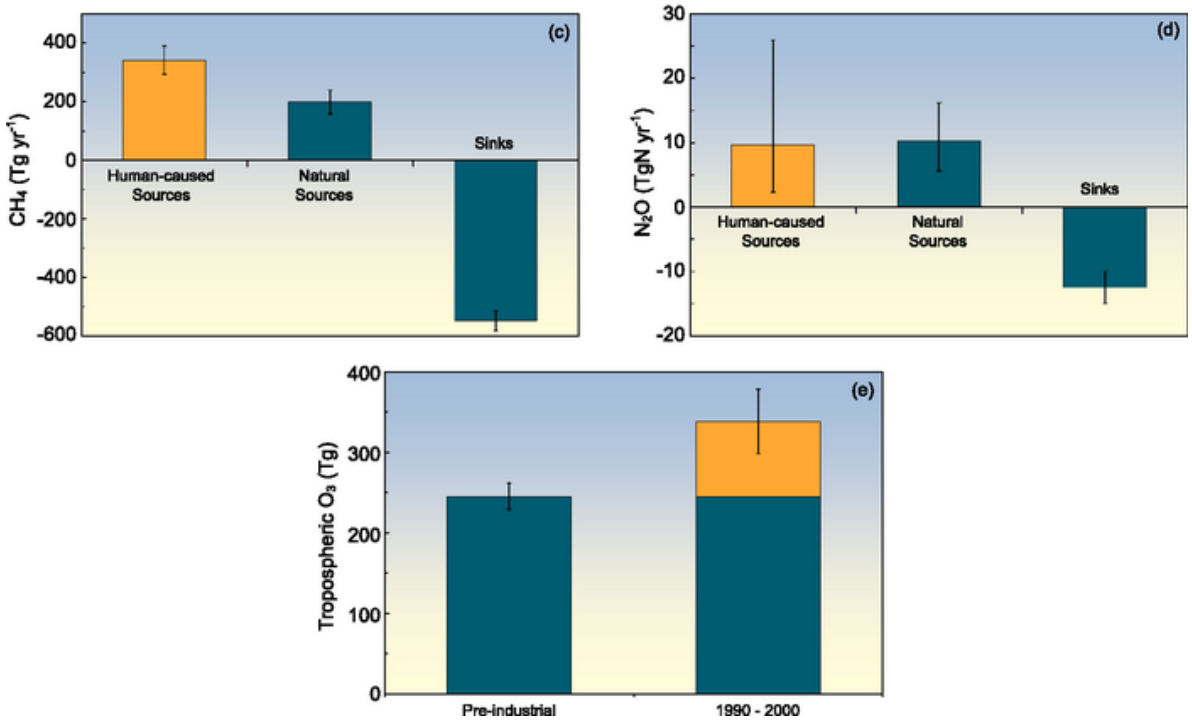
E. In small groups, students work in a think-pair-share format with these topics. Teacher differentiate based upon topic complexity

1. Guiding instructions:
   - identify ways in which humans added carbon to the atmosphere

- identify ways in which the carbon cycle naturally removes carbon from the atmosphere
- hand-draw a model representing how carbon cycles through your scenario
- In your model, identify the carbon emissions from consumers and decomposers
- In your model, identify the carbon emissions from humans burning fossil fuels
- Predict the effects if humans continue to increase levels of carbon dioxide in the atmosphere, from burning fossil fuel at our current rate

2. Here are examples of student topics, to assign to small groups
Group 1: Incorporates these graphs into group activity
Go to this NOAA website = *http://www.noaa.gov/resource-collections/carbon-cycle*:
Changes to the carbon cycle
The increasing human population and their activitiesoffsite link have a tremendous impact on the carbon cycle. Burning of fossil fuels, changes in land use, and the use of limestone to make concrete all transfer significant quantities of carbon into the atmosphere. As a result the amount of carbon dioxide (CO_2) in the atmosphere is rapidly rising and is already significantly greater than at any time in the last 800,000 years. This increase of CO_2 is affecting our ocean as it absorbs much of the CO_2 that is released from burning fossil fuels. This extra CO_2 is lowering the ocean's pH, this process is called ocean acidification and interferes with the ability of marine organisms (such as corals) to build their shells and skeletons.

Graphs below are from Intergovernmental panel on climate-change website:
http://www.ipcc.ch/publications_and_data/ar4/wg1/en/faq-7-1-figure-1.html



Frequently asked questions from Intergovernmental panel on climate-change website:
http://www.ipcc.ch/publications_and_data/ar4/wg1/en/faq-7-1-figure-1.html
FAQ 7.1, Figure 1. Breakdown of contributions to the changes in atmospheric greenhouse gas concentrations, based on information detailed in Chapters 4 and 7. In (a) through (d), human-caused sources are shown in orange, while natural sources and sinks are shown in green. In (e), human-caused tropospheric ozone amounts are in orange while natural ozone amounts are in green. (a) Sources and sinks of CO_2 (GtC). Each year CO_2 is released to the atmosphere from human activities including fossil fuel combustion and land use change. Only 57 to 60% of the CO_2 emitted from human

activity remains in the atmosphere. Some is dissolved into the oceans and some is incorporated into plants as they grow. Land-related fluxes are for the 1990s; fossil fuel and cement fluxes and net ocean uptake are for the period 2000 to 2005. All values and uncertainty ranges are from *Table 7.1*. (b) Global emissions of CFCs and other halogen-containing compounds for 1990 (light orange) and 2002 (dark orange). These chemicals are exclusively human-produced. Here, 'HCFCs' comprise HCFC-22, -141b and -142b, while 'HFCs' comprise HFC-23, -125, -134a and -152a. One Gg = 109 g (1,000 tonnes). Most data are from reports listed in *Chapter 2*. (c) Sources and sinks of CH_4 for the period 1983 to 2004. Human-caused sources of CH_4 include energy production, landfills, ruminant animals (e.g., cattle and sheep), rice agriculture and biomass burning. One Tg = 1012g (1 million tonnes). Values and uncertainties are the means and standard deviations for CH4 of the corresponding aggregate values from *Table 7.6*. (d) Sources and sinks of N_2O. Human-caused sources of N_2O include the transformation of fertilizer nitrogen into N_2O and its subsequent emission from agricultural soils, biomass burning, cattle and some industrial activities including nylon manufacture. Source values and uncertainties are the midpoints and range limits from *Table 7.7*. N_2O losses are from *Chapter 7.4*. (e) Tropospheric ozone in the 19th and early 20th centuries and the 1990 to 2000 period. The increase in tropospheric ozone formation is human-induced, resulting from atmospheric chemical reactions of pollutants emitted by burning of fossil fuels or biofuels. The pre-industrial value and uncertainty range are from Table 4.9 of the IPCC Third Assessment Report (TAR), estimated from reconstructed observations. The present-day total and its uncertainty range are the average and standard deviation of model results quoted in *Table 7.9* of this report, excluding those from the TAR.

Carbon Dioxide background information from Intergovernmental panel on climate-change website: *http://www.ipcc.ch/publications_and_data/ar4/wg1/en/faq-7-1-figure-1.html*

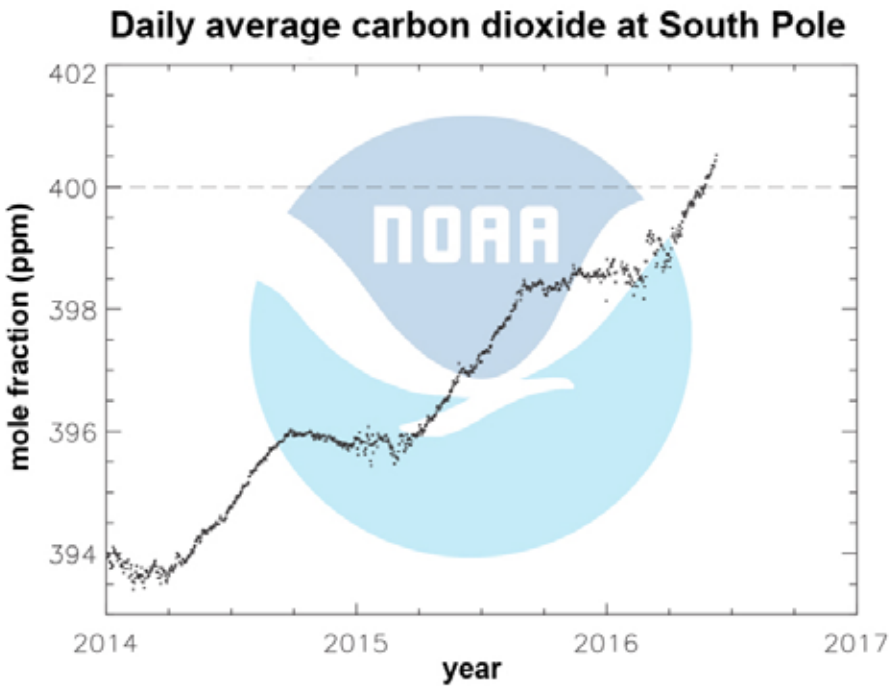
Carbon Dioxide

Emissions of CO_2 (Figure 1a) from fossil fuel combustion, with contributions from cement manufacture, are responsible for more than 75% of the increase in atmospheric CO_2 concentration since pre-industrial times. The remainder of the increase comes from land use changes dominated by deforestation (and associated biomass burning) with contributions from changing agricultural practices. All these increases are caused by human activity. The natural carbon cycle cannot explain the observed atmospheric increase of 3.2 to 4.1 GtC yr^{-1} in the form of CO_2 over the last 25 years. (One GtC equals 10^{15} grams of carbon, i.e., one billion tonnes.)

Natural processes such as photosynthesis, respiration, decay and sea surface gas exchange lead to massive exchanges, sources and sinks of CO_2 between the land and atmosphere (estimated at ~120 GtC yr^{-1}) and the ocean and atmosphere (estimated at ~90 GtC yr^{-1}; see figure 7.3). The natural sinks of carbon produce a small net uptake of CO_2 of approximately 3.3 GtC yr^{-1} over the last 15 years, partially offsetting the human-caused emissions. Were it not for the natural sinks taking up nearly half the human-produced CO_2 over the past 15 years, atmospheric concentrations would have grown even more dramatically.

The increase in atmospheric CO_2 concentration is known to be caused by human activities because the character of CO_2 in the atmosphere, in particular the ratio of its heavy to light carbon atoms, has changed in a way that can be attributed to addition of fossil fuel carbon. In addition, the ratio of oxygen to nitrogen in the atmosphere has declined as CO_2 has increased; this is as expected because oxygen is depleted when fossil fuels are burned. A heavy form of carbon, the carbon-13 isotope, is less abundant in vegetation and in fossil fuels that were formed from past vegetation, and is more abundant in carbon in the oceans and in volcanic or geothermal emissions. The relative amount of the carbon-13 isotope in the atmosphere has been declining, showing that the added carbon comes from fossil fuels and vegetation. Carbon also has a rare radioactive isotope, carbon-14, which is present in atmospheric CO_2 but absent in fossil fuels. Prior to atmospheric testing of nuclear weapons, decreases in the relative amount of carbon-14 showed that fossil fuel carbon was being added to the atmosphere.

Group 2 uses this example in their activity. From http://www.noaa.gov/south-pole-last-place-on-earth-to-pass-global-warming-milestone



South Pole carbon dioxide levels hit record
Daily average carbon dioxide readings at the South Pole from 2014 to present, as recorded by NOAA's greenhouse gas monitoring network. (NOAA)

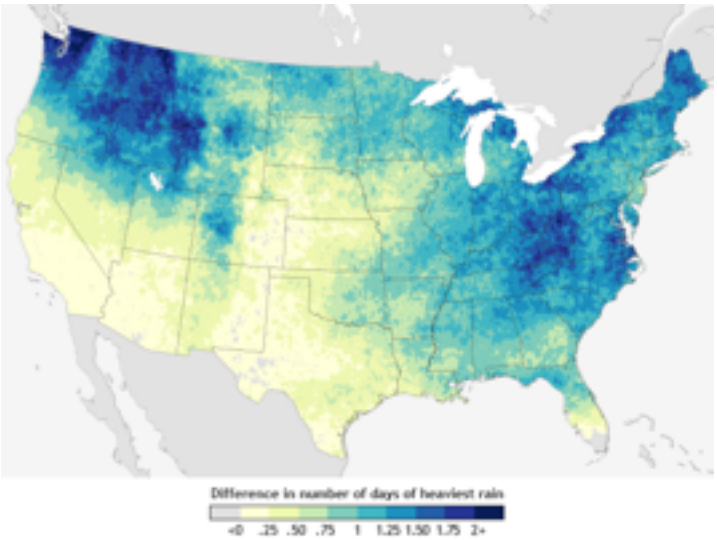
Group 3 uses this scenario in their activity. From: http://www.noaa.gov/news/noaa-s-greenhouse-gas-index-up-40-percent-since-1990

NOAA's Annual Greenhouse Gas Index, which tracks the warming influence of long-lived greenhouse gases, has increased by 40 percent from 1990 to 2016 — with most of that attributable to rising carbon dioxide levels, according to NOAA climate scientists.

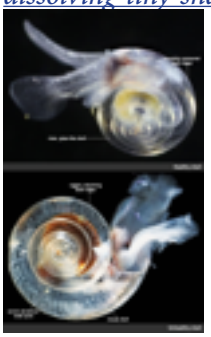
Group 4 uses this scenario. *https://www.climate.gov/news-features/climate-qa/how-much-will-earth-warm-if-carbon-dioxide-doubles-pre-industrial-levels*

Group 5 uses this scenario. *https://www.climate.gov/news-features/understanding-climate/carbon-dioxide-earths-hottest-topic-just-warming*

Group 6 uses this scenario

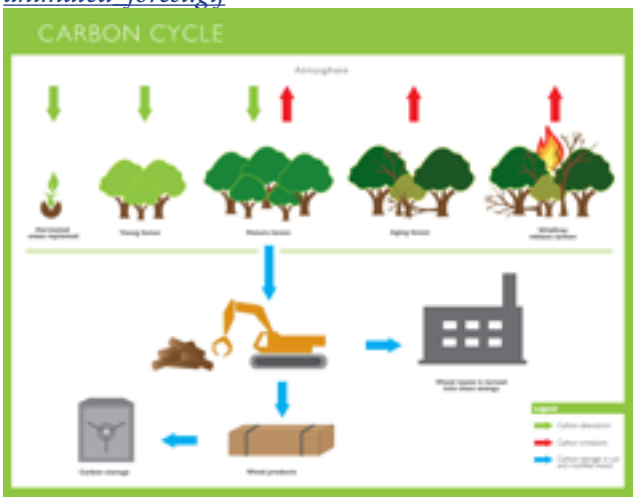


Group 7 uses this scenario. *https://www.climate.gov/news-features/featured-images/ocean-acidity-dissolving-tiny-snails%E2%80%99-protective-shell*

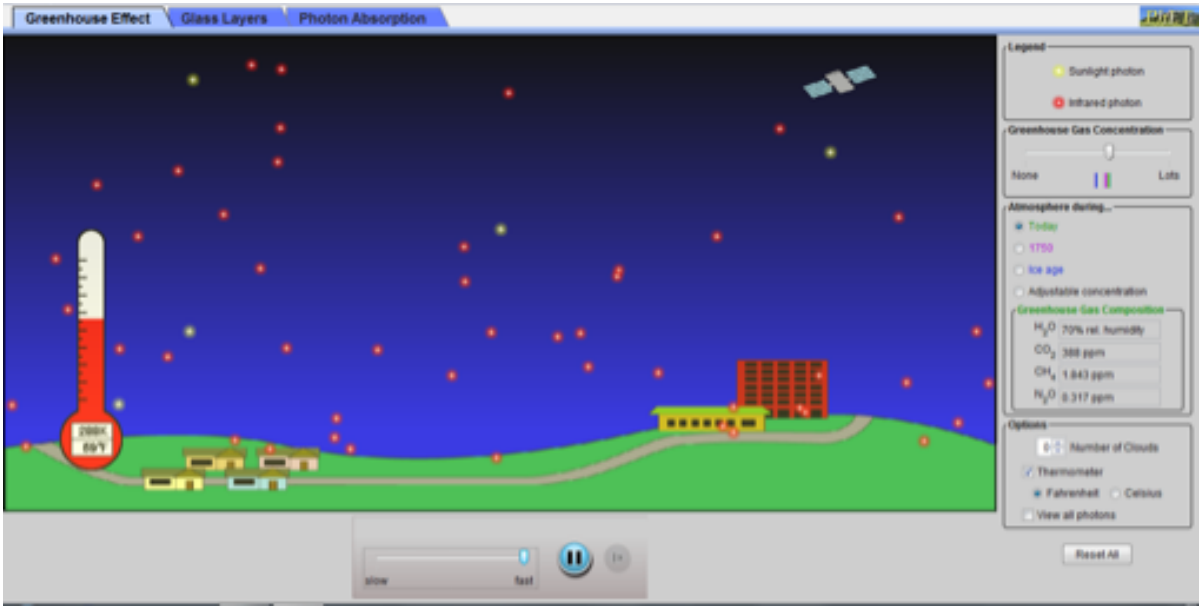


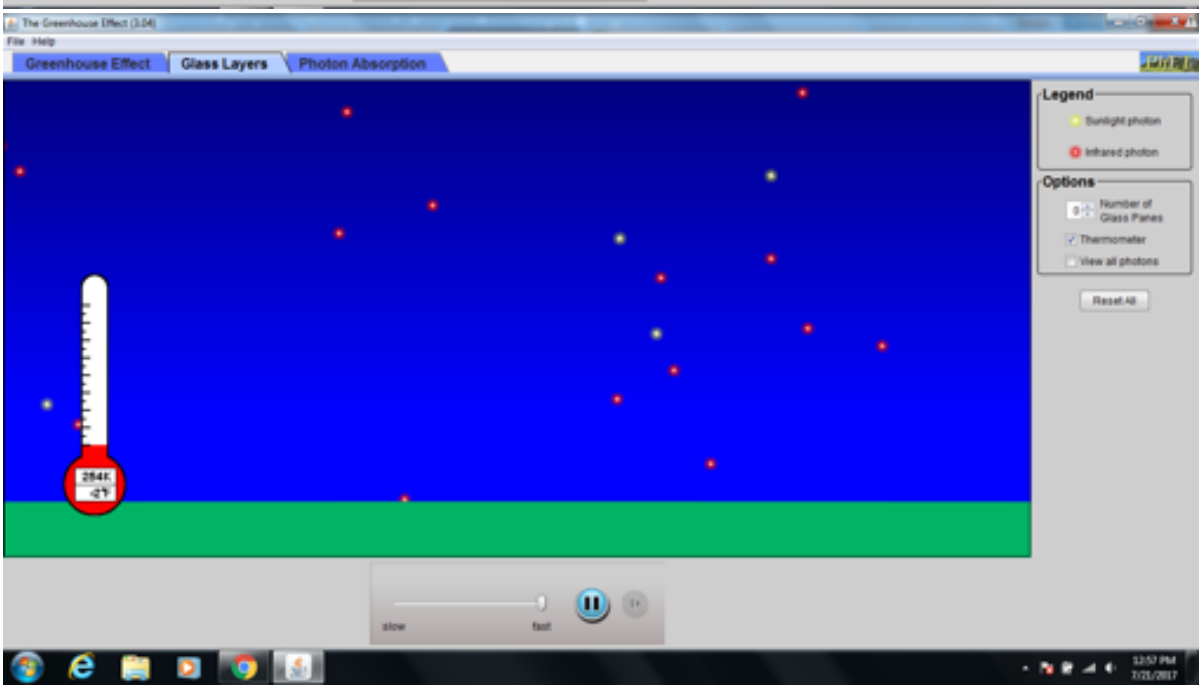
Group 8 uses this scenario. *https://www.climate.gov/news-features/featured-images/ocean-acidification-today-and-future*

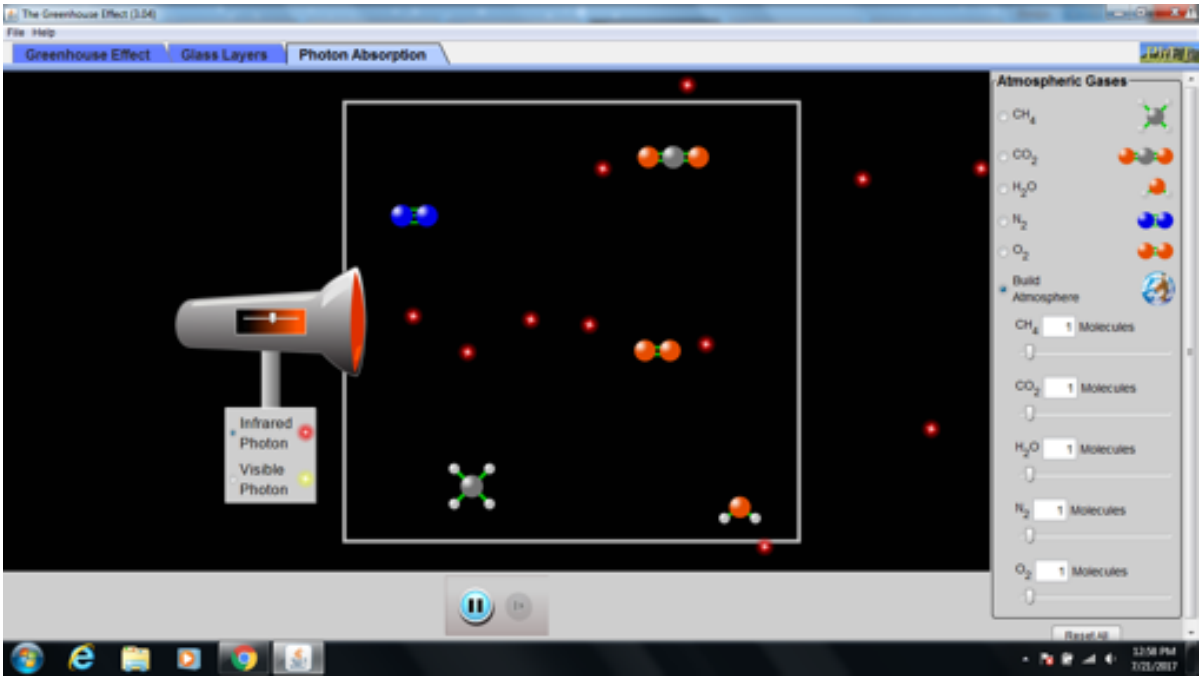
Group 9 uses this scenario. *http://www.res-bio.com/wp-content/uploads/2013/10/Carbon_Cycle-animated_forest.gif*



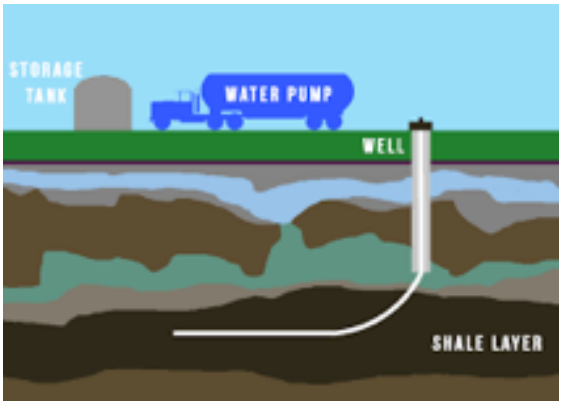
Group 10. Teacher encouraged to find local or interesting climate-change images.
Homework option from this webpage. *https://phet.colorado.edu/en/simulation/legacy/greenhouse*

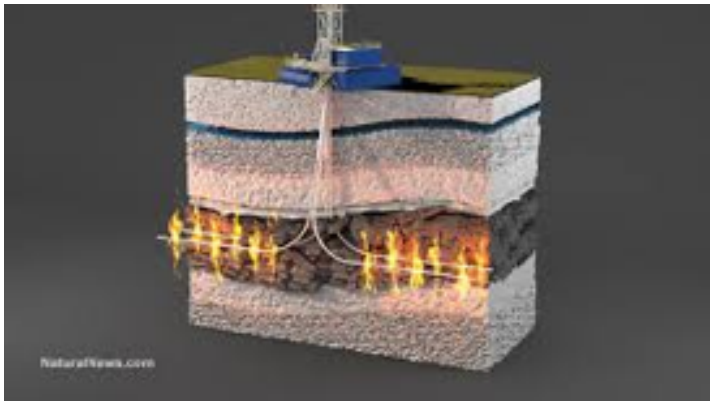

Greenhouse Effect
Glass Layers
Photon Absorption
Legend
Sunlight photon
Infrared photon
Greenhouse Gas Concentration
None
Lots
Atmosphere during...
Today
1750
Ice age
Adjustable concentration
Greenhouse Gas Composition
Options
Number of Clouds
Thermometer
Fahrenheit
Celsius
View all photons
Reset All
slow
fast


The Greenhouse Effect (3.04)
File Help
Greenhouse Effect
Glass Layers
Photon Absorption
Legend
Sunlight photon
Infrared photon
Options
Number of Glass Panes
Thermometer
View all photons
Reset All
254K
-2°F
slow
fast



Day 2: Hook: What is going on here?





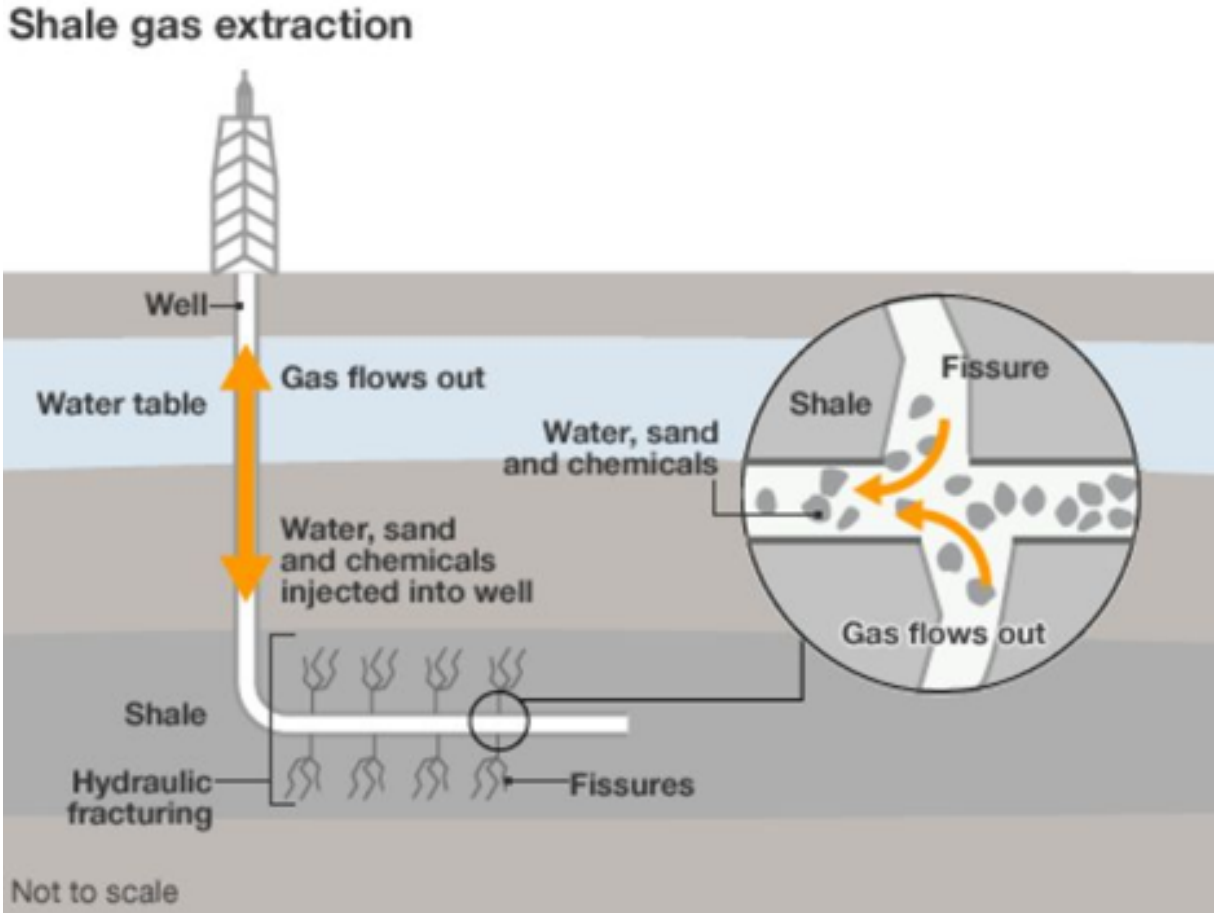
Fracking debate

1. Introduce this with about 10 minutes left in a class; it does involve homework in the form of an internet search.
   - **A.** Google provides many responses for each research topic. It is important that the teacher not provide an opinion so as to not influence students thinking.
2. 10 minute time: Some students may have heard about fracking (no, it is not a dirty word) but many others may not have heard about it.
   - **A.** Do not talk about how the process works as you do not want to influence student opinion.
   - **B.** OK to say that this is how we in the U.S. have developed a way to pull natural gas from deep inside the Earth and that this natural gas is taking the place of coal in many power plants. OK to mention that some people like this a lot and some do not like it, but do not give any reasons why.
   - **C.** Then assign half of the class to research and do a write-up of how many people think fracking is a good thing, and assign the other half to research and do a write up of why many people think fracking is a bad thing.

D. One way to do this is to assign the first and third row to research the positives and the 2nd and 4th row to research the negative. Inform students that the class will debate their findings during the next class.

3. Full-day debate:

A. First, do a quick intro to how fracking works. When companies first started searching for oil and natural gas, they drilled straight down. Then they used high pressure to pump water with sand and some chemicals down into the ground to fracture the rock (where the term fracking came from). If they found oil or gas or both, they extracted whatever they could and had to shut down that well, and drill another well nearby. This was a very expensive process and it took a lot of time to keep drilling new wells. Then an innovative engineer developed a way to not only drill down, but in the same well, deep down, start to drill at a 90 degree angle in any direction. This allowed the fracking companies to get a lot more oil and gas from the wells and it reduced the number of drilling sites a lot. (Image below to be used when explaining this — other images available on the web).



B. Then introduce the format of debating.

1. The teacher is the moderator. Remind students there are rules to follow for the debate. The rules are:

- Each person gets to make one statement based on what he or she researched;
- Everyone one else must listen and not comment or argue with the person making their statement.
- Rudeness is not allowed.
- Then the other side has one person make a statement about what they researched.
- Again, no one can argue or comment on what is stated.
- OK for the moderator to ask for sources if you are unfamiliar with the statement.

- This process will repeat itself until everyone has made a statement (inform students that they should try to not repeat the same statements).
- Before you actually begin, one idea is to separate students, with the pro-fracking group on the left side of the room and the anti-fracking group on the right side of the room.
- Then start taking statements, alternating between the pro and anti groups.
- When everyone has spoken, the students on one side can ask questions of students on the opposite side — all questions must be asked respectfully or the moderator will end the question. This is their time to debate statements made opposite each other.

C. When there are no other questions and no one else has anything to add to the debate, take a poll of who supports fracking and who is opposed to fracking.

- Again try not to influence students by giving your opinion.
- Remind students that this is what makes America such a good country, that everyone can have their own opinions.

D. Then introduce this hypothetical statement: You recently heard that some fracking companies want to come into your town because they heard the fracking would be good here. Now this means that some people, if they find natural gas under their house, may get rich from the subsidies the gas companies pay landowners. Now ask students who would be willing to allow the gas companies to come into their town and start fracking.

- Keep the debate format going without interrupting and ensure that anyone that has an opinion can take a turn speaking.
- OK to add questions as needed to be sure it is a realistic debate.
- At the end, ask for a vote of who would allow fracking in their town and who would say no to fracking in their town.

4. Homework Options

A. Fracking Explained: opportunity or danger? *https://youtu.be/Uti2niW2BRA*

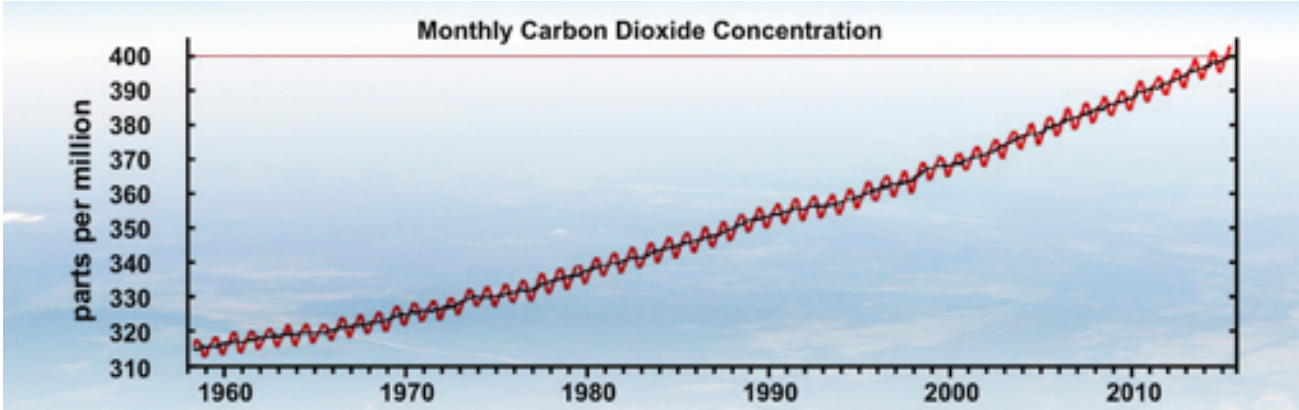
B. Bill Nye, are you for or against fracking, an 11-minute video = *https://youtu.be/QIQ5iBTkvMw*

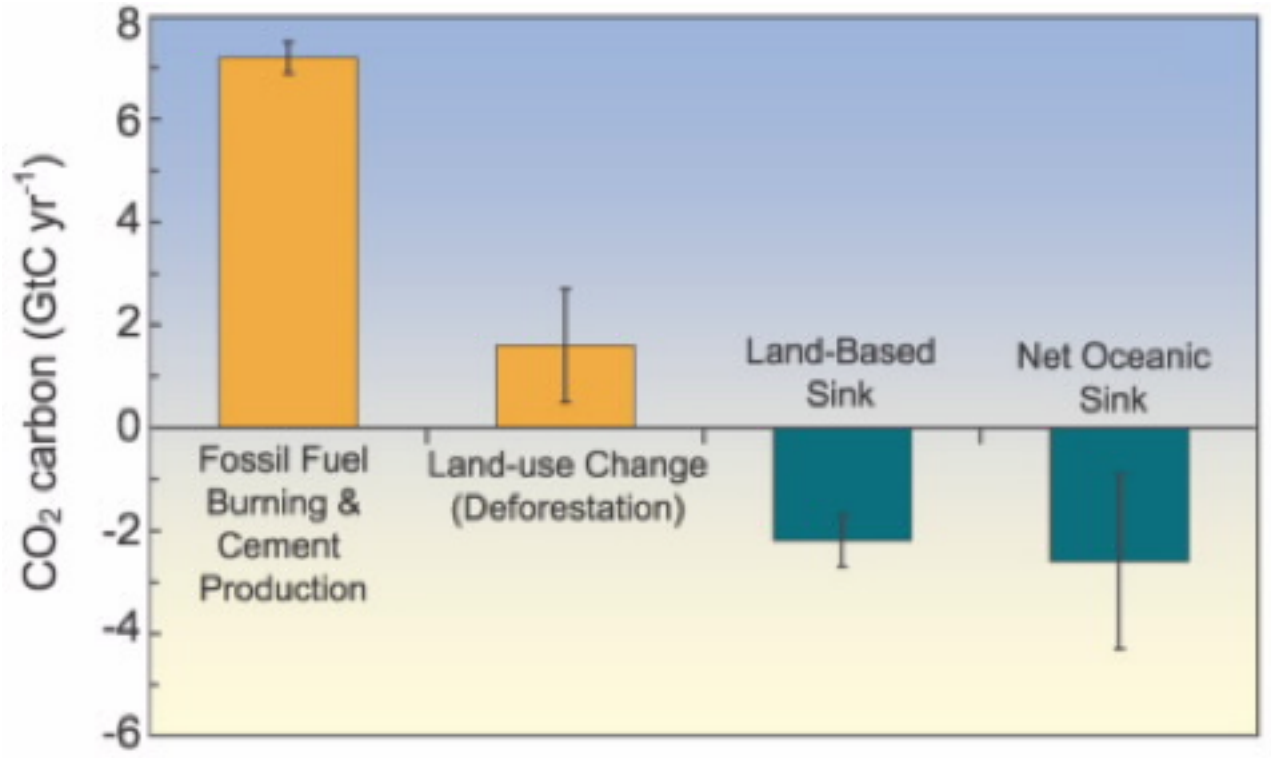
Materials

Day 1: student computer access

Teacher Website resource: *http://www.noaa.gov/resource-collections/carbon-cycle*

Global Climate-change NASA Frequently asked questions: *https://climate.nasa.gov/news/1009/just-5-questions-carbon-dioxide-and-nasas-oco-2-mission/*




8
6
4
2
0
-2
-4
-6
CO_2 carbon (GtC yr^{-1})
Fossil Fuel Burning & Cement Production
Land-use Change (Deforestation)
Land-Based Sink
Net Oceanic Sink