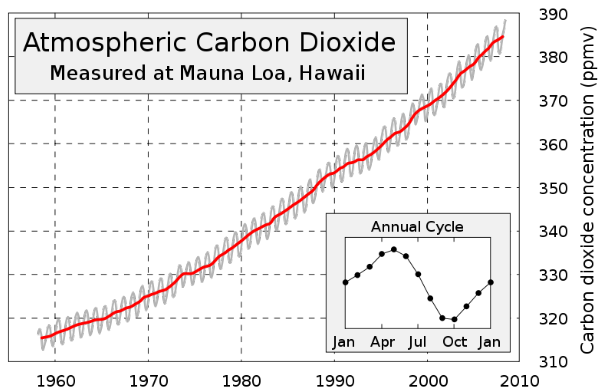
Activity 4.2 Carbon Pools and Fossil Fuels Reading

So far in the *Human Energy Systems* unit you have discussed a series of questions and answers:



- **Question:** Why is the Earth's sea level rising and Arctic ice melting?
- **Answer:** Because the Earth's average temperature is gradually getting warmer.
- **Question:** Why is the Earth's average temperature is gradually getting warmer?
- **Answer:** Because the atmospheric concentration of CO_2 is increasing (the Keeling Curve). This drives the greenhouse effect and increases the Earth's temperature.
- **Question:** *Why is the concentration of CO_2 in the atmosphere increasing?*

This last question is really important, and in this lesson you will figure out the answer to that question. The answer involves carbon pools for the Earth as a whole and the fluxes that move carbon from one pool to another. If you studied the *Ecosystems* unit, you will be familiar with the Large Scale Four Questions. A good explanation of how carbon moves through large-scale systems (like ecosystems or Earth systems) needs to answer (a) the Carbon Pools Question, (b) the Carbon Cycling Question, (c) the Energy Flow Question, and (d) the Stability and Change Question.

In the *Ecosystems* unit you studied how carbon moves between two carbon pools in an ecosystem: the atmospheric CO_2 pool and organic matter in plants, animals, and soils. Those pools are also important in the Earth as a whole. The Keeling Curve shows that one of those pools—atmospheric CO_2—is getting larger.

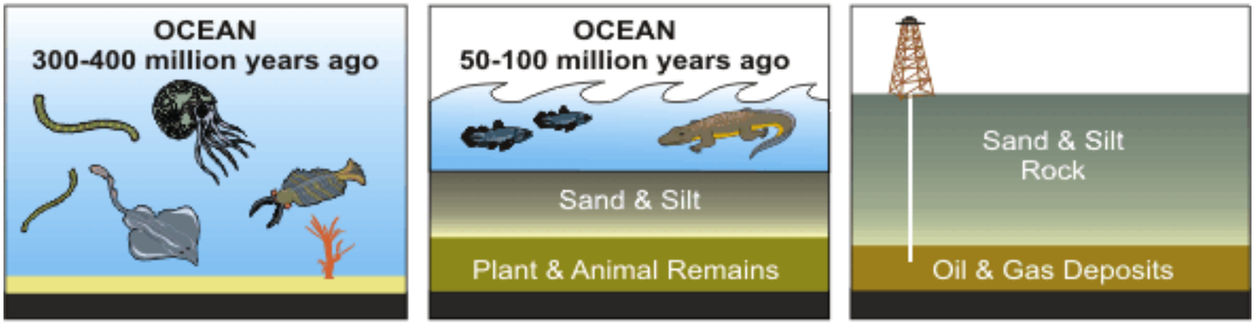
In order to explain why that pool is getting larger, we will investigate the balance of fluxes into and out of that pool. In the *Ecosystems* unit you studied two fluxes that move carbon back and forth between the atmospheric pool and organic matter in ecosystems: photosynthesis and cellular respiration. Those fluxes are still important, but they won't fully explain why the atmospheric CO_2 pool is getting larger.

A good answer to the question above involves another pool—*fossil fuels*—and another flux—*combustion.* In this reading and activity you will learn about the fossil fuels pool and the combustion flux by answering the Four Questions about them.

The Carbon Pools Question: What and Where Are Fossil Fuels?

Fossil fuels are mixtures of organic molecules (with high-energy C-C and C-H bonds) that people have found underneath the Earth's surface. They come in solid form (*coal*) in liquid form (*petroleum,* sometimes also called oil) and in gaseous form (*natural gas*). They were formed over many millions of years from the remains of plants and animals.

Petroleum and Natural Gas Formation



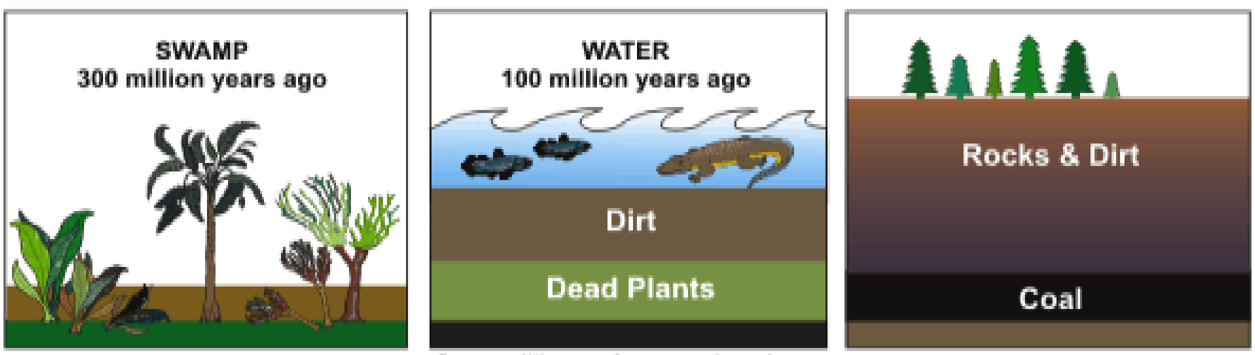
Tiny sea plants and animals died and were buried on the ocean floor. Over time, they were covered by layers of silt and sand.

Over millions of years, the remains were buried deeper and deeper. The enormous heat and pressure turned them into oil and gas.

Today, we drill down through layers of sand, silt, and rock to reach the rock formations that contain oil and gas deposits.

Oil (petroleum) and natural gas are formed from the remains of animals and plants that lived millions of years ago in a marine (water) environment that existed on Earth before the dinosaurs. Over the years, layers of mud covered the remains of these animals and plants. Heat and pressure from these layers transformed the organic molecules in these remains into other organic molecules made mostly of carbon and hydrogen atoms--petroleum and natural gas. The word "petroleum" means "rock oil" or "oil from the Earth."

Coal Formation



Before the dinosaurs, many giant plants died in swamps.

Over millions of years, the plants were buried under water and dirt.

Heat and pressure turned the dead plants into coal.

Coal was formed in a similar way, mainly from the plants that lived hundreds of millions of years ago, when the Earth was partly covered with swampy forests. Layers of water and dirt covered layers of dead plants. The heat and pressure from the top layers helped the plant remains transform into what we today call coal. Coal is composed primarily of carbon, hydrogen, and oxygen atoms.

The Matter Cycling and Energy Flow Questions: How Do Humans Use Fossil Fuels?

For most of human history, people used small amounts of coal that they found close to the Earth’s surface, but coal, petroleum, and natural gas mostly stayed underground. When people needed heat or light from combustion, they burned organic matter from the Earth’s ecosystems such as wood and animal fats.

Then, in England and Scotland in the 1700’s, a couple of important things happened. One was an energy crisis: English forests were disappearing because people were using so much firewood, so people needed another way to keep their homes and shops warm. The other was an invention: the steam engine.

Steam engines did something that humans had not been able to do before. They took heat energy from combustion and transformed it into mechanical energy—the ability to move things around. During the 1700's the first steam engines (invented by Thomas Newcomen and improved by James Watt) powered pumps that moved water out of mines—especially coal mines that produced still more coal.

During the 1800's people figured out how to use steam engines for other purposes, such as providing power for factories, locomotives, and steam ships. Then people invented other kinds of engines such as internal combustion engines that used a petroleum product—gasoline. Electrical engines convert electrical energy into motion, but the electrical energy often comes from plants that burn coal or natural gas, converting the chemical energy in their C-C and C-H bonds into electrical energy.

So today we have many ways of using fossil fuels, but almost all of them rely on combustion. So let's come back to the Carbon Cycling and Energy Flow Questions:

- **Energy Flow:** People take coal, petroleum, and natural gas out of the Earth because we want the energy in their C-C and C-H bonds—chemical energy that was converted from sunlight through photosynthesis millions of years ago. Combustion of fossil fuels is so useful to us because of the energy transformations that it sets in motion: chemical energy is converted into heat energy, which can be converted into motion, electrical energy, and all the other forms of energy that we use.
- **Carbon Cycling:** Combustion of fossil fuels is also a carbon flux. The organic molecules in fossil fuels combine with oxygen to produce CO_2 and H_2O. So carbon atoms from the fossil fuel pool move into the atmospheric CO_2 pool.

The Stability and Change Question: How Is the Fossil Fuel Flux Changing?

There is an online video that shows how large-scale combustion of fossil fuels started in England in the 1700's and has since spread across the Earth. Take a minute and 10 seconds to watch it: https://www.youtube.com/watch?v=SAhZ1fA1AJs .

This video shows an important story. The fossil fuel combustion flux—zero before 1700—has grown immensely as humans across the Earth have come to rely on combustion of fossil fuels as a source of energy. In the rest of this lesson you will study how combustion of fossil fuels affects the balance of fluxes into and out of the atmospheric CO_2 pool.

Digging Deeper

Here are some ways to learn more about how carbon pools and fluxes in Earth systems are changing:

- *The Wizard and the Prophet: Two Remarkable Scientists and Their Dueling Visions to Shape Tomorrow's World,* by Charles C. Mann, has interesting stories about the development of fossil fuels as energy sources in Chapter 6 (Fire: Energy)
- Watch a video about the process of coal mining: https://www.youtube.com/watch?v=ylkdUuNOJzw
- Read about the history of the steam engine and its creators here: https://www.egr.msu.edu/~lira/supp/steam/