Energy, Fossil Fuels, and the Carbon Cycle

Key Concepts:

- Carbon cycle
- Carbon sinks
- Carbon sources
- Coal
- Electricity
- Energy
- Natural gas
- Petroleum (oil)

WHAT YOU WILL LEARN

1. You will learn how energy is released from fossil fuels.
2. You will learn about the carbon cycle.
3. You will learn how the burning of fossil fuels impacts the environment.
4. You will investigate how we can reduce our carbon dioxide emissions.

Engage Your Thinking

Energy comes from many sources, occurs in many forms, and is used to perform many tasks. Natural gas, coal, and petroleum (oil) are non-renewable energy sources that are called fossil fuels. Wind, solar, hydro, and geothermal are considered renewable energy sources. In this activity you will learn about fossil fuels, the carbon cycle, and the environmental impact of the use of fossil fuels. Before starting the activity, however, answer the following questions based on what you currently know and think.

1. How is energy released from fossil fuels?

2. What is the carbon cycle?

3. How does the burning of fossil fuels impact the environment?

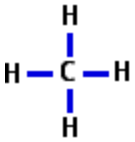
4. How could we reduce our carbon dioxide emissions?

Explore and Explain

The gasoline that fuels our cars, the coal we burn in power plants to generate electricity, and the natural gas that heats our homes, schools, and stores are all fossil fuels. **Fossil fuels** are compounds primarily composed of carbon and hydrogen atoms that were formed millions of years ago when living organisms were buried in layers of sediments. The weight of the sediments created high pressures and temperatures that changed the dead organisms into fossil fuels. Fossil fuels, therefore, are a form of stored chemical energy, and this chemical energy is released when the fossil fuel is burned. The released energy can take the form of heat energy used to cook food on a stove, the form of mechanical energy to move a car, or the form of electrical energy to produce electricity. Electrical energy is often considered a secondary energy source because it is generated through the burning of other (primary) energy sources such as coal, oil, and natural gas.

Energy in the form of heat, light, and motion is known as energy in action or kinetic energy. A lump of coal or a barrel of oil that may be used to produce heat, light and motion is stored energy or potential energy. It is important to note that energy *can be neither created nor destroyed* but it can be changed from one form to another (First Law of Thermodynamics). For example, when the plants of the Paleozoic swamps died and were buried in layers of mud over 300 million years ago, the chemical energy in the plants was stored as potential energy in coal. Today, when the coal is burned, its chemical potential energy is changed into heat energy, a form of kinetic energy. The general chemical reaction for this process is:

$$\text{Carbon (C)} + \text{Oxygen } (O_2) \rightarrow \text{Carbon dioxide } (CO_2) + \text{Energy (Heat)}$$



Methane

Just as energy is conserved in the above reaction, so is matter. As the carbon burns, some of the carbon bonds with oxygen forming **carbon dioxide**. There is the same number of carbon and oxygen atoms, but they are in a different form of matter. In this reaction the individual carbon and oxygen atoms bond to form carbon dioxide. The burning of coal and other fossil fuels results in the release of carbon dioxide and other gases, all of which are air pollutants (carbon monoxide, sulfur oxides, nitrogen oxides). Natural gas (methane) and petroleum contain hydrogen atoms as well as carbon atoms, they are called hydrocarbons. Gasoline used to run cars is made up of over 500 hydrocarbons. When natural gas and petroleum are burned they produce carbon dioxide, water, and Energy (heat). The general chemical reaction is:

$$\text{Hydrocarbon} + \text{Oxygen } (O_2) \rightarrow \text{Carbon dioxide } (CO_2) + \text{Water } (H_20) + \text{Energy (Heat)}$$

Matter, like energy, *can be neither created nor destroyed* (First Law of Thermodynamics). Matter cycles throughout the environment. So, when fossil fuels are burned, they release carbon dioxide (CO_2) into the atmosphere. Because fossil fuels release carbon dioxide when burned they are known as a **carbon source**. Humans (and other animals) are also carbon sources because when we breath (respire) we exhale carbon dioxide. Some of this carbon dioxide is absorbed by the oceans and some is used by plants during photosynthesis.

Since plants use carbon dioxide, they are known as a **carbon sink**. Much of the carbon dioxide absorbed by plants remains "locked up" in the plants' biomass (roots, stem, and leaves) until the plants are decomposed or burned, and the carbon dioxide is released back to the atmosphere. This natural process of cycling carbon dioxide through the environment is known as the **carbon cycle**; carbon cycles between the land, the oceans, and the atmosphere (Figure 1).

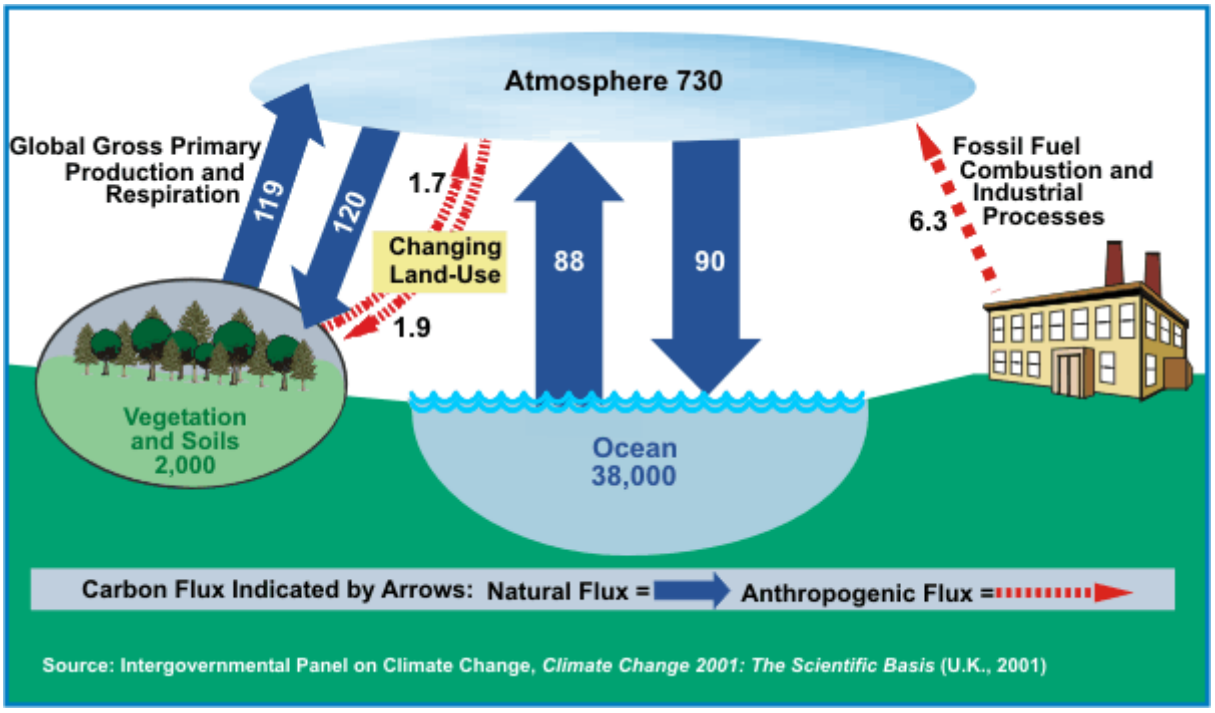


Figure 1. The Carbon Cycle. Source: NOAA

Based on the carbon cycle shown in Figure 1, answer the following questions:

5. What are two carbon dioxide sources?

6. What are two carbon dioxide sinks?

7. If humans produce carbon dioxide by burning fossil fuels at a faster rate than plants, land, and oceans can use and store carbon dioxide, what might happen to the amount of carbon dioxide in the atmosphere?

Extend Your Thinking

Carbon dioxide occurs naturally in the Earth's atmosphere and is naturally cycled between the atmosphere, the oceans, the land, and the plants during photosynthesis. The oceans and plants remove billions of tons of carbon dioxide from the Earth's atmosphere each year. Yet, this carbon dioxide is emitted back into the atmosphere through respiration, fires, and the oceans. The natural process of releasing and removing carbon dioxide maintains the Earth's carbon dioxide balance. Human activities, such as the burning of fossil fuels (coal, oil, and natural gas) add carbon dioxide to the Earth's atmosphere. Scientists at the Mauna Loa Observatory, Hawaii have been measuring atmospheric carbon dioxide levels since 1958 (Table 1).

Table 1: Annual Mean Atmospheric Carbon Dioxide Levels

S/N	Year	Annual mean	S/N	Year	Annual mean	S/N	Year	Annual mean
1	1959	316	20	1978	335	39	1997	364
2	1960	317	21	1979	337	40	1998	367
3	1961	318	22	1980	339	41	1999	368
4	1962	318	23	1981	340	42	2000	370
5	1963	319	24	1982	341	43	2001	371
6	1964	320	25	1983	343	44	2002	373
7	1965	320	26	1984	345	45	2003	376
8	1966	321	27	1985	346	46	2004	377
9	1967	322	28	1986	347	47	2005	380
10	1968	323	29	1987	349	48	2006	382
11	1969	325	30	1988	352	49	2007	384
12	1970	326	31	1989	353	50	2008	386
13	1971	326	32	1990	354	51	2009	387
14	1972	327	33	1991	356	52	2010	390
15	1973	330	34	1992	356	53	2011	392
16	1974	330	35	1993	357	54	2012	394
17	1975	331	36	1994	359	55	2013	396
18	1976	332	37	1995	361			
19	1977	334	38	1996	363			

Note: Unit is parts per million (ppm), rounded.

Create a graph that displays the data in Table 1, showing the relationship between the annual atmospheric carbon dioxide level and year. Based on your graph, answer the following questions:

8. What pattern(s) do you notice in the atmospheric carbon dioxide levels?

9. How would you explain the pattern(s) you noticed in the atmospheric carbon dioxide levels?

10. Based on your graph, what do you predict the atmospheric carbon dioxide levels to be in 20 years and why?

11. Based on the data in Table 1, calculate the mean and range for the 10 year time periods of 1959-1969, 1969-1979, 1979-1989, and 1989-1999, and 1999-present. Record your findings in Table 2.

Table 2. The Mean and Range of Atmospheric Carbon Dioxide Levels for Different Time Periods

	1959-1969	**1969-1979**	**1979-1989**	**1989-1999**	**1999-Present**
Mean					
Range					

12. Based on your findings shown in Table 2, what pattern(s) do you notice in the atmospheric carbon dioxide levels?

13. How would you explain the pattern(s) you noticed in the atmospheric carbon dioxide levels?

The historical use of energy in the U.S. is shown in Figure 2. The graph shows the change in fossil fuel (petroleum, natural gas, coal) use over time. The graph also shows how our use of hydroelectric power and nuclear energy has changed over time.

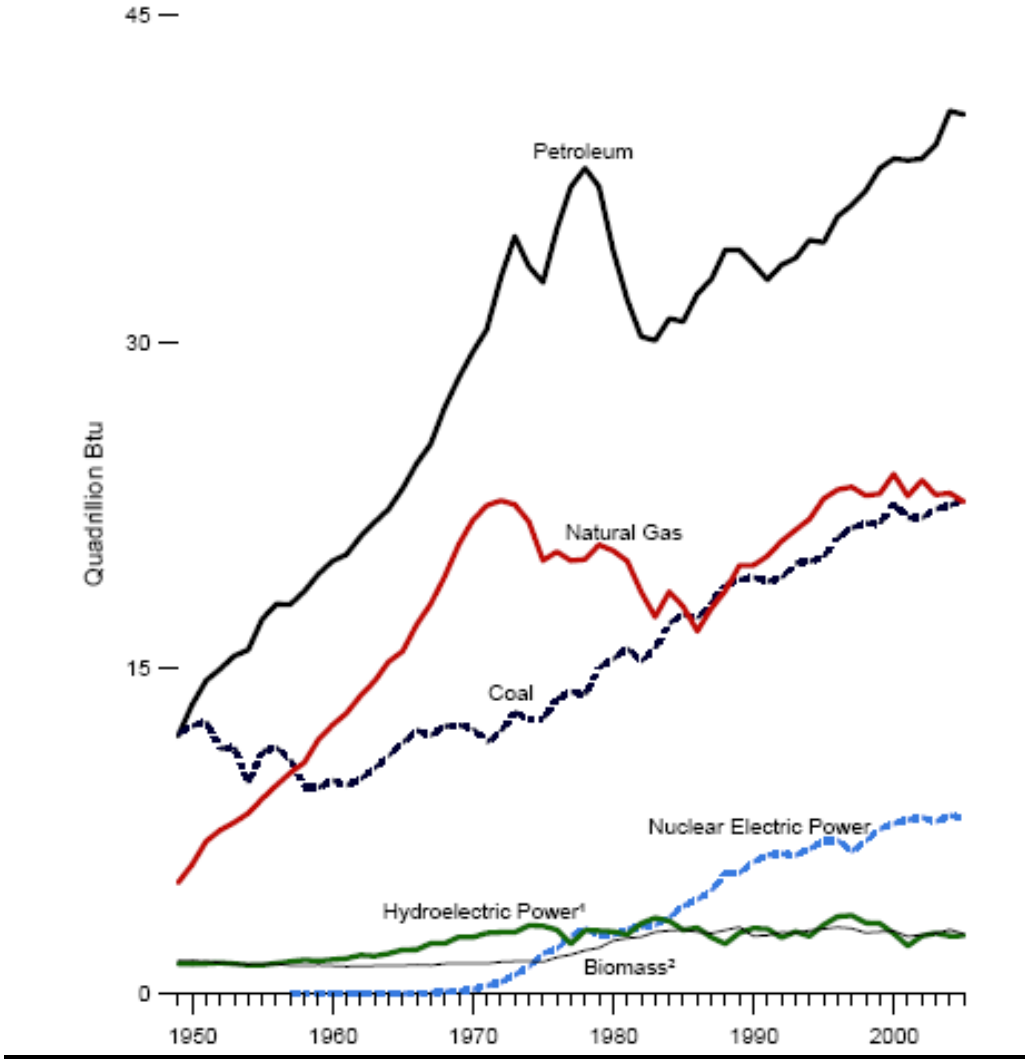


Figure 2. Historical Energy Use in the U.S. Source: EIA

14. Based on Figure 2, what is the trend in overall fossil fuel use?

15. Describe how the fossil fuel use data shown in Figure 2 might explain the increase in atmospheric carbon dioxide levels (see Table 1).

Apply What You Have Learned

Due to that fact that the burning of fossil fuels releases carbon dioxide into the atmosphere, some countries are working to lower carbon dioxide emissions from the burning of fossil fuels. If you were to propose a plan for the U.S. to lower carbon dioxide emissions from the burning of fossil fuels, what would your plan involve? Describe your plan below.

Reflect on What You Have Learned

16. How is energy released from fossil fuels?

17. What is the carbon cycle?

18. How does the burning of fossil fuels impact the environment?

19. How could we reduce our carbon dioxide emissions?

20. Please explain how your ideas and thinking about greenhouse gases has changed.