Study Guide for
Energy and CO_2 Management: Carbon Capture and Storage

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CO_2 Science

Jeopardy Answer No. 1: A molecule made of one atom of carbon and two atoms of oxygen.

1. What is carbon monoxide?
2. What is carbon dioxide?
3. What is calcium dioxide?
4. What is di-hydrogen oxide?

No. 2 is correct.

A colorless, odorless, noncombustible gas, it is a by-product of combustion.

We use it every day, e.g., coolant as dry ice, to make soda bubbly, in fire extinguishers.

One of nature's essential constituents:

- Critical to plant life
- An important greenhouse gas
- A trace gas (0.04%) in the atmosphere
- A by-product of respiration

It is also found in natural underground deposits like those for oil and natural gas and is present in oil and natural gas deposits.

The composition of the atmosphere is 78% nitrogen, 21% oxygen, and 1% other gases (mostly argon) including 0.04% CO_2.

The global carbon cycle has many parts. Some carbon is in long-term storage (atmospheric, oceanic, rock, and fossil fuel storage [also called sinks]), and some moves through the environment (cycling between the atmosphere and oceans and between the atmosphere and plants/soil).

Jeopardy Answer No. 2: The natural phenomenon that makes Earth warm enough to support life as we know it.

1. What is the atmosphere?
2. What is a volcano?
3. What is el Niño?
4. What is the greenhouse effect?

No. 4 is correct.

Without the greenhouse effect, the average annual temperature of Earth would be like North Dakota in winter!

Major players are water vapor and some trace gases (carbon dioxide, methane, and nitrous oxide), collectively called greenhouse gases. Nonplayers include the major components of the atmosphere, nitrogen, oxygen, and argon. Greenhouse gas levels and temperature have fluctuated over geologic time.

BONUS QUESTION: Is this natural phenomenon **good** or **bad** for inhabitants of Earth?

Good is correct.

Jeopardy Answer No. 3: CO_2 released to the atmosphere by human activities like burning fossil fuels, making cement, or plowing fields.

1. What is anthropogenic CO_2?
2. What is natural CO_2?
3. What is liquid CO_2?
4. What is exhalation?

No. 1 is correct.

Sources include:

- Fossil fuels (carbon in hydrocarbon fuels like coal, oil, and natural gas).
- Carbonates (carbon in seashells and limestone) heated to produce cement.
- Land use practices – soil microorganisms exposed to air by plowing, breaking down organic carbon stored in the soil (plant materials and other organic matter).

As part of the carbon cycle, carbon dioxide might form from several sources:

- Atmosphere – atmospheric CO_2 is the amount of CO_2 in the atmosphere at any time.
- Carbon cycle CO_2 – Cycling CO_2 continually moves between the atmosphere, soils, plants, animals, the oceans, and back to the atmosphere.
- Biological deposition (fossils/rocks) – fossil CO_2 used to be in the atmosphere but is now in long-term storage in geologic deposits like coal beds, oil reservoirs, and limestone rocks.
- Geothermal activity (e.g., volcanos) – new CO_2 develops from natural processes deep in Earth and is released to the atmosphere by volcanoes.
- Fossil fuel combustion/lime production – CO_2 that was in long-term storage (fossil CO_2) but is now being released by human action.

Combustion is a chemical energy conversion.

- Carbon-based fuel + oxygen + a little heat ➔ lots of heat + CO_2 + H_2O.
- Biofuels generate CO_2 from today's atmosphere.
- Fossil fuels generate CO_2 from ancient atmospheres.

Energy and Carbon

Jeopardy Answer No. 4: The fuel supplying 85% of the energy humans use today.

1. What is sunlight?
2. What is renewable energy?
3. What is electricity?
4. What is fossil fuels?

No. 4 is correct *(Coal, oil, and natural gas)*

How do we use these fuels?

- Oil used to make gasoline and diesel fuel for cars, trucks, airplanes, and ships.
- Coal used to generate electricity.
- Natural gas used to heat homes, offices, and stores.

Jeopardy Answer No. 5: The total amount of greenhouse gases humans release to the atmosphere.

1. What is anthropogenic CO_2?
2. What is our carbon footprint?
3. What is barely significant?
4. What is 17?

No. 2 is correct.

How is this total partitioned?

- 70% energy
- 13% agriculture
- 10% land use
- 3% waste

Jeopardy Answer No. 6: The year 1865.

1. When was the opening volley of the U.S. Civil War?
2. When was the sinking of the Titanic?
3. When was the end of the War of 1812?
4. When was the beginning of significant use of coal in America?

No. 4 is correct.

Jeopardy Answer No. 7: The year 1900.

1. When was electricity replacing horses on streetcars?
2. When had the global use of energy by humans doubled?
3. When did the global use of fossil fuels surpass the use of wood fuels?
4. When did U.S. auto production reach 4000 cars?
5. When did North Dakota have 73 coal mines?

All are correct.

Global energy demand is 10 times greater than it was 100 years ago. The demand is currently met by a combination of biofuel, hydroelectricity, fossil fuels, and nuclear energy.

What energy source is providing the lion's share? _____

Fossil fuels

With all this energy come more and more CO_2 emissions.

- CO_2 emissions from human activity to the atmosphere have been on the rise since the early 1800s.
    - In 1900, the annual emissions were around 2 billion metric tons CO_2.
    - In 2000, they were about 25 billion metric ton CO_2.
    - By 2006, annual emissions reached 30 billion metric tons CO_2 (which is 8.2 billion metric tons of carbon).
- Some of that anthropogenic carbon has been absorbed by the oceans and the terrestrial carbon cycle (trees, soils, etc.), but some remains in the atmosphere.
    - In 1800, atmospheric CO_2 is estimated to have been around 280 ppm (0.028%).
    - In 2006, atmospheric CO_2 was around 380 ppm (0.038%).
    - In June 2013, the concentration briefly topped 400 ppm.

Jeopardy Answer No. 8: Half again as much.

1. What is the amount of snow predicted for next winter?
2. What is the amount of energy needed in 2040?
3. What do you wind up paying in taxes?
4. What is how much longer should this presentation be?

No. 2 is correct.

Global energy demand is expected to increase by 50% in 25 years.

The video excerpt on the slide **Global CO_2 Emissions 1930 to 2006** is from the video clip "Energy and Carbon: The Big Picture" (and from the documentary *Global Energy and Carbon: Tracking Our Footprint*). The clip is available at http://www.undeerc.org/PCOR/Video-Clip-Library/.

We can control output of anthropogenic CO_2 and stabilize CO_2 in the atmosphere. BUT can we provide the energy we need, pay for the change, and maintain a strong economy?

Cutting Carbon

The video excerpt on the slide **Cutting Carbon** is from the video clip "Energy and Carbon: The Big Picture" (and from the documentary *Global Energy and Carbon: Tracking Our Footprint*). The clip is available at http://www.undeerc.org/PCOR/Video-Clip-Library/.

There are a range of CO_2 management options.

- As individuals, we can:
  - Use energy wisely.
  - Install energy-saving appliances and devices.
- As societies, we can:
  - Improve energy efficiency (in fossil fuel-fired systems).
  - Seek noncarbon energy technologies.
  - Implement carbon management techniques.

Learn more about the myriad options discussed by Socolow and Pacala in their paper in *Scientific American*, August 21, 2006, "A Plan to Keep Carbon in Check." That paper and other related information is available free online at http://cmi.princeton.edu/wedges/articles.php (accessed June 3, 2014).

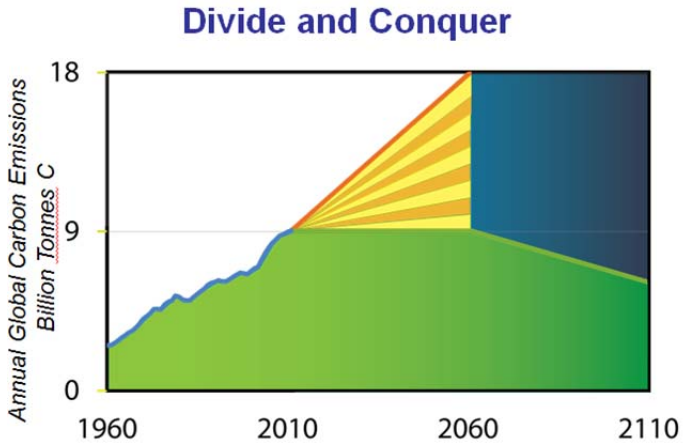

Figure 1. Cutting CO_2 emissions to stabilize anthropogenic contribution to the atmosphere over the next 50 years can be accomplished by dividing the task into smaller wedges and using a variety of strategies to reduce emissions. Each of the nine yellow or gold wedges represents 25 billion tons of carbon not emitted to the atmosphere by 2060 (with is also 1 billion tons of carbon in the 2060).

Jeopardy Answer No. 9: Capture and long-term storage of CO_2.

1. What is CO_2 localization?
2. What is CO_2 sequestration?
3. What is CO_2 serendipity?
4. What is the greenhouse effect?

No. 2 is correct.

Terrestrial sequestration absorbs CO_2 from the atmosphere and stores it in plant materials and soils.

Carbon capture and storage (CCS) captures CO_2 before it enters the atmosphere and puts it into storage deep underground for millions of years.

Geologic sequestration is also called:

- CCS.
- Geologic CO_2 sequestration.
- Carbon capture, utilization, and storage.

The video excerpt is from the video clip "Carbon Capture and Storage" (and from the documentary *Managing Carbon Dioxide: The Geologic Solution*). The clip is available at http://www.undeerc.org/PCOR/Video-Clip-Library/.

CO_2 Sequestration and CCS

Jeopardy Answer No. 10: 25 deposits on six continents.

1. What is the number of mafia bank accounts?
2. What is the number of pure carbon (diamond) mine areas?
3. What is the number of natural underground CO_2 deposits?
4. What is the number of major coal mines?

No. 3 is correct.

The video excerpt is from the video clip "World's Finest Fire Extinguisher" (and from the documentary *Managing Carbon Dioxide: The Geologic Solution*). The clip is available at http://www.undeerc.org/PCOR/Video-Clip-Library/.

Geologic CO_2 sequestration puts the storage in CCS.

- Carbon capture – separate and capture CO_2 at a stationary source like a power plant.
- Transport – compress the CO_2 and transport the CO_2 by pipeline to a central storage location.
- Storage – inject CO_2 into formations deep below the surface (at least a half-mile deep).
    - Depleted oil and gas reservoirs
    - Unminable coal seams
    - Deep saline formations

Certain conditions must exist to safely implement CCS:

- Right form of CO_2 – to be pumped underground, CO_2 must be under enough pressure to flow into the rock formation. It will be on the supercritical or dense phase, which happens naturally at depths below 2500 ft. This also provides maximum storage capacity.
- Right conditions underground – sedimentary rock structures and stable environment (e.g., areas of low seismic activity).
    - Over time, sediments are buried, compacted, cemented, and…become ROCK.

    - Rock-making, aka “lithification:”
        - Sand + lithification = sandstone.
        - Silt + lithification = siltstone.
        - Clay + lithification = claystone.
        - Coral reefs and shells + lithification = limestone = rock composed primarily of the mineral calcite ($CaCO_3$).
    - Most sedimentary rocks have pores, and many are permeable.
- Right rocks
    - Rock layer for CO_2 storage – porous and permeable rock layers like sandstones and some limestones.
    - Rock layer for seal – continuous, tight, impermeable rock layers like shales, mudstones, salts, and some limestones.
- Right operation – tailored design, expert personnel, and proven practices.
    - Drinking water protection is not only critical, it is the law. Regulations require that three layers of steel and two layers of durable cement surround the fluids of a well for the full extent of the drinking water zone (usually at least the first 500 ft of depth).
    - Injection pressure is high enough to get the CO_2 into the formation without disrupting the injection zone. CO_2 injection has been an industry practice in Texas for more than 35 years and at the Weyburn oil field for more than 10 years.
- Right safeguards:
    - Monitoring, safety protocols
- Right development path
- Regulatory process, community engagement

The video excerpt on the slide **What Works for Oil Works for CO_2** is from the video clip “Reservoir Geology 101: Fluids in the Rocks” (and from the documentary *Managing Carbon Dioxide: The Geologic Solution*). The clip is available at http://www.undeerc.org/PCOR/Video-Clip-Library/.

The video excerpt on the slide **Geologic CO_2 Sequestration** is from the video clip “Carbon Capture and Storage” (and from the documentary *Managing Carbon Dioxide: The Geologic Solution*). The clip is available at http://www.undeerc.org/PCOR/Video-Clip-Library/.

Local CCS: PCOR Partnership Region and Activities

North Dakota lies at the center of the PCOR Partnership Program region (North Dakota, South Dakota, Nebraska, Minnesota, Wisconsin, Iowa, Missouri, Manitoba, Saskatchewan, and parts of Wyoming, Montana, and Alberta) that:

- Covers 2.5% of Earth’s land surface.
- Accounts for 0.5% of Earth’s population.
- Accounts for 3.0% of global gross domestic product (GDP).
- Puts out 3.0% of Earth’s anthropogenic CO_2. This includes approximately 930 stationary sources for a total of ~560 million tons of CO_2 emissions a year.

The region also comprises part or all of eight sedimentary basins that hold potential opportunities for CCS operations. There have already been several test activities and ongoing commercial projects.

More Information

In your packet:

DVDs

PCOR Partnership Atlas, 4th Ed.

Flash drive with this presentation and a link to our Web site and fact sheets

Visit our Web site:

undeerc.org/pcor

Find related lesson plans:

www.prairiepublic.org/education/teachers/media-resources/eerc-2011-lesson-plans

Check out our next venue:

Prairie Public Teacher Institute 2015 Integrating Digital Media in Your Classroom: The Arts, History, Culture, and STEM, Concordia College, Moorhead, Minnesota, June 23–24, 2015

www.prairiepublic.org/education/teachers/professional-development/teacher-training-institutes/teacher-training-institute

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