Energy and CO$_2$ Management: Carbon Capture and Storage

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Dan Daly
Plains CO$_2$ Reduction (PCOR) Partnership

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Presentation Outline

• Carbon dioxide (CO$_2$) science
• CO$_2$ sequestration and carbon capture and storage
• Plains CO$_2$ Reduction (PCOR) Partnership activities
• More information
Jeopardy!
Rules!

- I give the answer (the hard part).

- You give the question … “What is…”
ANSWER 1:
One atom of carbon and two atoms of oxygen
The question is:

1. What is carbon monoxide?
2. What is carbon dioxide?
3. What is calcium dioxide?
4. What is di-hydrogen oxide?
What is carbon dioxide (CO$_2$)?

- Colorless, odorless gas
- Noncombustible
- By-product of combustion
What is carbon dioxide ($\text{CO}_2$)?

- Colorless, odorless gas
- Noncombustible
- By-product of combustion
- We use it every day:
  - Coolant as dry ice
  - Makes soda bubbly
  - Fire extinguisher
What is carbon dioxide (CO$_2$)?
78% Nitrogen
0.04%
1% Other Gases
21% Oxygen
Global Carbon Cycle

- 90 billion tons of carbon
- 60 (37,000)
- 120 (800)
- 60
- 90
- 60
- 90
- 90
- (2300)
- (10,000)
- (37,000)

Billion tons of carbon
ANSWER 2:
The natural phenomenon that makes Earth warm enough to support life as we know it.
The question is:

1. What is the atmosphere?
2. What is a volcano?
3. What is el Nino?
4. What is the greenhouse effect?
What is the greenhouse effect?
Greenhouse Gases

- Water vapor and trace greenhouse gases contribute the greatest portion of the greenhouse effect:
  - CO$_2$
  - Methane
  - Nitrous oxide (N$_2$O)

- Many atmospheric gases do not contribute to the greenhouse effect:
  - Nitrogen
  - Oxygen
  - Argon
BONUS QUESTION: Is the greenhouse effect good or bad for inhabitants of Earth?
ANSWER 3:

$\text{CO}_2$ released to the atmosphere by human activities like burning fossil fuels, making cement, or plowing fields
The question is:

1. What is anthropogenic CO$_2$?
2. What is natural CO$_2$?
3. What is liquid CO$_2$?
4. What is exhalation?
What is anthropogenic CO$_2$?
Wait a minute . . .

How many kinds of $\text{CO}_2$ are there?
In-the-Atmosphere CO$_2$
Cycling CO$_2$
Long-Lost CO$_2$
New-Kid-in-Town CO$_2$
Return-of-the-Long-Lost CO$_2$
Chemical Energy Conversion

Atoms recombine to form

Combustion

Atoms recombine to form

and
Biofuels: CO$_2$ from Today’s Atmosphere
Fossil Fuels: CO$_2$ from an Ancient Atmosphere
ANSWER 4:
The fuel supplying 85% of the energy used by humans today

Source: Science, v. 798, November 2002; photo from NASA.
The question is:

1. What is sunlight?
2. What is renewable energy?
3. What is electricity?
4. What are fossil fuels?
What are fossil fuels: coal, petroleum, and natural gas?
ANSWER 5:
The total amount of greenhouse gases humans release to the atmosphere
The question is:

1. What is anthropogenic CO$_2$?
2. What is our carbon footprint?
3. What is barely significant?
4. What is 17?

- 1: 28.6%
- 2: 28.6%
- 3: 28.6%
- 4: 14.3%
The amount of CO$_2$ and other greenhouse gases we humans release to the atmosphere.
ANSWER 6: The first American energy crisis
The question is:

1. What happened in 1973?
2. What happened in 1730?
3. What happened in 1859?
4. What happened in 1941?
What is 1730?
Fuel Wood Shortage in Boston

Coal imported from England!
ANSWER 7:
The year 1865
The question is:

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?
When was the beginning of significant use of coal in America?
ANSWER 8:
The year 1900
The question is:

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 questions are correct!
Global energy demand is 10 times more than it was 100 years ago.
Remember the types of CO$_2$?

Biomass = Cycling CO$_2$

Fossil Fuels = Fossil CO$_2$
CO$_2$ Emissions from Human Activity on the Rise Since the Early 1800s

Annual CO$_2$ Emissions, billion metric tons
Global Carbon Cycle

Yearly additions from human activities

Billion tons of carbon

(37,000)

(2300)

(10,000)

(800)

(9,000)
CO₂ Emissions from Human Activity on the Rise Since the Early 1800s
ANSWER 9:
Half again as much!
The question is:

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?
What is the amount of energy needed in 2040?

Global energy demand is expected to increase by 50% in 25 years.
Global CO₂ Emissions
1930 to 2006

In this video, look for . . .
How can we meet growing energy demand to improve quality of life?

And cut CO$_2$ emissions?
Cutting Carbon

In this video, look for . . .
A Range of CO₂ 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.
Example Options for Cutting Carbon

Each wedge represents 25 billion tons of carbon not emitted.
Divide and Conquer

Annual Global Carbon Emissions, billion metric tons C
ANSWER 10:
Capture and long-term storage of CO$_2$
The question is:

1. What is CO₂ localization?
2. What is CO₂ sequestration?
3. What is CO₂ serendipity?
4. What is the greenhouse effect?
What is CO$_2$ sequestration?

Geologic sequestration captures CO$_2$ before it enters the atmosphere and puts it into storage deep underground for millions of years.

Terrestrial sequestration absorbs CO$_2$ from the atmosphere and stores it in plant materials and soils.

Geologic sequestration is also called:

- Carbon capture and storage (CCS)
- Geologic CO$_2$ sequestration
- Carbon capture, utilization, and storage (CCUS)
What is CO$_2$ sequestration?

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Irrespective of the name, have you heard of geologic CO$_2$ sequestration?

1. Yes
2. No

50.0% 50.0%
Carbon Capture and Storage

In this video, look for . . .
Capturing Anthropogenic CO$_2$

Capturing CO$_2$ from millions of vehicles could be tough.

Capturing CO$_2$ from millions of houses? Not easy either.

Photo ©VermontDailyNews
ANSWER 11:
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 nearly pure natural underground CO₂ deposits?
4. What is the number of major coal mines?
What is the number of nearly pure natural underground CO₂ deposits?
Natural CO\textsubscript{2} Deposits

In this video, look for . . .
This video clip shows...
CCS Bill of “Rights”

- **Right form of CO$_2$**
- **Right conditions underground**
- **Right rocks**
  - Rock layer for CO$_2$ storage
  - Rock layer for seal
- **Right operation**
  - Tailored design, expert personnel, proven practices
- **Right safeguards**
  - Monitoring, safety protocols
- **Right development path**
  - Regulatory process, community engagement
Now, we’re gonna get technical!
The Physical Phase of the CO$_2$ Is Important

Matter’s three physical states:

- Solid
- Liquid
- Gas
Supercritical Fluid!

Highly compressed matter

- Exhibits some of the properties of gases and liquids.
- Requires conditions of high temperature and high pressure.
- The maximum number of molecules that can be crammed into a given volume.

*For CO₂, that point is 88°F and 73 columns of atmosphere on your head at sea level (1074 psi).*
Supercritical-Phase CO$_2$

400 m$^3$ compressed to 1 m$^3$

Maximum Storage Capacity!
Supercritical CO$_2$ Means Superstorage

- The deeper underground, the higher the temperature.
- The deeper underground, the higher the pressure.

- At 2500 feet below the surface, CO$_2$ is naturally in the supercritical phase.
Storage Depth

Zone of Prime Targets in the Williston Basin of North Dakota

Feet

Zone of Fresh Water
What kind of rock do we need for the storage zone?

A half a mile underground = supercritical conditions for CO$_2$!

From rim to river, the Grand Canyon is 1 mile deep (5280 feet, or 1672 meters).
Pore Space

Pores + Connections = Permeability

A good storage zone has connected pores!
What Works for Oil Works for CO$_2$

In this video, look for . . .
Sedimentary rocks occur in layers (strata).

We’re looking to store CO$_2$ in the pore spaces of the sedimentary rock.
Sedimentary Rocks as Storage Zones

- Sand Becomes Sandstone
- Clay Becomes Claystone or Shale
- Coral Reefs and Shells Become Limestone

Good Storage Reservoir

Poor Storage Reservoir

Good Storage Reservoir
Sand Becomes Sandstone
Clay Becomes Claystone or Shale
Coral Reefs and Shells Become Limestone

Porous and Permeable
Tight as a drum!
Variable permeability

Not a seal!
Geologic Storage a.k.a. CO$_2$ Sequestration

In this video, look for . . .
Regulations require:
- Three layers of steel.
- Two layers of durable cement.
Injection!
Safe Injection

• Injection pressure – enough pressure to get the CO₂ in place without disrupting the injection zone

• Periodic monitoring – Pressure and temperature in and above the injection zone – Soil and surface water
Any questions?

what the heck are you talking about?
Regional Carbon Sequestration Partnership Program
Led by the EERC at the University of North Dakota
On the Road to CCS!

Characterization

Field Tests and Demonstrations

Regional CCS Infrastructure
Regional Activities
PCOR Partnership Outreach Resources

www.undeerc.org/PCOR
PCOR Partnership Educator Resources

www.undeerc.org/PCOR
Household Energy and Carbon Footprint

In general, energy comes to your home in three forms: power lines (electricity), "gas" pipes or delivery trucks (natural gas, propane, and fuel oil), and from the pump (gasoline and diesel).

Most of these energy sources contribute to your carbon footprint because of carbon released to the atmosphere to obtain, deliver, and consume them in your home.

Depending on its source, each form of energy creates a different carbon trail as it travels to and through your home. The carbon trail and the amount of energy you use in your home determine your household carbon footprint.

VIDEO RESOURCES

*See how rural and urban family in the Upper Midwest use energy and build their carbon footprints.

ELECTRICITY AND CO2 FOOTPRINT
Electricity use contributes the largest share of the household carbon footprint for these families. See more.

HOME FUELS AND CO2 FOOTPRINT
Home fuels contribute the least to the household carbon footprint of these families. See more.

TRANSPORTATION AND CO2 FOOTPRINT
Transportation is an important component of the fuel of these Midwest families, and of their household carbon footprint. See more.
PCOR Partnership Teacher Packet
PCOR Partnership Teacher Packet

Have you used our materials in your classes?

1. Yes 1 50.0%
2. No 2 50.0%

www.undeerc.org/PCOR
Lesson 1

Play CO$_2$ Jeopardy
CO$_2$ Jeopardy!
Lesson 2

Geologic CO$_2$ Storage
Geologic CO₂ Storage

In Depth

Energy and CO₂ Management: Carbon Capture and Storage
Plains CO₂ Reduction (PCOR) Partnership

CO₂ Science

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?
List three places this gas is found: 1. 2. 3.
What causes this effect?
Is it good or bad for inhabitants of Earth?

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?

Write a formula for chemical energy conversion (combustion).

Answer No. 3: CO₂ released to the atmosphere by human activities like burning fossil fuels, making cement, or plowing fields.
1. What is anthropogenic CO₂?
2. What is natural CO₂?
3. What is liquid CO₂?
4. What is exhalation?

Burning wood makes CO₂ from:
Burning fossil fuels makes CO₂ from:

Answer No. 5: The amount of greenhouse gases humans release to the atmosphere.
1. What is anthropogenic CO₂?
2. What is our carbon footprint?
3. What is barely significant?
4. What is 17?

List three forms of this fuel:

List four main sources of greenhouse gases from human activity:

Study Guide for Energy and CO₂ Management: Carbon Capture and Storage
Presented by Dan Daly, Outreach Task Manager, Plains CO₂ Reduction (PCOR) Partnership
Energy & Environmental Research Center, University of North Dakota
Presented at the 2018 Lignite Education Seminar
Bismarck, North Dakota

CO₂ 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% CO₂.
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).
Prairie Public Teacher Institute

- Lesson plans
- Link on the PCOR Partnership Web site Educator page
Final Thought

As individuals, we can:

- Use energy wisely.
- Install energy-saving appliances and devices.

Our region is actively:

- Improving energy efficiency in fossil fuel-fired systems.
- Using noncarbon energy technologies.
- Sequestering CO$_2$. 
Final Thought

As individuals, we can:

• Use energy wisely.
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Our region is actively:

• Improving energy efficiency in fossil fuel-fired systems.
• Using noncarbon energy technologies.
• Sequestering CO$_2$.

Do you think that students should learn about carbon capture and storage?

1. Yes 1 50.0%
2. No 2 50.0%
Contact Information

Dan Daly
ddaly@undeerc.org
Energy & Environmental Research Center
University of North Dakota

www.undeerc.org/PCOR
Telephone: (701) 777-2822
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• Approximately 930 stationary sources
• Total CO₂ emissions: ≈560 million tons/yr