

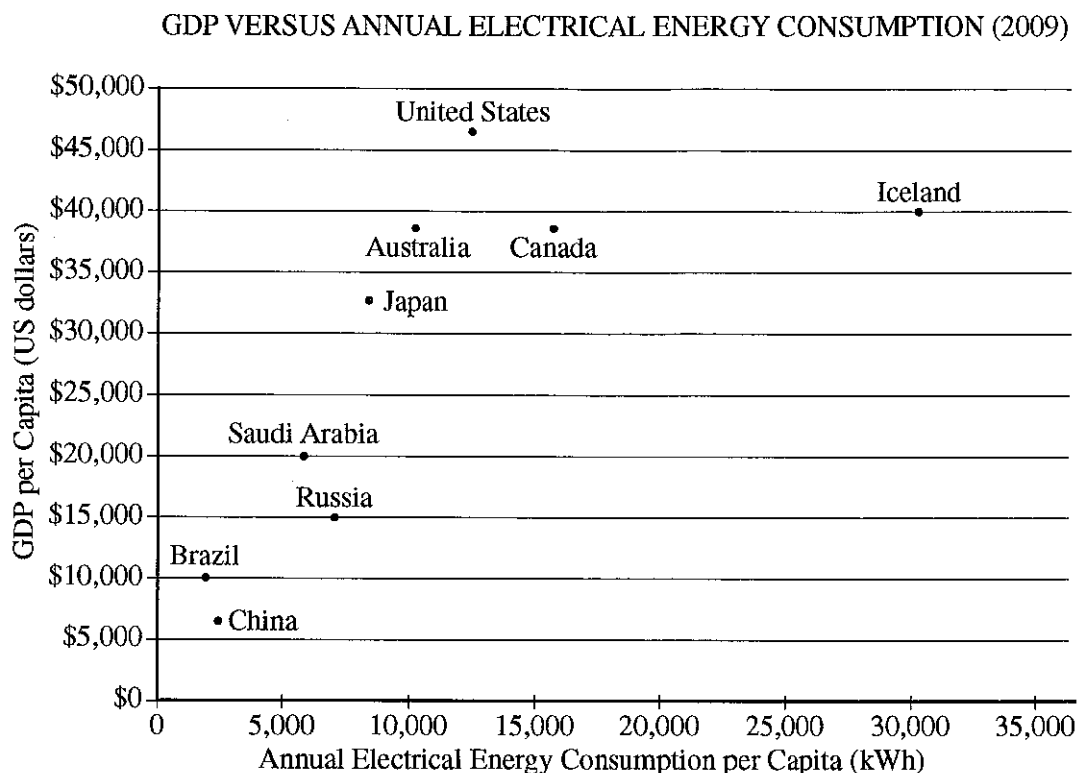
2014 AP[®] ENVIRONMENTAL SCIENCE FREE-RESPONSE QUESTIONS

4. Biogeochemical cycles describe the movement of certain elements (typically bound with other elements in compounds) through Earth's atmosphere, hydrosphere, biosphere, and lithosphere. These elements and their compounds are necessary components of all life, and because they cycle, they can be used repeatedly by new generations of organisms. Each biogeochemical cycle has different pathways with various reservoirs (sources and sinks) where elements may reside for days or millions of years.
- (a) The atmosphere is one important carbon reservoir.
 - (i) **Describe** a biological process by which carbon is removed from the atmosphere and converted to organic molecules.
 - (ii) **Describe** a biological process by which carbon is converted from organic molecules to a gas and returned to the atmosphere.
 - (b) Oceans and terrestrial systems are also important carbon reservoirs.
 - (i) **Explain** how atmospheric carbon is incorporated into two oceanic sinks.
 - (ii) **Identify** one terrestrial sink, other than fossil fuels, that stores carbon for thousands to millions of years.
 - (c) The burning of fossil fuels has been shown to increase the concentration of carbon in the atmosphere. **Discuss** TWO other human activities that increase the concentration of carbon in the atmosphere.
 - (d) **Identify** an environmental problem that results from elevated atmospheric carbon concentrations. **Discuss** one consequence of the problem you identified.
 - (e) Phosphorus is another element important to all organisms.
 - (i) **Describe** one major way in which the phosphorus cycle differs from the carbon cycle.
 - (ii) **Identify** one reason that phosphorus is necessary for organisms.

STOP

END OF EXAM

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3. Shown above is a graph of the gross domestic product (GDP) per capita versus the annual electrical energy consumption per capita for nine countries in 2009.
- Iceland's position on the graph is due in part to its access to geothermal energy sources. Describe how electricity is generated from a geothermal source.
 - Despite its low GDP per capita and low annual electrical energy consumption per capita, China has become the world's largest emitter of CO_2 . Explain this apparent contradiction.
 - In addition to contributing to increased atmospheric CO_2 concentrations, China is facing other air pollution issues related to the generation of electricity. Identify one such issue and describe the impact it has on human health.
 - Two countries shown on the graph have developed domestic energy sources: sugarcane in Brazil and tar sands in western Canada.
 - Choose EITHER sugarcane or tar sands, then briefly describe the process of fuel production from that energy source.
 - Describe TWO disadvantages of using the energy source that you chose in part (d)(i).
 - Which of the two energy sources is more sustainable? Justify your answer with an explanation.

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Question 3

- (a) Iceland's position on the graph is due in part to its access to geothermal energy sources. Describe how electricity is generated from a geothermal source. (2 points: 1 point for indicating how steam is produced to turn a turbine and 1 point for stating that the energy from the turbine is used to run a generator that produces electrical current)

Steam production (thermal energy into mechanical energy). Any of the following are correct responses:

- High-pressure hot water is pumped out of the earth and put into a low-pressure container to produce steam, which will in turn run a turbine (flash steam plant);
- Wells are drilled, and steam is piped directly to turn a turbine (dry steam plant);
- Hot water is pumped out of the earth; a heat exchanger is used to heat another liquid to produce vapor that is then used to turn a turbine (binary cycle);

Electrical production (mechanical energy into electrical energy)

- The energy from the turbine is used to run a generator.

- (b) Despite its low GDP per capita and low annual electrical energy consumption per capita, China has become the world's largest emitter of CO₂. Explain this apparent contradiction. (1 point)

Although the per capita electrical energy consumption is low, China is the most populous country on the planet. The sum of individual consumption is large.

- (c) In addition to contributing to increased atmospheric CO₂ concentrations, China is facing other air pollution issues related to the generation of electricity. Identify one such issue and describe the impact it has on human health. (2 points: 1 point for identifying an issue and 1 point for explaining its impact on human health)

Students can earn 1 point for naming an air pollution issue without mentioning an impact on human health. In order to earn both points, students must correctly link the impact on human health to the air pollution issue.

Issue (1 point)	Impact on human health (1 point)
SO ₂ or SO _x emissions from coal-burning power plants	<ul style="list-style-type: none"> • Respiratory irritant • Aggravates asthma, bronchitis • Can lead to emphysema • Throat irritant
Particulate matter	<ul style="list-style-type: none"> • Decreases lung function (lung irritant) • Aggravates asthma • Throat irritant
NO _x from coal and petroleum combustion	<ul style="list-style-type: none"> • Respiratory irritant • Aggravates heart disease
Ozone, PAN from photochemical smog	<ul style="list-style-type: none"> • Lung irritant • Eye irritant

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Question 3 (continued)

Hg from coal-burning power plants — deposition into surface waters	<ul style="list-style-type: none"> • Neurotoxin • Hearing loss • Impaired ability to learn
SO ₂ or NO _x aerosols from acid rain	<ul style="list-style-type: none"> • Lung irritant • Aggravates asthma

Note: Students will not receive credit for identifying the Asian brown cloud, smog, or photochemical smog as an issue. They must identify a specific component and describe a health impact associated with that component in order to earn 2 points.

- (d) Two countries shown on the graph have developed domestic energy sources: sugarcane in Brazil and tar sands in western Canada.

- (i) Choose EITHER sugarcane or tar sands, then briefly describe the process of fuel production from that energy source. (2 points: 1 point for describing the extraction process and 1 point for describing how the fuel is processed)

Sugarcane	
Extraction (1 point)	Processing (1 point)
Sugarcane is harvested and crushed. OR Sucrose is extracted from the sugarcane.	<ul style="list-style-type: none"> • The sucrose or mash is fermented to produce ethanol AND/OR bagasse (waste product) is collected after the sugarcane is processed.

OR

Tar Sands	
Extraction (1 point)	Processing (1 point)
Tar sands are extracted by surface mining.	<ul style="list-style-type: none"> • Tar sands are treated with hot water to extract the oil (bitumen). • Tar sands are treated with steam to extract the bitumen.

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Question 3 (continued)

- (ii) Describe TWO disadvantages of using the energy source that you chose in part (d)(i).**
(2 points; 1 point for each disadvantage described for EITHER tar sands or sugarcane)

Tar Sands

- Nonrenewable resource.
- Habitat destruction as a result of surface mining.
- Low net energy yield.
- Requires large amounts of water to produce.
- Produces large amounts of contaminated water.
- Requires conventional oil to produce oil from tar sands.
- Combustion of a fossil fuel — greenhouse gases are produced.
- Large amounts of mining waste are produced.
- Limited distribution of tar sand deposits.
- Processing requires combusting a fossil fuel.

Sugarcane

- Tropical rainforests are cut down to plant sugarcane, which thus decreases biodiversity.
- Fertilizer is used to increase crop yield:
 - Runoff will lead to eutrophication; or
 - Cost of producing sugarcane increases.
- Soil degradation.
- Requires large amounts of water.
- Competition between its use as a fuel and a food product will increase the cost of food.
- Ethanol is more corrosive to engine parts than traditional gasoline.
- Ethanol provides fewer miles per gallon than gasoline.
- Cannot be grown in all climates.
- Monoculture.
- Increased use of pesticides to increase crop yield.

- (iii) Which of the two energy sources is more sustainable? Justify your answer with an explanation.**

(2 points; 1 point for the correct choice and 1 point for a correct explanation)

Sugarcane is more sustainable, and any of the following is a correct explanation:

- Renewable resource — sugarcane can be replanted.
- Not a fossil fuel — new carbon is being consumed instead of old carbon.
- Little toxic sludge and land destruction in comparison with harvesting tar sands.

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Question 4

(a) The atmosphere is one important carbon reservoir.

(i) Describe a biological process by which carbon is removed from the atmosphere and converted to organic molecules.

(1 point for a correct description, with or without an equation. A student can earn the point even without explicitly identifying the process as photosynthesis if an accurate description is provided. No point is earned for naming photosynthesis without a description.)

Example:

Photosynthesis: the process by which plants/autotrophs take in carbon dioxide from the atmosphere and convert it into food/glucose/sugar/complex carbohydrates; plants/autotrophs fix carbon into food/glucose/sugar/complex carbohydrates.

(ii) Describe a biological process by which carbon is converted from organic molecules to a gas and returned to the atmosphere.

(1 point for a correct description: A student can earn the point even without explicitly identifying the process if an accurate description is provided. No point is earned for listing a word as an answer; the answer must identify the form of carbon being released into the atmosphere as part of the description.)

- Respiration breaks down food/glucose/sugar/complex carbohydrates and releases CO₂ into the atmosphere
- Animals digest food and produce gases such as methane that can be emitted either through belching or flatulence
- Decomposition of organic material by bacteria or fungi converts organic carbon into gases such as methane

(b) Oceans and terrestrial systems are also important carbon reservoirs.

(i) Explain how atmospheric carbon is incorporated into two oceanic sinks.

(2 points: 1 point for each correct description of carbon incorporation into an oceanic sink. Only the first two descriptions can earn points)

- Carbon (CO₂) can be taken up by organisms like phytoplankton for photosynthesis
- Carbon can be taken up by marine organisms and used for shells, skeletons, coral, etc.
- Biological pump (organisms in the upper ocean sink to the bottom of the ocean)
- Atmospheric CO₂ can dissolve directly into ocean water OR atmospheric CO₂ can dissolve into precipitation and ultimately reach the ocean
- Carbon can react with other elements/compounds and form carbonates/limestones/sedimentary rocks (just "rocks" is too vague to earn a point)

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Question 4 (continued)

(ii) Identify one terrestrial sink, other than fossil fuels, that stores carbon for thousands to millions of years.

(1 point for the correct identification of a long-term terrestrial sink of carbon)

- Old growth forests/trees that live for thousands of years (just "forests" does not earn credit)
- Trapped/incorporated into ice caps/glaciers
- Limestone or sedimentary rocks
- Incorporation into soil
- Freshwater wetlands/bogs
- Peat formation/burial of plant material under anaerobic conditions
- Dissolved in aquifers

(c) The burning of fossil fuels has been shown to increase the concentration of carbon in the atmosphere. Discuss TWO other human activities that increase the concentration of carbon in the atmosphere.

(2 points: 1 point for each accurate discussion of a human activity that increases atmospheric carbon compounds NOT related to burning fossil fuels)

- Deforestation—cutting down trees reduces the reservoirs for carbon OR cutting down trees can result in carbon being released back into the atmosphere through the process of decay/decomposition
- Biomass burning releases carbon (CO, CO₂, carbon particulates)
- Trash/waste incineration can release carbon (CO, CO₂, carbon particulates)
- Slash and burn agricultural practices—burning organic matter releases carbon (CO, CO₂, carbon particulates)
- Deep plowing or strip mining disrupts soil and releases carbon (CO₂)
- Humans make landfills that can produce carbon-containing carbon-based gases (mainly methane)
- Raising cows and/or other ruminant animals releases carbon-containing gases (methane)
- Manufacture and use of CFCs/HFCs/other carbon-containing compounds releases carbon
- Destruction of wetlands releases CO₂/removes sink for CO₂
- Production of cement releases CO₂

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Question 4 (continued)

- (d) Identify an environmental problem that results from elevated atmospheric carbon concentrations. Discuss one consequence of the problem you identified.**
(2 points: 1 point for identification of a specific environmental problem associated with elevated atmospheric carbon and 1 point for discussion of a consequence of the identified problem)

(Note: The discussion of a consequence must be connected to the stated environmental problem and must be connected to the environment. Examples of environmental problems and consequences are shown in the table below.)

Environmental problem	Environmental consequence
Global climate change/global warming/increased global temperatures	<ul style="list-style-type: none"> • some species of plants and/or animals will not be able to survive temperature changes • climate zones will shift so some species may not be able to adapt • sea level rise which will flood habitats
Sea level rise	<ul style="list-style-type: none"> • coastal habitats will be flooded
Ice caps/glaciers melting	<ul style="list-style-type: none"> • flooding and habitat loss
Ocean acidification	<ul style="list-style-type: none"> • shells of marine organisms may dissolve • lower pH may be below the tolerance level of some species
Reduction in air quality due to (for example) increased CO in the atmosphere	<ul style="list-style-type: none"> • hazardous to animals breathing it in

- (e) Phosphorus is another element important to all organisms.**

- (i) Describe one major way in which the phosphorus cycle differs from the carbon cycle.**
(1 point for a correct description of a difference between the phosphorus and carbon cycles)
- Phosphorus cycle does not typically have a gas/atmospheric phase
 - It is more difficult for living organisms to access phosphorus since it has to be weathered from rocks and minerals (phosphorus cycle is much "slower" than the carbon cycle; phosphorus has fewer sinks than carbon)
- (iii) Identify one reason that phosphorus is necessary for organisms.**
(1 point for a correct reason that phosphorus is necessary for organisms)
- Phosphorus is a component of nucleotides/ATP in cells
 - It is necessary for the formation of DNA and RNA
 - Phospholipids are a major component of all cell membranes
 - Phosphorus is found in/gives strength to the bones and/or enamel of teeth in mammals