

2012 AP® ENVIRONMENTAL SCIENCE FREE-RESPONSE QUESTIONS

2. The Fremont School District uses oil to heat school buildings. Go Green! is a new project the district will implement. The superintendent has declared that the district will dedicate itself to reducing its carbon footprint. In addition to taking serious energy-conservation measures, the district is planning to help offset its carbon dioxide emissions by raising money to help conserve a portion of a large tract of forest land adjacent to the high school campus.
- (a) Describe one alternative energy source that would reduce the carbon footprint of the school district. Discuss one environmental benefit (other than reduced CO₂ emissions) and one environmental drawback of using the alternative source instead of fuel oil.
- (b) Identify TWO ecological benefits provided by intact forest ecosystems (other than reducing CO₂ levels in the atmosphere).
- (c) Use the assumptions below to answer the questions that follow. For each calculation, show all work.

The biomass of the forest increases at an annual rate of 2.7×10^5 kg/ha.
The forest biomass is 50 percent carbon by mass.
Each year the district uses 3.0×10^5 gallons of fuel oil for heating and hot water.
10 kg of CO ₂ is produced when 1 gallon of fuel oil is burned.
1.0 kg of CO ₂ contains 0.27 kg of carbon.
The cost of putting 1 ha of the forest into conservancy is \$12,000.

- (i) Calculate the mass of carbon, in kg, that is accumulated and stored in 1.0 ha of forest in one year.
- (ii) Calculate the mass of carbon, in kg, that is emitted by the school as a result of its fuel-oil consumption in one year.
- (iii) Calculate the number of hectares of forest the school district needs to conserve in order to offset the carbon released in one year by the school burning its fuel oil.
- (iv) Calculate the amount of money the school district must raise for the conservation project.

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2012 SCORING GUIDELINES**

Question 2

The Fremont School District uses oil to heat school buildings. Go Green! is a new project the district will implement. The superintendent has declared that the district will dedicate itself to reducing its carbon footprint. In addition to taking serious energy-conservation measures, the district is planning to help offset its carbon dioxide emissions by raising money to help conserve a portion of a large tract of forest land adjacent to the high school campus.

- (a) Describe one alternative energy source that would reduce the carbon footprint of the school district. Discuss one environmental benefit (other than reduced CO₂ emissions) and one environmental drawback of using the alternative source instead of fuel oil.**
(3 points)

One point can be earned for describing an alternative energy source that would reduce the carbon footprint. One point can be earned for identifying an environmental benefit of the alternative source. One point can be earned for identifying an environmental drawback of using the alternative energy source. Acceptable examples include, but are not limited to, the following:

	Description	Environmental benefits/drawbacks
Wind	Turbines are used to capture energy from wind to produce electricity.	<u>Benefits</u> <ul style="list-style-type: none">• Minimal habitat disruption/alteration.• Used in agricultural areas where habitat destruction is already complete.• Land may also be used to raise livestock/grow crops.• Produces no air pollution. <u>Drawbacks</u> <ul style="list-style-type: none">• Often requires a large expanse of land/habitat.• Turbines are unsightly.• Sound/vibration is annoying.• Turbines kill/affect migration of birds/bats.• Requires toxic materials for production.
Nuclear	Uranium/plutonium/nuclear fission is used to create steam to rotate turbines to produce electricity.	<u>Benefits</u> <ul style="list-style-type: none">• Produces little/no air pollution (other than mining and reprocessing).• Reservoirs (for coolant water) provide recreational opportunities. <u>Drawbacks</u> <ul style="list-style-type: none">• Creates potential for radiation leaks/accidents.• Unsafe storage of nuclear wastes.

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Question 2 (continued)

	Description	Environmental benefits/drawbacks
Solar	Passive solar: south-facing windows or a solar sunspace can be used to capture sunlight to heat the school.	<u>Benefits</u> <ul style="list-style-type: none"> • Produces no air pollution. • Requires little/no disruption of land/habitat. <u>Drawbacks</u> <ul style="list-style-type: none"> • Could make school too warm in summer. • May require removal of trees to allow sunlight to enter. • Birds may fly into windows.
	Active solar: a collector is used to absorb solar radiation and transfer the heat to a fluid that is pumped through the device: <ul style="list-style-type: none"> • Fluid is used to heat water in a hot water tank, or • Air/water can be used directly for space heating. 	<u>Benefits</u> <ul style="list-style-type: none"> • Produces little/no air pollution. • Requires little/no disturbance of habitat. <u>Drawbacks</u> <ul style="list-style-type: none"> • Materials for panel need to be mined, causing habitat destruction/water pollution. • Collectors are unsightly. • May require removal of trees to allow sunlight to enter.
	Photovoltaic: photovoltaic/solar cells are used to convert energy from (photons of) light to electricity.	<u>Benefits</u> <ul style="list-style-type: none"> • Requires little/no disruption of land/habitat (especially if panels are installed on rooftops). • Produces little/no air pollution. <u>Drawbacks</u> <ul style="list-style-type: none"> • Photovoltaic cells are unsightly. • Materials for cells must be mined, causing habitat destruction/water pollution. • Requires toxic materials in production of cells and storage batteries. • Requires disposal of toxic materials in batteries/used panels.
Geothermal	Conventional: <ul style="list-style-type: none"> • Fluid naturally heated underground is used directly as a source of heat, or • Steam is used to rotate a turbine to produce electricity. 	<u>Benefits</u> <ul style="list-style-type: none"> • Requires little/no disruption of land/habitat. • Small-scale heat pump systems produce no air pollutants. <u>Drawbacks</u> <ul style="list-style-type: none"> • Systems are noisy. • Releases unpleasant odor (from H₂S). • Can cause land subsidence.
	Heat pump: pipes are used to transfer heat into the ground in the summer (to cool the school) and out of the ground in the winter (to heat the school).	<u>Benefits</u> <ul style="list-style-type: none"> • Requires little/no disruption of land/habitat. • Produces little/no air pollution. <u>Drawbacks</u> <ul style="list-style-type: none"> • Energy must be used to pump fluid, with the associated ecological impact, depending on the source of the energy.

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Question 2 (continued)

	Description	Environmental benefits/drawbacks
Biomass	Wood, charcoal, manure, garbage, plants, or crop residue are burned to produce electricity/heat.	<u>Benefits</u> <ul style="list-style-type: none"> • Burning garbage uses waste materials that would otherwise require destruction of habitat when placed in landfills. • Plants used for fuels can be grown on marginal land. <u>Drawbacks</u> <ul style="list-style-type: none"> • Requires destruction of habitat/biodiversity for fuel wood/plantations/monoculture crop production. • Causes increased soil erosion/water pollution in deforested areas. • Land could instead be used for growing (food) crops. • Depletes soil nutrients in plantations/agricultural areas. • Can produce air pollutants (e.g., CO).
	Solid biomass is converted to natural gas (biogas) via use of anaerobic bacteria/digester.	<u>Benefits</u> <ul style="list-style-type: none"> • Uses animal waste products that could otherwise pollute waterways or groundwater. • Converts animal waste products that could otherwise pollute waterways/groundwater. • Captures methane that would otherwise contribute to global climate change. <u>Drawbacks</u> <ul style="list-style-type: none"> • Produces unpleasant odor. • Could potentially leak methane (a greenhouse gas). • Manure could otherwise be used to replenish soil nutrients.
Hydropower	Flowing water is used to rotate turbines to create electricity.	<u>Benefits</u> <ul style="list-style-type: none"> • Hydroelectric dam/reservoir may provide flood control. • Reservoir provides recreational opportunities (e.g., boating, fishing). • Reservoir provides reliable water source for irrigation and drinking. • Produces little/no air/water pollution. <u>Drawbacks</u> <ul style="list-style-type: none"> • May cause displacement of people/animals living in area flooded by dam. • Can cause water loss via evaporation from reservoir. • Dam prevents/interferes with fish migration. • Soils saturated by/plants killed by flooding can produce methane (a greenhouse gas). • Can result in seismic activity beneath reservoir. • Causes habitat alteration/destruction (via flooding of habitat above dam, or alteration of water temperature/silt deposition in river below dam).

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Question 2 (continued)

(b) Identify TWO ecological benefits provided by intact forest ecosystems (other than reducing CO₂ levels in the atmosphere).

(2 points: 1 each for identifying two ecological benefits)

Intact forest ecosystems:

- Provide homes/shelter (students may say “habitat”) for organisms
- Provide food for organisms
- Maintain biodiversity
- Moderate/regulate (local) climate
- Produce oxygen
- Purify water
- Purify air
- Reduce soil erosion
- Absorb/store/regulate water
- Moderate stream temperature
- Moderate stream flow
- Aid in nutrient cycling
- Aid in soil formation

(c) Use the assumptions below to answer the questions that follow. For each calculation, show all work.

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The forest biomass is 50 percent carbon by mass.
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10 kg of CO₂ is produced when 1 gallon of fuel oil is burned.
1.0 kg of CO₂ contains 0.27 kg of carbon.
The cost of putting 1 ha of the forest into conservancy is \$12,000.

(i) Calculate the mass of carbon, in kg, that is accumulated and stored in 1.0 ha of forest in one year.

(1 point for a correct answer)

$$1 \text{ ha} \times \frac{2.7 \times 10^5 \text{ kg}}{\text{ha}} \times 0.5 = 1.35 \times 10^5 \text{ kg}$$

(ii) Calculate the mass of carbon, in kg, that is emitted by the school as a result of its fuel-oil consumption in one year.

(2 points: 1 point for the correct setup and 1 point for the correct answer)

$$3.0 \times 10^5 \text{ gal} \times \frac{10 \text{ kg CO}_2}{\text{gal}} \times \frac{0.27 \text{ kg C}}{\text{kg CO}_2} = 8.1 \times 10^5 \text{ kg}$$

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Question 2 (continued)

- (iii) Calculate the number of hectares of forest the school district needs to conserve in order to offset the carbon released in one year by the school burning its fuel oil.**

(2 points: 1 point for the correct setup and 1 point for the correct answer)

$$\frac{8.1 \times 10^5 \text{ kg}}{1.35 \times 10^5 \text{ kg/ha}} = 6 \text{ ha}$$

- (iv) Calculate the amount of money the school district must raise for the conservation project.**

(1 point for a correct answer)

$$6 \text{ ha} \times \frac{\$12,000}{\text{ha}} = \$72,000$$