

AP[®] ENVIRONMENTAL SCIENCE

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.

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 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)

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

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.

a) One alternative energy source is wind power. ~~One~~
~~environmental benefit~~ Wind power involves using large turbines that convert movement ^{of the blades} caused by wind into electrical energy. One environmental benefit of wind is that it is abundant and renewable. Unlike fuel oil, there is no shortage of wind. One drawback is the killing of birds. Birds can fly into the blades of wind turbines and die.

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b) One benefit is that they provide habitats for animals. Another benefit is that they produce oxygen through the process of photosynthesis.

$$c) (i) \frac{1.0 \text{ ha} \cdot 2.7 \times 10^5 \text{ kg}}{1 \text{ ha}} = 2.7 \times 10^5 \text{ kg}$$

$$\cancel{2.7 \times 10^5 \text{ kg}} \cdot 0.5 \cdot 2.7 \times 10^5 \text{ kg} = \boxed{1.35 \times 10^5 \text{ kg}}$$

$$(ii) \frac{1 \text{ year} \cdot 3.0 \times 10^5 \text{ gat} \cdot 10 \text{ kg CO}_2}{1 \text{ year} \cdot 1 \text{ gat}} = 3.0 \times 10^6 \text{ kg CO}_2$$

$$\frac{3.0 \times 10^6 \text{ kg CO}_2 \cdot 27 \text{ kg of carbon}}{1.0 \text{ kg CO}_2} = \boxed{8.1 \times 10^5 \text{ kg of carbon}}$$

$$(iii) \frac{8.1 \times 10^5 \text{ kg} \cdot 1 \text{ ha}}{1.35 \times 10^5 \text{ kg}} = \boxed{6 \text{ ha}}$$

$$(iv) \frac{6 \text{ ha} \cdot \$12,000}{1 \text{ ha}} = \boxed{\$72,000}$$

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- (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.

a) One alternative energy source is using solar energy. Solar energy is beneficial because it is a perpetual resource, meaning it is always available. However, energy may be spent on implementing solar cells throughout the school district. In addition, these solar cells can be used to provide heat & electricity, but these devices are expensive and may take a while before they become completely affordable.

b) Intact forest ecosystems help reduce soil erosion and provide biodiversity. The vast number of trees would allow many roots to hold on to the soil and keep it compact enough to reduce the chances of soil erosion. In addition, forest ecosystems provide a variety of niches for many organisms to live in, ranging from insects to birds to mammals.

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This large number of niches would allow an increase in biodiversity

c.) ~~is~~ ~~2.27 kg C~~ ~~10 kg CO₂~~ ~~300000~~ ~~kg~~ ~~emitted~~ ~~by~~ ~~the~~ ~~school~~

$$i.) \frac{1 \text{ ha}}{1} \times \frac{0.5 \text{ C}}{1 \text{ ha}} \times \frac{270000 \text{ kg}}{1 \text{ ha}} = 1.35 \times 10^5 \text{ kg C in 1 ha}$$

$$\begin{array}{r} 270000 \\ \times 0.5 \\ \hline 1350000 \end{array}$$

$$ii.) \frac{0.27 \text{ kg CO}_2}{1 \text{ kg CO}_2} \times \frac{10 \text{ kg CO}_2}{1 \text{ gal}} \times \frac{300000 \text{ gal}}{1} = 8.1 \times 10^5 \text{ kg C emitted by the school}$$

$$\begin{array}{r} 300000 \\ \times 27 \\ \hline 2100000 \\ 6000000 \\ \hline 8100000 \end{array}$$

$$iii.) \frac{8.1 \times 10^5 \text{ kg}}{1} \times \frac{1 \text{ ha}}{1.35 \times 10^5 \text{ kg}} = 6 \text{ ha}$$

$$\begin{array}{r} 6 \\ 135000 \overline{) 810000} \\ \underline{-810} \\ 0 \end{array}$$

$$iv.) \frac{6 \text{ ha}}{1} \times \frac{\$12000}{1 \text{ ha}} = \$72000$$

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

One alternative energy source would be to use solar energy. One environmental benefit would be no water or air pollution that would occur in the processing, shipping and use of oil. One drawback would it be extremely expensive to install solar panels.

One ecological benefit provided by intact forest ecosystems includes

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$$\begin{array}{r} 12,000 \\ \times 60 \\ \hline 220,000 \end{array}$$

ADDITIONAL PAGE FOR ANSWERING QUESTION 2

less runoff when rain occurs. The forest area will reduce the runoff and allow for more infiltration. Another benefit is with more forest area there will be more biodiversity, creating a more stable environment. Also with more biodiversity, there are more producers to absorb sunlight and produce energy needed to keep the ecosystem stable.

i) $2.7 \times 10^5 \text{ kg/ha} \times 50\% = 13,500 \text{ kg}$

$$\begin{array}{r} 2,700,000 \\ \times .50 \\ \hline 1,350,000 \end{array}$$

ii) $3.0 \times 10^8 \text{ gal} \times 10 \text{ kg} \times .27 \text{ kg} = 810,000 \text{ kg of carbon emitted in one year.}$

$$\begin{array}{r} 30,000,000 \times 10 = 300,000,000 \\ \times .27 \\ \hline 21,000,000 \\ + 60,000,000 \\ \hline 81,000,000 \end{array}$$

iii) $13,500 \text{ kg} \div 810,000 \text{ kg} = 60 \text{ ha of forest needed.}$

iv) $60 \text{ ha} \times \$12,000 = \$720,000 \text{ needed.}$

$$\begin{array}{r} 1 \quad 13,500 \\ \times 3 \\ \hline 40,500 \end{array} \quad \begin{array}{r} 2 \quad 13,500 \\ \times 6 \\ \hline 81,000 \end{array}$$

$$\begin{array}{r} 12,000 \\ \times 60 \\ \hline 720,000 \end{array}$$

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AP[®] ENVIRONMENTAL SCIENCE

2012 SCORING COMMENTARY

Question 2

Overview

This question presented data regarding the carbon footprint of a school. Students were asked to describe how a specific alternative energy source could be used in place of fuel oil to reduce the carbon footprint and to discuss one benefit and one drawback of using the alternative energy source in place of fuel oil. They were also asked to identify two ecological benefits of intact forest ecosystems, other than reduced CO₂ emissions. In addition, students were required to perform mathematical calculations and dimensional analyses relating to carbon storage in a forest.

Sample: 2A

Score: 10

Two points were earned in part (a): 1 point for indicating that wind power involves the use of “turbines that convert movement of the blades caused by wind into electrical energy” and 1 point for indicating that wind turbines can kill birds. No point was earned for stating that wind power “is abundant and renewable,” because the student does not identify an associated environmental benefit (rather, these characteristics are matters of economics and convenience). Two points were earned in part (b): 1 point for indicating that intact forest ecosystems “provide habitats for animals.” and 1 point for indicating that such ecosystems “produce oxygen through ... photosynthesis.” Six points were earned in part (c): 1 point for indicating the correct answer in part (i), 1 point for showing the correct setup (including units) in part (ii), 1 point for indicating the correct answer in part (ii), 1 point for showing the correct setup (including units) in part (iii), 1 point for indicating the correct answer in part (iii), and 1 point for indicating the correct answer in part (iv).

Sample: 2B

Score: 8

No points were earned in part (a). Two points were earned in part (b): 1 point for indicating that intact forest ecosystems “help reduce soil erosion” and 1 point for indicating that these ecosystems “provide biodiversity.” Six points were earned in part (c): 1 point for indicating the correct answer in part (i), 1 point for showing the correct setup (including units) in part (ii), 1 point for indicating the correct answer in part (ii), 1 point for showing the correct setup (including units) in part (iii), 1 point for indicating the correct answer in part (iii), and 1 point for indicating the correct answer in part (iv).

Sample: 2C

Score: 6

One point was earned in part (a) for indicating that using solar energy would prevent the water or air pollution associated with oil use. Two points were earned in part (b): 1 point for indicating that intact forest ecosystems reduce runoff and increase infiltration and 1 point for indicating that they provide more biodiversity and stability. Three points were earned in part (c): 1 point for indicating a correct answer in part (ii), 1 point for indicating an answer in part (iii) that is correct based on the answers from parts (i) and (ii), and 1 point for indicating an answer in part (iv) that is correct based on the answer from part (iii).