AP® ENVIRONMENTAL SCIENCE
2006 SCORING GUIDELINES

Question 1

(a) Describe one environmental benefit and one environmental cost of photovoltaic systems.

One point is earned for an environmental benefit:

- Use does not contribute to atmospheric pollution (emission of greenhouse gases, acid rain components, smog, etc.) associated with combustion or geothermal electrical generating systems.
- Use does not contribute to nuclear waste disposal associated with nuclear power facilities.
- Use does not contribute to modification of aquatic habitats associated with hydroelectric facilities.
- Use does not contribute to aquatic thermal pollution associated with steam-producing electrical generating facilities (combustion or nuclear).
- Land disturbance is minimal (little to no destruction of habitats), since most active solar collectors are placed on top of buildings.
- There is less environmental damage compared to the extraction of uranium or fossil fuel resources.

One point is earned for an environmental cost:

- Solar collectors must be manufactured, which uses energy and may contribute to increased atmospheric pollution.
- Production of solar cells produces moderate levels of water pollution.
- Some toxic wastes may be produced when manufacturing cells.
- Disposal of storage batteries (if used) may contribute to water and soil contamination.
- Solar collectors themselves have a limited lifetime and must eventually be replaced (adding to solid waste problem).
- Commercial systems may cause significant habitat disruption due to high land area requirements.
- There are environmental impacts associated with the infrastructure required for commercial photovoltaic systems, such as power lines that fragment habitat.
- There are environmental impacts associated with the extraction/refining of the raw materials necessary to manufacture the photovoltaic cells and batteries.

***One elaboration point is possible for extended description of either identified benefit or cost* (examples):**

- Unlike coal-burning power plants, the use of photovoltaics does not contribute greenhouse gases (such as CO_2) to the atmosphere. These greenhouse gases, in turn, could lead to increased global temperatures.
- The use of photovoltaics does not contribute to thermal pollution of aquatic systems as compared to nuclear or coal-burning power plants. Thermal pollution can lead to decreased levels of dissolved oxygen or cause thermal shock to organisms adapted to cooler water environments.

(b) From the two types of solar systems described on the government Web site, select the system (either stand-alone or grid-connected) that you think best meets the needs of the homeowners. Write an argument to persuade them to purchase the system you selected. Include the pros and cons of each system in your argument.

3 points possible: *Student must clearly indicate their selected system. One point is earned for each supporting statement for either system. Responses cannot earn the maximum of all 3 points unless the number of supporting statements for the chosen system equal or outnumber the supporting statements for the nonchosen system.*

Question 1 (continued)

	Pros	Cons
Grid-connected	There is a back-up energy source in case the home system does not provide enough. Less area is needed for system compared to stand-alone systems. Battery system is unnecessary. Surplus energy can be sold back to the local power company. System can be smaller than stand-alone since the grid can supply energy at peak usage times. Altruistic argument: Excess energy sold back to the utility decreases the need for consumption of other natural resources.	Net-metering hardware (grid exchange system) may be expensive. No battery back-up in case of power grid failure. Utility may require a large system for net-metering capability.
Stand-alone	Does not require the installation of grid-exchange equipment. Completely independent of the electrical grid.	Net metering is not available. May require additional secondary electrical-generating systems for reliability or peak demand. Limited battery storage capability may require secondary electrical-generating systems. A large area may be needed for cells in order to meet energy demands for the house.

(c) Describe TWO ways that government or industry could promote the use of photovoltaic power systems for homeowners in the future.

Two points: *One point is earned for each for the first two answers (must specifically address the increased use of photovoltaics, not just decreased energy use).*

Government

- Provide information/education to homeowners about the benefits of pv systems.
- Give tax credits to homeowners that use pv systems.
- Subsidize the cost of pv panels so that they are cheaper for homeowners to purchase.

Question 1 (continued)

- Appropriate additional funds for research and development into solar cell technology to make pv systems more cost-effective.
- Provide tax breaks for companies that produce the cells, potentially making them cheaper to the consumer.
- Require power companies to have net metering for all homes on a grid-connected system.
- Offer low-interest loans to homeowners to purchase pv systems.
- Mandate the use and installation of pv systems for new home construction.

Industry

- Lower the cost of pv panels/systems.
- Provide information/education to homeowners about the benefits of pv systems.
- Offer low-interest loans to homeowners to purchase pv systems.
- Develop more aesthetically pleasing systems.
- Subsidize the cost of grid-connection equipment.
- Purchase excess electricity generated using photovoltaics at a premium rate.
- Allocate additional resources for research and development into solar cell technology to make pv systems more cost effective.

(d) Describe TWO ways that homeowners could use passive solar designs and/or systems and, for each way, explain how it would reduce the homeowners' energy costs.

Four points: *One point is earned for each action utilizing passive solar design/systems, and 1 point each is earned for each explanation of how the identified design/system would reduce energy costs.*

General Type	Action	Energy Cost Benefit
Solar Obstruction Systems (SOSs)—Any device that prevents or reflects solar radiation from entering the dwelling	Plant trees/shrubs around dwelling (or "on" in the case of rooftop gardens)	• In temperate zones, deciduous trees in the winter will not have leaves so sunlight can shine into the house, warming it. In the summer, the trees will have leaves and will shade the house from sunlight, keeping it cooler. In both seasons, the trees will help keep the heating and cooling costs down. • In sub-tropical zones, trees and shrubs block solar radiation from reaching the house resulting in lower cooling costs year round.
	Reflective roof or wall materials	Decreases cooling costs.
	Window treatments (reflective or blocking)	Decreases cooling costs.
	Build a berm around the house blocking sunlight	Decreases cooling costs.
	Increase insulation in walls and/or use super-insulated windows	Insulated walls and/or windows prevent transfer of heat into the house in the summer, thus reducing cooling costs.

Question 1 (continued)

General Type	Action	Energy Cost Benefit
Building Design Elements	Orientation/siting of house to maximize solar input during colder months	Decreases heating and lighting costs.
	Orientation/siting of house to minimize solar input during warmer months	Decreases cooling and lighting costs.
	Daylighting—the installation of skylights, solar tubes, clerestory windows	Decreases expenses associated with lighting.
	Installation or use of solar oven technology	Decreases costs associated with cooking and cooling.
	Window overhangs and awnings	Can block sunlight during the summer but will allow sunlight in the house in the winter (when the sun is lower in the sky). This helps keep the house cooler in the summer and warmer in the winter reducing the need for air conditioning and heating.
	Use of Thermal Mass Devices (TMDs) such as stone or concrete floors and walls, Trombe walls, interior water reservoirs, etc.	Thermal mass devices store thermal energy during the day and release it at night. This reduces costs associated with heating.
	Installation of a solar chimney	Helps improve ventilation in the house and reduce cooling costs.
	Installation of a roof pond	Promotes evaporative cooling, reducing cooling costs during the summer.
	Installation of a solar water heater (must be nonmechanical)	Decreases costs associated with water heating.
	Removal of vegetation to allow increased solar input into house	Decreases lighting and heating costs.

Photovoltaic solar power systems are environmentally beneficial because they release no harful pollutants or emissions like CO_2, sulfur, or ozone into the atmosphere. An environmental cost of photovoltaic systems is that they require large amounts of open land to generate ample amounts of energy, and therefore may result in the clearing of a forest or natural habitat.

Homeowners: The ideal system for you is grid-connected photovoltaic system. This system would best fit your needs because any excess power produced by your solar system could be sold back to a local utility, potentially paying of the [redacted] $7,000-30,000 cost of the system. With a stand-alone system, excess power would either go to waste or sit in a storage battery. Another benefit to the grid-connected system is that you will always have a back-up power source in the event that your solar system fails to generate enough power. In the direct-couple system, you would only have electricity in the daytime, and [redacted] even with a stand-alone battery system, there is a risk of running out of electricity. Therefore, the grid-connected system would best address your needs.

The government could promote the use of photovoltaic powersystems by providing subsidies for photovoltaic manufacturers and by running media advertisements [redacted] showing the benefits of using photovoltaic power

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systems. By providing subsidies for companies that manufacture the systems, companies could charge much lower prices for the product, making the photovoltaic systems more appealing to consumers. Second, by using various media outlets like television and the internet, the government could show consumers the benefits of using photovoltaic systems, both for the environment and for the consumer's wallet.

Passive solar designs are another method for increasing energy efficiency. One example of a passive solar system involves positioning the windows of a house so that during the winter, when the sun is lower, sunlight will enter the house and heat the rooms. During the summer, when the sun is higher, sunlight will hit above the windows and not enter the house. This system reduces the need for heating during the winter, and reduces the need for cooling during the summer, thus drastically reducing the electric and gas bill. Another passive solar system is the solar-cooker. This system uses an insulated box wrapped in a metallic material to cook food using heat from the sun. The metallic outer layer absorbs the sun's heat while the insulation keeps the heat inside the box, cooking the food. This system reduces the consumer's need to

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ADDITIONAL PAGE FOR ANSWERING QUESTION 1

cook on a conventional gas or electric stove, therefore reducing their gas or electric bill.

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1B,

a) One environmental benefit of photovoltaic systems is that because you are getting your own energy from the sun, you don't need to burn coal, for example, and create air pollution to create electricity. One environmental cost of photovoltaic systems is that because the energy of the sun differs because of seasonal changes, the home owners might need to use other energy sources to get energy in their homes such as the use of wind to get energy. Using the wind requires the use of the "fans" which create light pollution and noise pollution.

b). The grid-connected system is the better photovoltaic system for the homeowners because the homeowners will never be low on energy and if there is a surplus of energy, it can be sold back to the utility. That will save the homeowners money and the energy won't run out on the homeowners when they are using it. However, the cons of this system is that arranging for the grid interconnection can be difficult. The other system, stand-alone system, is good because it can be more cost-effective than existing power lines. However, it needs battery power to have energy at night and in some systems it will have to combine with additional power sources. These additional power sources such as wind or diesel can create pollution in the environment such as noise pollution and air pollution from NO_x and SO_x from burning of fossil fuels.

1B2

ADDITIONAL PAGE FOR ANSWERING QUESTION 1

c). Government can promote the use of photovoltaic power systems by giving homeowners tax breaks if they use photovoltaic power systems. Industry can promote the use of PV power systems by increasing the price of the other energy systems such as natural gas.

d). Homeowners ~~could~~ who live the Southwest can build homes with windows facing the Northeast to help keep their homes cool from the sun. This would reduce the homeowners' ~~heating costs~~ cooling costs because they wouldn't have the Sun blasting its heat into the homes during the hottest time of the day. Homeowners could lower their thermostats during the winter and wear more layers of clothing to stay warm and reduce energy costs. They would reduce the costs by using the thermostat less and therfore using less energy

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a) An environmental benefit of photovoltaic systems is that this system uses solar energy as power and converts it to electricity. Solar power is a renewable resource, as well as it does not cause the vast amount of pollution into the atmosphere as other resources, such as a coal power plant, which emits excess amounts of CO_2 into the atmosphere. However, an environmental cost of a photovaltaic system is that the installation of either a stand alone or grid connected system could be damaging to the surface of the environment

b) A grid-connected system would be the more beneficial system for the homeowners in Arizona- I recommend this system because although it may be at first more expensive and more difficult to install than a stand alone system, the family will soon reap the benefits of it. Having a grid connected system removes the need for reliance on battery storage at night, as well as the initial excess cost will only prove to be a smart investment, when the family can sell excess power back to the utility and perhaps even make a profit! As well, the family never has to worry about a low power supply, because the grid-connected system automatically takes power from the utility grid when it is low! Stand alone systems do not have this benefit, and they rely on battery storage.

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c) The government or industry could promote the use of photovoltaic power systems to homeowners in many ways. First of all, it is absolutely necessary to educate the public about these systems, and make the benefits common knowledge. If the public does not know these systems even exist, then there is no way they could install them! The govt could advertise the use of this system with govt-funded TV and magazine ads, as well as promote an informative website. The govt could also work on lowering the price of these systems, or making more available and easier installation so more people will buy them.

d) Homeowners could use passive solar systems as a source for heat as opposed to gas powered heat, and because solar energy is a renewable resource, as opposed to gas, the price would be dramatically lower.

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AP® ENVIRONMENTAL SCIENCE
2006 SCORING COMMENTARY

Question 1

Overview

This document-based question required an understanding of passive and active solar energy systems and designs. The question also required the student to develop and support an argument in favor of either stand-alone or grid-connected photovoltaic systems utilizing information from the provided document.

Sample: 1A
Score: 10

Part (a): Two points were earned: 1 point for identifying an acceptable environmental benefit (reduction of atmospheric pollutants), and 1 point for identifying an acceptable environmental cost (habitat loss due to high space demands of photovoltaic systems).

Part (b): Three points were earned. One point was earned for identifying the net-metering capability of the grid-connected system; 1 point for knowing that the stand-alone system requires a battery storage system, unlike the grid-connected system; and 1 point for stating that the grid-connected system should always have a backup source for peak demand times.

Part (c): Two points were earned: 1 point for identifying government subsidies to lower the cost of photovoltaic cells, and 1 point for mentioning a government-supported educational campaign to advertise the benefits of photovoltaic systems to homeowners.

Part (d): Three points were awarded. Two points were earned for correctly describing the positioning of windows to take advantage of seasonal changes in the position of the sun and the associated heating and cooling cost benefits. Another point was earned for describing the use of a solar oven. An additional point would have been earned for describing the reduced costs associated with cooking, but the maximum 10 points for this question had already been awarded.

Sample: 1B
Score: 7

Part (a): One point was earned for an appropriate identification of an environmental benefit of using photovoltaic systems. No point was earned for the explanation of an environmental cost because the student fails to specifically address the environmental costs of photovoltaic systems.

Part (b): Three points were earned. One point was earned for each of two statements in support of the chosen system: no need for a supplemental energy source, and net-metering capability. A third point was earned for stating that the stand-alone system requires battery storage, as contrasted with the grid-connected system.

Part (c): One point was earned for the identification of government tax incentives. No point was earned for the second part of this response since the student does not specifically promote the use of photovoltaic systems for homeowners.

Part (d): Two points were earned: 1 point for the description of orienting the house to minimize heat input while allowing light in, and 1 point for correctly citing the cost benefit of decreased cooling expenses. No points were awarded for energy-efficiency methods, since this part of the response does not address passive solar design.

Question 1 (continued)

Sample: 1C
Score: 4

Part (a): One point was earned for an appropriate identification of an environmental benefit of using a photovoltaic system (reduction of CO_2 emission). The description of the environmental cost is insufficient to receive the second point.

Part (b): Two points were earned: 1 point for identifying the benefit of the grid-connected system is that it does not require a battery storage system at night or when power is low, and 1 point for identifying the benefit of net metering for the grid-connected system.

Part (c): One point was earned for correctly identifying public education programs as a method to promote the use of photovoltaic systems by homeowners. The statement about the government lowering the price of photovoltaic systems is too vague to earn a point.

Part (d): No points were earned because no specific suggestions are made.