ENVIRONMENTAL SCIENCE
SECTION II
Time—90 minutes
4 Questions

Directions: Answer all four questions, which are weighted equally; the suggested time is about 22 minutes for answering each question. Write all your answers on the pages following the questions in the pink booklet. Where calculations are required, clearly show how you arrived at your answer. Where explanation or discussion is required, support your answers with relevant information and/or specific examples.

1. Upon receiving notice from their electric utility that customers with solar power systems are permitted to sell excess power back to the utility, an Arizona family is considering the purchase of a photovoltaic solar energy system for their 2,700-square-foot suburban home. The initial costs of the systems they are considering range from $7,000 to $30,000. While gathering information prior to making a decision, the homeowners find the following information at the Web site of the United States Department of Energy.

> **Stand-Alone vs. Grid-Connected Systems**
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> Stand-alone systems produce power independently of the utility grid. In some off-the-grid locations as near as one-quarter mile from the power lines, stand-alone photovoltaic systems can be more cost-effective than extending power lines. Direct-coupled systems need no electrical storage because they operate only during daylight hours, but most systems rely on battery storage so that energy produced during the day can be used at night. Some systems, called hybrid systems, combine solar power with additional power sources such as wind or diesel.
>
> Grid-connected photovoltaic systems supply surplus power back through the grid to the utility and take from the utility grid when the home system's power supply is low. These systems remove the need for battery storage, although arranging for the grid interconnection can be difficult. In some cases, utilities allow net metering, which allows the owner to sell excess power back to the utility.

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

(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.

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

(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.

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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.