2. Anaerobic methane digesters have been used for many years to reduce energy costs on farms throughout Europe and on some large farms in the United States. The digesters operate by using anaerobic bacteria to break down animal waste. During the process, which typically uses a tank heated to about 100°F (38°C) to speed the reactions, raw manure is broken down and methane is produced. The methane can then be used to generate electricity or produce heat.

   For a certain dairy farm with 500 cows, the cost of installing a digester is approximately $400,000. Assume that the farm uses 800,000 kilowatt-hours (kWh) of electricity each year at a cost of $0.10 per kWh. The waste from a single cow can produce 3.0 kWh of electricity each day.

   (a) Describe the steps by which methane produced in the digester can be used to generate electricity.

   (b) Discuss TWO environmental benefits that may result from the installation of an anaerobic methane digester.

   (c) Assuming that the cost of electricity remains constant and the farmer starts using the manure from the cows in an anaerobic digester to produce electricity on the farm, calculate:

      (i) The number of kWh of electricity that can be produced in one year

      (ii) The amount of money the farmer can save in one year, NOT counting the installation cost of the digester. (You may round your answer to the nearest $1,000.)

      (iii) The amount of time, in years, that it will take to recover the cost of installing an anaerobic digester on the farm. (You may round your answer to the nearest whole number of years.)

   (d) Calculate the minimum number of cows the farm would need to produce 800,000 kWh of electricity per year.

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3. The Colorado River flows from the Colorado Rockies to the Gulf of California. The primary source of Colorado River water is melting Rocky Mountain snowpack. Once the river descends from the Rockies, it flows through a landscape that is dominated by desert. Colorado River water carries a high load of sediment.

   (a) Multiple dams have been erected along the Colorado River. Identify TWO benefits other than agriculture and recreation that people derive from that system of dams.

   (b) Discuss TWO potential environmental consequences of damming a major river.

   (c) Competition for access to Colorado River water has increased dramatically due to increased population size and intensive agricultural use. Describe TWO conservation strategies for reducing agricultural water consumption.

   (d) Identify TWO possible environmental consequences of climate change on the hydrology of the Colorado River system.

   (e) In addition to impacts on the Colorado River system, climate change is impacting the hydrology of coastal ecosystems. Identify and describe TWO possible consequences of climate change on coastal ecosystems.

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Question 2

(a) Describe the steps by which methane produced in the digester can be used to generate electricity.

Two points can be earned: 1 point for stating that methane can be burned and 1 point for describing how this generates electricity:

- By producing steam to turn a turbine (to rotate coils in a magnetic field), OR
- Through use in internal combustion engine to turn a turbine (to rotate coils in a magnetic field).

(b) Discuss TWO environmental benefits that may result from the installation of an anaerobic methane digester.

One point is earned for each of two environmental benefits discussed. (Only the first two answers are scored.)

Benefit	Discussion
Reduction in the amount of methane released to the atmosphere	• Methane contributes to climate change (greenhouse gas)
Reduction in runoff or spills of manure in local waterways	• Manure contains nutrients that lead to eutrophication/nutrient loading • Fecal coliform contamination may spread disease
Reduction in amount of manure/waste that needs to be disposed of	• Takes up less space in landfills/waste lagoons
Reduction in use of fossil fuels for electricity generation	• Fewer contaminants such as mercury/sulfur/ particulates in atmosphere • Extends the supply of fossil fuels • Less land disturbance from the extraction (mining) of fossil fuels • Unlike fossil fuels, manure is a renewable resource that can be regenerated, avoiding depletion of natural resources • No net increase in CO_2 emissions (CO_2 released by burning methane comes from plants removing CO_2 through photosynthesis now, rather than from fossil fuels formed millions of years ago)

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Question 2 (continued)

(c) Assuming that the cost of electricity remains constant and the farmer starts using the manure from the cows in an anaerobic digester to produce electricity on the farm, calculate:

(i) The number of kWh of electricity that can be produced in one year

One point is earned for the correct setup and 1 point for the correct answer. (Units are not required, but the student must show calculations in order to receive the answer point.)

$$\frac{500 \text{ cows}}{} \times \frac{3.0 \text{ kWh}}{\text{cow–day}} \times \frac{365 \text{ days}}{\text{year}} = 547{,}500 \text{ kWh/year}$$

or

$$\frac{1500 \text{ kWh}}{\text{day}} \times \frac{365 \text{ days}}{\text{year}} = 547{,}500 \text{ kWh/year}$$

(ii) The amount of money the farmer can save in one year, NOT counting the installation cost of the digester. (You may round your answer to the nearest $1,000.)

One point is earned for the correct setup and 1 point for the correct answer. (Units are not required, but the student must show calculations in order to receive the answer point.) Incorrect answers transferred from (c)(i) can still earn full credit if used correctly.

547,500 kWh × $0.10 = $54,750 ($55,000)

or

800,000 kWh – 547,500 kWh = 252,500 kWh needed from a utility

800,000 × $0.10 = $80,000
252,500 × $0.10 = $25,250 $80,000 – $25,250 = $54,750 or $55,000 saved

(iii) The amount of time, in years, that it will take to recover the cost of installing an anaerobic digester on the farm. (You may round your answer to the nearest whole number of years.)

One point is earned for the correct setup AND correct answer. (Units are not required, but the student must show calculations in order to receive the point). Incorrect answers transferred from (c)(ii) can still earn full credit if used correctly.

$400,000/$55,000 = 7.2 years (or 7 years)

Question 2 (continued)

(d) Calculate the minimum number of cows the farm would need to produce 800,000 kWh of electricity per year.

One point is earned for the correct setup and 1 point for the correct answer. (Units are not required, but the student must show calculations in order to receive the answer point.) Incorrect answers transferred from (c)(i) can still earn full credit if used correctly.

$$\frac{3.0 \text{ kWh}}{\text{cow–day}} \times \frac{365 \text{ days}}{\text{year}} = \frac{1095 \text{ kWh}}{\text{cow–year}}$$

or

$$\frac{800{,}000 \text{ kWh}}{\text{year}} \times \frac{1 \text{ year}}{365 \text{ days}} \times \frac{\text{cow–day}}{3 \text{ kWh}} = 730.5 \text{ cows} = 731 \text{ cows}$$

or

$$\frac{800{,}000 \text{ kWh/year}}{1095 \text{ kWh/cow–year}} = 730.5 = 731 \text{ cows}$$

or

$$\frac{500 \text{ cows}}{547{,}500} = \frac{x \text{ cows}}{800{,}000} = 730.5 = 731 \text{ cows}$$