

**AP<sup>®</sup> ENVIRONMENTAL SCIENCE  
2011 SCORING GUIDELINES**

**Question 3**

- (a) Iceland’s position on the graph is due in part to its access to geothermal energy sources. Describe how electricity is generated from a geothermal source.**

*(2 points; 1 point for indicating how steam is produced to turn a turbine and 1 point for stating that the energy from the turbine is used to run a generator that produces electrical current)*

Steam production (thermal energy into mechanical energy). Any of the following are correct responses:

- High-pressure hot water is pumped out of the earth and put into a low-pressure container to produce steam, which will in turn run a turbine (flash steam plant).
- Wells are drilled, and steam is piped directly to turn a turbine (dry steam plant).
- Hot water is pumped out of the earth; a heat exchanger is used to heat another liquid to produce vapor that is then used to turn a turbine (binary cycle).

Electrical production (mechanical energy into electrical energy)

- The energy from the turbine is used to run a generator.

- (b) Despite its low GDP per capita and low annual electrical energy consumption per capita, China has become the world’s largest emitter of CO<sub>2</sub>. Explain this apparent contradiction.**

*(1 point)*

Although the per capita electrical energy consumption is low, China is the most populous country on the planet. The sum of individual consumption is large.

- (c) In addition to contributing to increased atmospheric CO<sub>2</sub> concentrations, China is facing other air pollution issues related to the generation of electricity. Identify one such issue and describe the impact it has on human health.**

*(2 points; 1 point for identifying an issue and 1 point for explaining its impact on human health)*

Students can earn 1 point for naming an air pollution issue without mentioning an impact on human health. In order to earn both points, students must correctly link the impact on human health to the air pollution issue.

<b>Issue (1 point)</b>	<b>Impact on human health (1 point)</b>
SO <sub>2</sub> or SO <sub>x</sub> emissions from coal-burning power plants	<ul style="list-style-type: none"> <li>• Respiratory irritant</li> <li>• Aggravate asthma, bronchitis</li> <li>• Can lead to emphysema</li> <li>• Throat irritant</li> </ul>
Particulate matter	<ul style="list-style-type: none"> <li>• Decreases lung function (lung irritant)</li> <li>• Aggravates asthma</li> <li>• Throat irritant</li> </ul>
NO <sub>x</sub> from coal and petroleum combustion	<ul style="list-style-type: none"> <li>• Respiratory irritant</li> <li>• Aggravates heart disease</li> </ul>
Ozone, PAN from photochemical smog	<ul style="list-style-type: none"> <li>• Lung irritant</li> <li>• Eye irritant</li> </ul>

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**Question 3 (continued)**

Hg from coal-burning power plants — deposition into surface waters	<ul style="list-style-type: none"> <li>• Neurotoxin</li> <li>• Hearing loss</li> <li>• Impaired ability to learn</li> </ul>
SO <sub>x</sub> or NO <sub>x</sub> aerosols from acid rain	<ul style="list-style-type: none"> <li>• Lung irritant</li> <li>• Aggravate asthma</li> </ul>

*Note:* Students will not receive credit for identifying the Asian brown cloud, smog, or photochemical smog as an issue. They must identify a specific component and describe a health impact associated with that component in order to earn 2 points.

**(d) Two countries shown on the graph have developed domestic energy sources: sugarcane in Brazil and tar sands in western Canada.**

**(i) Choose EITHER sugarcane or tar sands, then briefly describe the process of fuel production from that energy source.**

*(2 points; 1 point for describing the extraction process and 1 point for describing how the fuel is processed)*

<b>Sugarcane</b>	
<b>Extraction (1 point)</b>	<b>Processing (1 point)</b>
Sugarcane is harvested and crushed. OR Sucrose is extracted from the sugarcane.	<ul style="list-style-type: none"> <li>• The sucrose or mash is fermented to produce ethanol AND/OR bagasse (waste product) is collected after the sugarcane is processed.</li> </ul>

OR

<b>Tar Sands</b>	
<b>Extraction (1 point)</b>	<b>Processing (1 point)</b>
Tar sands are extracted by surface mining.	<ul style="list-style-type: none"> <li>• Tar sands are treated with hot water to extract the oil (bitumen).</li> <li>• Tar sands are treated with steam to extract the bitumen.</li> </ul>

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**Question 3 (continued)**

- (ii) Describe TWO disadvantages of using the energy source that you chose in part (d)(i).**  
(2 points; 1 point for each disadvantage described for EITHER tar sands or sugarcane)

Tar Sands

- Nonrenewable resource.
- Habitat destruction as a result of surface mining.
- Low net energy yield.
- Requires large amounts of water to produce.
- Produces large amounts of contaminated water.
- Requires conventional oil to produce oil from tar sands.
- Combustion of a fossil fuel — greenhouse gases are produced.
- Large amounts of mining waste are produced.
- Limited distribution of tar sand deposits.
- Processing requires combusting a fossil fuel.

Sugarcane

- Tropical rainforests are cut down to plant sugarcane, which thus decreases biodiversity.
- Fertilizer is used to increase crop yield:
  - Runoff will lead to eutrophication; or
  - Cost of producing sugarcane increases.
- Soil degradation.
- Requires large amounts of water.
- Competition between its use as a fuel and a food product will increase the cost of food.
- Ethanol is more corrosive to engine parts than traditional gasoline.
- Ethanol provides fewer miles per gallon than gasoline.
- Cannot be grown in all climates.
- Monoculture.
- Increased use of pesticides to increase crop yield.

- (iii) Which of the two energy sources is more sustainable? Justify your answer with an explanation.**

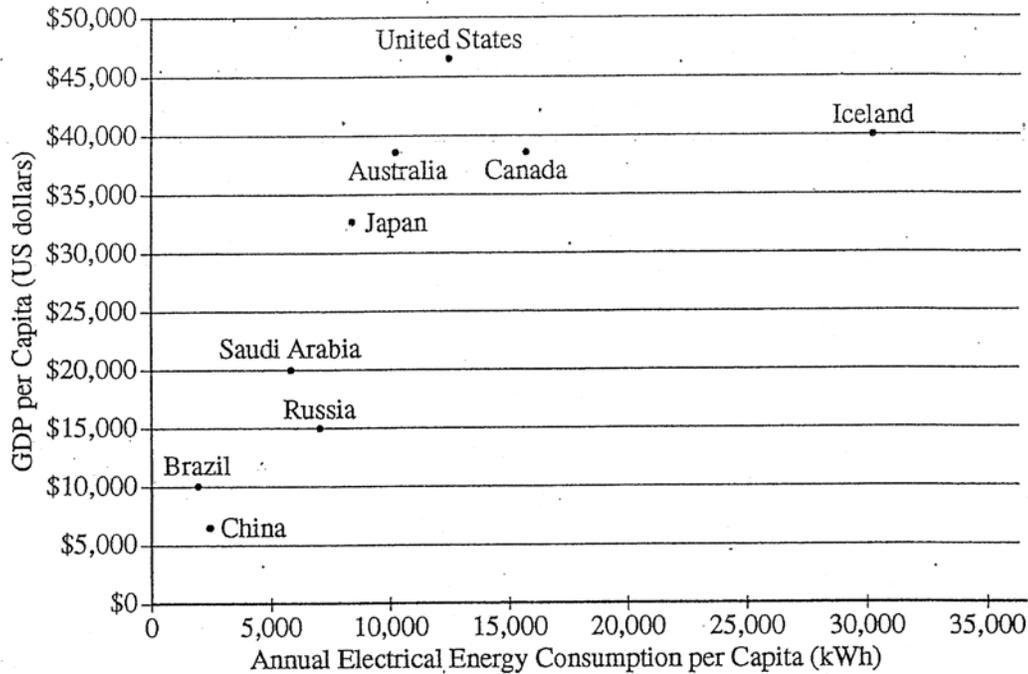
(2 points; 1 point for the correct choice and 1 point for a correct explanation)

Sugarcane is more sustainable, and any of the following is a correct explanation:

- Renewable resource — sugarcane can be replanted.
- Not a fossil fuel — new carbon is being consumed instead of old carbon.
- Little toxic sludge and land destruction in comparison with harvesting tar sands.

3A,

GDP VERSUS ANNUAL ELECTRICAL ENERGY CONSUMPTION (2009)



3. Shown above is a graph of the gross domestic product (GDP) per capita versus the annual electrical energy consumption per capita for nine countries in 2009.
- (a) Iceland's position on the graph is due in part to its access to geothermal energy sources. Describe how electricity is generated from a geothermal source.
  - (b) Despite its low GDP per capita and low annual electrical energy consumption per capita, China has become the world's largest emitter of CO<sub>2</sub>. Explain this apparent contradiction.
  - (c) In addition to contributing to increased atmospheric CO<sub>2</sub> concentrations, China is facing other air pollution issues related to the generation of electricity. Identify one such issue and describe the impact it has on human health.
  - (d) Two countries shown on the graph have developed domestic energy sources: sugarcane in Brazil and tar sands in western Canada.
    - (i) Choose EITHER sugarcane or tar sands, then briefly describe the process of fuel production from that energy source.
    - (ii) Describe TWO disadvantages of using the energy source that you chose in part (d)(i).
    - (iii) Which of the two energy sources is more sustainable? Justify your answer with an explanation.

3a. Electricity is usually generated from geothermal sources by heating up water in the heat exchangers with hot water from geothermal sources. The water will then vaporize

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~~to form~~

to form steam, which is then used to turn the turbine and power the generator. The steam is then cooled and liquified by ~~ground~~ surface water in pipes and then returned to the heat exchanger where the process repeats.

3b. China's annual electricity consumption per capita is deceptively low in comparison to its emission of CO<sub>2</sub> because it has the most population in comparison with all the other countries in the table. Therefore, even though its per capita electricity consumption is low, its total energy use exceeds the other countries. To generate all these energy massive amount of fossil fuel is used, resulting in vast quantity of CO<sub>2</sub> released, hence the greatest CO<sub>2</sub> emitter.

3c. SO<sub>2</sub> is another air pollution problem derived from burning of fossil fuels that release CO<sub>2</sub> such as coal. Sulfur dioxide, SO<sub>2</sub>, has the ability to scar lung tissue if inhaled and can cause asthma in people sensitive to it.

3d. i. Tar sands is essentially oil trapped in sand. It is first washed by hot water to separate the "tar" from the sand, and the water is either physically or chemically separated from the oil. The water is then recycled or disposed. The oil will undergo further refining into forms useable for domestic purposes such as cars or power plants.

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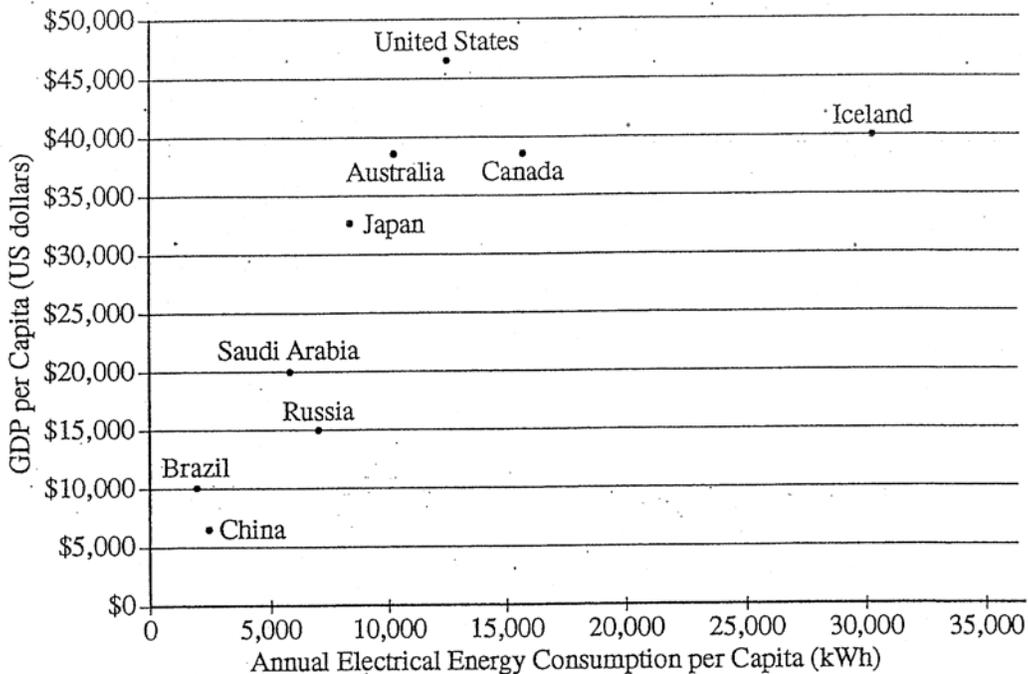
ii. The disadvantage to tar sands is the fact that it is not renewable. After the resource is depleted, W. Canada must find another resource to use.

Another disadvantage to tar sands is that the burning of its refined product releases greenhouse gases such as carbon dioxide and methane, causing climate change.

iii. Sugar cane is more sustainable than tar sands. It is a plant that can be harvested and, essentially, "renewed" every year. However, tar sands, in comparison, takes millions of years to form ~~from~~ from the compression of organic materials, which essentially render it too slow to renew to be sustainable.

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  - (i) Choose EITHER sugarcane or tar sands, then briefly describe the process of fuel production from that energy source.
  - (ii) Describe TWO disadvantages of using the energy source that you chose in part (d)(i).
  - (iii) Which of the two energy sources is more sustainable? Justify your answer with an explanation.

a) Energy is generated from geothermal sources by using steam emitted by the Earth to turn turbines, generating electricity in a generator.

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## ADDITIONAL PAGE FOR ANSWERING QUESTION 3

b) Although individuals in China, on average, do not consume much electricity, China is the most populous country in the world, so total energy use is high across the nation. China burns large quantities of coal to power the populous country, emitting high levels of CO<sub>2</sub> in the process.

c) Coal-fired powerplants emit mercury into the air, which can enter food supplies when it is deposited into fishable waters, where it bioaccumulates and biomagnifies. When humans ingest fish containing high levels of mercury due to biomagnification, they can be poisoned by the mercury, which causes a neurological disorder known as Minamata disease.

d) (i) Brazil's sugarcane can be turned into a fuel source through fermentation, a process involving chemical changes caused by bacteria, which results in the creation of ethanol, which can be used as fuel.

(ii) The use of ethanol requires a large amount of land use, and removes food crops from the marketplace which could be used to meet world hunger demand.

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3B<sub>3</sub>

ADDITIONAL PAGE FOR ANSWERING QUESTION 3

(iii) Ethanol derived from sugarcane is more sustainable than tar sands, because tar sands are finite and do not replenish on a human timescale, while more sugarcane can be grown to meet demand as long as there is enough arable land to do so.

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## ADDITIONAL PAGE FOR ANSWERING QUESTION 3

- A) Geothermal sources ~~have~~ utilize the earth's natural heat. Geothermal sources can turn water into steam which can then turn a turbine which can power a generator which can make electricity.
- B) China is a ~~an~~ <sup>growing</sup> industrial powerhouse, while its huge population drives down its ~~per~~ per capita GDP and energy consumption industry is still booming and pays little attention to ~~control~~ its CO<sub>2</sub> emission. Furthermore ~~the agricultural need~~ even if <sup>their</sup> per capita CO<sub>2</sub> emission is low, China's 1 billion ~~and~~ growing population is the reason ~~the~~ are the world's largest ~~and~~ emitter.
- C) Smog resulting from the generation of ~~and~~ electricity is a ~~is~~ major issue. Smog is laced with harmful pollutants that degrade ~~the~~ human health, especially increasing the likely hood of respiratory diseases.
- D) ~~Sugarcane is a biomass fuel. By burning it, the lost gas~~  
~~off can both water and steam.~~
- E) Sugar cane is much like corn in that it can be fermented, ~~and~~ ~~is~~ refined and turned into liquid fuel.
- F) This energy source is less cost-efficient than fossil fuels. ~~Sugarcane production and need for sugarcane production is often~~  
~~cleared from rainforests.~~
- The clearing of land for sugar cane production ~~is~~ results in habitat destruction.

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iii) The sugarcane fuel source is more sustainable. Sugarcane is an agricultural product that can be easily renewed by simply growing more. The tar sands are inorganic and take much longer to replenish.

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## 2011 SCORING COMMENTARY

### Question 3

#### Overview

The intent of this question was to have students demonstrate their understanding of energy resources and consequences associated with the use of those resources. Topics included describing how geothermal energy could be used to generate electricity, air pollution issues related to the generation of electricity, and the use of either sugarcane or tar sands, nontraditional energy resources.

#### Sample: 3A

**Score: 10**

Two points were earned in part (a) for stating, “water will then vaporize to form steam, which is then used to turn the turbine and power the generator.” One point was earned in part (b) for observing, in regard to China’s electrical energy consumption and carbon dioxide emissions, that “per capita is deceptively low in comparison to its emission of CO<sub>2</sub> because it has the most population.” Two points were earned in part (c): 1 for identifying sulfur dioxide and 1 for describing its impact on human health (“Sulfur dioxide ... has the ability to scar lung tissue if inhaled and can cause asthma”). One point was earned in part (d)(i) for describing how hot water is used to separate the oil from the tar sands. Two points were earned in part (d)(ii) for explaining that tar sands are nonrenewable and that they release greenhouse gases when burned. Two points were earned in part (d)(iii) for identifying sugarcane as sustainable and noting that it “can be harvested and, essentially, ‘renewed’ every year.”

#### Sample: 3B

**Score: 8**

One point was earned in part (a) for the mention of “turbines, generating electricity in a generator.” One point was earned in part (b) for noting that although average electrical consumption is low, “China is the most populous country in the world, so total energy use is high.” Two points were earned in part (c): 1 for identifying mercury and 1 for associating it with neurological disorders. One point was earned in part (d)(i) for describing the fermentation that leads to the production of ethanol; 1 point was earned in part (d)(ii) for noting that ethanol production “removes foodcrops from the marketplace”; and 2 points were earned in part (d)(iii) for identifying sugarcane as sustainable because more sugarcane can be grown.

#### Sample: 3C

**Score: 6**

One point was earned in part (a) for stating that turbines “can power a generator which can make electricity.” One point was earned in part (b) for noting that, even though the per capita value is low, China is the largest emitter of carbon dioxide because of its enormous population. No points were earned in part (c) because no specific component of smog (e.g., ozone, peroxyacetyl nitrates) is identified. One point was earned in part (d)(i) for the explanation that sugarcane “can be fermented, refined and turned into liquid fuel”; 1 point was earned in part (d)(ii) for describing land clearing, which “results in habitat destruction”; and 2 points were earned in part (d)(iii) for identifying sugarcane as sustainable because it “can be easily renewed by simply growing more.”