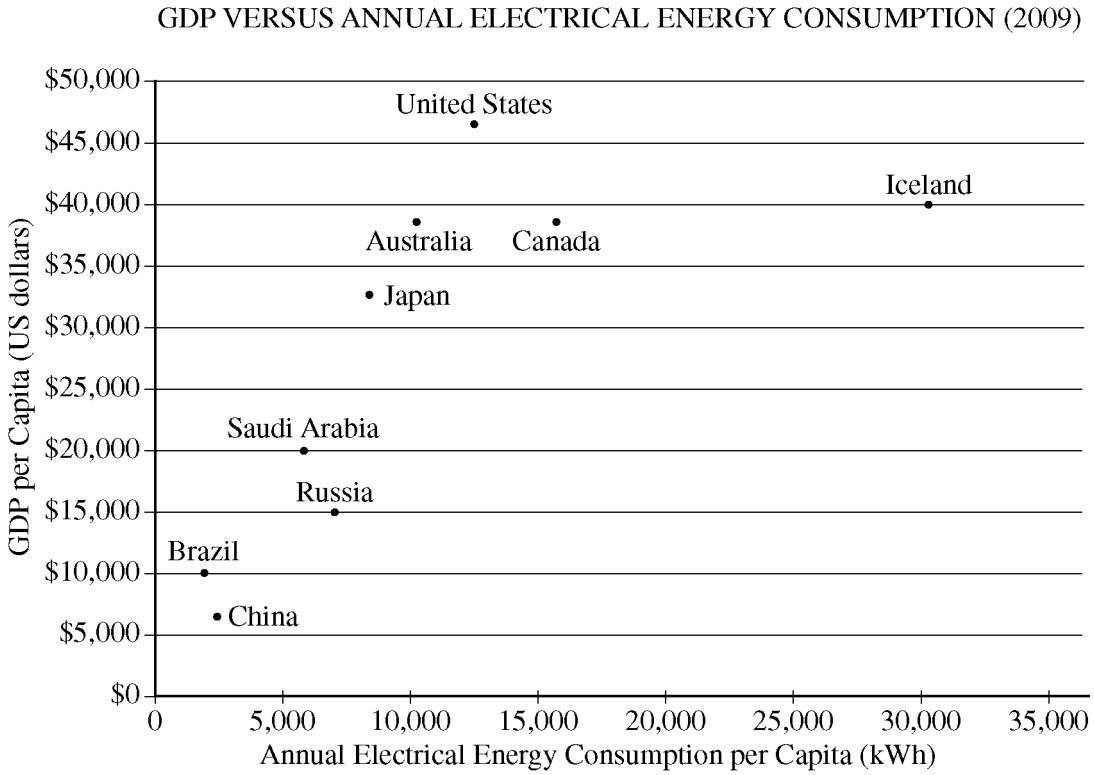

3. Shown above is a graph of the gross domestic product (GDP) per capita versus the annual electrical energy consumption per capita for nine countries in 2009.

   (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_2. Explain this apparent contradiction.

   (c) In addition to contributing to increased atmospheric CO_2 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.

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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_2. 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_2 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.

Issue (1 point)	**Impact on human health (1 point)**
SO_2 or SO_x emissions from coal-burning power plants	• Respiratory irritant • Aggravate asthma, bronchitis • Can lead to emphysema • Throat irritant
Particulate matter	• Decreases lung function (lung irritant) • Aggravates asthma • Throat irritant
NO_x from coal and petroleum combustion	• Respiratory irritant • Aggravates heart disease
Ozone, PAN from photochemical smog	• Lung irritant • Eye irritant

Question 3 (continued)

Hg from coal-burning power plants — deposition into surface waters	• Neurotoxin • Hearing loss • Impaired ability to learn
SO_x or NO_x aerosols from acid rain	• Lung irritant • Aggravate asthma

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*)

Sugarcane	
Extraction (1 point)	**Processing (1 point)**
Sugarcane is harvested and crushed. OR Sucrose is extracted from the sugarcane.	• The sucrose or mash is fermented to produce ethanol AND/OR bagasse (waste product) is collected after the sugarcane is processed.

OR

Tar Sands	
Extraction (1 point)	**Processing (1 point)**
Tar sands are extracted by surface mining.	• Tar sands are treated with hot water to extract the oil (bitumen). • Tar sands are treated with steam to extract the bitumen.

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.