Engineers have proposed using geothermal energy to air-condition The University of Western Australia (UWA) campus. The existing air-conditioning system uses chilled water that is reticulated through a network of pipes to cool campus buildings. Water is cooled overnight by a refrigeration system that uses cheap off-peak electricity, and stored in a 15 m diameter by 16 m high steel tank lined with 50 mm of insulating material.

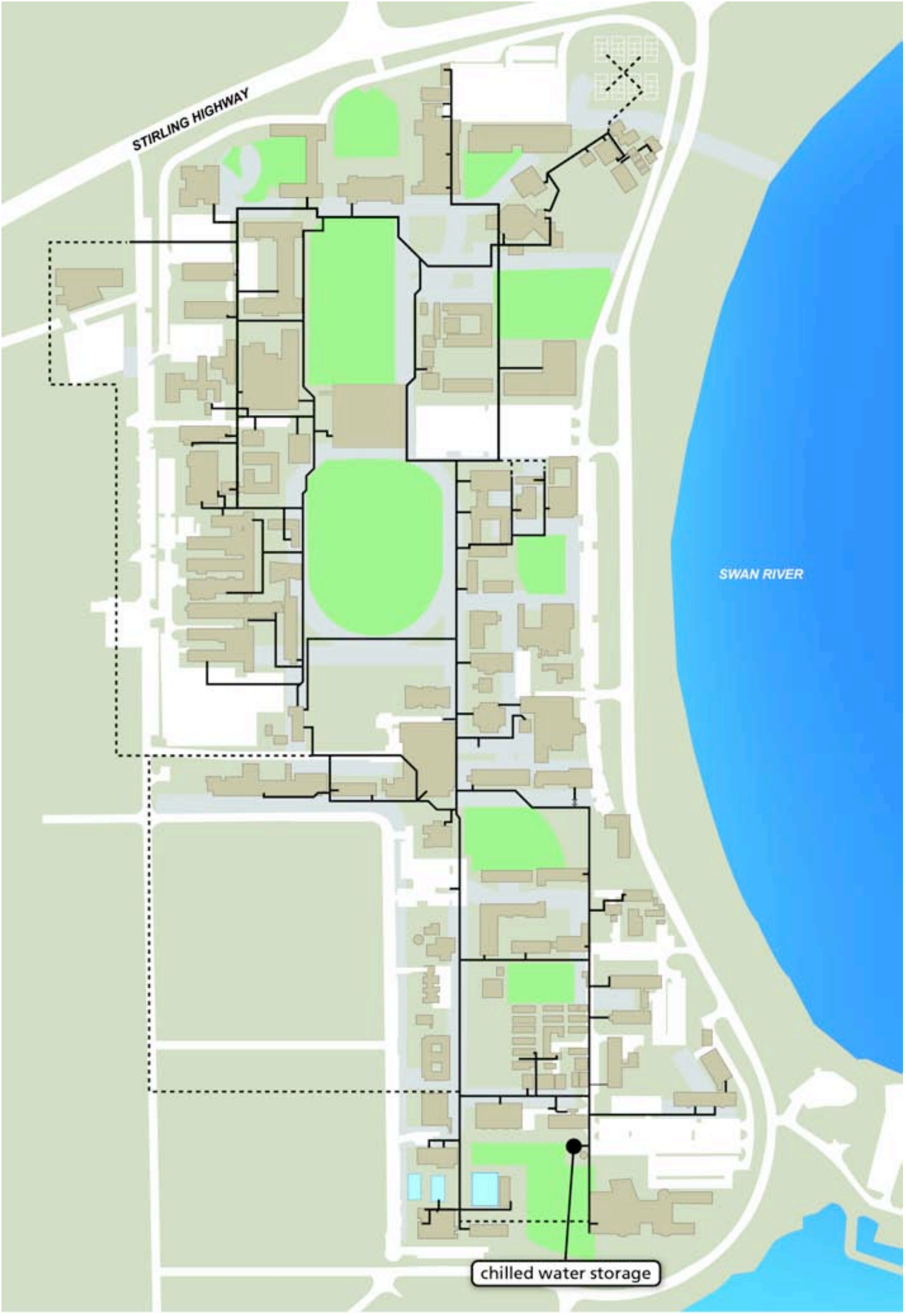

figure 1: The University of Western Australia chilled water system

The proposed system uses geothermal energy to supplement energy required to run the air-conditioning system. This will involve drilling to a depth of about 3000 m to access water at 80 °C to 100 °C. Hot water from sedimentary aquifers at this depth will be pumped to the surface and used as the heat source to run an absorption chiller. Hot water must be supplied to the chiller at the rate of between 60 and 80 L s^{-1} to achieve the required cooling.

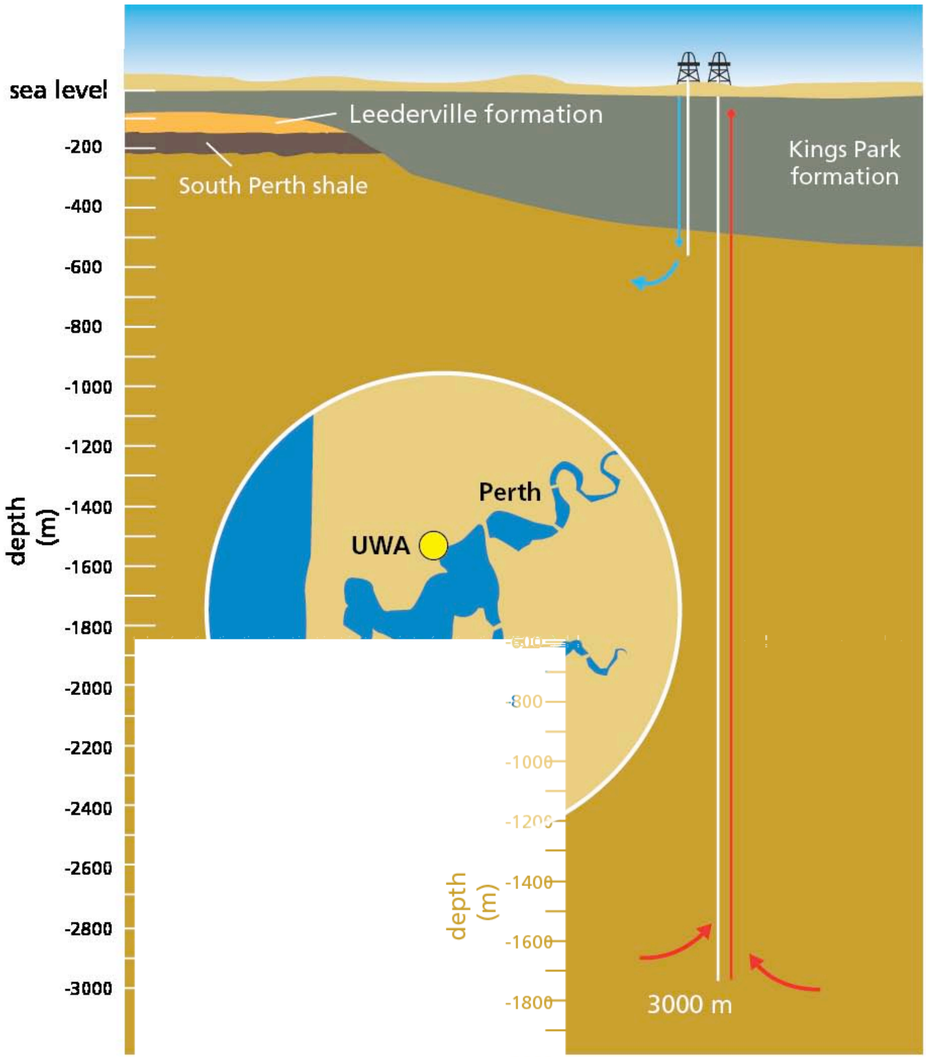

figure 2: bore cross-section

The absorption chiller applies the concepts of latent heat and depressed boiling point under low pressure to produce refrigerated water for use in the existing reticulation system.

Figure 3 shows how energy from geothermal water is used to evaporate water in a chiller to drive its operation. Other parts of the absorption chiller require comparatively little energy to produce and circulate cold water for air-conditioning.

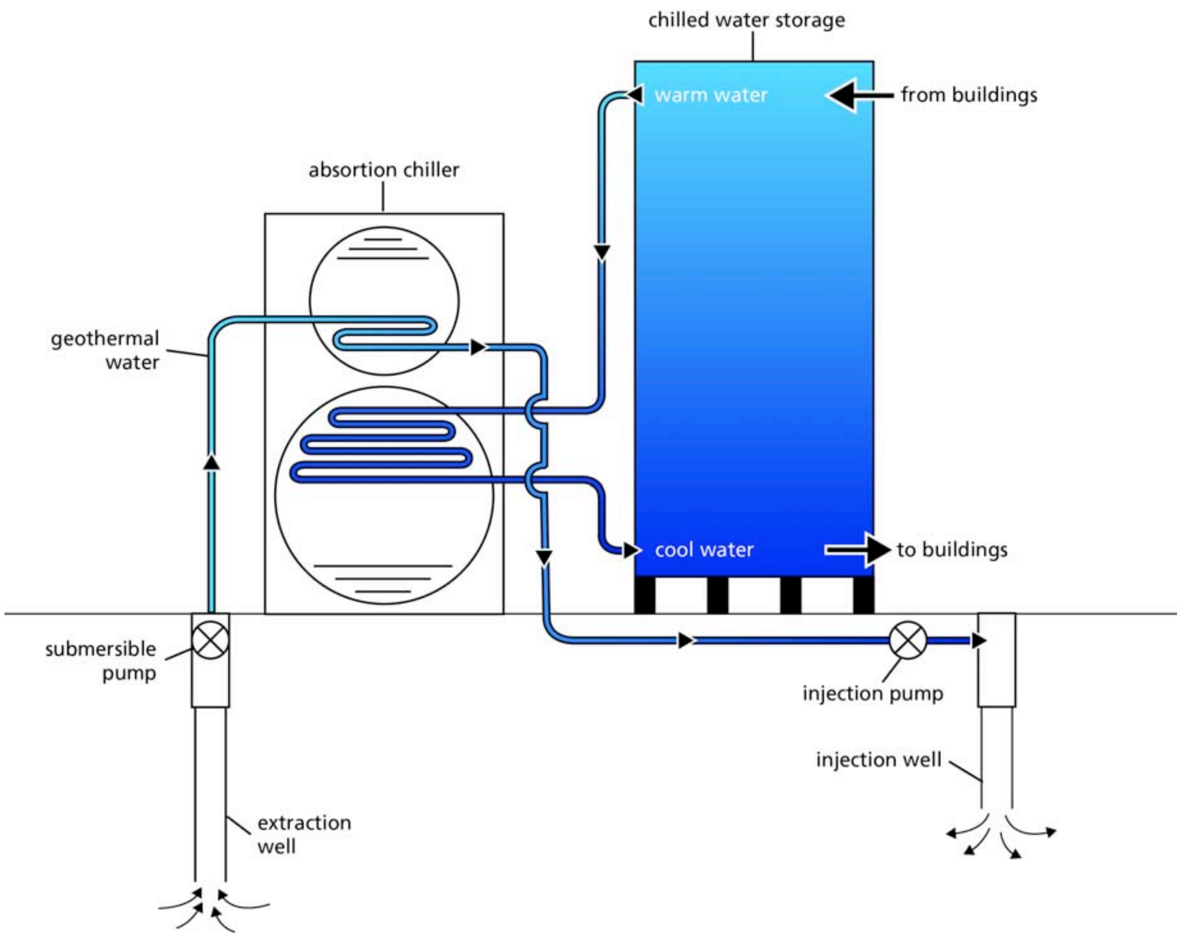

figure 3: simplified diagram of an absorption chiller

In contrast, a standard refrigerative air-conditioning system shown in figure 4 uses electricity to drive a compressor that pushes refrigerant around the system. Each cooling cycle produces vapour, then compresses it again.

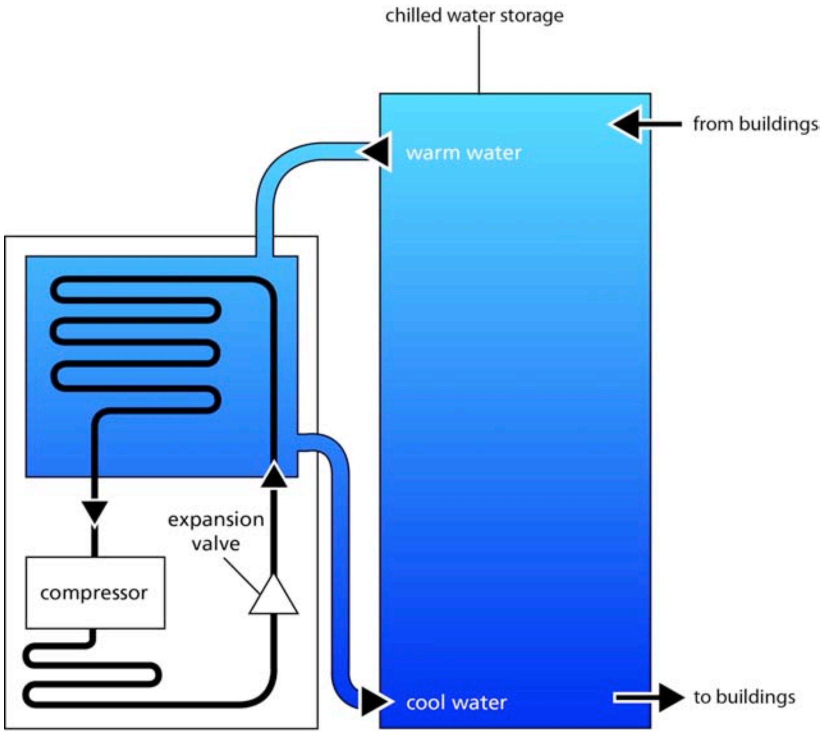

figure 4: refrigerative air-conditioning system

The University of Western Australia's proposal is to install a 2 MW geothermal energy system using an absorption chiller to cool water for the air-conditioning network. Electricity will be used to pump water around the system. In addition to financial savings, carbon dioxide emissions would be reduced by up to 1800 tonnes each year.

Before embarking on this ambitious project, modelling has been developed to examine the performance of the system on a typical Australian university campus. Figure 5 shows the variation in energy demand over a 12 month period. The lower horizontal line on this graph shows the 1 MW base load. This is the minimum amount of cooling energy (cooling load) needed in the university throughout the year. The upper horizontal line shows how a 2 MW geothermal chiller can easily satisfy the base load and partially meet peak load at some times of the year.

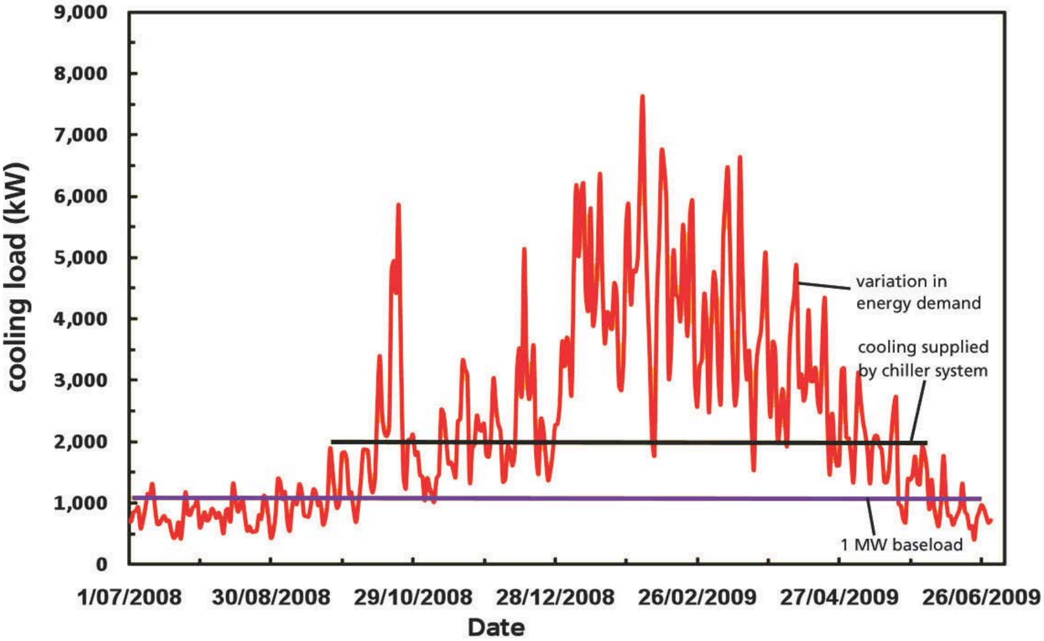

figure 5: cooling load profile

Figure 6 shows the quantity of electrical energy required to satisfy the cooling load of the university air conditioning system.

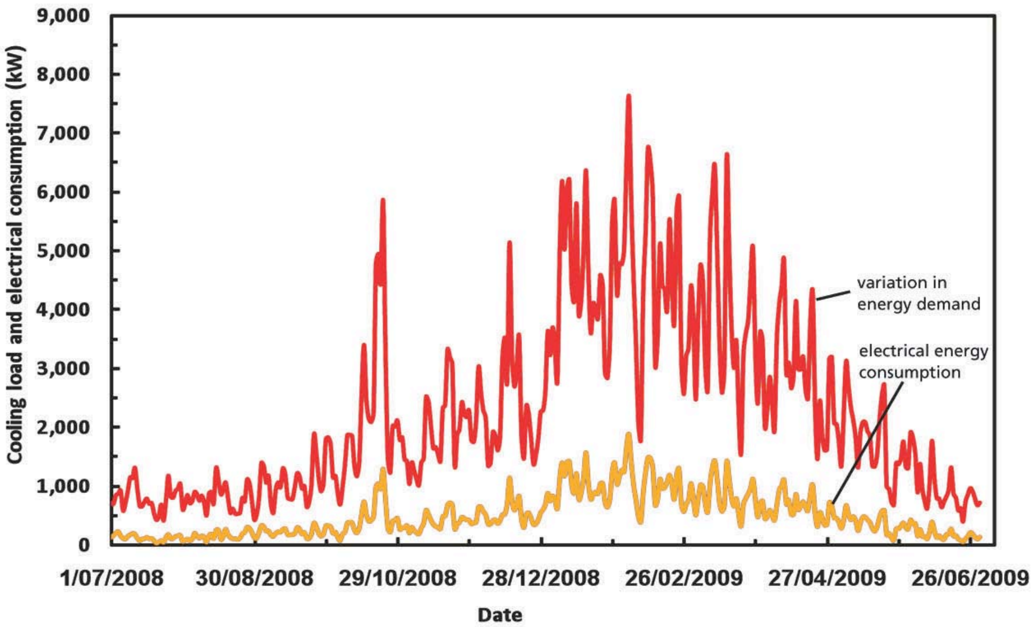

figure 6: cooling load and electrical consumption profile

The upper graph on figure 7 shows projected savings if a 2 MW geothermal air-conditioning system is built. At certain times of the year, dependency on the electrically-driven refrigerative air-conditioning system would be greatly reduced.

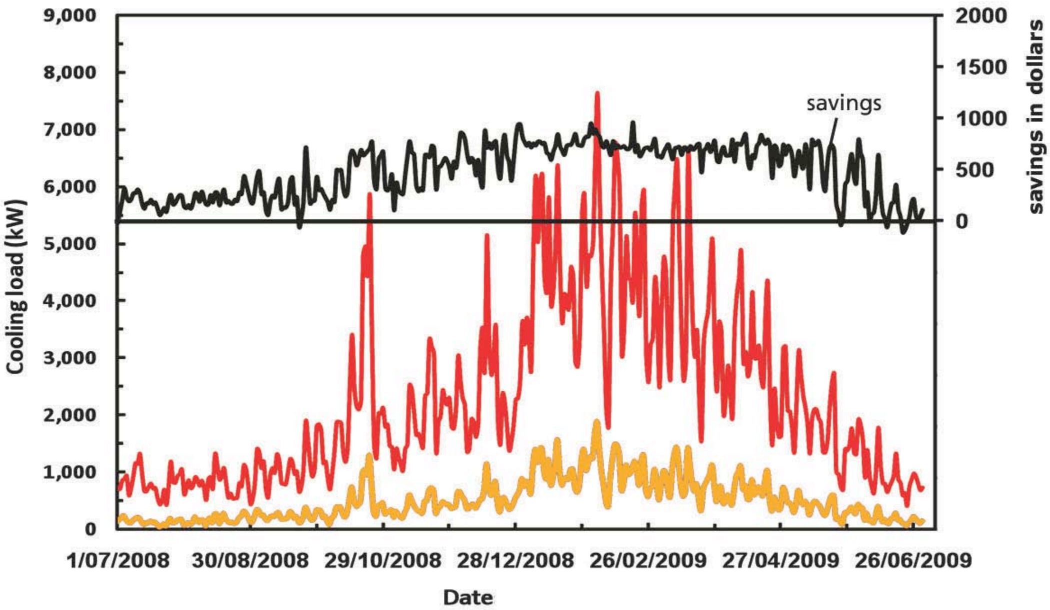

figure 7: base load savings

If predictions by the model are correct, The University of Western Australia will be the first establishment in Australia to benefit from power and cost savings by running a large-scale air-conditioning system using geothermal energy.

Questions

1. Apart from the low cost of running the chiller compared to an electrically operated air-conditioning system, what are major benefits of the geothermal arrangement?

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2. Explain why kilowatts (kW) can be used to describe the quantity of cooling?

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3. During which month(s) is the demand for energy to power the air conditioning greatest? Suggest reasons for this.

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4. The absorption chiller applies the concepts of latent heat and depressed boiling point under low pressure to produce refrigerated water for use in the existing reticulation system.

(a) What is meant by the phrase ‘depressed boiling point under low pressure’?

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(b) How can the latent heat of vaporisation be used, under these conditions, to produce a cooling effect?

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5. Calculate the quantity of heat energy per hour that is used by the proposed UWA chiller system to provide chilled water for the air-conditioning system.

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6. Figure 8 shows how the tariff for electrical energy is projected to increase in the future. Compare the impact of this projection on air-conditioning systems powered by (a) geothermal energy and (b) fossil fuels (electricity).

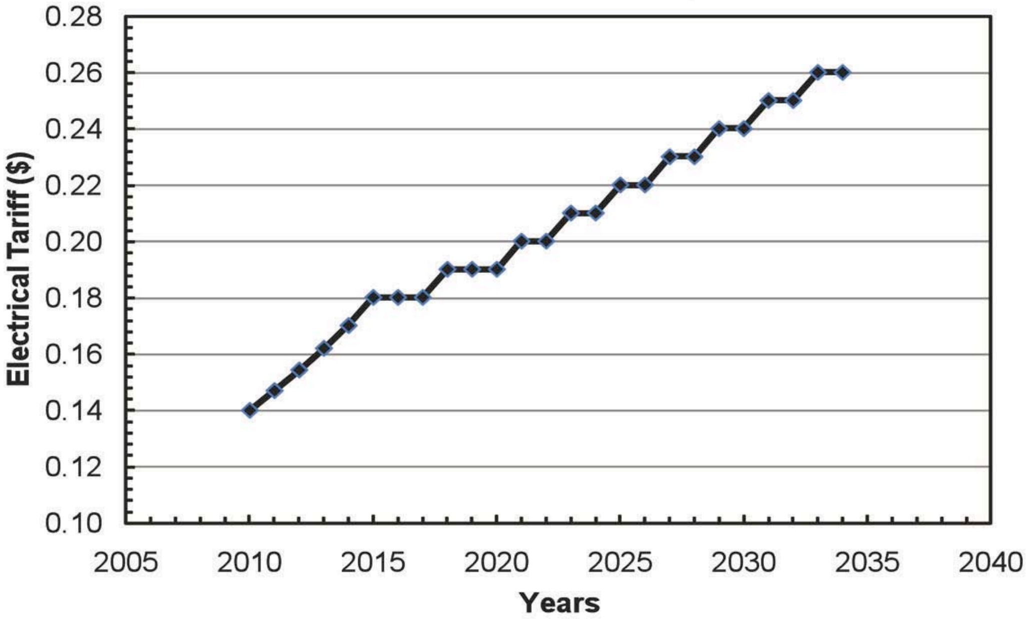

figure 8: electricity tariff projection

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7. If water is reinjected into the aquifer at a temperature of 70 °C, estimate the energy per hour extracted from geothermal water by the chiller.

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8. Why is the quantity of energy calculated in question 7 different to the amount of energy required to provide the 2 MW of power needed to run the geothermal air-conditioning system (see question 5)?

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9. Figure 5 shows that the amount of energy represented by the cooling load is much greater than the electrical energy required to produce the chilled water to run the air conditioning system.

   a. Select a few points on the graph to calculate the ratio between these two quantities of energy.

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   b. Explain how it is possible that the electrical energy consumed in this system is much less than the energy produced to satisfy the cooling load.

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10. Figure 1 shows the 5 km network of reticulation pipes that carry chilled water around the campus. What conditions are needed to deliver chilled water to all sections of the campus with minimum temperature gain?

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11. The following message was emailed to all staff on a University campus just before a 16 day Christmas/New Year break.

   Facilities Management asks all university staff to implement procedures to conserve energy over the Christmas closedown period. A 50% reduction in energy usage over this period will result in a saving of about 4000 GJ of energy and reduce carbon dioxide emissions by over 900 tonnes. This reduction will also lead to savings of about $65 000.

   Suggest ways in which staff could comply with this request.

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