Unit 2 Detailed study 3: Investigations: alternative energy sources

Chapter 18

Investigating energy alternatives

1. Renewable sources of energy replace themselves continuously. Non-renewable sources of energy rely on fuels that don't replace themselves.
2. Without a Greenhouse Effect to prevent too much energy leaving the Earth's atmosphere, the temperature at and near the Earth's surface would be too low for the survival of living things.
3. A high-grade form of energy can be efficiently converted into other useful forms of energy. Low-grade energy cannot be converted into another useful source of energy.
4. Internal energy is classified as a low-grade form of energy because it cannot be converted efficiently into other useful forms of energy.
5. In any energy conversion, some energy is always degraded into lower grade forms.
6. Estimate the area of the body facing the Sun. For example,

   $A = 1.5 \text{ m} \times 0.5 \text{ m}$

   $= 0.75 \text{ m}^2$

   $\dfrac{Q}{\Delta t} = 1200 \text{ W}$

   where Q is the quantity of energy received by an area of 1 m^2.

   $\Delta t = 30 \times 60 \text{ s}$

   $= 1800 \text{ s}$

   $\Rightarrow Q = 1200 \text{ W} \times 1800 \text{ s}$

   $\Rightarrow$ Energy received by body $= 1200 \text{ W} \times 1800 \text{ s} \times 0.75$

   $= 1.6 \times 10^7 \text{ J}$

   $= 16 \text{ MJ}$

   A major assumption is that the sky is clear. The value seems high but one must remember that:
   - some of the incident energy is reflected by the body and not absorbed
   - while radiant energy is being absorbed, the body is also cooling by conduction, convection and/or evaporation.
7. Energy used $= 110 \times 0.5$

   $= 55 \text{ kJ}$

   $$\text{Power} = \frac{\text{energy used}}{\text{time interval}} = \frac{55 \text{ kJ}}{55 \text{ s}} = 1.0 \text{ kW}$$

8. Answers will vary from school to school. Assumptions might include:
   - average power consumption for lighting and heating = 50 kW
   - hours of operation per day = 7
   - days of operation per year = 200

   For example,

   Energy $= 50\,000 \times 7 \times 60 \times 60 \times 200$

   $= 2.5 \times 10^{11} \text{ J}$

   Cost of lighting: Assume 1 kW power consumption.

   Energy used in one year $= 1 \text{ kW} \times (7 \times 200) \text{ h}$

   $= 1400 \text{ kWh}$

   Cost $= 1400 \times \$0.17$

   $= \$238$

9. (a) Insolation $= 6.5 \text{ kWh m}^{-2} \text{ day}^{-1}$

   $$= \frac{6.5 \text{ kWh}}{1 \text{ m}^2 \times 24 \text{ h}}$$

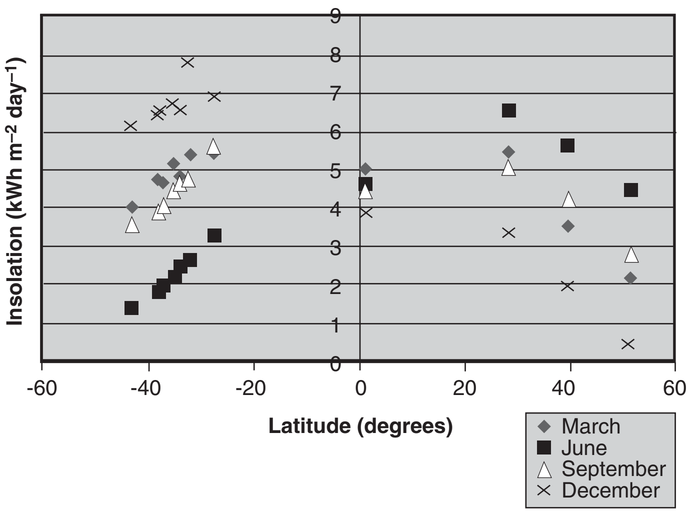
   $= (6.5 \div 24) \text{ kW m}^{-2}$

   $= 0.27 \text{ kW m}^{-2}$

   (b) $\% = \dfrac{0.27}{1.37} \times \dfrac{100}{1}$

   $= 19.7\%$ (20%)

10.



11. Energy collected $= \dfrac{4500 \text{ MW}}{0.15}$

    $= 30\,000 \text{ MW}$

    Each square metre collects 80 W

    $\therefore$ area needed $= 30\,000 \text{ MW} \div 80 \text{ W}$

    $= 3.0 \times 10^{10} \div 80$

    $= 3.8 \times 10^8 \text{ m}^2$

12. Insolation = $1.2\ \text{kW m}^{-2}$

$$\begin{aligned}\text{Area} &= 2000\ \text{m}^2\\ \text{Efficiency} &= 18\%\\ \text{Incident energy} &= 1.2 \times 2000\\ &= 2400\ \text{kW}\\ \text{Energy converted} &= 0.18 \times 2400\\ &= 432\ \text{kW}\\ &= 4.3 \times 10^2\ \text{kW}\end{aligned}$$

13. The increase of salt concentration with depth

14. The flow of water through a turbine is used to generate electricity in a hydroelectric power station. The speed of the water is determined mainly by the height the water has fallen through.

(a) Flow = $2\ \text{ML min}^{-1}$

$h = 180$ m

$$\begin{aligned}\text{Energy conversion} &= mgh\\ &= 2 \times 10^6 \times 9.8 \times 180\\ &= 3.53 \times 10^9\ \text{J min}^{-1}\\ &= \frac{3.53 \times 10^9\ \text{J}}{60\ \text{s}}\\ &= 5.9 \times 10^7\ \text{W}\\ &= 5.9 \times 10^4\ \text{kW or } 59\ \text{MW}\end{aligned}$$

(b) Some of the available energy is transferred as heat to the tunnel, turbine and surrounding air as a result of friction and magnetic effects.

15. (a)

Process	**Solar Two plant**	**EnviroMission plant**
Collection of solar energy	Mirrors that track the sun	Air in a 'greenhouse'
Turning of the turbine	Turned by steam	Turned by hot, moving air

(b) The Solar Two plant can generate electricity for the longest period each day because the water used to produce steam is heated by a fluid that is able to store solar energy for several hours.

16. Student research. Answers should include the size of the power plant (which will affect the cost) and the huge amount of time it would take to build. Because of its likely weight, it would have to be built in space.

17. Incident radiation = $1.37\ \text{kW m}^{-2}$

$$\begin{aligned}\text{Area of panel} &= 8\ \text{km} \times 8\ \text{km}\\ &= 8000\ \text{m} \times 8000\ \text{m}\\ &= 6.4 \times 10^7\ \text{m}^2\\ \text{Incident energy} &= 1.37 \times 6.4 \times 10^7\\ &= 8.768 \times 10^7\ \text{kW}\\ \text{Receiving energy rate} &= 8.768 \times 10^7 \times 0.18 \times 0.65\\ &= 1.0 \times 10^7\ \text{kW}\\ &= 10\,000\ \text{MW}\end{aligned}$$

18. Student answers will vary.

19. (a) $d = 65$ m   Area = $\dfrac{\pi d^2}{4}$

$$\begin{aligned}&= 3318\ \text{m}^2\\ &= 3.3 \times 10^3\ \text{m}^2\end{aligned}$$

(b) $\rho = \dfrac{m}{V}$

$$\begin{aligned}&= 1.22\ \text{kg m}^{-3}\\ V &= A \times \text{thickness}\\ &= 3318 \times 1\\ &= 3318\ \text{m}^3\\ m &= \rho \times V\\ &= 1.22 \times 3318\\ &= 4048\ \text{kg}\\ &= 4.0 \times 10^3\ \text{kg}\end{aligned}$$

(c) $P = \frac{1}{2}\rho v^3 \pi r^2$

$$\begin{aligned}&= \tfrac{1}{2}\rho v^3 \times \text{area}\\ &= \tfrac{1}{2} \times 1.22 \times 8^3 \times 3318\\ &= 1.0 \times 10^6\ \text{W}\\ &= 1.0\ \text{MW}\end{aligned}$$

(d) $P \propto v^3$

If v is reduced by $\frac{1}{2}$, v^3 is reduced by $(\frac{1}{2})^3 = \frac{1}{8}$

Power is reduced by $\frac{1}{8}$

(e) $$\begin{aligned}\text{Power output} &= 1.04 \times 10^6\ \text{W} \times 0.35\\ &= 3.6 \times 10^5\ \text{W}\\ &= 360\ \text{kW}\end{aligned}$$

20. Student research
21. Student research
22. Student research