Energy Sources

1. Wind is incident on the blades of a wind turbine. The radius of the blades is 12 m. The following data are available for the air immediately before and after impact with the blades.

    1. Determine the maximum power that can be extracted from the wind by this turbine.

    $$P = \frac{1}{2} 3DV^3$$

    $$P = \frac{1}{2} \times 1.20 \times 144\pi \times 8^3 = \boxed{138974}$$

    2. Suggest why the answer in (a) is a maximum.

    After impact, the blade's power is equal to 19109. Since 138974 > 19109, 138974 W is a maximum.

2. In a pumped storage hydroelectric system, water is stored in a dam of depth 34 m. The water leaving the upper lake descends a vertical distance of 110 m and turns the turbine of a generator before exiting into the lower lake. Water flows out of the upper lake at a rate of 1.2×10^5 per minute. The density of water is 1.0×10^3.

    1. Estimate the specific energy of water in this storage system, giving an appropriate unit for your answer.

    $$\text{Average height} = 127 \text{ m}$$

    $$\text{Specific Energy} = \frac{mgh}{m} = gh = 9.81 \times 127 = \boxed{1.2 \times 10^3 \frac{J}{kg}}$$

    2. Show that the average rate at which the gravitational potential energy of the water decreases is 2.5 GW.

    $$\frac{1.2 \times 10^5}{60} \times 10^3 = \boxed{2 \times 10^6 \frac{kg}{s}}$$

    $$2 \times 10^6 \times 9.81 \times 127 = \boxed{2.49 \times 10^9 \text{ W}}$$

    3. The storage system produces 1.8 GW of electrical power. Determine the overall efficiency of the storage system.

    $$\frac{1.8}{2.5} = \boxed{0.72}$$

    4. After the upper lake is emptied it must be refilled with water from the lower lake and this requires energy. Suggest how the operators of this storage system can still make a profit.

Water can be pumped when the demand for electricity is at a low.

3. Two renewable energy sources are solar and wind.

    1. Describe the difference between photovoltaic cells and solar heating panels.

        Photovoltaic cells produce electric energy, while solar heating panels produce heat energy.

    2. A solar farm is made up of photovoltaic cells of area $25000\ m^2$. The average solar intensity falling on the farm is $240 \frac{W}{m^2}$ and the average power output of the farm is $1.6\ MW$. Calculate the efficiency of the photovoltaic cells.

$$240 \times 24000 = 6.0\ MW$$

$$1.6/6 = \boxed{27\%}$$

    3. Determine the minimum number of turbines needed to generate the same power as the solar farm.

$$A = \pi \times 17^2 = 908 m^2$$

$$P = 0.5 \times 908 \times 1.3 \times 7.5^2 = 0.249\ MW$$

$$\text{Turbines} = \frac{1.6}{0.249} = 6.4 = \boxed{7}$$

    4. Explain two reasons why the number of turbines required is likely to be greater than your answer to (c)(i).

        Efficiency is less than 100%

        Not all KE of air can be converted to KE of blades

4. The following data are available for a natural gas power station that has high efficiency.

    1. Calculate, with a suitable, the electrical power output of the power station.

$$55.5 \times 14.6 \times 0.59 = \boxed{4.78 \times 10^5\ W}$$

    2. Calculate the mass of CO_2 generated in a year assuming the power station operates continuously.

$$14.6 \times 2.75 \times 3.16 \times 10^7 = \boxed{1.27 \times 10^9}$$

    3. Explain, using your answer to (b), why countries are being asked to decrease their dependence on fossil fuels.

$$\boxed{\text{CO2 is linked to the greenhouse effect, leading to climate change}}$$

    4. Describe in terms of energy transfers, how thermal energy of the burning gas becomes electrical energy.

        Internal energy of steam/particles OR KE of steam/particles