Environmental Science
FACT SHEET
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HYDROELECTRIC POWER

Hydroelectric power provides 24% of the world's electricity. Plants range in power output from a few hundred kilowatts up to 10,000 megawatts. The US is world leader in HEP production.

Site Requirements

- Fast-flowing rivers or sufficient rainfall to fill reservoir.
- Evenly distributed rainfall.
- Suitable topography: narrow valley exit which can be dammed, giving large volume but small surface area to reduce evaporation. So, ideally, a deep, steep-sided valley.
- Impermeable rocks/bedrock with no faults or seismic activity to prevent leakage.
- Close to consumers/demand centre.
- Climate that will result in a low evaporation rate.
- Low rate of silting.
- Site that allows easy access and construction.
- No urban area immediately upstream as this will be a potential source of pollution/will increase treatment costs.
- Site where construction will not cause serious damage to habitats or mean resettlement of people.

A typical hydroelectric plant is shown in *Fig.1*.

The Three Gorges Dam, China

- *1.5 miles wide, 400 miles long, allowing ocean freighters to increase imports/exports.*
- *Reduce flooding of Yangtze River.*
- *Completion date 2009.*
- *Will flood 632 km² of land and mean resettlement of 1.2 million people.*
- *26 HEP turbines will produce 18 million kW – 11% of China's consumption.*
- *The flooded areas include many contaminated with toxic material which may create a health hazard if the toxins leach into the water. However, much of the flooded land is also extremely fertile land that has been farmed for countless generations.*
- *There are also concerns that loss of river flushing will result in pollution from sewage released into the reservoir.*
- *Many believe that silting up of the dam will cause severe problems at the HEP plant resulting in loss of storage capacity.*

Fig. 1 How a hydroelectric dam works.

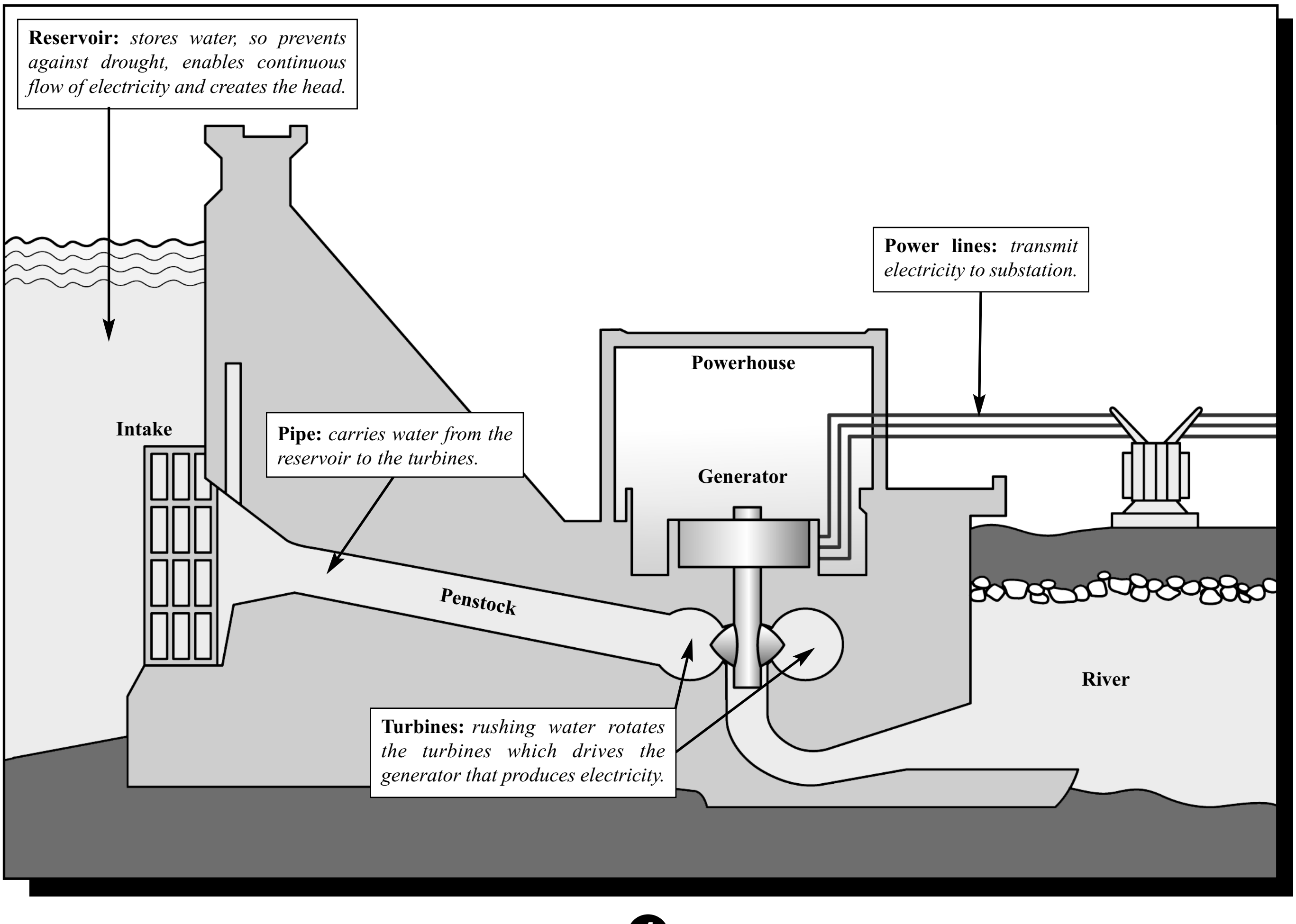
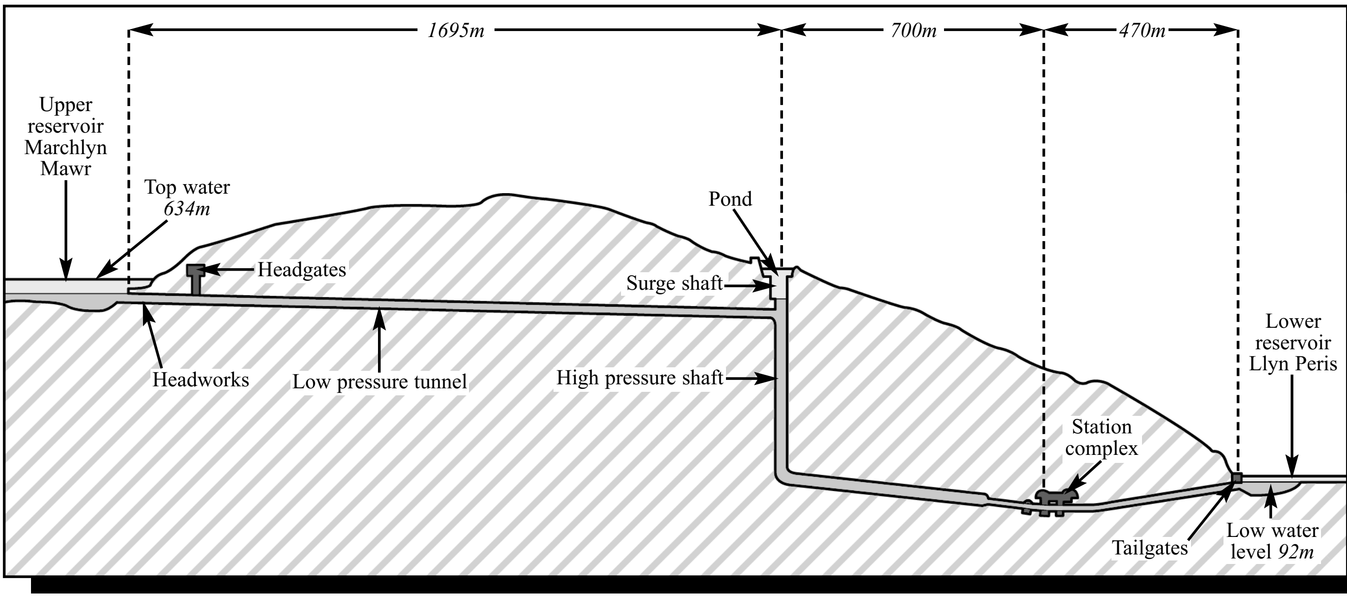


Fig 2 Cross-section of the Dinorwig scheme.



There are three types of Hydroelectric Power Plants:

1. ***Run-of-River:*** Water is not stored – instead, the power of fast-flowing rivers is harnessed.
2. ***Reservoir:*** (the most usual) – these feed the HEP plant with one-way water flow.
3. ***Pumped Storage Plants:*** After the water has run through the plant, some of it is pumped back up to the reservoir. This is done at night when energy production exceeds energy consumption. Pumping may actually use up more energy than that produced by the falling water! However, this is still performed since the water in the reservoir effectively acts as a store of energy that can be rapidly exploited at peak times of energy demand. This is the case at the pumped storage plant at Dinorwig in Wales. This plant acts as standby capacity for the national grid. If there is a sudden surge in demand, water in the upper dam can be released at the touch of a button and, just 10 seconds later, Dinorwig is supplying 1,320 megawatts to the grid. This is much more efficient than having fossil fuel plants on stand-by. *Fig. 2* shows the layout of the pumped storage HEP plant at Dinorwig in Wales.

HEP can be considered to be an indirect form of solar energy since it is solar energy that drives the hydrological cycle (evaporation → cooling/condensation → precipitation → potential energy → kinetic energy).

Energy transformation

The hydroelectric power plant that uses a reservoir converts the potential energy of the stored water into kinetic energy of falling water, which is in turn converted into electricity. Heat and sound energy are unwanted forms of energy also produced in the process.

The electricity production is proportional to the product of the flow rate (volume per unit time) and the 'head' – the vertical height difference between the water surface and turbines.

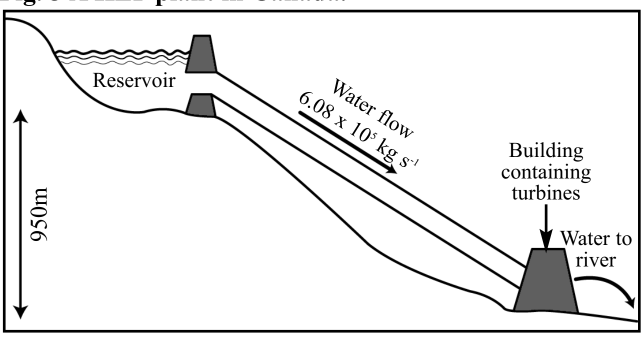
In exam questions, the following formula will be provided:

E (J) = Mass (Kg) x acceleration due to gravity (*g*) (N Kg^{-1}) x Head (m)

Typical Exam Question

The diagram below shows a HEP plant in Canada. The maximum flow rate is 6.08 x 10^5 kg s^{-1}, which can be maintained for 3 hours. The drop is 950m.

Fig. 3 A HEP plant in Canada.



The formula for calculating the energy output from the plant is shown below.

$$\text{Potential energy (J)} = \text{Mass of water (kg)} \times \text{acceleration due to gravity (N kg}^{-1}) \times \text{Height drop (m)}$$

Assume that the acceleration due to gravity (*g*) is 9.8 N kg^{-1}

a) Calculate the energy output per second.
b) The actual electrical output per second is 3.3 x 10^{9}J. Calculate the efficiency of the plant.

Answers

a) Energy = mass x acceleration due to gravity x height drop
= 6.08 x 10^5 x 9.8 x 950
= 5.66048 x 10^9 J (rounded to 5.66 x 10^9 J)
(or = 5.66048 x 10^6 KJ, or 5.66048 x10^3 MJ or 5.66048 GJ)

b) $$\text{Efficiency} = \frac{\text{actual energy output}}{\text{theoretical maximum energy output)}} \times 100\%$$

$$= \frac{3.3 \times 10^9}{5.66048 \times 10^9} \times 100\%$$

= 58.3 %

Note: *The examiner provided data on how long the flow rate could be maintained for. This information was not needed to answer the question. The examiner put it in as a distractor (in other words he tried to confuse you).*

Advantages and disadvantages of HEP

The major advantages of HEP include:
- Water is not turned into steam and released into the atmosphere – thus the water can be re-used for other purposes.
- Compared to fossil fuel-burning plants, HEP plants do not emit CO_2 or SO_2 - causes of the greenhouse effect and acid rain respectively.
- Compared to nuclear power stations, HEP plants present no danger of radioactive contamination.
- Reservoirs can also be used for shipping, recreation, water supply and to provide irrigation.

The major disadvantages of HEP include:
- Reservoirs flood habitats and can affect fish movement
- Submerged vegetation rots, releasing CO_2 and CH_4 – greenhouse gases. The World Commission on Dams (WCD) estimates that the decomposition of organic matter that is washed into the dams from upstream is a much more significant source of CO_2 and CH_4. The WCD reports that shallow, tropical dams are the greatest producer.
- Dams may silt up, therefore causing a decrease in capacity and depriving downstream areas of silt that would have been deposited on river plains during floods. Thus, the fertility of agricultural land downstream of the dam may decrease.

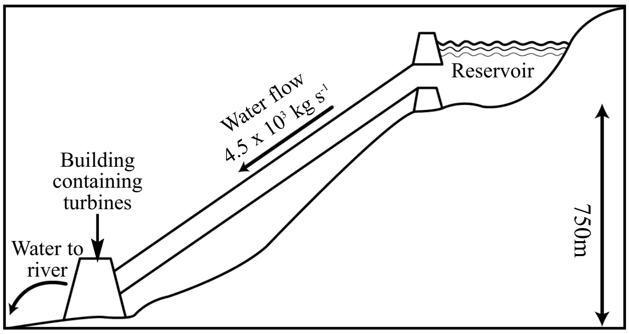
Summary

In N.America and Europe, most of the big potential HEP sites have already been developed. Most new potential areas are in Africa and Asia, but HEP proposals face huge environmental resistance. Small - scale developments will probably become more common and abandoned small HEP sites (a result of the fall in oil prices in the 1950s and 1960s) may be reclaimed.

The US, who have in the past championed large hydroelectricity projects, have drastically cut the number of projects they are backing - the environmental and economic costs are now seen as too great. However, despite the fact that HEP is growing much more slowly than any of the other key renewable sources of electricity, it remains the largest renewable source.

Practice Exam Questions

1. The diagram shows a HEP plant in Africa.



(a) Assuming that the plant is 75% efficient, use the equation below to calculate the energy output of the plant per second. Assume that the acceleration due to gravity (g) is 9.8 N kg^{-1}

Energy = mass (kg) x acceleration due to gravity (N kg^{-1}) x height drop (m)

(3 marks)

(b) Explain the effect of each of the following changes to the plant:
(i) making the water pipe narrower. *(2 marks)*
(ii) increasing the head to 1000m. *(2 marks)*

(c) Explain how each of the following may influence the choice of site of an HEP scheme.
(i) geology *(2marks)*
(ii) topography *(2 marks)*

Answers

1. (a) E = m x g x h
= 4.5 x 10^3 x 9.8 x 750;
= 3.3075 x 10^7 J;
Plant is 75% efficient, so:
output = (3.3075 x 10^7) x 0.75 = 2.48 x 10^7 J;

(b) (i) increases energy output;
because increases flow rate;

(ii) increases energy output by 33%;
because increases distance over which water falls/increases potential energy;

(c) (i) need stable geology / free of faults/seismic activity to prevent leaks;
need impermeable rocks to prevent seepage/leaks;

(ii) need steep sided valley/gorge which provides large volume to surface area;
minimising evaporation losses;
narrow exit to reduce damming costs;

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