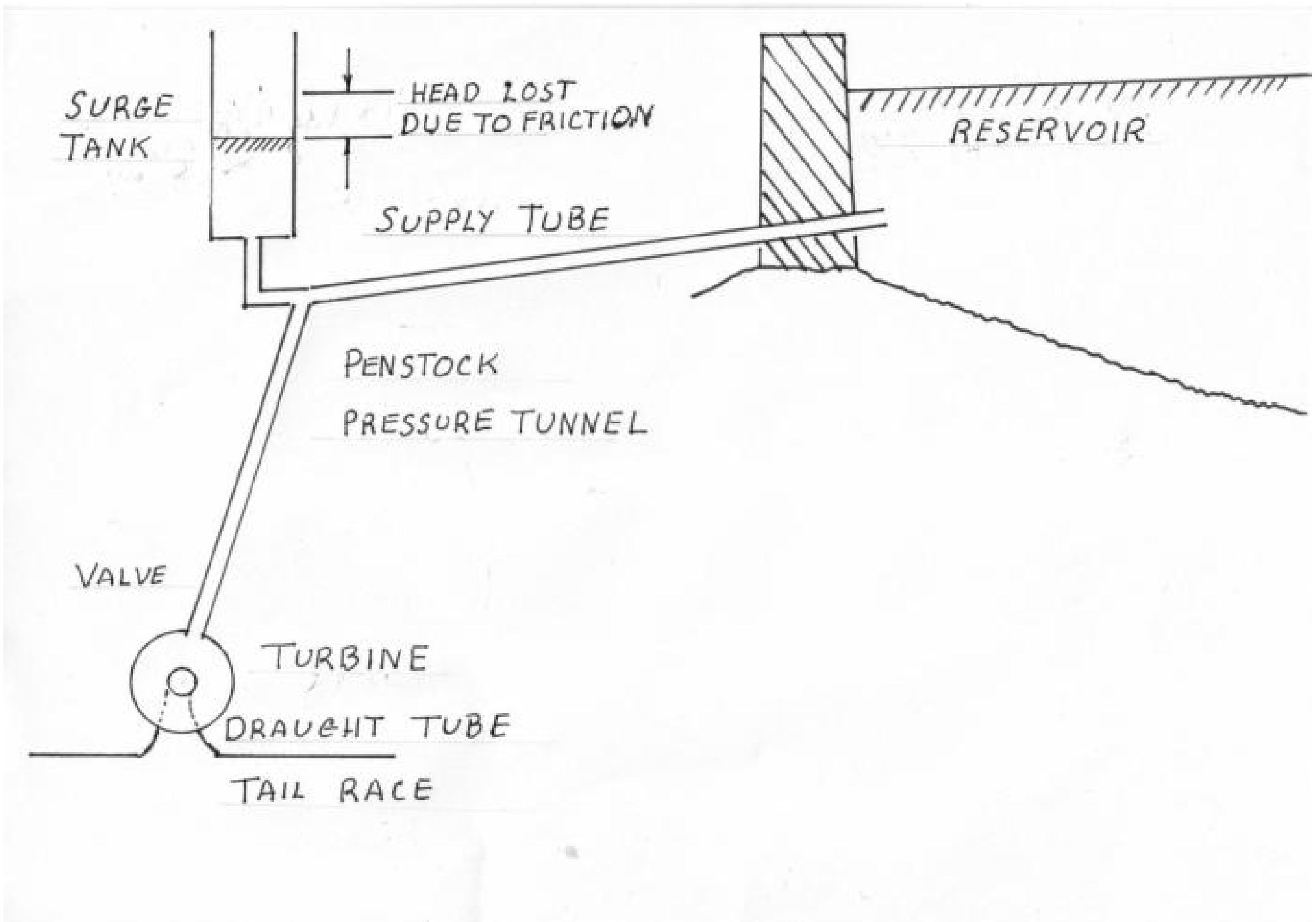
Renewable Energy Systems

EE—325

Principle Components of a Hydro-Electric Scheme

- The penstock should be located at such a level that sufficient water depth is provided above the penstock entrance in the foreway. If this is not so, and too little water depth is available, vortices and whirlpools will tend to form, which may carry air in the penstock and turbine wheels, and thus lowering efficiency of the turbine.
- Sharp bends must be avoided in the penstocks, because they cause loss of head and require special anchorages.

Surge Tank or Surge Chamber



Principle Components of a Hydro-Electric Scheme

- **Surge Tank or Surge Chamber**
- The simplest type of a surge chamber consists of a cylindrical chamber open to atmosphere and connected to the penstock as close to the power house as possible.
- When the load is rejected by the power house turbine, the water level in the surge chamber rises, and decelerates the flow upstream of it. But when additional load comes, the immediate demand is met by drawing water from the surge chamber, which accelerates the flow gradient and thus accelerates the flow in the reservoir. A surge tank therefore reduce the pressure fluctuations in the conduit pipe considerably, and thus prevents additional water hammer pressure from being exerted upon the wall of the conduit.

Principle Components of a Hydro-Electric Scheme

- Various types of surge tanks such as (i) simple surge tank (ii) Throttled surge chamber (iii) Differential surge chamber (iv) Multiple surge chamber.
- The main advantage of differential type of surge tank over simple tank lies in the fact that the retarding & accelerating heads are developed more quickly in differential types

Surge Tank or Surge Chamber

Surge Tank or Surge Chamber

Energy Conversion Schemes For Hydroelectricity-2

For utility supply companies, hydroelectricity provides an extremely flexible and reliable method of generating electricity, only constrained by lack of rainfall. The key feature is that power can be increased or decreased rapidly within seconds to fine-tune the power balance on a grid. If hydropower is offline, it can be brought fully online within a few minutes from a 'standing start'. If it is offline, no resource is being wasted.
A further benefit of hydropower is that a system powered from water in a reservoir and feeding water into a river or lake *can be reversed*.

Excess power on the grid (e.g. from wind farms and at night from nuclear power stations) may be used to pump water uphill to the reservoir. Later, when peak electricity is needed, the water can be returned downhill to generate the necessary 'extra' power.

Pumped Storage Scheme

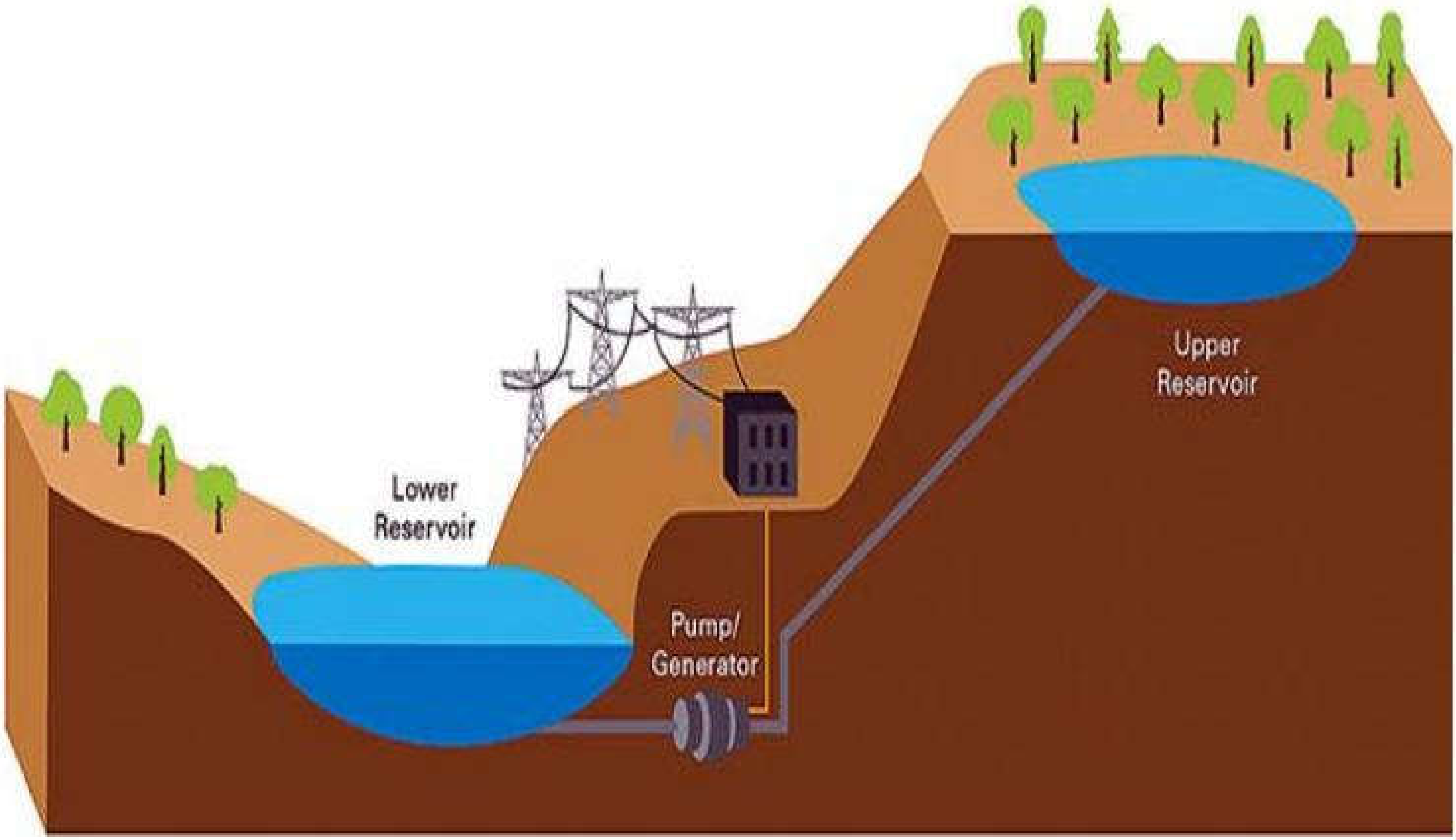
The top reservoir of a pumped storage scheme may (a) accept rainfall within a catchment (as with conventional hydropower), and (b) receive water pumped from the lower 'reservoir'.

You must have heard in TV and read in news-papers that a certain dam's water level is now only such and such Low level. Worst case is if the natural dam is empty then no electric power will be generated until the dam is refilled. So we have to wait for natural rain or snow to melt and transfer water from mountains to the dam.

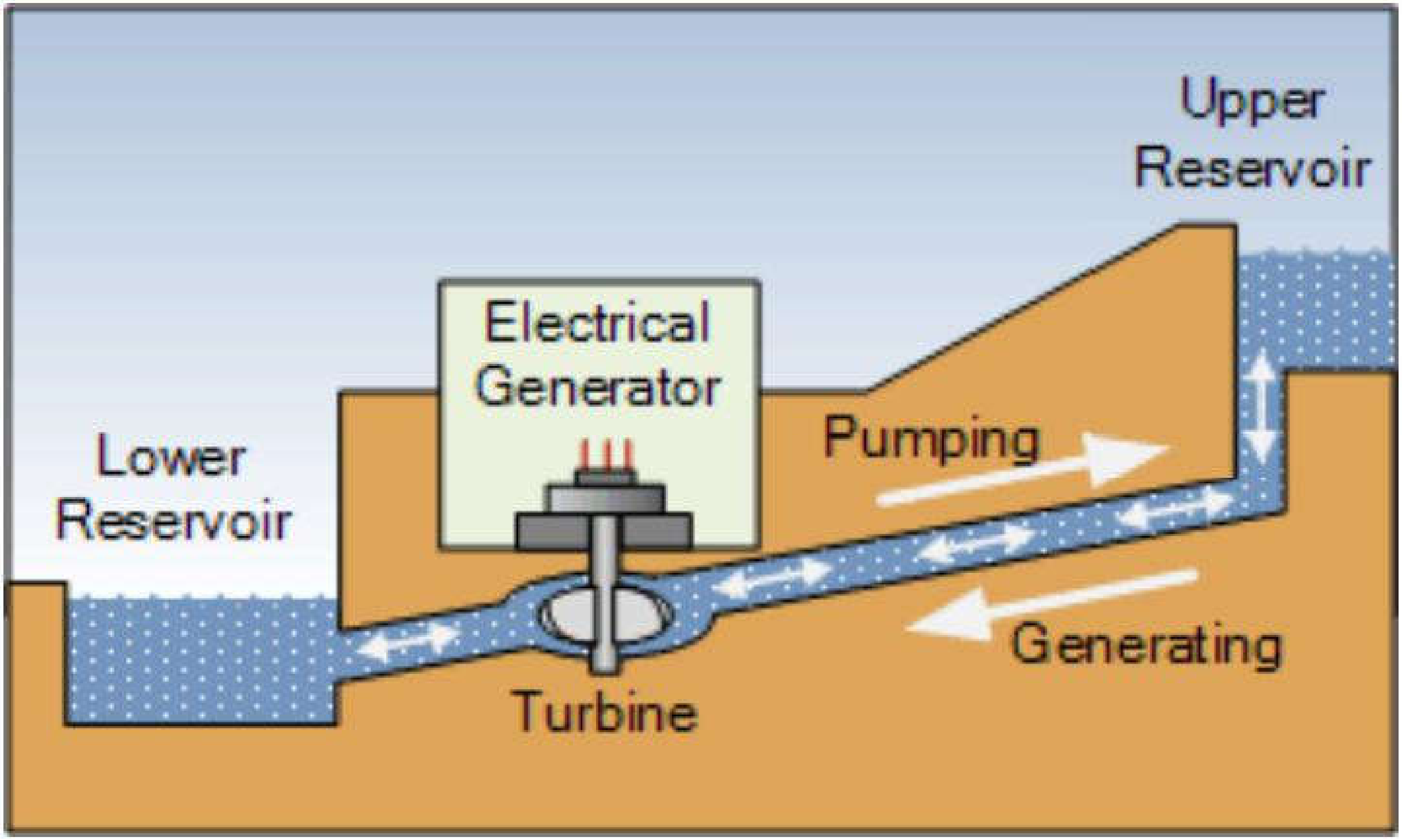
Engineers have proposed a solution for such situation. The solution is called **Pumped storage scheme**. The concept is to refill the dam with the same water by installing a ***pump*** to push the water back.

The ratio of energy out to energy in (i.e. the efficiency of storage) is about 70%.

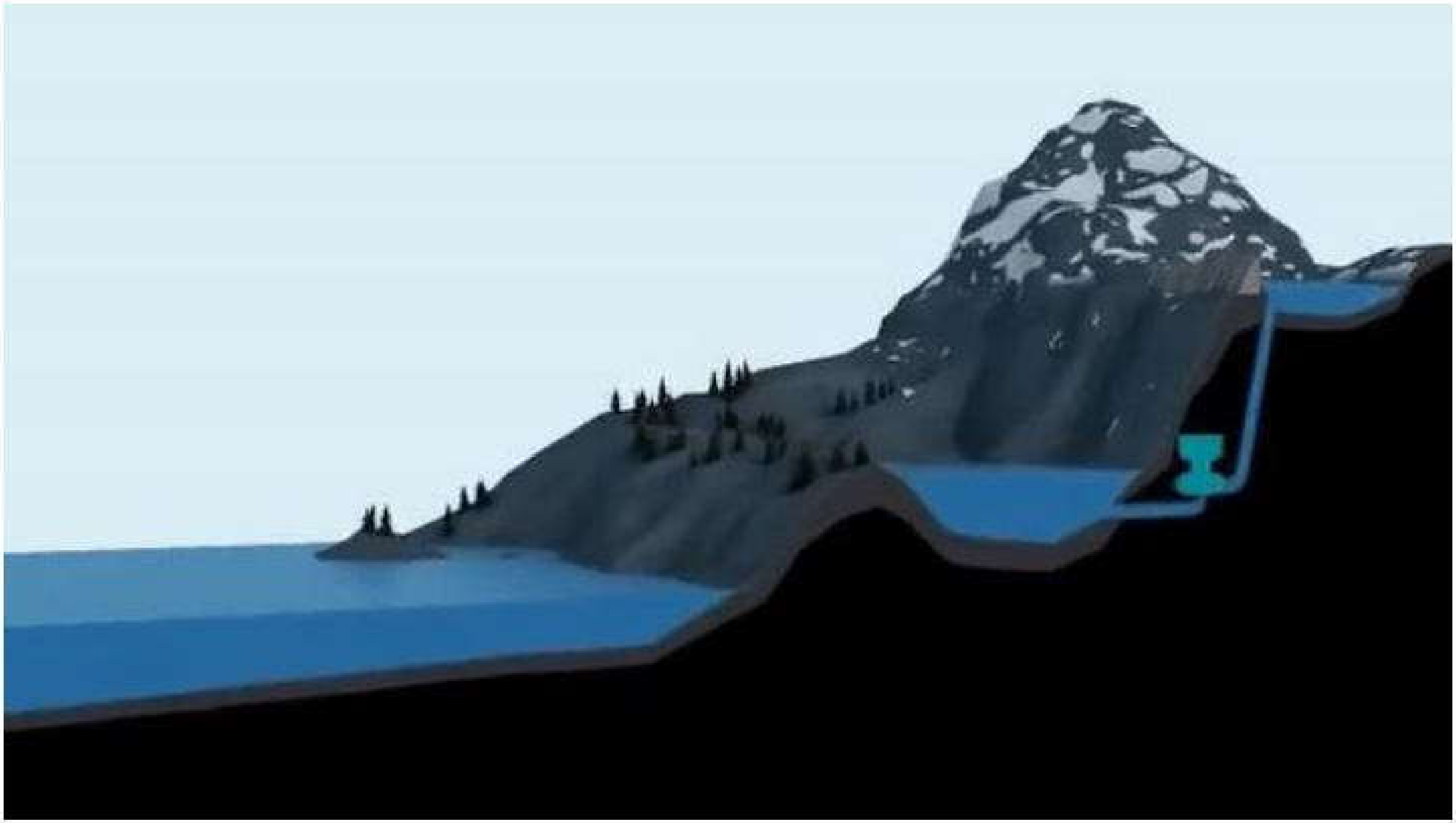
Pumped Storage Scheme



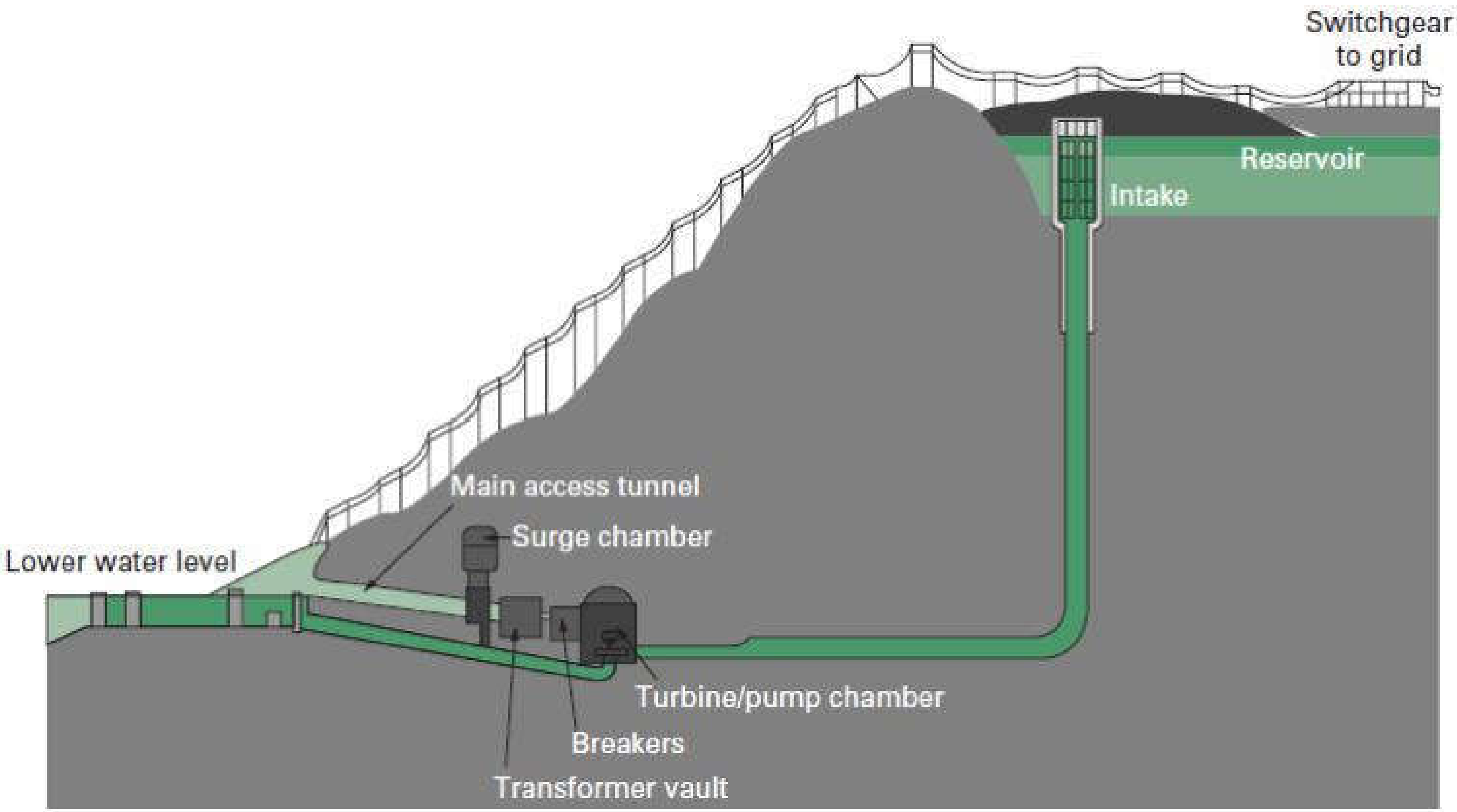
Pumped Storage Scheme

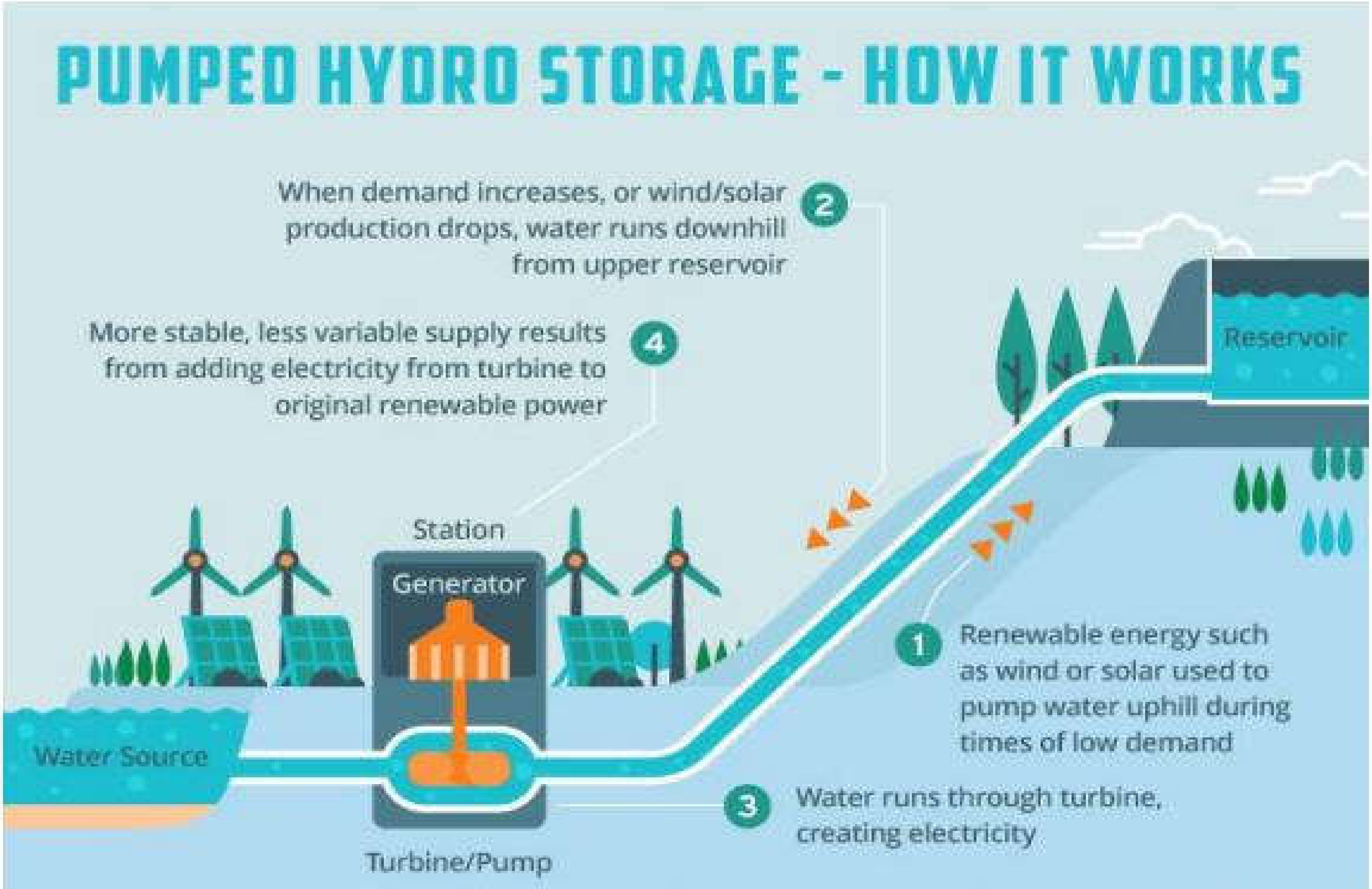


Pumped Storage Scheme...*Animation*

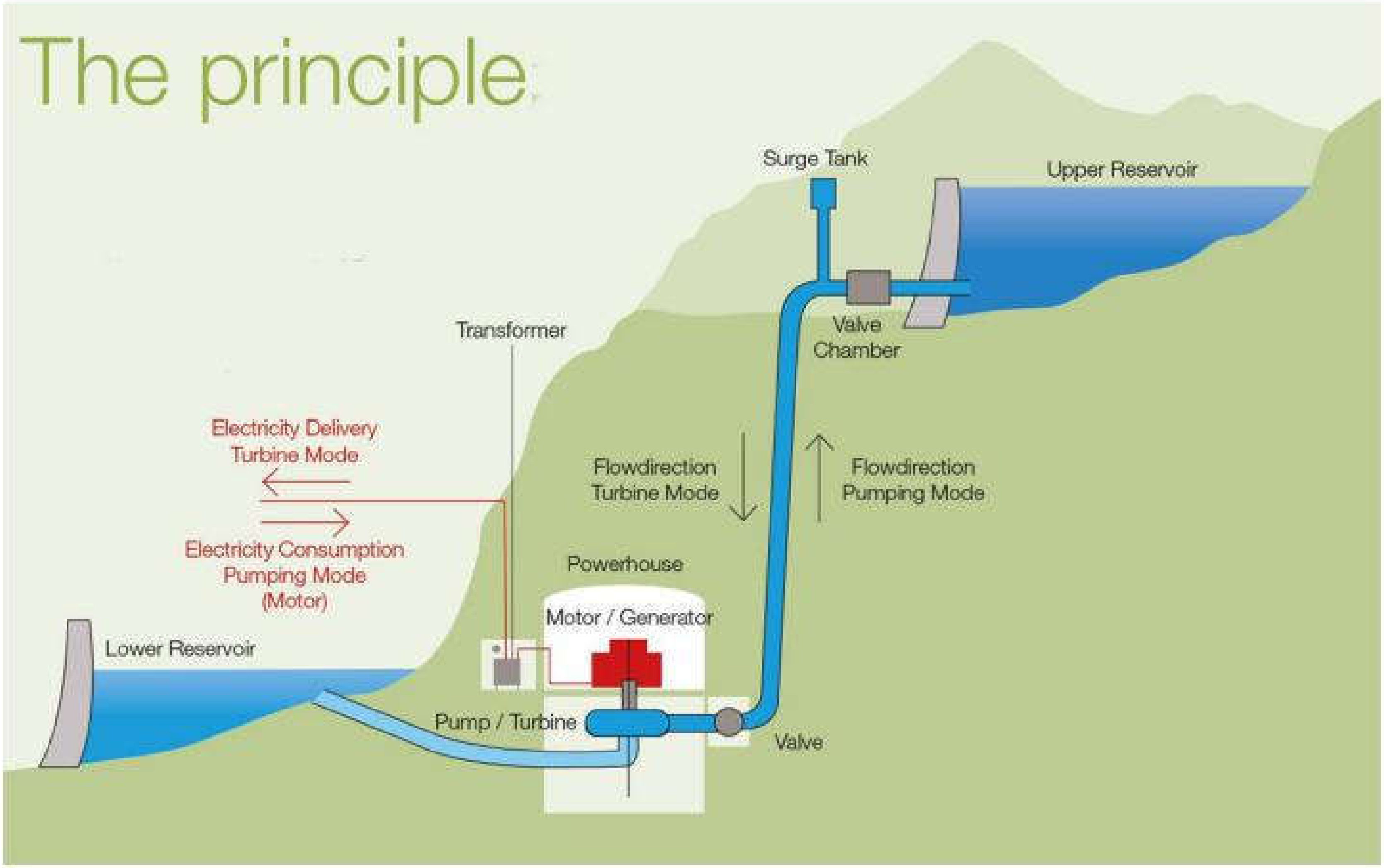


Pumped Storage Scheme




PUMPED HYDRO STORAGE - HOW IT WORKS
When demand increases, or wind/solar production drops, water runs downhill from upper reservoir
2
More stable, less variable supply results from adding electricity from turbine to original renewable power
4
Reservoir
Station
Generator
1
Renewable energy such as wind or solar used to pump water uphill during times of low demand
Water Source
3
Water runs through turbine, creating electricity
Turbine/Pump

Pumped Storage Scheme



Hydropower: Social and Environmental Aspects

Hydropower is a mature technology worldwide.
About 16% of world electricity is hydroelectricity. Hydroelectric plant is not thermally stressed and operates steadily; therefore it is long-lasting with relatively low maintenance requirements: many systems, both large and small, have been in continuous use for over 50 years and some early installations still function after 100 years.

The relatively large initial capital cost has been long since written off, with the 'levelized' cost of electricity produced (i.e. the cost per kWh averaged over the life of the system) much less than other sources,

For hydro plant with an ample supply of water, the flow can be controlled to produce either baseload or rapidly peaking power as demanded; if the water supply is limited, then sale of electricity at only peak demand is easy and most profitable.

Hydropower: Social and Environmental Aspects

Most large dams are built for multiple purposes: electricity generation, water for potable supply and irrigation, controlling river flow, mitigating floods, and providing road crossings, leisure activities, fisheries, etc.

National Social and economic development always requires electricity and water supply, so large-scale projects appeal to national development.

Hydropower: Social and Environmental Aspects

Hydropower, like all renewable energy sources, mitigates emissions of the greenhouse gas CO^2.

Estimates of the life cycle greenhouse gas (GHG) impact of hydropower systems are less than **40 gCO^2-eq/kWh**, which is an order of magnitude less than for fossil systems

Merits & Demerits of Hydro Electric Power

- **Merits**
- Once a dam is constructed, electricity can be produced at a constant rate.
- If electricity is not needed, the sluice gates can be shut, stopping electricity generation. The water can be saved for use another time when electricity demand is high.
- Dams are designed to last many decades and so can contribute to the generation of electricity for many years / decades.
- The Reservoir that forms behind the dam can be used for water sports and leisure / pleasure activities. Often large dams become tourist attractions in their own right.
- The Reservoir water can be used for other purposes such as irrigation.
- Minimum operating staff is required for the operation of hydro power plant.
- Non Polluting and hence environmental friendly energy is produced.
- Low cost of energy generation & maintenance.

Merits & Demerits of Hydro Electric Power

- **Demerits**
- Land acquisition is the major problem as construction of dam causes large submergence of land. Many political, regional, and social hurdles comes in the process of land acquisition
- Hydro- Power project takes long time for clearance.
- Rehabilitation and resettlement of displaced people is a major problem associated to any hydropower project.
- Large scale initial investment is required.

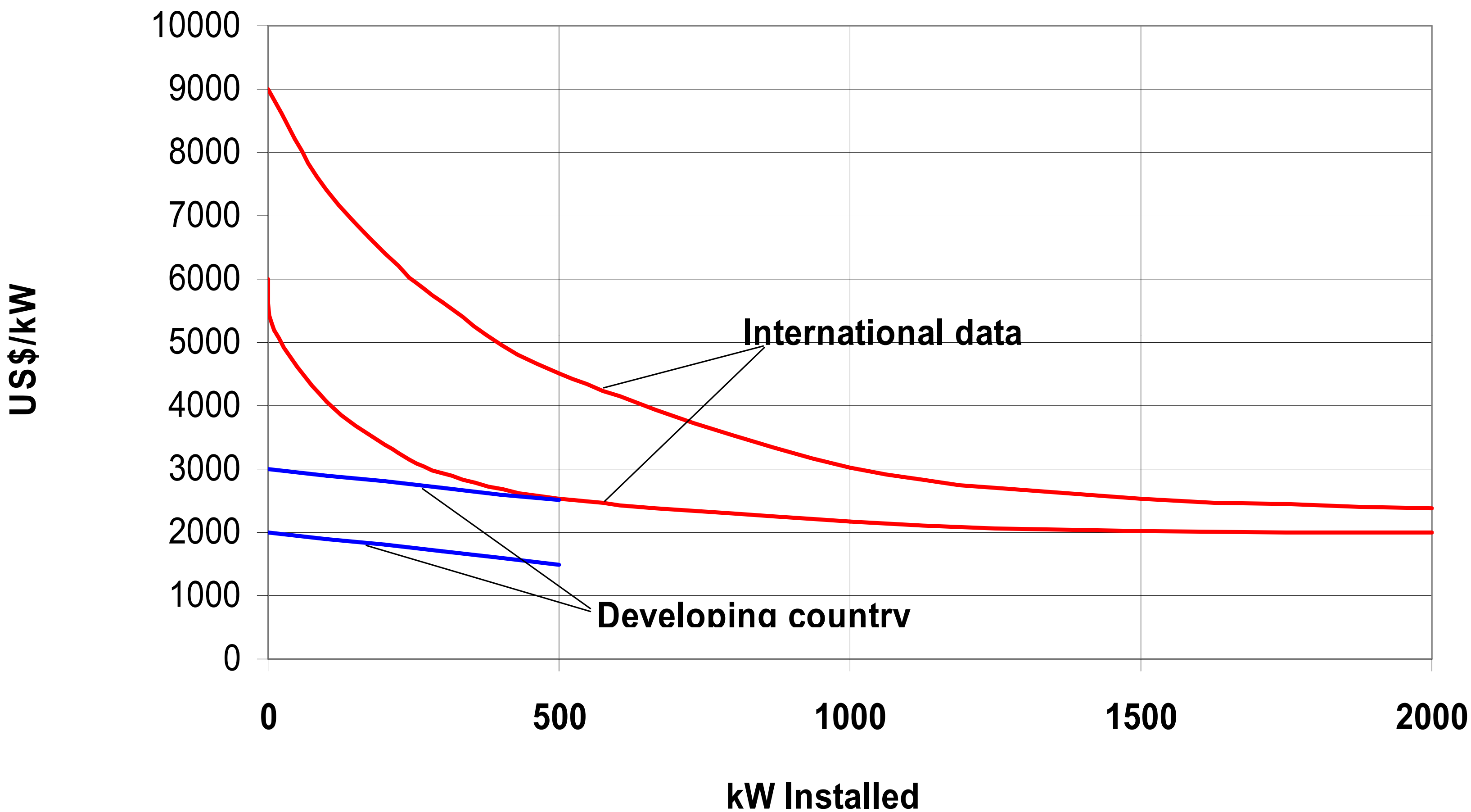
Merits & Demerits of Hydro Electric Power

- The high cost of dam construction means that they must operate for many decades to become profitable.
- The Submergence of large areas of land means that the natural environment is destroyed.
- The building of large dams can cause serious geological damage.
- Although modern planning and design of dams is good, in the past old dams have been known to be breached this has led to deaths and flooding.
- Dams built blocking the progress of a river in one country usually means that the water supply from the same river in the following country is out of their control. This can lead to serious problems between neighboring countries.
- Building a large dam alters the natural water table level.

Capital cost of hydro power plants

- Small hydro, $1000-3000/kW, developing countries
- Small hydro, $2000-9000/kW, developed countries
- Large hydro (involving dams and reservoirs), $2000-8000/kW (including access roads for high estimates)

Small-hydro capital cost



Source: Paish (2002, *Renewable and Sustainable Energy Reviews* 6, 537–556, http://www.sciencedirect.com/science/journal/13640321)

Cost of hydro-electricity (cents/kWh)

Table Cost of hydro-electric energy (cents/kWh) for various capital costs, interest rates, and capacity factors, assuming amortization of the initial investment over a 50-year period. Operation and maintenance, insurance, water rent, transmission, and administrative costs are not included.

Interest Rate:	0.03	0.03	0.06	0.06	0.09	0.09
Capacity Factor:	0.3	0.6	0.3	0.6	0.3	0.6
Capital Cost						
$1000/kW	1.48	0.74	2.41	1.21	3.47	1.74
$2000/kW	2.96	1.48	4.83	2.41	6.94	3.47
$4000/kW	5.92	2.96	9.66	4.83	13.89	6.94
$8000/kW	11.83	5.92	19.31	9.66	27.77	13.89

A hydro electric station is to be designed for a catchment area of 200 sq. km. run off of 70% and the average rainfall of 130 cm. per annum. The head available is 380 m. What power can be developed if the overall efficiency of the plant is 80%?