Chapter Seven

Hydroelectric Power Plants

محطات القدرة الكهرومائية

Introduction:

Water covers more than 70 percent of the Earth's surface. Using environmentally responsible technologies, we have a tremendous opportunity to harness water resources to provide clean and reliable power. Worldwide, hydropower plants produce about 19 percent of the world's electricity. The world's hydropower plants output a combined total of 675,000 megawatts, the energy equivalent of 3.6 billion barrels of oil.

We have four methods to obtain energy from water resources:

1. Utilizing the ocean waves.
2. Utilizing the temperature difference of the top and bottom of ocean (OTEC).
3. Utilizing the energy of the flowing water caused by hydrological cycle.
4. Utilizing the Tidal movements.

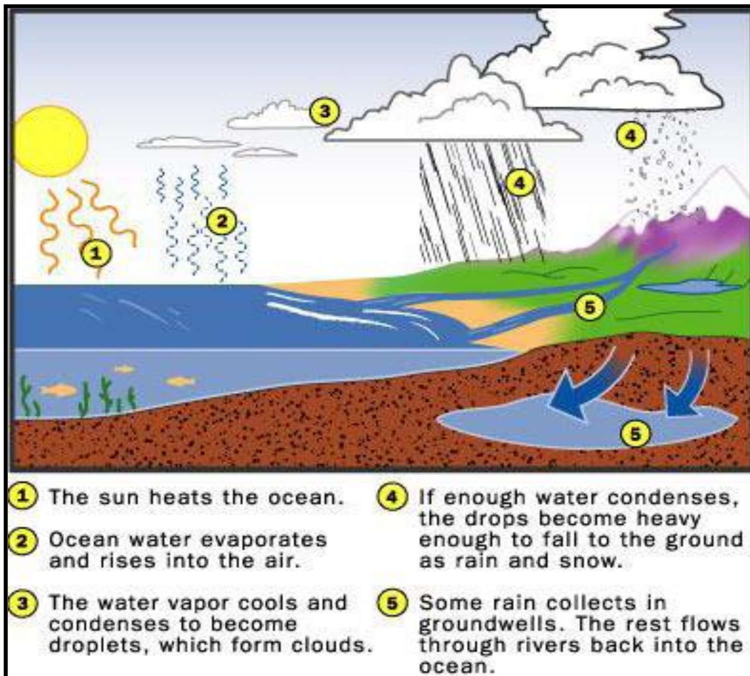


Fig.1 The hydrological cycle

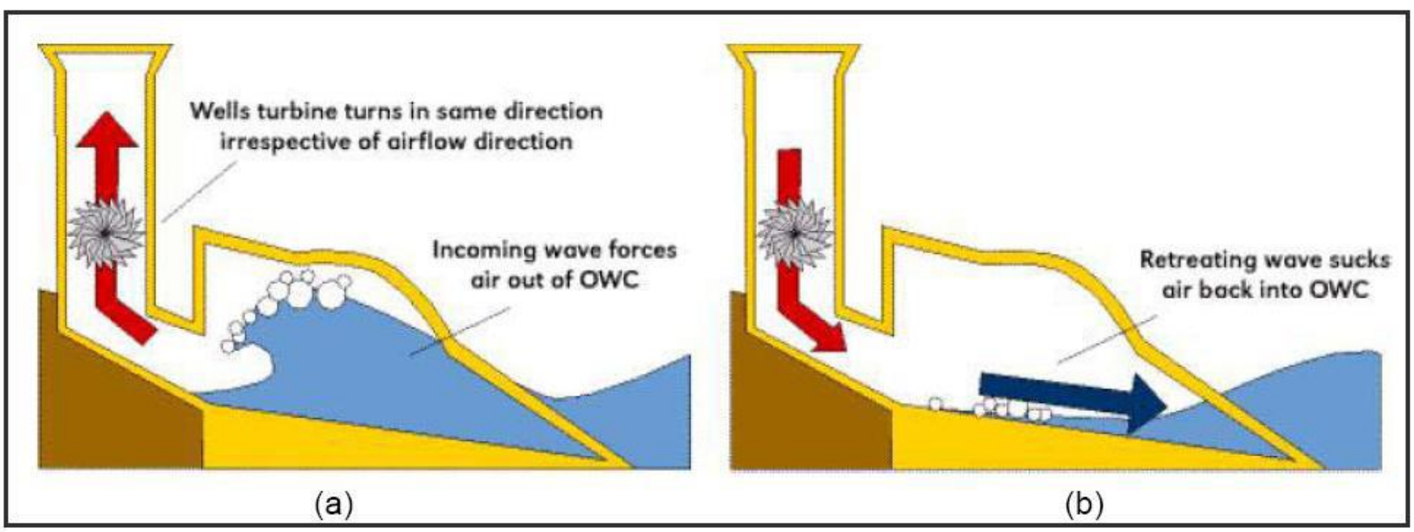


Fig.2 An Oscillating Water Column with (a) wave water flow and (b) wave water ebb

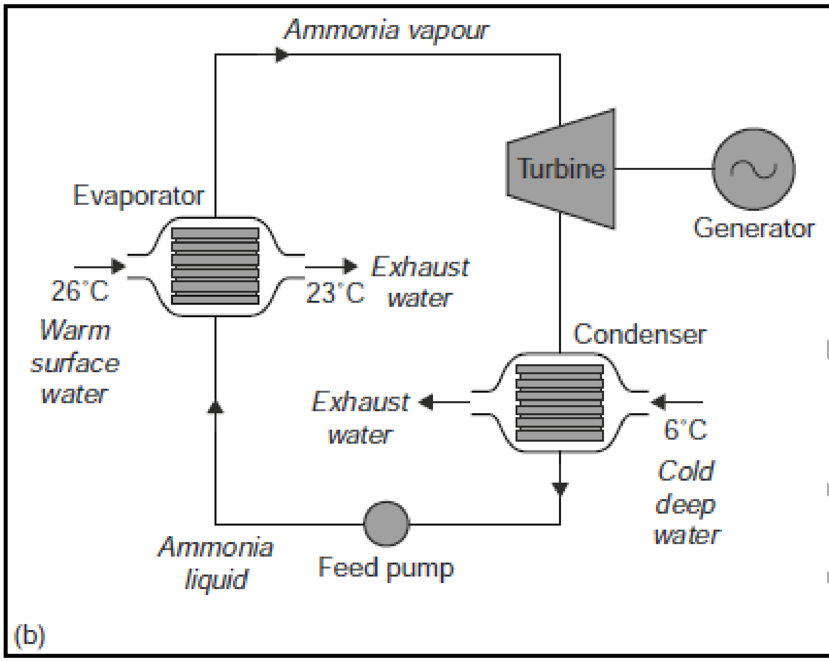
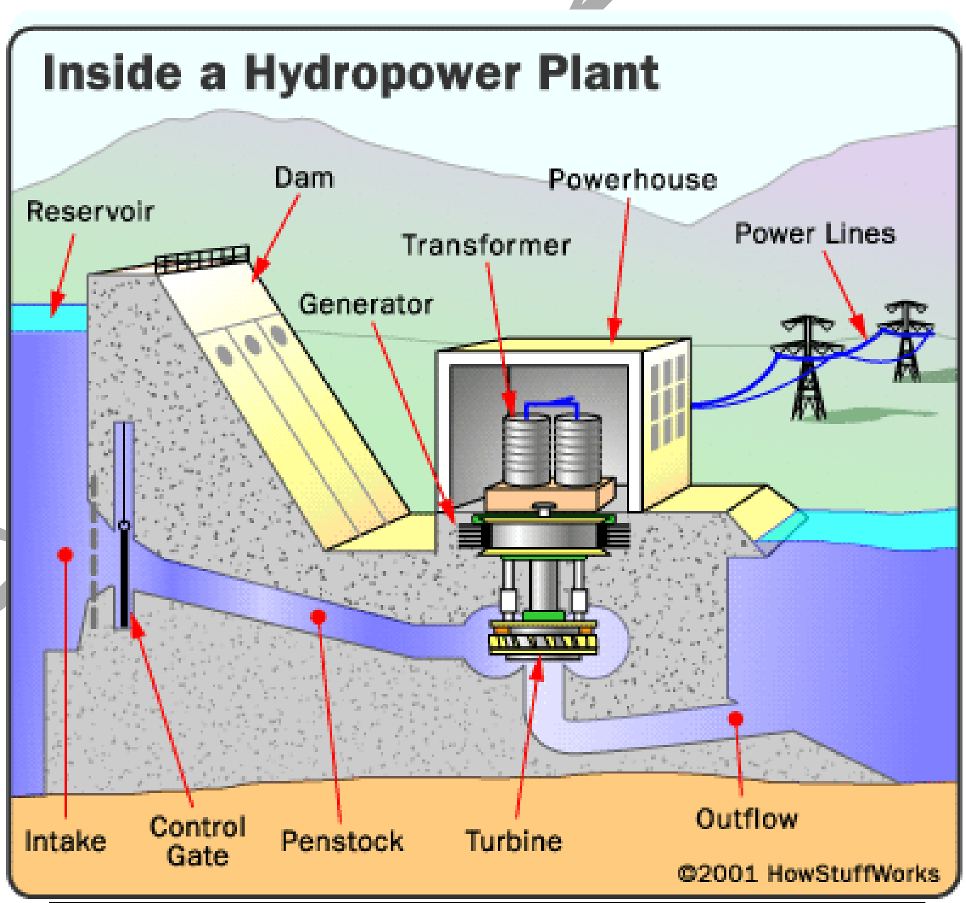


Fig.3 :Ocean thermal energy conversion (OTEC)



Hydroelectric power plant with dam

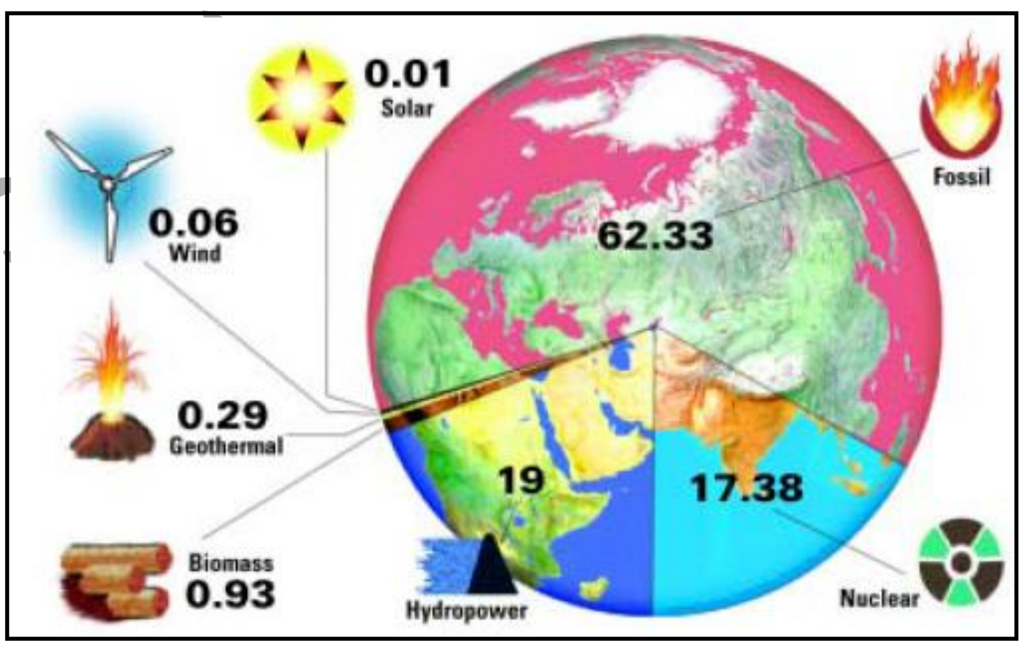
Energy conversion in hydroelectric power plant:

Potential energy of water (head) → Kinetic energy of water → Mechanical energy of rotating shaft → Electrical energy from generator

Main hydroelectric power plant in Iraq:

Name	No of units	company	Capacity-MW	Turbine type
Mousl	4	Toshiba-Japan	750	Frances
Haditha	6	INGRA CROATIA	660	Kaplan
Dokan	5	Techo Prom export-Russia	400	Frances
Darbendkan	2	Mitsubishi-Japan	166	Frances

World Energy Sources:



Advantages of Hydroelectric power plants:

Major advantages of hydroelectric stations are:

1. The plant is highly reliable and its operation and maintenance cost are very low.
2. It has quick starting and can be brought on load within few minutes.
3. The plant and associated civil engineering structure have a long life.
4. It has no smoke, exhaust gases, soot, or thermal pollution.
5. Due to low temperature and speed (300-400r.p.m) (compared to 3000-4000 r.p.m in thermal plants), the machines used has no complications concerning special alloys ..etc.

Disadvantages of Hydroelectric power plants:

The hydroelectric power plants have the following disadvantages:

1. The initial cost of the plant including the cost of dam is high.
2. It has special requirement of site which usually is an isolated area with difficult access.
3. The availability of the power from such plant is not much reliable because it depends on the quantity of rain which may be low.
4. It takes long time for construction compared to thermal plants.
5. While electricity from flowing water can be an excellent source of ‘renewable energy’, the generation of electricity in this way needs to be considered carefully for environment. This includes potentially significant impacts on fish and other species, and upstream and downstream human settlements.

History of Hydro Power:

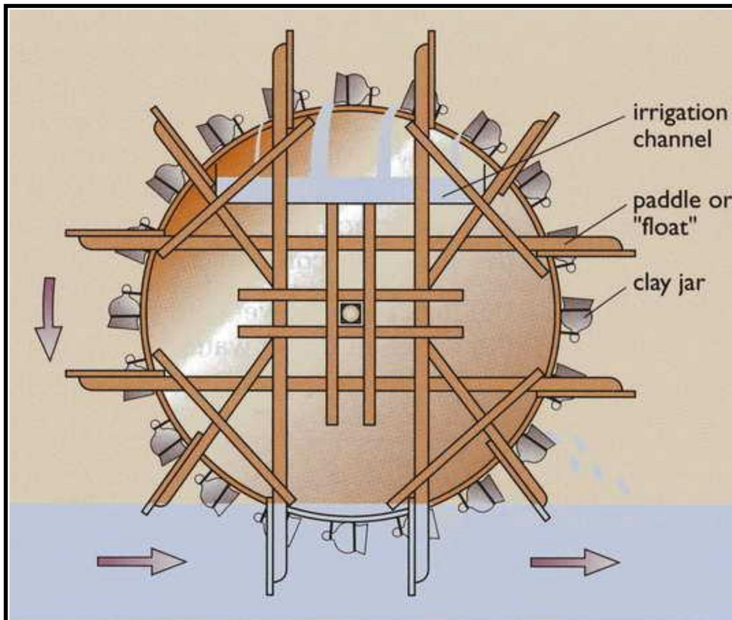


Figure 5.5 A noria. In this earliest water-wheel the paddles dip into the flowing stream and the rotating wheel lifts a series of jars, raising water for irrigation

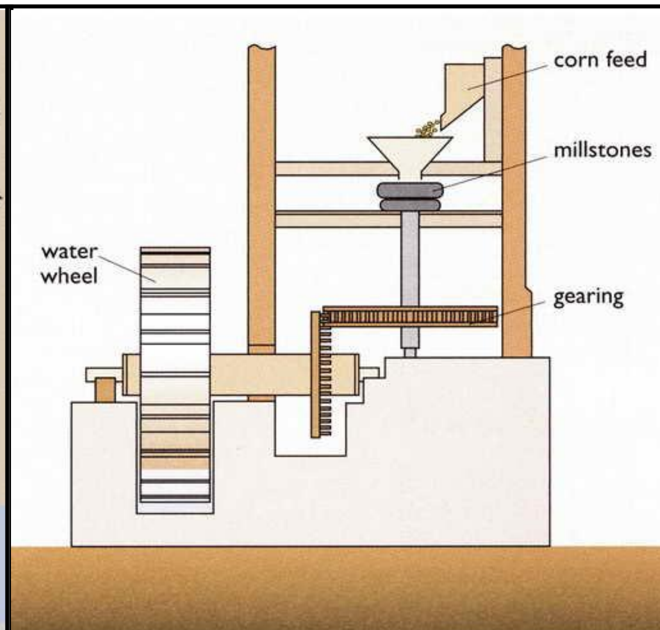


Figure 5.7 A Roman mill. This corn mill with its horizontal-axis wheel was described by Vitruvius in the first century BC. Note the use of gears

Water turbine Types used for hydroelectric power plants:

Water turbine is the prime mover of the hydroelectric power plant. It converts the power of water (head plus volume flow rate) into mechanical energy.

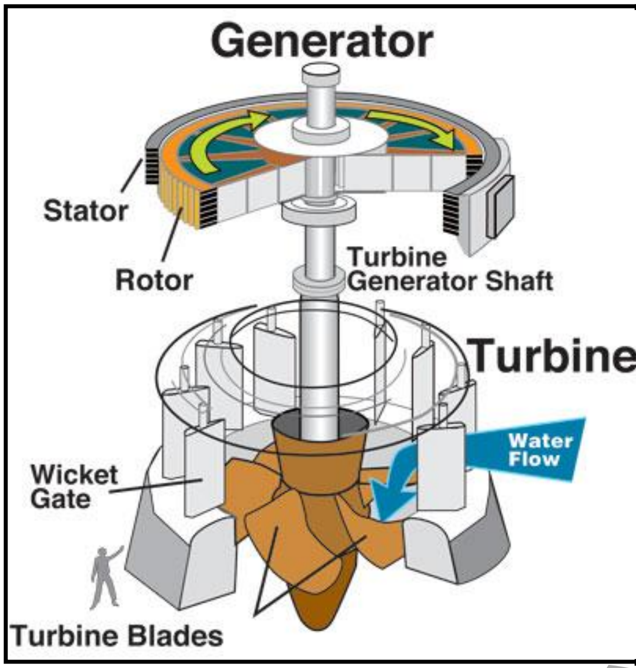
They can be divided into two main types:

1. Impulse Turbines: This works under atmospheric pressure. The whole energy of the water supplied to the wheel being in the form of kinetic energy and the expansion occurs in the nozzles only (No expansion in the turbine blades or No pressure drop across turbines)**.** This type of turbine is preferred to use with high heads (up to 300m).

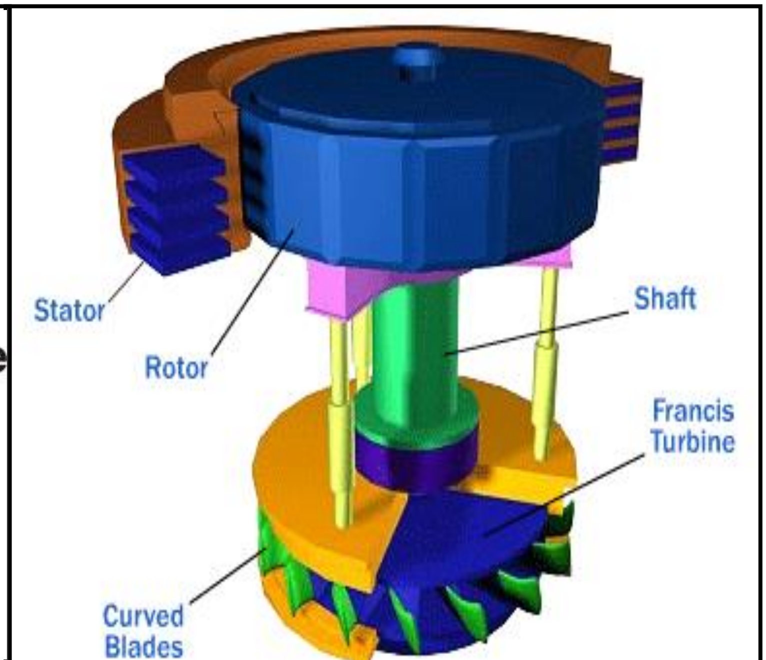
Examples are Pelton and Turgo

2. Reaction Turbines: This works under pressure much higher than atmospheric. The energy of the water supplied is mostly in the form of pressure energy, so they must be totally immersed in water. This type of turbines is preferred to use with low head

Examples are Francis, and Kaplan turbines



Kaplan Turbine Schematic



Francis Turbine Schematic

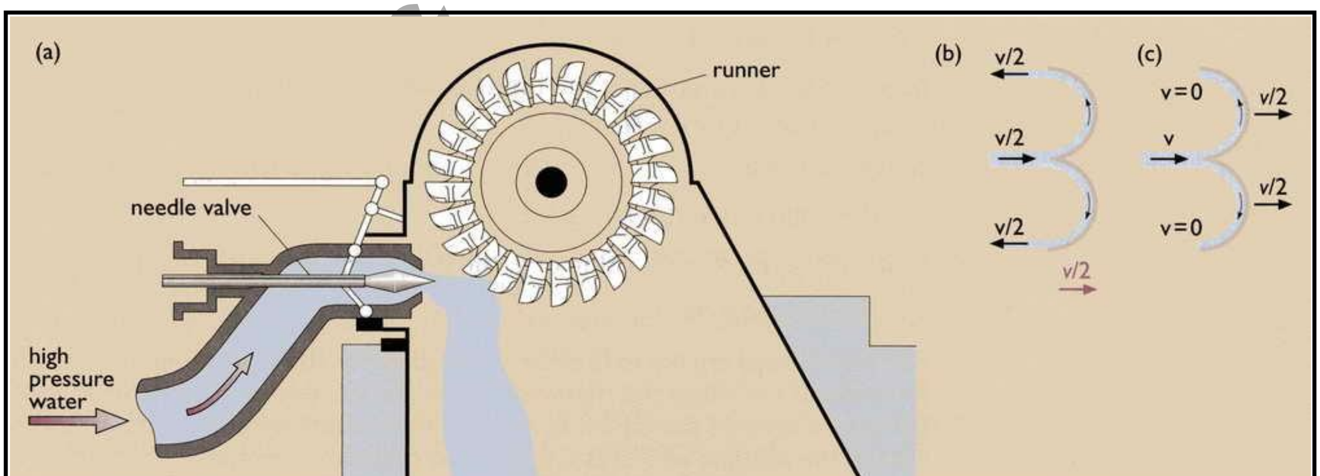


Figure 5.21 Pelton wheel turbine: (a) vertical section; (b) water flow as seen from moving cup; (c) actual motion of water and cup

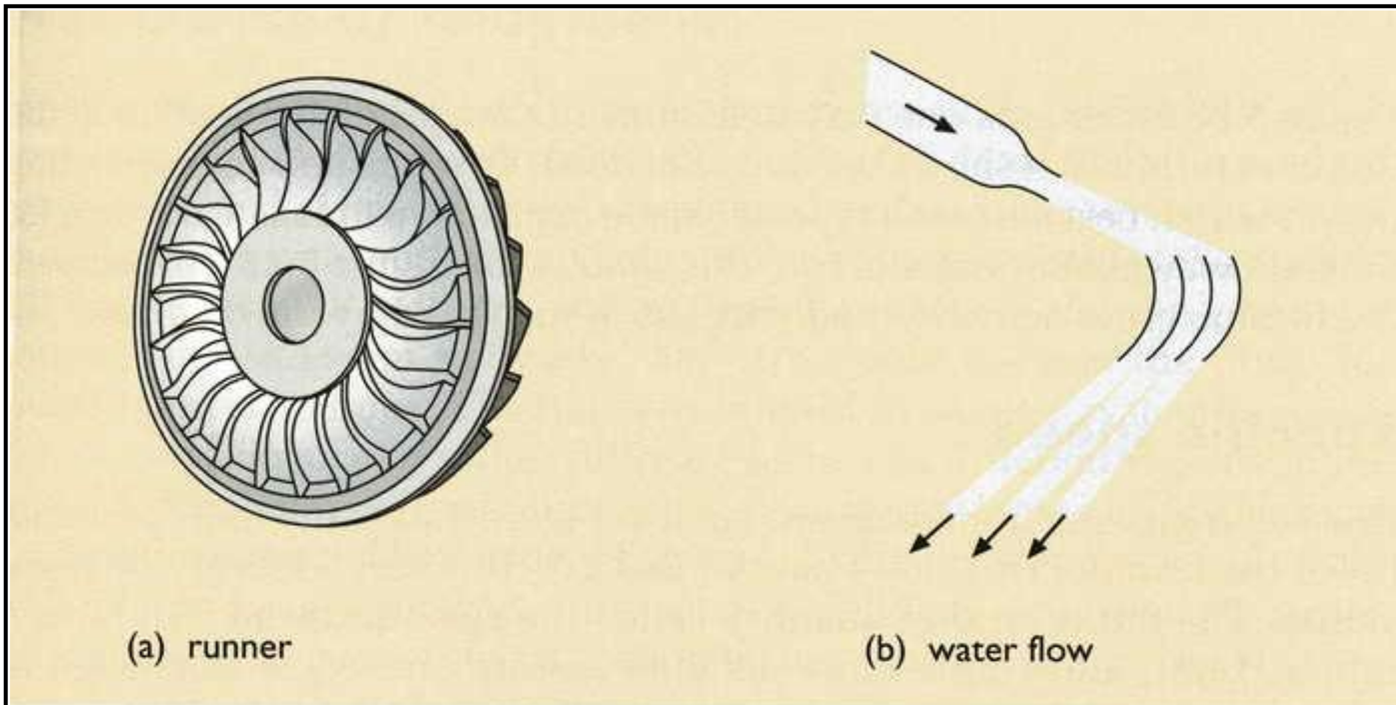
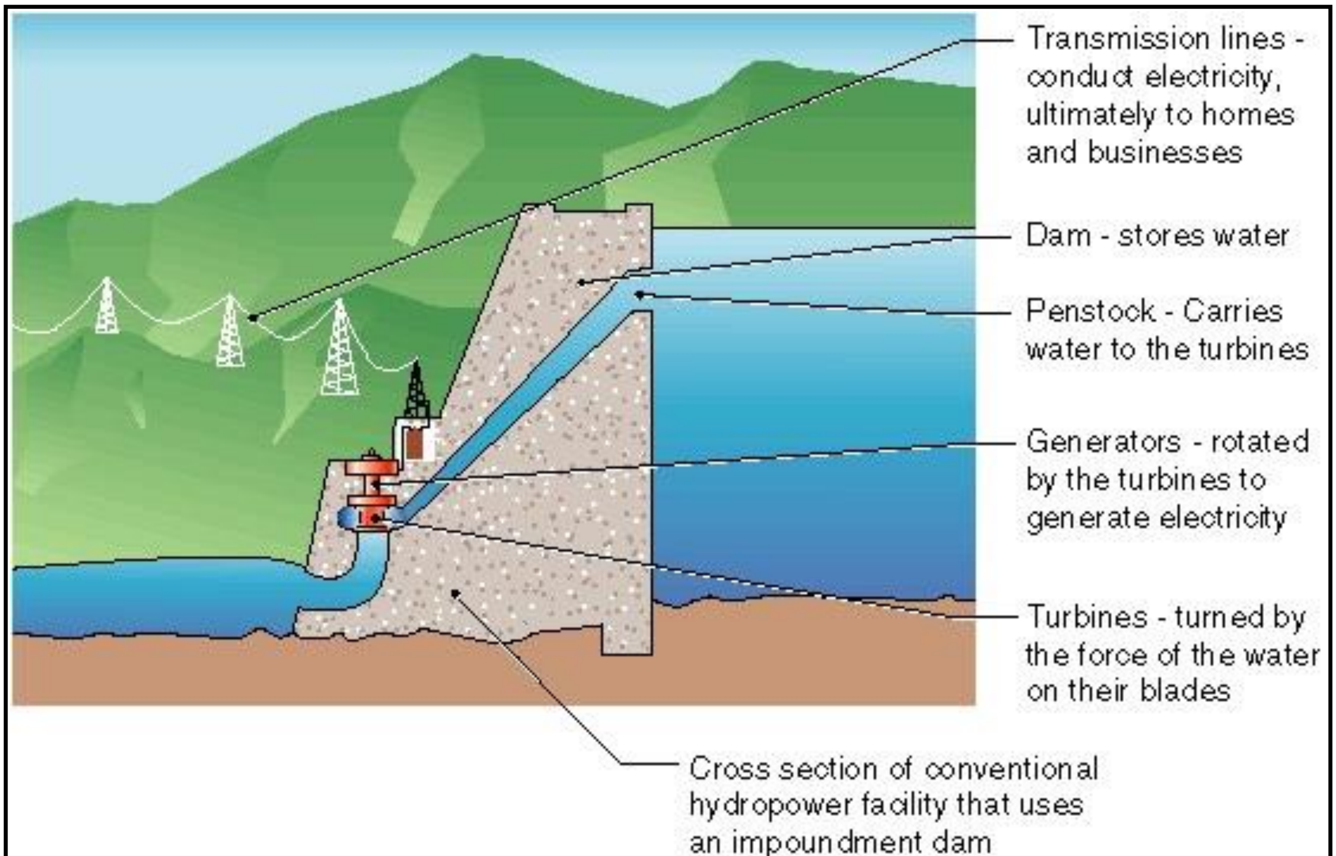


Figure 5.22 Turgo turbine: (a) runner; (b) water flow

Classification of hydroelectric power plants:

Hydroelectric power plants can be classified into three main types:

1. **Conventional**: Water stored in high-elevation lakes or held by dams creates high-pressure water at the bottom of the dam. The energy stored in the high-pressure water can be converted to shaft work using hydroelectric turbines to produce electricity.



2. Pumped storage:

When the demand for electricity is low, a pumped storage plant stores the surplus energy by pumping water from a lower reservoir to an upper reservoir using reversed turbine machinery. During periods of high electrical demand, the water is released back to the lower reservoir to generate electricity. So it is a two way flow and can be regarded as a mechanism for energy storage, not net energy production

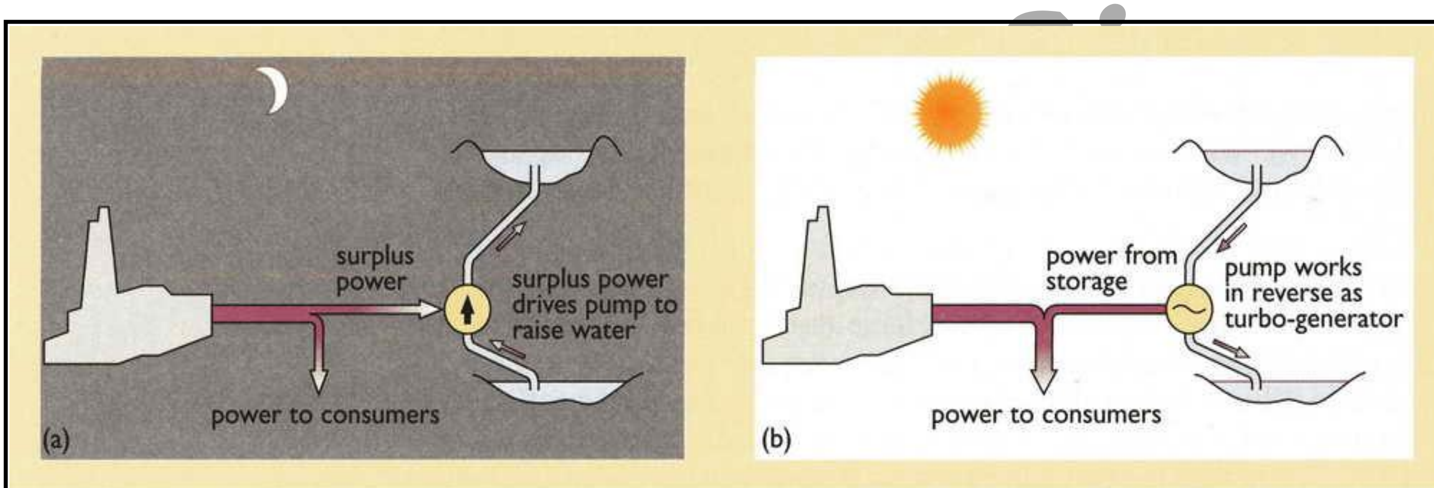


Figure 5.27 Pumped storage system: (a) at time of low demand; (b) at time of high demand

3. Diversion.

A diversion, sometimes called run-of-river, facility channels a portion of a river through a canal or penstock. It may not require the use of a dam.

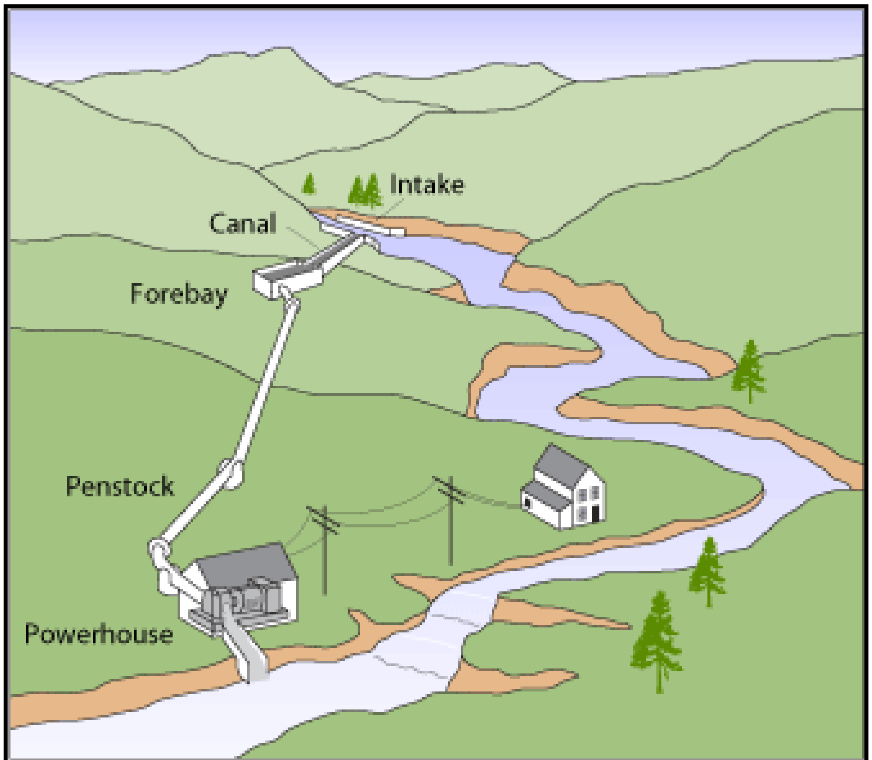


Fig. 4 : the diversion hydroelectric power plant

Hydro Power Calculations:

Hydroelectric power plant is very efficient. It has overall efficiency ranges from 75-95%.

Typical losses are due to:

*Frictional drag and turbulence of flow

*Friction and magnetic losses in turbine & generator

The power developed by the plant is given by:

$$P = (g \times \rho \times H) \times Q \times \eta$$

Where:

- P = power in kilowatts (W)
- g = gravitational acceleration (9.81 m/s^2)
- η = turbo-generator efficiency ($0<n<1$)

- Q = quantity of water flowing (m^3/sec)
- H = effective head (m)
- $\rho =$ water density ($1000\,kg/m^3$)

Example:

Consider a mountain stream with an effective head of 25 meters (m) and a flow rate of 600 liters (ℓ) per minute. How much power could a hydro plant generate? Assume plant efficiency (η) of 83%.

H = 25 m

Q=600(ℓ/min)×1(m^3/1000ℓ)×1(min/60sec)

Q = 0.01 m^3/sec

η = 0.83

P=9.81*$\eta QH\rho$=(9.81)(0.83)(0.01)(25)(1000)=2035.6W

How much energy (E) will the hydro plant generate each year?

E=P×t

E=2035.6W*(1/1000)*24hrs/day*365days/yr

E = 17831.64 kWh annually

About how many people will this energy support (assume approximately 3,000 kWh / person)?

People = E÷3000 = 17835.36/3000 = 5.944

About 6 people

H.W

Consider a second site with an effective head of 100 m and a flow rate of 6,000 cubic meters per second (about that of Niagara Falls). Answer the same questions.