HYDRO POWER

Flowing water creates energy that can be stored, captured and turned into electricity. Hydropower is the world's most important renewable energy source. It provides 7.2% of world's primary energy and 18.5% of electric power generation.

In the Philippines, hydropower provides 5% of primary energy and 16% of electric power generation. Again, hydropower owes its energy from the Sun, which causes water to move around the world in a never ending hydrologic cycle.

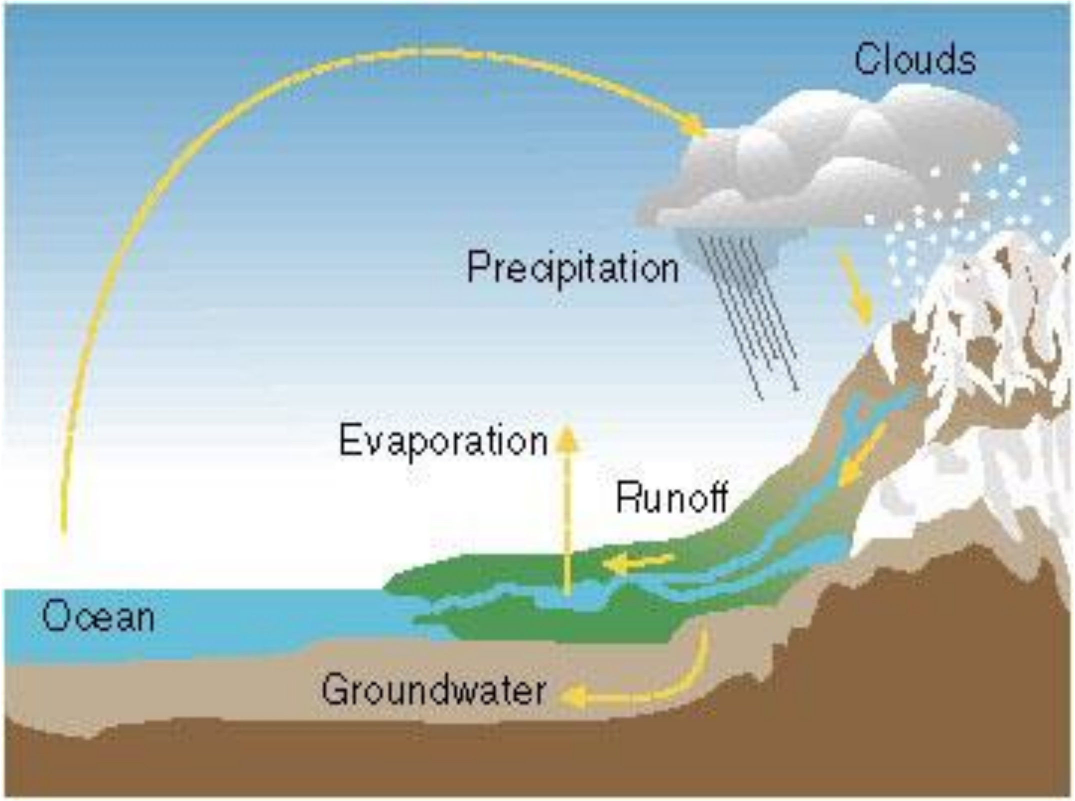
Topics – Hydro Power

- Hydro Power, Its Uses and History
- Hydrologic Cycle
- How Hydropower Works – Principle
- Hydropower Resource Potential
- Types of Hydropower
- Water Turbine Technologies
- Cost of Hydro Power (Capital, O&M, Levelized)
- Hydropower Plants in the Philippines
- Rainfall and River Flow (Hydrological Data)
- Environmental Impact & Risks

History of Hydropower

- **85 BC –** first known reference to hydropower in a Greek poem
- **First century AD –** waterwheels for grinding grain were used by the Romans
- **1086 AD –** the Doomsday Book recorded 5,000 were in use in South England; these early waterwheels were made of wood
- **18th century –** iron was first used by an English engineer – John Smeaton
- **19th century –** the modern hydraulic turbine descended from the Greek and Roman machines; developments in the 19th century led to two branches: impulse (Pelton, 95% efficiency) and reaction (Francis, Kaplan, > 75% efficiency) turbine.

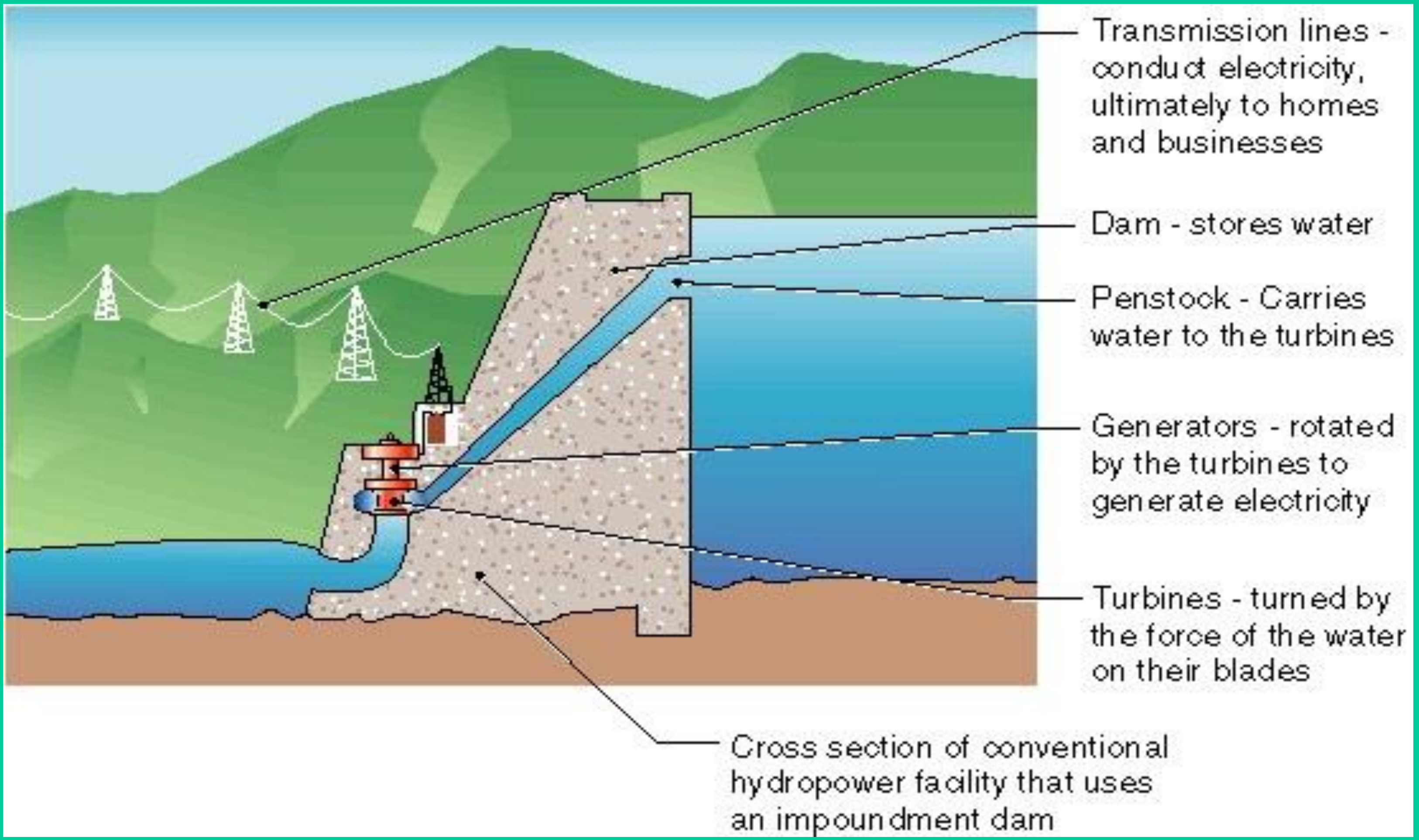
The Hydrologic Cycle



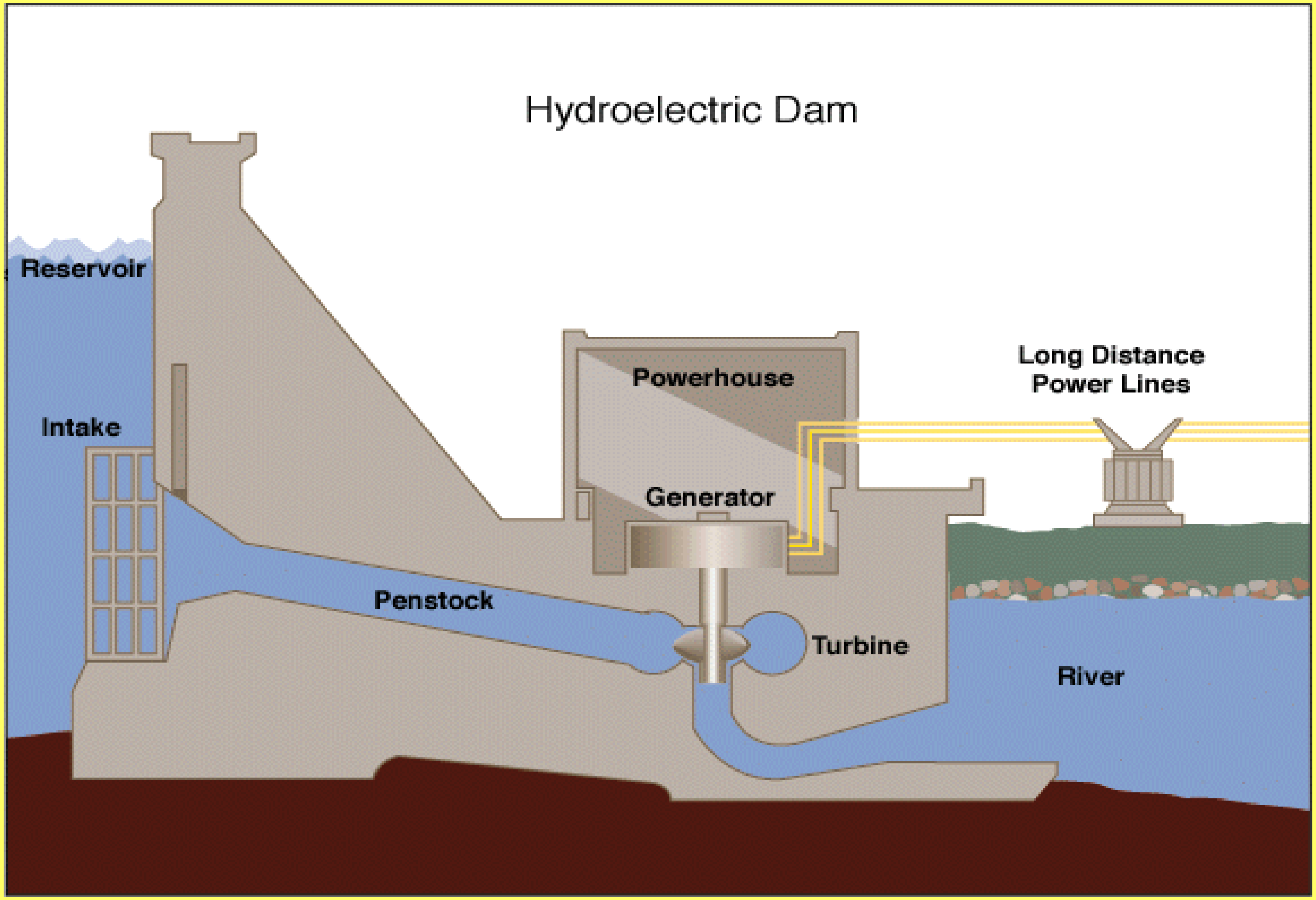
Water constantly moves through a vast global cycle, in which it evaporates from the lakes and oceans, forms clouds, precipitates as rain or snow and flows back as runoff to the ocean via lakes, rivers and groundwater.

The energy of this water or hydrologic cycle comes from the Sun, hence hydropower is renewable. But weather disturbances like **El Niño** and **La Niña** cause imbalance in the water supply worldwide.

How Hydropower Works



Hydroelectric Dam (Impoundment)



Hydropower Resource Potential

- Global installed hydropower capacity is around 610,000 MW generating about 2,240 TWh or 19% of total global output of 11,788,000 TWh (1990). (Global potential is 2,000 GW)
- World's hydropower potential is 34,231 TWh of which 13,100 has economic potential while 10,480 could be exploited further.
- Current exploitation of hydro is low in most parts of the world:

		Gross, TWh/year	**Exploited, %**
Africa		3,634	6
South America	)		18
North America	)	11,022	55
Asia/Middle East		13,399	18
Oceania		592	22
Europe		5,584	65
World Total		**34,231**	

Types of Hydropower

- **Impoundment –** typical large hydropower system use an impoundment facility like a dam to store river water in a reservoir; water may be released either to meet changing electricity needs or to maintain a constant reservoir level or to meet irrigation needs.
- **Diversion –** also called ***run-of-river***, channels a portion of a river through a canal or penstock to run a turbine; may not require the use of a dam.
- **Pumped storage –** when demand for electricity is low, say at night or weekend, a cheap source of electricity like nuclear power will pump water from a lower reservoir to an upper reservoir, where it is released back to the lower reservoir to generate electricity during periods of high or peak electrical demand

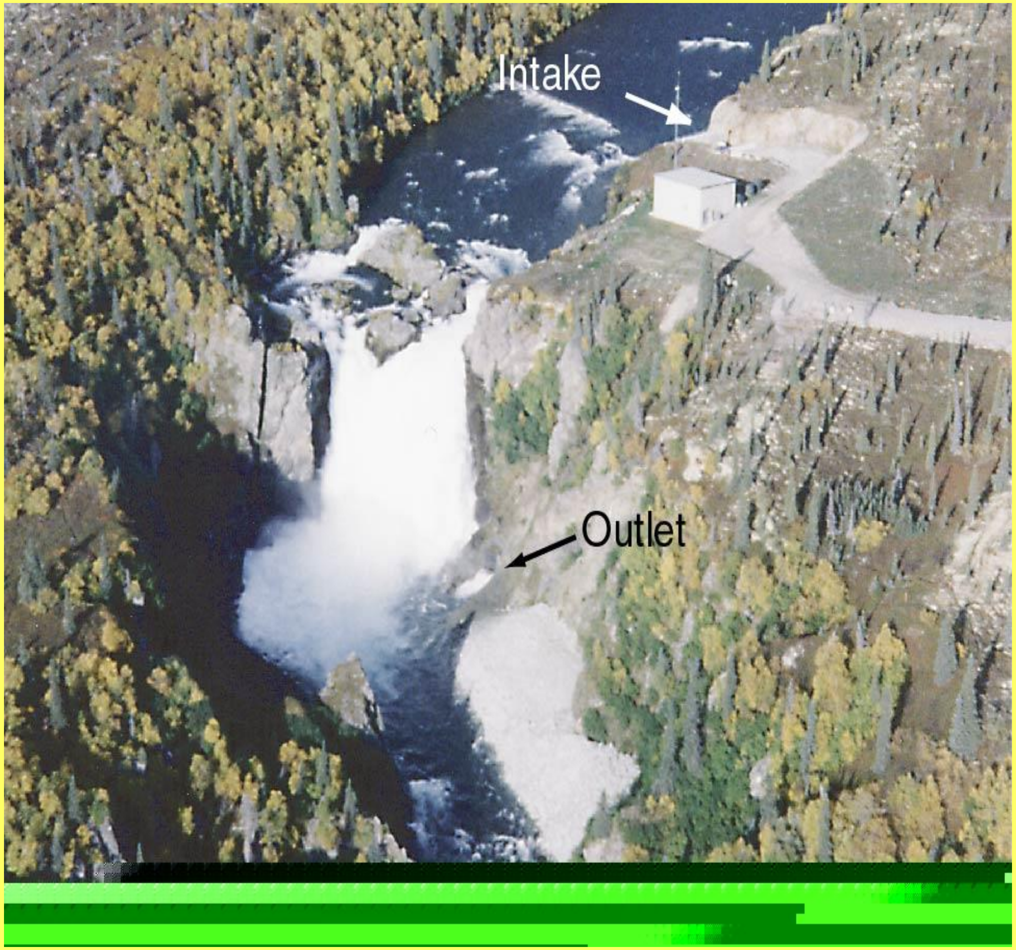
Impoundment Hydropower

The most common type of hydropower plant uses a dam on a river to store water in a reservoir. Water released from the reservoir turns a turbine that drives a generator.

Hoover Dam

NEVADA

Diversion Hydropower

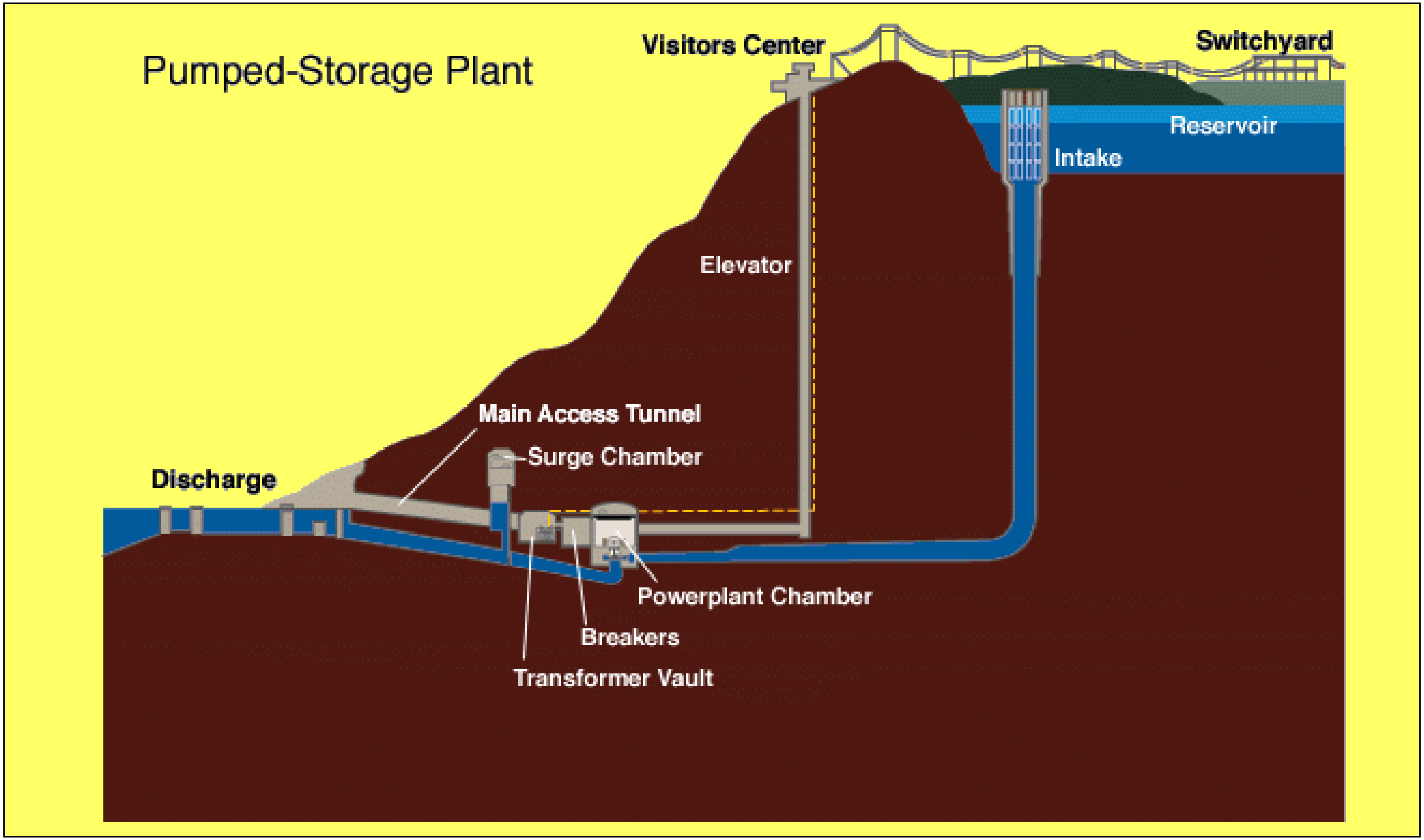


Diversion channels a portion of the river through a canal or penstock to turn a turbine. It may not require a dam, makes use of local topography.

Tazimina Project

ALASKA

Pumped Storage



Sizes of Hydropower Plants

- **Large hydropower –** US DOE defines large hydropower as facilities having capacity of greater than 30 MW. With regular maintenance, it could generate power for over 50 years.
- **Small hydropower –** capacity greater than 0.1 MW and up to 30 MW.
- **UNDP/WB**: 100 kW- 1 MW is **mini hydro**, 1 MW to 5-30 MW is **small hydro**).
- **Micro hydropower –** capacity of up to 100 kW.

Water Turbine Technologies

- **Pelton turbine –** has one or more jets of water impinging on the buckets of a runner that looks like a water wheel; used for high-head sites (50 to 6,000 ft) and as large as 200 MW.
- **Francis turbine –** has a runner with 9 or more fixed vanes; water enters the turbine in a radial direction with respect to the shaft and discharge in an axial direction; will operate form 10 to 2,000 ft of head and generate up to 800 MW.
- **Propeller turbine –** has a runner with 3-6 fixed blades like a boat propeller; water passes thru the runner and drives the blades; can operate from 10 to 300 ft of head and as large as 100 MW.
- **Kaplan turbine -** type of propeller turbine in which the pitch of the blades can be changed to improve performance, and can generate up to 400 MW.

Pelton Turbine

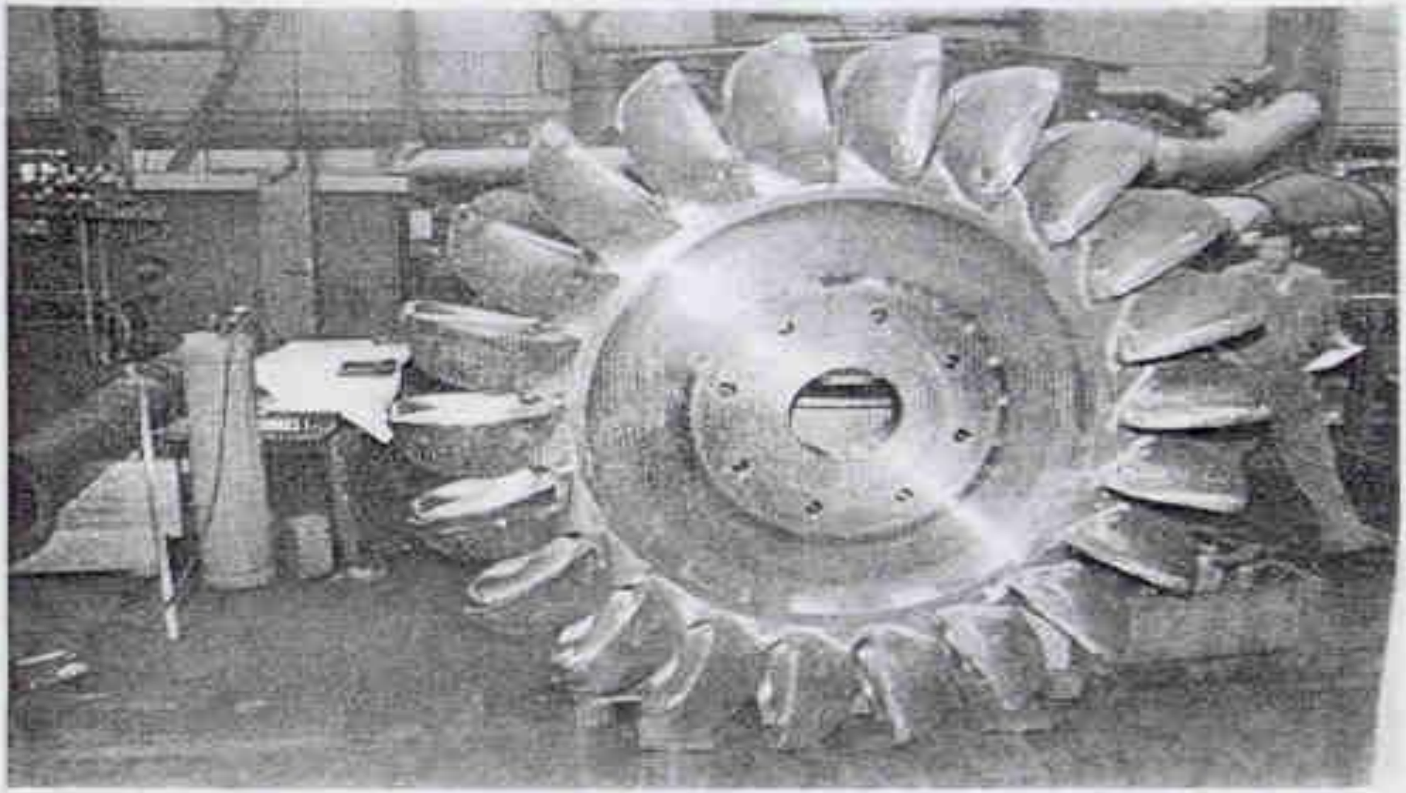


FIG. 6.9 Pelton turbine runner rated at 34.2 MW. *(Sulzer-Escher Wyss, Ltd.)*

Francis Turbine

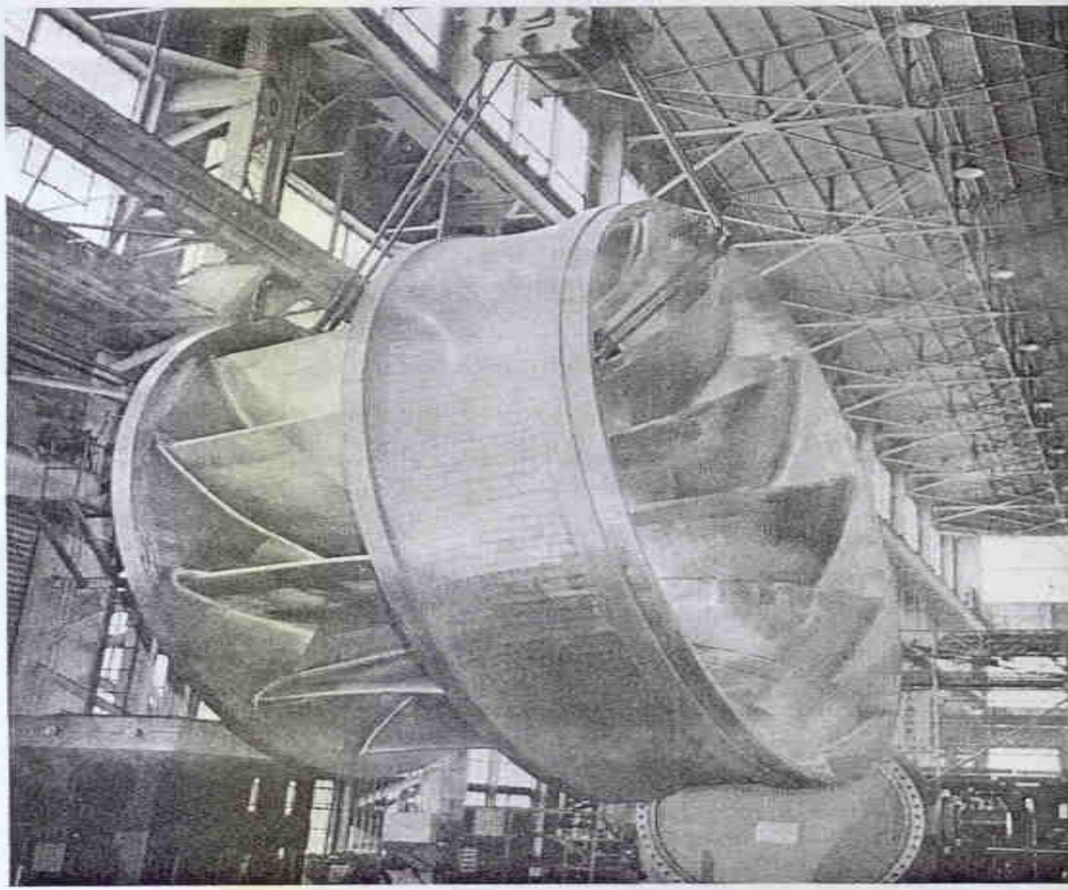


FIG. 6.2 Francis turbine runner rated at 200 MW. *(Toshiba Corp.)*

Kaplan Turbine

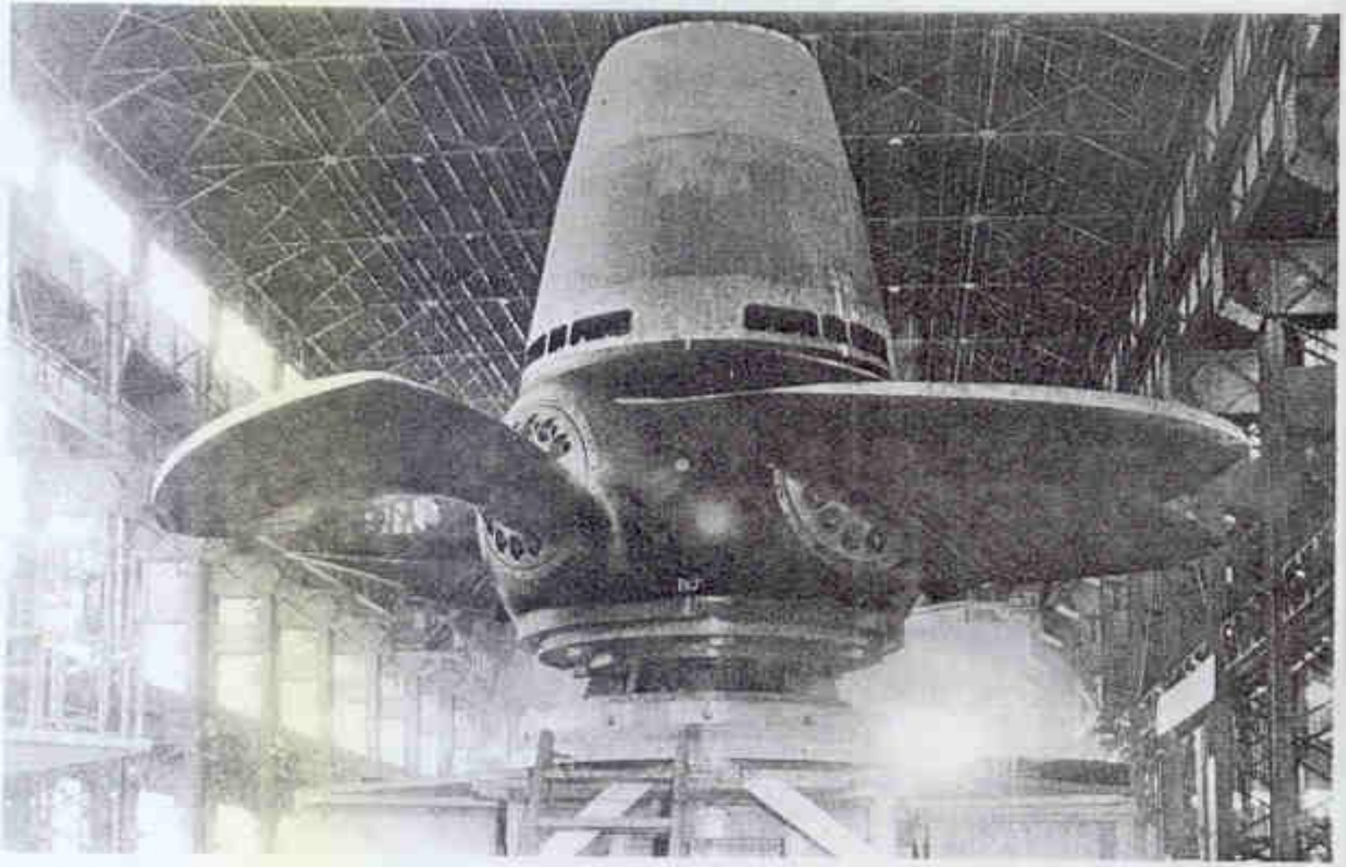


FIG. 6.4 Kaplan adjustable-blade runner rated at 26.8 MW. *(Fuji Electric Co., Ltd.)*

Cost of Hydropower

- The EIA estimates the overnight capital cost of hydropower (1996):

	US $ / kW
Big hydro (> 50 MW)	1,000-3,000
Small hydro (< 20 MW)	800-1,200
Micro hydro (< 100 kW)	2,500*

* PCIERD (P1,000,000 for 8 kW at P50/$)

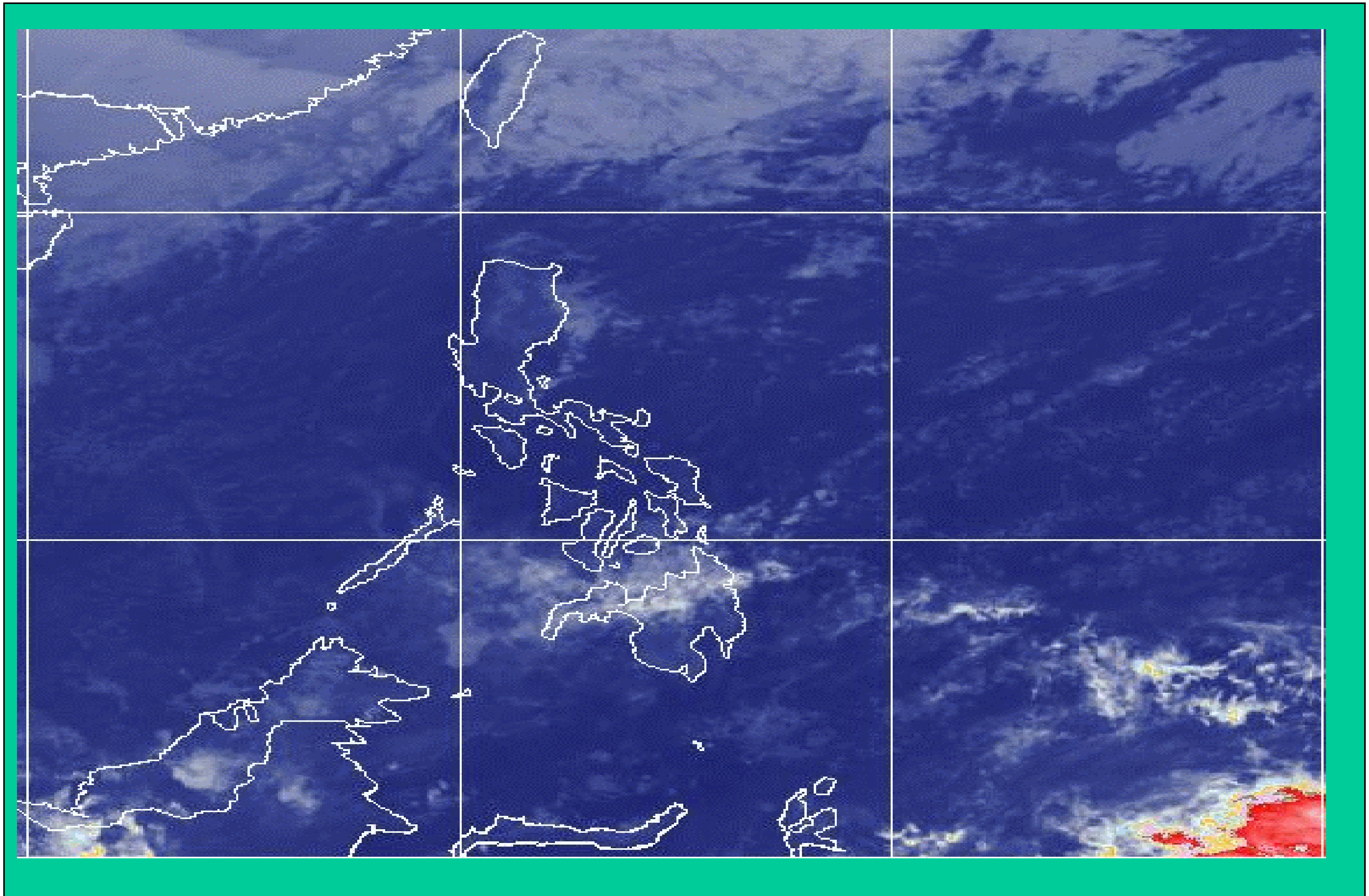
- Generation cost:

	US $ / kWh
Levelized cost of power (1996$)	6.4 – 13.8 cents / kWh
Big hydro (> 50 MW)	0.044
Small hydro (< 20 MW)	0.03 – 0.05
Micro hydro (< 100 kW)	n.a.

Hydropower Plants in RP

Hydro Power Plants in the Philippines									
Plant Name/ Proponent	Location	Owner	Contract Type	Grid	Region	Year Comm.	No.	Unit Size	Capacity MW
Ambuklao	Benguet, Bokod	NPC	ROL	Luzon	CAR	1956-57	3	25.0	75.00
Binga	Benguet, Itogon	NPC	ROL	Luzon	CAR	1960	4	25.0	100.00
Hedcor-Ampohaw	Benguet, La Trinidad	IPP	PPA	Luzon	CAR	1993			18.25
Northern M.H.	Benguet, La Trinidad	IPP	PPA	Luzon	CAR	1993			12.05
NIA-Baligatan	Isabela, Ramon	IPP	PPA	Luzon	II	1993			6.00
Magat HE	Isabela, Ramon	NPC		Luzon	II	1983-84	4	90.0	360.00
Angat Main HE	Bulacan, Norzagaray	NPC		Luzon	III	1967-68	4	50.0	200.00
Angat Auxilliary 1-3	Bulacan, Norzagaray	NPC		Luzon	III	1967-78	3	6.0	18.00
Angat Auxilliary 4 H	Bulacan, Norzagaray	NPC		Luzon	III	1978	1	10.0	10.00
Angat Auxilliary 5 H	Bulacan, Norzagaray	NPC		Luzon	III	1992	1	18.0	18.00
Pantabangan HE	Nueva Ecija, Pantabangan	NPC		Luzon	III	1977	2	50.0	100.00
Masiw ay HE	Nueva Ecija, Pantabangan	NPC		Luzon	III	1980	1	12.0	12.00
Caliraya HE-IMPSA	Laguna, Lumban	NPC-IPP		Luzon	IV	1942-50	4	8.0	32.00
KPSHPP-IMPSA	Laguna, Kalayaan	NPC-IPP		Luzon	IV	1982	2	150.0	300.00
Botocan HEP-IMPSA	Laguna, Majayjay	NPC-IPP	BROT	Luzon	IV	1979			35.00
Barit M.H.	Camarines Sur, Buhi	NPC		Luzon	V	1957			1.80
Loboc	Bohol, Loboc	NPC		Visayas	VII	1957-67	3	0.4	1.20
Janopol	Bohol, Janopol	IPP	PPA	Visayas	VII	1990			5.00
Amlan	Negros Oriental, Amlan	NPC		Visayas	VII	1962	2	0.4	0.80
Pulangi IV	Bukidnon, Maramag	NPC		Mindanao	X	1985-86	3	85.0	255.00
Agusan M.H.	Bukidnon, Damilag	NPC		Mindanao	X	1957	2	0.8	1.60
Talomo Hydro	Davao de Sur, Talomo	NPC		Mindanao	XI				3.50
Agus VII	Iligan City, Fuentes	NPC		Mindanao	XII	1982-83	2	27.0	54.00
Agus V	Iligan City, Ditucalan	NPC		Mindanao	XII	1985	2	27.5	55.00
Agus IV	Lanao Norte, Baloi	NPC		Mindanao	XII	1985	3	52.7	158.10
Agus II	Lanao Sur, Saguiran	NPC		Mindanao	ARMM	1979	3	60.0	180.00
Agus I	Lanao Sur, Maraw i	NPC		Mindanao	ARMM	1992-94	2	40.0	80.00
									2,092.30

Philippine Hydrological Data (Rainfall and River Flow)



Environmental Issues & Mitigation

- Hydropower technology is **essentially emission-free**
- **Fish injury and mortality** from passage through turbines, resulting in lower downstream water quality.
- Submergence of large areas of land results in **displacement of unique ethnic peoples** and the **destruction of endangered plant and animal life**.
- Because of **lower velocity**, sediment will form at the bottom.
- **Anaerobic fermentation** of tropical rainforest and organic materials releases carbon dioxide CO_2 and other greenhouse gases like methane CH_4 (11 times more potent than CO_2)
- **By choosing the site carefully** and **clearing trees before inundation**, the total greenhouse emissions would be as little as 10% of a similarly sized fossil-fueled plant.

Risks Associated with Hydropower

- **Geological risks –** concerned with the geology of the site of the dam. What type of rock lies beneath the site? Fault lines underneath? Seismic activity? If tremors are likely, the dam and powerhouse must be designed to withstand earthquake during construction and operation.
- **Hydrological risk –** historical records on river flows (max, min, average) and rainfall at the watershed for 10-40 years are needed to ensure sufficient supply of water for the project.
- **Financial risks –** associated with the above natural risks as they may cause schedule and cost overruns and undelivered power not satisfying power purchased agreements. Other financial risks include inflation and foreign exchange fluctuations in the host country.