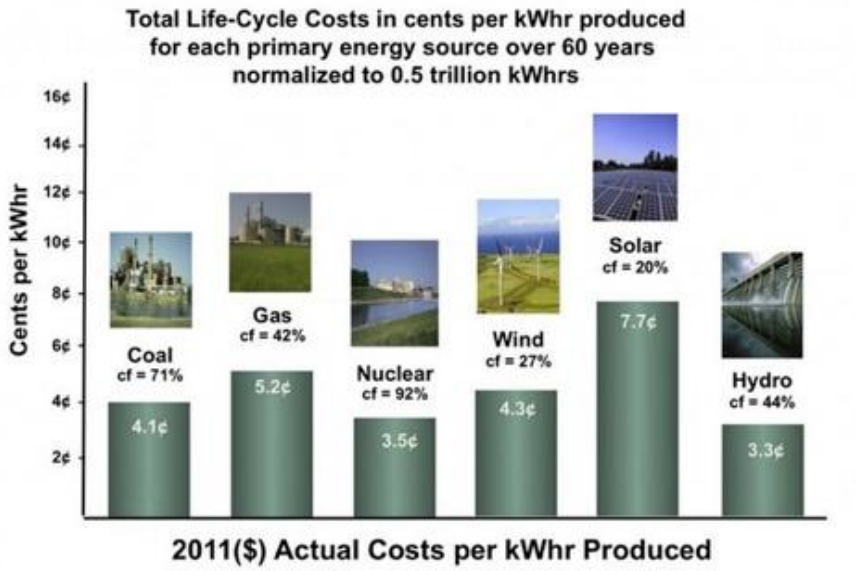
Renewable Energy Systems (12210588)

12. Hydropower I

Fathi Anayah, PhD

Lecture 12

Actual cost of actual energy produced



http://alfin2100.blogspot.com/2012/07/comparing-costs-of-energy-production.html

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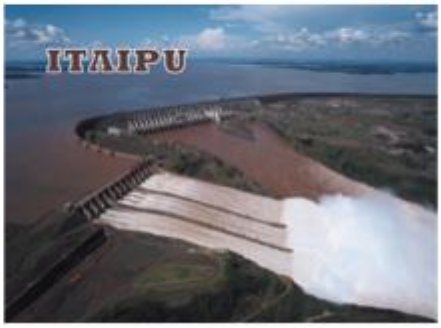
Major plants in World

Three Georges, 18460 MW, China

Itaipu, 14750 MW, Brazil/ Paraguay



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Some components of hydro plants

1. **Spillways**: release water downstream that is not used to make energy
2. **Penstock:** collects water from a upstream leading it to the turbine
3. **Draft tube:** is the passage below turbine
4. **Tailrace:** is the water passage from the draft tube to the river downstream
5. **Surge tank:** is a reservoir that vents sudden pressure built up in turbine

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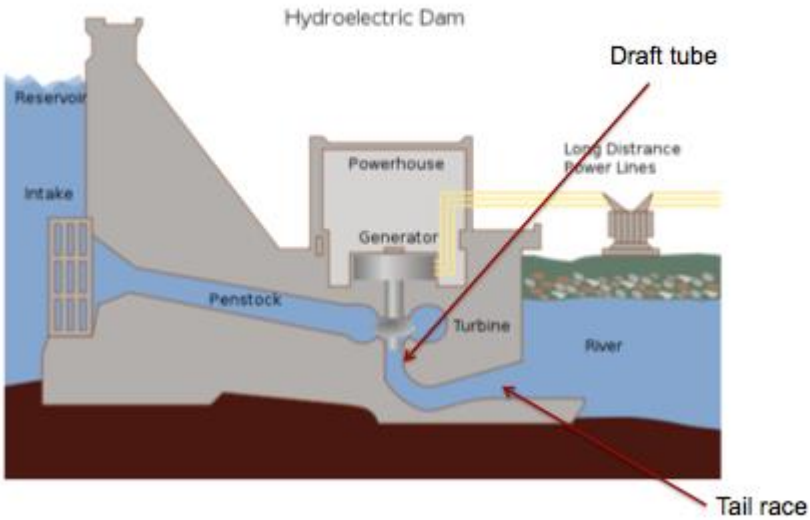
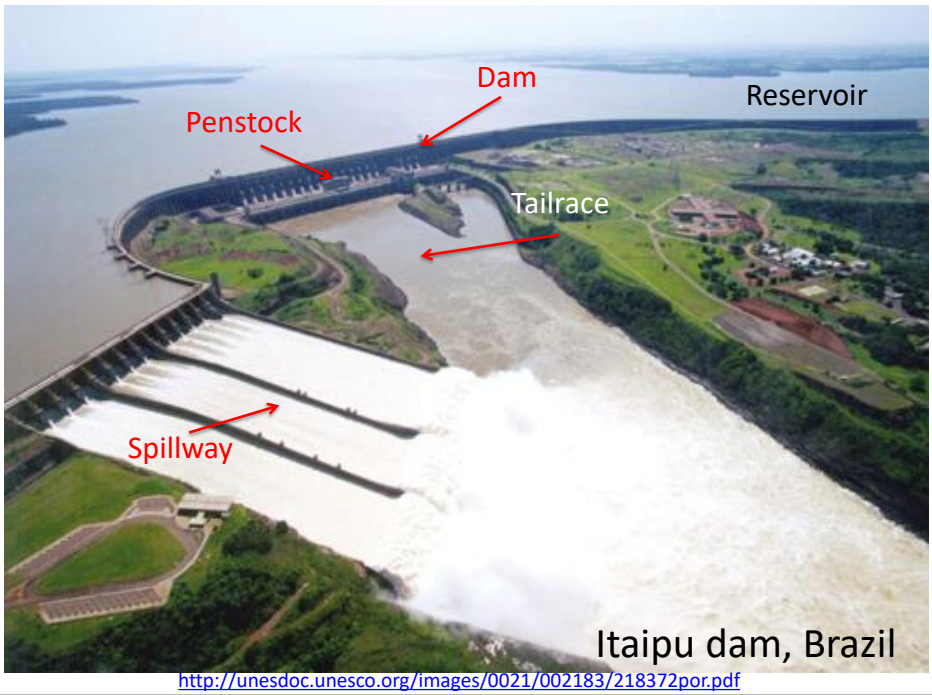
Components of hydroelectric plants



https://populationeducation.org/what-are-pros-and-cons-hydropower-and-tidal-energy/



http://unesdoc.unesco.org/images/0021/002183/218372por.pdf

Turbines

- A turbine is a rotary engine that exerts energy from a fluid flow and converts it into a useful work, e.g., electricity.

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Turbine choices

(Dynamic machine to extract energy from fluid)

1. **Reaction (Static pressure changes):**
   Converts both Flow & Kinetic energy
   - 1.1 Axial flow or propeller turbine (Kaplan, Bulb)
   - 1.2 Radial or Mixed flow (Francis turbine)

2. **Impulse: (Static pressure unchanged):**
   Converts only Kinetic energy
   - 2.1 Tangential flow on buckets (Pelton)

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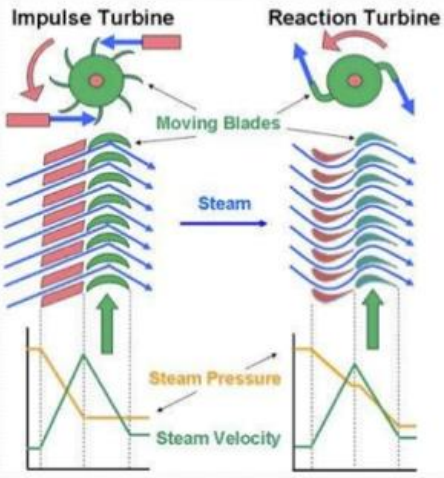
Comparison of turbine types

Pressure velocity graph of impulse and reaction turbines.



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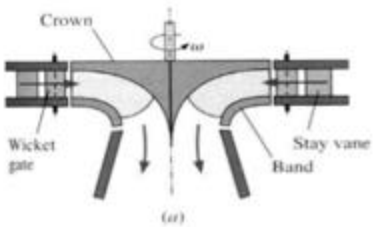
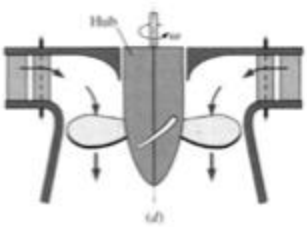
1. Reaction Turbines



Francis turbine



Kaplan turbine

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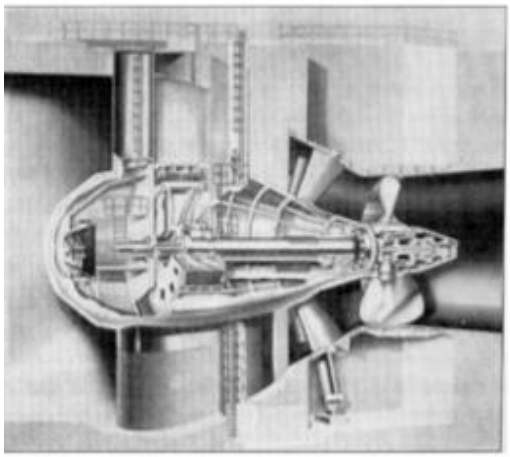
Kaplan Reaction Turbine

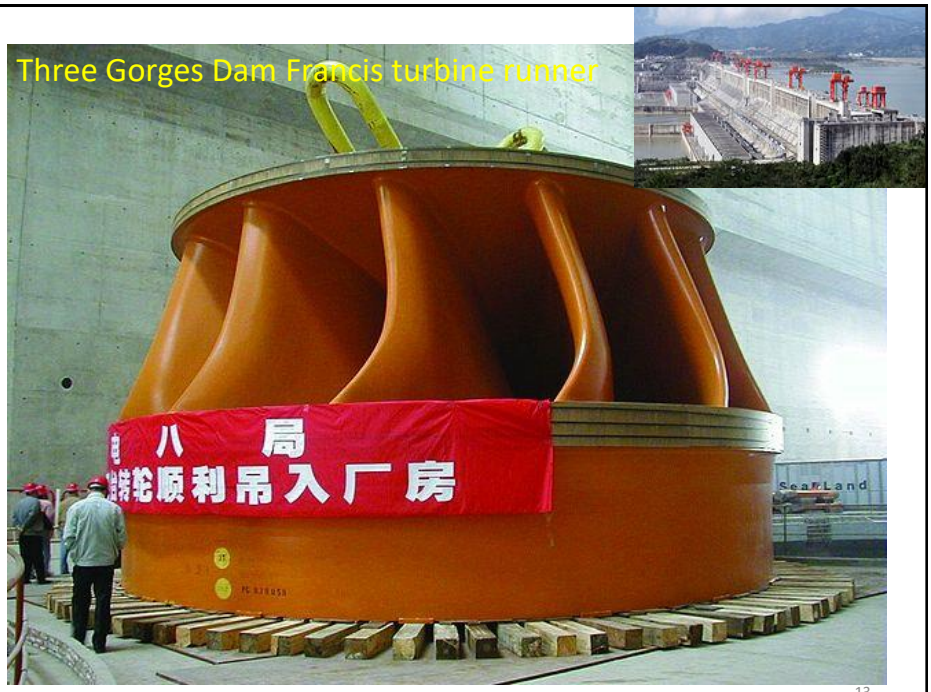
http://www.tbhic.cn/en/productview.asp?id=65

Runner of Kaplan Turbine Unit for Guangxi Dahua 110MW Hydropower Plant

1.1 Axial flow (Bulb) Turbine (propeller type) (Reaction)



- Used for very low head high volume flow
- Ideal for tidal power plant –



http://en.wikipedia.org/wiki/Three_Gorges_Dam

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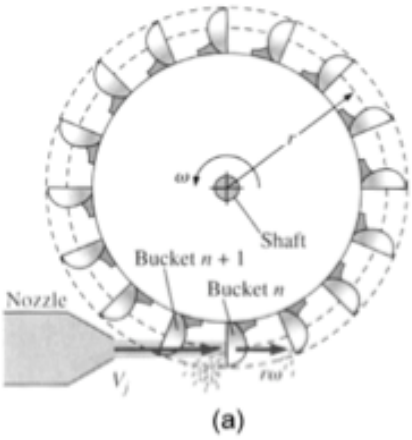
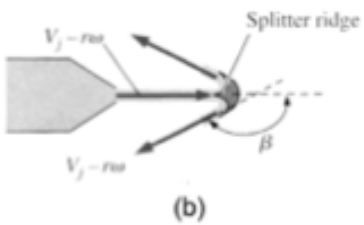
2.1 Pelton (Impulse) Turbine





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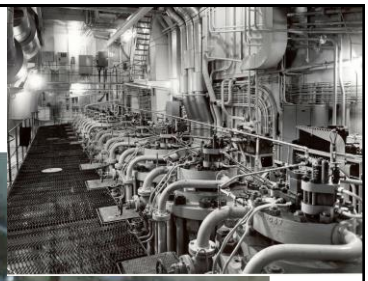
Pelton Impulse Turbine



http://www.gmsi.be/gmsi_fr/02_services_04_usinage_sur_site.php

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1 MW in-stream (axial flow) turbine in Nova Scotia

http://tomorrowspower.ca/story/timeline/

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Hydraulic analysis

$$\frac{P_A}{\rho g} + \frac{V_A^2}{2g} + Z_A = \frac{P_B}{\rho g} + \frac{V_B^2}{2g} + Z_B + H_L + \Delta H_T$$

Power extraction,
P = density x flow rate x head difference across turbine
$P = (\rho Q)\ (\Delta H_T g)$

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Specific Speed

- To help selection of a turbine we need a parameter which will include all items except for the **size**.
  Specific speed is such a parameter.
- Dimensionless Sp. speed Ω_T **for turbine**

$$\Omega_T = \frac{C_P^{0.5}}{C_H^{1.25}} = \frac{\omega\sqrt{P}}{\sqrt{\rho}(gH)^{1.25}}$$

Where ω is in rad/s, Q, H, P, ρ are in m^3/s, m, watt and kg/m^3. where H is height difference.

- **Specific speed refers to the best efficiency condition of a particular machine.**
- The 'best' efficiency of a family of machines depends on its specific speed
- Specific speed allows one to represent the whole family of machines by a single plot.

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Range of dimensionless Specific speeds for turbines

Types	Application	Turbine specific speed (Ω_T)
Axial flow	High flow, low head	7.0 – 14.0
Mixed flow		3.5 – 7.0
Centrifugal or Radial flow		1.0 – 3.5
Impulse	High head	0 – 1.0

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Specific speed with dimensions

- Specific speed Ω_P is dimensionless, but sometime g or ρ is dropped making Specific speed dimensional N'_{sp} (SI) or N'_{sd} (British):
- $$N'_{sd} = \frac{N\sqrt{HP}}{(H)^{1.25}}$$ Imperial unit

  where N - rpm, HP- horsepower, H –ft
- $$N'_{sp} = \frac{N\sqrt{P}}{H^{1.25}}$$ SI unit

  where N - rpm, P- kW, H –m

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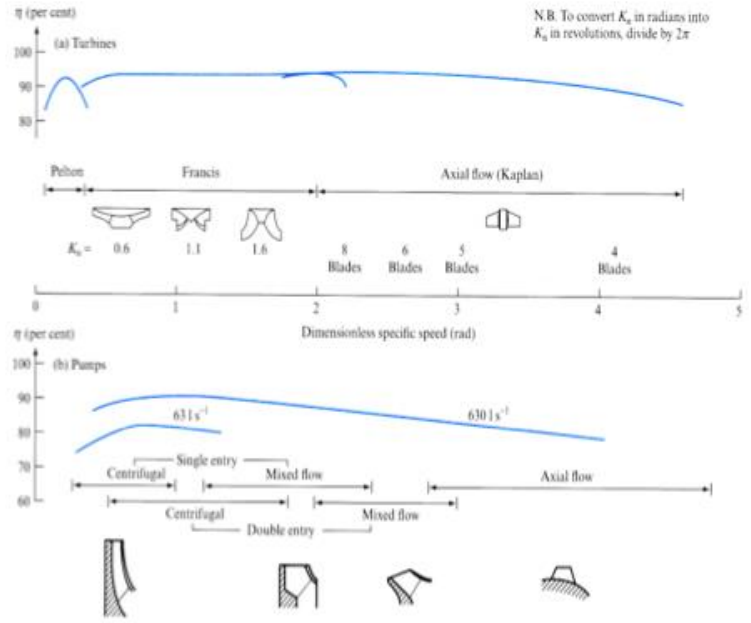
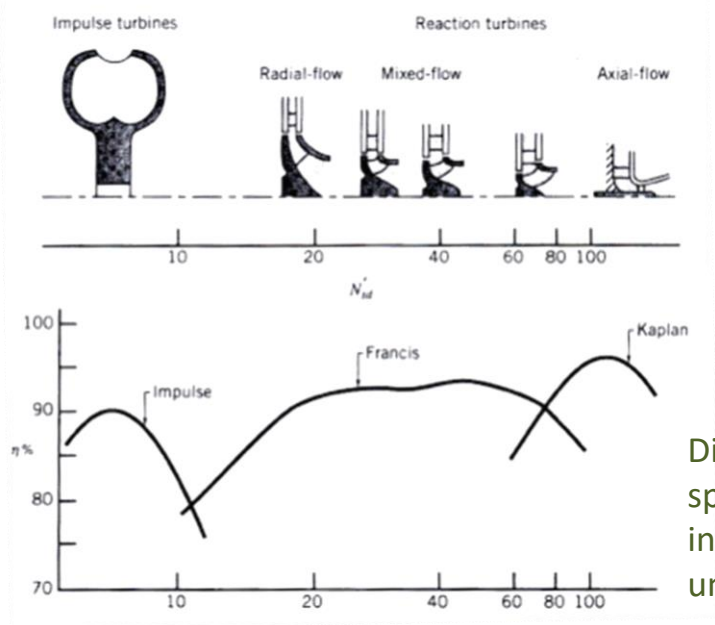
Efficiency vs Non-dimensional Specific speed

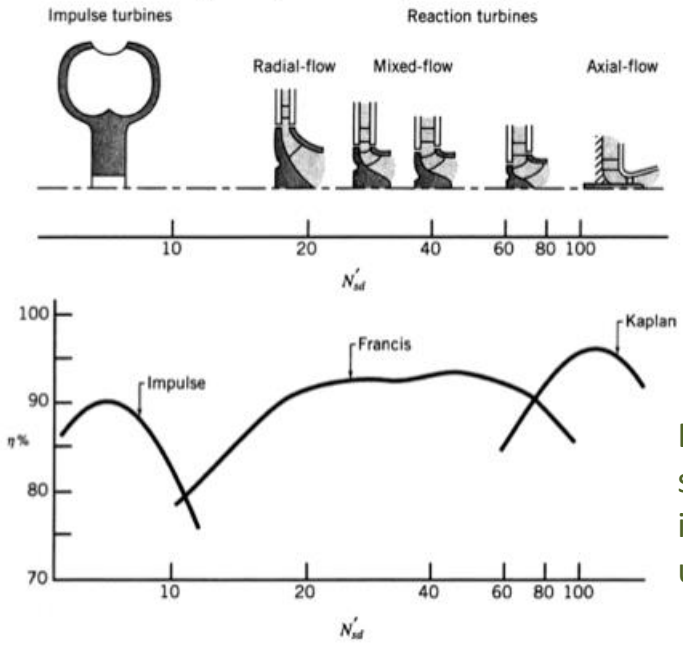


Efficiency against Dimensional Specific speed



Dimensional specific speed in Imperial units

Choice of turbine type depends on specific speed



Dimensional specific speed in Imperial units

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Micro-hydro

- **Micro hydro is a term used for** hydroelectric power installations that typically **produce up to 100 kW** of power. It can provide power to an isolated home or small community.
- Micro hydro is frequently accomplished with pelton wheel for high head, low flow.
- There are currently about 2000 MW worth of installed small hydro capacity in Canada.
- Nova Scotia operates about 40 small hydro plants supplying about 11% of provincial capacity

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