جامعة الانبار
كلية العلوم التطبيقية – هيت
قسم البيئة - المرحلة الرابعة

Renewable Energy Recourses

Hydropower

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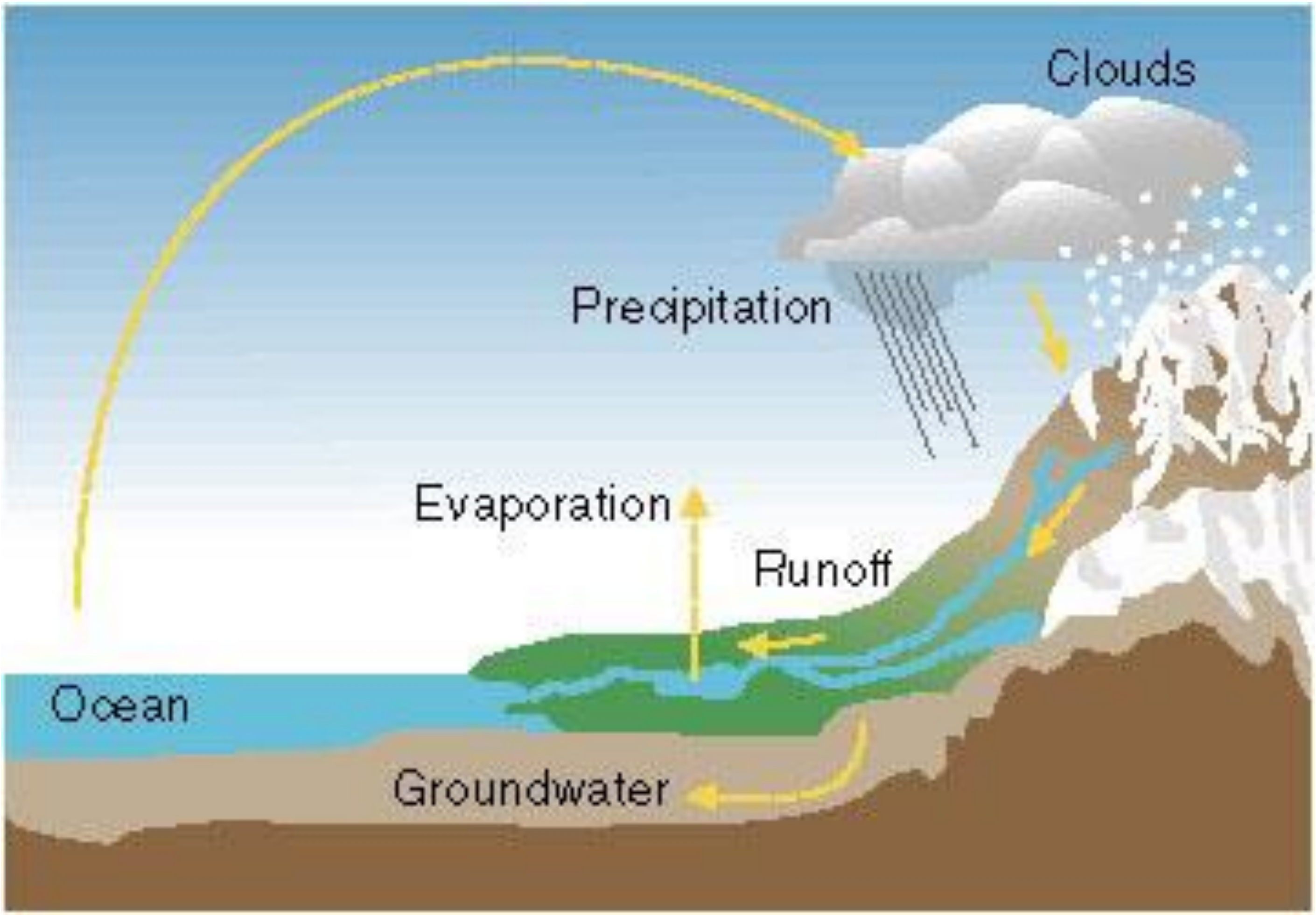
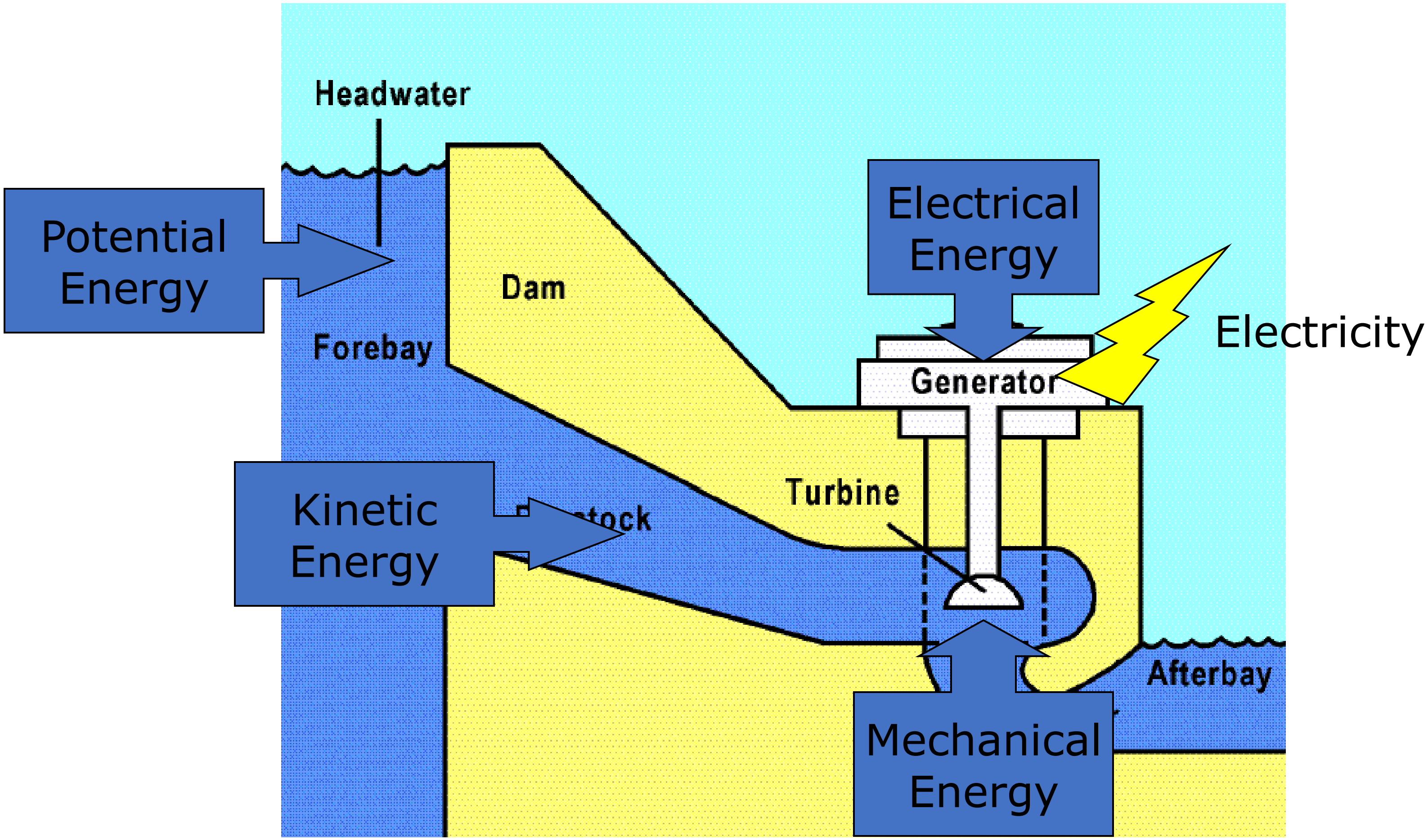
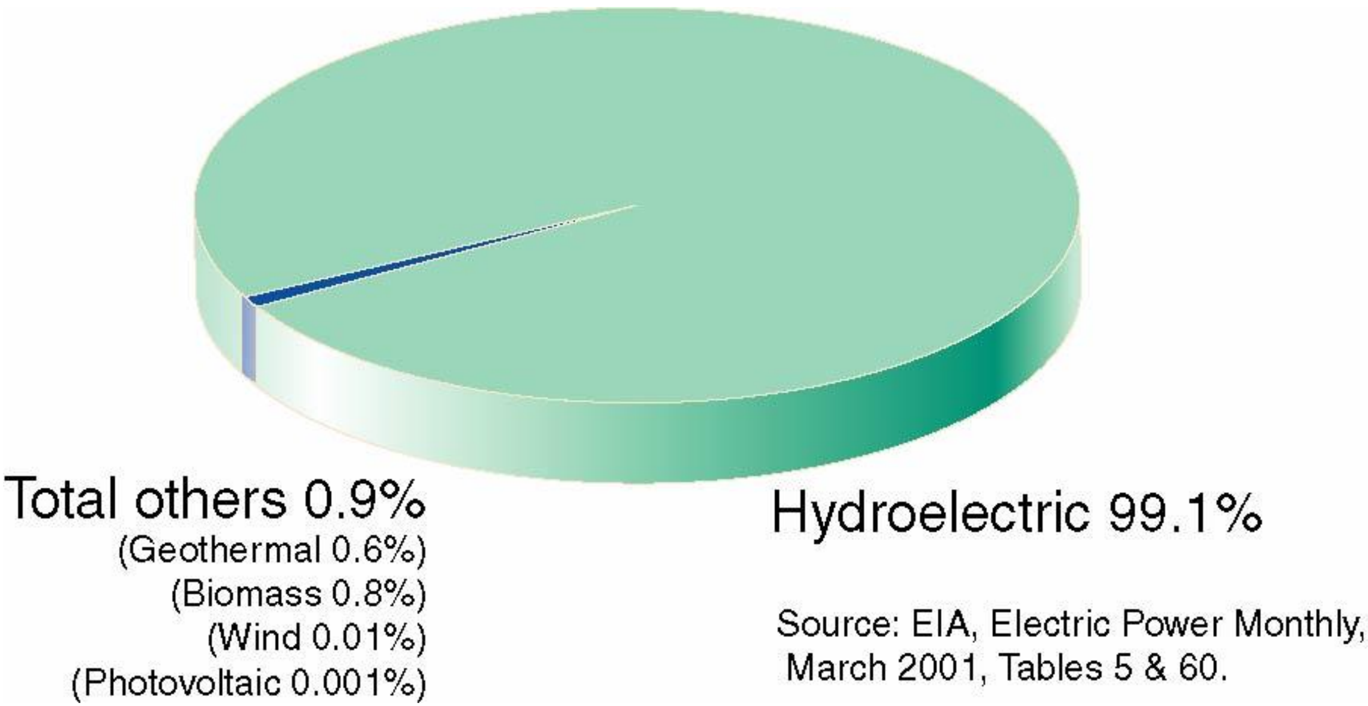
Hydrologic Cycle



Hydropower to Electric Power



Renewable Energy Sources



Wisconsin Valley Improvement Company, http://www.wvic.com/hydro-facts.htm

World Trends in Hydropower

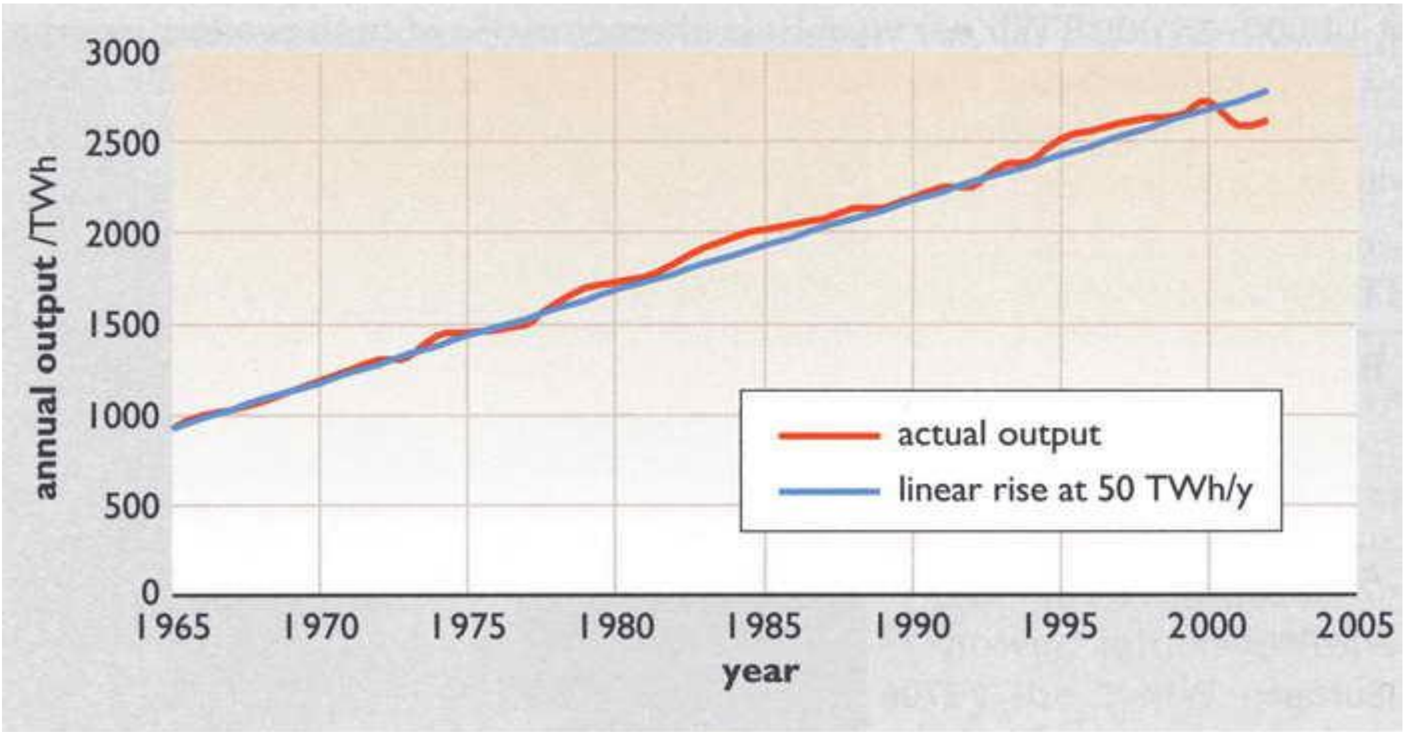
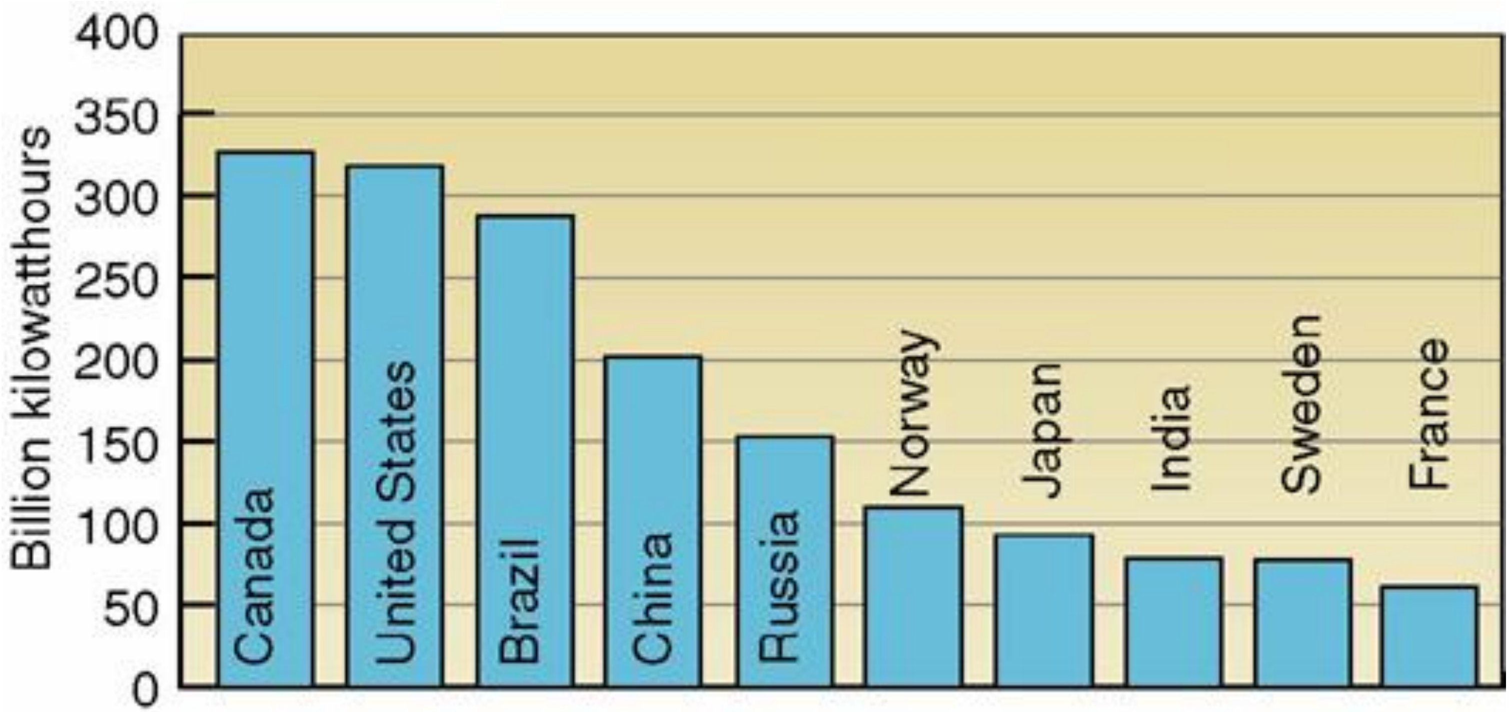


Figure 5.4 World annual hydroelectricity output, 1965–2002 (source: BP, 2003)

Boyle, *Renewable Energy*, 2nd edition, Oxford University Press, 2003

Major Hydropower Producers



Source: EIA, Annual Energy Review 1999, July 2000, Table 11.15

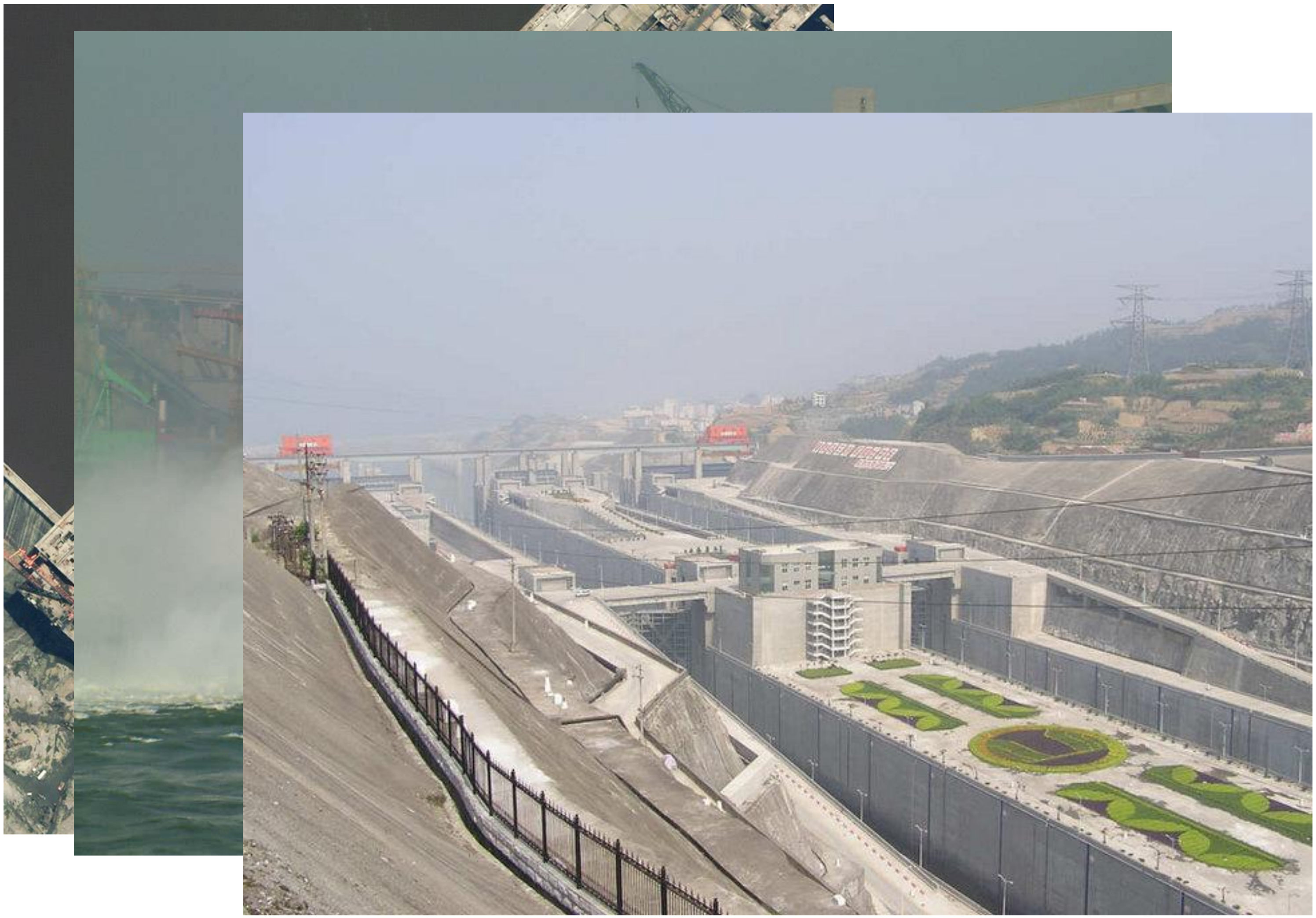
World's Largest Dams

Name	Country	Year	Max Generation	Annual Production
Three Gorges	China	2009	18,200 MW	
Itaipú	Brazil/Paraguay	1983	12,600 MW	93.4 TW-hrs
Guri	Venezuela	1986	10,200 MW	46 TW-hrs
Grand Coulee	United States	1942/80	6,809 MW	22.6 TW-hrs
Sayano Shushenskaya	Russia	1983	6,400 MW	
Robert-Bourassa	Canada	1981	5,616 MW	
Churchill Falls	Canada	1971	5,429 MW	35 TW-hrs
Iron Gates	Romania/Serbia	1970	2,280 MW	11.3 TW-hrs

Ranked by maximum power.

"Hydroelectricity," Wikipedia.org

Three Gorges Dam (China)



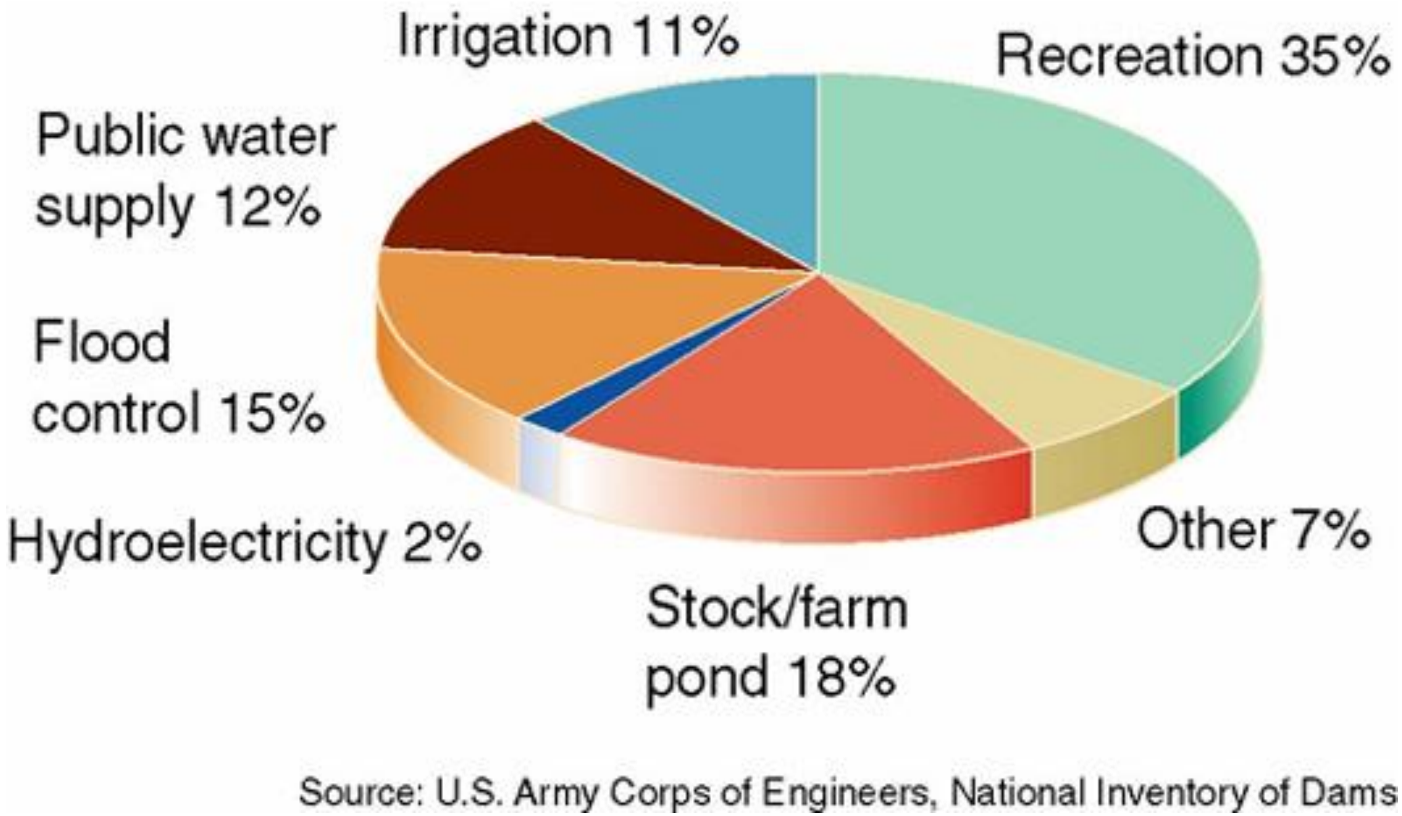
Itaipú Dam (Brazil & Paraguay)

"Itaipu," Wikipedia.org

Guri Dam (Venezuela)

http://www.infodestinations.com/venezuela/espanol/puerto_ordaz/index.shtml

Uses of Dams



Wisconsin Valley Improvement Company, http://www.wvic.com/hydro-facts.htm

History of Hydro Power

Early Irrigation Waterwheel

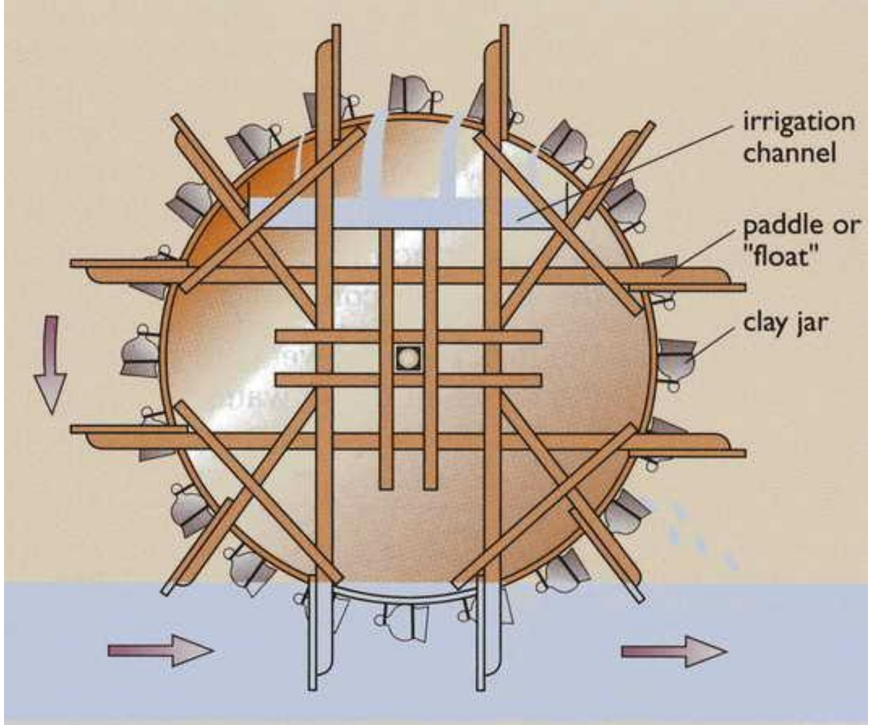


Figure 5.5 A noria. In this earliest water-wheel the paddles dip into the flowing stream and the rotating wheel lifts a series of jars, raising water for irrigation

Boyle, *Renewable Energy,* 2nd edition, Oxford University Press, 2003

Early Roman Water Mill

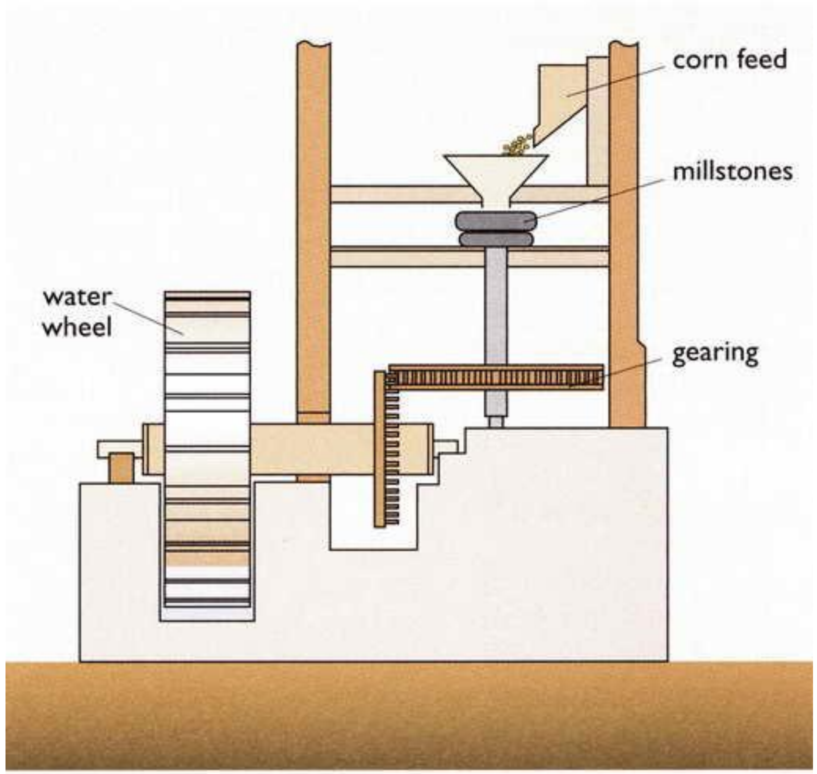
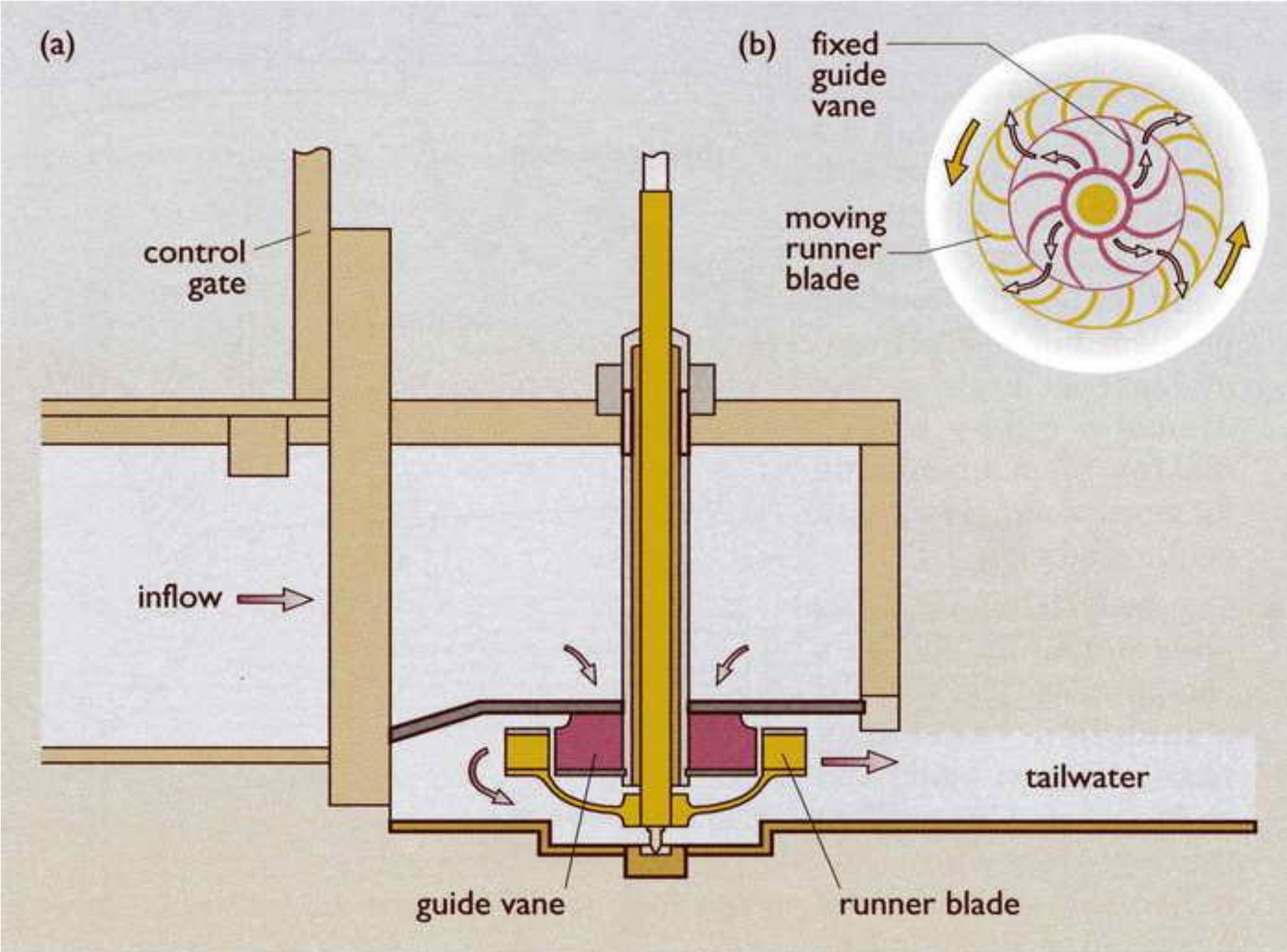


Figure 5.7 A Roman mill. This corn mill with its horizontal-axis wheel was described by Vitruvius in the first century BC. Note the use of gears

Boyle, *Renewable Energy*, 2nd edition, Oxford University Press, 2003

Fourneyron’s Turbine



Terminology (Jargon)

- Head
  - Water must fall from a higher elevation to a lower one to release its stored energy.
  - The difference between these elevations (the water levels in the forebay and the tailbay) is called **head**
- Dams: three categories
  - **high-head** (800 or more feet)
  - **medium-head** (100 to 800 feet)
  - **low-head** (less than 100 feet)
- Power is proportional to the product of

  p= *head x flow*

http://www.wapa.gov/crsp/info/harhydro.htm

Scale of Hydropower Projects

- Large-hydro
  - More than 100 MW feeding into a large electricity grid
- Medium-hydro
  - 15 - 100 MW usually feeding a grid
- Small-hydro
  - 1 - 15 MW - usually feeding into a grid
- Mini-hydro
  - Above 100 kW, but below 1 MW
  - Either stand alone schemes or more often feeding into the grid
- Micro-hydro
  - From 5kW up to 100 kW
  - Usually provided power for a small community or rural industry in remote areas away from the grid.
- Pico-hydro
  - From a few hundred watts up to 5kW
  - Remote areas away from the grid.

www.itdg.org/docs/technical_information_service/micro_hydro_power.pdf

Types of Hydroelectric Installation

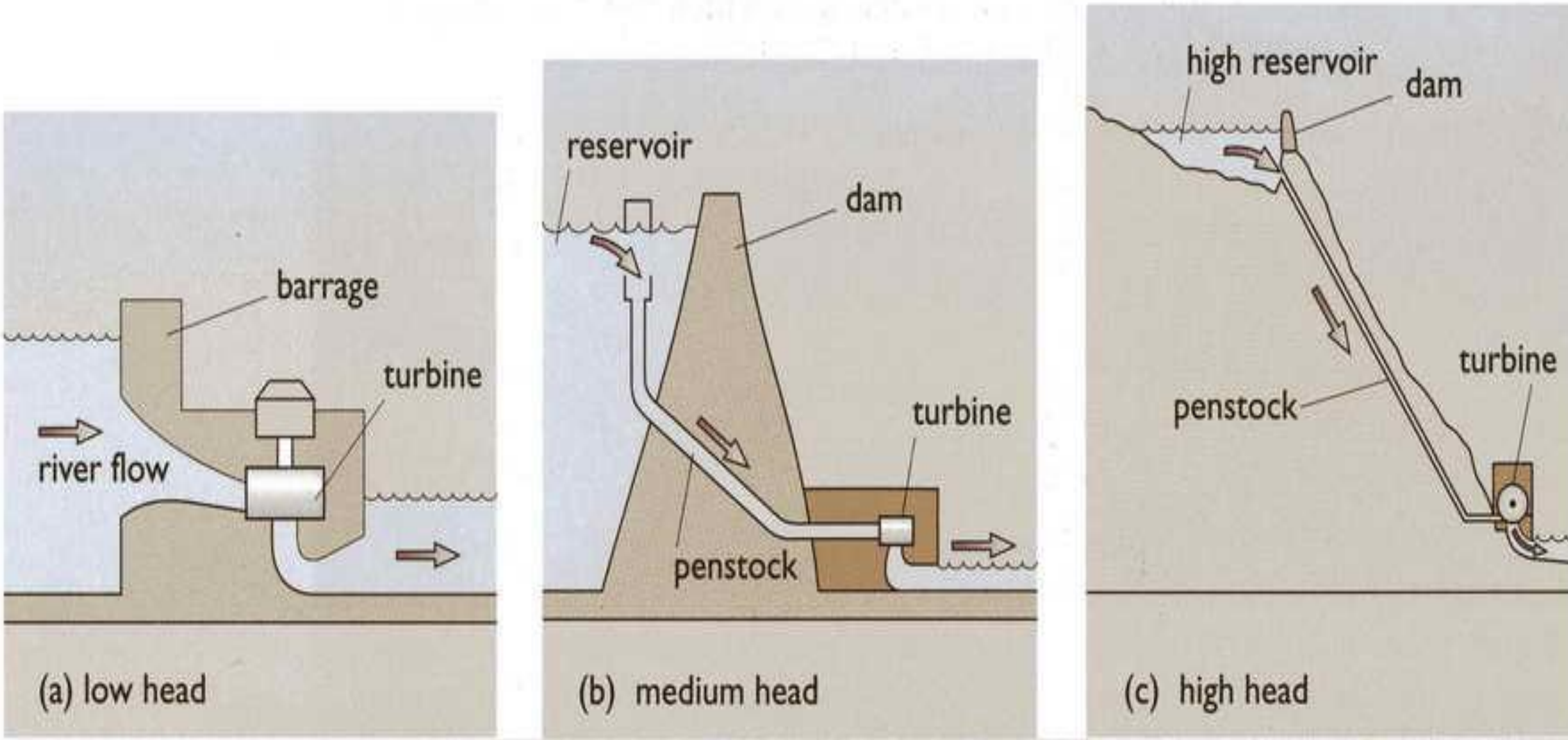


Figure 5.13 Types of hydroelectric installation

Meeting Peak Demands

- Hydroelectric plants:
  1. Start easily and quickly and change power output rapidly
  2. Complement large thermal plants (coal and nuclear), which are most efficient in serving base power loads.
  3. Save millions of barrels of oil

Types of Systems

- Impoundment
  - Hoover Dam, Grand Coulee
- Diversion or run-of-river systems
  - Niagara Falls
  - Most significantly smaller
- Pumped Storage
  - Two way flow
  - Pumped up to a storage reservoir and returned to a lower elevation for power generation
    - A mechanism for energy storage, not net energy production

Types of Hydropower Turbines

1. Francis Turbine
2. Kaplan Turbine
3. Pelton Turbine
4. Turgo Turbine
5. New Designs

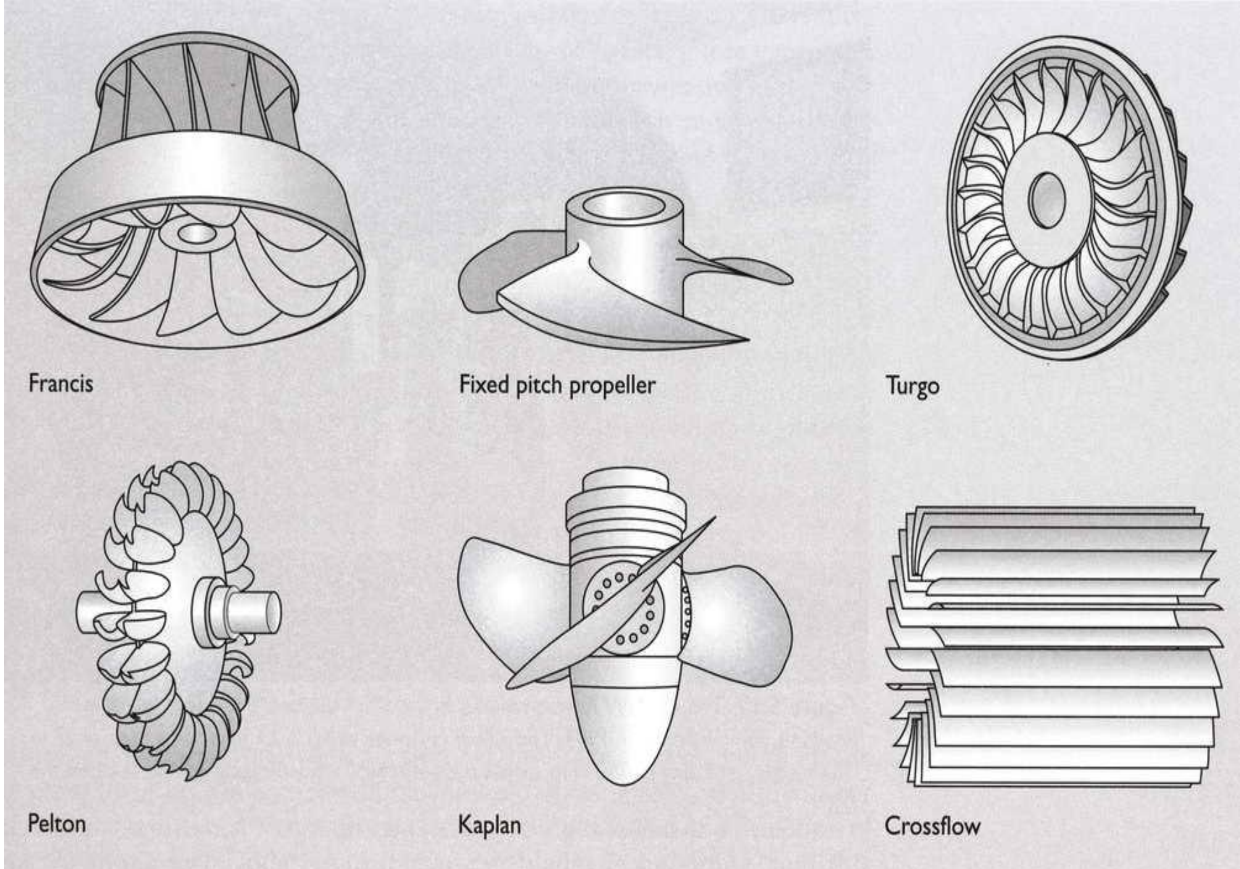


Figure 5.15 Types of turbine runner

Classification of Hydro Turbines

- Reaction Turbines
  - Derive power from pressure drop across turbine
  - Totally immersed in water
  - Angular & linear motion converted to shaft power
  - Propeller, Francis, and Kaplan turbines
- Impulse Turbines
  - Convert kinetic energy of water jet hitting buckets
  - No pressure drop across turbines
  - Pelton, Turgo, and crossflow turbines

Schematic of Francis Turbine

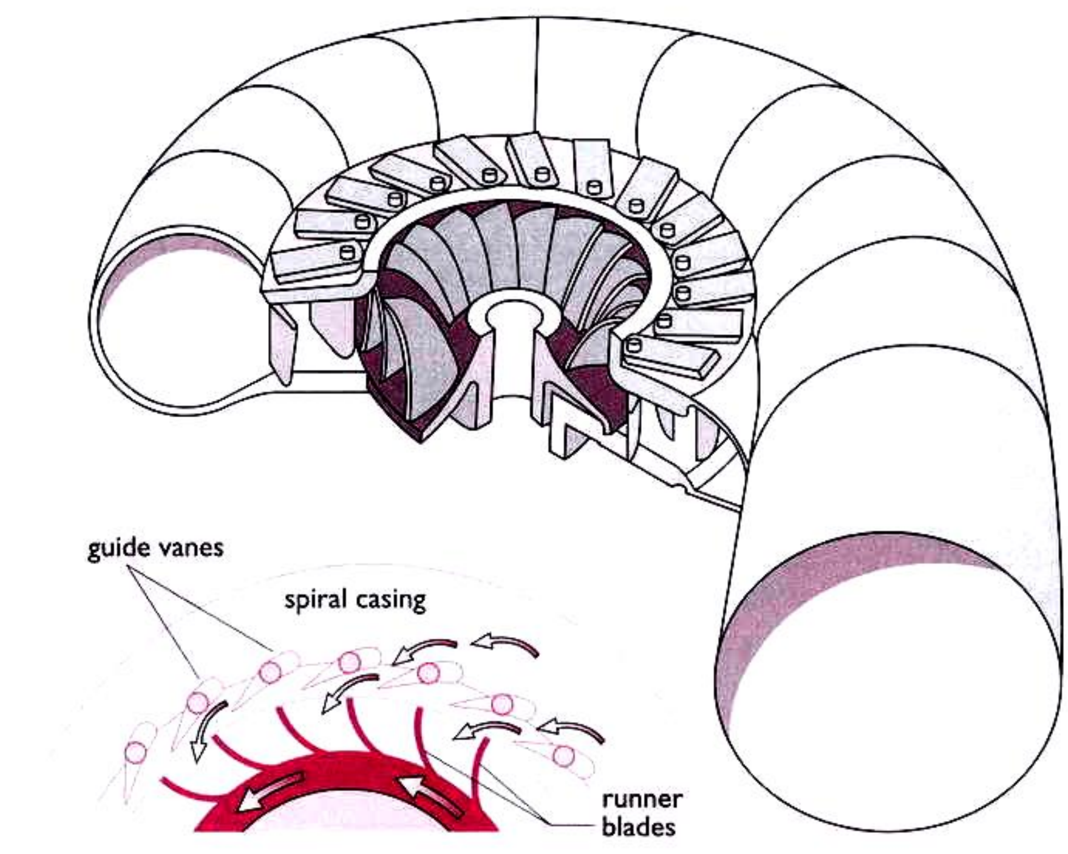
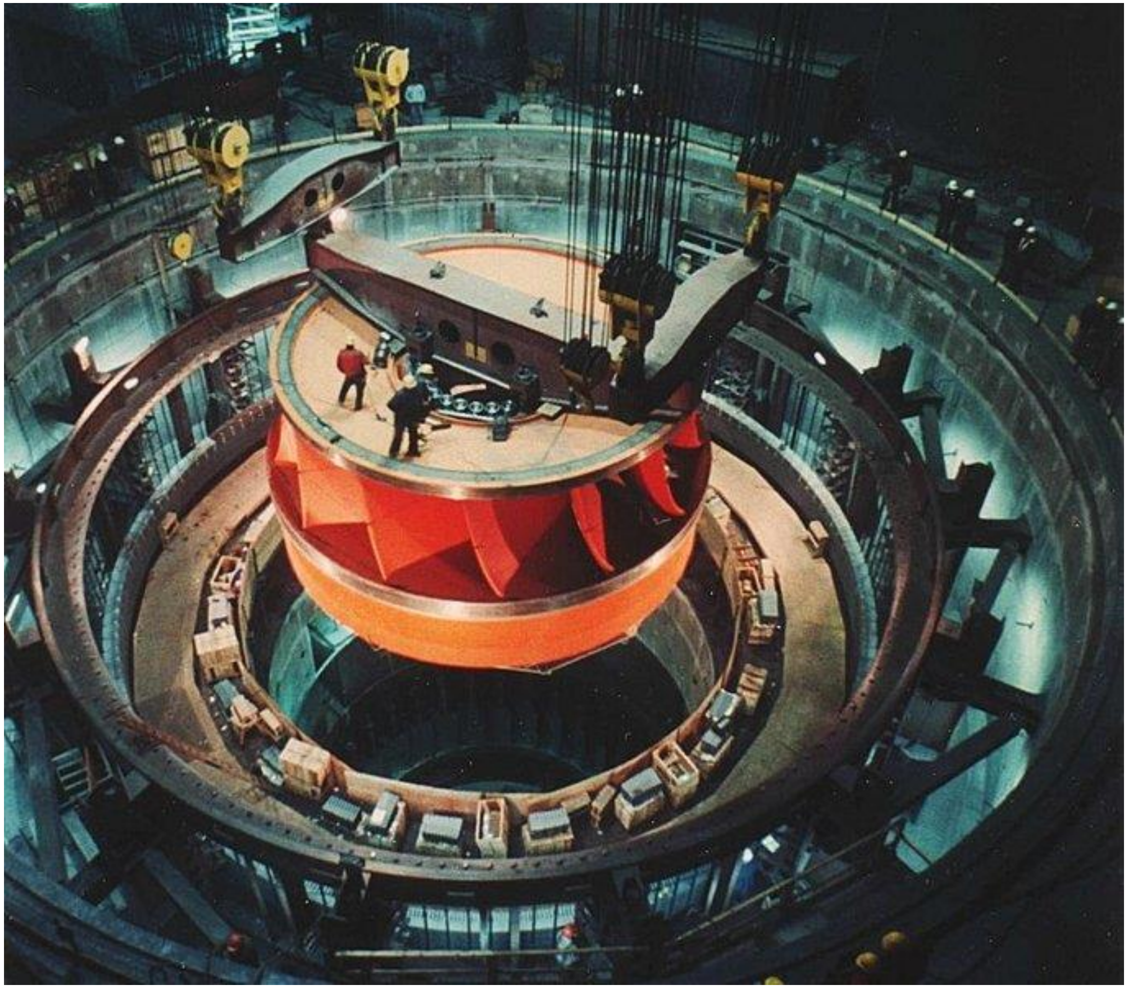


Figure 5.18 Francis turbine: (a) cut-away diagram; (b) flow across guide vanes and runner

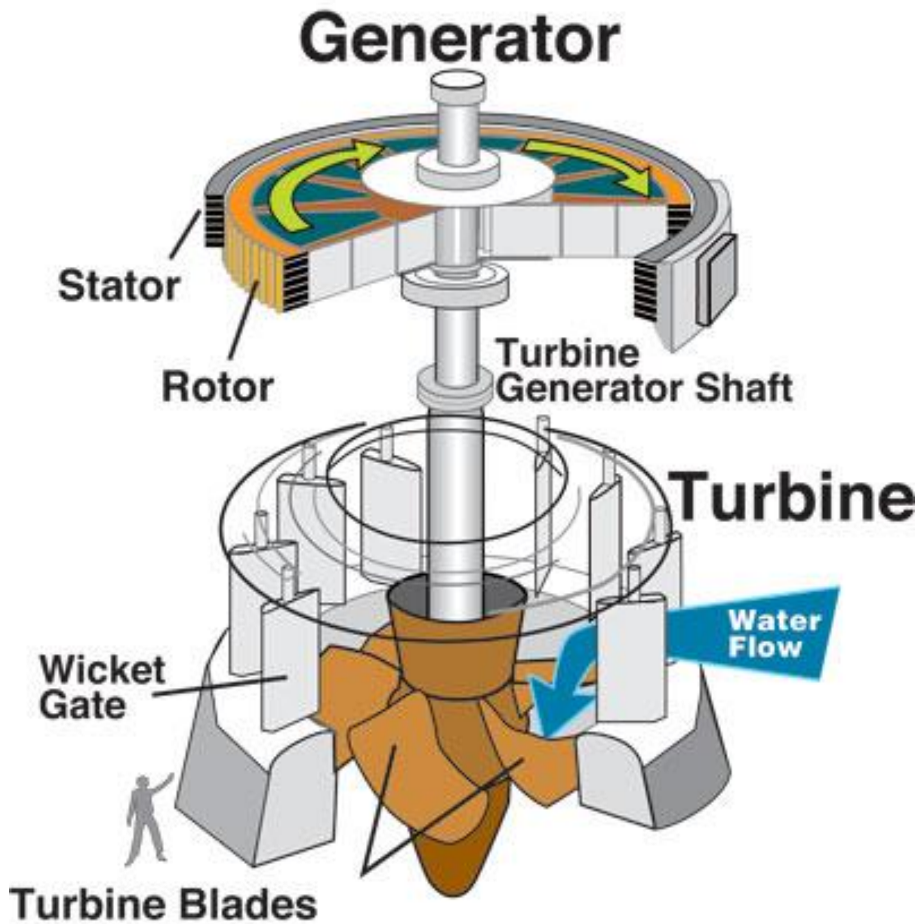
Francis Turbine – Grand Coulee Dam



Fixed-Pitch Propeller Turbine

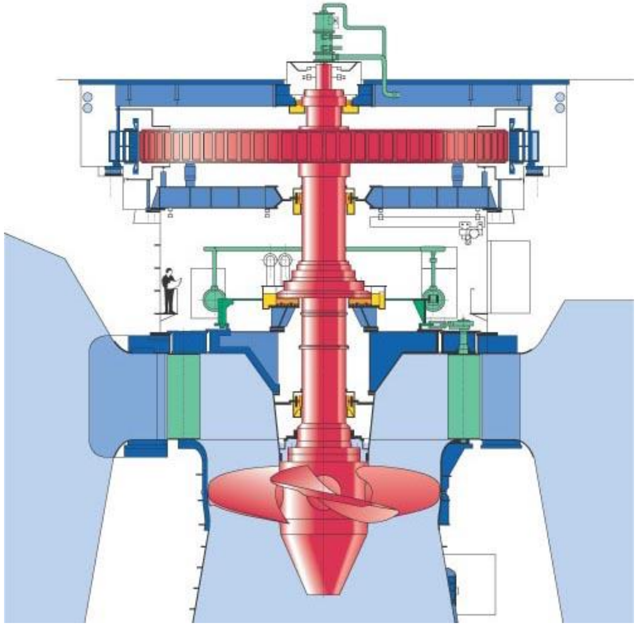
"Water Turbine," Wikipedia.com

Kaplan Turbine Schematic



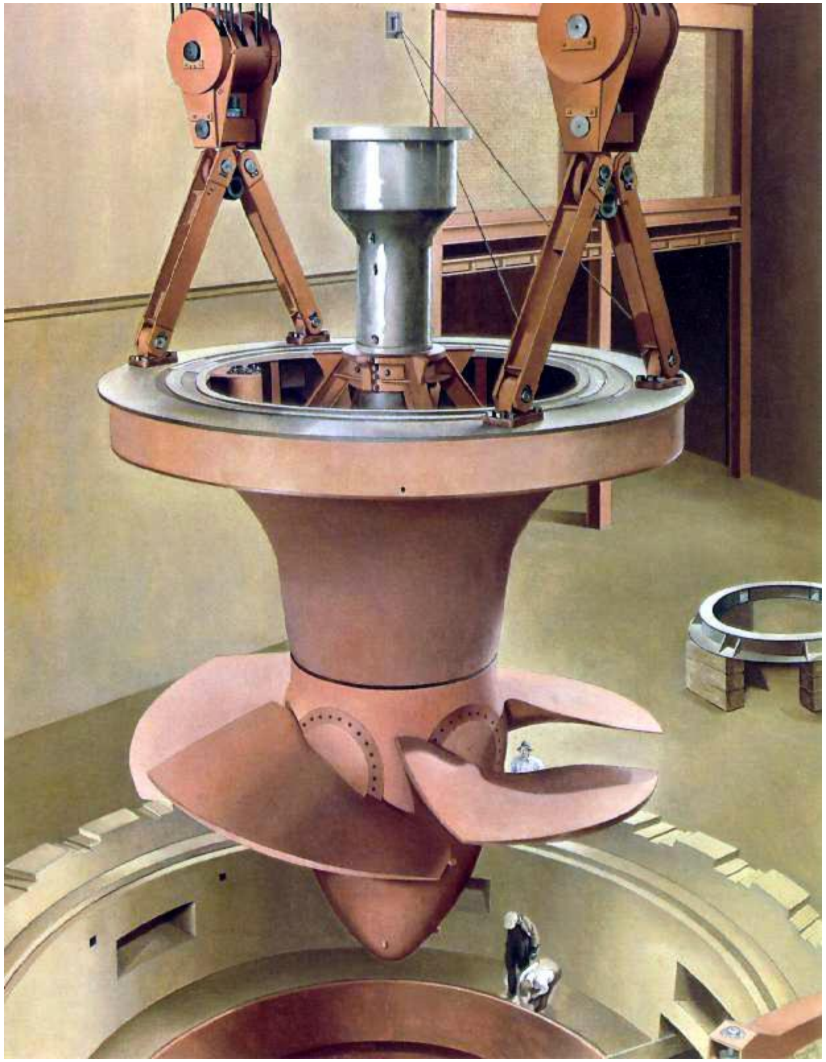
"Water Turbine," Wikipedia.com

Kaplan Turbine Cross Section



"Water Turbine," Wikipedia.com

Suspended Power, Sheeler, 1939



Pelton Wheel Turbine

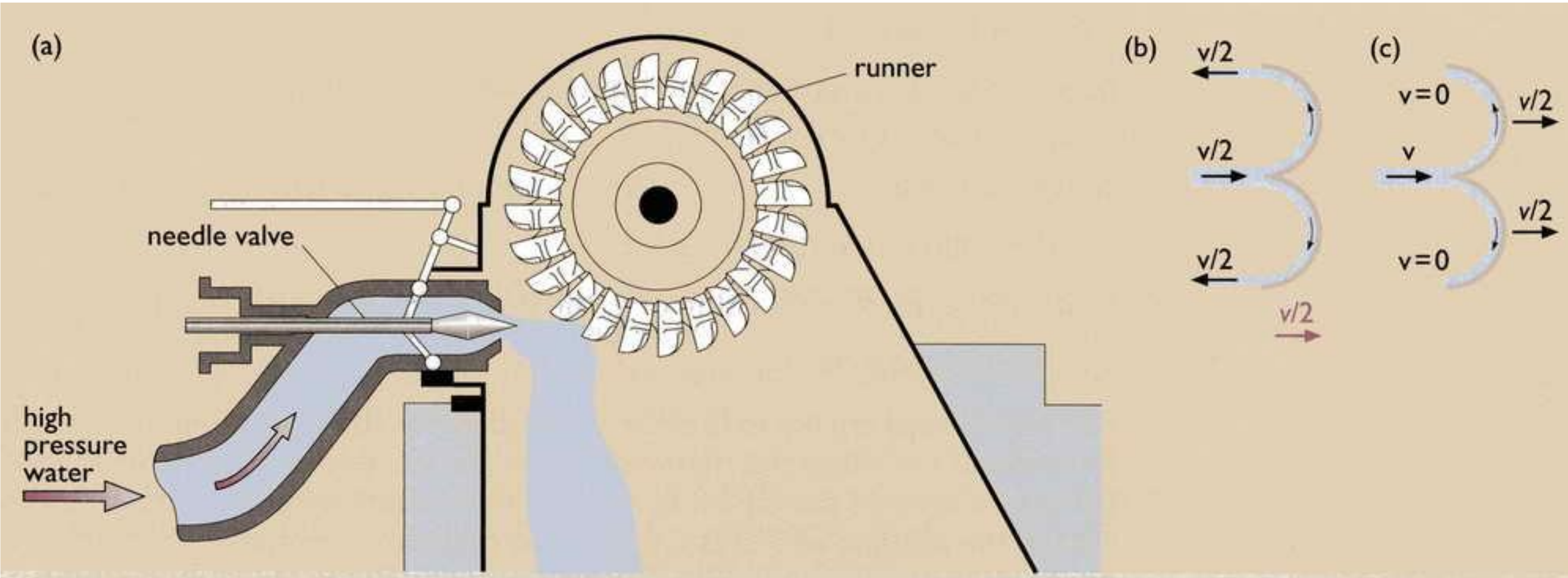


Figure 5.21 Pelton wheel turbine: (a) vertical section; (b) water flow as seen from moving cup; (c) actual motion of water and cup

Turgo Turbine

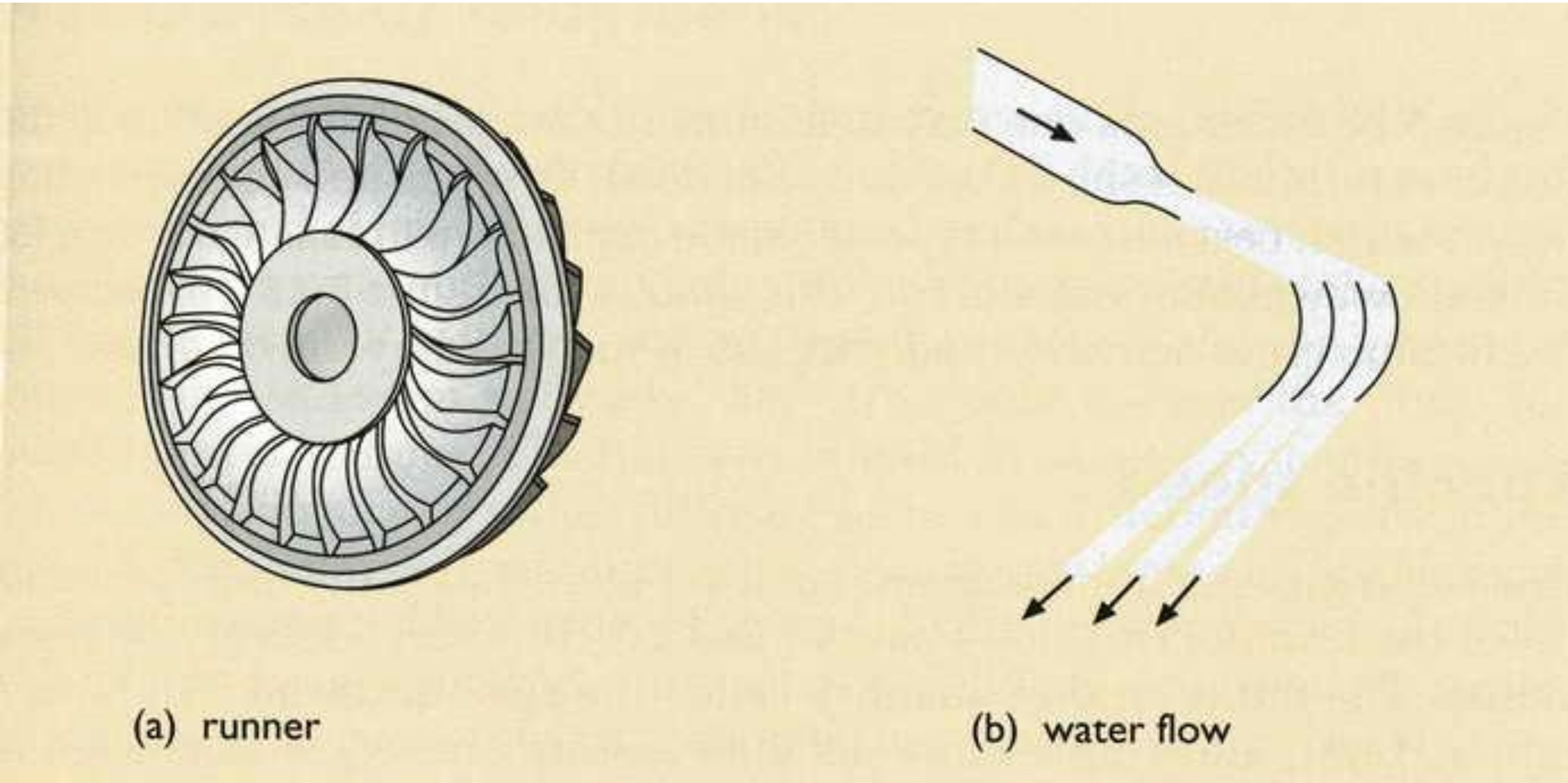


Figure 5.22 Turgo turbine: (a) runner; (b) water flow

Turbine Design Ranges

• Kaplan	$2 < H < 40$
• Francis	$10 < H < 350$
• Pelton	$50 < H < 1300$
• Turgo	$50 < H < 250$

(H = head in meters)

Turbine Ranges of Application

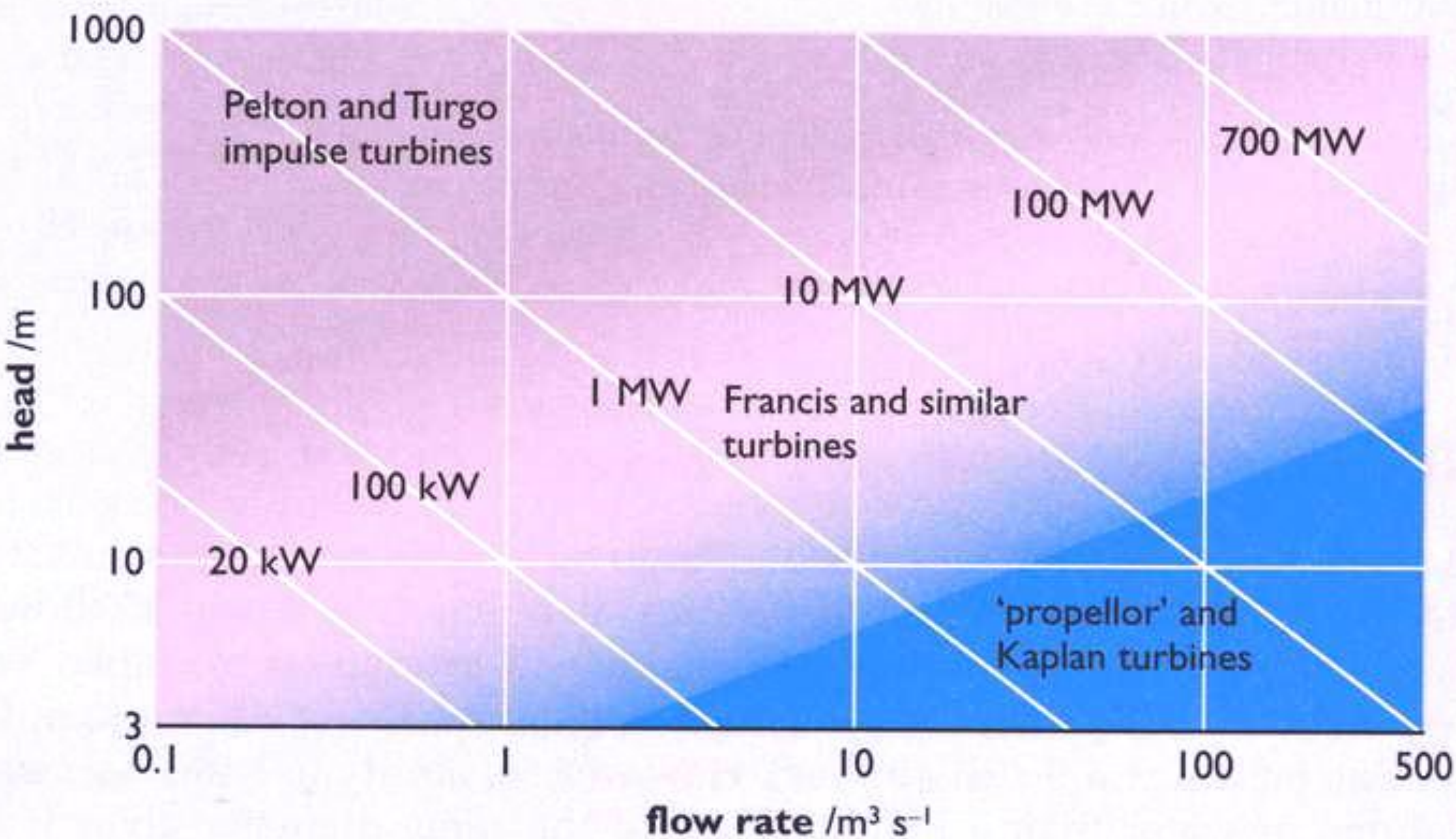


Figure 5.23 Ranges of application of different types of turbine. Note the overlap at the boundaries (see text)

Boyle, *Renewable Energy*, 2nd edition, Oxford University Press, 2003

Hydro Power Calculations

Efficiency of Hydropower Plants

- Hydropower is very efficient
  - Efficiency = (electrical power delivered to the “busbar”) ÷ (potential energy of head water)
- Typical losses are due to
  - Frictional drag and turbulence of flow
  - Friction and magnetic losses in turbine & generator
- Overall efficiency ranges from 75-95%

Hydropower Calculations

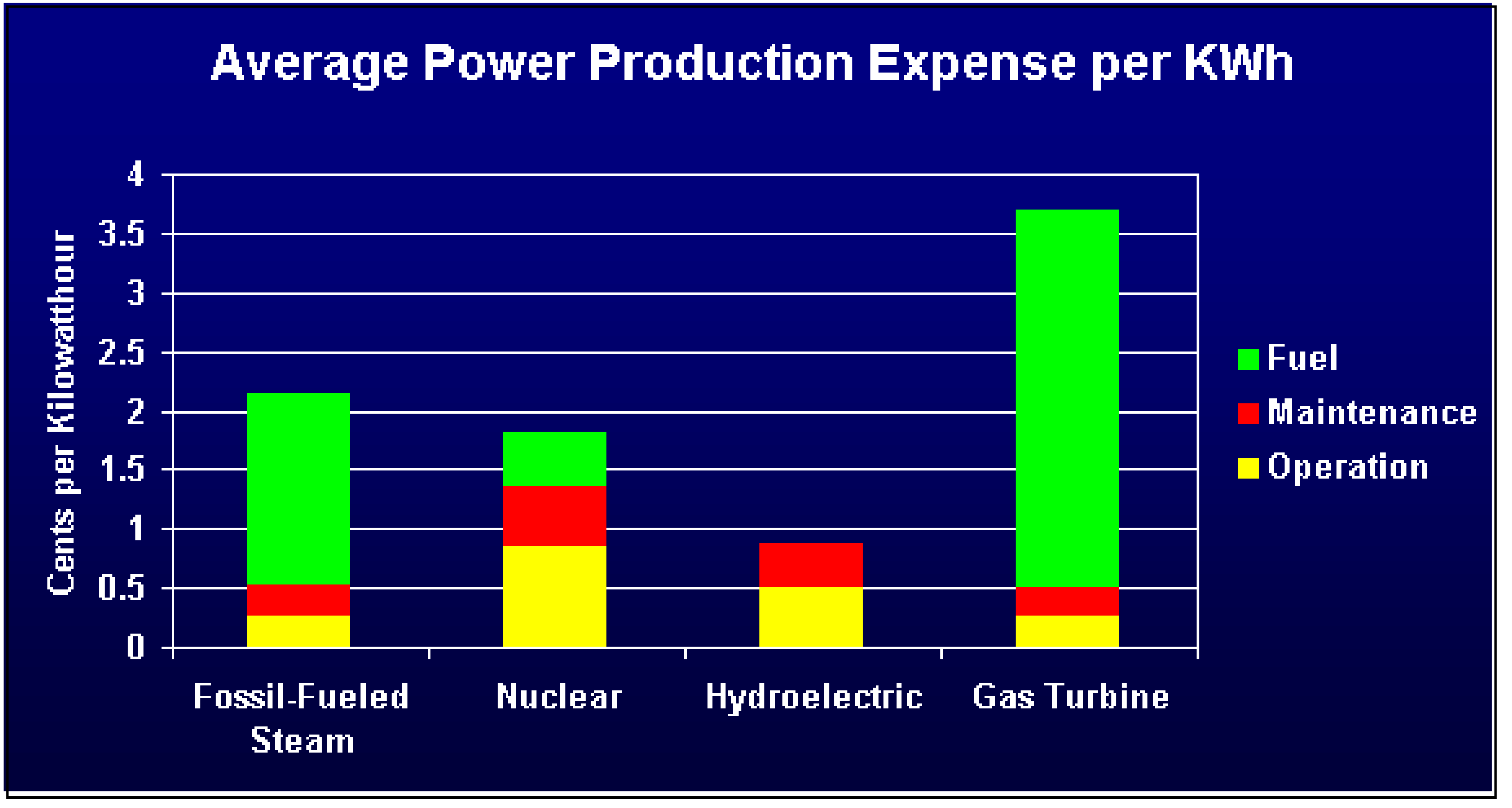
$$P = g \times \eta \times Q \times H$$

$$P \cong 10 \times \eta \times Q \times H$$

- P = power in kilowatts (kW)
- 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)

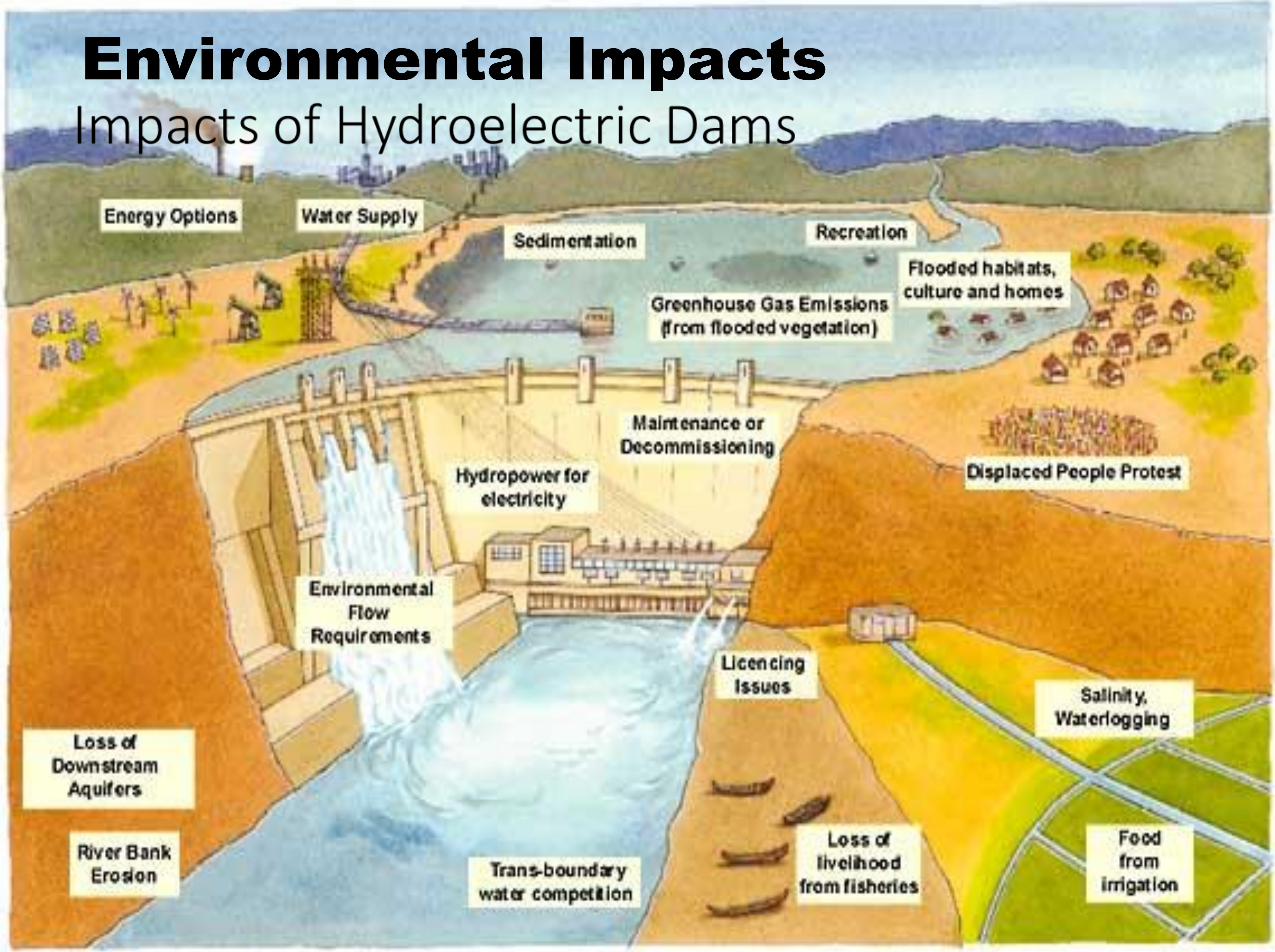
Economics of Hydropower

Production Expense Comparison



Environmental Impacts

Impacts of Hydroelectric Dams



Ecological Impacts

1. Loss of forests, wildlife habitat, species
2. Degradation of upstream catchment areas due to inundation of reservoir area
3. Rotting vegetation also emits greenhouse gases
4. Loss of aquatic biodiversity, fisheries, other downstream services
5. Cumulative impacts on water quality, natural flooding
6. Disrupt transfer of energy, sediment, nutrients
7. Sedimentation reduces reservoir life, erodes turbines
8. Creation of new wetland habitat
9. Fishing and recreational opportunities provided by new reservoirs

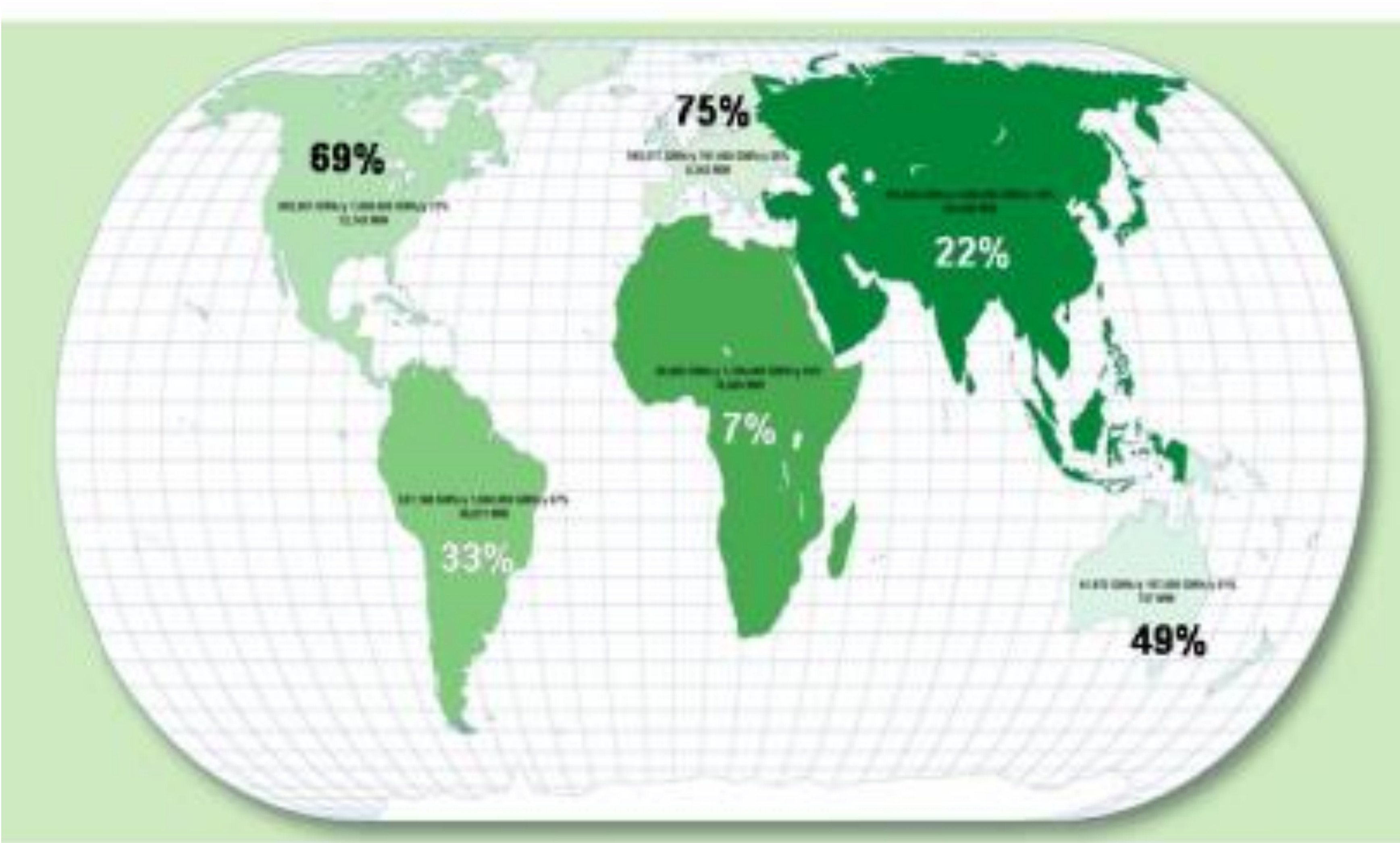
Environmental and Social Issues

1. Land use – inundation and displacement of people
2. Impacts on natural hydrology
   I. Increase evaporative losses
   II. Altering river flows and natural flooding cycles
   III. Sedimentation/silting
3. Impacts on biodiversity
   I. Aquatic ecology, fish, plants, mammals
4. Water chemistry changes
   I. Mercury, nitrates, oxygen
   II. Bacterial and viral infections
5. Structural dam failure risks
6. Seismic Risks

Hydropower – advantages and risks

Positive	Negative
Emissions-free, with virtually no CO2, NOX, SOX, hydrocarbons, or particulates	Frequently involves impoundment of large amounts of water with loss of habitat due to land inundation
Renewable resource with high conversion efficiency to electricity (80+%)	Variable output – dependent on rainfall and snowfall
Dispatchable with storage capacity	Impacts on river flows and aquatic ecology, including fish migration and oxygen depletion
Usable for base load, peaking and pumped storage applications	Social impacts of displacing indigenous people
Scalable from 10 KW to 20,000 MW	Health impacts in developing countries
Low operating and maintenance costs	High initial capital costs
Long lifetimes	Long lead time in construction of large projects

Developed Hydropower Capacity



Water Environmental Problems with Dams

1) Silt buildup fills reservoir (Yangtze; levees)

2) Fish migration disrupted (Columbia)

3)Water temperature decreases (Colorado)

4) Water gets more saline (Colorado)

5) Water loses oxygen (Brazil)

6) Water slows down, increases disease (mosquitos, Aswan))

7) Water traps pollution, slows pollution flushing

Major Hydropower Producers

- Canada, 341,312 GWh (66,954 MW installed)
- USA, 319,484 GWh (79,511 MW installed)
- Brazil, 285,603 GWh (57,517 MW installed)
- China, 204,300 GWh (65,000 MW installed)
- Russia, 173,500 GWh (44,700 MW installed)
- Norway, 121,824 GWh (27,528 MW installed)
- Japan, 84,500 GWh (27,229 MW installed)
- India, 82,237 GWh (22,083 MW installed)
- France, 77,500 GWh (25,335 MW installed)

1999 figures, including pumped-storage hydroelectricity

"Hydroelectricity," Wikipedia.org