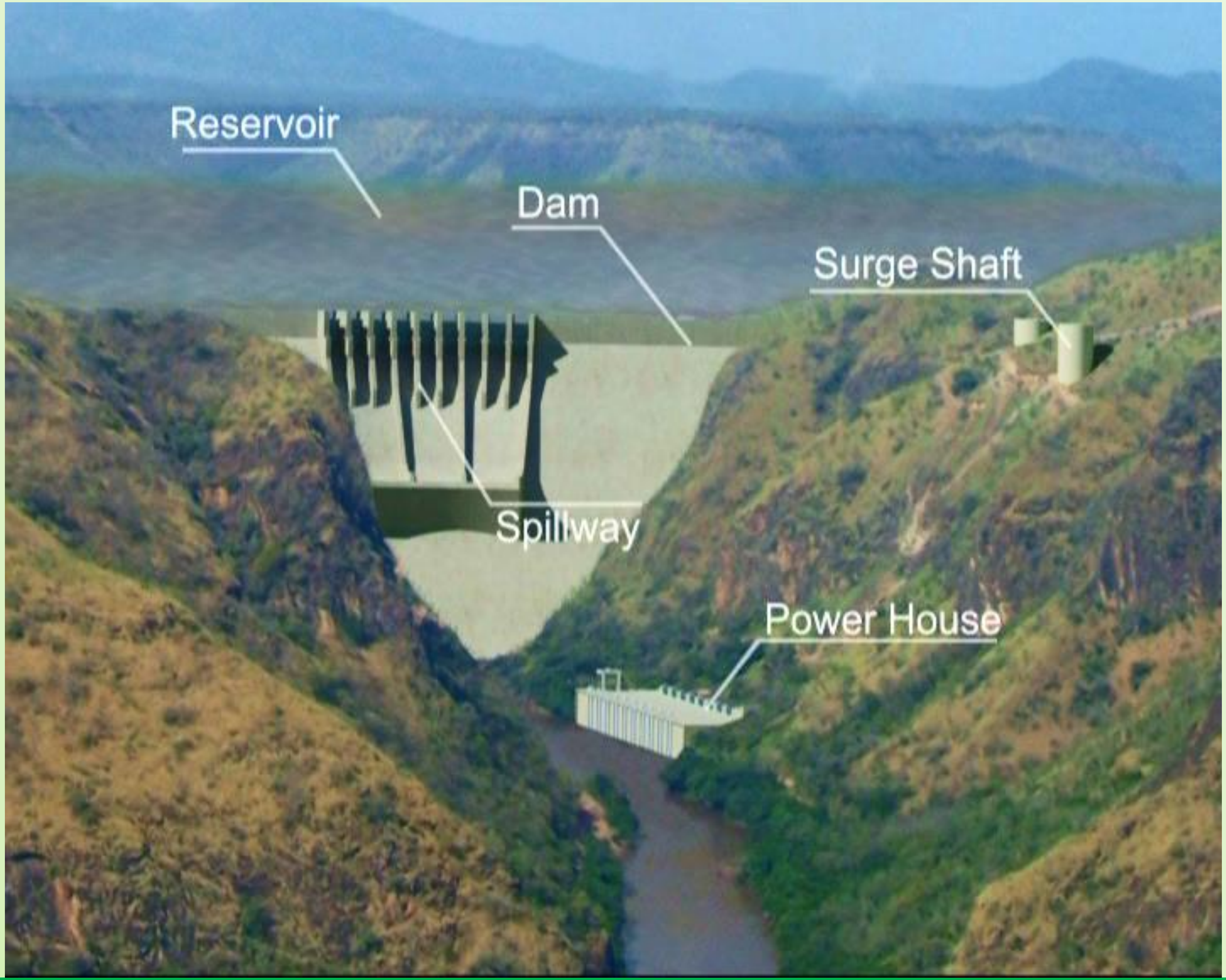
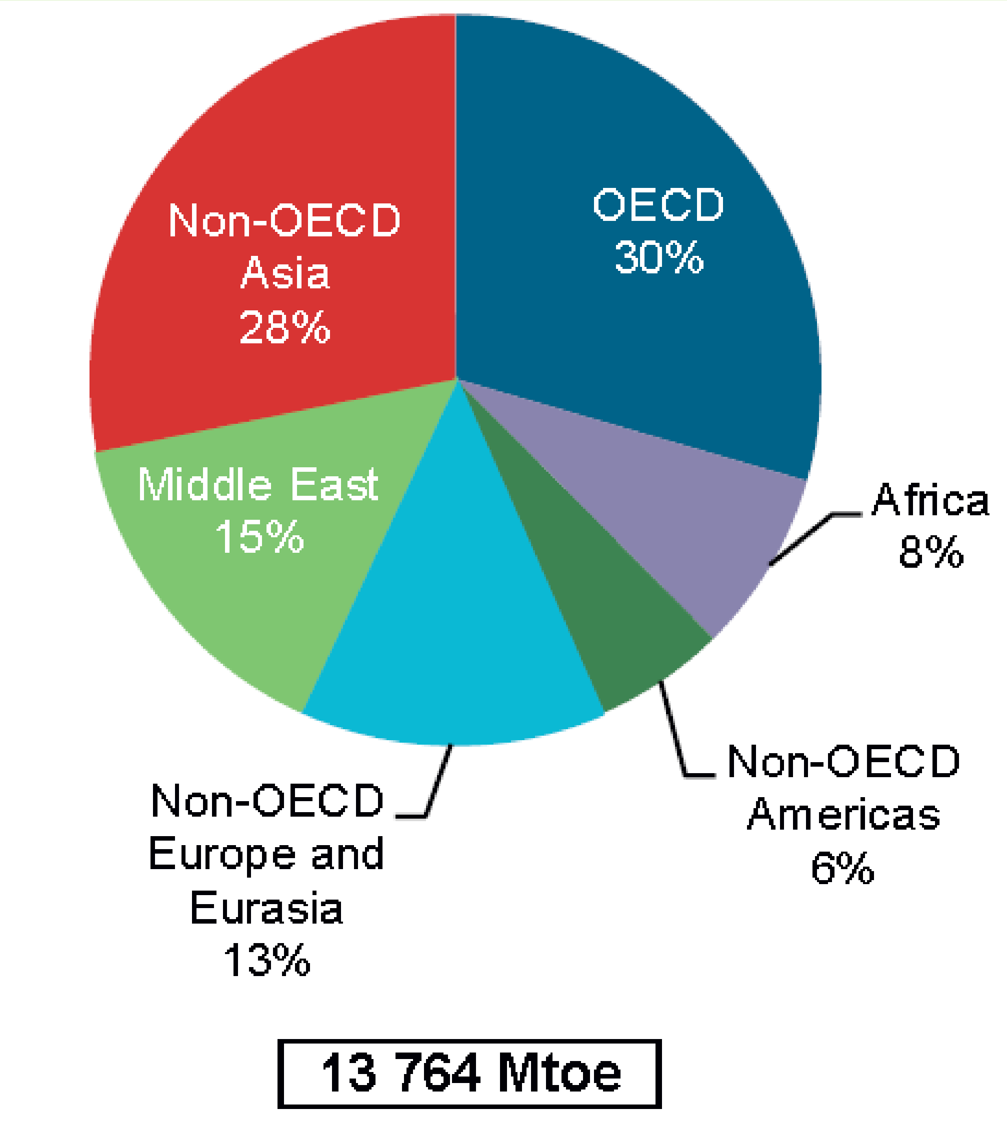
Hydropower Engineering :Heng 7011

Chapter 1: Energy sources and Hydropower



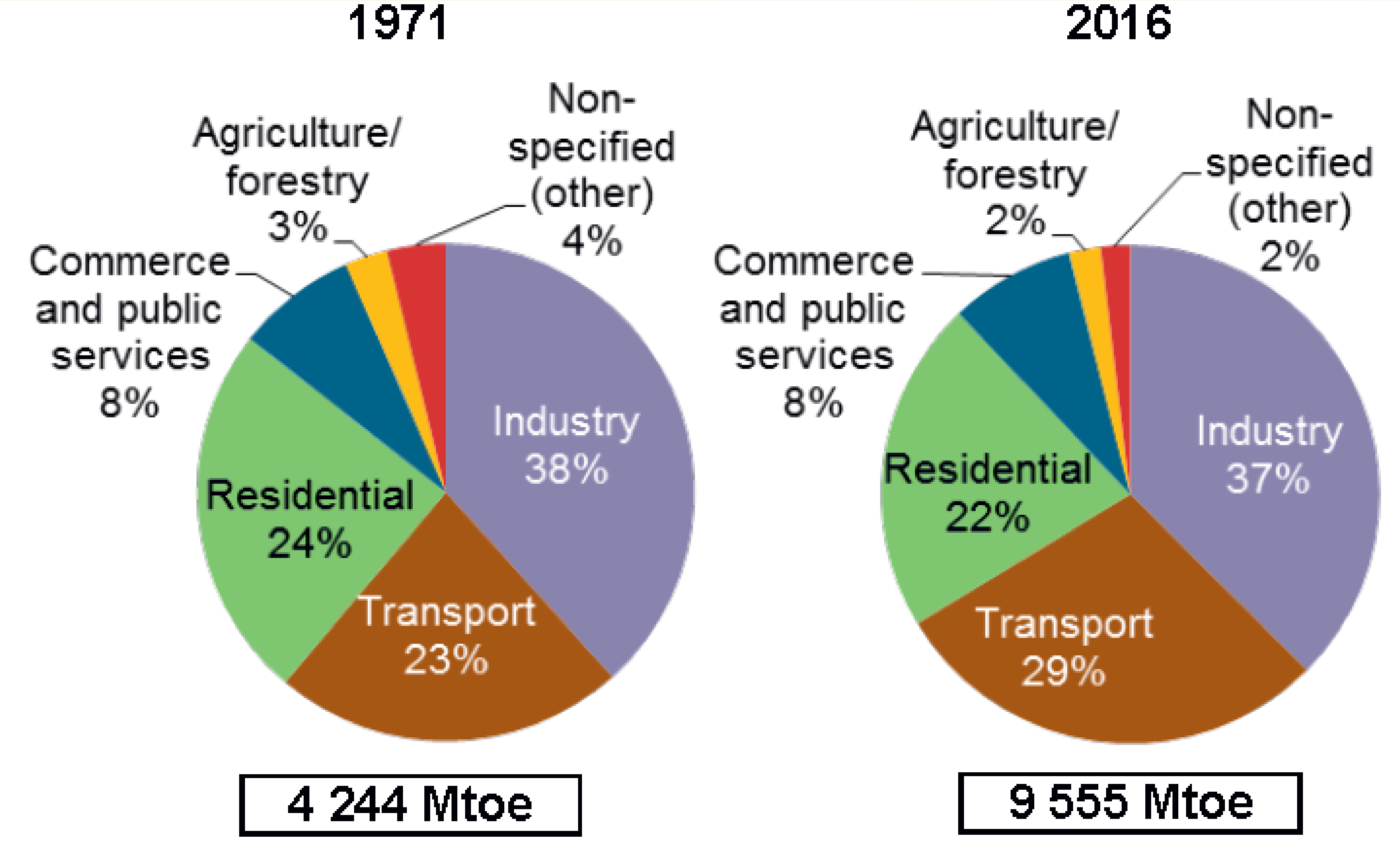
Total Energy production by region (2016)



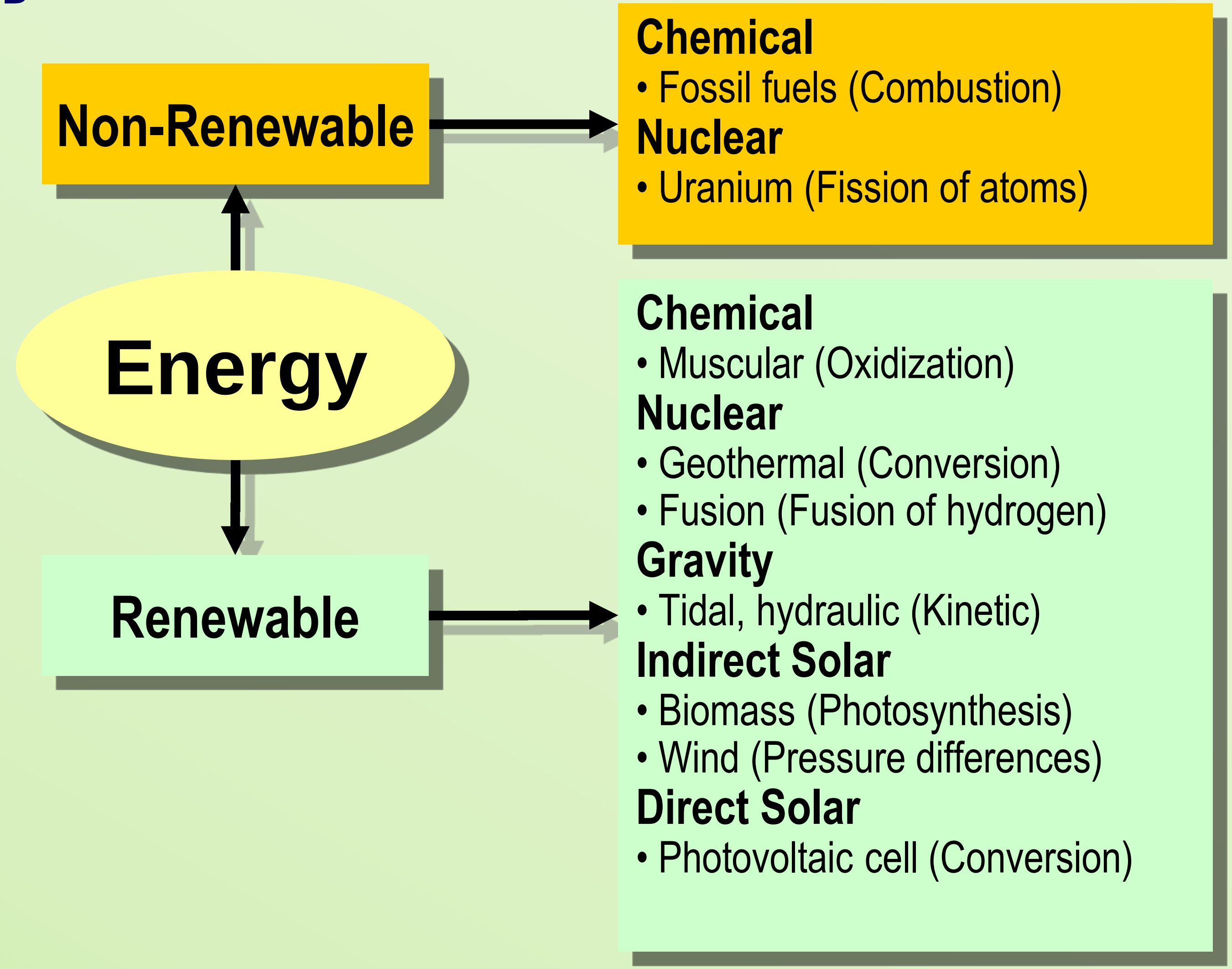
OECD-The Organisation for Economic Co-operation and Development

Mtoe. Millions of tonnes of oil equivalent (**Mtoe**) is a unit of **energy** used to describe the **energy** content of all fuels, typically on a very large scale. It is equal to 4.1868×10^{16} Joules, or 41.868 petajoules which is a tremendous amount of **energy**.

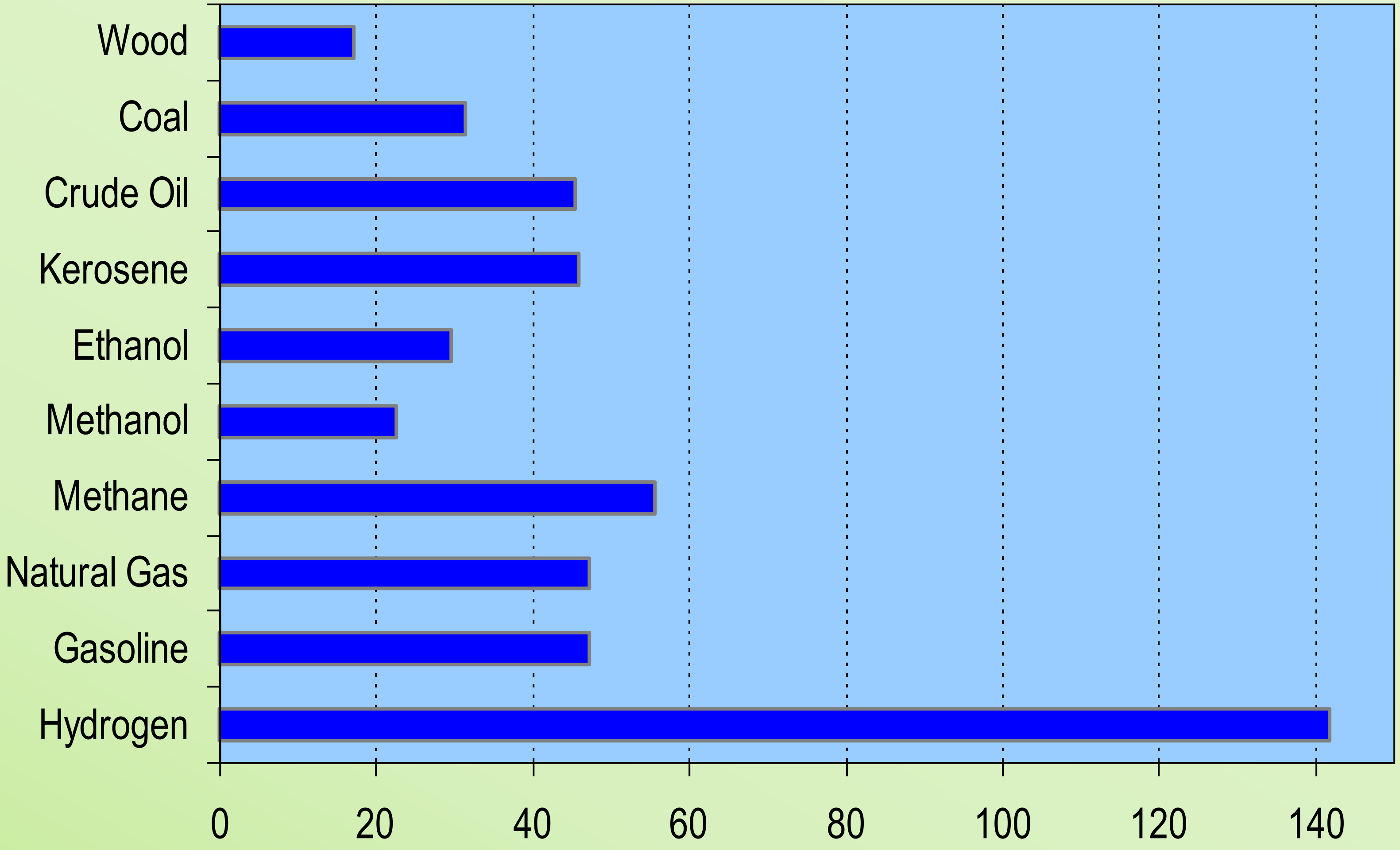
Total final consumption by sector



Sources of Energy

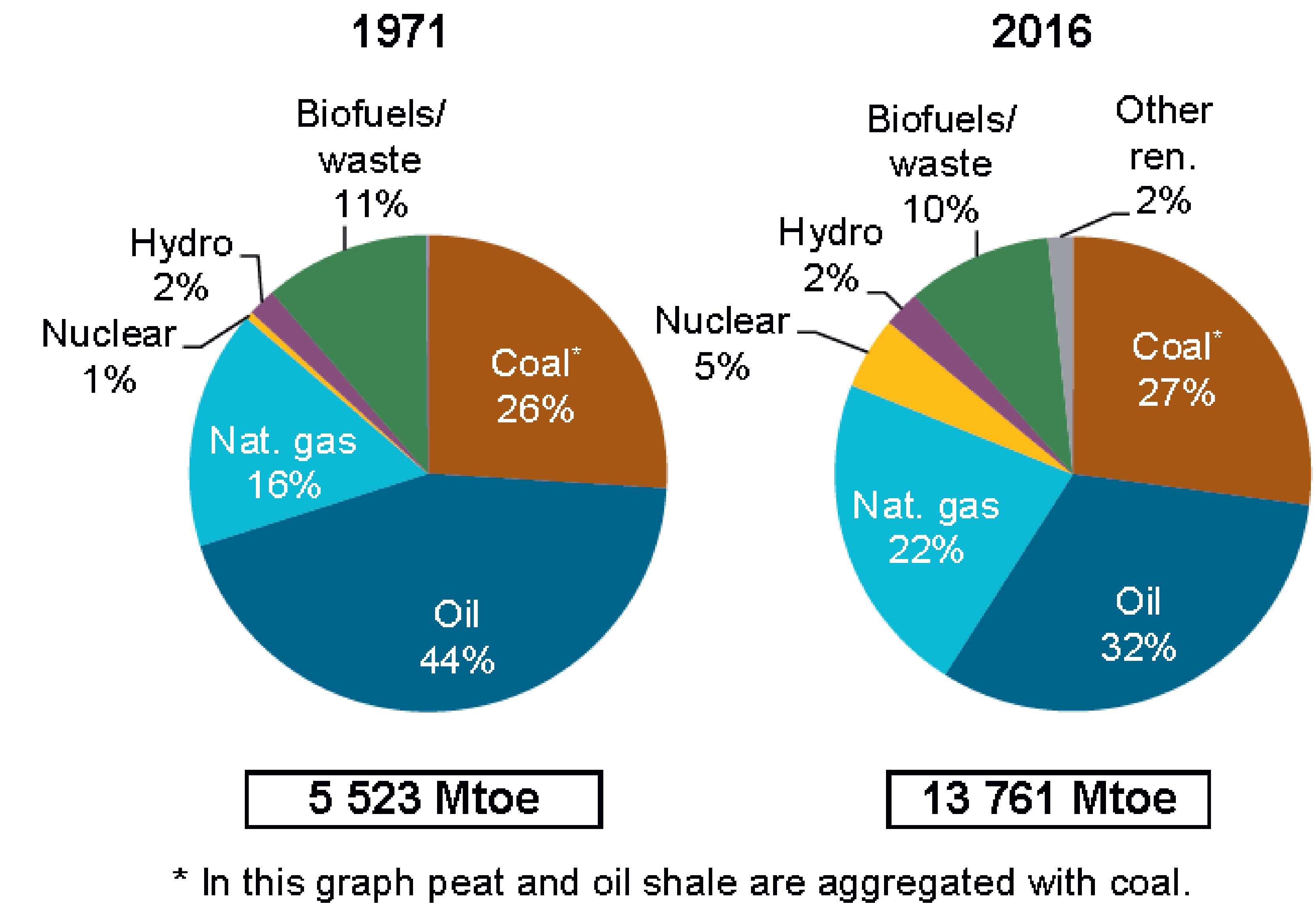


Chemical Energy Content of some Fuels (in MJ/kg)



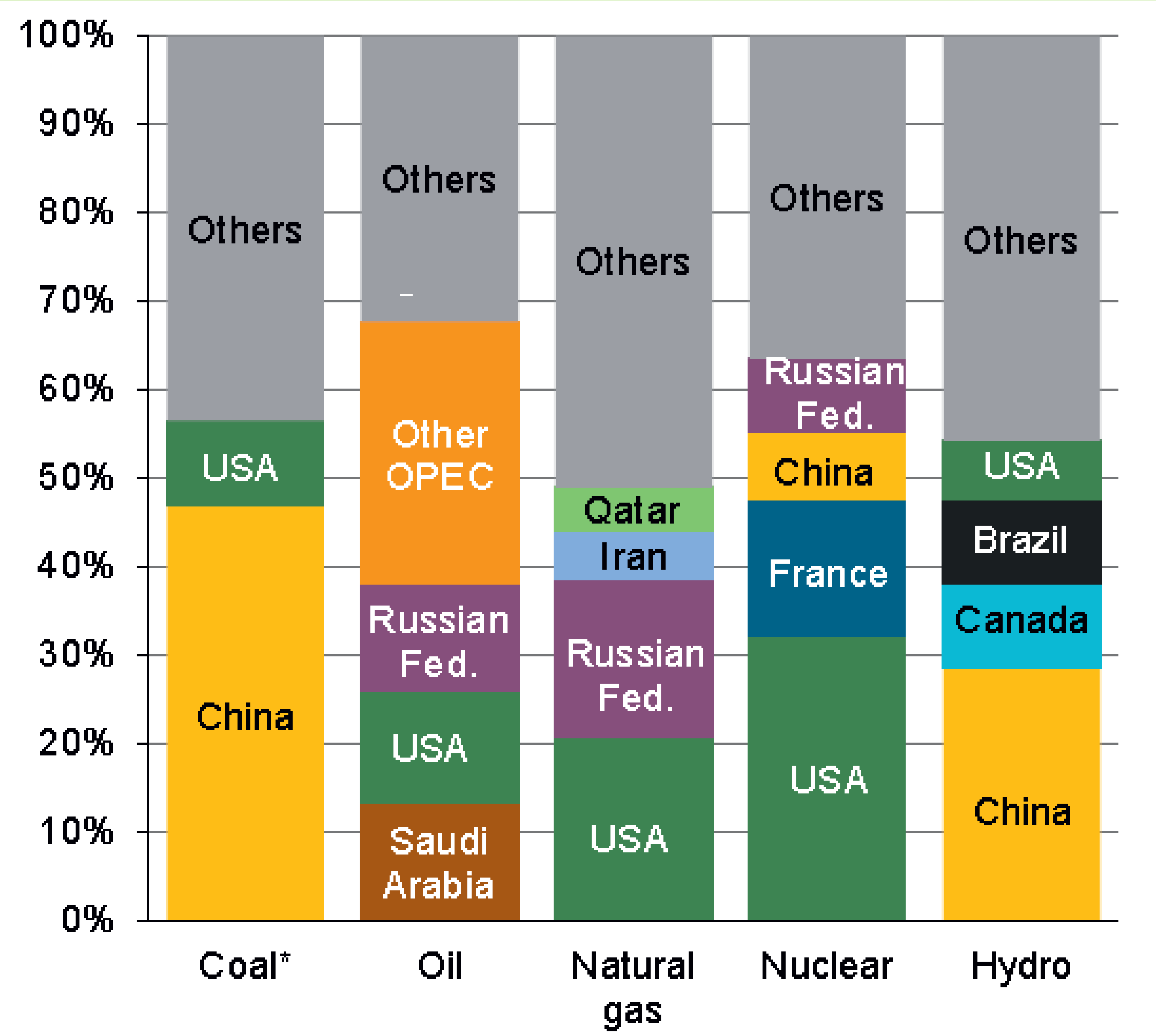
Source: adapted from C. Ronneau (2004), Energie, pollution de l'air et développement durable, Louvain-la-Neuve: Presses Universitaires de Louvain.

Total primary energy supply by fuel



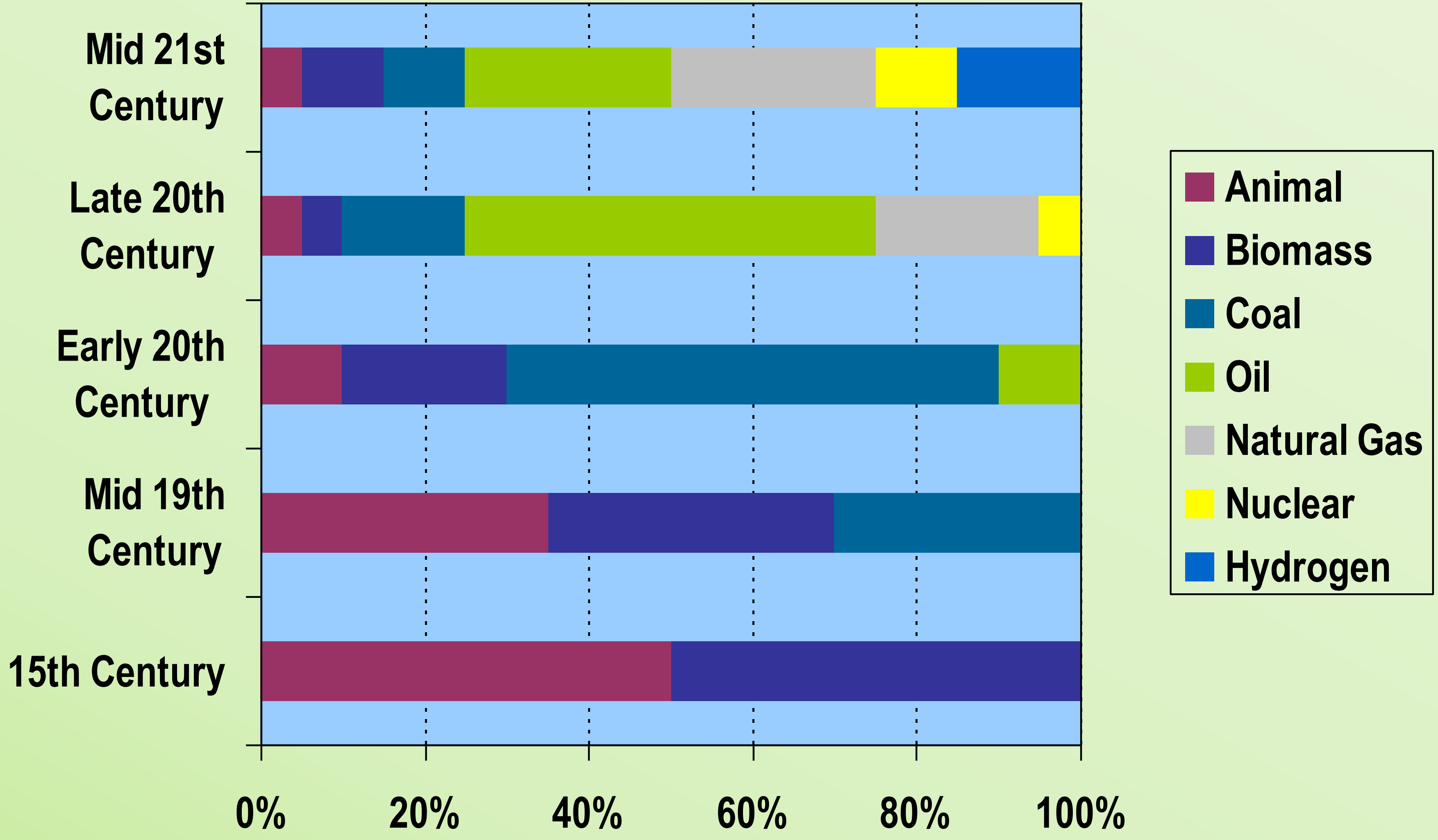
Primary energy (PE) is an energy form found in nature that has not been subjected to any human engineered conversion process. It is energy contained in raw fuels, and other forms of energy received as input to a system. Primary energy can be non-renewable or renewable.

Largest producers by fuel in 2016



* In this graph peat and oil shale are aggregated with coal.

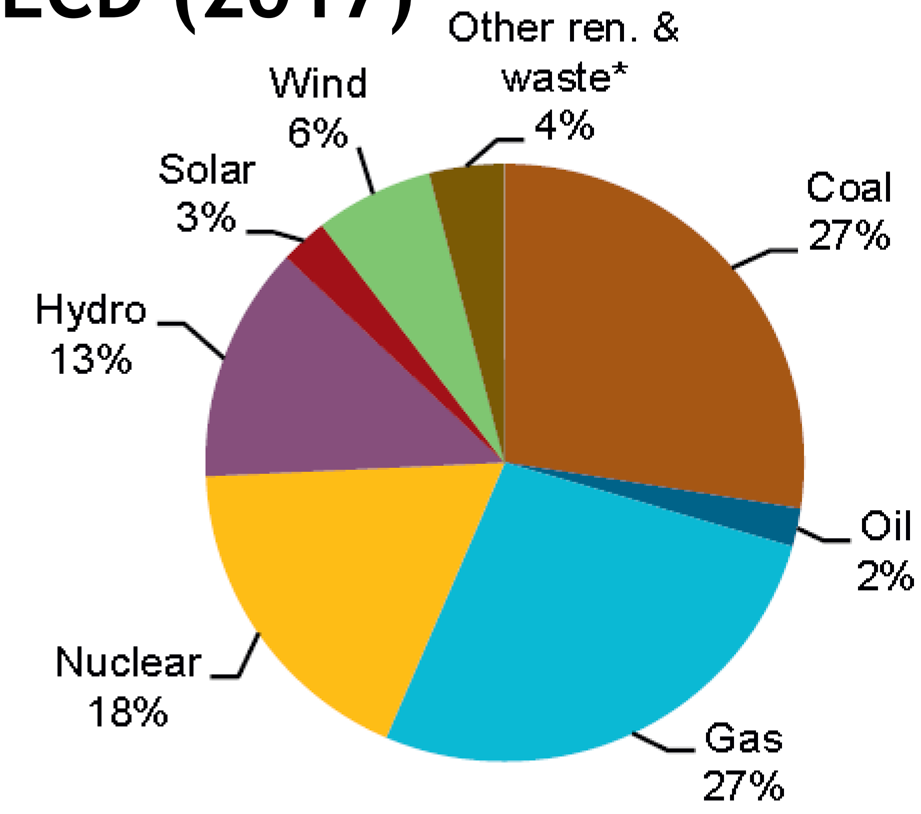
Evolution of Energy Sources



Source: Jean-Paul Rodrigue (2017)-The Geography of Transport Systems

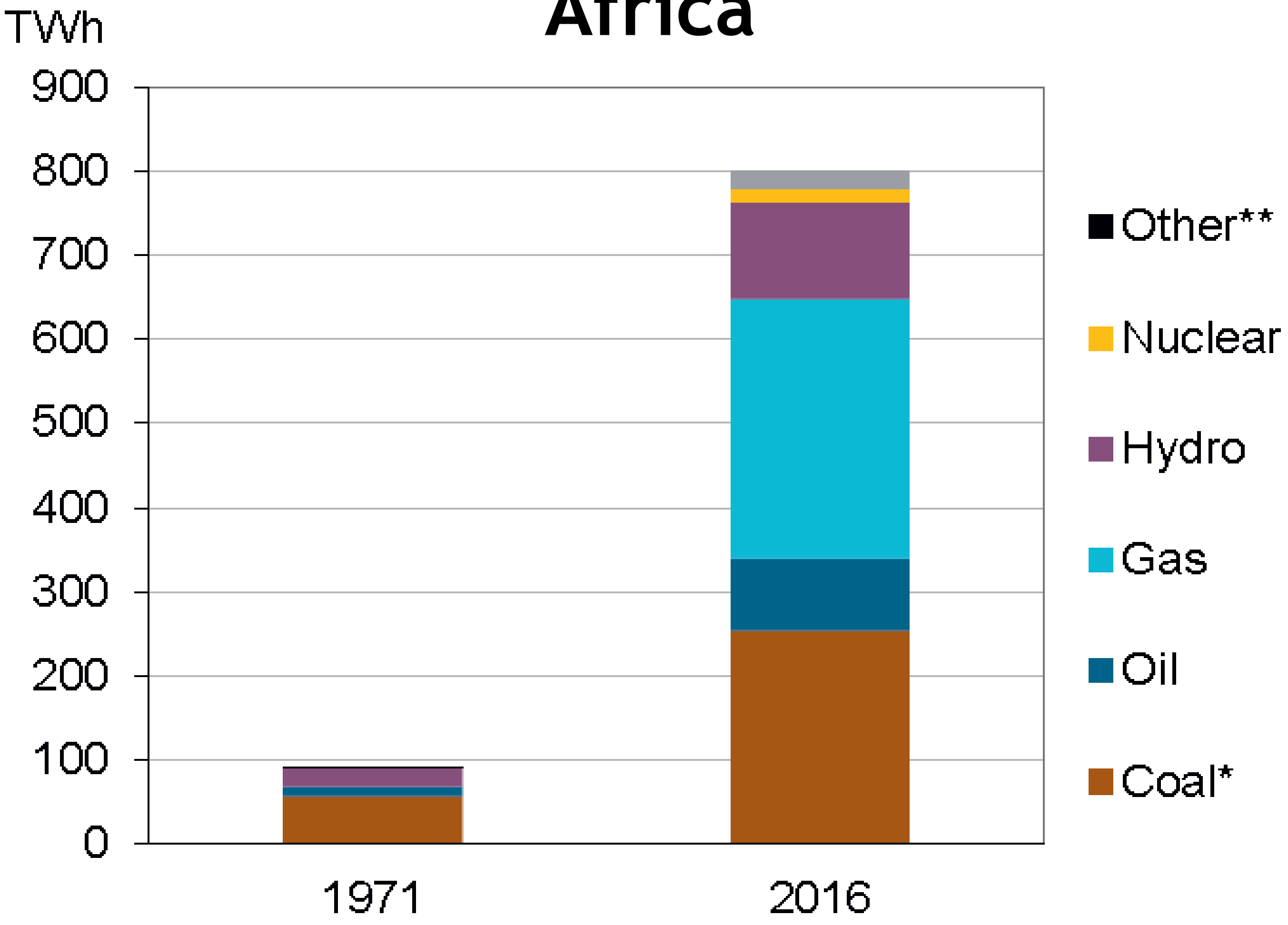
Electricity generation mix (2017)

OECD (2017)



*Includes geothermal, tide, biofuels, all waste and heat.

Africa



* In this graph peat and oil shale are aggregated with coal.

** Other includes non-renewable waste and non-renewable heat.

Challenges

- Energy Supply
  - Providing supply to sustain growth and requirements.
  - A modern society depends on a stable and continuous flow of energy.
- Energy Demand
  - Generate more efficient devices:
    - Transportation.
    - Industrial processes.
    - Appliances.
- Environment
  - Provide environmentally safe sources of energy.
  - Going through the energy transition (from solid to gazes).

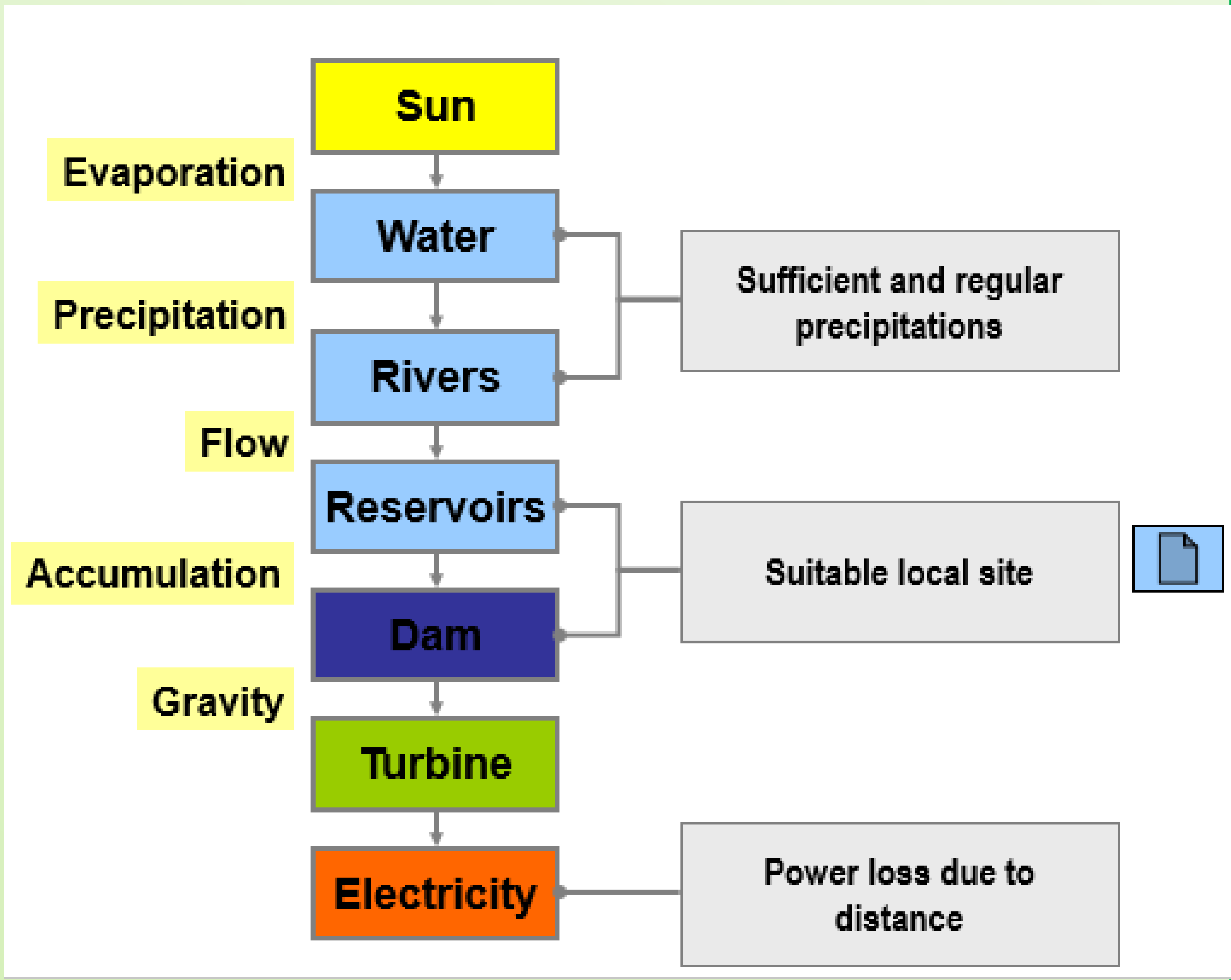
Conventional Energy Resources

What sources of energy have filled our requirements so far?

- 1. Coal
- 2. Petroleum
- 3. Natural Gas
- **4. Hydropower**
- 5. Nuclear Power

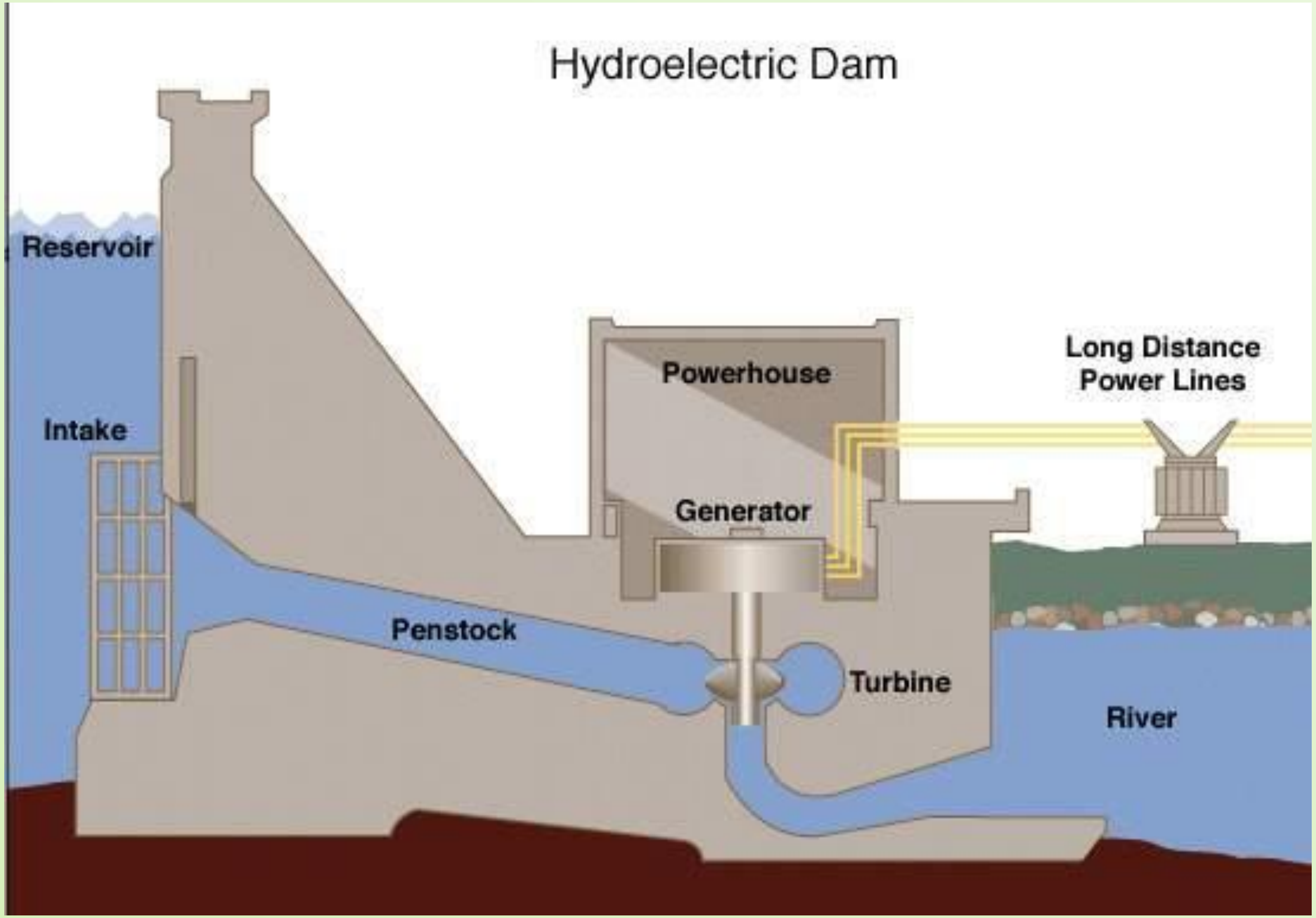
Hydropower

- Nature
  - Generation of electricity using the flow of water as the energy source.
  - Gravity as source.
  - Requires a large reservoir of water.
  - Considered cleaner, less polluting than fossil fuels.
- Tidal power
  - Take advantage of the variations between high and low tides.



- Hydropower engineering refers to the **technology** involved in converting the **pressure energy** and **kinetic energy** of water into more easily used **electrical energy.**

- The prime mover in the case of hydropower is a water wheel or **hydraulic turbine** which transforms the energy of the water into mechanical energy.
- It is necessary to create a head at a point of the stream and to convey the water through the head to the turbines.



Comparison with other methods of power generation

Positive sides

- Eliminates the flue gas emissions from fossil fuel combustion
- Avoids the hazards of coal mining and the indirect health effects of coal emissions
- Compared to nuclear power, hydroelectricity generates no nuclear waste, has none of the dangers associated with uranium mining, nor nuclear leaks
- Unlike uranium, hydroelectricity is also a renewable energy source
- Compared to wind farms, hydroelectricity power plants have a more predictable load factor*
- If the project has a storage reservoir, it can generate power when needed, Hydroelectric plants can be easily regulated to follow variations in power demand

*Demand Load Factor = KWh/KW/hours in the period

Challenges

- Construction of a hydroelectric plant requires a long lead-time for site studies, hydrological studies, and environmental impact assessment
- Hydrological data up to 50 years or more is usually required to determine the best sites and operating regimes for a large hydroelectric plant
- The number of sites that can be economically developed for hydroelectric production is limited; in many areas the most cost-effective sites have already been exploited
- New hydro sites likely to be far from population centers (extensive transmission lines)
- Hydroelectric generation depends on rainfall in the watershed, and may be significantly reduced in years of low rainfall or snowmelt
- Long-term energy yield may be affected by climate change
- Utilities that primarily use hydroelectric power may spend additional capital to build extra capacity to ensure sufficient power is available in low water years

History of Hydropower

B.C.	Hydropower used by the Greeks to turn water wheels for grinding wheat into flour, more than 2,000 years ago.
Mid-1770s	French hydraulic and military engineer Bernard Forest de Bélidor wrote *Architecture Hydraulique*, a four-volume work describing vertical- and horizontal-axis machines.
1775	U.S. Army Corps of Engineers founded, with establishment of Chief Engineer for the Continental Army.
1880	Michigan's Grand Rapids Electric Light and Power Company, generating electricity by dynamo belted to a water turbine at the Wolverine Chair Factory, lit up 16 brush-arc lamps.
1881	Niagara Falls city street lamps powered by hydropower.
1882	World's first hydroelectric power plant began operation on the Fox River in Appleton, Wisconsin.
1886	About 45 water-powered electric plants in the U.S. and Canada.

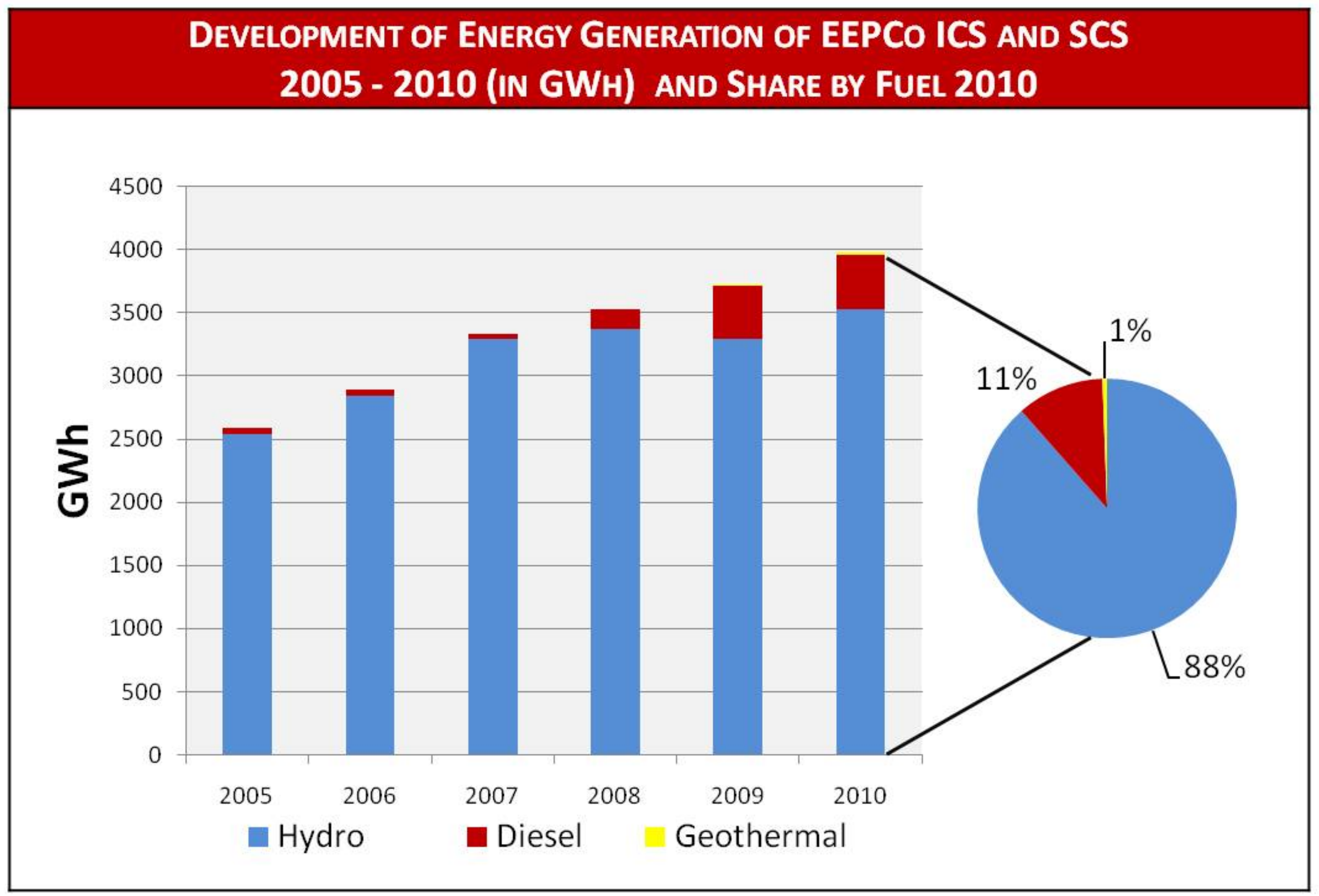
1887	San Bemardino, Ca., opens first hydroelectric plant in the west.
1889	Two hundred electric plants in the U.S. use waterpower for some or all generation.
1901	First Federal Water Power Act.
1907	Hydropower provided 15% of U.S. electrical generation.
1920	Hydropower provided 25% of U.S. electrical generation. Federal Power Act establishes Federal Power Commission authority to issue licenses for hydro development on public lands.
1937	Bonneville Dam, first Federal dam, begins operation on the Columbia River. Bonneville Power Administration established.
1940	Hydropower provided 40% of electrical generation. Conventional capacity tripled in United States since 1920.
1980	Conventional Capacity nearly tripled in USA since 1940

World's Largest Dams

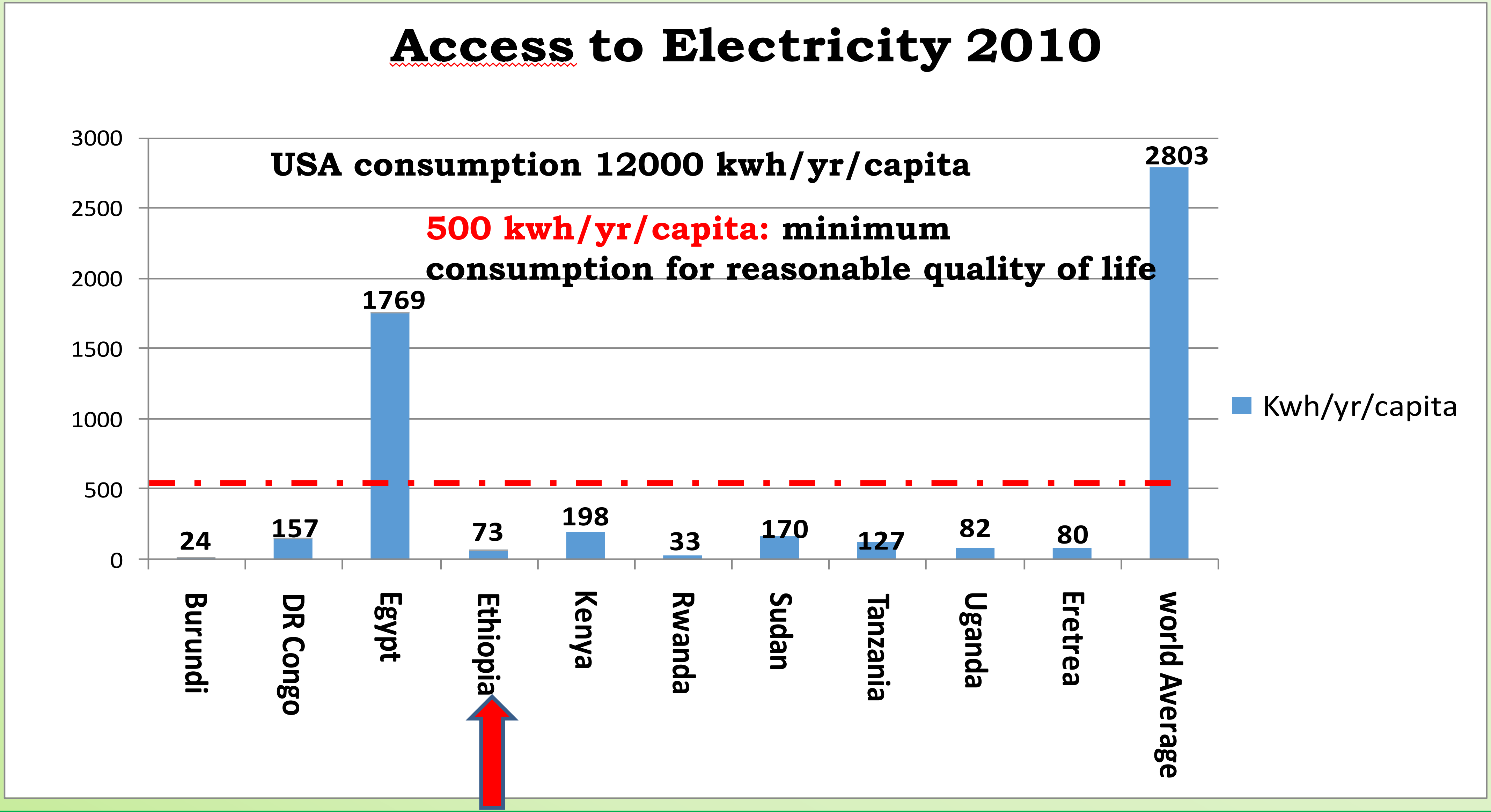
Name	Country	Year	Max Generation	Annual Production
Three Gorges	China	2009	18,200 MW	
Itaipú	Brazil/Paraguay	1983	12,600 MW	93.4 TW-hrs
Guri	Venezuela	1986	10,200 MW	46 TW-hrs
Grand Coulee	United States	1942/80	6,809 MW	22.6 TW-hrs
Sayano Shushenskaya	Russia	1983	6,400 MW	
Robert-Bourassa	Canada	1981	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

Ethiopian Energy Resources

Resources	Unit	Exploitable Reserve	Exploited Percent
Hydropower	MW	45, 000	< 5
Solar Energy	KWh/m^2	Av	
Wind Power	GWm/s	1,	
Geothermal	MW	7	
Wood	Million tons	1	
Agricultural waste	Million tons	1	
Natural Gas	10^9 m^3	1	
Coal	Million tons	3	
Oil Shale	Million tons	2	



Threshold : Access to Electricity



Ethiopia has immense amount of hydropower potential

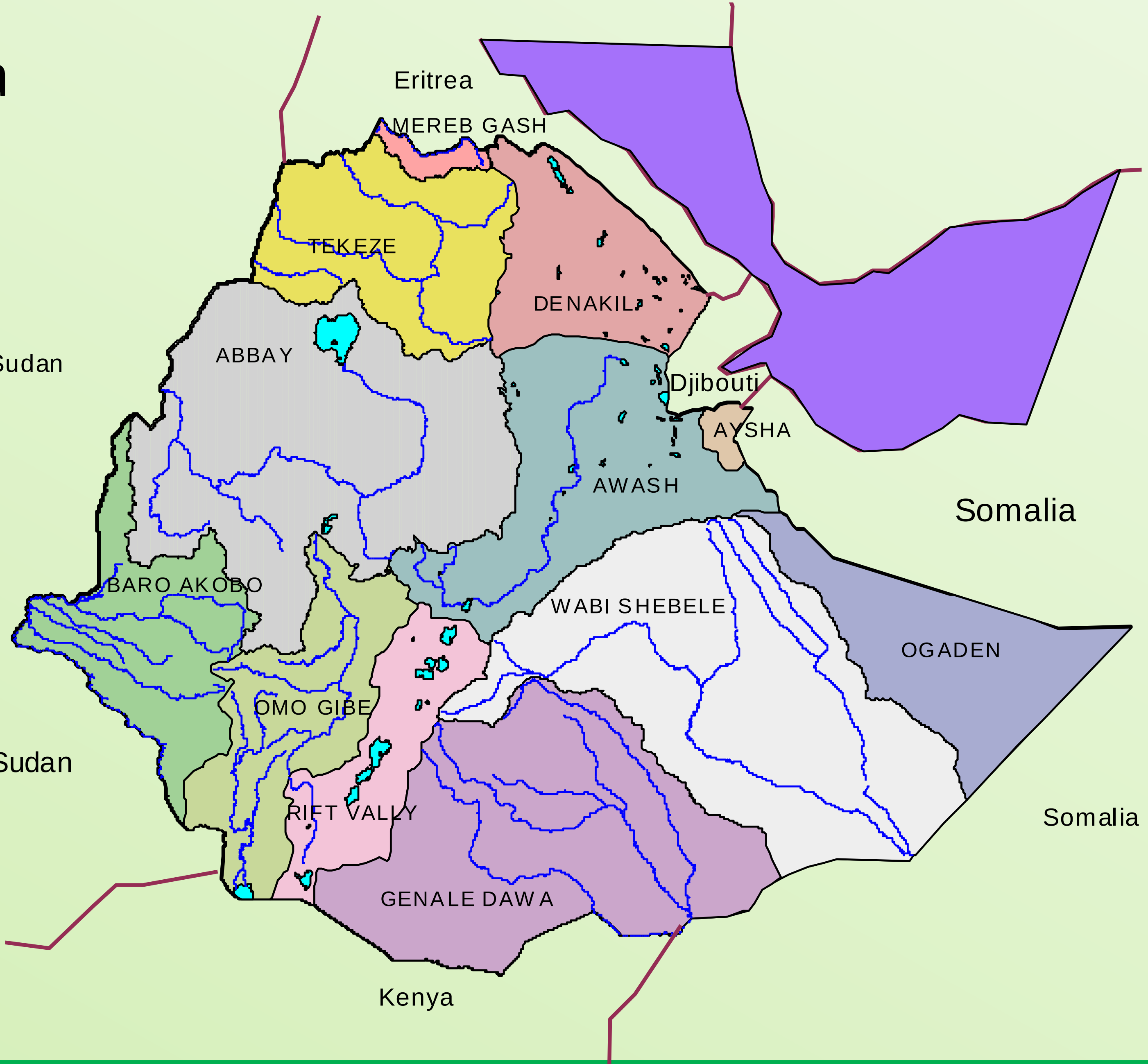
- Only a fraction of this potential has been harnessed so far
- In Ethiopia hydropower generation started in the beginning of 1930's, when Abasamuel hydropower scheme is commissioned in 1932.This station was capable of generating 6MW and operational up to 1970
- Middle class economy targets per capita energy level from 150 to 1500 KWh at least (6500 Europe to 13,500 USA)
- Access from 51% to 75% then 100% in GTP I and GTP II targets.

List of hydropower plants in Ethiopia

Name	Installed capacity (MW)	Commissioning	Basin
Koka	42	1960	Awash River
Awash II	36	1966	Awash River
Awash III	36	1971	Awash River
Fincha	134	1973	Fincha (Blue Nile)
Gilgel Gibe I	180	2004	Gilgel Gibe River
Tekeze	300	2009	Tekeze (Atbara)
Beles	460	2010	Lake Tana (Blue Nile)
Gilgel Gibe II	420	2010	Omo River (no dam, fed by GG I), Under construction
Gilgel Gibe III	1,870	2015	Omo River
Fincha Amerti Neshe	97	2012	Fincha (Blue Nile), Under construction
Halele Worabese	440	2014	Omo River
Gilgel Gibe IV	2,000	2015	Omo River
Chemoga Yeda	278	2013	Tributary of the Blue Nile
Tendaho Irrigation Dam	none	2014	Awash River
Tis Abbay I	11.5	1953	Blue Nile
Tis Abbay II	73	2000	Blue Nile
Sor (self contained)	5	1990	Baro-Akobo
Dembi (self contained)	0.71	1991	Baro-Akobo
Yadot (self contained)	0.35	1990	Genale-Dawa
Melka Wakena	153	1988	Wabi-Shebele
Abasamuel (not operational)	6		Awash River

Water Resources of Ethiopia

- 12 River Basins
- Total Surface water Potential of 122 BCM
- Renewable ground water Potential of 2.6 BCM
- About 97% of the surface water drains to neighbouring countries
- Water Tower of east Africa
- Contribution to Nile Water ca. 86 %



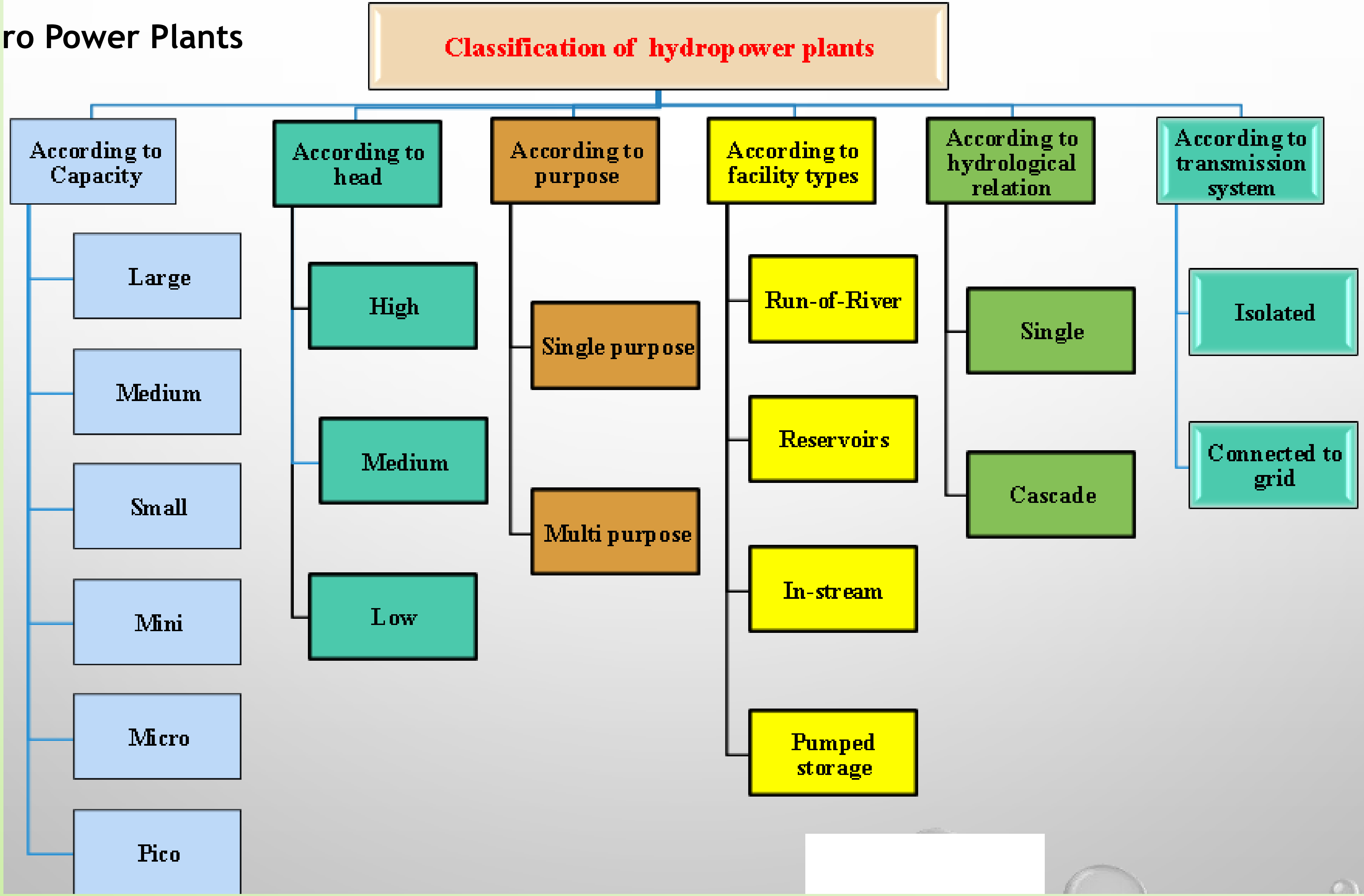
Summary of Hydropower status in Ethiopia

- Currently there are two different power supply systems (The Interconnected System (ICS), which is mainly supplied from hydropower plants) and the Self-Contained System (SCS), which consists of mini hydropower plants and a number of isolated diesel generating units that are widely spread over the country.
- Ethiopia is ranked at number 64 when all hydropower capacity is calculated.
- When completed the Grand Renaissance Dam (6.0GW) and be the largest hydropower plant in Africa.
- 2013 capacity data
  - o Pure Hydro: 1.89 GW
  - o Pumped Hydro: 0.00 GW
  - o Total Capacity: 1.89 GW

Projects included in the 25-year Master Plan

- Tekeze II 450 MW,
- Geba (Geba River in Tigray) , 336MW,
- Halele Werabesa (River Gibe in Turkana basin), 422 MW,
- Genale Dawa III, 258MW,
- Genale Dawa IV, 256 MW,
- Border 800 -1200 MW, located on the Blue Nile,
- Mendia 2400 -2800 MW, located on the Blue Nile,
- Beko Abo 2100 MW, located on the Blue Nile,
- Kara Dodi 1600 MW.

Classification of Hydro Power Plants

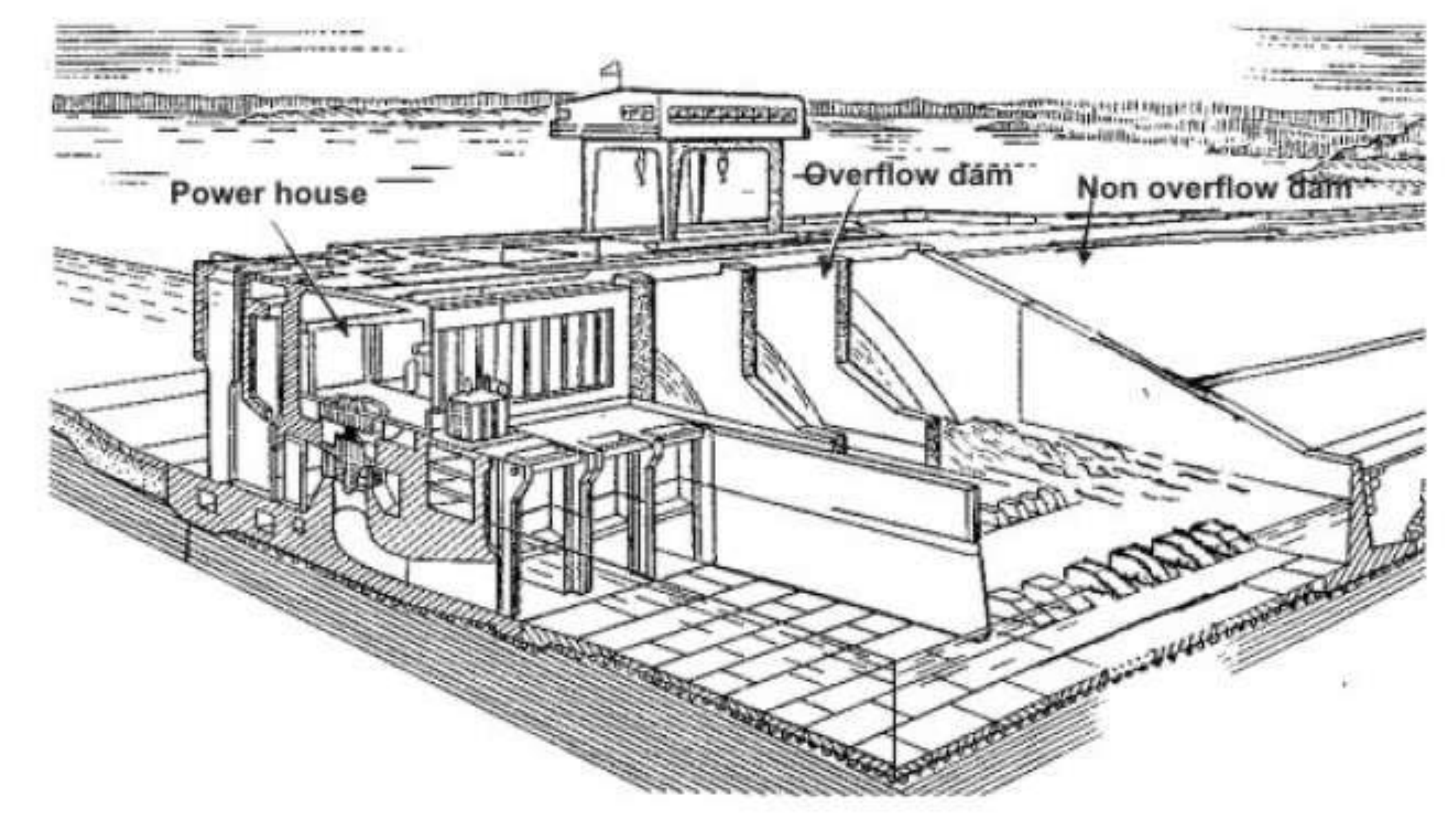


Classification based hydraulic characteristics (facility types)

- Run-of-river schemes
- Storage schemes
- Pumped-Storage schemes
- Tidal power development schemes

Run-of-river schemes

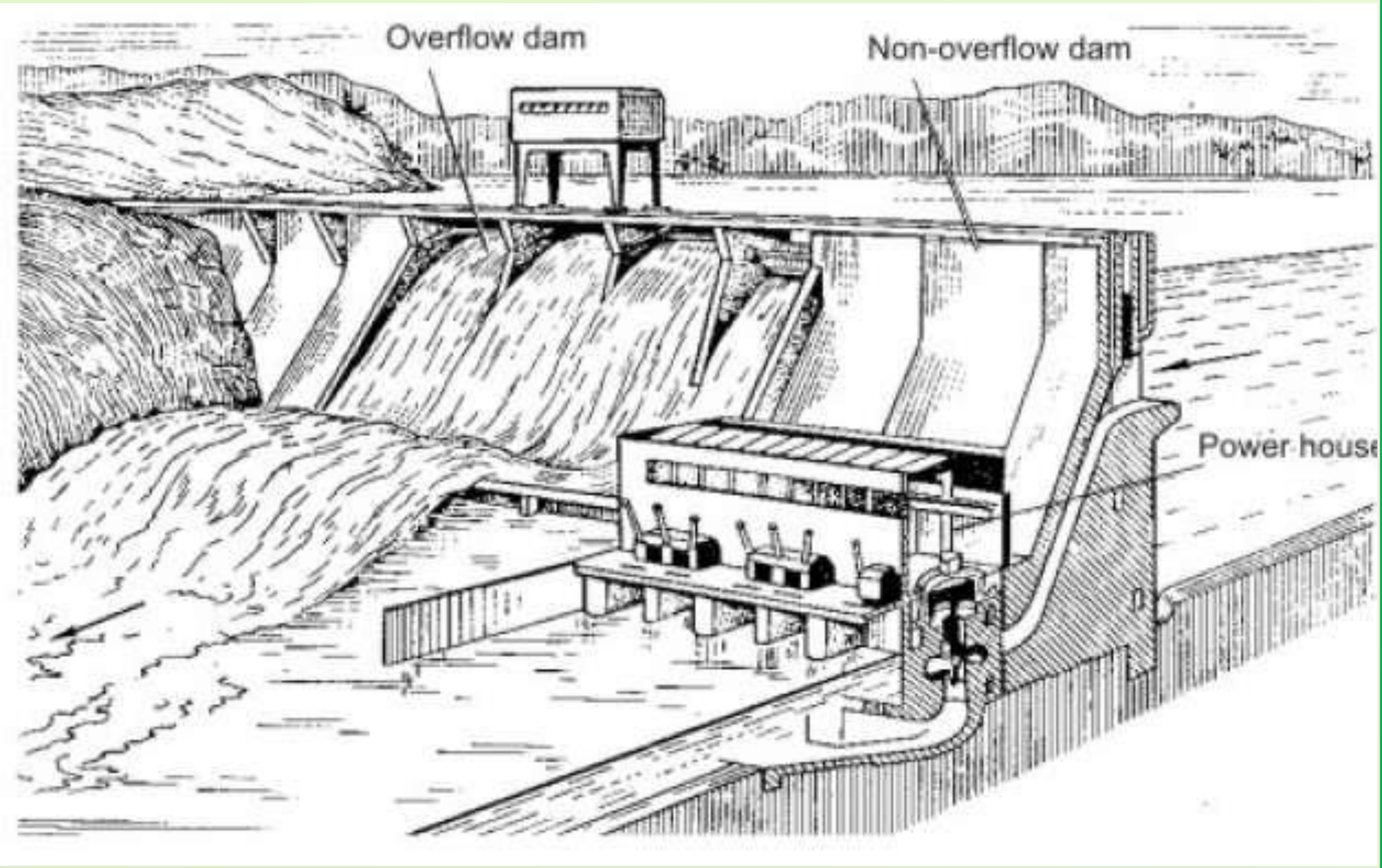
- These are hydropower plants that utilize the stream flow as it comes, without any storage being provided
- Generally, these plants would be feasible only on such streams which have a minimum dry weather flow of such magnitude which makes it possible to generate electricity throughout the year.



- Run-of-river plants may also be provided with some storage
- During off-peak hours of electricity demand, as in the night, some of the units may be closed and the water conserved in the storage space, which is again released during peak hours for power generation.

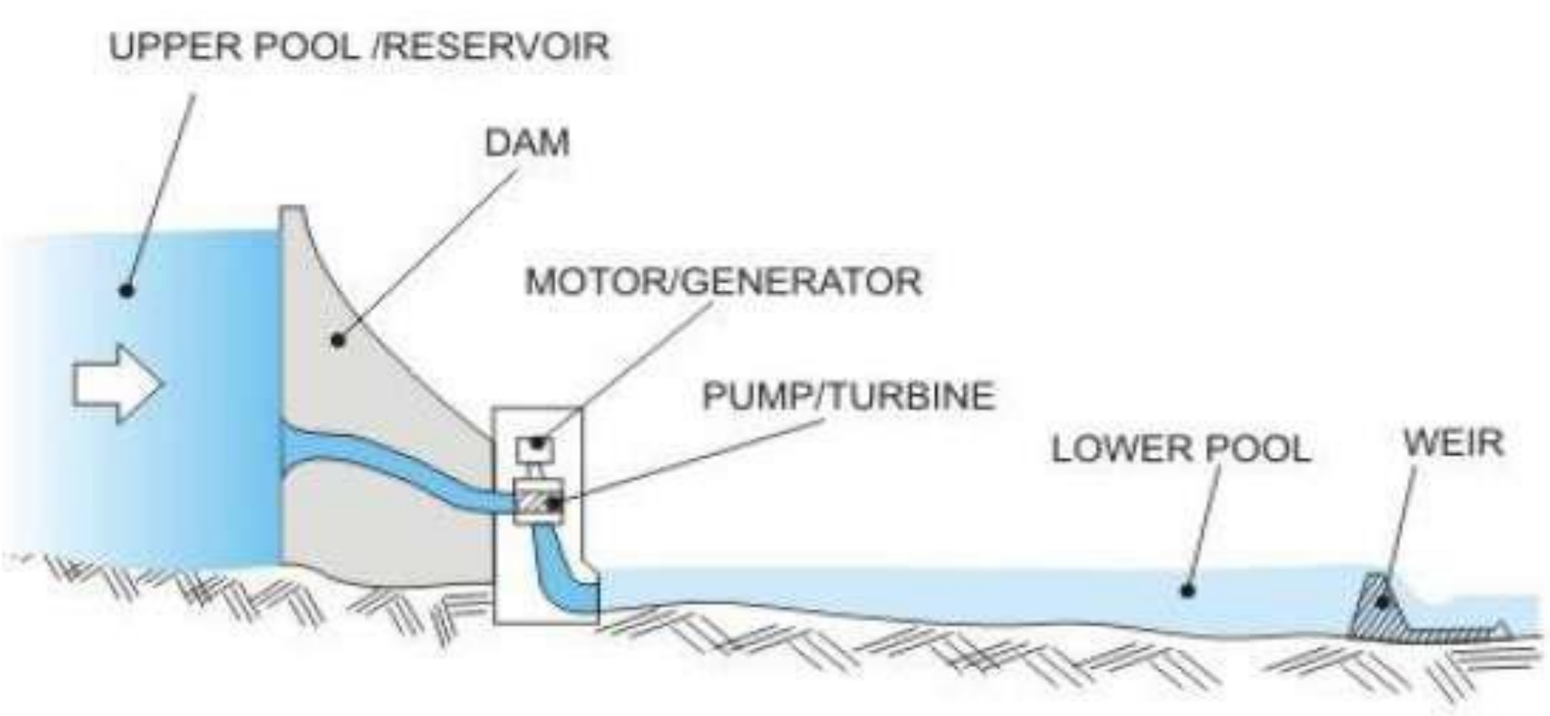
Storage schemes

- Water is supplied from large storage reservoir that have been developed by constructing dams across rivers.
- Generally, the excess flow of the river during rainy seasons would be stored in the reservoir to be released gradually during periods of lean flow.



- Naturally, the assured flow for hydropower generation is more certain for the storage schemes than the run-of-river schemes.

Pumped-Storage schemes



- During times of peak load, water is drawn from the head-water pond to run the reversible turbine-pump units in the turbine mode and the water released gets collected in the tail-water pond.

During off-peak hours, the reversible units are supplied with the excess electricity available in the power grid which then pumps part of the water of the tail-water pond back into the head-water reservoir.

Tidal power development schemes

These are hydropower plants which utilize the rise in water level of the sea due to a tide

- During high tide, the water from the sea-side starts rising, and the turbines start generating power as the water flows into the bay.
- As the sea water starts falling during low tide the water from the basin flows back to the sea which can also be used to generate power provided another set of turbines in the opposite direction are installed.
- Globally, so far around 265 MW has been developed, although around 120,000MW are in the planning stage.

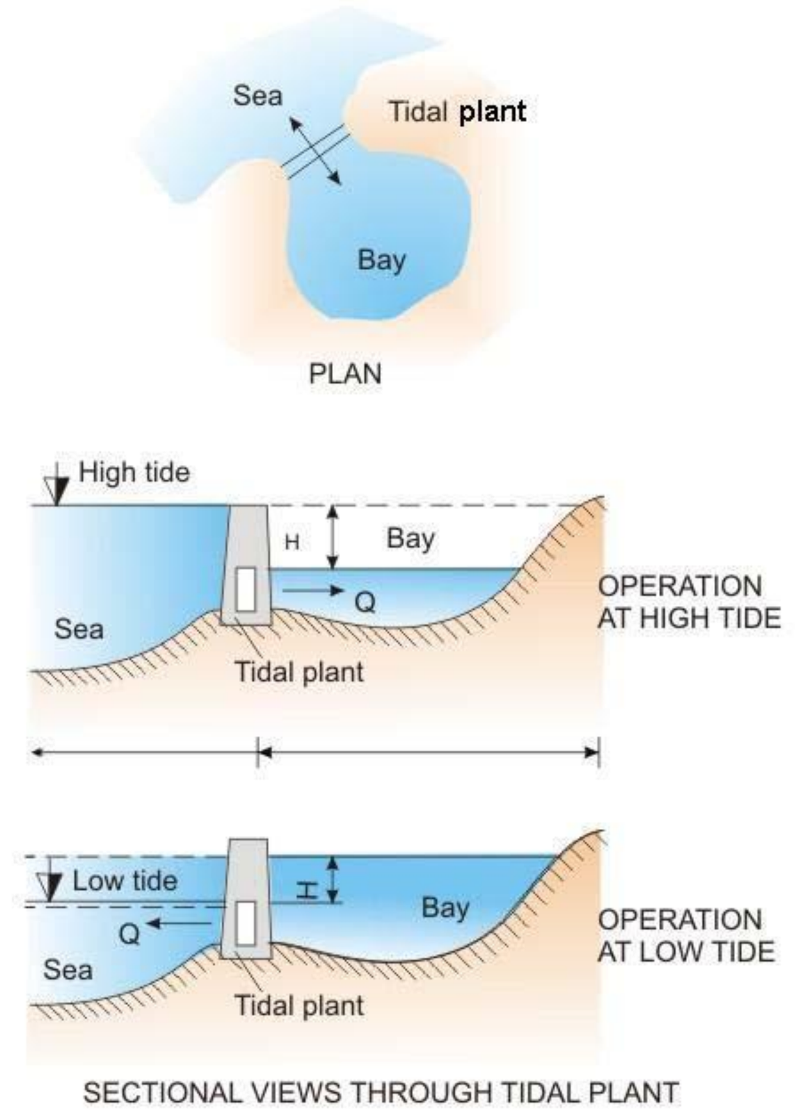
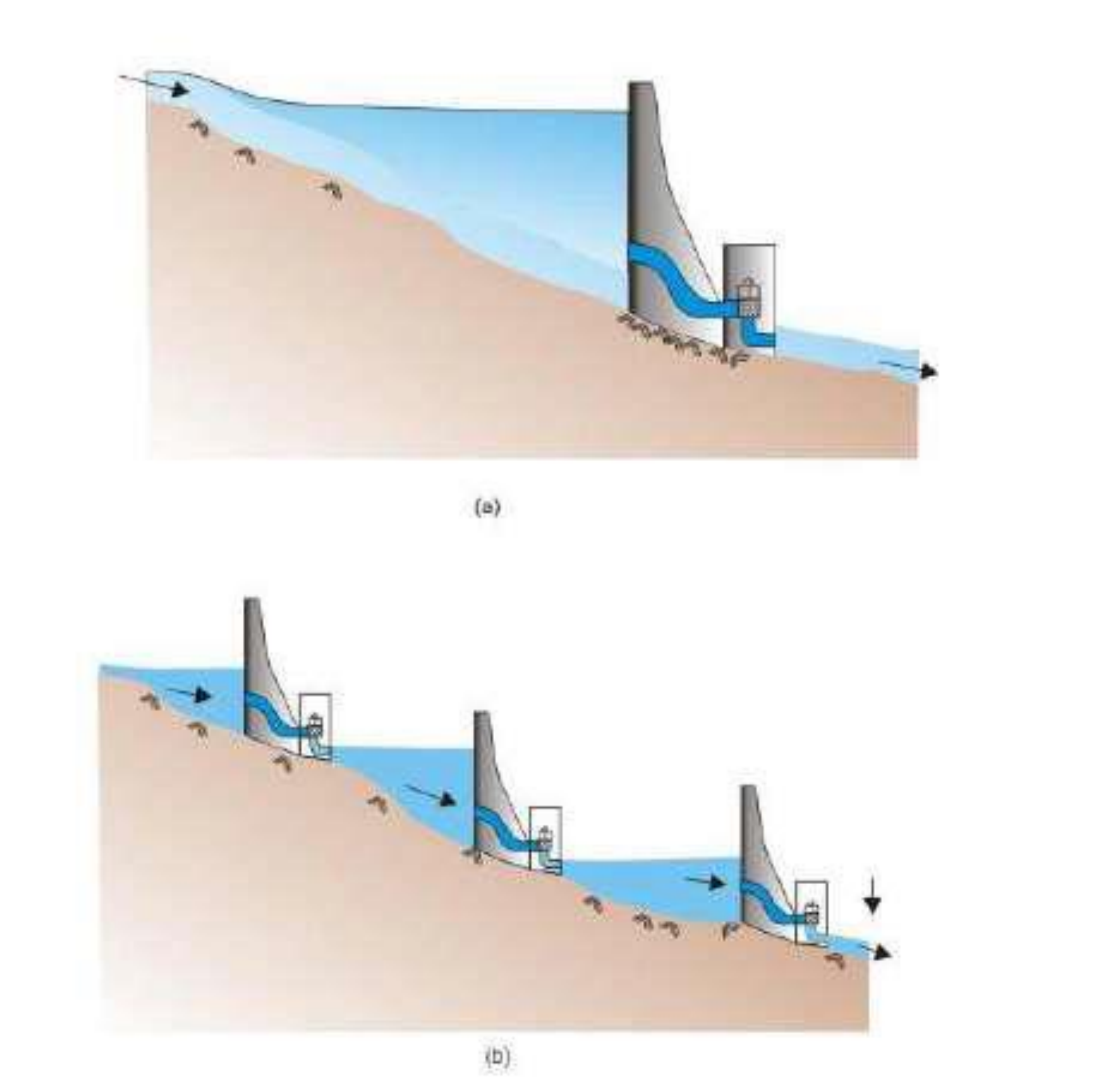


FIGURE 11. Concept of a tidal power development scheme

Classification according to Hydrological relation

SINGLE STAGE- When the run off from a single hydropower plant is diverted back into river or for any other purpose other than power generation, the setup is known as Single Stage.

CASCADE SYSTEM- When two or more hydropower plants are used in series such that the runoff discharge of one hydro power plant is used as an intake discharge of the second hydro power plant such a system is known as CASCADE hydropower plant.



Classification based on plant capacity

According to Mossonyi
- Midget plant up to 10 KW
- Low capacity < 1000KW
- Medium capacity < 10,000KW
- High capacity > 10,000KW

Present day classification
- Micro hydropower < 5 MW
- Medium plant 5 to 100 MW
- High capacity 100 to 1,000 MW
- Super plant above 1,000 MW

Classification based on head

Based on head on turbine:
- Low head plants < 15m
- Medium head plants 15-50m
- High head plants 50-250m
- Very high head plants > 250m

The figure may vary depending on the country standard