

ODA-UNESCO Project: Promotion of Energy Science Education for Sustainable Development in Lao PDR

Theme 3: Current Energy Technology

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Part 1. Traditional Energy Technology

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Part 2. Technology of Reducing Gaseous Emissions

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Part 1. Traditional Energy Technology

Outline:

1. Introduction
2. Fuels and combustion
3. Steam power plant
4. Hydroelectric power plant

Chapter 1. Introduction

- 1.1 Location of Lao PDR
- 1.2 Available fossil fuels in Lao PDR
- 1.3 Electricity consumption in Lao PDR
- 1.4 Electricity generation
- 1.5 Power plants and classifications
- 1.6 The main power plants in Lao PDR

1.1 Location of Lao PDR



Lao PDR map

Source:

<http://www.wordservicesgroup.com/countries.asp?c=la&country=laos>

Location:

Southeastern Asia

Total area: 236,800 sq. km country comparison to the word: 84

Land: 230,800 sq. km

Water: 6,000 sq. km

Arable land: 4.01% permanent

Crops: 0.34%

Other: 95.65% (2005)

Population:

6,477,211 (July 2011 est.) country comparison to the word: 104


No border with the sea

1.2 Available fossil fuels in Lao PDR

Natural resources

- **Low potential**

Conventional
energy resources




```
graph LR; A([Conventional energy resources]) --> B[No oil<br/>No natural gas<br/>Some coal];
```

- No oil
- No natural gas
- Some coal

- **High potential**

Renewable
Energy



```
graph LR; A([Renewable Energy]) --> B[Bioenergy<br/>Hydropower<br/>Solar];
```

- Bioenergy
- Hydropower
- Solar

1.2 Available fossil fuels in Lao PDR

1. Lao PDR is agriculture-based country

2. Abundant of natural resources such as
River, Forest, Mountain

These can turn into source of
energy generating production



Hydropower

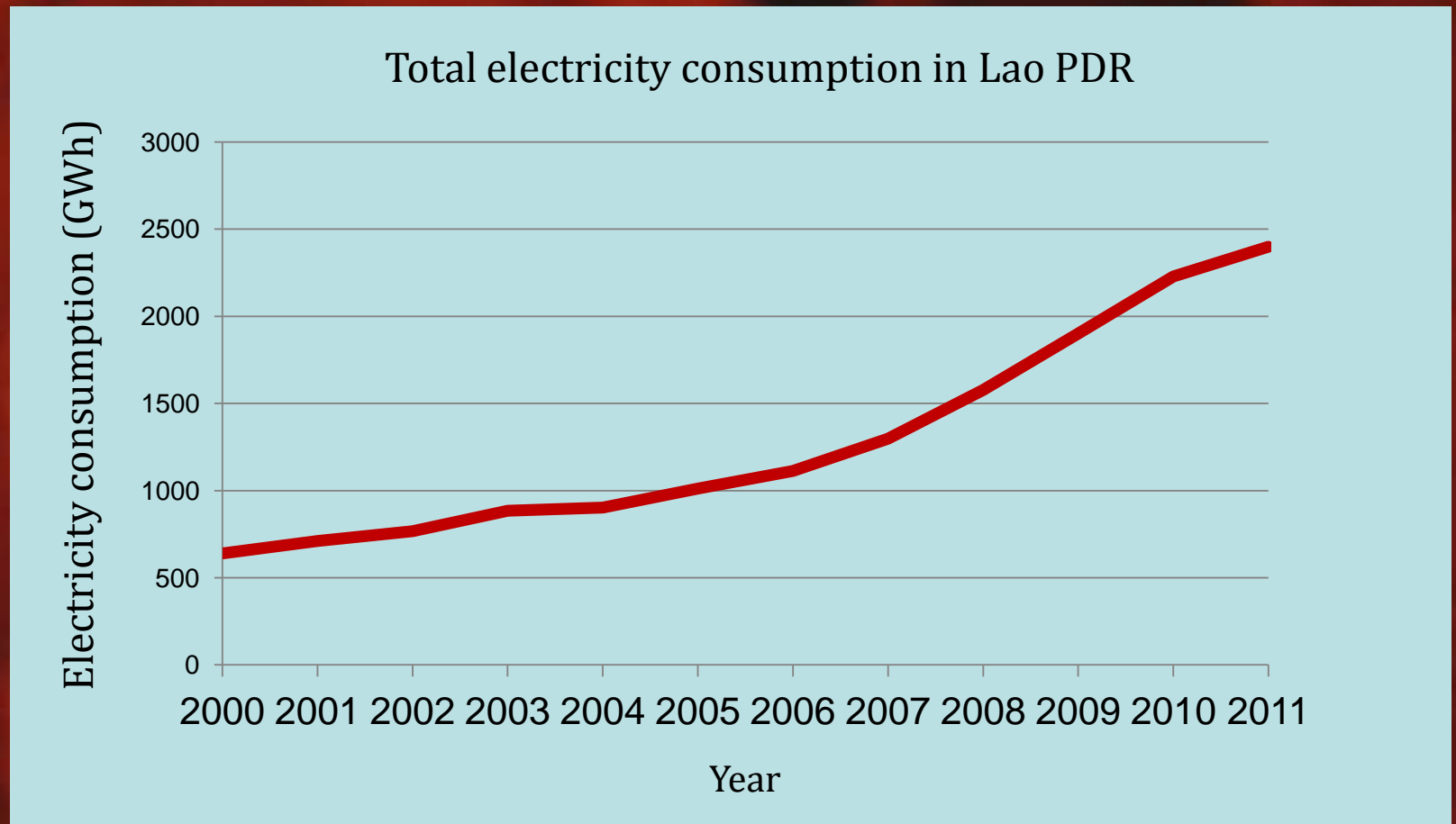


Solar and wind

1.3 Electricity consumption in Lao PDR

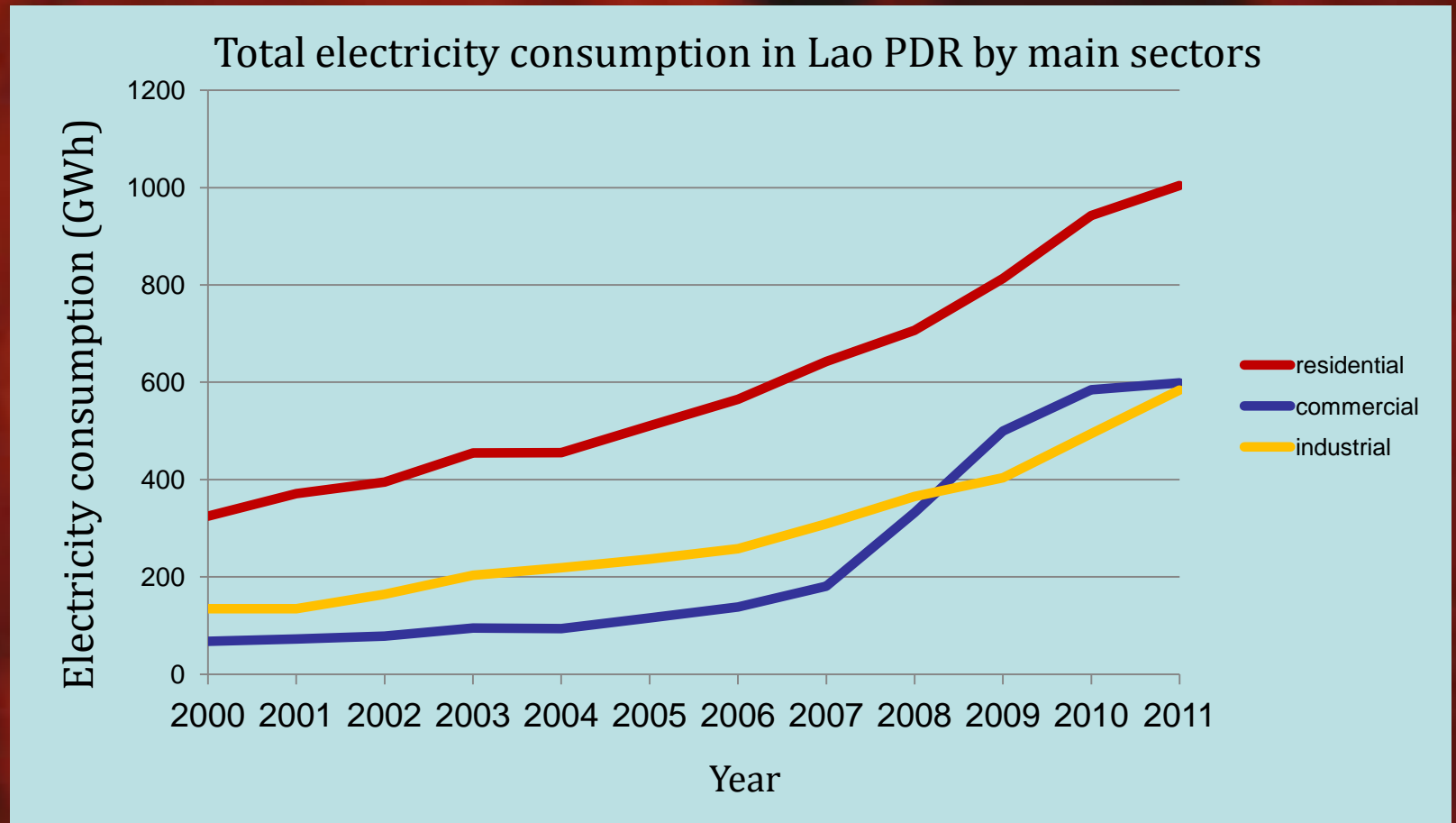


1.3 Electricity consumption in Lao PDR



Source: EDL (Electricite du Laos)

1.3 Electricity consumption in Lao PDR



Source: EDL (Electricite du Laos)

1.3 Electricity consumption in Lao PDR

Vientiane Capital

274.96 GWh/Year

Vientiane province

58.04 GWh/Year

Khammuane province

50.30 GWh/Year

Savannakhet province

228.83 GWh/Year

Champasack province

31.17 GWh/Year



Energy consumption by industrial sectors

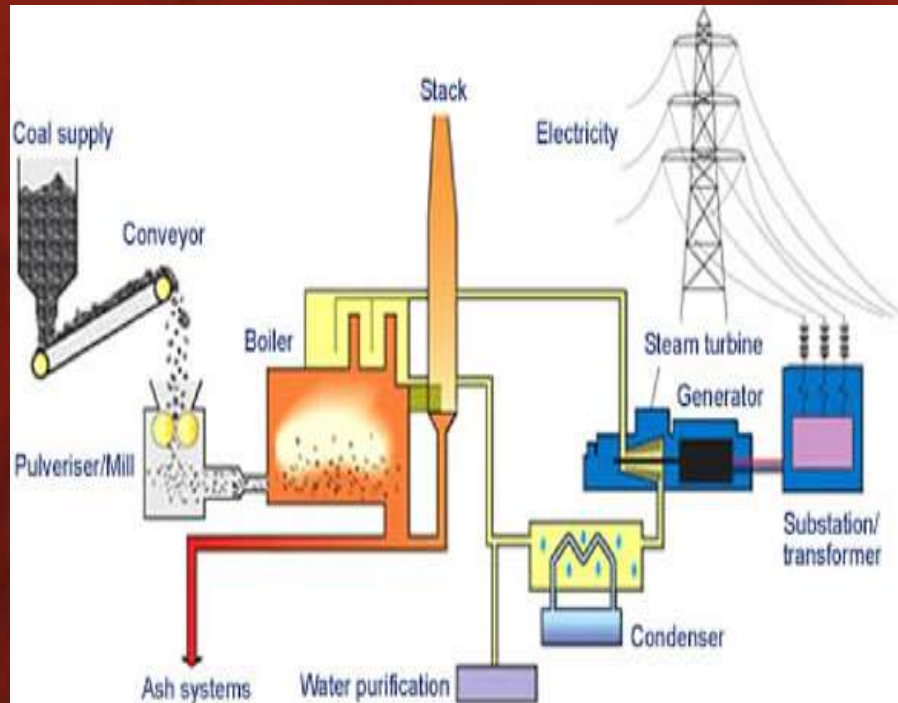
Source: EDL, 2010

1.4 Electricity generation

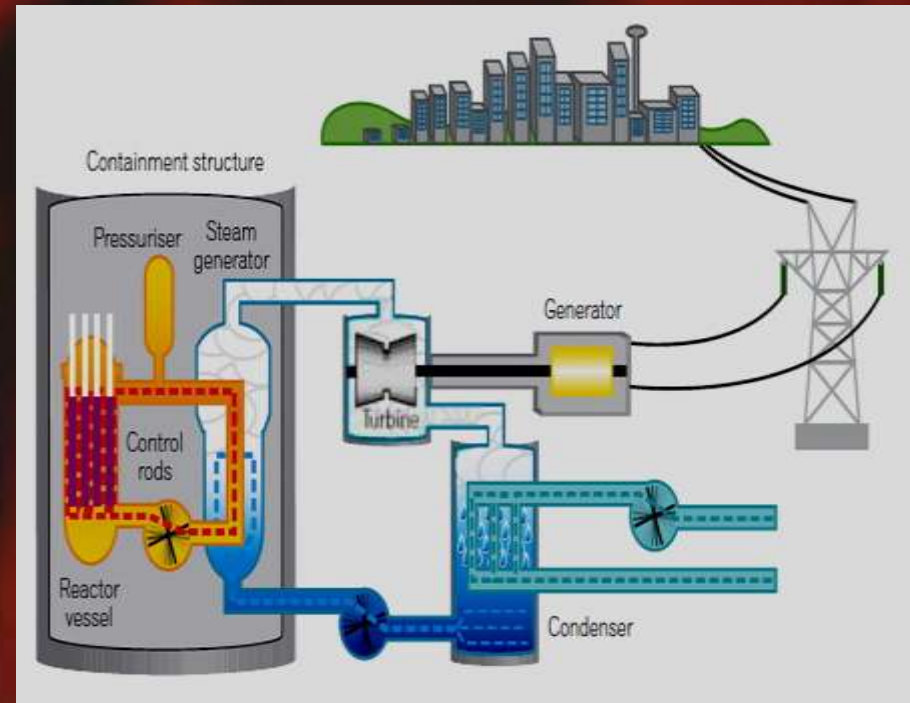
- Electricity generation is the process of generating electric power from sources of energy.
- Electricity is most often generated at a power plant by electromechanical generators, primarily driven by heat engines fueled by chemical combustion or nuclear fission but also by other means such as the kinetic energy of flowing water and wind.
- There are many other technologies that can be and used to generate electricity such as solar photovoltaic (solar cell) and geothermal power.



1.4 Electricity generation

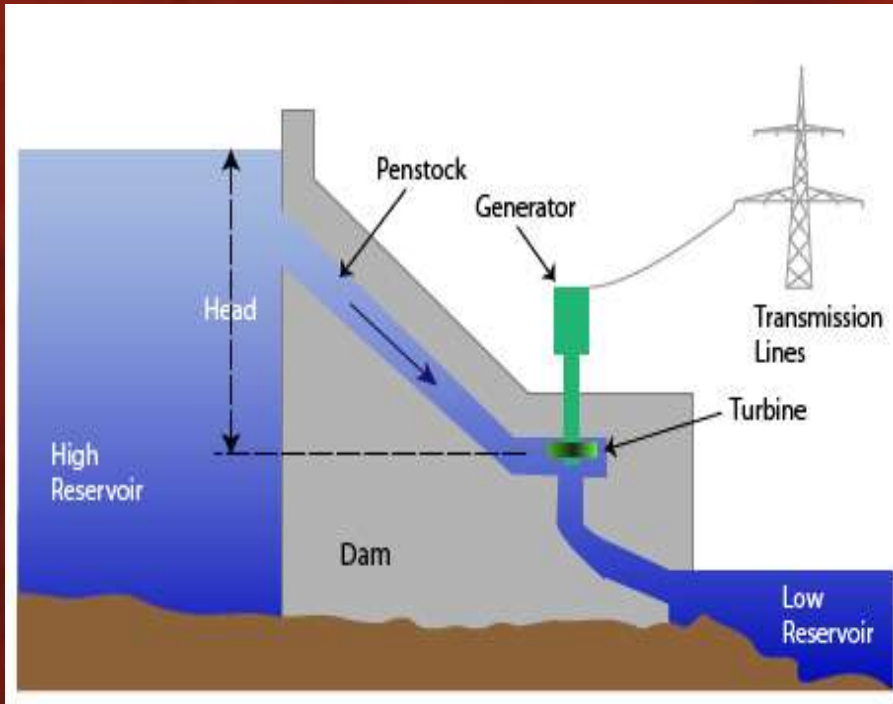


Coal-fired power plant

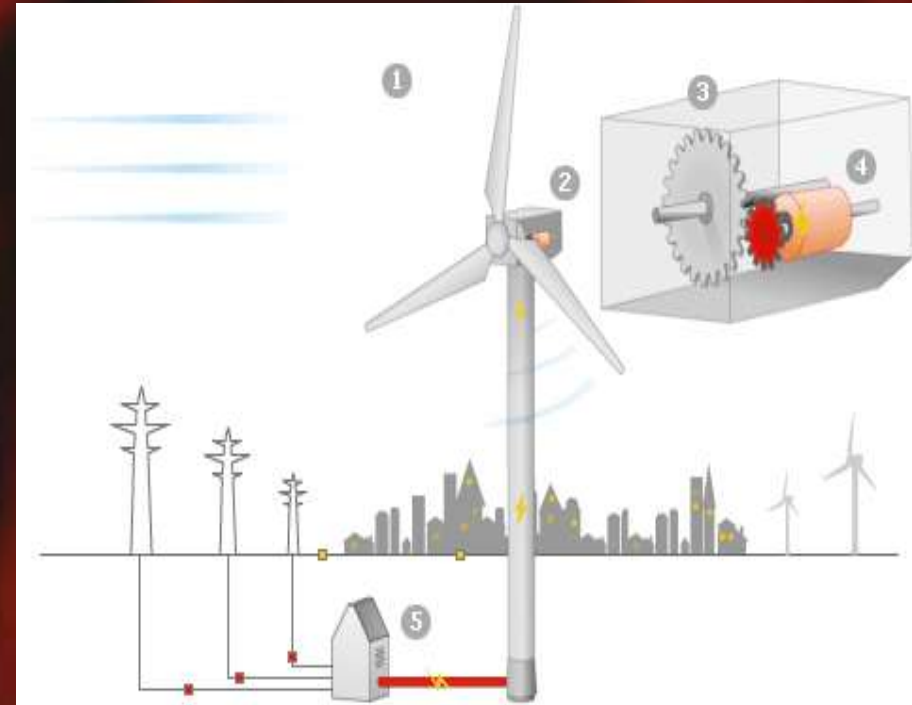


Nuclear power plant

1.4 Electricity generation

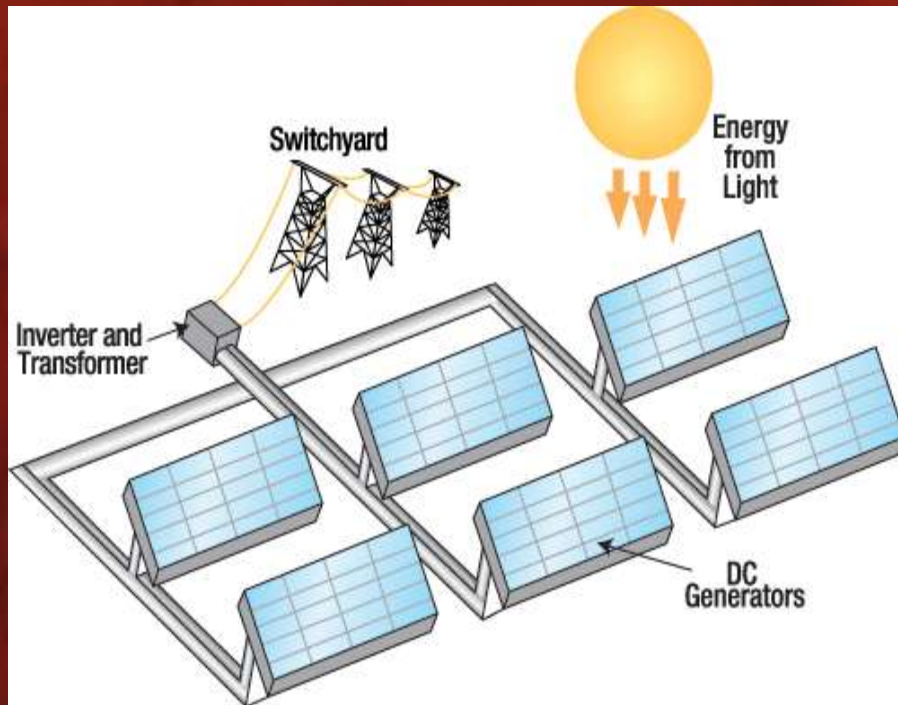


Hydroelectric power plant

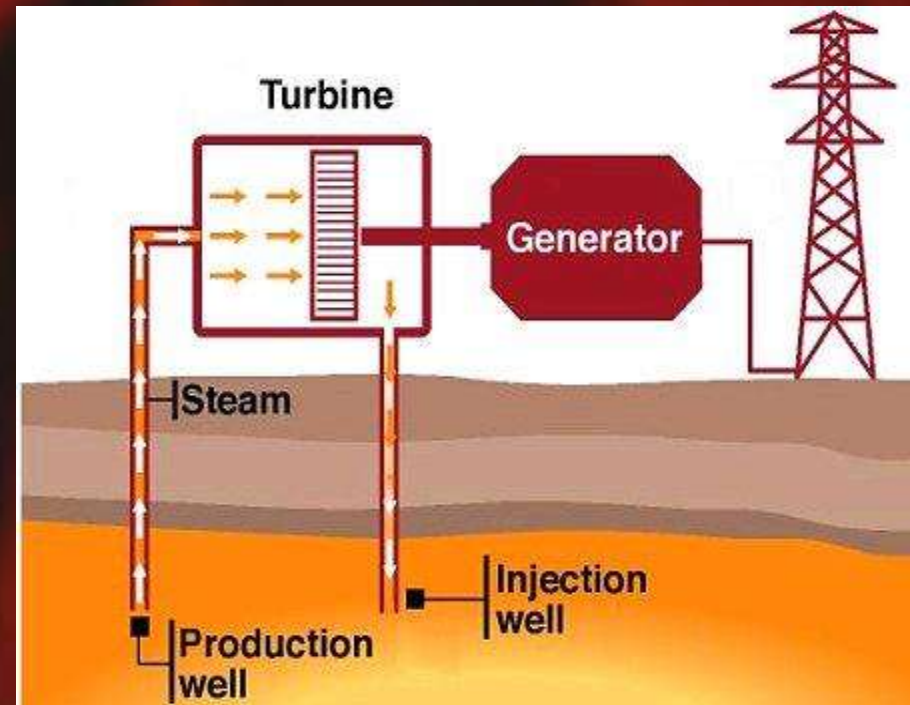


Wind power plant

1.4 Electricity generation



Solar photovoltaic power plant



Geothermal power plant

1.5 Power plants and classification

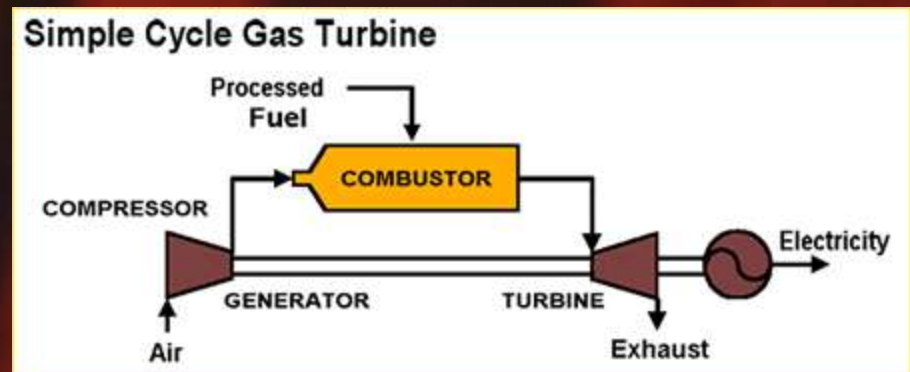
- A power plant is an industrial facility for the generation of electric power.
- At the center of nearly all power plants is a generator, a rotating machine that converts mechanical power into electrical power by creating relative a magnetic field and a conductor.
- Most power plants in the world burn fossil fuels such as coal, oil and natural gas to generate electricity and some use nuclear power, but there is an increasing use of cleaner renewable sources such as solar, wind and hydroelectric.

1.5 Power plants and classification

- There are three main types of power plants, according to function they form. These are called “base”, “intermediate” and “peaking” facilities.
- Depending upon the form of energy converted into electrical energy, the power plants are classified as under:
 - Thermal power plant (coal, oil, natural gas, nuclear, biomass)
 - Hydroelectric power plant
 - Diesel power plant
 - Solar power plant
 - Wind power plant



Solar thermal power plant



Gas turbine power plant

1.5 Power plants and classification

- In thermal power plants, mechanical power is produced by a heat engine that transforms thermal energy, often from combustion of a fuel, into rotational energy.
- Most thermal power plants produced steam, and these are sometimes called steam power plant.
- In hydroelectric power plants, the production of electrical power through the use of the gravitational force of falling or flowing water.

1.5 Power plants and classification

Thermal power plants can be categorized following types:

- Fossil-fueled power plant
- Nuclear power plant
- Geothermal power plant
- Biomass-fueled power plant
- Solar thermal power plant



Nuclear power plant



Coal-fire power plant



1.6 The main power plants in Lao PDR

All of power plants under operating in Lao PDR are hydroelectric power plants

Power plants	Location (Province)	Inst. Capacity (MW)	COD*
Nam Theun 2	Khammuane	1,088	2009
Nam Ngum 2	Vientiane	615	2010
Theun Hin Boun	Khammuane	220	1998
Nam Ngum 1	Vientiane	155	1971
Houay Ho	Attapeu	152	1999
Nam Lik 1/2	Vientiane	100	2010
Xe Set 2	Saravane	76	2009
Nam Leuk	Vientiane	60	2000
Xe Set 1	Saravane	45	1991
Nam Mang 3	Vientiane	40	2005

*COD = Commercial Operation Date

Source: EDL

1.6 The main power plants in Lao PDR



Nam Ngum 1 HPP



Nam Theun 2 HPP



Theun Hin Boun HPP



Nam Ngum 2 HPP

1.6 The main power plants in Lao PDR

- Under construction the first 1,878 MW coal-fired power plant in Lao PDR at Hongsa district, Sayaboury province.



Model of Hongsa coal-fired power plant



The 250 m chimney stack of Hongsa coal-fired power plant

Chapter 2. Fuels and combustion

- 2.1 Introduction
- 2.2 Principles of classification of fuels
- 2.3 Fossil fuels
- 2.4 Coal
- 2.5 Coal analysis
- 2.6 Heating value
- 2.7 Combustion process

2.1 Introduction

- Fuel is a substance which, when burnt, i.e. on coming in contact and reacting with oxygen or air, produces heat.
- Thus, the substances classified as fuel must necessarily contain one or several of combustible elements: carbon, hydrogen, sulphur, etc.
- In the process of combustion, the chemical energy of fuel is converted into heat energy.

2.2 Principles of classification of fuels

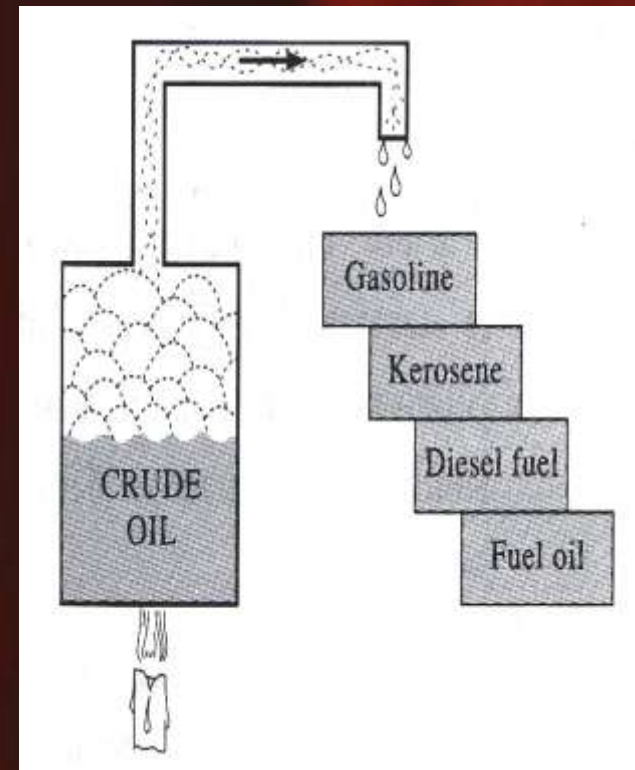
Fuels may broadly be classified in two ways, i.e.

(a) according to the physical state in which they exist in nature:

- Solid: Coal, Wood, etc.
- Liquid: Fuel oil, ethyl alcohol, etc.
- Gaseous: Natural gas, producer gas, etc.

(b) according to the mode of their procurement:

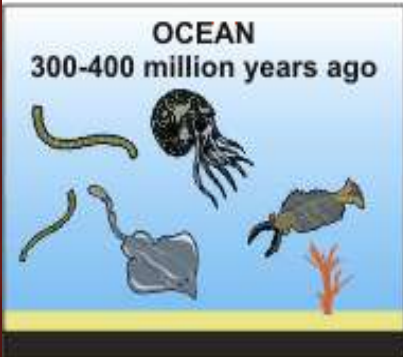
- Natural fuels (primary fuels): Coal, crude petroleum, nuclear fuel, etc.
- Manufactured fuels (secondary fuels): Gasoline, diesel oil, charcoal, etc.



2.3 Fossil fuels

Fossil fuels are hydrocarbon, primarily coal and petroleum (liquid petroleum or natural gas), formed from the fossilized remains of ancient plants and animals by exposure to high heat and pressure in the absence of oxygen in the earth's crust over hundred of millions of year.

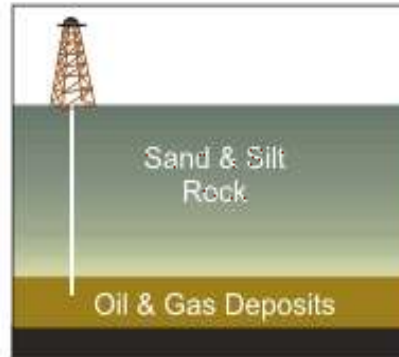
PETROLEUM & NATURAL GAS FORMATION



Tiny sea plants and animals died and were buried on the ocean floor. Over time, they were covered by layers of silt and sand.



Over millions of years, the remains were buried deeper and deeper. The enormous heat and pressure turned them into oil and gas.



Today, we drill down through layers of sand, silt, and rock to reach the rock formations that contain oil and gas deposits.



2.3 Fossil fuels

Summary of
oil reserve
data as of
2012

Source:

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

Remark:

bbl = barrel of oil

Country	Reserves 10^9 bbl	Reserves 10^9 m ³
Venezuela	296.5	47.14
Saudi Arabia	265.4	42.2
Canada	175	27.8
Iran	151.2	24.04
Iraq	143.1	22.75
United Arab Emirates	136.7	21.73
Kuwait	101.5	16.14
Russia	74.2	11.8
Kazakhstan	49	7.8
Libya	47	7.5
Nigeria	37	5.9
USA	26.8	7.0
Qatar	25.41	4.04
China	20.35	3.235

2.3 Fossil fuels

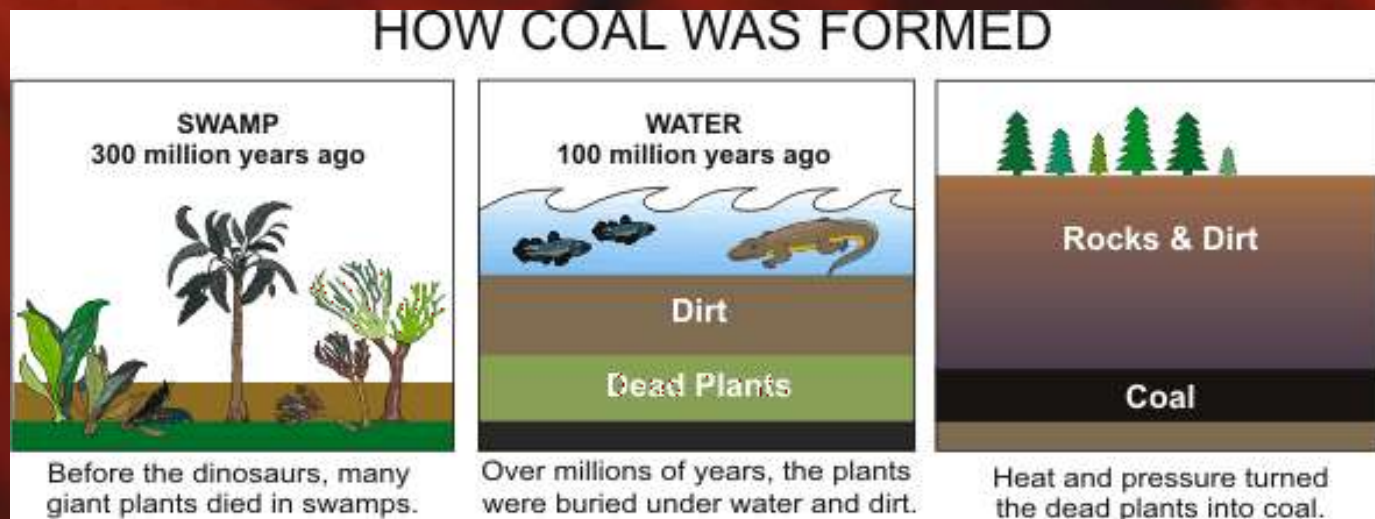
Summary of
natural gas
reserves
(1 Jan 2008 est.)

Source:
http://en.wikipedia.org/wiki/Natural_gas_by_country

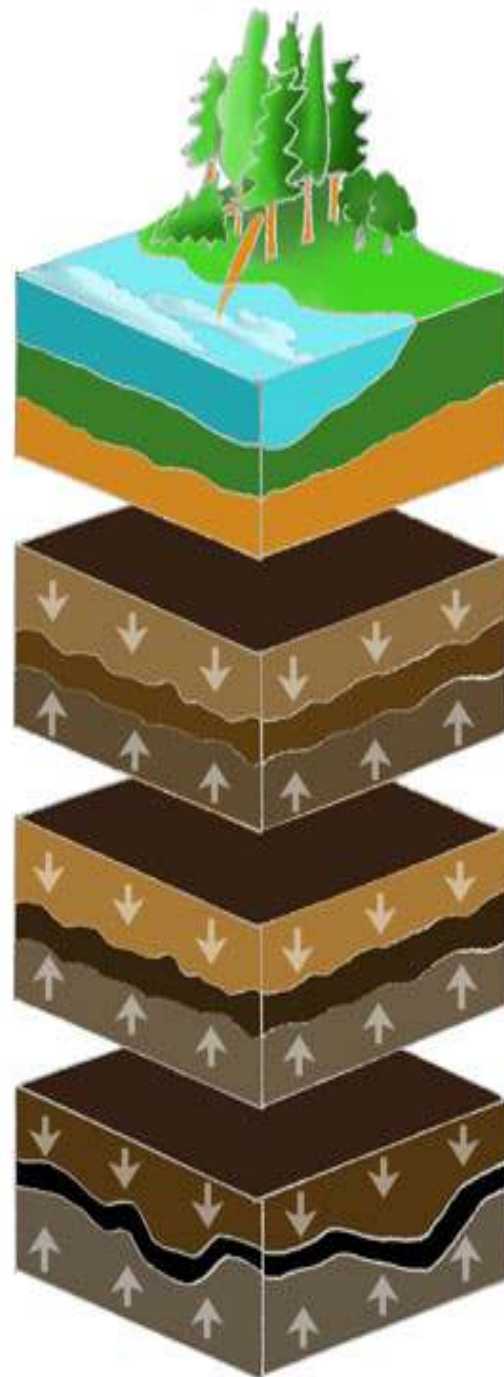
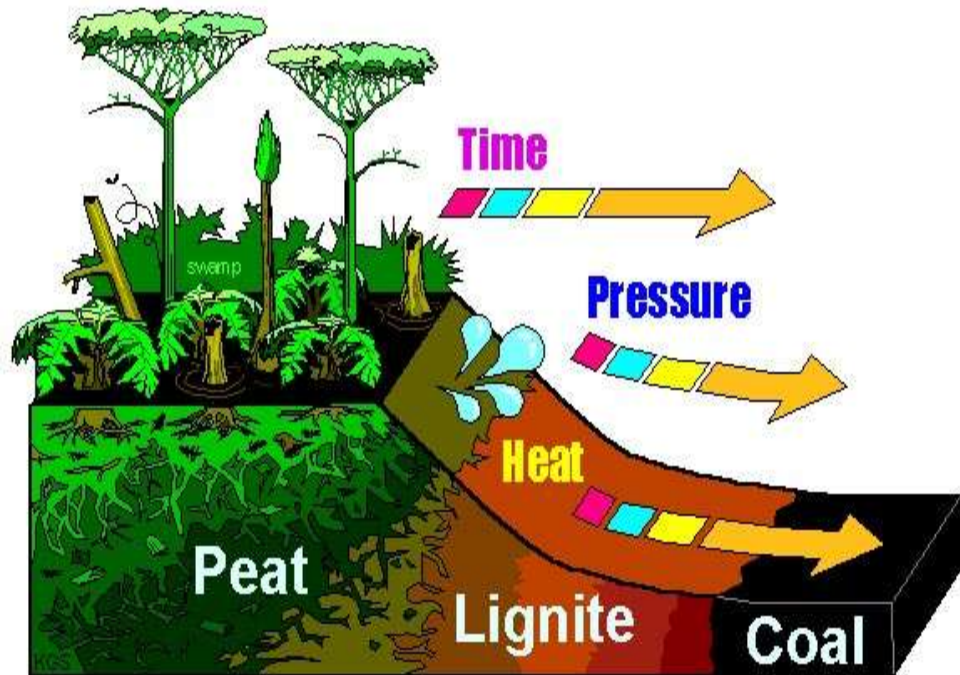
Country	Proven reserves (millions cu m)
Russia	44,650,000
Iran	26,850,000
Qatar	25,630,000
Saudi Arabia	7,167,000
United Arab Emirates	6,071,000
USA	5,977,000
Nigeria	5,210,000
Venezuela	4,708,000
Algeria	4,502,000
Iraq	3,170,000
Kazakhstan	2,832,000
Turkmenistan	2,832,000
Indonesia	2,659,000
European Union	2,476,000
Malaysia	2,350,000
China	2,265,000

2.4 Coal

- Coal originated from vegetable matter which grew millions of year ago.
- Trees and plants falling into water decayed and later produced peat bogs.
- Huge geological upheavals buried these bogs under layers of silt. Subterranean heat, soil pressure and movement of earth's crust distilled off some of the bog's moisture and hardened it to form brown coal or lignite.
- Continuing subterranean activity and metamorphosis produced higher grades of coal.



2.4 Coal



HUGE FORESTS GREW AROUND
300 MILLION YEARS AGO
COVERING MOST OF THE EARTH

THE VEGETATION DIES AND
FORMS PEAT

THE PEAT IS COMPRESSED BETWEEN
SEDIMENT LAYERS TO FORM LIGNITE

FURTHER COMPRESSION
FORMS BITUMINOUS AND
SUBBITUMINOUS COAL

EVENTUALLY ANTHRACITE FORMS

2.4 Coal

- According to geological order of formation, coal may be of the following types:
 - Peat
 - Lignite
 - Subbituminous
 - Bituminous
 - Anthracite

With increasing percentages of carbon.



Peat



Lignite



Subbituminous



Bituminous



Anthracite

2.4 Coal

Proved recoverable coal reserves at end-2008 (million tons)

Country	1	2	3	4	5
USA	108,501	98,618	30,176	237,295	22.6
Russia	49,088	97,472	10,450	157,010	14.4
China	62,200	33,700	18,600	114,500	12.6
Australia	37,100	2,100	37,200	76,400	8.9
India	56,100	0	4,500	60,600	7.0
Germany	99	0	40,600	40,699	4.7
Ukraine	15,351	16,577	1,945	33,873	3.9

Remark:

1 = Anthracite & Bituminous

2 = Subbituminous

3 = Lignite

4 = Total

5 = Percentage of world total

Source:

[http://en.wikipedia.org/
wiki/Coal](http://en.wikipedia.org/wiki/Coal)

2.5 Coal analysis

There are two types of coal analysis:

- Proximate analysis: It determines the mass of fixed carbon (FC), volatile matter (VM), moisture (M), and ash (A). Sulphur is obtained in a separate determination.

$$FC + VM + M + A = 100\% \text{ by mass}$$

- Ultimate analysis: A more scientific test than proximate analysis, ultimate analysis gives the mass percentages of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), sulphur (S), moisture (M), and ash (A).

$$C + H + O + N + S + M + A = 100\% \text{ by mass}$$

- The dry and ash free analysis on combustible basis is obtained on dividing C, H, O, N and S by the fraction

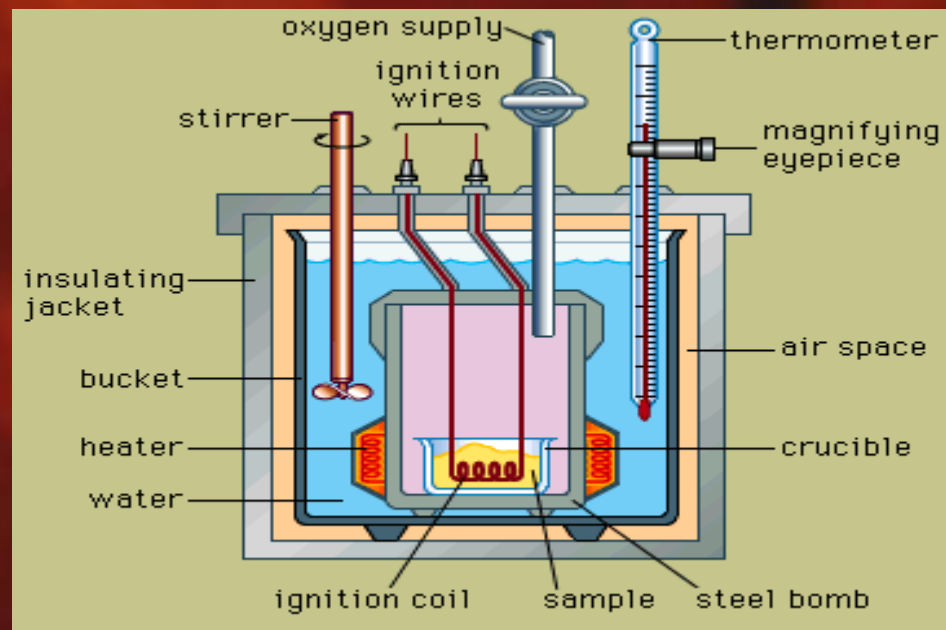
$$1 - [(M + A)/100]$$

2.6 Heating value

- The heating value (or calorific value) is the amount of heat released during the combustion of unit quantity of a fuel.
- It is measured in units of energy per unit of a fuel, usually mass, such as: kJ/kg, kJ/kmol, kcal/kg, etc.
- Heating value is commonly determined by used bomb calorimeter, where a coal sample of known mass is burnt with pure oxygen supply completely in a stainless steel bomb or vessel surrounded by a known mass of water, and the rise in water temperature is noted.

2.6 Heating value

- Bomb calorimeter consists of a hollow steel container, lined with platinum and filled with pure oxygen, into which a weighed quantity of substance is placed and ignited with an electric fuse.
- The heat produced is absorbed by water surrounding the bomb and, from the rise in temperature, the heating value is calculated.



Bomb calorimeter

2.6 Heating value

The heating value can be expressed as the HHV and LHV

- ❑ HHV (Higher heating value) assumes that the water vapor in the products condenses and thus includes the latent heat of vaporization of the water vapor formed by combustion.
- ❑ LHV (Lower heating value) assumes that the water vapor formed by combustion leave as vapor itself.

2.6 Heating value

Therefore,

$$\text{LHV} = \text{HHV} - m_w h_{fg}$$

Where m_w is the mass of water vapor formed given by

$$m_w = M + 9H + \gamma_A w_A$$

Where M and H are the mass fractions of moisture and hydrogen in the coal, γ_A is the specific humidity of atmospheric air and w_A is the actual amount of air supplied per kilogram of coal.

2.6 Heating value

If the ultimate analysis is known, the HHV of anthracite and bituminous coals can be determined approximately by using Dulong and Petit formula as given below:

$$\text{HHV} = 33.83 C + 144.45 [H - (O/8)] + 9.38 S \quad \text{in MJ/kg}$$

Where C, H, O and S are mass fractions of carbon, hydrogen, oxygen and sulphur respectively.

For example: C = 70%, H = 5%, O = 11%, S = 1%, N = 1% and ash = 12%

From equation in above, we can calculate HHV below:

$$\text{HHV} = (33.83)(0.7) + (144.45)[0.05 - (0.11/8)] + (9.38)(0.01)$$

$$\text{HHV} = 25.76 \text{ MJ/kg}$$

2.6 Heating value

Higher heating value of some fuels:

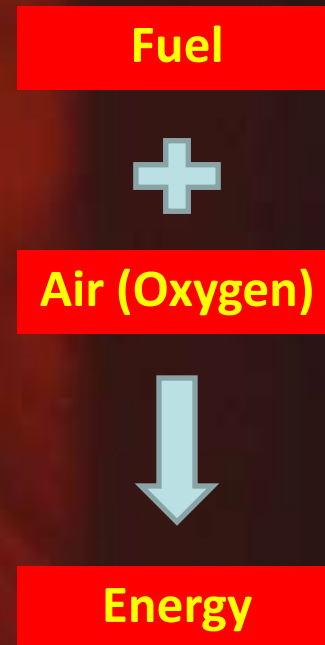
Types of fuels	HHV (MJ/kg)
Wood	18
Brown coal	21
Bituminous	29
Gasoline	46.5
Kerosene	46.4
Diesel	45.7
Fuel oil	42.9
Ethyl alcohol	27.2

2.7 Combustion process

Combustion or burning is a chemical process, an exothermic reaction between a fuel and an oxidizer, usually O_2 , to release thermal energy (heat), electromagnetic energy (light), mechanical energy (noise) and electrical energy (free ions and electrons)



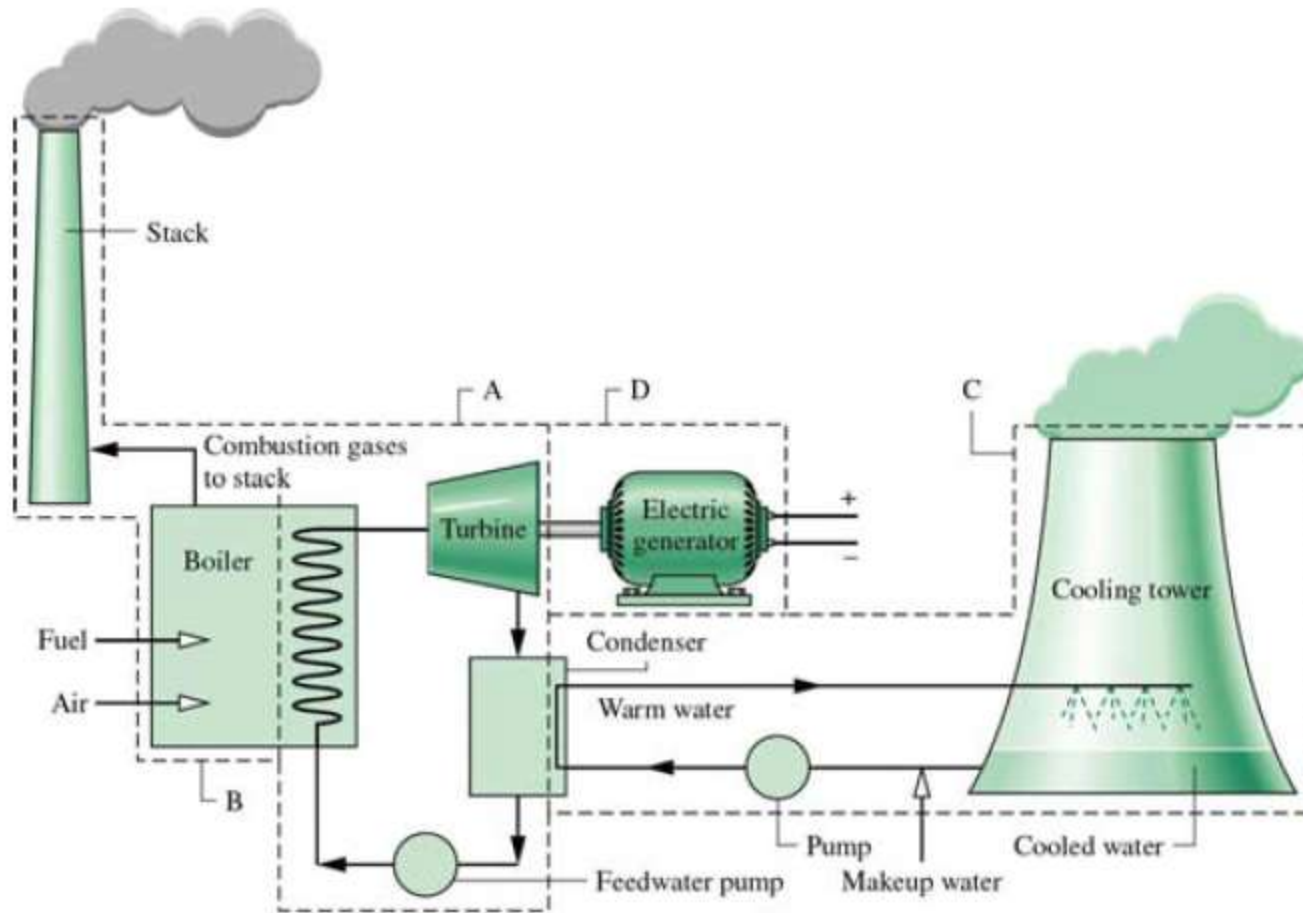
The flames caused as a result of a fuel undergoing combustion



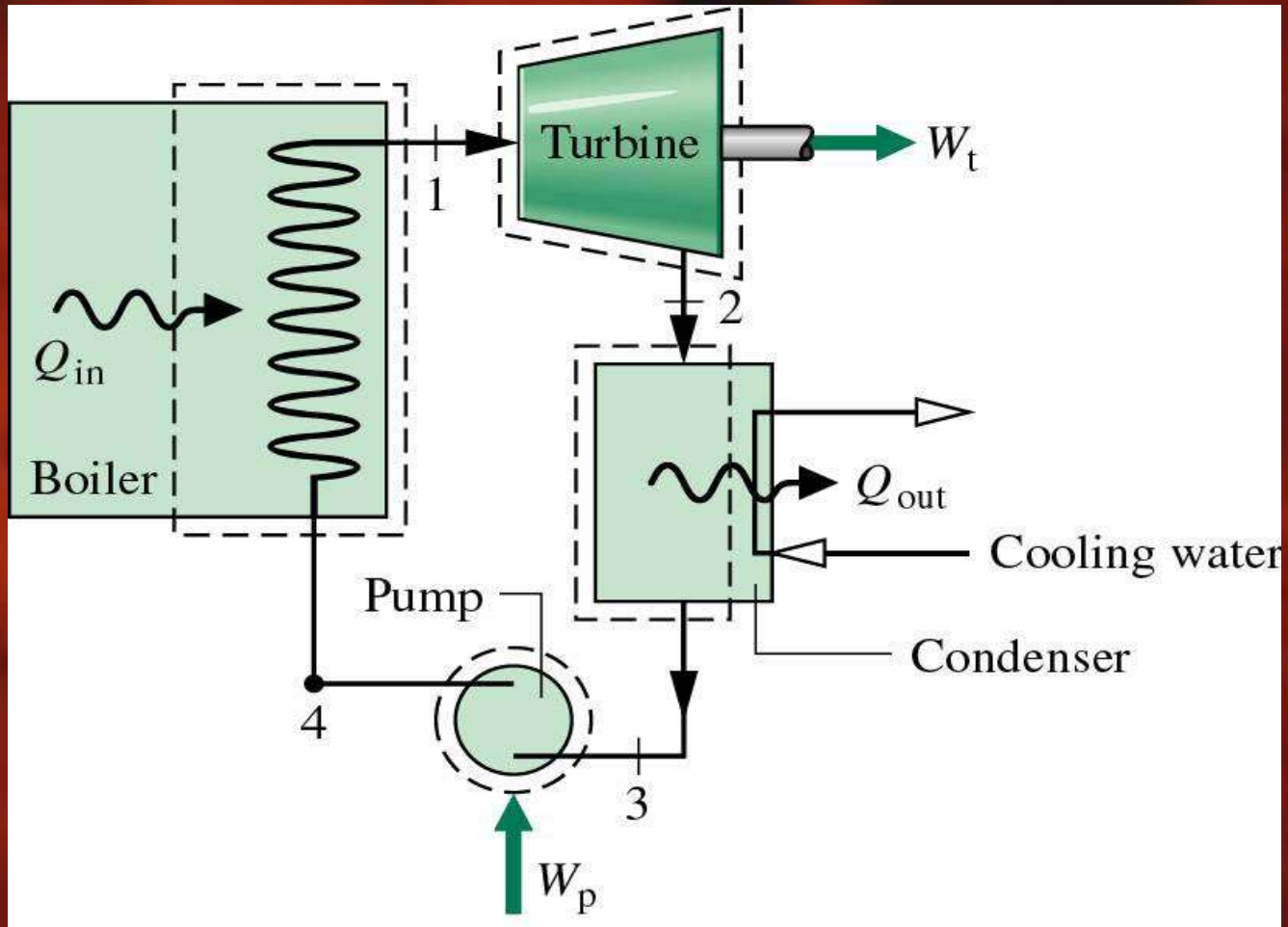
Chapter 3. Steam power plant

- 3.1 Components of a simple steam power plant
- 3.2 Rankine cycle
- 3.3 Steam boiler
- 3.4 Steam turbine
- 3.5 Condenser and cooling tower

3.1 The main components of a simple steam power plant



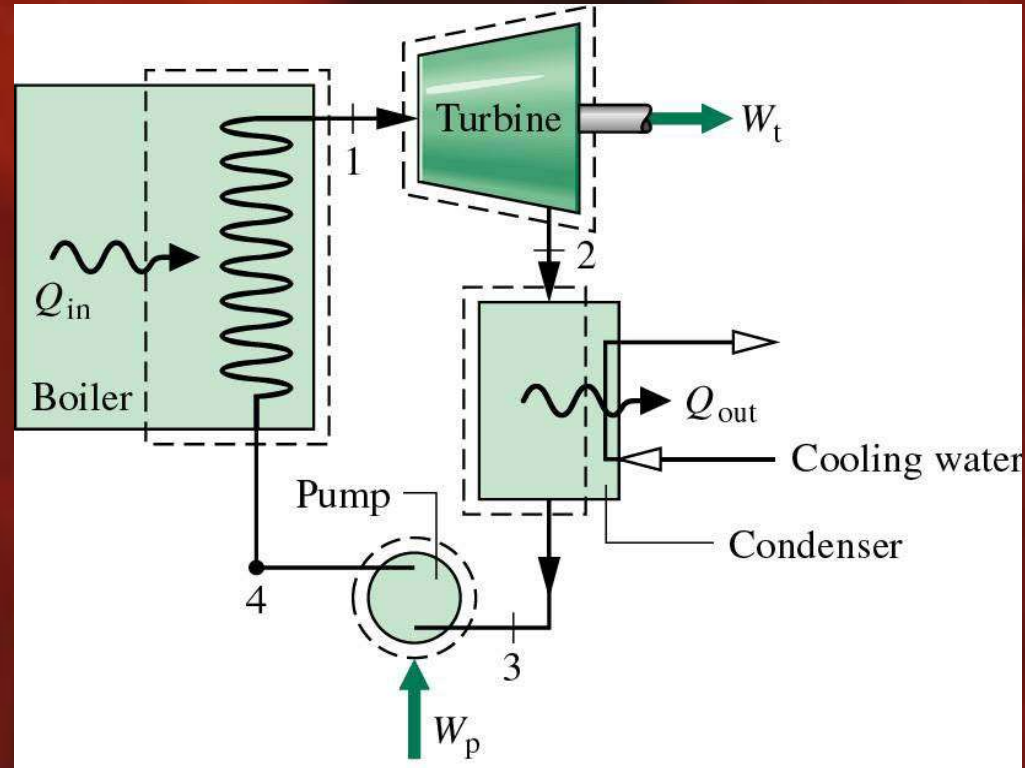
3.2 Rankine cycle



Simple Rankine cycle

3.2 Rankine cycle

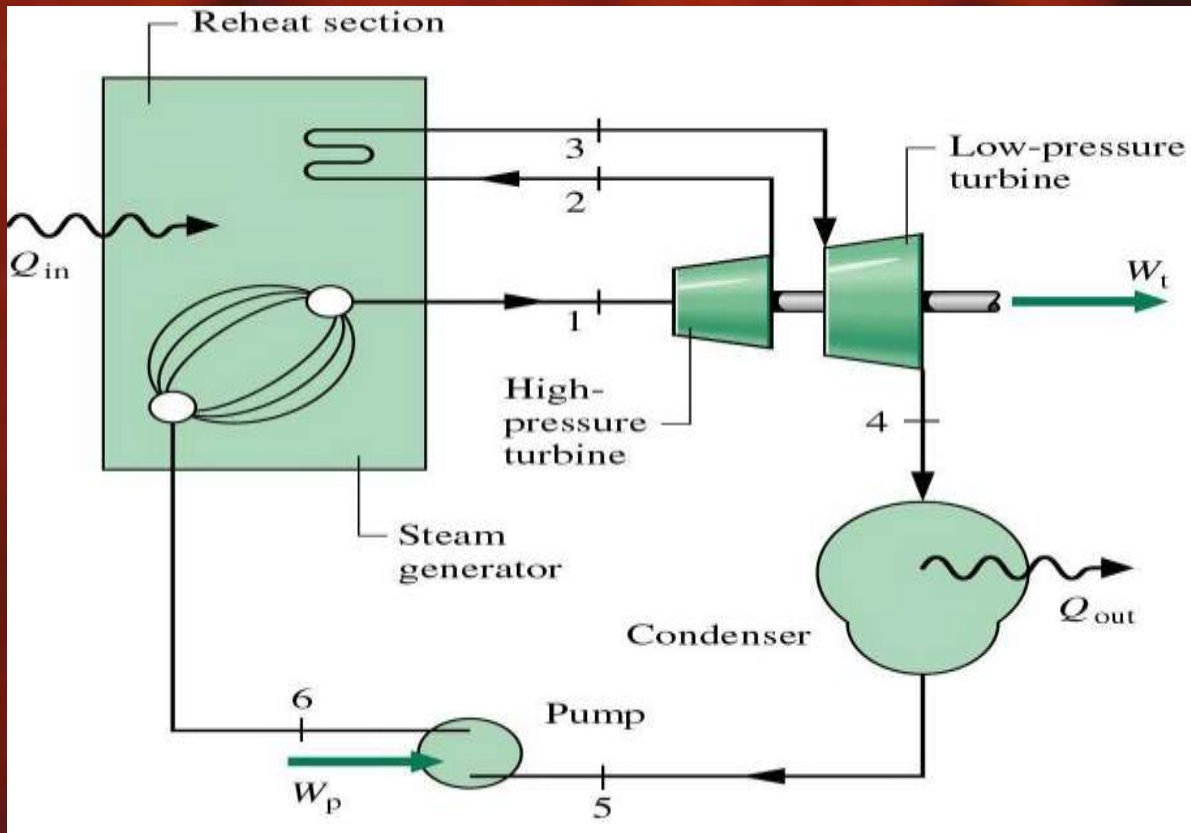
- ❑ Pump: $w_{pump} = h_4 - h_3$
- ❑ Turbine: $w_{turbine} = h_1 - h_2$
- ❑ Boiler: $q_{boiler} = h_1 - h_4$
- ❑ Condenser: $q_{condenser} = h_2 - h_3$
- ❑ Thermal efficiency:



$$\eta_{th} = w_{net}/q_{input} = (w_{turbine} - w_{pump})/q_{boiler}$$

$$= (q_{boiler} - q_{condenser})/q_{boiler}$$

3.2 Rankine cycle



Rankine cycle with reheat will be use in Hongsa Coal-fire power plant

Rankine cycle with reheat

- Net work output more than simple Rankine cycle
- More thermal efficiency compare with simple Rankine cycle

3.3 Steam boiler

- The boiler or steam generator is a device used to create steam by applying heat energy to water.
- Although the definitions are somewhat flexible, it can be said that older steam generators were commonly termed *boilers* and worked at low to medium pressure (1 – 300 psi) but, at pressures above this, it is more usual to call it a *steam generator*.

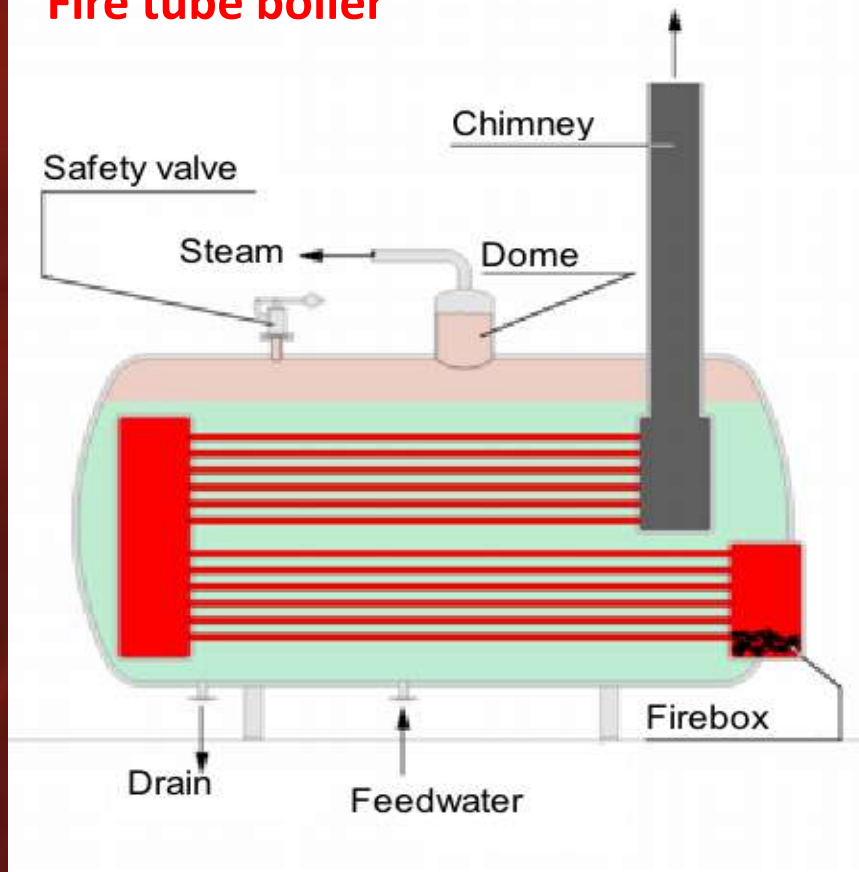


3.3 Steam boiler

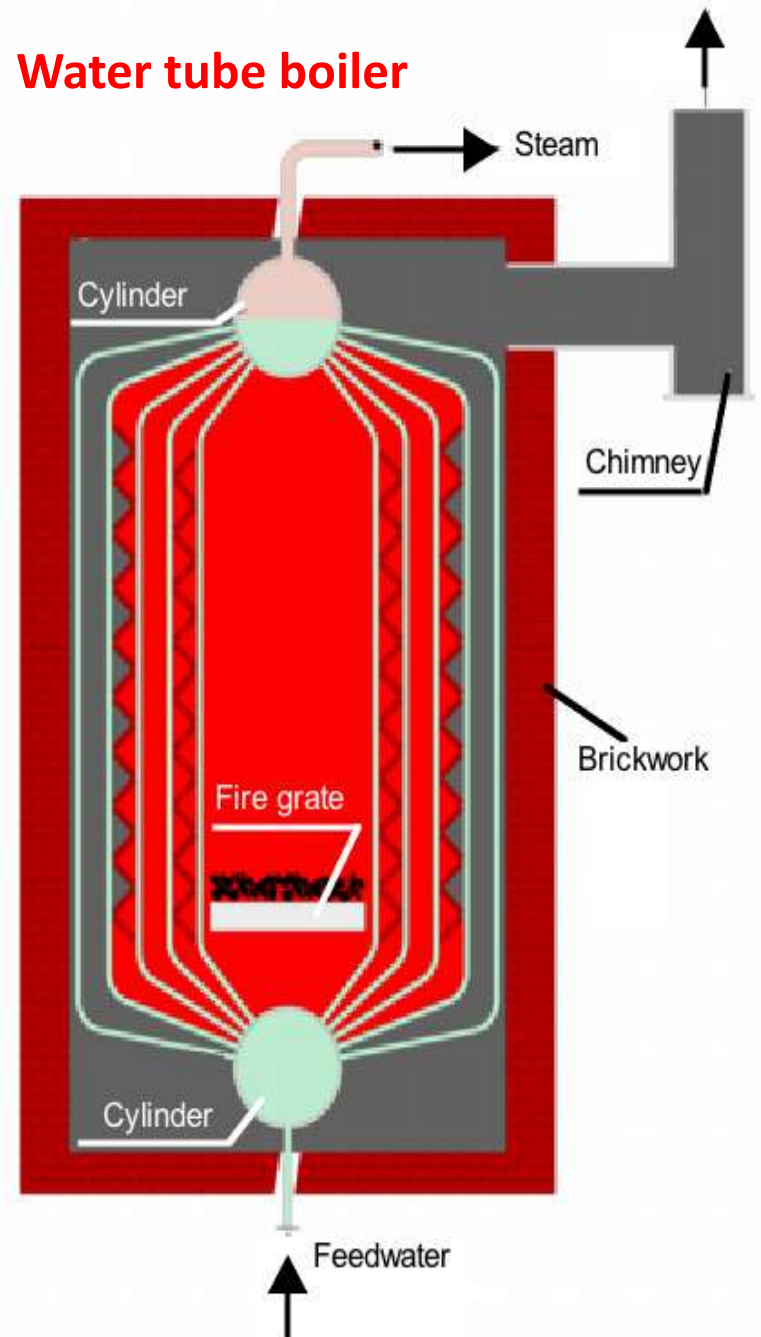
There are two main types of boilers:

- ❑ Fire tube boiler
- ❑ Water tube boiler

Fire tube boiler



Water tube boiler



3.4 Steam turbine

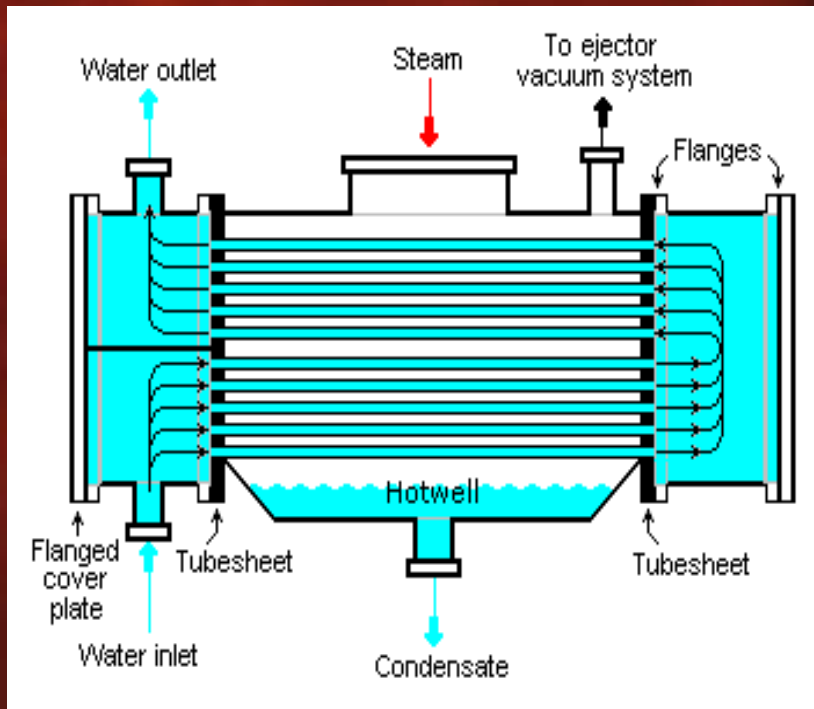
- A steam turbine is a device that extracts thermal energy from pressurized steam and uses it to do mechanical work on a rotating output shaft.



At Mae Moh coal-fire power plant, Lampang, Thailand

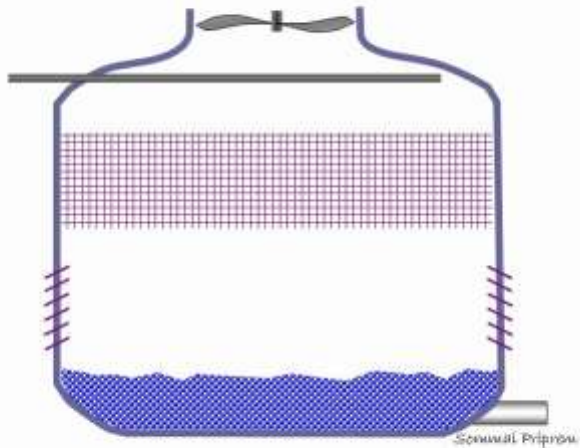
3.5 Condenser and cooling tower

- Condenser is a device or unit used to condense vapor into liquid.



3.5 Condenser and cooling tower

- Cooling towers are heat removal devices used to transfer process waste heat to the atmosphere.



4. Hydroelectric power plant

4.1 Hydroelectricity

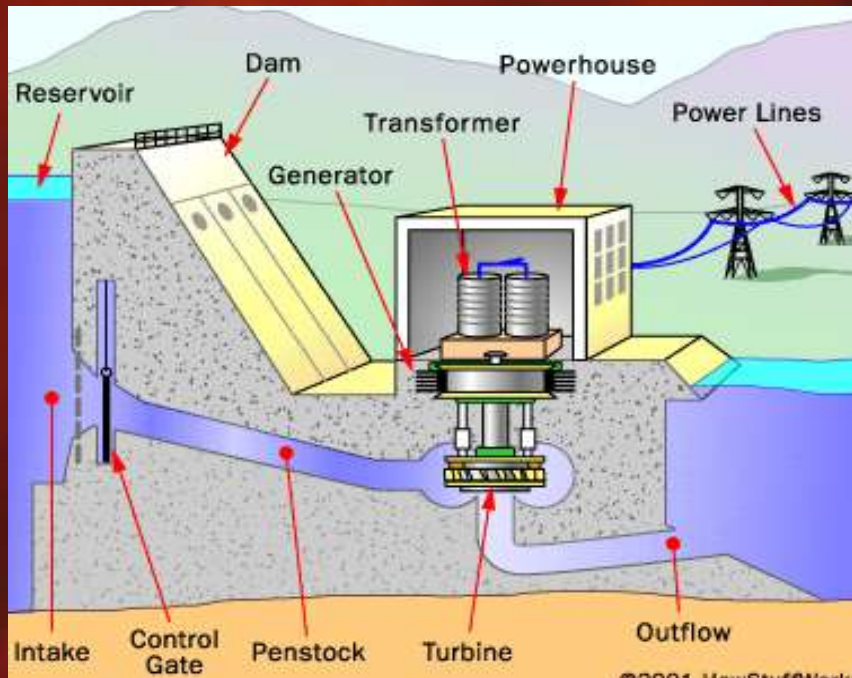
4.2 Types of hydroelectric power plant

4.3 Turbine

4.4 Advantages and disadvantages of hydroelectric power plant

4.1 Hydroelectricity

- Hydroelectricity is the term referring to electricity generated by hydropower, the production of electrical power through the use of the gravitational force of falling or flowing water.



Nam Ngum 1 HPP

4.2 Types of hydroelectric power plant

Hydroelectric power plants can be classified in the following way.

(a) According to the availability of head

- High head power plants (100 m and above)
- Medium heat power plants (30 – 100 m)
- Low head power plants (<30 m)

4.2 Types of hydroelectric power plant

(b) According to the nature of load

- Base load plants

These plants are required to supply constant power to the grid. They run continuously without any interruption and are mostly remote control.

- Peak load plants

They only work during certain hours of a day when the load is more than the average.

(c) According to the quantity of water available

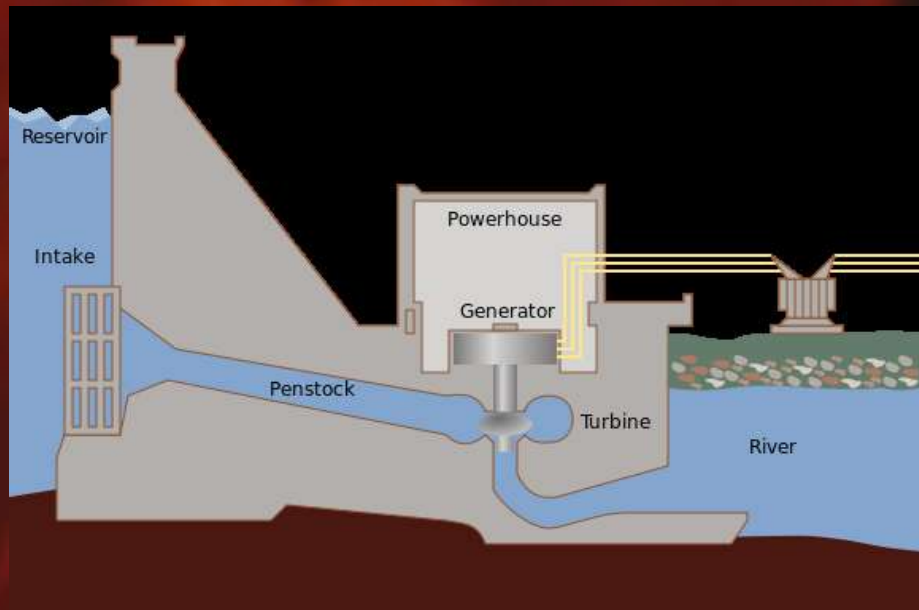
- Impoundment plant
- Run-of-river plant
- Pumped-storage plant

4.2 Types of hydroelectric power plant

There are three types of hydropower plant:

➤ Impoundment plant:

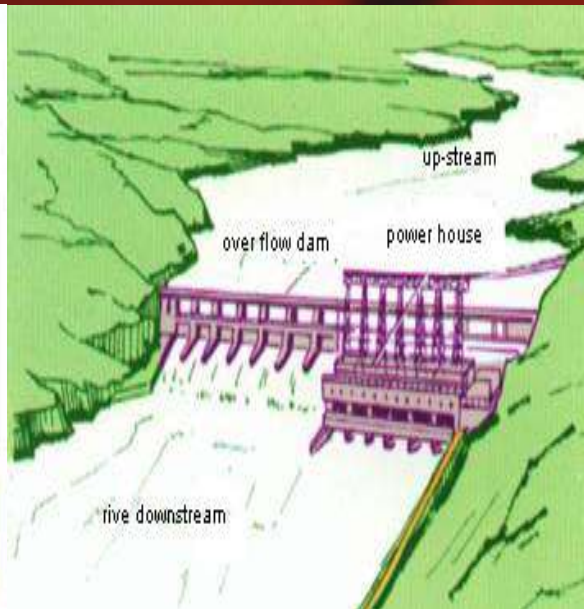
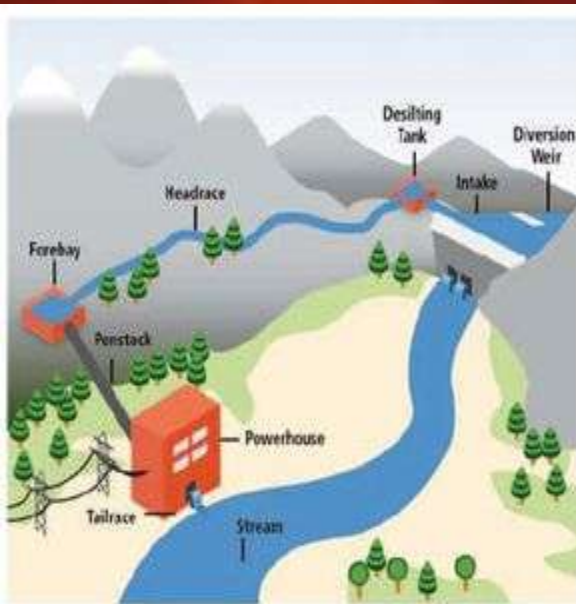
Most hydroelectric power comes from the potential energy of dammed water driving a water turbine and generator. The power extracted from the water depends on the volume and on the difference in height between the source and the water's outflow. This height difference is called the head.



4.2 Types of hydroelectric power plant

➤ Run-of-river plant

Run-of-river hydroelectric power plants are those with small or no reservoir capacity, so that the water coming from upstream must be used for generation at that moment, or must be allowed to bypass the dam.



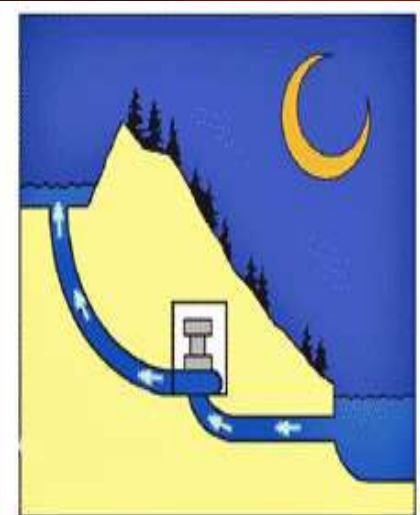
4.2 Types of hydroelectric power plant

➤ Pumped-storage plant

This method produces electricity to supply high peak demands by moving water between reservoirs at different elevations. At times of low electrical demand, excess generation capacity is used to pump water into the higher reservoir. When there is higher demand, water is released back into the lower reservoir through a turbine.



Daytime: Water flows downhill through turbines, producing electricity



Nighttime: Water pumped uphill to reservoir for tomorrow's use

4.3 Turbines

- A water turbine is a rotary engine that takes energy from moving water.
- The hydraulic turbines can be classified according to
 - (a) Head and quantity of water available
 - Low head (2 – 15 m)
 - Medium head (16 – 70 m)
 - High head (71 – 500 m)
 - Very high head (above 500 m)

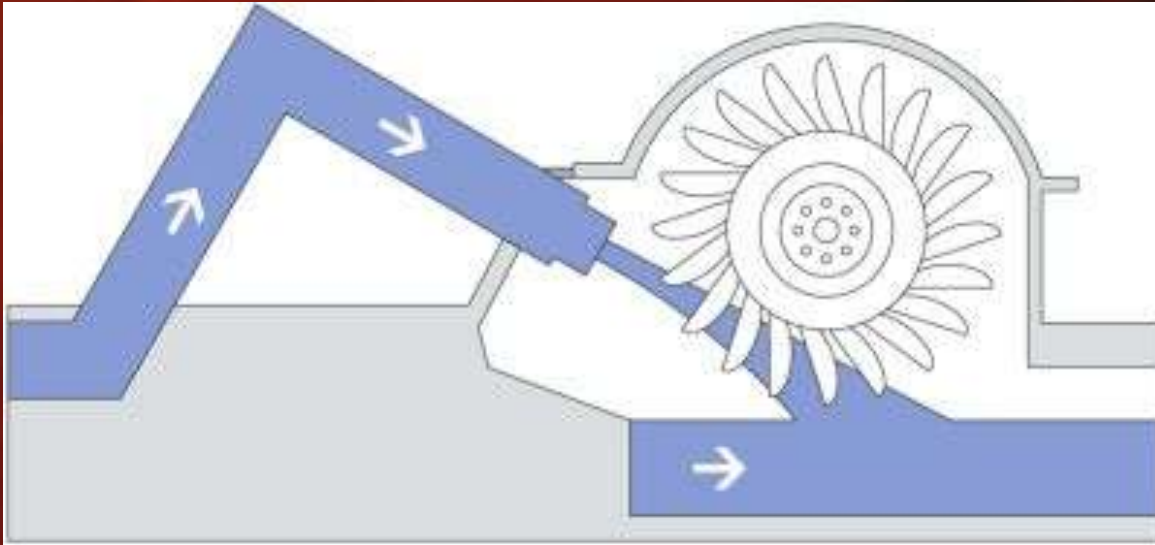
4.3 Turbines

(b) Name of the originator

- **Pelton turbine** – named after Lester Allen Pelton of the USA, an impulse turbine used for high head and low discharge.
- **Francis turbine** – named after James B. Francis, a reaction turbine used for medium head and medium discharge.
- **Kaplan turbine** – named after Dr. Victor Kaplan, a reaction turbine used for low head and large discharge.
- **Deriaz turbine** – named after Swiss engineer Deriaz, a reversible turbine-pump used up to a head of 300 m.

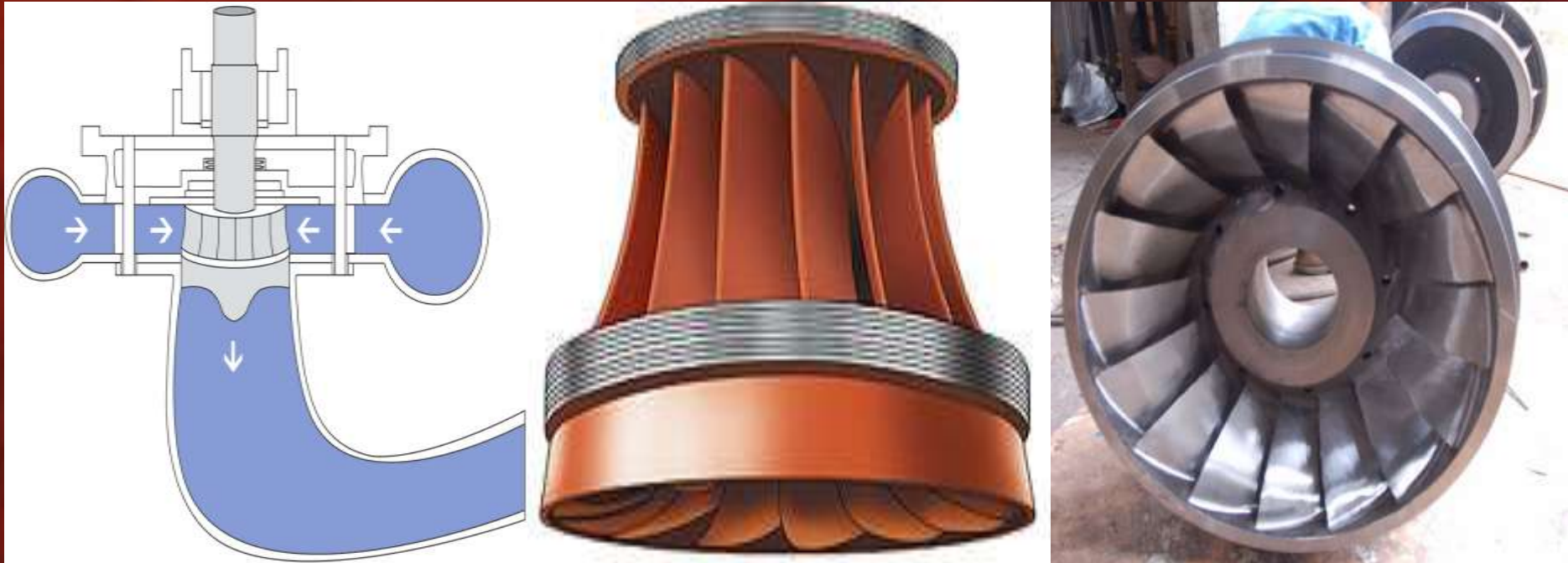
4.3 Turbines

Pelton turbine



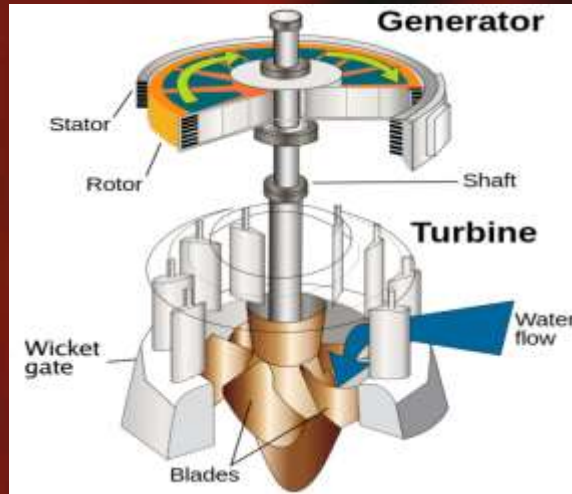
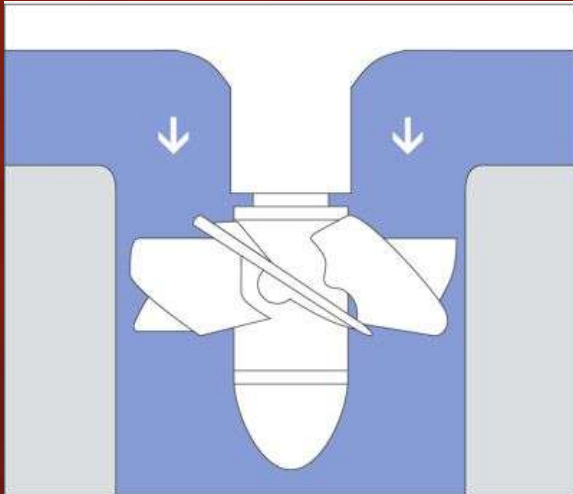
4.3 Turbines

Francis turbine



4.3 Turbines

Kaplan turbine



4.3 Turbines

Deriaz turbine



4.4 Advantages and disadvantages of HPP

❑ Advantages

- ✓ Water source is perennially available. No fuel is required to be burnt to generate electricity.
- ✓ Water passes through turbines to produce work and downstream its utility remains undiminished for irrigation of farms and quenching the thirst of people in the vicinity.
- ✓ The running costs of hydropower installations are very low as compared to thermal or nuclear power plants. In thermal power plants, besides the cost of fuel, one has to take into account the transportation cost of the fuel also.
- ✓ The hydraulic turbine can be switched on and off in a very short time. In thermal or nuclear power plant the steam turbine is put on turning gear for about two days during start-up and shut-down.

4.4 Advantages and disadvantages of HPP

❑ Disadvantages

- Hydro-power projects are capital-intensive with a low rate of return. The annual interest of this capital cost is a large part of the annual cost of hydro-power installations.
- The gestation period of hydro projects is quite large.
- Power generation is dependent on the quantity of water available, which may vary from season to season and year to year.
- Such plants are often far away from the load center and require long transmission lines to deliver power. Thus the cost of transmission lines and losses in them are more.
- Large hydropower plants disturb the ecology of the area, by way of deforestation, destroying vegetation and uprooting people.



Thank you for your attention!