2nd Workshop of ODA-UNESCO Project for Promotion of Energy Science Education for Sustainable Development in Myanmar

Theme 3

Current Energy Technology

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Objectives

- Understand the current energy technologies including conventional and clean energy technologies

- Merit, demerit and process of working of each technology is explained

- Current applicable energy technology that are using in Myanmar and in the region

Outlines

Part 1. Conventional Energy Technologies

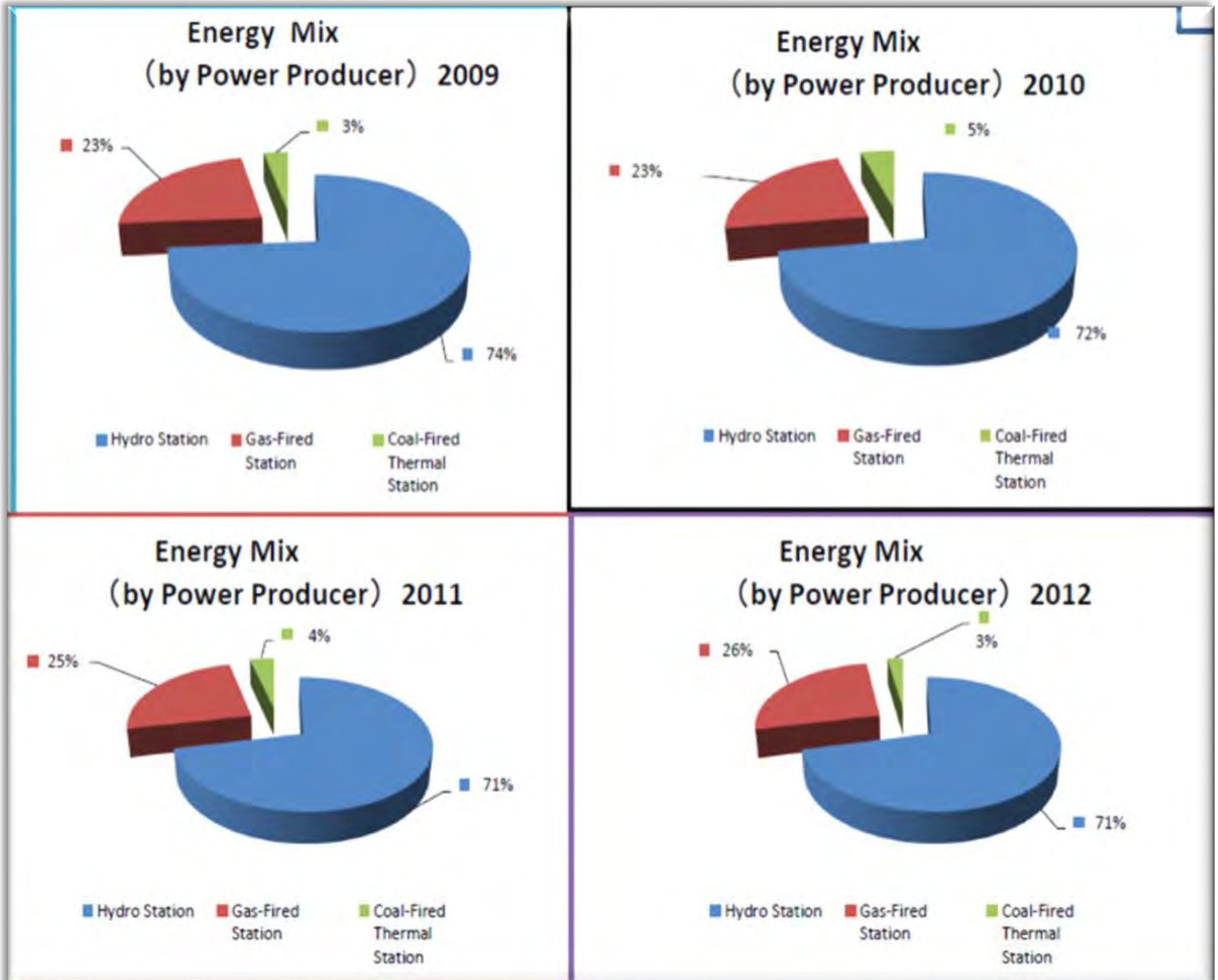
1.1 Hydro power technologies

1.2 Thermal power technologies

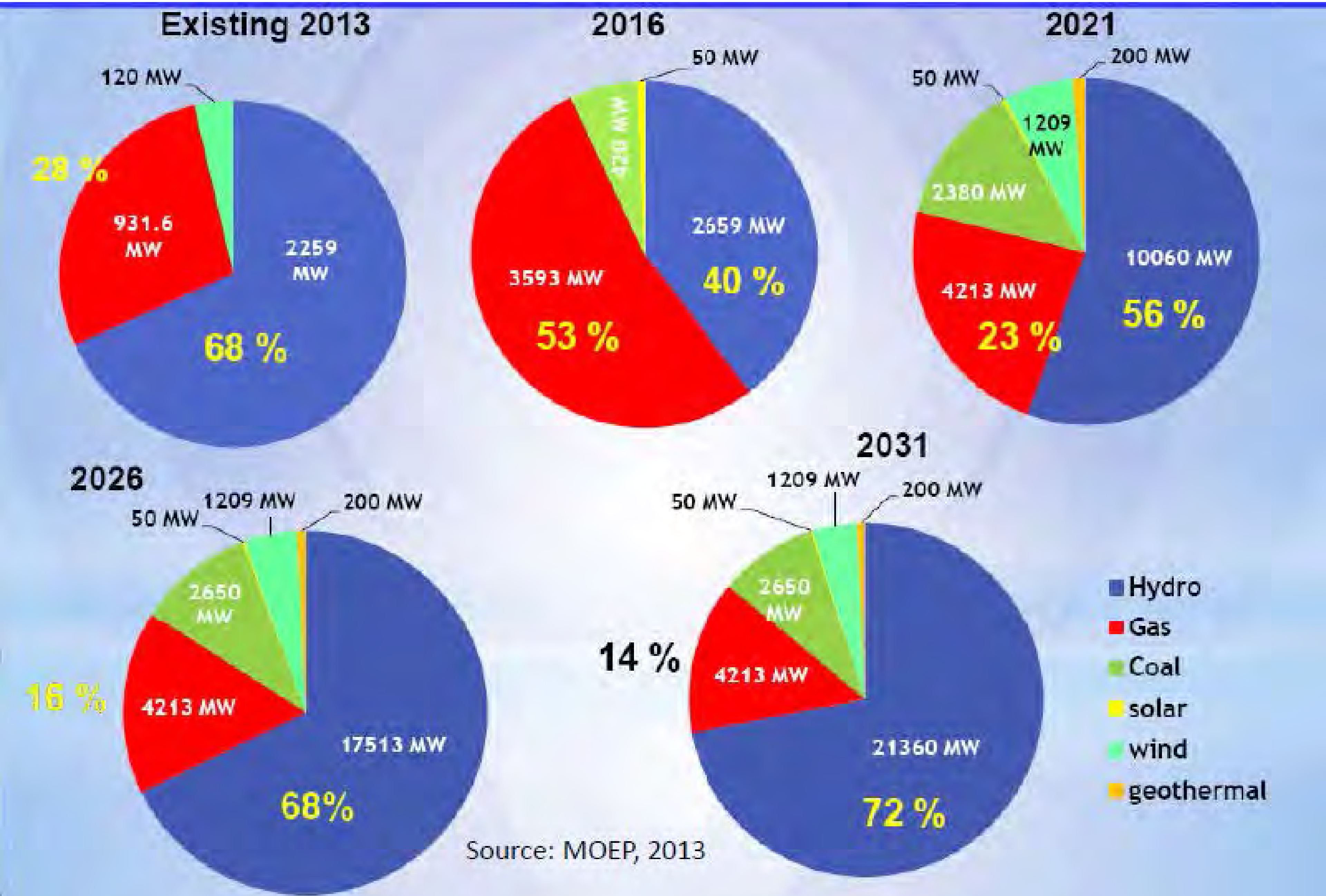
Part 2. Gaseous Emission Reduction Technologies

2.1 The effects and sources of exhaust gas emissions

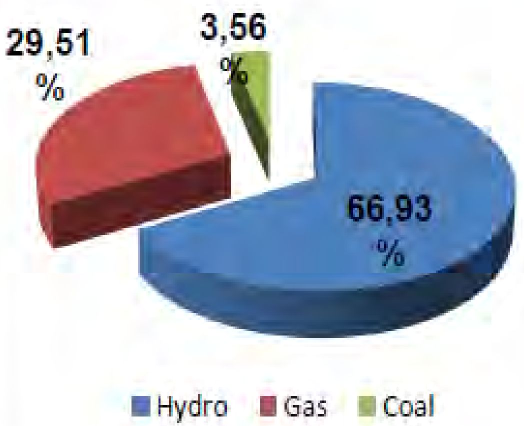
2.2 Gaseous emission reduction technologies for CO_2, SO_2, NO_x



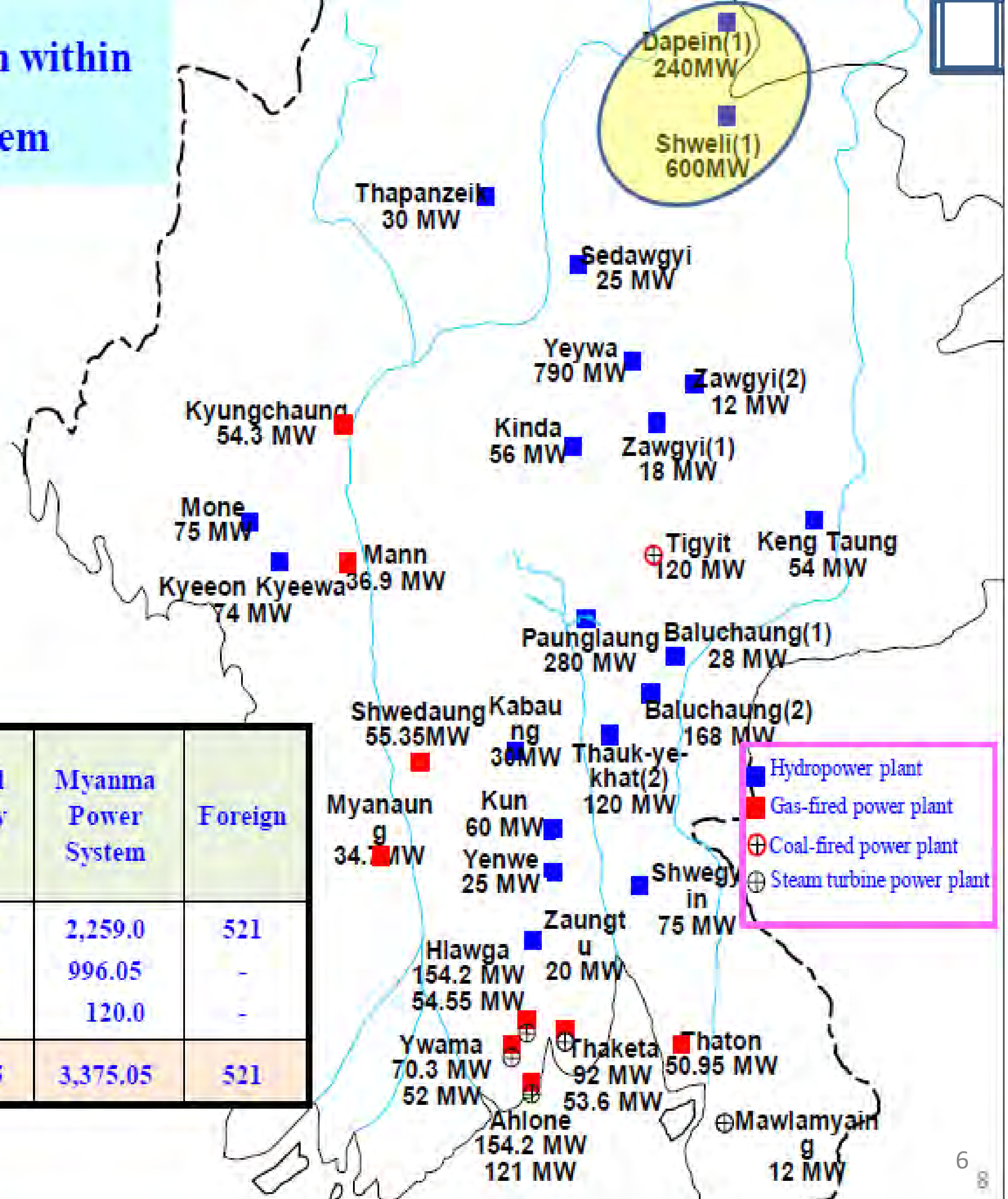
Myanmar Electric Power Enterprise (MEPE)
Ministry of Electric Power(MOEP)


Existing 2013
120 MW
28 %
931.6 MW
2259 MW
68 %
2016
50 MW
3593 MW
2659 MW
40 %
53 %
2021
50 MW
200 MW
1209 MW
2380 MW
10060 MW
4213 MW
23 %
56 %
2026
1209 MW
50 MW
200 MW
2650 MW
16 %
4213 MW
17513 MW
68%
2031
1209 MW
50 MW
200 MW
2650 MW
14 %
4213 MW
21360 MW
72 %
Hydro
Gas
Coal
solar
wind
geothermal
Source: MOEP, 2013

Location of Power Station within Myanma Power System



Sr	Description	Qty	Installed Capacity (MW)	Myanma Power System	Foreign
1	Hydropower	20	2,780.0	2,259.0	521
2	Gas-fired	14	996.05	996.05	-
3	Coal-fired	1	120.0	120.0	-
	Total	35	3,896.05	3,375.05	521



Part I: 1.1 Hydroelectric Power Technologies

Hydroelectricity

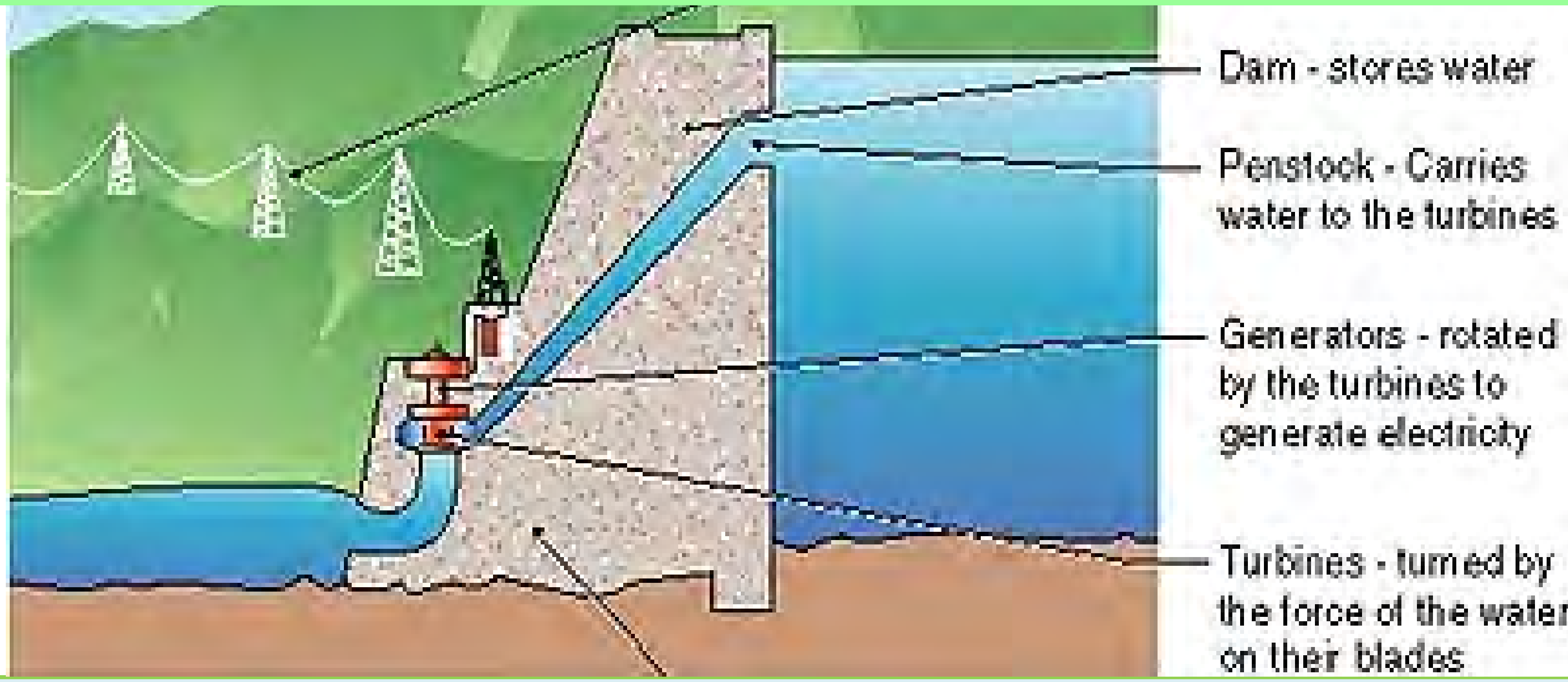
Types of Hydroelectric Power Plants

Hydro Turbine

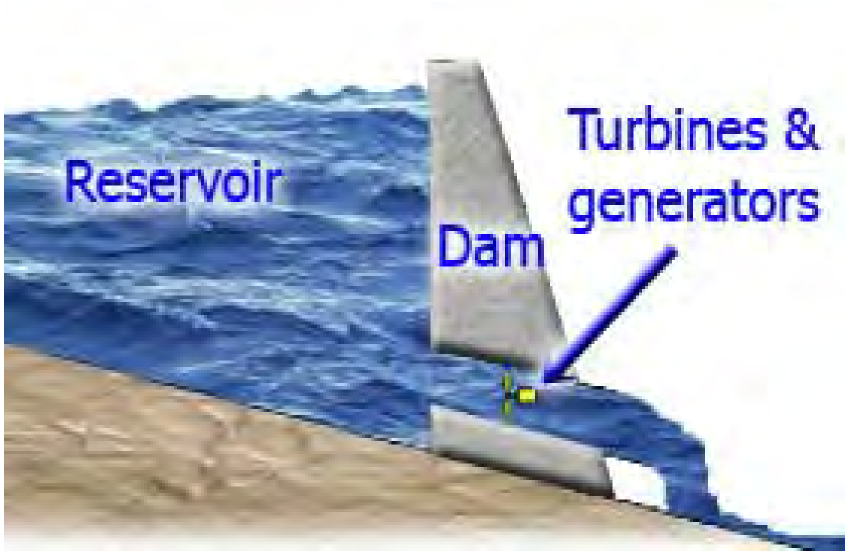
Advantages and Disadvantages of Hydroelectric Power Plant

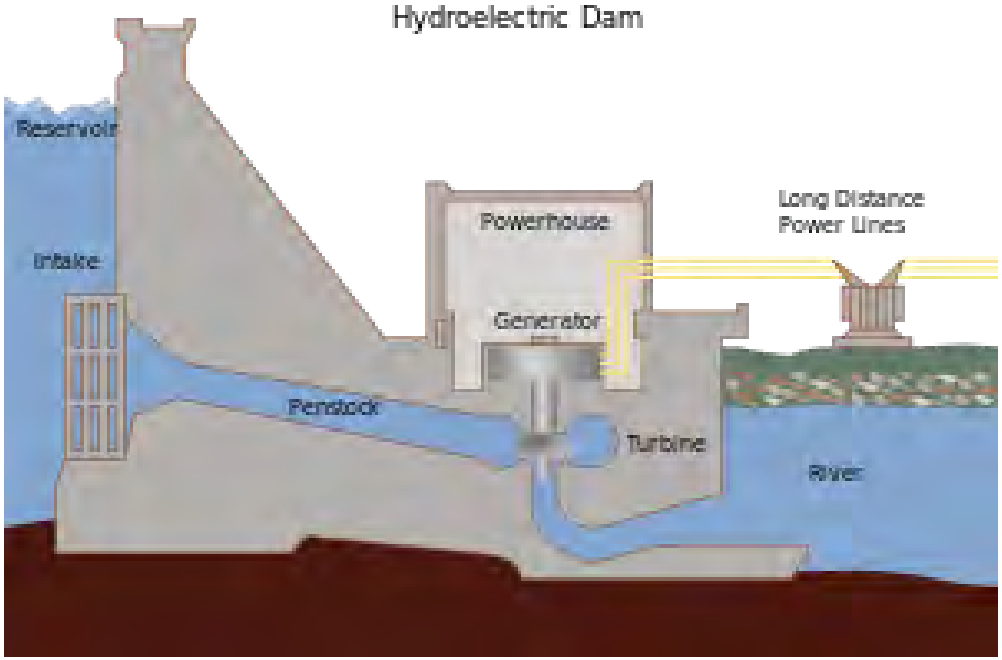
- **Hydroelectricity** is the electricity generated by hydropower
- Production of electrical power through the use of the gravitational force of falling or flowing water

How Hydroelectricity Works



Turbines and generators convert the energy into electricity, which is then fed into the electrical grid to be used in homes, businesses, and by industry.





A dam is built to trap water, usually in a valley where there is an existing lake.

Water is allowed to flow through tunnels in the dam, to turn turbines and thus drive generators.

The dam is much thicker at the bottom than at the top, because the pressure of the water increases with depth.

Types of Hydroelectric Power Plants

Three types of hydropower facilities:

(i) impoundment

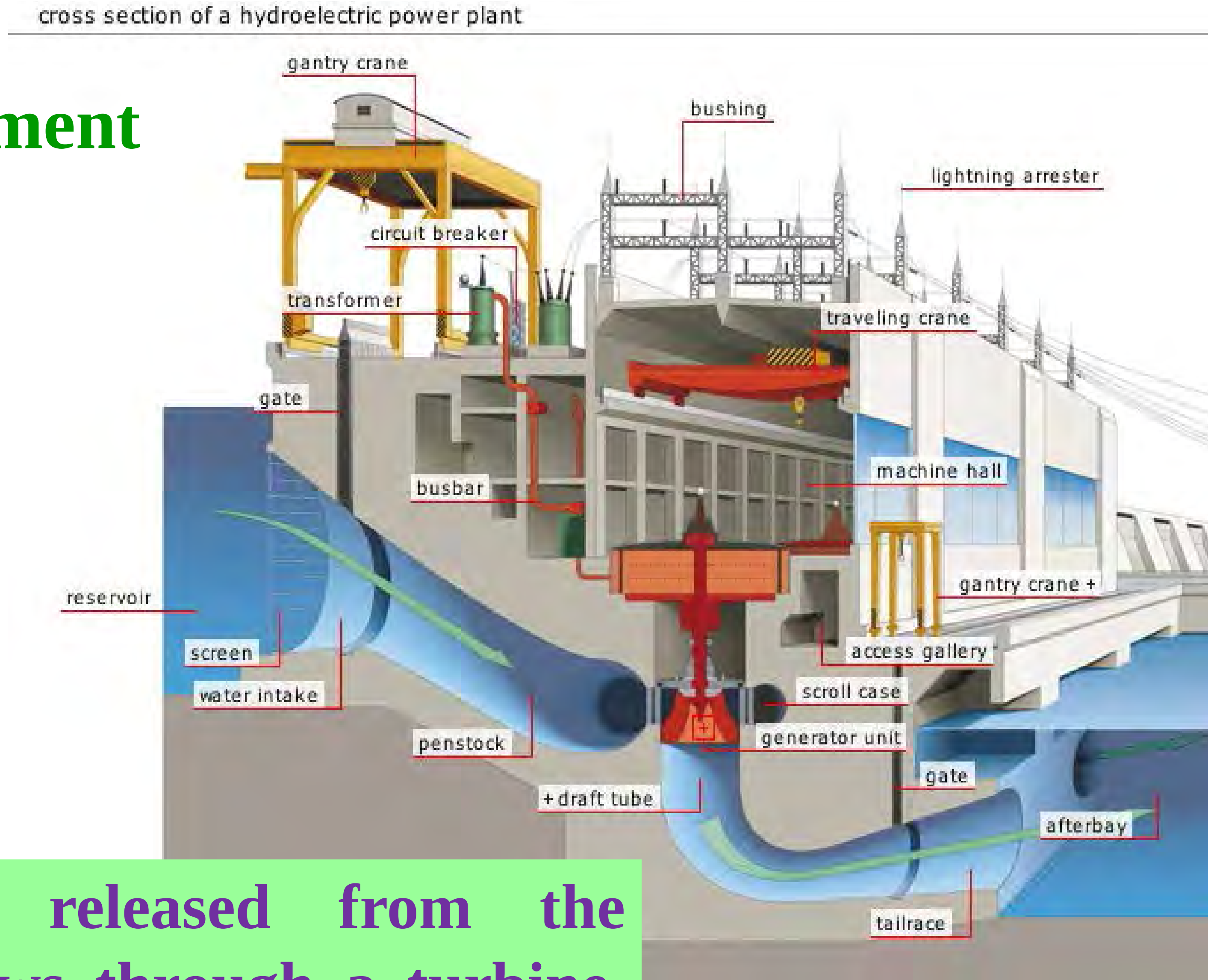
(ii) diversion

(iii) pumped storage

Impoundment

- **Most common type of hydroelectric power.**
- **Large hydropower system which uses a dam to store river water in a reservoir.**

Impoundment

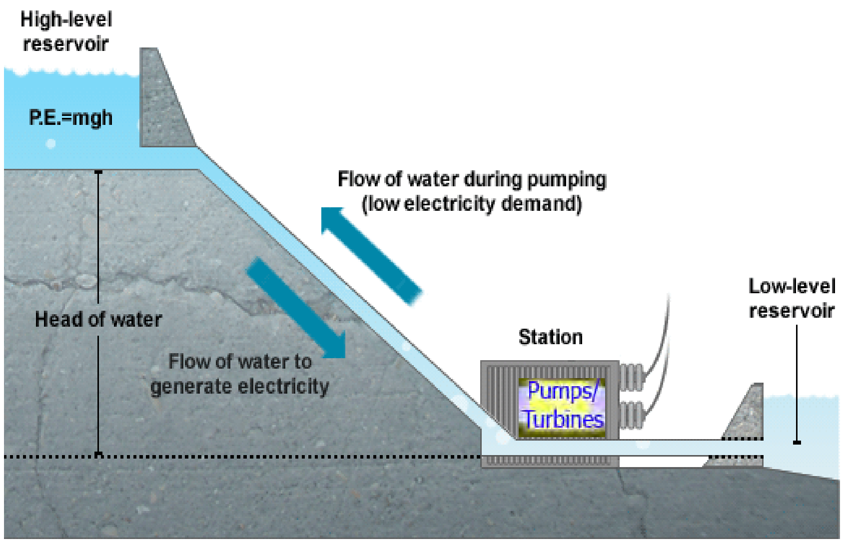


Water released from the reservoir flows through a turbine, spinning it, which in turn activates a generator to produce electricity.

Diversion

A diversion, run-of-river, facility channels a portion of a river through a canal or penstock. It may not require the use of a dam.

Pumped Storage



- Pumped storage works like a battery, storing the electricity generated by other power sources like solar, wind, and nuclear for later use.
- It stores energy by pumping water uphill to a reservoir at higher elevation from a second reservoir at a lower elevation.
- When the demand for electricity is low, a pumped storage facility stores energy by pumping water from a lower reservoir to an upper reservoir.
- During periods of high electrical demand, the water is released back to the lower reservoir and turns a turbine, generating electricity.

Sizes of Hydroelectric Power Plants

Large Hydropower — **Capacity of *more than 30 MW***

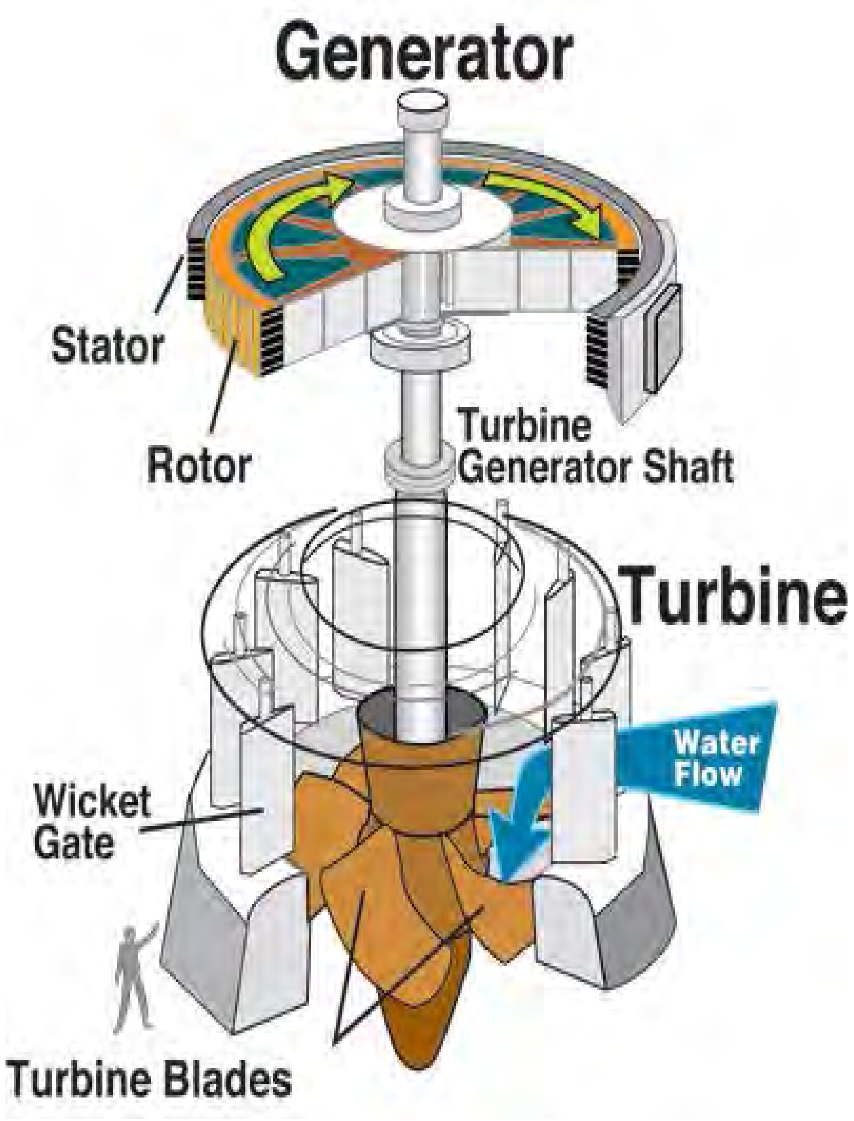
Small Hydropower — **Capacity of *100 kW to 30 MW***

Micro Hydropower — **Capacity less than *100 kW***

← GRAND CANYON
COLORADO RIVER
VIRGIN R.
RESERVOIR
AREA

Hydroelectric Generator

A mass of water moving down a height difference contains energy. This can be harvested. Moving water drives turbine. This rotation a generator which produces electric power.



Hydro Turbine

Two main types of Hydro Turbines:

(i) impulse

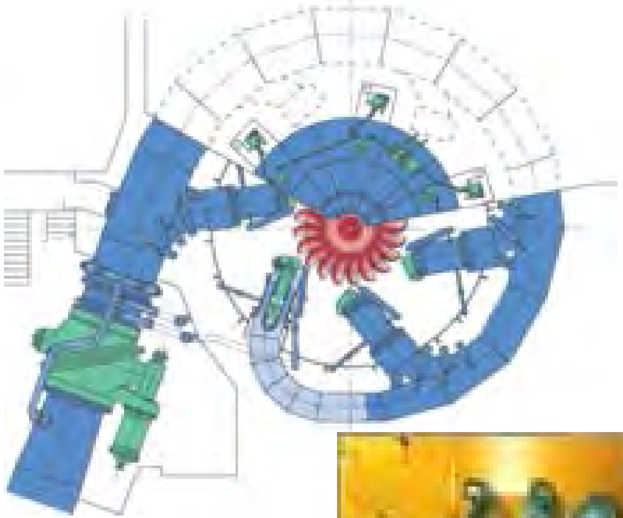
(ii) reaction

The type of hydropower turbine selected is based on the **height** of standing water “head” and the **flow or volume** of water, at the site.

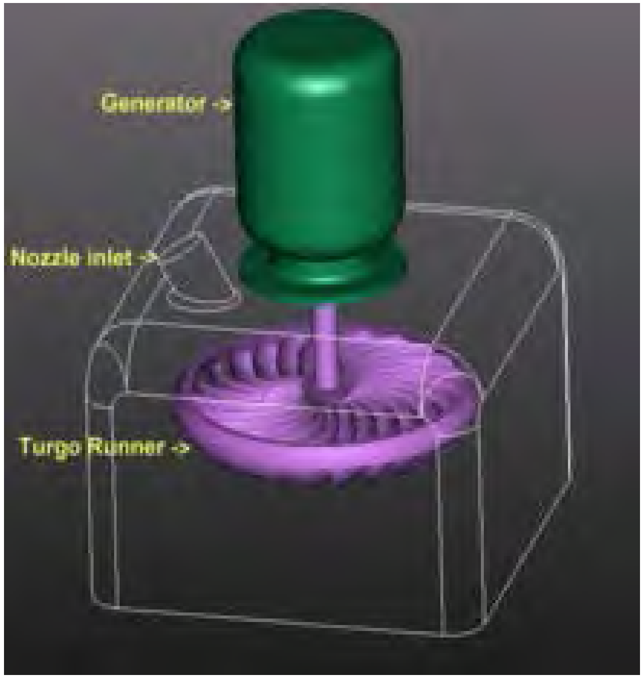
Other deciding factors include how **deep** the turbine must be set, **efficiency** and **cost**.

Impulse Turbine

The impulse turbine generally uses the velocity of the water to move the runner and discharges to atmospheric pressure. The water stream hits each bucket on the runner. There is no suction on the down side of the turbine, and the water flows out the bottom of the turbine housing after hitting the runner. An impulse turbine is generally suitable for high head, low flow applications.



Pelton



Turgo

Reaction Turbine

A reaction turbine develops power from the combined action of pressure and moving water. The runner is placed directly in the water stream flowing over the blades rather than striking each individually. Reaction turbines are generally used for sites with lower head and higher flows than compared with the impulse turbines.

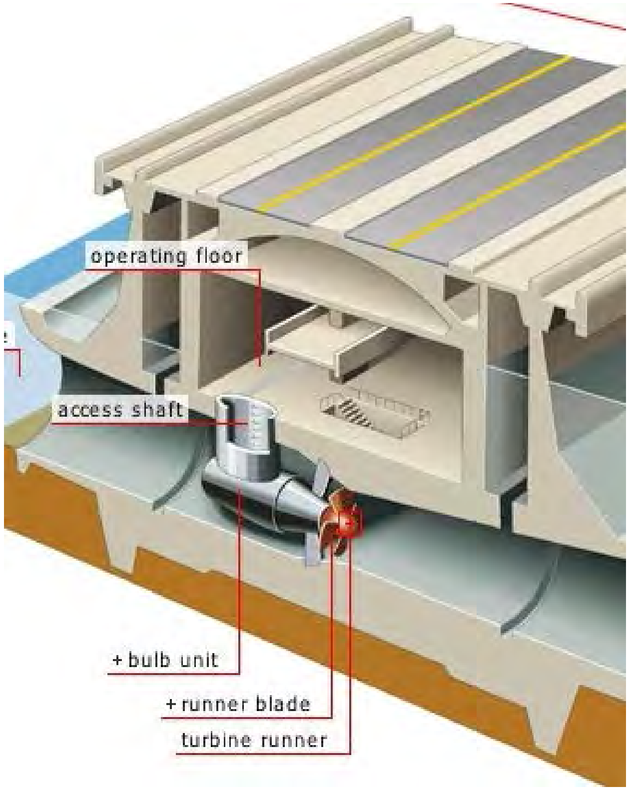
Propeller

Kaplan

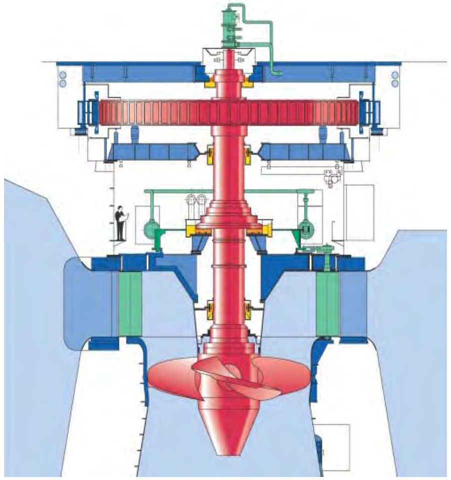
Bulb

Francis

Propeller

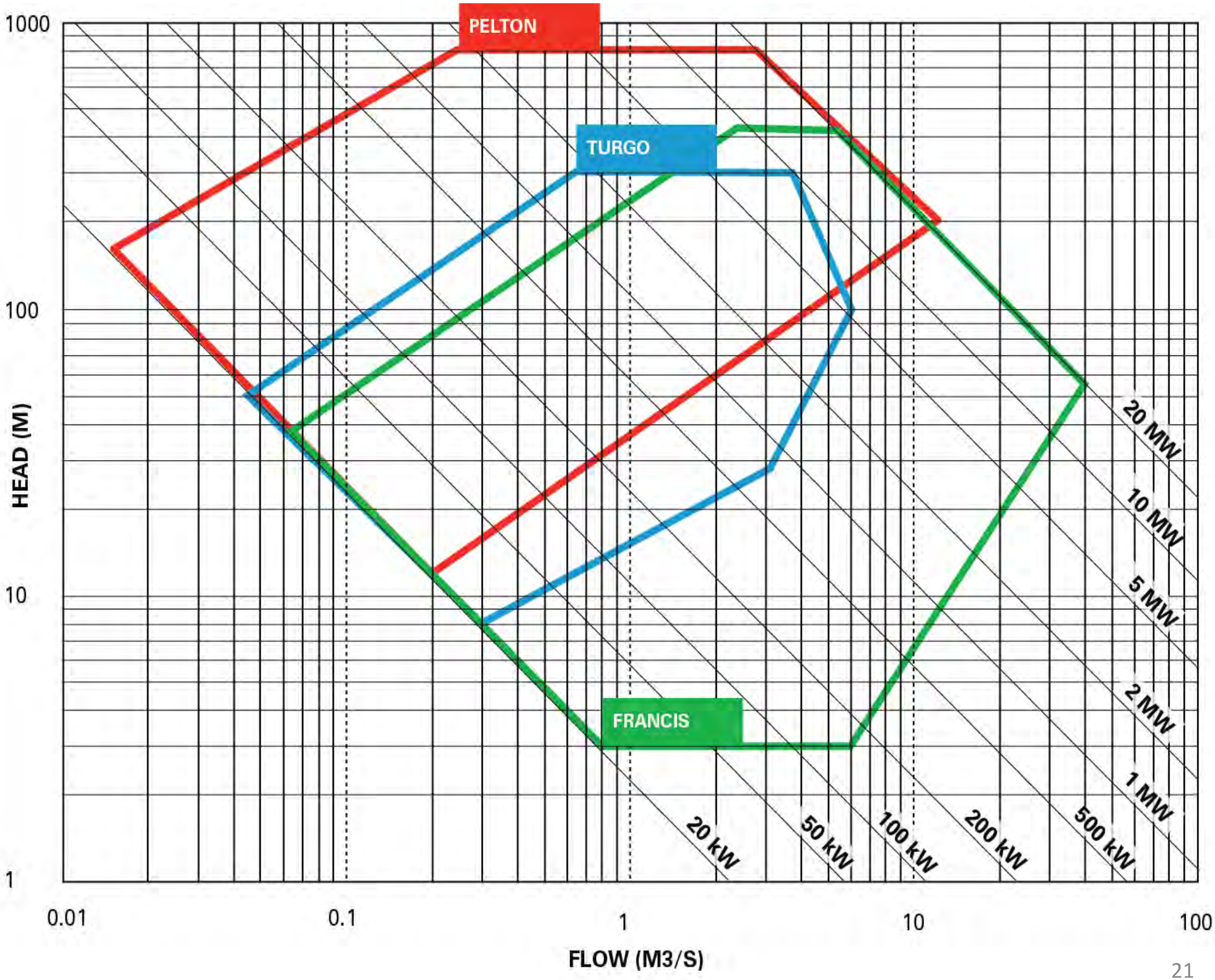


Kaplan_Turbine



Francis Turbine High flow

Low flow


PELTON
TURGO
FRANCIS
1000
100
10
1
HEAD (M)
0.01
0.1
1
10
100
FLOW (M3/S)
20 kW
50 kW
100 kW
200 kW
500 kW
1 MW
2 MW
5 MW
10 MW
20 MW

Advantages and Disadvantages of Hydropower

- ✓ Flexibility
- ✓ Low power costs
- ✓ Suitability for industrial applications
- ✓ Reduced emissions of CO, CO_2 SO_2, NO_2

- Ecosystem damage and loss of land
- Siltation and flow shortage
- Methane emissions (from reservoirs)
- Relocation

Part I: 1.2 Thermal Power Technologies

Fuels and Classification of Fuels

Principles and Combustion

- Fossil fuels (oil, gas, coal)
- Coal analysis
- Heating values
- Combustion processes

Fuel is the combustible substance which on burning in air produces large amount of heat

Combustion is the exothermal oxidation of a fuel, by air or oxygen occurring at a sufficiently rapid rate to produce a high temperature, usually with the appearance of a flame

Fuels mostly contain carbon or carbon and hydrogen and sulphur

C is oxidized to CO_2

Hydrogen to water

S is oxidized to SO_2

Classification of Fuels

Primary Fuels

Fuels which occur naturally such as coal, crude petroleum and natural gas. Coal and crude petroleum, formed from organic matter many millions of years ago, are referred to as fossil fuels.

Secondary Fuels

Fuels which are derived from naturally occurring ones by a treatment process such as coke, gasoline, coal gas etc.

Fossil Fuels

Fossil Fuels are formed from Living things millions of years ago

Fossil Fuels are ***Finite Fuels*** ie. They will run out in the future and cannot be *regenerated*

Three Main Fossil Fuels

Coal, Oil and Gas

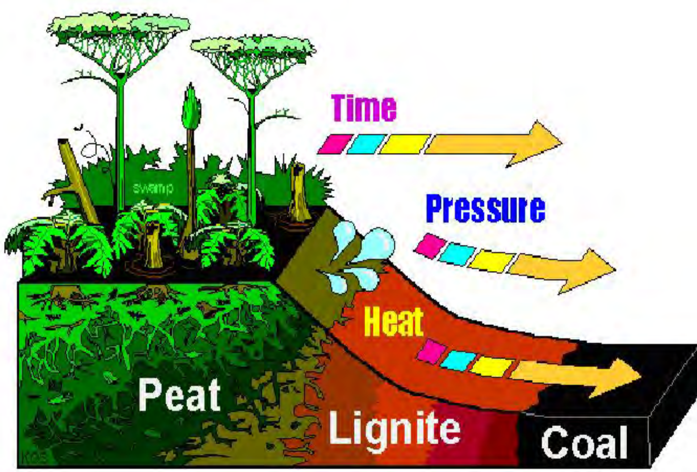
Oil: was formed by ***dead sea creatures*** falling to the sea-bed where they were subjected to chemical change by Bacteria

Coal: was formed by the *decay of Vegetation* which was subjected to heat and pressure over a very long period of time

Gas : was formed in much the same way as Oil. It is often collected when drilling for Oil.

Coal Analysis

Coal is a combustible black or brownish-black sedimentary rock composed mostly of carbon and hydrocarbons. Energy content (Btu/pound) ranges from 5,000 to 15,000 depending on the type of coal. When coal is used for electricity generation, it is usually pulverized and then combusted in a furnace with a boiler.



Calorific Value (Heating Value)

The amount of heat released when a unit mass of fuel is. All elements considered to be fuels have a calorific value. There are two calorific values for fuels: higher and lower.

$$HHV = LHV + h_v \times (n_{H_2O,out}/n_{fuel,in})$$

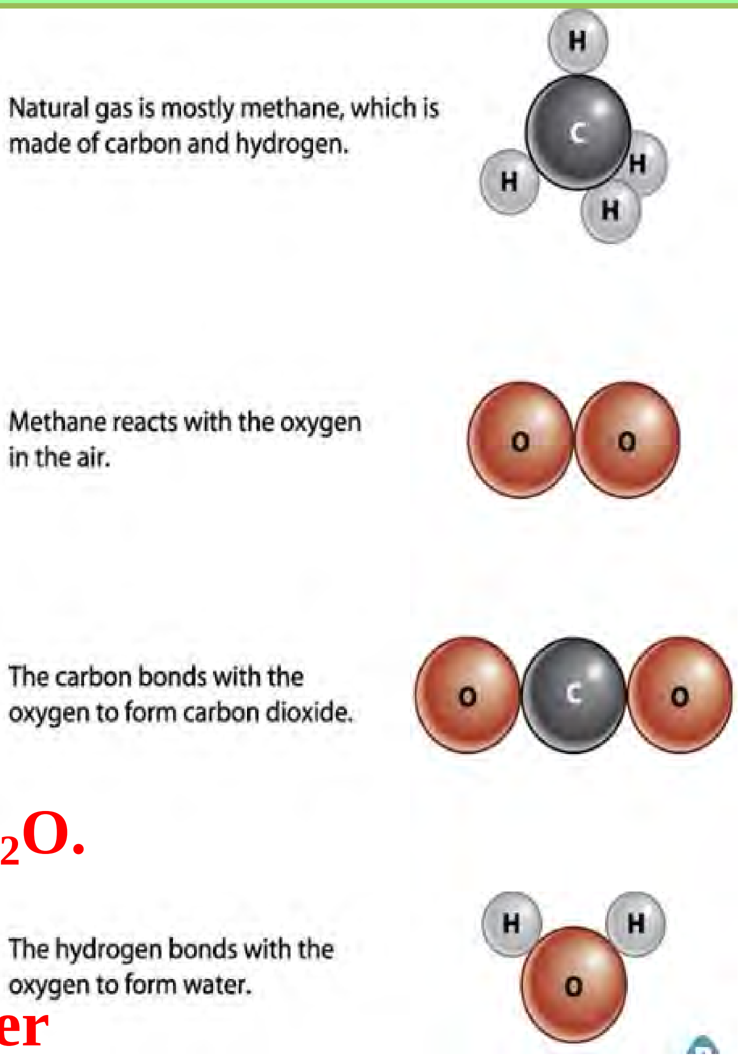
Btu/lb
kcal/kg
J/kg

where h_v = heat of vaporization of water
$n_{H_2O,out}$ = moles of water vaporized
$n_{fuel,in}$ = number of moles of fuel combusted

kcal/kg = MJ/kg * 238.846
Btu/lb = MJ/kg * 429.923
Btu/lb = kcals/kg * 1.8

Fuel	HHV MJ/kg	HHV BTU/lb	HHV kJ/mol	LHV MJ/kg
Hydrogen	141.80	61,000	286	119.96
Methane	55.50	23,900	889	50.00
Ethane	51.90	22,400	1,560	47.80
Propane	50.35	21,700	2,220	46.35
Butane	49.50	20,900	2,877	45.75
Pentane	48.60	21,876	3,507	45.35
Gasoline	47.30	20,400		44.4
Paraffin wax	46.00	19,900		41.50
Kerosene	46.20	19,862		43.00
Diesel	44.80	19,300		43.4
Coal (Anthracite)	32.50	14,000		
Coal (Lignite)	15.00	8,000		
Wood (MAF)	21.7	8,700		
Wood fuel	24.2	9,142		17.0
Peat (damp)	6.00	2,500		
Peat (dry)	15.00	6,500		

Combustion of Hydrocarbons



All ***Hydrocarbons*** burn to give **CO_2 and H_2O.**
Burning is also called combustion.

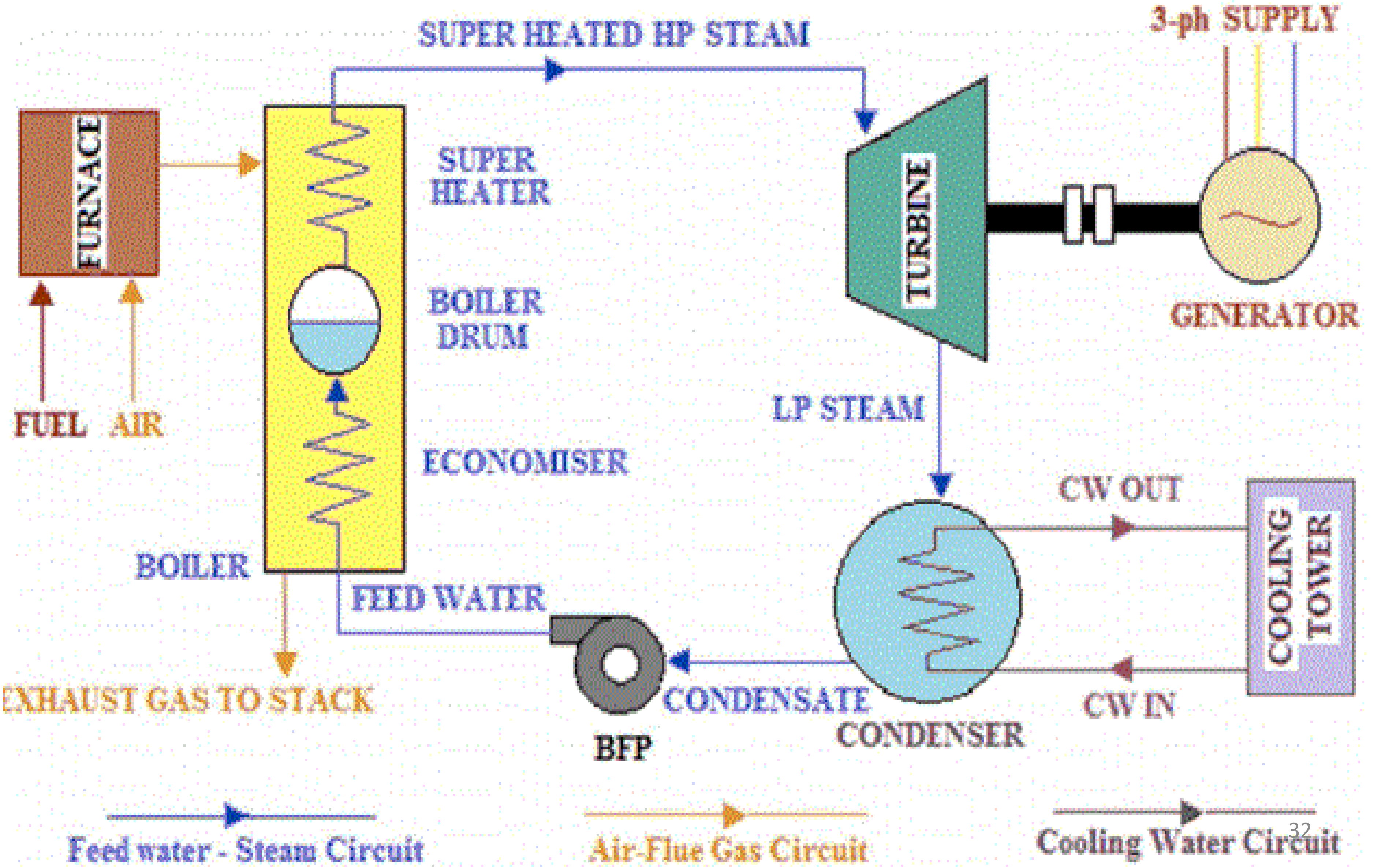
Fuel + oxygen -----› carbon dioxide + water

Any substance that contains **Carbon** and **Hydrogen** gives **CO_2** and **H_2O** when burned.

Principles of Carbon-based Fuels

- ✓ Carbon-based fuels dominate global energy use.
- ✓ Combustion releases carbon dioxide to the atmosphere.
- ✓ The release of carbon dioxide alters the global carbon cycle.
- ✓ Carbon dioxide is a greenhouse gas.
- ✓ Atmospheric greenhouse gas concentrations are at an 800,000 year maximum.
- ✓ Global warming is caused by rising greenhouse gas concentrations.
- ✓ Energy technologies vary significantly in their greenhouse gas emission.
- ✓ Huge amounts carbon-based energy remain in the Earth's crust.

Schematic Diagram of a Typical Thermal Power Plant



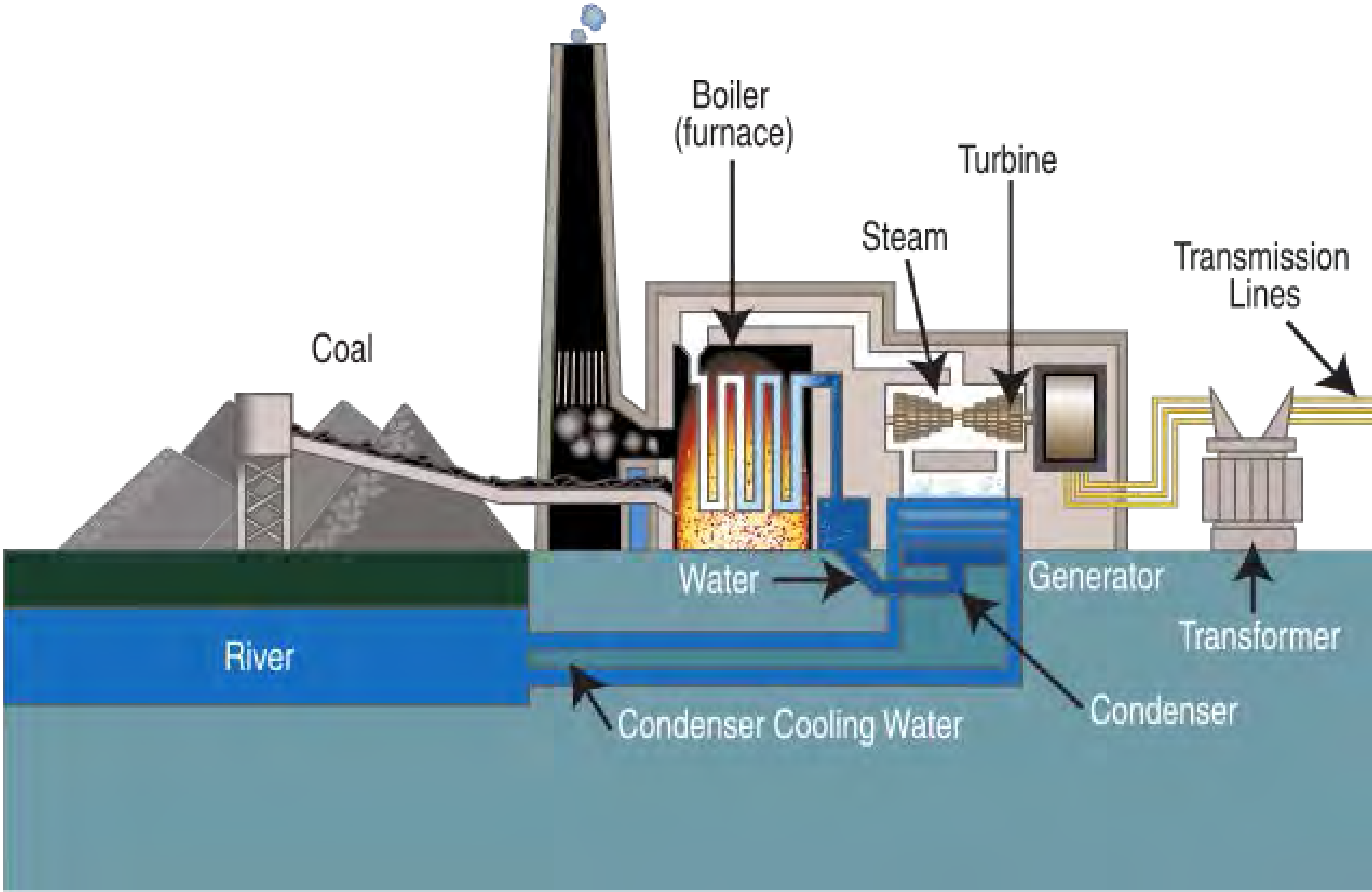


Diagram of a Typical Steam-Cycle Coal Power Plant

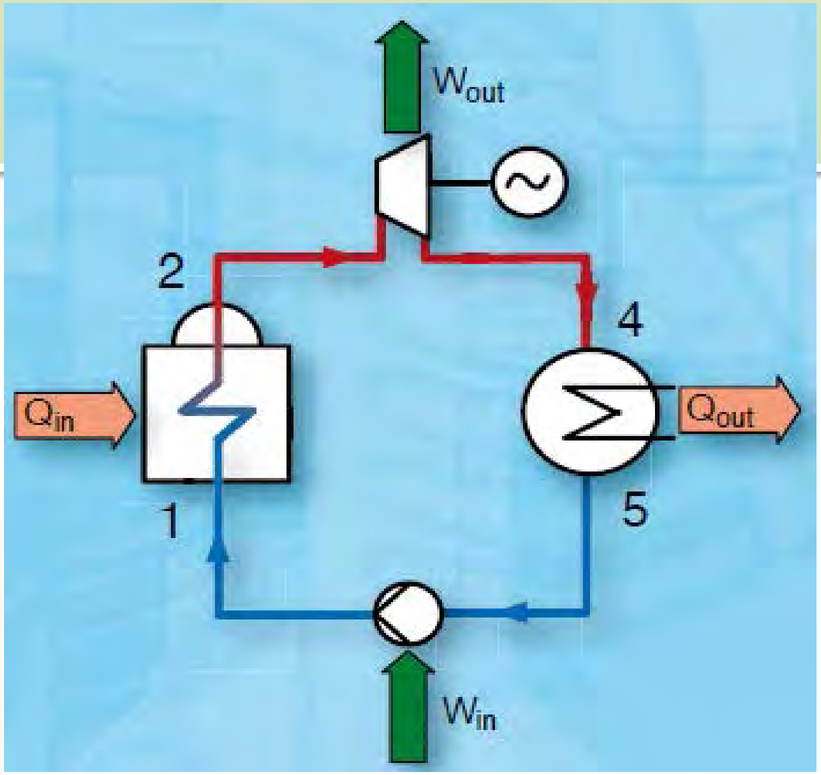
Part I: 1.2 Thermal Power Technologies

Steam Power Plant

- Components of a simple steam power plant
- Rankine cycle
- Steam boiler
- Steam turbine/generator
- Heat recovery steam generator
- Condenser and cooling tower

Components of a Simple Steam Power

1–2: Liquid pressurised water is evaporated in a boiler by input of heat



2–4: The steam expands associated with mechanical power output. The mechanical energy is transformed into electrical energy by a generator

1. Boiler
2. superheater
3. turbine / generator
4 . condenser
5. feed water pump

4–5: The expanded steam is condensed to water with associated heat output

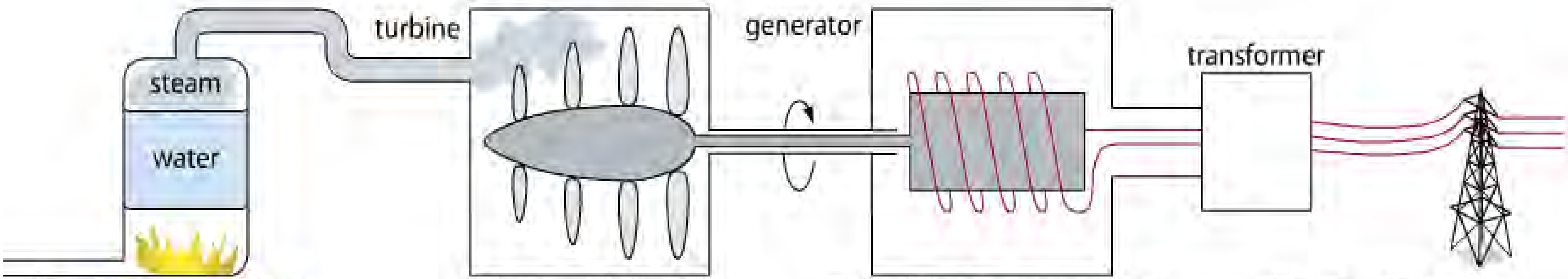
5–1: The condensed water is pressurized by a feed pump and delivered back into the boiler

Steam Turbine/Generator

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

Because the turbine generates rotary motion, it is particularly suited to be used to drive an electrical generator

Steam Turbines consist of many blades on a long shaft, like the inside of a jet engine. Steam blows them round, turning the shaft, which drives a generator



In many power stations, fossil fuels are burnt. The energy is used to heat water and turn it to steam.

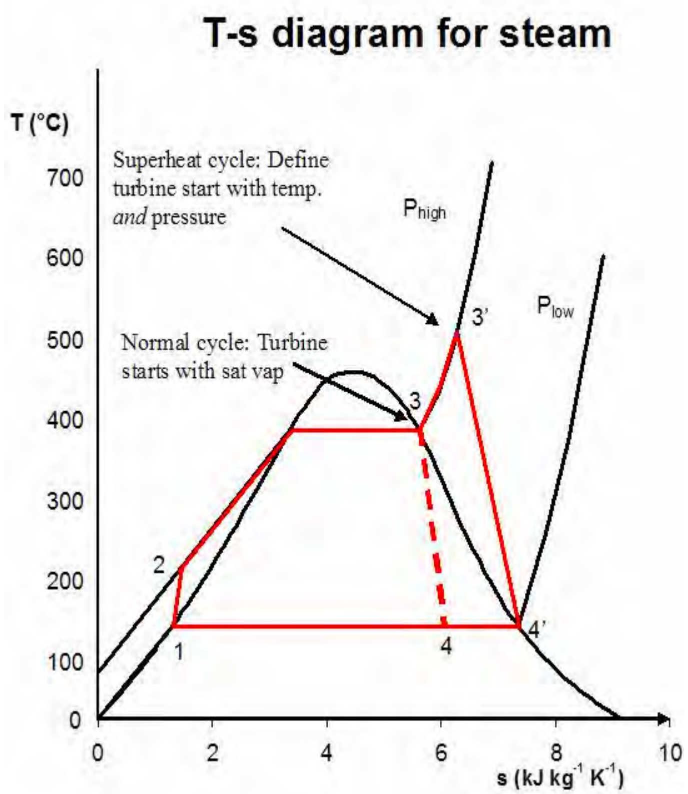
The steam is forced through large fans, called **turbines**, making them turn around.

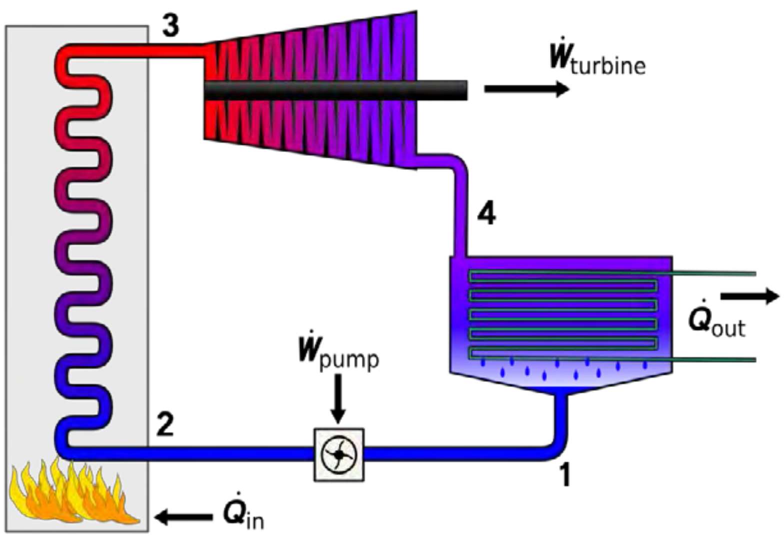
The turbines turn **generators.** These are large magnets inside massive coils of wire. A moving magnet inside a coil of wire creates electricity (an **electric current**).

The electricity flows along cables into the **National Grid**.

Rankine Cycle

The **Rankine cycle** is a model that is used to predict the performance of ***steam engines***. The Rankine cycle of a heat engine converts ***heat into mechanical work***. The Rankine cycle, in the form of steam engines, generates about ***90% of all electric power*** used throughout the world.





Four Processes in the Rankine Cycle

Process 1-2: The working fluid is pumped from low to high pressure. As the fluid is a liquid at this stage, the pump requires little input energy.

Process 2-3: The high pressure liquid enters a boiler where it is heated at constant pressure by an external heat source to become a dry saturated vapour. The input energy required can be easily calculated using mollier diagram or h-s chart or enthalpy-entropy chart also known as steam tables.

Process 3-4: The dry saturated vapour expands through a turbine, generating power. This decreases the temperature and pressure of the vapour, and some condensation may occur. The output in this process can be easily calculated using the Enthalpy-entropy chart or the steam tables.

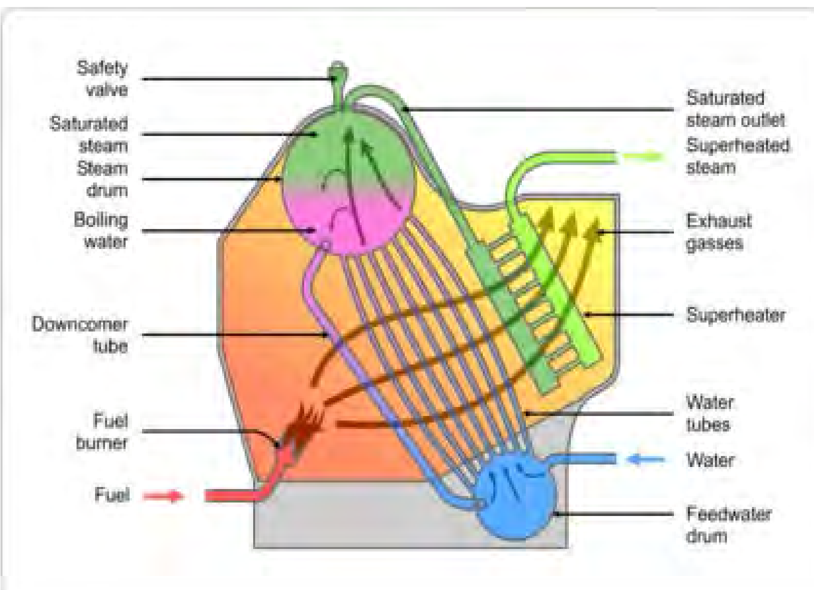
Process 4-1: The wet vapour then enters a condenser where it is condensed at a constant pressure to become a saturated liquid.

Steam Boiler

Water tube boiler

Types of Water Tube Boiler

1) Horizontal Straight Tube Boi
2) Bent Tube Boiler.
3) Cyclone Fired Boiler.



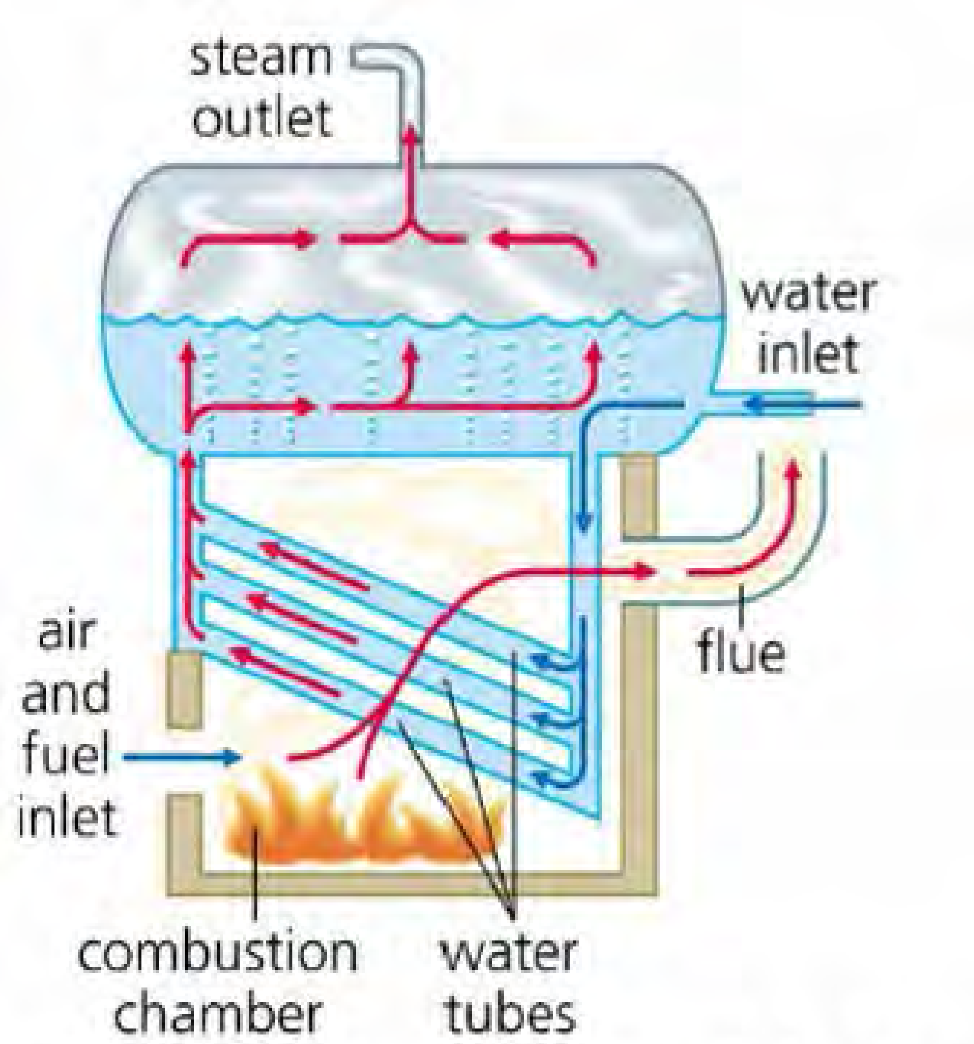
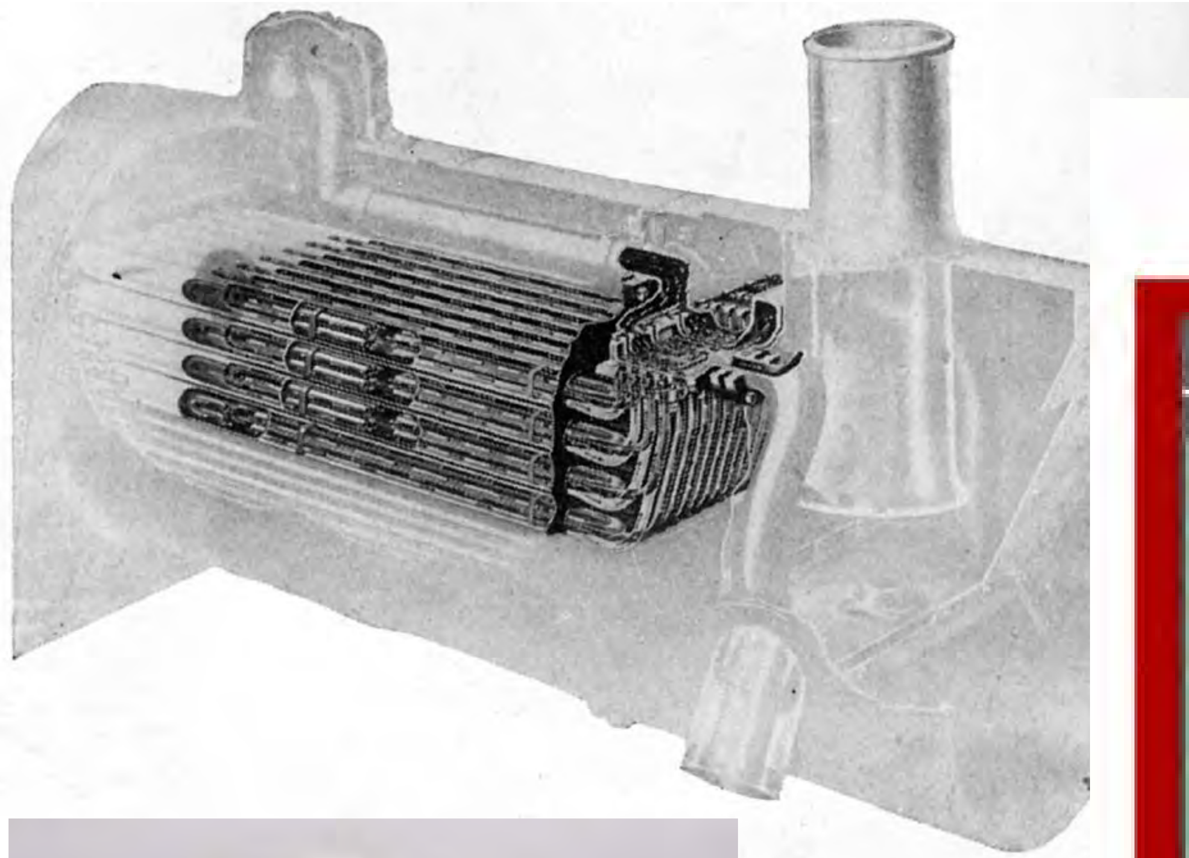
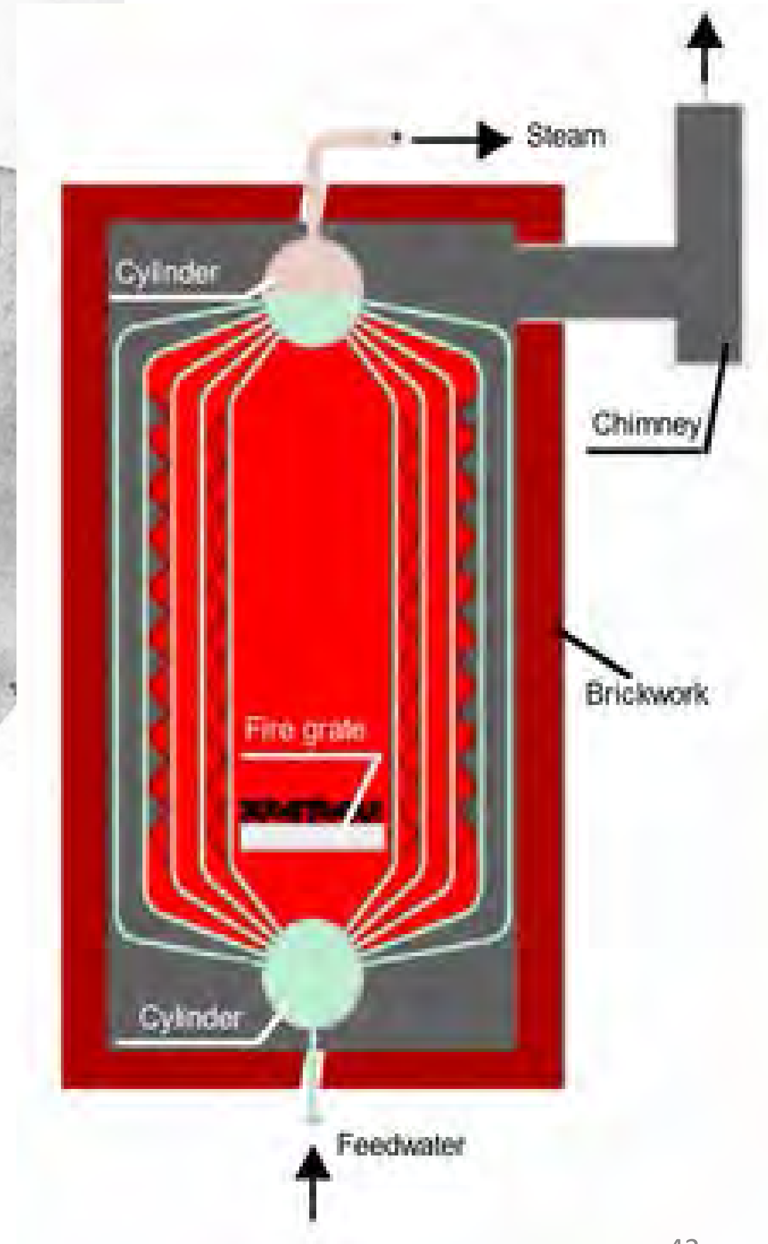


Fig: Simple Diagram of Water Tube Boiler

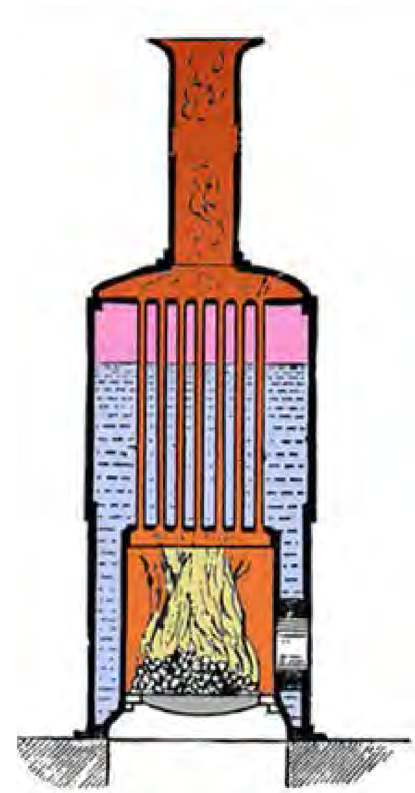
Water tube boiler

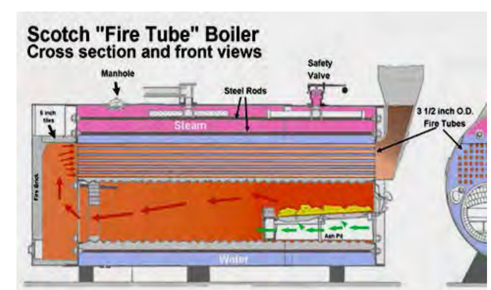
It consists of mainly two drums, one is upper drum called steam drum other is lower drum called mud drum. These upper drum and lower drum are connected with two tubes namely down-comer and riser tubes as shown in the picture. Water in the lower drum and in the riser connected to it, is heated and steam is produced in them which comes to the upper drums naturally. In the upper drum the steam is separated from water naturally and stored above the water surface. The colder water is fed from feed water inlet at upper drum and as this water is heavier than the hotter water of lower drum and that in the riser, the colder water push the hotter water upwards through the riser.




Steam
Cylinder
Chimney
Brickwork
Fire grate
Cylinder
Feedwater

Operation of fire tube boiler is as simple as its construction. In **fire tube boiler**, the fuel is burnt inside a furnace. The hot gases produced in the furnace then passes through the fire tubes. The fire tubes are immersed in water inside the main vessel of the boiler. As the hot gases are passed through these tubes, the heat energy of the gasses is transferred to the water surrounds them. As a result steam is generated in the water and naturally comes up and is stored upon the water in the same vessel of **fire tube boiler**. This steam is then taken out from the steam outlet for utilizing for required purpose. The water is fed into the boiler through the feed water inlet.





Types of Fire Tube Boiler

According to the location of furnace there are two **types of fire tube boiler** and these are external furnace and internal furnace type.

There are mainly three types of external furnace fire tube boiler.

1) Horizontal return tubular fire tube boiler.
2) Short fire box fire tube boiler.
3) Compact fire tube boiler.

Condenser of Steam Power Plant

The condensers are heat exchangers which convert steam from its gaseous to its liquid state at a pressure below atmospheric pressure. Where cooling water is in short supply, an air-cooled condenser is often used.

Surface condenser

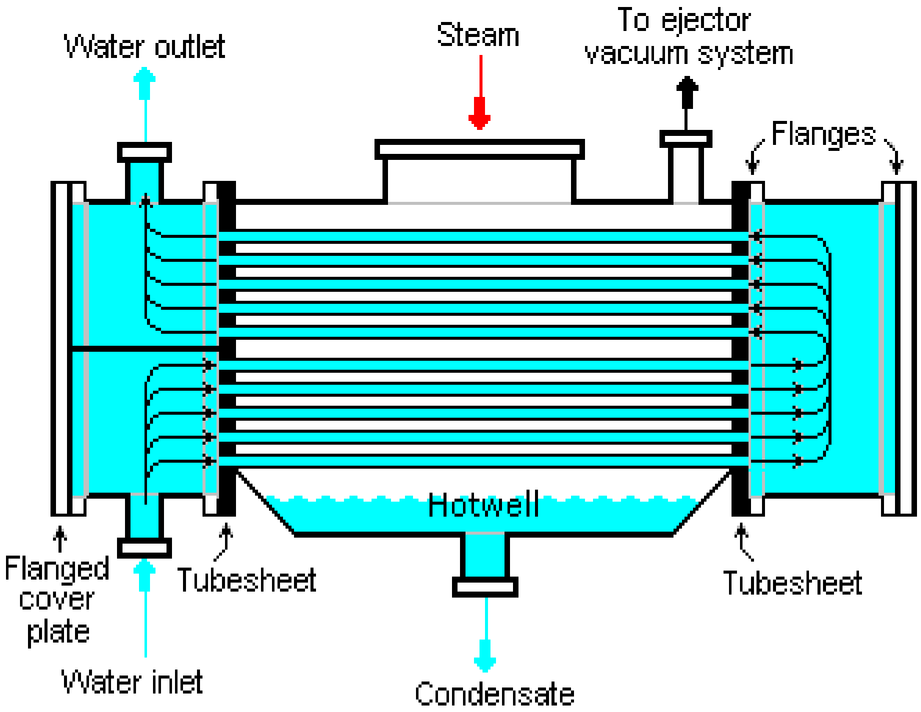


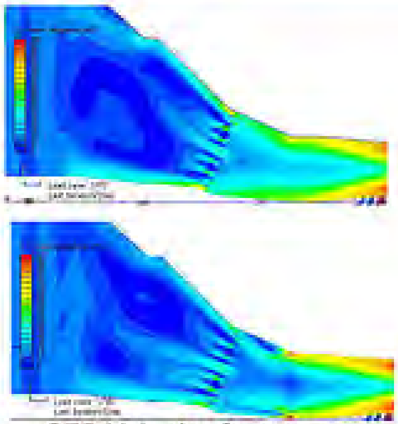
Diagram of a typical water-cooled surface condenser

Heat Recovery Steam Generator (HRSG)

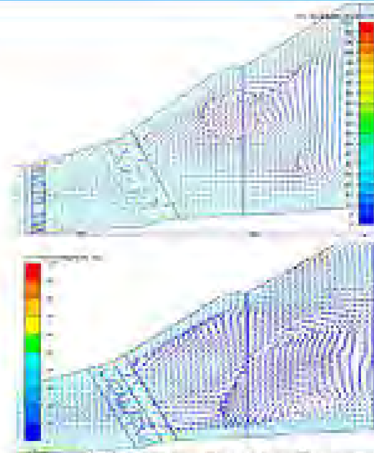
Heat recovery steam generator (HRSG) is an energy recovery heat exchanger that recovers heat from a hot gas stream. It produces steam that can be used in a process (cogeneration) or used to drive a steam turbine (combined cycle).

HRSGs consist of four major components: the economizer, evaporator, superheater and water preheater. The different components are put together to meet the operating requirements of the unit.

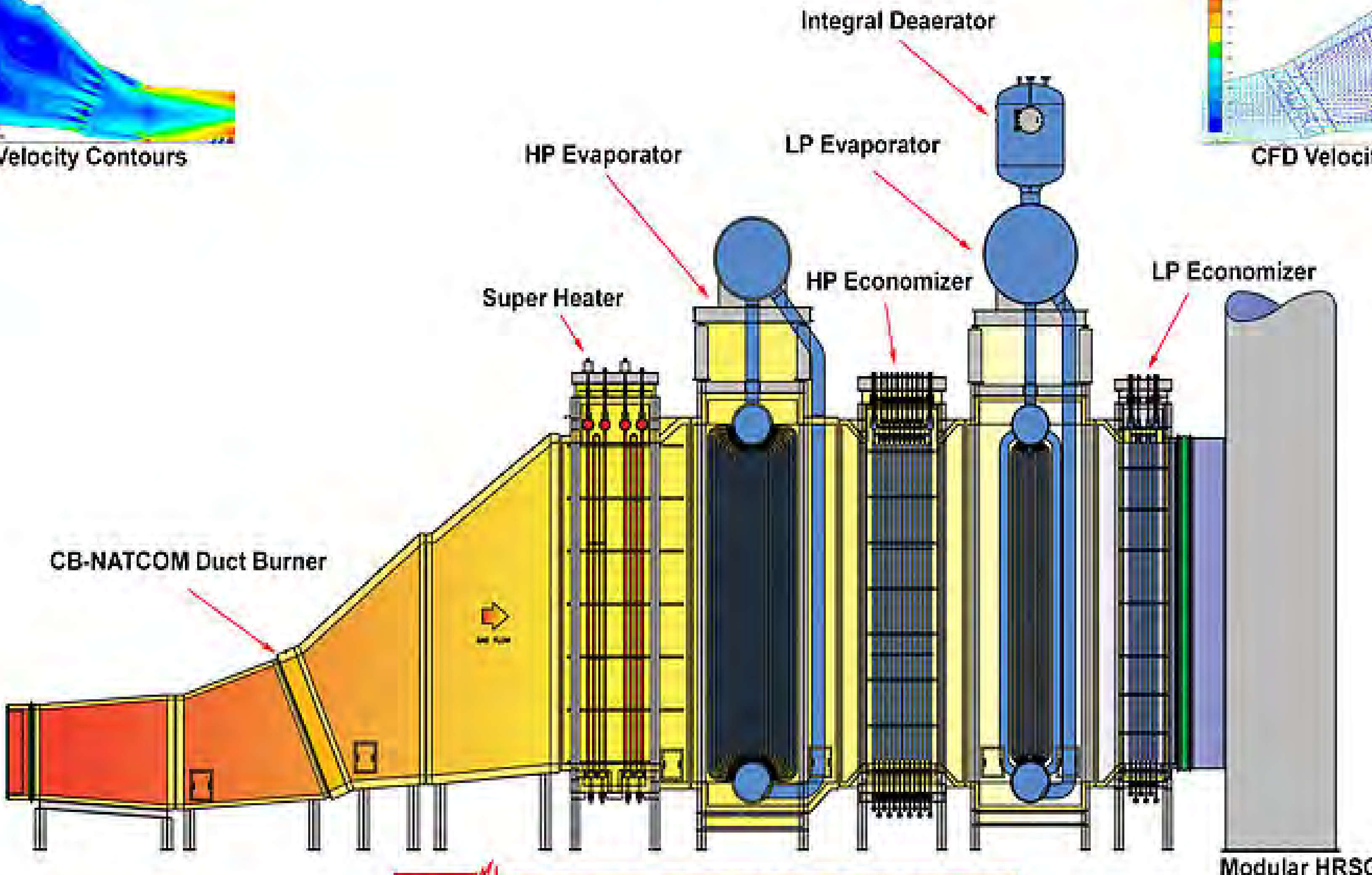
Modular HRSG



CFD Velocity Contours



CFD Velocity Vectors



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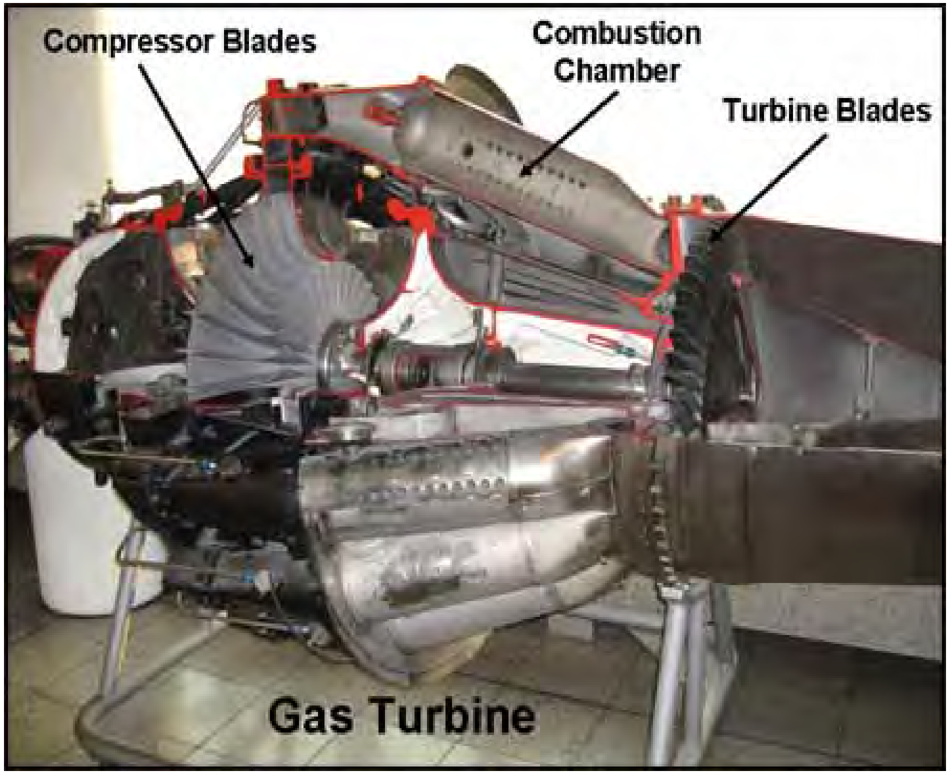
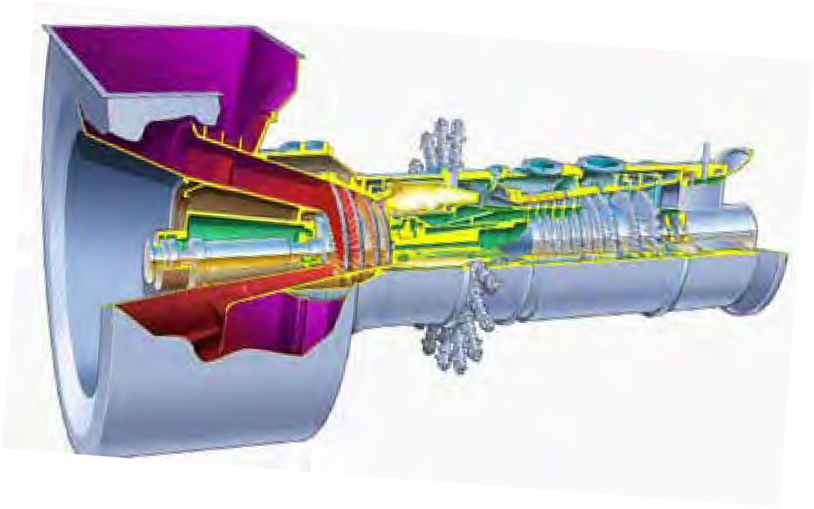
Part I: 1.2 Thermal Power Technologies

Gas Turbine Power Plant and Combine Cycle

- Components of a simple gas power plant
- Air compressor and Combustor
- Brayton cycle and Combine cycle
- Gas turbine

Components of a Simple Gas Power Plant





SGT-600 Industrial Gas Turbine - 25 MW
(former designation, Alstom's GT10)
(Source: Siemens Westinghouse)

The combustion (gas) turbines power plants are basically involved **three main sections**

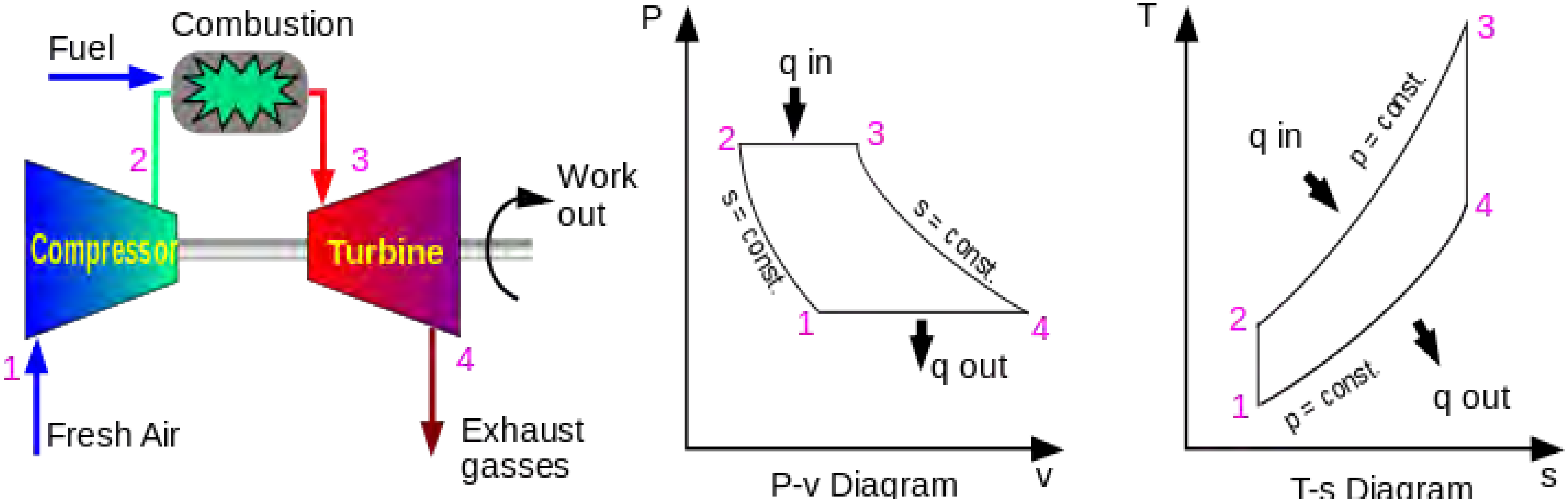
The compressor, which draws air into the engine, pressurizes it, and feeds it to the combustion chamber at speeds of hundreds of miles per hour.

The combustion system, typically made up of a ring of fuel injectors that inject a steady stream of fuel into combustion chambers where it mixes with the air. The mixture is burned at temperatures of more than 2000 degrees F. The combustion produces a high temperature, high pressure gas stream that enters and expands through the turbine section.

The turbine is an intricate array of alternate stationary and rotating aerofoil-section blades. As hot combustion gas expands through the turbine, it spins the rotating blades. The rotating blades perform a dual function: they drive the compressor to draw more pressurized air into the combustion section, and they spin a generator to produce electricity.

Brayton Cycle

A thermodynamic cycle consisting of **two constant-pressure** processes interspersed with two constant-entropy processes. Gas turbine engines and airbreathing jet engines use the Brayton Cycle.



Principle of Brayton Cycle

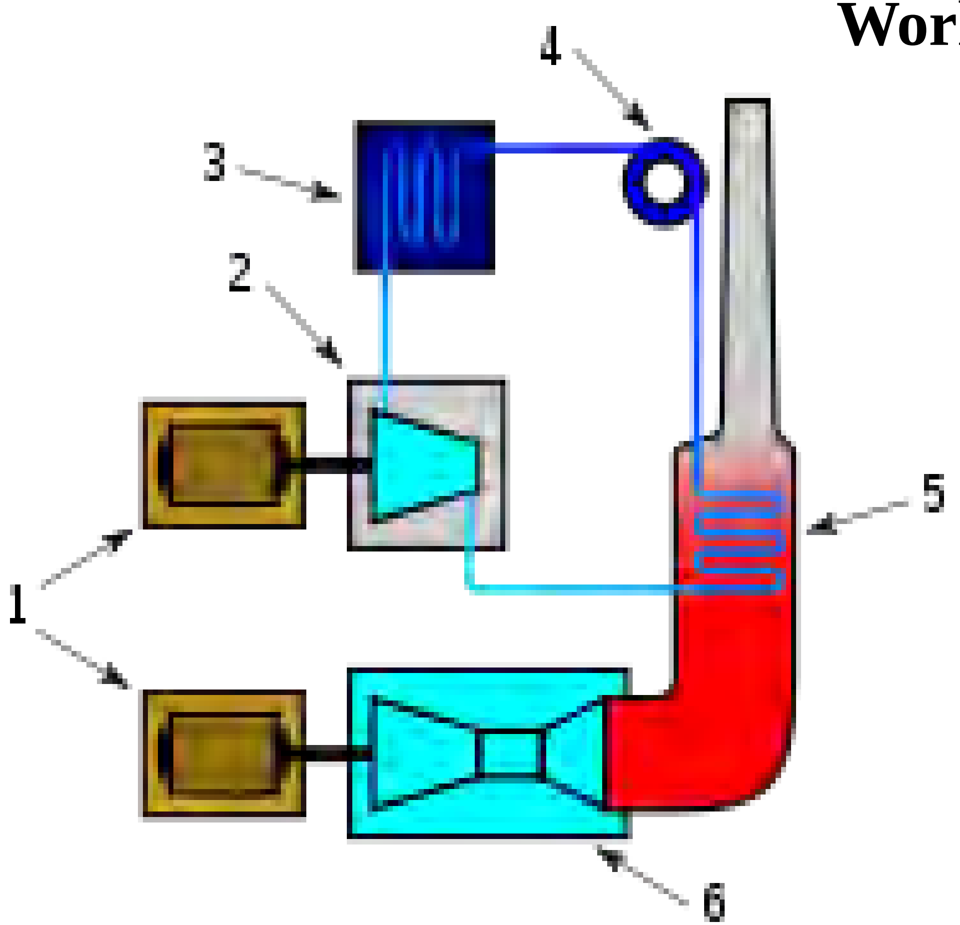
After completing its cycle (in the first engine), the working fluid of the first heat engine is still low enough in its Entropy that a second subsequent heat engine may extract energy from the waste heat (energy) of the working fluid of the first engine.

By combining these multiple streams of work upon a single mechanical shaft turning an electric generator, the overall net efficiency of the system may be increased by 50 – 60 percent. That is, from an overall efficiency of say 34% (in a single cycle) to possibly an overall efficiency of 51% (in a mechanical combination of two (2) cycles) in net Carnot thermodynamic efficiency.

This can be done because heat engines are only able to use a portion of the energy their fuel generates (usually less than 50%). In an ordinary (non combined cycle) heat engine the remaining heat (e.g., hot exhaust fumes) from combustion is generally wasted.

Combined Cycle

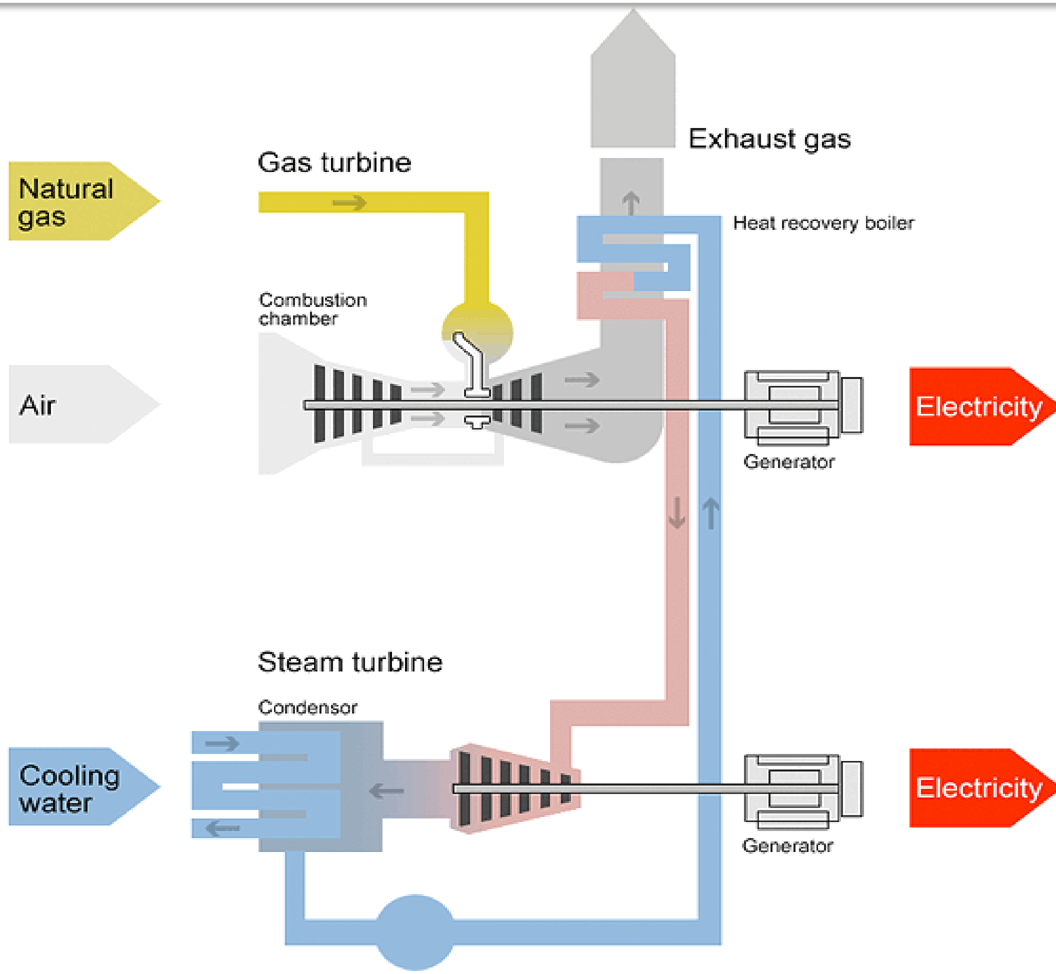
An electric power generating technology which combines the power production of a gas turbine and of a steam turbine



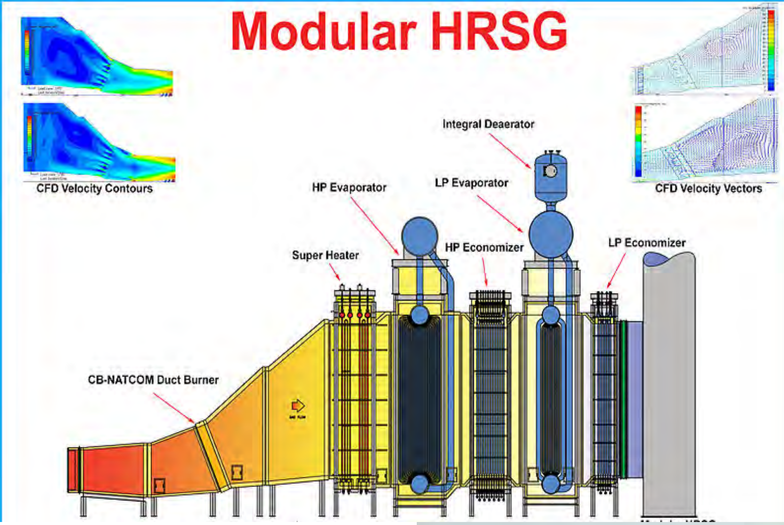
Working principle of a combined cycle power plant

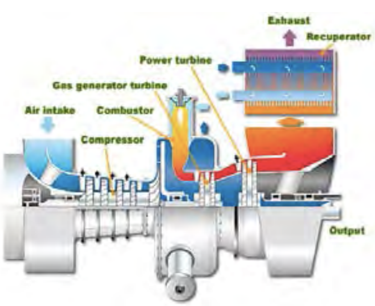
1. Electric generators
2. Steam turbine
3. Condenser
4. Pump,
5. Boiler/heat exchanger
6. Gas turbine

Components of a Combined Cycle



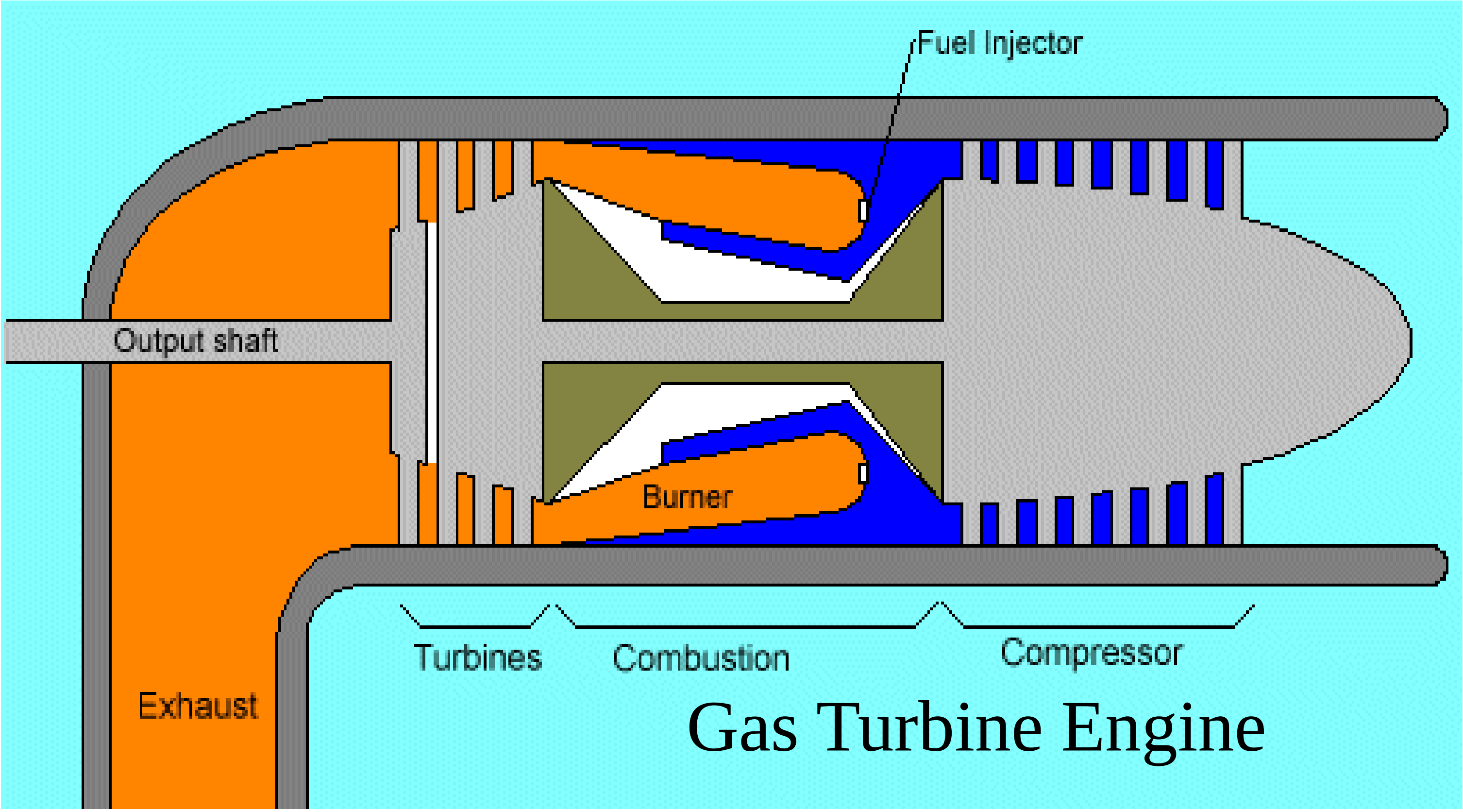
A gas and steam power plant combines the procedures of both a gas turbine and a steam power plant. The hot emissions of a gas turbine are used as a heat source for a downstream water vapor circuit with a steam turbine.


Modular HRSG
CFD Velocity Contours
CFD Velocity Vectors
Integral Deaerator
HP Evaporator
LP Evaporator
Super Heater
HP Economizer
LP Economizer
CB-NATCOM Duct Burner


Exhaust
Recuperator
Power turbine
Gas generator turbine
Air intake
Combustor
Compressor
Output

Gas Turbine

It is a **combustion turbine** and the type of internal combustion engine. It has an upstream rotating compressor coupled to a downstream turbine, and a combustion chamber in-between.



Gas Turbine Engine

A compressor to compress the incoming air to high pressure. A combustion area to burn the fuel and produce high pressure, high velocity gas. A turbine to extract the energy from the high pressure, high velocity gas flowing from the combustion chamber. In this engine, air is sucked in from the right by the compressor. The compressor is basically a cone-shaped cylinder with small fan blades attached in rows. Assuming the light blue represents air at normal air pressure, then as the air is forced through the compression stage its pressure and velocity rise significantly. In some engines the pressure of the air can rise by a factor of 30. The high-pressure air produced by the compressor is shown in dark blue. This high-pressure air then enters the combustion area, where a ring of fuel injectors injects a steady stream of fuel. The fuel is generally kerosene, jet fuel, propane, or natural gas.

Part I: 1.2 Thermal Power Technologies

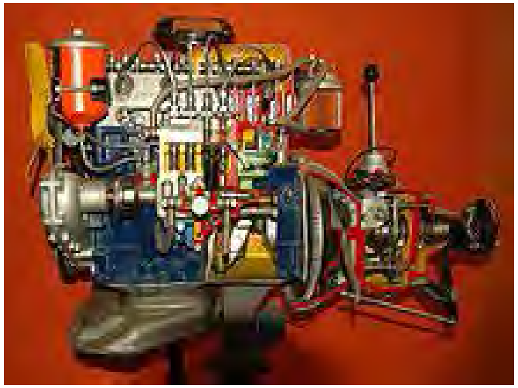
Diesel Engine Power Plant

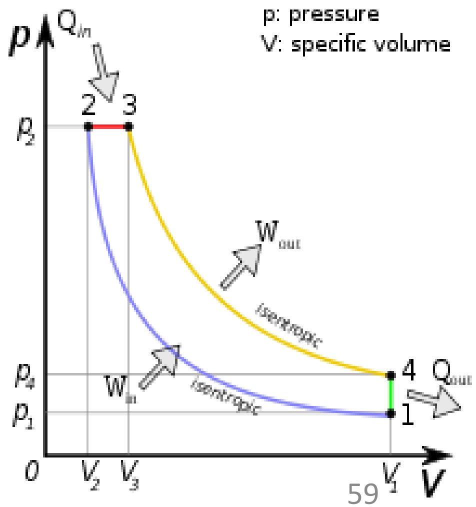
- Components of diesel engine power plant
- Co-generation
- Gasification technology

Diesel engine (compression-ignition engine)

An internal combustion engine that uses the heat of compression to initiate ignition and burn the fuel that has been injected into the combustion chamber

The diesel engine has the highest thermal efficiency of any standard internal or external combustion engine due to its very high compression ratio.





Cogeneration or **combined heat and power (CHP)**

The use of a heat engine or power station to simultaneously generate ***electricity and useful heat***.

Trigeneration or **combined cooling, heat and power (CCHP)**

The simultaneous generation of ***electricity and useful heating and cooling*** from the combustion of a fuel or a solar heat collector.

Cogeneration is a thermodynamically efficient use of fuel. In separate production of electricity, some energy must be discarded as waste heat, but in cogeneration this thermal energy is put to use.

All thermal power plants emit heat during electricity generation, which can be released into the natural environment through cooling towers, flue gas, or by other means.

Small CHP plants are an example of decentralized energy. By-product heat at moderate temperatures (100–180 °C, 212–356 °F) can also be used in absorption refrigerators for cooling.

Conventional electrical generation by a utility central plant is only about ***35% efficient compared to the 90% efficiency*** of a Cogeneration Unit

In Trigeneration, the waste heat is used for both heating and cooling, typically in an absorption refrigerator

CCHP systems can attain ***higher overall efficiencies*** than cogeneration

A cogeneration plant in Metz, France.

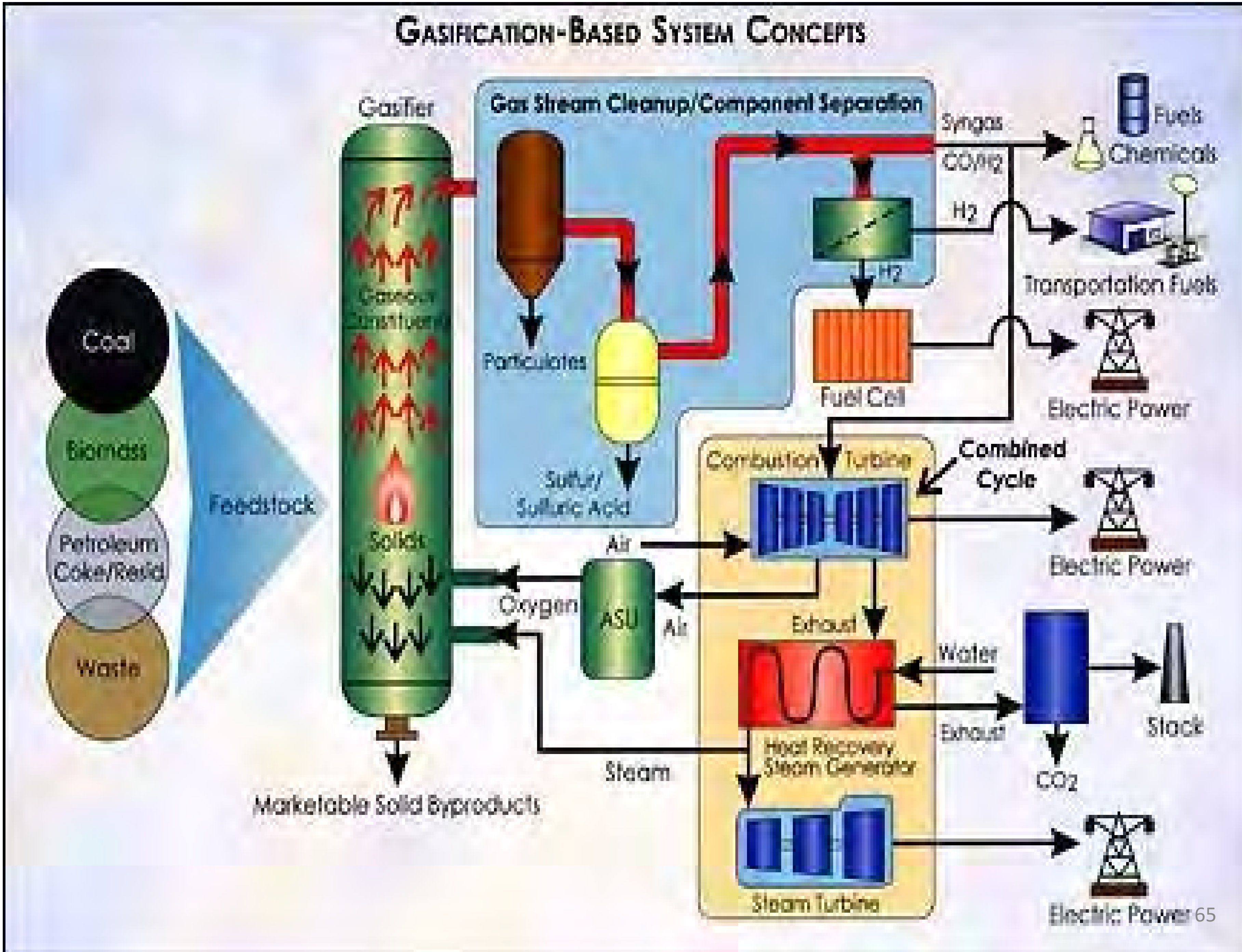
A 250 MW cogeneration plant in Cambridge, Massachusetts

Gasification is a process that converts organic or fossil fuel based carbonaceous materials into carbon monoxide, hydrogen and carbon dioxide.

This is achieved by reacting the material at high temperatures (>700 °C), **without combustion**, with a controlled amount of oxygen and/or steam.

Types of Gasifier

- ✓ **Counter-current fixed bed ("up draft") gasifier**
- ✓ **Co-current fixed bed ("down draft") gasifier**
- ✓ **Fluidized bed reactor**
- ✓ **Entrained flow gasifier**
- ✓ **Plasma gasifier**


GASIFICATION-BASED SYSTEM CONCEPTS
Gasifier
Gas Stream Cleanup/Component Separation
Syngas
CO/H2
Fuels
Chemicals
H2
Transportation Fuels
Particulates
Fuel Cell
Electric Power
Coal
Biomass
Petroleum Coke/Resid
Waste
Feedstock
Gaseous Constituents
Solids
Sulfur/ Sulfuric Acid
Combustion Turbine
Combined Cycle
Air
Oxygen
ASU
Exhaust
Water
Heat Recovery Steam Generator
Steam
Stack
CO2
Marketable Solid Byproducts
Steam Turbine

Gasifier for Rice Husk
(300 kVA at Kyeik Latt, Myanmar)

Part II: 2.1 The effects and sources of exhaust gas emissions

How the gaseous are emitted

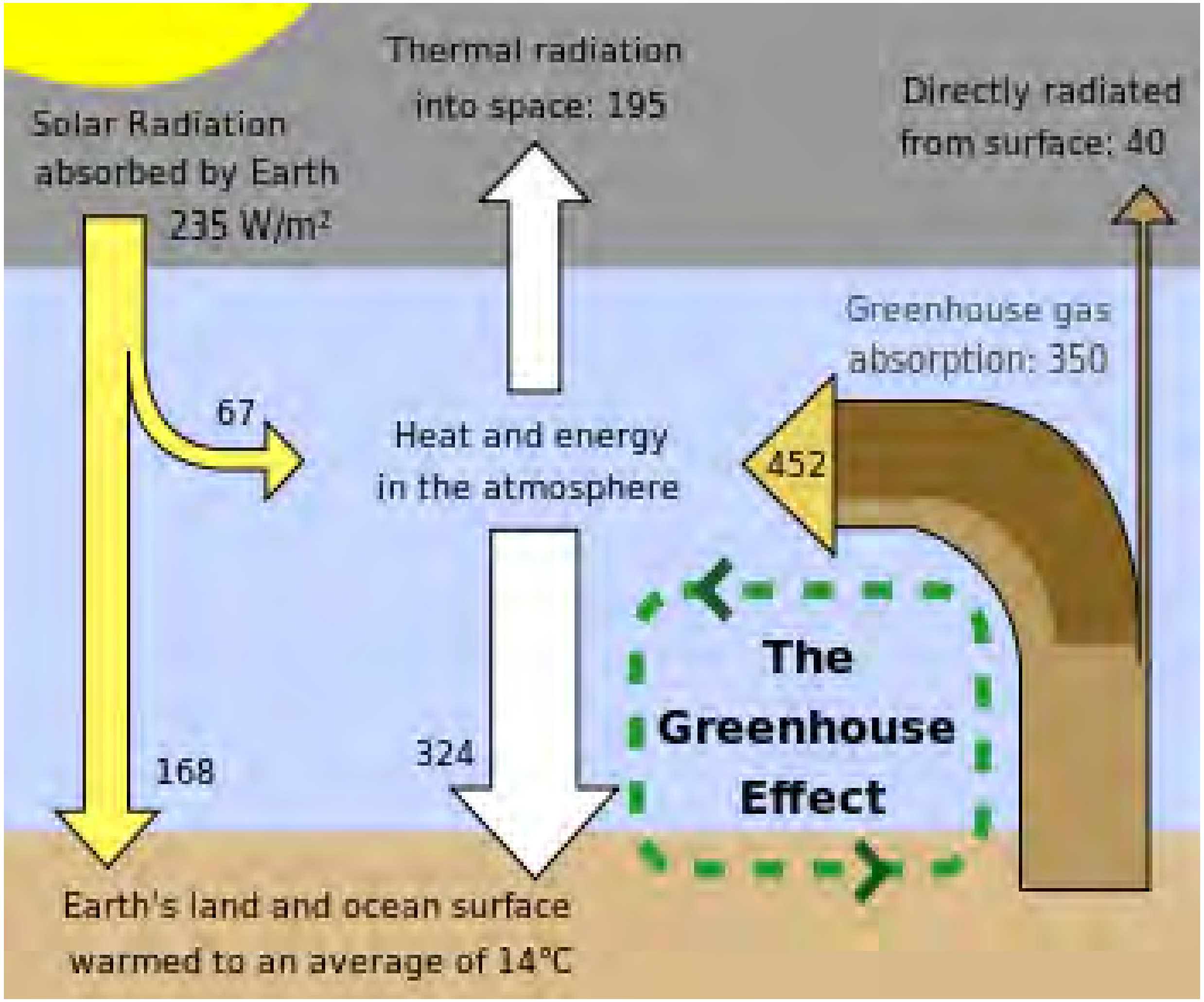
Affection from the gaseous emission to the environment

Amount of gaseous emitted to the environment

Formulas of converted from energy used to gaseous emission

Greenhouse gas (HGG) emits from fossil fuel combustion, clearing of forests, transportation, mobile

CO_2, N_2O, CH_4, black carbon



Exhaust gas (flue gas) is emitted by ***the combustion of fuels:*** natural gas, gasoline/petrol, diesel, fuel oil or coal. It is discharged into the atmosphere through an exhaust pipe, flue gas stack or propelling nozzle

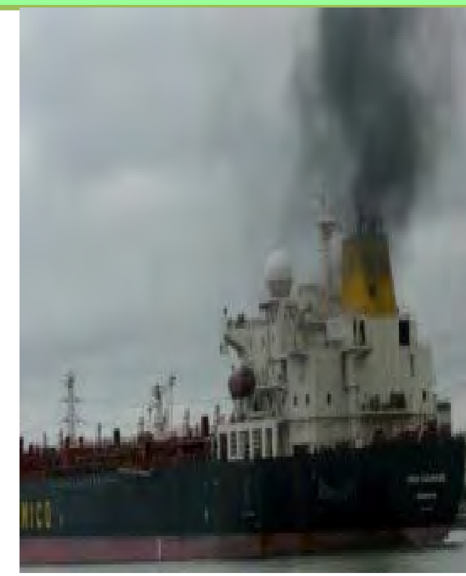
Most combustion gases - N_2, H_2O, CO_2.

A relatively small part of combustion gas-CO from incomplete combustion, hydrocarbons from unburnt fuel, nitrogen oxides (NO_x) from excessive combustion temperatures, O_3, soot.

Steam from tailpipe of cold car

A diesel-powered truck emits an exhaust gas when starting its engine.

Emissions from Industrial Smokestacks



Reducing NOx emission

- Humid Air Method
- Exhaust Gas Re circulation (EGR)
- Water Injection and Water emulsion
- High Scavenge Pressure and Compression Ratio
- Selective Catalytic Reduction
- Two Stage Turbocharger
- Engine Component Modification

Reducing SOx Emission

- Use of Low sulphur fuel oil
- Exhaust Gas Scrubber Technology
- Cylinder Lubrication

NOx damages our environment

NOx is a component in ground-level ozone and smog, and it contributes to acid rain. NOx is also an indirect greenhouse gas that contributes to ***global warming and climate change***. It leads to oxygen depletion in bodies of water, upsets chemical balance to aquatic wildlife, and creates acidic lakes and streams.

NOx causes health problems

NOx damages lung tissue and causes respiratory problems such as asthma, emphysema and bronchitis. NOx is a suspected carcinogenic, and it is known to aggravate existing heart disease.

Greenhouse gas (GHG) conversion factors

To calculate the amount of greenhouse gas emissions caused by energy use.
units (**kg carbon dioxide equivalent, kgCO_2e per unit)**

energy consumed (kWh) → ***multiplied by a conversion factor*** → kg of carbon dioxide equivalent per unit

Conversion factors example

To convert from 200 litres of petrol to kgCO_2e emissions?

200 litres petrol = 200 x **2.3144** = 462.88 kgCO_2e per unit

Converting fuel types by unit volume				CO_2	CH_4	N_2O	Total Direct GHG
Fuel Type	Amount used per year	Units	x	kg CO_2 per unit	kg CO_2e per unit	kg CO_2e per unit	kg CO_2e per unit
Aviation Spirit		litres	x	2.2205	0.0202	0.0220	2.2626
Aviation Turbine Fuel [1]		litres	x	2.5258	0.0013	0.0249	2.5519
Biofuels				See Annex 9			
Burning Oil[1]		litres	x	2.5319	0.0055	0.0069	2.5443
CNG [2]		litres	x	0.4758	0.0007	0.0003	0.4768
Diesel (average biofuel blend)[11,12]		litres	x	2.5636	0.0009	0.0190	2.5835
Diesel (100% mineral diesel)[14]		litres	x	2.6569	0.0009	0.0191	2.6769
Gas Oil [7]		litres	x	2.7595	0.0030	0.2587	3.0213
LNG [8]		litres	x	1.2302	0.0018	0.0007	1.2328
LPG		litres	x	1.5301	0.0007	0.0018	1.5326
Natural Gas		cubic metre	x	2.0280	0.0030	0.0012	2.0322
Petrol (average biofuel blend)[11,13]		litres	x	2.2332	0.0033	0.0058	2.2423
Petrol (100% mineral petrol)[14]		litres	x	2.3051	0.0033	0.0059	2.3144

Table 2: Source Emission Factors – Stationary Fuel Combustion[21]

Fuel Type	Units	Bio CO_2	CO_2	CH_4	N_2O	CO_2e
Natural Gas	kg/ m³	–	1.916	0.000037	0.000035	1.928
Propane	kg/ L	–	1.507	0.000024	0.000108	1.541
Acetylene	kg/m³	–	3.719	*	*	3.719
Light Fuel Oil	kg/ L	0.0980	2.616	0.000026	0.000031	2.626
Kerosene	kg/ L	–	2.534	0.000026	0.000031	2.544
Diesel Fuel	kg/ L	0.0980	2.557	0.000133	0.0004	2.684
Marine Diesel	Kg/L	0.0980	2.557	0.00015	0.0011	2.901
Gasoline	kg/ L	0.0747	2.175	0.0027	0.00005	2.247
Wood Fuel – Industrial (50% moisture)	kg/ kg	0.840	–	0.00009	0.00006	0.020
Wood Fuel - Residential	kg/ kg	1.696	–	0.015	0.00016	0.365
Ethanol (E100)	Kg/L	1.494	–	a	a	a
Biodiesel (B100)	Kg/L	2.449	–	b	b	b
Biomethane	Kg/m3	1.547	–	c	c	c

[a] Gasoline CH4 and N2O emission factors (by mode and technology) are used for ethanol.

[b] Diesel CH4 and N2O emission factors (by mode and technology) are used for biodiesel.

[c] Natural Gas CH4 and N2O emission factors (by mode and technology) are used for biomethane.

* Note: Literature on CH4 and N20 emissions from Acetylene could not be obtained.

Component	Emission Rate	Annual pollution emitted
Hydrocarbons	2.80 grams/mile (1.75 g/Km)	77.1 pounds (35.0 kg)
Carbon monoxide	20.9 grams/mile (13.06 g/Km)	575 pounds (261 kg)
NO_x	1.39 grams/mile (0.87 g/Km)	38.2 pounds (17.3 kg)
Carbon dioxide - greenhouse gas	0.916 pounds per mile (258 g/km)	11,450 pounds (5,190 kg)

United States from 2004-2007

Global emissions of greenhouse gases jumped 2.3 percent in 2013 to record levels

China's **carbon emissions** were set to rise **4.5 percent this year to 10.4 billion tonnes**, far more than U.S. emissions on **5.2 billion** and the **EU's 3.4 billion**. U.S. emissions would dip 0.9 percent in 2014 and EU emissions would be down 1.1 percent.

Emissions of carbon dioxide ***from burning fossil fuels and cement production*** will climb by 2.5 percent to a new record 37.0 billion tonnes in 2014, .


Grid Energy Storage
Distributed Generation
Switches &
Power Electronics
Distributed Generation
Monitoring,
Communications
& Control (MC²)
Energy Storage
Biopower Generation
Microturbine
Electric Vehicles (EV)
Fuel Cells
Distributed Generation
Home Energy System
Distributed Generation

Part II: 2.2 Gaseous Emission Reduction Technologies (for CO_2, SO_2, Nox)

CO_2 capture and storage (CCS)

CO_2 recycling / Carbon Capture and Utilization (CCU)

Circulating fluidized bed (CFB)

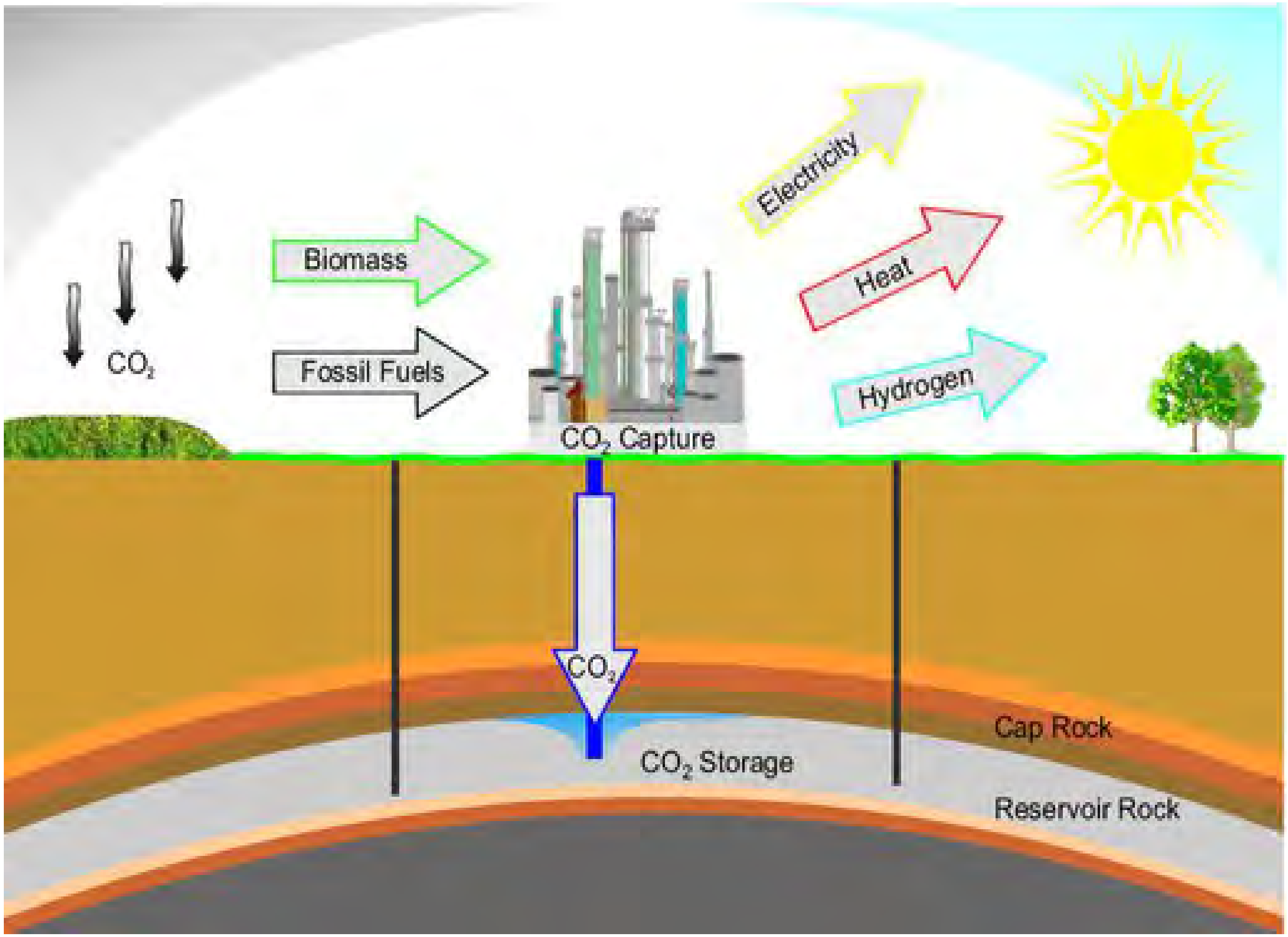
Carbon Capture and Storage (CCS)

The process of **capturing** waste CO_2 from fossil fuel power plants, transporting it to a storage site, and depositing it where it will not enter the atmosphere, normally an underground geological formation.

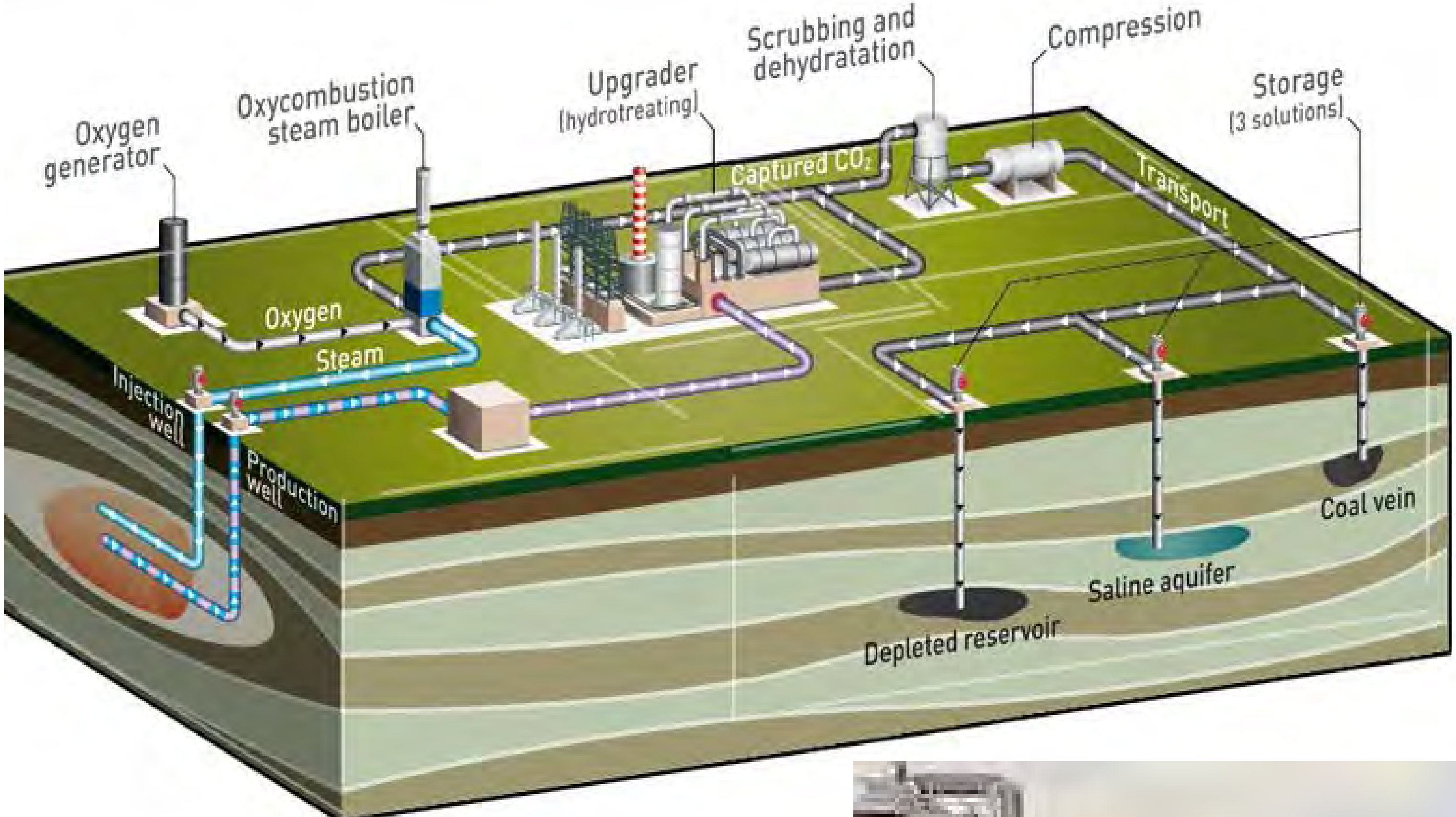
Various forms have been conceived for permanent storage of CO_2.

Geological storage
Ocean storage
Mineral storage

Principles behind carbon capturing and storage

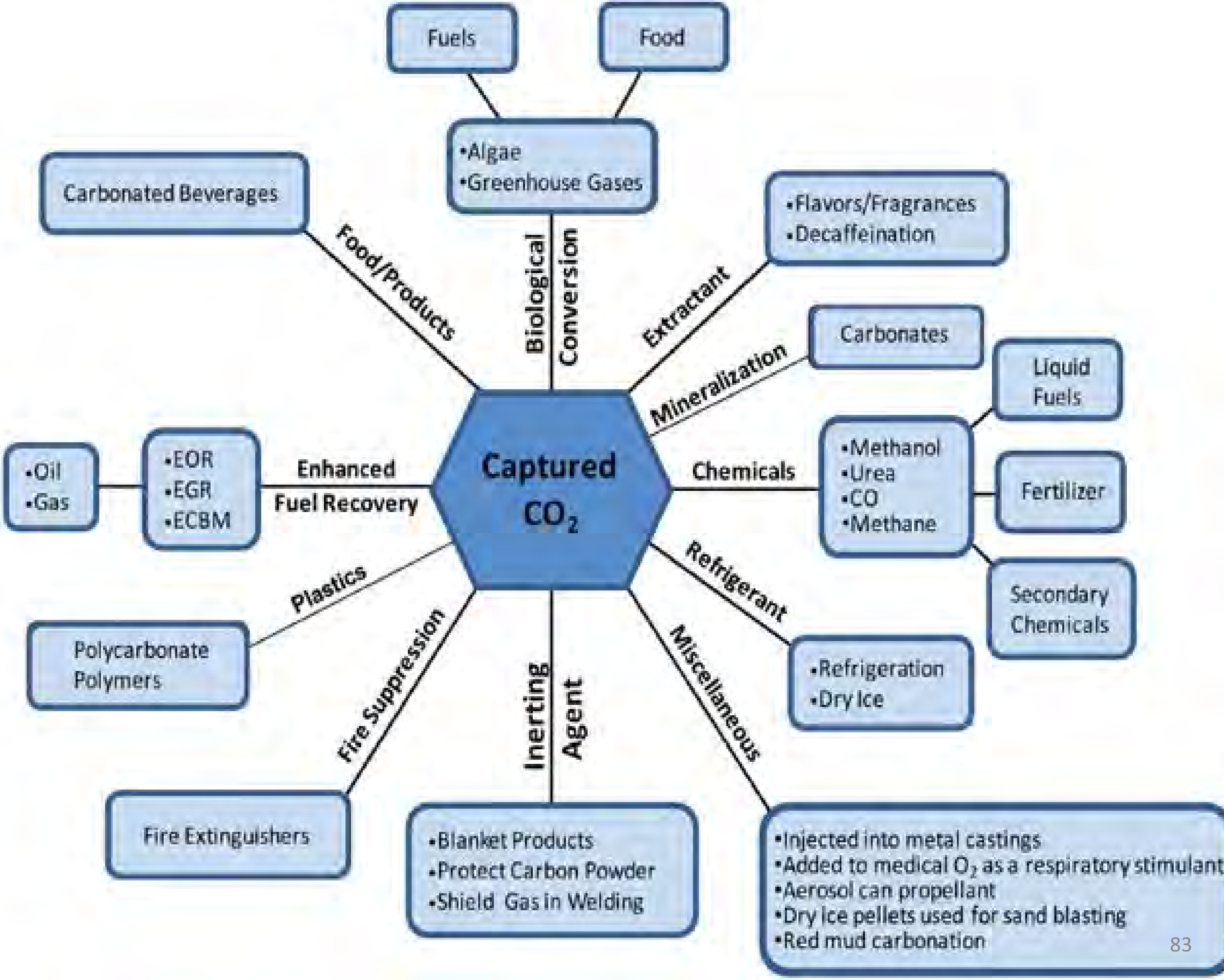


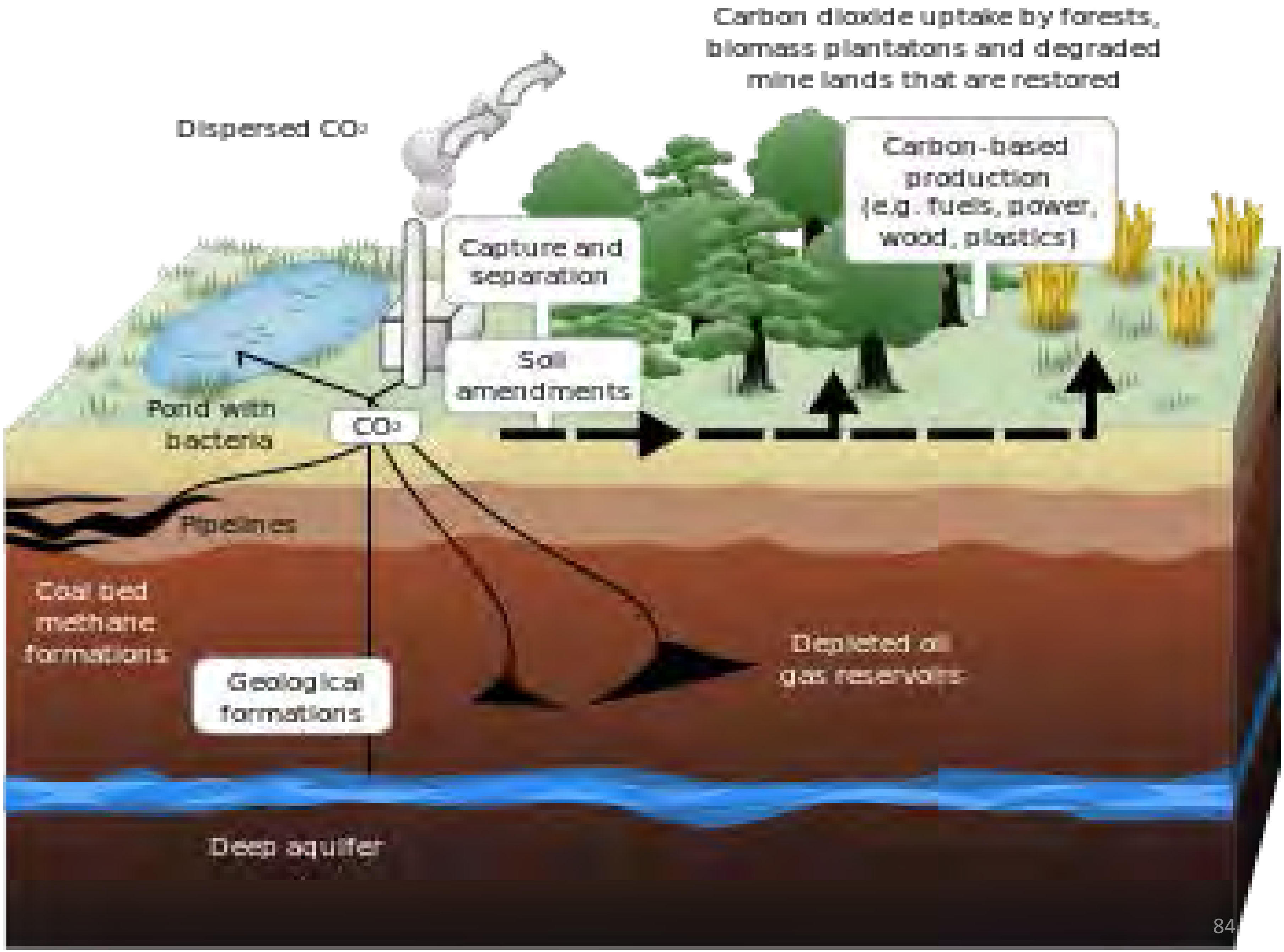
Carbon capture and storage encompasses a range of technologies that may cut CO_2 emissions by up to 90%


Oxygen generator
Oxycombustion steam boiler
Upgrader (hydrotreating)
Scrubbing and dehydratation
Compression
Storage (3 solutions)
Captured CO_2
Transport
Oxygen
Steam
Injection well
Production well
Coal vein
Saline aquifer
Depleted reservoir

Carbon Dioxide Recycling / Carbon Capture and Utilization (CCU)

Recycling CO_2 is usually considered a different technological category from CCS. The CO_2 and other captured greenhouse gases are injected into the membranes containing waste water and select strains of algae causing, together with sunlight or UV light, an oil rich biomass that doubles in mass every 24 hours


Fuels
Food
•Algae
•Greenhouse Gases
Carbonated Beverages
Food/Products
Biological Conversion
Extractant
•Flavors/Fragrances
•Decaffeination
Carbonates
Mineralization
Liquid Fuels
Captured CO_2
•Oil
•Gas
•EOR
•EGR
•ECBM
Enhanced Fuel Recovery
Chemicals
•Methanol
•Urea
•CO
•Methane
Fertilizer
Secondary Chemicals
Plastics
Refrigerant
Polycarbonate Polymers
Fire Suppression
Inerting Agent
Miscellaneous
•Refrigeration
•Dry Ice
Fire Extinguishers
•Blanket Products
•Protect Carbon Powder
•Shield Gas in Welding
•Injected into metal castings
•Added to medical O_2 as a respiratory stimulant
•Aerosol can propellant
•Dry ice pellets used for sand blasting
•Red mud carbonation


Carbon dioxide uptake by forests, biomass plantatons and degraded mine lands that are restored
Dispersed CO_2
Carbon-based production (e.g. fuels, power, wood, plastics)
Capture and separation
Soil amendments
Pond with bacteria
CO_2
Pipelines
Coal bed methane formations
Geological formations
Depleted oil gas reservoirs
Deep aquifer

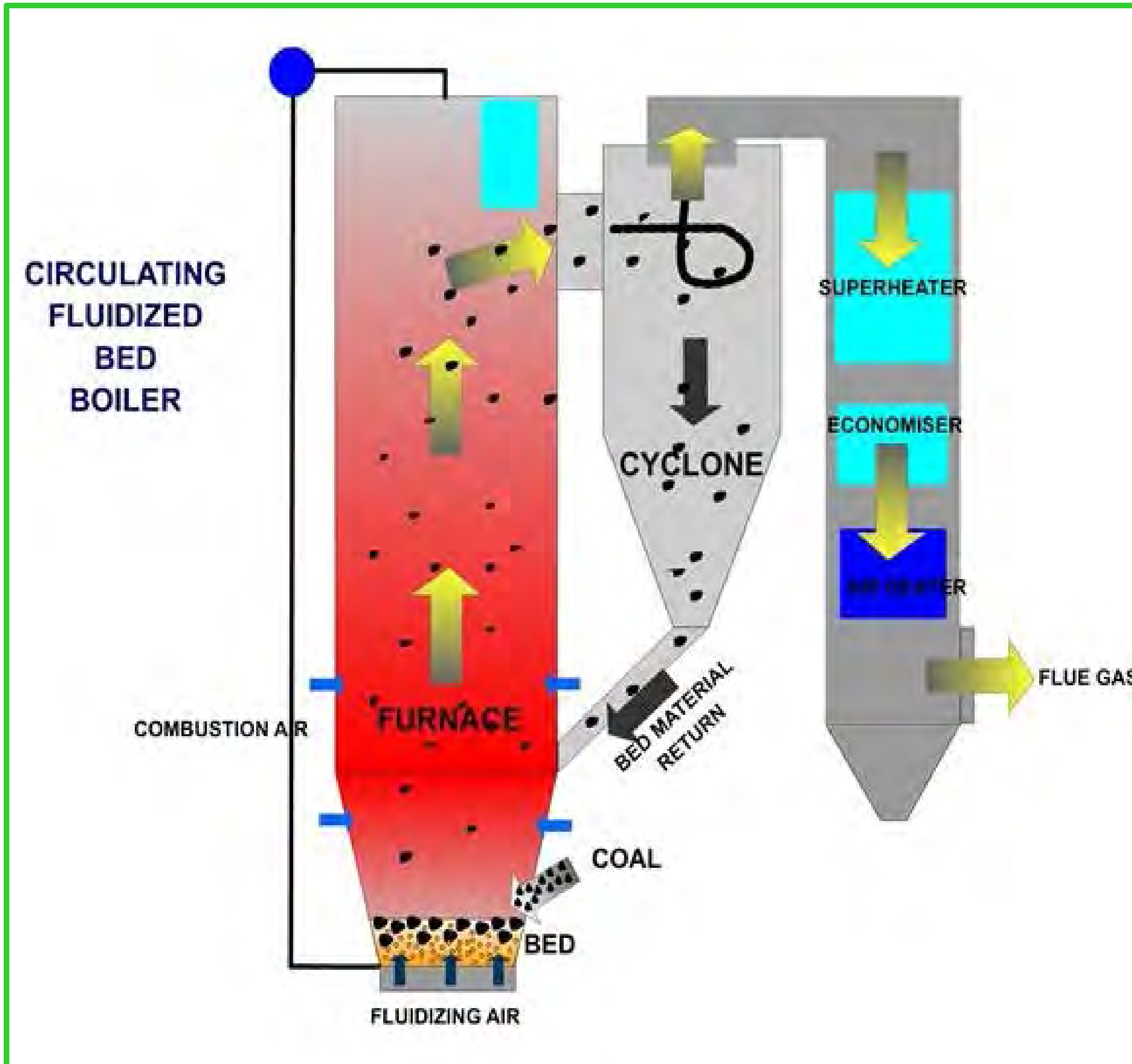
Circulating Fluidized Bed (CFB)

A clean process to achieve lower emission of pollutants. 95% of pollutants will be absorbed before being emitted to the atmosphere. It is a highly efficient cleaning technology for coal combustion.

Range of Applications

- ✓ **oil and gas to power stations**
- ✓ **circulating fluidized bed scrubber**
- ✓ **circulating fluidized bed gasification system**

Circulating Fluidized Bed Gasification System



•Fluidized Bed

At the bottom of the boiler furnace there is a bed of inert material. Bed is where the coal or fuel spreads. Air supply is from under the bed at high pressure. This lifts the bed material and the coal particles and keeps it in suspension. The coal combustion takes place in this suspended condition. This is the Fluidized bed.

Special design of the air nozzles at the bottom of the bed allows air flow without clogging. Primary air fans provide the preheated Fluidizing air. Secondary air fans provide pre-heated Combustion air. Nozzles in the furnace walls at various levels distribute the Combustion air in the furnace.

•Circulation

Fine particles of partly burned coal, ash and bed material are carried along with the flue gases to the upper areas of the furnace and then into a cyclone. In the cyclone the heavier particles separate from the gas and falls to the hopper of the cyclone. This returns to the furnace for recirculation. Hence the name Circulating Fluidized Bed combustion. The hot gases from the cyclone pass to the heat transfer surfaces and go out of the boiler.

- In the gasification process, fuel will be gasified at 850 ^{o}C in the presence of steam to produce a nitrogen-free clean synthetic gas.
- Charcoal will be burnt in air in the combustion chamber to provide the heating for the gasification process as it is an endothermic process.
- Thermal transfer will take place between the gasification and combustion chamber.

Gasification	$C + H_2O = CO + H_2$ $C + CO_2 = 2CO$
Combustion	$C + O_2 = CO$

Road Map of Energy Technology in Myanmar

Current Energy Technologies in Myanmar

- Hydro
- Gas
- Coal
- Diesel
- Biomass

Other Energy Sources

- Solar
- Steam
- Wind
- Nuclear

I. Literature Review

II. Mechanism of Energy Technology

III. Utilization of Energy

IV. Awareness

Knowledge Sharing
Research
Seminar and
Workshop

Inter-and-Multi disciplinary Collaboration

Course and Curriculum of Energy Technology

Advantages of Energy Technology

1.For country

Extending and upgrading the existing energy technology

2. For Education

Offering the special courses and new specializations

3. For Engineering

Providing engineers and scientists who have the same expertise as those in ASEAN countries

4. For Research

Research on semiconductor materials and on industrial development

Problems and challenges

- Fossil fuel resources are depleting rapidly
- Fossil fuel combustion emits more CO2, SO2, NOx , PM than renewable sources
- Gaseous fuels are the best one, very suitable to be utilized for multi-purposes
- Solid fuels are the worst one because they burn hardly and slowly
- Liquid fuels are appropriately used as transportation fuels.
- Do not use high sulfur and low heat capacity coal

Conclusions

The Myanmar has implemented the energy technology to generate electricity through sources of hydro, gas and coal power.

Myanmar initiates the solar, wind, biomass, geothermal technologies.

The goal of Theme 3 will be effective to the understating of the students both of the existing and state of the art of energy technologies.

The challenges are lack of technical capacity, regulatory energy policy, insufficient investment and weak awareness of new technology.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