Unit 1:- Energy Scenario Introduction

Syllabus…Unit 1

- Introduction: Classification of energy, domestic and global energy scenario, environmental impacts of fossil fuels, global primary energy reserves, energy consumption, energy sources and utilization, forms and characteristics of renewable. Work power energy types, their equations and conversions from one form to another.

Books

1. Gilbert M. Masters, *Renewable and Efficient Electrical Power Systems*, Wiley – IEEE Press, August 2004.
2. Godfrey Boyle, *Renewable Energy*, Third edition, Oxford University Press, 2012.
3. Chetan Singh Solanki, *Solar Photovoltaics-Fundamentals, Technologies and Applications*, PHI Third Edition, 2015.

Supplementary Reading:

- D.P.Kothari, K.C.Singal, Rakesh Rajan, *Renewable Energy Sources and Emerging Technologies*, PHI Second Edition, 2011.

Lecture 1

- Introduction
- Primary Energy & Secondary Energy
- Commercial energy & Non- commercial energy
- Renewable & Non Renewable Energy
- Global Primary Energy Reserves
- Coal
- How Coal Formed
- Coal statistics
- Oil
- Oil formation
- Oil statistics

Introduction

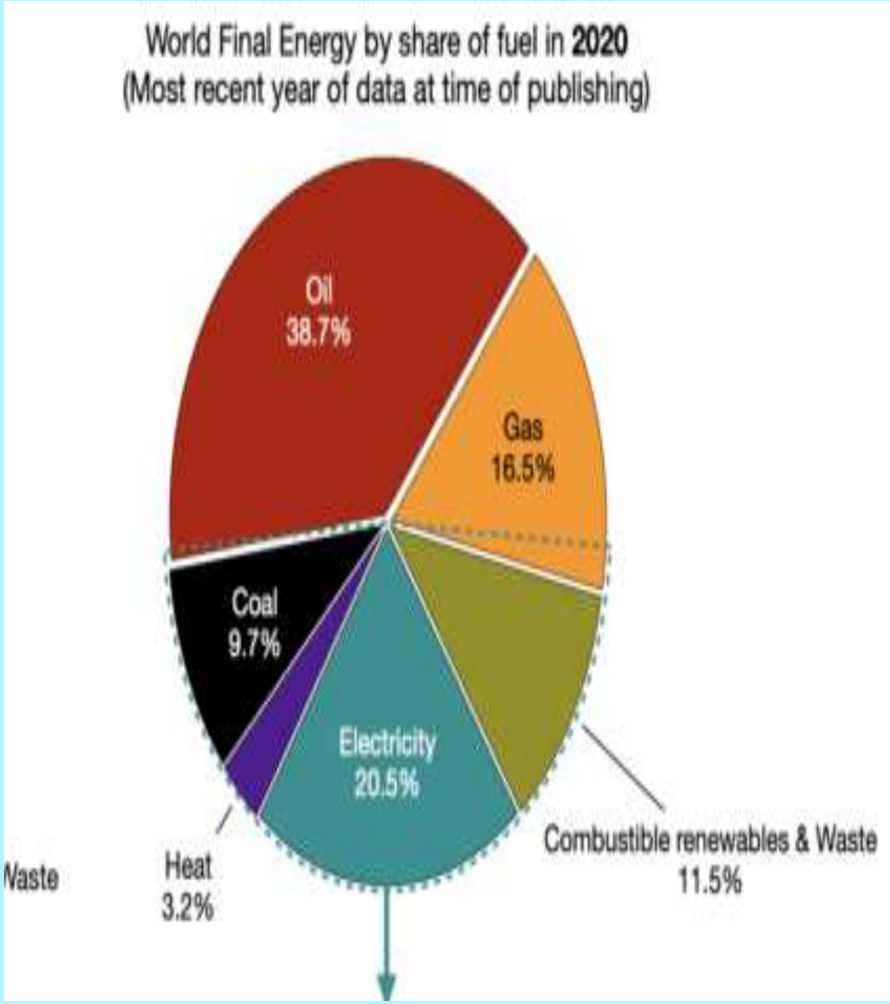
Energy is one of the major inputs for the economic development of any country. In the case of the developing countries, the energy sector assumes critical importance in view of the ever-increasing energy needs, requiring huge investments to meet them.

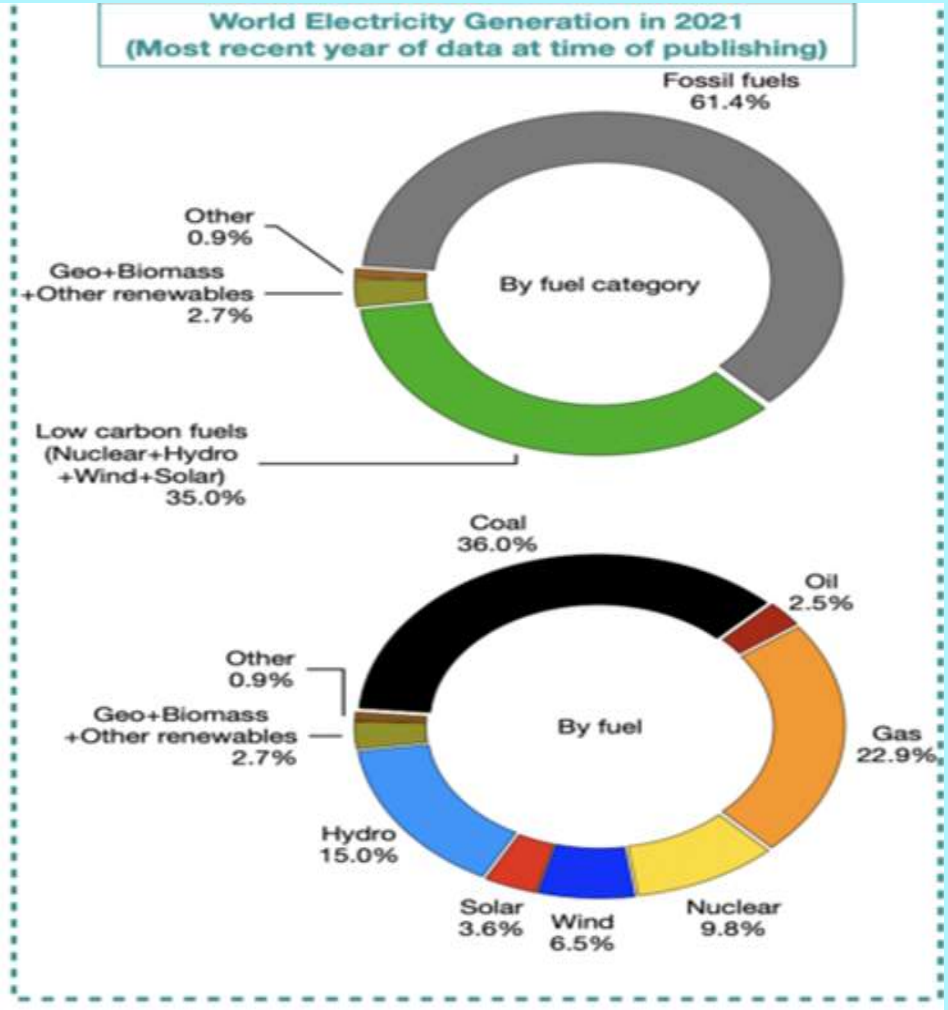
The consumption of energy is increasing at a fast pace while available resources remain limited. The global need for energy is increasing on an average by about 2.4% every year. Out of the total amount of primary energy, over 85% comes from fossil fuels. The current consumption of fossil fuels, particularly oil, is not sustainable in the long term.

Energy, that we use, can be classified into several types based on the following criteria:

- Primary energy and secondary energy
- Commercial and non commercial energy
- Renewable and non-renewable energy

Introduction





Primary Energy & Secondary Energy…

- **Primary Energy Resources:** The fossil fuels(oil, gas, and coal), nuclear energy, falling water, geothermal, and solar energy.

- **Secondary Energy Resources**: Those sources which are derived from primary resources such as electricity, fuels from coal, (synthetic natural gas and synthetic gasoline), as well as alcohol fuels.

Primary Energy & Secondary Energy…

Primary energy can be further divided into two distinctive groups:

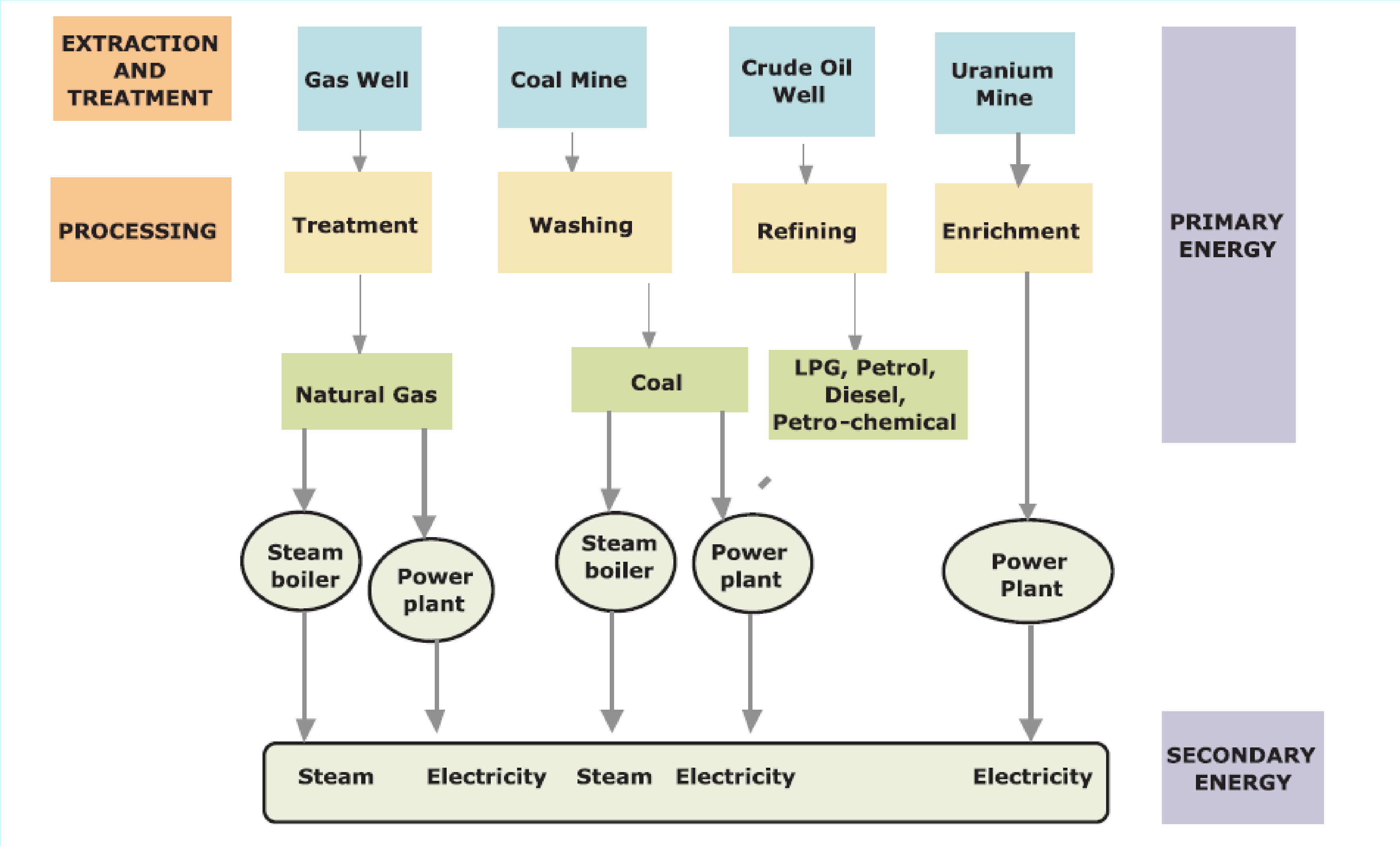
- Renewable (solar, wind, geothermal, tidal, biomass, hydel etc.)
- Non-renewable (fossil fuels: crude oil and its products, coal, natural gas, nuclear, etc.)

The primary energy content of all fuels is generally expressed in terms of toe (tonne of oil equivalent) and is based the following conversion factor.

One tonne of oil equivalent (toe) = 1 x 10^7 kcal = 11630 kWh = 41868 MJ

Primary energy sources are mostly converted in industrial utilities into secondary energy sources; for example coal, oil or gas converted into steam and electricity. Primary energy can also be used directly. Some energy sources have non-energy uses, for example coal or natural gas can be used as a feedstock in fertiliser plants. Primary energy is transformed in energy conversion process to more convenient forms of energy such as electricity, steam etc. These forms of energy are called secondary

Primary Energy & Secondary Energy…



Commercial & Non- commercial energy…

Commercial & Non- commercial energy…

Commercial Energy

- These are coal, petroleum and electricity. These are called commercial energy because they have a price and consumer has to pay the price to purchase them.

Commercial & Non- commercial energy…

Non-Commercial Energy

- These sources include fuel wood and dried dung. These are commonly used in rural India. According to an estimate, the total availability of fuel wood in India was only 50 million tonnes a year. It is less than 50% of the total requirements. In coming years, there would be shortage of fire wood.
- Agricultural wastes like straw are used as fuel for cooking purposes. According to one estimate agricultural waste used for fuel might be 65 million tonnes. Animal dung when dried is also used for cooking purposes. Total animal dung production is 324 million tonnes out of which 73 million tonnes are used as fuel for cooking purposes. The straw and dung can be used as valuable organic manure for increasing fertility of soil and in turn productivity.

Renewable & Non renewable energy…

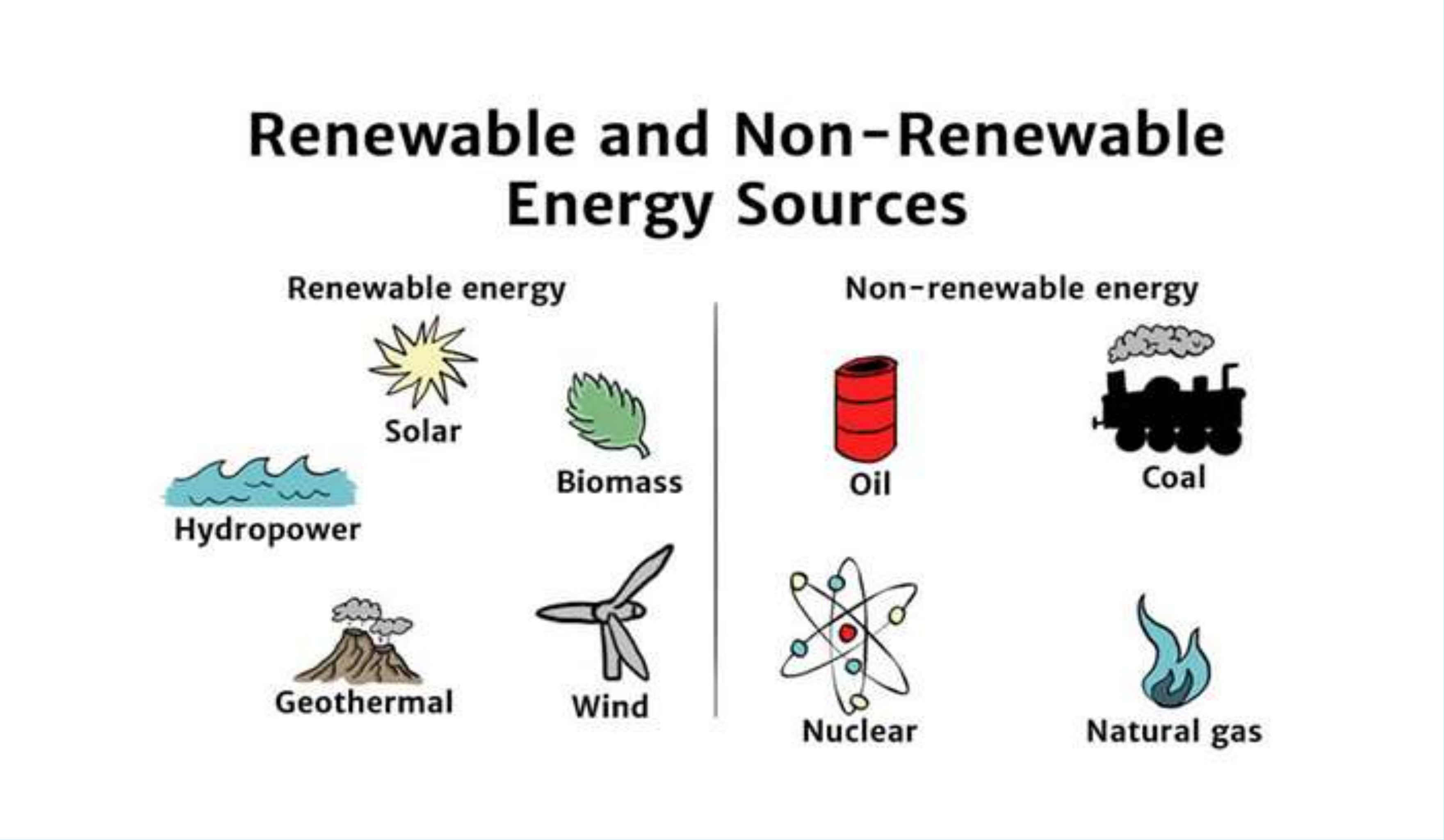
renewable resources

1) the resources that can be renewed by reproduction are called renewable resources.
2) Renewable resources are inexhaustible.
3) Renewable resources are not affected by the human activities.
4) All biotic resources are renewable.
5) For example: air and water.

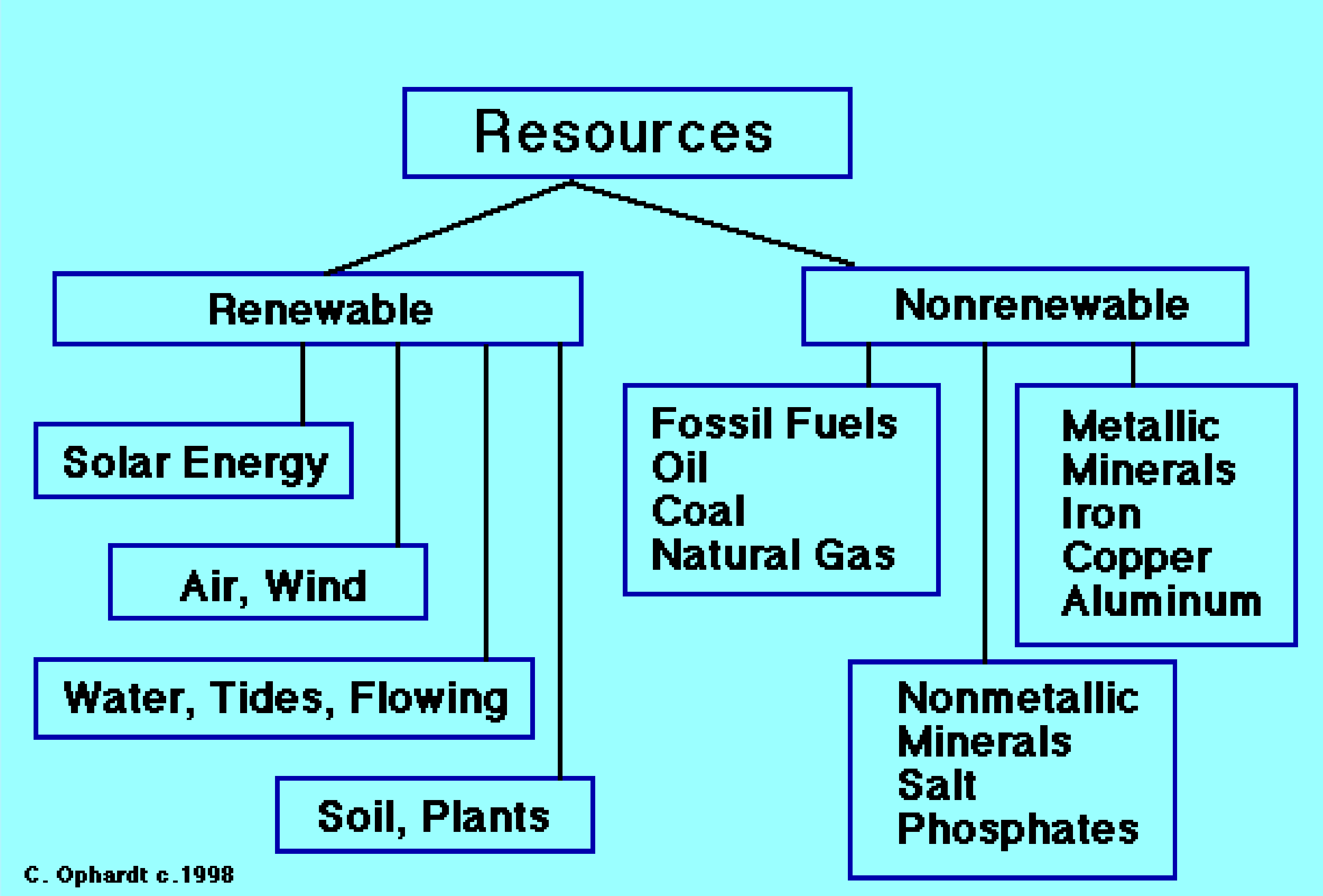
Renewable & Non renewable energy…

non-renewable resources
1)the resources that are present in fixed quantities are called non-renewable resources.
2) Non-renewable resources are inexhaustible.
3) Non renewable resources are affected by human activities.
4) Some abiotic resources are non-renewable.
5) For example- fossil fuels and minerals.
Renewable resources are resources that can be produced naturally and nonrenewable resources are resources

Renewable & Non renewable energy…



Renewable & Non renewable energy…

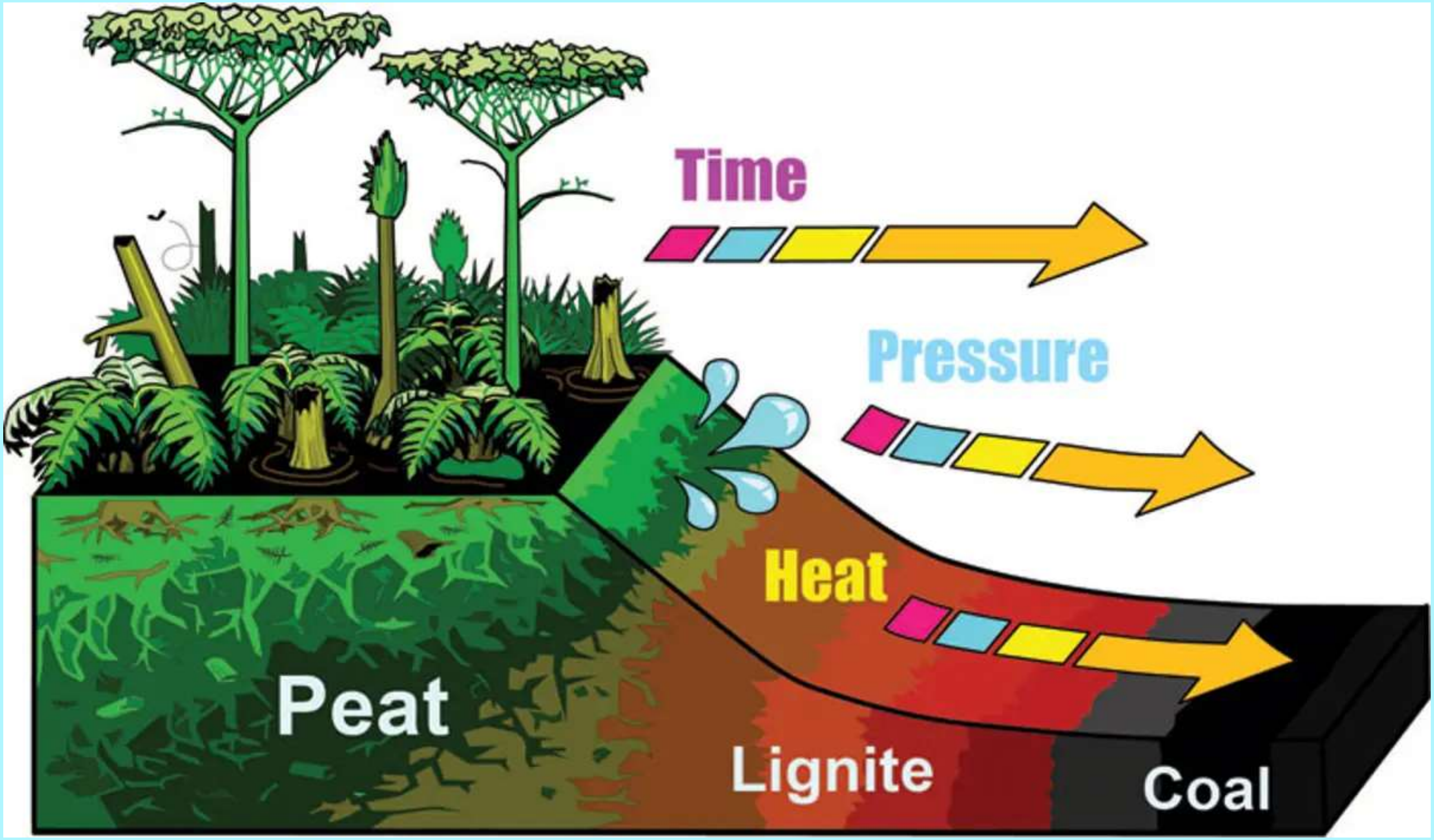


Global Primary Energy Reserves …

Coal

Coal is classified into four main types, or ranks: anthracite, bituminous, subbituminous, and lignite. The ranking depends on the types and amounts of carbon the coal contains and on the amount of heat energy the coal can produce.

How coal formed?…



Coal Reserves & Production…

Reserves/Production (R/P) - If the reserves remaining at the end of the year are divided by the production in that year, the result is the length of time that the remaining reserves would last if production were to continue at that level.

Table 1.1 Proven Coal Reserves by Country by end of 2013

Country	Million tonnes	Share of total, %	Reserve / Production (R/P in years)
US	237295	26.6	266
Russian Federation	157010	17.6	452
China	114500	12.8	31
Australia	76400	8.6	160
India	60600	6.8	100
Others	245726	27.6	
World	**891531**	100	**113**

Source: BP Statistical Review of World Energy June 2014

Coal Reserves & Production…

Countries by coal reserve JULY 2020							
Rank	Country	Anthracite & bituminous		Subbituminous & lignite		Total	
		Tonnes (mil)	%	Tonnes (mil)	%	Tonnes (mil)	%
1	United States	**220,167**	**30%**	**30,052**	**9.4%**	**250,219**	**24%**
2	Russia	**69,634**	**9.5%**	**90,730**	**28.4%**	**160,364**	**15%**
3	Australia	**70,927**	**9.7%**	**76,508**	**23.9%**	**147,435**	**14%**
4	China	**130,851**	**17.8%**	**7,968**	**2.5%**	**138,819**	**13%**
5	India	**96,468**	**13.1%**	**4,895**	**1.5%**	**101,363**	**10%**
6	Indonesia	**26,122**	**3.6%**	**10,878**	**3.4%**	**37,000**	**4%**
7	Germany	**3**	**0%**	**36,100**	**11.3%**	**36,103**	**3%**
8	Ukraine	**32,039**	**4.4%**	**2,336**	**0.7%**	**34,375**	**3%**

Coal Reserves & Production…

Table 1.2 Top Coal Producers in Million Tonnes (by end of 2013)		
Country	**Million tonnes**	**Share of total, %**
China	3680.0	47.4
US	892.6	12.9
Indonesia	421.0	6.7
Russian Federation	374.1	4.3
India	605.1	5.9
South Africa	256.7	3.7
Others	1666.9	19.1
World	**7896.4**	100

Source: BP Statistical Review of World Energy June 2014

Oil …

The global proven oil (crude oil) reserve was estimated to be 1687.9 billion barrels by the end of 2013. Almost, 48 % of the proven oil reserves are in the Middle East. Saudi Arabia has the largest share of the reserve with 15.8%. Top proven world oil reserves (in billion barrels) are given in Table 1.3.

Oil 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 the layers of sand,silt and rock to reach the rock formations that contain oil and gas deposits.

Oil …

Table 1.3 Proven World Oil Reserves by end of 2013

Country	Billion tonnes	Billion barrels	Share of total, %	R/P years
Venezuela	56.6	298.3	17.7	> 100
Saudi Arabia	36.5	265.9	15.8	63.2
Canada	28.1	174.3	10.3	> 100
Iran	21.6	157	9.3	> 100
Iraq	20.2	150.0	8.9	> 100
India	0.8	5.7	0.3	17.5
Others	74.4	636.7	37.7	-
World	**238.2**	**1687.9**	**100**	**53.3**

Source: BP Statistical Review of World Energy June 2014

(1 barrel ≈ 160 litres)

Oil Manufacturing …

Table 1.4 Top Oil Producing Countries by End of 2013

Region	Million tonnes per year	Share of total, %
Saudi Arabia	542.3	13.1
Russia	531.3	12.9
US	446.2	10.8
China	208.1	5.0
Canada	193	4.7
Iran	166.1	4.0
Iraq	153.2	3.7
Nigeria	111.3	2.7
Others	2351.5	43.1
World	**4130.2**	**100**

Source: BP Statistical Review of World Energy June 2014

Renewable & Non renewable energy…

Saudi Arabia was the largest oil producer in the world (end of 2013) followed closely by Russian Federation and US. Although the United States ranks third in terms of oil production, it only ranks tenth in terms of proven oil reserves. The top oil producing countries in 2013 are given in Table 1.4. As against the top producing countries (end of 2013), India's share is 42 million tonnes and share of total is 1%.

Oil Reserves

Oil shale generally refers to any sedimentary rock that contains solid bituminous materials (called **kerogen**) that are released as petroleum-like liquids when the rock is heated in the chemical process of pyrolysis.

Oil sands (also known as Tar sands) are a combination of clay, sand, water, and **bitumen**, a heavy black viscous oil. Tar sands can be mined and processed to extract the oil-rich bitumen, which is then refined into oil.

Natural bitumen is the portion of petroleum that exists in the semi-solid or solid phase in natural deposits. In its natural state it usually contains sulphur, metals and other non-hydrocarbons.

Extra Heavy Oil is the portion of heavy oil having an API gravity of less than 10°.

Natural Gas …

Natural Gas Proven Reserves: Top Countries

Country	Trillion cubic metres	Share of total, %	R/P (years)
Iran	33.8	18.2	> 100
Russia	31.3	16.8	51.7
Qatar	24.7	13.3	> 100
Turkmenistan	17.5	9.4	> 100
US	9.3	5	13.6
Others	69.1	37.3	-
World	**185.7**	**100**	**55.1**

Source: BP Statistical Review of World Energy June 2014

Reserves..

At current R/P ratio, World oil and gas reserves are estimated at just 53 years and 55 years respectively. Coal is likely to last for 113 years.

Global Primary Energy Consumption….

- At the end of 2014…
- 12730 Million Tones Oil Equivalent

Oil	Natural gas	Coal	Nuclear Energy	Hydro-Power	Renewable Energy	Total, Mmtoe
4185.1	3020.4	3826.7	563.2	855.8	279.3	12730.4
33%	24%	30%	4%	7%	2%	

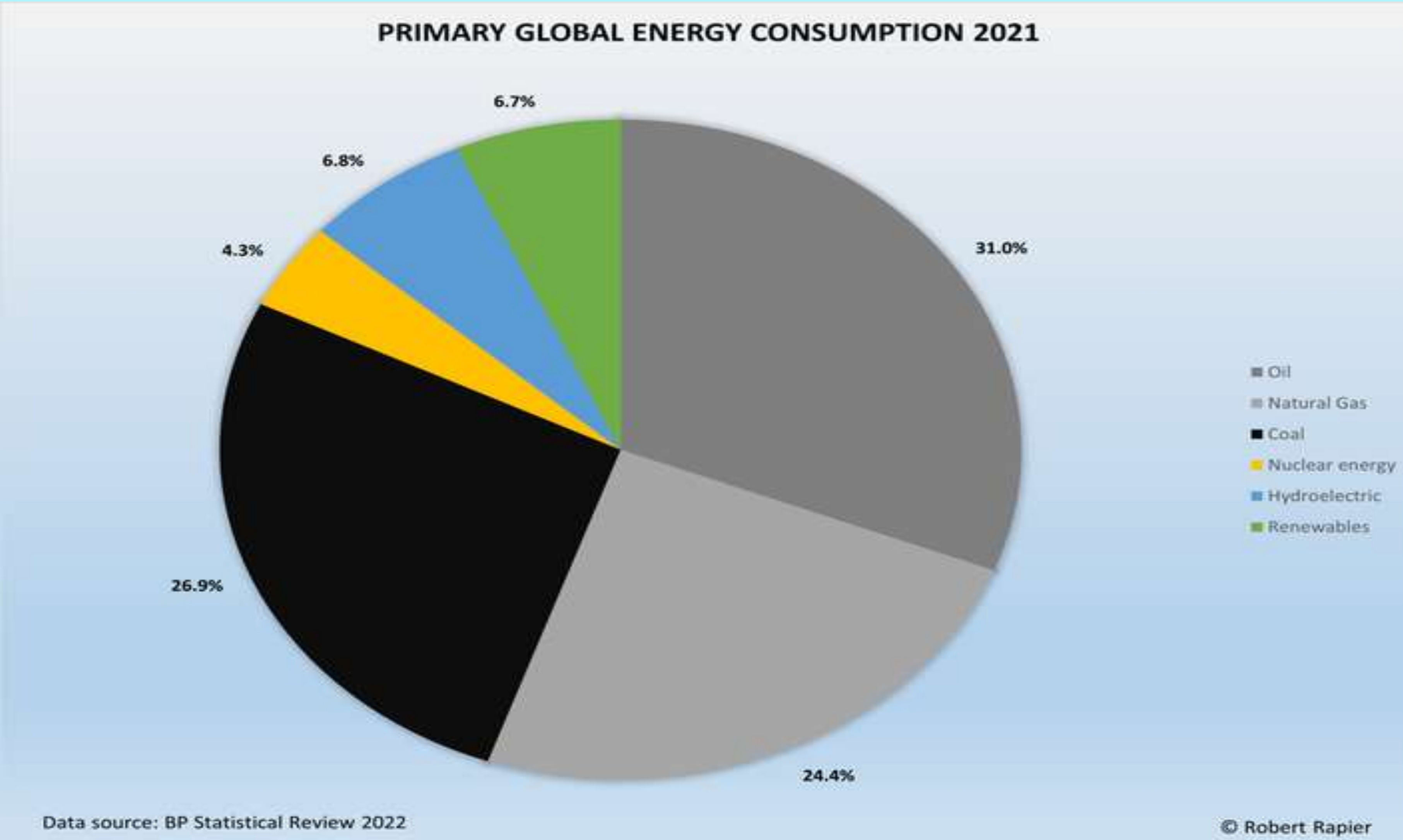
Source: BP Statistical Review of World Energy June 2014

Primary energy consumption in the world…

Table-1.7 Primary Energy consumption at the end of 2013								
	Million tonnes of oil equivalent (Mtoe)							% of Share
Country	**Oil**	**Natural gas**	**Coal**	**Nuclear Energy**	**Hydro-Power**	**Renewable Energy**	**Total**	
China	507.4	145.5	1925.3	25	206.3	42.9	2852.4	22.4
US	831.0	671.0	455.7	187.9	61.5	58.6	2265.8	17.8
Russia	153.1	372.1	93.5	39.1	41	0.1	699	5.5
India	175.2	46.3	324.3	7.5	29.8	11.7	595.0	4.7
Japan	208.9	105.2	128.6	3.3	18.6	9.4	474.0	3.7
Germany	112.1	75.3	81.3	22.0	4.6	29.7	325.0	2.6
Others	2197.4	1198.3	818	278.4	494	126.9	5519.2	43.3
World	**4185.1**	**3030.4**	**3826.7**	**563.2**	**855.8**	**279.3**	**12730.4**	**100**

Source: BP Statistical Review of World Energy, June 2014

Primary energy consumption in the world…



Final Energy consumption…

Industry :- 50%
Transportation:- 20%
Residential:- 18%
Commercial :- 12%
As per US energy information adminstration

Indian Energy Scenario…

An Annual Energy Consumption In India Is 595 Million Tones Of Oil Equivalent compared to World consumption of 12,730 Million Tones Of Oil Equivalent (Year 2013)

Energy Type	Mtoe	% share in total primary Energy Consumption
Oil	175.2	29.5%
Natural Gas	46.3	7.8%
Coal	324.3	54.5%
Nuclear energy	7.5	1.3%
Hydro Power	29.8	5.0%
Renewable energy	11.7	2.0%
Total Primary Energy consumption	595	100.00

Source: BP Statistical Review of World Energy, June 2014

Electrical Energy Supplied

Indian Scenario……

- *Installed Capacity:- 2,38,734 MW*

Power Generation Route	Capacity (MW)	%
Total Thermal	**1,63,304.99**	**68.4**
Coal	*1,40,723.39*	58.9
Gas	*21,381.85*	9.0
Oil	*1,199.75*	0.5
Hydro	**40,195.40**	**16.84**
Nuclear	**5,780.00**	**2.42**
Renewable energy sources (small hydro, wind, biomass and others)	**29,462.55**	**12.34**
Total	**2,38,742.94**	**100.0**

Sector wise energy consumption….

- India : Commercial energy uses

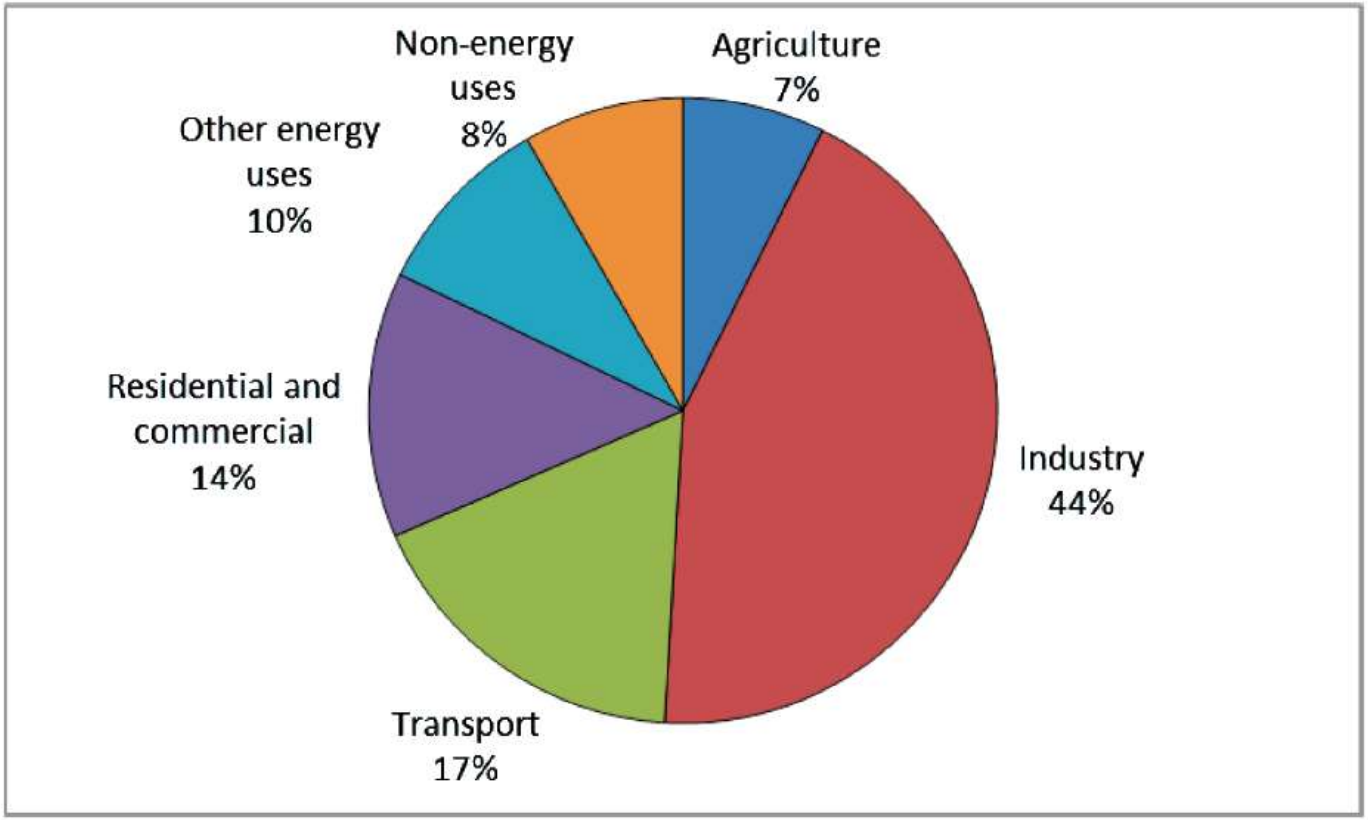


Figure 1.4 Sectorwise Energy Consumption
Source: TERI

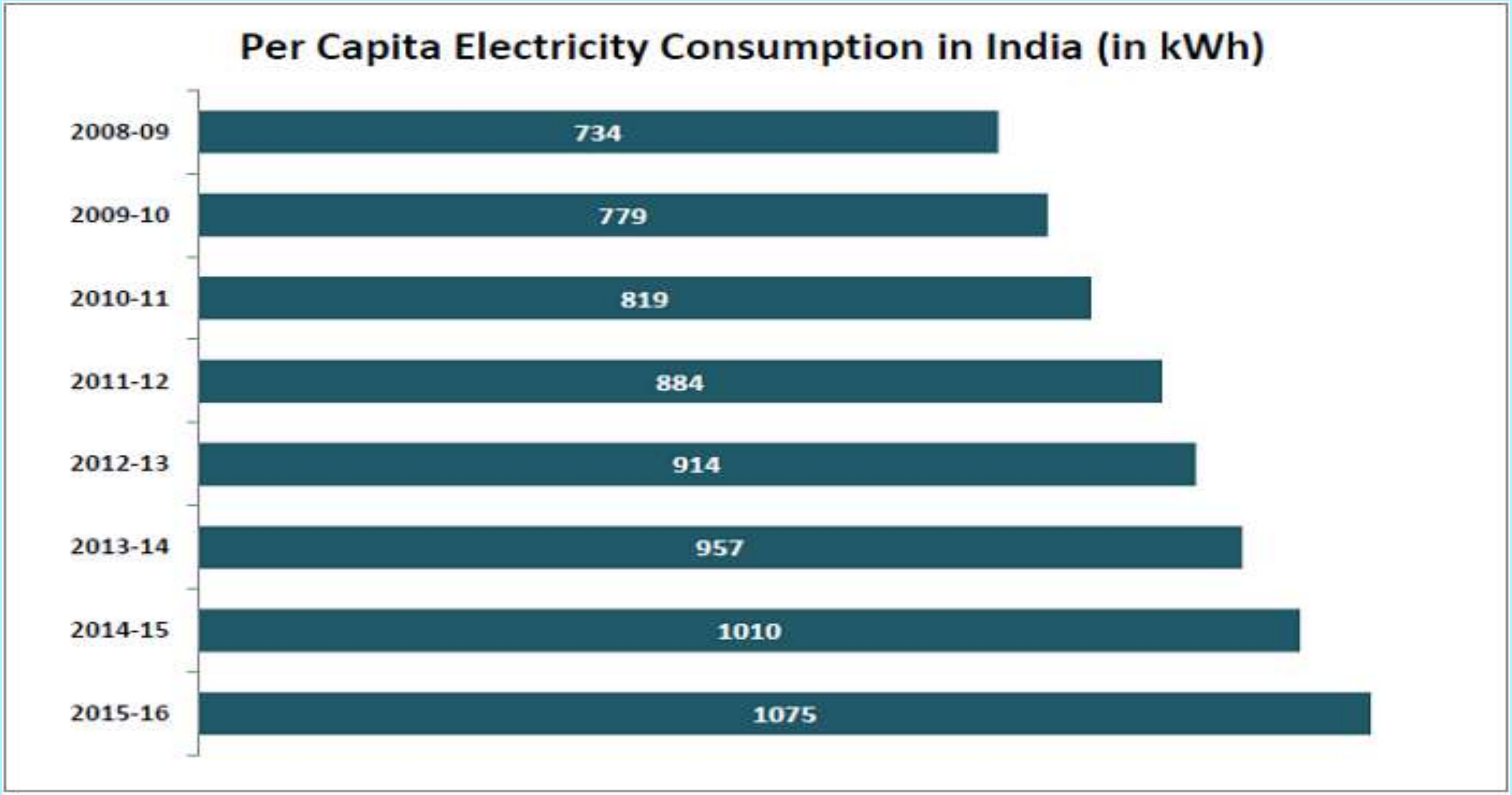
Sector wise energy consumption….

- India : Commercial energy uses

Industry	Specific Energy Consumption (SEC) in GJ/ tonne	
	India	World
Iron & Steel	25.5 –34.2	16.5-18.5
Cement	3.0-3.4	2.9-3.0
Fertilizers(Urea)	27.2-28.5	24.0-25.8
Pulp & Paper	31.0-51.0	25.0-30.0
Chlor Alkali (Caustic Soda)	7.8-8.6	7.1-7.5
Aluminum	75.6-83.2	70.5-73.0
Sugar	0.7-0.9	0.6-0.7

Source: Planning Commission, India Report

India : Per Capita usage



In 2018-19, India's per capita power consumption was **1181 kWh** as against the world average at 3,260 kWh.

India : Per Capita usage

Per Capita usage of INDIA is 917 KWh/ person /year

Where as some statistics for others are@ 2013 data

Japan	7848	KWh/ person /year
China	3298	KWh/ person /year
USA	13,246	KWh/ person /year
UK	6206	KWh/ person /year
Canada	16,473	KWh/ person /year

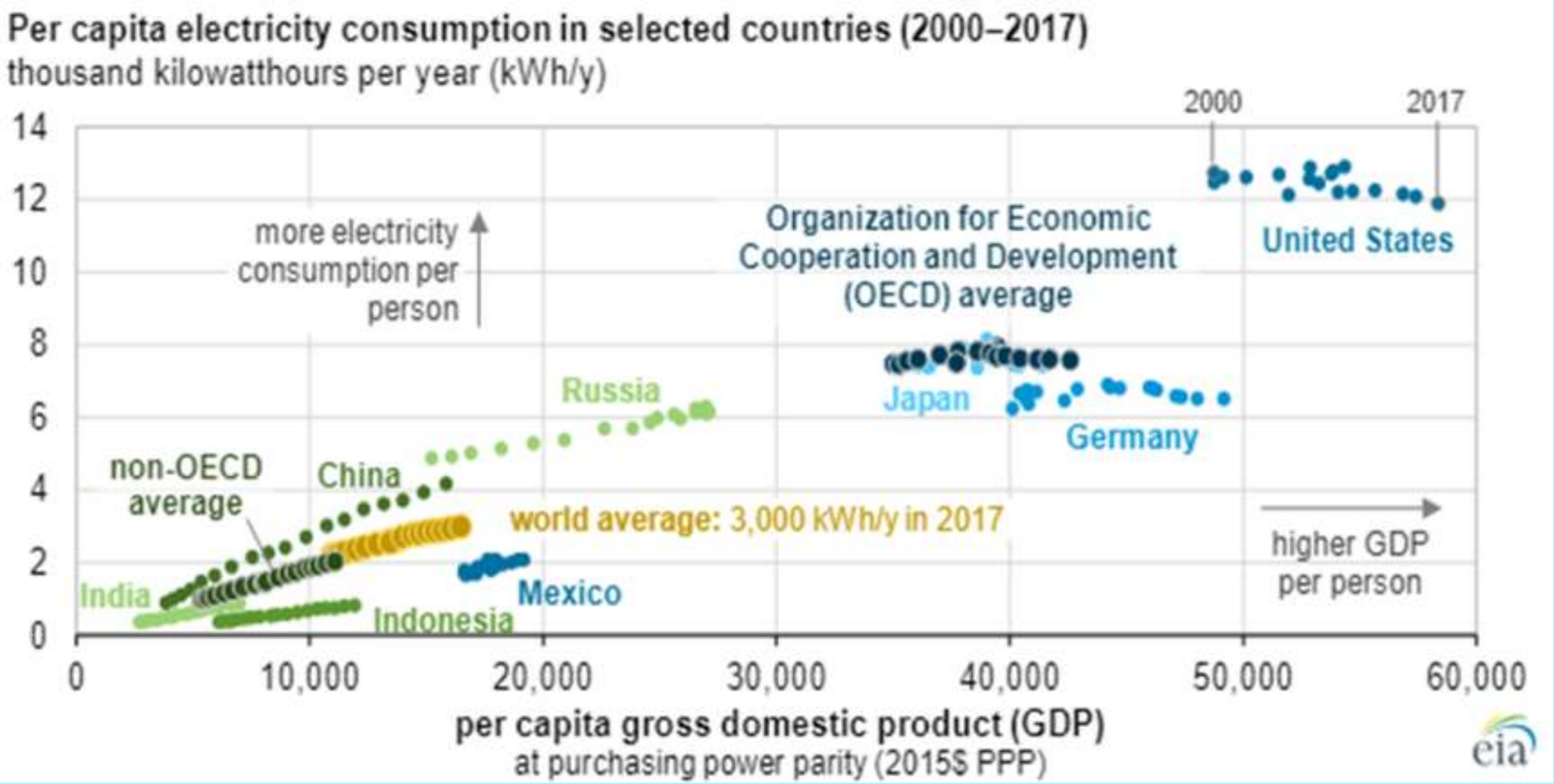
Worlds average is **2430** KWh/ person /year

INDIA imports 75% of its crude oil

Will raise to 90% as production is declining

Per Capita usage of INDIA is 1255 @2021

GDP Increases when Per Capita Energy Usage Increases




GDP
Nature
There is Something Wrong in the world

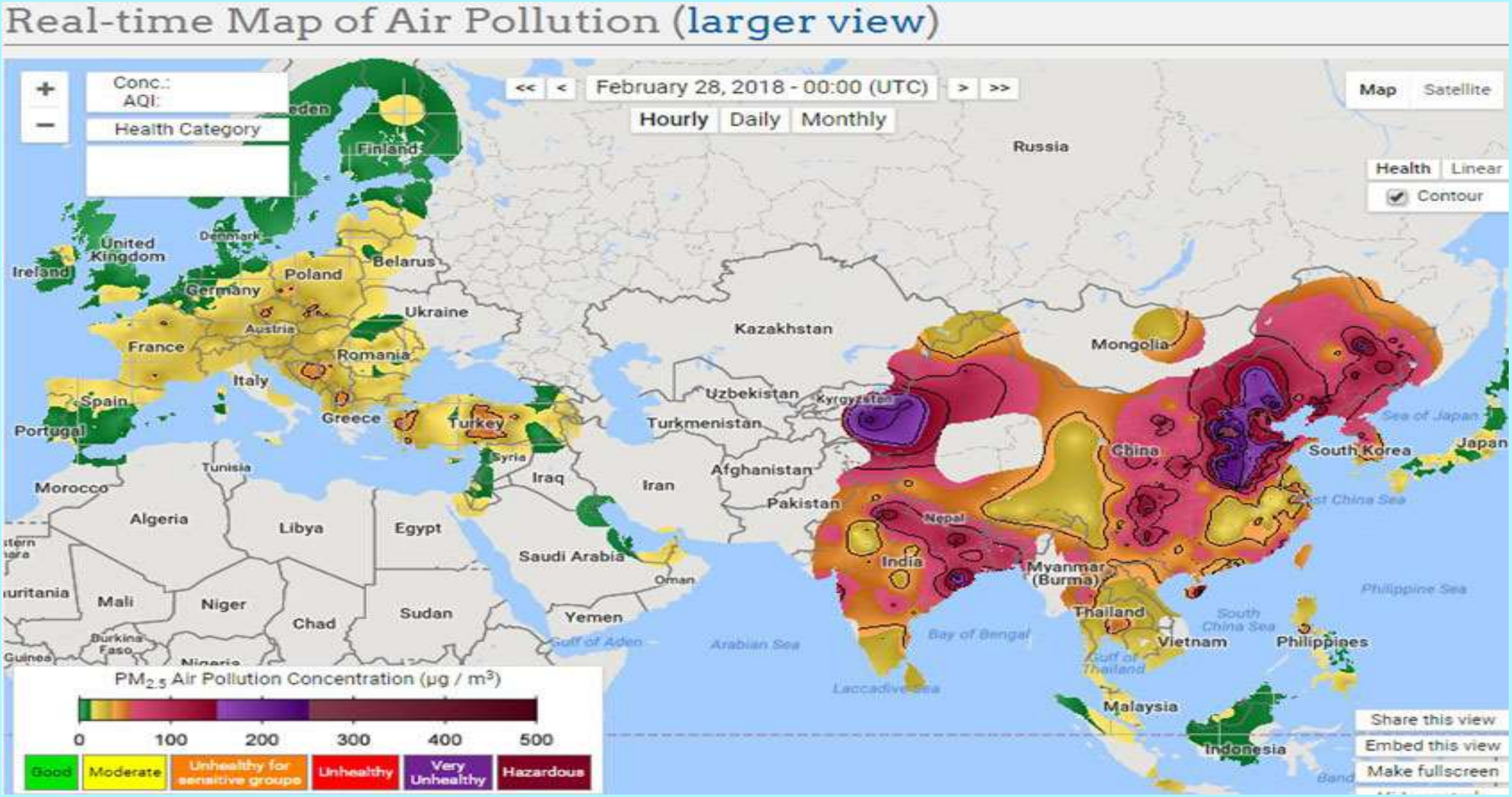

Water

FOREST

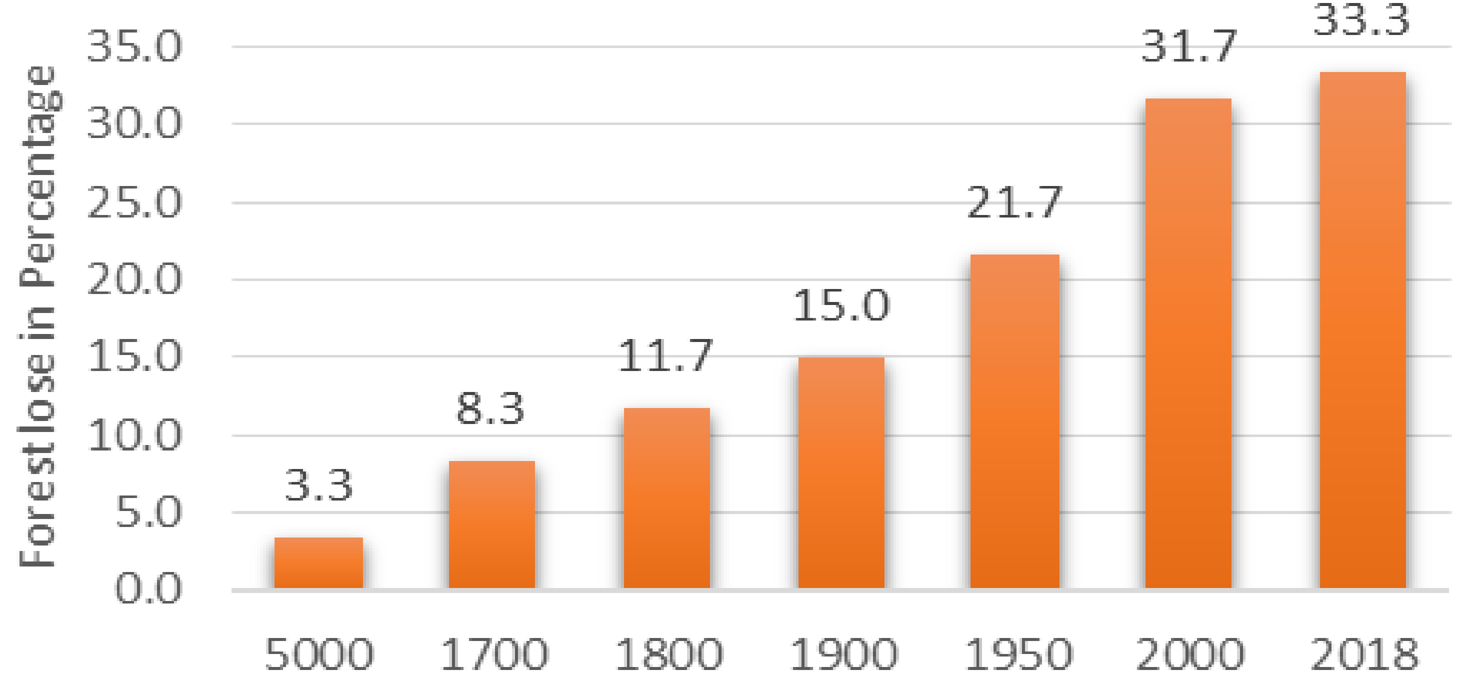
SOIL

AIR

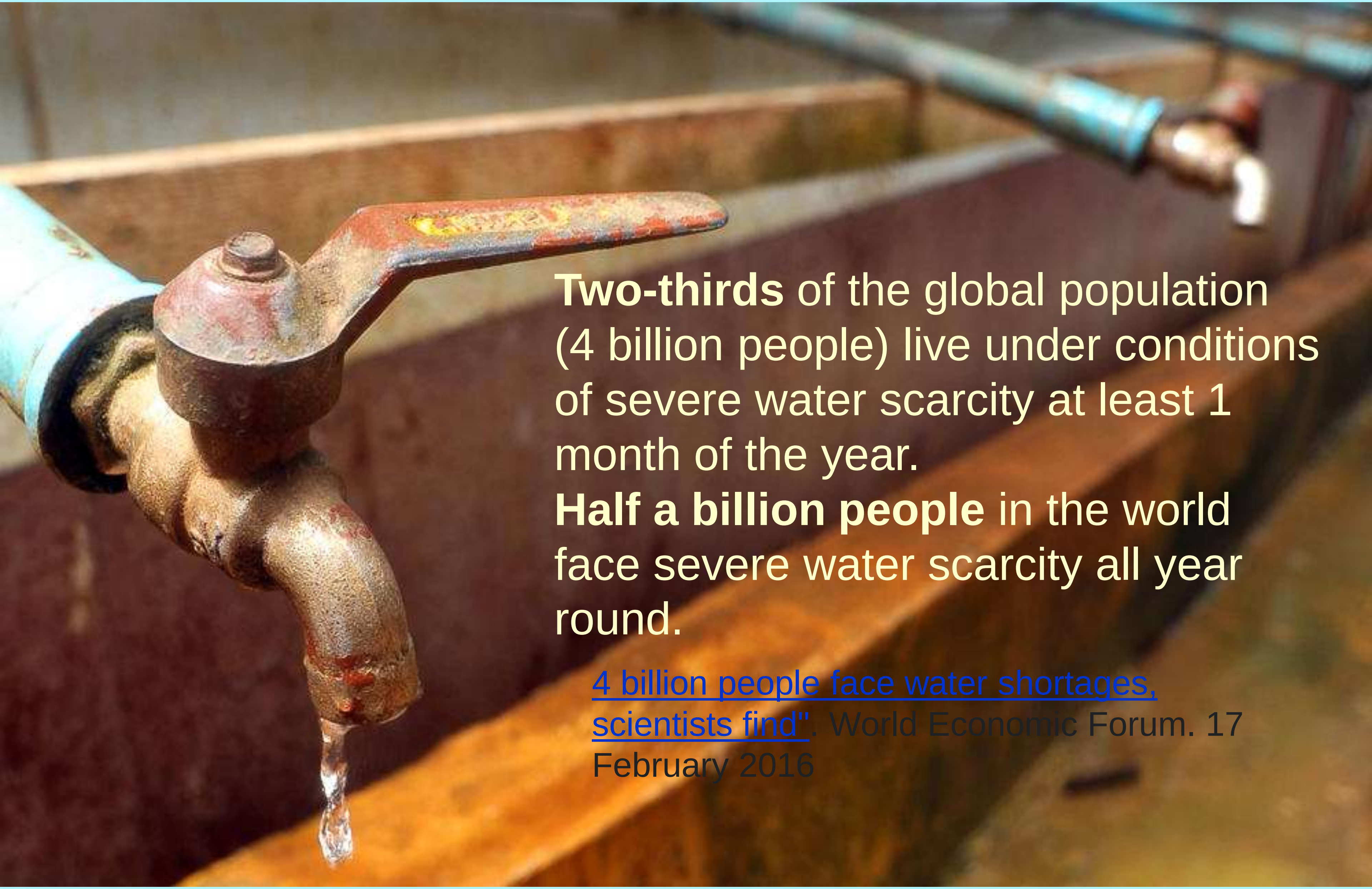
92% people lives in places where air quality levels exceed WHO limits. Air pollution is causing at least **4.5 million** premature deaths each year worldwide.



Forest Loss in Percentage in World



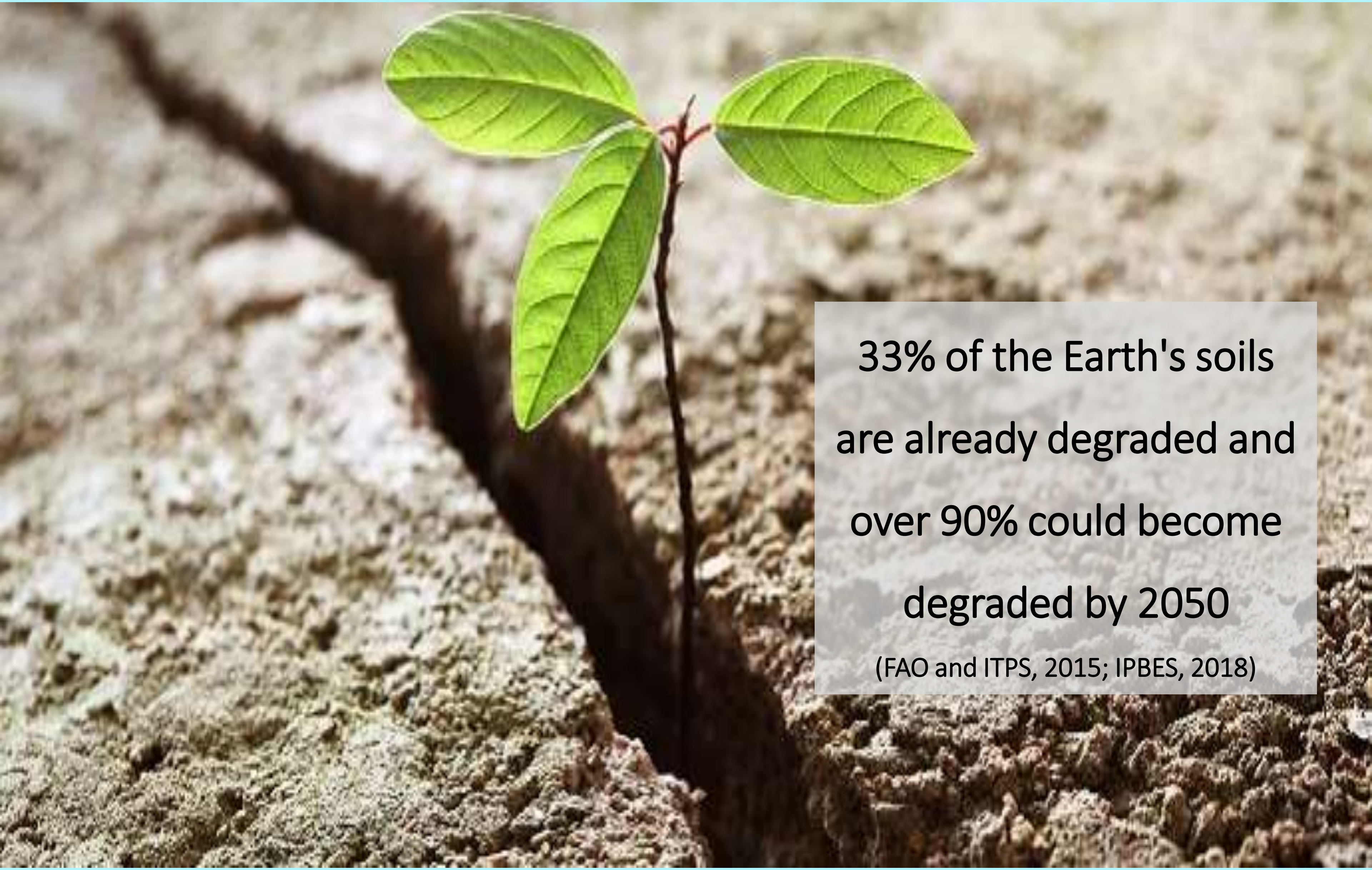
The world lost 1.5 billion hectares of forest-2020
An area 1.5-times the size of the United States



Two-thirds of the global population (4 billion people) live under conditions of severe water scarcity at least 1 month of the year.

Half a billion people in the world face severe water scarcity all year round.

4 billion people face water shortages, scientists find". World Economic Forum. 17 February 2016


33% of the Earth's soils
are already degraded and
over 90% could become
degraded by 2050
(FAO and ITPS, 2015; IPBES, 2018)

Pollutants and Greenhouse Gases….

- Particulate Matter
  - ✓ PM 10
  - ✓ PM 2.5
- CO,Co2
- CH4
- Nox
  - ✓ N2O
  - ✓ NO2
  - ✓ NO
- VOCs
- Hydrocarbons
- SOx
  - ✓ SO2

• Nitrogen oxides (NO_2)	• Volatile organic compounds(VOCs)	• Aldehydes
• Sulfur dioxide (SO_2)	• Peroxides	• Organic acids
• Ground level ozone (O_3)	• Particulate matter (PM)	• Hydrocarbons

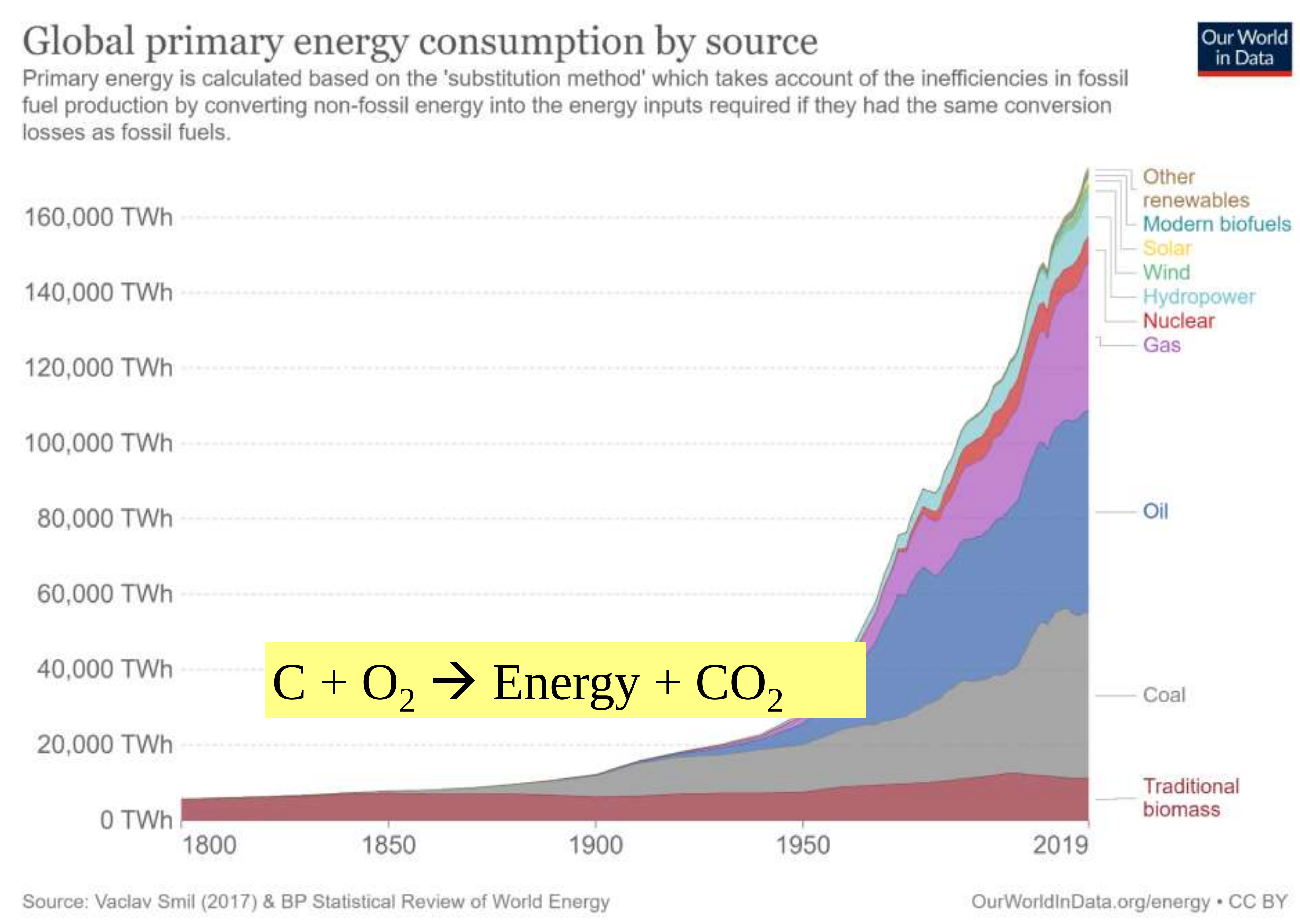
Pollutants and Greenhouse Gases….

- Particulate matter are particles released as a part of combustion cycle. These particles are extremely small in the range of micrometers. There fore, they enters the body and affect heart, lungs and brain and cancerous in nature
- PM particles less than 10 micrometer which is PM10 are very dangerous and if inhaled can cause severe damage. So these are clubbed and referred as PM2.5
- CO,Co2, CH4 and Nox gases are known as greenhouse gases. Due to the presence of these gases, the infrared radiations are trapped in the atmosphere and cause greenhouse effect such as climate change and global warming.
- Carbon Monoxide is a colorless, odorless gas which is very dangerous for human health. It is highly poisonous.

Pollutants and Greenhouse Gases….

- NOx gases, VOC and total hydrocarbons are responsible for building ground level ozone layer and is very dangerous for humans. It causes lining in the lungs and major respiratory illnesses such as asthma and lung inflammation.
- Diesel engine are the main source of NOx gases, can be filtered using catalytic converter but these devices are costly. NOx gases can be minimized by use of urea filters.
- Sulphur dioxide gas is released by coal based thermal power plants. Electricity is used in EVs, they are creating more SOx gases in the atmosphere. Sox reacts with oxygen and water present in atmosphere and creates sulphuric acid, major reasons for acidic rains.
- The solution is low Sulphur coal should be used for power generation which is costly of course.

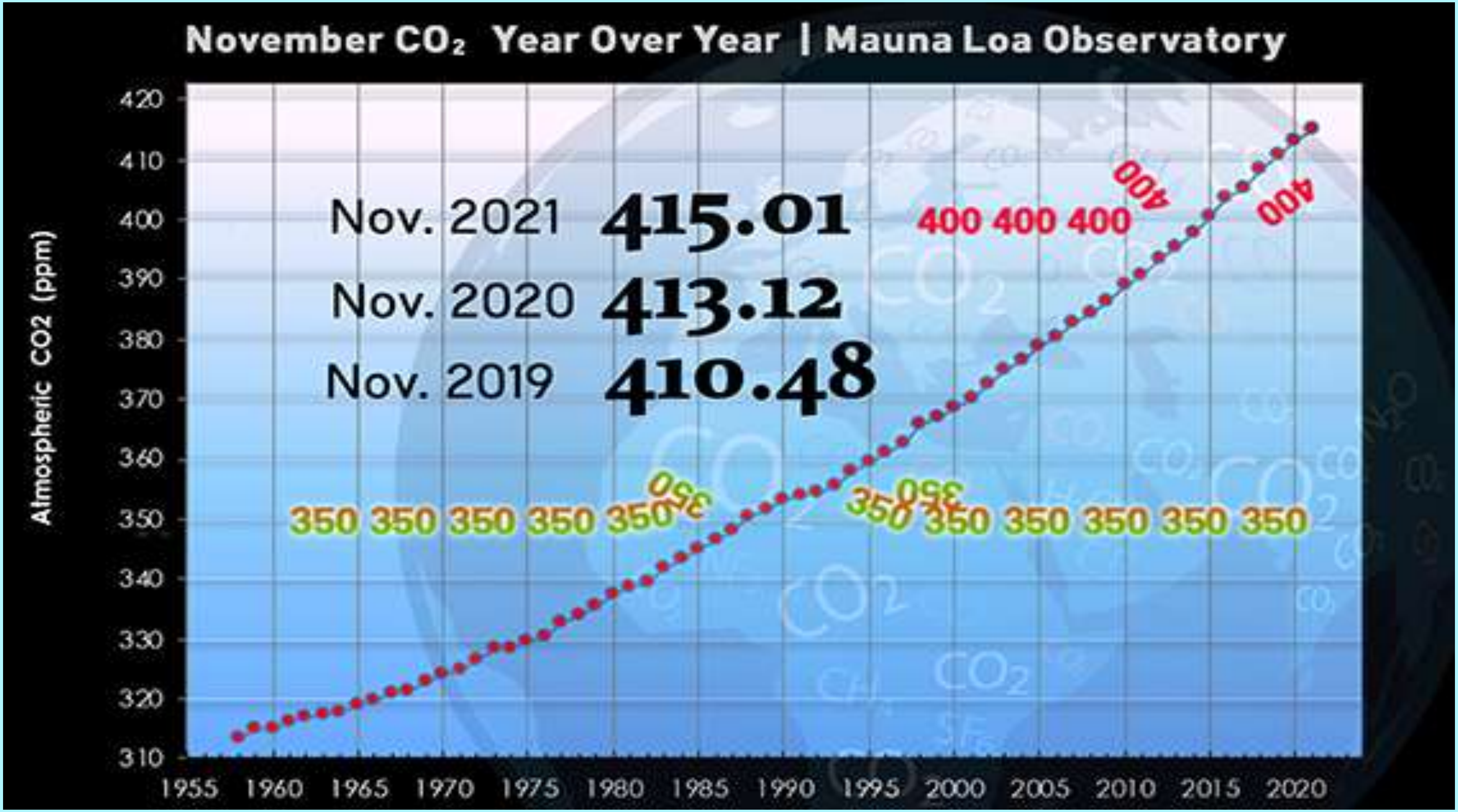
Sustainable Development Goals



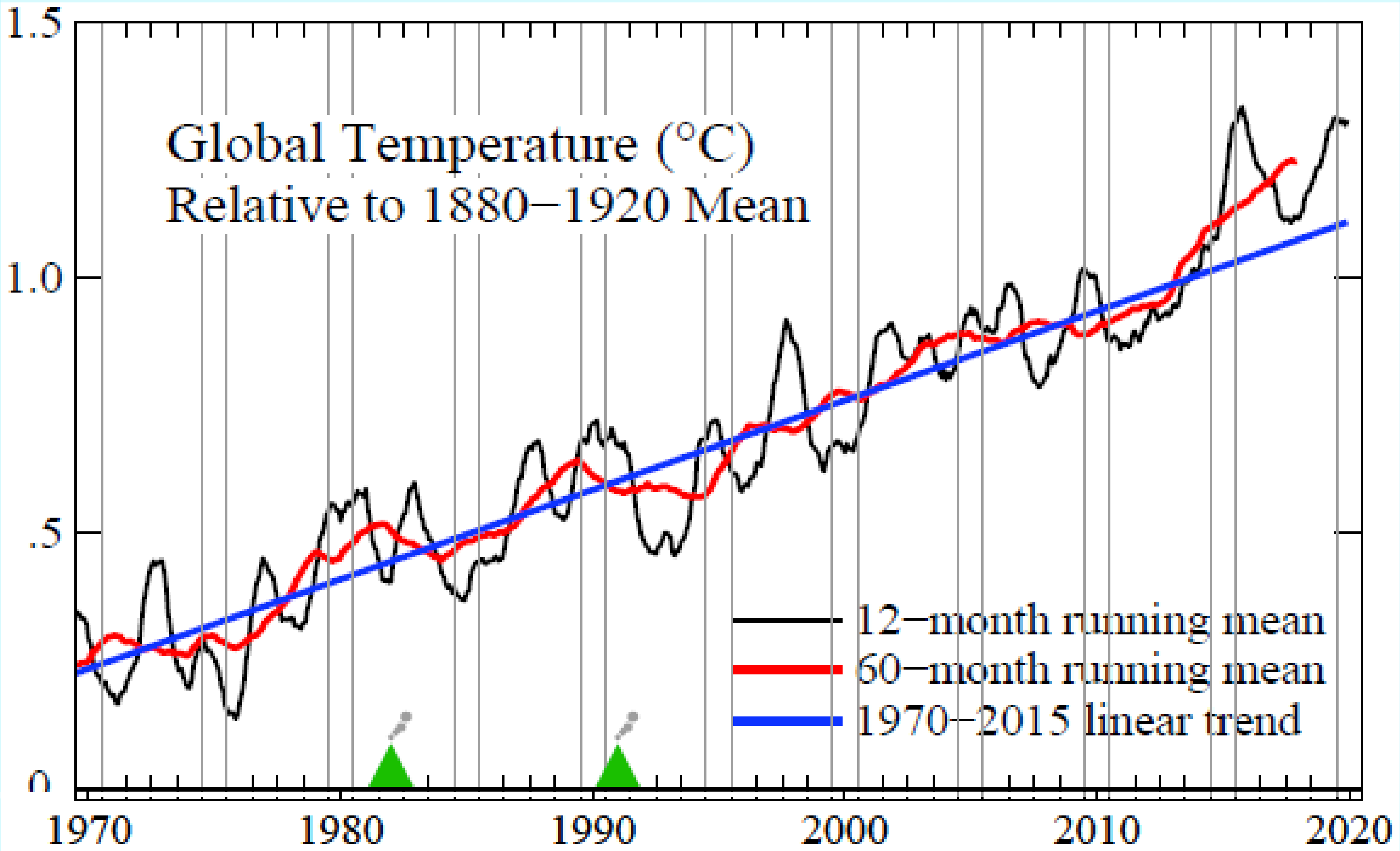
$$C + O_2 \rightarrow \text{Energy} + CO_2$$

CO2 Concentration

CO2 Concentration



Global Temperature



Planet is warmer by

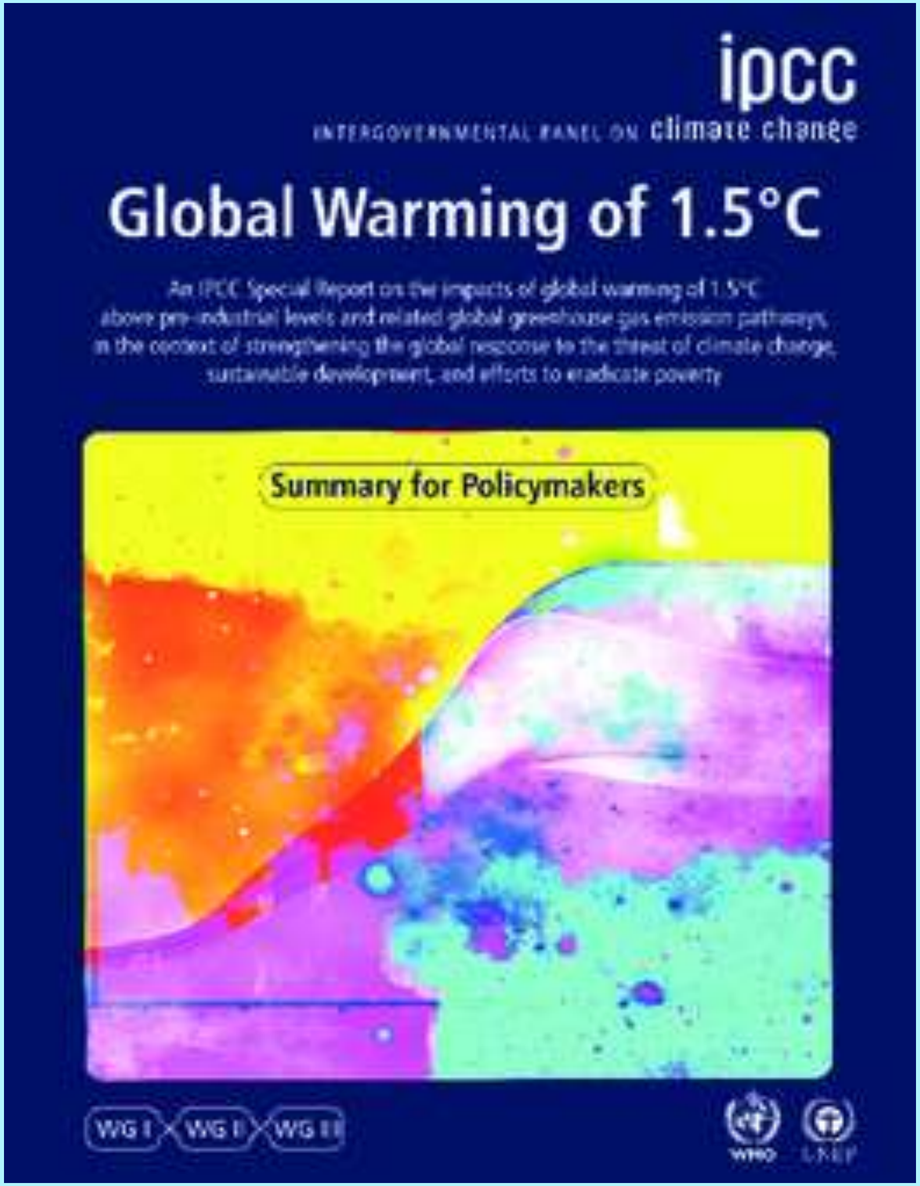
1.1 ^oC

1.98 ^oF

We need to limit global warming to ideally,

$1.5^{o}C$

maximum $2^{o}C$



Heatwaves

Ice melting

Floods


Storms


Sea Level Rise

Screenshot taken on 9th Nov 21

How much time is left?

- Remaining carbon budget

From 2021, 270 GT (1.5 oC) and 1050GT for (2oC)

- Rate of carbon emission

(1332000 kg/sec)

Energy Intensity on Purchasing Power Parity

Energy intensity is the ratio between the gross inland consumption of energy and the gross domestic product (GDP) for a given calendar year. It measures the energy consumption of an economy and its overall energy efficiency.

The gross inland consumption of energy is a measure of the energy inputs to the economy, calculated by adding total domestic energy production plus energy imports minus energy exports plus net withdrawals from existing stocks.

The GDP figures are taken at constant prices to avoid the impact of the inflation, in relation to a base year (say 2000). Since gross inland consumption is measured in toe (tons of oil equivalent) and GDP in millions of US \$, this ratio is expressed in toe per million US \$.

$$EI = \frac{FC}{GDP}$$

Where:

EI = Energy intensity, national level, toe per million US \$

FC = Total final consumption, national level, toe

GDP= Gross domestic product, million US \$

Sector wise energy consumption….

- Energy Intensity on Purchasing Power Parity

What is Purchase Power Parity (PPP)?

An egg in India costs Rs.3/- whereas it costs 30 Yens/- (equivalent to Rs.15) in Japan. The PPP for an egg between Japan and India is 30 Yens to Rs.3 or 10 Yens to a rupee. In other words, for every rupee spent on egg in India, 10 Yens would have to be spent in Japan to obtain the same quality of egg.

Applying actual exchange rates of Yen to Rupee in this process would overestimate the GDP of Japan with high price levels relative to India with low price levels. The use of PPPs ensures that the GDP of all countries is valued at a uniform price level and thus reflects only differences in the actual volume of the economy. Adjustments are required to give a better picture than comparing gross domestic products (GDP) using market exchange rates.

A purchasing power parity (PPP) exchange rate equalizes the purchasing power of different currencies in their home countries for a given basket of goods. These special exchange rates are often used to compare the standards of living of two or more countries. In their simplest form, PPPs are price relatives that show the ratio of the prices in national currencies of the same good or service in different countries.

Electricity Pricing in India….

- In terms of purchasing power parity…..

Indian power tariffs for industry and commercial customers are highest in the world.

Average tariff on PPP basis

India	**30.8 cents/ KWh**
US	7.7
Japan	15.3
China	20.6

- Consumer Prices Are Set By State Electricity Board Regulatory Commissions on cost plus basis
- It cross subsidize agricultural and domestic users over industrial and commercial users

Electricity Pricing in India….

- High tension consumers are charged on the basis of Demand (KVA) and Energy (KWh)
- Low Tension consumers are charged on the basis of only Energy consumed (KWh) as per tariff systems.
- Agricultural consumer supplied unmetered power
- Farmers pay highly subsidized lump sum amount based on declared HP pumps.
- Domestic consumer also avail subsidy.

- ‘Availability based Tariff’ ABT is introduced in 2003 act.

‘Availability based Tariff’ ABT ….

Introduction of Availability Based Tariffs (ABT) and unscheduled interchange charges for power, introduced in 2003 for inter-state sale of power, have reduced voltage and frequency fluctuations.

- It is a performance-based tariff system for the supply of electricity by generators owned and controlled by the central government
- It is also a new system of scheduling and dispatch, which requires both generators and beneficiaries to commit to day-ahead schedules.
- It is a system of rewards and penalties seeking to enforce day ahead pre-committed schedules, though variations are permitted if notified one and half hours in advance.
- The order emphasises prompt payment of dues. Non-payment of prescribed charges will be liable for appropriate action.

Energy Security….

The basic aim of energy security for a nation is to reduce its dependency on the imported energy sources for its economic growth. Energy security is defined as **"The continuous availability of energy in varied forms in sufficient quantities at reasonable prices".**

Some Strategies….

- Reducing energy requirements
  - Improving the efficiency of extraction of fossil fuels
  - Improving fuel efficiency of new coal-fired power plants by adopting new technology (i.e. super critical pulverized fuel fired boilers)
  - Adopting energy efficiency and demand side management
  - Promotion of public transport / mass transport (e.g. metro rail, light rail, monorail etc.) in urban areas
  - Developing renewable energy sources especially solar and wind

Some Strategies….

- Substituting imported oil/gas with domestic alternatives
  - Ethanol / Biodiesl as substitute for petrol / diesel
  - Biomass gasification for heat or power as alternative to gas / coal
  - Coal-to-oil technology as done in South Africa

- Diversifying energy supply sources
  - Mix of fuel comprising of coal, gas, nuclear, hydro and renewables with no dependence on any particular fuel
  - Sourcing oil / LNG from different countries
  - Importing gas through pipelines passing through countries who also benefit

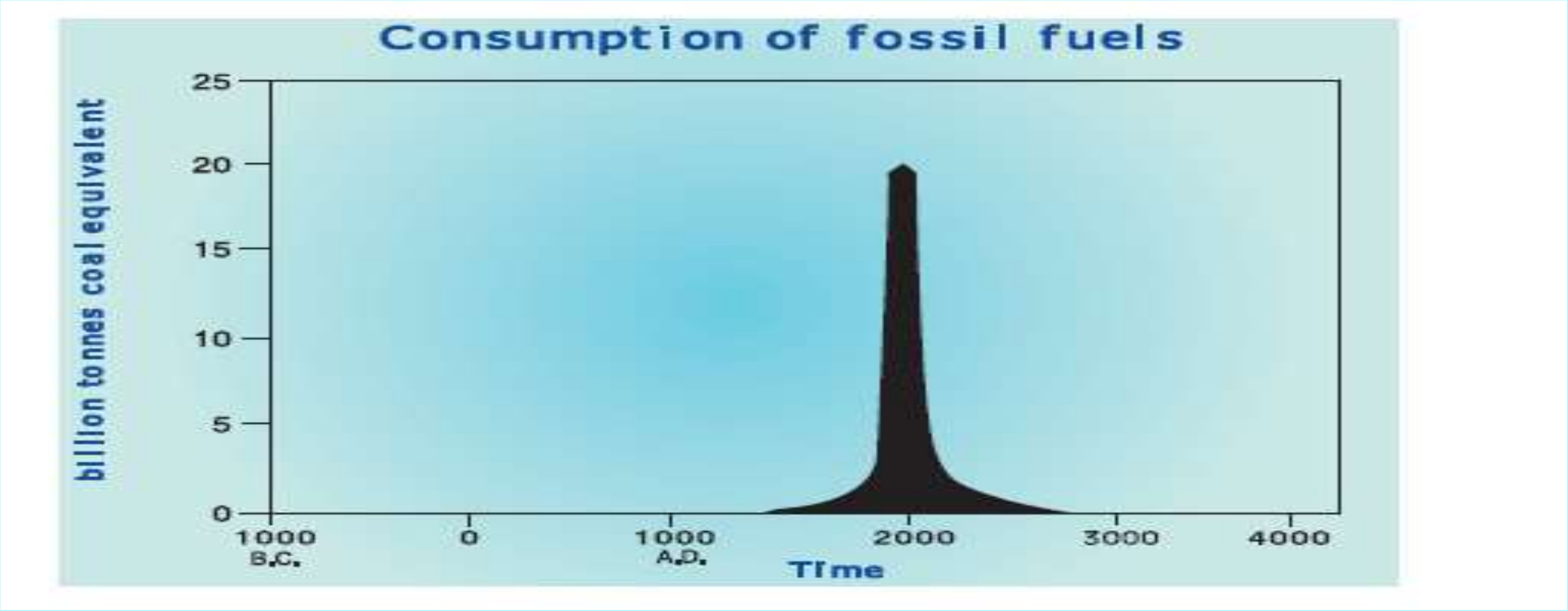
Some Strategies….

- Expanding energy resource and developing alternative energy sources
  - Improved Oil Recovery (IOR) and Enhanced Oil Recovery (EOR) for improving exploitation of reserves
  - Recovery of oil and gas from abandoned or marginal fields
  - In-situ coal gasification
  - Capturing Coal Bed Methane (CBM) which escapes from coal seams during mining
  - Conversion of coal to oil
  - Gas to Liquid (GTL)
  - Stepping up exploration to find new reserves (only one-third of oil bearing area explored so far)

Some Strategies….

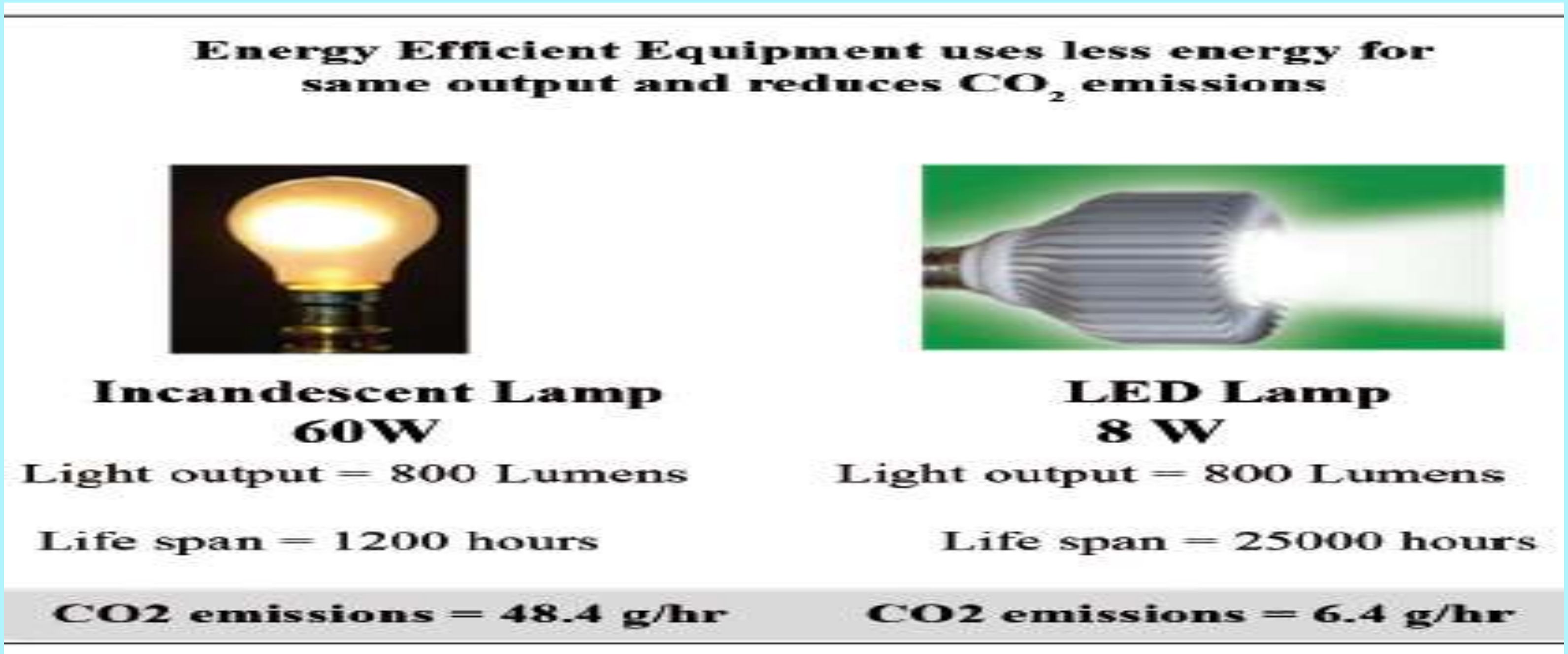
- Equity oil, gas, coal from other countries
- Setting up energy intensive units (i.e. fertilizer plants) abroad
- New domestic sources (nuclear –fast breeder reactor, thorium reactors, gas hydrates etc.)
- Promoting Community Biogas Plants
- Energy plantations

Energy conservation….



- Today 85% energy is from Non Renewable sources
- ‘these are continually diminishing and will not exist for future generation.

Energy conservation….



- Energy Conservation means growth of energy consumption is reduced.
- By improving Energy efficiency.

Basic forms of Energies

- Potential Energy
- Chemical energy
- Nuclear energy
- Stored Mechanical energy
- Gravitational energy
- Kinetic energy
- Radiant energy
- Thermal energy
- Sound energy
- Electrical energy

Energy can be transformed from one form to another form

Mathematically one should calculate the change.

Basic forms of Energies

- Potential Energy

Potential energy stored in a body due to its height above a datum level is expressed by:

Potential energy (E_p) = mass x gravitational acceleration x height= m g h.

- Chemical Energy

Chemical energy is the energy stored in the bonds of atoms and molecules and released as heat in a chemical reaction. This is specific to each reaction and is usually given as energy unit mass (e.g. kJ/kg) or number of molecules (e.g. kJ/mol). Biomass, petroleum, natural gas, propane and coal are examples of stored chemical energy.

Basic forms of Energies

- Nuclear Energy

Nuclear energy is the energy stored in the nucleus of an atom - the energy that holds the nucleus together. The nucleus of an Uranium atom releases nuclear energy when its' fission (split in two parts) results in a loss of mass and the corresponding loss of mass(m) is converted to nuclear energy by following famous equation of Einstein:

Nuclear energy (E_n) = mass x speed of light squared = m c^2 (where c = 3 x 10^8 m/s)

- Stored Mechanical Energy

Stored mechanical energy is energy stored in objects by the application of a force. Compressed springs and stretched rubber bands are examples of stored mechanical energy.

Basic forms of Energies

- Gravitational Energy

Gravitational energy is the energy of place or position. Water in a reservoir behind a hydropower dam is an example of gravitational energy. When the water is released to spin the turbines, it becomes motion energy **in the form of mechanical power-which drives the Generators/Alternators to produce electrical energy.**

- Kinetic Energy

It is the energy a body possesses by virtue of motion or velocity. For example, a moving vehicle, a flowing fluid and moving parts of machinery all have kinetic energy because of their motion. It exists in various forms: radiant energy, thermal energy, electrical energy, motion energy, sound energy, electrical energy etc.

Kinetic energy (E_k) = ½ mv^2 = half x mass x velocity squared = 1/2 x m x v^2

Basic forms of Energies

- Radiant Energy

Radiant energy is electromagnetic energy that travels in transverse waves. Radiant energy includes visible light, x-rays, gamma rays and radio waves. Solar energy is an example of radiant energy.

- Thermal Energy

Thermal energy is the internal energy in substances - the vibration and movement of atoms and molecules within substances. Geothermal energy is an example of thermal energy.

- Motion Energy

The movement of objects or substances from one place to another is motion. Wind and hydropower are **manifestations of motion energy.**

Basic forms of Energies

- Sound Energy

Sound is the movement of energy through substances in longitudinal (compression/rarefaction) waves.

- Electrical Energy

Electrical energy is the movement of electrons. Lightning and electricity are examples of electrical energy.

Work Power Energy….

- Work

Work done on a body, in Joules $W = Fs$

Where, F is the force in Newtons and s is the distance in meters moved by the body in the direction of the force.

In case of rotating body work done is expressed in Joules as: $W = T*(\theta/2\pi)$

Where T is the Torque in Newton-Meter and θ is the angle in radian the body rotated.

- Power & Energy

The *unit of power* is Watt (W), where one Watt is one Joule per second.

Thus, power in Watts, $P = W/t$

Where, W is the work done or energy transferred in Joules and t is the time in seconds.

Work Power Energy….

- Power & Energy

Thus, energy, in joules, $W = Pt$

1 kWh = 3600KJ =3.6MJ

In case of rotating body, power in Watts, $P=T*w= (2\pi*T*N)/60$,

Where T is the Torque applied in Newton-Meter, w is angular velocity in radian/sec. and N is the revolution per minute(RPM).

- Example?

A portable machine requires a force of 200 N to move it. How much work is done if the machine is moved 20 m and what average power is utilized if the movement takes 25 s?

Work Power Energy….

- Example 1

A portable machine requires a force of 200 N to move it. How much work is done if the machine is moved 20 m and what average power is utilized if the movement takes 25 s?

Solution

Work done = force x distance

= 200 N x 20 m

= 4000 Nm or 4 kJ

Power = Work done / time taken = 4000 J /25 s = 160 J/s =160 W

Work Power Energy….

- Electrical Energy

$$\textit{Power, in Watts } P = VI$$

$$\textit{Electrical energy} = \textit{Power x time}$$

$$= V \times I \times t \text{ Joules}$$

- Electrical Energy

Although the unit of energy is the Joule, when dealing with large amounts of energy, the unit used is the *kilowatt hour* (kWh) where

1 kWh = 1000 Watt hour

= 1000 x 3600 Watt seconds or Joules

= 3,600,000 J

Work Power Energy….

- Electrical Energy

Power, in Watts $P = VI$

Electrical energy = Power x time

$= V \times I \times t$ **Joules**

- Electrical Energy

Although the unit of energy is the Joule, when dealing with large amounts of energy, the unit used is the *kilowatt hour* (kWh) where

1 kWh = 1000 Watt hour

= 1000 x 3600 Watt seconds or Joules

= 3,600,000 J

Work Power Energy….

- Example 2

An electric heater consumes 1.8 MJ when connected to a 250 V supply for 30 minutes. Find the power rating of the heater and the current taken from the supply?

- Example 3

An electric kettle has a resistance of 30 Ω . What current will flow when it is connected to a 240 V supply? Find also the power rating of the kettle.

Work Power Energy….

- Example 2

Solution

Energy = power x time,

Power = Energy / time

$= 1.8 \times 10^6$ J / 30 x 60s

= 1000 J/s = 1000 W

i.e., Power rating of heater = 1 kW

Power $P = VI$ thus, $I = P/V = 1000/250 = 4$ A

Hence, the current taken from the supply is 4 A.

Work Power Energy….

- Example 3

Solution

Current, $I = V/R = 240/30 = 8$ A

Power, $P = VI = 240 \times 8 = 1920$ W

$= 1.92$ kW

= Power rating of kettle

Work Power Energy….

- Power & Power Factor

For a balanced three-phase load,

$$Power,\ Watts = \sqrt{3}\ V_L \times I_L\ Cos\theta$$

For a balanced single-phase load,

$$Power,\ Watts = V_L \times I_L\ Cos\theta$$

$$\mathrm{kW} = \mathrm{kVA} \cos\theta$$

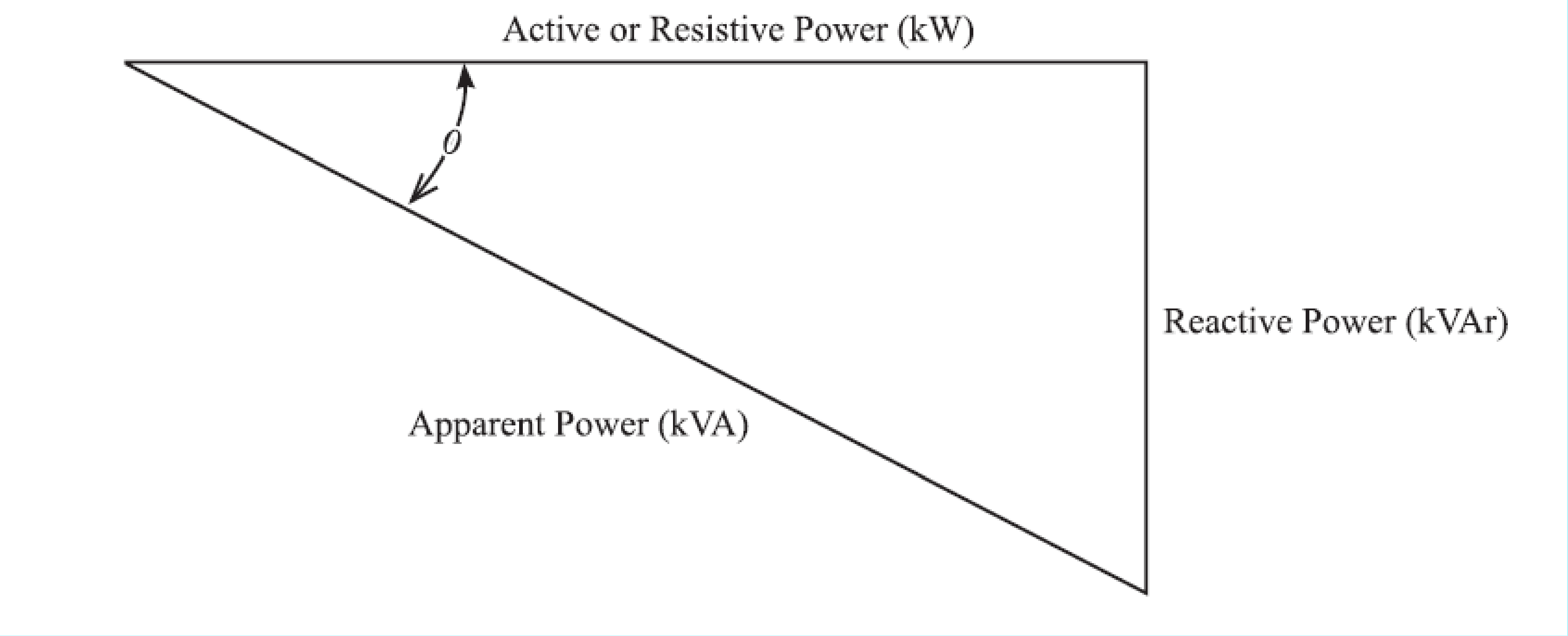
$$kVA = kW/\cos\theta$$

$$kVAR = kVA\ sin\ \theta$$

$$PF = \cos\theta$$

Work Power Energy….

- Power Triangle



Heat Energy….

- Calories

Calorie is the unit for measuring the quantity of heat. It is the quantity of heat, which can raise the temperature of 1 g of water by 1°C.

Calorie is too small a unit for many purposes. Therefore, a bigger unit Kilocalorie (1 Kilocalorie = 1000 calories) is used to measure heat. 1 kilocalorie can raise the temperature of 1000g (i.e. 1kg) of water by 1°C.

However, nowadays generally Joule as the unit of heat energy is used. It is the internationally accepted unit. Its relationship with calorie is as follows:

$$\mathbf{1\ Calorie = 4.187\ J \approx 4.2\ J}$$

Heat Energy….

- Specific Heat

If the same amount of heat energy is supplied to equal quantities of water and milk, their temperature goes up by different amounts. This is due to different specific heats of different substances. Specific heat is defined as the quantity of heat required to raise the temperature of 1kg of a substance through 1°C or 1 K. Specific heat is expressed in terms of kcal/kg°C or J/kg K. Specific heat varies with temperature. In case of gases-there are an infinite number of processes in which heat may be added to raise gas temperature by a fixed amount and hence a gas could have an infinite numbers of specific heat capacities. However-only two specific heats are defined for gases i.e. specific heat at constant pressure, c_p and specific heat at constant volume ,c_v. For solids and liquids, however, the specific heat does not depend on the process.

Heat Energy….

- Sensible Heat

The amount of heat which when added to any substance causes a change in temperature. The changes in temperature that do not alter the moisture content of air. It is expressed in calories or Joules.

Sensible heat = mass x specific heat x change in temperature

$$Q = m\, C_p\, \Delta T$$

- Latent Heat

It is the change in heat content of a substance, when its physical state is changed without a change in temperature.

$$Q_L = m \times h_{if}$$

Where Q_L = The quantity of latent heat in kilojoules

m = The mass in kg

h_{if} = The latent heat of fusion in kJ/kg

Energy….

- Example 4

In a hydroelectric generating station, difference in the level (head) is 425 m. if the overall efficiency is 69 % calculate the liters of water required for generating 1 KWH of electrical energy. (1Lit water has a mass of 1Kg.)

Heat Energy….

- Example 4

- Solution

$$P_{in} = \frac{P_{out}}{\eta} = \frac{1}{0.69} = 1.449Kwhr$$

$$\text{Input energy } E = 1.449 \times 3600 = 5216.4 \text{ KJ}$$
$$= 5216.4 \times 1000 \text{ J}$$

$$\text{Mass} = \frac{5216400}{\text{g}\times\text{h}} = 1251 \text{ Lit}$$