CH2356 Energy Engineering

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Environmental Impacts of Energy Production

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Introduction

- The amount of energy consumed per capita – standard of living. Demand for energy increases accordingly
- Most of our energy is currently produced from fossil fuels – increase of CO_2 production
- Increase of CO_2 – global warming, climate changes
- Current reserves of fossil fuels: Oil - 40 years, Gas - 60 years, Coal - 120 years
- The alternatives are expensive at present – little economic incentive to reduce consumption of fossil fuels

Environmental Impacts

- Production and consumption of almost any type of energy have environmental impacts.
- Harvesting of fuel-wood, in particular, contributes to deforestation, soil erosion, and desertification.
- Use of fuel-wood as an energy source can also contribute to the accumulation of CO_2, the main greenhouse gas, both because burning fuel-wood produces CO_2, and because deforestation destroys an important CO_2 sink.
- Use of biomass in traditional stoves exposes the users, mainly women and children, to high levels of indoor air pollution.
- The environmental consequences of energy production and use also adds on to waste management.

CO_2 Release due to Fossil Fuel Consumption

- Global combustion of fossil fuels and other materials places almost 7 billion tons of carbon, in the form of carbon dioxide into the atmosphere each year.

- On average, Earth's oceans, trees, plants and soils absorb about *one-half* of this carbon. The balance remains in the air and is responsible for the annual increase.

Environmental issues of Global significance

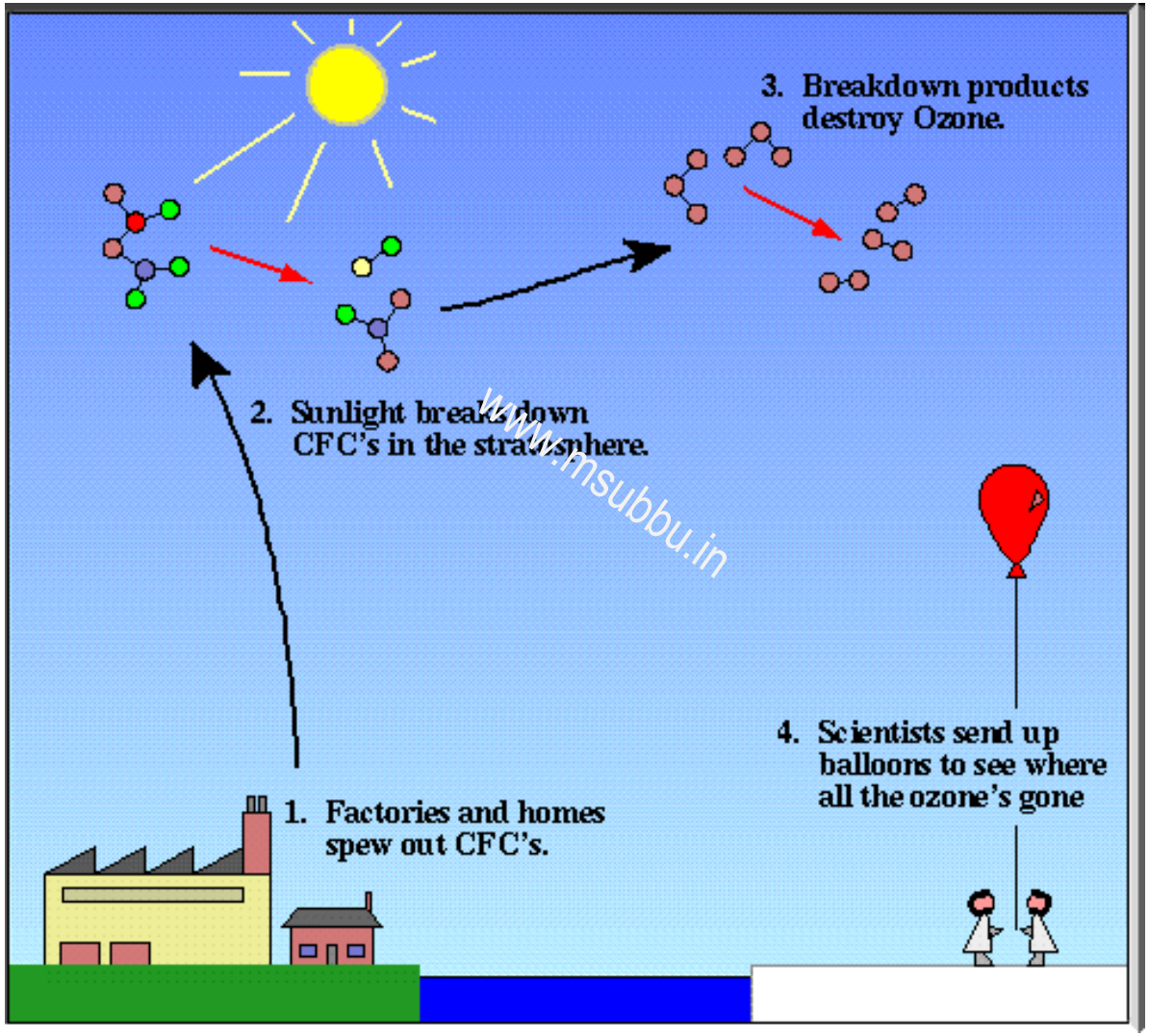
- Ozone Layer Depletion
- Global Warming
- Loss of Biodiversity
- Air and water pollution
- Land Degradation

Ozone Layer Depletion

Ozone Layer

- Ozone is a natural gas that exists in large quantities in the stratosphere, which is one of the upper layers of the Earth's atmosphere.
- There, ozone works to protect life on earth by absorbing ultraviolet (UV-B) rays and other harmful rays from the sun.
- Ozone layer and lies between 15 & 50 kilometers up in the earth's atmosphere.
- Ozone layer depletion is the process of reduction in thickness of the layer due to the presence of CFC's and related compounds.

Ozone Layer Depletion Process



More About Ozone Layer

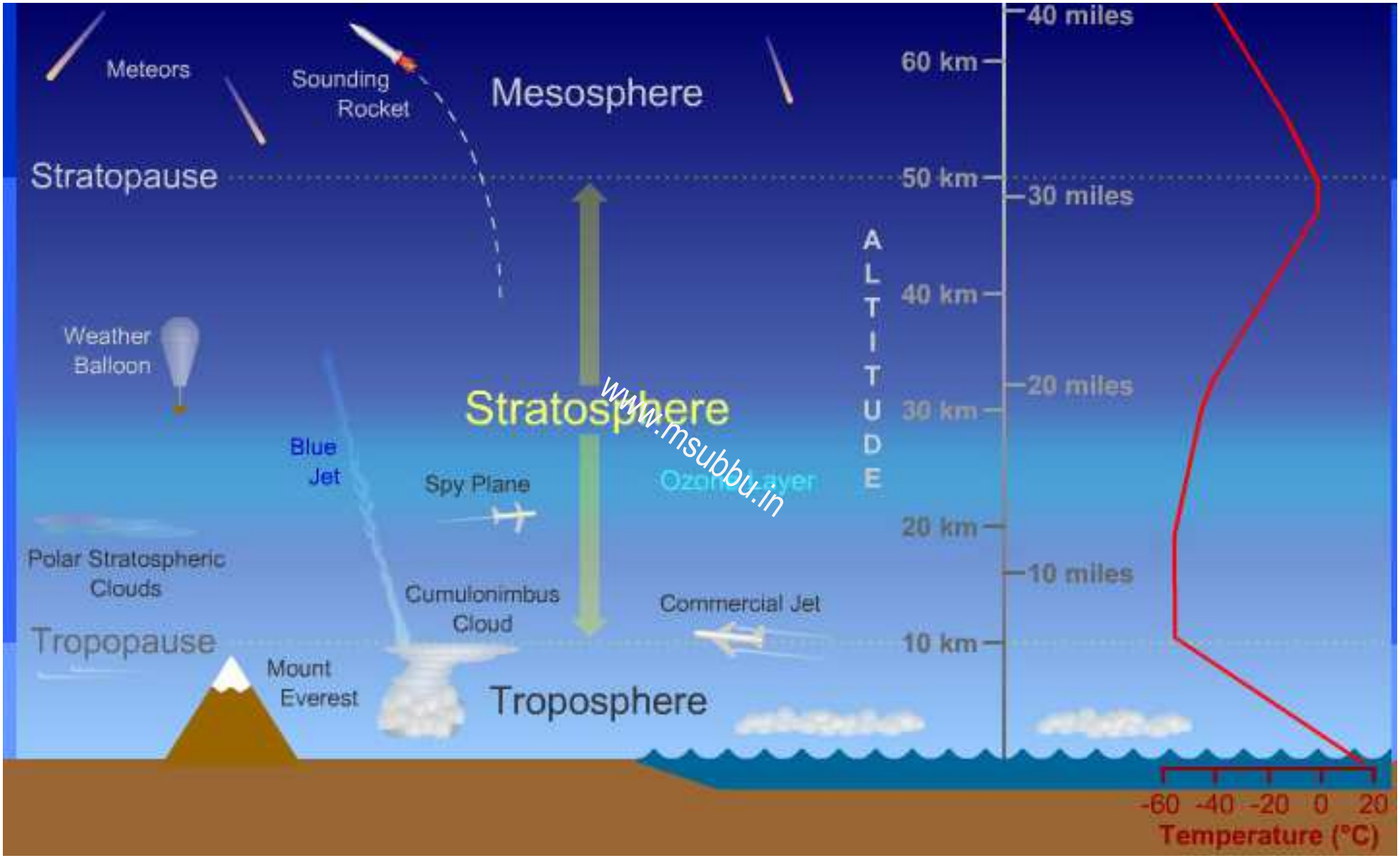
- The ozone layer comprises the greater part of the stratosphere between altitudes of 10 and 50 km. The highest concentration of ozone is reached between 15 and 30 km.

- The concentration of ozone molecules is 10 parts ozone per 1 million parts air. Ozone, which is a form of oxygen, forms naturally from the dissociation (splitting) of oxygen molecules by ultraviolet radiation.

- The average thickness of the ozone layer is about 50 km but if compressed by sea-level pressures, it would be only a few centimeters thick.

- The Dobson Unit (DU) is a scale for measuring the total amount of ozone occupying a column of air. One DU is defined as 0.01 mm thickness at zero degrees Celsius and one atmosphere.

- If the ozone layer over the US were subjected to 0°C and 1 atmosphere it would end up being 3 mm thick or 300 DU.


Meteors
Sounding Rocket
Mesosphere
Stratopause
Weather Balloon
Stratosphere
Blue Jet
Spy Plane
Ozone layer
Polar Stratospheric Clouds
Cumulonimbus Cloud
Commercial Jet
Tropopause
Mount Everest
Troposphere
ALTITUDE
60 km
50 km
40 km
30 km
20 km
10 km
40 miles
30 miles
20 miles
10 miles
-60 -40 -20 0 20
Temperature (°C)
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Impacts of Ozone layer depletion

- Effect on Human and animal health:
  - Increase incidences of eye diseases, skin cancer and infectious diseases.
- Effect on Terrestrial Plants:
  - Physiological and development process of plants affected
- Effect on Aquatic Eco systems:
  - Reduced survival rates of Phytoplankton communities (which form the foundation of aquatic web) and damage to early development of aquatic species.
- Effect on Bio-geo-chemical Cycles:
  - Affect terrestrial and aquatic bio chemical cycles thus altering both sources and sinks of GHG. These changes will contribute to the likely built up of these gases.
- Effect on Air quality
  - Higher photo dissociation rates of key trace gases and faster degradation of polymeric material (plastics) .

Global Warming

What is Global Warming and Climate Change?

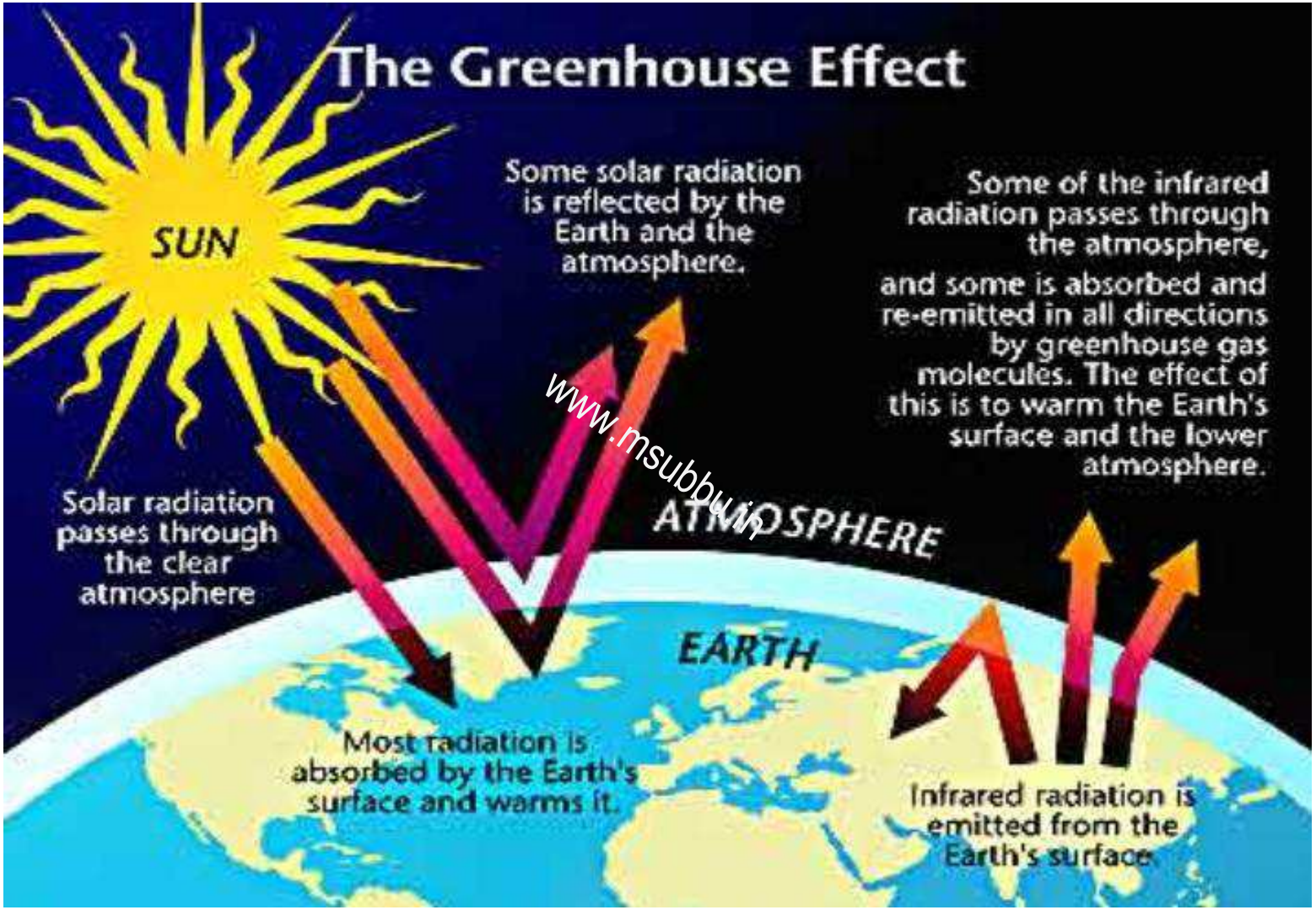
- Global warming and climate change refer to an increase in average global temperatures
- Natural events and human activities are believed to be contributing to an increase in average global temperatures
- This is caused primarily by increases in "greenhouse" gases such as Carbon Dioxide (CO_2)

What is Greenhouse Effect?

- Energy from the sun drives the earth's weather and climate, and heats the earth's surface. In turn, the earth radiates energy back into space

- Some atmospheric gases (water vapor, carbon dioxide, and other gases) trap some of the outgoing energy, retaining heat somewhat like the glass panels of a greenhouse; These gases are therefore known as greenhouse gases.

- The greenhouse effect is the rise in temperature on Earth as certain gases in the atmosphere trap energy.


The Greenhouse Effect
SUN
Some solar radiation is reflected by the Earth and the atmosphere.
Some of the infrared radiation passes through the atmosphere,
and some is absorbed and re-emitted in all directions by greenhouse gas molecules. The effect of this is to warm the Earth's surface and the lower atmosphere.
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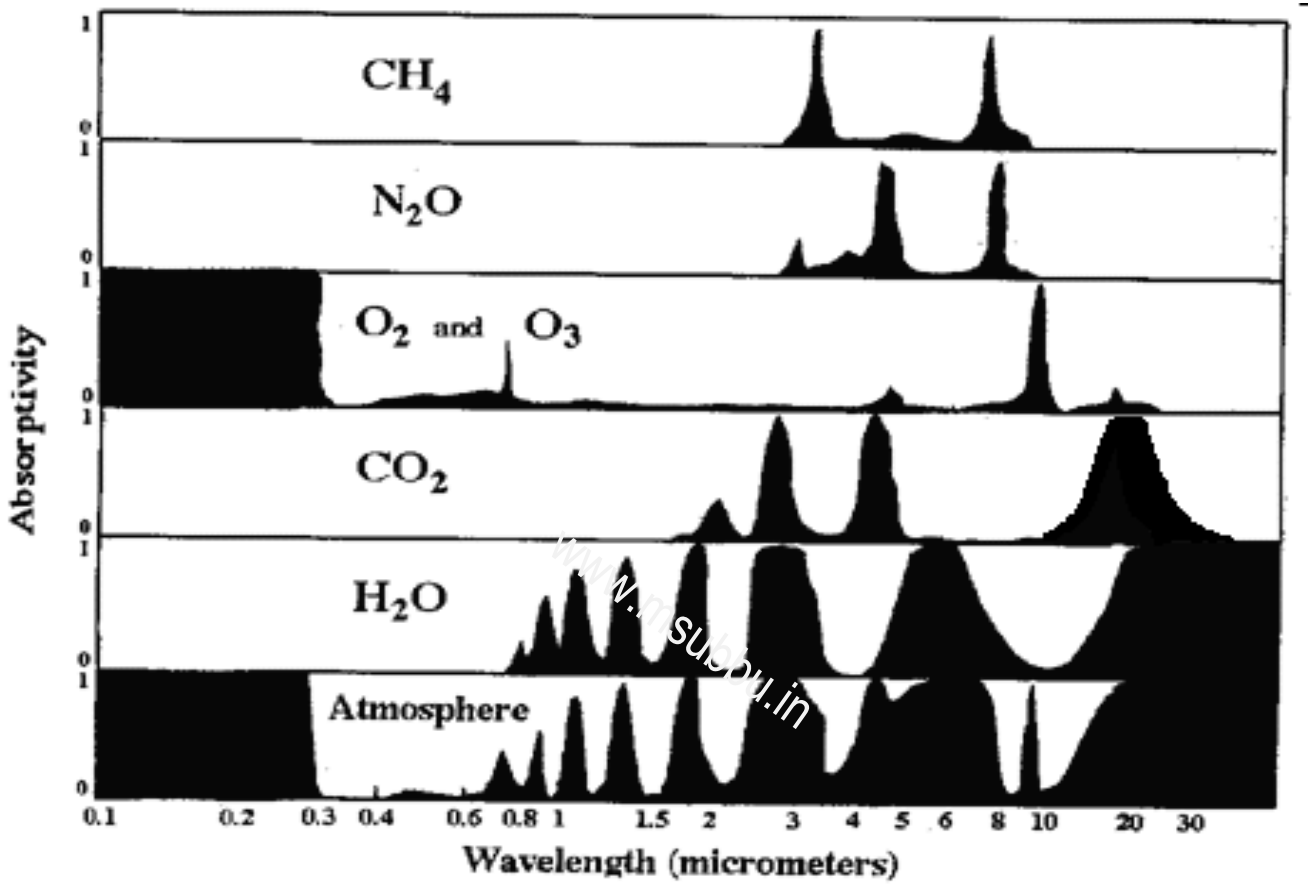
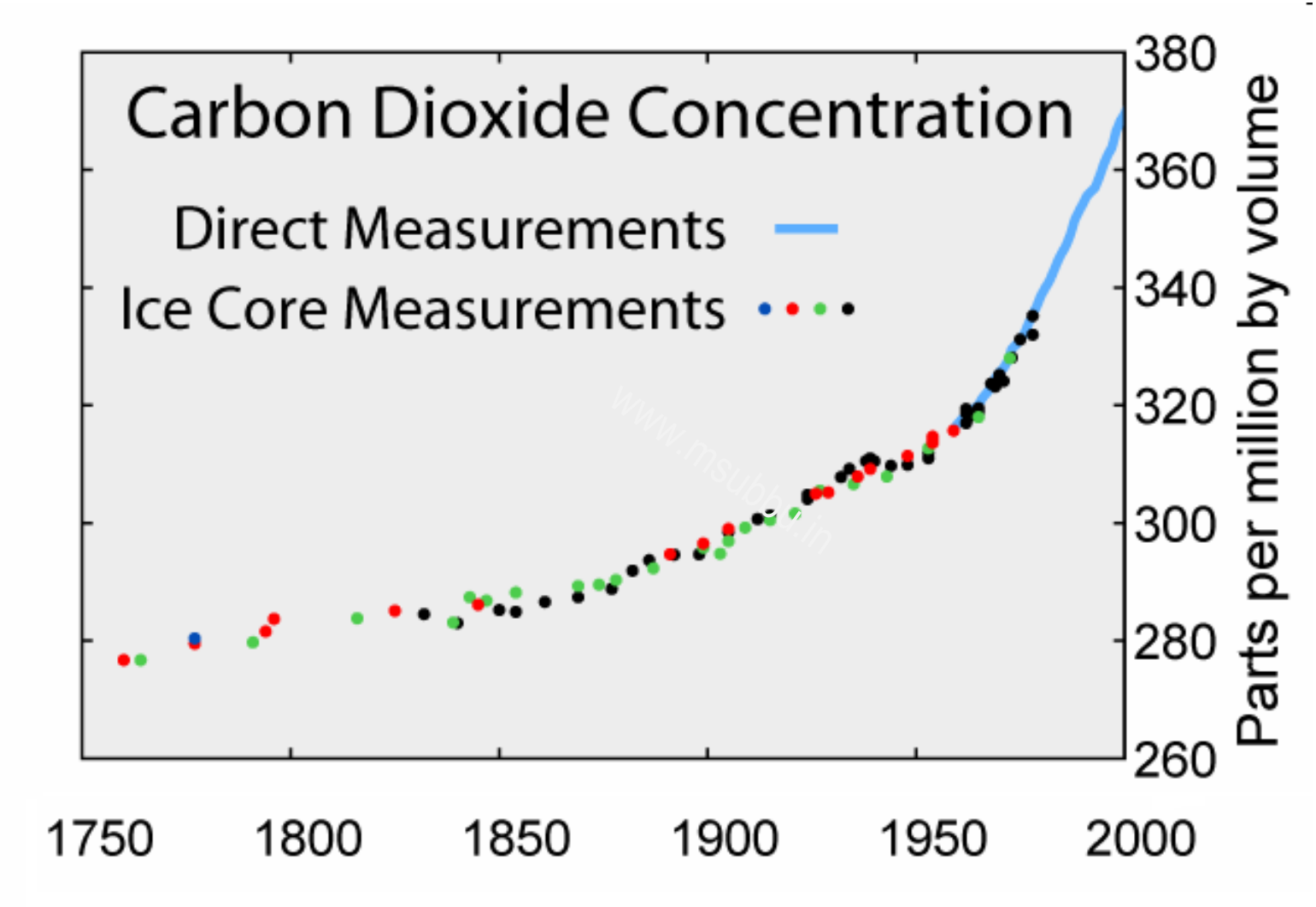
Solar radiation passes through the clear atmosphere
ATMOSPHERE
EARTH
Most radiation is absorbed by the Earth's surface and warms it.
Infrared radiation is emitted from the Earth's surface



Absorptivity of various gases of the atmosphere and the atmosphere as a whole as a function of the wavelength of radiation. An absorptivity of zero means no absorption while a value of one means complete absorption. The dominant absorbers of infrared radiation are water vapor (H_2O) and carbon dioxide (CO_2). Oxygen (O_2) and ozone (O_3) absorb much of the sun's ultraviolet radiation.

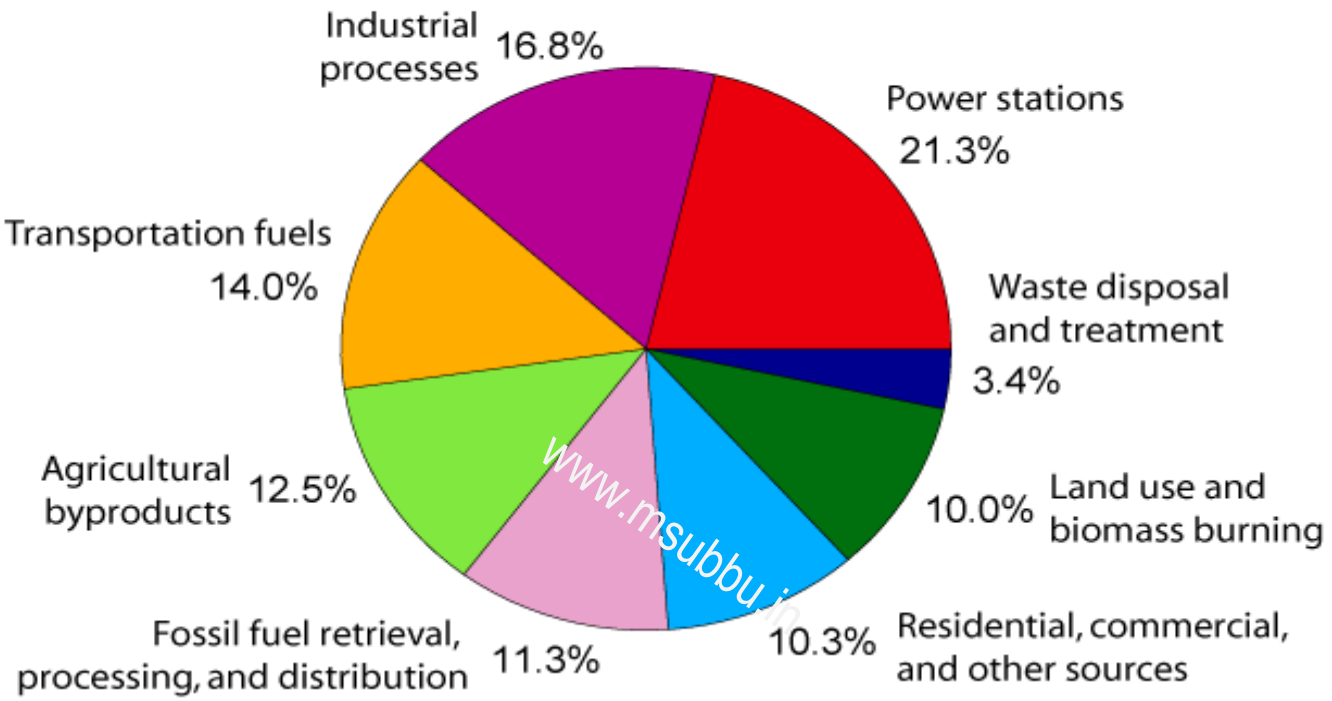

Carbon Dioxide Concentration
Direct Measurements
Ice Core Measurements
380
360
340
320
300
280
260
Parts per million by volume
1750
1800
1850
1900
1950
2000

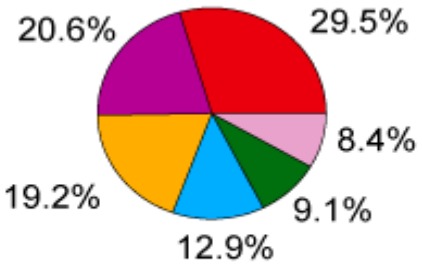
Greenhouse Gases

- Six main greenhouse gases are:
  - carbon dioxide (CO_2)
  - methane (CH_4) (which is 20 times as potent a greenhouse gas as carbon dioxide)
  - nitrous oxide (N_2O), plus
  - three fluorinated industrial gases:
    - hydrofluorocarbons (HFCs),
    - perfluorocarbons (PFCs) and
    - sulphur hexafluoride (SF_6).

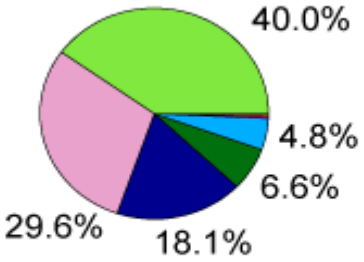
Gas	Pre-industrial Level	Current Level	Increase since 1750
Carbon dioxide	280 ppm	387ppm	104 ppm
Methane	700 ppb	1,745 ppb	1,045 ppb
Nitrous oxide	270 ppb	314 ppb	44 ppb
CFC-12	0	533 ppt	533 ppt

Annual Greenhouse Gas Emissions by Sector

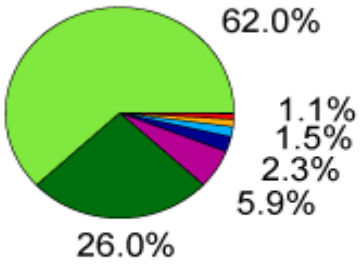




Carbon Dioxide
(72% of total)



Methane
(18% of total)



Nitrous Oxide
(9% of total)

The Greenhouse effect is natural. What do we have to do with it?

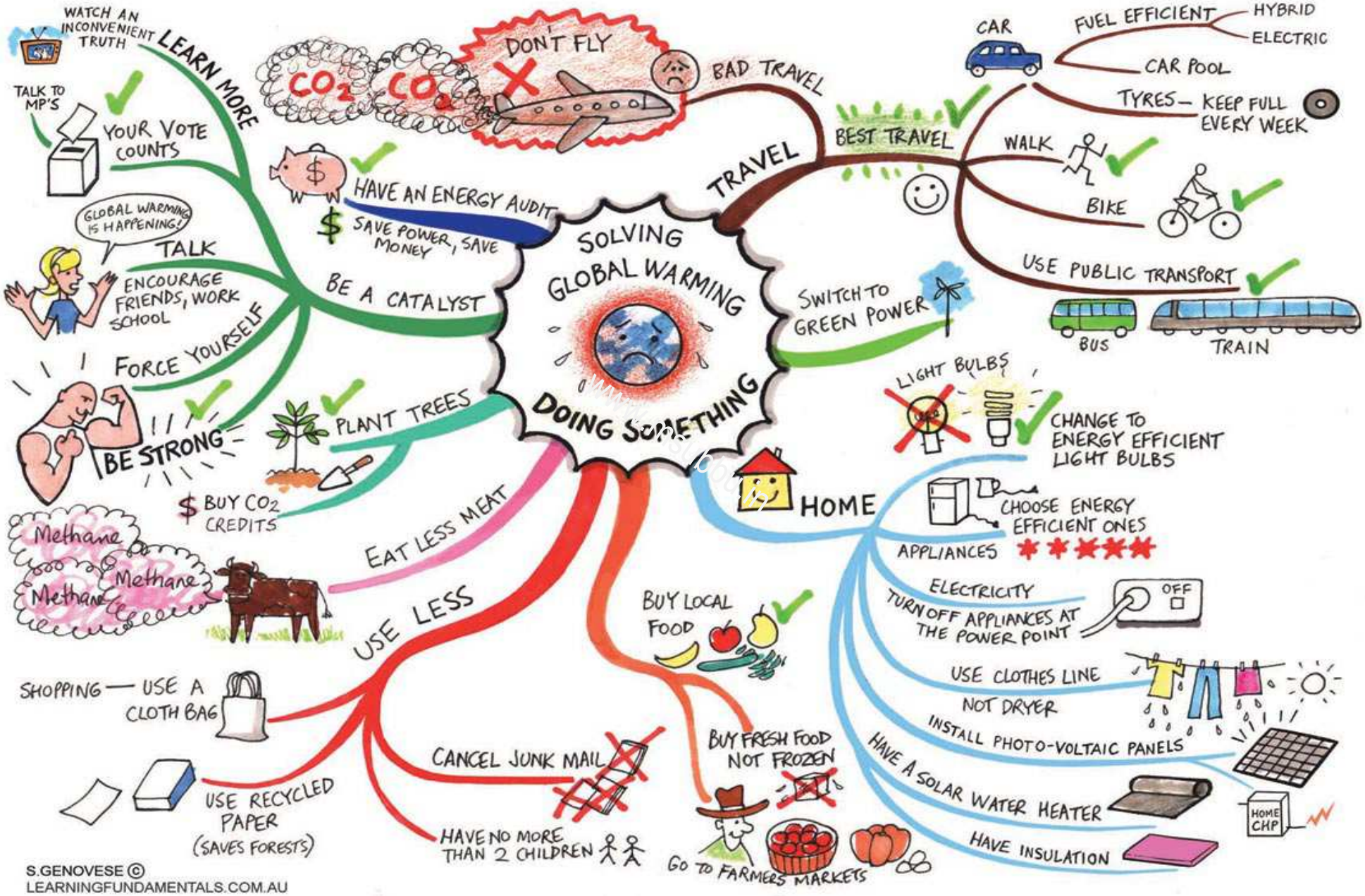
- Many of these greenhouse gases are actually life-enabling, for without them, heat would escape back into space and the Earth's average temperature would be a lot colder.

- However, if the greenhouse effect becomes stronger, then more heat gets trapped than needed, and the Earth might become less habitable for humans, plants and animals.

- Carbon dioxide, though not the most potent of greenhouse gases, is the most significant one. Human activity has caused an imbalance in the natural cycle of the greenhouse effect and related processes

Impacts of Global Warming

- Rapid changes in global temperature
- Extreme Weather Patterns
  - More hurricanes or drought
  - Longer spells of dry heat or intense rain
  - Scientists have pointed out that Northern Europe could be severely affected with *colder* weather if climate change continues, as the arctic begins to melt and send fresher waters further south. It would effectively cut off the Gulf Stream that brings warmth from the Gulf of Mexico, keeping countries such as Britain warmer than expected
- Ecosystem Impacts
- Rising sea levels
- Increasing ocean acidification
- Increase in pests and disease
- Failing agricultural output; Increase in World hunger


SOLVING GLOBAL WARMING
DOING SOMETHING
LEARN MORE
WATCH AN INCONVENIENT TRUTH
TALK TO MP'S
YOUR VOTE COUNTS
BE A CATALYST
GLOBAL WARMING IS HAPPENING!
TALK
ENCOURAGE FRIENDS, WORK SCHOOL
FORCE YOURSELF
BE STRONG
HAVE AN ENERGY AUDIT
SAVE POWER, SAVE MONEY
PLANT TREES
BUY CO_2 CREDITS
EAT LESS MEAT
Methane
Methane
Methane
USE LESS
SHOPPING — USE A CLOTH BAG
USE RECYCLED PAPER (SAVES FORESTS)
CANCEL JUNK MAIL
HAVE NO MORE THAN 2 CHILDREN
BUY LOCAL FOOD
BUY FRESH FOOD NOT FROZEN
GO TO FARMERS MARKETS
CO_2
CO_2
DON'T FLY
BAD TRAVEL
TRAVEL
BEST TRAVEL
CAR
FUEL EFFICIENT
HYBRID
ELECTRIC
CAR POOL
TYRES — KEEP FULL EVERY WEEK
WALK
BIKE
USE PUBLIC TRANSPORT
BUS
TRAIN
SWITCH TO GREEN POWER
HOME
LIGHT BULBS
CHANGE TO ENERGY EFFICIENT LIGHT BULBS
CHOOSE ENERGY EFFICIENT ONES
APPLIANCES
ELECTRICITY
TURN OFF APPLIANCES AT THE POWER POINT
OFF
USE CLOTHES LINE
NOT DRYER
INSTALL PHOTO-VOLTAIC PANELS
HAVE A SOLAR WATER HEATER
HOME CHP
HAVE INSULATION
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Differences in Greenhouse Gas Emission around the World

- In terms of historical emissions, industrialized countries account for roughly 80% of the carbon dioxide buildup in the atmosphere to date.
- Since 1950, the U.S. has emitted a cumulative total of roughly 50.7 billion tons of carbon, while China (4.6 times more populous) and India (3.5 times more populous) have emitted only 15.7 and 4.2 billion tons respectively (although their numbers will rise).
- Annually, more than 60 percent of global industrial carbon dioxide emissions originate in industrialized countries, where only about 20 percent of the world's population resides.

Differences in Greenhouse Gas Emission around the World (contd.)

- Much of the growth in emissions in developing countries results from the provision of *basic human needs for growing populations*, while emissions in industrialized countries contribute to growth in a standard of living that is already far above that of the average person worldwide

- The United States is the World's Largest Emitter of Greenhouse Gases Per Capita

- Around 2007, China surpassed the US as the world's largest emitter of greenhouse gases in terms of total output. Per person ("per capita"), however, China's emissions are much smaller.

Control Measures

Montreal Protocol

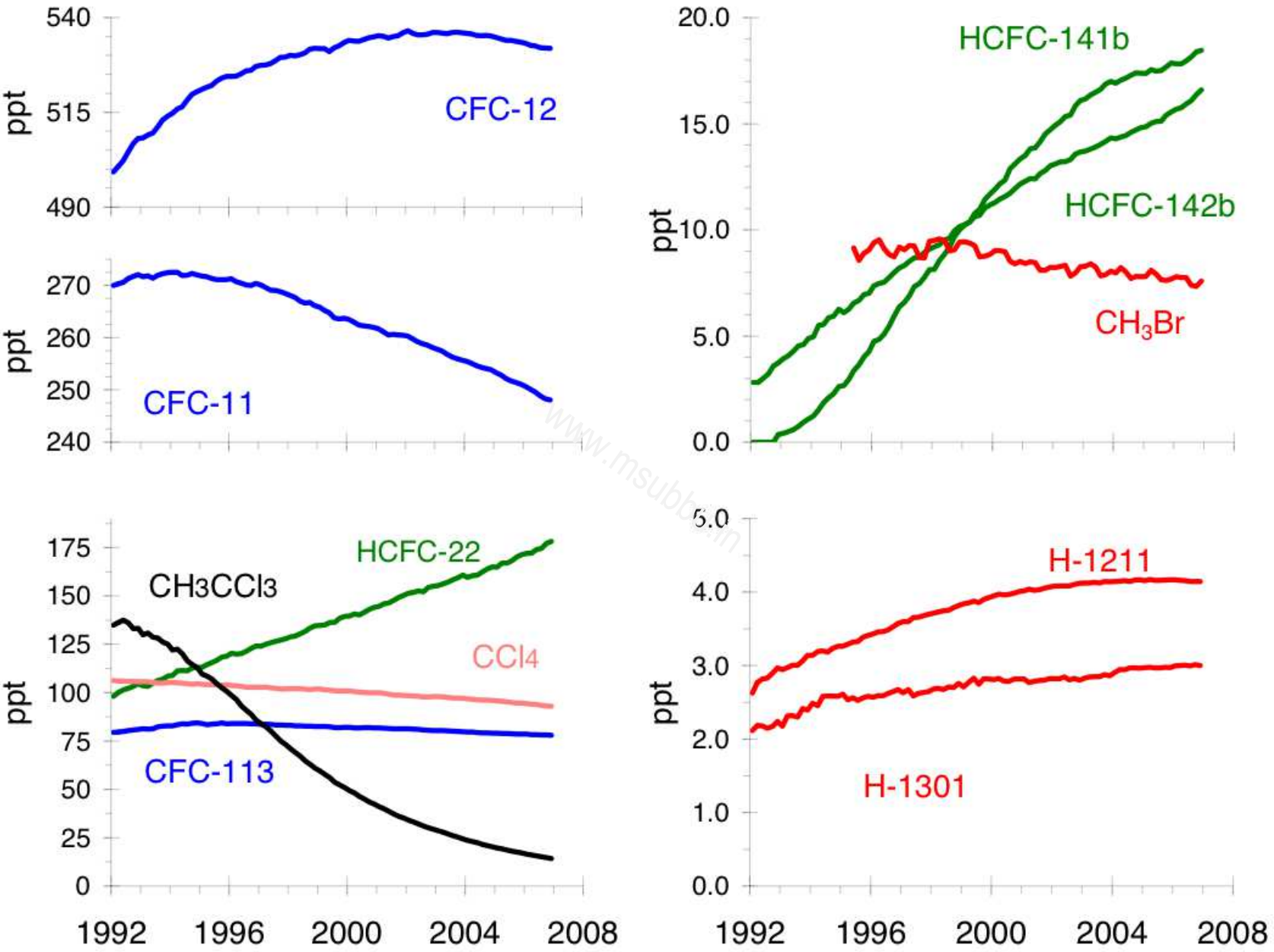
- Discovery of ozone hole – 1985.
- Montreal Protocol - International treaty to protect the ozone layer by phasing out the production of numerous substances believed to be responsible for ozone depletion. Came into force from 1989
- It is believed that if the international agreement is adhered to, the ozone layer is expected to recover by 2050
- Due to its widespread adoption and implementation it has been hailed as an example of exceptional international co-operation with Kofi Annan quoted as saying that "perhaps the single most successful international agreement to date has been the Montreal Protocol".

Fig. 3.4 Countries that have ratified the Montreal Protocol in green.

Afganistan, Cambodia, Somalia, Iraq, …

Implementation of Montreal Protocol

- A series of stepped limits on CFC use and production.
- Complete phase out of CFCl3 (CFC-11), CF2Cl2 (CFC-12), C2F3Cl3 (CFC-113), C2F4Cl2(CFC-114), C2F5Cl (CFC-115) by 1996.
- There is a slower phase-out (to zero by 2010) of other substances (halon 1211, 1301, 2402; CFCs 13, 111, 112, etc) and some chemicals get individual attention (Carbon tetrachloride; 1,1,1-trichloroethane).
- The phasing-out of the less active HCFCs started only in 1996 and will go on until a complete phasing-out is achieved in 2030.
- Since the Montreal Protocol came into effect, the atmospheric concentrations of the most important chlorofluorocarbons and related chlorinated hydrocarbons have either leveled off or decreased



Kyoto Protocol

- The objective is the "stabilization and reconstruction of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system

- The Kyoto Protocol was the climate change treaty negotiated in 1997, setting targets for emissions of greenhouse gases.

- 1997, at the Conference of Parties III (COP3), Kyoto, Japan, the Kyoto conference on climate change took place. There, developed countries agreed to specific targets for cutting their emissions of greenhouse gases

- In order to be binding under international law, the treaty would need ratification from the countries responsible for around 55% of the global greenhouse gas emissions of 1990.

- The United Nations Framework Convention on Climate Change agreed to a set of a common but differentiated responsibilities.

Implementing Kyoto Protocol

- Industrialized countries were committed to an overall reduction of emissions of greenhouse gases to 5.2% below 1990 levels for the period 2008 - 2012
- National limitations range from 8% reductions for the European Union and some others to 7% for the United States, 6% for Japan, and 0% for Russia. The treaty permitted GHG emission increases of 8% for Australia and 10% for Iceland
- Came into force from 2005
- Some opponents of the Convention argue that the split between Annex I and developing countries is unfair, and that both developing countries and developed countries need to reduce their emissions unilaterally.
- Some countries claim that their costs of following the Convention requirements will stress their economy.

Flexible Mechanisms of Kyoto Protocol

- **Emission trading** - is an administrative approach used to control pollution by providing economic incentives for achieving reductions in the emissions of pollutants. It is sometimes called *cap and trade*

- **Clean Development Mechanism** - is an arrangement under the Kyoto Protocol allowing industrialized countries with a greenhouse gas reduction commitment to invest in projects that reduce emissions in developing countries as an alternative to more expensive emission reductions in their own countries