CHAPTER 7.

E-Waste : Generation And Management

7.1 E-WASTE :

'e-waste' means electrical and electronic equipment, whole or in part discarded as waste by the consumer or bulk consumer as well as rejects from manufacturing, refurbishment and repair processes.

Rapid growth of technology, upgradation of technical innovations, and a high rate of obsolescence in the electronics industry have led to one of the fastest growing waste streams in the world which consist of end of life electrical and electronic equipment product such as : Refrigerator, Washing machines, Computers and Printers, Televisions, Mobiles, Ipods etc. Many of which contain toxic materials.

E-waste (Management) Rules, 2016, were published by the Government of India, Ministry of Environment, Forest and Climate Change. [Amended in 2018].

7.2 CLASSIFICATION OF E-WASTE [SOURCES OF E-WASTE] :

E-waste composed of discarded electrical and electronic appliances which have reached the end of their life and no longer serve the purpose they were intended for.

Categories of electrical and electronic equipment covered under the e-waste management rules,2016 are:

(I) Information technology and telecommunication equipment :

Centralized data processing: Mainframes, Minicomputers

Personal Computing: Personal Computers (Central Processing Unit with input and output devices)

Personal Computing: Laptop Computers (Central Processing Unit with input and output devices)

Personal Computing: Notebook Computers

Personal Computing: Notepad Computers

Printers including cartridges

Copying equipment

Electrical and electronic typewriters

User terminals and systems

Facsimile

Telex

Telephones

Pay telephones

Cordless telephones

Cellular telephones

Answering systems

(II) Consumer electrical and electronics:

Television sets (including sets based on (Liquid Crystal Display and Light Emitting Diode technology)

Refrigerator

Washing Machine

Air-conditioners excluding centralized air conditioning plants

Fluorescent and other Mercury containing lamps.

7.3 CONSTITUENT MATERIALS OF E-WASTE :

Various elements and substances contained in e-waste are as under:

1. Useful metals like-iron, steel, copper, aluminum.
2. Precious metals like-platinum, gold, silver.
3. Hazardous materials like- mercury, lithium, barium, radioactive isotopes.
4. Toxic substances like- Dioxins, polychlorinated biphenyls (PCBs), Lead, Zinc, Cadmium.
5. Plastics like- High Impact Polystyrene (HIPS), Acrylonitrile Butadiene Styrene (ABS), Polycarbonate (PC).
6. Glass materials like- Cathode Ray Tube (consists of glasses such as SiO, CaO, NaO).

E-waste mainly consists of Ferrous & Non-ferrous Metals, Plastics, Glass, Wood etc.

Iron & Steel	- 50%
Plastics	- 21%
Non-ferrous metal	
Mercury, Arsenic, Lead etc.	- 13%

7.4 E-WASTE GENERATION IN INDIA:

India has emerged as fourth largest electronic waste producer in the world. Computer devices account for nearly 70% of e-waste, with the contribution of telecom sector being 12%, medical equipment being 8%, and electric equipments being 7% of the annual e-waste production.

Projection by International Association of Electronic Recycler (IAER).

- 3 billion electronic and electrical appliances became e-waste in 2010.
- Globally about to 20 – 50 million tons of E-Waste is disposed of each year.
- Which accounts for 5% of all Municipal Solid Waste.

According to Comptroller and Auditor-General's (CAG) Report, over 7.2 MT of Industrial Hazardous Waste, 4 lakh Tones of electronic waste, 1.5 MT of Plastic waste, 1.7 MT of medical waste and 48 MT of municipal waste are generated in the country annually.

- CPCB has estimated that E-Waste exceeded 8 lakh tones mark in 2012.
- Annual growth rate of E-Waste generation – 10%
- There are 10 states that contribute to 70% of the total E-Waste generated in the country.
- 65 cities generate more than 60% of the total E-Waste in India.
- Among the top ten cities generating E-Waste, Mumbai ranks first followed by Delhi, Bengaluru, Chennai, Kolkata, Ahmedabad, Hyderabad, Pane, Surat & Nagpur.
- Maharashtra ranks first in generation of e-waste followed by Tamil Nadu and U.P.

- Main source of electronic waste in India are the government, public and private (Industrial) sectors – 70%.
- Contribution of individual house hold – 15%
- Rest being contributed by manufacturers.

Out of total E-Waste volume in India :

Computer devices	.....	70 %
Telecom sector	.....	12 %
Medical equipment	.....	8 %
Electrical equipment	.....	7 %

Despite 23 units currently registered with Govt. of India, Ministry of Environment and Forest / Central Pollution Control Board, as E-Waste recyclers / preprocessors, the entire recycling process more or less still exists in the unorganized sector.

Electronics waste in the Global context :

- It is estimated that more than 50MT E-Waste is generated globally every year.
- A report of the United Nations predicted that by 2020, E-Waste from old computers would jump by 400% on 2007 levels in China and by 500% in India.
- Additionally E-Waste from discarded mobile phones would be about seven times higher than 2007 levels in China and in India 18 timers higher by 2020.
- China already produces about 2.3 million tons of E-Waste domestically second only to the US with about 3 million tons.

According to the Global E-waste Monitor Report, 2017, the top 5 e-waste producing countries are as under:

Table 7.1 E- Waste generation- Top 5 Countries

Sr. No.	Country	E-waste generated (million metric tons)	E-waste Per capita (kg)
1.	China	7.2	5.2
2.	United States	6.3	19.4
3.	Japan	2.2	16.9
4.	India	2.0	1.5
5.	Germany	1.9	22.8

7.5 IMPACT OF E-WASTE ON ENVIRONMENT AND HUMAN HEALTH :

Electronic waste or e-waste is one of the rapidly growing problems of the world. E-waste comprises of a multitude of components, some containing toxic substances that can have an adverse impact on human health and the environment if not handled properly. In India, e-waste management assumes greater significance not only due to the generation of its own e-waste but also because of the dumping of e-waste from developed

countries. This is coupled with India's lack of appropriate infrastructure and procedures for its disposal and recycling.

The predictions highlight the urgent need to address the problem of E-Waste in developing countries like India where the collection and management of E-Waste and the recycling process is yet to be properly regulated. It may cause rising environmental damage and health problems if E-Waste recycling is left to the vagaries of the informal sector.

1. **Effect on Human Health :**

(i) The impact is found to be worse in developing countries like India where people engaged in recycling E-Waste are mostly in the unorganized sector, living in close proximity to dumps or landfills of untreated E-Waste and working without any protection or safe guards.

(ii) E-waste is much more hazardous than many other municipal wastes because electronic gadgets contain thousands of components made of deadly chemicals and metals like lead, cadmium, chromium, mercury, polyvinyl chlorides (PVC), brominated flame retardants, beryllium, antimony and phthalates. Long-term exposure to these substances damages the nervous systems, kidney, bones, reproductive and endocrine systems. Some of them are carcinogenic and neurotoxic.

Children are especially vulnerable to the health risks that may result from e-waste exposure and, therefore, need more specific protection. Children may be exposed through dump sites located close to their homes, schools and play areas.

2. **Effect on Environment :**

(i) Disposal of e-wastes is a critical problem faced and poses a threat to both health and vital components of the ecosystem. There are number of channels through which e-waste goes to the environment. E-waste that is land filled produces contaminated leachates, which eventually pollute the groundwater.

(ii) Acids and sludge obtained from melting computer chips, if disposed on the ground causes acidification of soil, leading to contamination of water resources.

(iii) Due to dumping of e-waste in to the land filling site, many toxic heavy metals and chemicals from e-waste enter the soils and then it follows the ' soil-crop-food pathway', which is one of the most significant routes for heavy metals exposure to humans.

(iv) Incineration of e-wastes can emit toxic fumes and gases, thereby polluting the surrounding air.

(v) Improper recycling and recovery methods can have major impacts on the environment. Crude forms of dismantling can often lead to toxic emissions, which pollute the air and thereby also expose the workers to the harmful materials.

(vi) The most dangerous form of recycling and recovery from e-waste is the open air burning of circuit boards (made of plastic) in order to recover copper,aluminum,silver and other metals. This will cause air pollution.

(vii) Extraction of metals through acid bath method or through mercury amalgamation also contributes to environmental degradation.

(vii) Burning of plastic casing of e-waste leads to liberation of toxic air pollutants.

(viii) Burning of computer monitors and other electronics produces dioxins causing cancer.

(vii) Mercury will leach when certain electronic devices, such as circuit breakers are destroyed. Not only does the leaching of mercury pose problems, the vaporization of metallic mercury and dimethylene mercury is also of concern.

Table 7.2 Pollutants and their occurrence in waste electrical and electronic equipment

Pollutant	Occurrence	Environmental and Health relevance
Liquid crystal	Displays	
Lithium	Mobile telephones, Photographic equipments, video equipments, batteries	may develop explosive gases (hydrogen) if wetted
Mercury	Components of Copper machines and steam irons, batteries in clocks and pocket calculators, switches, LCDs	acutely poisonous and injurious to health
Nickel	Alloys, batteries, relays, semiconductors, pigments	may cause allergic reactions
PCBs (poly chlorinated biphenyls)	Transformers, capacitors, softening agents for paints, glue, plastic	
Selenium	Photoelectric cells, pigments, photo copiers, fax machines	
Silver	Capacitors, Switches (contacts) batteries, resistors	
Zinc	Steel, brass, alloys, disposable and rechargeable batteries, luminous substances	toxic when inhaled
Arsenic	Semiconductors, diodes, microwaves, LEDs (light emitting diodes), solar cells	acutely poisonous and on a long-term perspective injurious to health
Barium	Electron tubes, filler of plastic and rubber, lubricant additives	may develop explosive gases (hydrogen) if wetted
Brominated flame proofing agent	Casings, circuit boards (plastic), cables and PVC cables	
Cadmium	Batteries, pigments, solders, alloys, circuit boards, computer batteries, monitor, cathode ray tubes (CRTs)	acutely poisonous and injurious to health
Chrome	Dyes/ Pigments, Switches, Solar	
Cobalt	Insulator	
Copper	Conductor Cables, copper ribbons, coils, circuitry, Pigments	
Lead	Lead reachable batteries, solar, transistors, lithium batteries, PVC (polyvinyl chloride), stabilizers lasers, LEDs, thermo electrical elements, circuit boards	causes damage to the nervous system, circulatory system

7.6 MANAGEMENT OF E-WASTE :

Role of Government :

The responsibility of the Government in e-waste management is to provide adequate system of laws, controls and administration. The Government should set up administrative agency to implement the set rules.

E-waste (Management) Rules, 2016, were published by the Government of India, the Ministry of Environment, Forest and Climate Change.

These rules shall apply to every manufacturer, producer, consumer, bulk consumer, collection centers, dealers, e-retailer, refurbisher, dismantler and recycler involved in manufacture, sale, transfer, purchase, collection, storage and processing of e-waste or electrical and electronic equipment listed in Schedule I, including their components, consumables, parts and spares. Central Pollution Control Board (CPCB), New Delhi, is the agency responsible for implementation of these rules.

These rules also includes Extended Producer Responsibility (EPR) in which a manufacturer of the product is responsible for post consumer stage of the product's life cycle, including its final disposal.

At present 90 % of recycling of e-waste in India is carried out by the informal sector. This practice should be stopped and e-waste recycling by certified recyclers should be ensured.

Responsibilities of the manufacturer :

'Manufacturer' means a person or an entity or a company which has facilities for manufacture of electrical and electronic equipment.

(1) Collect e-waste generated during the manufacture of any electrical and electronic equipment and channelize it for recycling or disposal.

(2) Ensure that no damage is caused to the environment during storage and transportation of e-waste.

(4) Maintain records of the e-waste generated, handled and disposed in Form-2.

Responsibilities of the producer :

'Producer' means any person who, irrespective of the selling technique used such as dealer, retailer, e-retailer, etc, manufactures and offers to sell electrical and electronic equipment and their components or consumables or parts or spares.

(1) Implementing the Extended Producers Responsibility with the following frameworks, namely, - collection and channelization of e-waste generated from the 'end-of-life' of their products or 'end-of-life' products.

- For disposal in Treatment, Storage and Disposal Facility, a pre-treatment is necessary to immobilize the mercury and reduce the volume of waste to be disposed off.
- Creating awareness through media, publications, advertisements, posters, or by any other means of Communication with regard to information on hazards of improper handling, disposal, accidental breakage, damage or improper recycling of e-waste.

Responsibilities of collection centres :

(1) Collect e-waste on behalf of producer or dismantler or recycler or refurbisher including those arising from orphaned products.

(2) Ensure that the facilities are in accordance with the standards or guidelines issued by Central Pollution Control Board from time to time.

(3) Ensure that the e-waste collected by them is stored in a secured manner till it is sent to authorized dismantler or recycler as the case may be.

(4) Ensure that no damage is caused to the environment during storage and transportation of e-waste.

Responsibilities of dealers :

(1) In the case the dealer has been given the responsibility of collection on behalf of the producer, the dealer shall collect the e-waste by providing the consumer a box, bin or a demarcated area to deposit e-waste, or through take back system and send the e-waste so collected to collection centre or dismantler or recycler as designated by producer.

(2) The dealer or retailer or e-retailer shall refund the amount as per take back system or Deposit Refund Scheme of the producer to the depositor of e-waste.

(3) Every dealer shall ensure that the e-waste thus generated is safely transported to authorized dismantlers or recyclers.

(4) Ensure that no damage is caused to the environment during storage and transportation of e-waste.

Responsibilities of the recycler :

(1) Shall ensure that the facility and recycling processes are in accordance with the standards or guidelines prescribed by the Central Pollution Control Board from time to time.

(2) Ensure that no damage is caused to the environment during storage and transportation of e-waste.

(3) Ensure that the recycling processes do not have any adverse effect on the health and the environment.

(4) Make available all records to the Central Pollution Control Board or the concerned State Pollution Control Board for inspection.

(5) Ensure that the fractions or material not recycled in its facility is sent to the respective authorised recyclers.

(6) Ensure that residue generated during recycling process is disposed of in an authorised treatment storage disposal facility.

7.7 RECYCLING OF E-WASTE :

E-waste recycling is the reuse and reprocessing of electrical and electronic equipment of any type that has been discarded or regarded as obsolete. Recycling of e-waste is a growing trend and was initiated to protect human and environmental health mainly due to the widespread environmental pollution impacts of e-waste.

Recycling process of electronic waste is quite hazardous. Printed circuit boards are scrapped by acid bath and de-soldering. Plastics used to make keyboards and other components are outmoded by chemical stripping using nitric and hydrochloric acid. Copper wires used in computers are burnt and stripped in the open to obtain copper, thus resulting in severe air pollution.

Step-by Step Process of E-waste Recycling :

The e-waste recycling process is highly labor intensive and goes through several steps. Below is the step-by-step process of how e-waste is recycled,

1. **Picking Shed :**

When the e-waste items arrive at the recycling plants, the first step involves sorting all the items manually. Batteries are removed for quality check.

2. **Disassembly :**

After sorting by hand, the second step involves a serious labor intensive process of manual dismantling. The e-waste items are taken apart to retrieve all the parts and then categorized into core materials and components. The dismantled items are then separated into various categories into parts that can be re-used or still continue the recycling processes.

3. **First size reduction process :**

Here, items that cannot be dismantled efficiently are shredded together with the other dismantled parts to pieces less than 2 inches in diameter. It is done in preparation for further categorization of the finer e-waste pieces.

4. **Second size reduction process :**

The finer e-waste particles are then evenly spread out through an automated shaking process on a conveyor belt. The well spread out e-waste pieces are then broken down further. At this stage, any dust is extracted and discarded in a way that does not degrade the environmentally.

5. **Over-band Magnet :**

At this step, over-band magnet is used to remove all the magnetic materials including steel and iron from the e-waste debris.

6. **Non-metallic and metallic components separation :**

The sixth step is the separation of metals and non-metallic components. Copper, aluminum, and brass are separated from the debris to only leave behind non-metallic materials. The metals are either sold as raw materials or re-used for fresh manufacture.

7. **Water Separation :**

As the last step, plastic content is separated from glass by use of water. One separated, all the materials retrieved can then be resold as raw materials for re-use. The products sold include plastic, glass, copper, iron, steel, shredded circuit boards, and valuable metal mix.

→ **Benefits of e-waste recycling :**

* Recycling Helps Protect The Environment
* Recycling Helps Conserve Limited Resources
* Recycling Promotes Energy Efficiency
* Recycling Helps Build A Strong Economy
* Recycling Creates Jobs
* Recycling Builds Community
* Recycling Can Be Financially Rewarding

E-waste recycling companies in India :

Some of the well known e-waste recycling companies are listed below :

Attero, a Roorkee-based e-waste management company, handles almost 500 tonnes of e-waste per month. Founded by Rohan and Nitin Gupta in 2007, the company currently provides its service to nearly 100 cities

across 22 states in the country. India's electronic industry is growing by 20% annually and one can expect 800,000 tons of e-waste generated every by 2020.

Bangalore-based **E-Parisaraa Pvt Ltd** is India's first government authorized electronic waste recycle company. Started in 2005, it extracts waste such as gold and silver and converts them into industrial raw materials.

Delhi-based **Karma Recycling** has launched an e-portal to offer a simple online electronics trade-in service, which makes it easy for commoners to resell or recycle their used electronic devices. Karma Recycling is also a government-authorized electronic waste collector and segregator that puts efforts on systematic electronics reuse and responsible recycling.

→ **Reuse of recycled e-waste :**

1. **Plastic.** All the plastic materials retrieved are sent to recyclers who use them to manufacture items such as fence posts, plastic sleepers, plastic trays, vineyard stakes, and equipment holders or insulators among other plastic products.
2. **Metal.** Scrap metals materials retrieved are sent to recyclers to manufacture new steel and other metallic materials.
3. **Glass.** Glass is retrieved from the Cathode Ray Tubes (CRTs) mostly found in televisions and computer monitors. Extracting glass for recycling from CRTs is a more complicated task since CRTs are composed of several hazardous materials.
4. **Mercury.** Mercury containing devices are sent to mercury recycling facilities that uses a specialized technology for elimination for use in dental amalgams and metric instruments, and for fluorescent lighting. Other components such as glass and plastics are re-used for manufacture of their respective products.
5. **Printed Circuit Boards.** Circuit boards are sent to specialized and accredited companies where they are smelted to recover non-renewable resources such as silver, tin, gold, palladium, copper and other valuable metals.
6. **Hard Drives.** Hard drives are shredded in whole and processed into aluminum ingots for use in automotive industry.
7. **Ink and Toner Cartridges.** Ink and toner cartridges are taken back to respective manufacturing industries for recycling. They are remanufactured while those that can't are separated into metal and plastic for re-use as raw materials.
8. **Batteries.** Batteries are taken to specialized recyclers where they are hulled to take out plastic. The metals are smelted is specialized conditions to recover nickel, steel, cadmium and cobalt that are re-used for new battery production and fabrication of stainless steel.

CHAPTER

8. Global Environmental Issues

8.1 INTRODUCTION :

In the present day scenario, the world community has realised the importance of environment. Significant changes has taken place in the global ecosystem.

The factors disturbing the global ecosystem are :

1. Population explosion
2. Rapid industrialization
3. Urbanization
4. Modern life style, etc.

Population explosion has created an imbalance in demand and supply by creating huge demands for shelter, food, water and other natural and man-made resources.

Rapid industrialization has resulted in more consumption of natural resources and more degradation of environment due to pollution.

Urbanization has resulted in an imbalance in villages and cities by the migration of people towards urban areas, which has deteriorated the quality of air, water and land of urban areas.

Modern life style of the people has contributed a lot in degrading our environment.

All these factors are responsible for the following global environmental problems :

(June 2014)

1. Climate change
2. Global warming and Green house effect
3. Acid rain
4. Ozone layer depletion

8.2 SUSTAINABLE DEVELOPMENT :

[Dec. 2014, June 2016]

Sustainable development is defined as a form of development or progress that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Sustainable development is a process of betterment of life in all the sectors like economic, social, educational, health, sanitation, food and housing, national security, etc. It means, every generation should leave air, water and soil, pure and unpolluted as possible, so that the next future generation is not jeopardize of their needs. Although, it is difficult thing, it can be achieved through proper environmental management,

In 1987, the **'World Commission on Environment and Development'** made sustainable development on the theme of its report **"our common future"**. The three important components highlighted in this report are :

1. **Economic development :**

This includes,

- Utilisation of natural resources
- Industrialisation
- raising quality of life
- Agricultural developments
- Creating job opportunities

2. Social development :

This includes,

- Providing the basic needs of life like, food, drinking water, shelter, fresh air, clothes, education, health and sanitation.

3. Environmental development : [Jan. 2017]

This includes providing safe environment by means of providing clean air, water and soil.

The idea of sustainable development was strongly supported by the **Earth Summit 1992,** held at Rio de Janerio, Brazil. It was the largest environmental conference ever held attracting 30,000 people and more than 100 heads of states. UN general assembly asked for a report on progress made towards sustainable development.

Sustainable development should be a part and parcel of national development plan of each country. It can be achieved by keeping the following points in consideration :

1. Controlling population explosion.
2. Reducting the over exploitation of resources.
3. Enhancing the conservation of natural resources like water, soil, forest and energy.
4. Minimising waste production by performing recycling and reuse.
5. Enhancing the use of non-conventional energy sources like solar, wind, wave and biomass energy.
6. Use of clean production technologies.
7. Providing housing, education and health care to poor people, particularly in rural areas.
8. Encouraging the empowerment and education of women.
9. Development of industrial pollution control methods to reduce level of pollution.
10. By marking strategies for eradication of poverty.
11. Arranging tree plantation programs.

8.3 CLIMATE CHANGE :

Climate change refers to any significant change in climatic factors such as temperature, wind, precipitation, lasting for an unexpected period.

The term **climate change** is very often used inter changeably with the **global warming**. But, the term global warming refers to rise in temperature of earth, while climate change refers to other changes in addition to global warming.

➜ **Causes of climate change :**

1. Change in the sun's intensity.
2. Slow changes in the Earth's orbit around the sun.
3. Change in ocean circulation.
4. Human activities that change the composition of atmosphere and land e.g..
   - burning fossil fuels
   - deforestation
   - desertification
   - urbanization
   - industrialization, etc.

Effects of climate change :

- extreme hot and cold spells of temperature
- wet or dry spells of rainfall
- cyclones
- Floods
- rise in sea level
- global warming

Key signs of climate change :

The reports published by Intergovernmental Panel on Climat Change (IPCC) and data published by NAOO, US provides clear evidence of the climate change and key signs of climate change.

(1) **Increase in global concentration of CO_2 and other green house gases :**

The concentration of CO_2 and other green house gases (CH_4, N_2O) has increased tremendously during the last few decades. The industrial revolution has resulted in an increase in the concentration of CO_2 in the atmosphere of about 30%, from 280 ppmv around the year 1700 to a value of over 360 ppmv in year 2011.

(2) **Increase in global temperature :**

The earth's average surface temperature has risen about 0.90°C since the late 19th century. The main reason for this rise is increased CO_2 and other man-made emissions into the atmosphere. Year 2016 was the warmest year on record.

The oceans have absorbed much of this increased heat with the top 700 m of ocean showing warming of 0.30°C since 1969.

(3) **Sinking of ice sheets :**

The Greenland and Antarctic ice sheets have decreased in mass. Data from NASA's report show Greenland lost an average of 281 billion tons of ice per year between 1993 and 2016, while Antarctica lost about 119 billion tons of ice during the same period. The rate of Antarctica ice mass loss has tripled in the last decade.

(4) **Sea level rise :**

Over the period 1901 to 2010, global sea level rose by 0.19 m (about 8 inch). It is nearly double that of the last century.

8.4 GLOBAL WARMING AND GREEN HOUSE EFFECT :

[Dec. 2010, June 2011, Jan. 2013, Dec. 2014, May 2015, Jan. 2016]

The increase in the average temperature of global atmosphere is called **global warming.**

The average temperature of the global atmosphere has increased by about 1°C in the last century. The main cause of this temperature rise is the abnormal increase in the concentration of green house gases in the atmosphere.

Green House Effect : **[Jan. 2017]**

Green House is a house made of glass to have higher temperature inside compared to outside temperature. It is used particularly in cold countries to grow tender (delicate) crops. Higher growth of plants inside the house is maintained by controlling the temperature, humidity and carbon dioxide (CO_2).

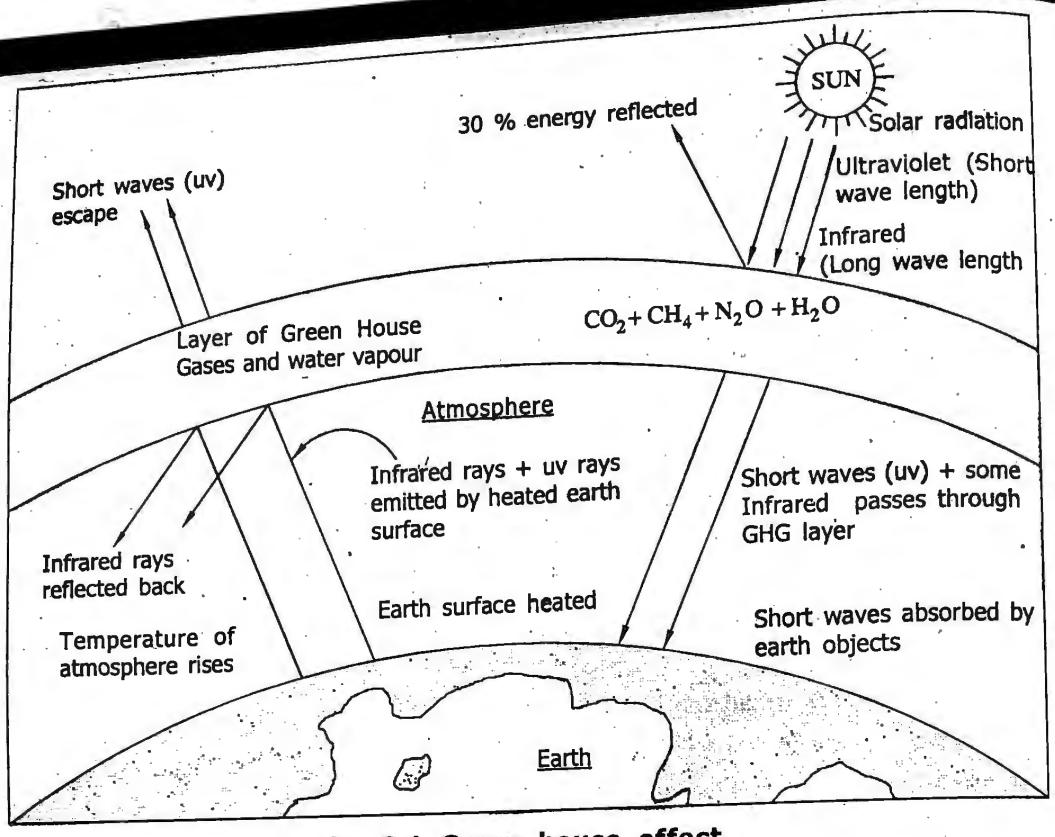


Fig. 8.1 Green house effect

Solar energy (light rays) from sun travels in the form of electro-magnetic waves as ultroviolet (short wavelength) radiations and infrared (long wavelength) radiations.

The short wave length radiations passes through the glass and are absorbed by the objects. In being thus absorbed, it is converted into heat energy, which is given off in the form of infrared radiations. Unlike short wave length radiations, infrared radiations (long wavelength) are prevented by glass walls from escaping. The trapped heat energy causes the inside air temperature to rise and keeps it warmer than the surroundings. This phenomenon is known as **green house effect.**

e.g. The heating of the car sitting in the sun is an example of green house effect.

In absence of green house effect, the average, temperature of earth surface would be (– 19°C) instead of present 15°C.

➜ **Earth as green house :**

Almost similar phenomenon takes place in the atmosphere where green house gases like carbon dioxide, methane, nitrous oxide, chloro fluoro carbons (CFC), ozone and water vapours act like a glass in the green house. Solar radiations in the form of long wave and in the short wave are absorbed by the earth's surface and converted to heat energy and emitted into the space as long wave radiation. The green house gases present in the atmosphere absorbs re-radiated long wave radiation and send them back and heat the earth's surface to maintain the temperature.

Most of the incoming short wave solar radiations are of 0.2 to 4 μm range which becomes long wave radiations (range 4 to 100 μm) after getting reflected by the earth. It is found that between the wavelengths of around 7 to 12 μm, absorption of reflected radiations is almost nil which is called **atmospheric window.**

Thus, a maximum of radiations absorbed by green house gases heat the atmosphere and a very little is passed to escape into space. Therefore, if the atmosphere had been free from green house gases then the earth would have been very cold because of complete radiation lost from atmosphere to space.

Green House Gases (GHG) : **[Jan. 2010, May 2015, June 2017]**

The green house effect is caused by gases in the atmosphere which have the ability to absorb the sun's energy that is usually radiated back into space from the earth. These gases are popularly known as the **green house gases.**

The major green house gases are :

1. Carbon dioxide (CO_2)
2. Methane (CH_4)
3. Nitrous Oxide (N_2O)
4. Chloro Fluoro Carbon (CFC)
5. Ozone (O_3)
6. Water vapour

1. Carbon dioxide (CO_2) :

Carbon dioxide contribute about 55 - 60% to global warming. It is released to the atmosphere by burning of fossil fuels (oil, natural gas and coal), respiration process of animals and plants, deforestation, decay of organic matter, etc.

The level of CO_2 has increased from 280 ppm to 370 ppm in the last five decades. It's residence time in the atmosphere is 100 years. The weighting assigned to it is unity, that is 1.

2. Methane (CH_4) :

Methane is second important gas responsible for global warming. It's contribution is about 18-20% to global warming. It is produced by the anaerobic decomposition of organic waste water and sludge by anaerobic bacteria called methanogens.

It is produced from dumped garbage, wetlands, biomass burning, petroleum exploration sites, agricultural rice fields, organic municipal wastes etc.

The concentration of methane in air is less than 2 ppm. However, its potential of global warming is very high and its weighting is 21, i.e. it is 25 times more powerful as compared to CO_2. It's residence time in the atmosphere is 12 years.

3. Nitrous Oxide (N_2O) :

Nitrous oxide is also known as laughing gas. Contribution of this gas towards global warming is about 6%.

Its main resources are agricultural activities, industrial activities, combustion of solid waste and combussion of fossil fuels. It is produced by the breakdown of nitrogen rich fertilizers in the soil and nitrate contaminated ground water, burning of nitrogen rich fuels, live stock waste and during nylon production.

The atmospheric concentration of nitrous oxide is 0.3 ppm. The residence time in the atmosphere is 120

4. Chloro Fluoro Carbon (CFCs) :

CFCs are highly stable, non-flammable man-made gaseous compounds of carbon and halogens. Major sources of CFCs are leaking of air conditioners, refrigeration units, cleaning of electronic components, production of plastic foams, spraying paints, etc.

CFC is a combination of carbon, hydrogen fluorine and chlorine. CFC-11 and CFC-12 are the most commonly used CFCs.

They have tremendous potential of global warming, some 12,000 to 16,000 times as compared to carbon dioxide. The atmospheric concentration of CFCs is 0.00225 ppm and is increasing at the rate of 0.5% annually.

5. Ozone (O_3) :

In the troposphere, ozone is a secondary pollutant. It is formed by the reaction of atomic oxygen with oxygen gas in the presence of nitrogen.

Ozone has strong absorption band at 9 µm and is quite unstable in troposphere. The contribution of ozone towards global warming is about 8%.

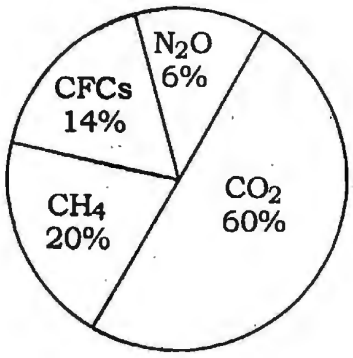


Fig. 8.2 Relative contribution of different greenhouse gases to global warming

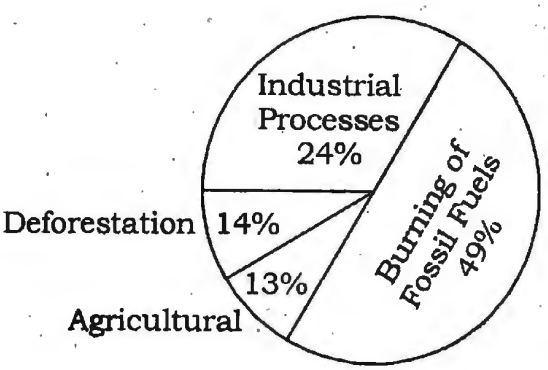


Fig. 8.3 Relative contribution of various human activities to the increase of greenhouse gases in the atmosphere from different sources

→ Effects of Global warming : **[June 2013]**

1. Change in climate :

Rising temperatures have a pronounced effect on the global climate regime.

Change in climate bring in following problems :

- Change in rainfall pattern
- Drying of surface water bodies
- Conversion of fertile land into deserts
- Serious water shortage
- Fall in ground water table
- Change in crop pattern
- Growth of micro-organisms and spread of diseases
- Change in vegetation pattern, etc.

2. **Rise in Sea level :**

High temperature on earth will melt polar ice caps and glaciers causing rise in the sea water level. Over the period of 1901 to 2010 global sea level rose by 0.19 m (about 8 inch). This rise is more than half of the rise in the preceeding 2000 years. It is estimated that if there is an increase in sea level by 1m, the costline moves inland by 1.5 kilometers.

- rising sea level will inundate coastal areas.
- Submergance of islands.

For example, Tuvalu country between Australia and Hawaii.

3. **Effect on human health :**

Human health may be adversely affected in hot climate. Climate changes and rise in average temperature of atmosphere has led to occurance of different new diseases.

Change in climate may generate drinking water problems at global level.

4. **Other effects :**

- Decrease in food production
- Adverse effect on flora and fauna.
- Adverse effect on many ecosystems.

➔ **Control of Global warming :**

[June 2013]

Some of the measures to control global warming are as follows :

1. Reduction in the use of fossil fuel for energy generation.
2. Promoting non-conventional energy sources like wind energy, solar energy, nuclear energy, etc.
3. Hydrogen as an energy source of the future is another proposal.
4. Reduction in N_2O emission by minimising the use of nitrogen fertilizers in agriculture.
5. Increase of the vegetation cover, particularly forest as it is sink for CO_2 absorpiton.
6. There is vast scope for energy conservation such as through introduction of mass transporation in cities, development of energy efficient devices, economic use of energy, etc.
7. By using the substitutes like HCFCs in place of CFCs.
8. Traping and use of methane as fuel.
9. Stabilize population growth.
10. Industrial processes have to be upgraded to release as little green house gases as possible.

➔ **Global Warming Potential (GWP) :**

Global warming potential is the ratio of the warming caused by a substance compared to the warming caused by a similar mass of CO_2.

The GWP of CO_2 is 1.0

	Green House Gas	GWP	Life (years)
(i)	CO_2	1	100
(ii)	Methane (CH4)	25	12
(iii)	N_2O	230	120
(iv)	CFC	12000-16000	800-50,000

8.5 ACID RAIN :

[Jan. 2010, April 2010, Jan. 2011, Jan. 2013, Jan. 2016, June 2016, Jan. 2017]

When the pH of rain water is less than 5.6, it is called **acid rain.**

Theoretically speaking, rain water (natural water) as it falls should be neither acidic nor alkaline. It should be neutral, i.e. pH = 7. But, in reality it is not so because of the dissolution of atmospheric CO_2 in rainwater to yield carbonic acid which imparts slight acidity to rainwater.

$$CO_2 + H_2O \longrightarrow H_2CO_3 \text{ (Carbonic acid)}$$

The adverse impacts of acid rain will be experienced only if the pH of rain water is about 4.5 and less. Europe, Netherland, Sweden, USA and other industrialized countries faced problem of acid rain with pH of 5.0 to 2.2. The phenomenon of acid rain has also been observed in cities like Kanpur and Mumbai.

The reduction in pH of rainwater is basically due to the dissolution of oxides of nitrogen and sulphur present in the atmosphere which forms nitric acid (HNO_3) and sulphuric acid (H_2SO_4) as shown below.

(1) $2\,SO_2 + O_2 \longrightarrow 2\,SO_3$

$SO_3 + H_2O \longrightarrow H_2SO_4$ (Sulphuric acid)

(2) $2NO + O_2 \longrightarrow 2\,NO_2$

$4NO_2 + 2H_2O + O_2 \longrightarrow 4\,HNO_3$ (Nitric acid)

(3) HCl gas $\xrightarrow{\text{dissolved in water}}$ HCl (Hydrocloric acid)

It is estimated that acid rain contribution of H_2SO_4 is 60-70% and that of HNO_3 is 30 - 40% Acidity contributed by HCl is very small.

➜ Causes of acid rain :

[June 2014, June 2016]

1. Dissolution of SO_2 and NO_2 formed by the burning of fossil fuels into rain water.
2. Dissolution of oxides of sulphur and nitrogen emitted from automobile exhaust into rain water.
3. Dissolution of oxides of sulphur and nitrogen released from the chimneys of smelting industries.
4. Industrial plants using sulphuric acid and nitric acid.

➜ Effects of acid rain :

[June 2014, June 2016]

1. Effect on human health :

Skin irritation and aggravation of respiratory diseases are frequently observed in acid rain affected areas.

2. Effects on aquatic life :

Acidification of lakes and streams due to acid rain may cause disapperence of aquatic species and killing of bacteria, algae and small fishes. It is reported that due to acidity there are thousands of lakes in Norway and Sweden that do not contain any fish.

3. Effects on Vegetation :

Acid rain may decolourise the leaves of plants and reduces chlorophyll content. In highly industrialized regious forests are virtually killed.

4. **Effect on water resources :**

Acidification of water resources, both surface and underground sources is a very critical outfall of acid rain. pH of water drastically reduces, which has a deleterious effect on fish population. Water treatment costs increase. Water storage structures are damaged.

5. **Damage to structures and property :**

Acid rain can damage the structural materials like marble and limestone. Monuments especially those structured that of marble such as the Taj Mahal in India are disfigured.

Vehicle finishes are also affected.

6. **Reduction in soil pH :**

Low soil pH diminishes the bacterial activity in soil, which has a serious repercussion on nutrient fixation. Also, the uptake of nutrients by plants is hindered due to leaching out of aluminium at low pH conditions.

7. **Effect on ecosystem :**

Acid rain affects the ecosystem as it breaks the food chain and food web and thereby reduces the bio-diversity.

→ **Control of acid rain :**

Remedial and control measures of acid rain are :

1. Decreasing the emissions of sulphur dioxide (SO_2) and nitrogen oxide (NO_2).
2. Adopting energy conservation measures.
3. Using less coal in power plants and utilizing non-polluting energy sources.
4. Lakes and soil that are extremely acidified can be treated with lime to rejuvenate them.
5. Release of SO_2 can be controlled by adopting suitable SO_2 reducing equipments in industries and thermal power plants.
6. Natural gas can be used in place of high-sulphur coal for producing electricity in thermal power plants.
7. Considering nuclear energy as an option for the future fuel.

8.6 OZONE LAYER DEPLETION :

[Dec. 2010, June 2011, May 2012, Dec. 2013, Dec. 2014, Jan. 2017]

The layer in the upper atmosphere (stratosphere), some 15 to 30 km above the earth's surfae, in which most of the atmospheric ozone (about 90%) is concentrated is called the **ozone layer.**

The ozone layer, absorbs most of the sun's ultra violet (uv) radiation and protects various life form on the earth. It acts like a natural sunscreen for the earth. Therefore, the ozone layer is often called the **ozone shield or earth's protective umbrella.**

→ **Formation of ozone :**

In the stratosphere, the formataion and destruction of ozone is a continuous phenomenon. In the stratosphere, UV radiation splits oxygen molecule into oxygen atoms, which combine with other oxygen molecules to form ozone.

The UV radiation splits oxygen molecule into oxygen atoms.

$$O_2 + hv \longrightarrow O + O$$

The atomic oxygen react with molecular oxygen to form ozone.

$$O + O_2 + M \longrightarrow O_3 + M$$

(M is third body necessary to carry away the energy released in the reaction)

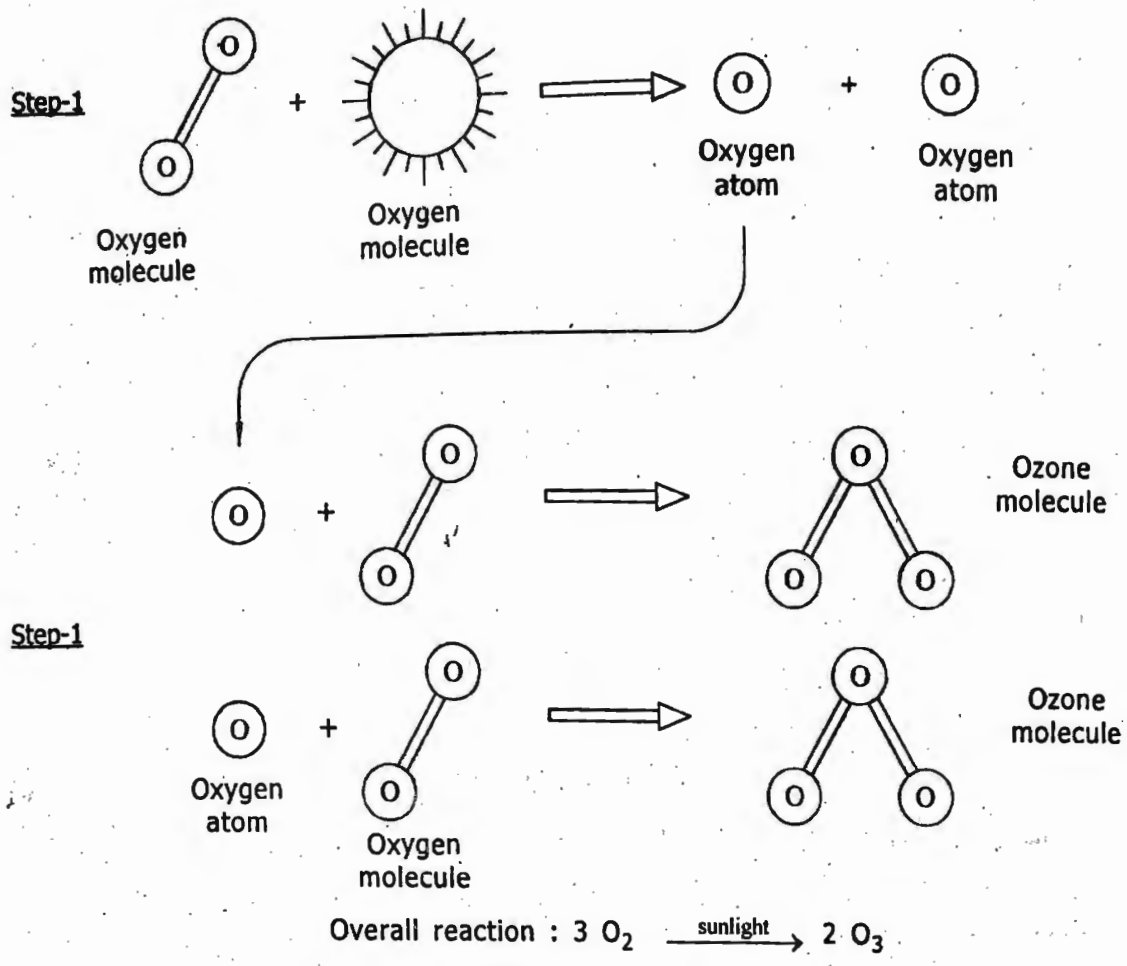


Fig. 8.4 Ozone Formation

Ozone thus formed distributes itself in the atmosphere and absorb harmful ultraviolet radiation (200 - 320 nm) and it continuously converted back to molecular oxygen.

$$O_3 + hv \longrightarrow .O_2 + O$$

➜ **Destruction of ozone layer :**

The main chemicals responsible for ozone layer depletion are chloro fluoro carbons (CFCs) and chlorofluoro bromines (CF_3 Br).

Among the CFCs, the main chemicals responsible for ozone depletion are referred to by trade names such as

Feron - 11 (C Cl_3 F)

Feron - 12 (C Cl_2 F_2)

They are largely used, and subsequently released into the atmosphere, by the following activities :

(i) Refrigeration
(ii) Air conditioning
(iii) Extinguishing fires
(iv) Cleaning solvents in industries
(v) Solvent in paint industry
(vi) Blowing agents in plastic industries

CFCs are destroyed by UV radiation in the atmosphere and releases atomic Cl which destroys the ozone layer as under.

$$C\,Cl_2\,F_2 \xrightarrow{UV} C\,Cl\,F_2 + Cl$$

$$Cl + O_3 \longrightarrow ClO + O_2$$

(Chlorine atom released from CFCs) (Ozone) (Chlorine monoxide) (Oxygen molecule)

The ClO so formed then react with another oxygen atom to form new oxygen molecule and a chlorine atom :

$$ClO + O \longrightarrow Cl + O_2$$

These chlorine atoms so formed break apart the ozone molecules in a drastic way leading to large scale ozone depletion.

In above reaction Cl just acts acts as a catalyst and reappears. It is estimated that one Cl atom can destroy 1,00,000 Ozone molecules in 1 to 2 years.

Other ozone depleting substances :

(i) Carbo tetra chloride (CTC)

(ii) Halon

(iii) Methyl bromide

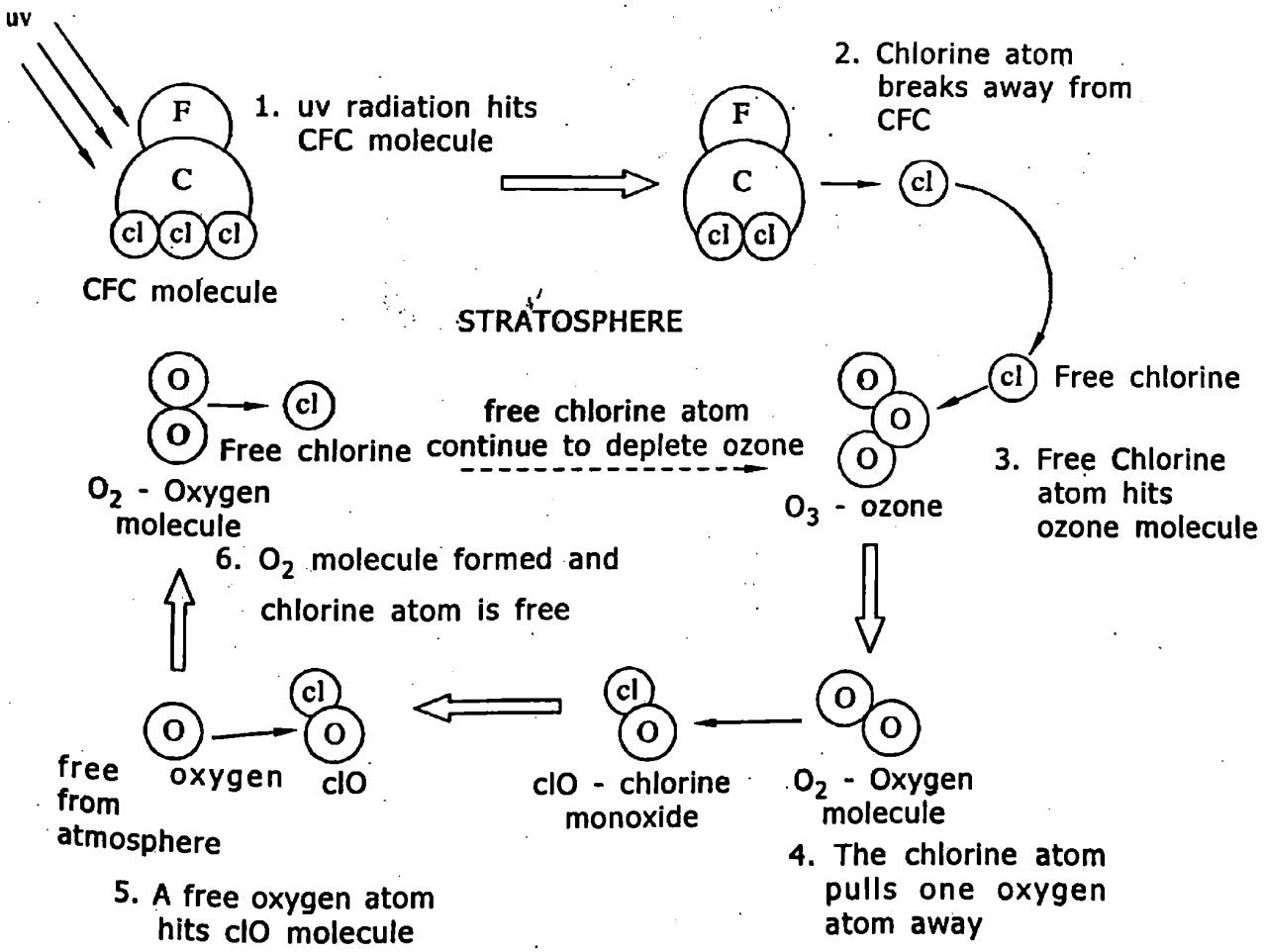


Fig. 8.5 Destruction of Ozone

→ **Dobson unit (DU) :**

Unit of measurement of ozone in atmosphere is **Dobson unit (DU).**

1 Dobson unit is equivalent to a concentration of 1 ppb (parts per billion) O_3.

1 Dobson unit (DU) is defined as 0.01 mm thick ozone layer at STP (i.e 0°C and 1 atm)

Under normal conditions, earth atmosphere contains about 300 DU i.e. 3 mm thick slab of ozone layer which is reduced to 100 DU, i.e. 1 mm thick ozone slab at **'Ozone holes'.**

Ozone Depleting Potential (ODP) :

It is the ratio of the impact on Ozone caused by a chemical compared to the impact of a similar mass of CFC-11.

The ODP of CFC-11 is 1.0.

→ **Ozone hole :**

The ozone hole is an area of the stratosphere where the concentration of ozone drops drastically. The average amount of ozone in the atmosphere is roughly 300 DU, i.e. 3 mm thick slab of ozone layer. Any place where the ozone concentration drops below 220 DU, it is considered as part of the ozone hole. Average concentrations in the ozone hole are around 100 DU (i.e. 1 mm thick slab).

Since 1985, it is observed that ozone layer is depleting in the stratosphere over the **Antarctic region** (South polar region) particularly in the late winter and early spring season. The ozone hole does not persist (exists) year round.

The cold environment forms tiny ice crystals and these crystals get accumulated, as very cold temperatures build up due to long nights. The CFCs brought from lower levels get attached to the tiny ice crystals. The CFCs may also breakdown into chlorine monoxide (ClO). Finally, when sun rises after a long night period, its light triggers a massive destruction of ozone by ClO. This vast depletion of ozone at that level in the stratosphere makes the ozone layer very thin. This is called formation of **ozone hole.** Ozone concentration decrease throughout August - September - October.

This serious problem has affected countries nearer to antarctic region such as Australia, New Zealand and Argentina. A similar situation but to a lesser degree is being felt in the north polar region countries like Europe, Russia, Canada, etc.

→ **Effects of Ozone Depletion :** **[Jan. 2017]**

- Ozone depletion in the stratosphere will result in more UV radiation reaching the earth especially UV–B (200 – 280 nm). The UV–B radiations affect DNA and the photosynthetic chemicals. Any change in DNA can result in mutation and cancer. Cases of skin cancer which do not cause death but cause disfigurement will increase.
- Easy absorption of UV rays by the lens and cornea of eye will result in increase in incidence of cataract.
- Melanin producing cells of the epidermis will be destroyed by UV–rays resulting in immune suppression. Fair people (can't produce enough melanin) will be at a greater risk of UV exposure.

- Phytoplankton are sensitive to UV exposure Ozone depletion will result in decrease in their population thereby affecting the population of Zooplankton, fish, marine animals, in fact the whole aquatic food chain.
- Yield of vital crops like corn, rice, soyabean, cotton, bean, pea and wheat will decrease.
- Degradation of paints, plastics and other polymer material will result in economic loss due to effects of UV radiation resulting from Ozone depletion.

8.7 CARBON FOOTPRINT :

The carbon footprint is a measure of the total amount of Carbon Dioxide (CO_2) and other greenhouse gas emissions that are directly or indirectly caused by an activity, or which are accumulated over the life span of a product, person, an organization, or even a city or state. Carbon foot printing is a measure by which a company or individual can calculate how much carbon emissions they have produced during a project or time period.

A carbon footprint is a measure of the impact our activities have on the environment, and in particular climate change. It relates to the amount of greenhouse gases produced in our day–to–day lives through burning fossil fuels for electricity, heating and transportation etc.

The carbon footprint is a measurement of all greenhouse gases we individually produce and has units of tones (or kg) of carbon dioxide equivalent.

Carbon footprint can sometimes also expressed in kg carbon rather than kg carbon dioxide. Kg carbon dioxide can be converted into kg carbon by multiplying with a factor 0.27. (1000 kg CO_2 equal 270 kg carbon)

A carbon footprint is made up of the sum of two parts:

(1) Primary footprint :

The primary footprint is a measure of our direct emissions of CO_2 from the burning of fossil fuels including domestic energy consumption and transportation (e.g. car and plane). We have direct control of these.

(2) Secondary footprint :

The secondary footprint is a measure of the indirect CO_2 emissions from the whole lifecycle of products we use – those associated with their manufacture and eventual breakdown. To put it very simply – the more we buy the more emissions will be caused on our behalf.

A ton of carbon is released when you :

- Travel 5,000 miles in an airplane
- Drive 2,500 miles in a medium–sized car
- Cut down and burn a tree that was about one foot in diameter and 40 feet tall.

Why are individual carbon footprints so alarmingly high?

- We cause huge amounts of air, water and land pollution;
- We are incredibly lazy in our home and work habits;
- We produce enormous and completely unjustifiable amounts of waste materials;

- We have been resistant to embrace alternative energy sources;
- We gorge ourselves on animal–based diets that not only destroy our health, but also cause unparalleled amounts of deforestation and shrink our fresh water supplies to nothing.

There are different types of carbon footprint, e.g. for organizations, individuals, products, services, and events. Different types of footprint have different methods and boundaries.

The full carbon footprint of an organization encompasses a wide range of emissions sources from direct use of fuels to indirect impacts such as employee travel or emissions from other organizations up and down the supply chain.

Three main types of emissions exist:

1. **Direct emissions that result from activities that the organization controls.** The majority of direct emissions will result from combustion of fuels which produce CO_2 emissions, e.g. the gas used to provide heating for a building. Some organizations will also directly emit other greenhouse gases e.g. the burning and production of cement.

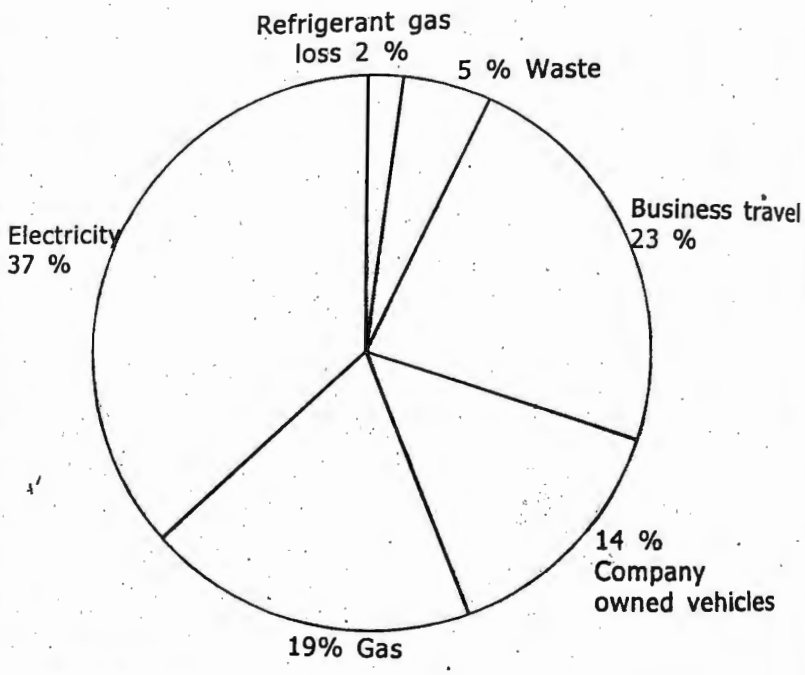


Fig. 8.6 Example of the breakdown of an organizational carbon footprint

2. **Emissions from the use of electricity.** Workplaces generally use electricity for lighting and equipment. Electricity generation comes from a range of sources, including renewable. In the UK however, around 75% is produced through the combustion of fossil fuels such as coal and gas. Although not directly in control of the emissions, by purchasing the electricity the organization is indirectly responsible for the release of CO_2.
3. **Indirect emissions from products and services.** Each product or service purchased by an organization contributes towards emissions. The way the organization uses products and services therefore affects its carbon footprint, e.g. a manufacturing company is indirectly responsible for the CO_2 that is emitted in the transport of the raw materials, as well as emissions from the distribution, use and disposal of its finished products.

CO_2 Equivalence :

CO_2 equivalence (or CO2e) is used to express a carbon footprint, which is made up of a number of different greenhouse gases, in a single figure. It is the quantity of CO2 which would have the equivalent global warming impact as the mixture of greenhouse gases in question.

A complete carbon footprint may include a number of types of greenhouse gas, e.g. all those controlled under the Kyoto Protocol. The Kyoto gases are listed in the table below with their global warming potential

(GWP). GWP is an index of global warming potency, with CO2 defined as having a GWP of 1 and all other gases measured relative to CO2.

Greenhouse Gas	Global Warming Potential
Carbon dioxide (CO2)	1
Methane (CH4)	25
Nitrous oxide (N2O)	230
Hydrofluorocarbons (HFCs)	124 – 14,800
Perfluorocarbons (PFCs)	7,500 – 12,200
Sulphur hexafluoride (SF6)	22,800

A quantity of greenhouse gas is converted into CO2e by multiplying its mass by its global warming potential, e.g. 1 kg of methane is equal to 25 kg of CO2e.

➔ **Benefits of carbon footprint :**

Calculating carbon footprint and taking measures to reduce it yields many environmental, social and economic benefits. Some of the benefits are:

(i) Calculating an organization's carbon footprint can be an effective tool for ongoing energy and environmental management. It helps in reducing emissions over time.

(ii) A carbon footprint helps to identify the inefficiencies or waste within a company in terms of energy and raw material consumption. It helps in reducing waste thus reducing cost of materials.

(iii) It helps to determine what quantity of emissions they need to offset for them to become 'carbon neutral'.

(iv) It helps to identify which activities contribute the most to a footprint (in order to identify the important areas for reduction efforts), typically including gas, electricity and transport.

(v) It can be used to report the footprint accurately to a third party.

(vi) It helps in measuring changes in emissions over time, and monitoring the effectiveness of reduction activities.

(vii) Organizations are also increasingly wanting to calculate their carbon footprint in detail for public disclosure e.g. for marketing purposes, to fulfill requests from customers or investors. It has positive impact on brand of business.

➔ **Methods of Minimizing the Carbon Footprint :**

Several methods exist for reducing an individuals or an organizations carbon footprint.

1. Planting trees is one of the most common and simplest forms of carbon footprint reduction. Trees absorb CO_2 from the atmosphere and hence can be used to offset carbon emissions.
2. Recycling waste materials such as household, industrial and construction waste can be a valuable method of carbon footprint reduction as the carbon content of the new materials which would have otherwise been used can be offset.
3. Many energy saving technologies exist which can contribute towards carbon footprint reduction, from cheap and simple measures such as installing low energy light bulbs to more expensive measures such as using electric vehicles.

4. Renewable energy generation can also be used for offsetting a carbon footprint, such as wind turbines and solar panels.
5. Inflate your tires. If you own a car, it will get better gas mileage when the tires are fully inflated, so it will burn less gas and emit less carbon.
6. Walk or bike instead of driving a car. Cars and trucks run on fossil fuels, which release carbon dioxide into the atmosphere.
7. Teleconference instead of flying. For office meetings, if you can telephone or videoconference, you will save time, money, and carbon emissions.
8. Turn down the heat or air conditioning when you leave the house or go to bed. You can easily install a programmable thermostat that can save up money and carbon.
9. Purchase a solar powered, biofuel–driven or hybrid vehicle. Purchase a solar energy system for your home. Purchase solar powered hot water heaters.

8.8 CLEANER DEVELOPMENT MECHANISM [CDM] :

The UN's Kyoto protocol [Japan-1997]established binding greenhouse gas emissions reduction targets for 37 industrialized countries and the European community. To help achieve these targets, the protocol introduced three "flexible mechanisms" – international emissions trading (IET), joint implementation (JI), and the clean development Mechanism (CDM).

To date the CDM has arguably been the most successful of the three flexible mechanisms. It has two main goals:

(1) To assist countries without emissions targets (i.e. developing countries-Annex B) in achieving sustainable development.

(2) Help those countries with emission reduction targets under Kyoto (i.e. developed countries-Annex I) in achieving compliance by allowing them to purchase offsets created by CDM projects.

The *CDM* allows emission-reduction projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one tonne of CO_2. These CERs can be traded and sold, and used by industrialized countries to a meet a part of their emission reduction targets under the Kyoto Protocol. The mechanism stimulates sustainable development and emission reductions, while giving industrialized countries some flexibility in how they meet their emission reduction limitation targets.

A broad range of projects are eligible for CDM accreditation, with the notable exceptions of nuclear power and avoided deforestation projects. They vary from hydropower and wind energy projects, to fuel switching and industrial efficiency improvements. Crucially, to qualify for accreditation the project developers must prove 'additionality', defined as emissions reductions that are additional to what would have otherwise occurred. This is calculated by using an approved methodology to subtract the estimated emissions of a given project from a hypothetical 'business-as-usual' emissions baseline.

Once registered, projects are then issued **Certified Emissions Reductions (CER)**, with each CER unit equal to a reduction of one tonne of carbon dioxide equivalent. CER is also known as **carbon credit.** These CERs, or offsets, can be bought and used by developed countries to meet their Kyoto commitments. Companies can also purchase CERs to contribute towards their own emission reduction targets under mandatory emissions trading schemes (such as the EU Emissions Trading Scheme, ETS) or voluntary schemes.

A carbon credit or CER is a tradable certificate or permit representing the right to emit 1 tonne of carbon or carbon dioxide equivalent.

1 CER = 1 carbon credit = 1 tonne CO_2 equivalent gases

or 1 tonne carbon

An organization which produces 1 tonne less carbon or carbon dioxide equivalent than the standard level of carbon emissions allowed, earns 1 carbon credit.

India and China are the biggest sellers of carbon credits and Europe is the largest buyer of carbon credits. Carbon credit trading is done globally.

Under the **'cap-and-trade'** or emissions program, a company, emitting less than its capped limit, may sell unused credits to a company exceeding its limit. For example, Company A has a cap of 10 tons but produces 12 tons of emissions. Company B also has an emission cap of 10 tons but emits only 8 tons resulting in a surplus of two credits. Company A may purchase the additional credits from Company B to remain in compliance. Without the purchased carbon credits, Company A would face penalties.

CDM Projects :

Because of their project-based character, CDM can assist project developers in enhancing the economics of their project by selling the resulting emission reductions. Not every project is eligible as a CDM project; this is subject to a number of activities and approvals.

Below is a list of some typical projects that may be eligible as CDM projects:

- The implementation of a renewable energy project, e.g. wind, or biomass;
- Demand-side energy efficiency improvement, e.g. implementation of energy saving light bulbs;
- Solar power
- Hydro power
- The reduction of methane emissions from a landfill site;
- Reduction of industrial process emissions;
- Forestry practices to store carbon.

Between 2004 and 2012, there was a steady increase in the number of registered CDM projects after which there has been a drastic decline. This could be a result of the crash in CER prices in the recent times. The price of CER, which was around $ 20 a tonne in 2008, fell to below $ 5 a tonne in 2012. This may be attributed to the lack of demand from the European Union (EU), which was the major market for CERs. Due to the industrial slowdown in EU as a result of Euro crisis as well as over-allocation of carbon quotas in EU's Emission Trading System there was slack demand for CERs. In july 2018 the CER prices were$ 16 a tonne.

Most of the CDM projects in India are concentrated in a few sectors, namely, those related to the renewable energy sector. The maximum number is in the wind energy sector. This sector accounts for 42 per cent of all CDM projects in India. Biomass energy projects come second with 15 per cent.

CER Markets in the world :

There are four markets in the world dealing with CER trading:

(i) Kyoto Protocol

(ii) EU Emissions Trading Scheme.

(iii) Canada Green house gas Offset System

(iv) Japan (Voluntary Trading System)

The Project Cycle in CDM :

Every CDM project has to go through a cycle before it is registered and CERs are issued to the project. There are seven steps in the project cycle:

(1) ***Project design***: the first step is the preparation of a project design document by the project participant detailing the project, the baseline and methodology and other details relevant to the project;

(2) ***National Approval***: the second step is securing the letter of approval from the Designated National Entity of the host party;

(3) ***Validation:*** the project is independently evaluated by a designated operating entity on whether it meets the requirements of CDM.

(4) ***Registration:*** validated projects are submitted to the CDM executive board for formal approval, which is called registration;

(5) ***Monitoring:*** Measurement of actual emissions is done by the project participant according to the approved methodology;

(6) ***Verification:*** Is the independent review of the emission reductions claimed by the project participant by a designated operating entity.

(7) ***CER issuance:*** Once the verification of the claimed emission reduction is done, the designated operating entity submits the verification report to the CDM board for the issuance of CERs.

Benefits of CDM :

The main benefits of CDM are :

- Sustainable development
- Conservation of environment- reduction of GNG emissions.
- Reduction in climate change phenomenon
- CDM projects include investment in climate change mitigation projects in developing countries,
- Transfer of technology in the host countries,
- Improvement in the livelihood of communities through the creation of employment or increased economic activity.
- Social and economic development in the host country.
- Development of environment friendly projects in Annex B countries.
- Increase in foreign direct investment in CDM projects in the country.
- Image enhancement at local level of the company developing CDM project.
- Development of new GNG emission reducing technologies.

Challenges for CDM :

- DNA (Designated National Authority) approval capacities.
- High methodology rejection rates.

- Annex I companies may only be interested in buying CER, not in investing CDM projects.
- Gap between CER and EU allowance prices.
- Interpretation of national policies in baseline methodologies.
- Availability of reliable and authentic data for establishing baselines.

8.9 INTERNATIONAL STEPS FOR MITIGATING GLOBAL CHANGE :

A list of Un Conferences & Protocols on Environment, Sustainable Development, Climate Change is as under:

- United Nations Framework Convention on Climate Change (1992)
- Vienna Convention (1985) (Protection of Ozone Layer)
- Montreal Protocol (1989) (Total Elimination of Ozone Depleting Substances)
- Basal Convention (1989) (Control of Trans-boundary Movements of Hazardous waste)
- Geneva Convention (1990) (Technology and financial help to Developing Countries)
- UN Convention on Climate Change, New York (1992) Economic Development and Environmental Protection.
- UN Conference on Environment and Development (Earth Summit) Rio de Janeiro, Brazil (1992) (Environment and Sustainable Development)
- Kyoto Protocol (1997) (Stabilization of Green House Gases)
- Copenhagen Summit (2009) (Road map for Post-Kyoto treaties)
- United Nations Climate Change Conference, Doha, Qatar (2012) (The Doha Climate Gateway)
- Paris Agreement (2016) (Targets for everyone).

Some important agreements/protocols are discussed below.

(1) Paris agreement (2015) :

The **Paris Agreement** is an agreement within the United Nations Framework Convention on Climate Change (UNFCCC), dealing with mitigation, adaptation, and finance, starting in the year 2020. The agreement's language was negotiated by representatives of 196 state parties at Paris, France on 12 December 2015.

The Paris Agreement's long-term goal is to keep the increase in global average temperature to well **below 2 °C** above pre-industrial levels; and to limit the increase to 1.5 °C, since this would substantially reduce the risks and effects of climate change.

Additionally, the agreement aims to strengthen the ability to deal with the impacts of climate change.

The Paris deal is the world's first comprehensive climate agreement.

The Paris Agreement and the outcomes of the UN climate conference (COP21) cover all the crucial areas identified as essential for a landmark conclusion:

- Mitigation – reducing emissions fast enough to achieve the temperature goal
- A transparency system and global stock-take – accounting for climate action
- Adaptation – strengthening ability of countries to deal with climate impacts
- Loss and damage – strengthening ability to recover from climate impacts
- Support – including finance, for nations to build clean, resilient futures.

(2) Montreal Protocol :

In 1987, twenty seven industrialized countries signed an international agreement to protect the ozone layer in the stratosphere. This agreement is known as Montreal Protocol.

The main points of the agreement are :

(i) To limit the production and use of ozone depleting substances.

(ii) To freeze production of CFCs at 1986 levels and to reduce production by 50% by 1999.

(iii) To help the developing countries to implement use of alternatives to CFCs.

Up till now, more than 175 countries have signed the Montreal protocol.

Due to this protocol, ozone layer is likely to return to normal level by 2050.

(3) Earth summit :

The United Nations conference on Environment and Development, the Earth summit, held at Rio de Janeiro, Brazil in 1992, established principles to reduce green house gases.

Objectives of the summit were :

- to secure renewed political commitment to sustainable development.
- to address new and emerging challenges.
- green economy and poverty eradication
- sustainable development.

(4) Kyoto protocol :

In December 1997, an international conference was held at Kyoto, Japan to discuss climate change. The conference was attended by 37 industrialised countries and the European community for reducing green house gases.

It was decided that the countries will reduce the green house emission by 5% compared to 1990 level up to 2012.

(5) Copenhagen International Conference :

During 7-19 December 2009, an international conference was held at Copenhegan (Denmark) after United Nations Climate change conference took place in Dec. 2007 at Bali to prevent Climate changes and carbon emissions.

Governmental representatives from 192 nations, NGO's, journalists and other representatives attended the conference. United Nations Framework convention on climate change (UNFCCC) has received submissions of national pledges to cut or limit emissions of green house gases by 2020 from 75 parties which togeter account for more than 80% of global emissions.

(6) Vienna Convention :

- Convention for the ***Protection of the Ozone Layer.***
- Often called a framework convention, because it served as a framework for efforts to protect the globe's ozone layer.
- The Vienna Convention was adopted in 1985 and entered into force on 22 September, 1988.
- The objectives of the Convention were for Parties to promote cooperation by means of systematic observations, research and information exchange on the effects of human activities on the ozone layer and to adopt legislative or administrative measures against activities likely to have adverse effects on the ozone layer.

- The Vienna Convention did not require countries to take concrete actions to control ozone depleting substances. Instead, in accordance with the provisions of the Convention, the countries of the world agreed the Montreal Protocol on Substances that Deplete the Ozone Layer under the Convention to advance that goal.
- The Parties to the Vienna Convention meet once every three years, back to back with the Parties to the Montreal Protocol, in order to take decisions designed to administer the Convention.
- In 2009, the Vienna Convention became the first Convention of any kind to achieve universal ratification.

(7) **Doha Climate Change Conference (2012) :**

- The 18th session of the COP to the UNFCCC, that started on 26 November and concluded on 8 December 2012 in Doha, Qatar has resulted in a set of decisions (clubbed together as 'Doha Climate Gateway') aimed at advancing the implementation of the UNFCCC and its Kyoto Protocol (KP).
- Key issues for the Doha conference were:
- Amending the KP to implement the second commitment period under the Protocol
- Successfully concluding the work of the Bali Action Plan (BAP) within which there was urgent need for a clear path to climate finance.
- planning the work under the Durban Platform (DP) for enhanced action.

→ **Key Doha Outcome:**

- It has been agreed that the Kyoto Protocol (KP), as the only existing and binding agreement under which developed countries commit to cutting emissions of GHGs, will enter a second commitment period that will run for eight years.
- Governments have agreed to speedily work toward a climate change agreement under Doha Protocol (DP) applicable to all countries from 2020, to be adopted by 2015. Further governments have decided to find ways to scale up efforts before 2020 to meet the gap in global ambition for emissions reduction.
- Governments have launched a robust process to review the long-term temperature goal. This will start in 2013 and conclude by 2015 and is a reality check on the advance of the climate change threat and the possible need to mobilize further action.

CHAPTER 9.

Basic Concept of Green Building and Smart Cities

9.1 THE GREEN BUILDING CONCEPT :

Our ancestors worshipped the five elements of nature -

Earth as 'Prithvi'

Water as 'Jal'

Agni as 'Energy'

Air as 'Vayu'

Sky as 'Akash'.

A **green building** or **environmental building** or **sustainable building** is a building which seek to harness all these natural elements in its design and construction to an optimum level so as to have an eco-friendly, low energy & low water consumption building and at the same time providing fresh and healthy environment to its occupants.

The term 'green building' apply not just to products, but building design, orientation, construction strategies, landscaping, building operations, maintenance, and more. The less impact a building has on human health and the environment, the more green it is.

The concept of green building incorporates and integrates a variety of strategies during its planning, design, construction and maintenance of building projects. Common goal of green building is achieving aesthetic harmony between a structure and its surrounding environment and use those resources that help in environmental protection or disturbs least to the environment compared to other alternatives available. Green building movement is infact the result of contribution from architects and engineers in maintaining the ecological balance, thus, a step forward by architects and engineers to work as an environmentalist.

As regards the cost impact in the design of a green building, the cost could be slightly higher than a conventional building. However green buildings, on account of their design features, consume less energy and less water vis-a-vis a conventional building. Thus this extra cost gets paid back in 3-5 years time.

9.2 OBJECTIVES OF GREEN BUILDING :

The design, construction and maintenance of buildings have a tremendous impact on our environment and our natural resources. Traditional building practices often overlook the interrelationships between a building, its components, its surroundings, and its occupants; and consume more of our resources than necessary, negatively impacting the environment. The basic resources like ground cover, water, forests and energy are depleted to construct and operate buildings. This is where green buildings step in with an aim to address all these issues in an integrated and scientific manner.

The main objective of green building is to reduce the overall impact of building on environment and on human health by minimising the usage of natural resources (like ground cover, water, forests, energy) and to maximize the benefits.

1. To minimise the use of natural resources like ground cover, water, forests, energy, etc.
2. To reduce overall impact of building on environment and human health.
3. To reduce waste, pollution and environmental degradation.
4. To select proper building materials and use recycled and scrap materials having low energy requirement.

5. To boost renewable energy usage, i.e. solar energy and wind energy.
6. To enhance interior lighting quality by increased use of natural day lighting to reduce energy demand.
7. To make efficient use of water in a building, reduce wastage and water pollution.
8. To improve human health and comfort.
9. To reduce global warming.

9.3 FEATURES (PRINCIPLES) OF GREEN BUILDING :

The different elements of a green building are as follows :

1. Sustainable site selection
2. Energy efficiency
3. Water efficiency
4. Materials efficiency
5. Design efficiency
6. Occupant Health and safety

1. Sustainable site selection :

Site selection, its development and construction process are basic considerations for any project. The impact of project should be minimum on the ecology, so that the nature adjusts itself within a short period. Therefore, the first objective of site selection is to select a site that does not disturb ecological balance of the area. The natural landscaping and natural features not be destructed as far as possible.

Architects and engineers including administrators have to consider the factors like

- Number of industries / buildings existing and proposed
- Surface and ground water quality
- Air quality
- Eco-system
- Land use
- Services existing near such development
- Flora/fauna conservation, etc.

during site selection process.

2. Energy efficiency :

Building consumes energy mainly for cooling, heating and lighting. The design of a building should be such that it can use maximum available energy of the nature and this type of design is termed as **passive design of a building.** Passive design of a building can dramatically change the energy use pattern of a building. The measures include building shape and orientation, passive solar design, and the use of natural lighting.

Some of the energy saving measures are :

- Use a properly sized and energy efficient heating /cooling system in a building.
- Use solar energy for lighting, water heating.
- Maximum use of natural lighting and air.

- Maximize light colours for roofing and wall finishing materials.
- Use minimam glass on east and west exposures.
- Insulate the walls. The options for insulation materials can be - Extruded polystyrene, Expanded polystyrene (thermocol), glass wool, etc.
- Brick wall with air cavity can also significantly reduce the heat ingress.
- Hollow blocks, fly ash bricks, Autoclaved Aerated concrete (AAC) blocks are also good insulators.
- Bureau of Energy efficiency (BEE) star rated lamps and tubelights should be used.

3. Water efficiency :

Water is going to be a scare natural commodity, leading to clashes between users and even between governments. Thus neither it can be wasted nor it can be polluted. Thus water efficiency can be achieved only if water is efficiently used without wastage, reused to the maximum extent and water pollution is stopped.

Avoiding wastage is considered better than production. To achieve this an integrated and holistic approach is to be adopted for water management.

→ **Measures to improve water efficiency :**

- Potable water should not be used for the purposes other than essential requirements.
- For other uses waste water is to be recycled. Waste water treatment plant should be installed at the project site.
- In buildings water saving materials are to be used like low capacity cisterns, showers, waterless urinals, etc.
- Water meters should be installed.
- Use waste water for floor washing and gardening.
- Instead of continuous supply of water adopt intermittent system of supply.

4. Materials efficiency :

Selection of new construction materials and use of recycled and scrap materials are the two important factors for the construction of green buildings. Such products promote resource conservation and efficiency. Using recycled materials also helps in solid waste management system.

Building materials consume a considerable energy and affect ecological balance due to extraction from the nature. Building material is to be examined for being a green material based on its energy requirement from raw stage to the providing and fixing stage in a building. These stages may be extraction, manufacturing, transportation, fixing, maintenance and disposal.

Green building materials offer the following benefits :

- Energy conservation
- Lower costs
- Greater design flexibility
- Reduced maintenance costs
- Improved occupant health and productivity

→ **Criteria to identify green materials :**

(i) **Local availability of materials.**

(ii) **Embodied energy - i.e. energy required for extraction, manufacturing, transportation, fixing, maintenance, disposal of materials.**

(iii) **% of recycled / waste materials used.**

(iv) Contribution in energy efficiency of buildings.

(v) Recyclability of materials.

(vi) Durability

(vii) Environmental impact.

→ **Various Green materials :**

(i) Fly ash :

Fly ash, a waste product from thermal power plant is a resource material now. Its use in cement as a substitute of cementitious material in manufacturing PPC, part replacement of cement and producing number of building products like fly ash cement concrete, fly ash bricks, fly ash hollow/solid blocks, fly ash concrete tiles, etc. has been well established. Pond ash and fly ash is also used in filling under floors and in embankments.

(ii) Green concrete :

Green concrete as the name suggests is eco-friendly and saves the environment by using waste products generated by industries in various forms like rice husk ash, micro silica and fly ash, etc. Use of green concrete helps in saving energy, reduces emissions, cheaper, has better strength and durability than the normal concrete.

(iii) Use of scrap and recycled aggregate in concrete.

(iv) Other waste materials such as

- Blast furance slag
- Silica fume
- red mud
- Marble dust
- cinder
- rice husk
- coconut husk
- waste glass
- Jute fibres
- rubber from automobile tires
- Bamboo strips

have also been demonstrated by research.

(v) Wood salvaged from old buildings has been used for doors and windows.

(vi) Wood substitutes like

- Particle boards
- Medium density fibre boards
- Block boards
- Rubber wood
- Glass fibre reinforced products

- PVC
- Gypsum boards, gypsum building blocks

Steel requires 3 times as much energy as compared to wood to extract, transport, manufacture and construct.

Aluminimum framing requires 10 times as much energy as compared to wood.

5. Design efficiency :

Design of a building is very important as it plays a vital role in reducing the energy requirement of a building during its life.

Design has to consider the following :

(i) Optimum use of solar energy.

(ii) Optimum use of renewable energy.

(iii) Selection of energy efficient fittings, plants and equipment.

(iv) Adoption of environment friendly and energy efficient materials.

(v) Adopting energy efficient design and technologies.

A good architectural design will take full advantage of sun, wind and trees around the building. The location of door, windows and walls will be designed in a way to have maximum advantage of nature to minimize energy requirements. While deciding the specifications of materials and adoption of technologies for execution of the work, civil engineer plays an important role.

6. Occupant health and safety :

Research findings reported in different literatures revealed that buildings with good overall environmental quality can reduce the rate of respiratory disease, allergy, asthma, and enhance worker performance. Choose construction materials and interior finish products with zero or low emissions to improve indoor air quality. Many building materials and cleaning/maintenance products emit toxic gases, such as volatile organic compounds (voc) and formaldehyde. These gases can have a detrimental impact on occupant's health and productivity .

Provide adequate ventilation and a high-efficiency, in-duct filtration system. Heating and cooling systems that ensure adequate ventilation and proper filtration can have a dramatic and positive impact on indoor air quality. Provide effective drainage from the roof and surrounding landscape.

9.4 BENEFITS OF GREEN BUILDINGS :

(a) Economic benefit (tangible benefits) :

1. **Energy efficiency :** Green buildings are around 25-30% more energy efficient, with gold-rated buildings as much as 37% efficient.
2. **Water efficiency :** Green buildings use 20-30% less water compared with similar conventional buildings. This reduces operating water costs.
3. **Waste reduction :** Green buildings emphasise waste reduction. Construction wastes and demolition debris are the main wastes produced during the construction process, which degrade the quality of environment.

- The reuse and minimisation of construction wastes and debris and diverting them to recycling units.
- The increased use of recycled content in construction materials.

4. Improve employee productivity and satisfaction.
5. Enhance asset value and profits.
6. Optimize life-cycle economic performance.
7. Incorporate latest techniques and technologies.

(b) **Environmental benefits :**

1. Enhance and protect ecosystems and biodiversity.
2. Improve air and water quality
3. Reduce solid waste
4. Conserve natural resources
5. Reduced water consumption

(c) **Health and community benefits :**

1. Improve air, thermal and acoustic environment.
2. Enhance occupant comfort and health.
3. Contribute to overall quality of life.
4. Enhanced image and marketability

9.5 GREEN BUILDING RATING SYSTEMS :

There have been buildings which adopt one or more green features. To recognize the extent of features that a building adopts, rating system have been evolved. The Green building rating systems are the qualitative and quantitative measures of sustainability and the actual benefits of green design.

Government body and policy guidelines responsible for assessing sustainability in buildings sector in India are :

- NBC (National Building Code),
- ECBC (Energy Conservation Building Code), 2007
- Local byelaws

The Indian Green Building Council (IGBC), 2009 is actively promoting green buildings in India.

The India has currently two green rating systems :

(a). LEED

(b). GRIHA

(a) LEED (Leadership in Energy and Environmental Design) :

LEED was developed by the US Green Building Council (USGBC), and it is the most widely used Green Building Rating System used in North America.

The Indian Green Building Council (IGBC) has taken steps to promote the green building concept in India. Currently IGBC is facilitating the LEED rating in India.

The first LEED India rating programme, referred to as LEED India Version 1.0, was launched during the Green Building Congress Conference in October 2006. The latest rating system is now called the LEED 2011 for India - New Commercial Construction and Major Renovations or LEED 2011 for India - NC.

LEED India for 2011 is a measurement system designed for rating new and existing commercial and institutional and residential buildings. It is based on accepted energy and environmental principles and strikes a balance between known established practices and emerging concepts.

LEED 2011 for India - NC addresses :

1. Sustainable Sites
2. Water Efficiency
3. Energy & Atmosphere
4. Materials & Resources
5. Indoor Environmental Quality
6. Innovation in Design
7. Regional Priority

LEED 2011 has adopted several benchmarks for building performance. The buildings are given ratings of **'Platinum'**, **'Gold'**, **'Silver'**, and **'Certified'** based on green building attributes.

Table 9.1 LEED 2011 Green Building Rating System

Rating	Points
Certified	40 - 49
Silver	50 - 59
Gold	60 - 79
Platinum	80 and above

Table 9.2 Examples of LEED rated Buildings in India

Green Building	Rating Received
1. ABN Amro Bank N.V., Ahmedabad	Platinum
2. Infinity Benchmark, Kolkata	Platinum
3. CRISIL House, Mumbai	Platinum
4. Biodiversity Conservation India Ltd. (BICL), Banglore	Platinum
5. Patni (i-Gate) Knowledge Centre, Noida	Platinum
6. CII-Sohrabji Godrej Green Business Centre, Hyderabad	Platinum
7. ITC-Green Centre, Gurgaon	Platinum
8. Indira Paryavaran Bhavan, New Delhi	Platinum
9. Suzlon Energy Limited, Pune	Platinum
10. Birla International School, Jaipur	Gold
11. American Embassy School, Delhi	Gold
12. Anna Centenary Library Building, Chennai	Gold
13. Olympia Technology Park, Chennai	Gold
14. Shapath - V, Ahmedabad	Gold
15. Rajiv Gandhi International Airport, Hyderabad	Silver

(b) GRIHA RATING SYSTEM :

GRIHA-Green Rating for Integrated Habitat Assessment, is the national rating system of India launched in 2008. It has been conceived by The Energy and Resources Institute (TERI).

ADARSH (Association for Development and Research of Sustainable Habitats) founded jointly by TERI and MNRE (Ministry of New and Renewable Energy, Government of India) promotes GRIHA as a design of evaluation tool for Green Buildings and Habitats.

All GRIHA Rating variants undergo periodical technical revisions under the supervision of GRIHA Technical Advisory Committee (TAC). The latest version of GRIHA, GRIHA version 2015 (GRIHA V2015), was introduced in January 2015.

The GRIHA V 2015 rating system consists of 31 criteria categorized under various sections such as Site Planning, Construction Management, Occupant Comfort and Wellbeing, Sustainable Building Materials, Performance Monitoring and Validation, and Innovation.

Eligibility :

All buildings, which are in the design stage and have built up area more than 2,500 m^2, are eligible for certification under GRIHA. Building types include, but are not limited to offices, retail spaces, institutional buildings, hotels, hospital buildings, healthcare facilities, residences, and multi-family high-rise buildings.

Criteria and their weightage :

GRIHA is a performance-oriented system where points are earned for meeting the design and performance intent of the criteria. Each criterion has certain points assigned to it. It means that a project demonstrating compliance with a criterion would achieve the associated points.

GRIHA is a 100-point system consisting of some core points, which are mandatory, while the rest are optional. Different levels of certification (one star to five stars) are awarded based on the number of points earned. The minimum points required for certification are 25.

The scores for achieving GRIHA rating have been revised. The new thresholds for achieving GRIHA rating are mentioned below:

Table 9.3 GRIHA Rating System

GRIHA V 2015 Rating Thresholds	GRIHA Rating
25-40	★
41-55	★★
56-70	★★★
71-85	★★★★
86 or more	★★★★★

Table 9.4 Set of 31 Criteria for GRIHA 2015 Rating System

Criterion 1	Site Selection
Criterion 2	Low-impact design
Criterion 3	Design to mitigate UHIE
Criterion 4	Site Imperviousness Factor
Criterion 5	Air and water pollution control
Criterion 6	Preserve and protect landscape during construction
Criterion 7	Construction Management Practices
Criterion 8	Energy efficiency
Criterion 9	Renewable energy utilization
Criterion 10	Zero ODP materials
Criterion 11	Achieving indoor comfort requirements (visual/thermal/acoustic)
Criterion 12	Maintaining good IAQ
Criterion 13	Use of low-VOC paints and other compounds in building interiors
Criterion 14	Use of low-flow fixtures and systems
Criterion 15	Reducing landscape water demand
Criterion 16	Water Quality
Criterion 17	On-site water reuse
Criterion 18	Rainwater Recharge
Criterion 19	Utilization of BIS recommended waste materials in building structure
Criterion 20	Reduction in embodied energy of building structure
Criterion 21	Use of low-environmental impact materials in building interiors
Criterion 22	Avoided post-construction landfill
Criterion 23	Treat organic waste on site
Criterion 24	Labour safety and sanitation
Criterion 25	Design for Universal Accessibility
Criterion 26	Dedicated facilities for service staff
Criterion 27	Increase in environmental awareness
Criterion 28	Smart metering and monitoring
Criterion 29	Operation, Maintenance Protocols
Criterion 30	Performance Assessment for Final Rating
Criterion 31	Innovation

Table 9.5 Examples of GRIHA rated Buildings in India

1.	BEL Academy for Excellence, Bangluru	5 star
2.	Indian Institute of Technology (IIT), Gandhinagar	5 star
3.	Engineers India Limited Campus, Gurugram	5 star
4.	IIM, Udaipur	5 star
5.	South Asian University, New Delhi	5 star
6.	Indian Institute of Technology (IIT), Ropar	5 star
7.	Manipal University, Jaipur	5 star
8.	VVIP Circuit House, Pune	5 star
9.	Sabarmati Hostel, IIT Madras	4 star
10.	Sports Facility, IIT Bombay	4 star

9.6 CONCEPT OF SMART CITY :

A smart city is the integration of technology into a strategic approach to sustainability. Although there is no clear definition to define smart city but broadly **"a city that monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water supply, power, even major buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens is known as smart city."**

The concept of a smart city is relatively new one. Smart cities are those which have smart (intelligent) physical, social, institutional and economic infrastructure. It is expected that such a smart city will generate options for all residents to pursue their livelihoods and interests meaningfully and with joy.

Smart cities are meant as virtual reconstructions of cities or virtual cities. The term 'smart city' has been broadly used as an equivalent to 'intelligent city', 'digital city', 'information city', 'knowledge based city', 'wired city', 'telecity', 'teletopia', 'cyberville, etc.

Apart from employment, it is also important for a Smart City to offer decent living options to every resident. This would mean that it will have to provide a very high quality of life (comparable with any developed Europen City) i.e. good quality but offordable housing, cost efficient physical infrastructure such as 24 × 7 water supply, sanitation, 24 × 7 electric supply, clean air, quality education, health care, security, entertainment, sports, robust and high speed interconnectivity, fast & efficient urban mobility etc.

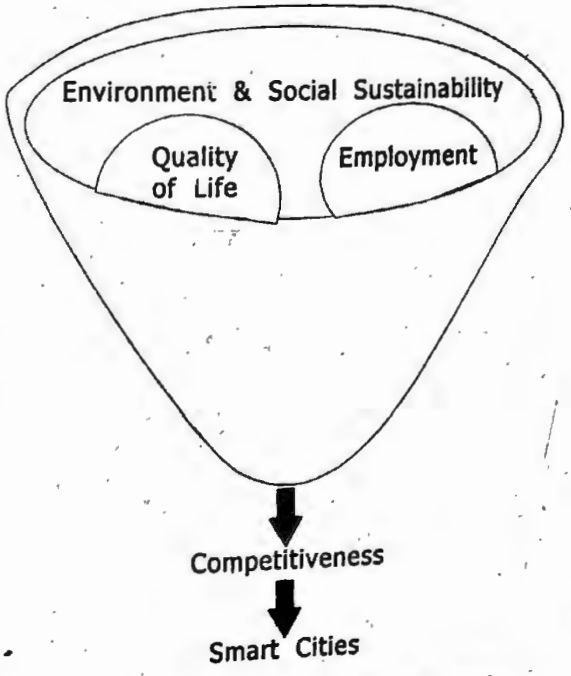


Fig. 9.1 What is a Smart City

In this context :

- **Competitiveness** refers to a city's ability to create employment opportunities, attract investments, experts, professionals and people. The ease of being able to do business and the quality of life it offer determines its competitiveness.
- **Sustainability** includes social sustainability, environmental sustainability and financial sustainability.
- **Quality of Life** includes safety and security, inclusiveness, entertainment, ease of seeking and obtaining public services, cost efficient healthcare, quality education, transparency, accountability and opportunities for participation in governance.

→ **Factors required to become a smart city :**

1. It should provide holistic urban environment embedded with the fundamental values along with the options to grow and prosper.
2. It should provide an opportunity to the new generations to participate in the City's management.
3. It should provide satisfactory lifestyle to the people.
4. It has to be a living city with respiratory system supported by its citizens and technology for its governance, management and functioning.
5. It should be technologically sound and efficient city.
6. It should have smart grids in infrastructure, transportation and energy.
7. It should offer quality water supply, sanitation, electrical supply, cost effective health care, quality education, communication network, clean environment, solid waste management, better public transport, safety, etc.

9.7 PILLARS OF A SMART CITY [REQUIREMENTS] :

Institutional Infrastructure (including Governance), **Physical Infrastructure, Social Infrastructure and Economic Infrastructure** constitute the four pillars on which a city rests. The centre of attention for each of these pillars is the citizen. In other words a Smart City works towards ensuring the best for its entire people, regardless of social status, age, income, levels, gender, etc.

- **Institutional Infrastructure** refers to the activities that relate to the planning and management systems in a city. The new technology has provided a new dimension to this system making it efficient, accountable and transparent. It includes the participatory systems of governance, e-governance, inclusive governance, the sense of safety and security and the opportunities for creativity.
- **Physical Infrastructure** refers to its stock of cost-efficient and intelligent physical infrastructure such as the urban mobility system, the housing stock, the energy system, the water supply system, sewerage system, sanitation facilities, solid waste management system, drainage system, etc. which are all integrated through the use of technology.
- **Social Infrastructure** relate to those components that work towards developing the human and social capital, such as the educational, healthcare, entertainment, etc. It also includes entertainment and sports, the open spaces and parks.

These together determine the quality of life of citizens in a city. It is also necessary that city promotes inclusiveness and city has structures which proactively bring disadvantageous sections i.e.. SCs, STs, socially and financially backwards, minorities, disabled and women into the mainstream of development.

- **Economic Infrastructure :**

For a city to attract investments and to create the appropriate economic infrastructure for employment opportunities, it has to first identify its core competence, comparative advantages and analyse its potential for generating economic activities. Once that is done, the gaps in required economic infrastructure can be determined. This would generally comprise the following :

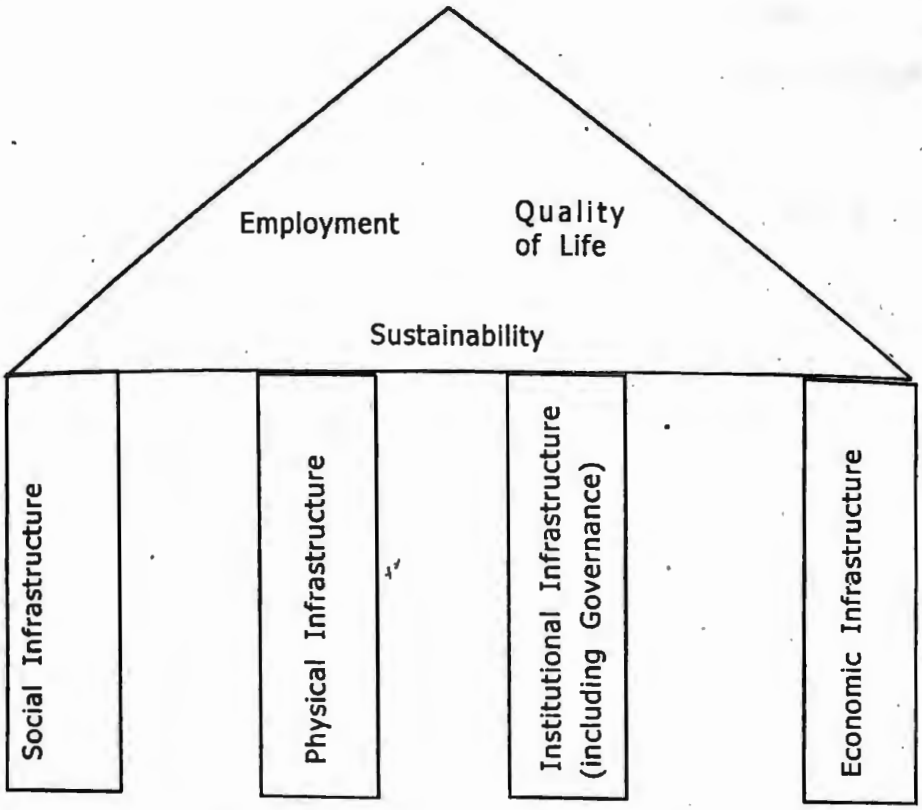


Fig. 9.2 Pillars of a smart city

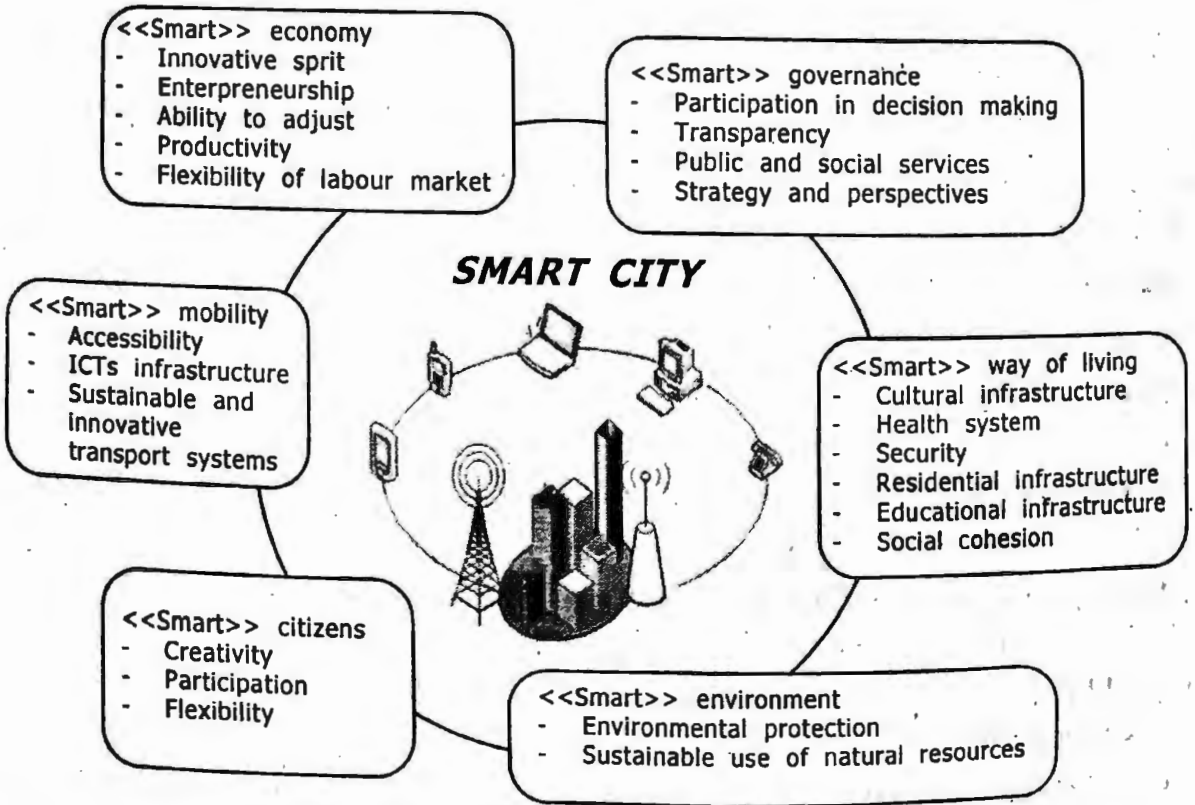


Fig. 9.3 Dimensions of smart city development

- Industrial parks and Export Processing Zones
- IT/BT Parks
- Trade centers
- Service Centers
- Skill Development Centres
- Financial Centers and Services
- Logistics hubs, warehousing and freight terminals
- Mentoring and Counselling services

9.8 FEATURES OF SMART CITY :

Some typical features of comprehensive development in Smart City solutions are described below.

1. **Promoting mixed land use in area based developments**–planning for 'unplanned areas' containing a range of compatible activities and land uses close to one another in order to make land use more efficient. The States will enable some flexibility in land use and building bye-laws to adapt to change;

2. **Housing and inclusiveness** - expand housing opportunities for all;

3. **Creating walkable localities** –reduce congestion, air pollution and resource depletion, boost local economy, promote interactions and ensure security. The road network is created or refurbished not only for vehicles and public transport, but also for pedestrians and cyclists, and necessary administrative services are offered within walking or cycling distance;

4. **Preserving and developing open spaces** - parks, playgrounds, and recreational spaces in order to enhance the quality of life of citizens, reduce the urban heat effects in Areas and generally promote eco-balance;

5. **Promoting a variety of transport options** - Transit Oriented Development (TOD), public transport and last mile para-transport connectivity;

6. **Traffic management**. Monitoring road systems will inform drivers about which route is best at any given time. Also, it will automatically manage the traffic lights in order to reduce congestion to the minimum taking into account the traffic volume at certain times of the day.

7. **Intelligent transport system**. Many public transport systems are already interconnected. This allows for different public transports to be coordinated and to provide information in real time.

8. **Smart parking**. There will be systems that will alert drivers when there is a free parking spot. Citizens will no longer waste their time looking for a place to park and the city will be less polluted. Did you know that by reducing the average time required to park a vehicle from 15 to 12 minutes can reduce CO_2 emissions by 400 tones in a city such as Barcelona?

9. **Making governance citizen-friendly and cost effective** - increasingly rely on online services to bring about accountability and transparency, especially using mobiles to reduce cost of services and providing services without having to go to municipal offices. Forming e-groups to listen to people and obtain feedback and use online monitoring of programs and activities with the aid of cyber tour of worksites;

10. **Giving an identity to the city** - based on its main economic activity, such as local cuisine, health, education, arts and craft, culture, sports goods, furniture, hosiery, textile, dairy, etc;

11. **Applying Smart city solutions providers to infrastructure and services** in area-based development in order to make them better. For example, making Areas less vulnerable to disasters, using fewer resources, and providing cheaper services.

12. **Waste management.** Not all places generate the same kind or the same amount of waste. With smart containers and a good fleet management system, the routes can be tailored to any situation. Thanks to this kind of solution, the efforts in waste collection will be much more efficient.

13. **Smart city maintenance.** Citizens will now be able to rely on systems to notify the City Council of any damages in the urban elements through their smart phones. This way things will be repaired faster.

14. **Smart grids.** They will provide the necessary amount of electricity depending on the demand. This way the power efficiency will be maximized. There are some cities that are testing these systems, as Malaga, for instance.

15. **Smart urban lighting.** Why waste energy if nobody is on the street? Smart urban lighting will adjust the intensity of the light depending on the people who are around.

9.9 DEVELOPMENT OF SMART CITIES IN INDIA :

Smart City mission is an Urban renewal and retrofitting programme launched by the Government of India, in the year 2015. The programme is to be rum in collaboration with the state governments of respective cities.

It is a five year programme where all the states except West Bangal would participate by nominating at least one city from the state, for the development as a Smart City. In August 2015, the list of 98 Cities was published by the ministry of Urban development. In June 2018 shilong (Meghalaya) got the smart city tag with total smart cities 100.

The required financial aid would be provided by the Central Government of India and by their respective state governments between the period 2017 and 2022. Each of the selected city, would create a special purpose vehicle (SPV) which will be headed by a full time CEO to implement the smart city mission. A joint company will be formed with Public Private Partnership (PPP). The centre and the state Government will provide Rs. 1000 crore to this company.

Cities selected from Gujarat for smart cities development are :

Ahmedabad, Surat, Rajkot, Vadodara, Gandhinagar, Dahod.

MULTIPLE CHOICE QUESTIONS

1. Which of the following is an element of a green building ?
   (a) Material efficiency (b) energy efficiency
   (c) Water efficiency (d) All the above
2. As per GRIHA rating system, for 4 star rating, a green building should score ..... points.
   (a) 41-55 (b) 71-85 (c) 56-30 (d) 86 or more
3. Which of the following is not a green building rating system ?
   (a) LEED (b) GRIHA (c) TERI (d) IGBC

CHAPTER

10. Concept of 4R's

10.1 PRINCIPLES OF 4R'S:

4R's refers to:

1. Reduce
2. Reuse
3. Recycle
4. Recovery.

(1) Reduce : Reduce means Prevent waste in the first place; by eliminating waste at source through better planning and design.

Reducing the amount you buy is the most significant of all the options to manage waste. The key is to only purchase goods that we need and in the right amount. If we never generate products in the first place, we do not have to extract raw resources, manufacture goods from scratch, come up with shipping materials, utilize additional resources for shipping, and then devise ways to dispose of them.

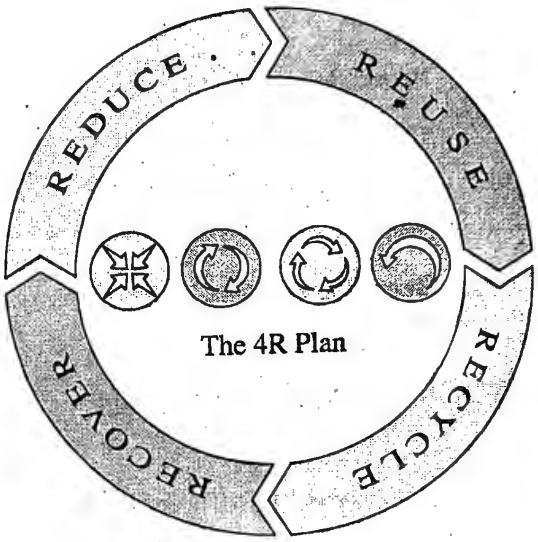


Fig. 10.1 4R Concept

We live in an era of over-consumption. Everything can be bought. Everything is monetized. Durable products are rare. And this consumption—goods production, transportation, packaging and waste management—is all too often at the expense of the environment. At the expense of life. At our children's and grandchildren's expense.

We must reduce waste production at the source. This means reducing the quantity of waste during production, distribution, purchasing, use and elimination.

Table below lays out how long it takes to decompose typical waste products.

Table 10.1 How Long Does It Take to Decompose

Paper towel 2–4 weeks	Plastic bag 10–20 years
Newspaper 6 weeks	Plastic film container 20–30 years
Apple core 2 months	Tin can 50 years
Plywood 1–3 years	Rubber boot sole 50–80 years
Wool sock 1–5 years	Aluminum can 80–200 years
Cigarette butt 1–5 years	Disposable diaper 450 years
	Plastic beverage bottle 450 years
	Glass bottle 1 million years

(2) **Reuse :** Reuse means to use things again that would be normally thrown away.

Reuse increases creativity on site. Reuse materials waste whenever possible; this is both cost-effective and reduces waste to landfill.

We are conditioned to think of things that are old, empty, worn, broken, ugly, or marred as useless, so we throw them away without much thought about the consequences. The process of reusing starts with the assumption that the used materials that flow through our lives can be a resource rather than refuse.

Waste, after all, is in the eye of the beholder. One person's trash is another person's treasure. If we really look at things we are throwing away, we can learn to see them as materials that can be reused to solve everyday problems and satisfy everyday needs. Most of us, however, haven't even begun to exploit the resources in our trash. Once you have made up your mind to use trash for positive uses, you can begin to brainstorm and generate ideas. Reusing saves money, conserves resources, and satisfies the human urge to be creative.

(3) **Recycle :** Recycle means the material/product goes through a mechanical process to change its original form.

Recycling ensure a good separation of waste into "one-material fractions" that can be more easily recycled. It enables segregation of at least 6 fractions: Wood, Concrete, Gypsum/Plasterboard, Metal, Plastic -soft and hard, Paper/Cardboard.

The main benefits of recycling are:

- Recycling generates industry
- Recycling creates jobs
- Recycling should be thought of as a cost-effective disposal option. It usually requires fewer government subsidies than land filling or incineration. It saves natural resources and helps protect the environment. Lower taxes, energy savings, and a cleaner environment are the real "bottom lines" in favor of recycling.

(4) **Recover :** Recovery means convert waste into resources like heat, electricity, fuel, compost, etc.

Energy Recovery can be an alternative, if recycling is not available.

10.2 LOGICAL SEQUENCE OF 4R :

The 4Rs principles provides an ecologically sound and environmentally friendly approach for minimizing and managing wastes. The logical sequence of 4R is **Reduce- Reuse - Recycle - Recover.**

The waste management hierarchy (sequence) is as follows:

1. Wherever possible, waste prevention is the most preferable option.
2. The second option is the waste minimization.
3. If waste is produced, every effort should be made to reuse it if practicable.
4. Recycling is the third option in the waste management hierarchy. Although recycling does help to conserve resources and reduce wastes, it is important to remember that there are economic and environmental costs associated with waste collection and recycling. For this reason, recycling should only be considered for waste which cannot be reduced or reused.

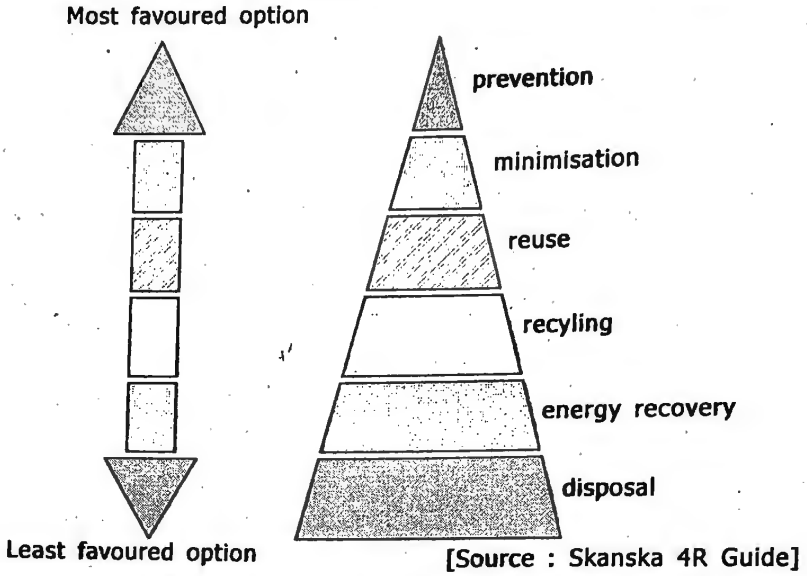


Fig. 10.2 Logical Sequence of 4R

5. Finally, it may be possible to recover materials or energy from waste which cannot be reduced, reused or recycled.

10.3 BENEFITS OF 4R :

The benefits derived from exercising 4R principles are :

- Less waste leads to fewer disposal facilities, which leads to less environmental issues .
- Reducing, reusing, and recycling C&D reduces greenhouse gas emissions.
- Deconstruction and selective demolition methods divert large amounts of materials from disposal and provide business opportunities within the local community.
- Recovered materials can be donated to qualified charities; results in tax benefit.
- Allows you to avoid disposal and purchasing costs.
- Generates revenue from the sale of materials.
- Creates opportunities for tax breaks through material donations.

Empirical evidence suggests that by practicing waste prevention, reusing products, recycling, and making environmentally conscious purchases, businesses can cut costs and increase profits. Cost savings take the form of:

- Lower waste disposal costs;
- Lower waste treatment costs;
- Lower energy costs;
- Savings on materials and supplies;
- A reduction in regulatory compliance costs;
- Lower storage costs;

- Cost recovery through the sale of recyclable materials;
- Cost recovery through sales of 4Rs technologies.

For example, in China, organic waste from thousands of small straw pulp mills is used as agricultural fertilizer.

In Kalundborg, Denmark, a coal-fired power station, an oil refinery, a plasterboard factory, a pharmaceutical plant and the municipality have created an *'industrial symbiosis'* by exploiting each other's waste streams.

10.4 APPLICATIONS 4R'S PRINCIPLES :

1. REDUCE :

We can reduce our consumption, our production of waste and our impact on the environment by practicing responsible consumption. All it takes is using our buying power carefully and respectfully in order to contribute positively to society, the environment and the world. Buying something means guaranteeing the waste and greenhouse gases that were caused in its production, transportation, packaging and future removal.

(i) Buying :

- Replace your consumption of disposable objects and products by reusable ones.
- Buy recyclable products; Buy products that contain recycled materials.
- Buy local products.
- Buy products that aren't over-packaged.
- Buy bulk whenever possible. Your supermarket should have a bulk section. Packaging is less present and often reusable. Some stores even sell household products in refillable containers.
- Avoid everything that's disposable.
- Reduce purchases of toxic products to a minimum.

(ii) Reducing use of Plastic :

- Find alternatives to plastic bags like cloth or paper bags for shopping.
- you can do shopping in markets and supermarkets that give paper or plastic bags.
- reduce use of plastic water bottles-you can carry water to work or school in your own bottle.
- In the case where water dispensers provide disposable plastic cups-you can help reduce plastic waste by carrying own bottle or cup.
- you can carry your cup or coffee mug around in case you will feel like having coffee at work or in school.
- when making purchases be conscious of the things you buy, ensuring that no unnecessary plastic is carried back home.
- Instead of using plastic containers to store water at home, you can go for an alternative like water pots that have been used for ages.
- Instead of having pre-packaged meals, you can opt for a more healthy homemade meals.
- you can make your own toys at very low cost.

(iii) Use Alternate Transportation :

- Avoid using car for travel.
- Use public transport like bus, train, auto, etc.
- practice walking and bicycling instead of using car or bike.

(iv) Reduce consumption of petrol or gas of your vehicle :

- Avoid abrupt stops and starts. Not only will you save the wear and tear on your breaks and tires, you could save up to 40% on every tank of gas.
- Don't drive too fast: Going from 90km/h to 100km/h increases your gas use by 10%; from 100km/h to 120km/h = 20% more! Gas consumption is optimal at 60-70 km/h.
- Turn off your engine as soon as you are parked or stopped for more than 10 seconds.
- Keep tire pressure up. Just one under-inflated tired could increase your gas consumption by 4%.
- Do regular oil and filter changes. Do preventive tune-ups. Poor maintenance can increase your gas consumption.
- Air conditioning can increase your gas consumption by 20%!.
- Before turning off your car, turn off all energy-consuming accessories: radio, telephone battery chargers, conditioning systems, etc.

(v) Reduce water use :

- Avoid flushing system in toilet, alternatively use bucket.
- A low-flow shower head can cut your water use in half.
- Take showers more frequently than baths: a shower takes 25-100 litres of water while baths require 250 litres.
- Avoid lawn sprinkling by fresh clean water, use grey water for it.
- Avoid pumping out ground water, store rain water in house tanks for daily use.

2. REUSE :

Reuse is thus about extending the life or giving a second life to something that we previously considered as "garbage".

- Use a reusable plastic or cotton bag for your purchases.
- Use and reuse cloth diapers instead of disposable ones.
- Reuse grey water from kitchen and bathroom for lawn sprinkling.
- Use one side printed waste paper for printing on other side.
- Donate your old clothes to needy persons or charitable trusts.
- Reuse your family-pack containers to buy in bulk.
- Reuse wrapping paper, plastic bags, boxes, and lumber.
- Buy beverages in returnable containers.
- Books and magazines can be donated to schools, public libraries, or nursing homes.
- Old tires can be used in the garden and in the play yard.

- Cement, bricks and other materials can be crushed and used as filling material.
- Demolition waste can be used as aggregate in concrete.
- Use Cloth napkins (thus washable) and washable rags instead of paper napkins and paper towels (single-use).
- Use Electric razor instead of disposable razors;
- Use rechargeable batteries instead of regular batteries.

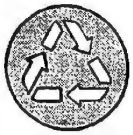
3. **RECYCLE :**

(i) Paper and cardboard :

- Instead of using virgin fiber paper, use recycled papers. A sheet of paper can only be recycled about seven times, since the fibers become shorter and more fragile during the recycling process.

Universal Recycling Symbol
(used as a generic symbol for recycling or to indicate the material is recyclable)

Black Universal Recycling Symbol



Recycled Paper Symbol
(used to indicate 100% recycled paper content).

Partially - Recycled Paper Symbol

Fig: 10.3 Recycling Symbols

(ii) Plastics :

- Various plastic bottles (bottled water, soft drinks, juice), cables, clothing can be recycled in to T-shirts, carpets, binders, pillow fillings, etc.
- Polyvinyl chloride Containers for household cleaning or personal care products (bleach, shampoo), mineral water, food boxes, blinds, cheese and meat packaging, credit cards, bottles, etc. can be recycled in to Coating, pipes, car parts, road cones, signs, construction materials, etc.
- Low density polyethylene Flexible containers (mustard, sauces), expandable bags and wrappings (bread bags), bags (garbage, grocery, freezer), tarps,etc. can be recycled in to Grocery bags, garbage bags, plastic lumber, etc.

(iii) Glass :

- Glass Like plastic, glass is an inert material, so it does not move or change. A buried glass bottle takes 4,000 years to decompose. This is why it's a good idea to recycle glass.
- Glass can be recycled indefinitely without losing its properties and quality. It is brought back to life as bottles, containers and jars of all sorts. It is also used :
- In glass-insulated wool ;
- As an aggregate for road sub bases, concrete blocks, asphalt and ceramic tiles;
- In reflective road paint (glass microbeads) ;
- As abrasive ;
- To replace fine sand for jetting.

For the time being, these products cannot be recycled: • Ceramic ; • Mirrors and window glass ; • Porcelain and pottery ; • Pyrex glass ; • Cups, dishes, drinking glasses ; • Crystal ; • Light bulbs and neon lights.

(iv) Metal :

Recycling metals preserves the environment in many ways. On the top of that list is mining, which is a very destructive and polluting activity. By recycling metal, we avoid extracting, refining, transporting—all activities requiring a lot of energy and water. In consequence, that keeps us from producing considerable greenhouse gases.

- 1 tonne of recycled aluminium saves 6 tonnes of greenhouse gases.
- Recycled aluminium is transformed into cans, wrapping paper, garden furniture and car parts.
- Presently, 65% of steel products are made from recycled steel. Recycled steel is used for making engine parts, steel structures and cans.
- What you can recycle : • Tin cans ; • Cans ; • Beer caps ; • Aluminum paper, foil and plates ; • Metal lids. - Getting Copper wires from old electrical equipment.

(v) Debris from construction, renovation and demolition :

- Cement, bricks and other materials can be crushed and used as filling material.
- Demolition waste can be used as aggregate in concrete.
- Reinforcement steel bars can be sent to steel recyclers or it can be used in flooring concrete.
- Old Timber can be used for doors, windows , furniture, etc.

4. RECOVER :

Most of the materials thrown in the garbage can be used and processed in ways other than being destroyed. This is what is called recovering. Reusing, recycling and composting are the most frequently used methods for recovering waste. When it's not possible to reuse or recycle objects—such as dead batteries, ink cartridges or cell phones, which all contain toxic elements labeled hazardous household waste—there is one last option before throwing them away: scrap dealers, recycling workers and recoverers.

Another alternative is recovering the energy stored in residual material. That means turning waste into a fuel for manufacturing processes or equipment designed to produce energy. Various mechanical, biological and caloric systems and technologies can convert, reprocess or break up wastes into new materials or energy. For example, the methane caused by rotting materials in dump sites can be recycled. This gas is converted into power, and thus eliminates its harmful effects on the environment.

For example,

- Use kitchen waste (organic waste) in manufacturing compost.
- Production of compost from municipal waste.
- Methane gas produced during decomposition of waste can be used as a fuel.
- Generation of electricity from waste (energy recovery).

10.5 TREATMENT OF DIFFERENT TYPES OF WASTE USING CONCEPT OF 4R :

Examples of different types of waste and how it can best be treated at end of life, using the 4R Best Practice are given below:

Table 10.2 Treatment of Different Types of Waste Using Concept of 4R

	Examples of Waste	4R Best Practice
[I] Construction waste:		
(i) Construction Waste	Concrete	Reuse
	Plasterboard/Gypsum	Recycle
	Paper	Recycle
	Metal	Recycle
Office Waste	Paper	Recycle
	Cardboard	Recycle
	Plastic (hard/soft)	Recycle or Recover
	Toners	Recycle
Waste from Manufacturing plants	Asphalt	Reuse
	Concrete	Reuse or Recycle
(II) Demolition Waste :	Concrete	Reuse
	Steel	Recycle
	Cabling	Recycle or Recover
	Glass	Recycle
	Timber	Reuse or Recycle
	Other materials	Reuse or Recycle