Dr. Rekha Tripathi

Department of Applied Sciences in Maharaja Surajmal Institute of Technology (affiliated to GGSIPU), India
Dr. Rekha Tripathi is presently working as Assistant Professor in the Department of Applied Sciences in Maharaja Surajmal Institute of Technology (affiliated to GGSIPU). She awarded her Ph.D in Chemistry in 1996 form University of Rajasthan, Jaipur. She has several research papers published in national and international journals.
ENERGY AND ENVIRONMENT
# Index

<table>
<thead>
<tr>
<th>UNITS</th>
<th>PAGE NUMBERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit I. Non Renewable Sources of Energy</td>
<td>3-18</td>
</tr>
<tr>
<td>Unit II. Renewable Sources of Energy</td>
<td>19-40</td>
</tr>
<tr>
<td>Unit III. Nuclear Energy</td>
<td>41-77</td>
</tr>
<tr>
<td>Unit-IV. Environmental Implications</td>
<td>78-114</td>
</tr>
<tr>
<td>Unit- V . References</td>
<td>115</td>
</tr>
</tbody>
</table>
UNIT-1 Non-renewable Sources of Energy

1. Energy

Energy causes things to happen around us. Look out the window.

During the day, the sun gives out light and heat energy. At night, street lamps use electrical energy to light our way.

When a car drives by, it is being powered by gasoline, a type of stored energy.

The food we eat contains energy. We use that energy to work and play.

We learned the definition of energy in the introduction:

"Energy Is the Ability to Do Work."

Energy can be found in a number of different forms. It can be chemical energy, electrical energy, heat (thermal energy), light (radiant energy), mechanical energy, and nuclear energy.

• Stored and Moving Energy

Energy makes everything happen and can be divided into two types:

- Stored energy is called potential energy.
- Moving energy is called kinetic energy.

With a pencil, try this example to know the two types of energy.

Put the pencil at the edge of the desk and push it off to the floor. The moving pencil uses kinetic energy.
Now, pick up the pencil and put it back on the desk. You used your own energy to lift and move the pencil. Moving it higher than the floor adds energy to it. As it rests on the desk, the pencil has potential energy. The higher it is, the further it could fall. That means the pencil has more potential energy.

2. Nonrenewable energy sources

Energy sources are classified as nonrenewable if they cannot be replenished in a short period of time. Nonrenewable energy sources come out of the ground as liquids, gases, and solids. Crude oil (petroleum) is the only commercial nonrenewable fuel that is naturally in liquid form. Crude oil is used to make liquid petroleum products like gasoline, diesel fuel, and heating oil. Propane and other gases such as butane and ethane are found in natural gas and crude oil. They are extracted and stored as liquids and are called liquid petroleum gases.

Coal, crude oil, and natural gas are all considered fossil fuels because they were formed from the buried remains of plants and animals that lived millions of years ago.

Fossil Fuels - Coal, Oil and Natural Gas

There are three major forms of fossil fuels: coal, oil and natural gas. All three were formed many hundreds of millions of years ago before the time of the dinosaurs – hence the name fossil fuels. The age they were formed is called the Carboniferous Period. It was part of the Paleozoic Era. "Carboniferous" gets its name from carbon, the basic element in coal and other fossil fuels.

The Carboniferous Period occurred from about 360 to 286 million years ago. At the time, the land was covered with swamps filled with huge trees, ferns and other large leafy plants, similar to the picture above. The water and seas were filled with algae – the green stuff that forms on a stagnant pool of water. Algae is actually millions of very small plants.
Some deposits of coal can be found during the time of the dinosaurs. For example, thin carbon layers can be found during the late Cretaceous Period (65 million years ago) – the time of Tyrannosaurus Rex. But the main deposits of fossil fuels are from the Carboniferous Period.

As the trees and plants died, they sank to the bottom of the swamps of oceans. They formed layers of a spongy material called peat. Over many hundreds of years, the peat was covered by sand and clay and other minerals, which turned into a type of rock called sedimentary.

More and more rock piled on top of more rock, and it weighed more and more. It began to press down on the peat. The peat was squeezed and squeezed until the water came out of it and it eventually, over millions of years, it turned into coal, oil or petroleum, and natural gas.

2.1 Coal

Coal is a hard, black colored rock-like substance. It is made up of carbon, hydrogen, oxygen, nitrogen and varying amounts of sulphur. There are three main types of coal – anthracite, bituminous and lignite. Anthracite coal is the hardest and has more carbon, which gives it a higher energy content. Lignite is the softest and is low in carbon but high in hydrogen and oxygen content. Bituminous is in between. Today, the precursor to coal—peat—is still found in many countries and is also used as an energy source.

The earliest known use of coal was in China. Coal from the Fu-shun mine in northeastern China may have been used to smelt copper as early as 3,000 years ago. The Chinese thought coal was a stone that could burn.

Coal is found in many of the lower 48 states of U.S. and throughout the rest of the world. Coal is mined out of the ground using various methods. Some coal mines are dug by sinking vertical or horizontal shafts deep under ground, and coal miners travel by
elevators or trains deep under ground to dig the coal. Other coal is mined in strip mines where huge steam shovels strip away the top layers above the coal. The layers are then restored after the coal is taken away.

The coal is then shipped by train and boats and even in pipelines. In pipelines, the coal is ground up and mixed with water to make what's called a slurry. This is then pumped many miles through pipelines. At the other end, the coal is used to fuel power plants and other factories.

2.1.1 Coal Classification

Coal is classified into three major types namely anthracite, bituminous, and lignite. However there is no clear demarcation between them and coal is also further classified as semi-anthracite, semi-bituminous, and sub-bituminous. Anthracite is the oldest coal from geological perspective. It is a hard coal composed mainly of carbon with little volatile content and practically no moisture. Lignite is the youngest coal from geological perspective. It is a soft coal composed mainly of volatile matter and moisture content with low fixed carbon. Fixed carbon refers to carbon in its free state, not combined with other elements. Volatile matter refers to those combustible constituents of coal that vaporize when coal is heated. The common coals used in Indian industry are bituminous and sub-bituminous coal. The gradation of Indian coal based on its calorific value is as follows: Grade Calorific Value Range (in kCal/kg)

<table>
<thead>
<tr>
<th>Grade</th>
<th>Calorific Value Range (in kCal/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Exceeding 6200</td>
</tr>
<tr>
<td>B</td>
<td>5600 – 6200</td>
</tr>
<tr>
<td>C</td>
<td>4940 – 5600</td>
</tr>
<tr>
<td>D</td>
<td>4200 – 4940</td>
</tr>
<tr>
<td>E</td>
<td>3360 – 4200</td>
</tr>
<tr>
<td>F</td>
<td>2400 – 3360</td>
</tr>
<tr>
<td>G</td>
<td>1300 – 2400</td>
</tr>
</tbody>
</table>
Normally D, E and F coal grades are available to Indian Industry.

2.2 Oil or Petroleum

Oil is another fossil fuel. It was also formed more than 300 million years ago. Some scientists say that tiny diatoms are the source of oil. Diatoms are sea creatures the size of a pin head. They do one thing just like plants; they can convert sunlight directly into stored energy.

In the graphic on the left, as the diatoms died they fell to the sea floor (1). Here they were buried under sediment and other rock (2). The rock squeezed the diatoms and the energy in their bodies could not escape. The carbon eventually turned into oil under great pressure and heat. As the earth changed and moved and folded, pockets where oil and natural gas can be found were formed (3).

Oil has been used for more than 5,000-6,000 years. The ancient Sumerians, Assyrians and Babylonians used crude oil and asphalt ("pitch") collected from large seeps at Tuttul (modern-day Hit) on the Euphrates River. A seep is a place on the ground where the oil leaks up from below ground. The ancient Egyptians, used liquid oil as a medicine for wounds, and oil has been used in lamps to provide light.

The Dead Sea, near the modern Country of Israel, used to be called Lake Asphaltites. The word asphalt was derived is from that term because of the lumps of gooey petroleum that were washed up on the lake shores from underwater seeps.

In North America, Native Americans used blankets to skim oil off the surface of streams and lakes. They used oil as medicine and to make canoes water-proof. During the Revolutionary War, Native Americans taught
George Washington's troops how to treat frostbite with oil.

As our country grew, the demand for oil continued to increase as a fuel for lamps. Petroleum oil began to replace whale oil in lamps because the price for whale oil was very high. During this time, most petroleum oil came from distilling coal into a liquid or by skimming it off of lakes – just as the Native Americans did.

Then on August 27, 1859, Edwin L. Drake (the man standing on the right in the black and white picture to the right), struck liquid oil at his well near Titusville, Pennsylvania. He found oil under ground and a way that could pump it to the surface. The well pumped the oil into barrels made out of wood. This method of drilling for oil is still being used today all over the world in areas where oil can be found below the surface.

Oil and natural gas are found under ground between folds of rock and in areas of rock that are porous and contain the oils within the rock itself. The folds of rock were formed as the earth shifts and moves. It's similar to how a small, throw carpet will bunch up in places on the floor.

To find oil and natural gas, companies drill through the earth to the deposits deep below the surface. The oil and natural gas are then pumped from below the ground by oil rigs (like in the picture). They then usually travel through pipelines or by ship.

Oil is found in 18 of the 58 counties in California. Kern County, the County where Bakersfield is found, is one of the largest oil production places in the country. But we only get one-half of our oil from California wells. The rest comes from Alaska, and an increasing amount comes from other countries. In the entire U.S., more than 50 percent of all the oil we use comes from outside the country... most of it from the Middle East.

Oil is brought to California by large tanker ships. The petroleum or crude oil must be changed or refined into other products before it can be used.
2.2.1 Petroleum and its Characteristics

Petroleum is a basic natural fuel. It is a dark greenish brown, viscous mineral oil, found deep in earth’s crust. It is mainly composed of various hydrocarbons (like straight chain paraffins, cycloparaffins or napthenes, olefins, and aromatics) together with small amount of organic compounds containing oxygen nitrogen and sulphur.

The average composition of crude petroleum is : C = 79.5 to 87.1%; H = 11.5 to 14.8%; S = 0.1 to 3.5%, N and O = 0.1 to 0.5%.

Petroleum are graded according to the following physio-chemical properties:

(a) Specific gravity,
(b) Calorific value,
(c) Fish point or ignition point,
(d) Viscosity,
(e) Sulphur contents,
(f) Moisture and sediment content, and
(g) Specific heat and coefficient of expansion.

2.2.2 Classification of Petroleum

The chemical nature of crude petroleum varies with the part of the world in which it is found. They appear, however, to be three principal verities.

Paraffinic Base Type Crude Petroleum

This type of petroleum is mainly composed of the saturated hydrocarbons from CH4 to C35 H72 and a little of the naphthalene and aromatics. The hydrocarbons from C18 H38 to C35 H72 are sometimes called waxes.

Asphalitic Base Type Crude Petroleum
It contains mainly cycloparaffins or naphthalene with smaller amount of paraffins and aromatic hydrocarbons.

**Mixed Base Type Crude Petroleum**

It contains both paraffinic and asphaltic hydrocarbons and are generally rich in semi-solid waxes.

**2.2.3 Manufactured Liquid Fuels and their Characteristics**

Manufactured liquid fuels include Gasoline, Diesel oil, Kerosene, Heavy oil, Naptha, Lubricating oils, etc. These are obtained mostly by fractional distillation of crude petroleum or liquefaction of coal.

**Gasoline or Petrol and its Characteristics**

The straight run gasoline is obtained either from distillation of crude petroleum or by synthesis. It contains some undesirable unsaturated straight chain hydrocarbons and sulphur compounds. It has boiling range of 40-120oC.

The unsaturated hydrocarbons get oxidized and polymerized, thereby causing gum and sludge formation on storing. On the other hand, sulphur compounds lead to corrosion of internal combustion engine and at the same time they adversely affect tetraethyl lead, which is generally added to gasoline for better ignition properties.

The sulphur compounds from gasoline are generally removed by treating it with an alkaline solution sodium plumbite. Olefins and colouring matter of gasoline are usually removed by percolating through ‘Fuller’s earth’ which absorbs preferentially only the colours and olefine. It is used in air-crafts. It is also used as motor fuel, in dry-cleaning and as a solvent. Some of the characteristics of an ideal gasoline are the following:

(a) It must be cheap and readily available.

(b) It must burn clean and produce no corrosion, etc. on combustion.
(c) It should mix readily with air and afford uniform manifold distribution, i.e. should easily vaporize.

(d) It must be knock resistant.

(e) It should be pre-ignite easily.

(f) It must have a high calorific value.

Petroleum Distillation

2.2.4 Diesel Fuel and its Characteristics

The diesel fuel or gas oil is obtained between 250-320°C during the fractional distillation of crude petroleum. This oil generally contains 85% C, 12% H. Its calorific value is about 11,000 kcal/kg.

The suitability of a diesel fuel is determined by its cetane value. Diesel fuels consist of longer hydrocarbons and have low values of ash, sediment, water and sulphalt contents.
The main characteristics of a diesel fuel is that it should easily ignite below compression temperature. The hydrocarbon molecules in a diesel fuel should be, as far as possible, the straight-chain ones, with a minimum admixture of aromatic and side-chain hydrocarbon molecules.

It is used in diesel engines as heating oil and for cracking to get gasoline.

2.2.5 Kerosene Oil and its Characteristics

Kerosene oil is obtained between 180-250oC during fractional distillation of crude petroleum. It is used as an illuminant, jet engine fuel, tractor fuel, and for preparing laboratory gas. With the development of jet engine, kerosene has become a material of far greater importance than it is used to be. When kerosene is used in domestic appliances, it is always vaporized before combustion. By using a fair excess of air it burns with a smokeless blue flame.

2.2.6 Heavy Oil and its Characteristics

It is a fraction obtained between 320-400oC during fractional distillation of crude petroleum. This oil on refractionation gives:

(a) Lubricating oils which are used as lubricants.

(b) Petroleum-jelly (Vaseline) which is used as lubricants in medicines and in cosmetics.

(c) Greases which are used as lubricants.

(d) Paraffin wax which is used in candles, boot polishes, wax paper, tarpolin cloth and for electrical insulation purposes.

2.3 Natural Gas

Sometime between 6,000 to 2,000 years BCE (Before the Common Era), the first discoveries of natural gas seeps were made in Iran. Many early writers described the natural petroleum seeps in the Middle East, especially in the Baku region of what is now
Azerbaijan. The gas seeps, probably first ignited by lightning, provided the fuel for the "eternal fires" of the fire-worshiping religion of the ancient Persians.

Natural gas is generally associated with petroleum deposits and is obtained from wells dug in the oil-bearing regions.

The approximate composition of natural gas is: CH4 = 70.9%, C2H6 = 5.10%, H2 = 3%, CO + CO2 = 22%

The calorific value varies from 12,000 to 14,000 kcal/m3.

It is an excellent domestic fuel and is conveyed in pipelines over very large distances. In America, it is available to a great extent, and so, is quite popular as a domestic fuel. It is now used in manufacture of chemicals by synthetic process. It is a colourless gas and is non-poisonous. Its specific gravity is usually between 0.57 to 0.7.

It is lighter than air and disperses into air easily in case of leak. This gas is highly flammable.

3. HCV AND LCV

3.1 HIGHER OR GROSS CALORIFIC VALUE

It is the total amount of heat produced, when unit mass/volume of the fuel has been burnt completely and the products of combustion have been cooled to room temperature (15° C or 60° F).

It is explained that all fuels contain some hydrogen and when the calorific value of hydrogen containing fuel is determined experimentally, the hydrogen is converted into steam. If the products of combustion are condensed to the room temperature, the latent heat of condensation of steam also gets included in the measured heat which is then called GCV.
3.2 LOWER OR NET CALORIFIC VALUE

It is the net heat produced, when unit mass/volume of the fuel is burnt completely and the products are permitted to escape.

In actual practice of any fuel, the water vapour and moisture, etc., are not condensed and escape as such along with hot combustion gases. Hence, a lesser amount of heat is available.

4. Effects of Mining and Processing of Mineral Resources on Environment


Mining and processing of mineral resources normally have a considerable impact on land, water, air, and biologic resources. Social impacts result from the increased demand for housing and other services in mining areas.

4.1 Pollution:

Mining operations often pollute the atmosphere, surface waters and ground water. Rainwater seeping through spoil heaps may become heavily contaminated, acidic or turbid, with potentially devastating effects on nearby streams and rivers.

Trace elements (cadmium, cobalt, copper and others) when leached from mining wastes and concentrated in water, soil or plants, may be toxic or may cause diseases in people and other animals who consume contaminated water or plants, or who use the soil. Specially constructed ponds to collect runoff can help but cannot eliminate all problems.

Huge volumes of dust generated by explosions, transportation and processing may lead to the death of surrounding vegetation. Chemicals used in the extraction processes, such as drilling muds, are often highly polluting substances.
4.2 Destruction of Land:

Mining activity can cause a considerable loss of land because of chemical contamination, destruction of productive layers of soil, and often permanent scarring of the land surface. Large mining operations disturb the land by directly removing material in some areas and by dumping waste in others. There can be a considerable loss of wildlife habitat.

4.3 Subsidence:

The presence of old, deep mines may cause the ground surface to subside in a vertical or horizontal direction. This may severely damage buildings, roads and farmland, as well as alter the surface drainage patterns.

4.4 Noise:

Blasting and transport cause noise disturbance to local residents and to wildlife.

4.5 Energy:

Extraction and transportation requires huge amounts of energy which adds to impacts such as acid rain and global warming.

4.6 Impact on the Biological Environment:

Physical changes in the land, soil, water and air associated with mining directly and indirectly affect the biological environment. Direct impacts include death of plants or animals caused by mining activity or contact with toxic soil or water from mines. Indirect impacts include changes in nutrient cycling, total biomass, species diversity, and ecosystem stability due to alterations in groundwater or surface water availability or quality.

4.7 Long-term Supplies of Mineral Resources:

The economies of industrialized countries require the extraction and processing of large amounts of minerals to make products. As other economies industrialize, their mineral
demands increase rapidly. The mineral demands of countries in Asia, such as Malaysia, Thailand and South Korea have grown phenomenally in the last twenty years.

Since mineral resources are a non-renewable resource, it is important for all countries to take a low-waste sustainable earth approach to dealing with them. Developed countries need to change from a high-waste throw away approach and developing countries need to insure that they do not adopt such an approach. Low-waste approach requires emphasis on recycling, reusing and waste reduction and less emphasis on dumping, burying and burning.

5. Resource Recovery

Resource recovery is the reclaiming of "garbage" materials for a new use. It includes collecting, sorting, and processing materials that are traditionally viewed as waste and transforming them into the raw inputs used to create new products. Recycling and composting are among the best known resource recovery practices.

Resource recovery is the practice of reclaiming materials that were previously thought of as unusable. It is not managing waste, which is the standard for most garbage companies.

Traditional waste companies collect and move wasted materials to large-scale, single-use sites such as landfills or incinerators. Unlike the management of waste, resource recovery recognizes that there is still value in those materials. Recology facilitates extracting the remaining value of these materials through our progressive programs, facilities and technologies.

The intention of resource recovery is always to make the best and highest use of all materials, and landfilling only those materials for which there is currently no use. Over time, we expect the volume of landfill-bound material to shrink to a negligible amount as a result of our creative resource recovery efforts. Recology is actively pursuing that goal.
Resource recovery is an important aspect of environment sustainability. Resources such as food scraps, yard trimmings, discarded paper, plastic, and fabrics are removed from the category of unusable materials, and recovered for their reuse while preserving the use of virgin materials. These are just a few examples of reusable materials that benefit the agricultural and manufacturing industries throughout the world.

5.1 Recycle (v)

1. To repeat a cycle
2. To use again after processing

Recycling is the process of collecting, sorting, and converting discarded materials into raw inputs used to produce new products.

All of the materials recycled as part of the programs provided by Recology reduce the consumption of virgin materials. Our recycling programs include collecting food scraps, yard trimmings, paper, plastics, glass, metal, and construction and demolition material, bulky items, clothing, carpets and much more.

There are many benefits to recycling. Between 17 and 31 trees are saved for every ton of 100% recycled paper purchased, says Recycled Papers, The Essential Guide by
Claudia Thompson, published by the MIT Press. The U.S. Environmental Protection Agency lists some of the positive impacts of recycling that go far beyond trees. These include:

- Protecting and expanding U.S. manufacturing jobs
- Reducing the need for landfilling and incineration
- Preventing pollution caused by the manufacturing of products from virgin materials, including keeping 60 pounds of air pollution out of the atmosphere for every ton of 100% recycled paper used
- Saving energy from natural resource extraction
- Decreasing greenhouse gas emissions that contribute to climate change
- Conserving natural resources such as timber, water, and minerals for future generations

Recycling is an important part of resource recovery but the benefits are not fully realized until consumers favor products with recycled content when shopping. Consider purchasing products made with recycled content to help sustain a viable market for recovered materials like plastic, fabric, glass and paper. Recycling is just one step in conserving resources, but it goes hand in hand with asking manufacturers to use recovered materials in their products, and to use less material in their packaging.
UNIT-2 Renewable Sources of Energy

1. Solar Energy

We have always used the energy of the sun as far back as humans have existed on this planet. As far back as 5,000 years ago, people "worshipped" the sun. Ra, the sun-god, who was considered the first king of Egypt. In Mesopotamia, the sun-god Shamash was a major deity and was equated with justice. In Greece there were two sun deities, Apollo and Helios. The influence of the sun also appears in other religions – Zoroastrianism, Mithraism, Roman religion, Hinduism, Buddhism, the Druids of England, the Aztecs of Mexico, the Incas of Peru, and many Native American tribes.

We know today, that the sun is simply our nearest star. Without it, life would not exist on our planet. We use the sun's energy every day in many different ways.

When we hang laundry outside to dry in the sun, we are using the sun's heat to do work – drying our clothes.

Plants use the sun's light to make food. Animals eat plants for food. And as we know, decaying plants hundreds of millions of years ago produced the coal, oil and natural gas that we use today. So, fossil fuels is actually sunlight stored millions and millions of years ago.

Solar radiation, electromagnetic radiation, including X-rays, ultraviolet and infrared radiation, and radio emissions, as well as visible light, emanating from the Sun. Of the $3.8 \times 10^{33}$ ergs emitted by the Sun every second, about 1 part in 120 million is received by its attendant planets and their satellites. The small part of this energy intercepted by Earth (the solar constant, on average 1.4 kilowatts per square metre) is of enormous importance to life and to the maintenance of natural processes on Earth’s surface.

Indirectly, the sun or other stars are responsible for ALL our energy. Even nuclear energy comes from a star because the uranium atoms used in nuclear energy were created in the fury of a nova – a star exploding.
People can harness the sun's energy in a few different ways:

- **Photovoltaic cells**, which convert sunlight into electricity.
- **Solar thermal technology**, where heat from the sun is used to make hot water or steam.
- **Solar water heater**, which can be as simple as letting the sun shine through windows to heat the inside of a building.

### 1.1 Solar Cells or Photovoltaic Energy

Solar cells are also called photovoltaic cells – or PV cells for short – and can be found on many small appliances, like calculators, and even on spacecraft. They were first developed in the 1950s for use on U.S. space satellites. They are made of silicon, a special type of melted sand.

When sunlight strikes the solar cell, electrons (red circles) are knocked loose. They move toward the treated front surface (dark blue color). An electron imbalance is created between the front and back. When the two surfaces are joined by a connector, like a wire, a current of electricity occurs between the negative and positive sides.
These individual solar cells are arranged together in a PV module and the modules are grouped together in an array. Some of the arrays are set on special tracking devices to follow sunlight all day long.

The electrical energy from solar cells can then be used directly. It can be used in a home for lights and appliances. It can be used in a business. Solar energy can be stored in batteries to light a roadside billboard at night. Or the energy can be stored in a battery for an emergency roadside cellular telephone when no telephone wires are around.

Some experimental cars also use PV cells. They convert sunlight directly into energy to power electric motors on the car.

But when most of us think of solar energy, we think of satellites in outer space. Here’s a picture of solar panels extending out from a satellite.

1.2 Solar Thermal Technology

Another way to tap solar energy is by collecting the sun’s heat. Solar thermal power plants use heat from the sun to create steam, which can then be used to make
electricity. On a smaller scale, solar panels that harness thermal energy can be used for heating water in homes, other buildings, and swimming pools.

1. Mirrors or reflectors concentrate the sun's rays to heat a special kind of liquid.
2. The heat from this liquid boils water to create steam.
3. Steam spins a turbine that is connected to a generator, which creates electricity.
4. The steam cools and condenses back to water, which is recycled, reheated, and converted into steam again.

Solar water heaters

Solar water heaters -- also called solar domestic hot water systems -- can be a **cost-effective way** to generate hot water for your home. They can be used in any climate, and the fuel they use -- sunshine -- is free.

Solar water heating systems include storage tanks and solar collectors. There are two types of solar water heating systems: active, which have circulating pumps and controls, and passive, which don't.
ACTIVE SOLAR WATER HEATING SYSTEMS

There are two types of active solar water heating systems:

- **Direct circulation systems**
  Pumps circulate household water through the collectors and into the home. They work well in climates where it rarely freezes.

- **Indirect circulation systems**
  Pumps circulate a non-freezing, heat-transfer fluid through the collectors and a heat exchanger. This heats the water that then flows into the home. They are popular in climates prone to freezing temperatures.

1.3 Passive solar water heating systems

Passive solar water heating systems are typically less expensive than active systems, but they're usually not as efficient. However, passive systems can be more reliable and may last longer. There are two basic types of passive systems:

- **Integral collector-storage passive systems**
  These work best in areas where temperatures rarely fall below freezing. They
also work well in households with significant daytime and evening hot-water needs.

- **Thermosyphon systems**
  Water flows through the system when warm water rises as cooler water sinks. The collector must be installed below the storage tank so that warm water will rise into the tank. These systems are reliable, but contractors must pay careful attention to the roof design because of the heavy storage tank. They are usually more expensive than integral collector-storage passive systems.

1.4 Storage tanks and solar collectors

Most solar water heaters require a well-insulated storage tank. Solar storage tanks have an additional outlet and inlet connected to and from the collector. In two-tank systems, the solar water heater preheats water before it enters the conventional water heater. In one-tank systems, the back-up heater is combined with the solar storage in one tank.

Three types of solar collectors are used for residential applications:
• Flat-plate collector
Glazed flat-plate collectors are insulated, weatherproofed boxes that contain a dark absorber plate under one or more glass or plastic (polymer) covers. Unglazed flat-plate collectors -- typically used for solar pool heating -- have a dark absorber plate, made of metal or polymer, without a cover or enclosure.

• Integral collector-storage systems
Also known as ICS or batch systems, they feature one or more black tanks or tubes in an insulated, glazed box. Cold water first passes through the solar collector, which preheats the water. The water then continues on to the conventional backup water heater, providing a reliable source of hot water. They should be installed only in mild-freeze climates because the outdoor pipes could freeze in severe, cold weather.

• Evacuated-tube solar collectors
They feature parallel rows of transparent glass tubes. Each tube contains a glass outer tube and metal absorber tube attached to a fin. The fin's coating absorbs solar energy but inhibits radiative heat loss. These collectors are used more frequently for U.S. commercial applications.

Solar water heating systems almost always require a backup system for cloudy days and times of increased demand. Conventional storage water heaters usually provide backup and may already be part of the solar system package. A backup system may also be part of the solar collector, such as rooftop tanks with thermosyphon systems. Since an integral-collector storage system already stores hot water in addition to collecting solar heat, it may be packaged with a tankless or demand-type water heater for backup.

2. Wind Energy
Wind can be used to do work. The kinetic energy of the wind can be changed into other forms of energy, either mechanical energy or electrical energy.
When a boat lifts a sail, it is using wind energy to push it through the water. This is one form of work.

Farmers have been using wind energy for many years to pump water from wells using windmills like the one on the right.

In Holland, windmills have been used for centuries to pump water from low-lying areas.

Wind is also used to turn large grinding stones to grind wheat or corn, just like a water wheel is turned by water power.

Today, the wind is also used to make electricity.

Blowing wind spins the blades on a wind turbine – just like a large toy pinwheel. This device is called a wind turbine and not a windmill. A windmill grinds or mills grain, or is used to pump water.

The blades of the turbine are attached to a hub that is mounted on a turning shaft. The shaft goes through a gear transmission box where the turning speed is increased. The transmission is attached to a high speed shaft which turns a generator that makes electricity.

If the wind gets too high, the turbine has a brake that will keep the blades from turning too fast and being damaged.

You can use a single smaller wind turbine to power a home or a school. A small turbine makes enough energy for a house. In the picture on the left, the children at this Iowa school are playing beneath a wind turbine that makes enough electricity to power their entire school.
2.1 Windmill

A windmill is a mill that converts the energy of wind into rotational energy by means of vanes called sails or blades. Centuries ago, windmills usually were used to mill grain, pump water, or both. Thus they often were gristmills, windpumps, or both. The majority of modern windmills take the form of wind turbines used to generate electricity, or windpumps used to pump water, either for land drainage or to extract groundwater.

The blades or sails of the windmill are turned by the wind. Gears and cogs make the drive shaft inside the windmill turn. In a windmill used for making flour, this turns the grinding stones. As the stones turn, they crush the wheat (or other grain) between them. In a windmill used for pumping water, turning the drive shaft moves a piston. The piston can suck up and push out water as it moves up and down. In a windmill used for generating power, the drive shaft is connected to many gears. This increases the speed and is used to turn a generator to make electricity.

State wise wind power

There is a growing number of wind energy installations in states across India.

A wind farm in Rajasthan.
### State Capacity (MW), as of 31 March 2016

<table>
<thead>
<tr>
<th>State</th>
<th>Capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tamil Nadu</td>
<td>7633.27</td>
</tr>
<tr>
<td>Maharashtra</td>
<td>4655.25</td>
</tr>
<tr>
<td>Rajasthan</td>
<td>4031.99</td>
</tr>
<tr>
<td>Gujarat</td>
<td>3930.94</td>
</tr>
<tr>
<td>Karnataka</td>
<td>2877.95</td>
</tr>
<tr>
<td>Madhya Pradesh</td>
<td>2165.49</td>
</tr>
<tr>
<td>Andhra Pradesh</td>
<td>1432.95.5</td>
</tr>
<tr>
<td>Telangana</td>
<td>77.70</td>
</tr>
<tr>
<td>Kerala</td>
<td>55.80</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>26860.34</strong></td>
</tr>
</tbody>
</table>

3. Hydropower
Hydropower is a renewable energy resource because it uses the Earth's water cycle to generate electricity. Water evaporates from the Earth's surface, forms clouds, precipitates back to earth, and flows toward the ocean. The movement of water as it flows downstream creates kinetic energy that can be converted into electricity. 2700 TWH is generated every year. Hydropower supplies at least 50% of electricity production in 66 countries and at least 90% in 24 countries. Out of the total power generation installed capacity in India of 1,76,990 MW (June, 2011), hydro power contributes about 21.5% i.e. 38,106 MW. A capacity addition of 78,700 MW is envisaged from different conventional sources during 2007-2012 (the 11th Plan), which includes 15,627 MW from large hydro projects. In addition to this, a capacity addition of 1400 MW was envisaged from small hydro up to 25 MW station capacity. The total hydroelectric power potential in the country is assessed at about 150,000 MW, equivalent to 84,000 MW at 60% load factor. The potential of small hydro power projects is estimated at about 15,000 MW.

3.1 Technology

A hydroelectric power plant consists of a high dam that is built across a large river to create a reservoir, and a station where the process of energy conversion to electricity takes place. The first step in the generation of energy in a hydropower plant is the collection of run-off of seasonal rain and snow in lakes, streams and rivers, during the hydrological cycle. The run-off flows to dams downstream. The water falls through a dam, into the hydropower plant and turns a large wheel called a turbine. The turbine converts the energy of falling water into mechanical energy to drive the generator. After this process has taken place electricity is transferred to the communities through transmission lines and the water is released back into the lakes, streams or rivers. This is entirely not harmful, because no pollutants are added to the water while it flows through the hydropower plant.
3.2 Potential in India

India is blessed with immense amount of hydro-electric potential and ranks 5th in terms of exploitable hydro-potential on global scenario. As per assessment made by CEA, India is endowed with economically exploitable hydro-power potential to the tune of 148,700 MW of installed capacity. The basin wise assessed potential is as under:

Basin/River probable installed capacity (MW)

<table>
<thead>
<tr>
<th>Basin/River</th>
<th>Capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indus Basin</td>
<td>33,832</td>
</tr>
<tr>
<td>Ganga Basin</td>
<td>20,711</td>
</tr>
<tr>
<td>Central Indian River system</td>
<td>4,152</td>
</tr>
<tr>
<td>Western Flowing Rivers of southern India</td>
<td>9,430</td>
</tr>
<tr>
<td>Eastern Flowing Rivers of southern India</td>
<td>14,511</td>
</tr>
<tr>
<td>Brahmaputra Basin</td>
<td>66,065</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,48,701</strong></td>
</tr>
</tbody>
</table>

In addition, 56 number of pumped storage projects have also been identified with probable installed capacity of 94,000 MW. In addition to this, hydro-potential from small, mini & micro schemes has been estimated as 6,782 MW from 1,512 sites. Thus, in totality India is endowed with hydro-potential of about 2,50,000 MW.

**Installed Capacity**

The total installed capacity of India is 36878 MW.

3.3 Ocean Thermal Energy Conversion (OTEC)

Ocean Thermal Energy Conversion (OTEC) is a marine renewable energy technology that harnesses the solar energy absorbed by the oceans. OTEC generates electricity by exchanging heat with the warm water from the ocean surface and with the cold water from the deep ocean. The exchanged heat drives a Rankine Cycle, which converts it to
electricity. The technology is viable primarily in equatorial areas where the year-round temperature differential is at least 20 degrees Celsius.

One of the main advantages when comparing OTEC to other renewables, such as wind and solar energy, is the fact that OTEC is a baseload source, available day and night. This is a big advantage for tropical islands that typically have a small, isolated, electric grids, not capable of handling a large share of intermittent power.

The potential of OTEC is vast. One square meter of Ocean surface area on average receives about 175 watts of solar irradiation. The total amount of globally received solar power is therefore about 90 petawatts. This is over 6,000 times the total global energy usage. If we exploit just of fraction of that energy, we have enough to power the world.

Today’s advanced offshore industry provides sufficient know-how for deployment and operation in the harsh oceanic environment. Offering a continuous and environmentally clean operation, OTEC is an attractive alternative form of energy.

3.4 Tidal Energy

Tidal energy, also referred to as tidal power, is the energy obtained from the rise and fall of tides. As the tides rise and fall, a massive amount of water moves toward and then away from shore. Turbines placed in the path of this moving water spin as the
water passes by. These spinning turbines are connected to generators that create electricity.

One way tidal energy is captured is with the use of **tidal turbines**. Tidal turbines look like and work like underwater windmills. They utilize turbines with short but strong blades that spin as the tides move and then transmit their energy to an electricity generator.

Another way tidal energy is captured is with the use of **tidal barrages**. Tidal barrages are special dams that take advantage of the difference in height between low and high
tides. Tidal barrages are built across an estuary or bay. When the tide comes in and the sea level rises, water passes through the dam and becomes trapped in a basin. When the tide goes out, gates within the dam release the water, allowing it to flow through turbines that spin and transfer energy to electric generators.

4. Geothermal energy

Geothermal energy has been used for thousands of years in some countries for cooking and heating. It is simply power derived from the Earth’s internal heat.

Earth's internal heat is thermal energy generated from radioactive decay and continual heat loss from Earth's formation. Temperatures at the core–mantle boundary may reach over 4000 °C (7,200 °F). The high temperature and pressure in Earth's interior cause some rock to melt and solid mantle to behave plastically, resulting in portions of mantle convecting upward since it is lighter than the surrounding rock. Rock and water is heated in the crust, sometimes up to 370 °C (700 °F).

This thermal energy is contained in the rock and fluids beneath Earth’s crust. It can be found from shallow ground to several miles below the surface, and even farther down to the extremely hot molten rock called magma.
These underground reservoirs of steam and hot water can be tapped to generate electricity or to heat and cool buildings directly.

A geothermal heat pump system can take advantage of the constant temperature of the upper ten feet (three meters) of the Earth's surface to heat a home in the winter, while extracting heat from the building and transferring it back to the relatively cooler ground in the summer.

Geothermal water from deeper in the Earth can be used directly for heating homes and offices, or for growing plants in greenhouses. Some U.S. cities pipe geothermal hot water under roads and sidewalks to melt snow.

To produce geothermal-generated electricity, wells, sometimes a mile (1.6 kilometers) deep or more, are drilled into underground reservoirs to tap steam and very hot water that drive turbines linked to electricity generators. The first geothermally generated electricity was produced in Larderello, Italy, in 1904.

There are three types of geothermal power plants: dry steam, flash, and binary. Dry steam, the oldest geothermal technology, takes steam out of fractures in the ground and uses it to directly drive a turbine. Flash plants pull deep, high-pressure hot water into cooler, low-pressure water. The steam that results from this process is used to drive the
turbine. In binary plants, the hot water is passed by a secondary fluid with a much lower boiling point than water. This causes the secondary fluid to turn to vapor, which then drives a turbine. Most geothermal power plants in the future will be binary plants.

Geothermal energy is generated in over 20 countries. The United States is the world's largest producer, and the largest geothermal development in the world is The Geysers north of San Francisco in California. In Iceland, many of the buildings and even swimming pools are heated with geothermal hot water. Iceland has at least 25 active volcanoes and many hot springs and geysers.

4.1 Advantages of geothermal energy: It can be extracted without burning a fossil fuel such as coal, gas, or oil. Geothermal fields produce only about one-sixth of the carbon dioxide that a relatively clean natural-gas-fueled power plant produces. Binary plants release essentially no emissions. Unlike solar and wind energy, geothermal energy is always available, 365 days a year. It's also relatively inexpensive; savings from direct use can be as much as 80 percent over fossil fuels.

4.2 Environmental problems: The main concern is the release of hydrogen sulfide, a gas that smells like rotten egg at low concentrations. Another concern is the disposal of some geothermal fluids, which may contain low levels of toxic materials. Although geothermal sites are capable of providing heat for many decades, eventually specific locations may cool down.

5. Biomass

Biomass is matter usually thought of as garbage. Some of it is just stuff lying around -- dead trees, tree branches, yard clippings, left-over crops, wood chips (like in the picture to the right), and bark and sawdust from lumber mills. It can even include used tires and livestock manure.

Your trash, paper products that can't be recycled into other paper products, and other household waste are normally sent to the dump. Your trash contains some types of biomass that can be reused. Recycling biomass for fuel and other uses cuts down on the need for "landfills" to hold garbage.
This stuff nobody seems to want can be used to produce electricity, heat, compost material or fuels. Composting material is decayed plant or food products mixed together in a compost pile and spread to help plants grow.

How biomass works is very simple. The waste wood, tree branches and other scraps are gathered together in big trucks. The trucks bring the waste from factories and from farms to a biomass power plant. Here the biomass is dumped into huge hoppers. This is then fed into a furnace where it is burned. The heat is used to boil water in the boiler, and the energy in the steam is used to turn turbines and generators.

Biomass can also be tapped right at the landfill with burning waster products. When garbage decomposes, it gives off methane gas. Pipelines are put into the landfills and the methane gas can be collected. It is then used in power plants to make electricity. This type of biomass is called landfill gas.

A similar thing can be done at animal feed lots. In places where lots of animals are raised, the animals - like cattle, cows and even chickens - produce manure. When
manure decomposes, it also gives off methane gas similar to garbage. This gas can be burned right at the farm to make energy to run the farm.

5.1 Anaerobic Digestion

Anaerobic digestion is a biological process that produces a gas principally composed of methane (CH₄) and carbon dioxide (CO₂) otherwise known as biogas. These gases are produced from organic wastes such as livestock manure, food processing waste, etc.

Anaerobic processes could either occur naturally or in a controlled environment such as a biogas plant. Organic waste such as livestock manure and various types of bacteria are put in an airtight container called digester so the process could occur. The picture to the right below shows a biogas digester at a dairy farm in Cottonwood, California. Depending on the waste feedstock and the system design, biogas is typically 55 to 75 percent pure methane. State-of-the-art systems report producing biogas that is more than 95 percent pure methane.

The process of anaerobic digestion consists of three steps:

1. The first step is the decomposition (hydrolysis) of plant or animal matter. This step breaks down the organic material to usable-sized molecules such as sugar.

2. The second step is the conversion of decomposed matter to organic acids.

3. Finally, the acids are converted to methane gas.

Process temperature affects the rate of digestion and should be maintained in the mesophillic range (95 to 105 degrees Fahrenheit) with an optimum of 100 degrees F. It is possible to operate in the thermophillic range (135 to 145 degrees F), but the digestion process is subject to upset if not closely monitored.

Many anaerobic digestion technologies are commercially available and have been demonstrated for use with agricultural wastes and for treating municipal and industrial wastewater.
We can capture this Biogas and burn it for cooking and heating. Actually, this is already being done in many parts of the world. Even small farms and households can utilize biogas generators to provide heat. In China there are an estimated seven million biogas generators being used to convert plant and animal waste into fuel for cooking and heating. India has about seven hundred fifty thousand generators in operation.

**Advantages of Biomass Energy**

In many ways, biomass is a new source of power. While wood has always served as a fuel source for fires and ovens and conventional heating methods, biomass energy advancements are a few steps beyond that. Now these biomass fuel products are harvested and mass-produced and used in everything from engines to power plants.

1. **No Harmful Emissions**: Biomass energy, for the most part, creates no harmful carbon dioxide emissions. Many energy sources used today struggle to control their carbon dioxide emissions, as these can cause harm to the ozone layer and increase the effects of greenhouse gases, potentially warming the planet. It is completely natural, has no such carbon dioxide side effects in its use.
2. **Clean Energy**: Because of its relatively clean use, biomass energy, when used in commercial businesses such as airlines, receives tax credit from the US government. This is good for the environment and good for business. It does release carbon dioxide but captures carbon dioxide for its own growth. Carbon dioxide released by fossil fuel are released into the atmosphere and are harmful to the environment.

3. **Abundant and Renewable**: Biomass products are abundant and renewable. Since they come from living sources, and life is cyclical, these products potentially never run out, so long as there is something living on earth and there is someone there to turn that living things components and waste products into energy. In the United Kingdom, biomass fuels are made from recycled chicken droppings. In the United States and Russia, there are plentiful forests for lumber to be used in the production of biomass energy.
4. **Reduce Dependency on Fossil Fuels**: It has developed as an alternate source of fuel for many homeowners and have helped them to reduce their dependency on fossil fuels.

5. **Reduce Landfills**: Another benefit of this energy is that it can take waste that is harmful to the environment and turn it into something useful. For instance, garbage as landfill can, at least partially, be burned to create useable biomass energy.

6. **Can be Used to Create Different Products**: Biomass energy is also versatile, as different forms of organic matter can be used to create different products. Ethanol and similar fuels can be made from corn and other crops. With so many living things on the planet, there is no limit to how many ways it can be found and used.

**Disadvantages of Biomass Energy**

Besides above advantages, there are also some downsides to it. Let’s see below some of its disadvantages.

1. **Expensive**: Firstly, it’s expensive. Living things are expensive to care for, feed, and house, and all of that has to be considered when trying to use waste products from animals for fuel.

2. **Inefficient as Compared to Fossil Fuels**: Secondly, and connected to the first, is the relative inefficiency of biomass energy. Ethanol, as a biodiesel is terribly inefficient when compared to gasoline, and it often has to be mixed with some gasoline to make it work properly anyway. On top of that, ethanol is harmful to combustion engines over long term use.

3. **Harmful to Environment**: Thirdly, using animal and human waste to power engines may save on carbon dioxide emissions, but it increases methane gases, which are also harmful to the Earth’s—ozone layer. So really, we are no better off environmentally for using one or the other. And speaking of using waste products, there is the smell to consider. While it is not physically harmful, it is definitely unpleasant, and it can attract unwanted pests (rats, flies) and spread bacteria and infection.
UNIT-3 Nuclear Energy

1. Fission and Fusion

Nuclear energy is energy in the nucleus (core) of an atom. Atoms are tiny particles that make up every object in the universe. There is enormous energy in the bonds that hold atoms together. Nuclear energy can be used to make electricity. But first the energy must be released. It can be released from atoms in two ways: nuclear fusion and nuclear fission. In nuclear fusion, energy is released when atoms are combined or fused together to form a larger atom. This is how the sun produces energy. In nuclear fission, atoms are split apart to form smaller atoms, releasing energy. Nuclear power plants use nuclear fission to produce electricity.

One of the laws of the universe is that matter and energy can't be created nor destroyed. But they can be changed in form.

Matter can be changed into energy. The world's most famous scientist, Albert Einstein, created the mathematical formula that explains this. It is:

This equation says: \( E=mc^2 \)

\( E \) [energy] equals \( m \) [mass] times \( c^2 \) [\( c \) stands for the velocity or the speed of light. \( c^2 \) means \( c \) times \( c \), or the speed of light raised to the second power — or \( c \)-squared.]

1.1 Nuclear Fission

An atom's nucleus can be split apart. When this is done, a tremendous amount of energy is released. The energy is both heat and light energy. Einstein said that a very small amount of matter contains a very LARGE amount of energy. This energy, when let out slowly, can be harnessed to generate electricity. When it is let out all at once, it can make a tremendous explosion in an atomic bomb.
A nuclear power plant (like Diablo Canyon Nuclear Plant shown below) uses uranium as a "fuel." Uranium is an element that is dug out of the ground many places around the world. It is processed into tiny pellets that are loaded into very long rods that are put into the power plant's reactor.

The word fission means to split apart. Inside the reactor of an atomic power plant, uranium atoms are split apart in a controlled chain reaction.

In a chain reaction, particles released by the splitting of the atom go off and strike other uranium atoms splitting those. Those particles given off split still other atoms in a chain reaction. In nuclear power plants, control rods are used to keep the splitting regulated so it doesn't go too fast.

If the reaction is not controlled, you could have an atomic bomb. But in atomic bombs, almost pure pieces of the element Uranium-235 or Plutonium, of a precise mass and shape, must be brought together and held together, with great force. These conditions are not present in a nuclear reactor.
The reaction also creates radioactive material. This material could hurt people if released, so it is kept in a solid form. The very strong concrete dome in the picture is designed to keep this material inside if an accident happens.

This chain reaction gives off heat energy. This heat energy is used to boil water in the core of the reactor. So, instead of burning a fuel, nuclear power plants use the chain reaction of atoms splitting to change the energy of atoms into heat energy.

This water from around the nuclear core is sent to another section of the power plant. Here, in the heat exchanger, it heats another set of pipes filled with water to make steam. The steam in this second set of pipes turns a turbine to generate electricity. Below is a cross section of the inside of a typical nuclear power plant.

### 1.2 Nuclear Fusion

Another form of nuclear energy is called fusion. Fusion means joining smaller nuclei (the plural of nucleus) to make a larger nucleus. The sun uses nuclear fusion of hydrogen atoms into helium atoms. This gives off heat and light and other radiation.
In the picture to the right, two types of hydrogen atoms, deuterium and tritium, combine to make a helium atom and an extra particle called a neutron.

Scientists have been working on controlling nuclear fusion for a long time, trying to make a fusion reactor to produce electricity. But they have been having trouble learning how to control the reaction in a contained space.

What’s better about nuclear fusion is that it creates less radioactive material than fission, and its supply of fuel can last longer than the sun.

2. Uranium Mining

- In the last 60 years uranium has become one of the world’s most important energy minerals.

- It is mined and concentrated similarly to many other metals.

While uranium is used almost entirely for making electricity, a small proportion is used for the important task of producing medical isotopes. Some is also used in marine propulsion, especially naval.

Uranium is a naturally occurring element with an average concentration of 2.8 parts per million in the Earth’s crust. Traces of it occur almost everywhere. It is more abundant than gold, silver or mercury, about the same as tin and slightly less abundant than cobalt, lead or molybdenum. Vast amounts of uranium also occur in the world’s oceans, but in very low concentrations.
Uranium mines operate in some 20 countries, though in 2014 some 54% of world production came from just ten mines in six countries (see Table 1), these six countries providing 85% of the world’s mined uranium.

Most of the uranium ore deposits at present supporting these mines have average grades in excess of 0.10% of uranium – that is, greater than 1000 parts per million. In the first phase of uranium mining to the 1960s, this would have been seen as a respectable grade, but today some Canadian mines have huge amounts of ore up to 20% U average grade. Other mines however can operate successfully with very low grade ores, down to about 0.02% U.

Some uranium is also recovered as a by-product with copper, as at Olympic Dam mine in Australia, or as by-product from the treatment of other ores, such as the gold-bearing ores of South Africa, or from phosphate deposits such as Morocco and Florida. In these cases the concentration of uranium may be as low as a tenth of that in orebodies mined primarily for their uranium content. An orebody is defined as a mineral deposit from which the mineral may be recovered at a cost that is economically viable given the current market conditions. Where a deposit holds a significant concentration of two or more valuable minerals then the cost of recovering each individual mineral is reduced as certain mining and treatment requirements can be shared. In this case, lower concentrations of uranium than usual can be recovered at a competitive cost.

Generally speaking, uranium mining is no different from other kinds of mining unless the ore is very high grade. In this case special mining techniques such as dust suppression, and in extreme cases remote handling techniques, are employed to limit worker radiation exposure and to ensure the safety of the environment and general public.

Searching for uranium is in some ways easier than for other mineral resources because the radiation signature of uranium’s decay products allows deposits to be identified and mapped from the air.

Thorium is a possible alternative source of nuclear fuel, but the technology for using this is not established. Thorium requires conversion to a fissile isotope of uranium actually in
a nuclear reactor. However, supplies of thorium are abundant, and the element currently has no commercial value. Accordingly, the amount of resource is estimated rather than directly measured as with uranium.

2.1 Different kinds of mines

2.1.1 Open pit and underground mining

Where ore bodies lie close to the surface, they are usually accessed by open cut mining, involving a large pit and the removal of much overburden (overlying rock) as well as a lot of waste rock. Where ore bodies are deeper, underground mining is usually employed, involving construction of access shafts and tunnels but with less waste rock removed and less environmental impact. In either case, grade control is usually achieved by measuring radioactivity as a surrogate for uranium concentration.* (The radiometric device detects associated radioactive minerals which are decay products of the uranium, rather than the uranium itself.)

* About 95% of the radioactivity in the ore is from the U-238 decay series, totaling about 150 kBq/kg in ore with 0.1% U₃O₈. The U-238 series has 14 radioactive isotopes in secular equilibrium, thus each represents about 11 kBq/kg (irrespective of the mass proportion). When the ore is processed, the U-238 and the very much smaller masses of U-234 (and U-235) are removed. The balance becomes tailings, and at this point has about 85% of its original intrinsic radioactivity. However, with the removal of most U-238, the following two short-lived decay products in the uranium decay series (Th-234 and Pa-234) soon disappear, leaving the tailings with a little over 70% of the radioactivity of the original ore after several months. The controlling long-lived isotope then becomes Th-230 which decays with a half-life of 77,000 years to radium-226 followed by radon-222. (Supervising Scientist Group, Australia).

At Ranger in north Australia, Rössing in Namibia, and most of Canada’s Northern Saskatchewan mines through to McClean Lake, the ore bodies have been accessed by open cut mining. Other mines such as Olympic Dam in Australia, McArthur River, Rabbit Lake and Cigar Lake in Northern Saskatchewan, and Akouta in Niger are underground,
up to 600 metres deep. At McClean Lake and Ranger, mining will be completed underground.

2.1.2 In situ leach (ISL) mining

Some ore bodies lie in groundwater in porous unconsolidated material (such as gravel or sand) and may be accessed simply by dissolving the uranium and pumping it out—this is in situ leach (ISL) mining (also known in North America as in situ recovery - ISR). It can be applied where the ore body's aquifer is confined vertically and ideally horizontally. Certainly it is not licensed where potable water supplies may be threatened. Where appropriate it is certainly the mining method with least environmental impact.

ISL mining means that removal of the uranium minerals is accomplished without any major ground disturbance. Weakly acidified groundwater (or alkaline groundwater where the ground contains a lot of limestone such as in the USA) with a lot of oxygen in it is circulated through an enclosed underground aquifer which holds the uranium ore in loose sands. The leaching solution dissolves the uranium before being pumped to the surface treatment plant where the uranium is recovered as a precipitate. Most US and Kazakh uranium production is by this method.

In Australian ISL mines the oxidant used is hydrogen peroxide and the complexing agent sulfuric acid to give a uranyl sulphate. Kazakh ISL mines generally do not employ an oxidant but use much higher acid concentrations in the circulating solutions. ISL mines in the USA use an alkali leach to give a uranyl carbonate due to the presence of significant quantities of acid-consuming minerals such as gypsum and limestone in the host aquifers. Any more than a few percent carbonate minerals means that alkali leach must be used in preference to the more efficient acid leach, though the cost is often double.

In either the acid or alkali leaching method the fortified groundwater is pumped into the aquifer via a series of injection wells where it slowly migrates through the aquifer
leaching the uranium bearing host sand on its way to strategically placed extraction wells where submersible pumps pump the liquid to the surface for processing.

For very small ore bodies which are amenable to ISL mining, a central process plant may be distant from them so a satellite plant will be set up. This does no more than provide a facility to load the ion exchange (IX) resin/polymer so that it can be trucked to the central plant in a bulk trailer for stripping. Hence very small deposits can become viable, since apart from the well field, little capital expenditure is required at the mine and remote IX site.

2.2 Heap leaching

Some ore, usually very low-grade (below 0.1%U), is treated by heap leaching. Here the broken ore is stacked about 5 to 30 metres high on an impermeable pad and irrigated with acid (or sometimes alkaline) solution over many weeks. The pregnant liquor from this is collected and treated to recover the uranium, as with ISL, usually using ion exchange. After the material ceases to yield significant further uranium, it is removed and replaced with fresh ore. Recoveries are typically 50-80%. The depleted material has the potential to cause pollution so must be emplaced securely so as not to affect surface water or groundwater. Usually this will be in mined-out pits.

2.3 Milling and processing

Conventional mines have a mill where the ore is crushed and ground to liberate the mineral particles, then leached in tanks with sulfuric acid to dissolve the uranium oxides. The solution is then processed to recover the uranium. With some South African uranium recovery from gold tailings, a pressure leach is necessary.

Sometimes a physical beneficiation process is used to concentrate the ore and increase the head grade before chemical treatment. This may be radiometric sorting as at Ranger, screening/gravity, or a new process called ablation.

Most of the ore is barren rock or other minerals which remain un-dissolved in the leaching process. These solids or ‘tailings’ are separated from the uranium-rich solution,
usually by allowing them to settle out. The remaining solution is filtered and the uranium is recovered in some form of ion exchange (IX) or solvent extraction (SX) system. The pregnant liquor from ISL or heap leaching is treated similarly. The uranium is then stripped from this and precipitated — see box. The final chemical precipitate is filtered and dried.

The crushed and ground ore, or the underground ore in the case of ISL mining, is leached with sulfuric acid:
\[ \text{UO}_3 + 2\text{H}^+ \rightarrow \text{UO}_2^{2+} + \text{H}_2\text{O} \]
\[ \text{UO}_2^{2+} + 3\text{SO}_4^{2-} \rightarrow \text{UO}_2(\text{SO}_4)_3^{4-} \]

The \( \text{UO}_2 \) is oxidized to \( \text{UO}_3 \).

With some ores, carbonate leaching is used to form a soluble uranyl tricarbonate ion: \( \text{UO}_2(\text{CO}_3)_3^{4-} \). This can then be precipitated with an alkali, eg. as sodium or magnesium diuranate.

The uranium in solution is recovered in a resin/polymer ion exchange (IX) or liquid ion exchange (solvent extraction – SX) system. The pregnant liquor from acid ISL or heap leaching is treated similarly.

Further treatment for IX involves stripping the uranium from the resin/polymer either with a strong acid or chloride solution or with a nitrate solution in a semi-continuous cycle. The pregnant solution produced by the stripping cycle is then precipitated by the addition of ammonia, hydrogen peroxide, caustic soda or caustic magnesia. Solvent extraction is a continuous loading/stripping cycle involving the use of an organic liquid to carry the extractant which removes the uranium from solution.

Typically, in solvent extraction, tertiary amines* are used in a kerosene diluent, and the phases move counter-currently.

\[ 2\text{R}_3\text{N} + \text{H}_2\text{SO}_4 \rightarrow (\text{R}_3\text{NH})_2\text{SO}_4 \]
\[ 2 (\text{R}_3\text{NH})_2\text{SO}_4 + \text{UO}_2(\text{SO}_4)_3^{4-} \rightarrow (\text{R}_3\text{NH})_4\text{UO}_2(\text{SO}_4)_3 + 2\text{SO}_4^{2-} \]

* "R" is an alkyl (hydrocarbon) grouping, with single covalent bond.

The loaded solvents may then be treated to remove impurities. First, cations are removed at pH 1.5 using sulfuric acid and then anions are dealt with using gaseous ammonia.

The solvents are then stripped in a countercurrent process using ammonium sulfate solution.

\[ (\text{R}_3\text{NH})_4\text{UO}_2(\text{SO}_4)_3 + 2(\text{NH}_4)_2\text{SO}_4 \rightarrow 4\text{R}_3\text{N} + (\text{NH}_4)_4\text{UO}_2(\text{SO}_4)_3 + 2\text{H}_2\text{SO}_4 \]
Precipitation of ammonium diuranate is achieved by adding gaseous ammonia to neutralize the solution (though in earlier operations caustic soda and magnesia were used).

$$2\text{NH}_3 + 2\text{UO}_2(\text{SO}_4)_3^{4-} \rightarrow (\text{NH}_4)_2\text{U}_2\text{O}_7 + 4\text{SO}_4^{2-}$$

The diuranate is then dewatered and roasted to yield $\text{U}_3\text{O}_8$ product, which is the form in which uranium is marketed and exported.

Peroxide products can be dried at ambient temperatures to produce a product containing about 80% $\text{U}_3\text{O}_8$. Ammonium or sodium diuranate products are dried at high temperatures to convert the product to uranium oxide concentrate – $\text{U}_3\text{O}_8$ – about 85% uranium by mass. This is sometimes referred to as yellowcake, though it is usually khaki.

In the case of carbonate leaching the uranyl carbonate can be precipitated with an alkali, eg as sodium or magnesium diuranate.

The product is then packed into 200 litre steel drums which are sealed for shipment. The $\text{U}_3\text{O}_8$ is only mildly radioactive (the radiation level one metre from a drum of freshly-processed $\text{U}_3\text{O}_8$ is about half that – from cosmic rays – on a commercial jet flight). In ISL mills the process of uranium recovery is very similar, without the need for crushing and grinding.

2.4 Tailings management and mine rehabilitation

From open cut mining, there are substantial volumes of barren rock and overburden waste. These are placed near the pit and either used in rehabilitation or shaped and revegetated where they are.

Uranium minerals are always associated with more radioactive elements such as radium and radon in the ore which arise from the radioactive decay of uranium over a few million of years. Therefore, although uranium itself is barely radioactive, the ore which is mined, especially if it is very high-grade such as in some Canadian mines, is handled with some care, for occupational health and safety reasons.
Mining methods, tailings and run-off management and land rehabilitation are subject to Government regulation and inspection. For instance in Australia the Code of Practice and Safety Guide: Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing was published in 2005, and updated in 2015.

Solid waste products from the milling operation are tailings, ranging in character from slimes to coarse sands. They comprise most of the original ore and they contain most of the radioactivity in it. In particular they contain all the radium present in the original ore. At an underground mine they may be first cycloned to separate the coarse fraction which is returned underground and used for underground fill. The balance is pumped as a slurry to a tailings dam, which may be a worked-out pit as at Ranger and McClean Lake, or an engineered structure.

When radium undergoes natural radioactive decay one of the products is radon gas. Because radon and its decay products (daughters) are radioactive and because the ground rock comprising the tailings is now on the surface, measures are taken to minimise the emission of radon gas. During the operational life of a mine the material in the tailings dam is often kept covered by water to reduce surface radioactivity and radon emission (though with lower-grade ores neither pose a hazard at these levels). This water needs to be recycled or evaporated since it contains radium, which is relatively soluble. Most Australian mines and many others adopt a ‘zero discharge’ policy for any pollutants.

On completion of the mining operation, it is normal for the tailings dam to be covered by some two metres of clay and topsoil with enough rock to resist erosion. This is to reduce both gamma radiation levels and radon emanation rates to levels near those normally experienced in the region of the orebody, and for a vegetation cover to be established.

3. Nuclear Power Reactors

A nuclear reactor produces and controls the release of energy from splitting the atoms of certain elements. In a nuclear power reactor, the energy released is used as heat to make steam to generate electricity. (In a research reactor the main purpose is to utilise
the actual neutrons produced in the core. In most naval reactors, steam drives a turbine
directly for propulsion.)

The principles for using nuclear power to produce electricity are the same for most
types of reactor. The energy released from continuous fission of the atoms of the fuel is
harnessed as heat in either a gas or water, and is used to produce steam. The steam is
used to drive the turbines which produce electricity (as in most fossil fuel plants).

Components of Nuclear Power Plant

- Nuclear Reactor
- Heat Exchanger (Steam Generator)
- Steam Turbine
- Condenser
- Electric Generator
- Cooling Tower

The world's first nuclear reactors operated naturally in a uranium deposit about two
billion years ago. These were in rich uranium ore bodies and moderated by percolating
rainwater. The 17 known at Oklo in west Africa, each less than 100 kW thermal,
together consumed about six tonnes of that uranium. It is assumed that these were not
unique worldwide.

Today, reactors derived from designs originally developed for propelling submarines
and large naval ships generate about 85% of the world's nuclear electricity. The main
design is the pressurised water reactor (PWR) which has water at over 300°C under
pressure in its primary cooling/heat transfer circuit, and generates steam in a secondary circuit. The less numerous boiling water reactor (BWR) makes steam in the primary circuit above the reactor core, at similar temperatures and pressure. Both types use water as both coolant and moderator, to slow neutrons. Since water normally boils at 100°C, they have robust steel pressure vessels or tubes to enable the higher operating temperature. (Another type uses heavy water, with deuterium atoms, as moderator. Hence the term ‘light water’ is used to differentiate.)

Components of a nuclear reactor

There are several components common to most types of reactors:

**Fuel.** Uranium is the basic fuel. Usually pellets of uranium oxide (UO$_2$) are arranged in tubes to form fuel rods. The rods are arranged into fuel assemblies in the reactor core.

**Moderator.** Material in the core which slows down the neutrons released from fission so that they cause more fission. It is usually water, but may be heavy water or graphite.

**Control rods.** These are made with neutron-absorbing material such as cadmium, hafnium or boron, and are inserted or withdrawn from the core to control the rate of reaction, or to halt it. In some PWR reactors, special control rods are used to enable the core to sustain a low level of power efficiently. (Secondary control systems involve other neutron absorbers, usually boron in the coolant – its concentration can be adjusted over time as the fuel burns up.)

**Coolant.** A fluid circulating through the core so as to transfer the heat from it. In light water reactors the water moderator functions also as primary coolant. Except in BWRs, there is secondary coolant circuit where the water becomes steam. (See also later section on primary coolant characteristics)

**Pressure vessel or pressure tubes.** Usually a robust steel vessel containing the reactor core and moderator/cooler/coolant, but it may be a series of tubes holding the fuel and conveying the coolant through the surrounding moderator.
**Steam generator.** Part of the cooling system of pressurised water reactors (PWR & PHWR) where the high-pressure primary coolant bringing heat from the reactor is used to make steam for the turbine, in a secondary circuit. Essentially a heat exchanger like a motor car radiator. Reactors have up to six 'loops', each with a steam generator. Since 1980 over 110 PWR reactors have had their steam generators replaced after 20-30 years service, 57 of these in USA.

**Containment.** The structure around the reactor and associated steam generators which is designed to protect it from outside intrusion and to protect those outside from the effects of radiation in case of any serious malfunction inside. It is typically a metre-thick concrete and steel structure.

Newer Russian and some other reactors install core melt localisation devices or 'core catchers' under the pressure vessel to catch any melted core material in the event of a major accident.

**3.1 Fuelling a nuclear power reactor**

Most reactors need to be shut down for refuelling, so that the pressure vessel can be opened up. In this case refuelling is at intervals of 1-2 years, when a quarter to a third of the fuel assemblies are replaced with fresh ones. The CANDU and RBMK types have pressure tubes (rather than a pressure vessel enclosing the reactor core) and can be refuelled under load by disconnecting individual pressure tubes.

If graphite or heavy water is used as moderator, it is possible to run a power reactor on natural instead of enriched uranium. Natural uranium has the same elemental composition as when it was mined (0.7% U-235, over 99.2% U-238), enriched uranium has had the proportion of the fissile isotope (U-235) increased by a process called enrichment, commonly to 3.5 - 5.0%. In this case the moderator can be ordinary water, and such reactors are collectively called light water reactors. Because the light water absorbs neutrons as well as slowing them, it is less efficient as a moderator than heavy water or graphite.
During operation, some of the U-238 is changed to plutonium, and Pu-239 ends up providing about one third of the energy from the fuel.

In most reactors the fuel is ceramic uranium oxide (UO$_2$ with a melting point of 2800°C) and most is enriched. The fuel pellets (usually about 1 cm diameter and 1.5 cm long) are typically arranged in a long zirconium alloy (zircaloy) tube to form a fuel rod, the zirconium being hard, corrosion-resistant and transparent to neutrons. Numerous rods form a fuel assembly, which is an open lattice and can be lifted into and out of the reactor core. In the most common reactors these are about 4 metres long. A BWR fuel assembly may be about 320 kg, a PWR one 655 kg, in which case they hold 183 kg uranium and 460 kgU respectively. In both, about 100 kg of zircaloy is involved.

Burnable poisons are often used in fuel or coolant to even out the performance of the reactor over time from fresh fuel being loaded to refuelling. These are neutron absorbers which decay under neutron exposure, compensating for the progressive build up of neutron absorbers in the fuel as it is burned. The best known is gadolinium, which is a vital ingredient of fuel in naval reactors where installing fresh fuel is very inconvenient, so reactors are designed to run more than a decade between refuellings. Gadolinium is incorporated in the ceramic fuel pellets. An alternative is zirconium diboride integral fuel burnable absorber (IFBA) as a thin coating on normal pellets.

Gadolinium, mostly at up to 3g oxide per kilogram of fuel, requires slightly higher fuel enrichment to compensate for it, and also after burn-up of about 17 GWD/t it retains about 4% of its absorptive effect and does not decrease further. The ZrB$_2$ IFBA burns away more steadily and completely, and has no impact on fuel pellet properties. It is now used in most US reactors and a few in Asia. China has the technology for AP1000 reactors.

The power rating of a nuclear power reactor

Nuclear power plant reactor power outputs are quoted in three ways:
• Thermal MWt, which depends on the design of the actual nuclear reactor itself, and relates to the quantity and quality of the steam it produces.

• Gross electrical MWe indicates the power produced by the attached steam turbine and generator, and also takes into account the ambient temperature for the condenser circuit (cooler means more electric power, warmer means less). Rated gross power assumes certain conditions with both.

• Net electrical MWe, which is the power available to be sent out from the plant to the grid, after deducting the electrical power needed to run the reactor (cooling and feed-water pumps, etc.) and the rest of the plant.

Nuclear Reactor

The relationship between these is expressed in two ways:
• Thermal efficiency %, the ratio of gross MWe to thermal MW. This relates to the difference in temperature between the steam from the reactor and the cooling water. It is often 33-37%.

• Net efficiency %, the ratio of net MWe achieved to thermal MW. This is a little lower, and allows for plant usage.

In WNA papers and figures and WNN items, generally net MWe is used for operating plants, and gross MWe for those under construction or planned/proposed.

3.2 Pressurised water reactor (PWR)

This is the most common type, with over 230 in use for power generation and several hundred more employed for naval propulsion. The design of PWRs originated as a submarine power plant. PWRs use ordinary water as both coolant and moderator. The design is distinguished by having a primary cooling circuit which flows through the core of the reactor under very high pressure, and a secondary circuit in which steam is generated to drive the turbine. In Russia these are known as VVER types – water-moderated and -cooled.
A PWR has fuel assemblies of 200-300 rods each, arranged vertically in the core, and a large reactor would have about 150-250 fuel assemblies with 80-100 tonnes of uranium.

Water in the reactor core reaches about 325°C, hence it must be kept under about 150 times atmospheric pressure to prevent it boiling. Pressure is maintained by steam in a pressuriser. In the primary cooling circuit the water is also the moderator, and if any of it turned to steam the fission reaction would slow down. This negative feedback effect is one of the safety features of the type. The secondary shutdown system involves adding boron to the primary circuit.

The secondary circuit is under less pressure and the water here boils in the heat exchangers which are thus steam generators. The steam drives the turbine to produce electricity, and is then condensed and returned to the heat exchangers in contact with the primary circuit.
3.3 Boiling water reactor (BWR)

This design has many similarities to the PWR, except that there is only a single circuit in which the water is at lower pressure (about 75 times atmospheric pressure) so that it boils in the core at about 285°C. The reactor is designed to operate with 12-15% of the water in the top part of the core as steam, and hence with less moderating effect and thus efficiency there. BWR units can operate in load-following mode more readily than PWRs.

The steam passes through drier plates (steam separators) above the core and then directly to the turbines, which are thus part of the reactor circuit. Since the water around the core of a reactor is always contaminated with traces of radionuclides, it means that the turbine must be shielded and radiological protection provided during maintenance. The cost of this tends to balance the savings due to the simpler design. Most of the radioactivity in the water is very short-lived, so the turbine hall can be entered soon after the reactor is shut down.

A BWR fuel assembly comprises 90-100 fuel rods, and there are up to 750 assemblies in a reactor core, holding up to 140 tonnes of uranium. The secondary control system involves restricting water flow through the core so that more steam in the top part reduces moderation.
3.4 Pressurised heavy water reactor (PHWR)

The PHWR reactor design has been developed since the 1950s in Canada as the CANDU, and from 1980s also in India. PHWRs generally use natural uranium (0.7% U-235) oxide as fuel, hence needs a more efficient moderator, in this case heavy water (D$_2$O). The PHWR produces more energy per kilogram of mined uranium than other designs, but also produces a much larger amount of used fuel per unit output.

The moderator is in a large tank called a calandria, penetrated by several hundred horizontal pressure tubes which form channels for the fuel, cooled by a flow of heavy water under high pressure in the primary cooling circuit, reaching 290°C. As in the PWR, the primary coolant generates steam in a secondary circuit to drive the turbines. The pressure tube design means that the reactor can be refuelled progressively without shutting down, by isolating individual pressure tubes from the cooling circuit. It is also
less costly to build than designs with a large pressure vessel, but the tubes have not proved as durable.

A CANDU fuel assembly consists of a bundle of 37 half metre long fuel rods (ceramic fuel pellets in zircaloy tubes) plus a support structure, with 12 bundles lying end to end in a fuel channel. Control rods penetrate the calandria vertically, and a secondary shutdown system involves adding gadolinium to the moderator. The heavy water moderator circulating through the body of the calandria vessel also yields some heat (though this circuit is not shown on the diagram above).

Newer PHWR designs such as the Advanced Candu Reactor (ACR) have light water cooling and slightly-enriched fuel.
CANDU reactors can accept a variety of fuels. They may be run on recycled uranium from reprocessing LWR used fuel, or a blend of this and depleted uranium left over from enrichment plants. About 4000 MWe of PWR might then fuel 1000 MWe of CANDU capacity, with addition of depleted uranium. Thorium may also be used in fuel.

3.5 Advanced gas-cooled reactor (AGR)

These are the second generation of British gas-cooled reactors, using graphite moderator and carbon dioxide as primary coolant. The fuel is uranium oxide pellets, enriched to 2.5-3.5%, in stainless steel tubes. The carbon dioxide circulates through the core, reaching 650°C and then past steam generator tubes outside it, but still inside the concrete and steel pressure vessel (hence ‘integral’ design). Control rods penetrate the moderator and a secondary shutdown system involves injecting nitrogen to the coolant.
The AGR was developed from the Magnox reactor, also graphite moderated and 
CO\textsubscript{2} cooled, and one of these is still operating in UK to late 2014. They use natural 
uranium fuel in metal form. Secondary coolant is water.

3.6 Light water graphite-moderated reactor (RBMK)

This is a Soviet design, developed from plutonium production reactors. It employs long 
(7 metre) vertical pressure tubes running through graphite moderator, and is cooled by 
water, which is allowed to boil in the core at 290°C, much as in a BWR. Fuel is low-
enriched uranium oxide made up into fuel assemblies 3.5 metres long. With moderation 
largely due to the fixed graphite, excess boiling simply reduces the cooling and neutron 
absorbtion without inhibiting the fission reaction

3.7 Advanced reactors

Several generations of reactors are commonly distinguished. Generation I reactors were 
developed in 1950-60s and only one is still running today. They mostly used natural 
uranium fuel and used graphite as moderator. Generation II reactors are typified by the 
present US fleet and most in operation elsewhere. They typically use enriched uranium 
fuel and are mostly cooled and moderated by water. Generation III are the Advanced 
Reactors evolved from these, the first few of which are in operation in Japan and others 
are under construction and ready to be ordered. They are developments of the second 
generation with enhanced safety. There is no clear distinction Gen II to Gen III.

Generation IV designs are still on the drawing board and will not be operational before 
2020 at the earliest, probably later. They will tend to have closed fuel cycles and burn 
the long-lived actinides now forming part of spent fuel, so that fission products are the 
only high-level waste. Of seven designs under development, 4 or 5 will be fast neutron 
reactors. Four will use fluoride or liquid metal coolants, hence operate at low pressure. 
Two will be gas-cooled. Most will run at much higher temperatures than today’s water-
cooled reactors.
More than a dozen (Generation III) advanced reactor designs are in various stages of development. Some are evolutionary from the PWR, BWR and CANDU designs above, some are more radical departures. The former include the Advanced Boiling Water Reactor, a few of which are now operating with others under construction. The best-known radical new design has the fuel as large 'pebbles' and uses helium as coolant, at very high temperature, possibly to drive a turbine directly.

Considering the closed fuel cycle, Generation 1-3 reactors recycle plutonium (and possibly uranium), while Generation IV are expected to have full actinide recycle.

3.8 Fast neutron reactors (FNR)

Some reactors (only one in commercial service) do not have a moderator and utilise fast neutrons, generating power from plutonium while making more of it from the U-238 isotope in or around the fuel. While they get more than 60 times as much energy from the original uranium compared with the normal reactors, they are expensive to build. Further development of them is likely in the next decade, and the main designs expected to be built in two decades are FNRs. If they are configured to produce more fissile material (plutonium) than they consume they are called Fast Breeder Reactors (FBR). See also Fast Neutron Reactors and Small Reactors papers.

3.9 Floating nuclear power plants

Apart from over 200 nuclear reactors powering various kinds of ships, Rosatom in Russia has set up a subsidiary to supply floating nuclear power plants ranging in size from 70 to 600 MWe. These will be mounted in pairs on a large barge, which will be permanently moored where it is needed to supply power and possibly some desalination to a shore settlement or industrial complex. The first has two 40 MWe reactors based on those in icebreakers and will operate at a remote site in Siberia. Electricity cost is expected to be much lower than from present alternatives.

The Russian KLT-40S is a reactor well proven in icebreakers and now proposed for wider use in desalination and, on barges, for remote area power supply. Here a 150 MWt unit produces 35 MWe (gross) as well as up to 35 MW of heat for desalination or...
district heating. These are designed to run 3-4 years between refuelling and it is envisaged that they will be operated in pairs to allow for outages, with on-board refuelling capability and used fuel storage. At the end of a 12-year operating cycle the whole plant is taken to a central facility for 2-year overhaul and removal of used fuel, before being returned to service. Two units will be mounted on a 21,000 tonne barge. A larger Russian factory-built and barge-mounted reactor is the VBER-150, of 350 MW thermal, 110 MWe. The larger VBER-300 PWR is a 325 MWe unit, originally envisaged in pairs as a floating nuclear power plant, displacing 49,000 tonnes. As a cogeneration plant it is rated at 200 MWe and 1900 GJ/hr.

3.10 Lifetime of nuclear reactors

Most of today’s nuclear plants which were originally designed for 30 or 40-year operating lives. However, with major investments in systems, structures and components lives can be extended, and in several countries there are active programs to extend operating lives. In the USA most of the more than one hundred reactors are expected to be granted licence extensions from 40 to 60 years. This justifies significant capital expenditure in upgrading systems and components, including building in extra performance margins.

Some components simply wear out, corrode or degrade to a low level of efficiency. These need to be replaced. Steam generators are the most prominent and expensive of these, and many have been replaced after about 30 years where the reactor otherwise has the prospect of running for 60 years. This is essentially an economic decision. Lesser components are more straightforward to replace as they age. In Candu reactors, pressure tube replacement has been undertaken on some plants after about 30 years operation.

A second issue is that of obsolescence. For instance, older reactors have analogue instrument and control systems. Thirdly, the properties of materials may degrade with age, particularly with heat and neutron irradiation. In respect to all these aspects, investment is needed to maintain reliability and safety. Also, periodic safety reviews are
undertaken on older plants in line with international safety conventions and principles to ensure that safety margins are maintained.

Another important issue is knowledge management (KM) over the full lifecycle from design, through construction and operation to decommissioning for reactors and other facilities. This may span a century and involve several countries, and involve a succession of companies. The plant lifespan will cover several generations of engineers. Data needs to be transferable across several generations of software and IT hardware, as well as being shared with other operators of similar plants. Significant modifications may be made to the design over the life of the plant, so original documentation is not sufficient, and loss of design base knowledge can have huge implications (eg Pickering A and Bruce A in Ontario). Knowledge management is often a shared responsibility and is essential for effective decision-making and the achievement of plant safety and economics.

3.11 Load-following capability

Nuclear power plants are essentially base-load generators, ideally running continuously at high capacity. This is because their power output cannot efficiently be ramped up and down on a daily and weekly basis, and in this respect they are similar to most coal-fired plants. (It is also uneconomic to run them at less than full capacity, since they are expensive to build but cheap to run.) However, in some situations it is necessary to vary the output according to daily and weekly load cycles on a regular basis, for instance in France, where there is a very high reliance on nuclear power.

BWRs can be made to follow loads reasonably easily without burning the core unevenly, by changing the coolant flow rate. Load following is not as readily achieved in a PWR, but especially in France since 1981, so-called ‘grey’ control rods are used. The ability of a PWR to run at less than full power for much of the time depends on whether it is in the early part of its 18 to 24-month refuelling cycle or late in it, and whether it is designed with special control rods which diminish power levels throughout the core
without shutting it down. Thus, though the ability on any individual PWR reactor to run on a sustained basis at low power decreases markedly as it progresses through the refueling cycle, there is considerable scope for running a fleet of reactors in load-following mode. European Utility Requirements (EUR) since 2001 specify that new reactor designs must be capable of load-following between 50 and 100% of capacity with a rate of change of electric output of 3-5% per minute. The economic consequences are mainly due to diminished load factor of a capital-intensive plant. Further information in the Nuclear Power in France paper and the 2011 Nuclear Energy Agency report, Technical and Economic Aspects of Load Following with Nuclear Power Plants.

3.12 Primary coolants

The advent of some of the designs mentioned above provides opportunity to review the various primary heat transfer fluids used in nuclear reactors. There is a wide variety – gas, water, light metal, heavy metal and salt:

**Water or heavy water** must be maintained at very high pressure (1000-2200 psi, 7-15 MPa, 150 atmospheres) to enable it to function well above 100°C, up to 345°C, as in present reactors. This has a major influence on reactor engineering. However, supercritical water around 25 MPa can give 45% thermal efficiency – as at some fossil-fuel power plants today with outlet temperatures of 600°C, and at ultra supercritical levels (30+ MPa) 50% may be attained.

Water cooling of steam condensers is fairly standard in all power plants, because it works very well, it is relatively inexpensive, and there is a huge experience base. Water is a lot more effective than air for removing heat, though its thermal conductivity is less than liquid alternatives.

**Helium** must be used at similar pressure (1000-2000 psi, 7-14 MPa) to maintain sufficient density for efficient operation. Again, there are engineering implications, but it can be used in the Brayton cycle to drive a turbine directly.
Carbon dioxide was used in early British reactors, and their current AGRs which operate at much higher temperatures than light water reactors. It is denser than helium and thus likely to give better thermal conversion efficiency. It also leaks less readily than helium. There is now interest in supercritical CO$_2$ for the Brayton cycle.

Kudankulam Nuclear Power Plant, in Tirunelveli district, Tamilnadu, India

4. Nuclear Waste

A typical nuclear power plant in a year generates 20 metric tons of used nuclear fuel. The nuclear industry generates a total of about 2,000 - 2,300 metric tons of used fuel per year.

Over the past four decades, the entire industry has produced 76,430 metric tons of used nuclear fuel. If used fuel assemblies were stacked end-to-end and side-by-side, this would cover a football field about eight yards deep.
High-level radioactive waste is the byproduct of recycling used nuclear fuel, which in its final form will be disposed of in a permanent disposal facility. NEI supports the recycling of used nuclear fuel as part of its integrated fuel management strategy, which includes 1) interim storage 2) research, development and demonstration to recycle nuclear fuel, and 3) development of a permanent disposal facility suitable for the final waste form.

4.1 Types of radioactive waste

There are four main types of nuclear waste:

- High-level waste: This is the waste that remains when nuclear fuel is used to make energy via a nuclear reactor. Because the fuel has been used, the waste takes the form of small pellets and fuel rods.

- Intermediate-level waste: This in-between level of radioactive waste is typically inclusive of materials that need to be properly stored away from land or human exposure, but doesn’t need to go through a cooling process before doing so. Oftentimes decommissioned nuclear plants have this level of radioactivity, and waste is typically handled depending on the time it takes for the radioactivity to decay.

- Low-level waste: This is typically materials used during a nuclear process that have become contaminated, such as rags used to clean up, tubes used to hold materials, or even clothing and tools. Hospitals commonly produce this kind of waste, which is one of the easiest to dispose of.

- Mill Tailings waste: Nuclear materials – particularly thorium and uranium – come from a special process of extraction used to remove them from naturally occurring ore. Mill tailings are the forms of residue produced during this extraction process.

4.2 Impact of Nuclear Waste
Radiation Effects on Humans

Certain body parts are more specifically affected by exposure to different types of radiation sources. Several factors are involved in determining the potential health effects of exposure to radiation. These include:

1. The size of the dose (amount of energy deposited in the body)
2. The ability of the radiation to harm human tissue
3. Which organs are affected

The most important factor is the amount of the dose - the amount of energy actually deposited in your body. The more energy absorbed by cells, the greater the biological damage. Health physicists refer to the amount of energy absorbed by the body as the radiation dose. The absorbed dose, the amount of energy absorbed per gram of body tissue, is usually measured in units called rads. Another unit of radiation is the rem, or roentgen equivalent in man. To convert rads to rems, the number of rads is multiplied by a number that reflects the potential for damage caused by a type of radiation. For beta, gamma and X-ray radiation, this number is generally one. For some neutrons, protons, or alpha particles, the number is twenty.

Hair

The losing of hair quickly and in clumps occurs with radiation exposure at 200 rems or higher.

Brain

Since brain cells do not reproduce, they won't be damaged directly unless the exposure is 5,000 rems or greater. Like the heart, radiation kills nerve cells and small blood vessels, and can cause seizures and immediate death.

Thyroid
The certain body parts are more specifically affected by exposure to different types of radiation sources. The thyroid gland is susceptible to radioactive iodine. In sufficient amounts, radioactive iodine can destroy all or part of the thyroid. By taking potassium iodide can reduce the effects of exposure.

**Blood System**

When a person is exposed to around 100 rems, the blood’s lymphocyte cell count will be reduced, leaving the victim more susceptible to infection. This is often referred to as mild radiation sickness. Early symptoms of radiation sickness mimic those of flu and may go unnoticed unless a blood count is done. According to data from Hiroshima and Nagasaki, show that symptoms may persist for up to 10 years and may also have an increased long-term risk for leukemia and lymphoma. For more information, visit Radiation Effects Research Foundation.

**Heart**

Intense exposure to radioactive material at 1,000 to 5,000 rems would do immediate damage to small blood vessels and probably cause heart failure and death directly.

**Gastrointestinal Tract**

Radiation damage to the intestinal tract lining will cause nausea, bloody vomiting and diarrhea. This is occurs when the victim's exposure is 200 rems or more. The radiation will begin to destroy the cells in the body that divide rapidly. These including blood, GI tract, reproductive and hair cells, and harms their DNA and RNA of surviving cells.

**Reproductive Tract**

Because reproductive tract cells divide rapidly, these areas of the body can be damaged at rem levels as low as 200. Long-term, some radiation sickness victims will become sterile.
<table>
<thead>
<tr>
<th>Dose (rem)</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-20</td>
<td>Possible late effects; possible chromosomal damage.</td>
</tr>
<tr>
<td>20-100</td>
<td>Temporary reduction in white blood cells.</td>
</tr>
<tr>
<td>100-200</td>
<td>Mild radiation sickness within a few hours: vomiting, diarrhea, fatigue; reduction in resistance to infection.</td>
</tr>
<tr>
<td>200-300</td>
<td>Serious radiation sickness effects as in 100-200 rem and hemorrhage; exposure is a Lethal Dose to 10-35% of the population after 30 days (LD 10-35/30).</td>
</tr>
<tr>
<td>300-400</td>
<td>Serious radiation sickness; also marrow and intestine destruction; LD 50-70/30.</td>
</tr>
<tr>
<td>400-1000</td>
<td>Acute illness, early death; LD 60-95/30.</td>
</tr>
<tr>
<td>1000-5000</td>
<td>Acute illness, early death in days; LD 100/10.</td>
</tr>
</tbody>
</table>

### 4.3 Effect on environment

Nuclear waste affects the environment primarily because it's extremely difficult to dispose of properly. If it isn't disposed of properly, it can cause extensive groundwater and soil contamination. The elements that make up nuclear waste often have long half-lives, which means that it may take millions or billions of years before the waste is safe for humans to be around.

### 4.4 Disposal of Nuclear Waste
• Incineration: Burning radioactive waste is largely done through commercially-operated incinerators developed for this purpose, although certain large companies have the means to do this on their own. Incineration is common with low-level waste, as this material usually consists of clothing or other common items that have simply been contaminated.

• Storage: Over time, the radioactivity of nuclear material does decay, so storing this material until it is no longer radioactive is another way to deal with proper nuclear waste disposal. This process, called radioactive decay, depends on the amount of materials and the radioactivity level. Therefore, storage is typically only done with radioactive waste that has a shorter half-life, or the amount of time it takes for the material’s radioactivity to be reduced by half. There are commercial storage facilities for this waste, while some approved companies have their own means of storage.

• Shallow Burial: Highly radioactive material is hard to bury, but when it comes to mill tailings, these remnants can often be buried in a specially-crafted spot nearby the mill itself. Often, this includes creating a pile of tailings, covering it with a non-permeable material like clay. The pile is often typically buttressed by a mix of rocks and soil so that it doesn’t erode.

• Deep Burial: While shallow burials can be done with low-level waste, the most common way of disposing of high-level waste is in deep burial pits. Many countries with natural resources follow this procedure of geological disposal, which consists of burying the material deep within the earth. Often times, underground laboratories are built to monitor usage and storage of the materials. However, as of now, there is no government that has a facility for this type of disposal, although one is being created in Finland.

• In water: At nuclear sites, a common way of storing material is in water. Nearly all of these sites have a special pond or have a special pool constructed, which is a
place that they can store fuel that has already been used for the process of generating power.

- Recycling: For some radioactive material, such as previously used fuel, certain radioactive elements can be processed or extracted for reuse. Uranium and plutonium elements have long lives, so they can be separated and recycled.

- The Ocean: A very small amount of liquid waste that is common when waste is reprocessed to extract usable elements is released into the ocean. This process is highly controlled, and radiation levels are deemed to be so low that they are inconsequential. However, recent agreements between companies that rely on nuclear materials have phased out this procedure.

While these are commonly used ways to dispose nuclear waste, there have been some proposals for alternate methods, although none of have been seriously considered. Some of these alternate disposal forms include:

Space Disposal: The expense related to this is far too prohibitive when compared with the positive effects.

Seabed Disposal: Another proposal was to embed waste deep within the seabed. However, international powers decided that the risk was far greater than the benefits.

Long-term aboveground Storage Bunkers: While some nuclear companies do have storage facilities above-ground, these are temporary and meant to make the waste more accessible for reuse, or to have it decay enough for another form of disposal. However, permanent above ground storage has been discarded in favor of deeper burials within the ground.

4.5 Effects of improper disposal of Nuclear Waste
While one can throw your household waste into a garbage can that makes its way to a landfill, other types of waste – such as the byproducts from nuclear activity – must be disposed of in a very carefully regimented way. Your old magazines may sit in that landfill for awhile, but if you were to throw out nuclear or radioactive waste in the same way, it would simply enter the air, ground, and water supply, leading to serious harm to local residents and wildlife. That’s why nuclear waste disposal is such an important factor in keeping the environment stable.

Because nuclear waste consists of radioactive materials, it must be properly disposed of or there is a risk of a larger contamination. Many governments have specific regulating agencies that provide strict procedures for those handling nuclear materials.

Proper nuclear waste is important, as it can take hundreds of years for the material to lose its radioactivity. During this process, remnants of radioactivity can and will affect many people, animals, and plants in a given region.

Some of the harm from improperly disposed material includes:

- **Affecting Human Populations:** Humans are significantly impacted by exposure to levels of radiation. Oftentimes, this exposure will affect many future generations, as it leads to a number of birth and developmental disabilities. Down syndrome, thyroid cancer, and a number of other issues have been found in people affected by radiation.

- **Affecting Wildlife:** One only need look to the Chernobyl disaster to see what the effects of radiation can be on wildlife in the area. Unfortunately, despite the fact that the event was 30 years ago, most of the animals are deemed to be affected by radioactivity. This manifests in reduced brain sizes, physical deformities, and other concerns that impact the survival of these creatures.

- **Affecting Local Flora:** Plant life is also susceptible to damage from nuclear radioactive waste. After Chernobyl, an entire pine forest needed to be destroyed because it was affected by radiation. Not to mention, radioactive soils and plants
dissuade bees and other important creatures from fertilizing and helping flora grow, which again, serves to impact future generations.

- **Affecting Nuclear Workers:** It goes without saying that those who work around nuclear materials are highly susceptible to negative effects. While rare, nuclear reactor accidents have led to many deaths in the past, both from those exposed and even some of whom were irradiated during the research or testing phases. Improperly stored waste at a nuclear site can also lead to levels of exposure that are beyond what is acceptable for humans.
UNIT-IV Environmental implications

1. Energy Scenario in India

The decade of seventies has witnessed major world oil supply disruptions. During the 1970s the OPEC production was cut down by two and a half per cent causing severe oil supply distortions. From 1975 oil prices remained high but not as high as in 1973-74. But the Iranian revolution in 1979 worsened the situation and oil prices again rose sharply in 1979, generating the second oil shock. From the mid 1980s, there was again a resumption of the growth of demand for refined products. This demand upsurge led to an increase in oil prices from the late 1980s. From July to October 1990, following Iraq’s invasion of Kuwait, there was a near doubling of oil prices. However, this 1990 oil price shock had substantially lesser impact on the world economy than the other two oil price shocks (Mukhopadhyay, 2002). The reason for this diminished effect was the short duration (only 4 months) of the 1990s oil price hike, the substitution of oil, to a large extent, by competing energy sources and an overall recession of economic activities that had already begun before the price hikes. India being an oil importing country witnessed significant changes in the energy consumption pattern due to the oil shocks.

Faced with rising inflation and a balance of payment crisis in mid 1991 the government of India introduced a fairly comprehensive policy reform package comprising currency devaluation, deregulation, de-licensing, privatization of the public sector. The government of India initiated these policy changes to overcome the critical situation. The rising oil import bill has been the focus of serious concerns due to the pressure it has placed on scarce foreign exchange resources.

1.1 Energy Consumption in India

India’s per capita commercial energy consumption, increased from 9% of global average in 1965 to 19.4% in 2000 (TERI, 2000). In 1998-99, commercial energy consumption in India was estimated at 195.11 MT of oil equivalent, indicating a 75% growth over a decade. However, India’s per capita consumption of commercial energy continues to be much lower than the global average of about 1684 Kg of oil equivalent.
and is 5-10% that of developed countries like; Japan, France and the USA. In India, commercial energy demand grew at six percent (CMIE, 2001).

1.2 Energy Consumption by Sources: Overall Production and Consumption

India is both a major energy producer and consumer. India currently ranks as the world’s eleventh greatest energy producer, accounting for about 2.4% of the world’s total annual energy production, and as the world’s sixth greatest energy consumer, accounting for about 3.3% of the world’s total annual energy consumption. Despite its large annual energy production, India is a net energy importer, mostly due to the large imbalance between oil production and consumption.

1.2.1 Petroleum

India’s proved oil reserves are currently estimated (January 2005) at about 5 billion barrels, or about 4.5% of the world total. Most of these reserves lie offshore near Mumbai and onshore in Assam state. However, exploration is still happening, and India’s off-shore and on-shore basins may contain as much as 11 billion barrels. India presently ranks as the 25th greatest producer of crude oil, accounting for about 1% of the world’s annual crude oil production. About 30% of India’s energy needs are met by oil, and more than 60% of that oil is imported. A strong growth in oil demand has resulted in India’s annual petroleum consumption increasing by more than 75% from what it was a decade ago. India is currently the world's sixth greatest oil consumer, accounting for about 2.9% of world's total annual petroleum consumption.

1.2.2 Natural Gas

India’s natural gas reserves are currently estimated (as of January 2005) at about 29-32 trillion cubic feet (tcf), or about 0.5% of the world total. Most of these reserves lie offshore northwest of Mumbai in the Arabian Sea and onshore in Gujarat state. India does not yet rank in the top 20 of the world’s greatest natural gas consumers, but that will soon change. Natural gas has experienced the fastest rate of increase of any fuel in India’s primary energy supply; demand is growing at about 4.8% per year and is forecast to rise to 1.2 tcf per year by 2010 and 1.6 tcf per year by 2015.
1.2.3 Coal

India's has huge proven coal reserves, estimated (as of January 2005) at more than 90 billion tons, or about 10% of the world's total. Most of these reserves are relatively high ash bituminous coal and are located in Bihar, West Bengal, and Madhya Pradesh states. At the current level of production and consumption, India's coal reserves would last more than two hundred years. India is currently the third-largest coal-producing country in the world (behind China and the United States), and accounts for about 8.5% of the world's annual coal production. India is also currently the third-largest coal consuming country (behind the China and the United States), and accounts for nearly 9% of the world's total annual coal consumption. More than half of India’s energy needs are met by coal, and about 70% of India's electricity generation is now fueled by coal. The annual demand for coal has been steadily increasing over the past decade, and is now nearly 50% greater than it was a decade ago. Even though India is able to satisfy most of its country's coal demand through domestic production, less than 5% of its reserves is coking coal used by the steel industry. As a result, India's steel industry imports coking coal, mainly from Australia and New Zealand, to meet about 25% of its annual needs.

1.2.4 Electricity

India is presently the sixth-greatest electricity generating country and accounts for about 4% of the world's total annual electricity generation. India is also currently ranked sixth
in annual electricity consumption, accounting for about 3.5% of the world's total annual electricity consumption. Overall, India’s need for power is growing at a prodigious rate; annual electricity generation and consumption in India have increased by about 64% in the past decade, and its projected rate of increase for electricity consumption is one of the highest in the world.

Electricity consumption in India has more than doubled in the last decade. The primary energy supply in the country is coal-dominant, with the power sector accounting for about 40 percent of primary energy and 70 percent of coal consumption (CMIE, 2000). The Indian power sector is characterized by large demand-supply gap. Faced with unreliable power supply, many industries have invested in on-site power generation that now accounts for more than 10 percent of total capacity (CMIE, 2000).

1.2.5 Renewable Energy Sources

Though the present contribution of renewable energy is small, existing capabilities offer the flexibility to respond to emerging environmental and sustainable development needs. Renewable energy technologies (RETs) have a vast potential and have the advantage of being environmentally sustainable.

Small Hydro Power

Hydro based power generation up to 25 MW capacities, classified as small hydropower, and offers a number of advantages for electricity generation. It has been one of the earliest known renewable energy sources, in existence in the country. Estimates place the small hydro potential in India at 15,000 MW (TERI 2000). Since a large potential of this technology exists in remote hilly areas, development of small hydropower for decentralized power generation leads to rural electrification and local area development. The gestation period of the technology is low and the indigenous manufacturing base is strong.
Wind Power

India is positioned among the top five countries in wind power installation after Germany, the USA, Denmark, and Spain. Wind power capacity reached nearly 1267 MW by December 2000 with an aggregate generation of about 6.5 billion units of electricity. Private projects constitute around 95.5 percent of the total capacity and the rest are demonstration projects. Out of the total energy generated, about 80 percent of consumption is for captive purposes while the rest is sold to the grid. Wind energy is one of the clean, renewable energy sources that hold out the promise of meeting energy demand in the direct, grid-connected modes as well as stand-alone and remote ‘niche’ applications (for instance water pumping, desalination, and telecommunications) in developing countries like India. Estimates place the economical wind energy potential in India at 45,000 MW (GOI, 2001).

Biomass-based Power Generation/Cogeneration

Biomass, consisting of wood, crop residues and animal dung continues to dominate energy supply in rural and traditional sectors, having about one-third share in the total primary energy consumption in the country. Cogeneration technology, based on multiple and sequential use of a fuel for generation of steam and power, aims at surplus power generation in process industries such as sugar mills, paper mills, rice mills, etc. The aggregate biomass combustion based power and sugar-cogeneration capacity by the end of December 2000 was 273 MW, with 210 MW of cogeneration and the rest biomass power. In the area of small scale biomass gasification, a total capacity of 35 MW has so far been installed, mainly for stand-alone applications (TERI, 2000).

Solar Technologies

Solar Photovoltaic (SPV) contributes at present around two and a half percent of the power generation based on renewable energy technology in India. Solar photovoltaic systems with 17 an aggregate capacity of 47 MW have been deployed for different applications (GOI, 2001), that includes solar photovoltaic power projects aggregating
1.615 MW for providing voltage support in rural areas and peak load shaving in urban areas. Solar thermal technologies have a very high potential for applications in solar water heating systems for industrial and domestic applications and for solar cooking in the domestic sector. Solar Thermal Power Generation potential in India is about 35 MW per Sq. Km Estimates indicate 800 MW per year potential for solar thermal based power generation in India during the period 2010 to 2015, with worldwide advancements in the parabolic trough technology (TERI, 2000). The technologies for power generation using solar thermal technology are parabolic dish, parabolic trough collectors, central receivers, solar ponds and solar chimneys. Dissemination of SPV technology has been undertaken by a technology-push approach adopted by the government.

2. World energy consumption

World energy consumption is the total energy used by all of human civilization. Typically measured per year, it involves all energy harnessed from every energy source applied towards humanity's endeavors across every single industrial and technological sector, across every country. Being the power source metric of civilization, World Energy Consumption has deep implications for humanity's social-economic-political sphere.

Institutions such as the International Energy Agency (IEA), the U.S. Energy Information Administration (EIA), and the European Environment Agency record and publish energy data periodically. Improved data and understanding of World Energy Consumption may reveal systemic trends and patterns, which could help frame current energy issues and encourage movement towards collectively useful solutions.

The IEA estimates that, in 2013, total world energy consumption was 9,301 Mtoe, or \(3.89 \times 10^{20}\) joules, equal to an average power consumption of 12.3 terawatts. From 2000–2012 coal was the source of energy with the largest growth. The use of oil and natural gas also had considerable growth, followed by hydro power and renewable energy. Renewable energy grew at a rate faster than any other time in history during this period, which can possibly be explained by an increase in international investment...
in renewable energy. The demand for nuclear energy decreased, possibly due to the accidents at Chernobyl and Three Mile Island.

In 2011, expenditures on energy totaled over 6 trillion USD, or about 10% of the world gross domestic product (GDP). Europe spends close to one quarter of the world's energy expenditures, North America close to 20%, and Japan 6%.

In 2013, world energy consumption by power source was oil 31.1%, coal 28.9%, natural gas 21.4%, bio-fuels and waste 10.2%, nuclear 4.8%, hydro 2.4%, and 'other' (solar, wind, geothermal, heat, etc.) 1.2%. Oil, coal, and natural gas were the most popular energy fuels.

2.1 Non Renewable energy

2.1.1 Petroleum

Coal fueled the industrial revolution in the 18th and 19th century. With the advent of the automobile, airplanes and the spreading use of electricity, oil became the dominant fuel
during the twentieth century. The growth of oil as the largest fossil fuel was further enabled by steadily dropping prices from 1920 until 1973. After the oil shocks of 1973 and 1979, during which the price of oil increased from 5 to 45 US dollars per barrel, there was a shift away from oil. Coal, natural gas, and nuclear became the fuels of choice for electricity generation and conservation measures increased energy efficiency. In the U.S. the average car more than doubled the number of miles per gallon. Japan, which bore the brunt of the oil shocks, made spectacular improvements and now has the highest energy efficiency in the world. From 1965 to 2008, the use of fossil fuels has continued to grow and their share of the energy supply has increased. From 2003 to 2008, coal was the fastest growing fossil fuel.

It is estimated that between 100 and 135 billion tonnes of oil has been consumed between 1850 and the present.

2.1.2 Natural Gas

In 2009, the world use of natural gas was 131% compared to year 2000. 66% of this growth was outside EU, North America Latin America and Russia. Others include Middle East, Asia and Africa. The gas supply increased also in the previous regions: 8.6% in the EU and 16% in the North America 2000–2009.

<table>
<thead>
<tr>
<th>Regional gas supply (TWh) and share 2010 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land</td>
</tr>
<tr>
<td>North America</td>
</tr>
<tr>
<td>Asia excl. China</td>
</tr>
<tr>
<td>China</td>
</tr>
<tr>
<td>EU</td>
</tr>
<tr>
<td>Africa</td>
</tr>
</tbody>
</table>
2.1.3 Coal

In 2000, China accounted for 28% of world coal consumption, other Asia consumed 19%, North America 25% and the EU 14%. The single greatest coal-consuming country is China. Its share of the world coal production was 28% in 2000 and rose to 48% in 2009. In contrast to China's ~70% increase in coal consumption, world coal use increased 48% from 2000 to 2009. In practice, the majority of this growth occurred in China and the rest in other Asia. China's energy consumption is mostly driven by the industry sector, the majority of which comes from coal consumption.

World annual coal production increased 1,905 Mt or 32% in 6 years in 2011 compared to 2005, of which over 70% was in China and 8% in India. Coal production was in 2011 7,783 Mt, and 2009 6,903 Mt, equal to 12.7% production increase in two years.

If production and consumption of coal continue at the rate as in 2008, proven and economically recoverable world reserves of coal would last for about 150 years. This is much more than needed for an irreversible climate catastrophe. Coal is the largest source of carbon dioxide emissions in the world. According to IEA Coal Information (2007) world production and use of coal have increased considerably in recent years. According to James Hansen the single most important action needed to tackle the climate crisis is to reduce CO₂ emissions from coal. Indonesia and Australia exported together 57.1% of the world coal export in

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Russia</td>
<td>3,709</td>
<td>4,259</td>
<td>4,209</td>
<td>4,335</td>
<td>13%</td>
</tr>
<tr>
<td>Latin America</td>
<td>1,008</td>
<td>1,357</td>
<td>958</td>
<td>nd</td>
<td>nd</td>
</tr>
<tr>
<td>Others</td>
<td>3,774</td>
<td>5,745</td>
<td>6,047</td>
<td>7,785</td>
<td>23%</td>
</tr>
<tr>
<td>Total</td>
<td>24,312</td>
<td>30,134</td>
<td>31,837</td>
<td>33,240</td>
<td>100%</td>
</tr>
</tbody>
</table>

Source: IEA, in 2009, 2010 BP
2011. China, Japan, South Korea, India and Taiwan had 65% share of all the world coal import in 2011.

2.1.4 Nuclear power

As of 1 July 2016, the world had 444 operable grid-electric nuclear power reactors with 62 others under construction. Since commercial nuclear energy began in the mid 1950s, 2008 was the first year that no new nuclear power plant was connected to the grid, although two were connected in 2009.

Annual generation of nuclear power has been on a slight downward trend since 2007, decreasing 1.8% in 2009 to 2558 TWh, and another 1.6% in 2011 to 2518 TWh, despite increases in production from most countries worldwide, because those increases were more than offset by decreases in Germany and Japan. Nuclear power met 11.7% of the world's electricity demand in 2011.

2.2 Renewable energy

Renewable energy is gradually replacing conventional fuels in four distinct areas: electricity generation, hot water/space heating, motor fuels, and rural (off-grid) energy services.

2.2.1 Hydro

Hydroelectricity is the term referring to electricity generated by hydropower; the production of electrical power through the use of the kinetic energy of falling or flowing water. In 2015 hydropower generated 16.6% of the world's total electricity and 70% of all renewable electricity, which continues the rapid rate of increase experienced between 2003 and 2009. Hydropower is produced in 150 countries, with the Asia-Pacific region generating 32 percent of global hydropower in 2010. China is the largest hydroelectricity producer, with 2,600 PJ (721 TWh) of production in 2010, representing around 17% of domestic electricity use. There are now three hydroelectricity plants larger than 10 GW: the Three Gorges Dam in China, Itaipu Dam in Brazil, and Guri Dam in Venezuela.
2.2.2 Wind

Wind power is growing at the rate of 17% annually, with a worldwide installed capacity of 432,883 megawatts (MW) at the end of 2015, and is widely used in Europe, Asia, and the United States. Several countries have achieved relatively high levels of wind power penetration, such as 21% of stationary electricity production in Denmark, 18% in Portugal, 16% in Spain, 14% in Ireland and 9% in Germany in 2010. As of 2011, 83 countries around the world are using wind power on a commercial basis. In 2013 wind generated almost 3% of the world's total electricity.

2.2.3 Solar

Solar energy, radiant light and heat from the sun, has been harnessed by humans since ancient times using a range of ever-evolving technologies. Solar energy technologies include solar heating, solar photovoltaics, concentrated solar power and solar architecture, which can make considerable contributions to solving some of the most urgent problems the world now faces. The International Energy Agency projected that solar power could provide "a third of the global final energy demand after 2060, while CO₂ emissions would be reduced to very low levels." Solar technologies are broadly characterized as either passive solar or active solar depending on the way they capture, convert and distribute solar energy. Active solar techniques include the use of photovoltaic systems and solar thermal collectors to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light dispersing properties, and designing spaces that naturally circulate air.

2.2.4 Geothermal

Geothermal energy is used commercially in over 70 countries. In 2004, 200 petajoules (56 TWh) of electricity was generated from geothermal resources, and an additional 270 petajoules (75 TWh) of geothermal energy was used directly, mostly for space heating. In 2007, the world had a global capacity for 10 GW of electricity generation and an additional 28 GW of direct heating, including extraction by geothermal heat pumps. Heat
pumps are small and widely distributed, so estimates of their total capacity are uncertain and range up to 100 GW.

2.2.5 Bio energy

Until the beginning of the nineteenth century biomass was the predominant fuel, today it has only a small share of the overall energy supply. Electricity produced from biomass sources was estimated at 44 GW for 2005. Biomass electricity generation increased by over 100% in Germany, Hungary, the Netherlands, Poland, and Spain. A further 220 GW was used for heating (in 2004), bringing the total energy consumed from biomass to around 264 GW. The use of biomass fires for cooking is excluded. World production of bio ethanol increased by 8% in 2005 to reach 33 gigalitres \((8.7\times10^9 \text{ US gal})\), with most of the increase in the United States, bringing it level to the levels of consumption in Brazil. Biodiesel increased by 85% to 3.9 gigalitres \((1.0\times10^9 \text{ US gal})\), making it the fastest growing renewable energy source in 2005. Over 50% is produced in Germany.

3 CO2 Emission

Sources: There are both natural and human sources of carbon dioxide emissions. Natural sources include decomposition, ocean release and respiration. Human sources come from activities like cement production, deforestation as well as the burning of fossil fuels like coal, oil and natural gas.

Due to human activities, the atmospheric concentration of carbon dioxide has been rising extensively since the Industrial Revolution and has now reached dangerous levels not seen in the last 3 million years. Human sources of carbon dioxide emissions are much smaller than natural emissions but they have upset the natural balance that existed for many thousands of years before the influence of humans.

This is because natural sinks remove around the same quantity of carbon dioxide from the atmosphere than are produced by natural sources. This had kept carbon dioxide
levels balanced and in a safe range. But human sources of emissions have upset the natural balance by adding extra carbon dioxide to the atmosphere without removing any.

3.1 Carbon Dioxide Emissions: Human Sources

Since the Industrial Revolution, human sources of carbon dioxide emissions have been growing. Human activities such as the burning of oil, coal and gas, as well as deforestation are the primary cause of the increased carbon dioxide concentrations in the atmosphere.

87 percent of all human-produced carbon dioxide emissions come from the burning of fossil fuels like coal, natural gas and oil. The remainder results from the clearing of forests and other land use changes (9%), as well as some industrial processes such as cement manufacturing (4%).

3.1.1 Fossil fuel combustion/use

The largest human source of carbon dioxide emissions is from the combustion of fossil fuels. This produces 87% of human carbon dioxide emissions. Burning these fuels releases energy which is most commonly turned into heat, electricity or power for transportation. Some examples of where they are used are in power plants, cars, planes
and industrial facilities. In 2011, fossil fuel use created 33.2 billion tonnes of carbon dioxide emissions worldwide.

The 3 types of fossil fuels that are used the most are coal, natural gas and oil. Coal is responsible for 43% of carbon dioxide emissions from fuel combustion, 36% is produced by oil and 20% from natural gas.

Coal is the most carbon intensive fossil fuel. For every tonne of coal burned, approximately 2.5 tonnes of CO$_2$e are produced. Of all the different types of fossil fuels, coal produces the most carbon dioxide. Because of this and it's high rate of use, coal is the largest fossil fuel source of carbon dioxide emissions. Coal represents one-third of fossil fuels' share of world total primary energy supply but is responsible for 43% of carbon dioxide emissions from fossil fuel use.

Anything involving fossil fuels has a carbon dioxide emission ticket attached. So for example, burning these fuels releases energy but carbon dioxide also gets produced as a byproduct. This is because almost all the carbon that is stored in fossil fuels gets transformed to carbon dioxide during this process.

The three main economic sectors that use fossil fuels are: electricity/heat, transportation and industry. The first two sectors, electricity/heat and transportation, produced nearly two-thirds of global carbon dioxide emissions in 2010.

3.1.2 Electricity/Heat sector

Electricity and heat generation is the economic sector that produces the largest amount of man-made carbon dioxide emissions. This sector produced 41% of fossil fuel related carbon dioxide emissions in 2010. Around the world, this sector relies heavily on coal, the most carbon-intensive of fossil fuels, explaining this sector giant carbon footprint.

Almost all industrialized nations get the majority of their electricity from the combustion of fossil fuels (around 60-90%). Only Canada and France are the exception. Depending on the energy mix of your local power company you probably will find that the electricity
that you use at home and at work has a considerable impact on greenhouse gas emissions.

Below is a chart for percentage of electrical energy produced by fossil fuel combustion for major industrialized nations, for the complete list of all nations.

The industrial, residential and commercial sectors are the main users of electricity covering 92% of usage. Industry is the largest consumer of the three because certain manufacturing processes are very energy intensive. Specifically, the production of chemicals, iron/steel, cement, aluminum as well as pulp and paper account for the great majority of industrial electricity use. The residential and commercial sectors are also heavily reliant on electricity for meeting their energy needs, particularly for lighting, heating, air conditioning and appliances.

3.1.3 Transportation sector

The transportation sector is the second largest source of anthropogenic carbon dioxide emissions. Transporting goods and people around the world produced 22% of fossil fuel related carbon dioxide emissions in 2010. This sector is very energy intensive and it uses petroleum based fuels (gasoline, diesel, kerosene, etc.) almost exclusively to meet those needs. Since the 1990s, transport related emissions have grown rapidly, increasing by 45% in less than 2 decades.

Road transport accounts for 72% of this sector's carbon dioxide emissions. Automobiles, freight and light-duty trucks are the main sources of emissions for the whole transport sector and emissions from these three have steadily grown since 1990. Apart from road vehicles, the other important sources of emissions for this sector are marine shipping and global aviation.

Marine shipping produces 14% of all transport carbon dioxide emissions. While there are a lot less ships than road vehicles used in the transportation sector, ships burn the dirtiest fuel on the market, a fuel that is so unrefined that it can be solid enough to be
walked across at room temperature. Because of this, marine shipping is responsible for over 1 billion tonnes of carbon dioxide emissions. This is more than the annual emissions of several industrialized countries (Germany, South Korea, Canada, UK, etc.) and this sector continues to grow rapidly.

Global aviation accounts for 11% of all transport carbon dioxide emissions. International flights create about 62% of these emissions with domestic flights representing the remaining 38%. Over the last 10 years, aviation has been one of the fastest growing sources of carbon dioxide emissions. Aviation is also the most carbon-intensive form of transportation, so it's growth comes with a heavy impact on climate change.

![Carbon dioxide emissions from fossil fuel combustion](image)

Emissions caused by the transportation of people and goods has grown so rapidly that it has surpassed emissions from the industrial sector, which has had a huge impact on climate change. This trend started in the 1990's and has continued ever since causing an increase in indirect emissions.

The emissions caused by the transportation of goods are examples of indirect emissions since the consumer has no direct control of the distance between the factory and the store. The emissions caused by people traveling (by car, plane, train, etc…) are examples of direct emissions since people can chose where they are going and by what method.
Since the distance traveled by goods during production is continuing to grow, this is putting more pressure on the transportation industry to bridge the gap and ends up creating more indirect emissions. What's worse is that 99% of the carbon dioxide emissions caused by transportation of people and goods all over the world comes from the combustion of fossil fuels.

### 3.1.4 Industrial sector

The industrial sector is the third largest source of man-made carbon dioxide emissions. This sector produced 20% of fossil fuel related carbon dioxide emissions in 2010. The industrial sector consists of manufacturing, construction, mining, and agriculture. Manufacturing is the largest of the 4 and can be broken down into 5 main categories: paper, food, petroleum refineries, chemicals, and metal/mineral products. These categories account for the vast majority of the fossil fuel use and CO2 emissions by this sector.

Manufacturing and industrial processes all combine to produce large amounts of each type of greenhouse gas but specifically large amounts of CO2. This is because many manufacturing facilities directly use fossil fuels to create heat and steam needed at various stages of production. For example factories in the cement industry, have to heat up limestone to 1450°C to turn it into cement, which is done by burning fossil fuels to create the required heat.

### 3.1.5 Land use changes

Land use changes are a substantial source of carbon dioxide emissions globally, accounting for 9% of human carbon dioxide emissions and contributed 3.3 billion tonnes of carbon dioxide emissions in 2011. Land use changes are when the natural environment is converted into areas for human use like agricultural land or settlements. From 1850 to 2000, land use and land use change released an estimated 396-690 billion tonnes of carbon dioxide to the atmosphere, or about 28-40% of total anthropogenic carbon dioxide emissions.
Deforestation has been responsible for the great majority of these emissions. Deforestation is the permanent removal of standing forests and is the most important type of land use change because its impact on greenhouse gas emissions. Forests in many areas have been cleared for timber or burned for conversion to farms and pastures. When forested land is cleared, large quantities of greenhouse gases are released and this ends up increasing carbon dioxide levels in three different ways.

Trees act as a carbon sink. They remove carbon dioxide from the atmosphere via photosynthesis. When forests are cleared to create farms or pastures, trees are cut down and either burnt or left to rot, which adds carbon dioxide to the atmosphere.

Since deforestation reduces the amount of trees, this also reduces how much carbon dioxide can be removed by the Earth’s forests. When deforestation is done to create new agricultural land, the crops that replace the trees also act as a carbon sink, but they are not as effective as forests. When trees are cut for lumber the wood is kept which locks the carbon in it but the carbon sink provided by forests is reduced because of the loss of trees.

Deforestation also causes serious changes in how carbon is stored in the soil. When forested land is cleared, soil disturbance and increased rates of decomposition in converted soils both create carbon dioxide emissions. This also increases soil erosion and nutrient leaching which further reduces the area’s ability to act as a carbon sink.

### 3.1.6 Industrial processes

There are many industrial processes that produce significant amounts of carbon dioxide emissions as a by product of chemical reactions needed in their production process. Industrial processes account for 4% of human carbon dioxide emissions and contributed 1.7 billion tonnes of carbon dioxide emissions in 2011.

Many industrial processes emit carbon dioxide directly through fossil fuel combustion as well indirectly through the use of electricity that is generated using fossil fuels. But there are four main types of industrial process that are a significant source of carbon dioxide emissions: the production and consumption of mineral products such as cement, the
production of metals such as iron and steel, as well as the production of chemicals and petrochemical products.

Cement production produces the most amount of carbon dioxide amongst all industrial processes. To create the main ingredient in cement, calcium oxide, limestone is chemically transformed by heating it to very high temperatures. This process produces large quantities of carbon dioxide as a byproduct of the chemical reaction. So much so that making 1000 kg of cement produces nearly 900 kg of carbon dioxide.

Steel production is another industrial process that is an important source of carbon dioxide emissions. To create steel, iron is melted and refined to lower its carbon content. This process uses oxygen to combine with the carbon in iron which creates carbon dioxide. On average, 1.9 tonnes of CO2 are emitted for every tonne of steel produced.

Fossil fuels are used to create chemicals and petrochemical products which leads to carbon dioxide emissions. The industrial production of ammonia and hydrogen most often use natural gas or other fossil fuels as a starting base, creating carbon dioxide in the process. Petrochemical products like plastics, solvents, and lubricants are created using petroleum. These products evaporate, dissolve, or wear out over time releasing even more carbon dioxide during the product's life.

3.2 Carbon Dioxide Emissions: Natural Sources

Apart from being created by human activities, carbon dioxide is also released into the atmosphere by natural processes. The Earth's oceans, soil, plants, animals and volcanoes are all natural sources of carbon dioxide emissions.

Human sources of carbon dioxide are much smaller than natural emissions but they upset the balance in the carbon cycle that existed before the Industrial Revolution. The amount of carbon dioxide produced by natural sources is completely offset by natural carbon sinks and has been for thousands of years. Before the influence of humans, carbon dioxide levels were quite steady because of this natural balance.
42.84 percent of all naturally produced carbon dioxide emissions come from ocean-atmosphere exchange. Other important natural sources include plant and animal respiration (28.56%) as well as soil respiration and decomposition (28.56%). A minor amount is also created by volcanic eruptions (0.03%).

3.2.1 Ocean-atmosphere exchange

The largest natural source of carbon dioxide emissions is from ocean-atmosphere exchange. This produces 42.84% of natural carbon dioxide emissions. The oceans contain dissolved carbon dioxide, which is released into the air at the sea surface. Annually this process creates about 330 billion tonnes of carbon dioxide emissions.

Many molecules move between the ocean and the atmosphere through the process of diffusion, carbon dioxide is one of them. This movement is in both directions, so the oceans release carbon dioxide but they also absorb it. The effects of this movement can be seen quite easily, when water is left to sit in a glass for long enough, gases will be released and create air bubbles. Carbon dioxide is amongst the gases that are in the air bubbles.

3.2.2 Plant and animal respiration

An important natural source of carbon dioxide is plant and animal respiration, which accounts for 28.56% of natural emissions. Carbon dioxide is a byproduct of the
chemical reaction that plants and animals use to produce the energy they need. Annually this process creates about 220 billion tonnes of carbon dioxide emissions.

Plants and animals use respiration to produce energy, which is used to fuel basic activities like movement and growth. The process uses oxygen to break down nutrients like sugars, proteins and fats. This releases energy that can be used by the organism but also creates water and carbon dioxide as byproducts.

### 3.2.3 Soil respiration and decomposition

Another important natural source of carbon dioxide is soil respiration and decomposition, which accounts for 28.56% of natural emissions. Many organisms that live in the Earth's soil use respiration to produce energy. Amongst them are decomposers who break down dead organic material. Both of these processes releases carbon dioxide as a byproduct. Annually these soil organisms create about 220 billion tonnes of carbon dioxide emissions.

Any respiration that occurs below-ground is considered soil respiration. Plant roots, bacteria, fungi and soil animals use respiration to create the energy they need to survive but this also produces carbon dioxide. Decomposers that work underground breaking down organic matter (like dead trees, leaves and animals) are also included in this. Carbon dioxide is regularly released during decomposition.

### 3.2.4 Volcanic eruptions

A minor amount carbon dioxide is created by volcanic eruptions, which accounts for 0.03% of natural emissions. Volcanic eruptions release magma, ash, dust and gases from deep below the Earth’s surface. One of the gases released is carbon dioxide. Annually this process creates about 0.15 to 0.26 billion tonnes of carbon dioxide emissions.

The most common volcanic gases are water vapor, carbon dioxide, and sulfur dioxide. Volcanic activity will cause magma to absorb these gases, while passing through the
Earth's mantle and crust. During eruptions, the gases are then released into the atmosphere.

### 3.3 CO2 - the major cause of global warming

Global warming is caused by the emission of greenhouse gases. 72% of the totally emitted greenhouse gases is carbon dioxide (CO2), 18% Methane and 9% Nitrous oxide (NOx). Carbon dioxide emissions therefore are the most important cause of global warming. CO2 is inevitably created by burning fuels like e.g. oil, natural gas, diesel, organic-diesel, petrol, organic-petrol, ethanol. The emissions of CO2 have been dramatically increased within the last 50 years and are still increasing by almost 3% each year.

The world-wide average CO2 emissions by capita was about 4 tons per year in 2005. For North America it was about 20 tons and for Europe about 10 tons per year per capita. By 2050, the world-wide average CO2 emission per capita needs to be reduced to 2 tons per year. In the following years, the emissions will need again to be cut by half.

---

**CO2 emissions world-wide**

<table>
<thead>
<tr>
<th>Year</th>
<th>CO2 Emissions (billion tonnes of CO2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>21.6</td>
</tr>
<tr>
<td>1993</td>
<td>21.8</td>
</tr>
<tr>
<td>1995</td>
<td>22.4</td>
</tr>
<tr>
<td>1997</td>
<td>23.2</td>
</tr>
<tr>
<td>1999</td>
<td>23.6</td>
</tr>
<tr>
<td>2001</td>
<td>24.2</td>
</tr>
<tr>
<td>2003</td>
<td>25.5</td>
</tr>
<tr>
<td>2005</td>
<td>27</td>
</tr>
</tbody>
</table>

**CO2 concentration in atmosphere**

<table>
<thead>
<tr>
<th>Year</th>
<th>CO2 Concentration (ppm CO2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>355.6</td>
</tr>
<tr>
<td>1993</td>
<td>357.1</td>
</tr>
<tr>
<td>1995</td>
<td>360.9</td>
</tr>
<tr>
<td>1997</td>
<td>363.8</td>
</tr>
<tr>
<td>1999</td>
<td>366.3</td>
</tr>
<tr>
<td>2001</td>
<td>371</td>
</tr>
<tr>
<td>2003</td>
<td>375.6</td>
</tr>
</tbody>
</table>
The carbon dioxide is released to the atmosphere where it remains for 100 to 200 years. This leads to an increasing concentration of carbon dioxide in our atmosphere, which in turn causes the average temperature on Earth to raise.

![World temperature increase in °C](image)

The surface temperature of the Earth increases - by $0.6^\circ C \pm 0.2^\circ C$ over the last century and the warming will increase with time, and could have disastrous consequences. These might include:

- **Sea level rise** - densely settled coastal plains would become uninhabitable with just a small rise in sea level, which would result from melting of the ice caps

- **Impacts on agriculture** - Global warming could have major effects on agricultural productivity

- **Reduction of the ozone layer** - Warming would result in increase high cloud cover in winter, giving chemical reactions a platform in the atmosphere, which could result in depletion of the ozone layer
**Increased extreme weather** - A warmer climate could change the weather systems of the earth, meaning there would be more droughts and floods, and more frequent and stronger storms

**Spread of diseases** - Diseases would be able to spread to areas which were previously too cold for them to survive in

**Ecosystem change** - As with the diseases, the range of plants and animals would change, with the net effect of most organisms moving towards the North and South Poles

As you can see, the effects of carbon dioxide emissions could be extremely far reaching and cause major problems. Even a small reduction in household emissions could help to alleviate the problems future generations are likely to face.

### 3.4 CO2 emission by Countries

**Six countries** produce nearly 60 percent of global carbon dioxide emissions. China and the United States combine for more than two-fifths. The planet’s future will be shaped by what these top carbon polluters do about the heat-trapping gases blamed for global warming.

#### 3.4.1 CHINA

It emits nearly twice the amount of greenhouse gases as the United States, which it surpassed in 2006 as the top emitter of carbon dioxide. China accounts for about 30 percent of global emissions. U.S. government estimates show China doubling its emissions by 2040, barring major changes. Hugely reliant on fossil fuels for electricity and steel production, China until recently was reluctant to set firm targets for emissions, which continue to rise, although at a slower rate.

That changed when Beijing announced last month in a deal with Washington that it would stem greenhouse gas emission growth by 2030. About a week later, China’s
Cabinet announced a coal consumption cap by 2020 at about 62 percent of the energy mix. While politically significant, the U.S.-China deal alone is expected to have little effect on the global thermostat.

3.4.2 UNITED STATES

It has never entered into a binding treaty to curb greenhouse gases. Nevertheless, it has cut more carbon pollution than any other nation. It is on pace to meet a 2009 Obama administration pledge to reduce emissions 17 percent from 2005 levels by 2020.

Carbon emissions are up, though, as the U.S. rebounds from recession. President Barack Obama has largely leaned on existing laws, not Congress, to make progress - boosting automobile fuel economy and proposing to reduce carbon pollution from new and existing power plants.

The White House vowed in the China deal to double the pace of emissions reductions, lowering carbon pollution 26 percent to 28 percent from 2005 levels by 2025. Expect resistance when Republicans control Congress in January.

3.4.3 INDIA

The U.S.-China agreement puts pressure on the Indian government, which could announce new targets during a planned Obama visit in January. Meantime, India plans to double coal production to feed a power grid still suffering blackouts.

Its challenge: to curb greenhouse gases as its population and economy grow. In 2010, India voluntarily committed to a 20 percent to 25 percent cut in carbon emissions relative to economic output by 2020 against 2005 levels. It has made recent strides installing solar power, which it is expected to increase fivefold to 100 gigawatts by 2030. Under current policies, its carbon dioxide emissions will double by then, according to the International Energy Agency.
3.4.4 RUSSIA

It never faced mandatory cuts under the 1997 Kyoto Protocol because its emissions fell so much after the Soviet Union collapsed. A major oil and gas producer, Russia in 2013 adopted a domestic greenhouse gas target that would trim emissions 25 percent from 1990 levels by 2020.

Russia’s carbon dioxide emissions today average 35 percent lower than 1990 levels. To meet its goal, Russia has set a goal for 2020 of boosting energy efficiency 40 percent and expanding renewable energy 4.5 percent. The state-owned gas company Gazprom has energy conservation plans, as has the federal housing program. But in 2006, Russia announced a move to more coal- and nuclear-fired electricity to export more oil and natural gas.

3.4.5 JAPAN

The shuttering of its nuclear power plants after the 2011 Fukushima nuclear disaster forced a drastic change in plans to curb carbon pollution. In November, Japanese officials said they would now reduce greenhouse gases 3.8 percent from 2005 levels by 2020.

With more fossil fuels in the mix, Japan’s emissions will be up 3 percent from 1990 levels, its benchmark for its pledge at a 2009 United Nations summit in Copenhagen to reduce emissions 25 percent. Beginning in 2012, Japan placed a carbon tax based on emissions of fossil fuels, with the proceeds going to renewable energy and energy-saving projects.

3.4.6 GERMANY

It has outperformed the 21 percent reduction in greenhouse gases it agreed to in 1997. Emissions are down 25 percent against 1990 levels. To comply with 2020 European Union-set goals, Germany must reduce greenhouse gases 40 percent by 2020.

On Wednesday, it boosted subsidies for energy efficiency to help it get there. Germany has in recent years seen back-to-back emissions increases due to higher demand for
electricity and a switch to coal after Fukushima, which prompted a nuclear power phase-out.

Coal use is down this year and renewables continue to gain electricity market share. Renewables already account for a quarter of Germany's electrical production. The country plans to boost that share to 80 percent by 2050 - and put a million electric cars on the road by 2020.

3.5 Carbon dioxide emissions in India

The rise in carbon emissions due to electricity generation was the highest in India even as the global economy moved away from carbon based energy sources, India being the fourth largest carbon emitter is expected to be the world’s fastest growing major economy. The report stressed that the country’s carbon intensity or measure of energy related greenhouse gas emissions per million dollars of GDP will have to be managed carefully.

Over a longer period, India has reduced its carbon intensity by 1.4% per year between 2000 and 2014. Its rate of reduction in carbon intensity is slightly better than the global average of 1.3% per year during 2000-2014.

The Kyoto Protocol to the United Nations Framework Convention on Climate Change
(UNFCCC) was adopted by more than 150 countries at the third session of the Conference of the Parties to the UNFCCC in Kyoto, Japan, on 11 December 1997. It is an international treaty containing binding constraints on greenhouse gas emissions and, mechanisms aimed at cutting the cost of reducing emissions and establishes global markets for greenhouse gas (GHG) emission permits. Under the Kyoto Protocol, industrialized countries and countries with economies in transition will reduce their combined GHG emissions by at least five per cent below their 1990 levels by the first commitment 2008 to 2012. The most important GHG is carbon dioxide (CO2) whose emissions are mainly related to combustion of fossil fuels.

The Protocol shall enter into force on the ninetieth day after the date on which not less than 55 Parties to the Convention, incorporating Annex I Parties which accounted in total for at least 55% of the total carbon dioxide emissions for 1990 from that group, have deposited their instruments of ratification, acceptance, approval or accession.

3.6 Kyoto Protocol

The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) was adopted by more than 150 countries at the third session of the Conference of the Parties to the UNFCCC in Kyoto, Japan, on 11 December 1997. It is an international treaty containing binding constraints on greenhouse gas emissions and, mechanisms aimed at cutting the cost of reducing emissions and establishes global markets for greenhouse gas (GHG) emission permits. Under the Kyoto Protocol, industrialized countries and countries with economies in transition will reduce their combined GHG emissions by at least five per cent below their 1990 levels by the first commitment 2008 to 2012. The most important GHG is carbon dioxide (CO2) whose emissions are mainly related to combustion of fossil fuels.

The Protocol shall enter into force on the ninetieth day after the date on which not less than 55 Parties to the Convention, incorporating Annex I Parties which accounted in total for at least 55% of the total carbon dioxide emissions for 1990 from that group,
have deposited their instruments of ratification, acceptance, approval or accession. The Kyoto protocol and the states that ratified the protocol could be found at the following website:

3.7 CDM (Clean Development Mechanism)

The UN's Kyoto protocol 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: one, to assist countries without emissions targets (ie developing countries) in achieving sustainable development. Two, help those countries with emission reduction targets under Kyoto (ie developed countries) in achieving compliance by allowing them to purchase offsets created by CDM projects.

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. 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.
There are currently over 3000 registered projects delivering an average of 500 million CERs per year. The overwhelming demand for CERs comes from the ETS, the world's largest functioning compliance carbon market. Between 2008 and 2010 European companies used 277 million CERs to meet their emissions reductions targets.

3.71 CDM - Paryavaran Mitra’s observations:

Paryavaran Mitra is closely observing the CDM policy in India and also at the proposed and implemented projects in Gujarat. Our research has led us to the following conclusions:

- The Ministry of Environment & Forest is the nodal agency for CDM projects in India. Thus for any CDM project introduced in India, NOC from SPCB and the permission of the MOEF is required. We have concluded that these have been reduced to mere formalities and paperwork instead of them acting as regulating bodies for CDM Projects.

- The Indian government acts as a mere promoter of CDM projects rather than monitoring and evaluating these projects. Till date, not a single proposal has been rejected by the Government, even if global companies believe that such a project is not worth Carbon Credits!

- In some cases, a CDM project is in operation while in same campus some other operation causes greater pollution; this defeats the greater objective of Kyoto-saving the Environment.

- In almost all such CDM projects, prior to its implementation the local communities have been victims of pollution from these industries especially due to greenhouse gases emissions. Ethically, CDM projects should share their revenue for the community’s welfare.

- Often, there is no appropriate public consultation about such CDM projects; the public is unaware of their implications. While EPH is mandatory for all other industrial setups, the MOEF is silent about making any Public Hearings for these
projects - creating double standards through the law. It seems obvious then that MNCs shall opt for CDM Projects in order to do away with Environmental procedure - what remains the largest hindrance for their unchecked proliferation.

- There are 104 registered CDM projects between India and UK alone. Under these projects 16586726 Certified Emission Reductions (Almost 650 to 900 crores INR) are traded every year. However, neither the Government nor the public are stakeholders for the benefits of such revenue. For CDM projects to achieve their objective - it must have a larger motive than profit-making.

3.7.2 Current problems of CDM

- Lack of transparency (only between Government, companies and International bodies)
- Cheap option for developed countries to buy carbon credits
- No transformational effects
- Community impacts (positive or negative) not evaluated.
- No monitoring at national and state government level
- How should mechanism be reformed? As the CDM process shall expire in 2012, what should be the future options available?

ON THE ISSUE OF CLIMATE CHANGE Paryavaran Mitra sees its role at two levels.

A) Studying specific protocols and their implication to the poor and marginalized and simplifying and communicating the implications as part of the Environmental Public Hearing process for clearances of Industrial Projects.

B) Promote and monitor the CDM projects as explained below:
• Gujarat is in forefront of industrial development. Many large and medium scale units of multinational projects have their units in Gujarat. Apart from that small scale industries are scattered all over Gujarat.

• For these industries, coal and other fossil fuel is the main source of energy.

• Burning of fossil fuel emits lots of carbon dioxide, carbon monoxide, nitrogen oxides and other gases, which comes under green house category gases.

• Gujarat has also large and medium scale Thermal Power Plants which are based on Coal and lignite. These altogether developments have created large amount of green houses gases in atmosphere.

• To overcome effect of green house gases and climate change United Nations has created United Nations Framework on Climate Change (UNFCCC).

• UNFCCC has developed two project based mechanism for reduction of GHC from global climate. One is Clean Development Mechanism- CDM and Joint Implementation- JI.

• In, CDM projects, GHG emission are reduced by developing countries projects and they earn Certified Emission rate- CER. They sale CER to developed countries and thus carbon trading comes in market.

• For implementation of CDM projects India is believed to be most potential country.

• CDM projects are implemented in India since 2005. Gujarat Fluro Chemical Ltd.- GFCI's HCFC reduction CDM project was third in world first in India.

• At this stage as many 300 CDM project are either implemented or under consideration in all over India.

• Ministry of Environment & Forest is nodal agency in India for implementation of CDM projects.
• SCDM projects are implemented haphazardly in India. Ministry of Environment & Forest is in promotional role not in scrutiny role. Public is not aware of any kind of such projects. Lots of foreign exchange in name of CDM comes to India but it goes to industry’s pocket. Local people neither aware nor beneficiary of project implementation. Due to this sometimes pollution does not comes under control and purpose of CDM projects does not serve.

• Major goal of CDM project for developing country is to achieve Sustainable Development Goals. Whether really this goal is achieved after project operation

• On basis of capacity of project to achieve Sustainable Development Goals, National Authority approves projects. Whether National Authorities are capable enough to assess project contribution to Sustainable Development Goals? Indian National Authority is only in role of encouragement and not in monitoring role.

• India has put criteria for development of CDM project to enhance environment/ecological/social/technological well being through CDM project. Whether it has been cross checked that project has enhance environment and social well being?

• As buying credits is cheap options for Developed countries, they will opt for it and emit more greenhouse gases. Developed countries are actually not interested in poverty alleviation or gas reduction but in using developing countries land/resources for project development.

• CDM has remained between private companies, global consultant and stock traders at large. Government and local people are unaware of process of CDM project. Consultation is mere formality at project development stage.

• There is no public accountability or transparency involved in project operation. No data on CERs selling and earning to company. Even Ministry of Environment & Forest is not aware on financial transactions.

Paryavaran Mitra’s Efforts
• Paryavaran Mitras demands are that CDM projects should be properly implemented, local state government should be made aware about projects, they should have monitoring role project apart from promotional role and local people should get benefited from revenue of CDM project.

• Paryavaran Mitra made series of meeting with State Environment and Forest Department to promote CDM projects and monitoring them.

• Paryavaran Mitra wrote a letter to chief Minister Shri Narendra Modi and Ministry of Environment & Forest regarding CDM projects of Gujarat. After that Paryavaran Mitra made application under Right to Information Act that what steps had been taken on our letter.

• In that regards it reveal that state government has formed CDM cell within Forest & Environment Department.

• Paryavaran Mitra also had campaign in Panchmahal district against GFCL. GFCL is first CDM project in India. They have said to reduction gases. On other hand surrounding villages people have lots of complains about air pollution from GFCL. Gas leakage incidences also reported in Company. So Paryavaran Mitra wrote to UNFCCC head quarter at Bonn, Germany about malfunctioning of project of GFCL.

• Head quarter had advised us to make presentation at validation stage of any projects.

• So Paryavaran Mitra now regularly makes presentation to various projects at their validation stage on UNFCCC website.

3.7.3 Our Demands:

• That CDM projects should be properly implemented (make Public hearings mandatory),

• Local self-governments should be made aware about such projects,
• They should have a monitoring role in the projects apart from just a promotional role.

• The local people should get an equal benefit from its revenue.

• Developed Countries should stop playing 'Green Politics' on the ever increasing Environment challenges.

• Developed Countries are buying 'carbon-credit' from the developing and under-developed countries but at the same time they have to make sure that actually the carbon is 'cut' (reduced) on reality basis at their own countries.

• CDM projects in developing countries should be monitored before buying carbon credits. They should encourage use of CDM revenue for local communities.

• People in developed countries should reduce their consumption patterns in order to reduce green house gases in the atmosphere.

• Moreover, the growing market for the super rich in India alone is a greater victim of such unchecked consumption. While we maintain the focus on CDM - there must be more awareness on these factors as well for achieving the greater purpose of reducing GHGs.

4. Exploitation of natural resources

The exploitation of natural resources is the use of natural resources for economic growth, sometimes with a negative connotation of accompanying environmental degradation. It started to emerge on an industrial scale in the 19th century as the extraction and processing of raw materials (such as in mining, steam power, and machinery) developed much further than it had in preindustrial eras. During the 20th century, energy consumption rapidly increased. Today, about 80% of the world’s energy consumption is sustained by the extraction of fossil fuels, which consists of oil, coal and gas. Another non-renewable resource that is exploited by humans
is subsoil minerals such as precious metals that are mainly used in the production of industrial commodities. Intensive agriculture is an example of a mode of production that hinders many aspects of the natural environment, for example the degradation of forests in a terrestrial ecosystem and water pollution in an aquatic ecosystem. As the world population rises and economic growth occurs, the depletion of natural resources influenced by the unsustainable extraction of raw materials becomes an increasing concern.

Why resources are under pressure

- Increase in the sophistication of technology enabling natural resources to be extracted quickly and efficiently. E.g., in the past, it could take long hours just to cut down one tree only using saws. Due to increased technology, rates of deforestation have greatly increased.

- A rapid increase in population that is now decreasing gradually. The current number of 7.132 billion humans consume many natural resources.

- Cultures of consumerism. Materialistic views lead to the mining of gold and diamonds to produce jewelry, unnecessary commodities for human life or advancement.

- Excessive demand often leads to conflicts due to intense competition. Organizations such as Global Witness and the United Nations have documented the connection.

- Non-equitable distribution of resources.

4.1 Problems arising from the exploitation of natural resources

Natural resources are not limitless, and the following consequences can arise from the careless and excessive consumption of these resources:

- Deforestation
- Desertification
• Extinction of species
• Forced migration
• Soil erosion
• Oil depletion
• Ozone depletion
• Greenhouse gas increase
• Extreme energy
• Water pollution
• Natural hazard/Natural disaster
UNIT –V  References


